CSIR-SERC

ENGINEERING SUSTAINABLE STRUCTURES

CSIR - STRUCTURAL ENGINEERING

RESEARCH CENTRE

CHENNAI

Annual Report

2013 - 2014

Cover: Demo building at CSIR-SERC using prefab large light weight wall and roof panel using EPS

Steel-GFRP 9 m high hybrid rooftop microwave tower during test

Casting of EPS test specimens

Annual Report
2013-2014

CSIR - Structural Engineering Research Centre
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DIRECTOR'S REPORT

CSIR-SERC has been a front runner in enabling new technologies which benefit the society at large. This year too has seen CSIR-SERC involved in high end research with its 12th Five Year Plan programs focused on offering innovative and out-of-the box solutions to some of the persistent problems be it depletion of natural resources, structural safety, environmental issues or durability of structures, etc. I would like to mention that we have taken the following new initiatives to meet the challenges and provide sustainable solutions:

- *Development of sustainable materials & construction technologies including nano/ engineered materials*
- *Integrated building management system & health management of infrastructure*
- *Light-weight and pre-engineered construction panels for fast construction & use in rural areas*
- *Construction materials replacing (part / full) a) cement, b) high energy intensive steel by 'Green' steel, metals & composites.*

- *Work towards development of geopolymer concretes, Ultra high strength concretes, etc. for durable and efficient structures*
- *Biomimetic/ Bio-inspired materials of construction & pavements*
- *Non-conventional energy (wind, solar and hybrid) structures*
- *Energy efficient buildings & infrastructure*
- *Effective waste utilization including construction & demolition waste*
- *Design of structure against natural and man-made disasters*
- *Innovative Transport infrastructure management system*
- *CSIR-800/MSME cluster programs*

I am extremely delighted to present the Annual Report of the CSIR-Structural Engineering Research Centre, Chennai for the year 2013-14. I would like to highlight some of the major activities and achievements during this period. Some of the major achievements under each R&D thrust areas are highlighted in the following.

SUSTAINABLE MATERIALS AND COMPOSITES & RETROFITTING/ REHABILITATION OF STRUCTURES

Multi-scale theoretical modeling methods for structural health assessment using nano-materials experimental techniques in hydration studies have been developed. Investigations have been carried out by incorporating foreign moieties namely nano SiO_2 , nano clay and Carbon Nano Tubes (CNT) into cement paste to assess their performance at micro level using sophisticated analytical techniques. Molecular dynamics (MD) simulations have been carried out on armchair and zigzag nanotubes with various diameters.

Studies on the development/synthesis of identified alternative binder and aggregate/ filler/fibre for concrete with recycled aggregates reclaimed from construction and demolition wastes and formulation of recommendations on utility of alternative binder, aggregate/ filler/fibre and the new concretes have been undertaken. The overall objective of this project is to characterize alternative binder and filler systems for concrete. Investigations on geopolymeric binder systems using various materials such as fly ash, blast furnace slag, micronized biomass silica has been the main focus as alternative binders. Copper slag and manufactured sand have been studied and characterized as alternates for river sand. Recycled aggregate especially recycled coarse aggregates obtained from various sources have been studied to find methods to improve their quality. Further studies on optimization of curing regime for ultra-high performance geopolymers concrete (UHPGPC) and experiments have been conducted using different types of curing. Studies were continued on the use of Micronized Biomass Silica (MBS) as a geopolymeric source material which is used as a partial replacement for cement to improve the properties of recycled aggregate concrete (RAC).

Towards developing an intelligent system for smart sustainable buildings, one day meet was organized at Engineering Services Division, New Delhi in January 2014. Representatives of architectural firms practicing in and around Delhi and architects from ESD participated in the meeting. A questionnaire was designed for capturing information into the intelligent system. This information would serve as a valuable source of input in the design of the cognitive engine for the proposed intelligent system. The work towards the development of the relevant modules is in progress by using open source tools. The intuitive framework fully exploits the capabilities of existing ICT tools and technologies and facilitates in designing energy efficient, smart and sustainable buildings ensuring seamless flow of information across all the modules. The knowledge base will serve as the main source of information for the cognitive engine. The cognitive engine analyses the building energy based on the knowledge captured and available in the knowledge repository for obtaining solutions and generate the suggestions automatically. The information obtained from architects based on the questionnaire as well as the details available

in National Buildings Code (NBC) and Energy Conservation Building Code (ECBC) will form as the major source to create the knowledge base.

Preliminary investigations have been carried out on three types of sandwich panels developed by using profile steel sheet as core material and by using different concretes as skins achieved by reinforcing with basalt fabric, glass fabric and steel fibers. When glass fabrics along with cementitious binder is used as skin, it is named as fabric reinforced concrete (FABcrete) panel; basalt fiber reinforced cementitious binder along with basalt mesh when used as skin is named as basalt fiber reinforced concrete (BFRC) panel and while using cementitious matrix and steel fibers as skin, the panel is named as ultra high strength concrete (UHSC). All the sandwich panels have been designed and developed to find their suitability as a structural floor member under flexural load. Experimental investigations have been carried out to determine the response behavior of the three sandwich panels.

Bio-calcification or bio mineralization is a process that leads to the formation of minerals using the biologically or biotechnologically mediated route. The bio mineral thus generated contributes towards strengthening and improvement of cementitious and sandy materials. The isolate IsAH-2 has been inoculated to the calcium carbonate precipitation medium and is observed to grow well in the medium with promising calcium carbonate precipitation. The colonies have been observed under optical/stereo microscope to confirm the crystal formation and to know the structure of the crystals. The crystals are found to be rhombohedral in structure.

Bacterial cement mortar cubes incorporated with isolate IsAH-2 have been cast to study the enhancement in the mechanical properties. The results reveal that bacteria has precipitated the calcium carbonate crystal which has led to increased compressive strength. Also it is noted that the presence of urea in the curing medium has induced the bacterial precipitation. XRD has clearly indicated the presence of the calcium carbonate in the control, Test-1 (Cured with 1g urea/L of water) and the Test-2 (Cured with water) mortar specimens.

The pozzolanic materials like blast furnace ash, fly ash and silica fume are being used as supplementary cement replacement materials. The X-ray diffractogram of the samples revealed that manually burnt ash samples showed the presence of polymorphs of silica crystals and decomposition is also seen at elevated temperatures. Sugarcane bagasse ash has shown the presence of the characteristic clear, crystalline and sharp peak of quartz and cristobalite.

STRUCTURAL CONCRETE ENGINEERING AND TECHNOLOGY

Studies towards development of risk-based methodologies for inspection/maintenance scheduling of RCC/PSC structural components – leading to their inspection/maintenance scheduling were prepared. A deterministic multi-scale model was developed for determining the concrete creep compliance using the recent formulations given in literature for upscaling the viscoelastic properties of concrete. From the results, it is noted that as the age at loading increases, the rate of increase in basic creep compliance with time reduces. The basic creep compliance increases at a higher rate at the initial stages, but reduces to a constant rate as age of concrete increases. At present the model can be used only for predicting the basic creep. Further investigations are required for including the drying creep component. I am happy to inform the readers that a new creep facility has been successfully established in the basement of ASTaR laboratory. Shrinkage moulds for the determination of hydraulic axial shrinkage of concrete specimens and mortar prisms; shrinkage measuring device/length comparator are procured, installed and commissioned for shrinkage studies.

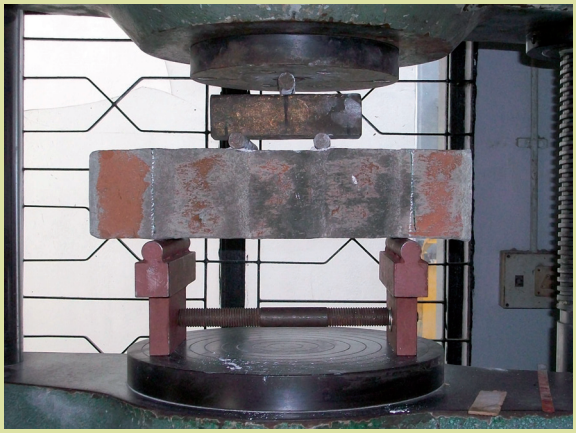
CONCRETE CREEP TESTING LABORATORY

As a part of developing concrete creep testing laboratory at CSIR-SERC, ten MICROTEST F-ECH-4c/1200 kN hydraulic systems for compression creep testing were procured and installed in the

basement of AsTAR Laboratory. Each machine has a rigid 4-legged frame with height adjustable upper crosshead and hinged upper plates, and has an axial compression capacity of 1200 kN. It has an integrated hydro-pneumatic loading device housed at the bottom with a single ended single acting hydraulic actuator. The special feature of the machine is the integrated automatic closed loop servo-controlled system which will enable the machine to maintain the load to within ±1%, without human interference, even when temperature varies within 14°C to 45°C. Each machine is capable of testing 4 numbers of 150 mm Ø × 300 mm high concrete cylinders in series. Training on the operation of these machines was also given by engineers from M/s Microtest, S.A., Spain, to the identified staff members.

In continuation of the studies on sustainable construction technologies for societal development: Phase-I (CSIR 800 Program), towards reviving a CSIR-SERC technology, shallow precast funicular shell for construction of floors and roofs is being taken up. A novel semi pre-fabricated system of flooring consisting of funicular shells, thin beams and top layer is development. Thin concrete beam for supporting the shells has been designed and mould for casting inverted T shaped concrete thin beams has been fabricated. Trial mix for casting the beams has been designed and the mix intended for casting the beam has been tested for compressive strength. As an alternate material, Geopolymer for concrete is being studied.

As a part of CSIR-800 program as well as the 12th Five Year program activity on studies on development of pre-engineered light weight structural components/systems, a demonstration building of about 150 sq.m. has been planned for construction at CSIR-CLRI,



Adyar, Chennai (construction of four Class rooms for Kendriya Vidyalaya) in which the following CSIR-SERC technologies are proposed to be extensively used :

i) Geopolymer Paver Blocks (blocks without "cement")

ii) A novel seamless, efficient, leak proof joint;

iii) Self-compacting concrete (SCC) – for column footing

iv) Foam concrete blocks

v) High volume fly ash concrete

vi) Composite Expanded Polystyrene(EPS precast panels/blocks

vii) Fast and affordable construction

This building structure is being planned to be completed in record time of 90 days, once all formalities of design and other procedures are completed.

Research project on condition assessment of concrete and heritage structures using advanced NDT techniques and recommendations/ guidelines on condition assessment of concrete and heritage structures have been carried out. An attempt is being made in identifying the

defects due to the frequency shift caused by the presence of defects. GPR image processing techniques are being used for the estimation of the embedded rebar's diameter. The radargram has been processed using sobel edge detection technique to estimate rebar diameter.

One of the major durability problems in reinforced concrete (RC) structures is the rebar corrosion due to the ingress of chlorides. Some of the mitigating techniques are the use of blended cements, corrosion inhibiting admixtures, etc. Extensive studies have been carried out in the laboratory and it is found that that Portland Pozzolana Cement (PPC) concretes is more superior in resisting chloride induced corrosion even in the presence of cracks up to 0.2 to 0.4 mm. The accelerated corrosion (impressed voltage) tests carried out earlier do not show any improvement in the corrosion resistance with the addition of calcium nitrite inhibitor (CNI).

STRUCTURAL HEALTH MONITORING AND EVALUATION & FORENSIC ANALYSIS

Development of damage diagnostic strategies using distributed wireless smart sensors (Motes) for sustainable SHM, recommendations for devising sustainable smart SHM strategies were the key targets in the study taken up. Several time domain techniques like Eigen value realization algorithm (ERA), Ibrahim time domain method (ITD), Least square complex exponential (LSCE), Stochastic subspace identification (SSI) techniques are implemented. Several new damage diagnostic algorithms are developed for structural health monitoring and they include: i) Damage diagnostic technique based on a technique inspired by subspace identification for handling environmental variability, ii) Kernal PCA based algorithms to identify the structural damages in the structures exhibiting nonlinearity, iii) Kernal PCA combined with Fisher Discriminant Analysis(FDA) for handling environmental variability, iv) Damage localisation technique using power spectral density highly adaptive for Wireless smart sensor networks.

Studies towards development of real-time continuous remote health monitoring system employing smart sensors and wireless sensor networks, Validation of wireless sensors for RHM at laboratory level and demonstration of RHM on selected structures have been carried out. A new methodology for corrosion monitoring using FBG sensors was developed. Studies were carried out to verify that the strain developed in the FBG sensors is only due to corrosion.

Research project on self-sensing structural health monitoring of concrete bridges were carried out. The application of the electro-mechanical impedance method to detect the presence of damage and monitor its progress in concrete structures was investigated using finite element analysis.

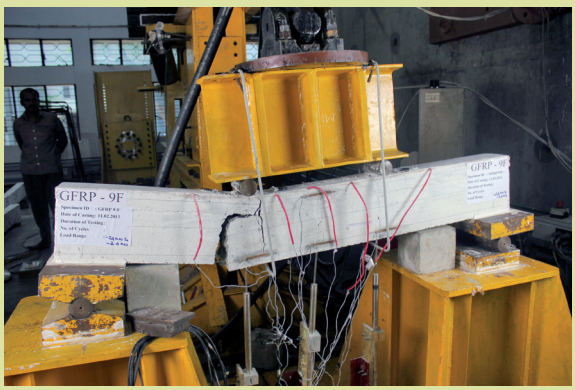
A two stage damage detection technique using time series models for structural health monitoring considering environmental variability and measurement noises is developed. The damage detection methodology consists of two phases. In the first phase, we identify the exact time instant of damage. A two-stage prediction model, combining auto-regressive (AR) and auto-regressive with exogenous inputs (ARX) techniques, is constructed from the current data and the corresponding matched reference data to identify the presence of damage. The proposed method uses a damage metric which involves the variances of the prediction errors from AR-ARX model constructed from reference and current datasets. Studies highlight the merits of the proposed two phase model for damage diagnostics and also the immunity of the proposed algorithm for measurement noise and also temperature variability.

Experimental studies on creep and shrinkage of engineered concrete specimens and development of deterministic- and stochastic-

mechanics based- multi-scale models of engineered concrete for estimation of creep compliance have been carried out. One of the objectives of the project is to carry out experimental studies on creep and shrinkage of engineered concrete. The experimental program has been finalized with main focus on the creep and shrinkage properties of M40 grade concrete with 30% and 40% fly ash replacement. A review of mix proportioning procedures given in different codes of practice is carried out to select suitable procedure for mix proportioning of concrete with different proportions (up to 40%) of fly ash. Sensitivity analysis is carried out to study the influence of cementing efficiency factor of fly ash on different ingredients of concrete with fly ash.

TRANSMISSION LINE TOWERS, METAL STRUCTURE BEHAVIOR & FATIGUE AND FRACTURE

Project on analytical and experimental studies on GFRP-Steel hybrid towers to determine the optimum parameters governing the tensile behavior of joints has been taken up. A series of experiments were conducted on GFRP plates and angle sections by varying the diameter, number of bolts, edge, pitch distances and plate washers. Experiments were conducted by varying the no. of bolts, diameter and bolt lines. Based on these studies, a 9 m high hybrid triangular based communication tower was designed, fabricated and tested for the specified wind speed and antennae configuration. The study led to the formulation of design guidelines/ recommendations.



Studies on fatigue and fracture behaviour of materials and components of sustainable structures and advanced fatigue and fracture studies on prototype piping components for energy sector have been undertaken. Investigations on static and fatigue strength of concrete beams reinforced with Glass Fibre Reinforced Plastic (GFRP) and TMT bars were carried out to study the flexural behaviour. An attempt has been made to evolve a procedure for accelerated corrosion fatigue studies in the laboratory which would give meaningful results of corrosion fatigue damage happening in real time and actual environment conditions. Studies on steel building components and connections under environmental and cyclic loads and experimental investigations on strength aspects of uncorroded and heated tubular joints under axial compression have been carried out in the laboratory. In order to address the corrosion effect on axial strength and behavior of tubular built-up joints, experimental studies have been taken up. Microstructure analysis has been carried out on the sample specimens to understand the effect of elevated temperature and corrosion on the metal surface.

Experimental studies are carried out by using Fiber Bragg Grating (FBG) based sensors and conventional electrical strain gauges to monitor the strains induced in tension coupons extracted as per ASTM 8M, under monotonically increasing loads. The study reveals the immense potential of FBG in severe atmosphere where conventional electrical strain gauges are not suitable. A full scale exterior beam-column connection has been studied experimentally to understand the behavior and failure modes.

In continuation with the testing of exterior self-drilling screw beam-column connections, numerical model has been developed for conducting further parametric studies.

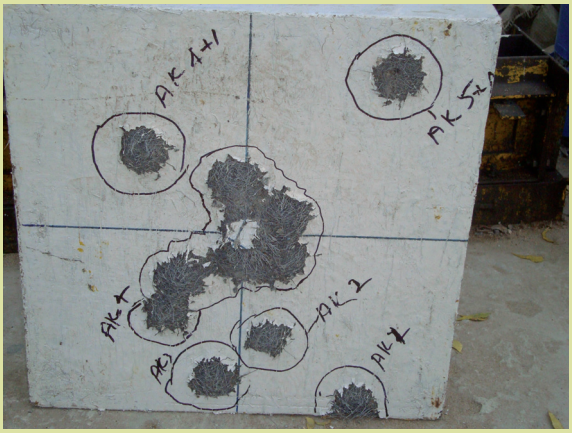
Finite element analysis (FEA) simulation of composite wall panels under axial loading has been performed by using Abaqus/Standard software. The elastic behavior of foamed concrete is modeled by using uniaxial compression elastic modulus. The plastic behavior is modeled by using the crushable foam material model.

Project on fatigue and fracture studies on selected steel materials and components have been carried out. Strain-controlled fatigue studies are very useful in the design of components that undergo either mechanically or thermally induced cyclic plastic strains wherein failure may occur within relatively few cycles.

Studies on Damage Assessment and Life Enhancement of Transmission Line Systems has been conducted. There are number of high wind load models available in literature for downburst, microburst and cyclones. Hence, it is proposed to study the statistical characteristics for measured high wind data. Based on these statistical characteristics, the available high wind load models can be improved for Indian meteorological conditions. The applicability of these high wind models will be studied for transmission line towers. A state-of-the-art report has been prepared on bolted joint damage assessment in transmission line towers. Analytical studies were conducted on the above mentioned bolted lap joint. The lap joint was modelled in NE NASTRAN, a nonlinear finite element software using beam element for plate and spring element for bolted connection.

COMPUTATIONAL STRUCTURAL MECHANICS FOR ANALYSIS AND DESIGN & SOFTWARE DEVELOPMENT

Studies towards effective structural protection against extreme loads, numerical and experimental investigation on impact performance of multi-layered cementitious fibre composites were carried out. The impact performance exhibited by 100 mm thick multi-layered cementitious fibre composite panels is taken as the basis to decide on the materials and layer configuration of the composite panels for experimental investigation. Compressive strength and acoustic impedance for SIFCON with different percentages of fibres, plain concrete (CCC), latex modified concrete (LMC) and mild steel were evaluated. It was noted that the compressive strength increases with increase in percentage of fibre up to 8%. The study conducted on LMC showed that by adding Styrene Butadiene Rubber (SBR) improved water resistivity, flexural and tensile strengths. Numerical investigations have been carried out on metallic sandwich panels with tube core to ascertain its applicability as structural protection system against blast loads. In this investigation, a metallic sandwich panel with tube core is taken for study. Numerical model of tube core sandwiched between cover plates, representing the geometrical as well as material characteristics, is generated. It is observed that blast response of panel obtained from the present study is in close agreement with the reference values, thus validating the numerical model.



A new controller based on fuzzy logic for RTHT is proposed. Advantage of a fuzzy-logic-based controller is that it is rule based and involves far less computations. Performance of the proposed controller is compared with the controllers widely used in RTHT through numerical simulations of a sub-structured linear and nonlinear single-degree-of-freedom system for two different damping ratios. Based on the studies carried out, it is decided to use the fuzzy controller for the performance evaluation of the seismic protection system based on RTHT.

WIND ENGINEERING & EARTHQUAKE ENGINEERING

Project on investigations on wind loads and effects for special structures, cyclones cause varied damage to housing/infra in coastal regions depending upon their intensity. It was observed that mainly the places in and around Brahmapur, Chhatrapur, Gopalpur and Ganjam were affected with failures of engineered structures like rooftop lattice tower, ground based communication / transmission line lattice towers and steel trusses with asbestos or G.I. sheet roofing of industrial sheds. These observations indicate the necessity for continued efforts in mitigating the damage to buildings and structures due to cyclones.

It is appropriate to mention here that the Eighth Asia-Pacific Conference on Wind Engineering (APCWE-VIII) was organized by CSIR – Structural Engineering Research Centre, in cooperation with International Association for Wind Engineering, Indian National Academy of Engineering and Indian Society for Wind Engineering, at Hotel Green Park, Chennai, during 10-14 December 2013. This event has returned to India after a gap of over 22 years. The Asia-Pacific Conference on Wind Engineering (APCWE) is an international event regularly convened every four years since 1985 under the umbrella of International Association for Wind Engineering (IAWE). The conference included fourteen themes. In all, 298 delegates, including about 90 from 15 countries such as China, Japan, Italy, USA etc., participated in the conference. There were totally 12 keynote speeches by experts from Canada, China, Japan, India, Italy, New Zealand, Poland and USA. One hundred and sixty-one technical papers under 13 different themes were published in the proceedings. Fourteen organizations (13 from India and one from USA) sponsored the event. More details are provided in this Report.

Studies on the development of mitigation strategies for structures located in seismically prone regions were conducted in the laboratory. A dynamic characterization study has been completed on a typical magneto-rheological (MR) fluid based supplemental damping device used for semi-active control of structures. Understanding the non-linearity of MR damper by dynamic characterization of the damper is a crucial step before the application of the damper in structural control. Experimental investigations are carried out on a prototype MR damper device using a computer-controlled Universal Testing Machine under a wide range of magnitudes of control current and excitation conditions to characterize the hysteretic force property. A parametric study is carried out considering the prescriptive reinforcements and dimensions of ground floor columns of the OGS buildings in India. A graphical user interface is developed to assess the seismic vulnerability of open-ground storey apartments based on the methodology.

A methodology to design and distribute dampers in ground floor level for seismic performance enhancement of a 20-storey, 2D benchmark building subjected to low intensity earthquakes with peak ground acceleration (PGA) of 0.2g using linear viscous fluid dampers (VFDs) is proposed. The proposed methodology is used for designing the linear VFDs to increase the effective damping with Chevron, upper-toggle and scissor-jack mechanisms in a 20-storey benchmark building. A design methodology for seismic performance enhancement of a 3D truss tower with scissor-jack viscous fluid damper systems is developed.

The above sums up the contributions and accomplishments made in different R&D programs during the year.

INTERNATIONAL COLLABORATION

In connection with the collobartive project on the "Visualization of automated multi-sensor NDT assessment of concrete structures", the automated scanner has been installed and commissioned at ACTEL, CSIR-SERC. The Radar and Ultrasonic Pulse Echo data were collected on the RCC wall (in vertical position) and on concrete test specimens in horizontal position) using the automated scanner. The data were analysed for the presence of reinforcements and defects.

This project has been undertaken in collaboration with Indo German Science / Technology Centre (IGSTC).

Under the collaborative project on 'Development of Textile reinforced polymer modified cementitious mortar for retrofitting applications' undertaken in collaboration with CNR, Institute of Chemistry and Technology of Polymers, Italy under CNR-CSIR Cooperation Program, a pre-fabrication technology was developed for producing textile reinforced concrete components. The characterization has been carried out for the textile reinforced concrete sheets produced and it showed a strain hardening behavior. A practical site application was demonstrated by making use of textile reinforced concrete sheets by lining an existing damaged brick canal at CSIR-SERC.

CONSULTANCY ASSIGNMENT / CONTRACT PROGRAMS

The Centre has completed 21 sponsored projects and has continued to work on existing 7 sponsored projects during the year. It has attracted two new sponsored projects. Among the on-going projects, some of the notable ones to be mentioned here are i) Performance evaluation of typical railway bridges under increased axle loads of freight wagons, ii) Experimental investigations on 220 ft single lane bridge in-house, iii) Study on seismic performance of DSRDMs, iv) Study on seismic performance of PSS assembly, v) Condition assessment off concrete in the SRP-II building at CPCL.

The Centre has carried out a number of consultancy assignments for the industry / user agencies who had approached CSIR-SERC to solve their current / urgent problems in structural engineering related to the areas of proven expertise of the laboratory. Notable among these are reflective of the range of expertise of CSIR-SERC, and some of them of national/strategic significance, that include i)

Investigations on added mass on shear wall, BARC, Mumbai; ii) Recommendation for the termination of intake well foundation, for NTPC, Mouda; iii) Mix design to attain compressive strength of 48.25 MPa and Flexural strength of 4.5 MPa, RMC Readymix (India), Mumbai; iv) Vibration measurement in RCC floor in machine shop area, for Larsen & Toubro Limited, Chennai; v) Assessment of concrete quality in the raft slab of discharge channel, NTPC, Anta; vi) Proof checking the rectification methodology for chimney shell concreting, for BGR Energy Systems Ltd., Chennai; and vii) Drag force measurement study on 1:10 scale rigid model of vehicle in wind tunnel, for Daimler India Commercial Vehicles Pvt. Ltd, Chennai.

GRANT-IN AID PROJECTS

As regards grant-in-aid projects, three projects have been successfully completed, one is ongoing, and the Centre has begun work on two new projects. In the following, salient features and achievements in some of the projects are provided.

***Development of Robust Damage Diagnostic Techniques for Engineering Structures using PCA and ICA** supported by the Aeronautical Research & Development Board, New Delhi. Salient features are made; i) Development of formulations for damage detection strategies using principal component analysis using time history data & implementation, ii) Extension of the PCA formulations using frequency response functions to handle problems with dominant higher & mid frequencies, iii) Development of strategies for assessment of damage distribution in laminate composite structures, iv) Development of optimal sensor placement techniques using principal component analysis, v) Development of modal identification techniques using ICA and blind source separation techniques and vi) Development of robust damage detection algorithm combining wavelets and Blind source separation techniques. Comparative studies made using AMUSE and SOBI algorithms.*

***Analytical and Experimental Investigations on Remaining Life and Residual Strength Assessment of Stiffened Panels under Constant and Variable Amplitude Loading** sponsorship of Aeronautical Research & Development Board, New Delhi*

The geometric and finite element (FE) modeling of the panels along with the fixtures including the bolts have been created. It is observed that the residual strength values predicted by using remaining life approach are lower compared to those predicted by using other two approaches. It is also observed that the residual strength is higher in the case of intermediate stiffened panels, when compared with unstiffened and edge stiffened panels.

***Development of Structural Health Monitoring Schemes for Civil Engineering Infrastructure in India using Smart Sensing Technologies** National Programme on Micro and Smart Systems, ADA, Bangalore*

Experimental studies at lab level have been performed by using concrete beam model and MEMS accelerometers and simulated damages eccentrically to validate the techniques. Modal identification algorithms including Blind source separation techniques, Hilbert-Huang transform based techniques, etc. are implemented as a toolbox

***Segmental Composite Slabs for Bridge Decks** This project has been undertaken under the sponsorship of Department of Science & Technology, New Delhi*

Studies are initiated for finite element modeling of precast slab segments that act initially as formwork and connected compositely with in-situ concrete segments using different shear connectors such as shear link, studs and/or steel truss to transfer the horizontal shear between the precast and cast-in-situ deck slab segments. The effectiveness and efficiency of different types of shear connector mechanisms to transfer the horizontal shear between the interfaces of the pre-cast and cast in-situ segments of concrete deck slab are studied and quantified towards identification of optimal type. It is noted that

the finite element results matches well with the reported experimental values till the first cracking load. Further studies are in progress.

SPONSORED PROJECTS

I am glad to present a core of the sponsored projects undertaken by this centre during the reporting period.

***Performance Evaluation of Typical Railway Bridges under increased Axle Loads of Freight Wagons** under the sponsorship of the Southern Railway, Chennai.*

Fourth cycle of investigations on Bridge Nos. 145 (UP) & 145A (DN) near Puttur in Arakkonam – Renigunta Section and Bridge No. 42 near Tiruttani of the Southern Railway zone were carried out to evaluate the response characteristics of the bridges. Analysis and processing of the measured data obtained during testing were carried out to study the static and dynamic responses due to the increased axle loads of train formation. Fourth cycle of investigations on Bridge No. 163A(UP) near Vadamalpet in Arakkonam – Renigunta section of the southern railway zone are also carried out. Post-processing and analysis of the measured data of static and dynamic tests due to increased axle loads are carried out. First and second cycles of instrumentation, testing and measurements on reinforced concrete I-girder bridge No. 44 near Ennore between Chennai-Gudur section of southern railway zone were carried out.

***Investigations on Performance Evaluation of Parallel Flange Sections for Specified Loads Phase-I: Beam Sections** sponsored by M/s. Jindal Steel and Power Limited, Raigarh.*

Experimental studies on NPB400, UB457, NPB450 and WPB600 parallel flange beam sections and ISMB300 beam have been completed. The beams have been tested for their flexure behavior under four point bending. The beam has been tested under monotonic load up to their plastic moment capacity. Strain and displacements have been measured automatically during testing by using data logger.

A 3D deformable solid finite elements with extrusion and parametric modelling options has been chosen for the study. Idealized bi-linear stress-strain relation is used for modeling the nonlinear material properties. Mechanical imperfection is due to the residual stress locked up in the member during the forming process of the steel sections. The geometric imperfections correspond to either lack of straightness of the structural member or the eccentricities of the applied load. The geometric imperfections has been achieved by modeling the structure with an initial out-of-plane deflection. All the beams are studied with pin-ended boundary conditions.

*Combat Vehicles Research & Development Establishment (CVRDE), Chennai sponsored a project on **Evaluation of Indigenous Bearing Material**.*

Tension tests were carried out at elevated temperature of +300° C on five numbers of specimens to evaluate sharp-notch tensile strength of the material. The sharp-notch strength gives a comparative measure of the resistance of thick-section materials to fracture under plane-strain conditions originating from a very sharp stress-concentrator or crack. Corrosion fatigue tests were carried out employing eccentrically-loaded single edge notch tension [ESE(T)] specimens. The tests were carried out under constant amplitude sinusoidal cyclic loading. The specimens were tested till failure. All the specimens were found to fail at the onset of crack initiation, i.e., the specimens failed as soon as crack initiated without any crack propagation life.

***Analysis of Single Lane Bridges of all Spans other than 220ft and 180ft for all Load Cases to Prepare Complete Load Span Charts** under the sponsorship of Garden Reach Shipbuilders & Engineers Ltd., Kolkata*

Modelling of single lane modular steel bridges of all spans (30ft onwards in steps of 10ft) other than 220ft and 180ft has been carried out based on the design documents and drawings

provided by the sponsor. Work towards analysis of these single lane modular steel bridges for the 70R load case as per IRC and its respective load combinations by using standard software has been initiated.

***Design Validation of 236 m High River Crossing 400 kV D/C Transmission Line Tower** sponsored by M/s. Power Grid Corporation of India Limited, Gurgaon*

This required proof checking of the structural analysis and design of the 236m high river crossing towers. The lattice tower is of 236m high, 55m base width and has a square cross-section. The dynamic behaviour of the tower structure is studied by transferring the conceptual model into mathematical model in FEA software. Wind loads due to hourly mean wind along with gust response factor are evaluated based on the codal provisions of IS:875 (Part 3)-1987. The tower has been analysed for several load cases as per IS: 802 (Part 1/Sec 1). The governing forces are computed as per the load combinations specified in the code. Design checking of tower members are carried out as per IS:802(Part 1 / Sec 2)- 1992, with a over load factor of 1.0 for dead load and 1.0 for wind load for a basic wind speed of 50 m/sec as specified by the sponsor. The feasibility of the members sections and connections were validated for the factor of safety of 1.5. P-Delta analysis is carried out by applying the body wind load and self-weight in the finite element model and it was found that the displacement is increased by 20% with P-Delta effect.

***Vibration Study of Control Valves through a Tri-Axial Base Excitation Input** under the sponsorship of AUDCO India Limited, Chennai.*

The resonance search tests and endurance tests were completed for three control valves. Endurance test with constant displacement amplitude and ramping up frequency were also completed on these control valves. Resonance search tests in each of the orthogonal directions are conducted using 4 m × 4 m shake table and dynamic characteristics of control valves are identified. It has been found that these valves are classified as stiff with a magnification factor from 1 to 1.5 within the normal earthquake frequency range. Experiments conducted using 4 m x 4 m shake-table were completed for all the six control valves. Resonance search tests in each of the three orthogonal directions are conducted and the associated dynamic characteristics of these control valves are evaluated. It has been found that these valves are classified as stiff with a magnification factor between 1 and 1.5 in the normal earthquake frequency range. Further, endurance tests with constant displacement amplitude and ramping up frequency are also conducted on these control valves.

***Condition Assessment of Civil Structures of Main Plant Buildings & SEF Structures of RAPS 3 & 4**, sponsored by Rajasthan Atomic Power Station, Kota, Rajasthan.*

Field investigations were undertaken to carry out nondestructive tests consisting of ultrasonic scanning, cover survey, half-cell potential survey and resistivity of concrete. Concrete powder samples were collected for determination of chloride content. Concrete core samples were also taken from the structure. The core samples were dressed in the laboratory and tested for its water absorption and compressive strength. The results are compiled and technical interpretations are provided to the sponsor.

***Study on Seismic Performance of DSRDMs** undertaken under the sponsorship of The Indira Gandhi Centre for Atomic Research, Kalpakkam.*

The seismic qualification of Diverse Safety Rod Drive Mechanism (DSRDM) of Prototype Fast Breeder Reactor (PFBR) using pseudo-dynamic test facility was conducted. Experiments were conducted with water filled condition for Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) criteria. Tests were conducted on DSRDM with de-energization of electromagnet at six different instants of time during OBE and SSE. The total duration of the OBE and SSE excitation is 19 sec and during this period the control rod is dropped at various time instances and the dropping time was measured. Measurement included dynamic strains,

accelerations and displacements at critical locations.

***Vibration Study on CSRDMs using Shake Table Facility** is a project sponsored by Control Instrumentation Division, BARC, Mumbai.*

Initial performance evaluation tests on two encoders of CG and EPS mechanisms of CSRDM are completed on the 2 m X 2 m, 5T shake table. The prototype CG and EPS mechanisms of CRDM to be tested on the shake-table are under fabrication by the sponsor.

HONORS / AWARDS

Like every year, this year too, the Centre with its dedicated S & T staff has been conferred with many honors, awards and recognitions. These are detailed in this Report. I congratulate the staff who have brought glory to the institution through their unstinted efforts.

MoUs SIGNED

This Centre entered into seven MoUs with various Universities, Institutions and organizations like St. Peter's Institute of Higher Education and Research, Chennai(10th July 2013), Sri Ramakrishna Institute of Technology, Coimbatore (30th August 2013), SRM University, Ramapuram Campus, Chennai (31st October 2013), Sri Sai Ram Engineering College, Chennai on 29th November 2013, Easwari Engineering College, Ramapuram (29th November 2013), Hitech Concrete Solutions Chennai Pvt. Ltd, Chennai (December 16, 2013) and Central Public Works Department on December 19, 2013.

ADVANCED COURSES

As a part of our charter to provide training and disseminate the advances made in different areas of structural engineering we conduct number of training programmes during the year. This provides an active forum for effective interaction. This year following two advanced courses were conducted:

- *An advanced course on Sustainable Engineered Concrete (SECON 2014) during February 5-7, 2014.*
- *An advanced course on Seismic Response Control and Damage Mitigation Methodologies for Buildings and Structures during 19-21 February 2014.*

The Courses received overwhelming participation and there was very effective Interaction among the faculty and Participants. There was good mix of representation from the academicians, practicing engineers, designers and students.

NEW FACILITIES ADDED / CREATION OF ASSETS

I am proud to report that we have created new assets and added new facilities as presented in the following that would facilitate our S&T staff to achieve excellence in their R&D activities.

- *The hydraulic hard line piping in the Fatigue & Fracture Laboratory (FFL) has been completely relaid. New hydraulic hard line piping of 210 bar operating pressure and 600 lpm flow with in-line hydraulic accumulators has been installed and commissioned.*
- *A ±500kN capacity fatigue rated multipurpose servo controlled UTM with total stroke of 250 mm and T-slot table base has been installed and commissioned in FFL*
- *Three numbers of hydraulic power packs of 170 lpm capacity each have been installed and commissioned for the use of FFL and Steel Structures Research Facility (SSRF). The room hosting hydraulic power packs has also been expanded.*
- *Shrinkage test facility for mortar and concrete: Shrinkage moulds for the determination of hydraulic axial shrinkage of concrete specimens and mortar prisms; shrinkage measuring device/length comparator are procured, installed and commissioned for shrinkage studies.*
- *Instrumented impact test facility was created in the basement of the ASTaR laboraty. Impact testing machine CEAST 9350 is installed. CEAST 9350 is a floor standing impact system designed to deliver 0.59-757 J or up to 1,800 J with optional high energy system. CEAST 9350 works with the impact software and*

data acquisition system to make analysis simple. This versatile instrument can be used to test anything from composites to finished products, and is suitable for a range of impact applications including tensile impact, puncture, Izod and Charpy.

Impact testing machines are used to characterize the impact performance of various materials and components. Impact tests on structural elements like beams, slabs, made of RCC, steel and composites can be carried out in the instrumented impact test facility. In addition to this, characterization of materials at high strain rate can be performed with the help of the facility. These tests will indicate the energy absorbing capacities of materials and failure pattern under impulsive loads.

- *For evaluation of mechanical properties of engineered cementitious composites at nano- and micro-level, a state-of-art nanoindentation facility has been created. The equipment can provide maximum load of 700 µN (with load resolution of ≤50 nN and maximum indentation depth ≥100 µm) at nano level and it is capable of providing maximum load of 10 N at micro level. The machine is fully automated for controlled loading/unloading in specified grid system. The indentation facility can determine load-deformation characteristics, hardness, elastic modulus, creep and relaxation, elastic and plastic energy, stress-strain information etc. of the materials.*

- *The automatic foam concrete machine has been installed for foam concrete production. The machine consists of a foam generator and a mixer, assembled on one frame connected with hoses. Protein based foaming agents are generally used for generation of foam. Mixing mechanism consists of two multidirectional blades. The capacity of the machine is up to 3 cubic meters per hour. The machine automatically produces foam concrete of definite density. Mixer can be used for foam concrete production, as a plaster station or for production of high quality mixture.*

BOOKS AUTHORED/EDITED BY SCIENTISTS/ STAFF

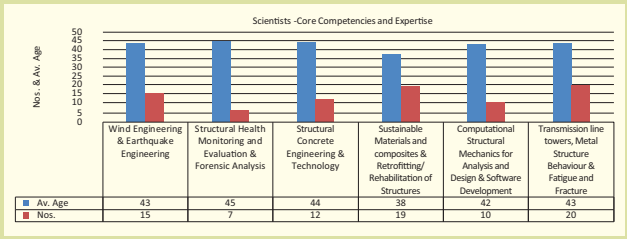
I am proud to place on record that in addition to the course volumes being edited and published by the scientists of this Centre, the Indian Building Congress has published the following three books which are authored by the scientists staff of CSIR-SERC.

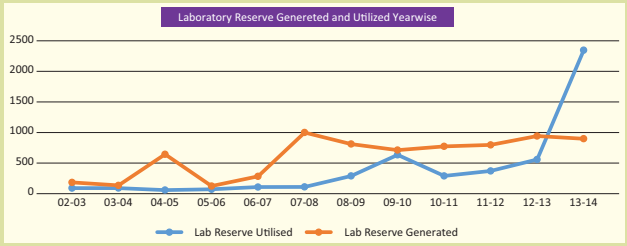
- *"Use of Ferrocement in Buiidings", Nagesh R. Iyer, T.S. Krishnamoorthy, P. Srinivasan, A.K. Farvaze Ahmed and J. Prabhakar, published by Indian Buildings Congress, New Delhi, ISBN : 978-81-925797-4-0, IBC : 19:2013.*
- *"New Building Materials & Technologies – Innovations in Concrete", Nagesh R. Iyer, K. Ravisankar, A. Rama Chandra Murthy, Simtha Gopinath, V. Ramesh Kumar, B.H. Bharathkumar, T.S. Krishnamoorthy and Past & Present Scientist/staff, published by Indian Buildings Congress, New Delhi, ISBN : 978-81-925797-5-7, IBC : 20:2013.*
- *"Concrete Technology", Nagesh R. Iyer, K. Ravisankar, J. Prabhakar, B.H. Bharathkumar, P.S. Ambily, K. Ramanjaneyulu, S. Sunder Kumar, A. Rama Chandra Murthy and Past & Present Scientist/staff, published by Indian Buildings Congress, New Delhi, ISBN : 978-81-925797-6-4, IBC : 21:2013.*

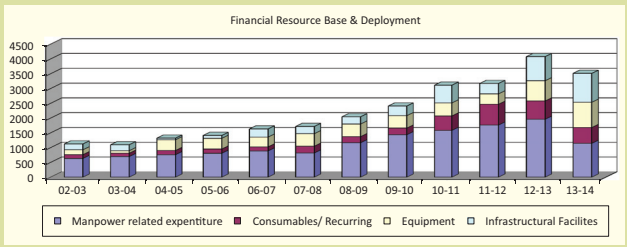
EVENTS OF SPECIAL MENTION

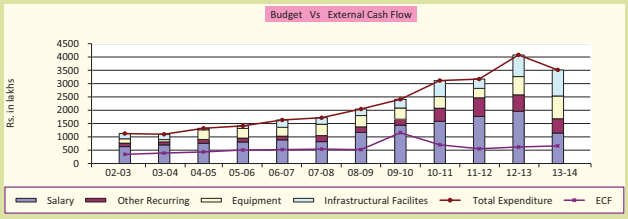
Ms. Franziska Lindhout, Director DAAD Information Center Chennai, German Academic Exchange Service, visited CSIR-SERC and delivered a special lecture on 'Research funding and fellowship opportunities in Germany for CSIRSERC'.

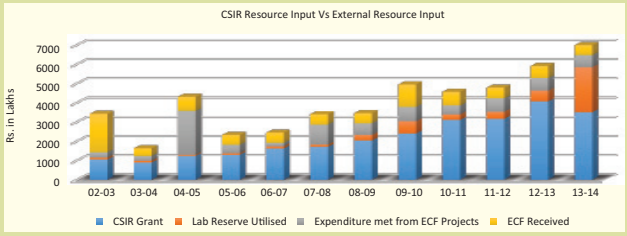
Prof. M.S. Swaminathan, Founder Chairman and Chief Mentor, UNESCO Chair in Ecotechnology, M.S. Swaminathan Research Foundation, Chennai, visited the Campus on the National Science Day and was the Chief Guest of the function. He also participated in the Science Exhibition organized by the students of the Renewable Energy program of AcSIR.

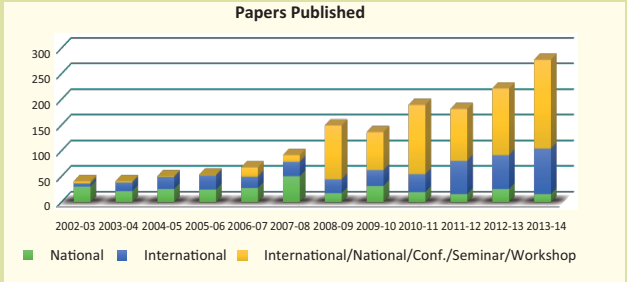


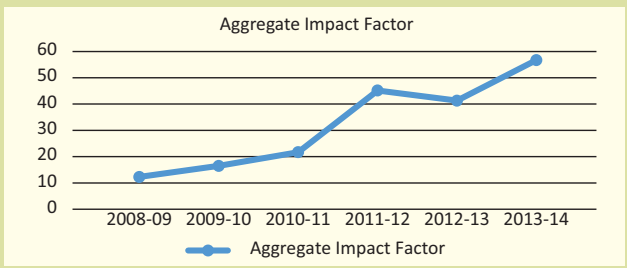


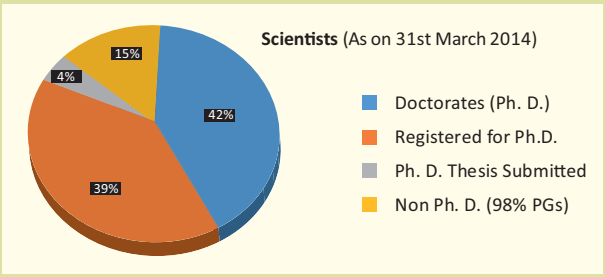












The Centre improved its infrastructural facilities by addition of new equipment / computational systems and enhancement of the existing ones. The whole campus has received a new look and environmental enrichment by carrying out necessary repairs and improvements.

TANGIBLE OUTPUTS/OUTCOMES

The Centre registered an impressive External Cash Flow receipt of nearly Rs. 6.62 crores during 2013-14, earned through contract R & D, grant-in-aid, consultancy assignments and technical services, carried out for governmental, public and private sector agencies / organizations. I am pleased to place on record that CSIR-SERC scored a 100 per cent satisfaction mark in responding to queries received under the RTI Act for the period of report.

With expansion of R & D thrust areas, and backed by renewed vigour and sense of performance oriented culture, CSIR-SERC looks forward to sustain excellence and quality, both in research programs and in the execution of projects of national importance and strategic significance in the field of civil and structural engineering.

This year an impressive total of 279 research papers have been published in various Journals as well as conference proceedings. The aggregate

Year	2009-10	2010-11	2011-12	2012-13	2013-14
Papers published in Journals					
International	30	30	54	66	89
National	32	20	25	24	17
Papers presented in Conference / Seminars					
International	27	46	63	63	128
National	47	85	39	63	39
Total	137	181	184*	216*	279*
Aggregate Impact Factor	16.50	21.70	45.60	43.84	61.60

Impact Factor has been 61.599. Based on the work carried out in various in-house projects and under contract research projects, 82 technical reports have been prepared.

Scientists, technical and administrative staff have been deputed to attend as many as 116 technical programmes/ conferences /seminars /workshops /training programmes across the country and to 9 programmes abroad.

Level	No of Staff / Programme	2013-14
S & T Staff (India)	Training Courses / Workshops	15
	Conferences / Seminars / Symposia etc.	88
S & T Staff (Abroad)		9
Administrative Staff	Training Courses / Workshops	4
Total		116

CSIR-SERC has functioned as an advanced postgraduate students level research guidance laboratory by facilitating the completion of as many as 86 student projects at M.E./M.C.A level during the year of report, besides giving opportunity for B.E/B.Tech summer internship to 85 students. A new Inegrated M.Tech-Ph.D program on Renewable Energy is also being offered in this campus in addition to the program on Engineering of Structures.

Guidance Provided to post-graduate students	2013-14
M.E./M. Tech. (Civil /Structural Engg.)	68
M.Sc., / MCA (Computer Science / Applications)	18
BE / B Tech Students	85
AcSIR- -Engineering of Structures -Renewable Energy -Ph. D	 4 9 8

This has been a year of accomplishments and successes in meeting the grand challenges. The support of the DG, CSIR, our RC members, colleagues from other CSIR Laboratories, our prestigious and beloved clients and last but not the least, the entire CSIR-SERC family have made all this happen!

At CSIR-SERC, we believe in the power of research to transform people's lives. We see research as an act of optimism and commitment to the future. We share this belief amongst ourselves and with our clients with a belief of personal engagement, a sense of ownership, and a commitment to pursue research in the interest of the future. I look forward to your feedback and will report next year our experiences taking the grand challenges, the achievements and performance that offers us thrilling opportunities!

July 2014
Chennai

Prof. Nagesh R. Iyer
Director, CSIR-SERC

Nanotechnology for Engineering Sustainable Materials

Scope /objectives

- Identification of potential nano-materials for engineering sustainable structures
- Development of new materials using nano-materials/nano composites for constructing sustainable infrastructure facilities
- Evaluation of mechanical properties of nano-bundled-materials using micro-mechanics approach and their responses under various types of loading
- Development of methodologies for structural health assessment using nano-materials

Significant achievements/ contributions

Understanding and interpreting the chemical and micro structural phenomena of different steps of the intrinsic cement hydration process through micro-analytical characterization is quite complex and interdependent. Further, resolving the individual mechanisms or the parameters which determine the key factor for hydration rate is extremely difficult. Therefore, by way of experimental techniques in hydration studies, it is a challenge to develop multi-scale theoretical modeling methods. Investigations are being carried out by incorporating foreign moieties namely nano SiO2, nano clay and Carbon nanotubes (CNT) into cement paste and their performance at micro level is being evaluated using sophisticated analytical techniques. Also proper functionalisation methods are being adopted to achieve absolute efficiency in engineered cementitious composites.

Many properties of cement paste are determined by its chemical nature and microstructure. Microstructure constitutes the nature of the solid body and that of the non-solid portion, viz, porous structure. In the present study, influence of nano silica (nS) at different phases of hydration has been investigated. Towards this, 0.25% 0.5%, 0.75% , 1% and 3% nS have been incorporated in cement paste, where w/c ratio is kept constant as 0.4. For comparative study, control samples have also been made with same w/c ratio. In this study, the following steps are followed. (i) Weighing of precursor materials such as cement (OPC- 53 grade) and nano silica. (ii) pH measurement: pH of the systems such as water used for hydration and nS solutions have been measured by using commercially available pH meter. (iii) The nS solutions are agitated by using water bath shaker for uniform dispersion of particles in water medium. Temperature was kept constant at 35°C and at 100 rpm. Agitation of the nS solution is carried out for 3-4 hrs and visual inspections are done for checking its dispersability. It is found that solution of 3% nano SiO_2 with water is extremely viscous and the workability is very low. (iv) Ultrasonication: After taking out the dispersion from water bath shaker, the same is sonicated for 1-2 min with 30% amplitude and 50 sec pulse. Three mixes having w/c 0.40 are cast. It is also found that no air bubbles formed during mixing showing that addition of nS does not attribute to any air entrapment in cement paste. While mixing the cement with nS dispersion, it is found that the consistency of the mix improves with the increased amount of nS. The as-prepared samples are collected for studying different stages of hydration. The hydration products formed with respect to the time of hydration are studied in detail since the system is likely to be perturbed in presence of foreign moieties. Further characterisation studies such as FT-IR, TGA-DTA, BET, TEM imaging are being carried out to couple the hydration behaviour of both the systems since slight modifications would considerably change the micro level characteristics of cement paste.

Nanoclay (NC) is one of the most affordable materials showing promising results in complex composites. Nanoclay is made from Montmorillonite (MMT) mineral deposits known to have “platelet” structure with average dimension of 1 nm thickness and 70 to 157 nm width. MMT is the main component of bentonite. Due to the inside layer, a negative charge imbalance is created at the layer surface along with the probability of cation exchange. MMT clays possess several qualities that make

them an excellent base for manipulation through nanotechnology. By observing the microstructure of different matrices of neat cement (Mix-1), nano modified cement (Mix-2) and nano f-clay modified cement (Mix-3) at 5hr and 24hr of hydration, one could refer that Mix 1 is having presence of type 1 C-S-H, Mix 2 is having presence of same type 1 C-S-H and Mix 3 consists of dense C-S-H in addition to type I C-S-H, which confirms the SP action at 24hr of hydration (Fig. 1). As far as cement hydration is concerned, the type I C-S-H will be produced during 24hr. The same scenario was present in all the three mixes, but in Mix 3 high dense gel was observed. This is mainly because of the advancement of hydration in presence of NC with chelating agent and also since as all the co-ordination sites of the clay particles are involved in the hydration leading to the formation of a high dense gel. It is significant to mention that the findings from the XRD and FT-IR are well aligned with the SEM results.

Unlike other composites materials, very little progress has been made on CNT/cementitious nanocomposites. The attributes that make CNT an unique material with a whole range of promising applications are the small dimension, high strength and other extraordinary physical properties. Its stiffness, strength, high thermal conductivity and Young's modulus make it the most promising of nano-reinforcement materials especially in the field of civil engineering. Nanocomposites are perfect materials for reinforcement in multi-functional and smart cement-based materials due to their aspect ratio and unique properties. The present study at CSIR-SERC attempts to explain the microstructure of cement-CNT nanocomposites, hydration behaviour, mechanical property, functionalisation methods and drawbacks such as agglomeration, poor dispersion etc. Research is being conducted on studying the crack bridging behaviour during the initial level hydration (such as 5hr and 24hr), since the micro cracks mainly forming at this stage are due to physically bound water evaporation. Poly carboxylic based Superplasticiser (Sp) is used as a water reducing as well as chelating agent. In order to chelate the MWCNT into superplasticizer and for good dispersion, sonochemical treatment is adopted. The systems with neat cement (Mix-1), nano modified cement (Mix-2) and f-CNT incorporated cement (Mix-3) are subjected to hydration (Fig. 2). Studies are being carried out for effectively dispersing and chelating of the CNT into a polymeric confinement which will promote the application of CNT incorporated cement/cementitious system towards early pore (precursor for crack) or crack termination.

Nanoindentation is commonly used for investigating local mechanical properties of mostly homogeneous materials modelled as isotropic or anisotropic solids. On the other hand, many materials, and especially structural ones, exhibit phase heterogeneity and mechanical differences of the phases on different length scales. In order to model heterogeneous material systems, multiscale approach that allows for separation of scales based on some characteristic dimension of a material microscopic feature for each level is often utilized. In this study, nano mechanical properties of cementitious composites (such as Calcium-Silicate-Hydrate, C-S-H) with different densities are investigated using simulated nano indentation. Computational study has

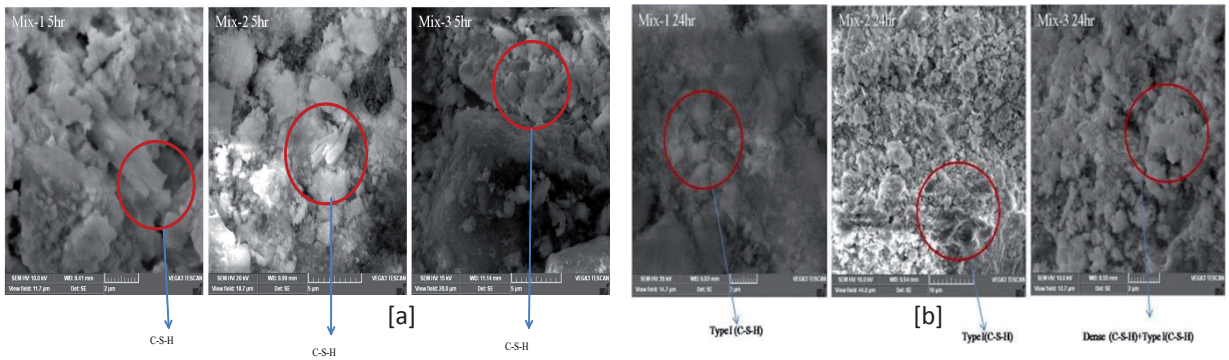
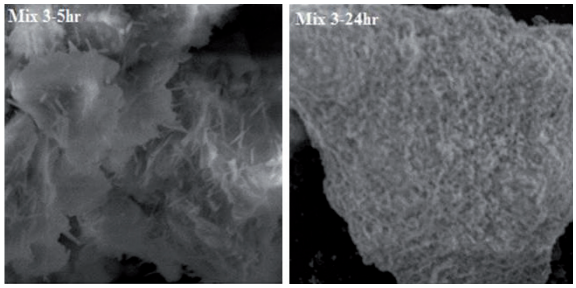


Fig. 1 SEM images of nano engineered cement (a) at 5 hr (b) at 24 hr



(a) (b)

Fig. 2 SEM images of nano engineered cement (a) at 5 hr, (b) 24 hr

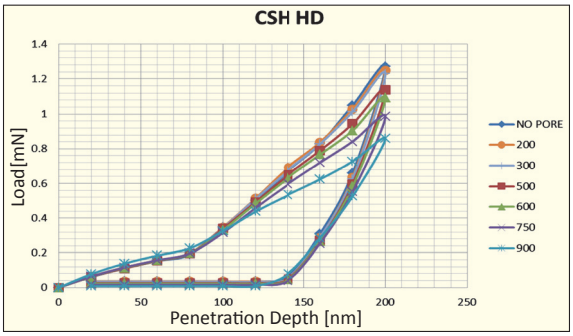


Fig. 3 Response of high density CSH obtained from simulated nanoindentation

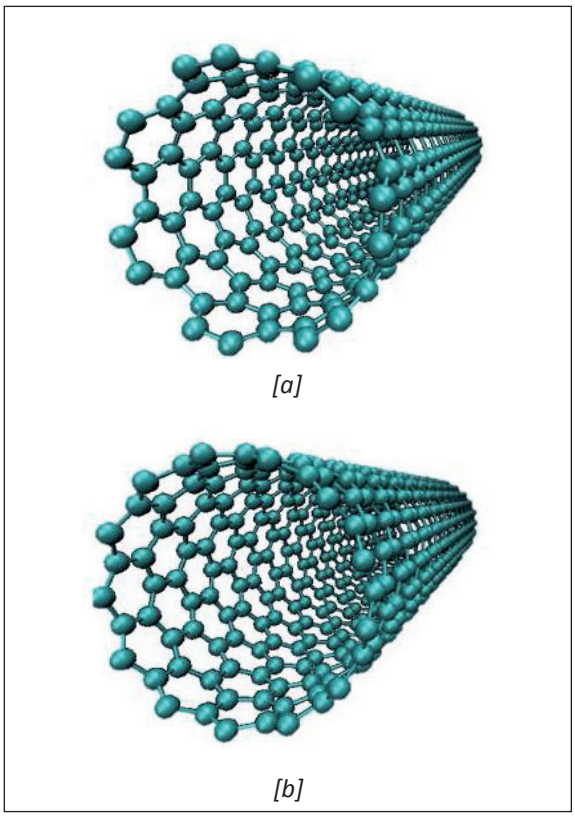


Fig. 4 Atomic structure of [a] 7,7 and [b] 13,0 nanotube

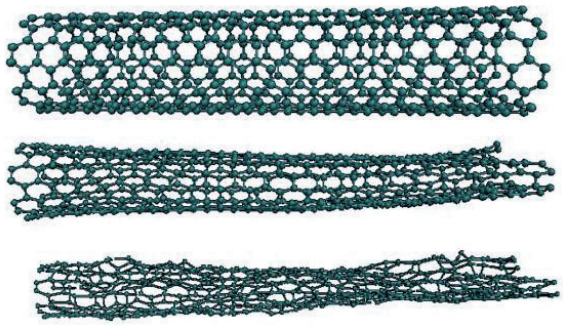


Fig. 5 Damage process of CNT under axial tension captured using MD

been carried out to determine the indentation response of a rigid axisymmetric indenter on a semi-infinite elasto-plastic matrix. It is found that the elastic modulus of low density and high density C-S-H is around 20 GPa and 30 GPa, respectively. The finite element method is employed to simulate the effect of material properties such as elastic modulus, contact friction, etc. on the indentation response of high and low C–S–H phases (shown in Fig. 3). In the present study, contact friction is varied from 0 to 1 with step of 0.25. Further investigations are carried out to identify the influence of local pores of C-S-H on its mechanical properties, namely, indentation modulus, indentation hardness.

The mechanical properties of nano materials such as CNT and CNT incorporated composites are not well established and the reported results are widely scattered. In order to judiciously use CNT in engineering applications, it is utmost important to understand mechanical properties of CNTs and influence of various geometrical parameters. Molecular dynamics (MD) simulations are carried out on armchair and zigzag nanotubes with various diameters. The influence of diameter and the chirality of CNT on its mechanical properties have been investigated. MD simulations were carried out using NPT ensemble with the time step of 1 femtosecond (fs) as shown in Fig. 4. The temperature was maintained at 300° K and pressure at 1 atm. CNTs were fixed at one end and subjected to constant velocity pulling on the other end using steered molecular dynamics (SMD). The spring constant of the virtual spring was 7 kcal/mol Å2 and the velocity with which it was pulled was 0.1 Å/ time step. The total

energy and the force-extension behaviour have been obtained and validated. The validated model is further used for different geometrical arrangements and the study indicates the considerable effect of various parameters on the mechanical properties of CNT. Damage sequence of CNT with different geometrical arrangements is successfully obtained using MD simulations (Fig. 5). The results of this study will be immensely useful for developing nano engineered composites. Further studies are being carried out to determine the nano-mechanical behavior of composites using MD simulations.

Team

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Synthesis of Alternative Binder and Aggregate / Filler / Fibre from Waste Materials

Scope/objectives

- Development/synthesis of identified alternative binder and aggregate/filler/fibre for concrete by
  - Characterization of conventional and non-conventional wastes
  - Studies on utility of identified source materials
- Evaluation of mechanical and durability characteristics of such concretes
- Evaluation of mechanical and durability characteristics of concrete with recycled aggregates reclaimed from construction and demolition wastes
- Formulation of recommendations on utility of alternative binder, aggregate/ filler/fibre and the new concretes

Significant achievements/contributions

The overall objective of this project is to characterise alternative binder and filler systems for concrete. Investigations on geopolymeric binder systems using various materials such as fly ash, blast furnace slag, micronized biomass silica has been the main focus as alternative binders. Copper slag and manufactured sand have been studied and characterised as alternates for river sand. Recycled aggregate especially recycled coarse aggregates obtained from various sources have been studied to find methods to improve their quality.

Geopolymeric binders with compressive strength ranging from 20 to 150 MPa have been developed under ambient curing conditions. Various tests to determine the mechanical and durability properties of concrete is being conducted. Summarily the performace of geopolymer concrete is on par with Ordinary Portland Cement (OPC) concrete. In some of the cases the water absorption and sorptivity results are on the higher side of the prescribed limit. The rate of strength gained in geopolymers is faster than in OPC. Geopolymer concrete (GPC) mixes were formulated to give a one day compressive strength of 25 to 30 MPa. A study was undertaken to understand the effect of different curing on Ground Granulated Blast Furnace Slag (GGBS) based GPC. At the age of 28 days specimens were tested for compressive strength. The different types of curing namely ambient curing, sunlight curing, water curing, steam curing and heat curing were adopted. From the studies it is found that ambient temperature curing and water curing is better compared to all the other types of curing for GGBS based geopolymer concrete. Further studies on optimization of curing regime for ultra-high performance geopolymers concrete (UHPGPC), mixes were prepared with a combination of 10 molar potassium hydroxide solution and potassium silicate as alkali activator. The experiments were conducted on UHPGPC by using different types of curing as mentioned above. One day compressive strength of the mixes was 70MPa

under ambient curing conditions. The tests are in progress for the specimens under different curing conditions at different ages. Studies were continued on the use of Micronized Biomass Silica (MBS) as a geopolymeric source material. Experiments were taken up on the GPC with varying percentage of GGBS and MBS. Trial GPC mixes were cast with different percentage replacement of GGBS by MBS (0%, 10%, 20%, and 30%). A slump of 190 mm-62 mm was obtained for mixes with varying percentages of MBS with respect to 190mm slump of 100% GGBS mix. Air curing was carried out under ambient temperature conditions. The one day and seven days compressive strength was 37.5 MPa, 38.6 MPa, 33.9 MPa, 26MPa and 55.2 MPa, 63.9 MPa, 59.5 MPa, 45.8MPa respectively for control mixes with different percentage of MBS.

MBS is used as a partial replacement for cement to improve the properties of Recycled Aggregate Concrete (RAC). It was observed that 8% replacement of MBS instead of cement in the cement mortar and concrete gave higher compressive strength than the other percentage replacement. The MBS increased the compressive strength of the recycled aggregate concrete by pozzolanic reaction. The silica content present in the MBS reacts with calcium hydroxide ($CaOH_2$), which is a cement hydration product and it forms an additional CSH gel. This gel has an ability to fill the pores present in the recycled aggregate concrete, thus results in the higher compressive strength of the recycled aggregate. In continuation of the durability studies on recycled aggregate concrete water penetration depth was carried out on cylindrical specimens of size of 100 mm diameter x200 mm length. In this test, a water column acts on the specimen for 72 hours under 5 bars of pressure, equivalent to keeping the specimens under a water column of 50 m. Water permeability increases with the percentage of incorporated recycled aggregate. The total incorporation of RCA increased by 6 times the penetration depth when compared with NAC. With the addition of fly ash/ silica fume, penetration depth of water reduced. It was confirmed that the differences observed between NAC and RAC with fly ash/ silica fume are minimal. A study was taken up to replace natural sand with M-sand. Physical properties such as particle size distribution, specific gravity and water absorption were determined as per the Indian standard specification. The M-sand analysed can be categorised under zone II as per IS 383: 1970. M25 and M30 mixes were designed and produced. The 28 days compressive strength developed were far higher than that required for their designed grade. The fresh M-sand concrete mixes had marginally less workability due to higher percentage of fine particles. The addition of mineral admixtures (fly ash or slag) improved the chloride conductivity, sorptivity and water absorption. Based on the studies, it is recommended that, in order to use M-sand as fine aggregate in concrete, certain changes have to be incorporated in mix design taking into account the higher fines to coarse particles ratio in M-sand.

Team

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Intelligent System for Smart Sustainable Buildings (IS^3B)

Scope/objectives

- Definition of frame work for structural/ architectural aspects of smart sustainable buildings
- Development of interfaces based on

cognitive science principles for training an intelligent system for structural performance and energy efficiency

- Performance evaluation of candidate solutions for selected sustainable buildings

Significant achievements/contributions

The work towards developing a Building Information Modelling (BIM) program module, to help creating a model for prototyping and for designing of sustainable eco-habitat solutions and energy efficient systems is in progress. In the proposed BIM, Autodesk product Building Design Suite 2013 is being used for creating an intelligent 3-D building model. Architecture and the orientation of a building is very important to calculate how much portion is exposed to sunlight, so that the calculation of the energy efficiency can be performed based on these parameters on the 3-D model. The Revit Architecture is used for the generation of 3-D models of a building from the given 2-D floor plans. These 3-D models can be exported in gbXML file format to energy analysis software for further calculations. 2-D floor plan of a typical building has been created in AutoCAD or Revit Architecture and the 3-D model for the given floor plan has been generated in Revit. Export of the 3-D model to the energy analysis software has been checked for typical buildings and also for further building energy analysis.

The EnergyPlus Simulation public domain software with full source code has been downloaded and installed on the Windows 7 platform and tested through simple programs. Based on the description of a building from the perspective of physical parameters and associated mechanical and other systems, EnergyPlus calculates the heating and cooling loads necessary to maintain thermal control, energy consumption by primary and secondary HVAC systems and primary plant equipments and coil loads. In order to understand the various data/information that are required by architects and building physicists, the input and output data processes for the EnergyPlus software has been studied in detail. Sample building parameters and weather data have been taken for energy simulation analysis under different time zones.

For the integrated energy design process, it is necessary to capture and generate knowledge bases specific to various related domains. In this process, it is essential to work together with a team of experts from cross-disciplinary domains from the conceptual to the final design phase. The input and output parameters to be used in the energy calculations including day light simulations has been identified, Appropriate web-based questionnaire has been designed and created to obtain all necessary and relevant parameters for a typical LEED/GRIHA rated buildings in and around Chennai and in New Delhi. Work towards development of knowledge bases for capturing and storing of the identified parameters through a back end database is also in progress.

A one day meet was organized at Engineering Services Division (ESD) of CSIR, New Delhi on 15th January 2014 in connection with the project. Representatives of six architectural firms practising in and around Delhi along with the architects from ESD participated in the meeting. The architects were briefed on the scope and objectives of the project on intelligent system for smart sustainable buildings including the conceptual design of the system proposed to be developed and also on how the cognitive engine would facilitate in the design of smart sustainable structures. The project was appreciated and all the architects unanimously agreed that the proposed intelligent system would provide a holistic solution to various issues involved in the design of sustainable structures considering all green features as prescribed by agencies such as GRIHA/LEED etc. Presentations were made by the architects from Abin Design Studios, Green Tree Building Energy (P) Ltd., Global Evolutionary Energy Design, Samyak Design Consultants Pvt. Ltd., and Design Plus Architecture. The limitations in proprietary tools were discussed in detail. The architects agreed that the

simulations generated by the proprietary tools were not accurate. The architects also felt that the capabilities of EnergyPlus, Daysim and other similar open source software need to be exploited. A questionnaire designed for capturing information into the intelligent system was distributed among the architects. From the feedback it is seen that some of the architects have shared the required information pertaining to medium or high rise buildings based on the projects executed by them. This information would serve as a valuable source of input in the design of the cognitive engine for the proposed intelligent system.

The work towards preparation of the Software Requirement Specifications (SRS) document for Intelligent System for Smart Sustainable Buildings (IS^{3}B) is in progress. The SRS contains definition of data to be processed, functional and behavioural description of the project and all the domain knowledge required for the development of each and every module of the proposed software related to IS^{3}B. It also includes the performance requirements, design constraints and the appropriate validation criteria for IS^{3}B. The details of cognitive engine, knowledge capturing, energy analysis, intelligent inferences and report module of IS^{3}B are also presented in the document. It includes all the possible parameters required for energy analysis such as weather, HVAC Systems, lighting system, building envelope, etc.

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Characterization and Performance Evaluation of Cementitious Composites

Scope/objectives

- Characterization of cementitious composite using basalt as reinforcement
- Development and performance evaluation of sandwich panels using basalt and glass fabric as reinforcement
- Experimental and numerical investigations on strengthening of RC beams using fiber and fabric reinforced concrete
- Development of pultrusion technique for fabric reinforced concrete
- Characterization of pultruded composite
- Mathematical modelling of fiber and fabric reinforced concrete using micro-meso-macro concepts

Significant achievements/contributions

Development of sandwich panels

Preliminary investigations have been carried out on three types of sandwich panels developed by using profile steel sheet as core material and by using different concretes as skins by reinforcing with basalt fabric, glass fabric and steel fibers. The panels have been named according to the materials used for skin. When glass fabrics along with cementitious binder is used as skin, it is named as fabric reinforced concrete (FABcrete) panel; basalt fiber reinforced cementitious binder along with basalt mesh when used as skin is named as basalt fiber reinforced concrete (BFRC) panel and while using cementitious matrix and steel fibers as skin, the panel is named as ultra high strength concrete (UHSC). All the sandwich panels have been designed and developed to find their suitability as a structural floor member under flexural load. For all the panels, profile steel sheet of size 650x 1500x1.2mm has been used as a core material

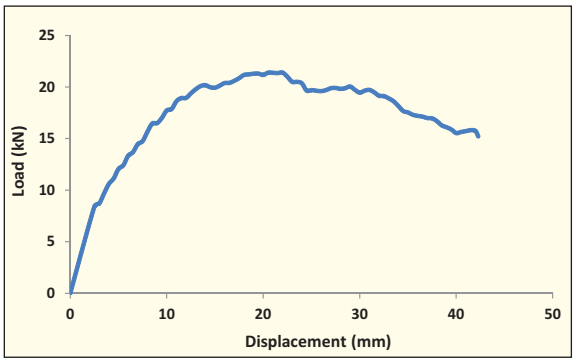

Fig. 1 Load vs displacement behaviour of FABcrete sandwich panel

between the top and bottom skins. In the case of FABcrete panel, both top and bottom skins of size 650x1500x10mm have been pre-fabricated separately. The connection between skin and core has been provided with self-tapping screws of 4mm diameter at 150mm spacing. For BFRC and UHSC panels, bottom skin of size 650x1500x10mm has been pre-fabricated and the top skin is cast-in-situ. Hat sections have been provided in the trough part of profile steel sheet in order to reduce the volume of UHSC and BFRC in the compression zone, while performing the cast-in-place process. The total thickness of sandwich panel in all the cases is 70mm. The weight of FABcrete panel, BFRC panel and UHSC panel are 75kg, 130kg and 150kg respectively.

Experimental investigations have been carried out to determine the response behavior of the three sandwich panels. All the panels have been tested under simply supported conditions. From the load vs displacement behavior of FABcrete

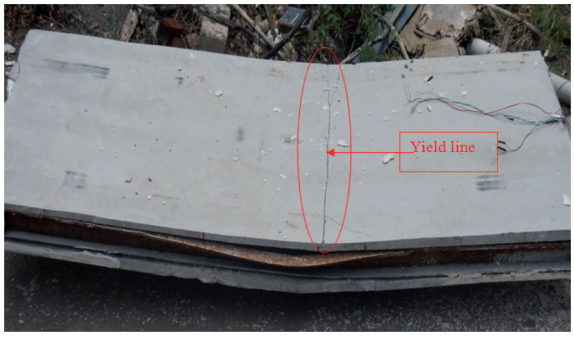

Fig. 2 Yield line formation in top skin of BFRC sandwich panel

panel, it is observed that the ultimate load is 21.39 kN for 20 mm deflection. In the post peak region, panel showed reduction of 25.29% in ultimate load corresponding to a deflection of 42mm (Fig. 1). The first crack appeared at the bottom side of the panel corresponding to a load of 16.24 kN. Bearing failure near screws on the top skin of FABcrete occurred corresponding to a load of 18.28 kN. Profile steel sheet bent is observed at a load of 17.65 kN and the corresponding central deflection is 34mm. In the case of BFRC panel, it is observed that the ultimate load taken by panel is 28kN and the corresponding displacement is 12 mm. The final failure of BFRC panel is attributed to crushing of top compression skin due to compressive stresses on the top skin (Fig. 2). From the experimental investigations of UHSC panel, it is observed that the ultimate load taken by the panel is 42.5kN corresponding to a maximum displacement of 43mm. Predominant crack propagation along the width of the panel is observed on the bottom face of the panel before final failure of this panel. In all cases, the maximum deflection is recorded as 43mm and experiments were stopped due to safety condition in the experimental setup.

Development of pultrusion technique for fabric reinforced concrete

A textile reinforced concrete prototyping technology (TRCPT) has been developed to produce fabric reinforced concrete sheets. One of the main function of this technology is pultrusion and the set-up differs from the existing pultrusion set-up available elsewhere. The TRCPT process developed employs a mortar applying system with a pressure plate controlled by the pneumatic system. A fabric feeding unit is attached to the set-up for the laying of the fabric. An arrangement is provided for stretching of the fabric during sheet production. A mortar leveling unit, which is controlled by a manual steering is attached to the mortar applying system to improve the bonding characteristics of mortar and fabric. A pulling unit is attached in the set-up wherein the fabric reinforced concrete

sheets are pulled through a roller mechanism. This will ensure a smooth finished product with improved bonding properties.

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Performance Evaluation of Concrete with Bio-minerals

Scope/objectives

- Isolation and identification of suitable microorganisms for synthesizing bio-nano composites.
- Characterization of the co-existence of guest-moieties in the bio-cementitious materials using micro-analytical techniques.
- Unveiling the form-structure-functions of the bio-nano composite generated by the microorganisms and using bio-organic template.
- Studies towards the evaluation of bio-mineralized concrete properties.

Significant achievements/contributions

Bio-calcification or biomineralization is a process that leads to the formation of minerals using the biologically or biotechnologically mediated route. Calcium carbonate is one such biomineral that is secreted by the ureolytic bacteria. The biomineral thus generated contributes towards strengthening and improvement of cementitious and sandy materials. The isolate IsAH-2 has been inoculated to the calcium carbonate precipitation medium and is observed to grow well in the medium with promising calcium carbonate precipitation. The colonies appeared white, dry with calcium carbonate precipitation. The colonies have been

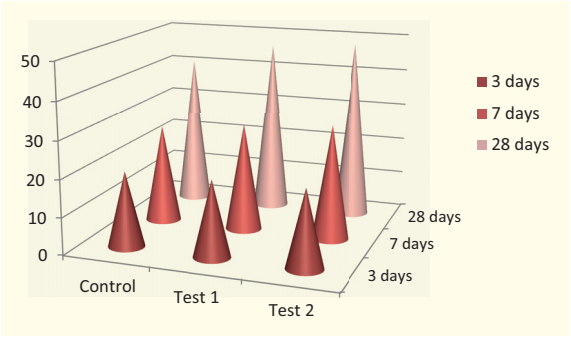

Fig. 1 Evaluation of compressive strength

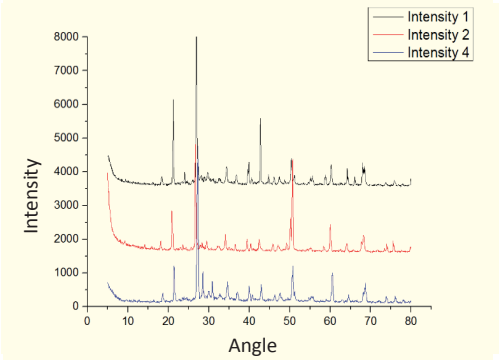

Fig. 2 XRD of mortar specimens

observed under optical/stereo microscope to confirm the crystal formation and to know the structure of the crystals. The crystals are found to be rhombohedral in structure.

Bacterial cement mortar cubes incorporated with isolate IsAH-2 have been cast to study the enhancement in the mechanical properties. It is found that bacterium incorporated specimens gain strength significantly compared to control specimens at all ages of curing as shown in Fig 1. The results reveal that bacteria has precipitated the calcium carbonate crystal which has lead to increased compressive strength. Also it is noted that the presence of urea in the curing medium has induced the bacterial precipitation. XRD has clearly indicated the presence of the calcium carbonate in the control, Test-1 (cured with 1g urea/L of water) and the Test-2 (cured with water) mortar specimens. The peaks observed at the 2θ (Bragg's angle) = 29 has confirmed the presence of calcium carbonate. Intensified peaks have confirmed a increase in the concentration of the precipitation as shown in Fig 2.

The pozzolanic materials like blast furnace ash, fly ash and silica fume are being used as supplementary cement replacement materials. The preliminary studies have revealed that the chemical composition of the bagasse and husk ash is appropriate for its application as a pozzolan, mainly due to its high silica content. On optimizing the combustion mode and temperature required for maximum extraction of silica from the agro wastes, it is understood that the silica is accumulated with increase in temperature and confined combustion modes. The X-ray diffractogram of the samples revealed that manually burnt ash samples showed the presence of polymorphs of silica crystals but the crystallization property and formation of the pure crystals of silica is increased when it was further burnt at 100°C, at micro wave conditions and 500°C at furnace conditions. This clearly depicts that the crystal formation and decomposition is maximum at the elevated temperatures. Sugarcane bagasse ash has shown the presence of the characteristic clear, crystalline and sharp peak of quartz and cristobalite. The cause for this is that the increased temperature has supported the decomposition of other debris and concentration and purification of the silicon materials in the sample. Whereas, in the rice husk ash the temperature applied for decomposition is not sufficient as it has not supported the total decomposition of the other debris and concentration of the silicon materials present in the sample.

There are two ways of precipitation of minerals, namely, the chemical precipitation and the biological precipitation. In this study, the $CaCO_3$ precipitate is prepared by: (i) Volumetric methods, and (ii) Gas diffusion method. Various kinds of biochemical precursors have been used in the precipitation method for synthesis of $CaCO_3$. The XRD results (Fig. 3) show the crystal structure of $CaCO_3$. No other peak in XRD pattern except $CaCO_3$ is observed, indicating the purity of the synthesized compound. All the reflections could be indexed to the calcite phase. Along with calcite phase, vaterite phase formation also occurs due to the effect of bio-organic template.

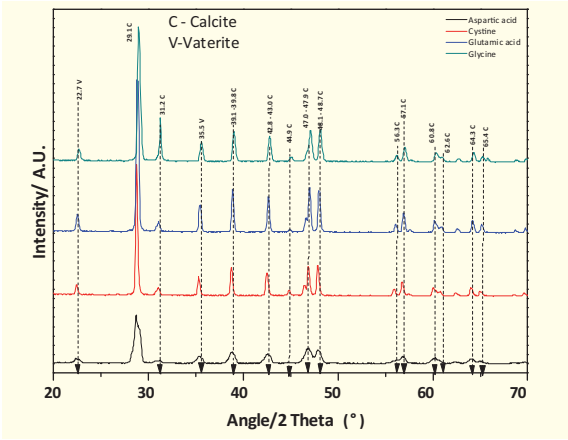

Fig. 3 XRD Analysis of synthesized calcium carbonate

Infrared spectra of $CaCO_3$ crystals produced in different amino acid systems shows the presence of simultaneous occurrence of absorption peaks at 876 and 712 cm^{-1}. These peaks indicate the presence of calcite. It is observed that there is a slight discrepancy between experimental and published IR values which could be attributed to the required grinding of a $CaCO_3$ sample with KBr to produce pellets. The absorption peak at 1409 cm^{-1} with a shoulder at 1498 cm^{-1} should be assigned to v3 characteristics of amorphous calcium carbonate. Along with the calcite peak, vaterite form of calcium carbonate is also observed at 850 and 1082 cm^{-1}.

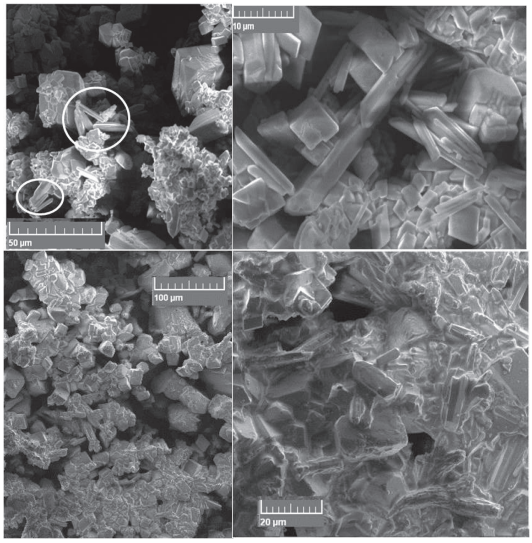

Fig. 4 SEM studies on synthesized calcium carbonate

SEM micrographs of $CaCO_3$ particles obtained in different amino acids solutions in water with pH 11.0 are shown in Fig. 4. It is observed that the

structure of agglomerated particles of $CaCO_3$ are rhombohedral and in regular plate-like form. Along with the rhombohedral calcite, needle shaped particles also form due to the formation of vaterite.

Effect of calcium carbonate incorporation in cement hydration process has been studied by XRD analysis starting from 1hr of hydration up to 90 days. It is noted that hydration of sulphate bearing moieties occurred very fast at the initial stage. The formation of hydrated C_3S is also observed as the peak intensity decreases with progress in the hydration process. It confirms the formation of semi crystalline C-S-H. Ettringite peak intensity disappears after 7 days which signifies the formation of monosulphate. Further the overall peak shift has been observed at 1hr, 3rd day and 7th day of hydration indicating the change in lattice expansion due to liberated heat.

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Effective Structural Protection against Extreme Loads

Scope/objectives

- Numerical and experimental investigation on impact performance of multi-layered cementitious fibre composites
- Strategies for improving blast resistance of structures/structural components
- Development and performance evaluation of seismic protection systems
- Formulation of recommendations for effective protection

Significant achievements/contributions

Impact behaviour of multi-layered cementitious fibre composite panels

The impact performance exhibited by 100 mm thick multi-layered cementitious fibre composite panels is taken as the basis to decide on the materials and layer configuration of the composite panels for experimental investigation. It is inferred that due to mismatch of acoustic impedance between core and outer layers, delamination occurred at interface. This is taken into consideration in arranging of layers by ensuring negligible mismatch in acoustic impedances between adjacent layers. Therefore, lay-up sequence and material are selected to have smooth propagation of shockwave through the material and thereby minimizing delamination during ballistic impact. Compressive strength and acoustic impedance for SIFCON with different percentages of fibres, Plain Concrete (PCC), Latex Modified Concrete (LMC) and mild steel are evaluated and shown in Fig. 1. It can be noted that the compressive strength increases with increase in percentage of fibre up to 8%. It is observed that there is negligible difference in compressive strength for fibre percentages between 8 and 10. Beyond 10%, the compressive strength is found to decrease. Acoustic impedance is found to be almost constant with percentage of fibres and is nearly equal to that of plain concrete. Acoustic impedance of LMC is nearly equal to that of plain concrete. It can be seen that acoustic impedance of mild steel is nearly four times that of plain concrete. Hence, introduction of steel in the form of wire mesh or perforated plate leads to delamination.

The study conducted on LMC shows that by adding Styrene Butadiene Rubber (SBR) improved water resistivity, flexural (Fig. 2) and tensile strengths (Fig. 3). However, it is found that there is negligible effect on compressive strength of LMC as compared to plain concrete. Increase in tensile strength makes it suitable as infill material for the applications involving impact resistance. The water absorption is as low as 1.76% for LMC with 8% SBR dosage. Compared with PCC, LMC with 8% dosage absorbs 38.64% less. Due to this property, LMC may provide stronger bond between two cementitious composite layers.

The effect of fibre content and thickness of panels on the high velocity impact response formed the second phase of experimental investigations. Panel thickness of 60 mm with minimum 10% fibres is found to be resistant to ballistic impact, while a panel of 50 mm thickness is found to be perforated. However, a panel of 75 mm thickness and 8% fibre volume is found to be adequate to defeat both the projectiles.

Strategies for improving blast resistance of structures/structural components

Numerical investigations are carried out on metallic sandwich panels with tube core to ascertain its applicability as structural protection system against blast loads. The principle involved is that under blast load, tube core undergoes plastic deformation to absorb major portion of the energy imparted by the blast load and transmits only a fraction to the protected structure. In this investigation, a metallic sandwich panel with tube core is taken for study. Numerical model of tube core sandwiched between cover plates, representing the

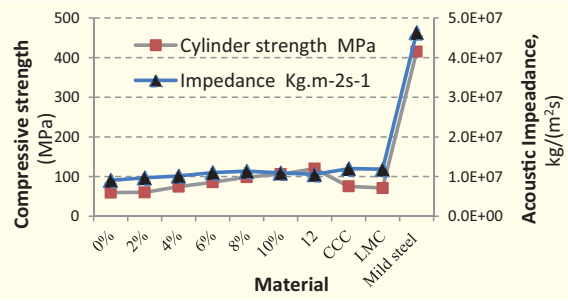


Fig. 1 Compressive strength and acoustic impedance for materials

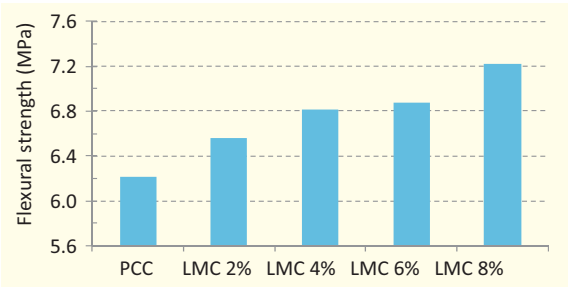


Fig. 2 Flexural strengths

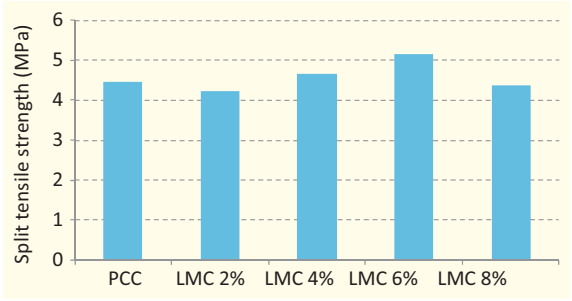


Fig. 3 Split tensile strengths

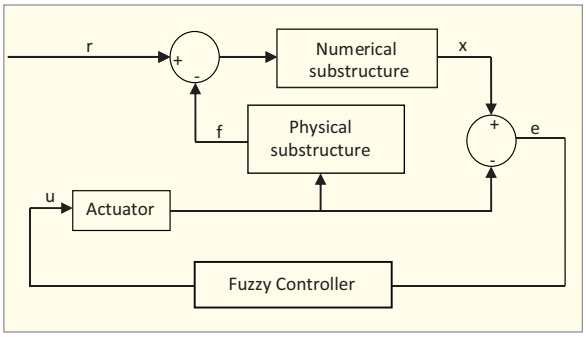


Fig. 4 Block diagram of controller based on fuzzy logic

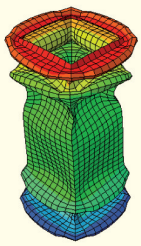
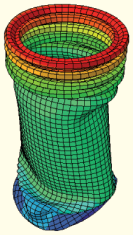
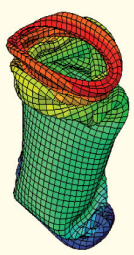
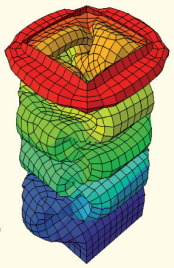
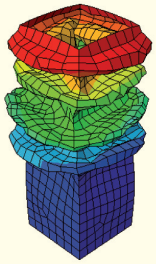
Configuration					
Deformed Shape					
Tube axi al deformation, mm	37.56	42.06	46.89	50.11	41.27
Mean reaction force, kN	16.37	14.17	12.44	12.73	15.45

Table 1 Blast response of metallic sandwiched panel with tube core

geometrical as well as material characteristics, is generated. An impulse of magnitude 55 Ns is applied in the nonlinear numerical simulations. The blast pressure is assumed to be uniform over the surface of the top plate. The pulse duration is chosen as 17.32 µs based on a problem available in literature. It is observed that blast response of panel obtained from the present study is in close agreement with the reference values, thus validating the numerical model.

Purpose of the parametric investigation is to identify effect of tube shape and provision of cut-out at mid-height of the tube on the energy transmitted to the protected structure. Tubes

of square, circular or elliptical in shape are considered. Three possibilities are identified with regard to provision of cut-out, namely, no hole, holes on either side and holes on all four sides at mid height of the square tube. Hence, in total, five different cases are analysed (Table 1). Responses in terms of tube deformation, energy absorbed and reaction force are obtained. Peak value of the reaction force and tube deformation are found to be highly sensitive to the cut-out provided in the tube. Providing a small circular cut-out in the tube is found to significantly influence the reaction force and deformation pattern. It is observed that provision of cut-out reduces the peak value of reaction force. From the numerical investigations, the panels having square tube cores with holes on either side or those having elliptical tubes are found to perform better under an impulsive load of 55 Ns.

Seismic protection system

A new controller based on fuzzy logic for Real Time Hybrid Testing (RTHT) (Fig. 4) is proposed. Advantage of a fuzzy-logic-based controller is that it is rule based and involves far less computations. Performance of the proposed controller is compared with the controllers widely used in RTHT through numerical simulations of a sub-structured linear and nonlinear single-degree-of-freedom system for two different damping ratios. The fuzzy logic controller is found to have the least error index for the chosen nonlinear system and performs satisfactorily for a linear system. Furthermore, the effectiveness of the proposed fuzzy logic controller is demonstrated by numerically evaluating the response of a portal frame pinned at one of the beam column joints for the El-Centro earthquake. The displacement time history response is found to closely match with that of the emulated system. Based on the studies carried out, it is decided to use the fuzzy controller for the performance evaluation of the seismic protection system based on RTHT.

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Development of Risk-based Methodologies for Inspection/ Maintenance Scheduling of RCC/ PSC Structural Components

Scope/objectives

- Development of stochastic models for: creep of concrete, and, long-term prestress losses, using appropriate existing database
- Development of methodologies for prediction of long-term performance degradation of RCC/PSC structural components – leading to their inspection/ maintenance scheduling

Significant achievements/contributions

A deterministic multi-scale model is developed for determining the concrete creep compliance using the recent formulations given in literature for upscaling the viscoelastic properties of concrete. The inputs required for the multi-scale model are: i) mix-design details, ii) elastic properties of cement paste constituents, iii) reaction kinetic model parameters and, iv) volume change parameters. Among these, ii to iv are intrinsic material parameters. This model can be used for determining the creep properties at the design stage. Validation studies are carried out using the experimental results available in literature. The results of experimental investigations (data taken from the catalogue of creep test results created at CSIR-SERC) on concrete square prisms of size 70 mm $\times$ 70 mm $\times$ 280 mm size are considered. From the results obtained, it is noted that as the age at loading increases, the rate of increase in basic creep compliance with time reduces. Also, the basic creep compliance increases at a higher rate at the initial stages, but reduces to a constant rate as age of concrete increases. The values of basic creep compliance obtained using the multi-scale model are in agreement with the experimental results (Fig.1), indicating usefulness of the proposed model for predicting basic creep of concrete. At present the model can be used only for predicting the basic creep. Further investigations are required for including the drying creep component. The creep compliance obtained from the multi-scale model is used in the finite element modelling for estimating the time-dependent creep deflection in a reinforced concrete beam, for which experimental results are available in literature. The finite element software ANSYS is used for this purpose. From the results obtained, it is noted that the long-term deflections obtained using finite element analysis are in satisfactory agreement with the experimentally observed deflections reported.

The long-term prestress losses are computed for the VPT post-tensioned prestressed concrete box girder bridge span using the models proposed in recent International and Indian codes of practices, viz., recent Indian Standard code of practice for prestressed concrete (IS 1343:2012), recent Code of practice for Concrete Road Bridges (IRC 112:2011), Eurocode 2:Part 1-1:2004, American Concrete Institute (ACI 209R:2010), American Association of State Highway and Transportation Officials (AASHTO LRFD:2007) and Precast/Prestressed Concrete Institute (PCI 2005). The computed values are compared with the prestress losses obtained from field investigations (Fig.2). From this study, it is noted that IRC 112:2011 and IS 1343:2012 are able to predict the observed trend of the field measurements and are conservative.

Towards inspection scheduling of the PSC girders in a bridge, a procedure integrating: i) the Polya Urn model (which is a pure birth process model), and, ii) prestress loss estimation method of ACI along with B3 model for creep- and shrinkage-strain estimations, and ACI model for relaxation, within stochastic framework, is proposed. It is assumed that the bridge consists of nominally similar PSC girders exposed to nominally similar environment. Stochastic analysis of the prestress loss is carried out at the design stage using Monte Carlo simulation, and the expected prestress losses at different times

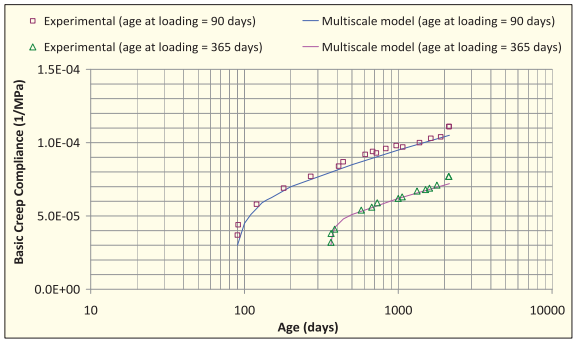

Fig. 1 Comparison of values of basic creep compliances obtained using multi-scale model with those from experimental investigations reported in literature

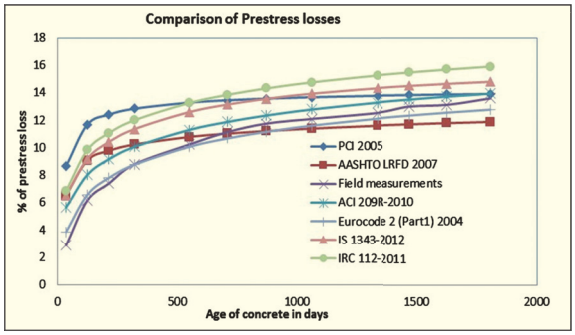

Fig. 2 Comparison of prestress loss estimates using different prestress loss models with those computed using the measured strain values for VPT post-tensioned prestressed PSC box girder bridge

are estimated. These values are considered as the allowable losses, since they are used in the design of the girder to meet the service life requirements. A small number of realisations are randomly selected from the simulation, which are assumed to represent the girders inspected/monitored for strains. From these realisations, the probabilities that exactly 50% of the girders in the bridge would have prestress losses more than the allowable prestress losses at any time are determined using the first passage probability of Polya urn model. These probabilities are compared with the value of acceptable probability (which is normally decided by the codal committees/decision making authorities), and inspection is scheduled at the time at which acceptable probability is reached. However, at present, there is a need to develop guidelines on selection of values for the acceptable probability. The procedure is

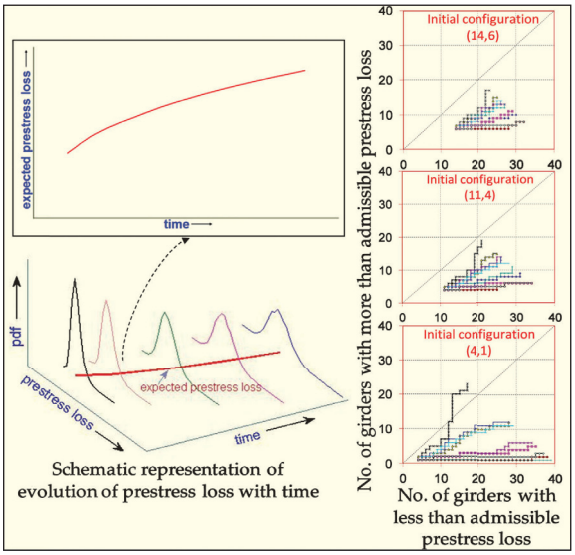

Fig. 3 Schematic representation of prestress loss with time and typical sample paths obtained using Polya Urn model for prestressed concrete bridge stock

illustrated by considering a bridge consisting of one hundred PSC bridge girders. Three typical scenarios, namely, *a*) five-, *b*) fifteen- and, *c*) twenty- PSC girders are inspected/monitored for strain, are considered (Fig.3). It is found from the results obtained that at initial ages, scenario *a* gives conservative results when compared with results obtained using scenarios *b* and *c*. While scenario *a* gives conservative results at higher ages also, the probability values obtained for the three scenarios are comparable. The probability values at different times can be compared with the value of acceptable probability to schedule the inspection.

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Sustainable Construction Technologies for Societal Development: Phase - I (CSIR 800 Program)

Scope/objectives

- Revival and transfer of selected CSIR-SERC technologies to the society
- Adoption and development of suitable technologies for affordable housing and construction products
- Evaluation and retrofitting strategies for masonry buildings

Significant achievements/contributions

This project on sustainable construction technologies has been initiated as a CSIR 800 programme which aims to improve the quality of life with the help of science and technology. Some of the technologies developed by CSIR-SERC are taken up for revival.

Technology for funicular shell

Towards reviving a CSIR-SERC technology, shallow precast funicular shell for construction of floors and roofs is being taken up. The funicular shell square in plan with inner dimension of 1mx1m is investigated. Masonry mould is prepared with wooden plank at bottom and in-fill masonry on the board and smooth top surface with the shape to the shell structure. The rises of the shell on discrete grid points are calculated and are made with nails pegged on the wooden board and filled with masonry to bring out the shape. The top surface is smooth finished. The rise of the shell is 80 mm at centre to maintain a shallow profile. Shallow funicular shells of 30 mm thick; 20 mm thick, 15 mm thick and 10 mm thick are cast and tested for its load carrying capacity. A novel semi pre-fabricated system of flooring system consisting of funicular shells, thin beams and top layer is under development. Thin concrete beam for supporting the shells has been designed and mould for casting inverted T shaped concrete thin beams has been fabricated. Trial mix for casting the beams has been designed and the mix is intended for casting the beam has been tested for compressive strength.

Geopolymer technology

Portland cement is widely used as a binder material for concrete in a wide variety of constructions. However, this cement is proving to be ecologically hazardous due to its inherent high internal energy content besides occurrence of emission of large quantities of carbon dioxide during its production. Therefore, there has been intense search for alternative binder material. As an alternate, Geopolymer for concrete is being studied. Geopolymer is a type of binder that can be obtained by activating silicon dioxide and aluminium oxide present in industrial wastes, such as Ground Granulated Blast furnace Slag (GGBS) and fly ash, to form inorganic polymer binder system. Effect of molarity of alkaline activators solution in geopolymer concrete is being studied. Studies on the influence of GGBS on strength of geopolymer concrete is being carried out using different types of mixes. Experimental studies are carried out on the development of strength for various grades of Geopolymer Concrete (GPC) with varying molarity. Different molarities of sodium hydroxide solution 3M, 5M and 7M are taken to prepare different mixtures. The curing period improves the polymerization process with the increase in molarity of the solution. GPC mix formulations with compressive strength ranging from 10 to 60 MPa are developed and GPC specimens tested for their compressive strength and the stress-strain characteristics. Investigations on workability, various mechanical and structural properties at element level have been carried out. The test results indicate that the geopolymer concrete can be used for construction of structures and structural components. With the scarcity of fired clay bricks, concrete building blocks and pavers are the most widely used. The

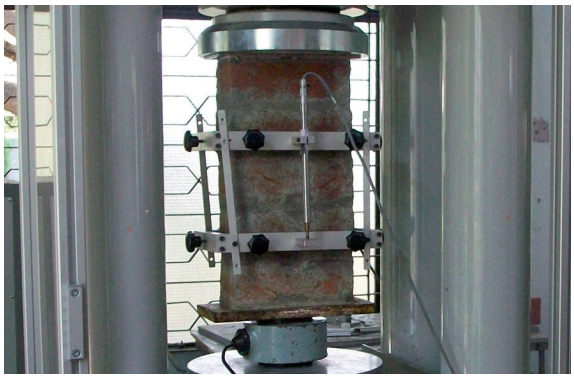
use of eco-friendly GPC in lieu of ordinary Portland cement concrete for the production of geopolymer brick and paver blocks is investigated. Casting of geopolymer bricks, paver blocks and cubes is done and testing for compressive strength and water absorption is done. From the investigation, it is found that GPC paver blocks based on high volume GGBS show excellent compressive strength (up to 54 MPa) and low water absorption (4%). By varying the mix proportions, it is possible to produce M-30 to M-50 grade paver blocks suitable for use in pedestrian and heavy traffic areas as per IS 15658:2006. The studies have demonstrated the feasibility of producing GPC paver blocks and building blocks of different grades on a large scale. As these blocks are non-Portland cement based and utilize large volumes of industrial wastes, they can be used as viable eco-friendly alternative to conventional concrete blocks.

Technology for stabilised soil blocks

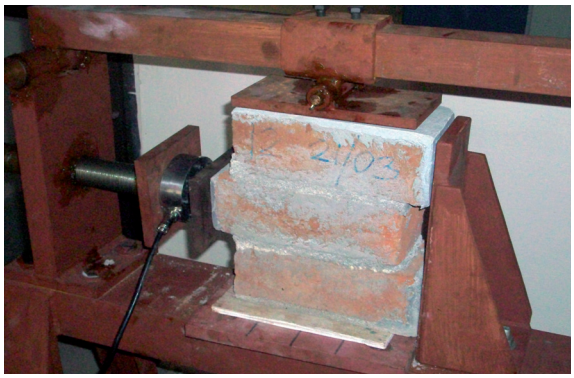
Cement stabilized soil blocks are developed with industrial waste material such as fly ash, copper slag and GGBS as additional replacement material to cement. A simple technology has been developed to produce these blocks. The blocks are water cured for strength. The technology is green and more suitable for application to the rural society as there is no burning of bricks, no steam curing or compacting machinery in this technology. Fine clay, required for making clay bricks, is a depleting natural resource and becoming scarce and costly. Ordinary Portland cement is added with other stabilizers such as fly ash, copper slag with different mix ratios. Blocks of size 200 mm x 200 mm x100 mm were cast and tested for 7th day and 28th day strength. The average compressive strength of 11 N/mm^2 has been obtained on 28th day.

Technology for brick masonry

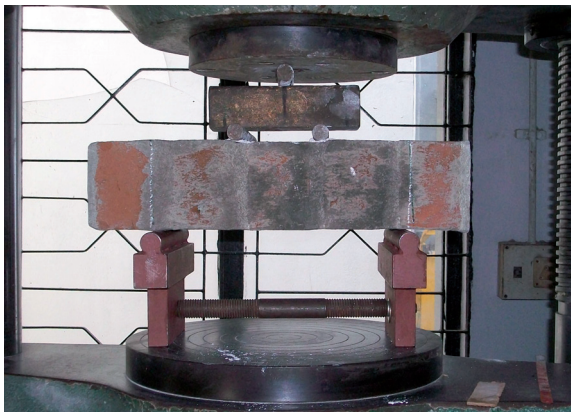
Towards improving the performance of masonry structures, experimental studies have been carried-out on a confined masonry wall panel. The technology adopted in this study is to



Compression stress-strain behaviour



Shear strength



Flexural strength

Split-tension strength

Fig1. Experimental studies on mechanical characterization of brick masonry

provide tooth like grooves on the masonry interfacial surface and the confining concrete. This ensures proper load transfer and integral action for lateral loads. The ultimate in-plane lateral load capacity of the confined masonry wall panel was proven to have been improved by more than four times, when compared to that of unreinforced masonry panel. The technique implies that this system can be useful to the society for earthquake resistant construction, as it absorbs more energy. Confined masonry structures are commonly adopted nowadays for residential buildings and this technique may be recommended as a useful construction practice.

Evaluation of unreinforced brick masonry buildings

It is important to characterize the mechanical properties of unreinforced brick masonry with respect to seismic performance evaluation/ assessment of unreinforced brick masonry dwellings, particularly in the Indian scenario. Procedures for carrying out tests on brick masonry specimen have been evolved based on a detailed review of literature and standards. Further, tests on brick masonry specimens and its constituents have been carried out. The tests on brick masonry specimens include compression stress-strain behaviour, flexural bond strength, shear strength and split-tensile strength.

As a part of development of retrofitting strategies, experimental studies on mechanical characterization of brick masonry including the statistical variations are carried out. For performing these tests, procedures are evolved based on review of literature, and also, few customized equipments have been designed and fabricated. As a part of utilization of industrial wastes /by products, an exploration on the possibility of manufacturing brick out of 'wastes only' is made. In an attempt to make use of the oxy-acetylene welding waste and fly-ash for stabilization, it is found that, the early age (10 days) compressive strength of the bricks so produced are satisfactory and the studies are continuing.

Micro Small and Medium Enterprises (MSME) brick cluster, Tirunelveli established a Vertical Shaft Brick Kiln (VSBK) and is run by Ganga Seva Sangam at Duraisamiapuram. Two scientists visited this site and other common facility centre at Panaiyur Panchayat in that brick cluster. They assessed the problems faced by the local manufacturers in brick making such as cracks developed in the brick and breaking of edges. Studies show that the wet bricks while moulding itself develop cracks due to deficiency in clay content. To improve this, it was suggested to add additional clay and thorough mixing without clots. It is observed that there are some undulations in the conveying roller which leads to cracks developing on the surface of the bricks. Small deviation in the cutting angle attributing for the edge breaking was observed and suggestions were given to rectify the above mentioned issues.

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Condition Assessment of Concrete and Heritage Structures using Advanced NDT Techniques

Scope/objectives

- Experimental and numerical investigations for condition assessment of concrete structures
- Experimental and numerical studies for condition assessment of heritage structures

- Durability studies on reinforced concrete and other materials
- Recommendations/guidelines on condition assessment of concrete and heritage structures

Significant achievements/contributions

Experimental and numerical investigations for condition assessment of concrete structures

The impact-echo method generally is not preferred for identification of defects at depths lesser than 50mm owing to the difficulties in generating very high resonant frequencies with manual impacts. An attempt is being made in identifying the defects due to the frequency shift caused by the presence of defects. For this, a concrete slab 1.5m long, 1m wide and having 0.15m thickness is used as test specimen. Artificial voids are created and placed at known locations within the slab specimen. The voids are of same size (150×150mm) placed at varying depths (between 15mm and 90mm from top surface) using cover blocks, as shown in Fig. 1. The material used for the specimens is high strength concrete with 28 day cube compressive strength of 71.3MPa.

On collecting data along the sections A-A, B-B and C-C (Fig.1) and processing them using codes written in Matlab, frequency shifts are observed. Along section A-A, frequency shift is observed at three locations (Fig.2a) indicating the presence of a defect at these locations. Measurement along section B-B indicate negligible frequency shift (Fig. 2b) indicating a completely solid portion without any major flaws in concrete. On observing section C-C, it is observed that there is also a similar shift in frequency as in the case of section A-A at three locations indicating defects. The shift in frequency of the stress pulse indicates the presence of defects in solid concrete. Hence, this method could be employed in the field for defect identification at shallow depths.

Ground Penetrating Radar (GPR) is a well known technique for locating embedded targets in concrete. Radar images obtained through GPR can be used to locate embedded rebars. However, rebar diameters cannot be estimated through a geometrical analysis of migrated images, since, the wave length (for the frequencies normally used for concrete inspections are 1-2 GHz) in general will be in the order of 5 - 10 cm, which is quite larger than the diameter of rebars. As a result migrated images tend to show rebars with overestimated diameters. Hence, image processing technique is being used for the estimation of rebar diameter. For estimating the diameter of rebar trial tests have been carried out using a box of size 1.2m×1.2m×0.4m. The box was filled with a mixture of fine aggregate and coarse aggregate for a depth of 0.3m leaving 10cm empty. Three different diameter rebars 16, 20 and 25mm were placed over the dry mix and the remaining portion was filled with dry mix. GPR data has been collected and the corresponding radargram has been processed using sobel edge detection technique (image processing technique) for the estimation of rebar diameters. Figure 3 shows the radargram for a typical bar diameter of 25 mm. The radargram has been processed using sobel edge detection technique to estimate rebar diameter (Fig. 4). Using the sobel edge detection image and the available models reported, the rebar diameter is estimated. The estimated rebar diameter is 26.15 mm, which is very close to the actual diameter of 25mm. The

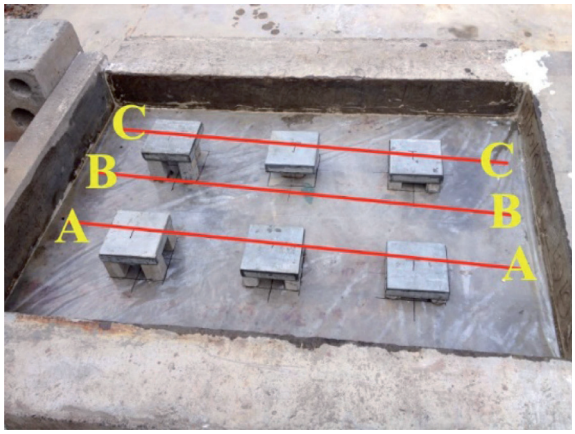
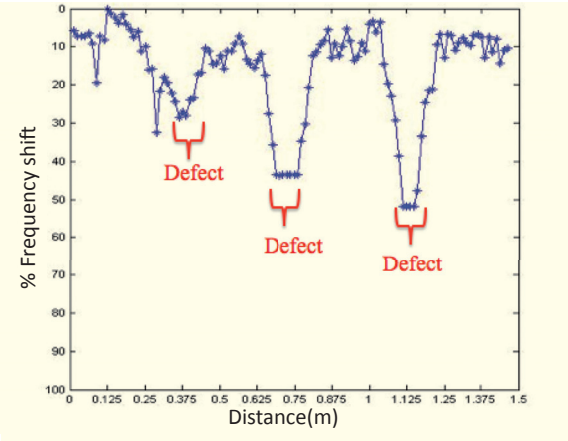
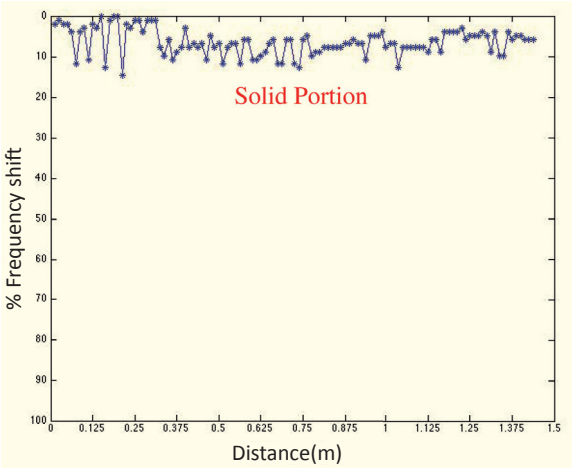


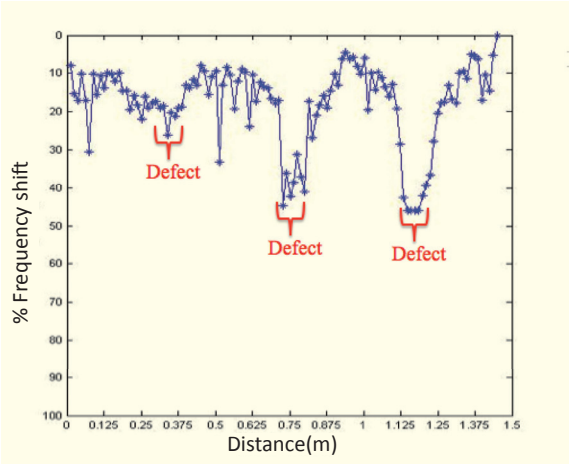
Fig. 1 Slab mould with defects in position before casting



(a). Section A-A



(b). Section B-B



(c). Section C-C

Fig. 2 Percentage frequency shift along three sections

diameters estimated were close to the actuals and the difference in estimation is in the range of 4 – 20%. Further studies are in progress.

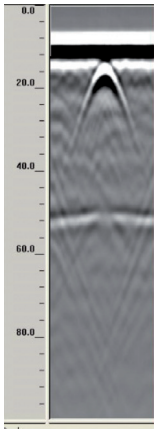


Fig.3 Radargram image

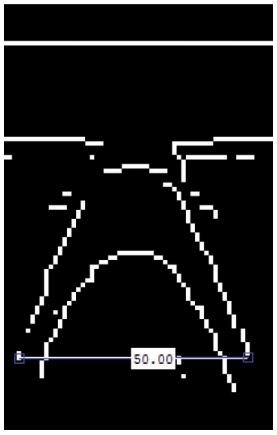


Fig. 4 Image after edge detection

Fig. 5 Exposed reinforcements of beam

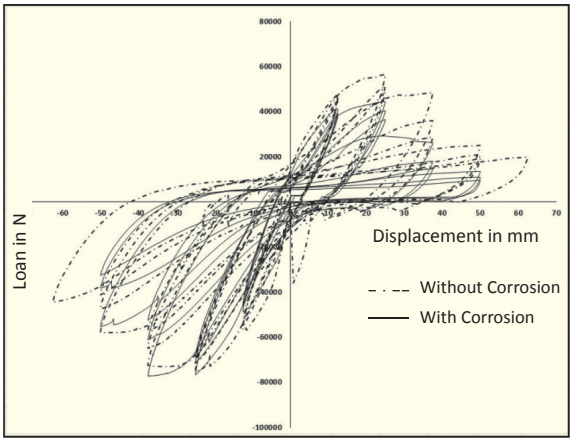


Fig. 6 Load vs. displacement curves of specimen with and without corrosion

In order to understand the effect of reinforcement corrosion on structural capacity, the beam column joint specimen is subjected to accelerated corrosion by immersing the beam segment and joint region in 3.5% NaCl solution. A potential of 64V DC power pack is

Fig. 7 Specimens (cast as per ASTM G109) exposed to alternate wetting and drying

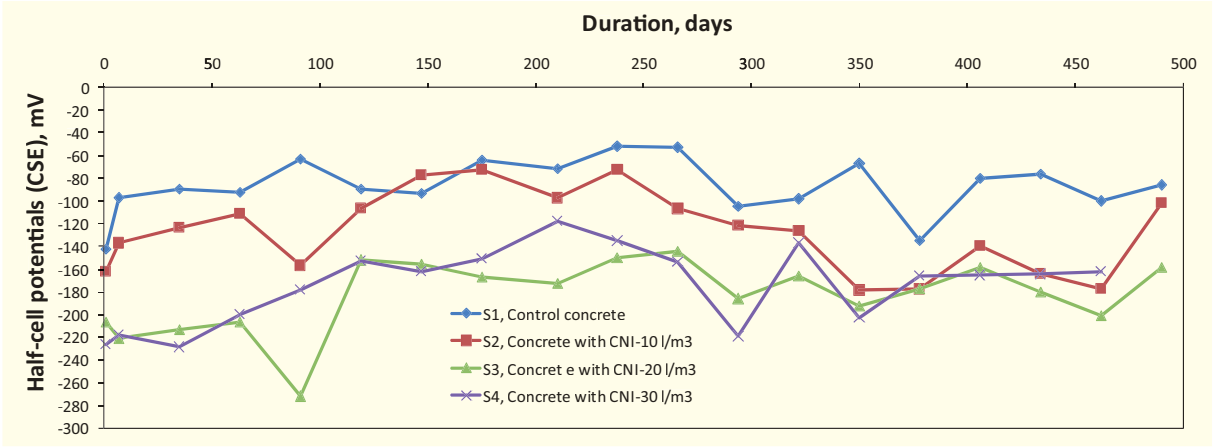


Fig. 8 Half-cell potential values on specimens with different dosages of CNI

used for applying impressed current of 5 amps for a period of seven days. Visible corrosion cracks and stains are observed on the beam segment and joint region. The beam column joint is tested under reverse cyclic loading with increased levels of displacement cycles. At each displacement level, the specimen is subjected to three cycles.

The test data of beam column joint (with corroded reinforcement) subjected to reverse cyclic loading is processed and the reinforcement bars of the tested specimen are exposed as shown in Fig. 5. Corrosion is observed on beam main reinforcement and on the stirrups of the beam, column and joint region. The level of corrosion is found to be higher in the case of stirrups. The load versus displacement curves of beam column joint specimen with and without corrosion is shown in Fig. 6. From the results of reverse cyclic test, it is observed that the load carrying capacity of corroded specimen is decreased by 2.9% and 21.2% in compression and tension load cycles respectively. It is also observed that the load carrying capacity of the corroded specimen decreased for each loading cycle compared to that of the corresponding uncorroded specimen. The maximum percentage weight loss due to corrosion in the top, bottom main reinforcement and stirrups is found to be 2.10%, 3.54% and 4% respectively. Further, experiments are planned to evaluate the mechanical properties of corroded reinforcement bars.

Durability studies on reinforced concrete and other materials

One of the major durability problems in Reinforced Concrete (RC) structures is the rebar corrosion due to the ingress of chlorides. Some of the mitigating techniques is the use of blended cements, corrosion inhibiting admixtures, etc. Extensive studies have been carried out in the laboratory and found Portland Pozzolana Cement (PPC) concretes are more superior in resisting chloride induced corrosion even in the presence of cracks up to 0.2 to 0.4 mm. The accelerated corrosion (impressed voltage) tests carried out earlier do not show any improvement in the corrosion resistance with the addition of Calcium Nitrite Inhibitor (CNI). Hence, long term studies are planned to

evaluate the performance of CNI. The concrete specimens cast as per ASTM G109 with different dosages of CNI, viz.,10 l/m3, 20 l/m3 and 30 l/m3 of concrete are exposed to alternate wetting and drying (Fig. 7). Half-cell potential measurements are being recorded at every fortnight during wetting and drying cycles. Fig. 8 shows the half-cell potential values collected using Copper/ copper sulphate electrode (CSE) during wetting cycles for a period of nearly 500 days. The half-cell potential values are in the range of -52 to -142; -72 to -179; -144 to -272 and -118 to -229, respectively for control concrete (S1); concrete with 10 l/m3 of CNI (S2); concrete with 20 l/ m3 of CNI (S3); and concrete with 30 l/m3 of CNI (S4). The trend of half-cell potential values indicates that the control concrete (without CNI) show lower negative half-cell potentials.

Experimental and numerical studies for condition assessment of heritage structures

Most of the heritage structures are constructed by brick and stone masonry. In order to understand the basic NDT&E parameters on brick masonry structures, Ultrasonic Pulse Velocity (UPV) and Rebound hammer tests are carried out on selected brick masonry units nearby ACTEL. The UPV values observed are in the range of 410 m/sec to 1790 m/sec; 405 m/sec to 1190 m/sec; and 1795 m/sec to 3760 m/sec respectively, for unplastered, one side plastered with cement mortar, and both sides plastered with cement mortar brick units. The Rebound hammer values are in the range 31-38. The range of values is lower to that of values for concrete and is in agreement with the reported literature. Tests are carried out using Ground Penetrating Radar (GPR) on selected brick masonry walls for the reliable thickness determination of brick masonry walls. Scanning and radar images are collected using 1.6 GHz antenna and evaluated for the thickness. Specimens with different variables such as different brick leafs, voids, etc., are cast for testing and calibration of different NDT techniques on brick masonry.

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Development of Pre-Engineered Light Weight Structural Components / Systems

Scope/objectives

- Experimental investigations to study the axial and flexural behaviour of light weight panels (EPS and foam concrete panels) with different height to width ratios
- Experimental investigations on behaviour of different types of joints/connections for large light weight composite panel assembly
- Formulation of guidelines and recommendations

Significant achievements/contributions

Construction of a building using Expanded Poly-styrene (EPS) panel at CSIR-CLRI Campus, Chennai for demonstration purpose is undertaken. The building consists of RCC columns and roof beams with EPS panels used for roof slab and for wall panels. Suitable dowel bars are provided in the RCC members for connecting the EPS panels. Concrete of 40 mm thick is placed over the EPS panels supported on the roof beams.

For studying the behaviour of EPS panels subjected to axial and flexural load, specimens of size 1.22 m x 1.22 m and 1.22 m × 1.80 m having a thickness of 0.15 m are cast using M40

grade concrete (Fig.1). Strain gauges are fixed on wires parallel to the panel surfaces and on the shear connectors at three locations (Top, middle and bottom of the panel).

Further, specimens are cast using EPS with different slenderness ratios for studying the behaviour of wall/roof panels under axial compression and bending. Compressive tests on 150 mm cubes with normal concrete and cubes inserted with EPS of 100 mm cube are carried out and observed to be 46.53 MPa and 26.50 MPa, respectively.

One of the main objectives of this study was to identify the most appropriate type and design of connections for large wall and roof panels particularly to resist seismicity. Hence, a comprehensive literature review is made to understand the findings from studies conducted to analyse and investigate the behaviour of precast concrete systems assembled with typical connections or joints under simulated earthquake loading. A good design for connecting two or three large walls and roof panels not only is able to withstand the required loadings, but is also to overcome the difficulties encountered during the erection. The design must be practical and constructable too. Taking the above into consideration a suitable connection system (device) has been devised. This device consists of two MS plates of size 108 mm x 82 mm and thickness 10 mm and the plates are connected to MS pipes of 20 mm dia. OD and 16 mm ID by welding at the centre of the plates.

Four different types of connectors are designed for connecting large panels depending upon the number of panels that are required to be connected. Joints for placing two or three wall and roof panels are designed by providing male and female coupler type arrangements. Suitable moulds are fabricated for casting the wall panels with connector arrangement. These connectors need to be inserted and connected by welding with main rods (4 Nos.) of RCC frame work surrounding the wall panels. Two wall panels of size 1.20 m x 1.20 m having a total thickness of 150 mm are cast with the connectors. The behaviour of connectors and the capacity of joints are studied by setting suitable test arrangements.

Prefab pre-cast large light weight wall and roof panels using EPS were used to construct a demo building in CSIR-SERC campus. The large wall and roof panels tested for seismic and push

Fig.1 Casting sequence of EPS test specimens

G+1Storey building used for seismic study

Window lintel using EPS

EPS roof panel for connecting two units

Two units of G+1 storey building

Demo building before colour washing

Final view of demo building

Fig. 2 Demo building at CSIR-SERC using prefab large light weight wall and roof panel using EPS

over at ASTaR lab were used for this purpose. The prefab building studied was G+1 and has total height of 6.20 m. There was no structural damage observed on the pre-fab building when the structure was subjected to seismic and pushover tests. Removing of the prefab building from ASTaR building was found difficult since the height of building was 6.20 m. Therefore, it was decided to separate the ground floor unit and first floor unit into two pieces by cutting the prefab building at first floor level using concrete saw for easy removal from the lab. The two units were shifted from the lab and placed near ACTEL building. These two units were converted as demo building as shown in Fig.2.

Permeability characteristics of sandwich panels was evaluated by inserting EPS of 100 mm cube in 150 mm cube mould and finished with 25 mm thick concrete all around. The specimens were weighed before placing for permeability test and observed to be 5.13 kg and 8.13 kg for cube with EPS and normal concrete, respectively. The specimens were set under permeability test and followed the standard procedure as per DIN 1048. The permeability test gives a measure of concrete's resistance against the penetration of water at 28 days after casting specimens. The concrete specimens were exposed to a water pressure of 0,5 N/mm² (72.5 psi or 5 bar) for a period of three days. Specimens were considered failed if water permeated through the opposing surface or through the sides. Immediately after termination of the tests, specimens were cut and measured for the depth of water permeation. It has been found that both the specimens behaved in similar manner and observed to be 2.5 mm to 3.00 mm. The percentage of water absorptions found were 0.19 %. This indicates that the EPS in large wall and roof panels can be used.

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Analytical and Experimental Studies on GFRP-Steel Hybrid Towers

Scope /objectives

- Studies on GFRP roof top towers/masts and hybrid towers
- Analytical and experimental studies on GFRP-steel hybrid connections
- Preparation of design recommendations/ guidelines

Significant achievements/contributions

To determine the optimum parameters governing the tensile behaviour of joints, a series of experiments were conducted on GFRP plates and angle sections by varying the diameter, number of bolts, edge, pitch distances and plate washers. Experiments were conducted by varying the no. of bolts, diameter and bolt lines (Figs. 1 to 3). Maximum tension capacity was achieved by using more number of smaller diameter bolts arranged in multiple gauge lines. Experiments were conducted on compression members at element and substructure level. The behaviour of compression member prior to failure was similar to the code but the final failure was different. The compressive strength was far less than the predicted values. Based on these studies, a 9 m high hybrid triangular based communication tower was designed, fabricated and tested (Refer Fig. 4) for the specified wind speed and antennae configuration. From the analytical and experimental investigations the following design guidelines/ recommendations were formulated.

- The modulus of elasticity and the maximum tensile stress of GFRP material varies between 18 to 30 GPa and 290 to 350 MPa depending upon the fiber content.
- For tension and compression members made of GFRP sections, it is recommended to provide a minimum edge and pitch distances of 4d.

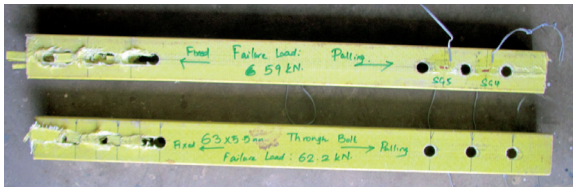

Fig. 1. Tested specimen (63 x 5.5mm) square hollow section

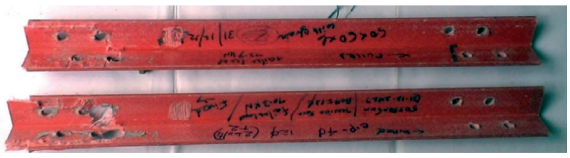

Fig. 2. Tested specimen (50 x 6 mm angle) with bolts along gauge line

Fig. 3 L75x75x6 mm angle with 6# 12 dia. bolts: along CG line

Fig. 4 Steel-GFRP 9 m high hybrid rooftop microwave tower during test

- Bearing stress can be considered as 0.8 F_{utc} ultimate tensile strength for the design of joints with steel bolts.
- To achieve maximum joint strength in angle section subjected to tension, minimum bolt diameter and maximum number of bolts shall be provided in more than one gauge line.
- The maximum tensile capacity observed in tests for angle sections connected on both the flanges is equivalent to 81% and 64% of net section capacity according to IS: 800 and IS:802 codal provisions respectively.
- GFRP 90° angle sections as compression members shall be checked for torsional flexural buckling also if the slenderness ratio exceeds 50. Specimen with slenderness ratio less than 50, the connections shall be designed to prevent local crushing of the GFRP material between the bolts.
- Maximum compressive stress on an axially loaded angle section can be considered as 40 to 50% of the maximum tensile stress observed in the coupon test depending on the flange width to thickness ratio.
- The compression capacity of single flange connected bracing member can be considered as 70 to 80% capacity of both the flanges connected leg member.
- Based on the analytical and experimental studies it is recommended that GFRP 60° angle sections shall be designed based on equivalent radius of gyration governing the torsional flexural buckling.
- Buckling resistance for GFRP 60° angle sections with width to thickness ratio greater than 15 is significantly less, since the failure is governed by torsional-flexural buckling and for a given sectional size and length, the torsional-flexural radius of gyration increases with increase in thickness. Hence, GFRP 60° angle sections with width to thickness ratio greater than 15 are not recommended.
- It is recommended to connect the secondary bracings with main members using two bolts to provide the required restraint to the main member.
- The GFRP roof top towers are economical since the weight is 44% less compared to steel tower and hence it is recommended to use GFRP towers for smaller heights.
- The hybrid tower, i.e. steel angles for leg members and GFRP angles for all other members offers an economical solution since the weight of hybrid tower is 36% less compared to steel tower and the stiffness is also closer to steel tower.

Team

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Studies on Fatigue and Fracture Behaviour of Materials and Components of Sustainable Structures

Scope / objectives

- Development of accelerated fatigue investigation methodology/procedure for structures exposed to aggressive environment
- Analytical and experimental studies on fatigue and fracture behaviour of special and sustainable structural materials and components
- Advanced fatigue and fracture studies on prototype piping components for energy sector

Significant achievements/contributions

Static and fatigue studies on concrete beams reinforced with GFRP bars

The use of Fibre Reinforced Plastic (FRP) bars to replace steel bars has emerged as one of the many techniques put forward to enhance

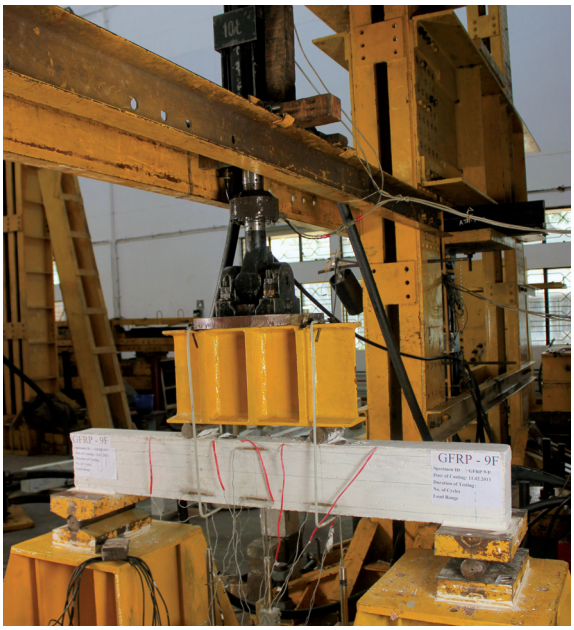


Fig. 1 Fatigue test set-up for concrete beams reinforced with GFRP bars

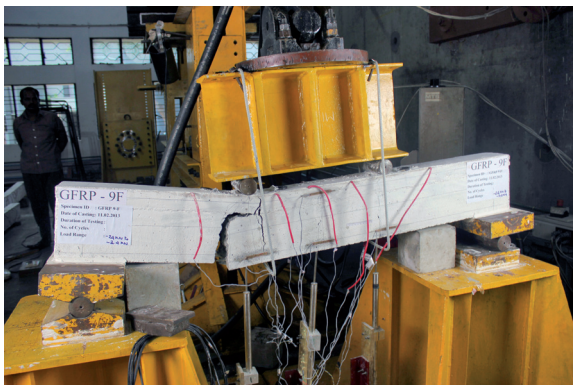
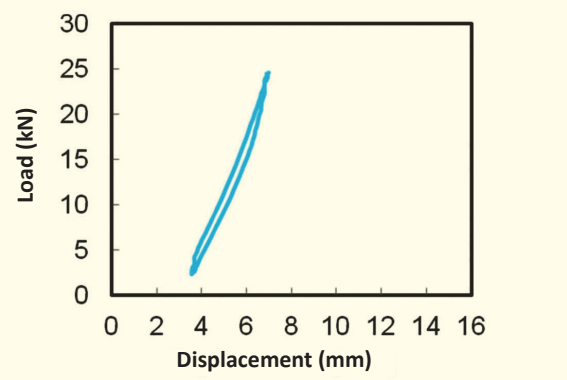


Fig. 2 A view of concrete beam reinforced with GFRP bars after failure

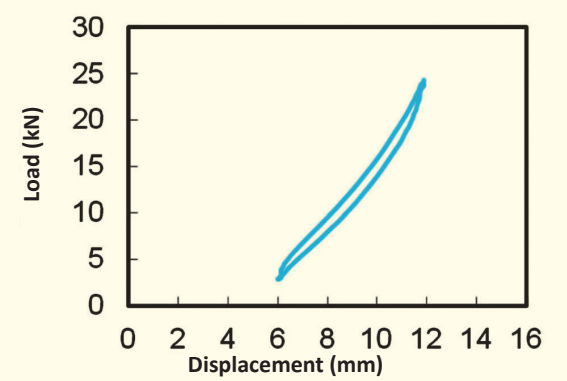
the corrosion resistance of reinforced concrete structures. FRP bar is gaining more and more attention as a reinforcing option for concrete. If correctly applied in the infrastructure area, composites can result in significant benefits related to both overall cost and durability. Other advantages include high strength and stiffness to weight ratios, resistance to corrosion and chemical attack, controllable thermal expansion and damping characteristics, and electromagnetic neutrality. In this background, investigations on static and fatigue strength of concrete beams reinforced with Glass Fibre Reinforced Plastic (GFRP) and TMT bars were carried out to study the flexural behaviour. The studies included tensile strength evaluation of GFRP and TMT bars, static strength evaluation of concrete beams reinforced with GFRP and TMT bars and fatigue investigations on concrete beams reinforced with GFRP bars. Fatigue investigations were carried out on concrete beams reinforced with 10 mm diameter GFRP bars under four different load ranges with a load ratio of 0.1. The load ranges were fixed in such way that the maximum cyclic load corresponded to 40%, 50%, 60% and 70% of the average ultimate static load carrying capacity of the three numbers of concrete beams reinforced with GFRP bars. The corresponding load range values were 21.6 kN, 27.0 kN, 32.0 kN and 37.8 kN. Out of the nine concrete beams, two were tested at 40%, three at 50%, two at 60% and the remaining two at 70% of the average ultimate static load carrying capacity of the concrete beams reinforced with GFRP bars. The beams were tested under four point bending with inner and outer spans of 450 mm and 1350 mm respectively. In all the GFRP beams, cracks initiated in the very first cycle of fatigue loading, when the load was being set to mean value before starting the fatigue load cycles. The values of average number of cycles to failure, for the beams under the four different load ranges, were 5708, 1286, 3224 and 293 respectively. Based on the results of fatigue studies carried out on concrete beams reinforced with GFRP bars under four different load ranges, load range vs. number of cycles curve was obtained.

Fatigue crack growth studies on SA 333 Gr.6 steel

Fatigue Crack Growth (FCG) studies were carried out on a Compact Tension, C(T), specimen made of SA 333 Gr. 6 carbon steel to obtain fatigue crack growth constants. The C(T) specimen had a V-notch. The length, width and thickness of the specimen were 105.6 mm, 110 mm and 10 mm respectively. ASTM E 647-08 : "Standard Test Method for Measurement of Fatigue Crack Growth Rates" was followed in preparing the test specimen and carrying out the fatigue experiment. Constant amplitude fatigue load



1st cycle



5593rd cycle

Fig. 3 Load vs. displacement curves during fatigue test for a typical concrete beam reinforced with GFRP bars

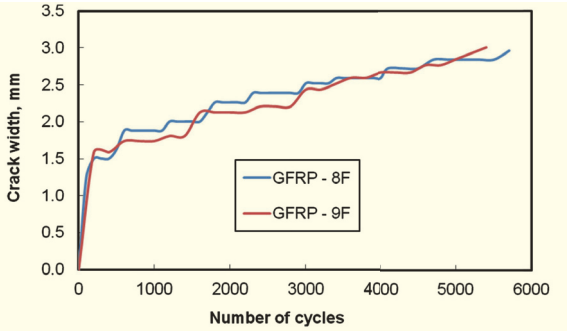


Fig. 4 Typical crack width vs. number of cycles curves obtained during fatigue test

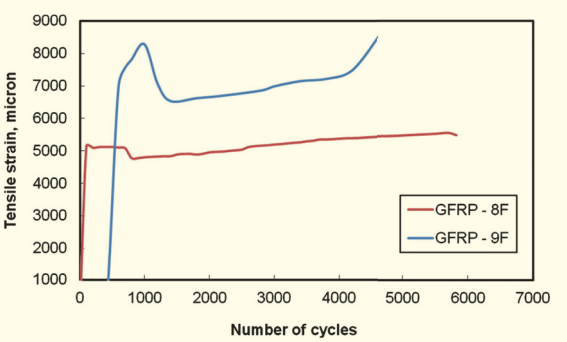


Fig. 5 Typical tensile strain vs. number of cycles curves obtained during fatigue test

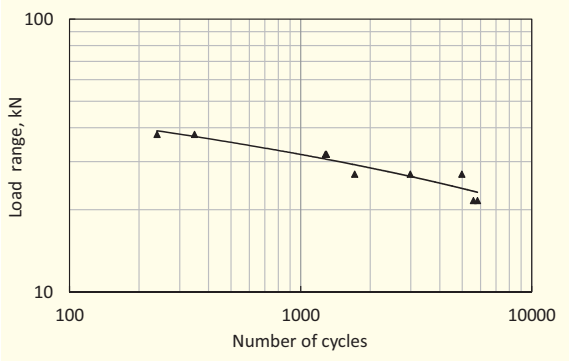


Fig. 6 Fatigue studies on concrete beams reinforced with GFRP bars: Load range vs. number of cycles curve

was applied on the specimen using a ±250 kN capacity fatigue rated UTM. The test frequency was maintained in the range of 5 Hz to 15 Hz and the load ratio was 0.5. The maximum and minimum load values were 18 kN and 9 kN respectively. The load values were fixed in such way that most part of the test specimen was under elastic condition.

Crack growth was observed and images of surface crack length were recorded at regular intervals

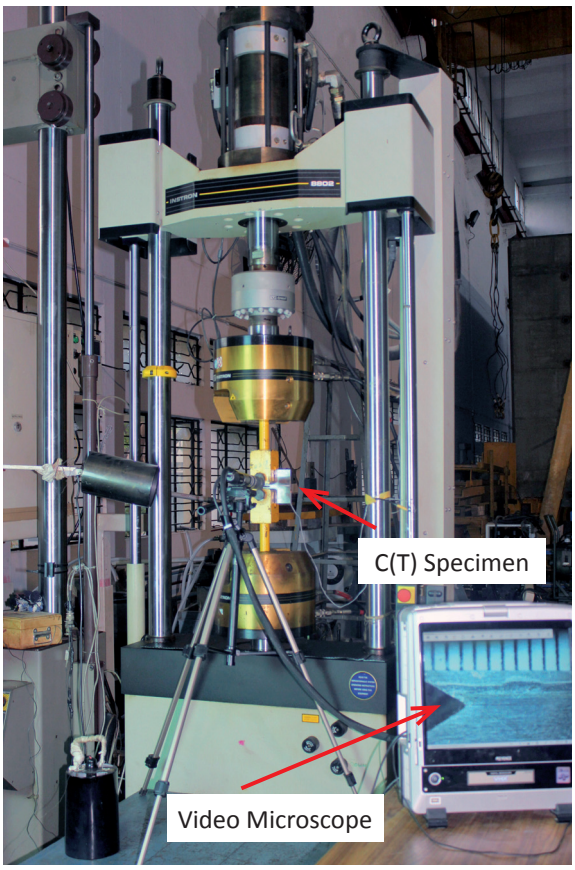


Fig. 7 Fatigue crack growth experiment on C(T) specimen FCOF10-8(V)

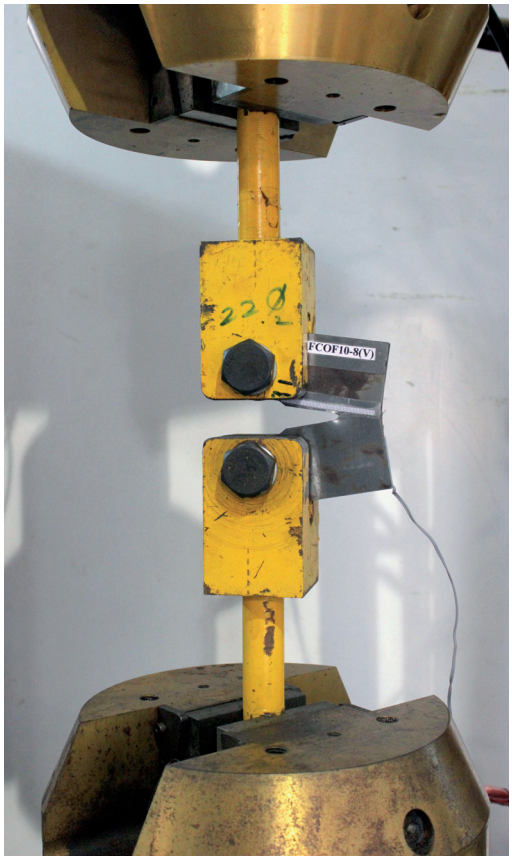


Fig. 8 Close-up view of C(T) specimen after failure

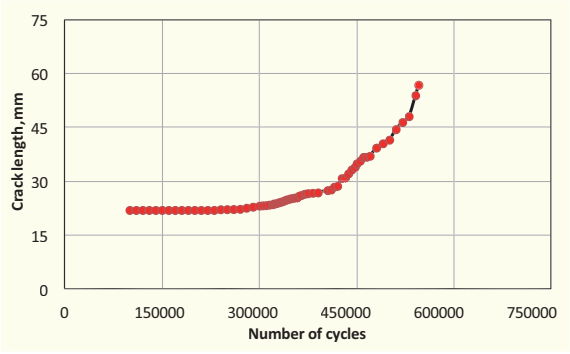


Fig. 9 Crack length vs. number of cycles curve

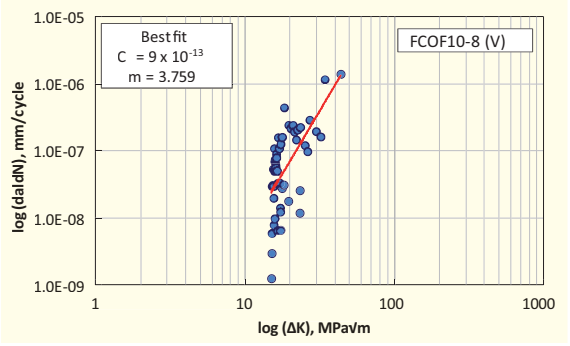


Fig. 10 Crack growth rate vs. SIF range curve for specimen FCOF10-8(V)

of fatigue cycles using a video microscope. The number of cycles for crack initiation was 240000. The FCG test was continued till the crack length became 56.6 mm. The corresponding number of cycles was 547068. The crack growth data were anlaysed and using Paris law, FCG constants *C* and *m* were determined. The values of *C* and *m* were found to be 9.0×10^{-13} MPa$\sqrt{m}$ and 3.7 respectively. These values will be useful in predicting the crack growth behaviour in components made out of this material.

This project has been completed successfully after achieving all the objectives envisaged.

The following conclusions and guidelines are arrived at, based on the studies carried out under the three objectives of the project, as given below:

Development of accelerated fatigue investigation methodology/procedure for structures exposed to aggressive environment

An attempt has been made to evolve a procedure for accelerated corrosion fatigue studies in the laboratory which would give meaningful results of corrosion fatigue damage happening in real time and actual environment conditions. Such accelerated studies reduce the test time drastically. Based on the corrosion fatigue tests conducted under this project, at different levels of corrosion current induced from an external source, it has been found that a current density value in the range of 1250 µA/Cm^2 to 2500 µA/Cm^2 gives good corrosion fatigue crack growth results and also corrosion fatigue process would be more pronounced than general corrosion of the specimen during the experiment.

Analytical and experimental studies on fatigue and fracture behaviour of special and sustainable structural materials and components

Two out of the three cruciform joints with load-carrying welds conforming to Constructional Detail 26, tested at a maximum stress value of 80% of the yield strength of the base material (stress range = 220 MPa) failed to satisfy the

IS 800 codal provisions. Fatigue crack growth studies were carried out on Compact Tension, C(T) specimens made of SA 312 and SA 403 Type 304LN stainless steels and SA 333 Gr. 6 carbon steel. Based on the crack growth data and using Paris law, values of the fatigue parameters C and m were determined. These values will be useful in predicting the crack growth behaviour in components made out of this material. In concrete beams reinforced with TMT bars, the reinforcement bars were found to yield before failure (crushing of concrete) whereas in the case of concrete beams reinforced with GFRP bars, the failure was sudden due to snapping of GFRP bars. Sudden failure due to snapping of bars is highly undesirable in the design of reinforced concrete structures. Based on the results of fatigue studies carried out on nine numbers of concrete beams reinforced with GFRP bars under four different load ranges, load range vs. number of cycles curve was obtained. Even at the lowest load range tested, i.e., load range equal to 40% of static load carrying capacity, the number cycles endured was so less that these bars are not desirable in structures subjected to repeated loading.

Advanced fatigue and fracture studies on prototype piping components for energy sector

In the case of carbon steel elbows with axial part-through notch at intrados and crown locations, the crack growth was insignificant, i.e., the applied load has negligible effect on crack growth, in the cases of with and without internal pressure. The fracture behaviour of elbows with axial part-through notch at intrados and crown locations was almost similar to that of a defect-free elbow. In other words, presence of axial notch at intrados and crown locations is not critical from the point of failure. Stable crack growth was observed in all the notched carbon steel elbows, which is a basic requirement for LBB justification. The pipe specimens tested with different spans under finite compliance condition have shown consistent increase in the maximum load carrying capacity with decreasing span with no sign of drooping from the peak load.

The straight pipes have undergone significant ratchet swelling (ballooning), ovalization and consequent thinning of the cross-section during ratcheting. The ballooning in straight pipes was found to be varying from 13.4% to 19.0% with respect to the original diameter in the gauge length portion. In the case of elbows, the ballooning was found to be varying from 3.8% to 5.8% and the reduction in thickness was around 12-15%.

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Studies on Steel Building Components and Connections under Environmental and Cyclic Loads

Scope/objectives

- Analytical and experimental studies on strength behaviour of steel built-up sections under simulated corrosion and fire conditions
- Investigations on behaviour of hot rolled and cold formed steel beam-column connections under cyclic loading
- Investigations on behaviour of steel concrete composite light weight panels
- Guidelines/recommendations based on the above investigations

Significant achievements / contributions made

Experimental investigations on strength aspects of uncorroded and heated tubular joints under axial compression

In order to address the corrosion effect on axial strength and behaviour of tubular built-up joints,

experimental studies have been taken up. In the present study, three hollow uncorroded steel tubular built-up joints made out of 65 NB (light) and 80 NB (medium) tubes. The specimens failed by flexural buckling at mid-height. It is also observed that local buckling in the compression side occurs in the form of rings after attaining the ultimate load near the joint region as well as the bottom of the 80NB tube. The type of buckling to which a tube is susceptible depends on both slenderness ratio and the ratio of diameter to thickness. Compression behaviour of steel tubular members subjected to various amount of corrosion and elevated temperature effect have been studied.

Microstructure analysis has been carried out on the sample specimens to understand the effect of elevated temperature and corrosion on the metal surface. From the microstructure studies, it is observed that uniform distribution of ferrite and pearlite in unheated and uncorroded sample, whereas heated sample has more ferrite than pearlite and increase in grain size. The heated and corroded sample has more ferrite than pearlite, and reduction in grain size compared to heated specimen. From the studies, it is inferred that, the initiation of corrosion might have attributed to precipitation of ferrite and carbide phases. These phases lead to setting up of micro galvanic cells within the microstructure with the carbide phase becoming cathodic and the ferrite anodic. As the rate of corrosion increases, more ferrite participates and subsequently significant change in microstructure takes place at the grain boundaries combined with weight loss. This affects the strength and stiffness characteristics of the structural element. This may be the reason for 22% strength reduction of specimen STC-2. Work towards characterisation of mechanical properties of heated steel is under progress for simulating this effect through FEA.

Experimental studies are carried out by using Fiber Bragg Grating (FBG) based sensors and conventional electrical strain gauges to monitor the strains induced in tension coupons extracted as per ASTM 8M, under monotonically increasing loads. The post yield behaviour of FBG is found to be much better than conventional electrical strain gauge. The study reveals the immense potential of FBG in severe atmosphere where conventional electrical strain gauges are not suitable.

Moment-rotation behaviour of cold-formed steel self-drilling screw beam-column connections

In order to verify the codal equations for evaluating the capacity of self-drilling screw joints, experimental studies on single-lap shear connections have been carried out. The studies have been conducted on connection between the three different plate thicknesses (3, 2.5 and 2mm). The specimens with 3 and 2 mm plates failed by bearing-tilting mode. The specimens with 3 and 2.5 mm plates failed by shearing of screw. Hence, the load is resisted by bearing-tilting and shearing of screw. Based on these studies for single screw combination, it can be concluded that (i) as the thickness reduces, the load is resisted by bearing and tilting and (ii) as the thickness increases, the ductility reduces due to screw shearing. The ultimate capacity of each specimen has been calculated analytically as per IS: 801-draft code. It is found that the values closely match with the respective experimental results. Subsequently, the connection between beam and column has been designed as per IS: 801-draft code. Based on the number of screws, the size of gusset plate has been determined.

A full scale exterior beam-column connection has been studied experimentally to understand the behaviour and failure modes. Lipped channel cross-section is chosen for beam and column. The photographic views of the column and beam specimens are shown in Fig 1. It is found that the ultimate moment capacity of the connection is about 10.5 kNm against the moment capacity of beam of about 12 kNm. The rotation at the ultimate load is 0.016 radians. The strain in beam on the compression and tension flange of the beam, remains linear till 50% of its moment capacity. The strain value of the gusset plate is 11500 and 17200 micro strain at

tension and compression side respectively. The specimen failed due to gusset plate buckling, leading to dropping of load. After the gusset plate buckling, the beam slips laterally in the direction of gusset buckling.

In continuation with the testing of exterior self-drilling screw beam-column connections, numerical model has been developed for conducting further parametric studies. The geometrical details used for the models are same as that of the experimental specimen. It is found that the results and failure modes of the FEA are closer to the experiment (Fig. 2 and Fig. 3).In order to enhance the moment capacity after attaining ultimate, the gap between beam and column, i.e. 10 mm, which is adopted in the experiment, has been varied from 0 mm to 10 mm. As the spacing reduces, part of the load is transferred to the column directly from beam flange and hence the moment capacity is retained to about 80% of ultimate moment capacity with acceptable deformation capacity as shown in Fig 4.

Fig. 1 Beam-column joint specimen

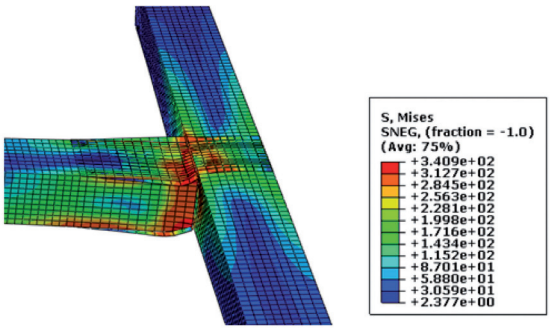


Fig. 2 Gusset buckling in FEA

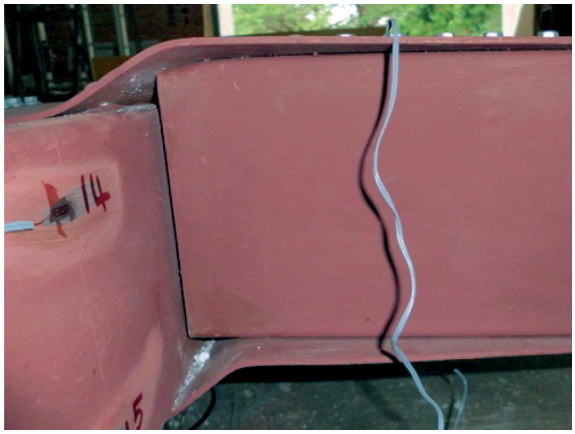


Fig. 3 Buckled view of the gusset plate

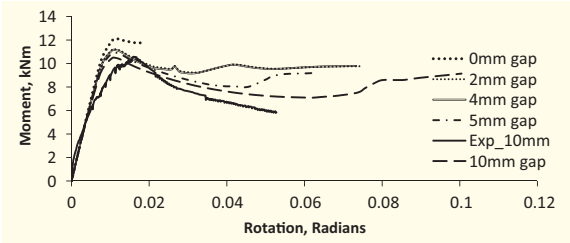
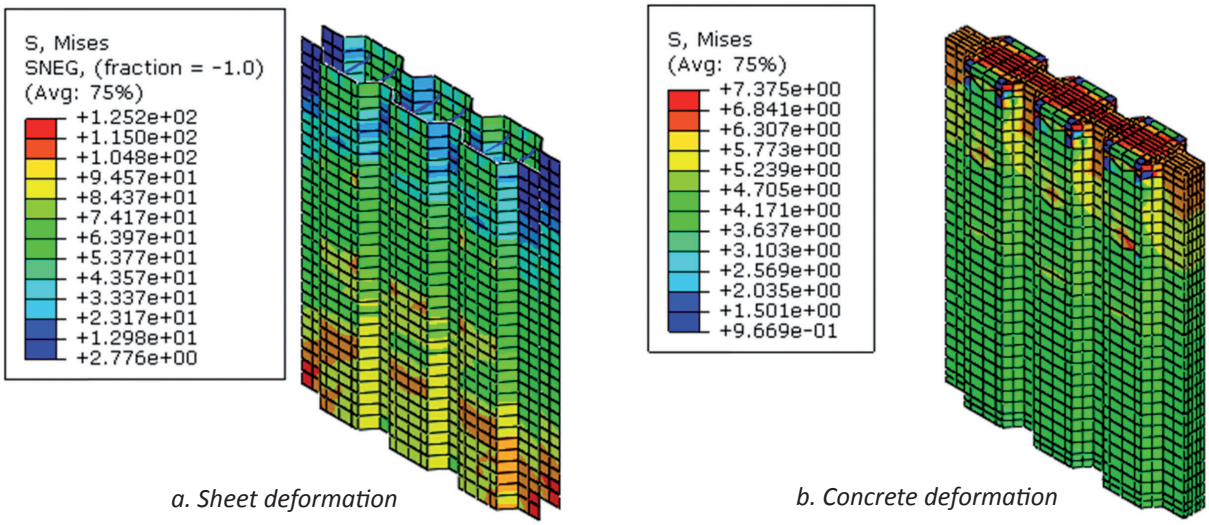


Fig. 4 Moment-rotation behaviour of beam - column joint

Numerical investigations on axial compression behaviour of light weight wall panels

Finite Element Analysis (FEA) simulation of composite wall panels under axial loading has been performed by using Abaqus/Standard software. The test data is used for developing the numerical models. The elastic behaviour of foamed concrete is modeled by using uniaxial compression elastic modulus. The plastic behaviour is modeled by using the crushable foam material model. Bi-linear stress-strain curve is used to define the behaviour of stud fasteners. Static nonlinear analysis has been conducted by considering material, geometrical and contact nonlinearities. The interface between sheeting



a. Sheet deformation *b. Concrete deformation*

Fig. 5 Stress contour of typical light weight wall panel

and concrete, channel section and concrete are modeled as “friction surface to surface contact” interaction. Fastener elements are embedded in the concrete elements by using the “embedded region constraint” interaction, which transfers shear by bond action. The interface between steel and the channel section has been given "tie constraint" interaction. The connection between stud fasteners and the sheeting are achieved by using connector elements, which constraints its two end nodes to have equal values for all six degrees of freedom. This element simply transfers any force and does not carry force by itself. This will simulate the welded connection between stud fasteners and the sheeting. The maximum stress undergone by the sheeting in specimen 1 (Fig. 5) is 125.2MPa, which is below the yield stress value due to the local bending and the crippling of sheets in between the fasteners. The concrete has undergone a maximum stress of 7.3MPa.

The comparison of FEA results with that of experimental results is made by considering the deformation and stress distribution, failure load of wall panel and load-deformation behaviour. The comparison of load-deformation behaviour is plotted and a typical comparison is given in Fig.6 for the specimen 1. The initial stiffness portion of the curve has better correlation with

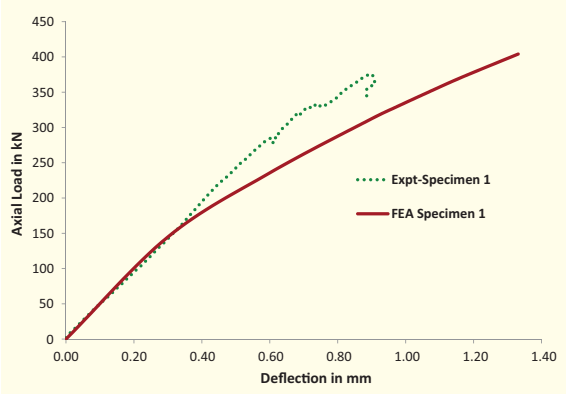


Fig. 6 Load-deformation response for typical light weight wall panel

the experimental results. The FE model over estimates the capacity in the range of 7% for the wall panel specimens as the FE model lack in predicting the experimental failure modes.

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Fatigue and Fracture Studies on Selected Steel Materials and Components

Scope/objectives

- Corrosion fatigue investigations on selected low-carbon steels
- Fatigue and fracture studies on materials and components under different loading conditions
- High cycle fatigue studies on structural connections

Significant achievements/contributions

Strain-controlled fatigue studies on M50 alloy steel

Strain-controlled fatigue studies are very useful in the design of components that undergo either mechanically or thermally induced cyclic plastic strains wherein failure may occur within relatively a few cycles, approximately less than 10^5 cycles, due to 'low cycle fatigue'. Strain-controlled fatigue test results are useful in the areas of material research and development, process and quality control, product performance, and failure analysis. Examination of the cyclic stress-strain curve gives useful information regarding the cyclic stability of a material, for example, whether a material will harden, soften, or be stable because of cyclic plastic straining.

In connection with the objective related to fatigue and fracture studies on materials and components under different loading conditions, strain-controlled fatigue studies were carried out on M50 alloy steel. ASTM E 606 : "Standard test method for strain-controlled fatigue testing" was followed in preparing the test specimens and carrying out the fatigue tests. The specimens used in the studies were fabricated from the raw material, which was in the form of a rod of 105 mm diameter. After fabrication, the specimens were heat treated. After that, minor changes in dimensions due to heat treatment were corrected by re-machining. The overall length of the specimen was 150 mm. The diameter at the gauge section was 6.35 mm

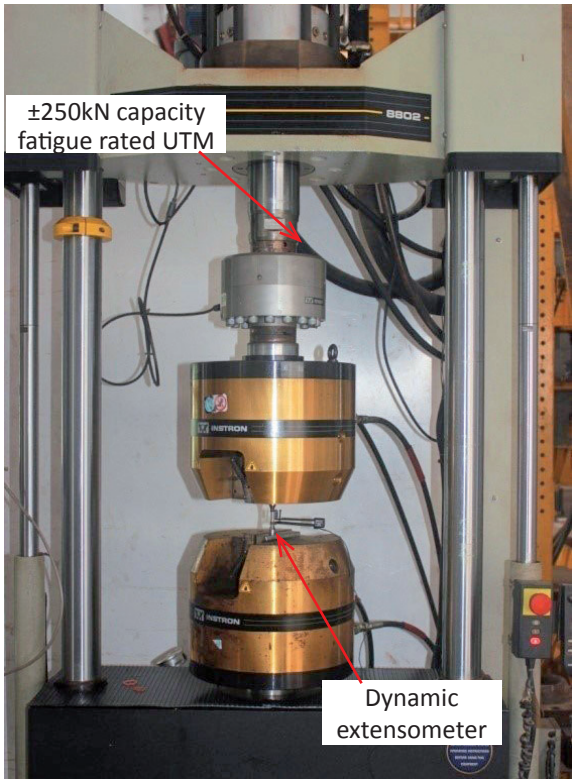

Fig. 1 Set-up for strain-controlled fatigue test on M50 alloy steel

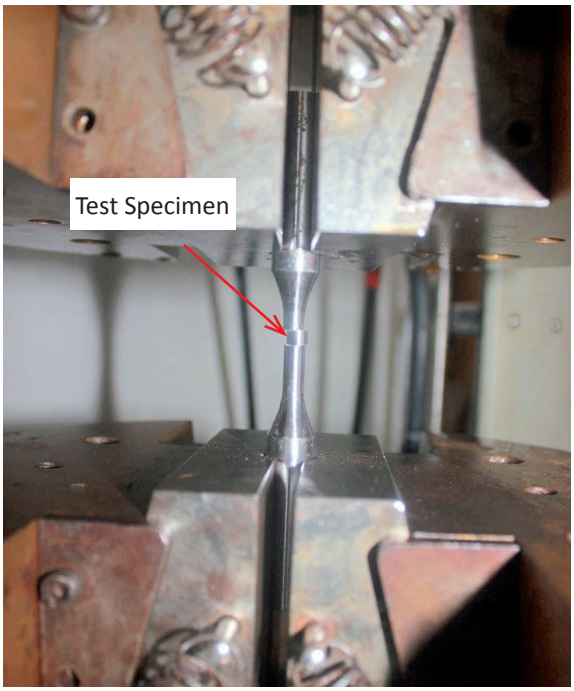

Fig. 2 Close-up view of M50 alloy steel specimen after fatigue failure

and the gauge length was 25.4 mm. The tests were carried out on the heat treated samples using a ±250 kN capacity servo-hydraulic fatigue rated UTM. Fig. 1 shows the set-up for strain controlled fatigue test. Fig. 2 shows close-up view of the specimen after failure. Totally, three specimens were tested under constant amplitude triangular cyclic loading. The applied strain range was 0.6% and the value of maximum strain was zero. The test frequency was maintained between 1.5 Hz and 2.0 Hz. The values of number of cycles to failure for the three specimens were 1541, 1407 and 1496. Fig. 3 shows typical stress-strain hysteresis curves at various loading cycles obtained during the fatigue test.

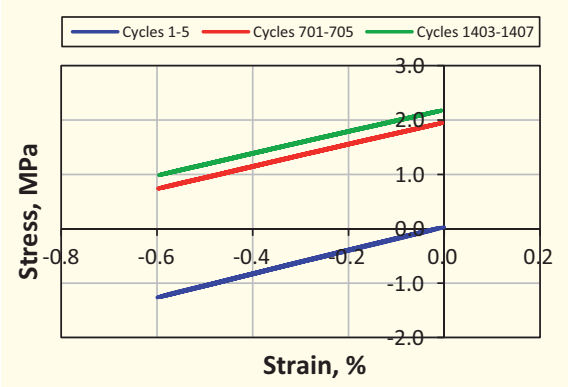

Fig. 3 Typical stress-strain hysteresis curves for M50 alloy steel at various loading cycles; cycles 1-5 (Initial), cycles 701-705 (mid-life) & cycles 1403-1407 (final)

Evaluation of plane-strain fracture toughness of M50 alloy steel

Plane-strain fracture toughness tests on M50 alloy steel were carried out as per ASTM E 399 : "Standard test method for linear-elastic plane-strain fracture toughness K_{Ic} of metallic materials" employing compact tension [C(T)] specimens. The specimens used in the studies were fabricated from the raw material, which was in the form of a rod of 105 mm diameter. After fabrication, the specimens were heat treated. After that, minor changes in dimensions due to heat treatment were corrected by re-machining. The length, width and thickness of the specimens were 48 mm, 50 mm and 10 mm

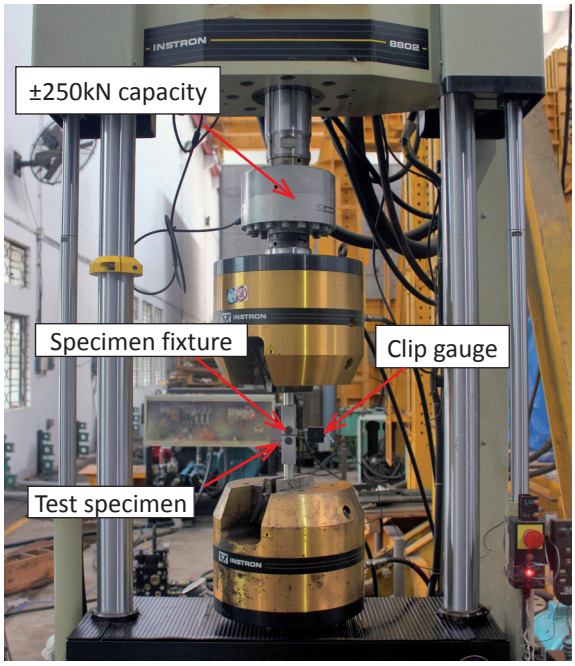

Fig. 4 Set-up for plane-strain fracture toughness test on a C(T) specimen

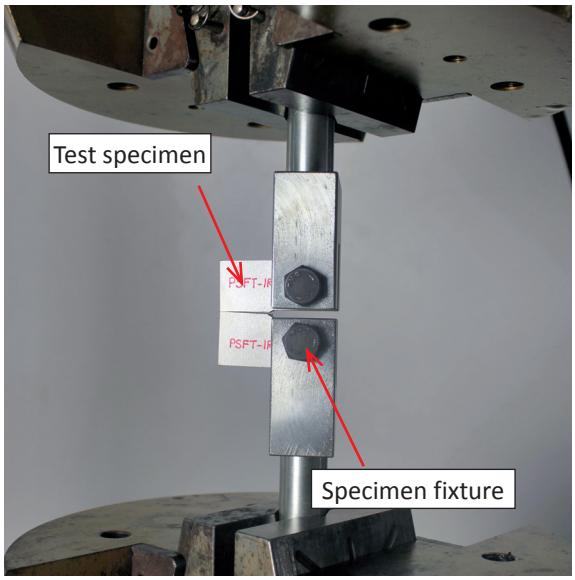

Fig. 5 Close-up view of a C(T) specimen after failure

respectively. A straight through notch of length 28 mm was made in the specimen at mid height by electrical discharge machining. The tests were carried out on the heat treated samples using a ±250 kN capacity servo-hydraulic fatigue rated UTM. Fig. 4 shows the set-up for plane-strain fracture toughness test. Fig. 5 shows close-up view of the specimen after failure. Prior to the fracture tests, the specimens were fatigue pre-cracked in order to produce a sharp crack front. Fatigue pre-cracking was carried

out by applying sinusoidal constant amplitude cyclic loading. The maximum and minimum load values during fatigue pre-cracking were 5 kN and 0.5 kN respectively; the test frequency was maintained as 10 Hz. Fatigue pre-cracking was carried out for 2500 cycles.

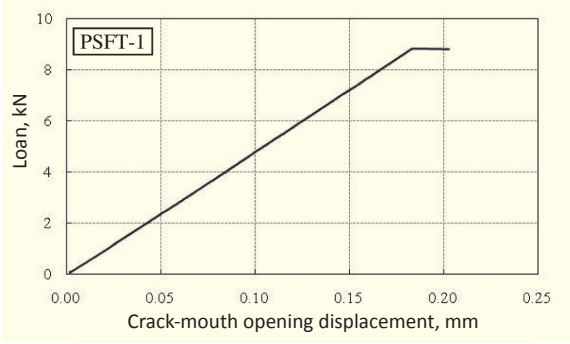

Fig. 6 Typical load versus crack-mouth opening displacement plot obtained during plane-strain fracture toughness test on a C(T) specimen

Subsequent to fatigue pre-cracking, fracture toughness tests were conducted by loading the specimens in tension and the load (P) versus crack-mouth opening displacement (CMOD) values were recorded. The tests were carried out under load control and the rate of loading was 0.25 kN/sec. The rate of loading was decided in such a way that the rate of increase in stress intensity factor was maintained between 0.55 MPa√m/s and 2.75 MPa√m/s, as specified in the ASTM standard. Fig.6 shows typical load versus CMOD plot obtained during plane-strain fracture toughness test. The value of fracture toughness (KIC) was calculated using the P-CMOD record and specified equations based on elastic stress analysis. Based on the five tests, fracture toughness of the material was obtained as 35 MPa√m.

Fatigue life estimation of type 304LN stainless steel

Evaluation of fatigue parameters and life of materials under strain-controlled cyclic loading becomes important in understanding the behaviour and life prediction of components and structures subjected to large amplitude cyclic loading. Fatigue properties of materials are characterized by the curves of strain amplitude versus number of load reversals, obtained from strain-controlled fatigue testing of smooth specimens. Since fatigue testing requires a lot of time and effort, there have been many attempts to predict strain-life fatigue of materials using the monotonic tensile material properties and hardness of the material.

Four-point correlation method by Manson, modified four-point correlation method by Ong, universal slopes method by Manson, modified universal slopes method by Muralidharan and Manson, uniform material law by Baumel and Seeger, hardness method by Roessle and Fatemi, median's method by Meggiolario and Castro, and methods proposed by Mitchell et al. and Basan et al. are some of the existing methods for strain-life fatigue prediction using monotonic tensile material properties and hardness of the material. In the present studies, fatigue life of Type 304LN stainless steel under strain-controlled cyclic loading has been estimated using the above methods. The results of the studies are compared with the available results of strain-controlled constant amplitude fatigue tests carried out earlier on Type 304LN stainless steel under six different strain amplitude values, viz, 0.20%, 0.35%, 0.50%, 0.65%, 0.80% and 0.95%. The values of material properties of the steel used in the studies are: ultimate tensile strength = 614 MPa, Young's modulus = 198 GPa, percentage reduction in area = 80, Brinell hardness number = 217.

It is observed that the above methods are generally non-conservative in predicting the strain-life fatigue of the material for all strain amplitude values except the median's method for strain amplitude of 0.80%. The strain-life fatigue predicted by Mitchell's method is highly non-conservative compared with the other methods for the material. Median's method is found to estimate the strain-life fatigue of the material with a better accuracy. Basan's method, modified universal slopes method and uniform material law are found to give predictions with a reasonable accuracy. Estimations by original

and modified four-point correlation methods, original universal slopes method and hardness method are found to be non-conservative to an extent of 1.5 to 4.5 times of the observed strain-life fatigue.

Evaluation of cyclic hardening parameters for type 304 LN stainless steel

Cyclic loading with large amplitude may induce stress reversals that exceed the elastic limit of the material leading to low cycle fatigue damage in components and structures. Materials under such loading conditions may exhibit strain hardening or strain softening or initial strain hardening followed by strain softening, depending on the material. The elastic-plastic response of the material is described by constitutive models based on isotropic or kinematic hardening rules. Prager, Armstrong and Frederick, Chaboche, and Ohno and Wang proposed linear and nonlinear models to describe the cycle hardening/softening behaviour of materials. The hardening parameters include: (i) isotropic parameters Q and b, and (ii) kinematic hardening parameters σ_0, C_1, C_2, C_3, γ_1, γ_2 and γ_3. Where Q is the maximum change in the size of the yield surface, b is the rate of change of yield surface during plastic deformation, σ_0 is the size of the yield surface, C is the hardening modulus and γ is the rate at which the kinematic hardening modulus decreases with increase in plastic deformation.

Cyclic hardening parameters for Type 304 LN stainless steel were evaluated based on the results of strain-controlled fatigue studies carried out earlier on the steel at different values of strain amplitudes. The strain-controlled fatigue tests were carried out under constant amplitude under fully reversed condition using a ±250 kN capacity fatigue rated UTM. Fig. 7 shows the superimposed mid-life stabilised hysteresis curves obtained under different strain amplitudes. The hardening parameters were evaluated by decomposing the mid-life stabilised hysteresis curves into three segments as follows:

(i) the initial modulus when yield starts, (ii) the non-linear transition of the hysteresis curve after yielding starts until the curve becomes linear again, and (iii) the linear segment of the curve in the range of higher strain.

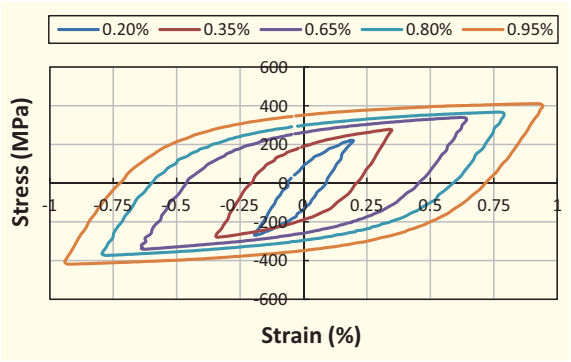

Fig. 7 Superimposed mid-life stabilised hysteresis curves obtained during strain-controlled fatigue tests on type 304LN stainless steel

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Damage Assessment and Life Enhancement of Transmission Line Systems

Scope/objectives

- Evaluation of high wind load models for transmission line towers.
- Studies on damage assessment of transmission line tower members and joints.
- Studies on damage assessment of conductors.
- Development of probabilistic methodology to assess the remaining life of transmission line system.

- Life extension of transmission line towers by strengthening the members and joints using fiber reinforced polymer.

Significant achievements/contributions

There are number of high wind load models available in literature for downburst, microburst and cyclones. As these models are for other countries, they cannot be directly used for Indian meteorological conditions. Hence, it is proposed to study the statistical characteristics for measured high wind data. Based on these statistical characteristics, the available high wind load models can be improved for Indian meteorological conditions. The applicability of these high wind models will be studied for transmission line towers. A state-of-the-art report has been prepared for the high wind load models available in the literature.

Damage in bolted joint affects the structural response of the transmission line tower. It is observed that the instantaneous and continuous bolt slippage model with force and displacement boundary conditions are available but the three dimensional stiffness characteristics of bolted tower joints with different bolt size, arrangement pattern and member cross sections are not well understood. The modification of existing bolt slippage model to simulate the behaviour of bolted joint in transmission line tower is being conducted. A state-of-the-art report has been prepared on bolted joint damage assessment in transmission line towers.

Component level experimental and analytical studies on bolted joint damage assessment

Bearing type bolted connections are normally used in transmission line towers. Damage in these connections occur due to loosening of bolts because of reversal of stress under wind loads. Damage detection in these joints was studied experimentally at component level. The element level experimental studies were carried out separately on bolted lap joint with steel plates of size 60 × 8 mm and steel angles of size L 50 × 50 × 6 mm with 16 mm diameter bolts. Damage was inflicted in these joints through variation in applied torque to the bolts. The joint was fixed at one end and tensile load applied through hydraulic jack at the other end. The lateral movement of the joint was measured through digital dial gauges. Typical experimental setup in the test rig is shown in Fig.1.

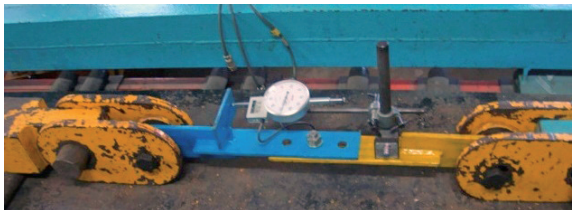

Fig. 1 Typical experimental set up for lap joint

The defined pre-tension was applied to the bolts using torque wrench. The lap joint was subjected to tensile load up to 40 kN and the load vs lateral deflection was recorded. The bolt was loosened after this test, again placed in the bolt hole and then the bolt is tightened to the next level of torque and the lateral deflection of the bolt for this applied torque was recorded. The slip in the joint occurs when the bolt clamping frictional force exceeded by the axial force in the joint.

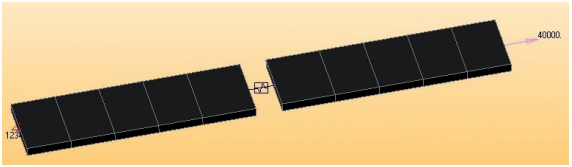

Fig. 2 FE model for plate lap joint

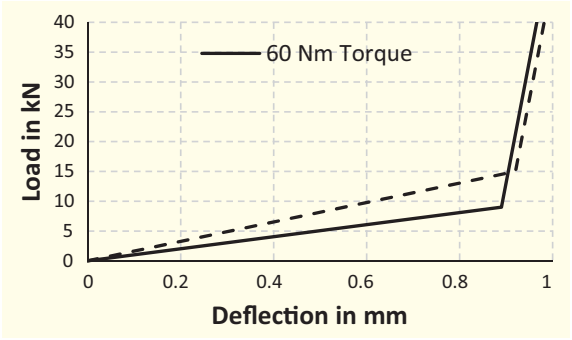

Fig. 3 Load vs deflection plot

Analytical studies were conducted on the above mentioned bolted lap joint. The lap joint was modelled in NE NASTRAN, a nonlinear finite

element software using beam element for plate and spring element for bolted connection. A typical model of the lap joint is shown in Fig. 2. Damage was simulated in these joints through variation in applied torque to the bolts. The stiffness of the bolted connection was varied for different torques ranging from 60 to 100 Nm. Step analysis was carried out with change in stiffness for bolted connection before and after the slip. A typical load vs deformation behaviour of lap joint with different torque level is shown in Fig. 3.

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Development of Damage Diagnostic Strategies using Distributed Wireless Smart Sensors (Motes) for Sustainable SHM

Scope/objectives

- Development of output only damage diagnostic techniques for civil engineering infrastructure
- Development of feature extraction techniques using on-chip and off-chip processing in smart wireless sensor, Implementation on motes and validation
- Recommendations for devising sustainable smart SHM strategies

Significant achievements/contributions

Several time domain techniques like Eigen value Realization Algorithm (ERA), Ibrahim Time Domain method (ITD), Least Square Complex Exponential (LSCE), Stochastic Subspace Identification (SSI) techniques are implemented. Similarly, the frequency domain techniques like Frequency Domain Decomposition technique (FDD), Enhanced Frequency Domain Decomposition (EFDD) technique, Frequency Spatial domain decomposition technique, Hilbert Huang transform, blind source separation etc., are implemented. All these techniques are integrated in the form of a matlab toolbox for operational modal analysis with GUI facilities. Interfaces are developed to use numerically simulated data or experimental data. These operational modal analysis techniques are validated using the numerical simulated ambient vibration data on simply supported beam girders and cantilever beam problems of varying span and natural frequencies. Apart from this, several test problems like ASCE benchmark problem, cable stayed bridge Harbin Inst. Tech, China, Guangzhou TV Tower, 76 storey tall building (controls benchmark problem) are solved and demonstrated the effectiveness of the algorithms built into the toolbox. The operational modal analysis techniques are investigated with respect to their sensitivities to measurement noise, accuracy and robustness. Further, the Blind source separation method is extended to a case where the number of sensors employed are much less than the number of modes required. The modal identification details of Guangzhou TV tower are shown in Figs. 1 and 2.

When operational modal analysis techniques are employed, the forces are unknown and hence the mode shapes obtained are un-scaled ones and therefore, methods to calculate the scaling factors are needed. An iterative approach based on mass scaling is developed to compute scaling factors and the method is validated.

HHT based system identification algorithm is developed and evaluated with the experimental data of several bench mark problems available in the web and found to be very effective for system identification

A system identification algorithm based on blind source separation techniques is developed. Algorithms like AMUSE and SOBI are integrated into the algorithm. The BSS based algorithm is found to be very effective for system identification. Several tests have been carried out with experimental data available in the web including the popular Guangzhou new TV tower and the results found to be quite impressive. SOBI seems to be more versatile when compared to AMUSE and works well with measurement noise.

Modal identification with limited number of sensors has been attempted using BSS algorithms by combining with Empirical mode decomposition and showed that it is possible to extract modes larger than the number of sensors.

Considerable research contributions are made in the sensor fault diagnosis, isolation and sensor correction, which is an essential ingredient for sustainable structural health monitoring. Notable original contributions are:

Guangzhou TV Tower

(http://www.cse.polyu.edu.hk/benchmark)

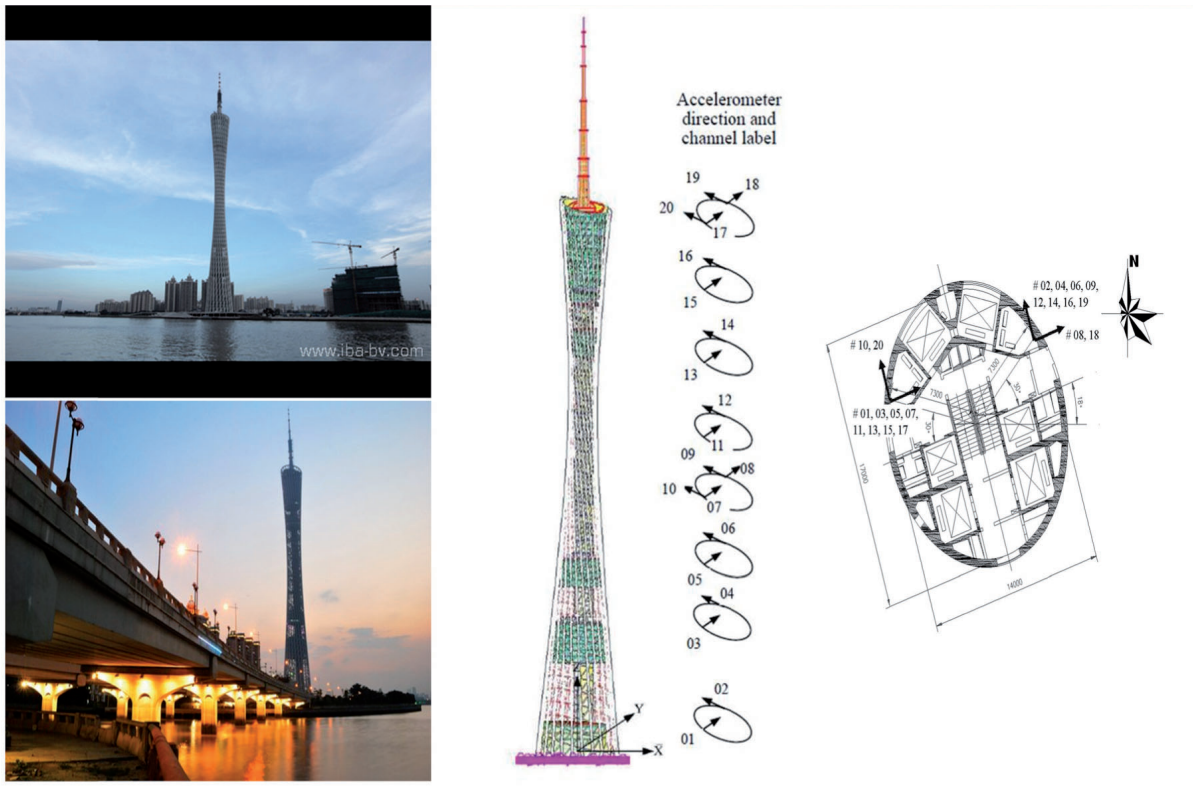

Fig. 1 Guangzhou TV tower, China

Guangzhou TV Tower Identified mode shapes

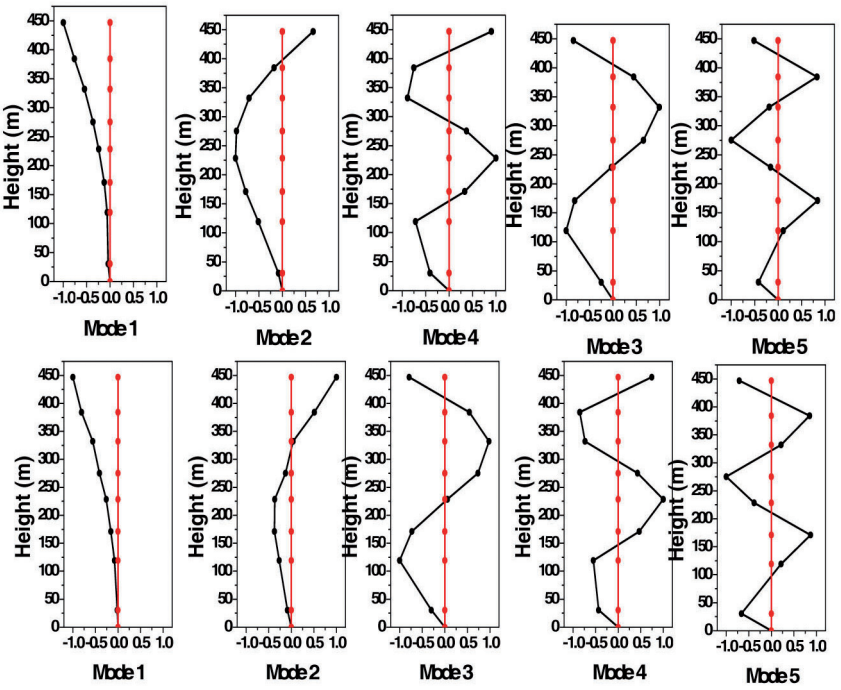

Fig. 2 Modal identification of Guangzhou TV tower using BSS algorithm

Detection of Delamination & Matrix cracking in laminate composites using PCA

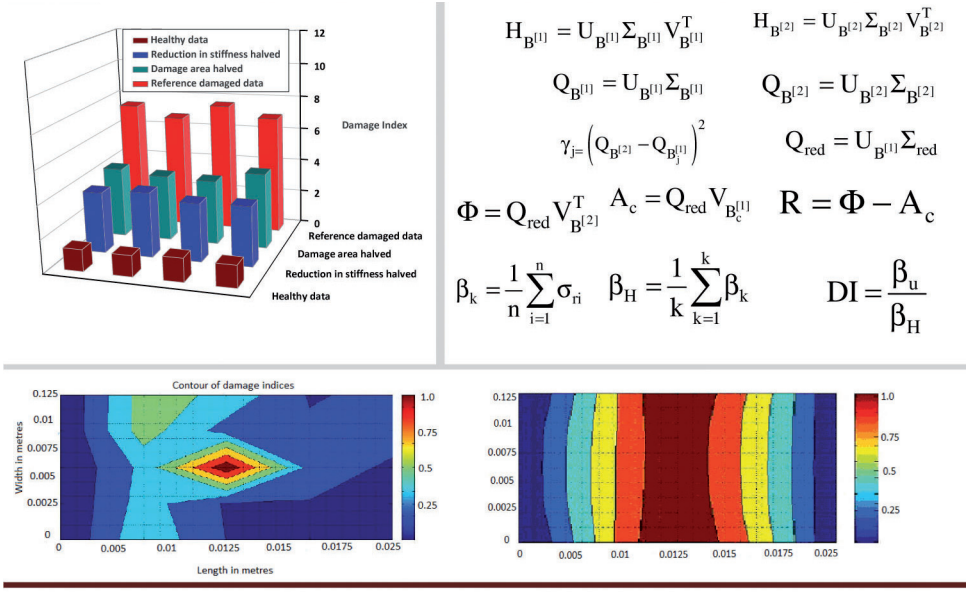

Fig. 3 Detection of delamination & matrix cracking of laminate composite plates using PCA based algorithms

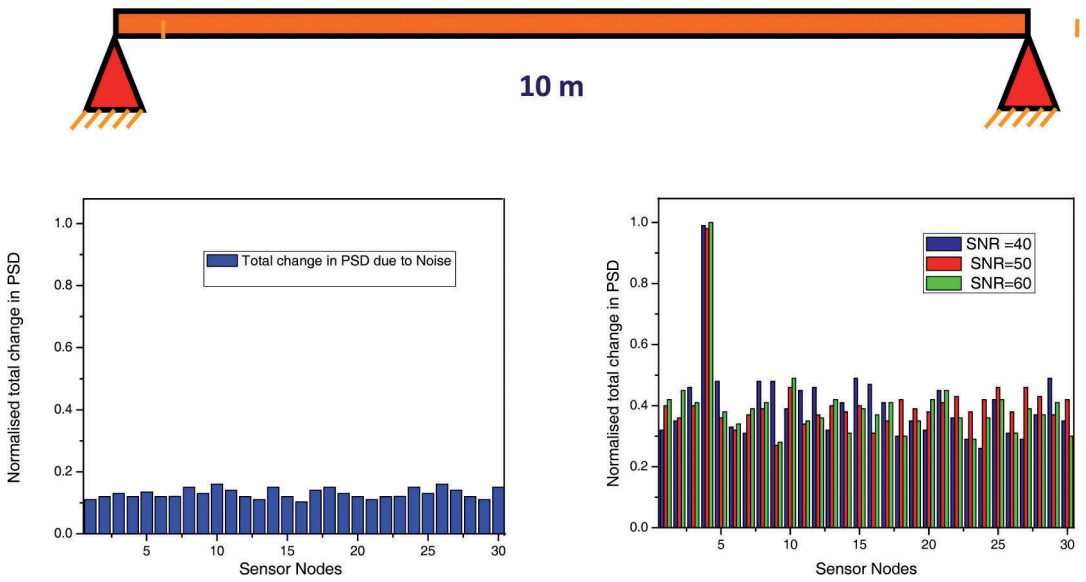

Fig. 4.. Damage localisation using power spectral density-simply supported beam

i Null space based sensor fault detection algorithm.

ii Hybrid sensor fault algorithms by combining Principal Component Analysis(PCA) based sensor fault detection and Minimum Mean Square Error(MMSE) based algorithm with Quantum Particle Swarm Optimisation (QPSO) algorithm.

iii Hybrid sensor placement algorithm by combining MMSE with PCA based algorithm to improve computational efficiency.

iv A fast multilevel algorithm for sensor fault detection and isolation to act as an accelerator for PCA or Null space based algorithm to make them amenable for real-time online Structural Health Monitoring (SHM) schemes.

Several new damage diagnostic algorithms are developed for structural health monitoring and they include:

i Damage diagnostic technique based on a technique inspired by subspace identification for handling environmental variability

ii Kernal PCA based algorithms to identify the structural damages in the structures exhibiting nonlinearity

iii Kernal PCA combined with Fisher Discriminant Analysis(FDA) for handling environmental variability

iv PCA based delamination detection techniques for laminate composites. Fig. 3 illustrates the technique developed

v Damage localisation technique using power spectral density highly adaptive for wireless smart sensor networks. The damage location is illustrated in Fig. 4.

vi Model updating and damage diagnostic technique using pseudo tests.

Experimental verification of sensor fault diagnostic algorithms

Demonstration of remote vibration monitoring using wireless sensors (IMOTE-II) on a bridge at Velachery, Chennai.

Development of a matlab toolbox for operational modal analysis is developed with several popular algorithms and also built with a couple of modern algorithms which has considerable merits over its older counterparts.

Development of a toolbox for sensor fault identification, isolation and correction is developed.

Efforts are being made to develop damage diagnostic techniques in the form of a tool box for structural health monitoring.

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Development of Real-time Continuous Remote Health Monitoring (RHM) System Employing Smart Sensors and Wireless Sensor Networks

Scope/objectives

- Performance evaluation of packaged FBG sensors and smart sensors
- Development of real-time, continuous Remote Health Monitoring (RHM) system employing Motes, MEMS, GPS, GSM, satellite and RF technologies
- Development of wireless sensor networks and management with integration of few technologies
- Validation of wireless sensors for RHM at laboratory level and demonstration of RHM on selected structures

Significant achievements/contributions

A new methodology for corrosion monitoring using FBG sensors was developed. Studies were carried out to verify that the strain developed in the FBG sensors is only due to corrosion. Two FBG sensors, FBG-t (covered with epoxy) and FBG-b were instrumented in a mild steel rod and were embedded in a concrete cylinder. The instrumented cylinders were subjected to accelerated corrosion. The wavelength values obtained from both the FBG sensors (FBG-t and FBG-b) were recorded at regular intervals. It is seen that the sensor FBG-t gives a constant strain value throughout, whereas FBG-b shows continuous variations in the strain value. This shows that no corrosion has occurred in the epoxy coated region and it is reflected from the response measured from the sensor at that location, as there is no change in strain being recorded. In order to apply this corrosion monitoring technique to existing structures, studies have been taken up by instrumenting RCC beam. Accelerated corrosion testing of the instrumented RCC beam was carried out. Based on this study the methodology to apply this technique to field problems is being developed.

Studies were carried out on the performance evaluation of fully packaged indigenous FBG sensors. In this connection, a packaged embeddable type FBG sensor, developed by CSIR-CGCRI Kolkata for monitoring both temperature and strain simultaneously in concrete was used. The package consists of two FBG sensors; FBG-T measures only temperature whereas FBG-S is sensitive to both strain and temperature. To evaluate the performance, the packaged sensor was embedded in a concrete cylinder. Temperature calibration was carried out on the instrumented concrete cylinder and apparent strain curve for packaged FBG sensor in concrete is generated.

Studies were carried out on the newly procured Wireless Structural Testing System by applying it to a steel plate girder bridge. Strain transducers, displacement transducers and accelerometers were instrumented and connected to wireless nodes along with conventional sensors on the steel plate girder bridge. Responses from the sensors were acquired from the nodes to the base station wirelessly during the passage of trains. The displacement response acquired from wireless sensor and conventional sensor is given in Fig. 1, the variation between the two sensors was less than 2%. Studies were further continued by instrumenting strain transducers, displacement transducers and accelerometers on a masonry stone arch railway bridge (Fig. 2). Responses from the sensors were measured during the passage of trains from wireless sensors as well as from conventional sensors and were compared. The studies show that the wireless structural testing system can be used for field applications.

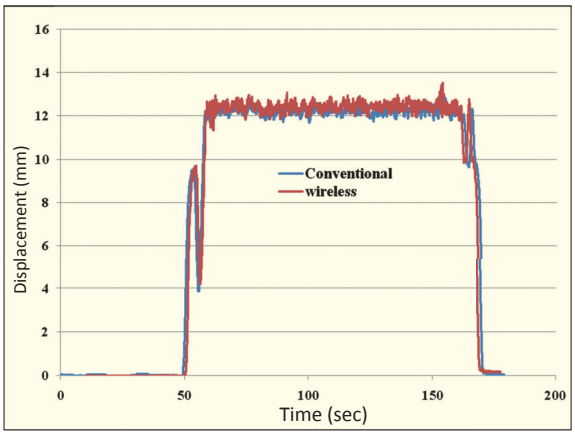

Fig. 1 Comparison of displacement between wireless & conventional sensors

It was found that some prototypes of Wireless Sensor Network (WSN)-based Structural Health Monitoring (SHM) systems like Motes are constrained by the low wireless bandwidth, limited node resources and lack of efficient coordination mechanisms. To address these problems, study has been carried to develop a versatile high-performance Wireless Sensor Network (WSN) platform termed as “Smote” for SHM applications. It is flexible and supports on-line configuration of parameters or mechanisms to address requirements of various SHM applications. Smote Wireless sensor node is a battery powered sensor capable of reporting sensor data back to the host server and is built upon the standard zigbee wireless

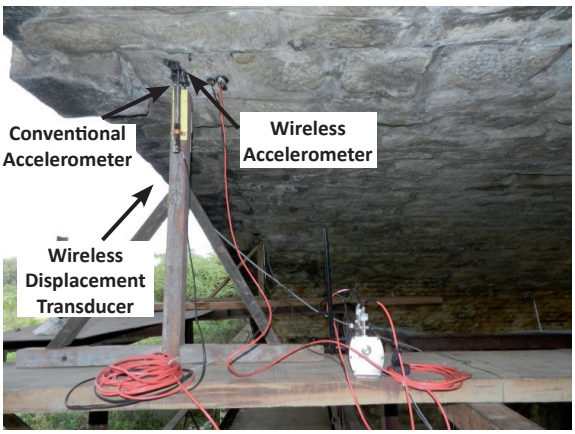

Fig. 2 Wireless sensors instrumented in a stone arch bridge along with conventional sensors

infrastructure, making it easier to monitor and track the sensor readings. The designed sensor functional modules consist of (a) Accelerometer, (b) Strain Conditioner module and (c) Temperature Sensor. ATmega328 is a low-power CMOS 8-bit microcontroller used for the initial studies on the development of indigenous wireless sensor. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega 328 is a powerful microcontroller that provides highly flexible and cost effective solution to many embedded control applications. A three axis MEMS based accelerometer was connected to the microcontroller board. For initial studies a low range Zigbee transceiver was used for communication between the wireless sensor and the host system through wireless mode. The gateway node can be directly connected through the USB port to the host system for logging the data using comp port terminal which was developed using C sharp programming. A coding has been developed for acquiring the data from the MEMS sensor using C++.

Degradation and deterioration are a major concern for civil engineering structures worldwide. The damages must be detected and quantified at an early stage for the improvement of safety. An efficient SHM technique should be adequately sensitive to detect even minor structural damages. A vibration based damage identification technique called the Modal Strain Energy (MSE) approach has been carried out for the identification and location of damages. The modal strain energy approach for damage detection was demonstrated by carrying out numerical simulations using finite element method. A simply supported beam was modelled and various damage scenarios were assumed. Different beam models were created by varying the degrees of damage at various locations. Modal Strain Energy Change Ratio (MSECR) is used to identify the damage and it is good indicator for location of damage. Based on MSECR value the damaged elements were identified for different damage scenarios which

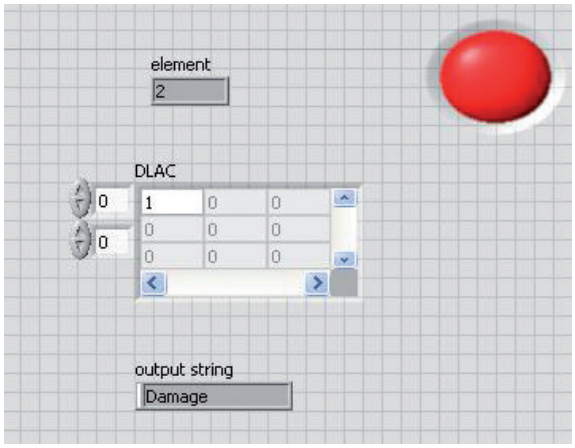

Fig. 3 Output for damaged element (DLAC method)

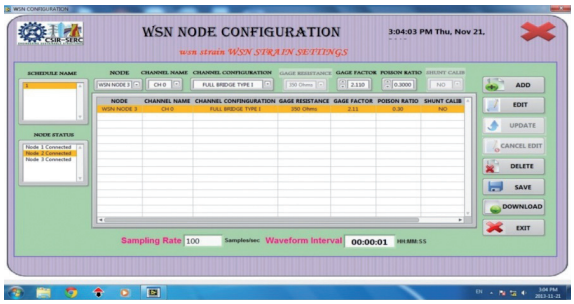

Fig. 4 Screenshot of the developed software for wireless sensor network

are matching with the simulated elements with damage. The purpose of this study is to interface the algorithm with measured data for online health assessment.

Studies have been carried out on another method of damage detection based on the concept of linear correlation. Based on the concept of Modal Assurance criterion (MAC) the Damage Location Assurance Criterion (DLAC) is developed. A cantilever beam was considered in this study. The modal analysis is initially carried out for undamaged and damaged cantilever beam. Making DLAC as a basis of damage detection, algorithm for damage detection has been developed using LabVIEW. From the DLAC value the undamaged and damaged elements were identified and a typical output window is shown in Fig.3. Condition of the elements are given in green and red graphical indicator representing undamaged and damage condition respectively. The above numerical studies were used for integrating it into WSN.

Studies were carried out on Damage Locating Vector (DLV) method based upon comparative analysis of stiffness reduction of damaged and undamaged state. Flexibility matrices for both damaged and undamaged states are found using static data. Using singular value decomposition of the change in flexibility matrix DLVs are arrived which are then applied to the undamaged model of the structure. The members with zero stress are the probable candidates of damage. In this connection, both 2D truss and 3D truss were modelled. Damage was induced in the model by reducing the cross section of some members in the truss. The probable damage locating vectors were used on the undamaged truss and stress in each member of the truss was computed. Based on this analysis and the singular values obtained, the damage locating vectors were finalized. Using stress data corresponding to the finalized damage locating vectors, weighted stress index was obtained which if less than one indicates damage. The analysis showed damaged members in the truss model. Further studies are continued for analysis of beams and frames.

Studies were initiated towards the development of software for real time wireless data acquisition using LabVIEW for WSN. In this connection hardware obtained from National Instruments, gateway (NI WSN 9791) and NI WSN node (3214) are used. The NI-WSN 3214 is a four-channel, low-power, wireless quarter-bridge, half-bridge, and full-bridge device that works with gateways to form a wireless sensor network. The measurement nodes and gateways communicate wirelessly using 2.4 GHz radios based on IEEE 802.15.4. The network can accommodate up to 36 nodes per gateway. Gateway has Ethernet port of 10/100 Mb/s Ethernet for flexible connectivity to Windows or LabVIEW Real-Time host controllers. The user interface of the developed software has options for login & configuration, display setting, real time data acquisition and display, networking and post processing (Fig. 4). Login & configuration section consist of user-friendly login with information regarding the authentication details, path of the acquired data file to store. The configuration setup helps in incorporating the configuration of the sensors used. The display section includes three major options like node status display, standby mode and battery life indicator. The node status display indicates the status of the connected node including power, signal strength etc. Strain gage with different bridge configuration has been incorporated in the developed software. Excitation voltage, range, bridge configuration is also incorporated in the software for each channel and can be selected easily by the user. Coding has also been developed for acquiring the strain values from the wireless sensor nodes. Laboratory studies were carried out to evaluate the performance of the developed software. Instrumented cantilever beam was subjected to known loads and strains were measured through the wireless nodes. The measured strains were transmitted wirelessly to the gateway and the data was viewed in real time in the host PC. Laboratory studies were continued to evaluate the performance of the NI hardware. The response obtained from the wireless sensor and conventional strain indicator is found to be matching well and the variation is found to be less than 2 percent.

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Self-Sensing Structural Health Monitoring of Concrete Bridges

Scope objectives

- Evaluation of smart materials and sensors for self-diagnostic health monitoring
- Development of self-sensing techniques and experimental methodologies for health monitoring of bridges
- Investigations on feature extraction methodologies for health assessment of bridges
- Development of methodologies for damage prognostics and mitigation

Significant achievements/contributions

The application of the electro-mechanical impedance method to detect the presence of damage and monitor its progress in concrete structures was investigated using finite element analysis. The progression of distress at a fixed location is studied for the concrete slab specimen having the dimensions of 150×150×10 mm by coupling Piezo Electric Ceramic (PZT) patch bonded to concrete structures in undamaged and damaged conditions with voids of different extents. From the analysis, it has been proved that embedded PZT Transducer is more sensitive to detect the voids in the large structure than the surface bonded PZT Transducer as shown in Fig.1. Further, the variation of admittance with respect to change in material properties of the concrete beam was studied. The difference of admittance between the various characteristic strengths with the base line value of 15 MPa is considered for evaluation. It has been observed that the increase in characteristic strength shows increase in difference in admittance at a frequency of 280 kHz. In the case of the PZT patch embedded inside the beam, it was observed that the increase in characteristic strength shows decrease in difference in admittance at a frequency of 310 kHz. Experimental studies are being carried out to verify the analytical results.

An experimental work was performed on mild steel beams with various cross-sections and lengths to analyse the variation of admittance and phase angle with respect to the cross-section of the beam. Fig 2 shows the comparison of admittance among the three types of mild steel beam with different lengths. It has been observed that the shift in the peaks of admittance signal with decrease in the length of beams in the frequency range of 400MHz to 600MHz. Fig 3 shows the comparison of admittance signal and phase angle among the three type of mild steel beam with different lengths. It was observed that maximum peaks occurred at 1.5MHz and also increase in peaks occurred with decrease in length of the beam. The smaller length beam shows larger shift in phase angle with the base line beam in the same frequency range of 400MHz to 600MHz, i.e the shorter in length shift right ward and larger length shift left ward directions.

In order to understand the behavior and influence of the interface of PZT with the structure, micro-modeling studies are carried out numerically on a Representative Volume Element (RVE) of a fibre composite to evaluate the failure behaviour of composite at microstructure level of fiber and surrounding matrix. The influence of relative strength and relative toughness of the interface of fiber-epoxy on the failure mechanisms are studied. A single fiber embedded in epoxy matrix is simulated under tensile loading conditions under plane strain conditions. From the axial normal stress of the deformed model under tensile load, it is observed that the failure pattern initiates at the interface between fiber and matrix. The crack propagates along the fiber-matrix interface as shown in Fig.4 and the crack penetrates into the matrix material when the stress locally reaches to tensile strength of the matrix.

Studies are being carried out on the fatigue behaviour of concrete subjected to cyclic loading. A comparative study on compression fatigue using the classical S-N fatigue models was carried out. It was observed that the fatigue

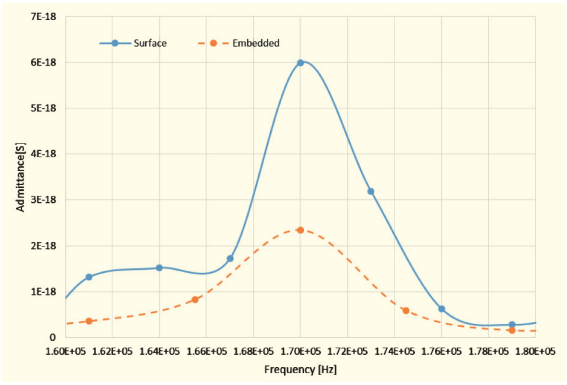


Fig. 1 Comparison of admittance of embedded sensor with surface bonded sensor for 8 mm void

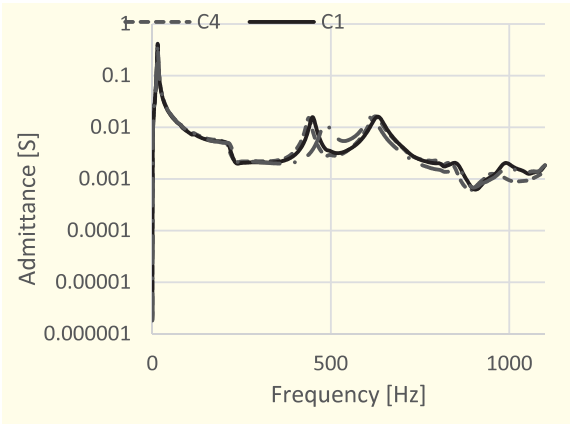


Fig. 2 Comparison of admittance signal among the three type of mild steel beam

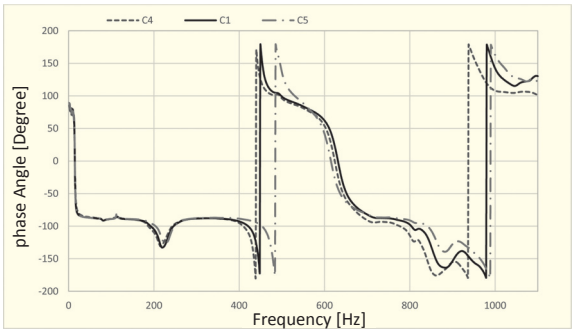


Fig. 3 Comparison of phase angle among three type of mild steel beam

life of a structure depends very much on stress ratio. To verify and developing a generalized S-N equation, thirty three cylinders 150×300 mm and thirty prisms 100×100 ×500 mm of M30 grade of concrete were prepared and the experimental tests carried out.

Acoustic emission testing of concrete structures shows great potential for monitoring and assessing their condition. Experimental studies were carried out on six rectangular shear deficient Reinforced Concrete beams under four point bending. RC beams were loaded under monotonic load and were monitored throughout the test using an AE monitoring system as shown in Fig 5. Total 21 AE sensors are used for monitoring during loading of the specimen. After loading, the failure mode of

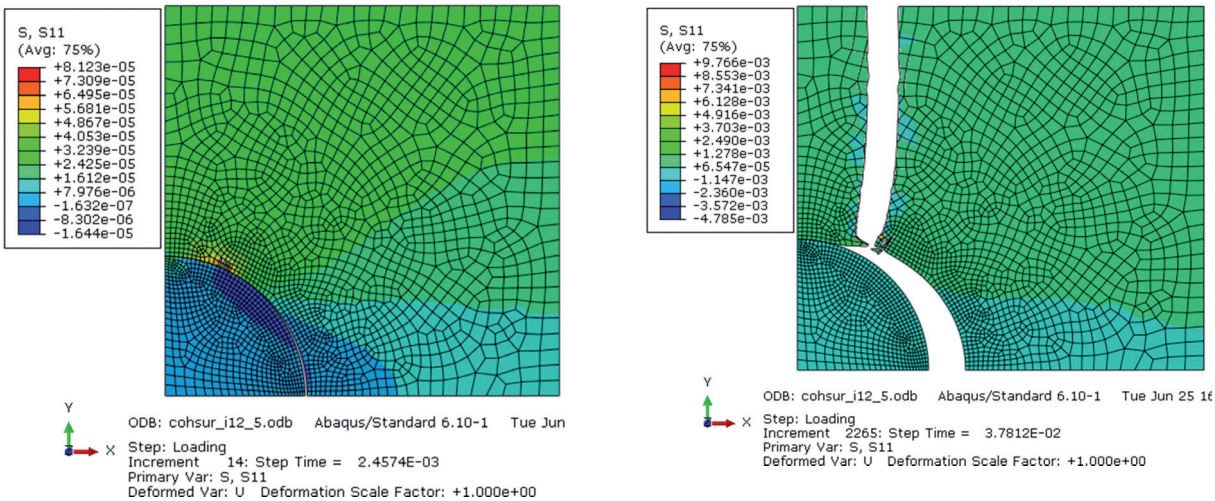


Fig. 4 Initial and final failure patterns of the single fiber-epoxy system showing interface failure and crack propagation into the epoxy.

Fig. 5(a) Laboratory set up

Fig. 5(b) Crack pattern obtained by visual observation

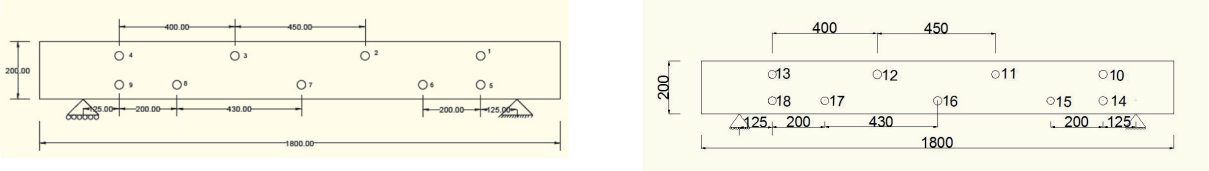
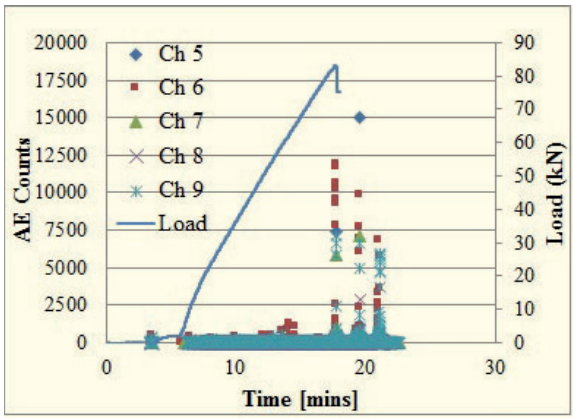
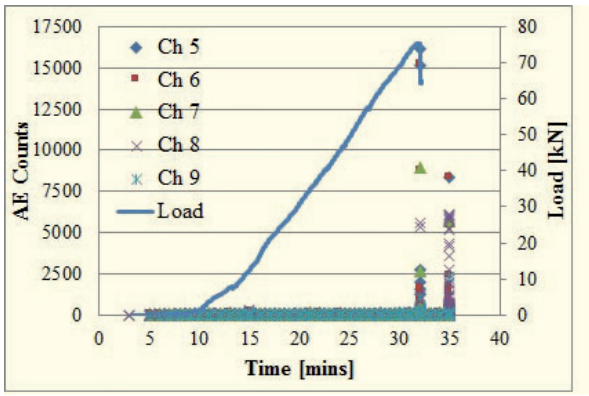


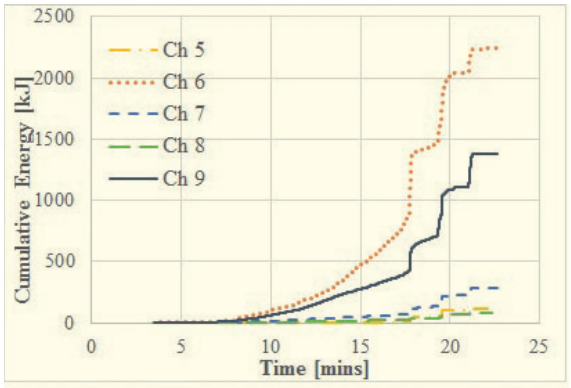
Fig. 6 Sensors arrangement (Side A view and Side B view)



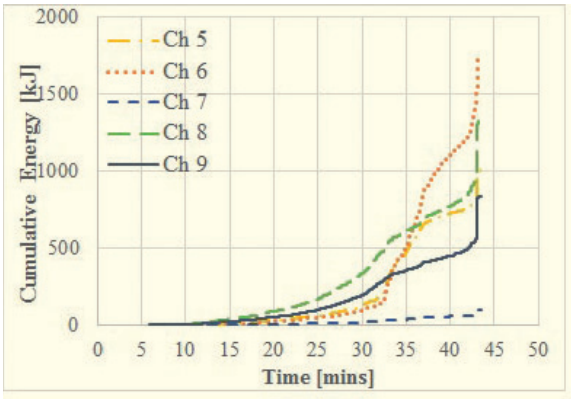
(a)



(b)



(c)
SA1 beam



(d)
SA2 beam

Fig. 7: Results from AE (a) Count and applied load and (b) Cumulative energy

beam obtained as shown in Fig. 6. Generally, the initial cracking position depends on the internal cracks and flaws during loading. The AE parameters such as energy, rise time, count, duration, amplitude and time are recorded. The information regarding to crack propagation is acquired through each channels and graph is plotted for each channels with AE parameter such as amplitude, cumulative energy, rise time, count (y-axis) versus time (X-axis). The first crack obtained in the tensile zone at an amplitude of 47dB, energy 5J at time 300 sec. By increasing the load, new cracks developed, existing cracks propagated vertically towards the compression

zone. Shear cracks were observed near the support, at a load of approximately 35-40% of maximum load as shown in Figs. 7a and 7b. The graph of energy vs. time is compared, CH1 showed higher value than CH2 indicating that crack is near to CH1. In CH3, the energy is less than CH4 that may be due to internal cracking at that location. CH5 has less value than CH6 because the crack is near to CH6. CH7 has some energy because of flexural crack. The CH9 has higher value than CH8. At bottom, CH19, CH20 have higheer energy than CH21 because crack is near to the support. Figs. 7c and 7d reveals that much of AE energy was detected by channel 6, 9 & 4 because the intermediate failure initiated along right side of beam. It was observed that energy is more at the location of occurrence of cracks. At the failure, AE events of amplitude are 97dB and rise time above 50000 sec and for SA2 beam amplitude of 99dB and rise time 55000sec were recorded.

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Time-Frequency and Time Series Models for Structural Health Monitoring

Scope/objectives

- SHM using signal processing techniques capable of handling non-stationary signals and also structural nonlinearities
- Development of robust damage diagnostic algorithms under ambient vibration using linear and nonlinear time series models for SHM
- Development of techniques to handle environmental variability in SHM
- Validation of the SHM tools developed using benchmark problems and lab level experiments

Significant achievements/contributions

Extensive literature survey has been carried out on applications of time series algorithms for system identification and structural damage diagnosis and a report prepared.

A two stage damage detection technique using time series models for structural health monitoring considering environmental variability and measurement noises is developed. The damage detection methodology consists of two phases. In the first phase, we identify the exact time instant of damage. A two-stage prediction model, combining Auto-Regressive (AR) and Auto-Regressive with Xogenous inputs (ARX) techniques, is constructed from the current data and the corresponding matched reference data to identify the presence of damage. The proposed method uses a damage metric which involves the variances of the prediction errors from AR-ARX model constructed from reference and current datasets. Once the presence of damage is identified, in the second phase, vector autoregressive model is employed to extract the spatial damage feature. Numerical simulation studies have been carried out by solving a simply supported beam girder and a twenty storey framed structure. Studies highlight the merits of the proposed two phase model for damage diagnostics and also the immunity of the proposed algorithm for measurement noise and also temperature variability.

The effectiveness of a two phase damage identification technique developed for structural health monitoring (SHM) using Autoregressive time series models is demonstrated using two bench mark problems. In the first phase, the presence of damage (i.e., the exact time instant of damage) is identified using the prediction errors of Autoregressive (AR) and Autoregressive with exogenous inputs (ARX) models, constructed from the current data and the corresponding matched reference data. Once the presence

of damage is identified, the second phase is activated in which Vector Autoregressive model (VAR) is employed to extract the spatial damage feature in order to precisely locate the spatial location of the damage.

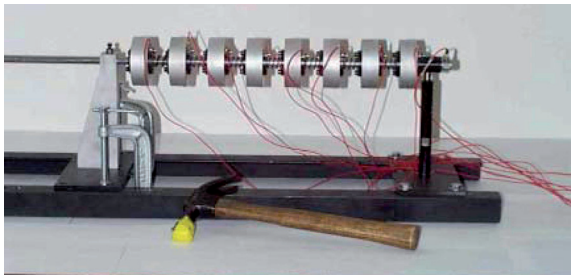

Fig. 1 LANL 8 DOF system

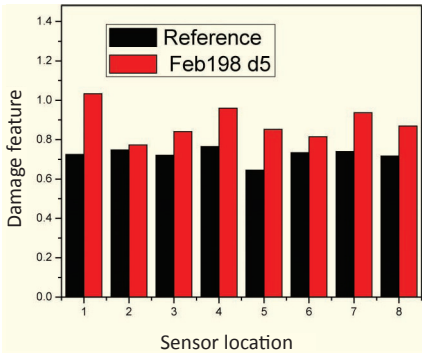

Fig. 2 ARX damage features of Feb198d5 scenario of 8 DOF

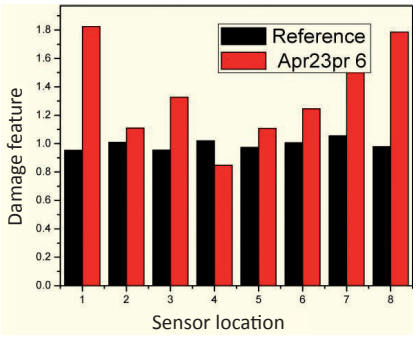

Fig.3 ARX damage features of Apr23pr6 scenario of 8 DOF.

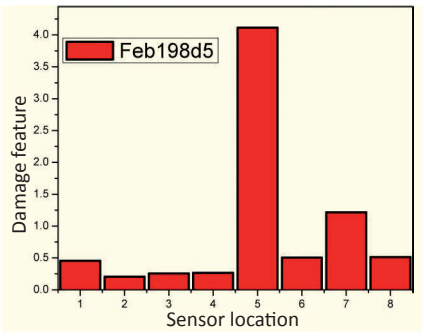

Fig. 4 ARV damage features of Feb198d5 damage scenario

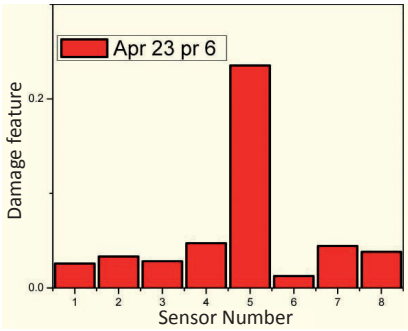

Fig. 5 ARV damage features of Apr23pr6 damage scenario

Fig. 6 IASC-ASCE steel frame benchmark structure

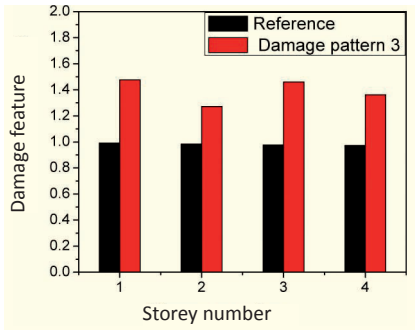

Fig. 7 ARX damage features of damage pattern 3 of 12 DOF ASCE frame

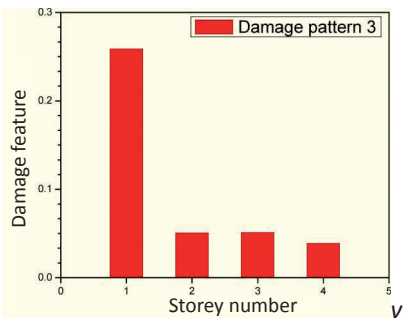

Fig. 8 ARV damage features of damage pattern 3 of 12 DOF ASCE frame

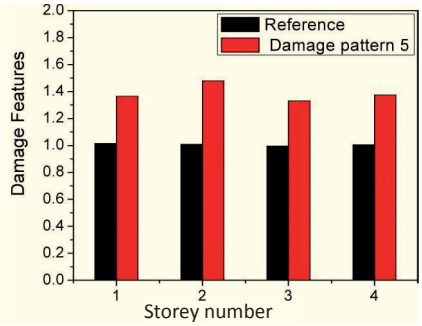

Fig. 9 ARX damage features of damage pattern 5 of 120 DOF ASCE frame

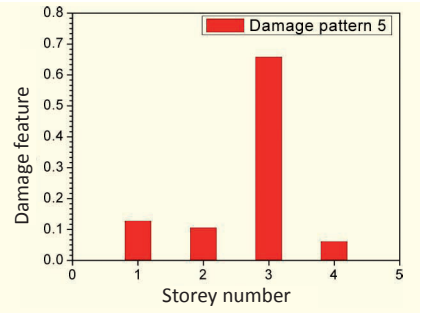

Fig. 10 ARV damage features of Damage pattern 5 of 120 DOF ASCE frame

Two benchmark problems for damage detection, 8-DOF system from Los Alamos National Laboratory (LANL) and ASCE experimental structure from IASC–ASCE Structural Health Monitoring Task Group are used to demonstrate the proposed damage identification technique. The results of the studies carried out indicate that the proposed two phase model is robust in identifying the time instant of damage, as well as the spatial location of damage in the structure, even with practical levels of measurement noise.

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Experimental and Analytical Investigations on Creep and Shrinkage of Engineered Concrete

Scope/objectives

- Experimental studies on creep and shrinkage of engineered concrete specimens
- Development of deterministic- and stochastic-mechanics based multi-scale models of engineered concrete for estimation of creep compliance

Significant achievements/contributions

One of the objectives of the project is to carry out experimental studies on creep and shrinkage of engineered concrete (i.e., concrete with mix proportion to achieve a specified 28 day compressive strength). The experimental program has been finalized with main focus on the creep and shrinkage properties of M40 grade concrete with 30% and 40% fly ash replacement. A review of mix proportioning procedures given in different codes of practice is carried out to select suitable procedure for mix proportioning of concrete with different proportions (upto 40%) of fly ash. It is noted that the Department of Environment (DOE) method is suitable for design of normal concrete mixes with fly ash content up to 50%, as it provides equations for calculating the cement content and fly ash content, utilizing cementing efficiency factor of fly ash. Sensitivity analysis is carried out to study the influence of cementing efficiency factor of fly ash on different ingredients of concrete with fly ash. Concrete mixes with 0%, 30% and 40% fly ash to the total cementitious material by mass are designed for achieving specified 28 day compressive strength using DOE method.

Concrete cubes are cast using these mixes and tested for compressive strength at 7, 14, 21 and 28 days. It is noticed that the mixes designed using cementing efficiency factor of fly ash are giving satisfactory results.

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Investigations on Wind Loads and Effects on Special Structures

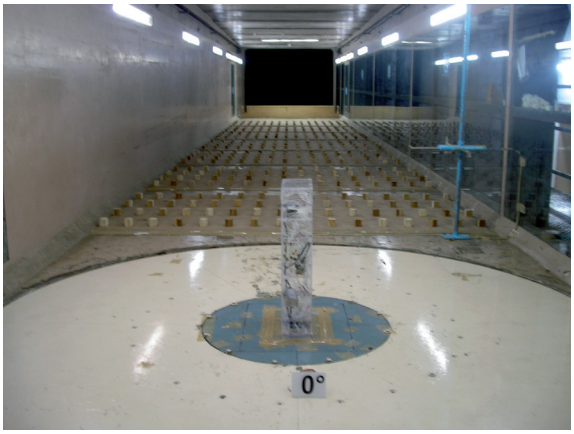
Scope/objective

- Characterisation and modelling of extreme winds towards mitigation of damage to structures
- Aerodynamic studies on selected bluff-body structures using wind tunnel and CFD
- Studies on aerodynamics of tall buildings with various unconventional configurations
- Formulation of recommendations/guidelines for design of structures

Significant achievements/contributions

Cyclones cause varied damage to housing/infra in coastal regions depending upon their intensity. A very severe cyclonic storm ('PHAILIN') crossed near Gopalpur (Odisha) on 12th October 2013. It was observed that mainly the places in and around Brahmapur, Chhatrapur, Gopalpur and Ganjam were affected with failures of engineered structures like rooftop lattice tower, ground based communication / transmission line lattice towers and steel trusses with asbestos or G.I. sheet roofing of industrial sheds (either mono or double sloped). These observations indicate the necessity for continued efforts in mitigating the damage to buildings and structures due to cyclones.

Most of the national/international codes on wind loads provide mean drag coefficient values for rectangular buildings in the form of uniform pressure/force coefficients. The coefficients provided in IS 875 (Part 3) -1987 are mainly based on wind tunnel model studies under uniform smooth flows, whereas many of the current international standards consider the boundary layer flow effects on the local force coefficients for tall buildings. Further, these codes do not explicitly address the effect of terrain condition and the effect of oblique angles of wind incidence on these coefficients.



Rectangular Building Model (1:2:5) inside Wind Tunnel

In the present study, pressure measurements on two rectangular building models (1:2:5; 1:2:7) with plan dimensions of 10 cm x 20 cm and heights (H) of 50 cm and 70 cm have been made under open and suburban terrain conditions (1:300 geometric scale). Both the models have been instrumented with 28 taps at each of 5 different levels, viz. 0.1H, 0.3H, 0.5H, 0.7H and 0.9H. Pressure data has been acquired for 12 different angles of wind incidence (θ) between 0° (corresponds to wind direction normal to face with 10 cm width) and 90°. In general, the local mean drag coefficients are observed to be more for (1:2:7) building than for (1:2:5) building, which corroborated with the expected trend. Further, the local mean drag coefficients are observed to be less under sub-urban terrain than under open terrain due to decrease in suction pressures on the leeward face under suburban terrain. For different oblique angles of wind incidence, by considering projected width of the building as reference characteristic dimension, the local mean drag coefficient is

Instrumented Curved Roof Structure insite Wind Tunnel

observed to be nearly same between 0° and 63.5° and beyond which the value is observed to be linearly increasing to the value corresponding to θ of 90°. It is observed that the IS codal values (max. of the two values provided) are either conservative or comparable to the experimental values of both the buildings for 0° angle of wind incidence. However, for 90° angle of wind incidence, the IS codal values are observed to be less (i) for bottom half of the (1:2:7) building under open/sub-urban terrains, (ii) for bottom half and for all levels of (1:2:5) building under sub-urban terrain and open terrain, respectively. Similar observations have been made while comparing American/Australian/Japan codal values with the present experimental values. In order to study the effect of turbulence within the same terrain category, another rectangular building with same plan and aspect ratios but with plan dimension of 5 cm x 10 cm and height (H) of 25 cm has been chosen and has been instrumented with 24 pressure taps at each of 4 different levels along the height. The mean drag coefficient values are observed to be comparable to those measured for 50 cm high model in respective terrain conditions. Further, comparison of the standard deviation values of drag and lift force coefficients is being studied.

Earlier the effect of terrain on pressures over 1:300 scale model of a ground based curved roof structure has been studied using pressure measurements. In the present study, the effect due to the presence of side walls, with height to span ratios of 0.0, 0.15 and 0.29, on the distribution of pressures over the roof of the 1:300 scale model have been investigated under sub-urban and open terrain conditions. The roof portion of the model has been instrumented with point pressure taps of 165 nos. along the arch direction at three regions, viz. edge (E), middle of centre to edge regions (M) and centre region (C), and also over one quarter region of the roof. In addition to the pressure taps provided on the roof portion, area averaged pressure taps have been provided on the side walls. Pressures have been measured on the roof and side walls of the models for 16 different angles of wind incidence ranging from θ = 0° to 360°. The results corresponding to sub-urban terrain condition are highlighted here. For wind direction parallel/perpendicular to the ridge, the values of mean suction pressure coefficients and the values of standard deviation of pressure coefficients at centre half portion of the arch are observed to be increasing with increase in height of the side walls. The values of mean pressure coefficients for the windward quarter and centre half portions of the roof compared reasonably well with various codal values, viz. IS: 875 (Part 3): 1987, ASCE/SEI 7-05, GBJ 9-87, and EN 1991-1-4: 2004. However, considerable differences have been observed between the measured values and the codal values for the leeward quarter portion for both height to span

(a)

(b)

Collapse of (a) Communication Lattice Tower and (b) Transmission Tower during Cyclone 'PHAILIN'

ratios of 0.0 and 0.29. Further, a value of mean pressure coefficient of +0.62 is obtained for windward wall with height to span ratio of 0.29, which is observed to be less than the codal value of +0.80 (IS and GBJ codes). In order to study the effect of skewed angle of wind incidence on the wind induced pressures on the curved roof, the distributions of mean and standard deviation of pressure coefficient values for wind angles, θ = 30°, 45° and 60° under open and suburban terrain conditions were evaluated. In general, mean and standard deviation Cp distribution trends for different angles of wind incidence at edge and mid locations are found to be similar under both open and suburban terrain conditions. For wind angle between 30° and 90° (flow perpendicular to the ridge), a small windward portion of the roof is observed to be subjected to positive pressure and remaining portion of the roof is observed to be subjected to suction pressure at both edge and mid locations under both terrain conditions, due to flow separation. Further, for angle of wind incidence between 30° and 90°, trend of distribution of standard deviation of Cp is found to be gradually decreasing at edge location, whereas an increasing trend is found at mid location. The distributions of pressure coefficients (mean and standard deviation) for skewed wind angles are found to be significantly different from the distributions of pressure coefficients for wind angle parallel and perpendicular to the ridge, which emphasizes the need to consider the pressure coefficient distributions corresponding to skewed wind angle also for the design of support frames/trusses of industrial buildings with curved roofs.

With the newly procured high speed pressure scanning system consisting of 384 channels, wind induced pressures have been simultaneously measured over the entire roof of the model under open and suburban terrain conditions for various angles of wind incidence. The pressure data has been sampled at a sampling rate of 650 Hz. For wind direction parallel to the ridge of the roof, the variations of mean pressure coefficient values along the length of the building at the crown is observed to have a high value of about -0.9 near the windward edge of the building and is observed to reduce to nearly 0 at about (3/4)th the length of the building. Beyond which the mean suction pressure coefficient is observed to be nearly uniform at a value of about 0. Similar observation has been made at the eaves region also except for the mean suction pressure coefficient value near the windward edge of the building being about -0.7. The variations of standard deviation values of pressure coefficients at the crown and near the eaves regions of the building for wind direction parallel to the ridge of the roof are almost comparable for both the locations with less than 10% difference. The maximum standard deviation value is observed to be about 0.4 near the windward edge of the building and is observed to be gradually reducing to about 0.1 near the leeward edge of the building. Detailed spatial and temporal correlation studies on the measured pressures is being carried out using Proper Orthogonal Decomposition (POD) method.

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Development of Mitigation Strategies for Structures Located in Seismically Prone Regions

Scope/objectives

- Development of experimental and analytical methodologies for mitigating seismic distress adopting supplemental damping and semi-active control strategies

- Development of strategies for mitigating distress of seismically vulnerable open ground storey structures

- Formulation of design guidelines

Significant achievements/contributions

Supplemental damping is one of the potential strategies for improving the seismic performance of buildings and structures towards mitigating the seismic distress. Supplemental damping can be provided to structures through incorporating damper devices of passive and semi-active types within the structural framework along the height through different placement schemes. Different supplemental damping devices of passive type including yielding, extrusion, friction, Visco-Elastic (VE) and semi-active type including Magneto-Rheological (MR), Electro-Rheological (ER) and Shape Memory Alloy (SMA) are deployed globally for seismic distress mitigation applications.

In this line, a dynamic characterization study has been completed on a typical MR fluid based supplemental damping device used for semi-active control of structures (Fig. 1). Understanding the non-linearity of MR damper by dynamic characterization of the damper is a crucial step before the application of the damper in structural control. Experimental investigations are carried out on a prototype MR damper device using a computer-controlled Universal Testing Machine under a wide range of magnitudes of control current and excitation conditions to characterize the hysteretic force property. The experimental data of the parametric study for MR dampers are typically grouped according to the variability of the different parameters sets as current input tests, frequency-dependent tests and amplitude-dependent tests to obtain the characteristic curves of MR damper. Based on the characteristic study, the hysteretic behaviour of the damper will be modelled and the same can be used in semi-active control of structures. During the period, similar dynamic characterization studies are also carried out on typical supplemental damping devices made using SMA wires used in semi-active control to mitigate the seismic distress of structures.

In order to assess the level of severity of Open Ground Storey (OGS) buildings stock in India, a simple procedure is developed using plastic hinge concept. The main assumption in this method is that the whole structure behaves as a single degree of freedom system as an inverted pendulum with a heavy mass at the top such that the entire elastic deformation of the structure is felt only by the OGS columns. Further the columns in the OGS are rotationally restrained at top of the stilt floor and at the foundation level. They are free to translate at top of the stilt floor only. The displacement demand capacity ratio is used to evaluate the severity of risk of an OGS building for local seismic hazard. The displacement demand

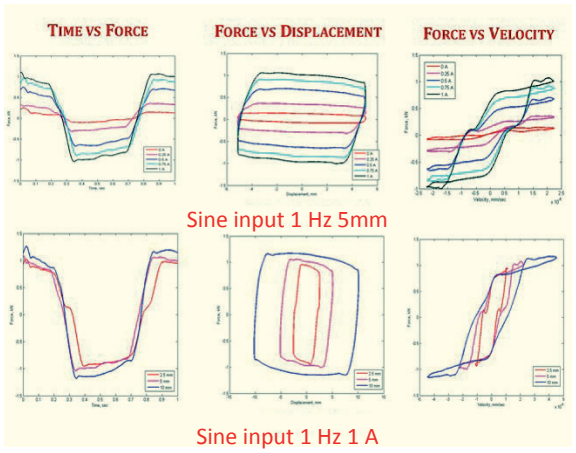


Fig 1. Dynamic characterisation study on magneto-rheological (MR) fluid based supplemental damper device

capacity ratio is calculated using yield and ultimate curvature of the column section. A parametric study is carried out considering the prescriptive reinforcements and dimensions of ground floor columns of the OGS buildings in India. A programme is developed in Visual Studio platform using Visual c# with graphical user interface to assess the seismic vulnerability of open-ground storey apartments based on above methodology (Fig. 2). Pushover analysis is done for better understanding the behaviour of soft storey buildings using SAP software. The simplified methodology is described above is validated using pushover analysis. In-fills interfere with the lateral deformations of the RC frame; separation of frame and in-fill takes place along one diagonal and a compression strut forms along the other. The stiffness and strength contribution of the in-fills are considered by modelling the in-fill as an equivalent compression strut.

Soil structure interaction refers to the effects of the elasticity of supporting foundation medium on the response of the structure. The movement of soil underneath foundation interacts with the response of the structure. An analytical study is made to understand the effect of soil flexibility on seismic response of soft storey buildings. A five-storied OGS building is modelled in SAP software and response is observed for soft storey building by varying the soil flexibility. The soil characteristics are modelled as translational and rotational springs. Spring stiffness has been assigned to simulate three different soil conditions soft, medium and hard, classified as mentioned in IS 1893, Part 1 (2002). A comparative study is done with fixed and hinged support also. The lateral displacements of the soft-storey buildings are further aggravated due to soil flexibility.

A half-scale model of a reinforced concrete open ground storey (OGS) building is constructed for performing shake table experimental investigations to establish the vulnerability of open ground storey / soft storey effect including torsional effect (Fig. 3). The building model

Fig. 2 Graphical user interface of the developed software to assess vulnerability of Open Ground Storey (OGS) buildings

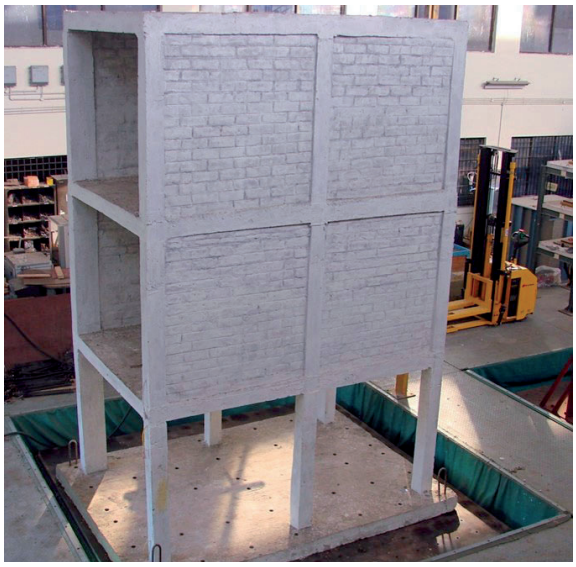
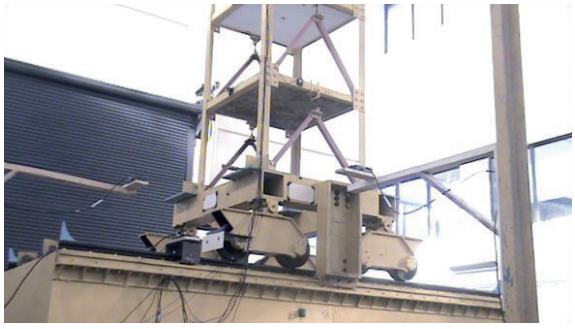


Fig. 3 Half-scale model of a reinforced concrete open ground storey building for performing shake table experimental investigations to establish soft storey effect including torsional effect



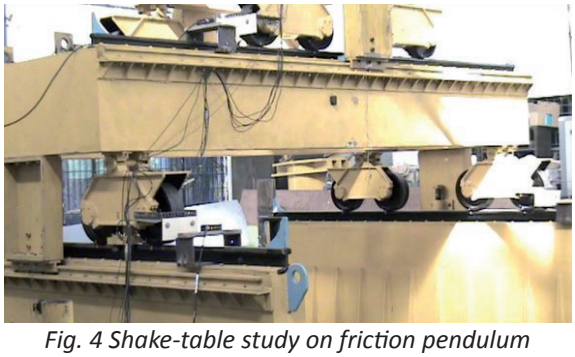


Fig. 4 Shake-table study on friction pendulum system (FPS)

constructed is a three storied framed building with a total height of 4.8m, having in-fills at higher floors and kept open at the ground floor.

Concentrically braced frame, with buckling restraint braces, (BRB) is a form of frame system in which the braces are part of a core of a concentric larger section, which provides restraint against buckling, but does not participate in the axial loading and stiffness. Buckling restrained brace frames (BRBF) have a high degree of ductility and energy absorbing capability, and good lateral stiffness and are relatively simple to repair after a major earthquake. A detailed literature review is made on the research and development made on various types of BRBs with different configurations available worldwide and a state of the art report is prepared.

Isolators with energy dissipation, termed as Friction Pendulum Systems (FPS) have been a successful class of isolators and whose natural frequency under sliding mode is controlled by the radius of curvature of the curved surface. Unlike the case of conventional isolators, it is theoretically possible to achieve very low lateral frequencies using these isolators without compromising on the vertical load capacity. Two tired planar rolling isolator system, similar to an FPS of large curvature is experimentally investigated (Fig. 4). Two tired rolling isolation system is adapted to result in an isolation system, whose relative performance is compared with a fixed un-isolated structure. The toppling and instability of the structure for a typical FPS system limits its use to structures of low height like bridges and medium rise buildings. The in-stability problem is over-come by a restrainer which prevents any abnormal rocking and vertical movements. This test set-up has a 1:4 scale-modelled steel structure also fitted with X-plate supplemental damping devices of yielding type. The experimental program include (a) steady state harmonic excitation, (b) sweep sine excitation and (c) earthquake excitation of a (i) normal frequency content and a (ii) time-scaled excitation (1:4) to induce high-frequency content in the input as typical of a model structure. Threshold input acceleration which will be transmitted to the super-structure and controlled by the coefficient of rolling friction is studied for varying magnitudes of input earthquake excitation levels. Seismic response influenced by the frequency of excitation and non-linearity arising out of friction are studied.

Team

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Control Devices for Seismic Damage Mitigation of Structures

Scope/objectives

- Carrying out investigations on structural systems with viscoelastic fluid dampers, magnetorheological dampers and tuned mass dampers
- Development of methodologies for modelling and analyses of structural systems with energy dissipation devices for site-specific earthquake
- Formulation of recommendations for performance based design of structural systems with passive and hybrid control devices

Significant achievements/contributions

A methodology to design and distribute dampers in ground floor level for seismic performance enhancement of a 20-storey, 2D benchmark building subjected to low intensity earthquakes with peak ground acceleration (PGA) of 0.2g using linear Viscous Fluid Dampers (VFDs) is proposed. The proposed methodology is used

for designing the linear VFDs to increase the effective damping with Chevron, upper-toggle and scissor-jack mechanisms in a 20-storey benchmark building.

A design methodology for seismic performance enhancement of a 3D truss tower with scissor-jack viscous fluid damper systems is developed. The finite element model of 3D truss tower used for analysis is shown in Fig.1. From the modal analysis of the truss model, the fundamental period of the truss is found to be 3.09s.

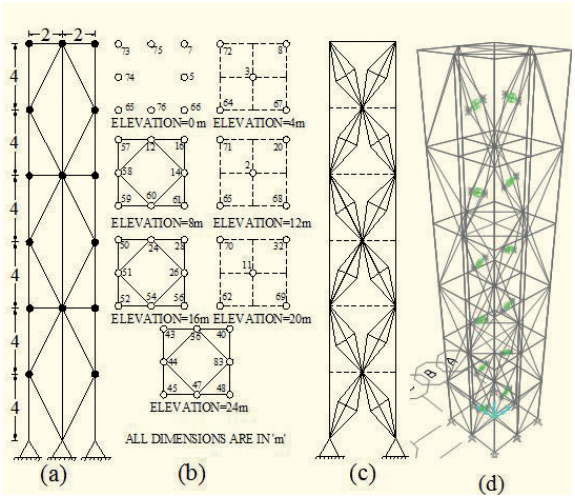


Fig.1 Truss Model (a) Elevation view of original truss, (b) Node coding (c) Truss tower with scissor-jack dampers on both sides (d) 3D model of truss with scissor-jack dampers

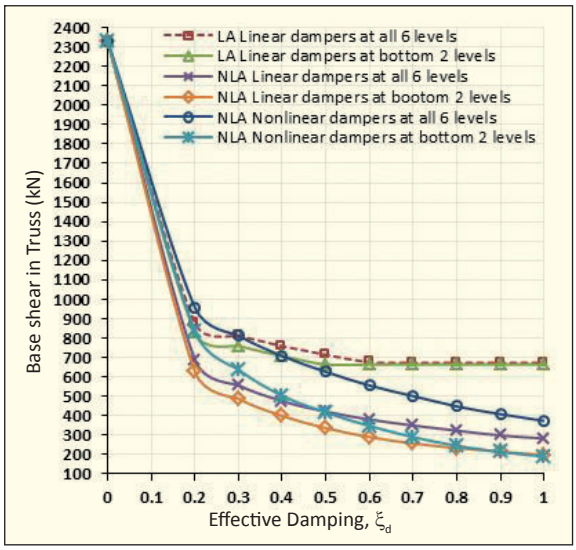
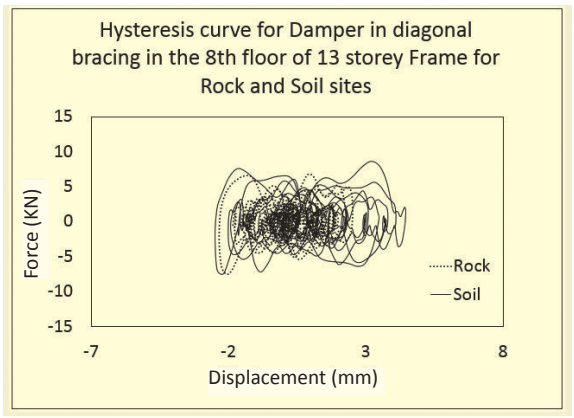
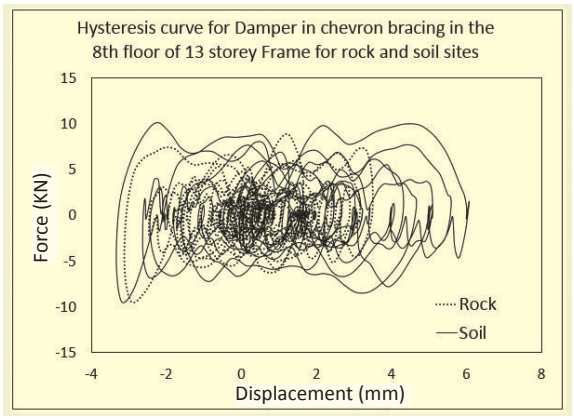


Fig. 2 Variation of base shear with different effective damping in the truss model with two types of scissor-jacks with linear and nonlinear damper arrangements



(a)



(b)

Fig. 3 Hysteresis output for viscoelastic dampers in the 8th floor of 13 story RC frame for rock and soil sites (a) Diagonal bracing (b) Chevron bracing

The truss tower model was retrofitted to accommodate two scissor-jack damper systems placed at each of its six levels as shown in Figs. 1c and 1d. For retrofitting with scissor-jack damper systems, additional bays with horizontal members are provided at elevations of 4, 12 and 20m as shown in Figs. 1b, 1c and 1d.

For retrofitting the truss, two types of arrangements of scissor-jack systems are used. In the first type of arrangement, only first two bottom levels are fitted with scissor–jack damper systems. In the second type of arrangement, the scissor-jack systems are provided at all six levels. For both the types of arrangements, each level has two scissor-jack systems (see Figures 1c and 1d). The design methodology developed can be for both linear and nonlinear dampers. The variations of base shear for all the cases

considered are shown in Fig. 2. It is observed from this figure that the decrease in base shear beyond an effective damping of 0.3 is negligible. The same observation was made in literature that damping ratio of the structure beyond 0.3 results in small decrease in response, and such increase in damping would not, in general, lead to economical use of dampers. For all the cases considered using the parameters arrived by methodology developed, for effective damping of 0.3, analyses are carried out and the responses such as base shear, storey displacements, inter-storey drifts and percentage reduction of these values comparing with bare frame are found. The maximum damper forces and displacements in the dampers for all the cases considered are found. From these cases, the damper capacities and stroke lengths are chosen from available dampers by Taylor devices corresponding to maximum damper force and displacements in different dampers in the truss.

A one-fourth scale model of 3-storey SMRF structure with two scissor-jack mechanisms is designed and fabricated to carry out experimental studies. By carrying out sweep sine test on the frame model with scissor-jack-MR damper system, the effective damping ratio (ξ) of the model at different input currents (viz., 0.25A, 0.5A, 0.75A and 1A) is found using half power band width method. It is observed that ξ of the frame model with scissor-jack-MR damper system is maximum (0.133) at 0A input current to MR dampers, and ξ is decreasing with increase in input current to MR dampers (the damping ratio decreasing from 0.133 to 0.063 with the variation of input current from 0A to 1A). The frame model with scissor-jack-MR damper system is excited with two near field and two far field time histories. For both near field and far field excitations, the displacements and inter-storey drifts are decreasing in frame model with scissor-jack-MR damper system, with different input currents (0A, 0.25A, 0.5A, 0.75A and 1A) to MR dampers. The storey-shears and inter-storey drifts in the frame model are found to be increasing with increase in input currents in MR dampers beyond 0A.

Nonlinear time history dynamic analyses of a 13 storey reinforced concrete (RC) frame with and without viscoelastic dampers has been carried out for site-specific scenario earthquake of moment magnitude of 7.6. Artificial ground motion is generated using finite source stochastic model with seismological parameters of Bhuj 2001 earthquake for rock outcrop and the same is propagated through a typical 100m soil profile with one dimensional equivalent linear analysis program and surface level time history is obtained for a soil site of Ahmedabad city. The dampers in the frame are provided in diagonal and Chevron bracings. Dampers are assumed to be linear and Maxwell model is adopted for computational modelling of viscoelastic dampers in the analysis. Three parameter Park Model is adopted for modelling nonlinear behavior of RC beams and columns. The typical comparison of hysteresis curves indicating the energy dissipation of viscoelastic dampers in diagonal bracing and chevron bracing in 8^{th} floor of RC frame are shown in Fig. 3. The schemes suggested can be adopted for retrofitting the building located at soil sites which is expected to suffer more damage than that of rock site. This study brings out the importance of carrying out site specific analyses for retrofitting the building with passive energy dissipators towards the mitigation of structural damage during future earthquakes.

An experiment on 2mx2m shake table has been conducted simulating the phenomenon of liquefaction for scenario earthquake of M_w 7.6 simulated at Kandla port with focal parameters of Bhuj 2001 earthquake and the accelerations, dynamic pressures at different levels and horizontal and vertical displacement of prototype building model are measured. The numerical simulations of liquefaction with SDOF

for prototype building are done with 3D finite element model. Good agreement has been observed between numerical and experimental simulations.

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Project Team Members of Structural Health Monitoring and Evaluation & Forensic Analysis

Innovative Technologies for Health Assessment and Damage Mitigation of Structures (I-HEAL)

Project No. ESC0110 (I-HEAL)

Date of commencement : April 2012

Target date for completion : March 2017

Nodal Officer : Dr. K. Ramanjaneyulu

Co-nodal Officers : Dr. G.S. Palani
: Dr. N. Gopalakrishnan

Scope and objectives

- Development of new sensor technologies and methods for structural health monitoring and assessment
- Evolve techniques for real-time, continuous remote health monitoring employing motes, self-sensing & Global Positioning System (GPS), Global System for Mobile communications (GSM), satellite, Radio Frequency, image processing and Wireless Sensor Network (WSN)
- Condition assessment and forensic analysis for damage / defect identification and evaluation
- Develop strategies for damage mitigation of hazards-induced distresses in structures
- Service life assessment/enhancement of structures
- Establish a composite 'National facility for materials, sensors and mechanics'

Nodal Laboratory : CSIR-SERC

Participating Laboratories :

CSIR-CEERI, CSIR-CMERI, CSIR-CRRI, CSIR-CECRI, CSIR-CGCRI, and CSIR-CSIO

WP-1: Development of methodologies for health assessment, damage identification and service life enhancement of structures

Evaluation of smart sensors for health monitoring of structures

Evaluation of smart sensors for monitoring the health of structures is under progress. As a part of the study, numerical modeling of piezo electric sensors was carried out to evaluate the signature of damage by mounting the piezoelectric ceramic transducers (PZT) on the surface of the structure and embedding inside the structural component. From the analysis, it had been proved that embedded PZTs are more sensitive to detect the voids in structure than the surface bonded PZT. Parametric studies were carried out using the same FE model harmonic analysis for different applied excitation voltages in the frequency range of 125kHz to 215kHz

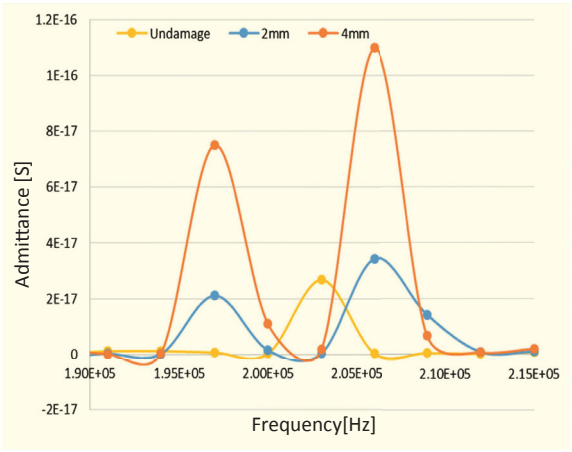


Fig. 1a Variation of admittance with respect to void size

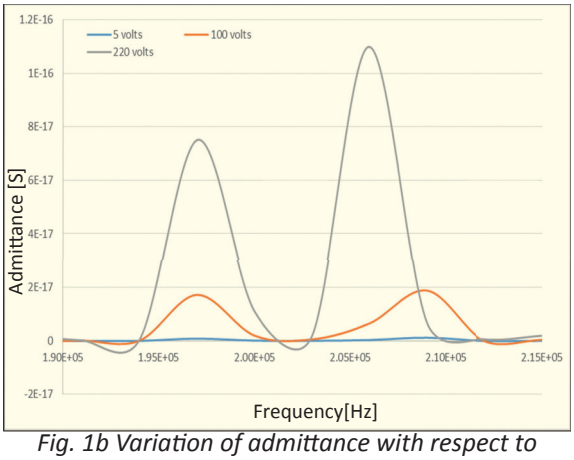


Fig. 1b Variation of admittance with respect to voltage

along the boundary of PZT. Analysis was carried out for the undamaged blocks and damaged blocks for different void sizes in the concrete specimen. The admittance in siemens [S] of damaged specimens was compared with undamaged one. Fig.1a shows the variation of admittance with respect to void size. It was observed that the admittance increases with the increase in void size. Fig.1b shows the variation of admittance with respect to different voltage excitations which shows increase in the admittance with increase in voltage.

Development of damage detection methodology for transmission tower

Series of experiments were conducted to examine the vibration response of a transmission line tower. The tower considered for experimental investigation is a 240kV Double Circuit 'K' Tower with staggered bracing system. All the members such leg, bracing and tie are confirming to ASTM A572 grade with yield strength of 350 MPa. The 33.5m high square tower has a base width of 7.175m at base level and reduces to 1.60m at 18m level. The configuration of the tower, dimensions and member sizes as shown in Fig. 2. The natural frequency and mode shape of the healthy (undamaged) tower and the damaged

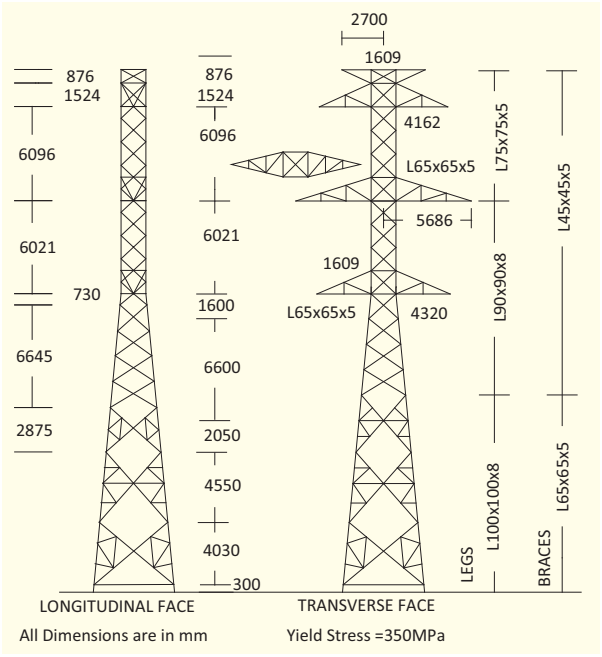


Fig. 2 Basic configuration of 240 kV D/C 'K' type tower

Fig. 3 Location of accelerometer and strain gauges in the experimental tower

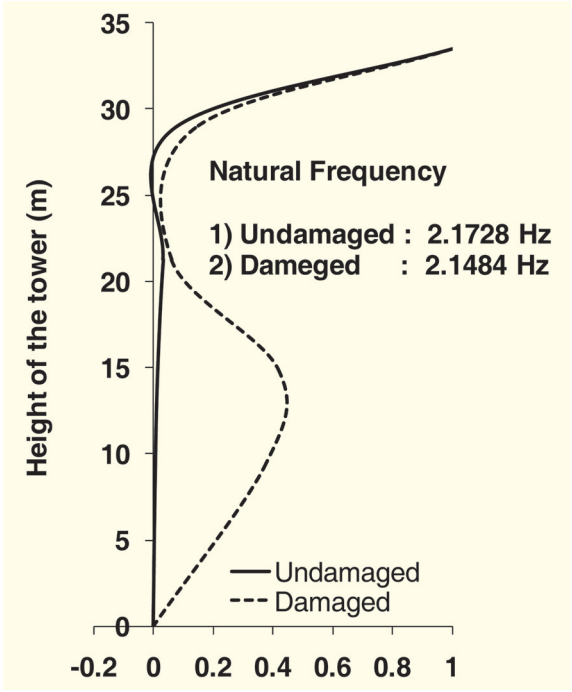


Fig. 4 Experimental comparison of mode shape (first mode)

tower were identified from the vibration data measured experimentally. The locations of the accelerometers were determined by the pre-vibration analysis of the tower prior to testing. To utilize full vibration data of the tower, the acceleration measurements were taken at the points, at which all modes of the tower are fully represented. The uni-axial accelerometers were placed on the longitudinal face of the tower perpendicular to the plane of the loading. The accelerometers were fixed at heights of 33.5m, 28.9, 21.29m, 14.81m and 9.43m respectively on both legs of the

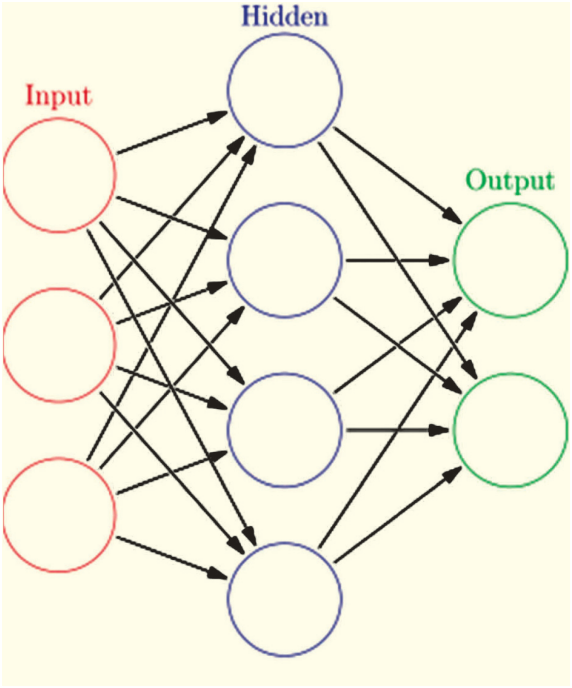


Fig. 5 Typical artificial neural network (ANN)

longitudinal face of the tower as shown in Fig. 3. The damage was inflicted by cutting a small portion of the flange of the compression leg member at 1.0 m height from stub level. The vibration was induced by flame cutting of the manila rope after applying 7.5 kN force. During the test, free vibration characteristics of the tower were recorded at fourteen points. The sampling rate for accelerometer readings was kept at 200 samples/sec (200 Hertz). The recorded data were processed through Fast Fourier Transform technique for both the states (healthy and damaged condition) of the tower. The experimental fundamental natural frequency for undamaged and damaged condition was obtained. From the values, the variation was found to be in the order of 1.5 %. The corresponding displacement mode shape is shown in Fig. 4. It has been observed from the first mode shape that there is a variation below the waist level of the tower.

Image processing & artificial intelligence techniques for damage/defect identification

Artificial neural networks are models inspired by animal central nervous systems (in particular the brain) that are capable of machine

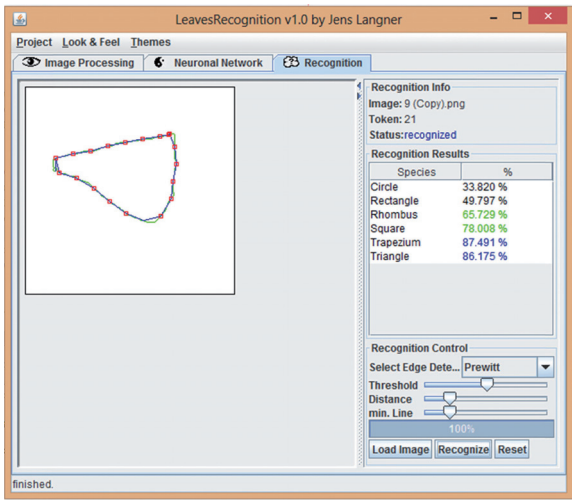


Fig. 6(a) Token generation

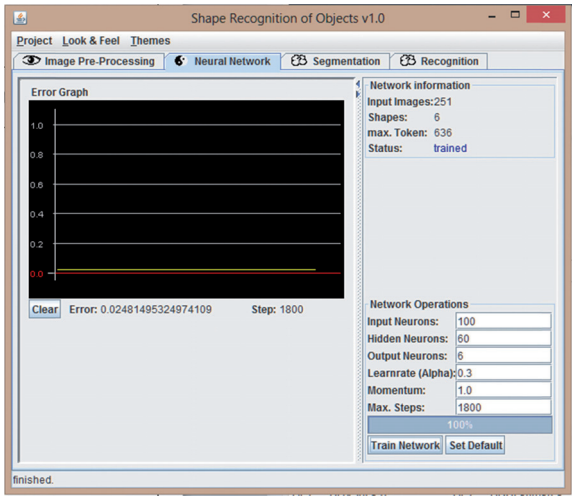


Fig. 6(b) Training of ANN

learning and pattern recognition. They are usually presented as systems of interconnected "neurons" that can compute values from inputs by feeding information through the network (Fig. 5).

ANN algorithm has been implemented. Various defects available on the net have been collected. These images serve as the training for the ANN and for testing using few of the images chosen randomly. ANN algorithm has been tested using images comprising of single defects.

For training purpose, a database of images containing 6 basic shapes - Circle, Rectangle, Rhombus, Square, Trapezium and Triangle – was collected. These shape templates were first processed and then the tokens generated were

passed to the network for training purpose. This process of training the network from a set of images was done automatically when the application was initialized. The neural network is now trained using the input shape templates. The process of token generation and training of the network is as shown in Figs. 6 (a) & (b). At present, continuous testing of the input data to determine the shape of the voids is being carried out.

Subsurface defect detection in active infrared thermography

Subsurface defect detection using active infrared thermography was carried out. A mild steel specimen of thickness 1 cm with cylindrical voids of diameter 1 cm and thickness 1mm was used for experimental investigations (Fig. 7).

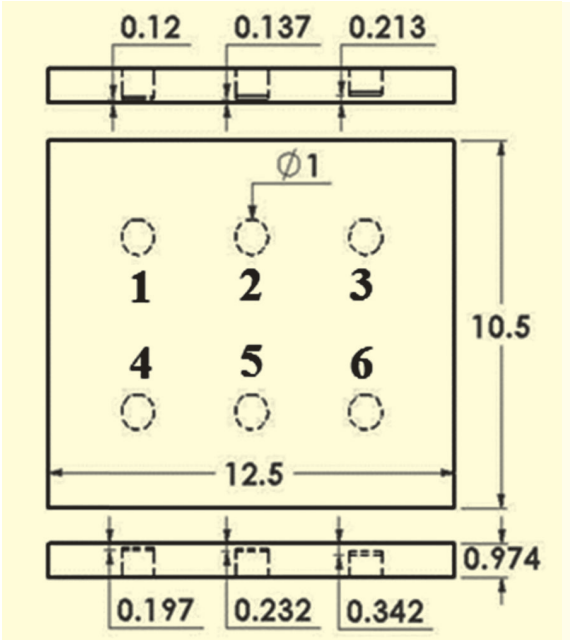


Fig. 7 Mild steel specimen with cylindrical voids numbered as 1-6 at different depths

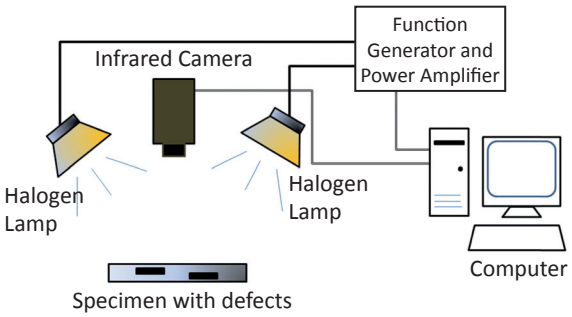


Fig. 8 Experimental setup for active infrared thermography

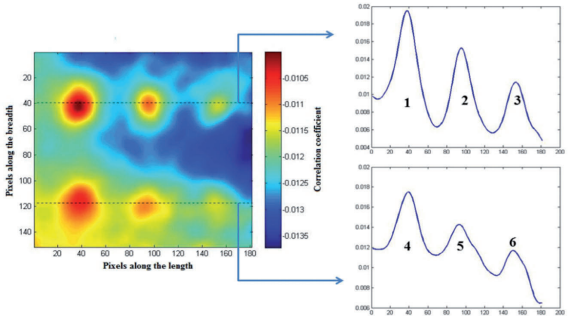


Fig. 9 Detected defects in the correlation image using pulse compression and the corresponding locations of defects

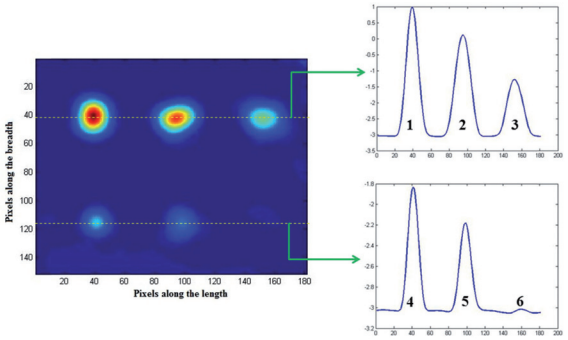


Fig. 10 Detected defects in the phase image of the correlation coefficients and corresponding locations of defects

This specimen was excited with the frequency modulated heat source producing a heat flux of 2000 W/m^2 with a linear frequency variation from 0.01 Hz to 0.1 Hz in 100 seconds duration. The setup is shown in Fig.8. The infrared camera acquired the thermal profile of the specimen for the required time duration of 100 seconds. The phase and cross-correlation amplitude images at different time instants were obtained. The phase images were observed to provide finer details of the defects in comparison to the amplitude images. By qualitative analysis of phase image and the surface profile, it was observed that the pulse compression based result is more effective than the phase image (Figs. 9 &10). In the present context, the pulse compression approach was carried out using the correlation method. The results obtained are promising and the defects are visualized in the correlation images.

WP-2: Development / performance evaluation of sensors for application in real time structural health monitoring

Development of packaged embeddable FBG sensor for temperature and strain measurement in concrete structures and packaged weldable FBG sensor for steel structures

Packaged FBG sensor for simultaneous strain and temperature measurement has been developed by CSIR-CGCRI. Temperature sensitivity in embeddable form has been evaluated at CSIR-SERC. Simultaneous strain and temperature measurement is under process. Housing for development of embeddable sensor array has been fabricated (Fig. 11) and encapsulation of the FBG sensor for array formation is underway.

Design of packaged strain sensors, which are weldable on steel structures, has been done by CSIR-CGCRI. Design of an appropriate metal substrate/housing on which the FBG sensor would be placed is an important issue towards the development of surface mountable packaged sensor. Strain transfer from the structure to the sensor has been investigated theoretically using Finite Element analysis. The housing (Fig.12) will be fabricated shortly.

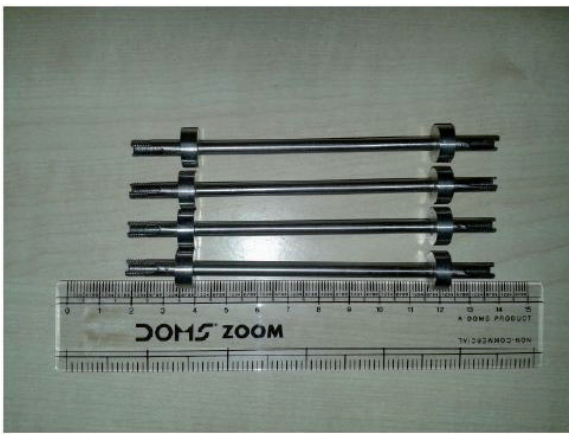


Fig. 11 Sensor housing for embeddable strain sensor array

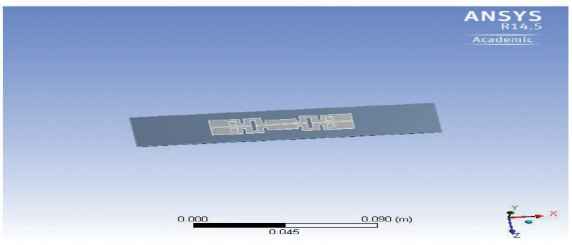


Fig. 12 Sensor housing for weldable FBG strain sensor

In the simulation, the sensitivity characteristics of FBG strain sensor along with the sensor housing has been studied. The strain transfer from the structure to the sensor was found to be > 0.9.

Performance evaluation of packaged FBG sensors

To study the behaviour of packaged strain-temperature FBG sensor under temperature, temperature calibration study was carried out on a concrete cylinder of 150mm x 300mm cast with packaged strain-temperature FBG sensor at the centre of the cylinder as shown in Fig. 13. Monitoring of strain and temperature during curing process is measured. After curing, the finished surface of the specimen was instrumented with strain gage based temperature sensor. The concrete cylinder was completely soaked under water in temperature controlled water bath for sufficient period under ambient temperature. The temperature was increased from ambient to 50˚C at 5˚C

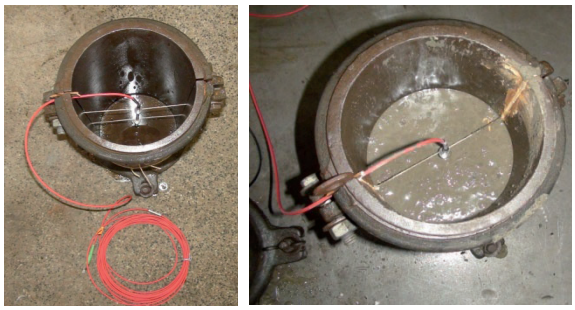


Fig. 13 Packaged embeddable type strain-temperature FBG sensor during embedding

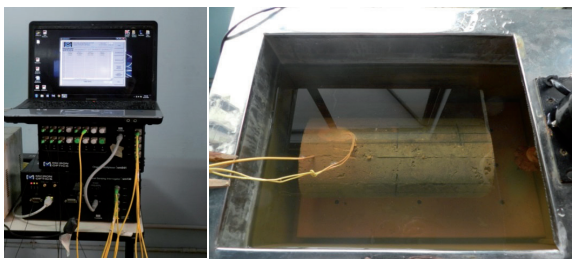


Fig. 14 Experimental set-up for temperature calibration of packaged strain-temperature FBG sensor

Fig. 15 (a) Aluminium mould for sensor fabrication

Fig. 15 (b) PDMS liquid

interval and corresponding wavelength shifts from both FBG sensors of packaged FBG sensor and temperature from strain gage based temperature sensor were recorded (Fig. 14). Analysis of the recorded data in under progress.

Development of Eutectic Gallium Indium based Microfluidic Sensor for corrosion monitoring

Eutectic Gallium Indium based Microfluidic Sensor for corrosion monitoring was developed by CSIR-CECRI. The sensor for corrosion monitoring was fabricated using Polydimethylsiloxane (PDMS). An aluminium mould was fabricated by CNC machining process. The PDMS was poured on top of the mould and cured at 250°c. Two such layers were joined together to form a micro-channel (Fig. 15). Eutectic Gallium Indium was injected into the micro-channel and electrical connections were made. Electrical resistance of eutectic gallium-indium changes almost linearly with respect to the applied force. This intrinsic property of eutectic gallium-indium can be utilized in fabrication of smart sensing systems for corrosion monitoring application. Evaluation is under progress.

Development of integrated embeddable RFID based wireless sensor for monitoring the level of temperature, humidity and corrosion in concrete structures

Integrated embeddable RFID based wireless sensor is being developed for monitoring the level of temperature, humidity and corrosion in concrete structures. Schematic of RFID based measurement system is shown in Fig.16. It contains a corrosion sensor or humidity sensor, temperature sensor, interface electronics that can be queried remotely both to identify it and to indicate sensor readings such as corrosion / humidity level and temperature. The device is powered remotely, thus eliminating the need for any batteries. It is designed to be embedded in the structure either during the initial construction, maintenance period or in a core hole, which can be filled up. The developed prototype device has undergone several modifications with the choosing of suitable

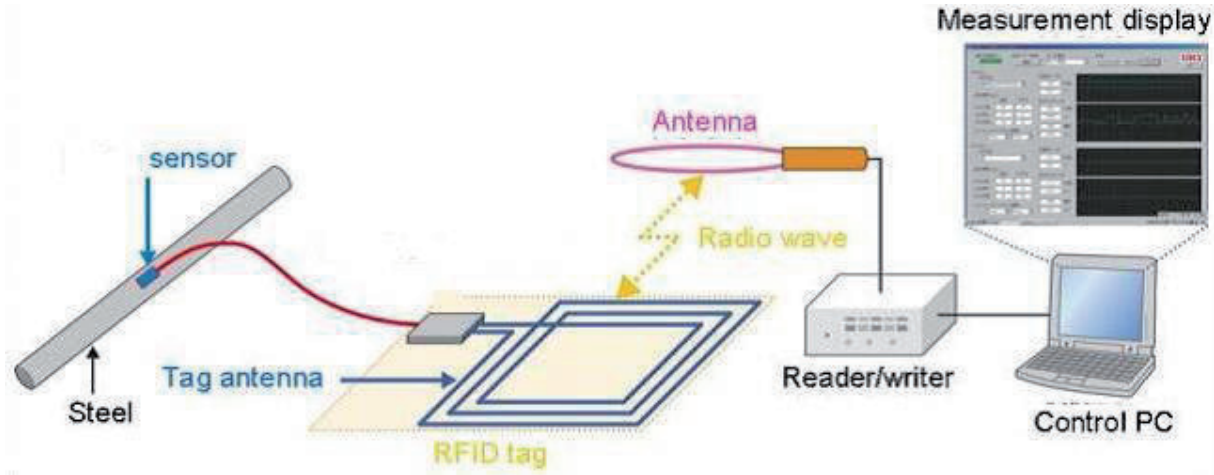


Fig. 16 Schematic of RFID based measurement system

components like signal conditioning amplifiers, voltage reference, sensor interfacing, antenna matching network, etc. The challenge was to make the above components to work with the energy harvested from the RF field and transpond useful data. A prototype device has been developed and preliminary field-testing was done. A concrete specimen with reinforcement was cast and the data from the wired corrosion sensor, RFID based corrosion sensor, temperature and humidity sensor were logged. To evaluate the sensor performance, accelerated corrosion tests are planned to be conducted.

WP-3: Development of real-time, continuous remote health monitoring (RHM) system and application of wireless sensor networks (WSN)

Study on effective communication in the existing power line cables using two pl nodes logically bounded

Development & testing of Energy node which measures the voltage, current and energy consumption etc, Physical parameter node capable of measuring multiple parameters from transmitters (temperature, humidity, light level, etc.) for communicating over power line is completed. Typical arrangement of modules is shown in Fig. 17.

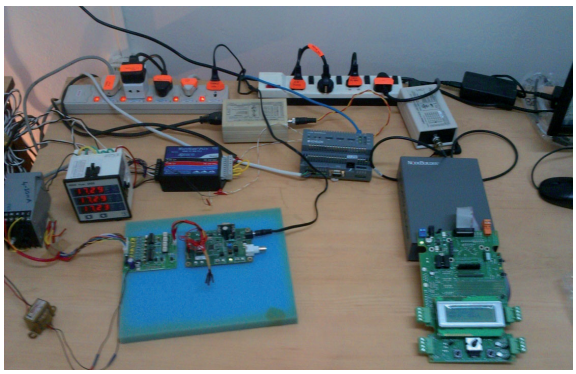


Fig. 17 Power line working setup with energy nodes, physical node and internet server module

The distance of communications with two PL nodes logically bounded, is evaluated (Fig.18). By pressing the switch in one node will play the keyboard application (sound with different notes) in another node. Distance of communication is evaluated between CMC substation and different laboratories.

Development of wireless sensor node (MEMSIC)

This wireless sensor node consists of sensor board (MTS 400), and processor board with radio (LPR2400) developed around the 32-bit ARM Cortex-M3 CPU and LPC 1768 microcontroller, for use in structural health monitoring application. Testing and minor correction of the developed prototype of double layer controller (LPC1768) board with zigbee transceiver module are carried out.

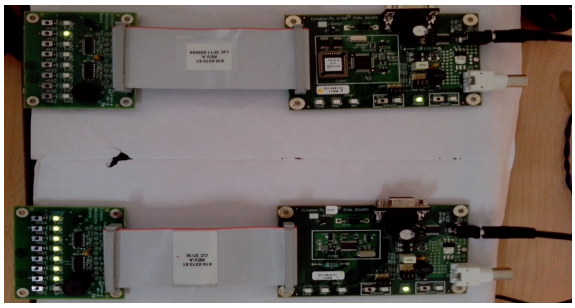


Fig. 18 two pl nodes logically bounded for control application & to test distance of communication

Software was developed for data reading from temperature, humidity and two-axis accelerometer sensors, using the developed sensor board and the procured LPC1768 microcontroller kit. The wireless sensor setup is as shown in Fig. 19.

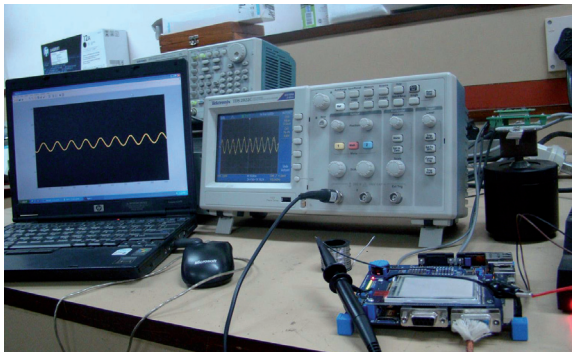


Fig. 19 Wireless sensor setup

Laboratory Evaluation of wireless sensor nodes for remote health monitoring

Wireless sensor nodes, Imote2 and Waspmote

were evaluated for the vibration characterization in the triaxial shake table of ASTaR Lab. The test node of the Imote2 and Waspmote were fixed along with the piezoelectric conventional wired accelerometer on the shake table (Fig. 20). The conventional accelerometer was connected to a data logger system to acquire the vibration data. The gateway node of the Imote2 was attached to the computer, which acts as the base station. Vibrations to the shake table were given in two axes and data were recorded from all the sensors. Testing of Imote2 and Waspmote was carried out for different vibration levels and the response of the sensors was recorded. The WASPMOTE has ability to store data in SD memory card for the event based logging. The vibration measurements were stored in the serial data FLASH memory. The acceleration response measured from WASPMOTE and FFT plot of measured response are being processed.

Fig. 20 Test setup on shake table for evaluation of wireless sensors

WP-4: Advanced NDT & E techniques for condition assessment and forensic analysis

Identification of defects in concrete structures using impact-echo (IE)method based on shift in frequency

A concrete slab of 1.5m long, 1m wide and having 0.15m thickness is used as test specimen. Artificial voids of size 150 × 150mm are created and placed at known locations in the slab specimen. IE data is collected along different sections and processed them using codes written in Matlab, frequency shifts have been observed. A shift in the frequency of the stress pulse indicates the presence of defects in solid concrete. Therefore, this method can be used in the field for defect identification at shallow depths.

Condition assessment of masonry structures

Ground Penetrating Radar (GPR) data was collected using 1.6 GHz antenna on selected brick masonry walls of varying thickness. The aim was to know the effectiveness of GPR in finding the thickness of brick masonry walls when only one side is accessible. Number of radargram and wiggle mode images have been collected. Based on the trials, a dielectric constant in the range of 4 – 5 is assumed and is in agreement with the reported literature. Tests have been repeated on selected brick masonry walls for the reliable thickness determination. Fig. 21 represents the Radargram and wiggle mode of a line scan on a brick wall. The thickness estimated from the Radargram is 263 mm, where as the actual thickness of wall is 260 mm. The hyperbola below the back wall indicates the presence of a pipe outside the wall. To understand the application of different NDT tests for masonry, brick masonry wall panels were cast. Burnt clay bricks available in the market were procured and wall specimens/panels with different variables such as single leaf (wall without continuous vertical joint), double leaf, voids, etc. were cast for testing and calibration of different NDT techniques on brick masonry. Fig. 22 shows the casting of typical brick masonry wall panel with variables such as cavities, stone, thermocole etc., at pre-defined locations. The brick walls were constructed with cement mortar. Rebound Hammer (RH) test and Ultrasonic Pulse Velocity (UPV) tests were carried out on finished walls. Fig.23 shows the RH data collection on a typical wall. The RH values observed were in the range of 30-38, where as the UPV values were in the

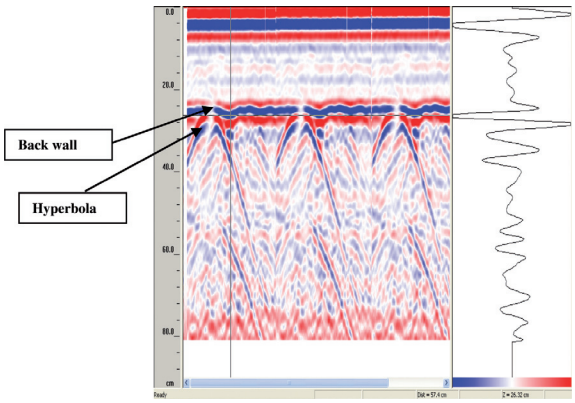


Fig. 21 Radagram and wiggle mode

Fig. 22 Typical brick wall specimen with different variables such as materials, voids, etc.

Fig. 23 Rebound hammer data collection on a finished brick wall

range of 3 – 4 km/sec. The range of UPV is lower in double leaf wall portion (3-3.5 km/sec) when compared to that of single leaf wall portion (3.6-4.0 km/sec).

Electrochemical Chloride Removal (ECR) from concrete structure using various anode materials and electrochemical inhibitor injection for corrosion mitigation

CSIR-CECRI is developing techniques for mitigation of corrosion in concrete structures using Electrochemical Chloride Removal (ECR) and electrochemical inhibitor injection. An attempt was made to compare the performance of three different types of counter electrodes viz. Thermally Sprayed Aluminum (TSA), Stainless Steel (S.S) and Conducting Cement Paste (CCP) anode, for ECR (Figs. 24 to 26).

Measured Open circuit potential shows that Ti mesh anode provide high and stable potential when compared to Stainless Steel and Conductive Cement Paste (CCP) anode. Ti anode is found to be better for gradual removal of chloride compared to the other two anodes.

Fig. 27 shows electrochemical inhibitor injection process. Concrete specimen was placed in an electrolytic cell immersed with inhibited injection solution. Rebar embedded in concrete acts as cathode and stainless steel plate act as anode. The electrolytic cell was galvano-statically maintained at a D.C current density of 0.5 $A.m^{-2}$ with respect to steel. The Open Circuit Potential of embedded steel in different concrete systems was noted during the electro

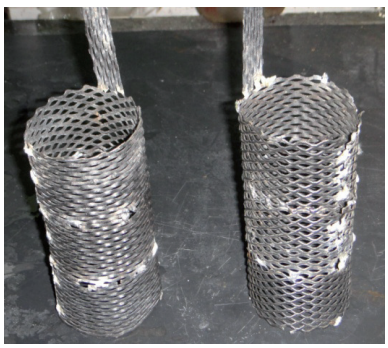


Fig. 24 TSA anode material

Fig. 25 Stainless steel

Fig. 26 Conducting cement paste anode

Fig. 24-26 Different types of counter electrodes used for ECR

injection process. It was observed that inhibited injection system shifted the potential towards a more positive direction when compared to a system without injection.

WP-5: Modelling and response evaluation under extreme loads and damage mitigation of hazards-induced distress

Modelling and response evaluation under cyclonic wind load

Wind data had been acquired during the landfall of cyclone 'Nilam' (track is shown in Fig. 28), by using propeller type anemometers with wind vanes installed on a 32 m tall guyed lattice tower at 10m, 20m and 32m, located at Annamalai University, Parangipettai campus. Photo view of the instrumented tower during landfall of cyclone is shown in Fig. 29. A total number of 30 datasets (each 15 minutes duration) had been collected continuously between 11.45 a.m. and 07.15 p.m. on 31st October 2012. Analysis of wind speed data has been carried out and the following observations have been made .

Important statistics such as hourly mean, 3-sec gust and instantaneous maximum wind speeds were evaluated for the along-wind speed for the day of landfall (31.10.2012) of cyclone 'Nilam', as shown in Fig. 30. It is observed from Fig. 30 that the highest maximum instantaneous and 3-sec gust wind speeds are observed to be 26.6 m/s and 24.9 m/s at 32 m level at the site (which is about 150 km away from the landfall, i.e. Mahabalipuram) and 22.7m/s and 20.7m/s at 10m level, which corroborates with the reported maximum sustained surface wind speed of 20.83m/s (corresponds to 10 m level) at Chennai during landfall of cyclone 'Nilam', as reported by Indian Meteorology Department. Intensity of turbulence is another important wind characteristic which influences the peak effects and the dynamic behaviour of buildings/structures. The evaluated value of turbulence intensity at the measurement location during the cyclone is observed to be about 0.22 at 32 m level.

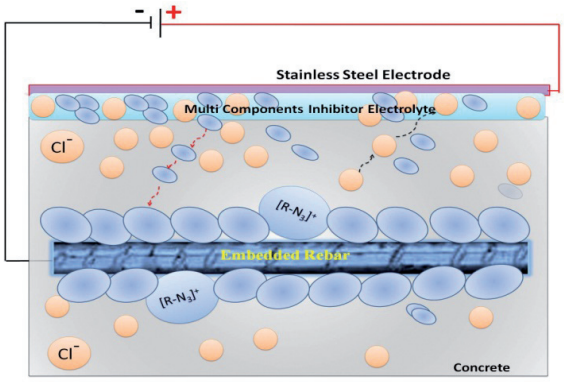


Fig. 27 Graphical representation of electrochemical injection process

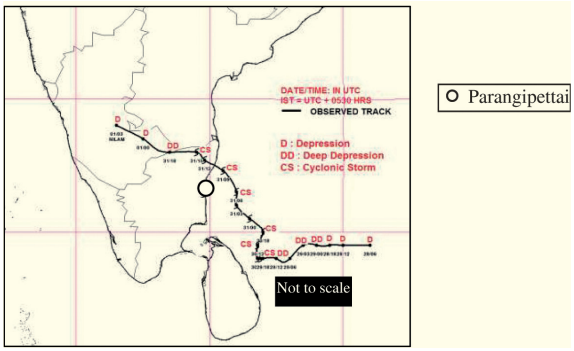


Fig. 28 Track of storm and location of measurement site w.r.t landfall.

Post-cyclone 'Phailin' damage survey

A post cyclone structural damage survey has been conducted by two scientists of CSIR-SERC in cooperation with scientists of CSIR-IMMT, Bhubaneswar after the passage of a very severe cyclonic storm ('phailin') which crossed near Gopalpur (Odisha) around 2230 hrs of IST on 12th October 2013 with a sustained maximum surface wind speed of 200-210 kmph gusting to 220 kmph. It was observed that mainly places in and around Brahmapur, Chhatrapur, Gopalpur and Ganjam along the coast were affected due to their proximity to the cyclone track. Discrete failures of engineered structures such as rooftop lattice tower, ground based communication / transmission line lattice towers and steel trusses with asbestos or G.I. sheet roofing of industrial sheds (either mono or double sloped) were observed. In addition, total / partial collapse of semi / non-engineered structures like compound walls, roofs of dwelling units (kutcha

Fig. 29 Photo shows instrumented tower

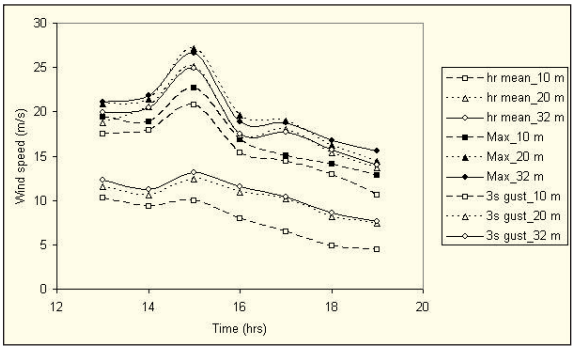


Fig. 30 Variation of along-wind speeds averaged over different periods

/ thatched houses), power distribution system (transformers and electrical posts) were also observed. Damage to roofs of fuel filling stations and façade (glass) of buildings including glass panels of windows were observed to be other common failures. Views of the some of the typical failures observed during damage survey are given in Fig. 31.

Two dimensional ground response analysis for earthquake

Though one dimensional analysis is widely adopted for layered deposits, two dimensional analysis has been recommended for deeper alluvial basins. Hence, two dimensional linear ground response analyses is carried out for Sabarmathi river basin. In the two dimensional model considered for analyses (Fig.32) rock layers of thickness 300m, 500m and 1000m with different shear wave velocities simulating the field conditions are also included in addition

Fig. 31 (a) Transmission Line Tower (b) Industrial shed (c) Free standing communication tower, (d) Damage to sheathing of boiler structure in a chemical plant

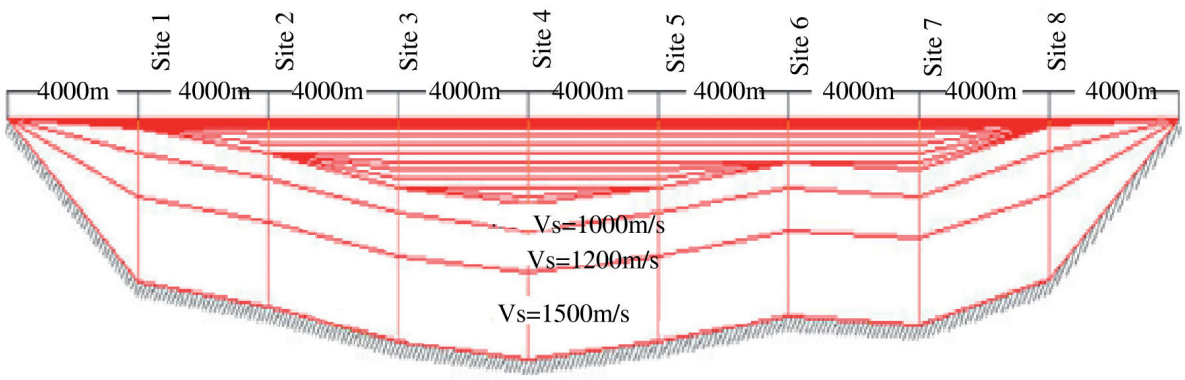


Fig. 32 Typical model of Sabarmati basin considered for the present study

to the soil layers and the ground motion is applied at the base. Solid elements having unit thickness are adopted during the present study. Young's modulus obtained from shear wave velocity, Poisson's ratio and the density of soil and rock layers the main inputs defining the material behaviour for 2D analyses in the study. Acceleration time histories and response spectra are obtained at the top of soil surface for 15 Bhuj earthquake simulations at 8 different site locations of the basin. Time period of the basin is found to be 4 seconds in two dimensional linear ground response analyses. Comparison of surface level average response spectra of fifteen simulations from 2D ground response analyses with the response spectra of recorded ground motion at passport office building for Bhuj for the 8 sites are as shown in Fig. 33, and it is seen that higher amplification is observed for sites 3, 4 and 5 with soil depths of 800m, 1000m and 800m which are at the centre of the basin and lower amplification is observed for the sites 1 and 8 with soil depth of 80m and 100m which are near the basin edge.

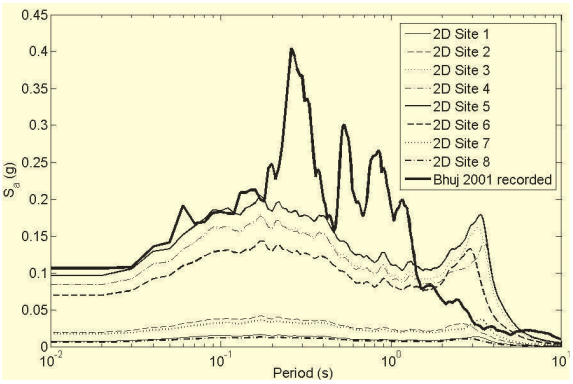


Fig. 33 Comparison of surface level average response spectra of fifteen simulations from 2D ground response analyses with the response spectra of recorded ground motion at passport office building for Bhuj earthquake

Nonlinear time history analysis of RC frame with visco-elastic dampers in diagonal and chevron bracing for site-specific earthquake

Nonlinear time history dynamic analyses of a thirteen storey Reinforced Concrete (RC) frame with and without viscoelastic dampers

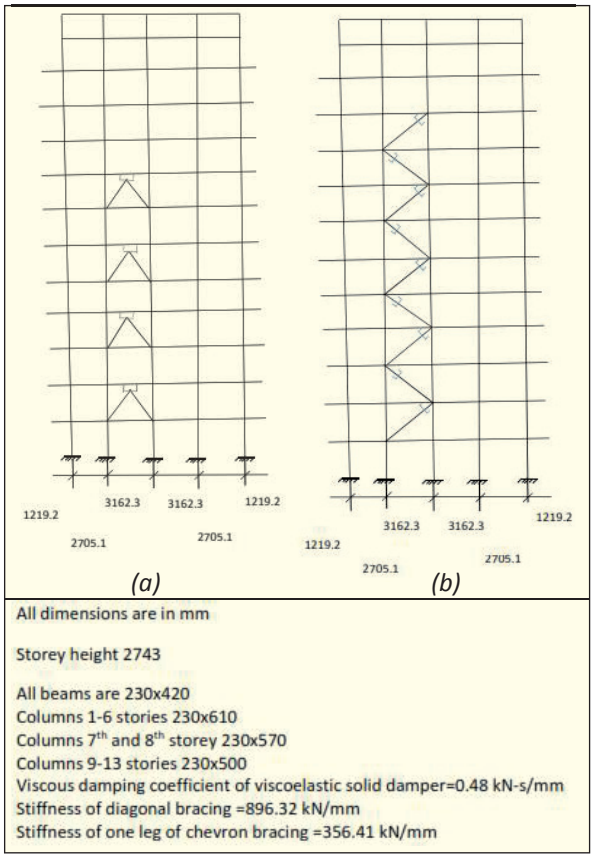


Fig. 34 Thirteen storey RC frame with viscoelastic dampers placed in (a) diagonal bracing (b) chevron bracing

has been carried out for site-specific scenario earthquake of moment magnitude 7.6. Artificial ground motion is generated using finite source stochastic model with seismological parameters of Bhuj 2001 earthquake for rock outcrop and the same is propagated through a typical 100m soil profile with one dimensional equivalent linear analysis program and surface level time history is obtained for a soil site of Ahmedabad city. The dimensions, properties of frame (with overhang on both sides) and the location of viscoelastic solid dampers in diagonal bracings and chevron bracings are shown in Fig. 34. Dampers are assumed to be linear and Maxwell model is adopted for computational modelling of viscoelastic damper in the analysis. Three parameter Park Model is adopted for modelling nonlinear behavior of RC beams and columns. The comparison of storey shears and displacements are shown in Fig.35. The schemes suggested can be adopted for retrofitting the buildings located at soil sites, which are expected to suffer more damage than that of the rock site. This study brings out the importance of carrying out site-specific analyses for retrofitting the buildings with passive energy dissipaters towards the mitigation of structural damage during future earthquakes.

Numerical analysis of flanged beam under shock loads

A finite element model based on Lagrangian approach is developed to simulate the impact loading on flanged section. Three dimensional solid elements are used for concrete and reinforcement is modelled using beam elements embedded into concrete. The details of the finite element mesh and boundary conditions are shown in Fig. 36. The mesh size of a concrete element is taken as 15 mm. Total numbers of elements are 352230 in slab and 57525 for steel reinforcement.

Different impact cases are considered for a projectile mass of 10.575 kg with different velocities of 100m/s, 50 m/s and 25m/s. The shock loading can be applied either by impulsive forces or by hitting a projectile to the target structure. The equivalent mass of projectile corresponding to ultimate moment resistance is determined and then the velocities are changed to determine the safe velocity at which the flanged beam section will resist the shock caused due to projectile impact. The gauge points are fixed (Fig. 37) at the critical sections at obtained time varying responses. The material input parameters are provided for M35 grade concrete in the numerical model.

The critical response for the impact at mid span is obtained at the bottom of beam denoted by gauge point # 15. The results for spherical steel projectile (mass =10.575 kg) impact are obtained for the same location at different velocities. Longitudinal strain exceeds the failure strain of concrete as well as steel hence considered as plastic hinge formed for 100 m/s and 50 m/s cases.

Damage contours for impact at the mid span for projectile velocity of 100m/s is shown in

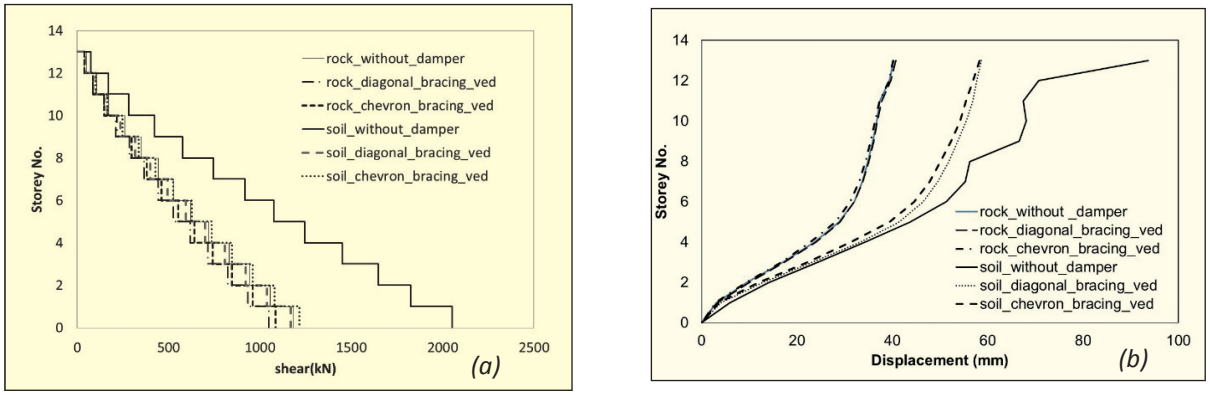


Fig. 35 Response of 13 storey frame for one simulation of site-specific earthquake of moment magnitude 7.6 (a) Peak storey shears (b) Peak displacements

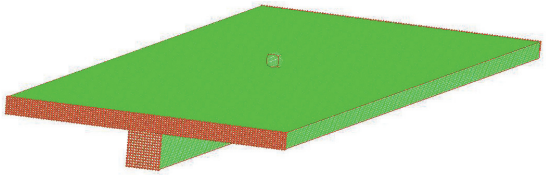
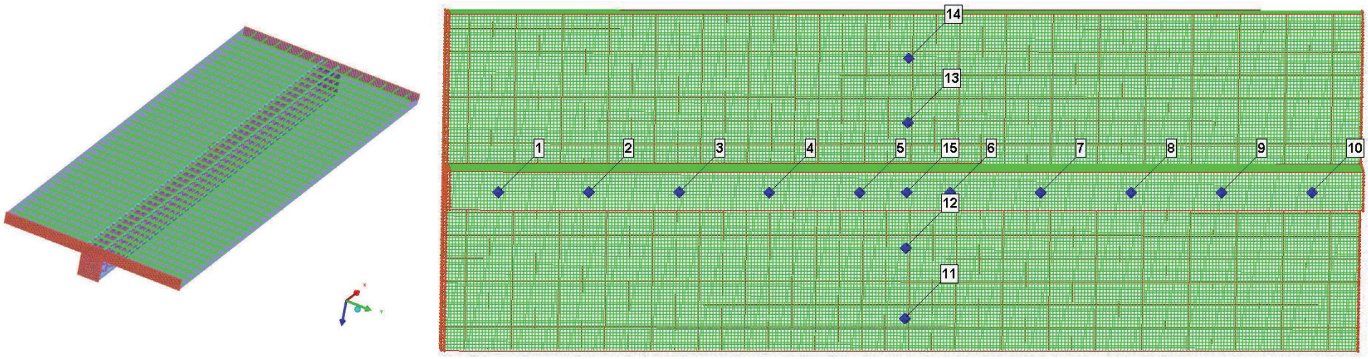


Fig. 36 FE Mesh and boundary conditions

Fig. 38. It is observed that at projectile velocity of 25 m/s the flanged beam reinforcement is adequate and hence it can resist this impact safely. The principal strain in concrete has exceeded maximum allowable limit for concrete indicate failure.

evaluate the supplemental damping provided by the designed PED devices towards enhancing its seismic performance.

The test structure identified for the experimental verification is a single-bay three-story RC framed structure having an overall height of 3.6 m (1.2 m story height) and plan dimensions of 1.44 m x 0.75 m. Using M20 grade concrete, the three-story RC framed structure is being constructed. The column members are of size 75 mm x 75 mm with 4 numbers of 12 mm diameter high strength deformed bars and 6 mm diameter

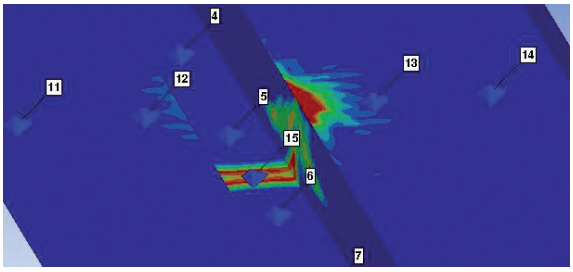


(a) *(b)*

Fig. 37 Location of (a) reinforcement and (b) critical points in FE model

Alternate seismic performance enhancement method for improving sustainability and seismic disaster resistance of buildings and structures

A procedure for estimating the supplemental damping required to satisfy the given performance level objective is developed. The basic idea is to compute the required damping from the difference between the total effective damping needed to meet the target displacement and the equivalent damping provided by the structure at the target displacement. The proposed DBD method for supplemental damping using PED devices is being validated through an extensive shake-table experimental investigation on a single-bay three-story RC framed structure. Shake-table experiments are to be performed on the selected single-bay three-story RC framed structure in bare and retrofitted conditions to



Velocity 100m/s

Fig. 38 Damage contours at different projectile velocities

stirrups at a spacing of 100 mm centre to centre. Similarly, the beam members are also of size 75 mm x 75 mm with 4 numbers of 12 mm diameter high strength deformed bars and 6 mm diameter stirrups at a spacing of 100 mm centre to centre. The floor slabs are made of rigid RC slabs having a thickness of 25 mm with suitable provisions for adding steel blocks in each floor to represent the live load. The details of the test structure

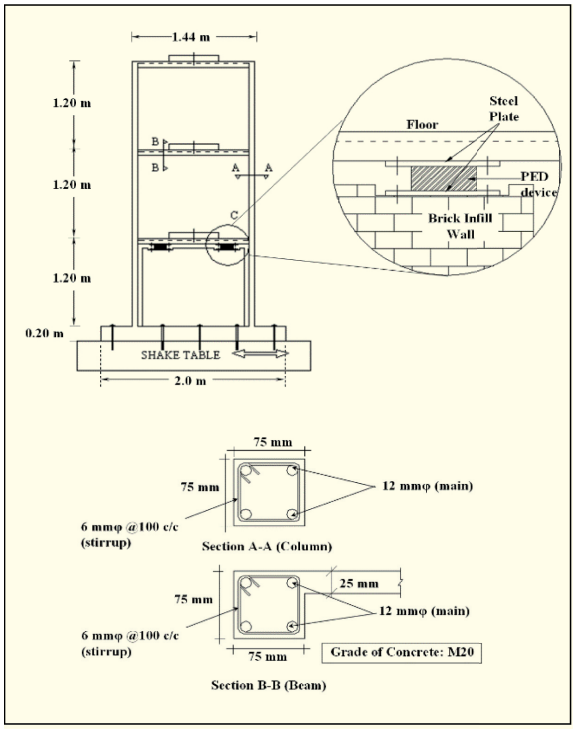


Fig. 39 Details of the RC framed structure chosen for the study

identified for the experimental verification of the proposed DBD method for supplemental damping using PED devices is shown in Fig.39.

Initially, the RC framed structure was designed for gravity loads only. Then the required supplemental damper devices were designed based on the direct displacement based design methodology developed earlier for improving the sustainability and disaster resistance of the chosen RC framed structure to meet a desired performance level objective of Immediate Occupancy. In the present study, to design the PED devices, a target roof drift ratio of 0.01 (1 percent) to meet the desired performance level and design acceleration response spectrum given in IS 1893-Part 1 (2002) for DBE, seismic zone IV, 5 percent damping, medium soil condition was used. Based on this exercise, the number, capacity and the sizes of the PED devices required to retrofit the frame structure to meet the desired performance objective (10 percent target total effective damping ξ_{eff}) were arrived. Four numbers of visco elastic PED devices of size 50 mm x 100 mm x 20 mm made of high damping rubber (Storage shear modulus G': 1.73 MPa, Loss shear modulus G'': 1.89 MPa & Loss modulus η_d: 1.10) will be added for retrofitting the chosen RC framed structure through a pair of non-structural infill wall in the first story only. The non-structural infill wall is of 100 mm thickness. Sufficient gap of 75 mm was provided between the column and infill wall facilitating restraint free displacement of the column members.

WP-6 Establishment of composite 'National facility for materials, sensors and mechanics'

A composite 'National facility for materials, sensors and mechanics' is to be developed as combined output of the activities of the three projects of CSIR-SERC in the XII Five Year Plan period (eNano-Tics, SUSMAS, and I-HEAL). The tendering process for construction of foundation, test floor and superstructure for the national facility is completed. Piling work of foundation is in progress.

Engineering Sustainable Materials and Structures Action Plan I: Sustainability through Eco-balancing (SUSMAS)

Project No. ESC0208 (SUSMAS)

Date of commencement : April 2012

Target date for completion : March 2017

Nodal Officer : Dr. J. Rajasankar

Co-nodal Officer : Dr. B.H. Bharatkumar

Scope and objectives

- Development of eco-friendly, durable, energy-efficient construction materials and characterization
- Evolution of eco-balancing structural systems
- Green buildings for reduced carbon foot print based on non-conventional methods

- Development of design philosophy and functional characterization for realizing sustainable structures (performance-based life-cycle design approach)
- Establish a composite 'National facility for materials, sensors and mechanics'

Work was continued under the various tasks and the highlights of the progress achieved is given below:

WP-1: Effective utilisation of waste material for construction

Task 1.1 Synthesis & evaluation of alternate binder system for concrete from conventional and non-conventional wastes

Statistical analysis was carried out on the compressive strength of Green Geopolymer Concrete (GGPC) made of Ground Granulated Blast Furnace Slag (GGBS) for various types of curing like ambient curing, sunlight curing, water curing, steam curing and heat curing. The standard deviation of the values for ambient and water curing was found to be 2.09 and 2.03, which shows a very good quality concrete. For sunlight curing, heat curing and steam curing, the standard deviation values were high compared to those of ambient and water curing. The mean, median and mode were equal for all cases except heat curing. The coefficient of variance was found to be negligible for ambient curing and water curing; high for heat curing; and medium for steam and sunlight curing. The analysis indicates that ambient and water curing are most preferred.

Table 1 Details of HGPC using MBS

Specimen ID	SGC1	SGC2
SH molarity	10	10
SS/SH ratio	2.5	3

Studies were continued on geopolymer concrete that uses Micronized Biomass Silica (MBS) as source material. High Strength Geopolymer Concrete (HGPC) mixes were developed using MBS. In order to see the effect of silicate on alkali activator solution, two mixes (SGC1 and SGC2) were prepared with sodium silicate (SS) to sodium hydroxide ratio of 2.5 and 3 and with a 10 molar sodium hydroxide (SH) solution (Table 1). Trial concrete mixes were designed for GGBS, fly ash and MBS as binder materials. Cubes of 10 cm sizes were cast and the compressive strength was determined at the age of 1, 7, 14 and 28 days. The results are presented in Table 2. Ambient temperature cured GPC with one day compressive strength of the order of 55-60 MPa has been developed using MBS. From Table 2, it was seen that when the silicate content was increased from 2.5 to 3, the 28 days compressive strength was same even though the early strength was low and also at the age of 14 days itself about 98% of the 28 days strength was obtained.

Table 2 Compressive strength (MPa)

Age	SGC1	SGC2
1 day	55	63
7 days	75	70
14 days	80	80
28 days	81	81

Task 1.2 Synthesis & evaluation of alternate aggregate/filler/fibre for concrete from conventional and non-conventional wastes.

Studies were carried out on concrete mixes with copper slag as replacement for river sand. Concrete mixes containing copper slag and sand as fine aggregate were designed for three w/c ratio. The mix details are given in Table 3. It was observed that the concrete mixes containing copper slag were more fluidic in nature. However their performance in terms of strength was at par with concrete made with river sand. The comparison of 28 days strength for 3 different w/c ratios is given in Fig. 1.

Studies on recycled aggregate concrete was continued. The concrete made using recycled aggregate was subjected to tests for water depth penetration and rapid chloride penetration.

Table 3 Mix details of the concrete mixes*

	Cement	Water	Fine Aggregate	Coarse Aggregate	W/C	Fine aggregate type
	kg/m^3					
CCM	425	170	763	1030	0.37	River sand
	362	170	831	1030	0.47	
	298	170	885	1030	0.57	
CSCM	425	170	951	1030	0.37	Copper slag
	362	170	1055	1030	0.47	
	298	170	1122	1030	0.57	

* CSCM - Copper slag concrete mix; CCM - River sand concrete mix

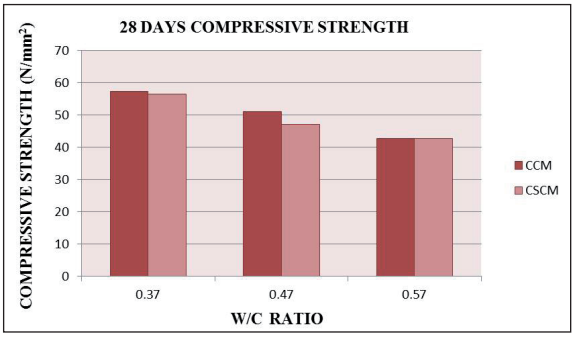


Fig. 1 Compressive strength of concrete at 28 days

Water depth penetration under pressure

Concrete cubes of size 150 mm were cast using recycled aggregate (RA) to determine the water depth penetration under pressure. In this test, a water column acts on the specimen for 72 hours under 5 bar pressure, equivalent to keeping the specimens under a water column of 50 m. Fig.2 shows the test set up. The specimens were cast in four series. The composition details of the specimens with replacement of natural aggregates (NA) are given in Table-4.

Table 4 Percentage replacement with recycled aggregate

Series	Percentage replacement and details
1	0%, 50% and 100% RA without treatment
2	50% and 100% heat-treated RA
3	50% and 100% heat-treated RA with fly ash* (10% coarse aggregate content)
4	50% and 100% heat-treated RA with silica fume* (5% coarse aggregate content)

* - Addition of fly ash or silica fume was adjusted against the volume of coarse aggregate

Fig. 2 Test set up for water depth penetration under sustained pressure

Water permeability was found to increase with the percentage of incorporated RA. With respect to series 1-RA50 and RA100, it was observed that the water penetration showed very high values. The total incorporation of RA increased 6 times the penetration depth (60mm) when compared with NA (10mm). The presence of adhered mortar increases the maximum penetration depth of water. Series 2 presented intermediate results. In Series 3 and 4, with addition of fly ash/ silica fume, penetration depth was found to be 13mm and 11mm, respectively, when 100% heat-treated RA were used. It can be confirmed that the differences observed between the concrete containing NA or RA with fly ash/ silica fume are minimal. Thus, the pore structure of the heat-treated RA concrete with addition of fly ash/silica fume guarantees impermeability and sufficient durability throughout the service life of such specimens.

Rapid chloride permeability test (RCPT)

RCPT is a test where the amount of charge passed under a standard potential gradient is measured. Fig.3 shows the RCPT set up used in the present study. Table 5 shows the average

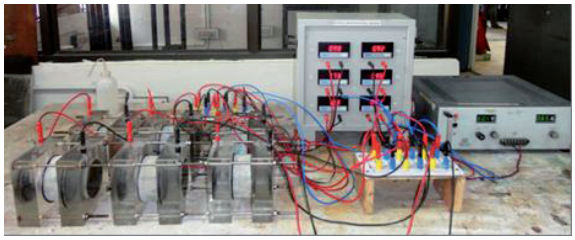


Fig. 3 RCPT set up

charge passed in the RA concrete. The values measured in conventional concrete, RA without any treatment, and concrete containing heat-treated RA were found to be 2232, 3386, and 2563 Coulombs, respectively. The use of fly ash or silica fume as an addition to the cement reduces the water to binder ratio, which would improve resistance to chloride ion penetration. The average charge passed in the 100% RA concrete with the addition of fly ash was 1152 Coulombs, and with the addition of silica fume, it was 603 Coulumbs. From the results, it can be seen that chloride ion permeability of RA concrete with the addition of fly ash or silica fume was low and very low, respectively, as per ASTM C 1202 (2010). Hence, a significant improvement was observed in the durability properties of concrete with heat-treated RA and addition of mineral admixtures.

Table 5 Rapid chloride permeability test on RA concrete

Specimen Id	Average Charge passed (Coulombs)	Chloride ion permeability	Remarks
NA	2232	moderate	Normal concrete
RA-50	3197	moderate	50% RA
HTRb50	2541	moderate	50% heat treated RA
RA-50-FA-10	1142	low	50% RA with 10% fly ash
RA-50-SF-5	906	very low	50% RA with 5% silica fume
RA-100	3386	moderate	100% RA
HTRb100	2563	moderate	100% treated RA
RA-100-FA-10	1152	low	100% RA and 10% fly ash
RA-100-SF-5	603	very low	100% RA and 5% silica fume

Task 1.3 Assessment of the behaviour of structural elements made using the alternate binder system / aggregates / fillers / fibres under static and cyclic loading

Bottom ash is used as partial replacement of sand in concrete. In this study coal bottom ash obtained from Neyveli thermal power station, Tamil Nadu is used to make concrete by two different ways.

- Raw bottom ash (RBA)
- Washed bottom ash (WBA)

Aggregate grading is very important in relation to the properties of concrete and might affect the properties in hardened state. The sieve analysis was conducted to find the values of fineness modulus as 3.12 for RBA and 2.82 for WBA. To understand the effect of bottom ash on the compressive strength of concrete, studies were conducted by replacing sand with bottom ash by 40 %. Both RBA and WBA were used. The mix ratio of 1:1.7:3 with w/c ratio of 0.5 was used. Table 6 gives the strength at 7 days and 28 days.

Table 6 Compressive strength of concrete cubes

Sl. No	Specimen ID		Comp. Strength (7 days) MPa	Comp. Strength (28 days) MPa
1	C1		33.7	48.3
2	C2		36.7	50.5
3	C3		32.6	45.4
		Avg	34.3	48.1
1	RBA1		27.3	40.7
2	RBA2		27	42.4
3	RBA3		27.3	40.2
		Avg	27.3	41.1
1	WBA1		31. 8	45.2
2	WBA2		33.3	43.4
3	WBA3		30.6	44.8
		Avg	31.9	44.5

The 7 days compressive strength of concrete containing RBA was found to be reduced by 24% while the 28 days strength was found to be reduced by 14.5 % compared to that of control concrete. For the WBA, the reduction was only 7 % at both 7 and 28 days.

WP-2: Evolution of engineering materials and structural components/systems

Task 2.1 Development of micro alloy/green steel structural components

Finite element analysis was conducted on a composite girder made of concrete slab and ISMB 250 as web. The width and depth of the slab are chosen as 375 mm and 100 mm while the length is fixed as 6 m. Parametric investigations were carried out by changing the grade of concrete

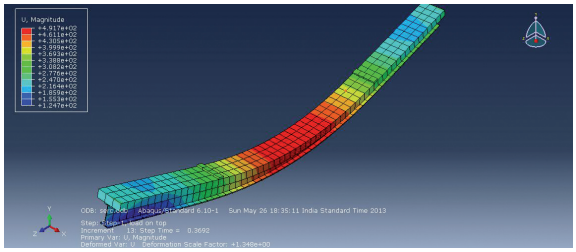


Fig. 4 Displacement contour of the composite girder

and steel for the identified dimensions. The selected concrete grades are M30, M50 and M100. The web is chosen to be made of Fe250, Fe415 and Fe500 steel. Finite element analysis is carried out to know the response of the girder till failure. The displacement response obtained from the finite element analysis for a typical case is shown in Fig. 4.

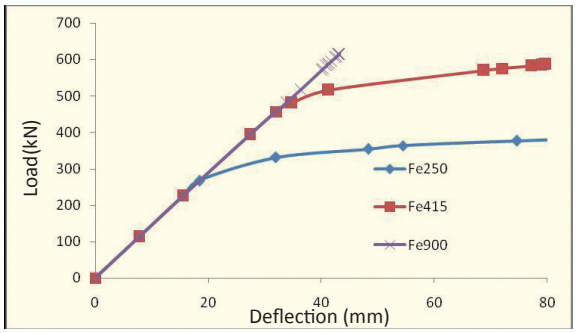


Fig. 5 Load deflection curve of girder with M30 concrete slab

Fig.5 shows the load-deflection response of the girder with slab made of M30 concrete and web made of different grades of steel. As seen from the figure, the section with Fe 250 steel underwent full plastification before the failure of concrete. In the case of Fe415, it is seen that plastification of the steel member is initiated but the failure in concrete is achieved even before the yield plateau of the steel. In the case of Fe900 steel, the concrete failure is reached before the plastification is initiated in the steel section.

The load deflection behaviour of the girder with slab made of M50 concrete and web made of different grades of steel is presented in Fig.6. It can be seen from the figure that the section with Fe250 steel displayed the same behaviour as that of the case of M30 concrete. But in the case of Fe415 steel, the specimen was able take 10% higher load than that of M30 concrete specimen but at the same time the ductility of the specimen is reduced. This is due to the increase in brittleness of concrete with increase in the strength. But the specimen with Fe900 steel was able to take 25% more load than that of the M30 specimen as the strength of the steel is fully exploited by the higher strength and stiffness of M50 grade concrete.

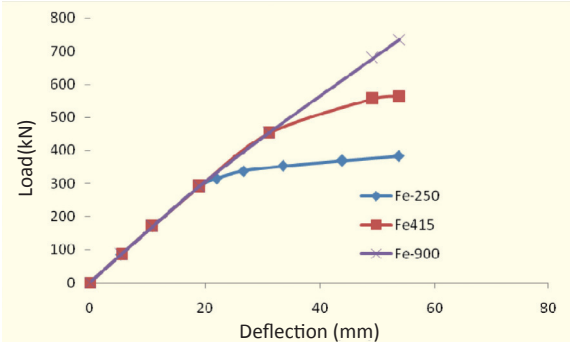


Fig. 6 Load deflection curve of girder with M50 concrete slab

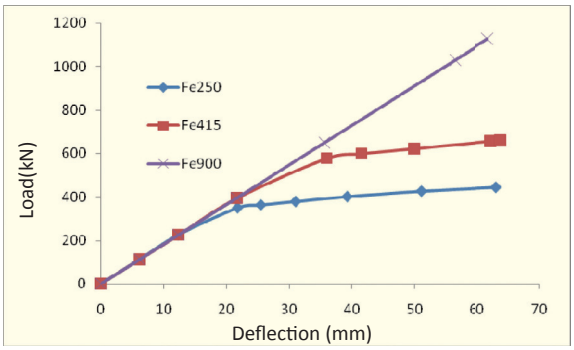


Fig. 7 Load deflection curve of girder with M100 concrete slab

The load deflection behaviour of the girder with slab made of M100 concrete is produced in Fig.7. From the figure, it can be seen that behaviour of the specimen with Fe 250 steel is more or less the same as that of the specimen with M30 and M50 grade concrete. In the case of specimen with Fe415 grade steel, strength was equivalent to that of specimen with M50 grade concrete but higher than that of M30 specimen and it can also be seen that the specimen has undergone considerable amount of plastification. But in the case of Fe900 specimen, the strength was 50% higher than that of the specimen with M50 grade concrete slab and 100% higher than

that of the one with M30 grade concrete slab. Reduction in concrete ductility with increase in strength is identified as the main reason for this behaviour.

From the above study, it can be seen that the strength and stiffness behaviour of composite members strongly depends on the combination of on the grade of concrete and steel. It is observed that in the section with lower grade of steel, strength is the governing factor, even with lower grade of concrete. This is evident from the similar behaviour (full plastification of the section) exhibited by the specimen made of Fe250 steel. Generally in the steel-concrete composite member, the failure should be ductile which means steel should yield first so that sufficient warning is noticed before collapse. But as the strength of the steel is increased, it is seen that the low strength concrete tends to fail first even before plastification is initiated in steel. Hence as the strength of steel goes up, the specimens exhibit brittle failure which is not desirable. The use of micro alloy steel requires an appropriate grade of concrete (normally higher strength) in composite sections in order to fully exploit the strength capacity of such material.

Task 2.3 Laboratory investigations on engineering structural component/system under static and cyclic loading

To investigate the behaviour of GFRP tension members, experiments were conducted on GFRP angle sections connected on both flanges and subjected to axial tensile load. The hybrid connection was simulated by providing steel end fixtures. The flanges of the GFRP angle sections were connected to the flanges of the steel angle at both the ends and the load was applied on a steel plate welded to the steel angle. The tension tests on GFRP leg members were conducted on 75x75x6, and 75x75x8 mm size angle sections. The specimens were instrumented with strain gauges near bolt hole locations and at mid length. The joint deformation was measured with respect to the applied load using digital dial gauge.

The experiments were conducted by varying the number of bolts, bolt diameter and bolt arrangement pattern. First series of experiments were conducted by varying the number of bolts by keeping the bolt diameter constant (16 mm). The second series of experiment were conducted by changing the diameter of bolt to 12mm from 16mm, while maintaining the number of bolts as constant (6 Nos). Keeping the 12mm bolt diameter as constant, the variation in tension capacity was studied by changing the bolt arrangement pattern, bolt arranged in single line i.e., (i) along the centre of gravity line or (ii) along the gauge line and (iii) in double gauge lines. All the three series of experiments were repeated for L 75x75x 6 mm and L 75x75x 8 mm angle sections. The average failure loads observed in all these tests were compared with tension capacities calculated based on IS:800 and IS:802 codal recommendations.

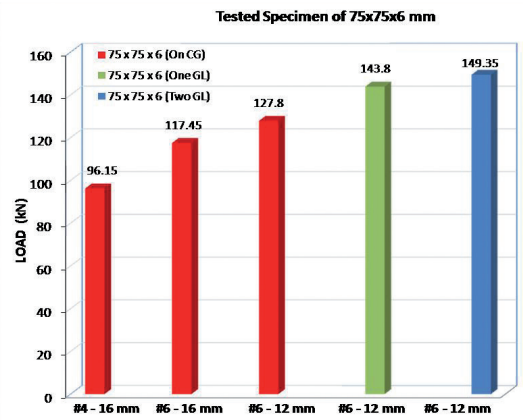


Fig. 8 Comparison of tensile capacity of GFRP 75x75x6 mm angle section

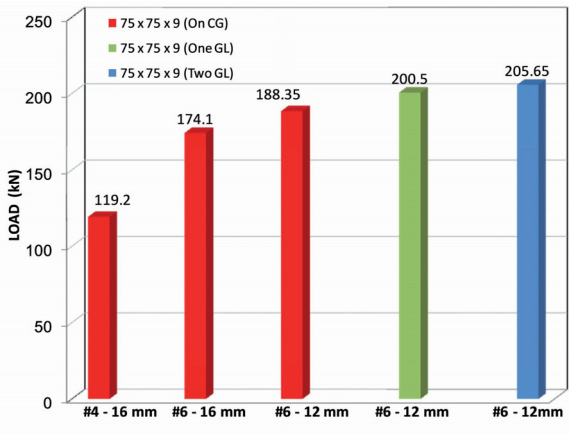


Fig. 9 Comparison of tensile capacity of GFRP 75x75x8 mm angle sections

For all the specimens, the failure occurred in the connection region only. Failure by bearing of section material at bolt hole locations and net section fracture type failures was observed. The test results on 75x75x6 and 75x75x8 mm sections are compared in Figs. 8 and 9. The tension experiments were conducted on square hollow sections of size 25x3 mm, 50x6 mm and 63x5 mm with 6 nos. (3 bolts each on two faces of the box section) of 12 & 16 diameter bolts. For all the specimens, the failure was observed in the connection region with tilting of bolts and bearing of section material at bolt hole locations.

Experimental Studies on GFRP Compression Members

Glass Fibre Reinforced Plastic (GFRP) L 50x50x6 angle with slenderness ratios of 30 and 53 were tested. Three specimens were tested with edge and pitch distances as 4d. The specimens were instrumented with strain and dial gauges to measure the strain, axial and lateral deformation of the flanges. The pre-buckling behaviour of angle specimens in all the tests was similar to that of the hot rolled sections but the final failure mode was different. For L 50x50x6 mm angle with slenderness ratio 30, the average failure compressive stress was observed to be 72.5 MPa and the failure occurred near end connections (bolt holes) due to fracture of fibers. For specimens with slenderness ratio 53, the average failure stress was 60 MPa and the failure occurred due to de-bonding and fiber fracture at mid length.

WP-3: Performance assessment of sustainable structures / structural components against design and accidental loads

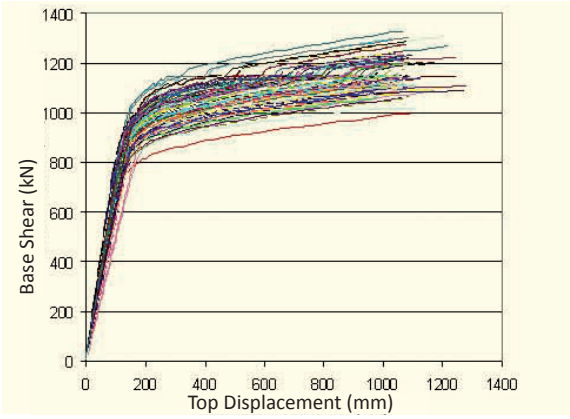
Task 3.1 Performance evaluation for design loads

In the present study, an effort has been made to carry out nonlinear static analyses and determine the statistical properties in terms of mean and coefficient of variation (COV) of spectral displacements at the top of building for typical low rise and high rise buildings designed for zone III and zone V. The uncertainties involved in various identified input parameters are modeled for nonlinear static analysis. Cross sectional dimensions of beams and columns, density and compressive strength of concrete, yield strength and elastic modulus of steel, live load and PGA are chosen as random variables. Distribution functions were chosen for the identified random variables based on literature information.

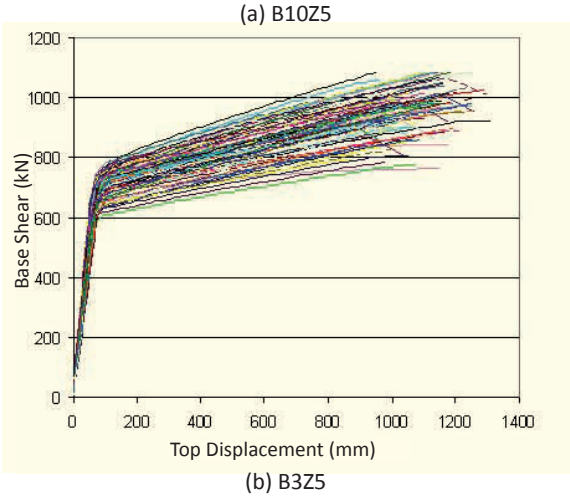
A three storey building designed using IS 456:2000 and IS 1893(Part 1):2002 for seismic zone v is designated as B3Z5 and another three storey building designed for seismic zone III is designated as B3Z3. Similarly, a ten storey building designed for seismic zone V is designated as B10Z5 and another ten storey building designed for seismic zone III is designated as B10Z3. A typical plan and elevation were chosen for the three and ten storey buildings.

The capacity curve is a plot between base shear and roof displacement. The capacity curves for B3Z5, B3Z5, B10Z5 and B10Z3 are shown in Fig. 10. About hundred analyses were carried out and from the ensemble of capacity curves, the mean capacity curve and mean (±) sigma capacity curve for the all the four cases were obtained based on inelastic damage analysis of reinforced concrete buildings. The values of spectral acceleration and spectral displacement, Sa and Sd, corresponding to the performance point from the intersection of values obtained from the mean demand curve and mean capacity curve for all the four cases considered are given in Table 7.

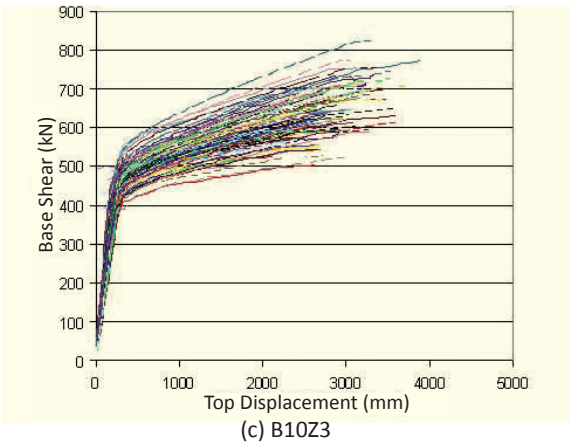
The spectral displacement (Sd) is a useful and important response parameter of building which is used for defining damage states in vulnerability and hazard analysis. The values of Sa and Sd given in Table 7 correspond to performance points obtained from the intersection of mean demand and capacity curves for all the four cases. However from the intersection of each capacity curve and demand curve from the sample, an ensemble of one hundred performance points was obtained. The statistical properties viz., minimum, maximum,



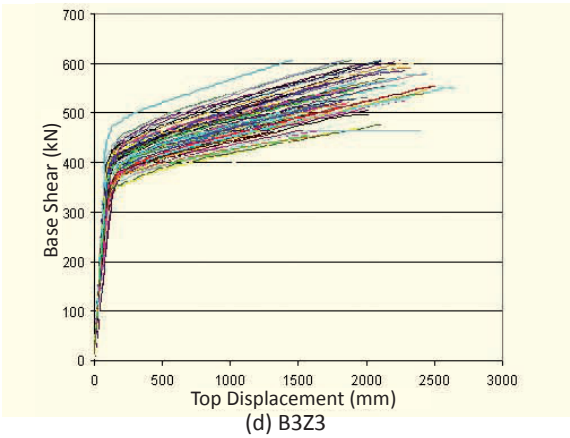
(a) B10Z5



(b) B3Z5



(c) B10Z3



(d) B3Z3

Fig.10 Capacity curves from NSA

mean and COV of Sd from the ensemble of performance points are given in Table 8.

Table 7 S_a and S_d corresponding to performance points

Case	Type	Performance Point	
		S_a(g)	S_d (m)
1	B10Z5	0.109	0.074
2	B3Z5	0.272	0.029
3	B10Z3	0.026	0.061
4	B3Z3	0.076	0.021

Table 8 Statistical Properties of S_d from NSA

Case	Type	S_d (m)			
		Min.	Max.	Mean	COV
1	B10Z5	0.018	0.404	0.068	0.721
2	B3Z5	0.007	0.154	0.028	0.679
3	B10Z3	0.010	0.245	0.052	0.673
4	B3Z3	0.004	0.092	0.019	0.684

Task 3.2 Studies on impact and blast resistance

Laced Steel-Concrete Composite (LSCC) system (Fig. 11) has been found to possess the essential properties, namely, high ductility, support rotation and structural integrity for resisting blast loads. The system consists of two thin steel cover plates connected using lacings and cross rods, and filled with concrete. This method of fabrication avoids welding in total. Numerical studies were carried out to understand the behaviour of LSCC system for blast loads.

LSCC slab system is conceptually proposed by connecting individual units of LSCC beam. Individual LSCC units are arranged sideways and cross rods were extended throughout all the LSCC units so that the units act as a single structural system and as a one way slab. In this study, two LSCC beams excluding cross rods were separately modelled. Finite element model with solid, shell and beam elements

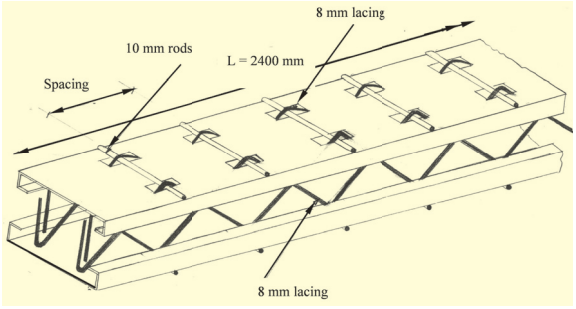
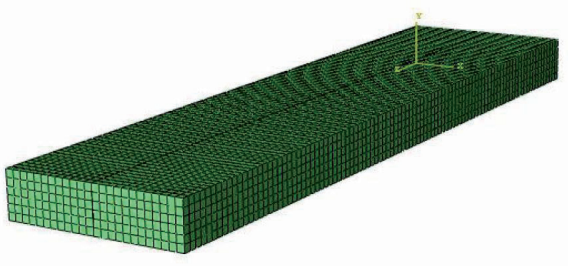
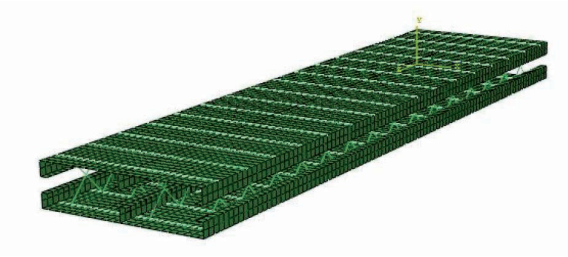


Fig. 11 Isometric view of LSCC configuration

representing concrete core, cover plates and lacings respectively, was generated for numerical analysis.



(a) Concrete core



(b) Steel plate with lacings, cross rod

Fig. 12 Finite element model of LSCC one way slab system

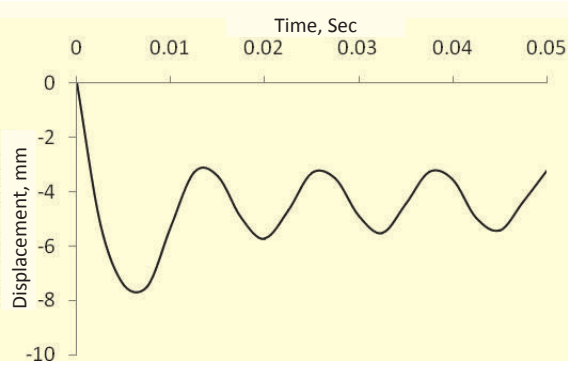


Fig. 13 Time history of displacement for slab

Table 9 Comparison of response of LSCC slab and SCSS panel

Parameter	LSCC slab	SCSS panel
Span, m	2.4	2.2
Depth, mm	150	1t50
Top and bottom plate thickness, mm	3	9
Grade of concrete, MPa	30	30
Peak displacement, mm	7.468	11

Finite element model of LSCC one way slab system developed by connecting two LSCC beam units is shown in Fig.12. Appropriate models were used to represent the material behaviour, geometry characteristics and interaction response of concrete and the steel. The slab was subjected to air blast loading of 100 kg TNT at a distance of 5m. The blast load was characterized using a triangular pressure pulse. Transient dynamic analysis was carried out. Time history of displacement at the centre of the slab is shown in Fig.13. Peak maximum displacement was found to be about 7.5mm. The deflection reaches a maximum value at about 5ms and then rebounds and oscillates around its permanent value (5.3mm). Blast response of LSCC slab was compared with that of steel-concrete-steel sandwich (SCSS) composite panel of similar size. Table 9 gives the summary of the comparison. It can be observed that the peak displacement of LSCC slab is nearly 40% less compared to the SCSS panel of similar size for the same loadig.

Engineering Sustainable Materials and Structures Action Plan II: Sustainability through Nanotechnology and Biomimetics (eNano-Tics)

Project No. ESC0209 (eNano-Tics)

Date of commencement : April 2012

Target date for completion : March 2017

Nodal Officer : Dr.-Ing. Saptarshi Sasmal

Scope and objectives

- Evolve green and smart engineered construction materials
- Develop computational tools for multi-scale modeling of materials
- Formulate methodologies and guidelines for application of engineered materials for civil engineering applications
- Establish a composite 'National facility for materials, sensors and mechanics'

WP-1: Evolution of potential nano-materials promising for developing new cementitious materials

Design and development a state of the art knowledgebase on usage of nanotechnology and biomimetics towards developing smart and green construction materials are being carried out. A detailed study was conducted on existing resources available on nano materials worldwide and the use of nanotechnology and biomimetics for developing smart and green construction materials. The Knowledge base will serve as a one stop resource for obtaining information pertaining to the usage of nanotechnology and biomimetics in construction. A web based interface which can facilitate the researchers by providing relevant information through various search options and also help in contributing to the knowledge base by reporting his research findings etc is being created. This database will be of immense value to others pursuing research in this field.

The following modules are being developed in the first stage:

Knowledge Repository – This contains all documented resources such as patents, publications, conference proceedings, etc. Provisions for both - capturing the information through appropriate data entry screens and also for information retrieval through appropriate search options, have been made in this module.

Nanomaterial Registry - This module enables reporting of information related to knowledge of newly identified nano materials in construction

Based on the system analysis and requirements, the preliminary design of the prototype knowledge database (Fig.1) is being designed using SQL Server 2008, which will serve as the back end database. Suitable web based interfaces are being developed using ASP.NET which will help in the capture of information and population of the database. Sample forms for searching the database based on the size, surface area and other properties are also being created which will be further improved to include advance search features.

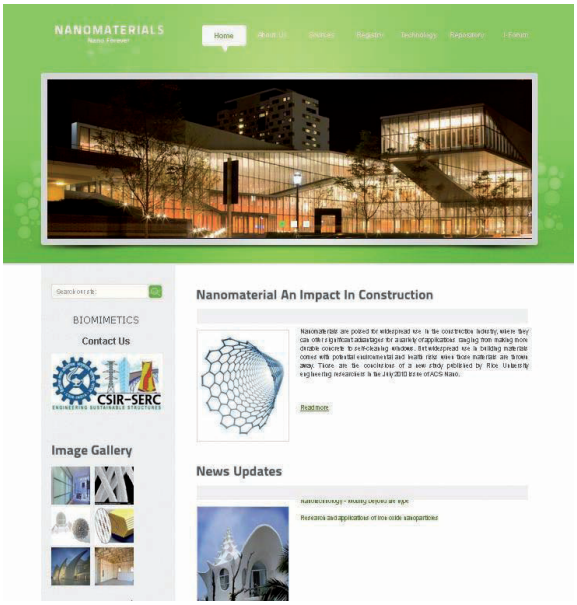


Fig. 1 Preliminary design of the prototype knowledge database

Studies on cement-Carbon Nano Tubes (CNT) nanocomposites

In order to make cement-nanocomposites as a functional composites for civil engineering applications, studies are conducted on mixing or blending the nano particles with cementitious material and their hydration characteristics by using micro-analytical characterisation techniques such as XRF, XRD, Particle Size analysis, Zeta potential, SEM and FT-IR. The nano particle/tubes chosen for the above mentioned studies are nano SiO_2, nano clay, nano Al_2O_3 and CNT. Effective functionalisation methods of nano particles with cementitious composites with respect to the mixing procedure and the energy requirement are conducted to optimize them for further test. Rheological study of the as prepared composites is conducted to reveal the effect of functionalisation achieved by ultrasonication towards achieving the required workability. Further studies are extended to characterize and test the mixed nano-cementitious mortars towards assessing their performance at complex hydration state which is under progress.

Studies on polymer nano composites for structural applications

Fiber reinforced polymer (FRP) composites are playing a vital role in repair and rehabilitation application, due to their inherent tensile properties. Epoxy polymers are used as bonding agent in the FRP applications. As epoxy is moisture sensitive, it is very much required to tailor them to make it hydrophobic to control the delamination of epoxy at interface. In the present study, functional modification of epoxy by using nano SiO_2 has been conducted. Ultra sonication and solvent evaporation methods are used for the insertion of SiO_2 into backbone of epoxy polymer. The proposed structure of functionally modified epoxy using SiO_2 is shown in Fig 2. Micro-analytical characterization techniques have been conducted to study the interaction of nano SiO_2 with epoxy resin. It is found that matrix toughening has increased due to nano modification leading to increased hydrophobicity. Further studies related to structural element analysis of FRP is under progress.

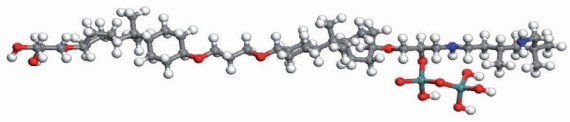
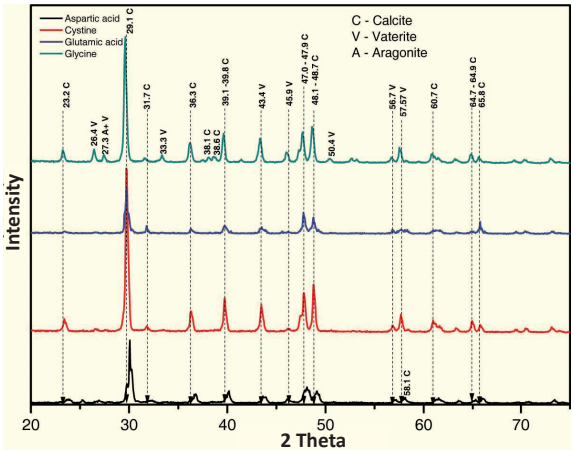


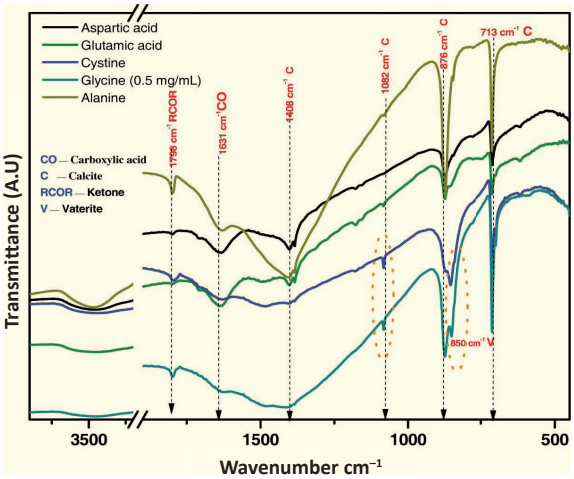
Fig. 2 Proposed structure for functionally modified epoxy

Bio-mineralisation of calcium carbonate

Various phases of calcium carbonate has been prepared by taking calcium chloride ($CaCl_2$) as calcium source and sodium carbonate (Na_2CO_3) or ammonium carbonate as carbonate precursor depending on the process. Different concentrations of different amino acid solutions are prepared and it is used as biochemical template for bio-mineralization process. Simple precipitation and gas diffusion methods were followed using the respective precursors to get the bio-mineralized product. XRD pattern of $CaCO_3$ obtained by precipitation method is shown in Fig. 3 (A). The results indicated that the crystal structure of $CaCO_3$ is rhombohedral. No other peaks in XRD pattern except $CaCO_3$



(a)



(a)

Fig. 3 (a) XRD patterns and (b) FTIR spectra of calcite prepared with different biochemical template

were observed indicating the purity of the compound. All the reflections could be indexed to the calcite phase and very less amount of vaterite and aragonite phase were also noticed. All the products obtained were examined by FT-IR spectra were shown in Fig.3(B). In pure calcite phase, characteristic CO32- peak at 1400 cm-1 and C–O stretching band at 711 cm-1 were observed. Unstable vaterite crystals phase observed at 850 and 746 cm -1. Further studies related to the stability of the bio-mimetic calcite under various pH environments are under progress.

Hydration study on titania incorporated cement

The hydration process of 1% and 5% weight of nano-titania incorporated cement paste is thoroughly investigated using the DR-FTIR

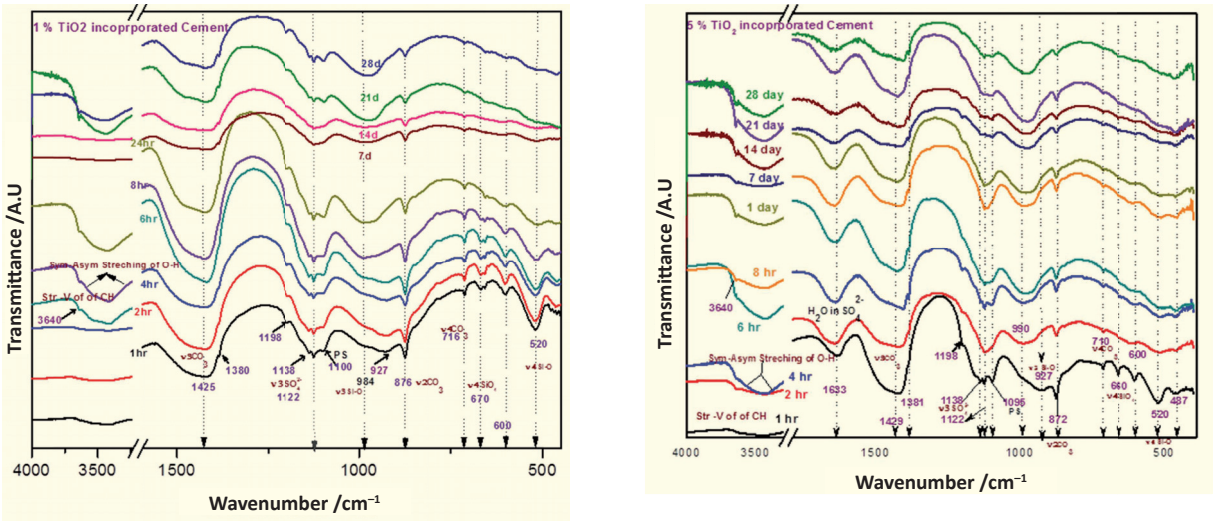


Fig. 4 FT-IR curve of (a) 1 % and (b) 5% titania incorporated cement paste

spectra and the recorded absolute spectra are displayed in Fig. 4.

Weak signatures of hydration are seen in the 900–1100 cm^{-1}region. Characteristic sulphate absorption bands are found in the range of 1100–1200 cm^{-1} due to the υ_3 which causes lots of overlaps with υ_3 vibration of the polymerized SiO_4^{2-}-group. After mixing with water some sharp absorption bands developed at 1122 cm^{-1}, 1198 cm^{-1} and 3320 cm^{-1} give strong indication of sulphates, however, due to very rapid dissolution the peak become obsolete after 24 hours. In 1 % titania incorporated cement paste shift in new spectral intensity are observed from ~927 cm^{-1} towards ~1000 cm^{-1} after about 8th hr of hydration, which proposes rearrangements in the silica system. However, same observations are noticed in 5 % titania incorporated cement paste within 2nd hour of hydration which attributes to the faster rate of hydration as the effect of higher dosage of titania. It is noticed that the dissolution of in-plane and out of plane Si-O bond mainly at 487, 520, 600 and 670 cm^{-1} is faster in case of 5 % titania incorporated cement paste than 1 % titania incorporated cement paste. Growth of the C-S-H is confirmed by associated absorption intensities at 970-1100 cm^{-1}. The very prominent peak at 3650 cm^{-1} corresponds to $Ca(OH)_2$, is formed as distinct phases in the hydrated cement after 6th hour of hydration.

WP-2: Development of computational tools for multi scale modeling of materials

Application of structural mechanics for the evaluation of behaviour parameters of nano materials

Since the discovery of Carbon Nanotubes (CNTs), it has been creating waves in almost all possible fields owing to its extra-ordinary mechanical, thermal and electrical properties. Researchers around the world are considering it as a material that would engineer all the available materials and techniques for creating a new class of next generation materials and techniques. Construction materials like cement mortar and concrete are brittle and very weak in tension. They suffer from formation of micro cracks and pores due to emanation of excess water and thermal & shrinkage strains. These distributed micro cracks propagate and get connected to form macro cracks when load is applied. The macro cracks propagate as load gets increased or as time goes on and leads to material failure when it reaches the condition of critical crack growth. Hence, it becomes necessary to stop the propagation of micro cracks in order to improve the life of the material. It can be observed from the reported studies that CNTs are being extensively used in order to improve various properties of cementitious

materials, with major concern on improving its mechanical properties. While characterizing the mechanical properties of cementitious composites, it is more important to understand the mechanical behaviour of each and every material that constitutes the composite for the sake of developing an efficient and multi-specialized composite material. Hence, in order to effectively and efficiently use CNT in cement matrix, it is utmost important to understand the behaviour of CNT when it is subjected to different types of loads.

In this regard, various investigations have been carried out by the researchers around the world to understand the mechanical characteristics of CNTs. It is observed that the elastic moduli of CNT was dependent on tube radius for thinner tubes and then attained a constant value. It can be seen from the above observations that the investigations have been limitedly carried out on a particular behaviour and there is no correlation between the individual methods and the results. But, in order to effectively use CNT in a composite material it is utmost important to understand its complete mechanical behaviour. Hence in this study, an attempt has been made to understand the behaviour of CNT when subjected to axial tension, axial compression, bending and free vibration. The influence of parameters like chirality, aspect ratio and diameter on the axial stiffness, bucking load, bending stiffness and fundamental frequency have been thoroughly investigated.

Finite Element Modelling of CNT

CNT has a hexagonal lattice structure in which the carbon atoms are connected by covalent bonds. When CNTs are subjected to loads, its atomic structure gets distorted. Due to this distortion, the potential energy of CNT gets increased. The increase in potential energy is due to the resistance offered by the CNT to the applied load. This is similar to the strain energy concept in continuum mechanics. Consider carbon atoms of CNT as nodes and covalent bonds present between them as beam elements. They form a space frame like structure. When this space frame like structure is subjected to external loads, the internal energy i.e., the strain energy gets developed. It can be seen from the above illustration that the behaviour of CNT when subjected to load is similar to the behaviour of space frame. Hence in order to understand the behaviour of CNT when subjected to different types of loads, it can be modelled as a space frame with appropriate boundary conditions. The great challenge in carrying out this kind of simulation is describing proper sectional and material properties to the elements forming the space frame. This challenge is overcome by linking the energies stored in the atomic system and the energies stored in the space frame when it is subjected to loads (response behavior shown in Figs. 5 to 7). The study is under progress.

Micro-mechanical properties of cementitious matrix using simulated nanoindentation techniques

Nanoindentation is commonly used for investigation of local mechanical properties of materials modelled as isotropic or anisotropic solids. Many engineering materials, especially, cement and concrete composites which are used extensively as building material, exhibit phase heterogeneity and mechanical differences of the phases on different length scales. In order to develop mathematical model for heterogeneous material systems, multi-scale approach that allows the separation of scales based on certain characteristic dimension of microscopic feature of the material at each level is often utilized. In this study, mechanical properties of cementitious composites in nano/micro scale are investigated using simulated nanoindentation technique. Calcium-Silicate-Hydrate (C-S-H), which is the primary element of the composite matrix to provide mechanical characteristics such as strength is considered in the present study. Computational study has been carried out to determine the indentation response of a rigid axisymmetric indenter on a semi-infinite elasto-plastic matrix (as shown in Fig. 8 and Fig. 9). Finite element method is

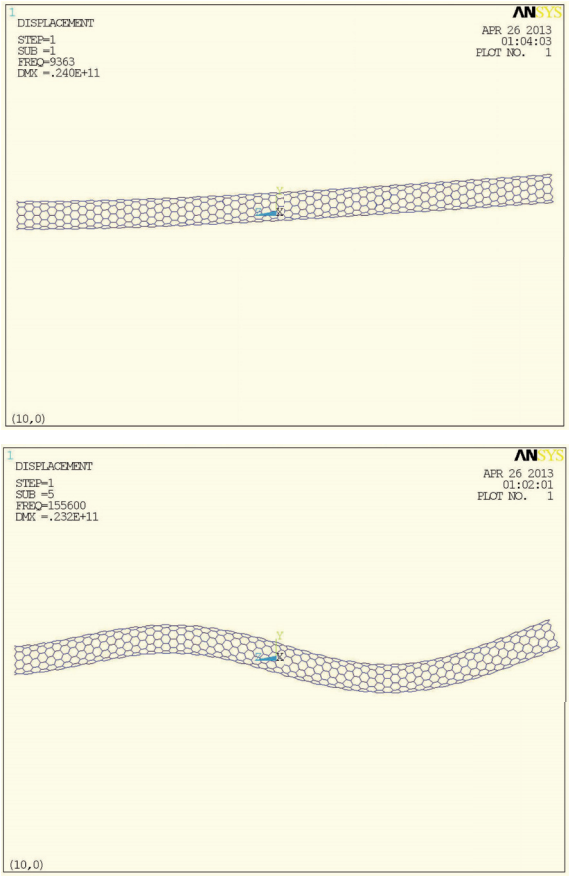


Fig. 5 Finite element modelling and mechanical response obtained from simulated CNT

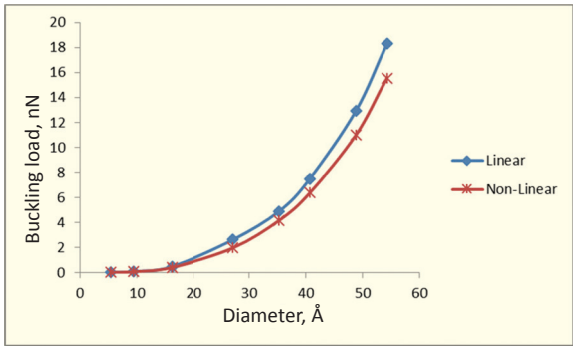


Fig. 6 Buckling load of Armchair CNT

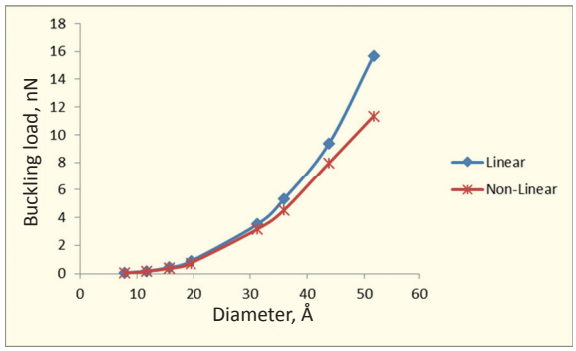


Fig. 7 Buckling load of Zigzag CNT

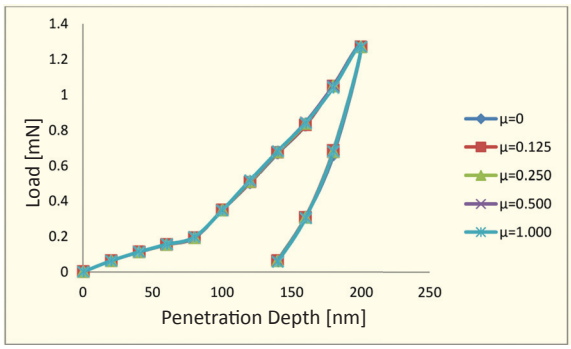


Fig. 8 Influence of friction coefficient on HD C-S-H

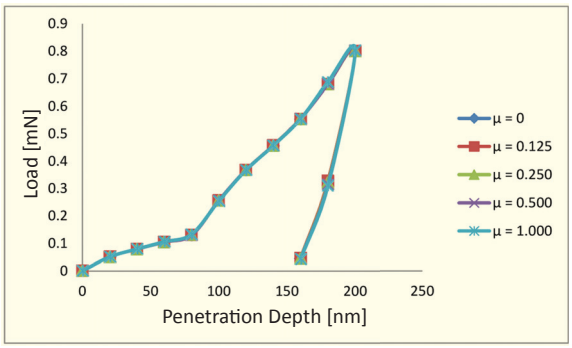


Fig. 9 Influence of friction coefficient on LD C-S-H

employed to simulate the effect of material properties such as elastic modulus, contact friction, etc. on the indentation response of both low- and high- density C-S-H phases.

Linking the nanostructure of cement clinkers to their micro properties and evaluation of their mechanical behaviour is an active area of research. Development of molecular models of amorphous and inhomogeneous nanoparticles will give a better understanding of the cohesive property of cement paste and its tensile behaviour. Molecular Dynamic simulations enable to model interactions at a length scale of nanometers over a time scale of femtoseconds which is difficult to obtain through experimental or analytical investigations. The present work is aimed to simulate the molecular structures of the cement clinkers, such as Tri Calcium Silicate (C_3S), Tri Calcium Aluminate (C_3A) to evaluate the mechanical properties such as Young's modulus, etc. A typical molecular model of C_3A as used in the present study is shown in Fig. 10. Energy of the system is minimized by adjusting

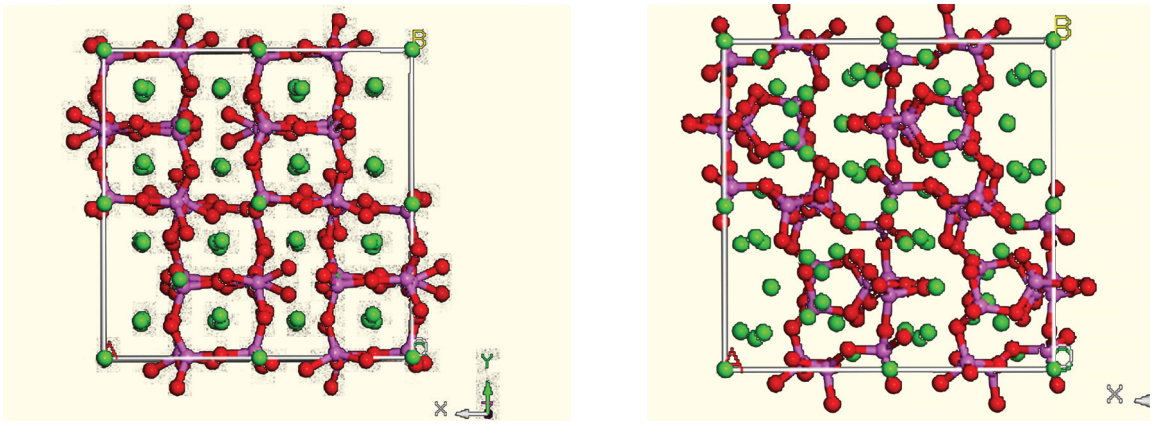


Fig. 10 Molecular model of Tri Calcium Aluminate (C_3A) (Before and after Geometry Optimisation [Green: Calcium, Red: Oxygen, Pink: Aluminium])

the atomic coordinates. The parameters of COMPASS force field used in the simulation are valance, bond and van der Waals terms. The system is brought down to NPT conditions of temperature and pressure. Applying a suitable strain rate, simulation is carried out to evaluate the load-deformation behaviour of the clinkers.

The properties of the cement clinkers evaluated in the present study will be further used for molecular modelling of hydrated cement paste, i.e., Calcium Silicate Hydrate (C-S-H) which is the major strength providing composite developed during hydration process of cementitious composites. This study will provide important information for multi-scale modelling of cementitious composite.

Determination of concrete creep compliance through multiscale modeling of concrete

Studies on determination of concrete creep compliance through multiscale modelling of concrete are continued. The creep compliance obtained from the multi-scale model is used in the finite element modelling for estimating the time-dependent creep deflection in a reinforced concrete beam, for which experimental results are available in literature. The results of experimental investigations carried out by Gilbert and Nejadi (2003) on long-term deflections of reinforced concrete beams are used for this purpose. The values of creep coefficient at different ages are determined using the multiscale model developed at CSIR-SERC. The variation in creep coefficient with age obtained using the multi-scale model, is shown in Fig. 11. The creep coefficient obtained from the multi-scale model is used in the finite element modelling for estimating the time-dependent creep deflection of the reinforced concrete beam. The finite element software ANSYS is used for this purpose. From the results obtained (Fig. 12), it is noted that the long-term deflections obtained using finite element analysis are in satisfactory agreement with the experimentally observed deflections reported.

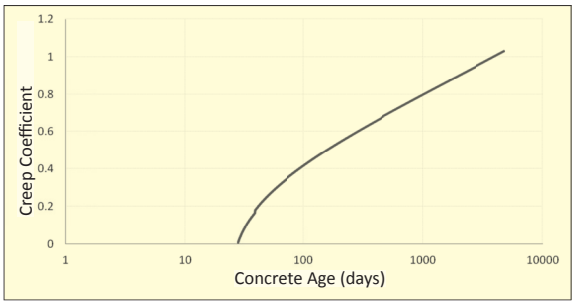


Fig. 11 Variation in creep coefficient with age using multiscale model (age at loading = 28 days)

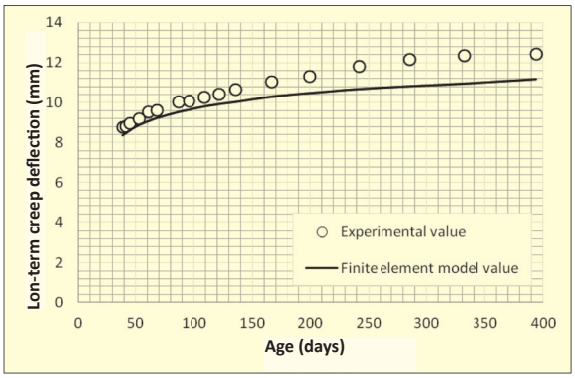
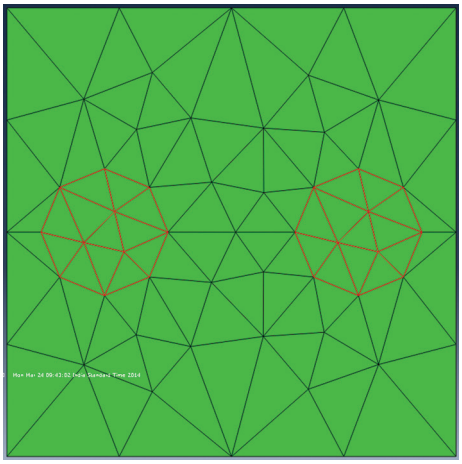


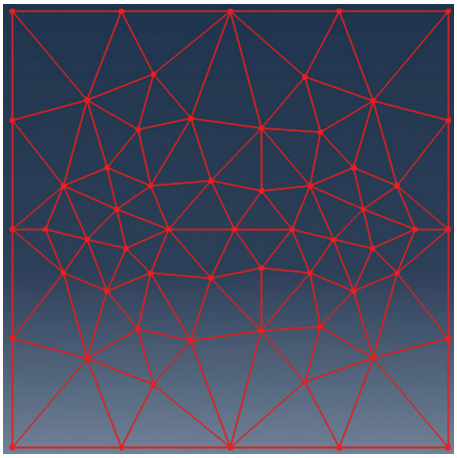
Fig. 12 Comparison of experimentally determined long-term creep deflections with those obtained using finite element analysis

Concrete structure at meso-level consists of three phases namely the aggregate phase, the mortar phase and the interfacial transition zones (ITZ). The ITZ's are found to be the weakest link in the chain and so major cracks arise in these zones. For the crack prediction in the concrete specimens lattice model is adopted. Heterogeneous lattice models are formulated by considering the continuum concrete model as the base. Continuum model is discretized into a network of beam elements to form the lattice model, which are assumed to have a linear elastic behaviour. Both the models are analysed under similar loading conditions and the load displacement behaviour is compared.

A concrete cube is taken up for numerical studies. Initially, the cube is subjected to loading, initially micro cracks occur. As the load intensity increases these cracks open out and pave way to the macro-cracks resulting in the failure of the concrete specimen. To understand and validate the response obtained from lattice model, only 2 aggregates embedded in matrix is considered initially. A slice from concrete cube of thickness 1 mm is modelled. 2D stress elements are used for continuum model, while 2D beam elements are used for lattice model. Figure 13 shows both the models. Material properties adopted in the study are given in Table 6.2. Poisson's ratio is assumed to be 0.2.



(a) Continuum



(b) Lattice

Fig. 13 Finite element model of concrete slice continuum model

WP 3: Experimental and analytical investigations on performance of structural components with engineered concrete

Experimental investigations on performance of structural components with engineered concrete

Experiments have been carried out to evaluate compressive strength of nano modified High Strength Concrete (HSC) and Ultra High Strength Concrete (UHSC). Various cementitious materials, namely, Ordinary Portland Cement (OPC), Silica Fume powder (SF), Nano SiO_2 (NS) have been used in experimental investigations. Nanoparticles with the average particle size of 15nm produced from Sigma Aldrich Imports and Export Trade Co, Ltd., are used as received. A polycarboxylate superplasticizer manufactured by BASF (Master Glenium Sky 8233) is used to improve the workability of concrete. The final mix proportion for HSC and UHSC mix containing 0%, 1% and 2% replacement of cement by nano silica are given in Table 1.

Table 1 Mix proportion for HSC and UHSC specimen

Mix ID	W/C	Cement (kg/ m^3)	Silica fume (kg/ m^3)	Quartz Sand (kg/ m^3)	Quartz powder (kg/ m^3)	Nano silica (kg/ m^3)	Water (kg/ m^3)	SP (%)
HSC - 0	0.4	730	183	1095	-	-	292	0.4
HSC - 1	0.4	722.7	183	1095	-	7.3	292	0.4
HSC - 2	0.4	715.4	183	1095	-	14.6	292	0.4
UHSC - 0	0.4	730	183	803	292	-	292	0.6
UHSC - 1	0.4	722.7	183	803	292	7.3	292	0.6
UHSC - 2	0.4	715.4	183	803	292	14.6	292	0.6

Specimens of HSC and UHSC have been prepared by using the above mix and they were cured in water. Compressive strength tests were conducted on HSC and UHSC concrete specimens (70.7mm size) with and without nano particles at 7 and 28 days. Fig.14 presents graphical representation of compressive strength obtained for various cases. As general observation, it can be noted that the compressive strength of HSC and UHSC is considerably improved by using nano SiO_2 particles as a part of cementitious materials. For the case of HSC-1 (1% nano silica) and HSC-2 (2% nano silica), the compressive strength at 28th day is increased by about 8% and 18% respectively compared to control. Similar observation has been made w.r.t UHSC mix. For the case of UHSC -1 (1% nano silica) and UHSC-2 (2% nano silica), the compressive strength at 28th day is increased by about 16% and 21% respectively compared to control.

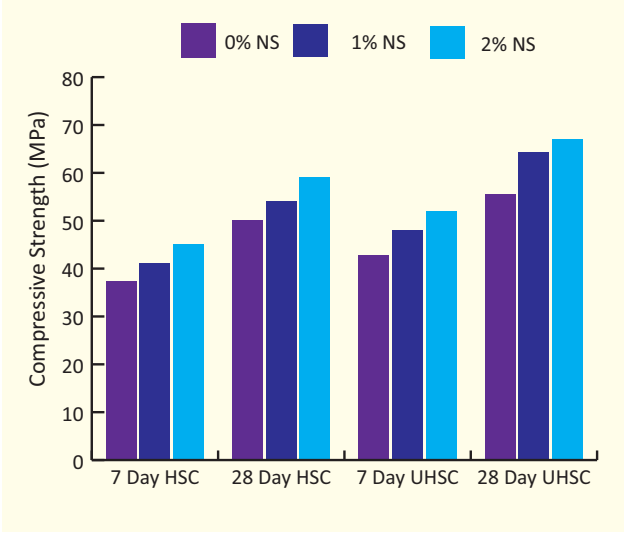


Fig. 14 Compressive strength of HSC & UHSC mix

WP 5 Establishment of advanced facilities for synthesis, characterization and performance evaluation of sustainable construction materials

A composite 'national facility for materials, sensors and mechanics' is being established at CSIR-SERC as combined output of the activities of the three proposed projects of CSIR-SERC in the XII Five Year Plan period namely, Engineering Sustainable Materials and Structures Action Plan I: Sustainability through Eco-balancing (SUSMAS); Engineering Sustainable Materials and Structures Action Plan II: Sustainability through Nanotechnology and Biomimetics (eNano-Tics); and Innovative Methods for Health Assessment and Damage Mitigation of Structures (I-HEAL). Further, sophisticated experimental- and computational- facilities are being created to bring up a state of the art facility on synthesis, characterization, and multi-scale modelling and analysis of nano engineered sustainable materials.

Potassic (K) Fertiliser Technology to Empower the Nation (K-TEN)

Project No. CSC0105

Date of commencement : April 2012
Date of commencement : April 2012
Target date for completion : March 2017
Nodal Laboratory: CSIR-CSMCRI, Bhavnagar

Participating Laboratories :
CSIR-SERC, Chennai; CSIR-CECRI, Karaikudi; CSIR-CIMFR, Dhanbad; CSIR-IMMT, Bhubaneshwar; and CSIR-NGRI, Hyderabad

Nodal Officer (CSIR-SERC) : Dr. J. Rajasankar

The contribution of CSIR-SERC is to design scalable structural modules (frames) for offshore (deep-sea) cultivation of seaweed Kappaphycus alvarezii.

Progress made during the year

Two simple structural frames - Octogonal and square shaped - have been designed by considering the forces due to nominal wave conditions. The design has been theoretically verified for strength and stability under offshore conditions.

A study has been initiated to understand the structural and functional performance of the designs in association with the scientists of the Nodal laboratory at Mandapam, Tamil Nadu. An octagonal frame has been fabricated for 0 and 45 degrees vertical orientations which are shown in Figs.1(a) and (b).

a) 0 degree *b) 45 degree*

Fig. 1 Typical octogonal shaped structural frames

Fig. 2 An octagonal frame with fully grown seaweed

As an initial step, the frames were deployed in near-shore location at Mandapam for a period of 45 days, that is one growth cycle of the seaweed. The growth rate was recorded regularly during the period. The results were found to be encouraging and better compared to that obtained using conventional frames. The frame with fully grown seaweed is shown in Fig.2. Further studies are being carried out to understand the repeatability of the frame performance in conjunction with the associated environmental parameters.

Segmental Composite Slabs for Bridge Decks

This project has been undertaken under the sponsorship of Department of Science & Technology, New Delhi

Scope /objectives

- To evaluate effectiveness and efficiency of different types and spacing of shear connectors for segmental composite slabs for bridge decks through numerical investigations and to arrive at optimal option
- To carryout experimental investigations for evaluating the shear resistance of the composite slab with identified shear connector mechanism
- To evaluate the load deflection characteristics and ultimate load behaviour of segmental composite slab with an identified shear connection mechanism under monotonic loading
- To evaluate the behaviour of segmental composite slab with an identified shear connection mechanism under cyclic loading
- To formulate guidelines/recommendations for the design of segmental composite slabs for bridge decks

Progress made during the year

Studies are initiated for finite element modeling of precast slab segments that act initially as formwork and connected compositely with in-situ concrete segments using different shear connectors such as shear link, studs and/or steel truss to transfer the horizontal shear between the precast and cast-in-situ deck slab segments. The effectiveness and efficiency of different types of shear connector mechanisms to transfer the horizontal shear between the interfaces of the pre-cast and cast in-situ segments of concrete deck slab are studied and quantified towards identification of optimal type.

A typical slab of size 750 mm × 2000 mm x 120 mm for which reported experimental results are available is taken up for the study. The slab consists of two concrete wythes of 40mm thick separated by insulation layer. The reinforced concrete wythes are interconnected by the continuous steel truss shear connectors with 250 mm spacing. The concrete wythes are modelled using solid element. The insulation layer is not modelled for the analysis. The mesh reinforcement and shear connectors are modelled using the reinforcement element. A perfect connection is assumed between the reinforcement and concrete and also between shear connector and the reinforcement. Owing to the symmetry, half of the slab is modelled. The steel plates are modelled at the support and loading location. Simply supported boundary conditions are assigned. A uniform pressure load is applied on the steel plates. The load versus displacement relationship obtained from the analysis is compared with the experimental results reported in the literature. It is noted that the finite element results match well with the reported experimental values till the first cracking load. Further studies are in progress.

Future programme of work

- Evaluation of efficiency of different types of shear connectors for segmental slabs
- Experimental evaluation of slabs with shear connectors

Team

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Dr. Nagesh R. Iyer

Analytical and Experimental Investigations on Remaining Life and Residual Strength Assessment of Stiffened Panels under Constant and Variable Amplitude Loading

This project has been undertaken under the sponsorship of Aeronautical Research & Development Board, New Delhi

Objectives

- Development of analytical methodologies for remaining life and residual strength assessment of stiffened panels under CAL and VAL
- Experimental studies to determine the fatigue crack growth constants for the aluminium alloy used in the stiffened panels
- Experimental investigations on aluminium alloy stiffened panels subjected to tensile-tensile fatigue loading
- Development of program modules for remaining life and residual strength assessment of stiffened panels
- Corroboration of remaining life of stiffened panels obtained from analytical and experimental studies

Scope

- The analytical methodologies will be developed based on linear elastic fracture mechanics (LEFM) principles and incremental crack growth approach.
- Experimental studies will be carried out on pre-notched aluminium alloy plate panels with stiffeners.
- Locally available aluminium alloy sheet material will be used for fabrication of stiffened panels.
- Experimental studies to determine the fatigue crack growth constants will be as per ASTM standards.
- Typical block of fatigue load spectrum available in the literature will be used in the analytical and experimental investigations.
- The remaining life obtained from analytical studies will be validated against the results of the proposed experimental studies and the available results in the literature.
- The computer program for the analytical studies with necessary user interfaces and interactive features will be developed using VC++ as front-end and MS-Access as back-end on MS-Windows platform.

Progress made during the year

The geometric and finite element (FE) modeling of the panels along with the fixtures including the bolts have been created. Final mesh configuration and elements used have been decided upon based on convergence of solution and computational efficiency. Mesh refinement is carried out near holes and crack tip. Quarter point crack-tip elements are employed to represent singularity around the crack-tip.

Static analysis has been performed to compute SIF to determine the crack propagation rate by comparing the critical value of SIF i.e., KIC with KI value associated with a specific crack length. It is observed that SIFs computed for edge stiffened panel is lesser, when compared with the unstiffened center cracked plate. SIFs computed for intermediate stiffened panel is lesser, when compared with the edge stiffened panel. SIF's for concentric stiffeners is lesser, when compared with the eccentric stiffener case irrespective of the position of the stiffener. Parametric studies on stiffened panels have been conducted for computation of SIF at increments of crack length 2.5 mm by conducting FE analysis.

Numerical studies on remaining life prediction and residual strength evaluation of unstiffened and stiffened panels have been conducted. SIF has been calculated for 0.05 mm increments of crack length by using finite element analysis (FEA) software. Best fit equation has been obtained

by using MATLAB and then SIF is calculated for every 0.01 mm increments of crack length. The predicted values of crack growth and remaining life have been compared with that of center cracked plate. Studies have been conducted for both eccentric and concentric type of stiffener cases. It is observed that the predicted life obtained in the present study is in good agreement with the theoretical results. It is also observed that the remaining life is significantly higher in the case of concentric stiffener, when compared with the eccentric stiffener for both edge and intermediate stiffened panels.

Studies on residual strength evaluation has been conducted by using (i) plastic collapse condition or yield criterion (ii) fracture toughness criterion and (iii) remaining life approach for the unstiffened, edge and intermediate stiffened center cracked plates. It is observed that the residual strength values predicted by using remaining life approach are lower compared to those predicted by using other two approaches. It is also observed that the residual strength is higher in the case of intermediate stiffened panels, when compared with unstiffened and edge stiffened panels. Further, it is significantly higher in the case of concentric stiffener, when compared with the eccentric stiffener for both edge and intermediate stiffened panels.

Experimental studies on a plate with a center crack of dimension 300x150 mm with a sharp notch of size 18mm has been conducted for remaining life assessment. The studies have been conducted on fatigue rated UTM of ±250 kN capacity under constant amplitude fatigue load. Crack length is monitored and images of the surface crack length have been recorded at regular intervals of fatigue load cycles by using a Video Microscope. Strain gauges have been placed along the crack growth path to capture the strains. The strain values are recorded automatically by using a data acquisition system. The fatigue crack growth test has been continued till the crack length in the specimen reached the full width of the plate i.e. tearing of the plate on one side.

Future programme of work

- Experimental studies on cracked stiffened panels
- Preparation of completion report

Team

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Development of Robust Damage Diagnostic Techniques for Engineering Structures using PCA and ICA

This project has been undertaken under the sponsorship of Aeronautical Research & Development Board, New Delhi

Scope

- Development of robust damage diagnostic tools for health monitoring of engineering structures using statistical based techniques like PCA and ICA and experimental verification

Progress made during the year

- Developmentof formulations for damage detection strategies using principal component analysis using time history data & implementation
- Extension of the PCA formulations using frequency response functions to handle problems with dominant higher & mid frequencies

- Development of strategies for assessment of damage distribution in laminate composite structures
- Development of optimal sensor placement techniques using principal component analysis
- Evaluation of various blind source separation techniques
- Development of modal identification techniques using ICA and blind source separation techniques
- Development of BSS based identification method with limited sensors
- Development of robust damage detection algorithm combining wavelets and Blind source separation techniques. Comparative studies made using AMUSE and SOBI algorithms
- Validation of the techniques by conducting experiments on cantilever aluminum plate with and without damage and also simulating environmental variability

A detailed presentation on the complete research work carried out in the project is presented during the Annual ARDB structures panel meeting. The panel appreciated the work carried out under this project.

Team

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Development of Structural Health Monitoring Schemes for Civil Engineering Infrastructure in India using Smart Sensing Technologies

This project has been undertaken under the sponsorship of National Programme on Micro and Smart Systems, ADA, Bangalore

Scope

- Development of robust damage diagnostic tools for remote health monitoring of engineering structures
- Experimental verification of the damage diagnostic techniques by conducting laboratory experiments to evaluate their feasibility for application on real-time structures

Progress made during the year

Number of novel output-only damage diagnostic tools using principal components, Kernel principal components, Null space based, time series , time frequency based algorithms, etc. were developed and validated using several standard bench mark problems. All the damage diagnostic techniques can handle environmental variability. Experimental studies at lab level have been performed by using concrete beam model and MEMS accelerometers and simulated damages eccentrically to validate the techniques.

Modal identification algorithms including Blind source separation techniques, Hilbert-Huang transform based techniques, etc. are implemented as a toolbox The techniques developed are evaluated by solving several benchmark problems and other numerically simulated practical engineering problems. Investigations with limited number of sensors are carried out. A technique combining BSS algorithm with empirical mode decomposition was used to extract more modes than the

number of sensors placed on the structure. Several model updating methods to update the finite element models using experimental data are developed. The method include direct methods, method based on Lagrange multiplier and penalty function based methods

Studies on EMI based damage identification technique on a metallic model was carried out and studies related to the effect of mass loading, sensitivities of impedance measurements with respect to the distance from spatial damage location are investigated. Further, the effect of environmental variability on EMI signatures is investigated by subjecting the specimen to temperature variations ranging from 25°C to 50°C and relative humidity of 80% to 90%. Investigations carried out on the EMI signatures with environmental variability clearly indicate that the temperature variations significantly affect the EMI signatures and the humidity has less impact on EMI signatures.

A model of a reinforced concrete bridge was fabricated. It was scaled down from the Dharapuram bridge for which live measurements have been taken as part of the project and reported earlier. Details of instrumentation embedded in the bridge include strain gauges on the reinforcing steel, piezo patches on the reinforcing steel and smart piezo patches for electro mechanical impedance measurements. The EMI signatures during the curing process have been collected from the bridge model using the embedded piezo patches in the form of clinkers and investigated for the stiffness variation of the bridge during the curing process. Lab level demonstration of remote monitoring of structures has carried out using MOTES and also Micro Strain wireless sensors by monitoring the scaled down model of bridge.

Field level demonstrations of remote monitoring of structures are carried out on road-over bridge across the Velacheri-St Thomas Mount railway line of the Chennai MRTS system Velacheri bridge. Two spans of the bridge are selected for ambient vibration measurements, middle span (Span-1) of 48 m and the south-side adjacent span (Span-2) of 32 m. The bridge is a bow-string girder type with the maximum rise of 7.0 m. Main bottom girder and the transverse girders are pre-stressed. Five points are chosen for measurements using Imote2 sensors typically oriented symmetrically about the mid-span and each sensor is kept right below the vertical ties. Parallel measurements are also taken using the low-frequency strain-based accelerometers and the voltage signals are recorded in the digital tape recorder, which are later on played back on the data acquisition system in the laboratory. The remote monitoring of the bridge is continued for a day and acceleration measurements obtained are continuously recorded at the base station placed near the bridge and was transmitted to the server located in CSIR-SERC. This demonstration clearly illustrates the difficulties associated with conventional SHM schemes and advantages in using wireless remote health monitoring.

The project team participated in the industry meet of NPMASS held at Indian Institute of Science, Bangalore and demonstrated to the industry participants, the three products developed under this project: SPIESE, Bridge-LCRIDE, Low cost impedance analyzer and the visitors have exhibited keen interest on the products demonstrated.

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Performance Evaluation of Typical Railway Bridges under Increased Axle Loads of Freight Wagons

This project has been undertaken under the sponsorship of Southern Railway, Chennai

Scope /objectives

- Development of instrumentation schemes and testing methodology for evaluation of response characteristics of the selected bridges
- Instrumentation of superstructure and substructure and response measurements of the bridges during periodic testing
- Processing of measured data to evaluate various response parameters of the bridges
- Preparation of reports

Progress made during the year

Fourth cycle of investigations on Bridge Nos. 145 (UP) & 145A(DN) near Puttur in Arakkonam – Renigunta Section and Bridge No. 42 near Tiruttani of the southern railway zone are carried out to evaluate the response characteristics of the bridges. Analysis and processing of the measured data obtained during testing are carried out to study the static and dynamic responses due to the increased axle loads of train formation.

Fourth cycle of investigations on Bridge No. 163A(UP) near Vadamalpet in Arakkonam – Renigunta section of the southern railway zone are also carried out. Post-processing and analysis of the measured data of static and dynamic tests due to increased axle loads are carried out.

First and second cycles of instrumentation, testing and measurements on reinforced concrete I-girder bridge No. 44 near Ennore between Chennai-Gudur section of southern railway zone were carried out. Strain gage instrumentation was carried out at various locations of rails and girders for obtaining strains due to longitudinal force, bending, and shear, etc. Strain gage instrumentation was also carried out on pier to measure the strains due to bending and axial forces. Displacement transducers were used to measure both static as well as dynamic deflections of the superstructure and tilt of the pier. Accelerometers were used for measuring the acceleration at selected locations of superstructure. For the purpose of calibration, static load tests were conducted initially by keeping the loco and wagons at various positions on the superstructure. Dynamic load tests at various speeds of the test train formation were conducted. Responses of the bridge were measured for tractive effort, braking and uniform speed cases. Analysis and processing of the measured data obtained during the tests are carried and the reports are prepared based on the results of investigations.

Future programme of work

- Third and fourth cycles of instrumentation, testing and measurement of bridge No. 44 near Ennore

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Investigations on Performance Evaluation of Parallel Flange Sections for Specified Loads Phase-I: Beam Sections

This project has been undertaken under the sponsorship of M/s. Jindal Steel and Power Limited, Raigarh

Objectives

- To conduct coupon tests for obtaining the stress-strain curve for specified steel grades for beams.
- Experimental studies to determine the fatigue crack growth constants for the aluminium alloy used in the stiffened panels
- Experimental and numerical studies on flexural behavior of UB, NPB and WPB sections
- Experimental and numerical studies on ISMB sections towards comparison of flexural behavior with that of parallel flange sections (PFS)
- Parametric studies on beams to prepare a suitable handbook for PFS

Scope

- Independent axial and moment capacity only will be considered.
- Length of the beam will be selected based on the available test facility.
- Investigations will be limited only to I-Sections.
- Experimental studies for flexural behavior will be studied by using four point bending specimens with simply supported conditions.
- Experiments and numerical studies and corroboration will be limited to 3 specimens each for UB, NPB, WPB.
- Parametric studies will be limited to NPB, WPB as given in IS:12778-2004 and UB as given in BS4-1-1993.
- Handbook will be developed based on the design criteria available in IS:800-2007, wherever applicable.

Progress made during the year

Experimental studies on NPB400, UB457, NPB450 and WPB600 parallel flange beam sections and ISMB300 beam have been completed. The beams have been tested for their flexure behavior under four point bending. Supporting pedestals have been mounted along with the hinge, roller and lateral restraints. Further, the beams have also been provided with torsional restraints at the support points. The reaction frame with 200 Ton jack has been used for testing of the beams. The beam has been tested under monotonic load upto their plastic moment capacity. Strain and displacements have been measured automatically during testing by using data logger.

A 3D deformable solid finite elements with extrusion and parametric modelling options has been chosen for the study. Idealized bi-linear stress-strain relation is used for modeling the nonlinear material properties. All the parallel flange beam sections tested so far are found to contain both geometric and mechanical imperfections, which can have significant influence on their structural behavior. Mechanical imperfection is due to the residual stress locked up in the member during the forming process of the steel sections. The geometric imperfections correspond to either lack of straightness of the structural member or the eccentricities of the applied load. The residual stress has been evaluated by using blind hole drilling technique and included in the FE model as stress variation across the section. The geometric imperfections has been achieved by modeling the structure with an initial out-of-plane deflection. The overall imperfection is applied in both depth and breadth direction in the form of the global elastic buckling mode with amplitude of length/1000. All the beams are studied with pin-ended boundary conditions.

Future programme of work

- Further experiments related to beam specimens having capacity beyond 150 Tons
- Measurement of residual stresses in parallel flange beam sections
- Further numerical studies on the parallel flange beam sections

Team

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Smt. P. Prabha
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Dr. Nagesh R. Iyer

Evaluation of Indigenous Bearing Material

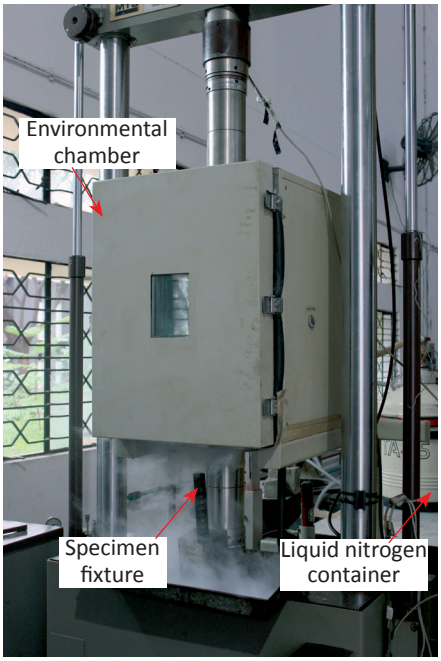
This project has been undertaken under the sponsorship of Combat Vehicles Research & Development Establishment (CVRDE), Chennai

Scope /objectives

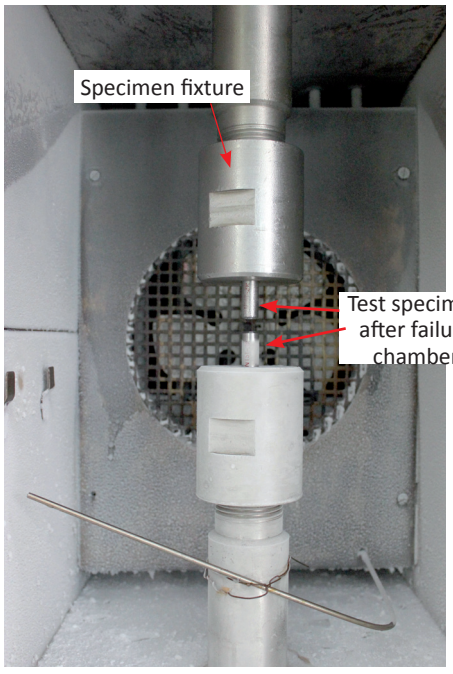
- Static tests including tension, sharp notch tension and uniaxial compression tests at room, elevated (up to +350°C) and sub-zero (-75°C) temperatures
- Plane strain fracture toughness tests at room temperature
- Low cycle and high cycle fatigue studies at room temperature under various strain and stress ranges
- Corrosion fatigue studies

Progress made during the year

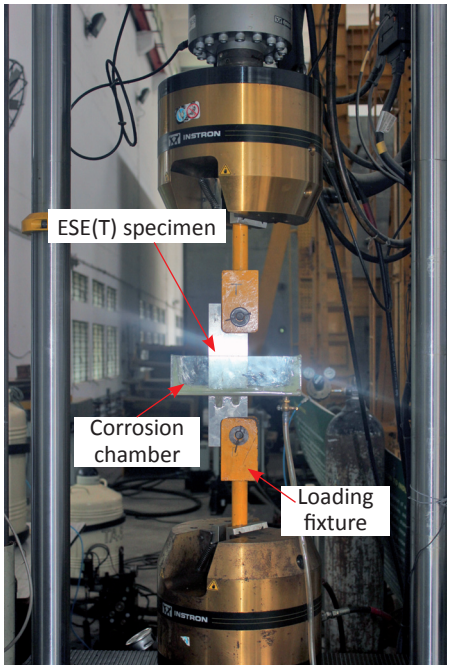
Tension tests were carried out at elevated temperature of +300°C on five numbers of specimens to evaluate sharp-notch tensile strength of the material. The specifications of ASTM E 602 were followed to prepare the test specimens and carry out the tests. The sharp-notch strength gives a comparative measure of the resistance of thick-section materials to fracture under plane-strain conditions originating from a very sharp stress-concentrator or crack. The overall length and



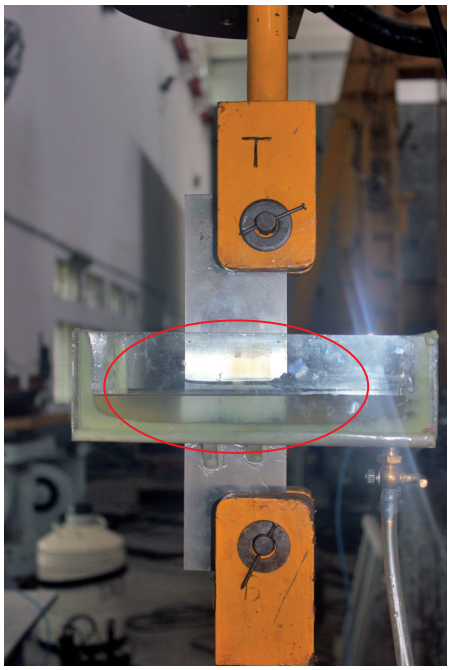
Set-up for sharp-notch tension test at sub-zero temperature



Close-up view of sharp-notch tension test specimen after failure at sub-zero temperature



Set-up for corrosion fatigue test on ESE(T) specimen



Close-up view of ESE(T) specimen after failure

diameter of the specimens were 150 mm and 12.7 mm respectively. The specimens had a sharp notch at the centre. The depth and angle of the notch were 3.7 mm and 60° respectively. The specimens were heat treated. The tests were carried out on the heat treated samples using a ±500 kN capacity servo-hydraulic UTM fitted with an environmental chamber. The tests were carried out under displacement control. Based on the five tests, the average sharp-notch strength of the material at +300°C was found to be 1185 MPa.

Uniaxial compression tests were also carried out at elevated temperature of +300°C and at sub-zero temperature of -75°C on solid cylindrical specimens to evaluate compressive strength of the material by following standard specifications. The tests were carried out on the heat treated samples using a ±500 kN capacity servo-hydraulic UTM fitted with an environmental chamber. The tests were carried out under displacement control at a rate of 0.3 mm/min. The average compressive strength of the material at elevated as well as sub-zero temperatures was calculated based on five samples. All the specimens are found to fail by crushing and the material was found to be highly brittle in nature.

Plane-strain fracture toughness tests were carried as per ASTM E 399 - 09 employing compact tension [C(T)] specimens. The specimens were loaded in tension and force (P) versus crack-mouth opening displacement (CMOD) was recorded. The value of KIC was calculated using the P-CMOD record and the specified equations established based on elastic stress analysis. Low cycle fatigue tests were carried out under four values of strain ranges, viz., 0.3%, 0.4%, 0.5% and 0.6%. The tests were carried out under strain-control and the specimens were subjected to constant amplitude triangular cyclic loading. The value of maximum strain was zero in all the four cases. High cycle fatigue tests were also carried out under load-control and the specimens were subjected to constant amplitude sinusoidal cyclic loading. Maximum value of compressive stress is taken as zero in all the four cases.

Corrosion fatigue tests were carried out employing eccentrically-loaded single edge notch tension [ESE(T)] specimens. A corrosion chamber made of perspex sheet was fixed to the test specimen at the notch portion; this chamber contained 3.5% sodium chloride solution, which

acted as the corrosive environment. The tests were carried out under constant amplitude sinusoidal cyclic loading. The specimens were tested till failure. All the specimens were found to fail at the onset of crack initiation, i.e., the specimens failed as soon as crack initiated without any crack propagation life.

Team

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Shri M. Saravanan

Analysis of Single Lane Bridges of all Spans other than 220ft and 180ft for all Load Cases to Prepare Complete Load Span Charts

This project has been undertaken under the sponsorship of Garden Reach Shipbuilders & Engineers Ltd., Kolkata

Objectives

- Modelling and analysis of single lane modular steel bridges of all spans (30ft onwards in steps of 10ft) other than 220ft and 180ft for all load cases
- Proof checking of the design of the above bridges
- Preparation of load span chart for all spans and all load cases
- Evaluation of fatigue endurance limit for the critical member/joint under critical load condition

Scope

- Linear static/quasi-static analysis of one span of the bridges will be conducted by using the finite element method (FEM) employing beam/truss elements appropriately.
- The bridges will be analysed for as per IRC –6 load class of 24R, 30R, 40R, 50R, 70R, A and AA and AASHTO – HS20 and HS25.
- In addition to the above, dead load, machinery loads, wind load and seismic loads will be considered in the analysis as per the data furnished by GRSE.
- Load values and their combinations for analysis will be calculated according to the respective Indian Standards of code of practice.
- Bridge span will be analysed for ideal boundary conditions as per the structural detailing adopted.
- Standard/available in-house/commercial finite element analysis software will be used.
- Material constants based on the data/ information provided by GRSE will be made use of in the analysis.
- Structural adequacy checking will be carried out as per IS:800-2007.

Progress made during the year

Modelling of single lane modular steel bridges of all spans (30ft onwards in steps of 10ft) other than 220ft and 180ft has been carried out based on the design documents and drawings provided by the sponsor. Work towards analysis of these single lane modular steel bridges for the 70R load case as per IRC and its respective load combinations by using standard software has been initiated.

Future programme of work

- Analysis and design checking of the bridges for all the load cases and combinations

- Preparation of load span chart for all spans and all load cases

Team

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Design Validation of 236 m High River Crossing 400 kV D/C Transmission Line Tower

This project has been undertaken under the sponsorship of M/s. Power Grid Corporation of India Limited, Gurgaon

Objectives

- Study the dynamic behaviour of the 236m transmission line tower
- Study the wind effect on the tower by computation of wind loads using different methods viz. 3-sec, hourly wind and 10-min gust
- Static linear and non-linear analysis of the tower
- Design of the tower members and joints for different load combinations
- Report on the study

Scope

- Dynamic effects of wind gusts
- Gust response factor method for wind load calculation
- Patch load techniques
- Static linear analysis
- Dynamic analysis of the tower
- P-Delta analysis
- Checking the structural adequacy of the sizes of the members of the tower and their connections

Progress made during the year

The sponsor approached CSIR-Structural Engineering Research Centre (CSIR-SERC), Chennai, for carrying out the proof checking of the structural analysis and design of the 236m high river crossing towers. The lattice tower is of 236m high, 55m base width and has a square cross-section. The dynamic behaviour of the tower structure is studied by transferring the conceptual model into mathematical model in FEA software. Free vibration analysis of the tower is carried out and found that is dynamic sensitive. The behaviour due to dynamic effects of the wind on the tower is accounted for by calculating the wind load using different methods viz. 3-sec, hourly wind and 10-min gust as per IS: 875(Part-3).

Wind loads due to hourly mean wind along with gust response factor are evaluated based on the codal provisions of IS:875 (Part 3)-1987. A scale factor of 1.5 is assumed for taking into the account of square box sections for calculating the effective force coefficients in the panel. Wind loads due to 10 minutes gust are calculated based on the codal provisions of IS:802 (Part 1 / Sec 1)-1995. The basic wind speed is considered as 50 m/s. The reliability level 3 (500 years return period of design loads) for the river crossing tower is considered. A scale factor of 1.5 is assumed as mentioned earlier for calculating the effective force coefficients in the panel. The gust response factor for towers, insulators, conductors and ground wires are extrapolated by using the power law. Since there is not much difference between the wind load evaluated based on IS:875 (Part 3) and IS:802(Part 1/Sec 1)-1995, the wind loads corresponding to IS:802 (Part 1/Sec 1) have been considered for the analysis of the tower. Transverse, vertical and longitudinal loads for

reliability, security and safety requirements are appropriately evaluated as per codal provisions of IS:802 (part 1 / sec 1)-1995.

Static analysis is carried out for the wind loads under normal and broken wire conditions. The tower has been analysed for several load cases as per IS: 802 (Part 1/Sec 1). The governing forces are computed as per the load combinations specified in the code. Design checking of tower members are carried out as per IS:802(Part 1 / Sec 2)- 1992, with a over load factor of 1.0 for dead load and 1.0 for wind load for a basic wind speed of 50 m/sec as specified by the sponsor. The feasibility of the members sections and connections are validated for the factor of safety of 1.5. P-Delta analysis is carried out by applying the body wind load and self-weight in the finite element model and it is found that the displacement is increased by 20% with P-Delta effect.

The project has thus been completed successfully after achieving all the objectives envisaged.

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Vibration Study of Control Valves through a Tri-Axial Base Excitation Input

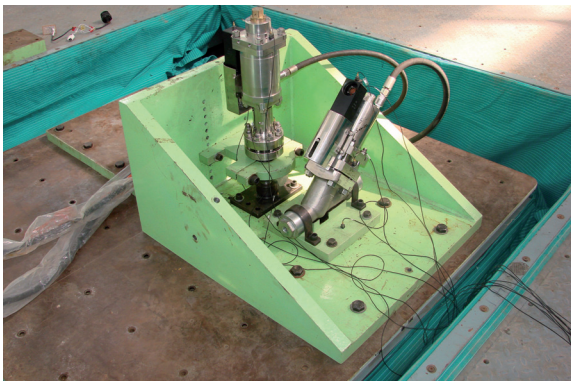
This project has been undertaken under the sponsorship of AUDCO India Limited, Chennai

Scope

- Shake table testing of six numbers of control valves
- Resonance search test in each of the orthogonal directions
- Endurance test with constant displacement amplitude and ramping up frequency

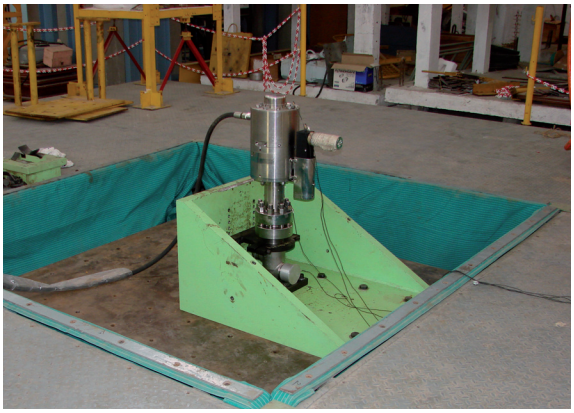
Progress made during the year

The resonance search tests and endurance tests are completed for three control valves. Endurance test with constant displacement



Seismic qualification studies on control valves (S06 & S12) using 2mx2m Tri-axial shake-table facility

Seismic qualification studies on control valve (S14) using 2mx2m Tri-axial shake-table facility



Seismic qualification studies on control valve (S14-SN1) using 2mx2m Tri-axial shake-table facility

amplitude and ramping up frequency are also completed on these control valves. Resonance search tests in each of the orthogonal directions are conducted using 4 m × 4 m shake table and dynamic characteristics of control valves are identified. It has been found that these valves are classified as stiff with a magnification factor between 1 to 1.5 within the normal earthquake frequency range.

Experiments conducted using 4 m x 4 m shake-table are completed for all the six control valves. Resonance search tests in each of the three orthogonal directions are conducted and the associated dynamic characteristics of these control valves are evaluated. It has been found that these valves are classified as stiff with a magnification factor between 1 to 1.5 in the normal earthquake frequency range. Further, endurance tests with constant displacement amplitude and ramping up frequency are also conducted on these control valves.

Team

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Ms. C. Bharathi Priya

Condition Assessment of Civil Structures of Main Plant Buildings & SEF Structures of RAPS 3 & 4

This project has been undertaken under the sponsorship of Rajasthan Atomic Power Station, Kota, Rajasthan.

Scope and objectives

- Visual observation by photographic documentation
- Ultrasonic Pulse Velocity (UPV) test– To evaluate the quality and integrity of concrete
- Rebar potential measurement (Half-cell potential measurements) – To check the probability of occurrence of corrosion
- Concrete powder sample collection– To evaluate the chloride contents in the cover concrete
- Core sampling and testing – To assess the carbonation depth, concrete quality and strength
- Submission of a project report giving recommendations based on the field study

Progress made during the year

Field investigation was undertaken to carry out non destructive tests consisting of ultrasonic scanning, cover survey, half-cell potential survey and resistivity of concrete. Concrete powder samples were collected for determination of chloride content. Concrete core samples were also taken from the structure. The core samples were dressed in the laboratory and tested for its water absorption and compressive strength. The results are compiled and technical interpretations are provided to the sponsor.

Team

Dr. P. Srinivasan
Dr. B.H. Bharatkumar
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Dr. Nagesh R. Iyer
Dr. S. Bhaskar
Shri G. Ramesh

Studies on Fatigue Strength Evaluation of Drag Link Assemblies used in Automobile Vehicles

This project has been undertaken under the sponsorship of M/s. Rane (Madras) Limited, Chennai

Objectives

- To evaluate the fatigue strength of :
- Five different categories of drag link assemblies up to 1,00,000 cycles of loading
- A drag link assembly up to 1,53,500 cycles of loading
- A drag link assembly under block loading consisting of seven different load amplitudes

Scope

- Totally twenty eight numbers of drag link rods are to be studied.

Progress made during the year

Various drag linkages including DLA front, DLA rear, first relay rod, second relay rod, and rear drag link were studied for fatigue strength evaluation. The number of samples studied in each category varies from one to seven, depending upon the requirement. The studies were carried out using a fatigue rated servo controlled hydraulic actuator. The actuator has a maximum capacity of ±100 kN with a stroke of ±125 mm. The fatigue studies were carried out under constant amplitude sinusoidal loading except for one type of linkage, for which block loading was used. The block loading consists of seven different load amplitudes with specified no. of cycles in each load amplitude. The frequency of loading was maintained between 2-5 Hz.

During the test, the maximum and minimum loads, displacement and the number cycles were monitored continuously. Throughout the tests, the specimens were visually observed at regular intervals of loading for possible crack initiation/failure. The failure of the linkages was noticed by identifying a crack/fracture either in the tube or ball joint and the corresponding number of cycles and location of the crack were recorded for all the specimens. Majority of the linkages were found to be qualified against the test criteria specified by the sponsor.

Team

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Dr. S. Vishnuvardhan
Shri M. Saravanan

Study on Seismic Performance of DSRDMs

This project has been undertaken under the sponsorship of The Indira Gandhi Centre for Atomic Research, Kalpakkam

Scope

- Conduct of seismic qualification studies on DSRDMs of PFBR using pseudo-dynamic test facility for different cases
- Interpretation and analysis of the test results
- Submission of a report based on the studies

Progress made during the year

The seismic qualification of Diverse Safety Rod Drive Mechanism (DSRDM) of Prototype Fast Breeder Reactor (PFBR) using pseudo-dynamic test facility is conducted. Experiments are conducted with water filled condition for Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) criteria. Tests are conducted on DSRDM with de-energisation of electromagnet at six different instants of time during OBE and SSE. The total duration of the OBE and SSE excitation is 19 sec and

during this period the control rod is dropped at various time instances and the dropping time is measured. Measurement includes dynamic strains, accelerations and displacements at critical locations.

Future programme of work

Submission of a report based on the studies

Team

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Ms. C. Bharathi Priya

Vibration Study on CSRDMs using Shake Table Facility

This project has been undertaken under the sponsorship of Control Instrumentation Division, BARC, Mumbai

Scope

- To conduct resonance search tests on CG and EPS mechanisms
- To conduct shake table test to evaluate the vibration proof and vibration resistance characteristics of the CG and EPS mechanisms
- Interpretation of test results and submission of a report based on the studies

Progress made during the year

Initial performance evaluation tests on two encoders of CG and EPS mechanisms of CSRDM are completed on the 2 m X 2 m, 5T shake table. The prototype CG and EPS mechanisms of CRDM to be tested on the shake-table are under fabrication by the sponsor.

Future programme of work

- Testing to evaluate vibration proof and vibration resistance characteristics of the CG and EPS mechanisms on the 2 m × 2 m, 5T shake-table.

Vibration studies on CRDMs (EPS 1) using 4mx4m Tri-axial Shake-Table Facility at ASTaR Laboratory

Team

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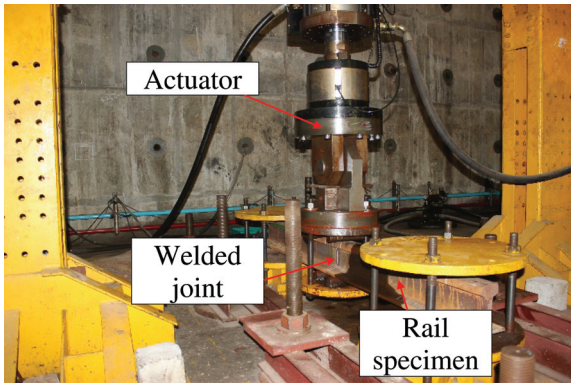
Dr. C.K. Madheswaran
Smt. R. Sreekala
Shri G.V. Rama Rao
Ms. C. Bharathi Priya
Dr. Nagesh R. Iyer

Fatigue Strength Evaluation of Flash Butt Welded Rail Joints

This Project has been undertaken under the sponsorship of M/s. L&T Construction, Hyderabad Metro Rail Project, Hyderabad

Scope

- Fatigue strength evaluation of two grades of flash butt welded rail joints, three in each type, up to two million cycles or failure whichever is earlier



Close-up view of welded rail joint under fatigue test

Fatigue test on a typical welded rail joint

Progress made during the year

Fatigue strength evaluation of welded rail joints were carried out using a fatigue rated servo controlled hydraulic actuator on two categories of welded rail joints as per the required specifications. The fatigue studies were carried out on 2 m long flash butt welded rail joints under constant amplitude sinusoidal loading. The tests were conducted under four point bending. The rail samples were supported over a span of 1.50 m and the cyclic load was applied as two point loads at a distance of 75 mm from the centre. Out of the three joints tested in 880 grade, two joints have complied with the specifications while the third joint has failed to satisfy the same.

Future programme of work

- Fatigue strength evaluation of remaining two numbers of flash butt welded rail joints

Team

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Shri M. Saravanan

Condition Assessment of Converter & ID Fan Foundation of Visakhapatnam Steel Plant, Visakhapatnam

This Project has been undertaken under the sponsorship of M/s. Visakhapatnam Steel Plant, Visakhapatnam

Scope and objectives

- Visual observation by photographic documentation
- Ultrasonic Pulse Velocity (UPV) test– To evaluate the quality and integrity of concrete
- Rebar potential measurement (Half-cell potential measurements) – To check the probability of occurrence of corrosion
- Concrete powder sample collection– To evaluate the chloride contents in the cover concrete
- Core sampling and testing – To assess the carbonation depth, concrete quality and strength
- Submission of a project report giving recommendations based on the field study

Progress made during the year

Field investigation was undertaken for carrying out non destructive tests consisting of ultrasonic scanning, cover survey and half-cell potential survey. Concrete powder samples were collected for determination of chloride content. Concrete core samples were also taken from the structure. The core samples were dressed in the laboratory and tested for its water absorption and compressive strength. The results are compiled and technical interpretations are provided to the sponsor.

Team

Dr. P. Srinivasan
Dr. S. Saibabu
Dr. J. Prabakar
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Structural Health & Integrity Checking of the Existing Shop Floor Buildings of BHPV, Visakhapatnam: Phase – I

This Project has been undertaken under the sponsorship of M/s. Bharat Heavy Plate & Vessels Ltd, Visakhapatnam

Objectives

- Measurement of the camber of the crane girders without load in Building No. 3 and Building No. 1
- Measurement of the deflection and strains in the crane girders, crane supporting girder and the columns under fully loaded conditions in Building No. 3 and Building No. 1
- Measurement of the deflection and strains in the crane girders under unloaded condition in Building No. 3 and Building No. 1
- Structural adequacy checking for the frame work of the Building No. 3 and Building No. 1 including the t russes for the fully loaded condition and appropriately making use of the measured deflections and strains

Scope

- Tensile testing of coupons cut from the crane girders, crane supporting girders and the columns, which were replaced by BHPV, will be carried out after receipt of the same from BHPV.
- Deflection measurement will be limited to the crane girders (26 numbers) in Building No. 3 and Building No.1 by using total station and LVDTs.
- Instrumentation of selected crane girders, crane supporting girders and the columns will be carried out by using strain gages.
- Both the Building No. 3 and Building No.1 with the existing structural arrangement will be considered in the analysis for assessing the stress state in crane supporting girder and columns for unloaded and fully loaded condition.
- Linear static/quasi-static analysis of the buildings will be conducted by using the finite element method (FEM) employing beam /truss elements appropriately.
- Dead load and the crane loads will only be considered in the analysis to assess the state of structural members of both the buildings. Load values and their combinations for analysis will be calculated according to the input provided by BHPV.
- The buildings will be analysed for ideal boundary conditions as per the structural detailing adopted.
- Standard/available in-house/commercial finite element analysis software will be used.
- Material constants based on the data/ information obtained through the coupons samples will be made use of in the analysis.

- Structural adequacy checking will be carried out as per IS:800-2007.

Progress made during the year

Experimental investigations have been carried out in the loaded condition of all the cranes in Building No. 1 (HMS) and Building No. 3 (LMS). The loads upto the level of design capacity of the cranes have been placed at the center, quarter and end span positions of the crane girder. The deflections have been measured for all the 27 cranes by using total station. The flexural and shear strains in 5 and 10 Tons cranes of Bay 1 in LMS and 20 Tons (Bay 6) and 60 Tons (Bay 4) cranes in HMS have been measured by using strain gauges and rosettes and acquired by using computer controlled data logger. Also the crane load has been moved across the span at the maximum velocity to obtain the fluctuations in the flexural and shear strains. The gantry girders in Bay 1 of LMS and in Bay 4, Bay 6 and cantilever portion between Bay 4 and Bay 5 of HMS have also been instrumented for measuring deflections and flexural strains. The load has been placed appropriately to get the maximum responses. The axial strain in the column has been acquired at four different locations across the cross-section for the self-weight of the cranes.

The initial camber of the crane girder has been documented and plotted. The modelling and analysis of LMS has been completed. The 3D frame work of the building has been modelled by using STAAD Pro. The model has been analysed for dead, live, wind loads and their combinations. Capacity of the members have been calculated and compared with the forces obtained from analysis. It is found that the design of LMS building is in order as per IS:800-1984. Work towards modeling and analysis of HMS building is in progress.

Future programme of work

- Data evaluation of the field investigations
- Completion of modelling and analysis of HMS building

Team

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Proof Checking the Design of 185m High Natural Draught Cooling Tower of RRVUNL Power Project at Chhabra Units 5 and 6

This project has been undertaken under the sponsorship of M/s. L&T ECC, Chennai

Scope and objectives

- Proof checking the Analysis of cooling tower shell, columns and foundation
- Proof checking the design of cooling tower shell, columns and foundation
- Identifying the deficiencies, if any, in the analysis adopted and the design carried out by the client
- Documentation of the findings in the form of a report

Progress made during the year

The 184.5m high natural draught cooling tower (NDCT) of Chhabra Power project was modelled using ANSYS. An appropriate finite element

model of the tower was developed by using a combination of elements for shell, columns, pedestal, raft and foundation soil. The soil stiffness in three directions were modelled using equivalent springs. Analyses are carried out for a) Self weight, b) Peak wind, c) Mean wind, d) Wind load case – I and e) wind load case-II. Distribution of wind pressure coefficients for the critical incident angles viz., 150o (case-I) and 75o (case-II) were arrived based on wind tunnel studies on cooling tower geometry including interference effects. The results of the analysis carried out for the above load cases are being studied in detail.

Future programme of work

- Proof checking the design of different components of NDCT

Team

Dr. K. Ramanjaneyulu
Dr. G.S. Palani
Dr. V. Srinivas
Dr. S. Bhaskar
Dr. -Ing. Saptarshi Sasmal
Shri K. Saravana Kumar
Smt. A. Kanchana Devi

Seismic Performance Tests on Steel Frame with Energy Absorbing Device (EAD)

This project has been undertaken under the sponsorship of Bhabha Atomic Research Centre, Mumbai

Scope

- Seismic performance evaluation of a one-third scaled model steel frame with energy absorbing device by shake table testing using appropriate ground acceleration input and comparison with pushover performance
- Interpretation and analysis of the test results
- Submission of a report based on the studies

Progress made during the year

Dimensioning of the test specimen made of structural steel frame to suit the capacity and the plan dimensions of the 4 m X 4 m tri-axial shaking table is carried out. The fundamental period of the test specimen will be arrived in such way that it falls in the peak plateau of the design acceleration response of the Test Response Spectrum (TRS). As an initial trial value for this exercise, a fundamental period of 0.333 sec (3 Hz) is considered, so that this value falls well within the peak plateau (between 3 to 5 Hz). Attention is given such that the increased fundamental natural frequency of the test structure due to addition of energy absorbing device towards improving the seismic performance also lies in the same peak plateau. Accordingly the configuration and member dimensions of single storey onebay steel frame is being worked out.

Future programme of work

- Fabrication of the model steel frame, EA Devices and braces
- Experimental study on the model steel frame using shake table and pushover test

Team

Shri G.V. Rama Rao
Dr. K. Muthumani
Dr. N. Gopalakrishnan
Dr. K. Sathish Kumar
Dr. C.K. Madheswaran
Smt. R. Sreekala
Ms. C. Bharathi Priya
Dr. Nagesh R. Iyer

Condition Assessment of Concrete in the SRP-II Building CPCL and Recommendations for Possible

This project has been undertaken under the sponsorship of M/s. Chennai Petroleum Corporation Ltd., Manali, Chennai

Scope and objectives

- To check the integrity of concrete in the selected locations of SRP-II building using visual inspection data, UPV test, rebound hammer test, cover meter survey and half cell potential survey
- To evaluate the chloride and pH of the concrete powder samples taken from the selected locations of SRP-II building
- To evaluate the compressive strength of concrete through concrete core test (CPCL shall make necessary arrangement to engage external agencies to extract concrete core samples (9-12 numbers) from locations in consultation with CPCL designers). Carbonation test and compressive strength test will be carried out by CSIR-SERC.
- Recommendations of remedial measures for rectification of SRP-II building based on the above investigations

Progress made during the year

SRP-II building is a RCC framed structure with 4 floors consisting of ground and three upper floors. The earlier Ammonia Stripper facility was modified and converted to UF-RO plant recently. The building houses many lines carrying gases and steam etc. along with other equipments. The building also houses tanks that store corrosive chemical like caustic soda, acids, etc.. Due to continuous operation, the concrete framed structure has started showing distress at several locations. The preliminary inspection followed by a detailed NDT investigation indicated that the building need repair / strengthening of major load-bearing structural elements.

A report outlining the details of the site investigations; analysis of data obtained during the site investigation, the findings on the quality of concrete in the structure and the repair / strengthening measure to be adopted were prepared and submitted to the sponsor.

Team

Dr. B.H. Bharatkumar
Shri T. S. Krishnamoorthy
Smt. P.S. Ambily
Shri S. Sundar Kumar
Shri G. Ramesh
Shri Bhashya Vankudothu

Analytical and Experimental Investigations on Typical Span of Bridge No.7DB at Mokameh to Evaluate the Response of Road Cross Girders and Formulate Remedial Measures

This project has been undertaken under the sponsorship of East Central Railway, Danapur

Scope and objectives

- Testing of coupons (6 Nos.) cut from the road cross girders of the existing bridge No.7DB
- Vibration measurement of a typical span due to highway vehicular loading for the existing structural arrangement
- Strain measurement at selected locations of identified cross girders, stringers and gusset plate connecting the star angles with the cross girder of a typical span
- Modelling and analysis of a typical span of existing bridge for the designed highway loads
- Analysis for identification of appropriate structural arrangement for improving the behaviour of the existing bridge

- Analysis of a typical span with modified structural arrangement for different highway load cases
- Comparative analysis of response of the modified structural arrangement with that of the existing structural arrangement
- Rating of the bridge with modified structural arrangement for permissible highway loads
- Design details of modifications, if required, for road cross girder/stringer at intermediate expansion joints
- Formulation of remedial measures to reduce vibration level of the bridge due to highway loading

Progress made during the year

Analytical and experimental investigations on a typical span of bridge No. 7DB at Mokameh are carried out to evaluate the response of road cross girders. It is a through type road-cum-rail steel truss bridge of more than 60 years old. Each of the spans is more than 100 m. It is found that few of the cross girders and the supporting system near the intermediate expansion joint are severely damaged. Under light vehicular load (as per current restriction), the bridge is found to experience excessive vibration. Numerical and analytical studies were carried out to find out the cause of damage, reason for excessive vibrations and to provide remedial measures. Global analysis has been carried out on a typical span of the bridge considering the different load cases as specified by IRC-6. Further, local analysis of a damaged portal frame has been analysed using 3D FE modelling. The cross girder, gusset and the bracing are modelled using 8 noded shell element. Loads obtained from the global analysis are imposed on the portal. The response obtained from the FE analysis clearly shows considerable stress concentration in gusset plate and in the web of the cross beam where the cracks are observed during the field inspection. Field investigations are carried out to obtain the strain behaviour, deformation pattern and vibration characteristics. Further, retrofitting schemes are being developed to avoid the stress concentration in the gussets and in the web of the cross beam by suitability modifying the load transfer mechanism of the existing structural system.

Future programme of work

- Processing of data acquired during experimental investigations
- Formulation of remedial measures

Team

Dr. K. Ramanjaneyulu
Dr. G.S. Palani
Dr. V. Srinivas
Dr.-Ing. Saptarshi Sasmal
Shri Nawal Kishor Banjara
Smt. A. Kanchana Devi
Smt. B.S. Sindhu
Dr. Nagesh R. Iyer

Proof Checking of TG Foundation of Power House Building for 2 × 660 MW, Stage-II, Units 5 & 6, Chhabra Super Critical TPS at Rajasthan, India

This project has been undertaken under the sponsorship of M/s. L&T ECC, Vadodara

Scope

- Proof checking for the design of TG foundation
- Proof checking of design and connection for power house building main structural frame work
- Preparation and submission of report

Progress made during the year

Proof checking of design and connection for power house building main structural frame

work of Chhabra Super Critical TPS at Rajasthan is done.

Future programme of work

- Proof checking for the design of TG foundation
- Preparation and submission of report

Team

Dr. N. Gopalakrishnan
Dr. K. Muthumani
Dr. G.S. Palani
Dr. K. Sathish Kumar
Dr. C.K. Madheswaran
Smt. R. Sreekala
Shri G.V. Rama Rao
Ms. C. Bharathi Priya
Shri V. Marimuthu
Smt. P. Prabha
Shri M. Saravanan
Shri M. Surendran
Dr. Nagesh R. Iyer

Structural Analysis and Design Checking of Coal Silo and Supporting Structure

This project has been undertaken under the sponsorship of M/s. L&T MHI Boilers (LTMHIB), Faridabad

Objectives

- Modelling and structural analysis of silo
- Design checking of silo and connections

Scope

- Linear static/quasi-static analysis of silo will be conducted by using the finite element method (FEM) employing discrete elements appropriately
- The silo will be analysed for loading conditions and combinations as per relevant IS codes of practice
- The dead load, imposed loads, wind load and seismic loads will be considered in the analysis as per the data furnished by LTMHIB
- The silo will be analysed for ideal boundary conditions as per the structural detailing adopted
- Standard/available in-house/commercial finite element analysis software will be used
- Material constants based on the data/ information provided by LTMHIB will be made use of in the analysis
- Structural adequacy checking will be carried out as per IS:800-2007

Progress made during the year

Structural analysis and design checking of the coal silo structure and connections provided in the mill and bunker bay for 2X660 MW Chabra TPS, Stage-II, Unit 5&6 thermal power plant has been carried out. Design of the basic structural plate/member sizes provided for the silo structure, ring girder, stiffener plates and the connections required for the silo have been checked. The proof checking has been carried out with respect to the finite element model file, documents and the drawings provided by the sponsor. Using member forces and stresses obtained from the analysis, design checking of the silo structure and connections has been carried out by using working stress method as per IS:800-2007. Based on the observations and suggestions made by CSIR-SERC during proof checking, documents and the drawings have been revised by the sponsor. Based on the revised documents and drawings, it is observed that the analysis and design calculations related to the coal silo structure and the connections are in order.

Team

Dr. G.S. Palani
Shri V. Marimuthu
Smt. P. Prabha
Shri M. Saravanan
Shri M. Surendran
Dr. Nagesh R. Iyer

Analytical and Field Investigations of Cooling Tower CT3 (Stage-I) of TPS-II at NLC, Neyveli

This Project has been undertaken under the sponsorship of Neyveli Lignite Corporation (NLC) Ltd., Neyveli

Phase–I: Field Investigations

Objectives

- To assess the column and the shell in its present condition with respect to corrosion of reinforcement
- To assess the condition of the shell and the columns based on the results of non-destructive tests (NDT) and partially destructive tests (PDT) with respect to the integrity and strength and also the corrosion related parameters

Scope

- To make a visual survey of the columns and shell upto 12.0 m height above ground level and document through photographs
- To measure the carbonation depth on the concrete cores (to be extracted from the shell by an external agency engaged by NLC) by spraying phenolphthalein solution at site. Further, the core samples will be tested for its density, water absorption and compressive strength after dressing at CSIR-SERC laboratory. The l/d ratio of the cores will be between 1 and 2 and will be tested as per IS: 516
- To determine the pH and chloride content in the concrete powder samples collected from the structure by an external agency engaged by NLC
- To measure the corrosion current in the rebar of the shell at selected locations (maximum of eight locations will be considered) using linear polarization technique (LPR) for assessing the corrosion rate of the rebars (upto 12.0 m height)
- To analyse the test results and its interpretation

Phase–II: Analytical Investigations

Objectives

- To conduct static/quasi-static analysis of cooling tower by using finite element method for (a) dead load, (b) wind load and (c) seismic load considering the current concrete strength and current codes of practice for load calculations
- Structural adequacy checking of the cooling tower including the raker columns and the pedestals as per the design criteria in current codes of practice

Scope

- The RC cooling tower along with the raker columns and pedestals will be considered in the analysis and for structural adequacy checking, as per the design basis report to be supplied by NLC
- Linear static/quasi-static analysis of the cooling tower will be conducted by using the Finite Element Method (FEM) employing 3-D finite element model
- Following three loads, namely, a) dead Load, b wind Load, and c) seismic load will only be considered in the analysis. Load values and their combinations for analysis will be calculated according to the input provided by NLC and respective current Indian codes of practice. The analysis will include the

imperfections, if applicable, for assumed deviations

- The cooling tower will be analysed for ideal/ fixed boundary conditions at the foundation level. Soil-structure interaction effects will not be included
- Standard/available in-house/commercial finite element analysis software will be used
- Material constants based on the data/ information obtained through the core samples will be made use of in the analysis
- The finite element model of the cooling tower will be developed by satisfying the standard modelling requirements on aspect ratio and the angle condition of the elements. This will ensure the convergence of the results obtained
- For the load cases corresponding to wind, the effect of interference will be considered based on the values provided by NLC

Progress made during the year

Field investigations have been undertaken for carrying out non-destructive tests consisting of ultrasonic scanning, cover survey and half-cell potential survey on the cooling tower. Concrete powder samples have been collected for determination of chloride content. Concrete core samples have also been extracted from the cooling tower. The corrosion rates have also been measured by using the corrosion rate meter at selected locations. The core samples are being dressed in the laboratory for determination of water absorption and compressive strength. Work towards instrumentation on the core samples for obtaining the stress-strain curve to be employed in the finite element analysis is in progress.

Finite Element (FE) modelling of the cooling tower has been initiated. The geometric profile of the cooling tower has been generated and the work towards FE modelling is in progress.

Future programme of work

- Data evaluation of the field investigations and testing of core samples
- FE modelling and analysis of cooling tower

Team

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Dr. P. Srinivasan
Dr. S. Saibabu
Dr. J. Prabakar
Dr. A. Ramachandra Murthy
Dr. N. Anandavalli
Smt. Smitha Gopinath
Shri V. Ramesh Kumar
Shri B. Arun Sundaram
Shri Vimal Mohan
Shri M. Surendran
Dr. K. Ramanjaneyulu
Dr. K. Ravisankar
Dr. Nagesh R. Iyer

Experimental investigations on Super structure of the Godavari Pipeline Bridge (GPB) at Rajahmundry

This project has been undertaken under the sponsorship of Hindustan Petroleum Corporation Limited (HPCL), Rajamundry

Hindustan Petroleum Corporation Limited (HPCL) is owning and operating a 18” dia multi product pipeline to transport finished petroleum products from their refinery at Vishakapatnam to the city of Secunderabad. This pipeline crosses Godavari River over a trestle bridge of 2.65 km length between Sitanaram Village of East Godavari district and Gutala Village of West Godavari District (Fig. 5). This trestle bridge was constructed in the year 1998. The bridge consists of simply supported I – girder 50m spans and balanced cantilever

Bridge across River Godavari carrying HPCL and GAIL Pipeline

spans. Two of the balanced cantilever span (at P1 and P6) is connected with I – Girder. During 2006, large deflection of the cantilever spans due to the weight of the simply supported I – Girder was observed. Additional supports were provided by HPCL at these locations and the deflected cantilever span was raised to keep the profile horizontal. In order to know the health, an experimental investigation was carried out to measure the level of stress in the selected spans using concrete core trepanning technique. Suitable locations were identified on the spans of P1 and P6. For comparison of the level of stress in the unaffected span, span of P2 and P5 were also instrumented. Linear electrical resistance strain gage of 30mm size was used in this investigation. The strain release at each location was measured using core trepanning technique. From the measurement, existing stress was evaluated which will give the present condition of the structure.

Based on the investigation, repair and retrofitting measures can be designed to extend the service life of the structure.

Team

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Dr.S. Parivallal
Shri K. Kesavan
Shri B. Arunsundaram
Shri A.K. Farvaze Ahmed
Shri Vimal Mohan

Visualization of Automated Multi-sensor NDT Assessment of Concrete Structures (NDT DATA FUSION)

Collaborators

Institutional (Academic Research)	Industrial
India	
CSIR-Structural Engineering Research Centre (CSIR-SERC), Chennai	Lucid Software Limited (Lucid), Chennai
Germay	
Bundesanstalt für Materialforschung- und –prüfung (BAM), Berlin	Specht, Kalleja + Partner GmbH, Berlin

Scope and objectives

- To establish an automated scanning system which is technically suitable to collect multi-sensor data on the concrete structures
- Data fusion techniques to be developed as a semi-automatic, physics-based, method to segment and identify various types of common defects present in concrete structures
- Implementation of the automated test system for field structures

Progress made during the year

Discussions have been held with the industrial partners of the project about the modalities of data handling. The working of scanner system for automated data collection is studied and the arrangement of the same from BAM has been mutually agreed upon. The automated scanner system has been installed and commissioned in the laboratory. The Ultrasonic Pulse Echo (UPE) and Ground Penetrating Radar (GPR) data were collected using the automated scanner system on concrete slab specimens and also on wall specimens. The scanner was held on the surface wall using vacuum suction feet. The data collected was processed using the INTROVISIO software and RADAN software. The thickness, voids and presence of reinforcements were evaluated. Two reinforced concrete slabs of size 1.0 m x 1.0 m with different thicknesses were cast. The slab has been cast with M50 grade concrete and by including suitable reinforcement grill at the top and bottom.

Future programme of work

- Experiments on multi sensor investigations on concrete specimens using automated scanner system

Team

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Shri S.G.N. Murthy
Dr. S. Bhaskar
Dr. K. Ramanjaneyulu
Dr. K. Ravisankar
Dr. Nagesh R. Iyer

Development of Textile Reinforced Polymer Modified Cementitious Mortar for Retrofitting Applications

Collaborators

India	Italy
CSIR-Structural Engineering Research Centre (CSIR-SERC), Chennai	CNR- Institute of Chemistry and Technology of Polymers (CNR-ICTP), Rome

Scope and objectives

- Development of a polymer compatible in cementitious binder and also capable of wetting the textiles
- Development of a high performance polymer modified cementitious mortar and its optimization for embedding textile reinforcement

- Micro structural analysis of polymer modified cementitious mortar
- Setting up of pultrusion machine for producing textile embedded cementitous sheets
- Experiments to find out the uniaxial behaviour of pultruded textile embedded polymer modified cementitious mortar
- Application of pultruded sheets on strengthening of typical structural members

Progress made during the year

Rheological studies have been initiated towards development of a polymer modified cementitious mortar. Different binder compositions consisting of cement and various mineral admixtures have been considered to find the optimal dosage of SBR latex polymer in the polymer modified cementitious mortar.

A pultrusion set-up has been developed to produce textile embedded cementitious sheets. This set-up differs from the existing pultrusion methodology available in literature. The pultrusion process developed at CSIR-SERC employs a mortar applying system with a pressure plate controlled by the pneumatic system. A textile feeding unit is attached to the set-up for laying of textile. An arrangement is provided for stretching the textiles during sheet production. A mortar leveling unit, which can be controlled by a manual steering is attached to the mortar applying system to improve the bonding characteristics of mortar and textile. A pulling unit is attached in the set-up wherein the textile embedded cementitious sheets will be pulled through a roller mechanism, which is capable of applying a pulling force. This will ensure the product uniformity and better bonding of final sheet constituents.

Future programme of work

Investigations on the strengthening of RC beams with pultruded cementitious sheets

Team

Smt. Smitha Gopinath
Dr. A. Ramachandra Murthy
Shri S. Maheswaran
Shri Bhashya Vankudothu
Dr. Nagesh R. Iyer

AcSIR (Academy of Scientific and Innovative Research)

Activities at CSIR-SERC, CHENNAI

CSIR-Structural Engineering Research Centre (CSIR-SERC), Chennai, is part of the nationwide CSIR-PGRPE/AcSIR programme 'Learn, Earn & Lead India' for inducting fresh Engineers into CSIR. CSIR-SERC, Chennai is offering 'Engineering of Structures' as a PGRPE course from the academic year 2009 onwards to specifically train the young and bright engineers in the areas of structural engineering. The PGRPE/ AcSIR programme on Engineering of Structures at CSIR-SERC is being coordinated by Dr. A. Rama Mohan Rao, Chief Scientist and the renewable energy programme is being coordinated by Dr. Bala Pesala, Senior Scientist of CEERI extension centre, CSIR campus, Chennai.

The main aim of CSIR-PGRPE is to select bright B.E./B.Tech. graduates and train them into research-ready scientists/engineers. For this purpose, a structured semester-wise scheme of grooming such graduates was prepared. This 4-semester scheme includes elements of conceptual understanding (through course teaching), practical skills (through laboratory courses) and application of the knowledge gained and skills acquired (through live project work). The course on 'Engineering of Structures' being offered by CSIR-SERC, is designed to provide a solid foundation for practice in both classical and newly developing areas of structural engineering including structural analysis and design, engineering materials, computational methods, and sustainable built environments. The programme features strong components in laboratory experimentation, basic theory, information technology, and engineering design. Two batches of PGRPE trainees i.e. PGPRE-2009 and PGRPE-2010 have successfully completed their M.Tech Programme and are pursuing their Ph. D Programme.

The third batch of PGRPE scientist trainees i.e. PGRPE-2011 has successfully completed all the formalities for the award of postgraduate degree. The M.Tech degree provisional certificate has been given to all the scientist trainees. The degree will be awarded soon in the next convocation.

The fourth batch of IMP-2012(PGRPE-2012) with 7 candidates for Engineering of Structures and 8 candidates for Renewable energy have completed their course work and pursuing their thesis work. The research areas being pursued by the 4th year batch of IMP-2012 candidates are part of the ongoing research activities of CSIR-SERC and also forms part of the proposed 12th five year plan projects.

The first batch of AcSIR-Ph.D candidates admitted during January, 2012 have completed their course work and also the comprehensive examination. The second batch of AcSIR-Ph. D candidates admitted during August, 2012 have completed their course work. The third batch of AcSIR-Ph. D candidates admitted during August, 2013 have completed their registration and have to take up their course work in the next semester. The selection process for AcSIR-Ph. D programme for August 2014 session is under progress .

Specialized Facilities / Equipment that rank among the best five in India

When compared with CSIR - SERC it would be rather rare to find another institution anywhere in the world which has experimental and test facilities to cater to various aspects of structural engineering under one roof. All the infrastructure required, to install and commission the state of the art equipment and hardware, has been planned and designed by the scientists of CSIR - SERC themselves. Further, the core competencies and the facilities would rank individually as the best or the next best in Indian context. This has been possible due to generous funding from CSIR and successive UNDP programmes undertaken at CSIR-SERC.

Structural Testing Laboratory

- Heavy duty floor for testing prototypes as well as model structural components
- Hydraulic loading plant up to 100 t capacity for static and dynamic loading
- Servo-controlled electro-hydraulic system with 250kN and 500kN actuators
- Instrumentation for measurement of deflection, strains, rotation, etc. during testing
- M/s Microepsilon make noncontact laser type displacement transducers
- Low-capacity high sensitive UTM of 25kN capacity for mechanical characterization of non-engineered cementitious materials, Make : M/s Instron
- High capacity Compression Testing Machine (CTM) of 300kN capacity for compression, split tensile and flexural tests on specimens, Make : M/s Micotest
- Reaction frames
- EOT crane of 10t capacity

Prototype bubble-type Dome unit undergoing strength evaluation test

Heavy testing laboratory

Advanced Concrete Testing and Evaluation Laboratory

Laboratory facilities for evaluating physical and chemical parameters of concrete including:

- Large casting yard, concrete mixers and concrete specimens casting facility.
- Concrete cutting machine for dressing concrete specimens
- Compression (200t) and Flexural testing machines (10t)
- Table vibrator for compacting concrete specimens
- Large capacity carbonation chamber of size 3.6mX3.6mX2.4m with regulation for temperature, humidity & CO_2 for accelerated carbonation test on concrete specimens
- Rapid chloride analysis test kit (RCT-500 Kit) for chlorides determination in concrete
- Diffusion cells with accessories for determining diffusion co-efficient of concretes

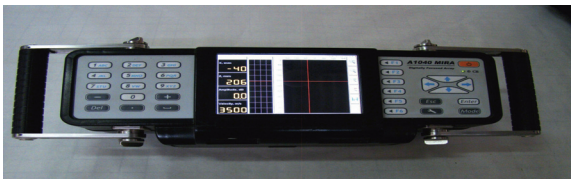
- Rapid chloride permeability test (RCPT) facility
- Rapid chloride migration test (RCMT) facility for determining diffusion co-efficient of concretes
- Data logging system for recording current
- AC impedance based corrosion measurement system for current, voltage, polarization studies, etc.

Facilities for field investigation for assessment of concrete quality:

- Rebound Hammer for determining surface hardness of concrete structures
- Ultrasonic pulse velocity tester for determining concrete quality with respect to integrity and homogeneity
- Impact Echo systems for flaw detections and thickness measurement

Ground Penetrating Radar (GPR) with antenna

Impact Echo (IE) with scanner



Low frequency ultrasonic tomograph (pulse array)

- Ultrasonic pulse echo for measurement of thickness & concrete quality
- Low frequency ultrasonic tomograph (pulse array) for determination of concrete quality & thickness
- Ground penetrating radar (GPR) for image processing of reinforcement, embedded ducts and quality of concrete
- Microscope for crack width measurement
- Core drilling and sampling equipment (50-300mm dia & 1200mm depth) for concrete
- Cover meter for cover depth determination

Facilities for field investigation for assessment of corrosion damage:

- Half-cell potential survey
- Resistivity meter for resistivity survey of concrete
- Corrosion rate measurement using AC impedance based corrosion measurement system with different guard rings

Rapid Chloride Test (RCT) kit

AC impedance based corrosion measurement system

Scanner for Non-destructive testing of concrete structures NDT-CE Scanner)

For the non-destructive evaluation of concrete structures, advanced techniques such as ground penetrating radar, impact echo and ultrasonic pulse echo are used. The data can be collected manually with each of the techniques and post processed separately. For larger areas and better accuracy, automatic data collection is required. For this, an automated scanner under the collaborative project is procured from BAM, Berlin and installed at ACTEL, CSIR-SERC. Using this scanner, different heads such as radar, impact echo and ultrasonic pulse echo can be mounted. The scanner can be fixed in horizontal and vertical position and also under the bottom side of a slab. The scanner will be helpful in the data collection for large reinforced concrete structures.

Structural Health Monitoring Laboratory

- Data Loggers for Static Strain Measurement - up to 300 channel capacity
- Dynamic Data Acquisition System - up to 88 channel capacity
  - 64 Channels for Strain Measurement
  - 8 Channels for Displacement Measurement
  - 8 Channels for Voltage Measurement
  - 8 Channels for Acceleration Measurement
- Data Loggers for Vibrating Wire Sensors - up to 60 channel capacity
- Data Loggers for Fiber Optic Sensors – EFPI and FBG types
- Non-Destructive Residual Stress Evaluation by Magnetoelasticity
- Blind-Hole Drilling Equipment for Residual Stress Measurement
- Displacement Transducers and Total Station for Deflection Measurement
- Tilt and Inclinometer System for Structural Monitoring
- Modems, Antennas, Hardware and Software for Remote Structural Health Monitoring
- Equipments for In-Situ Stress Measurements in Concrete / Masonry Structures (Core Drilling / Flat Jack technique)
- Wireless Structural Testing System of 64 channel capacity with various wireless sensors for measurement of strain, displacement, tilt, acceleration.

FBG (Fiber Bragg Grating) Interrogator

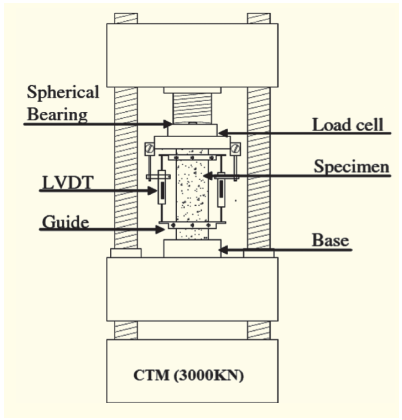
- It is a four channel FBG interrogator for taking measurements from Fiber Bragg Grating strain sensors, temperature sensors, pressure sensors, acceleration sensor and etc. It is lightweight, portable and ruggedness for field measurements. The scanning frequency of this interrogator per channel is 1000Hz. It is compatible with existing HBM strain gage data logger. It is also compatible with existing 64 channel FBG interrogator. This FBG interrogator enables the simultaneous acquisition of data from both electrical resistance strain gages and FBG strain sensors. This equipment will be used for research and development in the area of structural engineering.

Reinforced Concrete Structures and Bridge Engineering Instrumentation

- 96-channel MGC plus Data Acquisition System (M/s HBM make) consisting of
  - 48 strain gage channels
  - 16 LVDY channels
  - 16 Accelerometer channels
  - 16 Voltage channels
  - Multi-shaker excitation system for forced vibration testing of bridges consists of

1. Six Inch Throw APS – 400 make Electro dynamic (ED) shakers – 4 nos.
2. Model 4001 Horizontal Operation Reaction Mass system for low frequency excitation

3. Reaction mass assemblies – 4 Nos.
4. Dual Mode Amplifier (144) – 4 Nos.
5. Jaguar High Performance Desktop Acquisition/Control Peripheral with 6 input channels, 2 output channels;)up to 36 input channels) by M/s Spectral Dynamics
6. Force Transducers (PCB208 A12) with cables
7. Accelerometers (PCB393B04) with cables
8. SUN Ultra system loaded with MIMO analysis
9. Laptop with MISO analysis and Star analyzer software
10. JAGUAR Signal Analysis Software for MIMO analysis
    - Sensors
    - Inductive displacement transducers, Probe version Measuring Ranges of ±10 mm, ±25 mm and ±50 mm
    - ±100 mm, Laser based displacement sensor
    - Deltatron Miniature Accelerometers
    - Catman Professional Data acquisition Software
    - ME'scopeVES Visual Modal Analysis Software
    - Instrumented sledge hammer kit for forced vibration testing of bridges.
    - M/s Crystal make 31-channel ambient vibration testing system for operational model analysis of structures.
    - Force balanced triaxial accelerometers, Model: Episensor ES-T, Kinemetrics, Inc, USA.
    - Agilent 4294A Precision Impedance Analyzer with 3499 Switch/Control System with 20/40 channel multiplexer module.



Compression Testing Machine

Compression Testing Machine (CTM) is used to test the compressive strength of the materials or structural elements. It helps to determine the behaviour of material under compressive load. The compressive strength for cubical and cylindrical specimen, split tensile strength for cylindrical specimen and flexural test for prismatic specimen can also be determined. The CTM installed at CSIR-SERC is the product of Microtest. Its compressive load capacity is 3000KN and flexural load capacity is 250KN. Since the machine is directly connected to the computer with software named SCM3000, it can be monitored and regulated using the same and

both in load and displacement control mode, thus reducing the risk of using regulating and loading buttons in the machine. The deformation of the specimen at each point is recorded and its stress - strain behaviour of specimens can be obtained. This helps in determining the elastic limit, proportionality limit, yield point, yield strength and ultimate load. The load – deflection curve can also be retrieved directly from the CTM application in the computer to which the machine is connected. The fiber closing around the machine has also reduced the risk of causing accidents due to sudden failure of the materials/ specimen.

Advanced Materials Laboratory

- Facilities for testing physical properties of cements and cementitious materials.
- Testing equipment for the assessment of resistance of cement concrete composites to carbonation and chloride permeability/ diffusion.
- Special mixing equipment for concrete- Eirich mixer machine / Pan mixer machine/ ribbon type mixer.
- Concrete cutting machine for preparation of test specimen from samples taken from structures.
- Non-destructive testing equipment for concrete (PUNDIT, Schmidt/ Rebound hammer, etc.,)
- 1000 kN capacity Universal Testing Machine (UTM)
- 3000 kN capacity servo control Compression Testing Machine (CTM)

Eirich mixer machine

- Walk in temperature cum relative-humidity chamber
- Thermal cyclic chamber
- Temperature cum relative-humidity chamber
- Carbonation chamber
- Walk in steam curing chamber
- 2500 kN servo-hydraulic Universal Testing Machine

Walk in steam curing chamber

Carbonation chamber

Temperature cum relative-humidity chamber

3000 kN capacity servo control Compression Testing Machine

Thermal cyclic chamber

Steel Structures Research Facility

- Medium duty test floor measuring a plan area of 12 m x 5 m and a shake table bay of size 5 m x 3.5 m.

  Test floor supports loading frame up to 10t dynamic load. Test floor grid helps to simulate dynamic loads using the mechanical electro-hydraulic actuators.
- Computer controlled closed loop unidirectional shake table (2.5 m x 2.5 m) coupled with a servo actuator (100 kN capacity)
- Ultrasonic Flaw Detector – EPOCH-4
- Ultrasonic Thickness Gauge – EDISON-1M
- Integrated Portable Hardness Tester – TH-130
- Coating Thickness Gauge – TT-210
- Digital Data Logger-48 Channels – MGC Plus
- Inclinometer – WYLER
- Magnetic particle Inspection tools consisting of Y-7 Yoke and ketos test ring – Magnaflux
- Dye penetrant Kit – Magnaflux

Advanced Seismic Testing and Research Laboratory

- 30 t capacity, 4 m x 4 m, tri-axial shake table facility
- 5t capacity, 2 m x 2 m, tri-axial shake table facility
- Pseudo-dynamic test facility consisting of four numbers of ± 5 t & ± 50 mm actuator
- Response measurement and data acquisition capabilities for 128 channel
- Hydraulic power supply system
- Servo controlled unidirectional slip table (0.9 m x 0.9 m) coupled with an electro-dynamic shaker (5 kN capacity)
- Heavy duty test floor of plan dimension 10.5 m x 14 m with an anchor grid of 1 m x 1 m
- Heavy duty box shaped reaction well for multi-level and multi-directional dynamic/ pseudo-dynamic testing of structural components up to a height of 14 m with an anchor grid of 1 m x 1

4 m x 4 m and 2 m x 2 m tri-axial shake table facilities

- Two numbers of heavy duty EOT crane each with a load handling capacity of 20 t with synchronous operation
- Captive power supply by two diesel generator sets each of 750 kVA with facility for synchronous operation
- Digital ambient vibration measurement system (micro-microtremor recorder)
- Pile Integrity Testing Equipment
- Assorted range of vibration measuring system (accelerometers, velocity sensors and LVDTs) with matching amplifiers
- Portable recording devices (e.g., multi-channel digital recorder)
- Vibration exciters/shakers of mechanical and electro-electrodynamic types
- Building shaker for 0.1 Hz to 20 Hz with 10 t force

Pseudo-dynamic testing facility

- Ultrasonic test equipment for assessment of concrete quality/dynamic modulus
- Computational facilities for dynamic analysis of structures & Modal analysis software
- High Speed Camera with 1000 frames/ second for digital image processing response data
- Long stroke Actuator (500 kN and ± 250mm)

Instrumented Impact Test Facility

Impact testing machines are used to characterize the impact performance of various materials and components. These impact testing systems utilize various technologies to deliver impact forces - including pendulum styles, drop weight styles, and machines to simulate high-rate loading. CEAST 9350 is a floor standing impact system designed to deliver 0.59-757 J or up to 1,800 J with optional high energy system. As the premier model in the CEAST 9300 line, this model includes many time-saving features and supports a large variety of options–from chambers to extra energy. CEAST 9350 works with the impact software and data acquisition system to make analysis simple. This versatile instrument can be used to test anything from composites to finished products, and is suitable for a range of impact applications including tensile impact, puncture, Izod, and Charpy.

A view of CEAST 9350 model machine

Features of the Instrumented Impact Test Facility:

- High-performance test frames with powerful belt drive and motor system
- Easy-to-use operator control panel for precision manual control
- Protective doors and panels on all sides for operator safety
- Modular crossheads with interchangeable drop weights - change weights safely in seconds
- Visual IMPACT Software - for collecting, analyzing, and reporting detailed impact performance data
- High-speed data acquisition rates: up to 2 MHz simultaneous sampling - more data where you need it
- Features such as high-energy configuration, weighing system, automatic lubrication, anti-rebound, environmental chamber, pivoting specimen loader, and automatic specimen feeding system

Standards

The tests on materials as per various codes such as: ASTM D3763, ASTM D7136, ASTM D7192, ISO 6603, ISO 11343, ISO 8256, and other similar standards are possible on this machine.

Impact tests on structural elements like beams, slabs, made of RCC, steel and composites can be carried out in the instrumented impact test facility. In addition to this, characterization of materials at high strain rate can be performed with the help of the facility. These tests will indicate the energy absorbing capacities of materials and failure pattern under impulsive loads.

Concrete Creep Testing Laboratory

As a part of developing concrete creep testing laboratory at CSIR-SERC, ten MICROTEST F-ECH-4c/1200 kN hydraulic systems for compression creep testing were procured and installed in the basement of AsTAR Laboratory. Each machine has a rigid 4-legged frame with height adjustable upper crosshead and hinged upper plates, and has an axial compression capacity of 1200 kN. It has an integrated hydro-pneumatic loading device housed at the bottom with a single ended single acting hydraulic actuator. The special feature of the machine is the integrated automatic closed loop servo-controlled system which will enable the machine to maintain the load to within ±1%, without human interference, even when temperature varies within 14°C to 45°C. Each machine is capable of testing 4 numbers of 150 mm ∅ × 300 mm high concrete cylinders in series. Training on the operation of these machines was also given by engineers from M/s Microtest, S.A., Spain, to the identified staff members.

Concrete Creep Testing Laboratory

Fatigue & Fracture Laboratory

- Heavy duty test floor of size 36 m x 10.5 m and two vertical reaction walls of 10.5 m width and 7 m height
- Computer-controlled closed loop servo-hydraulic fatigue testing systems with actuators of capacities ± 50 kN, ± 100 kN, ±500 kN (2 nos.), ±1000 kN (2 nos.) and ±2000 kN
- Fatigue rated, computer-controlled Universal Testing Machines (UTMs) of capacities ±250 kN and ±500 kN; ±250 kN capacity machine has top mounted actuator and load cell and hence can be used for corrosion fatigue studies.
- Loading frames for static and fatigue testing, of capacity up to 4000 kN static and ±2000 kN fatigue

A computer control room cum data acquisition facility in Fatigue & Fracture Laboratory

- Portable data acquisition systems for measuring strain, pressure and temperature, including high speed data acquisition unit
- Crack depth gauges for detection and sizing of surface cracks by ACPD technique
- Ultrasonic flaw detector including phased array ultrasonics
- Environmental chambers for carrying out tests on materials and components at sub-zero and elevated temperatures
- Digital image processing system for on-line image acquisition and surface crack growth studies and during tests
- Portable thickness meter with measuring range 0.6 – 399.9 mm
- Hydraulic power packs of total capacity 390 lpm
- Back-up of diesel generator for uninterrupted test programmes
- Software for carrying out constant amplitude and random load tests using the actuators under load and displacement controls
- Software for carrying out static, fatigue and fracture toughness studies using the UTMs under load and displacement controls
- Digital Video Microscope for surface crack growth measurement with magnification upto 200x

A general view of the Fatigue & Fracture Laboratory facilities

Tower Testing & Research Station

- Test bed with prestressed rock anchors of each 500 kN uplift capacity
- Sophisticated servo-controlled hydraulic loading system
- Simultaneous application of loads at all loading points of the tower being tested
- Continuous monitoring of resultant loads and angles of their application
- Strain gauge instrumentation and on-line data acquisition and processing
- Video cassette recording and closed loop TV systems for observation, recording and documentation
- Value added tower crane and other handling equipment for erection and dismantling of test towers

Control room of TTRS

- Calibration arrangement for load cell and angle transducers
- Fabrication facilities

  Loading capacities and measurement accuracies are as follows:

Transverse	12,000 kN
Longitudinal	5,500 kN
Vertical	5,000 kN
Accuracy of loading	± 1%
Accuracy of angle of application of load	± 20 min.

An aerial view of the TTRS facilities

- Deflection measurements made digital records using total station theodolite – polygonal
- Test pad developed for testing circular / mono-pole towers
- Uninterrupted power supply during testing ensured with high power generators with auto-main-failure (AMF) system

Wind Engineering Laboratory

- Atmospheric boundary layer wind tunnel capable of generating wind speeds in a range of 0.5m/sec to 55m/sec and consisting the following features and instrumentation/ equipment:
  - Features of the boundary layer wind tunnel:

Tunnel	:	Open circuit blower type
Variable speed	:	0.5m/sec – 55m/ sec
Fan	:	Axial flow
Fan motor and power rating	:	Howden-Siroco make; 600HP, 740rpm
Test section	:	18m x 2.5m x 1.8m (adjustable ceiling)
Contraction ratio	:	1:5
Exit velocity	:	11m/sec (max)

  - Dantec traversing system accommodating hot-wire probe
  - Hot-wire anemometer system with lineariser, signal conditioner and welding units
  - 160-channel (PC based digital, remote A/D) high speed pressure measurement system (Scanivalve)
  - High speed 384 channel, electronic pressure measurement system (DTC series) with a scan rate of 650Hz/channel
  - Particle Image Velocimetry (PIV) system
  - Six-component force balances
  - Data translation cards capable of recording 64 analog single ended signals

A view of the 52 m long Boundary Layer Wind Tunnel

Particle image velocimetry (PIV) facility

  - – Uniaxial accelerometers (±10g)
  - – Ultra-miniature accelerometers
- Full-scale field measurement of wind data using wind monitoring system including remote data acquisition system
- Mobile filed instrumentation laboratory consisting the following sensors/equipment for field measurement of wind data and structural response:
  - – Gill sonic and RM Young sonic and propeller anemometers
  - – Piezoelectric type accelerometers; tri-axial accelerometers
  - – Ten-channel portable digital oscilloscope with built-in printer and RS 232 interface cable
  - – Card module of 12 channel dynamic strain gauge signal conditioner
  - – Data acquisition system with 24 analog and 24 strain channels
- Parallel computational facility for Computational Fluid Dynamics (CFD) studies comprising 8-processor computational services and FLUENT software

Advanced Computational Mechanics Facilities

Computational facilities include:

a) High and low end Servers and Workstations

b) Parallel processing facility with cluster of workstations

c) High end PCs

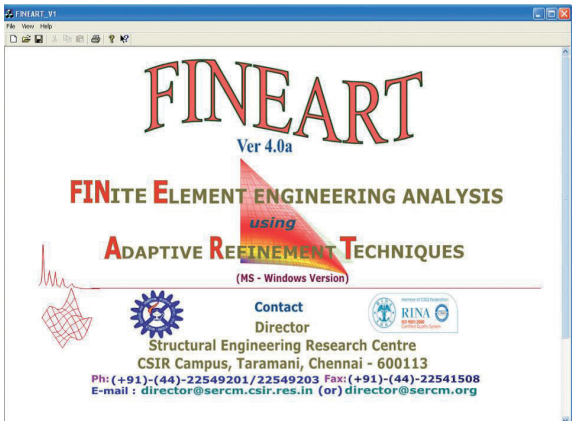
d) A strong Local Area Network

The campus-wide local area network is based on the state-of-the art high-speed fibre optic backbone. The backbone connects over 275 nodes spread over the campus offering 100 Mbps and giga-bit speeds and good bandwidth. The nodes not only connect all the work places of the scientists and laboratories but also connect the infrastructural places and the entire administrative and maintenance sections. The campus-wide network is linked to a 3 Mbps Internet connectivity. There is also a state-of-the art video conferencing facility. Finger based bio-metric attendance systems established over the campus-wide LAN. SERC/CSIR Madras campus and TTRS are connected with RF link.

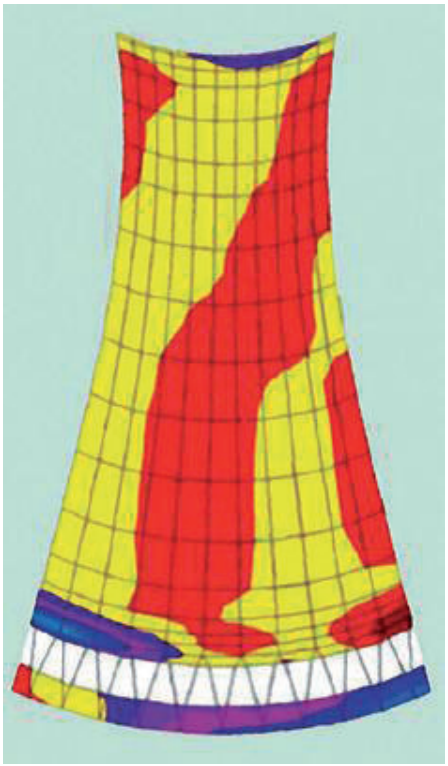
FINEART - a world-class FE based software, has been developed by CSIR - SERC. Realizing the power and potential of the FEM and anticipating the needs of industry, CSIR - SERC was one of the first civil engineering institutions in the country to develop computer software for analysis and design of structures/components as early as in 1969. Continued and sustained development of FINEART (FINite Element analysis of structures using Adaptive Refinement Techniques) package is an effort in this direction.

It is a multi-physics computational analysis package with the following features:

- Advanced finite element analysis (FEA) software
  - – To provide solution for engineering problems
  - – To illustrate performance of different types of elements and modeling methods
- A tool for solution of real life industrial problems involving engineering analysis and design.



Main Screen of FINEART software



Analysis of a cooling tower

- A research, and/or applications environment to address new problem areas or analysis requirements

Application Softwares, such as ANSYS, ABAQUS, LS DYNA, NISA II, ALGOR, STAAD III, MATLAB, MATHCAD, ATENA, MASAS, AUTOCAD, RM2006 Bridge Analysis software, etc., besides database packages (RDBMS) such as Visual Studio, FOXPRO, SQL, and Oracle, etc. are available at SERC.

Information Resource Base

There is an excellent collection of knowledge based literature with the state-of-the art Library having some of the best book / journal / literature collection in the area of structural engineering. The statistical information is given below:

Sl. No.	Description	Nos
1	Books(new books added = 190)	14374
2	No. of Journals subscribed	84
3	Journal Back Volumes	7091
4	Standards /Codes	3505
5	Hindi Books	539
6	Microfiche	2053
7	DVD/CD/Floppies	658
8	Research Alert – a monthly service	1
9	Access to e-publisher site [through CSIR Consortium]	7
10	Access to e-journals [through CSIR Consortium]	250
11	Access to e-database [through Subscription]	3

R&D MANAGERIAL BASE

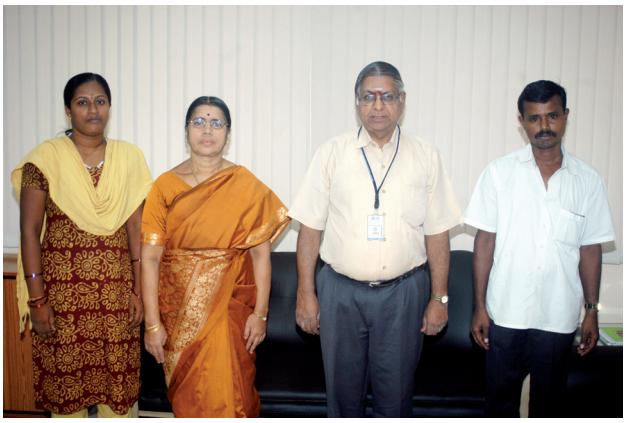
- System of skills upgradation and staff training

Level	No of Staff / Programme	2009 – 10	2010 - 11	2011- 12	2012-13	2013-14
S & T Staff (India)	Training Courses / Workshops	54	45	36	21	15
	Conferences / Seminars / Symposia etc.	48	86	49	113	88
S & T Staff (Abroad)		12	9	9	10	9
Admin. Staff	Training Courses / Workshops	7	13	13	7	4
	Conferences / Seminars / Symposia etc.				8	
Total		184	153	107	159	116

Extramural R&D Human Resource Development

Guidance Provided to post-graduate students	2009 – 10	2010 - 11	2011- 12	2012-13	2013-14
M.E./M. Tech. (Civil / Structural Engg.)	44	46	76	65	68
M.Sc., / MCA (Computer Science / Applications)	9	14	17	6	18
BE / B Tech Students	-	49	50	117	85
In-house Ph.D. produced/Ph.D. (Doctoral) Engg. Engineering/ General	7	5	2	3	21
Total	60	114	145	191	192

Director's Secretariat



Infrastructural Divisions

TECHNICAL KNOW-HOW TRANSFERRED / DISSEMINATED FOR INDUSTRIAL UTILISATION

The Centre has developed, over the years, process/product know-how on precast building & concrete products, as well as repair techniques with polymer concretes. These are being continuously transferred/disseminated to many governmental and other agencies for field application in the building construction and housing sector, directly and/or through NRDC, publications and presentations in workshops/ seminars. Following are the important processes/ products released over the years:

1. High strength deformed (HSD) bar for concrete reinforcement
2. A process for making prestressed concrete poles using HSD bars and portable stressing beds
3. Small capacity ferrocement water tanks
4. Prestressed concrete monoblock railway sleepers
5. A process for manufacture of latoblocks (building blocks from lateritic soils)
6. Fibre reinforced concrete - light, medium, and heavy duty manhole covers
7. Ferrocement service core units
8. Techniques for repair of cracks in concrete by polymer injection
9. Polymer impregnated concrete products- tiles, pipes and panels
10. Polymer overlays for industrial floor, deck slabs and pavements
11. Light weight prefabricated seismic resistant building using expanded polystyrene.

PATENT FILED

Patent filed	:	Precast Concrete Lightweight Large Panel
Inventors	:	Jolly Annie Peter, Narayanan Lakshmanan, Palaniswamy Sivakumar, Nagesh Ranganatha Iyer
Application No.	:	2441DEL2013

LIST OF COMPUTER SOFTWARE PACKAGES

Name	Detail
INTRAN	Interactive analysis of pin jointed 2-D and 3-D truss system
INFRAN	Interactive analysis of plane rigid jointed 2-D frames
INGRID	Interactive analysis of grids of various patterns
INSPACE	Interactive analysis of 3-D rigid jointed space frames
INFOLD	Interactive analysis of folded plate structures
INCYSHELL	Interactive cylindrical shell analysis
MICSTRAN	Interactive analysis of 2-D, 3-D trusses, 2-D frames and grids
RC SLABS	Interactive design of RC slabs
RC SLABS (G)	Interactive design of RC slabs (graphics enhanced)
RC BEAMS	Interactive design of RC Beams (T, L, rectangular)
RC BEAMS (G)	Interactive design of RC Beams (T, L, rectangular) (graphics enhanced)
RC COLUMNS	Interactive design of RC columns subjected to axial load and uniaxial or biaxial moments
RC COLUMNS (G)	Interactive design of RC columns subjected to axial load and uniaxial or biaxial moments (graphics enhanced)
RC FOOTINGS	Interactive design of RC isolated footings
RC FOOTINGS (G)	Interactive design of RC isolated footings (graphics enhanced)
RC COMBINED FOOTINGS	Design program for RC combined footings
RC COMBINED FOOTINGS (G)	Design program for RC combined footings (graphic enhanced)
RC FLAT SLABS	Design program for RC flat slabs
RC FLAT SLABS (G)	Design program for RC flat slabs (graphics enhanced)
RC STRIP FOOTINGS	Interactive design of RC strip footings
WINFRAN	Windows based frame analysis system [in C/C++]
RC INTZE TANK	Design of RC water tank
INDROOS	Analysis of industrial roof systems
FINEART**	Finite element engineering analysis using Adaptive Refinement Techniques

*** Demo kit available for testing and feedback, pending release.*

Note:

1) The above programs are released as load modules on systems ranging from microcomputer to main frame system.
2) The programs are released+ under a licence agreement. Details of licence fee, etc., can be obtained from the Director, CSIR-Structural Engineering Research Centre, Chennai, on request.

+ except FINEART

GRANT-IN-AID PROJECTS

Sl No.	Title	Sponsor	Duration
1.	Development of robust damage diagnostic techniques for engineering structures using PCA and ICA	ARDB, New Delhi	Dec 2009 – May 2013
2.	Analytical and experimental investigations on remaining life and residual strength assessment of stiffened panels under constant and variable amplitude loading	ARDB, New Delhi	Apr. 2010 – March 2014
3.	Development of structural health monitoring schemes for civil engineering infrastructure in India using smart sensing technologies	NPMASS, Bangalore [Ministry of Defence]	Apr. 2010 – Jul. 2013
4.	Segmental Composite slabs for bridge decks	Department of Science & Technology, New Delhi	Aug.2012 – Jul. 2015

SPONSORED RESEARCH PROJECTS

Sl No	Title of the Project	Client	Duration
1.	Performance evaluation of typical railway bridges under increased axle loads of freight wagons	Southern Railway, Chennai	Jan. 2010 – Mar 2014
2.	Investigation on performance evaluation of parallel flange sections for specified loads - Phase – I: Beam Sections	Jindal Steel & Power Ltd., Raigarh	Apr 2012- Mar 2014
3.	Evaluation of indigenous bearing materials	CVRDE, DRDO, Avadi, Chennai	Nov 2011- Nov 2013
4.	Analysis of single lane bridges of all spans other than 220 ft and 180 ft for all load cases to prepare complete load span charts	Garden Reach Shipbuilders & Engineers Ltd., Kolkata	Feb 2013- Feb 2014
5.	Experimental investigations on 220 ft single lane bridge in-house (within GRSE, Kolkata)	Garden Reach Shipbuilders & Engineers Ltd., Kolkata	Feb. 2013- July 2013
6.	Design validation of 236m high river crossing 400 kV D/C transmission line tower	Power Grid Corporation of India Limited, Gurgaon	Nov 2012- April 2013
7.	Vibration study of control valves through a tri-axial base excitation input	Audco India Limited, Chennai	Nov 2012- Sep 2013

Sl No	Title of the Project	Client	Duration
8.	Condition assessment of civil structure of main plant buildings & SEF structures of RAPS 3&4	Senior Maintenance Engineer (Civil), RAPS 3&4, Kota, Rajasthan	Jan 2013 - May 2013
9.	Studies on fatigue strength evaluation of drag link assemblies used in automobile vehicles	Rane (Madras) Limited, Chennai	Nov 2012- May 2013
10.	Study on seismic performance of DSRDMs – BRNS Project	IGCAR, Kalpakkam	Feb 2013-Jan 2014
11.	Vibration study on CSRDMs using shake table facility – BRNS Project	Y.K. Taly, Head, Control Instrumentation Division, BARC, Mumbai	Apr 2013- June 2014
12.	Fatigue strength evaluation of flash butt welded rail joints	L&T Construction, Hyderabad Metro Rail Project, Madhapur, Hyderabad	Mar 2013- June 2014
13.	Condition assessment of converter & ID fan foundation of Visakhapatnam Steel Plant	Engineer-in-charge, Visakhapatnam Steel Plant, Visakhapatnam	May 2013-July 2013
14.	Structural health & integrity checking of existing shop floor buildings of BHPV, Visakhapatnam: Phase-I	BHPV, Visakhapatnam	Jun 2013 – Mar 2014
15.	Study on seismic performance of PSS assembly	Nuclear Power Corporation of India Ltd., Mumbai	May 2013- June 2014
16.	Studies on fatigue behavior of reinforcing bars	TATA Steel Ltd., Jamshedpur	Jan 2014 – Jan 2015
17.	Proof checking the design of 185m high natural draught cooling tower of RRVUNL Power Project at Chhabra Units 5&6	L&T ECC, Mount Poonamalle Road, Chennai	Aug 2013- Mar 2014
18.	Condition assessment of converter & ID fan foundation, RCC floors and steel members at different elevations of Visakhapatnam Steel Plant	Engineer-in-charge, Visakhapatnam Steel Plant, Visakhapatnam	Aug – Sep 2013
19.	Seismic performance tests on steel frame with energy absorbing device (EAD)	Bhabha Atomic Research Centre, (BARC) Mumbai	Aug 2013- Jul 2014
20.	Condition assessment of concrete in the SRP-II building at CPCL and recommendations for possible.	Chennai Petroleum Corporation Limited, Chennai	Aug - Oct 2013

Sl No	Title of the Project	Client	Duration
21.	Analytical and experimental investigations on typical span of bridge No.7DB at Mokameh to evaluate the response of road cross girders and formulate remedial measures	East Central Railway, Danapur	Oct 2013-Mar 2014
22.	Proof checking of TG foundation of power house building for 2 × 660 MW, Stage-II, Unit 5 & 6, Chhabra Super Critical TPS at Rajasthan,	M/s L&T ECC, West Block, L&T Knowledge city, Vadodara-390 019.	Oct 2013 - Mar 2014
23.	Structural analysis and design checking of coal silo and supporting structure	M/s. L&T MHI Boilers, Faridabad	Oct 2013 - Dec 2013
24.	Analytical and field Investigations of cooling tower CT3 (stage-I) of TPS II at NLC, Neyveli	Deputy General Manager, TPS-I, Neyveli Lignite Corporation, Neyveli.	Oct 2013 - Mar 2014
25.	Condition assessment of concrete in the diaphragm walls of CMRL, Chennai	Afcons Transftonnelstroy-Afcons Joint Venture, Chennai	Dec 2013- Mar 2014
26.	Condition assessment of selected stationery mechanical structure at NMDC, Bacheli	NMDC, Bailadila Iron Ore Mine, Bacheli	Feb 2014– July 2014
27.	Experimental investigations on super structure of the Godavari pipeline bridge (GPB) at Rajamundry	Hindustan Petroleum Corporation Limited, Mumbai	Jan 2014 – Mar 2014
28.	Analytical and field investigations of 275m chimney (Phase - 1) of 1215MW capitive power plant at SSL, Jharsuguda	Sesa Sterlite Limited, Jharsuguda	Feb-March 2014

COLLABRATIVE PROJECTS

Project No.	Title of the Project	Collaborator / Client	Duration
CLP 004	Visualization of automated multi-sensor NDT assessment of concrete structures	Indo German Science / Technology Centre (IGSTC)	Apr 2012– Mar 2015
CLP 005	Development of textile reinforced polymer modified cementitious mortar for retrofitting applications	CNR, Institute of Chemistry and Technology of Polymers, Italy under CNR-CSIR Cooperation Programme	Sep 2012– Jun 2014

CONSULTANCY PROJECTS/SERVICES

Providing consultancy services continues to be one of the major activities of the Centre. Several governmental agencies and public and private sector organisations sought the help of the Centre for solving different types of structural engineering problems. The following consultancy projects were handled by CSIR-SERC during the year.

Project No.	Client	Title	Duration
CNP 6321	BARC, Mumbai	Investigation on Added Mass on shear wall	Apr 2010-Mar 2014
CNP 6400	NTPC, Mouda	Recommendation for the termination of intake well foundation	Aug 2011-Apr 2013
CNP 6409	RMC Readymix (India), Mumbai	Mix design to attain compressive strength of 48.25 MPa and Flexural strength of 4.5 MPa	Sept.2012 – May 2013
CNP 6430	Wheels India Ltd, Padi	Fatigue strength evaluation of spherilastic bushes	Mar 2013 -Jun 2013
CNP 6433	Larsen & Toubro Limited, Chennai	Vibration measurment in RCC floor in machine shop area	Mar 2013 - May 2013
CNP 6434	Larsen & Toubro Limited, Chennai	Proof checking of wind mill foundation	April-May 2013
CNP 6435	M/s. India Thermit Corporation Ltd, Kanpur -208 012	Fatigue strength evaluation of 52 kg 90 UTS rail joints	June 2013 - Oct 2013
CNP 6436	M/s Larsen & Toubro Ltd., Chennai	Proof checking design of RCC shell and raft foundation for 275m tall chimney	June 2013 - Jul 2013
CNP 6437	NTPC, Anta	Assessment of concrete quality in the raft slab of discharge channel	Aug 2013 - Oct 2013
CNP 6438	M/s J B Engineering Corporation, Industrial Area, AMB, Dist. Una-177212 (HP)	Performance evaluation of JB-19 32mm coupler under low cycle fatigue (10000 cycles)	Jul 2013 - Aug 2013
CNP 6439	M/s Oberoi Thermit Pvt. Ltd, Noida	Fatigue strength evaluation of alumino thermit welded rail joints	Aug 2013 - Dec 2013
CNP 6440	The Residency Towers, Chennai	Investigation of the condition assessment of corrosion affected RCC slabs and beams in the basement (2) floor roof of Residency Towers and recommendations for remedial measures	Sep 2013 - Oct 2013
CNP 6441	M/s. BGR Energy Systems Ltd, Anna salai, Chennai	Proof checking the rectification methodology for chimney shell concreting	Oct 2013 - Nov 2013

Project No.	Client	Title	Duration
CNP 6442	Wheels India Ltd, Padi	Static strength evaluation of block handler wheel	Nov 2013 - Dec 2013
CNP 6443	Daimler India Commercial Vehicles Pvt Ltd, Chennai	Drag force measurement study on 1:10 scale rigid model of vehicle in wind tunnel	Dec 2013 - Jan 2014
CNP 6444	Audco India Limited, Chennai	Seismic qualification test on two valves	Mar 2014 - May 2014

TESTING OF TOWERS

Tests on the following prototype towers/related hardware were conducted at the Tower Testing and Research Station (TTRS) of CSIR-SERC:

Sl No	Title	Client	User	Duration
1.	Testing of 275 kV / 132 kV "SL" type tower with +6m body extension for establishment of double circuit 275 & 132 kV transmission line from Kimanis and SPR Power Stations to PMU Kolopis and PMU Lok Kawi, Sabah, SESB T.6316 (C)	M/s. H.G. Power Transmission SDN, BHD, Malaysia	M/s. Sabah Electricity SDN, BHD, Malaysia	May-June 2013
2.	Testing of 275/132 kV M/C tower, 'M' type with +3m body extension for establishment of double circuit 275 & 132 kV transmission line from Kimanis and SPR Power Stations to PMU Kolopis and PMU Lok Kawi, Sabah, SESB T.6316 (C)	M/s. H.G. Power Transmission SDN, BHD, Malaysia	M/s. Sabah Electricity SDN, BHD, Malaysia	June-July 2013
3.	Investigation on mechanical strength assessment of (i) 400 kV quadruple tension string with standard insulator discs and (ii) 400 kV quadruple tension string with antifog insulator discs (with 4x24 units of 160 kN along with IAC Electricals Hardware)	M/s. Bharat Heavy Electricals Ltd., Jagadispur, Dist. Amethi, (U.P.)	M/s. Bharat Heavy Electricals Ltd., Jagadispur, Dist. Amethi, (U.P.)	July – Aug 2013
4.	Testing of 132 kV SL+3m body extension for Establishment of Double Circuit 275 kV & 132kV transmission line from Kimanis and SPR Power Stations to PMU Kolopis and PMU Lok Kawi Sabah: SESB T. 6316 (C)	M/s. H.G. Power Transmission SDN, BHD, Malaysia	M/s. Sabah Electricity SDN, BHD, Malaysia	Aug 2013

Sl No	Title	Client	User	Duration
5.	Testing of 132 kV "S"+0m type tower for establishment of double circuit 275 kV & 132kV transmission line from Kimanis and SPR Power Stations to PMU Kolopis and PMU Lok Kawi, Sabah : SESB T.6316 (C)	M/s. H.G. Power Transmission SDN, BHD, Malaysia	M/s. Sabah Electricity SDN, BHD, Malaysia.	Aug-Sept. 2013
6.	Testing of 275 kV "24S+MA"+25M type tower for proposed 275 kV double circuit looping IN/OUT from exiting 275 kV Segari-Ayer Tawar to Vale Iron Ore Plant (Mainhead 'Ā'): TNB 193/2012	M/s. H.G. Power Transmission SDN, BHD, Malaysia	M/s. Tenaga Nasional Berhad, Malaysia.	Sept-Oct 2013
7.	Testing of 275 kV "SL"+0M type tower for establishment of double circuit 275 kV & 132kV transmission line from Kimanis and SPR Power Stations to PMU Kolopis and PMU Lok Kawi, Sabah : SESB T.6316 (C)	M/s. H.G. Power Transmission SDN, BHD, Malaysia	M/s. Sabah Electricity SDN, BHD, Malaysia	Nov 2013-Feb 2014
8.	Establishment of double circuit transmission line 'SA' type 275 kV tower with + 0 m for Kimanis and SPR Power Stations to PMU Kolopis and PMU Lok kawl Sabah SESBT, 6366 (C)	M/s. H.G. Power Transmission SDN, BHP, Malaysia	M/s. Sabah Electricity SDN, BHD, Malaysia	Dec 2013

LECTURES / COLLOQUIA

It is our normal practice to make presentations of the contributions made by one of the co-authors of each paper that has been approved by the Director on the recommandations of the Publication Committee. These presentations are made on Wednesdays of each week to other groups/teams of scientists, before the manuscripts are sent for publication to various Journals/ Technical Meets.

The following lectures delivered by Scientists of CSIR-SERC were organised by the Centre during the year:

Date	Speaker	Topic
03.04.2013	Dr. P. Kamatchi	Response of steel framed buildings with passive energy dissipaters for site-specific earthquakes
03.04.2013	Dr. K.N. Lakshmikandhan	Damage assessment and strengthening of reinforced concrete beams with CFRP
10.04.2013	Dr. A. Rama Mohan Rao	Structural damage detection using Hilbert Huang transform, proper orthogonal decomposition and quantum PSO
10.04.2013	Shri Amar Prakash	Influence of adhesive joint thickness on high velocity impact performance of composite targets

Date	Speaker	Topic
17.04.2013	Dr. S. Saibabu	Experimental investigations on performance evaluation of dry and epoxy jointed segmental box girders
17.04.2013	Shri G. Ramesh	Bond behavior and test methods of externally bonded reinforcement (ERB) FRP composites in concrete elements – A critical review
08.05.2013	Dr. V. Srinivas	(i) Experimental modal analysis for evaluating influence of damage on vibration characteristics of reinforced concrete structures (ii) Influence of test conditions on modal characteristics of reinforced concrete structures under different damage scenarios
15.05.2013	Dr. V. Srinivas	(i) Nonlinearity in vibration characteristics for structural damage assessment (ii) Damage sensitive features from nonlinear vibration responses of Reinforced concrete structures
22.05.2013	Dr. N. Anandavalli	Cyclic response of laced steel concrete composite (LSCC) beams
29.05.2013	Smt. R. Sreekala	Near fault earthquakes and behaviour of liquid storage tanks
05.06.2013	Dr. C.K. Madheswaran	Shear behaviour of reinforced geopolymer concrete thin webbed tee beams
05.06.2013	Dr. K.N. Lakshmikandhan	Investigation on the effect of shear connector in composite space structure
12.06.2013	Dr. (Ing.) SaptarshiSasmal	Numerical evaluation of bond-slip relation or near-surface mounted carbon fiber bars embedded in concrete
12.06.2013	Shri Vimal Mohan	Joint stiffness of cold formed pallet rack steel connections: A comparison of the methodology
19.06.2013	Dr. K. Ramaraju	Experimental studies on use of scissor-jack mechanism fitted with magnetorheological dampers for seismic performance enhancement of 3-storey SMRF model
19.06.2013	Dr. N. Prasad Rao	Schifflerized angle sections for triangular based communication towers
03.07.2013	Dr. K. Balaji Rao	Probabilistic fatigue life analysis of welded steel slab bridge girders using S-N curve approach
10.07.2013	Shri Mohit Verma	Fuzzy logic controller for real-time substructuring

Date	Speaker	Topic
10.07.2013	Smt. M. Keerthana	Application of CFD for assessment of galloping stability of rectangular sections
17.07.2013	Shri P. Gandhi	Experimental fracture studies on carbon steel elbows with and without internal pressure
17.07.2013	Shri S. Sundar Kumar	Effect of NaOH concentration and molar ratios on strength development in geopolymer mortars
31.07.2013	Smt. S. Chitra Ganapathi	(i) Experimental investigations on light weight sandwich panels under flexural loading and (ii) Behaviour of an innovative light weight sandwich panels under out of plane bending loading through an experimental and numerical approach
21.08.2013	Shri S. Maheswaran	Strength improvement studies using new type wild strain Bacillus cereus on cement mortar
21.08.2013	Dr. Saptarshi Sasmal	Methodology for simulation and numerical investigations on behavior of concrete at meso-scale
11.09.2013	Dr. M.B. Anoop	Performance-based remaining life assessment of reinforced concrete bridge girders considering human judgemental aspects
11.09.2013	Dr. S. Vishnuvardhan	Ratcheting failure of pressurised straight pipes and elbows under reversed bending
18.09.2013	Smt. A. Kanchana Devi	Ultimate load behaviour of beam with corroded reinforcement
18.09.2013	Dr. T. Hemalatha	Influence of admixtures on the size effect of self compacting concrete (SCC)
09.10.2013	Dr. R. Manisekar	Behaviour of RC beams strengthened by external prestressing using trapezoidal tendons
09.10.2013	Dr. T. Hemalatha	Fracture properties of SCC using acoustic emission and digital image correlation
06.11.2013	Smt. Smitha Gopinath	Flexural behaviour of concrete beams strengthened with fabric reinforced concrete
06.11.2013	Shri V. Rameshkumar	Studies towards strength improvement in concrete using lime water
13.11.2013	Smt. Smitha Gopinath	Low and high velocity impact studies on fabric reinforced concrete panels
13.11.2013	Shri V. Bhashya	Investigations on recycled aggregate concrete made using filed demolished concrete as coarse aggregates with addition of flyash / silicafume
20.11.2013	Dr. N. Anandavalli	Multiscale modelling: Basics and advances

Date	Speaker	Topic
27.11.2013	Dr.S. Bhaskar	Studies on mechanical and durability parameters of concrete with PCE super plasticizer and calcium nitrite inhibitor
27.11.2013	Shri Prabhat Ranjan Prem	Influence of curing regimes on compressive strength of ultra high performance concrete
18.12.2013	Dr. S. Vishnuvardhan	Fatigue life assessment of typical welded steel structural joints
18.12.2013	Smt. Smitha Gopinath	Low velocity impact behaviour of ultra high strength concrete panels
08.01.2014	Dr. P. Kamatchi	Site specific analysis of framed buildings located at deeper alluvial basin through 1D and 2D ground response analyses
08.01.2014	Shri J. Daniel Ronald Joseph	Establishing hierarchical order of influence of factors affecting concrete creep
24.02.2014	Shri Amar Prakash	(i) Development of SFRCC panel for high velocity impact resistance (ii) Effect of tile pattern on multiple high velocity impact response of ceramic / aluminium composite target
12.03.2014	Dr. P. Kamatchi	Estimation of long-term prestress losses of box-girder bridge span using the models in Indian and International codes of practices and comparison with field measurements.
12.03.2014	Shri G.V. Rama Rao	Studies on non-linear behaviour of shear walls with medium aspect ratio under monotonic loading

SPECIAL LECTURE

13.03.2014: Ms. Franziska Lindhout, Director, DAAD Information Center Chennai, German Academic Exchange Service, visited CSIR-SERC and delivered a special lecture on 'Research funding and fellowship opportunities in Germany for CSIR-SERC'.

INVITED LECTURES/TALKS AT COURSES SEMINARS/ WORKSHOP/ SYMPOSIA

UNIVERSITY / COLLEGE

St. Peter's University, Chennai

Dr. K. Ravisankar, inaugural address, CSIR Sponsored National Seminar on Effective Utilisation of Industrial Wastes, August 8, 2013

Dr. K Balaji Rao, invited lecture, 'Risk and vulnerability analysis for earthquake disaster reduction', International Conference on Disaster Management, January 23-24, 2014

Kumaraguru College of Technology, Coimbatore

Dr. K.N. Lakshmikandhan, invited lecture, 'Engineering and economics of reinforced conretre buildings', One-day Workshop on Engineering and Economics of Reinforced Concrete Buildings, August 30, 2013

Vel Tech High Tech Dr. Rangarajan and Dr. Sakunthala Engineering College, Chennai

Dr. K. Balaji Rao, keynote address, 'Innovations in civil engineering', National Seminar on Quest for Innovations in Civil Engineering – QICE'13, Department of Civil Engineering, October 30, 2013

Vel Tech High Tech Dr. RR & Dr.SR Technical University, Chennai

Dr. K. Balaji Rao, guest lecture, 'Advances and innovations in civil and mechanical engineering', 3rd National Conference on Advances and Innovations in Civil and Mechanical Engineering, September 5, 2013

Dr. S. Selvi Rajan, guest lectures on (i) 'Mitigation of stuctures against cyclones' and (ii) 'Aeroleasticity', December 23, 2013

Rajalakshmi Engineering College, Chennai

Dr. G. Raghava, guest lecture, 'Fatigue and fracture in structures and components', September 10, 2013

AMS College of Engineering, Chennai

Dr. A. Ramachandra Murthy, guest lecture, 'Advances in Civil Engineering', Engineer's Day, September 16, 2013

Government Engineering College, Thrissur, Kerala

Dr. K. Muthumani, invited lecture, 'Dynamic analysis of tall buildings', Short Term Training Program on Design Aspects and Soil Exploration for High rise Structures, September 29, 2013

Vel Tech, Chennai

Dr. P. Sivakumar, guest lecture , 'Design of RC elements (Limit State Design)', October 9, 2013

Sri Ramakrishna Institute of Technology, Coimbatore

Dr. J. Annie Peter, invited lecture, 'Innovative materials and technologies in concrete construction', National Seminar on Innovative Practices in Construction and Waste Management', October 9, 2013

Velammal College of Engineering & Technology, Madurai

Dr. J. Annie Peter, invited lecture, 'High performance concretes for durable structures', National Seminar on Recent Trends in Corrosion Studies, October 10, 2013

Coimbatore Institute of Technology, Coimbatore

Dr. A. Rama Chandra Murthy, lecture, 'A Practical Approach on Non Destructive Testing Techniques', Civil Engineering Workshop, October 23, 2013

Shri V. Marimuthu, invited lecture, 'Design of steel tension members according to IS:800-2007', TEQIP-II Sponsored One Week Faculty Development Programme on Limit State Design of Steel Structures, November 9, 2013

Dr. A. Ramachandra Murthy, invited talk , 'Different types of concretes', Civil Engineering Workshop, October 23,2013

Misrimal Navajee Munoth Jain Engineering College, Chennai

Dr. J. Prabakar, invited lecture, 'Repair and rehabilitation of concrete structures', November 8, 2013

Dr. K. Ramanjaneyulu, inaugural lecture, 'Investigations on bridge structures, August 8, 2013

Dr. K. Ramanjaneyulu, keynote lecture, 'Seismic retrofitting of exterior beam-column sub-assemblage', National Conference on Emerging Trends in Civil Engineering, February 28 – March 1, 2014

Siddaganga Institute of Technology, Tumkur

Dr. G. Raghava, guest lecture, 'Importance of considering fatigue and fracture resistance of components and structures', February 15, 2014

Anna University, Chennai

Dr. N. Prasad Rao, invited lecture, 'Design of transmission and communication towers based on IS: 800 and other codal provisions', Training Programme on Design of Structures-I, November 27 - December 4, 2013

Shri R. P. Rokade, 'Design of Connections based on IS: 800 codal provisions', Training Programme on Design of Structures-I, November 27 - December 4, 2013

Pondicherry Engineering College, Pondicherry

Dr. Saptarshi Sasmal, invited lecture, 'Application of nanotechnology for developing sustainable building materials', TEQIP Sponsored Short-Term Training Programme on Materials and Technologies for Sustainable Construction, June 10-14, 2013

Smt. Smitha Gopinath, invited lecture, 'Application potential of fibres towards sustainable construction', TEQIP Sponsored Short-Term Training Programme on "Reinforced Concrete: Deterioration Process and Its Control Measures", May 2, 2013

Smt. P.S. Ambily, invited lecture, 'Advanced cementitious composites and polymer composites for repair and rehabilitation of reinforced concrete structures', TEQIP Sponsored Short-Term Training Programme on "Reinforced Concrete: Deterioration Process and Its Control Measures", May 2, 2013

Rajalakshmi Engineering College, Chennai

Dr. Saptarshi Sasmal, invited talk, 'Nano engineering of materials for sustainable environment', AICTE Sponsored Seminar on Application of Nano Technology in Composite Materials and Structures, February 28, 2014

Government College of Engineering, Salem

Shri S. Sundar Kumar, invited talk, 'Fibre reinforced concrete – properties, characterization and applications', TEQIP Sponsored Faculty Development Program on Behaviour and Applications of Ferrocement and Fibre Reinforced Composites', June 7, 2013

Vellore Institute of Technology, Vellore

Shri S. Sundar Kumar, invited talk,'Role of NDT in health monitoring, repair and rehabilitation of concrete structures', One-day Workshop on NDT Techniques for Assessment of Reinforced Concrete Structures', February 21, 2014

Shri P. Srinivasan, invited talk, 'Condition assessment of corrosion affected concrete structures with case studies', Workshop on NDT Techniques for Assessment of Reinforced Concrete Structures, February 21, 2014

Dr. K. Muthumani, invited talk, 'Relevance of standards in civil engineering', Standards Week Celebrations, March 5, 2014

Dr. A. Rama Mohan Rao, invited talk, 'Metaheuristic algorithms for engineering design optimisation', Seminar on Recent Advances in Mathematical Computing, August 23, 2013

Dr. A. Rama Mohan Rao, invited lecture, 'Recent advances in nature inspired computing', October 01, 2013

Tagore Engineering College, Chennai

Dr. S. Selvi Rajan, guest lecture, 'Industrial aerodynamics', November 11, 2013

B.S. Abdur Rahman University, Chennai

Dr. N. Anandavalli, invited lecture, 'Structural response under exceptional loads', Workshop on Aspects of Earthquake Disaster Mitigation and Management, April 17-19, 2013

Dr. K. Muthumani, invited talk, 'Role and responsibilities of different professionals in earthquake', Workshop on Aspects of Earthquake Disaster Mitigation and Management, April 17, 2013

Karur Engineering College, Karur

Dr. J. Rajasankar, keynote lecture, 'Characteristics of shock loads and design of structures', National Conference on Anti-terrorism Construction for a Safer India. Extra-terrestrial Construction-The Future of Humanity and Space-Elevator Construction-The Bridge to Heaven, February 6, 2014

Annamalai University, Chidambaram

Dr. K. Ramanjaneyulu, Engineers' Day Lecture, 'Analysis and design of tall reinforced concrete natural draught cooling towers', September 19, 2013

Mar Baselios College of Engineering and Technology, Trivandrum

Shri P. Srinivasan, keynote lecture, 'Condition assessment of corrosion-affected concrete structures', National Seminar on Advances in Structural Engineering, December 17, 2013

V.R.S. College of Engineering & Technology, Villupuram

Dr. R. Manisekar, invited lecture, 'Retrofitting by external prestressing', January 27, 2014.

Easwari Engineering College, Chennai

Dr. A. Rama Chandra Murthy, invited talk, 'Suspension bridges with two and three hinged stiffening girders', Faculty Development Programme, December 10, 2013

Excel Engineering College, Erode

Dr. K. Muthumani, invited talk, 'Seismic performance and mitigation', Faculty Development Programme, May 11, 2013

TKM College of Engineering, Kollam

Dr. N. Gopalakrishan, invited lecture, 'Introduction to structural dynamics and experimental modal analysis', Faculty Development Programme on Experimental Techniques in Materials and Structures, January 24, 2014

Dr. N. Gopalakrishan, invited lecture, 'System and damage identification techniques', Faculty Development Programme on Experimental Techniques in Materials and Structures, January 24, 2014

Ms. C. Bharathi Priya, invited lectures, (i) 'Structural control for vibration mitigation' and (ii) 'Some spectacular tests and experiments conducted in ASTAR Lab - CSIR-SERC', Faculty Development Programme on Experimental Techniques in Materials and Structures, January 24, 2014 January 24, 2014

K.S. Rangasamy College of Technology, Tiruchengode

Dr. K. Rama Raju, keynote address, 'Analysis of structures subjected to wind and seismic loads', National Conference on Emerging Technologies in Civil Engineering, April 12, 2013

Government Engineering College, Trichur

Dr. K. Muthumani, invited talk, 'Dynamic analysis of tall structures', STTP on Design Aspects and Soil Exploration for High Rise Structures', September 25, 2013.

V.R.S College of Engineering Technology, Arasur, Villupuram

Dr. R.Manisekar, guest lecture on "Retrofitting by external prestressing" on January 27, 2014.

TECHNICAL INSTITUTIONS

Institution of Engineers (India), Chennai

Dr. G.S. Palani, invited lecture, 'Seismic performance evaluation and technical highlights of 10 storied building in 48 hours in Mohali', All India Seminar on Structural Aspects of Architectural Engineering in Property Development Institution of Engineers (India), September 20-21, 2013

National Institute of Technical Teachers Training and Research, Chennai

Dr. S. Parivallal, invited talk, 'Health monitoring of civil engineering structures', Short Course on Repair and Renovation of Structures, August 26, 2013

Dr. N. Anandavalli, guest lecture, 'Applications of finite element analysis in structural engineering', Short Course on Computer Application in Structural Engineering, January 27-31, 2014

Indian Concrete Institute, Hyderabad

Dr. Nagesh R. Iyer, guest lecture, 'Structural engineering research – GenNext', Dr. M. Ramaiah Endowment Lecture, October 25, 2013

National Institute of Technical Teachers Trainign and Research, Chennai

Dr. S. Selvi Rajan, special guest lecture, 'Wind disaster management', Short Course on Disaster Management, October 29, 2013

Metrowater Training Centre, Chennai

Dr. B.H. Bharatkumar, invited talk, 'Condition assessment of corrosion affected reinforced concrete structures', Refresher Course, November 29, 2013

Dr. B.H. Bharatkumar, invited talk, 'Corrosion control measures for reinforced concrete structures including latest technology book reviews/chapters', Refresher Course, November 29, 2013

Kakatiya Institute of Technology and Science, Warangal

Dr. K. Balaji Rao, invited lecture, 'Reliability in structural health monitoring', National Seminar on Health Monitoring of RC Structures for Sustainability, December 27-28, 2013

Indian Institute of Science, Bangalore

Dr. K. Balaji Rao, invited talk, 'Research in structural engineering – possible projects', Workshop on Research in Structural Engineering, January 30-31, 2014

National Institute of Technology, Tiruchirappalli

Shri P. Srinivasan, invited lecture, 'Condition assessment of corrosion-affected concrete structures with case studies', TEQIP II International Workshop on Structural Life Assessment and Failure Diagnosis, December 6-7, 2013

Dr. K. Muthumani, key note lecture, 'Health monitoring of structures by vibration testing', International Workshop on Structural Life Assessment and Failure Diagnostics, December 7, 2013

Public Works Department, Chennai

Shri P. Srinivasan, invited talk, 'Conditional assessment of corrosion in RCC structures', XVIIIth Training Course on Cost Effective Technology in Building Construction, February 12, 2014

M.P.N.M.J.Engineering College, Sennimalai, Erode

Dr. A. Rama Mohan Rao, keynote address, 'Recent advances in structural health monitoring of civil engineering infrastructure', National

Conference on Advances in Civil Engineering, May 4, 2013

CMWSSB-CPHEEO, Chennai

Dr. S. Bhaskar, invited talks, (i) 'Fundamentals of corrosion', (ii) 'Forms of corrosion', (iii) 'Cathodic protection', and (iv) 'Corrosion inhibition', Refresher Course on Corrosion Control, November 26-27, 2013

IMC –fib of The Institution of Engineers (India), Mumbai

Dr. S. Bhaskar, invited lecture, 'Fly ash based pozzolana concrete for improved corrosion resistance of reinforcing steel', Fourth International fib Conference on Influence of SCMs on Durability of Concrete, February 14, 2014

DISTINGUISHED VISITORS

Mr. Ong Khim Chye Gary from National University of Singapore visited CSIR-SERC on August 7, 2013.

Mr. Kane Ian Ironside, R&D Manager from Asia Gysnm visited the ASTaR Lab, CSIR-SERC, on August 28, 2013 to discuss about panel tests.

Mr. Sylvie Perez, France visited the ASTaR Lab, CSIR-SERC, on August 28, 2013 to discuss about Gypsum Panel.

Mr. Juan Carlos Junquera Aubele from Walter Bai AG, Switzerland was visited Fatigue & Fracture Laboratory, CSIR-SERC on November 11, 2013 and discussed about Material Testing Facilities.

Mr. Brent Ross Robinson from Pile Dynamics, Inc., GRL Engineers Inc (USA), visited ASTaR Laboratory, CSIR-SERC on November 11, 2013 and discussed about the technical aspects of pile integrity tester & pile dynamics.

Mr. Tongjun Gong from Asia Trade Centre, Kwai Chung, Hong Kong visited ASTaR Laboratory of CSIR-SERC on November 11,2013 and discussed about the technical aspects of PIT and EPI products.

Mr. Hanazato Toshikazu from MIE University & Dr.Chikahiro Minowa from NIED, Japan, visited ASTaR Laboratory, CSIR-SERC from January 3 to 4, 2014 and discussed about the exchange of information and knowledge of shake table tests.

Mr. John Philip Holler from California, U.S.A. visited the Structural Testing Laboratory of CSIR-SERC for upgradation and calibration of the existing spider-80 vibration signal analysis.

Prof. Herbert Wiggenhauser, Head, NDT in Civil Engineering, BAM, Berlin, Germany, visited the laboratory and was also the Chief Guest for the inaugural function of SECON 2014 held at CSIR-SERC on February 5, 2014.

SPECIAL PUBLICATIONS

The Centre's Knowledge Management Division has brought out the following publications during the year.

- Annual Report 2012-2013
- Journal of Structural Engineering (Bi-monthly)
- News letter (Quarterly)
- Samachar Patra (in Hindi - Quarterly)

KNOWLEDGE RESOURCE DIVISION (KRD)

KRD added 116 books in the year 2013-2014, taking the total collection to 14300. The division subscribes to 67 foreign journals covering all the major areas of structural and civil engineering. Seventeen Indian journals of diverse focus are also being subscribed. In addition, journals are being received through membership and exchange. The KRD has a stock of over 6835 back volumes and 2000 microfiches. Photocopying services and a microfiche reader facility is also available.

KRD houses a large number of international standards such as American, British, Canadian, Japanese, German and Russian. Also codes from organizations such as the Indian Roads Congress (IRC), American Concrete Institute (ACI), American Society of Mechanical Engineers

(ASME), American Petroleum Institute (API), American Society of Civil Engineers (ASCE), Applied Technology Council (ATC), Eurocodes from European Committee for Standardization, American Association of State Highway and Transportation Officials (AASHTO), International Conference of Building Officials (ICBO), etc are available. In addition, the KRD preserves doctoral dissertations from the University Microfilms International (UMI), NTIS reports, etc.KRD is a member of the American Concrete Institute (ACI), Federation Internationale dıı Beton (FIB), International Association for Bridge and Structural Engineering (IABSE), Indian National Science Academy (INSA), Construction Industry Development Council (CIDC), Consultancy Development Centre (CDC), Indian Institution of Bridge Engineers (IIBE), Indian Buildings Congress (IBC), Computer Society of India (CSI), Institute for Steel Development & Growth (INSDAG), Multidisciplinary Center for Earthquake Engineering Research (MCEER), The British Council Library, Indian Institute of Technology Madras Library and IDARC 2D Users Group.

KRD is a part of the National Knowledge Resource Consortium (NKRC) managed by CSIR-NISCAIR and has online access to numerous journals published by international and national publishers such as Nature, ASTM, Sage, IOP, Taylor & Francis, etc. KRD also has access to Web of Science, a citation database. KRD provides online access to 24 Elsevier and all other international journals that are subscribed in print.

An online catalogue is available to users for various searches. The users can access the KRD services from their desktops through KRD website available as a part of the campus intranet. KRD website is updated daily and serves as a gateway to all the KRD services and resources. KRD continues to use the AutoLib software, which has been customized to provide the services on the campus intranet.

The RFID system has been adopted for issue and return of books and publications. RFID is a combination of radio-frequency-based technology and microchip technology and is being used as tracking and theft detecting system. RFID facilitates easier and faster discharge, inventorying, and materials handling.

KRD brings out a monthly current awareness service titled Research Alert that covers articles of journals received in KRD. This is a monthly service being offered since 1993 and has subscribers nationwide at present. A copy is also hosted in the CSIR-SERC intranet.

KRD also attracts non-SERC/CSIR users and the services are offered through different categories of membership. At present there are thirteen corporate / academic members.

An online project research profile service has been initiated by KRD, which serves as a tool to collect and organize resources for individual users thereby helping them stay informed of the new resources being added to the KRD. Online project research diary is another feature that allows users to search the databases in the KRD for a particular search topic and make personal notes on the retrieved documents. This facility is of vital use for future research activities, writing research papers, project proposal presentations, report writings, etc.

An auto alert service has also been developed that automatically runs the user profiles against newly added records, on a daily basis. The results are mailed to the user's mail box. A database of journal articles published by the scientists of the centre, since inception, and as reported in the annual reports, has been compiled. This can be accessed and statistically analyzed by author, year, title of journal, etc.

Digitization activities have also been initiated. The cover and contents pages of the recent book additions are scanned regularly and are available on the KRD website. A repository of the full text articles published by the scientists in the Journal of Structural Engineering (CSIR-SERC) is being built up.

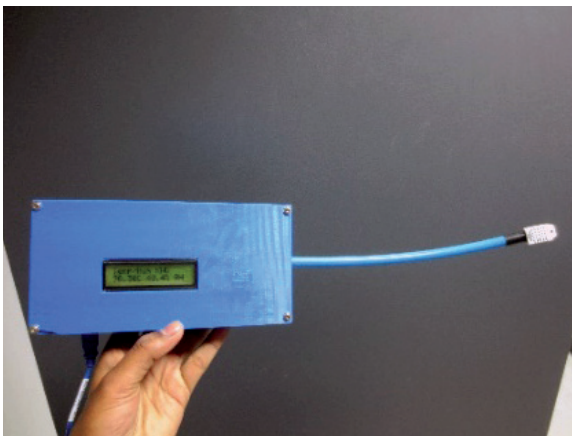
KNOWLEDGE NETWORK UNIT (KNU)

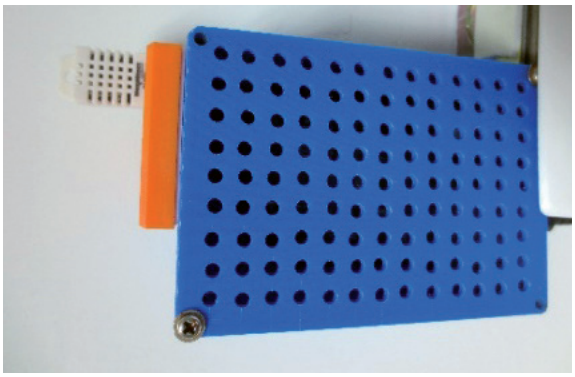
Establishment of Infrastructure

KNU houses the Data Centre of CSIR-SERC which is catering to the ICT requirements of the campus. The necessary infrastructure for deployment of ERP applications of both CSIR-SERC and CSIR-CMC are located in the data centre. The NKN connectivity for both CSIR-SERC and CMC also terminate at the data centre. At present the ERP applications have been deployed at the CSIR-SERC site and all the CSIR Labs are accessing the systems located at CSIR-SERC. The CSIR-SERC web site, AcSIR site and intranet are maintained at the Data Centre. A number of B.E/B.Tech (IT / Computer Science) and MCA students from reputed colleges carry out their projects at the KNU which has been remodeled to accommodate a number of students, project trainees and staff.

Deployment of ERP applications

- The enterprise applications developed as part of the CSIR ICT project initiative have been deployed at CSIR-SERC Data Centre. These applications are being accessed by all the CSIR Laboratories. Most of the HR related activities have gone live while other modules are being thoroughly evaluated with real time data.
- Continuous back-up of the data is being taken up as per the schedule. The data is being backed up (cloned) periodically on the SAN storage devices. Back-up on tapes is also being taken to ensure that the data is safe.
- The Data Centre is being maintained for 24 x 7 operations. In order to maintain the temperature and humidity at the Data Centre, it is necessary that the Precision Air Conditioners (PAC) are up and running. An auto diesel generator has also been provided at the Data Centre for the PACs to function in case of any power failure. An alert system has been developed by the students of the Renewable Energy Program of AcSIR. The device will monitor the temperature and humidity at the Data





Centre and in case of any change in the predefined threshold value, SMS alerts are sent to identified mobile numbers for necessary action. Another device has also been installed which can help in monitoring the temperature and humidity at the Data Centre through web interface. These devices have been very useful in maintaining the cooling requirements of the data centre.

NKN Connectivity

CSIR-SERC being one among the approved institutions of higher learning for NKN fiber optic connectivity, a 100 Mbps link has been provided to CSIR-SERC. The mail services and Quick SMS services offered by NIC are being extended to the staff of CSIR-SERC.

PAPERS PUBLISHED

1. Abhishek Kumar, Ramachandra Murthy, A. and Nagesh R. Iyer, 'A study of the stress ratio effects on fatigue crack growth using LOWESS regression', Proceedings of the International Conference on Advances in Civil Mechanical and Structural Engineering, Hong Kong, August 3 - 4, 2013, pp.47-51

2. Abishek Kumar,Ramachandra Murthy, A. and Nagesh R. Iyer, 'Crack growth prediction under variable amplitude loading considering elastic-plastic stress field ahead of crack tip', Proceedings of the 1st International Conference on Structural Integrity, Kalpakkam, February 4 - 7, 2014, pp.1445-1450

3. Abraham, A., Harikrishna P., Selvi Rajan, S., Ramesh Babu, G., Chitra Ganapathi, S., Nagesh R. Iyer, Arunachalam, S. and Kishor Kumar, 'Interference effects of mean wind loads for a group of high-rise buildings with unconventional plan shape', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.309-317

4. Abraham, A., Nagesh R. Iyer, Muthumani, K., Samuel Knight, G.M. and Lakshmanan, N., 'Wind tunnel pressure measurement studies on a model of curved roof : Influence of wind angles on mean suction pressures', Proceedings of the National Conference on Wind Tunnel Testing, Thiruvananthapuram, August 23-24, 2013, pp.1-6

5. Abraham, A., Nagesh R. Iyer, Samuel Knight, G.M., Muthumani, K. and Lakshmanan, N., 'Wind loads on curved roofs: effect of side walls', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013 pp.786-794

6. Abraham, A., Selvi Rajan, S., Ramesh Babu, G., Harikrishna, P. and Chitra Ganapathi, S., 'Simulated cyclonic wind characteristics on a low-rise building model', Proceedings of the International Conference on Disaster Management, Chennai, January 23-24, 2014, pp.C11-1 – C11-11

7. Aditya Kaushik, Arun Sundaram, B., Farvaze Ahmed, A.K., Parivallal, S. and Ravisankar, K., 'Numerical studies on the damage locating vector approach for damage detection using static load data', Proceedings of the International Conference on Structural Integrity, Kalpakkam, Feburary 4-7, 2014, pp.1080-1087

8. Aishwariya, V.S., Smitha Gopinath, Rama Chandra Murthy, A., Nagesh R. Iyer and Easwaramoorthi, P., 'Numerical simulation for response prediction of undamaged and damaged RC beams', Proceedings of the International Conference on Advances in Engineering and Technology, Chennai, April 5-6, 2013, pp.13-16

9. Akilan, R., Amar Prakash, Arunachalam, N. and Anandavalli, N., 'Steel-concrete composite girder under shock loads - A review', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.1-6

10. Amar Prakash, Nagesh R. Iyer, Anandavalli, N., Bharatkumar, B.H., Krishnamoorthy, T.S. and Kulbhushan Rai, 'Application of slurry infiltrated fiber concrete in protective engineering', Proceedings of the International Joint Conference on Scientific and Technological Rajbhaasha : Samkaleen Vignyan, Delhi, December 5-7, 2013, (in Hindi)

11. Amar Prakash, Rajasankar, J., Nagesh R. Iyer, Anandavalli, N., Biswas, S.K. and Mukhopadhyay, A.K., 'Prediction of behavior of ceramic/metal composite panels under two consecutive ballistic impacts', International Journal for Computational Methods in Engineering Science and Mechanics, Vol.15 No.3 , 2014, pp.192-202

12. Ambily, P.S., Tanuja, B.B., Sundar Kumar, S., Nagesh R. Iyer and Dakshayani R.S., 'Effect of curing on the properties of GGBS based geo polymer concrete', The 4th International fib Congress, Mumbai, February 10-14, 2014, pp.898-908

13. Ambily, P.S., Bharatkumar, B.H. and Nagesh R. Iyer, 'Geopolymer concrete blocks / pavers for precast applications', Concrete Plant International Journal, Issue No.5, October 2013, pp.96-104

14. Ambily, P.S., Ravisankar, K., Chockkalingam Umarani, Jamboor K. Dattatreya and Nagesh R. Iyer, 'Development of ultra-high-performance geopolymer concrete', Magazine of Concrete Research, Vol.66 No.2, November 2013, pp.82-89

15. Anand Kumar, S., Anoop, M.B., Balaji Rao, K. and Rajadurai, A., 'Fuzzy-probabilistic analysis of fatigue life of steel plate girder of a Indian railway bridge using fracture mechanics based approach', First International Conference on Structural Integrity, Kalpakkam, February 4-7, 2014, pp.1-8

16. Anandavalli, N., Lakshmanan, N., Nagesh R. Iyer, Rajasankar, J. and Amar Prakash, 'Finite element analysis of reinforced concrete (RC) beams with continuously inclined shear reinforcement by using an equivalent constitutive property', Journal of Structural Engineering, Vol. 40 No.1, April-May 2013, pp.1-6

17. Anoop, M.B., Balaji Rao, K. and Raghuprasad, B.K., 'Remaining life estimation of corrosion affected RC bridge girders using online monitoring data – a fuzzy-random approach', Life Cycle Reliability and Safety Engineering, Vol. 2 No.1, 2013, pp.60-71

18. Anoop, M.B. and Balaji Rao, K., Generation of site-specific response spectra through fuzzy-stochastic modelling, Life Cycle Reliability and Safety Engineering, Vol.2 No.3, 2013, pp.1-7

19. Anupama Krishna, D., Cinitha, A., Umesha, P.K, Nagesh R. Iyer and Ramasamy, J.V., 'A comprehensive review on behaviour of steel structural elements under elevated temperatures', Proceedings of International Conference On Futuristic Innovation and Developments in Civil Engineering, Sivakasi, April 18-20, 2013, pp.1-18

20. Anupama Krishna, D., Cinitha, A., Umesha, P.K., Nagesh R. Iyer and Ramasamy, J.V., 'Studies on Thermal Buckling of Steel Angle Section', Proceedings of the National Symposium for Recent Trends in Civil Engineering, Coimbatore, April 26, 2013, pp.1-16

21. Apurva Sankaran, Bhuvaneshwari, B., Maheswaran, S., Santhi, A.S. and Nagesh R. Iyer, 'Application of multi-layer composites in construction and their future challenges', Research Journal of Material Sciences, Vol.1 No.3, 2013, pp.1-5

22. Arun Balaji, S., Vijayarangan, R., Vivekananthan, S., Bhuvaneshwari, B., Jeyavel, R., and Nagesh R. Iyer, 'Hydrothermal synthesis and characterisation of V205/MWNT composites', International Conference on Advanced Nanomaterials and Emerging Technologies, Chennai, July 24-26, 2013, pp.120-122

23. Arun Sundaram, B., Parivallal, S., Farvaze Ahmed, A.K., Kesavan, K., Ravisankar,

K. and Senthil, R., 'Structural health monitoring using wireless sensor networks', Proceedings of the Third International Conference on Global Innovations in Technology and Sciences, Kottayam, April 4-6, 2013, pp.30-37

24. Arun Sundaram, B., Parivallal, S., Farvaze Ahmed, A.K., Kesavan, K., Ravisankar, K. and Senthil, R., 'Structural health monitoring using wireless sensor networks', International Journal of Scientific and Engineering Research, Vol.4 No.8, August 2013, pp.1-8

25. Arun Sundaram, B., Ravisankar, K., Senthil, R. and Parivallal, S., 'Wireless sensors for structural health monitoring and damage detection techniques – An overview', Current Science, Vol.104 No.11, June 2013, pp.1496-1505

26. Arunachalam, S., Lakshmanan, N. and Ramesh Babu, G., 'A method for evaluation of across-wind response of a circular chimney including lock-in effects and comparison with ACI code of practice', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.113-119

27. Arunachalam, S., Kamatchi, P., Rama Raju, K., Anoop, M.B., Balaji Rao, K., Harikrishna, P. and Nagesh R. Iyer, 'Methodology for deriving multihazard factors for design base shear of buildings for wind and earthquake hazard for peninsular India', Journal of Structural Engineering, Vol.40 No.4, 2013, pp.333-343

28. Ashwathi Arya, M., Sarayu, K., Ramesh Kumar, V., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Basalt degrading bacteria for the enhanced CSH formation', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.580-583

29. Athiban, P., Dickson John, S., Selvi Rajan, S. and Jaya, K.P., 'POD analysis on a gabled roof low rise building subjected to wind loading', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.218-226

30. Aysha, H., Hemalatha, T., Arunachalam, N., Prabat Ranjan Prem, Ramachandra Murthy, A. and Nagesh R Iyer, 'Microstructural investigations on ultra high performance concrete under various curing regimes', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.21-28

31. Bala Monica, K., Sathish Kumar, K., Gopalakrishnan, N. and Muthumani, K., 'Magneto rheological elastomer based isolators for seismic control of structures', Proceedings of the International Conference on Disaster Management, Chennai, January 23-24, 2014

32. Balagopal, R., Ananth Ramaswamy, Palani, G.S. and Prasad Rao, N., 'Experimental studies on bolted joint damage assessment due to wind load', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.371-374

33. Balagopal, R., Prasad Rao, N., Rokade, R.P. and Mohan, S.J., 'Studies on GFRP angles with steel bolted connections', Proceedings of the National Conference on Recent Trends in Overhead Transmission Lines, Bangalore, December 19-20, 2013, pp.43-50

34. Balaji Rao, K. and Anoop M.B., 'Condition assessment of structures: some issues related to handling uncertainties', International Journal of Forensic Engineering, Vol.1 No.3/4, 2013, pp.238-259

35. Balaji Rao, K. and Anoop, M.B., 'Advanced models for condition survey and inspection planning of RC structures in marine environment', International Journal of SEWC, Vol. 3, No.1, pp.37-43

36. Balaji Rao, K. and Anoop, M.B., 'Why do we need probability distributions with fat tails to describe the surface strain evolution in reinforced concrete flexural members', Meccanica, Vol.48, 2013, pp.1517-1542

37. Balaji Rao, K., Anoop, M.B., Harikrishna, P., Selvi Rajan, S. and Nagesh R. Iyer, 'Alpha-stable distribution for prediction of negative peak wind pressures on roofs of low-rise building', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.958-967

38. Balaji Rao, K., Anoop, M.B., Kesavan, K., Balasubramanian, S.R., Ravisankar, K. and Nagesh R. Iyer, 'Modelling of strains in reinforced concrete flexural members using alpha-stable distribution', Computers and Concrete, Vol.11 No.5, 2013, pp.411-414

39. Balaji Rao, K., Anoop, M.B., Raghava, G., Prakash, M. and Rajadurai, A., 'Probabilistic fatigue life analysis of welded steel plate railway bridge girders using S-N curve approach', Proceedings of the Institution of Mechanical Engineers Part O: Journal of Risk and Reliability, Special Section on Railway Risk and Reliability, Vol.227 No.4, 2013, pp.385-404

40. Balaji Rao, K. and Anoop, M.B., 'Handling large uncertainties in mechanics', SRESA National Conference on Reliability and Safety Engineering (NCRS'14), Tiruchirappalli, February 13-15, 2014, pp. 1-18

41. Balaji Rao K. and Anoop M.B., 'Stochastic model for condition assessment of structures', Proceedings of the International Workshop on Advances in Fibre Reinforced Polymers and Composites, Hyderabad, March 13-14, 2014, pp.14-31

42. Balamonica, K. and Gopalakrishnan, N., 'Seismic response evaluation of structures subjected to multisupport excitation using ritz vectors', Proceedings of International Conference on Advances in Civil Mechanical and Structural Engineering, Hong Kong, August 3-4, 2013, pp.54-58

43. Bhagavan, N.G., Ramachandra Murthy, A. and Sivakumar, P., 'Improving seismic performance of building structures with RCC confining elements', The 4th International fib Congress, Mumbai, February 10-14, 2014, Vol. I, pp.654-657

44. Bharathi Priya, C., Balamonica, K., Gopalakrishnan, N., Sathish Kumar, K., Muthumani, K., Venkatumesh, S. and Mahadev, C.V.K., 'Design methodologies of wind-sensitive tower foundations under conditions of partial contact', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, 10-14, December 2013, pp.1316-1324

45. Bharatkumar, B.H., 'Advances in cementitious concrete towards sustainability', Proceedings of National Seminar on Effective Utilization of Industrial Wastes, Chennai, August 8-9, 2013, pp.1-15

46. Bhashya, V., Ramesh, G., Bharat Kumar, B.H. and Nagesh R. Iyer, 'Improving properties of recycled aggregate concrete using heat treated recycled aggregates', The 4th International fib Congress, Mumbai, February 10-14, 2014, pp.890-897

47. Bhashya, V., Ramesh, G. and Bharatkumar, B.H., 'Mechanical and durability properties of recycled aggregates concrete', Proceedings of International Conference on Engineering Materials

and Processes, Chennai, May 2013, pp.187-201

48. Bhaskar, S., Bharatkumar, B.H. and Ravindra Gettu, 'Assessment of chloride induced corrosion of steel in concrete using half-cell potential and resistivity methods', International Corrosion Conference, New Delhi, Sept.30 to Oct. 3, 2013,pp.1-6

49. Bhaskar S., Radhakrishna, G., Pillai, Ravindra Gettu, Bharatkumar, B.H. and Nagesh R. Iyer, 'Influence of Portland pozzolana cement on the service life of reinforced concrete under chloride attack', Proceedings of the 3rd International Conference on Sustainable Construction Materials and Technologies, Kyoto, Japan, August 18-21, 2013, pp.1-10

50. Bhuvaneshwari, B., Karunya, R., Hemalatha, T., Maheswaran, S. and Nagesh R. Iyer, 'Improving the performance of C-S-H by nano-moieties', The 4th International fib Congress, Mumbai, February 10-14, 2014, pp.2376-2385

51. Bhuvaneshwari, B., Saravana Karthikeyan, S.K.S., Saptarshi Sasmal and Nagesh R. Iyer, 'Performance of Functionally Modified Epoxy using Nano Oxides in Fibre Reinforced Polymer Matrices', 6th Bangalore India NANO 2013 conference, Bangalore, December 4-6, 2013, pp.22

52. Bhuvaneshwari, B., Vivekananthan, S., Maitri Mapa, Palani, G.S. and Nagesh R. Iyer, 'Synthesis, characterization and electrochemical evaluation of cerium doped SnO2 as nano inhibitor for rebar corrosion', 6th Bangalore India NANO 2013 conference, Bangalore, December 4-6, 2013, pp.22

53. Bhuvaneshwari, B., Selvaraj, A., Nagesh R. Iyer and Ravikumar, L. 'Electrochemical investigations on the performance of newly synthesized azomethine polyester on rebar corrosion', Materials and Corrosion, Vol.65, 2014, pp.2-12

54. Bhuvaneshwari, B. and Nagesh R. Iyer, 'Influence of cellulose superplasticiser on the strength property of cementitious materials', Research Journal of Recent Sciences, Vol. 2 2013, pp.1-6

55. Chitra Ganapathi, S., Harikrishna, P. and Nagesh R. Iyer, 'Numerical investigations of aerodynamic forces on 2-D square lattice tower section using two-equation turbulence models', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.640-649

56. Chitra Ganapathi, S., Harikrishna, P. and Nagesh R. Iyer, 'Numerical assessment of aerodynamic forces on 2-D L-angle section using CFD', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.650-657

57. Chitra Ganapathi, S., Annie Peter, J., Nagesh R. Iyer and Lakshmanan, N., 'Experimental investigations on light weight sandwich panels under flexural loading', Journal of Structural Engineering, Vol.40 No.5, 2013, pp.442-448

58. Cinitha, A., Umesha, P.K. and Nagesh R. Iyer, 'Experimental studies on corroded steel angle and tubular compression members', International Corrosion Conference and Expo, CORCON 2013, New Delhi, September 30 - October 03, 2013, pp.1-10

59. Cinitha, A., Umesha, P.K. and Nagesh R. Iyer, 'Performance levels and acceptance criteria for joints with rigid, semi-rigid and flexible connections' International Journal of Civil and Structural Engineering, Vol.3 No.3, 2013, pp.526-535

60. Cinitha, A., Umesha, P.K., Kesavan K. and Ravisankar, K., 'Fiber bragg grating sensors to monitor corrosion of structural

steel', International Corrosion Conference and Expo, CORCON 2013, New Delhi, September 30 - October 03, 2013, pp.1-11

61. Cinitha, A., Umesha, P.K., and Nagesh R. Iyer, 'Evaluation of seismic performance and review on retrofitting strategies of existing RC buildings', Asian Journal of Applied Sciences, Vol.7, 2014, pp.169-181

62. Cinitha, A., Umesha, P.K. and Nagesh R. Iyer, 'Evaluation of seismic performance of existing steel buildings', American Journal of Civil and Structural Engineering, Vol.1 No.2, 2014, pp.23-33

63. Cinitha, A., Umesha, P.K. and Marimuthu, V., 'Behaviour of heated and naturally cooled steel tubular joints', Proceeding of National Conference on Fire Research & Engineering: FiRE 2014, Roorkee, March 1-2, 2014, pp.1-8

64. Cinitha, A., Umesha, P.K. and Nagesh R. Iyer, 'Behaviour of steel tubular compression members under simulated fire and corrosion', Proceedings of the First International Conference on Structural Integrety, Kalpakkam, February 4-7, 2014, pp.1517-1524

65. Constanze Rohm, Balthasar Novak, Ramanjaneyulu, K., Saptarshi Sasmal, 'Zum Tragverhalten von Rahmenknoten mit Stahlfaserbeton unter seismischer Belastung (Behaviour of FRC beam column joints under seismic loading)', Beton und Stahlbetonbau, Vol. 108 No. 5, May 2013, pp.303-314

66. Daniel Ronald Joseph, J., Balaji Rao, K. and Anoop, M.B., 'Determination of hierarchical order of 'objects' affecting interaction equations of steel beam-column using cluster analysis', International Journal of Scientific & Engineering Research, Vol.4 No. 8, 2013, pp.1-5

67. Daniel Ronald Joseph, J., Balaji Rao, K. and Anoop, M.B., 'Establishing hierarchical order of influence of variables of B3 creep model', ICI Journal, Vol.13 No.4, 2013, pp.24--28

68. Deepan, N., Farvaze Ahmed, A.K., Ravisankar, K., Parivallal, S. and Dinesh Kumar, P., 'Influence of concrete strength in evaluating in-situ stress in concrete members using finite element approach' Second National Conference on Mechanical, Mechatronics and Building Sciences, Erode, March 7, 2014, pp.21-28

69. Devandiran, P., Kamatchi, P., Balaji Rao, K., Ravisankar, K. and Nagesh R. Iyer, 'Probabilistic analysis of spectral displacement by NSA and NDA', Earthquakes and Structures, Vol. 5, No. 4, October 2013, pp 439-459

70. Dhanyasree, S., Linushiya Ranjani, L., Sarayu, K., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Role of bacteria in silica accumulation from agro ash', Proceedings of the National Conference on Bioengineering, Chennai, March 27, 2014, pp.24-28

71. Dharinee, R., Smitha Gopinath, Ramachandra Murthy, A., Nagesh R. Iyer, and Sivakumar, C.G., 'Analytical modul for RC beams with textile reinforced concrete cover under fire conditions', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, Vol. 1, pp.624-629

72. Dikshita Nath, Saptarshi Sasmal and Mohan Ganesh G., 'Development of Upgradation strategies for critical components of Reinforced Concrete Structures under Earthquake Loading', International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.1-8

73. Divyapriya, C., Anoop, M.B., Balaji Rao, K., and Sivakumar, C.G., 'Multiscale modeling of concrete for determining concrete creep compliance, National Symposium for Recent Trends in Civil Engineering, Coimbatore, April 26, 2013, pp.1-5

74. Farvaze Ahmed, A.K., Ravisankar, K., Arun Sundaram, B., Parivallal, S., and Kesavan, K., 'Studies on calibration factor of flatjack for measurino in-situ stress on concrete members', Proceedings of the Third International Conference on Global Innovations in Techniology and Sciences, Kottayam, April 4-6, 2013, pp 38-43

75. Farvaze Ahmed, A.K., Ravisankar, K., Arun Sundaram, B., Parivallal, S. and Kesavan, K., 'Studies on calibration factor of flatjack for measuring in-situ stress on concrete members', International Journal of Scientific and Engineering Research, Vol.4 No.8, August 2013, pp.1-6

76. Gandhi, P., Saravanan, M., Vishnuvardhan, S., Pukazhendhi, D.M., Raghava, G., Sahu, M.K., Chattopadhyay, J., Dutta, B.K. and Vaze, K.K., 'Experimental fracture studies on carbon steel elbows with and without internal pressure', International Journal of Pressure Vessels and Piping, Vol.111-112, November-December 2013, pp.262-268

77. Gokul, N., K. Alagusankareswari, S.K.S, Saravana Karthikeyan, Bhuvaneshwari, B. and Palani, G.S. 'Retrofitting of structural members using FRP composite materials', National Level Technical Seminar (STHULAAZ' 14), Chennai, March 2014

78. Gunavadhi, M., Hemalatha, T., 'Impact of nanosilica addition on microstructure of hydrated cement paste', National Conference on Quest for Innovation in Civil Engineering, Chennai, October 27, 2013

79. Harikrishna, P., Abraham, A., Selvi Rajan, S., Ramesh Babu, G., Chitra Ganapathi, S. and Nagesh R. Iyer, 'Wind induced interference effects on a row of three buildings with irregular plan shape', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.895-902

80. Harikrishna, P., Nagesh R. Iyer and Selvi Rajan, S., 'Cyclone disaster mitigation efforts by CSIR-SERC towards engineering of non-engineered and semiengineered dwellings' Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.K247-K259

81. Harikrishna, P., Selvi Rajan, S., Abraham, A., Ramesh Babu, G., Chitra Ganapathi, S. and Nagesh R. Iyer, 'Wind tunnel experimental investigations on natural draught cooling towers in a typical power plant complex', Proceedings of the National Conference on Wind Tunnel Testing, Thiruvananthapuram, August 23-24, 2013, pp.1-13

82. Harikrishnan, M., Balagopal, R. and Elangovan, N.S., 'Time cost benefit analysis of transmission tower foundations', Proceedings of International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014

83. Harishkumar, S., Smitha Gopinath, Ramesh Kumar, V., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Numerical simulation of pre-fabricated FABcrete sandwich panels', Proceedings of International Conference on Disaster Management, Chennai, January 23-24, 2014, pp.C10-1 to C10-3

84. Harsha, P.K., Rokade, R.P. and Sivakumar, A., 'Studies on stress concentration at bolt hole location lap joint using finite element analysis', Proceedings of

International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014

85. Hemalatha, T., Bhagya Laxmi Kar, Bhuvaneshwari, B. and Nagesh R. Iyer, 'Study of effect of replacement of fly ash and silica fume on calcium leaching rate of cement mortar', Proceedings of International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.58-62

86. Hemalatha, T., Gunavadhi, M., Bhuvaneshwari, B., Saptarshi Sasmal and Nagesh R. Iyer, 'Assessment of particle packing in cementitious composites using image analysis', The 4th International fib Congress, Mumbai, February 10-14 2014, pp.2367-2375

87. Hemalatha, T. and Bhagyalaxmi Kar, 'A comparative study of microstructure of self compacting concrete (SCC) and normal vibrated concrete (NVC)', Proceedings of the National Conference on Quest for Innovation in Civil Engineering, Chennai, October 27, 2013, pp.51-55

88. Janasher Sadik, Farvaze Ahmed, A.K., Ravisankar, K., Parivallal, S. and Dinesh kumar, P., 'Study on Stress field of a plain and RC slab with slot by finite element approach' International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.615-625

89. Jim, J.R., Sivakumar, P., Lakshmikandhan, K.N., Annie Peter, J. and Ashok Manikandan, S., 'Construction of monolithic building structure using self compacting concrete and ferrocement', National Conference on Innovative Solutions for Sustainable Construction, Chennai, May 2-3, 2013, pp.SII-22 - SII-32

90. Jinu Mary Mathew, Cinitha, A., Umesha, P.K., Nagesh R. Iyer and Eapen Sakaria, 'Seismic response of RC building by considering soil structure interaction', Proceedings of the 2nd National Conference on Recent Advances In Civil Engineering, Kottayam, September 6-7 , 2013, pp.1-16

91. Jyotirmayee Dash, Shaumik Ray, Kathirvel Nallappana, Saptarshi Sasmal and Bala Pesala, 'Terahertz spectroscopy of concrete for evaluating the critical hydration level', Terahertz, RF, Millimeter, and Sub-Millimeter-Wave Technology and Applications VII Conference, San Francisco, February 1-6, 2014, pp.1-7

92. Jyotirmayee Dash, Shaumik Ray, Kathirvel Nallappana, Saptarshi Sasmal and Bala Pesala, 'Non-destructive inspection of concrete structure using continuous wave 2D terahertz imaging system', Proceedings of the 38th International Conference on Infrared, Millimeter and Terahertz Waves, Germany, September 1-6, 2013, pp.1-2

93. Kamatchi, P., Anoop, M.B., Balaji Rao, K. and Nagesh R. Iyer, 'Ground response analyses including uncertainties in peak ground acceleration and shear wave velocity for Delhi region', Third International Convention on Advances in Earthquake Sciences, Gandhi Nagar, January 4-6, 2014, pp.43

94. Kamatchi, P., Balaji Rao, K., Rama Raju, K. and Nagesh R. Iyer, 'Probabilistic analyses of base shear and roof displacement for wind and earthquake load along with gravity loads', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.978-981

95. Kamatchi, P., Ramana, G.V., Nagpal, A.K., and Nagesh R Iyer, 'Modelling propagation of stress waves through soil medium for ground response analysis', Engineering, Vol.5, 2013, pp.611-621

96. Kanchana Devi, A. and Ramanjaneyulu, K., 'Nonlinear FEA for ultimate strength behaviour of corrosion damaged RC beam', Journal of Structural Engineering, Vol.40 No.1, April-May 2013, pp.12-20

97. Kannan, S., Marimuthu, V., Palani, G.S., Surendran, M. and Arumugam, M., 'Behaviour of self-drilling screw lap-joints connecting cold-formed steel sheets', International Conference on Innovative Materials and Construction, Chennai, April 8-9, 2013, pp.1-8

98. Karihaloo, B.L., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Determination of size - independent specific fracture energy of concrete mixes by the tri-linear model', Cement and Concrete Research, Vol.49, 2013, pp.82-88

99. Karunya, R., Bhuvaneshwari, B., Murugesan, T. and Nagesh R. Iyer, 'Functions of CNT incorporated nanocomposites in civil engineering', Third National Conference on Latest Advancements in Civil Engineering, Chennai, April 2013

100. Keerthana, M. and Harikrishna, P., 'Numerical simulation of lock-in effect of a 2-D rectangular section under forced oscillations', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.12-21

101. Keerthana, M., and Harikrishna, P., 'Application of CFD for assessment of galloping stability of rectangular and H sections', Journal of Scientific and Industrial Research, Vol. 72, July 2013, pp.419-427

102. Keerthana, M., and Harikrishna, P., 'Experimental assessment of galloping stability of rectangular section with B/D of 2 using pressure measurements', Proceedings of the National Conference on Wind Tunnel Testing, Thiruvananthapuram, August 23-24 2013, pp.1-10

103. Keerthana, M., Harikrishna, P., Ramesh Babu, G., Abraham, A. and Selvi Rajan, S., 'Experimental validation of numerical simulations of wind induced pressures on 2:1 rectangular section under smooth flow', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.168-174

104. Keerthana, S., Sathish Kumar, K., Bala Monica, K. and Jagannathan, D.S., 'Seismic response control using base isolation strategy', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, India, 13-14 March 2014, pp.803-807

105. Keerthana, S., Sathish Kumar, K., Bala Monica, K. and Jagannathan, D.S., 'Base isolation strategy for seismic control of structures', Proceedings of the National Conference on Recent Advances in Structural Engineering, Coimbatore, March 22, 2014, pp.11-14

106. Kesavan, K., Ravisankar, K., Senthil, R. and Farvaze Ahmed, A.K., 'Experimental studies on performance of reinforced concrete beam strengthened with CFRP under cyclic loading using FBG array', Measurement, Vol.46 No.10, December 2013, pp.3855 – 3862

107. Lakshmanan, N., Muthumani K. and Gopalakrishnan, N., 'Forensic engineering for machine foundation', International Journal of Forensic Engineering, Vol.1 No.3/4, 2013 pp.301–319

108. Lakshmanan, N., Ramesh Babu, G., Devdas Menon and Arunachalam, S., 'Simplified analytical model for across-wind response of chimneys around critical wind velocity regions', Proceedings of the Eighth Asia-Pacific Conference on Wind

Engineering, Chennai, December 10-14, 2013, pp.K97-K114

109. Lakshmi, K. and Rama Mohan Rao, A., 'Hybrid shuffled frog leaping optimisation algorithm for multi-objective optimal design of laminate composites', Computers and Structures, Vol.125, September 2013, pp.200-216

110. Lakshmi, K., Rama Mohan Rao, A., 'Multi-objective optimal design of laminated composite skirt using hybrid NSGA', Meccanica, Vol.48, 2013, pp.1431–1450

111. Lakshmi, K., Rama Mohan Rao, A.,' Optimal design of laminate composite isogrid with dynamically reconfigurable quantum PSO', Structural and Multidisciplinary Optimization, Vol.48 No.5, November 2013, pp.1001-1021

112. Lakshmikandhan, K.N., Sivakumar, P., Ravichandran, R., Arul Jayachandran, S. and Senthil, R., 'Investigation on the effect of shear connector in composite space structures', Journal of Structural Engineering, Vol.40 No.5, 2013, pp.466-476

113. Lakshmikandhan, K.N., Sivakumar, P. and Ravichandran, R., 'Damage assessment and strengthening of reinforced concrete beams', International Journal of Material and Mechanical Engineering, Vol.2 No.2, 2013, pp.34-42

114. Lakshmikandhan, K.N., Sivakumar, P., Ravichandran, R., and Arul Jayachandran, S., 'Investigations on efficiently interfaced steel concrete composite deck slabs', Journal of Structures, Vol.2013, pp.1-10

115. Lakshmikandhan K.N., Sivakumar P., Ravichandran R. and Senthil R., 'Performance evaluation of passive control device for efficient steel space structures', Journal of Structural Engineering, Vol.40 No.6, February - March 2014, pp.521-529

116. Lalanthi, M.C., Kamatchi, P., Kiran Kumar, S. and Nagesh R. Iyer, 'Finite element modelling of prestressed concrete beam', Proceedings of National Conference on New Horizons in Civil Engineering (NHCE), Manipal, April 12-13, 2013, pp.651-656

117. Lavanya, D., Sarayu, K., Ramesh Kumar, V., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Exploration of bacterial strains secreting cementitious materials', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.583-588

118. Lincy Rubina, S., Vishnuvardhan, S., Raghava, G. and Sivakumar, A., 'Fatigue life estimation of Type 304LN stainless steel under strain-controlled cyclic loading', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13 and 14, 2014, pp.110-117

119. Linu, T.J., Lakshmikandhan, K.N., Sivakumar, P., Ravichandran, R. and Selwyn, B.J., 'Finite element parametric study on funicular shells', Proceedings of the International Conference on Futuristic Innovations & Developments in Civil Engineering, Sivakasi, April 18-20, 2013, pp.232-238

120. Madheswaran, C.K., Ambily, P.S., Lakhsmanan, N., Dattatreya, J.K. and Jaffersathik, J.A., 'Shear behaviour of reinforced geopolymer concrete thin webbed T-beams', ACI Materials Journal, Vol.111 No.1, 2014, January 2014, pp.89-98

121. Madheswaran, C.K., Ambily, P.S., Rajamane, N.P. and Arun, G., 'Studies on flexural behavior of reinforced geopolymer concrete beams with light weight aggregates', International Journal

of Civil and Structural Engineering, Vol.4 No.3, 2014, pp.295-305

122. Madheswaran, C.K., Gnanasundar, G. and Gopalakrishnan, N., 'Effect of molarity in geo-polymer concrete', International Journal of Civil and Structural Engineering, Vol.4 No.2, pp.106-115

123. Madheswaran, C.K., Gnanasundar, G. and Gopalakrishnan, N., 'Effect of molarity of alkaline activator solution in geopolymer concrete', Proceedings of the International Conference on Futuristic Innovations and Development in Civil Engineering, Sivakasi, 18-20 April 2013, pp.276-280

124. Madheswaran, C.K., Gnanasundar, G., and Gopalakrishnan, N., 'Utilization of quarry dust and copper slag for replacement of sand in concrete', Proceedings of the National Conference ENTROIDOS'13, Virudhunagar, April 16-17, 2013, pp.38-44

125. Madheswaran, C. K., and Gnanasundar, G., 'Influence of ground granulated blast furnace slag in geopolymer concrete', The 4th International fib Congress, Mumbai, February 10-14, 2014, pp.331-334

126. Madheswaran, C.K., Dattatreya, J.K., Ambily, P.S., Karansingh, P.R. and Arongilbert, V., 'Investigation on behaviour of reinforced geopolymer concrete slab under repeated impact loading', Proceedings of the International Conference on Trends in Mechanical, Aeronautical Civil, Computer, Communication and Electrical Sciences, Kanyakumari, 19-20 February 2014, pp.1-8

127. Madhuree Dharpure, Bhuvaneshwari, B., Siva Kumar, E.K.T. and Nagesh R. Iyer, 'Hydration studies on nano clay incorporated complex composites', International conference on Engineering Materials and Processes, Chennai, May 2013, pp.1-4

128. Maheswaran, S., Kalaiselvam, S., Arunbalaji, S., Palani, G.S. and Nagesh R. Iyer, 'Synthesis of belite from lime sludge with nano-SiO2 by solid state reaction', International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014

129. Maheswaran, S., Kalaiselvam, S., Gunavadhi, M., Palani, G.S. and Nagesh R. Iyer, 'Formation of calcium silicate hydrate [C-S-H] from calcined lime sludge using nano silica', International Conference on Structural and Physical Properties of Solids, Dhanbad, November 18-20, 2013. pp.92

130. Maheswaran S., Dasuru S. S., Rama Chandra Murthy A., Bhuvaneshwari B., Ramesh Kumar V., Palani G.S., Nagesh R. Iyer, Sarayu Krishnamoorthy and Sandhya, S., 'Strength improvement studies using new type wild strain Bacillus cereus on cement mortar', Current Science, Vol.106 No.51, 2014, pp.50-57

131. Manikandan, P., Rokade, R.P.,and Sivakumar, A., 'First Order Reliability Studies of compression struts in Lattice Tower', International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014

132. Manisekar, R. and Sivakumar, P., 'Strengthening of distressed RC beams by external prestressing: experimental studies', The Indian Concrete Journal, Vol.88, No.1, 2014, pp.45-52

133. Manisekar, R. and Sivakumar, P., 'Strengthening of Distressed RC Beams by External Prestressing: Experimental Studies', Fourth International Workshop on Performance, Protection and Strengthening of Structures under

Extreme Loading, Mysore, August 26-27, 2013, pp.1-12

134. Manisekar, R., Sivakumar, P. and Lakshmikandhan, K.N., 'Experimental investigations on strengthening of RC beams by external prestressing', Asian Journal of Civil Engineering, Vol.15 No.3, 2014, pp.350-363

135. Maitri Mapa, Bhuvaneshwari, B., Madevi P. and Nagesh R. Iyer, 'Photo Catalyst in Concrete: An Approach for Innovative Infrastructure', The 4th International fib Congress, Mumbai, February 10-14, 2014, pp.583-585

136. Mareena, G., Lakshmi, K. and Rama Mohan Rao, A., 'Damage diagnostic technique for SHM combining PCA and time series models', Proceedings of International conference on Futuristic innovations & Developments in Civil Engineering, Sivakasi, April 18-20, 2013

137. Mohamed Meeran, A., Parivallal, S., Arun Sundaram, B., Ravisankar, K. and Prabavathy S., 'Experimental investigations on a steel plate girder bridge using wireless sensors', Proceedings of the International Conference on Futuristic Innovations and Developments in Civil Engineering, Sivakasi, April 18-20, 2013, pp.1-7

138. Mohit Verma, Rajasankar, J. and Nagesh R. Iyer, 'Numerical evaluation of controllers for delay compensation in real-time substructuring', Journal of Structural Engineering, Vol.40, No.1, April-May 2013, pp.29-34

139. Mohit Verma, Rajasankar, J. and Nagesh R. Iyer, 'Fuzzy logic controller for real-time substructuring applications', Journal of Vibration and Control, Vol.20 No.8, June 2014, pp.1103-1118

140. Muthalagan, V., Abraham, A., Antony Jayasehar, C., Palani, G.S., Nagesh R. Iyer, Harikrishna, P. and Selvi Rajan, S., 'Field measurement of cyclone wind data using wind monitoring system', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.748-757

141. Nagendra, C.V.S., Prabakar, J. and Seetharaman, S., 'Influence of different types of admixtures in cement composite on physiscal and mechanical properties', Conference on Emerging Trends in Civil Engineering, Chennai, February 28 - March 1, 2014, pp.497-510

142. Nagesh R. Iyer and Srinivasan, P., 'Forensic analysis of RC structures', Conference and Exhibition on Forensic Civil Engineering, Bangalore, August 23-24, 2013, pp.1-15

143. Nagesh R. Iyer, 'An integrated approach to construction management', Proceedings of the Seminar on Structural Aspects of Architectural Engineering in Property Development, Chennai, September 20-21, 2013, pp.1-16

144. Nagesh R. Iyer, 'Contemporary wind engineering studies in India', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.K-115- K129

145. Nagesh R. Iyer, Bharatkumar, B.H., Bhashya, V. and Prameetthaa, J., 'Investigation on the recycled aggragate concrete with mineral admixture', Proceedings of Intermational Workshop on Construction and Demolition Waste Recycling, Chennai, August 5-6, 2013, pp.75- 82

146. Nagesh R. Iyer, Srinivasan, P. and Rajesh R. Nair, 'Forensic applications including mapping and classification of tsunami sand deposits and sand dunes with ground penetrating radar', International Journal of Forensic Engineering, Vol.1 No.3/4, 2013, pp.290–300

147. Nawal Kishor Banjara and Saptarshi Sasmal, 'Remaining fatigue life of steel

railway bridges under enhanced axle loads', Structure and Infrastructure Engineering, Vol.10 No. 2, 2014, pp.213-224

148. Nawal Kishor Banjara and Saptarshi Sasmal, 'Evaluation of fatigue remaining life of typical steel plate girder bridges under railway loading', Structural Longevity, Vol.10 No. 3, 2013, pp.155-166

149. Negi, S.K. and Srinivasan, V., 'Construction Practices and Vernacular Architecture in hilly state of Uttarakhand', Proceedings of the International Conference on Disaster Mitigation and Management Towards Sustainable Development, Thanjavur, December 2-4, 2013

150. Nithya, N., Amar Prakash, Robert Ravi, S. and Rajasankar, J., 'Behaviour of RCC Flexural Member under Shock Loading', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.142-149

151. Niveditha, C., Sarayu, K., Ramachandra Murthy, A., Ramesh Kumar, V., Nagesh R Iyer, 'Marine algae for cement mortar strengthening', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.149-153

152. Niveditha, C., Sarayu, K., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Halimeda sp as source of calcium carbonate and silica', Proceedings National Conference Bio-Engineering, Chennai, March 27, 2014, pp.25-35. (First Prize)

153. Olutoge, F.A., Bhashya, V., Ramesh, G., Bharatkumar, B.H. and Sundar Kumar, S., 'Evaluation of residual strength properties of steel fiber reinforced concrete', Journal of Emerging Trends in Engineering and Applied Sciences, Vol.4 No.2, 2013, pp.168-172

154. Padmapriya, V., Anandavalli, N. Rajasankar, J. and Mohan Ganesh, G., 'Nonlinear Static Analysis of Recycled Aggregate Reinforced Concrete Columns', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.153-158

155. Prabakar, J., 'EPS Precast Lightweight Large Panel Wall and Roof Elements – Modern Construction Material for Seismic Resistant Buildings', Proceeding of the International Conference on |Innovative Materials and Construction, Melmaruvathur, April 8-9, 2013, pp.59-70

156. Prabakar, J., 'Precast lightweight large wall and roof panels using EPS – A modern construction material for affordable housing', Proceedings of the All India Seminar on Structural Aspects of Architectural Engineering in Property Development, Chennai, September 20-21, 2013, pp.1-15

157. Prabha, M., Smitha Gopinath, Rama Chandra Murthy, A., Nagesh R. Iyer and Elangovan, G., 'Numerical modelling of RC beam strengthened with basalt fiber reinforced polymer', International Conference on Advances in Engineering and Technology, Chennai, April 5-6, 2013, pp.43-45

158. Prabha, M., Smitha Gopinath, Rama Chandra Murthy, A., Nagesh R. Iyer, and Elangovan, G., 'Flexural behaviour of RC beam strengthened with basalt reinforced concrete', Proceedings of the Fifth National Level Conference on Innovations in Civil Engineering, Coimabtore, April 19, 2013, pp.161-165

159. Prabhat Ranjan, P., Bharatkumar, B.H., and Nagesh R. Iyer. 'Influence of curing regimes on compressive strength of ultra high performance concrete', Sadhana, Vol.38 No.6, 2013, pp.1421-1431

160. Prabhat Ranjan Prem, A Ramachandra Murthy, G Ramesh and Nagesh R. Iyer, "Ultra high performance concrete as an overlay for repair and retrofitting applications", Proceedings of the International Conference on Disaster Management, Chennai, January 23-24, 2014, pp. C8-1- C8-7

161. Prameethaa, J. and Bharatkumar, B.H., 'Experimental investigation on the influence of micronized biomass silica in the recycled aggregate concrete', Proceedings of the International Conference on Advances in Civil Mechanical and Structural Engineering, Hong Kong, August 3-4, 2013

162. Prasad Rao, N., Balagopal, R., Rokade, R.P. and Mohan, S.J., 'Schifflerised angle sections for triangular- based communication towers', The IES Journal Part A: Civil and Structural Engineering, Vol.6 No.3, 2013, pp.189-198

163. Prema, S., Vimal Mohan, Parivallal, S., Ravisankar, K. and Robert Ravi, S. 'Correlation based damage detection for structural health assessment', International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March13-14 2014, pp.99-105

164. Priya Dharsini, S., Bhuvaneshwari, B., Palani, G.S., Mohan Ganesh, G. and Nagesh R. Iyer, 'Micro-mechanical simulation of interfacial behaviour of epoxy-CFRP composites using FEM', International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March13-14 2014

165. Priyanga, K.S., Harikrishna, P., Jaisankar, G. and Selvi Rajan, S., 'Wind tunnel pressure measurement studies on 1:2:7 rectangular building model under uniform flow', Proceedings of the First National Conference on Recent Advances in Structural Engineering, Pollachi, March 22, 2014, pp.19-25

166. Pukazhendhi, D.M., Raghava, G. and Samuel Knight, G.M., 'Fatigue crack growth studies on SA403 TP 304LN SS elbows', Procedia Engineering, Vol.55, 2013, pp.699-702

167. Punit Arora, Singh, P.K., Bhasin, V., Vaze, K.K., Pukazhendhi, D.M., Gandhi, P. and Raghava, G., 'Fatigue crack growth behavior in pipes and elbows of carbon steel and Stainless Steel Materials', Procedia Engineering, Vol. 55, 2013, pp.703-709

168. Raghava, G., Gandhi, P. and Vaze, K.K., 'Cyclic fracture, FCG and ratcheting studies on yype 304LN stainless steel straight pipes and elbows', Procedia Engineering, Vol.55, 2013, pp.693-698

169. Raghava, G., Vishnuvardhan, S., Gandhi, P. and Vaze, K.K., 'Fracture studies on stainless steel straight pipes under earthquake-type cyclic loading', Invited keynote paper, Proceedings of the International Conference on Disaster Management, Chennai, January 23 & 24, 2014, pp.K11/1-11

170. Raghava, G., 'Contribution to structural integrity: Fatigue and fracture related full scale experimental investigations carried out at CSIR-SERC', Invited keynote paper, Proceedings of the First International Conference on Structural Integrity, Kalpakkam, February 4-7, 2014, pp.1597-1608

171. Raghava, G., Vishnuvardhan, S. and Gandhi, P., 'Corrosion fatigue crack growth studies on IS 2062 steel', Proceedings of the First International Conference on Structural Integrity, Kalpakkam, February 4-7, 2014, pp.976-982

172. Raghu Prasad, B.K., Lakshmanan, N., Gopalakrishnan, N., Sathish Kumar, K. and

Sreekala, R., 'Damage identification of beam-like structures with contiguous and distributed damage', Structural Control and Health Monitoring, Vol. 20 No.4, April 2013, pp.496-519

173. Raghuvaran, E., Aishwarya, A. and Prabakar, J., 'Precast prefab building components and its connections – An overview', Conference on Emerging Trends in Civil Engineering, Chennai, February 28 - March 1, 2014, pp.511-526

174. Rajamane, N.P. and Ambily, P.S., 'Fly ash as a sand replacement material in concrete - A study', The Indian Concrete Journal, Vol.87 No.7, July 2013, pp.11-17.

175. Rajamane, N.P. and Ambily, P.S., 'Discussion on fly ash as a sand replacement material in concrete - A study, The Indian Concrete Journal, Vol. 87 No.9, September 2013, pp.44-48

176. Rajendra, T.N., Anoop, M.B., Balaji Rao, K. and Vanakudre, S.B., 'Load carrying capacity of RC slabs using modified yield-line theory', International Conference on Engineering Materials and Processes, Chennai, May 23-14, 2013, pp.1-6

177. Rama Mohan Rao, A., Lakshmi, K. and Karthik Ganeshan, 'Structural system identification using quantum behaved particle swarm optimisation algorithm', Structural Durability and Health Monitoring, Vol.9 No.2, 2013, pp.99-128

178. Rama Mohan Rao, A., Varun Kasi Reddy and Lakshmi, K., 'Modal identification of Guangzhou new TV tower by blind source separation using output-only ambient data', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.711-718

179. Rama Raju, K., Shereef, M.I., Nagesh R. Iyer and Gopalakrishnan, N., 'Analysis and design of RC tall buildings subjected to wind and earthquake loads' Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.844-852

180. Rama Raju, K., Shereef, M.I., Nagesh R. Iyer and Gopalakrishnan, N., 'Analysis of Tall building subjected to wind and seismic loads', National Conference on Emerging Technologies, Tiruchengode, April 12, 2013, pp.103-111

181. Rama Raju, K., Ansu, M., and Nagesh R. Iyer, 'A methodology of design for seismic performance enhancement of buildings using viscous fluid dampers', Journal Structural Control and Health Monitoring, Vol.21 No.3, March 2014, pp.342-355

182. Rama Raju, K., Jame, A., Gopalakrishnan, N., Muthumani, K. and Nagesh R. Iyer, 'Experimental studies on seismic performance of three-storey steel moment resisting frame model with scissor-jack-magnetorheological damper energy dissipation systems', International Journal Structural Control and Health Monitoring, Vol.21 No.5 May 2014, pp.741–755

183. Rama Rao, G.V., Gopalakrishnan, N., Jaya, K.P. and Muthumani, K., 'Performance based seismic design – Indian prospective', Proceedings of the Fourth International Workshop on Performance, Protection and Strengthening of Structures under Extreme Loading, Mysore, August 26-27, 2013, pp.1-10

184. Rama Rao, G.V., Gopalakrishnan, N., Muthumani, K., Sathish Kumar, K., Jaya, K.P., Parulekar, Y.M. and Reddy, G.R., 'Experimental investigations on lateral load behaviour of an RC shear wall', Proceedings of the Fourth International Workshop on Performance, Protection and Strengthening of Structures under Extreme Loading, Mysore, August 26-27, 2013, pp.1-10

185. Rama Rao, G.V., Sreekala, R., Sathish Kumar, K., Gopalakrishnan, N., Muthumani, K.,

Nagesh R.Iyer, Lakshmanan, N. and Reddy, G.R., 'Seismic response measurement of an under-water model through high speed camera and feature tracking', Experimental Techniques, Published online on June 2013, pp.1-8

186. Ramachandra Murthy, A., Karihaloo, B.L., Nagesh R. Iyer and Raghu Prasad, B.K., 'Bilinear tension diagrams of concrete mixes corresponding to their size-independent specific fracture energy', Construction and Building Materials, Vol.47, 2013, pp.1160-1166

187. Ramachandra Murthy, A., Nagesh R. Iyer and Raghu Prasad, B.K., 'Evaluation of mechanical properties for high strength and ultra high strength concrete', Advances in Concrete Construction : An International Journal, Vol.1 No.4, 2013, pp.341-358

188. Ramachandra Murthy, A., Palani, G.S. and Nagesh R. Iyer, 'A simple analytical model for evaluation of penetration depth and resistant strength of concrete targets', International Journal of Structural Stability and Dynamics, Vol.13 No.3, 2013, pp.1-17

189. Ramachandra Murthy, A., Raghu Prasad, B.K. and Nagesh R. Iyer, 'Estimation of fracture properties for high strength and ultra high strength concrete beams and size effect', International Journal of Damage Mechanics, Vol.22 No.8 , May 2013, pp.1109-1126

190. Ramachandra Murthy, A., Karihaloo, B.L., Nagesh R. Iyer, and Raghu Prasad, B.K., 'Determination of size - independent specific fracture energy of concrete mixes by two methods', Cement and Concrete Research, Vol.50, 2013, pp.19-25

191. Ramachandra Murthy, A., Palani, G.S., Smitha Gopinath, Ramesh Kumar, V. and Nagesh R. Iyer. 'An improved concrete damage model for impact analysis of concrete structural components by using finite element method', CMC: Computers, Materials & Continua, Vol.37 No.2, 2013, pp.77-96

192. Ramanathan, M., Ramesh Babu, C., Kesavan, K. and Senthil, R., 'Studies on performance of CFRP strengthened flexural members using FBG sensors', Proceedings of the International Conference on Futuristic Innovations and Developments in Civil Engineering, Sivakasi, April 18-20, 2013, pp.

193. Ramanjaneyulu, K., Balthasar, N., Saptarshi, S., Constanze, R., Lakshmanan, N. and Nagesh R. Iyer, 'Seismic performance evaluation of exterior beam-column sub-assemblages designed according to different codal recommendations', Structure and Infrastructure Engineering, Vol.9 No.8, 2013, pp.817-833

194. Ramanjaneyulu, K., Srinivas, V. and Saptarshi Sasmal, 'Damage identification based on vibration data', International Journal of Forensic Engineering, Vol.1 Nos.3/4, 2013, pp.209-226

195. Ramesh, G., Ravindra Gettu and Bharatkumar, B.H., 'An improved methodology for tensile tests on fibre reinforced polymers', 11th International Symposium on Fiber Reinforced Polymer for Reinforced Concrete Structures, Guimaracs, Portugal, June 26-28, 2013.

196. Ramsundar, K.R., Hemalatha, T., Arun, M., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Phase identification of nano clay incorporated self-compacting concrete using X-ray diffraction', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.176-182

197. Ramya Narayana, Saptarshi Sasmal and Mohan Ganesh, G., 'Development of methodology for structure integrity

assessment using acoustic emission technique' International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014,pp.1-8

198. Ravindra Gettu, Bhaskar, S. and Bharatkumar, B.H., 'Effect of fly ash based Portland pozzolana cement on chloride induced corrosion of reinforcement in concrete', ICI-IWC 2013 Innovations in Concrete for Meeting Infrastructure Challenge : Proceedings of the International Conference on Innovations in Concrete 2013, Hyderabad, October 23-26, 2013, pp.81-91

199. Ravindra Gettu, Jayasree, C., Elson John, Bhaskar S., Betiglu Eshete and Vinayak S., Plenary lecture on 'More sustainable concrete technology through the effective use of superplasticizers', Proceedings of the 3rd International Conference on Sustainable Construction Materials and Technologies, Kyoto, Japan, August 18-21, 2013, pp.1-18

200. Ravisankar, K., Kesavan, K., Parivallal, S., Arun Sundaram, B. and Farvaze Ahmed, A.K., 'Fibre optic sensors as a non-destructive tool for structural monitoring', International Journal of Forensic Engineering, Vol.1 No.3/4, 2013, pp.260 – 276

201. Renish, J., Dhaduk, Rama Rao, G.V., Gopalakrishnan, N. and Muthumani, K., 'Non-linear analysis of medium aspect ratio shear walls', Proceedings of 28th Indian Engineering Congress, Chennai, December 20-22, 2013

202. Rokade, R.P., Prasad Rao, N., Balagopal, R. and Mohan, S.J., 'Experimental investigations on GFRPSteel hybrid lattice tower', Proceedings Of The National Conference on Recent Trends in Overhead Transmission Lines, Bangalore, December 19-20, 2013, pp.22-34

203. Sadhasivam, K.J., Sathish Kumar, K., Bharathi Priya, C., and Jagannathan, D.S., 'Seismic response control using semi-active dampers', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.738-741

204. Sadhasivam, K.J., Sathish Kumar, K., Bharathi Priya, C., Gopalakrishnan, N. and Jagannathan, D.S., 'Analytical modelling of MR dampers – A comparative study', Proceedings of the National Conference on Recent Advances in Structural Engineering, Coimbatore, March 22, 2014, pp.15-18

205. Sankaranarayanan, K., Krishnakumar, S., Victor Paul Raj, G., Rahul, R. and Chitra Ganapathi, S., 'Wind tunnel experiment on a small horizontal axis wind turbine', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, pp.1218-1228

206. Santhosh, H.P., Manjunath, K.S. and Sathish Kumar, K., 'Seismic base isolation of a RC framed structure', Proceedings of the National Conference on Recent Trends in Engineering and Technology, Coimbatore, April 20, 2013, pp.1-8

207. Santhosh, H.P., Manjunath, K.S., and Sathish Kumar, K., 'The influence of masonry infill on the base isolated structure', International Journal of Civil Engineering and Applications, Vol.3 No.7, 2013, pp.27-31

208. Santhosh, H.P., Manjunath, K.S., and Sathish Kumar, K., 'Seismic analysis of low to medium rise building for base isolation', Proceedings of the International Conference on Recent Innovations in Civil Engineering, Gulbarga, June 5-6, 2013, pp.1-5

209. Santhosh, H.P., Manjunath, K.S., and Sathish Kumar, K., 'Seismic analysis of low to medium rise building for base

isolation', International Journal of Research in Engineering and Technology, IC-RICE Conference Issue, Vol.2 No.11, November 2013, pp.1-5

210. Santhosh, H.P., Manjunath, K.S. and Sathish Kumar, K., 'The influence of masonry infill on the base isolated structure', Proceedings of the International Conference on Sustainable Innovative Techniques in Civil and Environmental Engineering, New Delhi, June 5-6, 2013, pp.1-5

211. Saptarshi, S., Chandra Prakash, K., Ramanjaneyulu, K. and Srinivas, V., 'Numerical evaluation of bond-slip relations for near-surface mounted carbon fiber bars embedded in concrete', International Journal of Construction and Building Materials, Vol.40, 2013, pp.1097-1109

212. Saptarshi Sasmal, Bhuvaneshwari, B. and Nagesh R. Iyer, 'Can carbon nano tubes make wonders in civil/structural engineering', Progress in Nanotechnology and Nanomaterials, Vol.2 No.4, 2013, pp.117-129

213. Saptarshi Sasmal, Kalidoss, S. and Srinivas, V., 'Nonlinear finite element analysis of FRP strengthened reinforced concrete beams', Journal of Institution of Engineers – India, Series-A, Vol.93 No.4, 2013, pp.241-249

214. Saptarshi Sasmal, Ramanjaneyulu, K., Balthasar Novak and Lakshmanan, N., 'Analytical and experimental investigations on seismic performance of exterior beam-column sub-assemblages of existing RC framed building', Earthquake Engineering and Structural Dynamics, Vol. 42, 2013, pp.1785-1805

215. Saptarshi Sasmal, Srinivas, V. and Ramanjaneyulu, K., 'Evolution of effective non-invasive retrofitting strategies for gravity load designed beam-column sub-assemblages under seismic loading', The 4th International fib Congress, Mumbai, February 10-14, 2014, pp.575-585

216. Saravana Kumar, K., Saptarshi Sasmal, Srinivas, V., and Ramanjaneyulu, K., 'Evaluation of dynamic amplification factor for beam like structure subjected to moving load', Journal of the Bridge and Structural Engineer, Vol.43 No.3, 2013, pp.117-129

217. Saravanan, M., Gandhi, P., Vishnuvardhan, S., Raghava, G., Pukazhendhi, D.M., Sahu, M.K., Chattopadhyay, J. and Dutta, B.K., 'Fracture behaviour of large size carbon steel elbows with and without internal pressure', Proceedings of the International Conference on Disaster Management, Chennai, January 23 - 24, 2014, pp.C14/1-7

218. Sarayu, K. and Sandhya, S. 'Role of chemical and biological nanoparticles in water disinfection', International Journal of Geology Earth and Environmental Science, Vol.3 No. 3, 2013, pp.197-212

219. Sarayu, K., Nagesh R. Iyer, and Ramachandra Murthy, A., 'Exploration on the biotechnological aspect of the ureolytic bacteria for the production of cementitious materials - A review', Applied Biochemistry Biotechnology, Vol.172, 2014, pp.2308-2323

220. Sasikala, K., Selvi Rajan, S., Lakshmanan, N., Ramesh Babu, G. and Harikrishna, P., 'Linear and polynomial fit to process pressure calibration in a boundary layer wind tunnel facility', Proceedings of the International Conference on Mathematical Computer Engineering, Chennai, November 29-30, 2013, pp.1276-1285

221. Sathish Kumar, K., Muthumani, K., Antony Jeyasehar, C. and Nagesh R. Iyer, 'Newmark implicit time integral for application in pseudo-dynamic testing – mathematical verification', Asian Journal of Civil Engineering (Building and

Housing), Vol.15 No.1, February 2014, pp.61-77

222. Sathish Kumar, R.D., 'Patent information search strategies for information professional – Case Study', National Conference on Next Generation Library Services, August Date 2013, pp.437-442

223. Selvi Rajan, S., 'Design of cyclone shelters based on wind tunnel studies', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.K199-K210

224. Selvi Rajan, S., Harikrishna P., Senthilkumar, S. and Parammasivam K.M., 'Aerodynamic drag reduction on a sedan car by provision of vortex generators through wind tunnel studies', Proceedings of the National Conference on Wind Tunnel Testing, Thiruvananthapuram, August 23-24 , 2013, pp.1-7

225. Selvi Rajan, S., Nagesh R. Iyer, Sasikala, K., Harikrishna, P., Keerthana, M. and Arun Raje, 'Wind velocity measurement in the wake of a rectangular section using particle image velocimetry', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.364-369

226. Selvi Rajan, S., Ramesh Babu, G., Arunachalam, S., Nagesh R. Iyer and Lakshmanan, N., 'Interference factors for natural draught cooling towers based on wind tunnel experiments', Proceedings of the Eighth Asia-Pacific Conference on Wind Engineering, Chennai, December 10-14, 2013, pp.490-498

227. Selvi Rajan, S., Ramesh Babu, G., Chitra Ganapathi, S., Arunachalam, S., Harikrishna, P., Abraham A., and Nagesh R. Iyer, 'Evaluation of aerodynamic parameters for a cooling tower model', Journal of Wind and Engineering, Vol.10 No.1, 2013, pp.24-36

228. Selvi Rajan, S., 'Simulation of vortex flows in boundary layer wind tunnel', Keynote paper, Proceedings of the International Conference on Disaster Management, Chennai, January 23 – 24, 2014, pp.K4-1 – K4-8

229. Selvi Rajan, S., Keerthana, M., Harikrishna, P., Abraham, A., Ramesh Babu, G. and Kameshwaran, M., 'Wind tunnel pressure measurement studies on models of cyclone shelters under simulated cyclonic wind characteristics', Proceedings of the International Conference on Disaster Management, Chennai, January 23 – 24, 2014, pp.C12-1 – C12-7

230. Shanmuga Priya, D., Cinitha, A. and Umesha, P.K., 'Enhancing the seismic response of buildings with energy dissipation methods-an overview', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.229-234

231. Sharmila, C., Anandavalli, N., Arunachalam, N. and Amar Prakash, 'Pressure Impulse Diagram for Damage Assessment of Structural Elements Subjected to Blast Loads: A State-of-Art', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.234-241

232. Sharon Ann Mathew, Parivallal, S., Ravisankar, K., Kesavan, K., and Saravanakumar, P., 'Recent Trends in Structural Health Monitoring and Damage Detection of Civil Infrastructure-an overview' Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.241-246

233. Shrithi, S., Badami, Kamatchi, P., Vanakudre, S.B. and Nagesh R Iyer, 'Site-specific analysis for deeper soil strata', International Conference on Engineering Materials and Processes, Chennai, May 23-24, 2013, pp.1-3

234. Shruthi, B.T., Cinitha, A., Umesha, P.K., Nagesh R. Iyer and Sankarasubramanian, G., 'A Comprehensive Review on Genesis of Corrosion and Modelling Aspects of Structural Steel', Proceedings of International Conference On Futuristic innovation and Developments in Civil Engineering, Sivakasi, April 18-20, 2013, pp.1-10

235. Shruthi, B.T., Cinitha, A., Umesha, P.K., Nagesh R. Iyer and Sankarasubramanian, 'Numerical investigation of corroded steel angle members', Proceedings of National Symposium for Recent Trends in Civil Engineering, Coimbatore, April 26, 2013, pp.1-4

236. Sindu, B.S., Saptarshi Sasmal and Smitha Gopinath, 'A multi-scale approach for evaluating the mechanical characteristics of carbon nanotube incorporated cementitious composites', Construction and Building Materials, Vol.50, 2013, pp.317-327

237. Sindu, B.S. and Saptarshi Sasmal, 'Investigations on interaction behavior of nano modified epoxy based polymers using molecular dynamics simulation', 6th Bangalore India NANO 2013 Conference, Bangalore, December 4-6, 2013,pp.20

238. Sivapriya, S., Kesavan, K., Ravisankar, K., Parivallal, S. and Metro, M.M. 'Studies on embeddable type packaged strain-temperature FBG sensor for concrete structures', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.636-642

239. Sivasubramanian, K., Jaya, K.P., Ramanjaneyulu, K. and Neelamegam, M., 'Impact-echo method: The technological growth in two decades', Proceedings of the Fourth International Workshop on Performance, Protection and Strengthening of Structures under Extreme Loading, Mysore, August 26-27, 2013, pp.1-10

240. Sivasubramanian, K. and Umesha, P.K., 'Wavelet transform for damage identification in continuous beams', International Journal of Applied Sciences and Engineering Research, Vol.2 No.3, 2013, pp.294-306

241. Smitha Gopinath, Madheswaran, C.K., Rama Chandra Murthy, A., Nagesh. R. Iyer, and Barkavi, T., 'Low and high velocity impact studies on fabric reinforced concrete panels', CMES: Computer Modeling in Engineering & Sciences, Vol.92 No.2, 2013, pp.151-172

242. Smitha Gopinath, Ramachandra Murthy, A. and Nagesh R Iyer, 'Experimental investigations on the glass fabrics for confinement of concrete specimens', International Journal Structural Durability and Health Monitoring, Vol.9 No.1, 2013, pp.20

243. Smitha Gopinath, Ramachandra Murthy, A., Nagesh R. Iyer and Prabha, M., 'Behaviour of reinforced concrete beams strengthened with basalt textile reinforced concrete', Journal of Industrial Textiles, Online version published on Jan 2014, pp.1-11

244. Smriti Raj, Smitha Gopinath and Nagesh R. Iyer, 'Compressive behaviour of basalt fibre reinforced composite', Proceedings of International Conference on Advances in Civil Mechanical and Structural Engineering, Hong Kong, August 3-4, 2013, pp.32-36

245. Sreekala, R., Meher Prasad, A. and Muthumani, K., 'Near fault earthquakes and behaviour of liquid storage tanks', Journal of Structural Engineering, Vol.40 No.5, December 2013-January 2014, pp.433-441

246. Sreekala, R., Gopalakrishnan, N., Muthumani, K., Sathish Kumar, K., Rama Rao, G.V., and Nagesh R. Iyer, 'Seismic protection of critical infrastructures through innovative technologies', International Journal of Critical Infrastructures, Vol.9 No.4, 2013, pp.351-367

247. Srinivas, V., Antony Jeyasehar, C. and Ramanjaneyulu, K., 'Computational methodologies for vibration-based damage assessment of structures', International Journal of Structural Stability and Dynamics, Vol.13 No. 8, 2013, pp.01-27

248. Srinivas, V., Saptarshi Sasmal and Ramanjaneyulu, K., 'Nonlinear damage indicators from modal data of reinforced concrete structures', The 4th International fib Congress, Mumbai, February 10-14, 2014, pp.125-135

249. Srinivas, V., Saptarshi Sasmal, Nawal Kishor Banjara, Ramanjaneyulu, K. and Nagesh R. Iyer, 'Health assessment of a plate girder railway bridge under increased axle loads', ASCE Journal of Bridge Engineering, Vol.18 No.10, October, 2013, pp.969–979

250. Srinivas, V., Saptarshi Sasmal, Ramanjaneyulu, K. and Antony C. Jeyasehar, 'Influence of test conditions on modal characteristics of reinforced concrete structures under different damage scenarios', Archives of Civil and Mechanical Engineering, Vol.13 No.4, 2013, pp.491-505

251. Srinivasan, P., Ravisankar, K. and Thirugnanasambandam, S., 'Forensic evaluation of a large reinforced concrete specimen using radar and ultrasonic pulse echo', International Journal of Forensic Engineering, Vol.1 No.3/4, 2013, pp.198-208

252. Srinivasan, V. and Negi, S.K., 'Design of Sustainable Energy Efficient small Settlement', Proceedings of the International Conference on Disaster Mitigation and Management Towards Sustainable Development, Thanjavur, December 2-4, 2013

253. Sumana, B., Sarayu, K., Bruno, B., Udhaya, R. and Sandhya, S. 'Solar light induced bactericidal activity of silver doped TiO2 ', International Journal of Environmental Sciences, Vol.4, 2013, pp.106-112

254. Sujatha, S., Sarayu, K., Ramachandra Murthy, A., Ramesh Kumar, V. and Nagesh R. Iyer, 'Soil bacteria for the strength enhancement of cement mortar', Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014, pp.575-580

255. Sujatha, S., Sarayu, K., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Marine bio-mineralizing calcaereous bacteria', Proceedings of the National Conference on Bioengineering, NCBE-2014, Chennai, March 27, pp.22-26

256. Sujin Varghese, Prasad Rao, N. and Jemimah Carmichael, 'Design of transmission line tower based on is 800: 2007 – related issues', Proceedings of International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March13-14, 2014

257. Sundar Kumar, S., Vasugi, J., Ambily, P.S., and Bharatkumar, B.H., 'Development and determination of mechanical properties of fly ash and slag blended geopolymer concrete', International Conference

on Global Innovations in Technology and Science, Kottayam April 4-6, 2013, pp.131-137

258. Sundar Kumar, S., Vasugi, J., Ambily, P.S., and Bharatkumar, B.H., 'Development and determination of mechanical properties of fly ash and slag blended geopolymer concrete', International Journal of Scientific & Engineering Research, Vol.4 No.8, August 2013, pp.1-5

259. Sundar Kumar, S., Ramesh G, Jaffer Sathik S. A. and Bharatkumar B.H., 'Effect of NaOH concentration and molar ratios on strength development in geopolymer mortars' , Journal of Structural Engineering, Vol. 40, No. 6, February - March 2014, pp.558-564

260. Sundaramoorthi, A. and Srinivasan, V., 'An adaptive teaching system using ubiquitous learning', National Conference on Recent Trends in Library and Information Sciences, Chennai, April 12-13, 2013, pp 380-386

261. Swaminathan, K.S., Anandavalli, N., Bhuvaneshwari, P. and Rajasankar, J., 'Critical-Review on Multi-Scale modeling of cement based Composites', Proceedings of International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March13-14, 2014, pp.649-655

262. Thirumalaiselvi, A. and Anandavalli, N., 'Numerical investigation on static response of laced steel-concrete composite (LSCC) slabs', Proceedings of International Conference on Advances in Civil Mechanical and Structural Engineering, Hong Kong, 3-4 August, 2013, pp.37-41

263. Tina Abey Joseph, Bhaskar, S. and Eapen Sakatia, P., 'GPR technique for thickness estimation and identification of characteristic features of brick masonry', Proceedings of 2nd National Conference on Recent Advances in Civil Engineering, Kotayyam, September 6-7, 2013, pp.31-40

264. Tony, P.J., Prabakar, J., Ramanjaneyulu, K. and Mohan, G.G., 'Performance evaluation on geopolymer concrete using metakaolin and GGBS', Proceeding of the International Conference on |Innovative Materials and Construction, Melmaruvathur, April 8-9, 2013, pp.259-265

265. Veena, A.R., Sivakumar, P. and Sakaria Eapen, 'Experimental investigation on cement stabilized soil blocks', International Journal of Structural and Civil Engineering Research, Vol.3 No.1, pp.44-53

266. Vijaya, R., Rama Rao, G.V., Gopalakrishnan, N. and Solanki, C.H., 'Soil structure interaction studies on soft storey buildings', Proceedings of 28th Indian Engineering Congress, Chennai, December 20-22, 2013

267. Vijayasimhan, M., Marimuthu, V., Palani, G.S. and Rama Mohan Rao, P., 'Comparative study on distortional buckling strength of cold-formed steel lipped channel sections', Research Journal of Engineering Sciences, Vol.2 No.4, April 2013, pp.10-15

268. Vimal Mohan and Vishnu, C.R., 'Joint Stiffness of cold-formed steel pallet rack connections: a comparison of the methodology', Journal of Structural Engineering, Vol. 40 No.5, December 2013-January 2014, pp.395-403

269. Vimal Mohan, Parivallal, S., Kesavan, K., Arun Sundaram, B., Farvaze Ahmed, A.K. and Ravisankar, K., 'Studies on damage detection using frequency change correlation approach for health assessment', Proceedings of the 1st International Conference on Structural Integrity, Kalpakkam, Feburary 4-7, 2014, pp.21-28

270. Vimal Mohan, Rajasankar, J. and Nagesh R. Iyer, 'Response simulation of micro reinforced concrete target under ballistic impact', International Journal for Computational Methods in Engineering Science and Mechanics, Vol.15 No.3, 2014, pp.302-308

271. Vishnuvardhan, S., Raghava, G., Gandhi, P., Saravanan, M., Sumit Goyal, Punit Arora, Suneel, K., Gupta and Vivek Bhasin, 'Ratcheting failure of pressurised straight pipes and elbows under reversed bending', International Journal of Pressure Vessels and Piping, Vols. 105-106, May- June 2013, pp.79-89

272. Vishnuvardhan, S., Raghava, G., Gandhi, P., Sumit Goyal, Suneel, K., Gupta and Vivek Bhasin, 'Ratcheting Strain Assessment in Pressurised Stainless Steel Elbows subjected to in-plane Bending', Procedia Engineering, Vol. 55, 2013, pp.666-670

273. Yuvaraj, P., Ramachandra Murthy, A., Nagesh R. Iyer, Pijush Samui and Sekar, S.K., 'Multivariate adaptive regression splines model to predict fracture characteristics of high strength and ultra high strength concrete beams', CMC:Computers, Materials & Continua, Vol.36 No.1, 2013, pp.73-97

274. Yuvaraj, P., Ramachandra Murthy, A., Nagesh R Iyer, Pijush Samui and Sekar, S.K., 'Prediction of fracture characteristics of high strength and ultra high strength concrete beams based on relevance vector machine', International Journal of Damage Mechanics, Published online January 2014, pp.1-27

275. Yuvaraj, P, Ramachandra Murthy, A., Nagesh R. Iyer, Sekar, S.K. and Pijush Samui, 'Prediction of critical stress intensity factor for high strength and ultra high strength concrete beams using support vector regression', Journal of Structural Engineering, Vol.40 No. 3, August-September 2013, pp.224-233

Book Chapters

1. Nagesh R. Iyer., Krishnamurthy, T.S., Srinivasan, P., Farvaze Ahmed, A.K. and Prabakar, J., In : Use of Ferrocement in Buildings, Indian Buildings Congress, 2013

2. Nagesh R. Iyer., Ravisankar, K., Ramachandra Murthy, A., Smitha Gopinath., Ramesh Kumar, V., Bharathkumar, B.H. and Krishnamurthy, T.S., In : New Building Materials & Technologies – Innovations in Concrete, Indian Building Congress, 2013

3. Nagesh R. Iyer., Ravisankar, K., Prabakar, J., Bharathkumar, B.H., Ambily, P.S., Ramanjaneyulu, K., Sundar Kumar, S. and Ramachandra Murthy, A., In : Concrete Technology, Indian Building Congress, 2013

4. Balaji Rao, K., 'Characterisation of large fluctuations in response evolution of reinforced concrete members', In : Proceedings of the International Symposium on Engineering under Uncertainty: Safety Assessment and Management, S. Chakraborty and G. Bhattacharya (Editors), Springer India, 2013, pp.259-295

5. Anoop, M.B. and Balaji Rao, K., 'Performability analysis of reinforced concrete bridge girders in corrosive environments using Markov chains with fuzzy states', In : Proceedings of the International Symposium on Engineering under Uncertainty: Safety Assessment and Management, S. Chakraborty and G. Bhattacharya (Editors), Springer India, 2013, pp.1165-1181

6. Ravi, R., Sarayu, K., Sandhya, S., Swaminatha, T., 'Rotating biological contactors' In : Air pollution prevention control: bioreactors and bioenergy, Christian Kennes and Maria C. Veiga (Editors), Wiley Publishers, 2013, pp.207-220

TECHNICAL REPORTS

1. Abraham, A., Harikrishna, P., Ramesh Babu, G., Keerthana, M. and Selvi Rajan, S., 'Influence of side wall height on distribution of pressures over a curved roof structure - A wind tunnel model study', CSIR-SERC Research Report No. R&D 01–MLP 16841–RR-09, July 2013

2. Abraham, A., Ramesh Babu, G., Keerthana, M., Chitra Ganapathi, S., Harikrishna, P., Selvi Rajan, S. and Nagesh R. Iyer, 'Post-cyclone structural damage survey of very severe cyclonic storm 'Phailin'', CSIR-SERC Research Report No. R&D 01–MLP 16841–RR-11, January 2014

3. Amar Prakash, Anandavalli, N., Rajasankar, J., Mohit Verma and Nagesh R. Iyer, 'High velocity impact damage assessment in fibre reinforced cementitious composite panels', CSIR-SERC Research Report No. R&D 04–MLP 16941–RR-10, November 2013

4. Amar Prakash, Anandavalli, N., Rajasankar, J., Mohit Verma and Nagesh R. Iyer, 'Impact damage detection and performance evaluation of multi-layered cementitious fibre composites', CSIR-SERC Research Report No. R&D 04–MLP 16941–RR-08 May 2013.

5. Anandavalli, N., Rajasankar, J., Amar Prakash, Mohit Verma and Nagesh R. Iyer, 'Blast response studies on sandwich panels with prismatic tube core', CSIR-SERC Research Report No. R&D 04-MLP 16941-RR-09, June 2013

6. Anoop, M.B., Balaji Rao, K., Kamatchi, P., Parivallal, S., Arun Sundaram, B., Ravisankar, K. and Nagesh R. Iyer, 'Determination of concrete creep compliance through multiscale modeling of concrete', CSIR-SERC Research Report No. R&D 04-MLP 15841-RR-06, July 2013

7. Arun Sundaram, B., Parivallal, S., Kesavan, K., Farvaze Ahmed, A.K., Vimal Mohan, Kathiresan, S. and Ravisankar, K., 'Measurement and acquisition using WiFi based wireless structural testing system', CSIR-SERC Research Report No. R&D 02-MLP 16541-RR-10, June 2013

8. Arun Sundaram, B., Parivallal, S., Kesavan, K., Farvaze Ahmed, A.K., Vimal Mohan and Ravisankar, K., 'Performance evaluation of WiFi based wireless structural testing system on a plate girder', CSIR-SERC Research Report No. R&D 02-MLP 16541-RR-11, July 2013

9. Balagopal, R., Prasad Rao, N., Rokade, R.P., Mohan, S.J. and Raghunathan, M.D., 'Design of 15 m roof top hybrid communication tower using 90º GFRP angles', CSIR–SERC Research Report No. R&D 04-MLP 15541-RR-16, June 2013.

10. Balagopal, R., Prasad Rao, N., Rokade, R.P., Mohan, S.J. and Raghunathan, M.D., 'A state-of-the-art-report on bolted joint damage assessment in transmission line towers', CSIR-SERC Research Report No. R&D 03- MLP 180 41-RR-02, January 2014

11. Balagopal, R., Prasad Rao, N., Rokade, R.P., Mohan, S.J. and Raghunathan, M.D., 'Design of 15 m roof top hybrid communication tower using 90^{o} GFRP angles', CSIR–SERC Research Report No. R&D 04-MLP 15541-RR-16, June 2013

12. Balagopal, R., Prasad Rao, N., Rokade, R.P., Mohan, S.J. and Raghunathan, M.D., 'Studies on GFRP tension members with hybrid connections', CSIR–SERC Research Report No. R&D 04-MLP 15541-RR-14, June 2013

13. Balaji Rao, K., Anoop, M.B., Kamatchi, P., Balasubramanian, S.R., Daniel Ronald Joseph, J., Vijaya Bhaskara, G.S., Parivallal, S., Arun Sundaram, B., Rama Raju, K., Ravisankar, K. and Nagesh R. Iyer, 'Development of risk-based methodologies for inspection/ maintenance scheduling of RCC/PSC

structural components', CSIR-SERC Research Completion Report No. R&D 04-MLP 15841-RR-07, September 2013

14. Balasubramanian, S.R., Sivakumar, P., Annie Peter, J., Jeyabal, C., Bhagavan, N.G., Madheswaran, C.K., Saibabu, S., Sivasubramanian, K. and Lakshmikandan, K.N., 'Review of literature and standards for testing of brick masonry specimens', CSIR-SERC Research Report No. CSIR800-MLP 17141-RR-02, July 2013

15. Bhagavan, N.G., Sivakumar, P., Jolly Annie Peter, Jeyabal, C., Madheswaran, C.K., Saibabu, S., Sivasubramanian, K., Balasubramanian, S.R. and Lakshmikandan, K.N., 'Experimental investigations on confined masonry shear wall, towards development of effective earthquake resistant construction system', CSIR-SERC Research Report No. CSIR800-MLP17141-RR-03, January 2014

16. Bharathi Priya, C., Rama Rao, G.V., Sreekala, R., Sathish Kumar, K., Madheswaran, C.K., Gopalakrishnan, N. and Muthumani, K., 'Damage mitigation of seismically excited structures using semi-active control – A state of the art report', CSIR-SERC Research Report No. R&D 01-MLP 17641-RR-01, July 2013

17. Bharathi Priya, C., Rama Rao, G.V., Sreekala, R., Sathish Kumar, K., Madheswaran, C.K., Gopalakrishnan, N. and Muthumani, K., 'Dynamic characterization of supplemental damping device made using magneto-rheological MR fluid', CSIR-SERC Research Report No. R&D 01-MLP 17641-RR-03, October 2013

18. Bharatkumar, B.H., Krishnamoorthy T.S., Ambily, P.S., Sundar Kumar, S., Ramesh, G., Bhashya, V. and Murugesan, M., 'Condition assessment of concrete in the SRP-II building at CPCL and recommendations for possible remedial measures', Report on Sponsored Research Project No. R&D 05-SSP13341-SR-01, October 2013

19. Bhashya, V., Sundar Kumar, S., Ramesh, G., Ambily, P.S., Bharatkumar, B.H., Krishnamoorthy, T.S. and Nagesh R. Iyer, 'Studies on recycled aggregate concrete from construction and demolition waste', CSIR-SERC Research Report No. R&D 05-MLP 16441-RR-9, June 2013

20. Bhashya, V., Sundar Kumar, S., Ramesh, G., Ambily, P.S., Prabat Ranjan Prem, Bharatkumar, B.H., Krishnamoorthy, T.S. and Nagesh R. Iyer, 'Mechanical and durability properties of recycled aggregate concrete made using heat treated recycled aggregates', CSIR-SERC Research Report No. R&D 05-MLP 164 41-RR-13, November 2013

21. Bhaskar, S., Ramanjaneyulu, K. and Nagesh R. Iyer, 'Condition assessment of masonry structures - A state-of-the-art review', CSIR-SERC Research Report No. R&D 02-MLP 17241-RR-01, July 2013

22. Bhaskar, S., Ramanjaneyulu, K., Prabakar, J. and Srinivasan, P., 'Service life prediction of reinforced concrete structures - A state-of-the-art review', CSIR-SERC Research Report No. R&D 02-MLP 17241-RR-02, January 2014

23. Bhuvaneshwari, B., Hemalatha, T. and Nagesh R. Iyer, 'Hydration studies on secondary cementitious materials in the presence of polycarboxylate superplasticizer', CSIR-SERC Research Report No. R&D 05–MLP175–RR-06, January 2014

24. Bhuvaneshwari, B., Maitri Mapa and Nagesh R. Iyer, 'Investigations of bio-calcite formation through biological and organic template approaches', CSIR-SERC Research Report No. R&D 05-MLP 17541-RR-02, July 2013

25. Bhuvaneshwari, B., Palani, G.S., Marimuthu, V. and Nagesh R. Iyer, 'Investigation of structural steel in different corrosive media', CSIR-SERC

Research Report No. R&D 03-MLP 16641-RR-17, December 2013

26. Bhuvaneshwari, B., Ramesh Kumar, V., Maheswaran, S., Saptarshi Samal and Nagesh R. Iyer, 'Functions of FRP composites and application of nanotechnology towards the failure interfaces', CSIR-SERC Research Report No. R&D 05-OLP 16341-RR-4, July 2013

27. Bhuvaneshwari, B., Saptarshi Sasmal and Nagesh R. Iyer, 'Hydration studies on Cement/CNT composites', CSIR-SERC Research Report No. R&D 05-OLP 16341-RR-1, January 2014

28. Bhuvaneshwari, B., Saptarshi Sasmal, Hemalatha, T. and Nagesh R. Iyer, 'Functionalisation of nano SiO2 and their functions during cement hydration', CSIR-SERC Research Report No. R&D 05-OLP 16341-RR-3, July 2013

29. Chitra Ganapathi, S., Keerthana, M., Abraham, A., Ramesh Babu, G., Harikrishna, P., Selvi Rajan, S., Nagesh R. Iyer, Krishna Kumar, S., Sasikala, K., Sankaranarayanan, K. and Muthalagan, V., 'Installation and performance evaluation of high speed pressure scanning system consisting of DTC pressure scanners', CSIR-SERC Research Report No. R&D 01–MLP 16841–RR-12, January 2014

30. Cinitha, A., Umesha, P.K., Marimuthu, V., Prabha, P., Saravanan, M., Palani, G.S., Surendran, M. and Nagesh R. Iyer, 'Behaviour of tubular joints subjected to elevated temperature effect and naturally cooled', CSIR-SERC Research report No.R&D 03-MLP 16641-RR-14, December 2013

31. Cinitha, A., Umesha, P.K., Marimuthu, V., Prabha, P., Saravanan, M., Palani, G.S., Surendran, M., Pandian, N. and Nagesh R. Iyer, 'Experimental investigation on tubular joints under compression', CSIR-SERC Research Report No. R&D 03-MLP 16641-RR-13, June 2013

32. Daniel Ronald Joseph, J., Prabakar, J., Bhaskar, S. and Lakshmikandhan, K.N., 'Light weight pre-engineered panels for building system - A state-of-the-art review', CSIR-SERC Research Report No. R&D 02-MLP 17341-RR-02, July 2013

33. Farvaze Ahmed, A.K., Ravisankar, K., Parivallal, S., Arun Sundaram, B. and Kesavan, K., 'Numerical studies on calibration factor of rectangular shaped flat jack for measuring in-situ stress in concrete members', CSIR-SERC Research Report No. R&D 02-MLP 16541-RR-12, July 2013

34. Gandhi, P., Pukazhendhi, D.M., Vishnuvardhan, S., Saravanan, M. and Raghava, G., 'Studies on fatigue and fracture behaviour of materials and components of sustainable structures', CSIR-SERC Research Completion Report No. R&D 03-MLP-14941-RR-11 September 2013

35. Gopalakrishnan, N., Muthumani, K., Sathish Kumar, K., Madheswaran, C.K., Sreekala, R., Rama Rao, G.V., Bharathi Priya, C. and Nagesh R. Iyer, 'Completion report on performance based approach for design of buildings with shear walls', CSIR-SERC Research Completion Report No. MLP 15441/07, July 2013

36. Harikrishna, P., Keerthana, M., Ramesh Babu, G., Abraham, A. and Selvi Rajan, S., 'Pressure measurement studies on 1:2:5 tall rectangular building model under open and suburban terrain conditions', CSIR-SERC Research Report No. R&D 01–MLP 16841–RR-10, July 2013

37. Hemalatha, T., Bhuvaneshwari, B. and Nagesh R. Iyer, 'Influence of sulfonate based superplasticizer during the hydration of cementitious system', CSIR-SERC Research Report No. R&D 05–MLP175–RR-07, January 2014

38. Hemalatha, T., Bhuvaneshwari, B., Maitri Mapa and Nagesh R. Iyer, 'Clay as potential

cementitious material- An overview', CSIR-SERC Research Report No. R&D 05-OLP 16341-RR-4, January 2014

39. Keerthana, M., Harikrishna, P., Ramesh Babu, G., Abraham, A. and Selvi Rajan, S., 'Probabilistic and correlation analysis of pressure data of 2:1 rectangular sectional model', CSIR-SERC Research Report No. R&D 01–MLP 16841–RR-07, July 2013

40. Lakshmi, K., Rama Mohan Rao, A., Goplakrishnan, N. and Nagesh R. Iyer, 'A damage diagnostic algorithm based on power spectral density for civil structures', CSIR–SERC Research Report No. R&D 02-MLP 15641-RR-05, July 2013

41. Lakshmikandan, K.N., Sivakumar, P., Annie Peter, J., Balasubramanian S.R., Sivasubramanian, K., Jeyabal, C., Bhagavan, N.G., Madheswaran, C.K. and Saibabu, S., 'Nonlinear finite element parametric study on funicular shell roofs', CSIR-SERC Research Report No. CSIR800-MLP 17141-RR-01, June 2013

42. Madheswaran, C.K., Bharathi Priya, C., Rama Rao, G.V., Sreekala, R., Sathish Kumar, K., Gopalakrishnan, N. and Muthumani, K., 'A state of the art report on retrofitting of seismically damaged reinforced concrete structures using geopolymer concrete composites', CSIR-SERC Research Report No. R&D 01-MLP 17641-RR-05, December 2013

43. Maitri Mapa, Bhuvaneshwari, B., Hemalatha, T., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Characterization of cement hydration process by various analytical techniques', CSIR-SERC Research Report No. R&D 05–MLP175–RR-05, December 2013

44. Maitri Mapa, Bhuvaneshwari, B., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Role of photo catalyst in cement and its various application', CSIR-SERC Research Report No. R&D 05-MLP 17541-RR-03, July 2013

45. Marimuthu, V., Palani, G.S., Saravanan, M., Surendran, M., Prabha, P., Cinitha, A. and Umesha, P.K., 'Numerical studies on cold-formed steel self-drilling screw beam-column connections', CSIR-SERC Research Report No. R&D 03-MLP 16641-RR-15, December 2013

46. Marimuthu, V., Palani, G.S., Surendran, M., Saravanan, M., Prabha, P., Umesha, P.K., Cinitha, A., Pandian, N. and Nagesh R. Iyer, 'Investigations on self-drilling screw lap joints and beam-column joint', CSIR-SERC Research Report No. R&D 03-MLP 16641-RR-12, June 2013

47. Mohit Verma, Rajasankar, J., Anandavalli, N., Amar Prakash and Nagesh R. Iyer, 'Controller synthesis in hybrid testing', CSIR-SERC Research Report No. R&D 04-MLP 16941-RR-11, December 2013

48. Mohit Verma, Rajasankar, J., Anandavalli, N., Amar Prakash and Nagesh R. Iyer, 'Experimental investigations on silica-based shear thickening fluids (STF)', CSIR-SERC Research Report No. R&D 04-MLP 16941-RR-07, May 2013

49. Nagesh R. Iyer, Bharatkumar, B.H., Bhaskar, S., Murugesan, M. and Jeyapaul, M., 'Fire damage assessment of concrete in the administrative block of DST, New Delhi and recommendations for possible remedial measures', Report No. R&D 02-DST-01, May 2013

50. Nawal Kishor Banjara and Srinivas, V., 'Experimental and numerical studies on shear deficient reinforced concrete beams', CSIR-SERC Research Report No. R&D 02–MLP167–RR–07, January 2014

51. Nawal Kishor Banjara and Srinivas, V., 'Studies on fatigue behaviour of plain concrete under compression loading', CSIR-SERC Research Report No. R&D 05-MLP 16741-RR-05, July 2013

52. Parivallal, S., Kesavan, K., Arun Sundaram, B., Farvaze Ahmed, A.K., Vimal Mohan

and Ravisankar, K., 'Damage assessment of structural elements using vibration based methodology for wireless sensor network', CSIR-SERC Research Report No. R&D 02-MLP 16541-RR-09, June 2013

53. Prabakar, J., 'Experimental demonstration building using light weight EPS panels', CSIR-SERC Research Report No. R&D 02-MLP 17341-RR-01, July 2013

54. Prabakar, J., Daniel Ronald Joseph, J., Bhaskar, S. and Lakshmikandhan, K.N., 'Connection and joints details of pre-engineered precast panels for building system- A state-of-the-art review', CSIR-SERC Research Report No. R&D-02-MLP 17341-RR-03, December 2013

55. Prabha, P., Marimuthu, V., Palani, G.S., Saravanan, M., Surendran, M., Cinitha, A. and Umesha, P.K., 'Numerical studies on axial compressive load behaviour of steel concrete composite light weight panels', CSIR-SERC Research Report No. R&D 03-MLP 16641-RR-16, December 2013

56. Prabha, P., Marimuthu, V., Saravanan, M., Surendran, M., Palani, G.S. and Nagesh R. Iyer, 'Structural analysis and design checking of coal silo and supporting structure', Report on Sponsored Research Project No. R&D 03-SSP13641-SR-01, December 2013

57. Prabhat Ranjan Prem, Bharatkumar, B.H. and Nagesh R. Iyer, 'Ultra high performance concrete and application on repair and retrofit of structures: A review', CSIR-SERC Report No. R&D 05-MLP 16441-RR-11, October 2013

58. Prameetthaa, J., Bharatkumar, B.H. and Nagesh R. Iyer, 'Experimental Investigation on reinforced recycled aggregate concrete beam with and without MBS', CSIR-SERC Report No. R&D 05 MLP 16441-RR-15, November 2013

59. Prameetthaa, J., Bharatkumar, B.H. and Nagesh R. Iyer, 'Relation between mechanical and durability properties of recycled aggregate concrete', CSIR-SERC Report No. R&D 05 MLP 16441-RR-14, November 2013

60. Prasad Rao, N., Rokade, R.P., Balagopal, R., Mohan, S.J. and Raghunathan, M.D., 'Completion report on analytical and experimental studies on GFRP- steel hybrid towers', CSIR–SERC Research Completion Report No. R&D 04-MLP 15541-RR-17, September 2013

61. Pukazhendhi, D.M., Gandhi, P., Saravanan, M., Vishnuvardhan, S. and Raghava, G., 'Static and fatigue behaviour of concrete beams reinforced with GFRP bars', CSIR-SERC Research Report No. R&D 03-MLP-14941-RR-10, July 2013

62. Rama Mohan Rao, A. and Lakshmi, K., 'Time series models for structural health monitoring', CSIR-SERC Research Report No. R&D-02-MLP 17741-RR-01, January 2014

63. Rama Mohan Rao, A., Lakshmi, K. and Gopalakrishnan, N., 'Robust damage diagnostic techniques for engineering structures using PCA and ICA', CSIR-SERC-ARDB Research Report No. ARDB-SP-TR-06-1523-03, May 2013

64. Rama Mohan Rao, A., Lakshmi, K., Gopalakrishnan, N. and Nagesh R. Iyer., 'Development of damage diagnostic strategies using distributed wireless smart sensors (Motes) for sustainable SHM', CSIR–SERC Research Completion Report No. R&D-02-MLP 15641-RR-06, September 2013

65. Rama Mohan Rao, A., Lakshmi, K., Goplakrishnan, N. and Nagesh R. Iyer, 'Optimal selection of boundary conditions for damage detection using pseudo tests', CSIR–SERC Research Report No. R&D 02-MLP 15641-RR-06, July 2013

66. Rama Mohan Rao, K., et al., 'Development of structural health monitoring schemes

for civil engineering infrastructure in India using smart sensing technologies', CSIR-SERC-NPMASS Research Report, R&D 01-GAP 043-SR03, December 2013

67. Rama Rao, G.V., Bharathi Priya, C., Sreekala, R., Sathish Kumar, K., Madheswaran, C.K., Gopalakrishnan, N. and Muthumani, K., 'Studies on seismic behavior of buckling restrained braces', CSIR-SERC Research Report No. R&D 01-MLP 17641-RR-04, October 2013

68. Ramanjaneyulu, K., et al., 'Performance evaluation of PSC slab bridge No. 163A(UP) under increased axle loads of freight wagons (Cycle-IV Measurements)', Sponsored Research Project Report No. R&D 04-SSP 07641-SR-16, July 2013

69. Ramanjaneyulu, K., et al., 'Performance evaluation of railway plate girder bridge No.145(UP) under increased axle loads of freight wagons (Cycle-IV Measurements)', Sponsored Research Project Report No. R&D 04-SSP 07641-SR-13, May 2013

70. Ramanjaneyulu, K., et al., 'Performance evaluation of railway plate girder bridge No. 145A(DN) under increased axle loads of freight wagons (Cycle-IV Measurements)', Sponsored Research Project Report No. R&D 04-SSP 07641-SR-14, May 2013

71. Ramanjaneyulu, K., et al., 'Performance evaluation of railway stone masonry arch bridge No. 42(DN) under increased axle loads of freight wagons (Cycle-IV Measurements)', Sponsored Research Project Report No. R&D 04-SSP 07641-SR-15, July 2013

72. Ramanjaneyulu, K., et al., 'Performance evaluation of reinforced concrete I-girder railway bridge No.44 (DN) near Ennore under increased axle loads of freight wagons (Cycle-I Measurements)', Sponsored Project Report No. R&D04-SSP076-SR-17, December 2013

73. Ramanjaneyulu, K., et al., 'Performance evaluation of reinforced concrete I-girder railway bridge No.44 (DN) near Ennore under increased axle loads of freight wagons (Cycle-II Measurements)', Sponsored Project Report No. R&D04-SSP076-SR-18, January 2014

74. Rokade, R.P., Mohan, S.J., Prasad Rao, N., Balagopal, R. and Raghunathan, M.D., 'Experimental studies on '9 m roof top hybrid communication tower using 60º GFRP angles', CSIR–SERC Research Report No. R&D 04-MLP 15541-RR-15, June 2013

75. Rokade, R.P., Prasad Rao, N., Balagopal, R., Mohan, S.J. and Raghunathan, M.D., 'State-of-the-art-report on high wind load models', CSIR-SERC Research Report No. R&D 03-MLP 180 41-RR-01, January 2014

76. Saptarshi Sasmal, Sindu, B.S. and Nagesh R. Iyer, 'Evaluation of effect of micro structure on the nano mechanical properties of cement clinkers using simulated nanoindentation technique', CSIR-SERC Research Report No. R&D 05-OLP 16341-RR-2, January 2014

77. Saptarshi Sasmal, Sindu, B.S. and Nagesh R. Iyer, 'Evaluation of nano-mechanical properties of cement clinkers using simulated nanoindentation', CSIR-SERC Research Report No. R&D 05-OLP 16341-RR-1, July 2013

78. Saravana Kumar, K. and Srinivas, V., 'Evaluation of damage using coupled field FE analysis of piezo sensor', CSIR-SERC Research Report No. R&D 02-MLP167-RR-06, January 2014

79. Sarayu, K., Maitri Mapa, Bhuvaneshwari, B., Hemalatha, T., Maheswaran, S., Ramachandra Murthy, A. and Nagesh R. Iyer., 'Biominerals and their applications in building materials – A critical review', CSIR-SERC Research Report No. R&D 05–MLP 17541–RR-01, July 2013

80. Sarayu, K., Ramachandra Murthy, A. and Nagesh R. Iyer, 'Characterization and utilization of phyto waste as a source of pozzolane', CSIR-SERC Research Report No. R&D 05–MLP175–RR-04, December 2013

81. Sathish Kumar, K., Gopalakrishnan, N., Muthumani, K., Madheswaran, C.K., Sreekala, R., Rama Rao, G.V., Bharathi Priya, C., Harish Kumaran, S., Prakashvel, J. and Vasudevan, P., 'Vibration study of high pressure valves (S12-Serial No: 002)', Report on Sponsored Research Project No. R&D 01-SSP 119-SR-01, August 2013

82. Sathish Kumar, K., Gopalakrishnan, N., Muthumani, K., Madheswaran, C.K., Sreekala, R., Rama Rao, G.V., Bharathi Priya, C., Harish Kumaran, S., Prakashvel, J and Vasudevan, P, 'Vibration study of high pressure valves (06-Serial No: 001)', Sponsored Research Project No. R&D 01-SSP 119-SR-02, August 2013

83. Sathish Kumar, K., Gopalakrishnan, N., Muthumani, K., Madheswaran, C.K., Sreekala, R., Rama Rao, G.V., Bharathi Priya, C., Harish Kumaran, S., Prakashvel, J and Vasudevan, P., 'Vibration study of high pressure valves (S13-Serial No: 001)', Sponsored Research Project No. R&D 01-SSP 119-SR-03, August 2013

84. Sathish Kumar, K., Gopalakrishnan, N., Muthumani, K., Madheswaran, C.K., Sreekala, R., Rama Rao, G.V., Bharathi Priya, C., Harish Kumaran, S., Prakashvel, J and Vasudevan, P, 'Vibration study of high pressure valves (S14-Serial No: 001)', Sponsored Research Project No. R&D 01-SSP 119-SR-04, August 2013

85. Sathish Kumar, K., Gopalakrishnan, N., Muthumani, K., Madheswaran, C.K., Sreekala, R., Rama Rao, G.V., Bharathi Priya, C., Harish Kumaran, S., Prakashvel, J and Vasudevan, P, 'Vibration study of high pressure valves (S14A1-Serial No: 001)', Sponsored Research Project No. R&D 01-SSP 119-SR-05, August 2013

86. Selvi Rajan, S., Keerthana, M., Harikrishna, P., Abraham, A. and Ramesh Babu, G., 'POD analysis of wind loads on a gable roof low-rise building', CSIR-SERC Research Report No. R&D 01–MLP 16841–RR-08, July 2013

87. Sindu, B.S., Saptarshi Sasmal and Nagesh R. Iyer, 'Atomistic simulation of nano materials for evaluation of the mechanical properties', CSIR-SERC Research Report No. R&D 05-OLP 16341-RR-2, July 2013

88. Sindu, B.S., Saptarshi Sasmal and Nagesh R. Iyer, 'Molecular dynamics simulation for determination of the mechanical properties of nano composites', CSIR-SERC Research Report No. R&D 05-OLP 16341-RR-3, January 2014

89. Smitha Gopinath, Ramachandra Murthy, A., Maheswaran, S., Bashya, V. and Nagesh R. Iyer, 'Review on methodologies for composites laminae production', International Collaborative Project Report No. R&D 05 – CLP 00541–RR-01, June 2013

90. Sreekala, R., Bharathi Priya, C., Rama Rao, G.V., Sathish Kumar, K., Madheswaran, C.K., Gopalakrishnan, N. and Muthumani, K., 'Dynamic characterization of supplemental damping device made using shape memory alloy SMA', CSIR-SERC Research Report No. R&D 01-MLP 17641-RR-02, September 2013

91. Srinivas, V., Saptarshi Sasmal, Saibabu, S., Saravana Kumar, K., Nawal Kishor Banjara, Annie Peter, J. and Nagesh R. Iyer, 'Fatigue strength evaluation of precast prestressed concrete beams', Sponsored Research Project Report No. R&D 04–SSP0109–SR–01, April 2013

92. Srinivasan, P. and Murthy, S.G.N., 'State of the art in the automated scanning for NDT in concrete', CSIR-SERC Research Report No. R&D-02 CLP 0041-RR-01, December 2013

93. Srinivasan, P., Bharatkumar, B.H., Prabakar, J., Ramanjaneyulu, K., Bhaskar, S., Nagesh R. Iyer and Ramesh, G., 'Condition assessment of civil structures of main plant buildings & SEF structures of RAPS 3 & 4', Sponsored Research Project Report No. SSP 12041, July 2013

94. Srinivasan, P., Prabakar, J., Bhaskar, S., Sivasubramanian, K., Kanchana Devi, A., Ramanjaneyulu, K., Ravisankar, K., Bharatkumar, B.H., Murthy, S.G.N. and Nagesh R. Iyer, 'Development of methods for characterisation of sustainable materials and damage evaluation of RC structures using forensic analysis', CSIR-SERC Research Completion Report No. R&D 02-OLP 15241-RR-06, April 2013

95. Srinivasan, P., Saibabu, S., Bhaskar, S, Ramanjaneyulu, K. and Nagesh R. Iyer, 'Condition assessment of converter & ID fan foundation (Unit-1) of Visakhapatnam Steel Plant, Visakhapatnam', Sponsored Research Project No. SSP-13141, October 2013

96. Srinivasan, P., Saibabu, S., Prabakar, J., Ramanjaneyulu, K., Bhaskar, S. and Nagesh R. Iyer, 'Condition assessment of converter & ID fan foundation of Visakhapatnam steel plant, Visakhapatnam', Sponsored Research Project Report No. SSP-12641, July 2013

97. Sundar Kumar, S., Ambily, P.S., Bharatkumar, B.H. and Nagesh R. Iyer 'A review on recent developments in alkali activated concretes', CSIR-SERC Report No. R&D 05-MLP 16441-RR-10, October 2013

98. Sundar Kumar, S., Bhashya, V. and Bharatkumar, B.H., 'An experimental study on notched steel fibre reinforced geopolymer concrete beams in flexure', CSIR-SERC Research Report No. R&D 05-MLP 16441-RR-12, November 2013

99. Thirumalaiselvi, A., Anandavalli, N., Rajasankar, J., Amar Prakash, Mohit Verma and Nagesh R. Iyer, 'Laced steel-concrete composite slab for blast protection: numerical studies', CSIR-SERC Research Report No. R&D 04-MLP 16941-RR-12, January 2014

100. Vijaya Bhaskara, G.S., Balaji Rao, K., Anoop, M.B., Ramesh Kumar, V., Kamatchi, P., Srinivas, V., Sindu, B.S. and Nagesh R. Iyer, 'Critical evaluation of procedures for mix proportioning of concrete with fly ash', CSIR-SERC Research Report No. R&D 06-MLP 179-RR-01, January 2014

101. Vijayalakshmi, S., Sundaramoorthi, A., Ananthakrishnan, G.V., Surya, E., Palani, G.S., Rajasankar, J. and Nagesh R. Iyer, 'State-of-the-art review on intelligent system for smart sustainable buildings', CSIR-SERC Research Report No. R&D 05-MLP 17041-RR-01, June 2013

102. Vimal Mohan, Parivallal, S., Kesavan, K., Arun Sundaram, B., Farvaze Ahmed, A.K. and Ravisankar, K., 'Damage detection using frequency change correlation approach', CSIR-SERC Research Report No. R&D 02-MLP 16541-RR-13, July 2013

103. Vishnuvardhan, S., Raghava, G., Gandhi, P. and Saravanan, M., 'Corrosion fatigue crack growth and life evaluation in low-carbon steels: Experimental studies and numerical modeling - A state-of-the-art review', CSIR-SERC Research Report No. R&D 03-MLP 18141-RR-01, January 2014

104. Vishnuvardhan, S., Raghava, G., Gandhi, P., Saravanan, M. and Muthuramalingam, G., 'Static and fatigue studies on indigenous bearing material M50 alloy steel', Sponsored Research Project (Completion) Report No. R&D 03-SSP 10641-SR-03, November 2013

105. Vishnuvardhan, S., Saravanan, M., Raghava, G., Gandhi, P. and Muthuramalingam, G., 'Static and fatigue studies on indigenous bearing material

M50 alloy steel', Sponsored Research Project Report No. R&D 03-SSP 10641-SR-02, October 2013

DEPUTATION / TRAINING

Abroad

1. Dr. G. Raghava, Chief Scientist, nominated as a Member of the Indian delegation for Exposure Visit to Germany during May 27-31, 2013.

Dr G. Raghava (left side) at the Fraunhofer Head-quarters, Munich

2. Shri G. Ramesh, Junior Scientist attended 11th International Symposium on Fiber Reinforced Polymers for Reinforced Concrete Structures (FRPRCS-11) , held at University of Minho, Portugal during June 26-28, 2013.

3. Ms. K. Balamonica, Mr. Abhishek Kumar, Ms. Smriti Raj, Ms. A. Thirumalaiselvi, Ms. J. Prameetthaa, PGRPE Quick Hire Scientists (Trainees) attended the International Conference on Advances in Civil, Structural and Mechanical Engineering (CSM-2013) held at Hong Kong, China during August 3-4, 2013.

4. Dr. N. Anandavalli, Principal Scientist, attended Multiscale Modelling Course for Concrete at Delft University, The Netherlands, during October 21-25, 2013.

5. Shri P. Srinivasan, Senior Principal Scientist, attended Indian delegate to the 20th Plenary Meeting of ISO / TC 71 and its Sub-committees held at Sydney, Australia during January 28-31, 2014.

India

1. Shri S. Sundar Kumar, Shri A.K. Farvaze Ahmed, Shri Arun Sundaram, Scientists and Shri J. Daniel Ronald Joseph, Junior Scientist attended the International Conference on Global Innovations in Technology and Sciences, Kotayam, Kerala, April 4-6, 2013.

2. Shri A. Sundaramoorthi, Senior Technical Officer, attended the National Conference on Recent Trends in Library and Information Sciences, Hindustan University, Chennai, April 12-13, 2013.

3. Dr. M. Mymoon, Senior Technical Officer, Smt. R Lakshmi Poorna, Technical Assistant, attended the Springers Database Summit on Databases, April 15, 2013.

4. Dr. C.K. Madheswaran, Principal Scientist, attended the National Conference on 'ENTROIDOS 2013', Virudhunagar, April 16-17, 2013.

5. Dr. N. Prasad Rao, Dr. M.B. Anoop, Principal Scientists, attended Leadership Development Programme at CSIR-HRDC, Ghaziabad, May 29-June 08, 2013.

6. Shri V. Bhashya, Scientist, attended the International Conference on Engineering Materials and Processes, Chennai, May 23-24, 2013.

7. Smt. S. Vijayalakshmi, Senior Technical Officer, and Shri G.V. Ananthakrishnan, Technical Assistant, attended the National Symposium on Recent Advances in Cyber Security, Bangalore, June 6-7, 2013.

8. Smt. K. Sasikala, Senior Technical Officer, attended the Short Term Course on JAVA Chennai, June 17-22, 2013.

9. Dr. J. Rajasankar, Chief Scientist, and Dr. G.S. Palani, Senior Principal Scientist, attended the Seminar on Big Data and Analysis, Chennai, June 26, 2013.

10. Dr. K. Rama Raju, Chief Scientist, Shri A.K. Farvaze Ahmed, and Shri Prabhat Ranjan Prem, Scientist attended the Seminar on Design and Analysis of Systems using MATLAB & Simulink, Chennai, July 04, 2013.

11. Smt. R. Sreekala, Senior Scientist, Smt. Smitha Gopinath and Smt. K. Lakshmi, Scientist, attended workshop on Patent Drafting, Chennai, July 15-17, 2013.

12. Shri Nawal Kishor Banjara, Scientist attended the Course on Fatigue and Fracture of Advanced Materials, Roorkee, July 20-23, 2013

13. Smt. Chitra Sankaran, Senior Technical Officer, attended the International Conference on Recent Trends in Information Technology, Chennai, July 25-27, 2013.

14. Shri V. Bhashya, Scientist, and Shri G. Ramesh, Junior Scientist, attended the Workshop on Construction and Demolition Waste Recycling, Chennai, August 5-6, 2013.

15. Shri R.D. Sathish Kumar, Senior Technical Officer, attended the Conference on 'Next Generation Library Services',Chennai, 16- 17 August, 2013

16. Dr. P. Harikrishna, Principal Scientist, and Shri A. Abraham, Senior Scientist, attended the National Conference on 'Wind Tunnel Testing (NCWT-03)', Thiruvanathapuram, August 23- 24, 2013.

17. Shri M. Palanisamy, Shri S. Kannappan, and Shri J. Govindarajulu attended the Programme on Supply Chain Management in R & D organisations and CSIR Purchase Procedure, Ghaziabad, August 19-23, 2013.

18. Dr.R.Manisekar, Shri K. Sivasubramanian, Senior Scientists, and Shri G.V. Rama Rao, Scientist, attended the Fourth International workshop on 'Performance, Protection and Strengthening of Structures under Extreme Loading', Mysore, August 26- 27, 2013.

19. Dr. G.S. Palani, Senior Principal Scientist, Dr. J. Prabakar, Principal Scientist, and Shri A. Sundaramoorthy, Senior Technical Officer, attended the All India Seminar on Structural Aspects of Architectural Engineering in Property Development, Chennai, September 20-21, 2013.

20. Dr. S. Bhaskar, Principal Scientist, and Dr. A. Cinitha, Scientist, attended the International Corrosion Conference & Expo,New Delhi, September 30–October 03, 2013.

21. Smt. K. Sasikala, Technical Officer attended the National Workshop on Rapid Miner: A Data Mining Tool at VIT,Chennai, October 05, 2013.

22. Shri M. Saravanan, Scientist, attended the Training Programme on Communication and Presentation Skills, Institute of Management Training and Research, Goa, October 21-25, 2013

23. Dr. M. Mymoon, Technical Officer, attended the National Seminar on Bridging the Knowledge Access Gap – Integrating Content, Technology and Services, Chennai, October 21, 2013.

24. Smt. M. Vani Satyanarayana, Hindi Officer, attended the Training Programme on Rajbhasha Kaaryanvayan-Ek Naya Drushtikon at Human Resource Development Centre, Ghaziabad, October 24-26, 2013.

25. Dr. P. Srinivasan, Senior Principal Scientist, attended the Asia Pacific Conference on Non Destructive Testing, Mumbai, November 18-22, 2013.

26. Shri S. Maheswaran, Senior Scientist, attended the International Conference on Structural and Physical Properties of Solids, Dhanbad, November 18-20, 2013.

27. Smt. K. Sasikala, Senior Technical Officer, attended the International Conference on Mathematical Computer Engineering, Chennai, November 29-30, 2013

28. Shri V. Srinivasan, Senior Scientist, attended the International Conference on Disaster Mitigation and Management towards Sustainable Development, Vallam, December 02-04, 2013.

29. Ms. B. S. Sindu, Scientist, and Ms. B. Bhuvaneshwari, Senior Project Fellow, attended the 6th Bangalore India NANO 2013, Bangalore, December 4-6, 2013

30. Dr. K. Ravisankar, Dr. K. Muthumani, Dr. S. Selvi Rajan, Dr. A. Rama Mohan Rao, Dr. K. Rama Raju, Dr. K. Balaji Rao, Dr. N. Gopalakrishnan, Chief Scientists, Dr. G.S. Palani, Dr. K. Sathish Kumar, Senior Principal Scientists, Dr. P. Harikrishna, Dr. N. Prasad Rao, Shri G. Ramesh Babu, Dr. P. Kamatchi, Dr. M.B. Anoop, Principal Scientists, Shri A. Abraham, Senior Scientist, Ms. S. Chitra Ganapathi, Ms. K. Lakshmi, Shri R. Balagopal, Ms. C. Bharathi Priya, Ms. M. Keerthana, Ms. K. Bala Monica, Scientists, Ms. K. Sasikala, Shri V. Muthalagan, Shri K. Sankaranarayanan, Shri K. Krishna Kumar, Senior Technical Officers, attended the APCWE-VIII, December 10-14, 2013.

31. Shri R.P. Rokade, Senior Scientist, and Shri R. Balagopal, Scientist, attended the National Conference on Recent Trends in Overhead Transmission Lines, Bangalore, December 19-20, 2013

32. Shri Prabhat Ranjan Prem, Scientist, Ms. Prameetthaa, and Ms. K. Balamonica, Ph.D students attended the International Workshop on Recent Advances in Civil Engineering, Hyderabad, January 3-4, 2014

33. Smt. M. Annaselvi, Senior Technical Officer, and Ms E. Surya, Technical Assistant, attended the Training Programme on Cloud Computing, MSME Development Institute, Chennai, January 6-10, 2014.

34. Shri A. Abraham, Senior Scientist, Shri M. Saravanan and Mrs. Keerthana, Shri Prabhat Ranjan Prem, Scientists, Ms. K. Balamonica, Quick Hire Scientist attended the International Conference on Disaster Management, Chennai, January 23-24, 2014.

35. Dr. G. Raghava, Chief Scientist, Dr. M.B. Anoop, Principal Scientist, Dr. S. Vishnuvardhan, Dr. A. Cinitha, Ms. K. Lakshmi, Shri Vimal Mohan, Scientists and Mr Abhishek Kumar, Research Scholar attended the 1st International Conference on Structural Integrity, Kalpakkam, February 4-7, 2014

36. Shri N. G. Bhagavan, Senior Principal Scientist, Dr. C.K. Madheswaran, Dr. V. Srinivas, Principal Scientists, Dr. Saptarshi Sasmal, Senior Scientist, Dr. S. Bhaskar, Principal Scientist , Shri S. Sundar Kumar, V. Bhashya, Dr. T. Hemalatha, Scientists, Ms. Maitri Mapa, QHS, Ms. B. Bhuvaneshwari, SPF attended the 4th International FIB Congress 2014, Mumbai, February 10-14, 2014

37. Shri S.R. Balasubramanian, Scientist, attended the Short Course on Seismic Design of Reinforced and Confined Masonry Buildings, Gandhinagar, February 17-21, 2014

38. Dr. T. Hemalatha, Scientist, and Ms. Prameetthaa, QHS Trainee, attended the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials, Chennai, March 13-14, 2014

ADVANCED COURSES ORGANISED

Advanced Course on Sustainable Engineered Concrete (SECON 2014)

An Advanced Course on Sustainable Engineered Concrete (SECON 2014) was organized by CSIR-SERC during February 5-7, 2014. The objective of the course was to familiarize the participants with the various sustainable materials, synthesis of binder and aggregate from waste materials, preparation of recycled aggregate concrete, bio-mineralization towards development of bio-concrete, usage of fibers and textiles in concrete and evaluation of mechanical properties and durability aspects.

Prof. Herbert Wiggenhauser, BAM, Berlin, Germany

The course was attended by 70 participants from different parts of the country, comprising of academicians, research scholars, students and practising engineers from public and private sector organizations. Prof. Herbert Wiggenhauser, Head, NDT in Civil Engineering, BAM, Berlin, Germany, was the Chief Guest for the inaugural function held on February 05, 2014. He delivered the inaugural lecture on "NDE of Thick and Highly Reinforced Concrete Structure: State of the Art".

Prof. N. Rajagopalan at Valedictory Function

The Valedictory function was held on February 07, 2014 and Prof. N. Rajagopalan, Retd. Professor, IIT Madras, Chief Technical Advisor, L&T Ramboll Consulting Engineers Ltd., and Chairman, Research Council, CSIR-SERC, was the Chief Guest. He delivered the Valedictory Lecture on "Variations in Structural Concrete - A demand for Sustainability" and distributed the course certificates to the participants. The course coordinators for this programme were Dr. B.H. Bharatkumar and Dr. A. Ramachandra Murthy.

Advanced Course on Seismic Response Control and Damage Mitigation Methodologies for Buildings and Structures

An advanced course on Seismic Response Control and Damage Mitigation Methodologies for Buildings and Structures was organized by CSIR-SERC during 19-21 February 2014. A total of 72 participants drawn from Government organizations, public and private sector organizations and educational institutions (faculty, research scholars and students) have attended the course.

Dr. Nagesh R. Iyer delivering the inaugural lecture

The course was inaugurated by formally Dr. Nagesh R. Iyer, Director, CSIR-SERC with an inaugural lecture titled 'Efficient Methodologies for Dynamic Response of Structures'. This was followed by thirteen lectures delivered by eminent scientists of the center on various topics of seismic response control damage mitigation of buildings and structures including application of passive, active, semi-active and base isolation strategies; application of smart materials for seismic response control; retrofit

technologies for seismic damage control; design methodologies for multi-hazard and contemporary seismic testing and evaluation methods.

Participants visiting ASTaR laboratory

Laboratory visits and conceptual demonstrations were arranged for the participants to get a better understanding on the modern state- of-the-art testing facilities established at Advanced Seismic Testing and Research Laboratory and Wind Engineering Laboratory.

Dr. Ravindra Gettu, Professor, IIT- Madras, was the Chief Guest for the valedictory function on February 21, 2014 and he delivered a valedictory lecture on 'Principles of Repair and Retrofitting'.

EIGHTH ASIA-PACIFIC CONFERENCE ON WIND ENGINEERING (APCWE-VIII)

The Eighth Asia-Pacific Conference on Wind Engineering (APCWE-VIII) was organised by CSIR-Structural Engineering Research Centre (SERC) at Chennai, during 10th to 14th December, 2013, under the Chairmanship of Prof. Nagesh R. Iyer, Director, CSIR-SERC. The conference has its legacy starting with the first event held at Roorkee/India (1985), moving to Beijing/China (1989), Hong Kong/China (1993), Gold Coast/Australia (1997), Tokyo/Japan (2001), Seoul/Korea (2005) and Taipei/Taiwan (2009). The conference is convened every four years and CSIR-SERC had the privilege of hosting the event in India after 28 years. The Patron of the conference was Prof. Samir K. Brahmachari, Director General, CSIR, and Secretary, DSIR, Government of India. The international scientific advisory board had experts in the field of wind engineering.

The conference was conducted at Hotel Green Park, Chennai. The ice-breaking session on 10th December 2013, involved informal introduction and interaction among delegates. There were 298 registered participants including 124 students representing 16 countries.

A total of 161 technical papers, grouped under 13 technical themes were finally accepted for publication, out of 198 technical papers received. The 4-page extended abstracts were published in hard copy form in Proceedings and the full-length papers were published in soft copy form in a flash drive. A souvenir containing messages for the conference from eminent personalities and a directory of wind tunnel facilities in India was also brought out. The papers were grouped under thirteen conference themes.

The conference was inaugurated by the Chief Guest, Honourable Member, National Disaster Mitigation Authority (NDMA) Shri Bhattacharjee in traditional manner by lighting the lamp. Prof. Nagesh R. Iyer, Chairman, APCWE-VIII welcomed the participants and media personnel and briefed the gathering about the significance of the conference. He also emphasised the fact that the world is focussing on harnessing Wind Energy as well as mitigating the effects of cyclonic wind storms and other extreme wind events. Honourable Member, NDMA, Shri Bhattacharjee delivered the inaugural address, wherein he mentioned about the role of modern technology in providing early warning systems during cyclones, which could greatly facilitate in reducing loss of human lives. He also stated the fact that cyclone shelters constructucted along the coastal regions had saved lives of lakhs of people even during recent cyclone "Phailin" in India. The inaugural function had Prof. Yukio Tamura, President, International Association for Wind Engineering (IAWE) and Prof. Prem Krishna, Founder President, Indian Society for Wind Engineering and Vice-President, Indian National Academy of Engineering (INAE) as guests of honour. Prof. Yukio Tamura briefed about vaiours activities in the field of wind engineering at international level, while Prof. Prem Krishna discussed about the Past, Present and Future of Wind Engineering. The conference proceedings was released by the Chief Guest.

Chief Guest, Honourable Member NDMA Shri Bhattacharjee lighting the lamp

Release of Conference Proceedings

Prof. Kishor C. Mehta delivering valedictory address

A cultural program featured Bharata Natyam, a classical dance form of Tamil Nadu was organised which followed 20 year celebration of ISWE.

The technical sessions were followed by the official valedictory function of the conference. The Chief Guest of the valedictory function was Prof. Kishor C. Mehta Director, Hazard Mitigation and Structural Engineering Program, National Science Foundation, USA. In the valedictory address, he emphasised three key aspects, viz, "resilience, adaptability and sustainability" to be considered by young researchers in their future as these three parameters would lead to better environment. Prof. Nagesh R. Iyer, Chairman, APCWE-VIII, briefed about the intense knowledge sharing that took place during the conference, giving it a completely new dimension. He also mentioned that every presentation was being assessed for probable publication in the Journal of Wind Energy as well as Journal of Structural Engineering.

NATIONAL TECHNOLOGY DAY

National Technology Day was celebrated in CSIR-SERC on May 13, 2013. Dr. K. Ravisankar, Chief Scientist & Advisor (Management), CSIR-SERC, presided over the function and in his presidential address he emphasized that the challenge before science today is to make significant improvement in the technological design and development.

Dignitaries - National Technology Day

Two lectures were delivered on 'Social Media and Related Technologies for Emergency Readiness' by Dr. Carmalin Sophia, Scientist, CSIR- NEERI, and 'Promise of Terahertz Technology and Applications in Imaging, Spectroscopy and Non-destructive Testing' by Dr. Bala Pesala, Senior Scientist, CSIR-CEERI.

CSIR-SERC FOUNDATION DAY

The CSIR-SERC Foundation Day was celebrated on June 10, 2013 at CSIR campus, Chennai. The function was presided over by Dr. Nagesh R. Iyer, Director, CSIR-SERC and Coordinating Director, CMC, Chennai. Shri S.A. Reddi, Ex. Deputy Managing Director, Gammon India Ltd., Bangalore was the Chief Guest and delivered the Prof. G.S. Ramaswamy Memorial Lecture on 'Sustainable Concrete for 21st Century'.

CSIR-SERC Foundation Day-Director felicitating Chief Guest

Director presenting Certificate of Appreciation for excellence in Business Development

The Director gave away Certificates of Appreciation and cash awards to different categories of employees for achieving Excellence in Business Development of CSIR - SERC. He also felicitated the octogenarian members of the CSIR family with a Citation and Silver Plaque.

CSIR FOUNDATION DAY

Seventy-first CSIR Foundation Day was celebrated on September 26, 2013 at CSIR Campus, Taramani, Chennai, by CSIR-Structural Engineering Research Centre (CSIR-SERC) and the Regional Units of CSIR-CECRI, CSIR-CEERI, CSIR-CSIO, CSIR-NEERI and CSIR-NML.

OPEN DAY was observed in the morning hours and as many as 6,200 persons comprising of students, faculty from about 70 Engineering Colleges/ Polytechnics, University Departments, senior secondary schools, employees of Corporate Sectors and Government Institutions visited the Campus. They had first-hand information on the multifarious and multi-disciplinary R & D programmes and on-going projects, and state-of-the-art facilities of various laboratories.

A multimedia video documentary covering the scientific activities of CSIR-SERC and CMC was projected in the Lecture Hall for the benefit of visitors.

Students observing explanation at WEL

The CSIR Foundation Day Function was held at the Vigyan Auditorium of this Centre. Prof. Nagesh R. Iyer, Director, CSIR-SERC & Co-ordinating Director, CMC welcomed the gathering. In his speech, he reiterated that once again it is time for preparing to meet challenges, find new opportunities to grab and work hard with dedication and commitment. He also listed some of the individual and institutional glories brought to this campus during the year.

CSIR Foundation Day

Dr. Manamohan R. Kalgal, Senior Vice President, Ultra Tech Cement Ltd., Bengaluru was the Chief Guest. Dr. Manamohan R. Kalgal in his special lecture on "Appropriate Technologies for Rural India - R&D needs" explained the rural housing construction technologies developed by various CSIR Laboratories and other research institutions.

Dr.Manamohan R. Kalgal gave away the "Dr. M. Ramaiah Prize" for the best technical paper published by the Scientists of CSIR-SERC during the year 2012-13.

Prof. Nagesh R. Iyer, Director, honoured the retirees with Samman Patra, shawl and wrist watches. Staff members who had completed 25 years' service in CSIR were also recognized by presenting them with wrist watches. Director also presented cash award for the wards of CSIR-SERC & CMC staff members, who had secured more than 90% marks in three science subjects in 12th Standard. Inter-School Science Quiz Eureka 2013 conducted on September 17, 2013 with Shri V.V. Ramanan of Hindu as Quiz Master. Director, CSIR-SERC and Co-ordinating Director, CMC gave away the glittering shields for the schools and cash prizes for the individual prize winners.

Shri V.V. Ramanan conducting Science Quiz Eureka 2013

Dr. K. Ravisankar, Advisor(M) gave away prizes to the wards of CSIR-SERC and CMC staff members who had participated in various Science competitions.

NATIONAL SCIENCE DAY

National Science Day function was celebrated in CSIR-SERC & CMC on February 28, 2014 at Vigyan Auditorium, CSIR Campus. Dr. Nagesh R. Iyer, Director, CSIR-SERC and Co-ordinating Director, CMC, welcomed the Chief Guest and addressed the gathering.

Dr. K. Ravisankar, Chief Scientist & Advisor (M), introduced the Chief Guest to the audience. Prof. M.S. Swaminathan, Founder Chairman and Chief Mentor, UNESCO Chair in Ecotechnology, M.S. Swaminathan Research Foundation, Chennai, delivered the National Science Day Lecture on "The Zero Hunger Challenge : Achieving the Right to Food for All".

Prof. M. S. Swaminathan with Director and Advisor (M) - National Science Day

HINDI FORTNIGHT CELEBRATIONS

Hindi Fortnight 2013 was celebrated in CSIR Campus from August 26 - September 16, 2013. During the fortnight, Hindi typing & stenography, conversation in Hindi, Hindi writing, Hindi antakshari and Hindi quiz competitions were organized for the staff members of CSIR-SERC and CMC. To ensure more participation and effective implementation of the Official Language policy in the Campus, the participants were categorised into various groups keeping in view their academic qualification in Hindi and their mother tongue. As a part of the Hindi Fortnight Celebrations, an invited lecture on "Knowing your Inner Self" was delivered by Shri. Premshankar Kamble, IT Consultant on August 02, 2013. A Hindi workshop was conducted for all scientists of CSIR-SERC and CMC by Shri R. Gnanasekharan, Assistant Director, Directorate of Census Operations, Chennai on the topic "Census and National Population Register (NPR)" on August 03, 2013. A cultural programme by the staff of CSIR-SERC and CMC was organised on September 05,2013. The valedictory function of Hindi Fortnight celebrations 2013 was organised on 16th September, 2013. Prof. Nagesh R. Iyer, Director, CSIR-SERC presided over the function Shri A. L. Prabhakar, IRSS, Senior EDP Manager, Southern Railway, Chennai, was the Chief Guest and delivered the Hindi Day lecture. He also released the in-house Hindi magazine "SPANDAN" on this occasion. The Chief Guest and the Director, CSIR-SERC presented the prizes to the winners of the competitions. Six officials of CSIR-SERC also won cash prize for writing 5000 words in Hindi in official notings,

correspondence, for writing a scientific paper and also making power point presentation in Hindi.

Release of Hindi in-house magazine "SPANDAN" by the Chief Guest Shri A. L. Prabhakar

THE VIGILANCE AWARENESS

Vigilance Awareness Week was observed at CSIR-SERC and CMC. As part of this, Vigilance Awareness pledge was administered by Director, CSIR-SERC on October 28, 2013. Shri C.N. Ramdas, IAS., Retired Secretary Govt. of India & Chairman, GNG Group had delivered a special lecture on "Promoting Good Governance – Positive Contribution of Vigilance" on October 30, 2013.

Chief Guest Shri C.N. Ramdas, IAS., Retired Secretary of Govt. of India Delivering the Special Lecture

Shri Ramdas, drew on his rich administrative experience in the Govt. of India and Govt. of Tamil Nadu. He related examples of using Govt. organizations for vigilance free execution of urgent works and cited the intervention of the Border Road Organisations in the efficient restoration of roads in the Nilgiris, due to rainfall/ landslide. Banners were displayed during the Vigilance Awareness Week in the Campus.

THE INTERNATIONAL WOMEN'S DAY

International Women's Day was celebrated in CSIR-SERC on March 10, 2014. Dr. (Ms.) N. Anandavalli, Principal Scientist, CSIR-SERC welcomed the Chief Guest, Ms. Romaine San Francesco, Samarpan Foundations, Chennai. She highlighted the importance of change required for equality for women. Smt. P. Chenthamarai Selvam, Senior Principal Scientist, CSIR-CSIO introduced the chief guest to the audience.

Ms. Romaine San Francesco with women employees of CSIR-SERC & CMC

Ms. Romaine San Francesco in her address, mentioned about the activities of the Samarpan Foundation and involvement of women in her organisation. She also highlighted the initiatives taken by the Foundation towards water retention by planting Mangroove trees and mosquito eradication followed by a presentation on the use of pet bottles in construction of Green Buildings.

During the function, it was mentioned that Dr. Chenthamarai Selvam, Senior Principal Scientist, CSIR - CSIO, Dr. N. Anandavalli, Principal Scientist, CSIR - SERC, Smt. Smitha Gopinath, Scientist, CSIR - SERC and Dr. Carmalin Sophia Ayyappan, Scientist, CSIR - NEERI were recognised as one among the 50s of 'India's most inspiring women scientists and engineers' for their exemplary work in the field of Science and Technology. The award instituted by by 'Engineering Watch', one of India's most prestigious magazine dedicated to Engineering Community was presented at New Delhi on 8th March 2014.

Vote of thanks was proposed by Ms. Chitraleka Krishnan, COA, CSIR-CMC.

HONOURS/AWARDS/ DEGREE CONFERMENTS

1. Dr. V. Srinivas, Principal Scientist, has successfully completed his doctoral thesis work entitled 'Structural Damage Assessment Based on Vibration Characteristics' from Annamalai University.

2. The research paper entitled 'Nonlinear Finite Element Analysis of FRP Strengthened Reinforced Concrete Beams', published in Series 'A' Journal of Institution of Engineers, India (IEI), Vol. 93, Issue 4, 2013 authored by Saptarshi Sasmal, S. Kalidoss and V. Srinivas has been selected for the E.P.NICOLAIDES Prize.

3. Shri Mohit Verma was awarded the Fulbright Nehru Fellowship, USA.

4. The technical paper titled 'Assessment of chloride induced corrosion of steel in concrete using half-cell potential and resistivity methods' (Authors: Bhaskar, S., Bharatkumar B.H. and Ravindra Gettu) presented by Bhaskar, S., adjudged as the best paper award in the symposium of Reinforced concrete in International Corrosion Conference, CORCON 2013 during September 30 – October 03, 2013 at New Delhi, India.

5. Dr. Saptarshi Sasmal has been selected as a Member of the Editorial board of Structural Engineering and Mechanics, an International Journal

6. Dr. P. Kamatchi visited the Department of Structural Engineering, University of California, San Diego under Raman Research Fellowship during the period August 2013-November 2013.

7. The Dr Jai Krishna Prize for best paper award was conferred on the paper, 'Experimental and analytical studies on use of Magnetorheological dampers fitted with scissor jack mechanism' by K. Rama Raju, Alexander Jame, S.P.N. Shanmugam and Jemimah Carmichael.

Dr. K. Rama Raju receiving the Dr. Jai Krishna Prize

8. Dr. Jai Krishna Prize for the research paper entitled 'Experimental Investigations on Effect of Damage on Vibration Characteristics of a Reinforced Concrete Beam', published in Series 'A' Journal of Institution of Engineers, India (IEI), Vol. 93 Issue 1, 2013 by Srinivas V., Antony Jeyasehar C., Ramanjaneyulu K., Saptarshi Sasmal, was presented at the Prize Distribution Ceremony of the 28th Indian Engineering Congress held in Chennai on December 20, 2013.

9. The paper titled 'Development and determination of mechanical properties of fly ash and slag based geopolymer concrete', presented by Sundar Kumar S., in the three day International Conference, ICGITS 2013, was adjudged best paper in civil engineering category.

10. Dr. M.B. Anoop, Principal Scientist, received Membership for the following international professional associations: Gnedenko e-Forum, International Group on Reliability IAENG (International Association of Engineers)

11. Dr. K. Balaji Rao, Chief Scientist, was a Panel Member for the Civil R&D Meeting of Vel Tech Dr. RR & Dr. SR Technical University, Chennai, held on June 21, 2013

12. ACCE(I)-Sundaram Merit Award 2013 for the project work 'Effect of curing on the strength development of geopolymer concrete', M.Tech thesis submitted to Visvesvaraya Technological University, Belgaum, Karnataka- Student: Ms.Tanuja B.B, Guide: Smt. P.S. Ambily

13. Dr. K. Balaji Rao, Chief Scientist, was invited as the Guest of Honour for the 3rd National Conference on Advances and Innovations in Civil and Mechanical Engineering (AICME '13), held at Vel Tech Dr. RR & Dr. SR Technical University, Chennai, on September 5, 2013

14. Dr. S. Bhaskar, Principal Scientist, received 'best PhD thesis award' in the field of concrete for his thesis on 'Study of chloride induced corrosion of reinforcement steel in cracked concrete' from ICI Tamil Nadu Chennai Chapter on 19th September 2013 at Chennai, during concrete day celebrations. He also received the same award during the 21st ICI Annual Awards on October 25, 2013 at Hyderabad.

15. Dr. (Ing.) Saptarshi Sasmal, Senior Scientist, has been awarded the "ICI- Ramakrishnan Young Scientist Award 2013" on October 25, 2013, by Indian Concrete Institute in recognition of novel innovations and outstanding contributions in the field of Structural Engineering, at HITEX Exhibition Centre, Hyderabad.

16. The Outstanding achievement award (Institutional award and individual medallion and citation for the project champions) was awarded to CSIR-SERC for the distinguished contribution and meritorious achievement for the CSIR Transformation Initiatives and Enterprise Application for Automotive of Operations on the occasion of 71st Foundation Day of CSIR on September 26, 2013, CSIR, New Delhi.

Prof. Samir K. Brahmachari, Director General, CSIR presenting the outstanding achievement award to Shri K. Gunasekaran, CSIR-SERC

17. Best paper award to Niveditha C., Sarayu K., Ramachandra Murthy A., Ramesh Kumar V., Nagesh R. Iyer, for the paper, 'Marine algae for cement mortar strengthening', in Proceedings of the International Conference on Advances in Civil Engineering and Chemistry of Innovative Materials (ACECIM-2014), SRM University, Chennai, March 13-14, 2014, pp. 149-153.

18. Niveditha, C., Sarayu, K., Ramachandra Murthy, A., Nagesh R. Iyer (2014). "Halimeda sp. as source of calcium carbonate and silica", Proeedings of the National Conference on Bioengineering, NCBE-2014, Chennai, March 27, 2014, pp 25. (First Prize).

Dr. M. Ramaiah Prize for the best technical paper

Dr. M. Ramaiah Prize for the best technical paper published during the year 2012-13 has been jointlty awarded to:

Dr. M. Ramaiah Prize for the best technical paper awarded to Dr. K. Sathish Kumar & Dr. K. Muthumani

Dr. M. Ramaiah Prize for the best technical paper awarded to Dr. K. Rama Raju, Dr. K. Muthumani, Dr. N. Gopalakrishnan, Prof. Nagesh R. Iyer, Dr. N. Lakshmanan

(i) K. Sathish Kumar, C. Antony Jeyasehar, K. Muthumani, for their paper "A Design methodology for supplemental damping for seismic performance enhancement of frame structures", published in Asian Journal of Civil Engineering (Building and Housing), Vol. 13, No.5, pp 659-678 and

(ii) K. Rama Raju, A. Meher Prasad, K. Muthumani, N. Gopalakrishnan, Nagesh R. Iyer, N. Lakshmanan, for their paper "Experimental studies on use of toggle brace mechanism fitted with magnetorheological dampers for seismic performance enhancement of three storey steel moment resisting frame model", published in Structural Control and Health Monitoring, Vol. 20, No.3, March 2013, pp 373-386.

Certificates of Merit have been presented to:

(i) S. Parivallal, K. Ravisankar, K. Nagamani, for their paper 'Studies on special strain gage configuration for evaluation of existing stress in concrete structures by hole drilling technique', published in the Journal of Structural Engineering, Vol 39, No.1, April-May 2012, pp 69-76

(ii) A. Ramachandra Murthy, Nagesh R. Iyer and B.K. Raghu Prasad, for their paper 'Fatigue crack growth study and remaining life assessment of high strength and ultra high strength concrete beams', published CMES: Computer Modeling in Engineering & Sciences, Vol 89, No.6, 2012, pp 459-480 and

(iii) P.S. Ambily, B.H. Bharatkumar, Nagesh R. Iyer, 'Geopolymer concrete blocks / pavers for precast applications', Proceedings of the International Conference on UKIERI Concrete Congress Innovations in Concrete Construction, Jalandhar, March 2013, pp 601-611

STAFF DURING THE YEAR ENDING 31 MARCH, 2014

Director

Nagesh R. Iyer, B.E.(Civil), M.E.(Struct.), Ph.D, F.N.A.E., F.I.E., M.I.C.I., M.I.S., M.C.S.I., M.I.S.E., M.I.S.M

Advisor(M)

K. Ravisankar, B.E. (Civil), M.E.(Struct.), Ph.D., F.I.E

Chief Scientist

T.S. Krishnamoorthy, B.E.(Civil), .E.(Struct.)

K. Muthumani, B.E.(Hons.) (Civil), M.Tech.(Engg. Mechanics), Ph.D., F.I.E.

K. Vasudevan, M.Com., B.G.L., A.I.C.W.A., A.C.S.

Jolly Annie Peter, B.Sc.Engg. (Civil), M.E (Const. Engg.).,Ph.D.

S.J. Mohan, B.E.(Civil), M. Tech. (Struct.)., Ph.D.

S. Selvi Rajan, B.Tech.(Civil), M.E. (Hydro.& Water Reso.) Ph.D.

P.K. Umesha, B.E. (Civil), M.Tech. (Struct.), Ph.D., F.I.E.

K. Balaji Rao, B.Tech.(Civil), M.E.(Struct.), Ph.D.

A. Rama Mohan Rao, B.Tech.(Civil), M.E.(Struct.), Ph.D.

K. Ramanjaneyulu, B.Tech.(Civil) M.E. (Struct.), Ph.D.

G. Raghava, B.E.(Civil), M.Tech.(Indu. Struct), Ph.D.

N. Gopalakrishnan, B.E (Civil), M.Tech.(Struct.), Ph.D.

J. Rajasankar, B.E.(Civil), M.Tech.(Struct.), Ph.D., F.I.E.

K. Rama Raju, B.Tech.(Civil), M.Tech.(Struct.)., Ph.D.

C. Jeyabal, M.Sc.(Mech. Engg.)

P. Sivakumar, B.E.(Civil), M.E.(Struct.), Ph.D., F.I.E.

Senior Principal Scientist

N. Pandian, B.E.(Civil), M.S.(Civil), Ph.D.(till 31.08.2013)

S. Sankar, B.E.(Elec. & Commn. Engg.)

N.G. Bhagavan, B.Tech.(Civil), M.Tech.(Ocean Engg.)

P. Gandhi, B.E.(Civil), M.Sc.(Engg.) (Struct.)

G.S. Palani, B.E.(Civil), M.E.(Struct.),Ph.D.

R. Ravichandran, M.Sc.

K. Satish Kumar, B.E.(Civil), M.E.(Struct.), Ph.D.

H. Bhajantri Bharathkumar, B.E. (Civil), M. Tech. (Marine Struct.), Ph.D.

P. Srinivasan, B.E. (Civil), M.E. (Struct.)

C.K. Madheswaran, B.E.(Civil), M.Tech. (Ocean Engg.)., Ph.D.

Pabbisetty Harikrishna, B.E. (Civil), M.E. (Struct.), Ph.D.

S.G.N. Murthy, M.Sc.,(Elec.)

K. Dilli, B.E. (Mech.)

J. Prabakar, B.E.(Civil),M.Tech. (Found. Engg.), Ph.D.

S. Saibabu, B.E.(Civil), M.Tech.(Struct.), Ph.D.

Principal Scientist

S. Parivallal, B.E.(Civil), M.E.(Struct.), Ph.D.

G.N. Narasimhan, M.Sc.

M.D. Raghunathan, B.E. (Civil), M.Tech. (Indl. Struct.)

K. Kesavan, B.E.(Civil), M.Tech.(Civil)

Gajjala Ramesh Babu, B.Tech (Civil) M.Tech (Civil)

Napa Prasad Rao, D.C.E., B.E., M.Tech (Civil), Ph.D.

K. Gunasekaran, M.Sc. (Stat.)

V. Srinivas, B.Tech (Civil), M.E.(Civil), Ph.D.

S. Bhaskar, B.E (Civil),M.Tech.(Struct.), Ph.D.

N. Anandavalli, B.E. (Civil), M.E. (Struct.), Ph.D

M.B.Anoop, B.Tech (Engg), M.E. (Struct.) , Ph.D.

S. Maheswaran, M.Sc. (Phys.), PGDCA,MBA

Rokade Rajendra Pitambar, DCE, B.E., M.E. (Civil)

R. Sreekala, B.Tech (Civil)., M.Tech.(Struct.)

P. Kamatchi, B.E. (Civil), M.E. (Struct.),Ph.D.

D.M. Pugazhendi, Dip. in Civil Engg. B.E. (Civil.), M.E. (Struct.)

Senior Scientist

A. Ramachandra Murthy, B.Tech (Civil), M.E.(Struct), Ph.D.

Saptarshi Sasmal, B.E.(Civil), M.E. (Struct.), Ph.D.

A. Abraham, B.E. (Civil), M.E (Struct.)

C. Kumarasekar, B.E. (Electronics), M.E. (Control & Instru.), MBA

R. Manisekar, BE (Civil), ME(Struct.), Ph.D.

K. Sivasubramanian, B.Tech (Civil), M. E. (Struct.)

Amar Prakash, DCE, B.Sc (Engg.), M.E.(Earthquake Engg.)

V. Srinivasan, BE (Civil), M.E.(Urban Engg.)

Scientist

Ambily, P.S., B.Tech.(Civil), M.Tech.(Struct.)

Marimuthu, V., B.E.(Civil), M.E.(Struct.)

Balagopal, R., B.E. (Civil), M.E.(Struct.)

Smitha Gopinath, B.Tech.(Civil), M.E.(Struct.)

A. Cinitha, B.Tech. (Civil), M.Tech. (Civil),Ph.D.

S.R. Balasubramanian, DCE, B.E. (Civil),M.E.(Struct.)

S. Vishnuvardhan B.E.(Civil),M.E.(Civl), Ph.D.

P. Prabha, B.E.(Civil), M.E.(Struct.)

S. Chitra Ganapathi, B.E.(Civil)., M.E. (Civil)

Venkata Rama Rao, G., B.Tech.(Civil), M.E. (Civil)

K.N. Lakshmikandhan B.E. (Civil), M.E. (Struct.), Ph.D.

J. Daniel Ronald Joseph, B.E. (Civil), M.E.(Struct.)

M. Saravanan (ID-164), B.E(Civil), M.E. (Struct.)

K. Saravana Kumar, B.E.(Civil), M.E. (Struct.)

V. Rameshkumar, B.E.(Civil), M.Tech.(Civil)

A.K. Farvaze Ahmed, B.E.(Civil)., M.Tech.(Civil)

B. Arun Sundaram, B.E.(Civil). M.E. (Struct.)

M. Saravanan (ID-172), DCE, BE(Civil),ME(Struct.)

S. Sundar Kumar, B.E.(Civil),M.Tech.(CAD of Struct.)

K. Lakshmi, BE(Civil)., ME(Struct.)

Vimal Mohan, B.E.(Civil), M.Tech.(CADS)

A. Kanchanadevi, B.E. (Civil), M.E. (Struc.Engg.)

T. Hemalatha, B.E. (Civil), M.Tech.(Struc.Engg.), Ph.D.

M. Keerthana, B.E.(Civil), M. Tech. (Engg. of Structures)

Mohit Verma, B.E.(Civil), M. Tech. (Engg. of Structures)

C. Bharathi Priya, B.E.(Civil), M. Tech.(Engg. of Structures)

Nawal Kishor Banjara, B.E.(Civil), M. Tech. (Engg. of Structures)

G. Ramesh, DCE, BE(Civil),

Bhashya Vankudothu, B.Tech. (Civil), M.E. (Civil)

B.S. Sindu, B. Tech. (Civil), M. Tech.(Engg. of Struct.)

M. Surendaran, B. E. (Civil), M. Tech. (Engg. of Struct.)

Prabhat Ranjan Prem, B. Tech. (Civil), M. Tech (Engg. of Struct.)

G.S. Vijaya Bhaskara, B.E.(Civil), ME.(Civil)

Principal Technical Officer

E. Nalinikumar, Dip. in Appld. Arts (till 31.01.2014)

A. Hariharan, B.Sc., M.A., BLIS, A.I.Sc, Dip in German, Ph.D.

K. Raghavan, B.Sc., MCA

R.D. Sathish Kumar, B.Sc, P.G.D.L.I.S, M.L.I.S.

M. Venkatesan B.Sc., MCA

Senior Technical Officer(3)

M. Murugesan, Dip. in Electronics, B.E.(Electronics & Comm. Engg.), Dip. in Medical Equipment Tech., MBA

C. Murugaiyan, Dip. in Electronics, AMIE (till 02.03.2014)

G. Muthuramalingam, DE&EE, BE(E&EE), M.Tech.(EE)

M. Jeyapaul, DCE,DCT, BE(Civil)

G. Jayaraman, B.E. (Elect.)

M. Kumarappan, B.E.(Civil)

P.P. Koyamoideen, D.M.E.

Rajiv Khanna, Dip.in Instrument Tech.

K. Sasikala, B.Sc., DACP, DCO, MCA, MBA

R. Amourdhavally, M.Sc

A. Sundaramoorthy, M.Sc.

E. Jeyakumar, B.A., Dip. in Film Tech

M. Annaselvi, B.Sc.MCA

Chitra Sankaran, B.Sc.MCA

Senior Superintending Engineer (Civil)

M.S. Balasundaram, DCE, B.E.(Civil), M.E (CE&M)

Superintending Engineer (Civil/Elec.))

D.J. Ravichandran, DEE

R. Chandrasekar, DCE

Senior Technical Officer (2)

S. Srinivasan, DECE

S. Vijayalakshmi, M.Sc (Maths), M.S. (SS)

S. Kanniah Sah, DME

Mymoon Moghul, B.Sc., BLIS., MLIS, MA (Psych), Ph.D.(Lib.& Info.Science)

K. Sankaranarayanan, AMIE (Sec.A & B)

Senior Technical Officer(1)

V. Muthalagan, D.E.E.

S. Krishnakumar, ITI Mech.(Instru.)., D.E.& C.E.

CT. Subramanian, Dip. in E&EE (Till 22.01.2014)

S. Harishkumaran, PGD in PCI&A, B.E(E&CE)

J. Prakashvel, BE(Civil), M.S.(By Research)

S. Muraleeswaran, DME, B.E.(Mech.Engg.)

E. Kanmani, B.E. (Elec. & Inst. Engg.)

Prasenjit Das, MSc., PG Dip.in IPR, (From 17.03.2014)

Technical Officer

P. Vasudevan, BE(E&CE)

R. Lakshmi Poorna, B.Sc., M.A(J&MC), M.A (Pol. Sc.), MS, BLIS

Assistant Engineer (Elect.)

K. Kumaran, DEEE

Technical Assistant

E. Surya, DCE

G.V. Ananthakrishnan, DCE, BSc(IT)

S. Viswanatha Manikandan, DCE

G. Lakshmikanth, D.M.E., B.E. (Mech.Engg.)

Senior Technician (3)

K. Ethirajulu, ITI, DEEE

Senior Technician (2)

M. Moorthy, VIII Std.

S. Suryakala, BA, MLIS

R. Gandhi, DCE

J. Inbasekaran, ITI (Till 30.06.2013)

Sulochana Peethambaram, DCE

S. Latha Balasundar, DCE

G. Gunasekar, ITI

R. Ravindran, PUC (Till 31.07.2013)

D. Deivaraj, ITI, DECE

R. Viswanathan, ITI

R. S. Ramanujam, DECE

A. Kannan, DME

G. Victor Paulraj, DCE (Till 30.06.2013)

N. Subramani, ITI

R. Sriraman, DME

K. Elumalai, ITI

G. Ponnan, DME

N. Chenguttuvan, ITI

M.A. Swaminathan, ITI

E. Vijayakumar, ITI

J. Rajalakshmi, M.Com ., Certificate Course in Hotel Management

S. Srinivasan, B.Sc.

Senior Technician(1)

B. Ravikumar, MA, DCE

N. Bhaskaran, HSC, IRT

V. Krishnan, ITI

Technician(1)

R. Rajesh, DME

G. Poovendan, ITI

S. Bala Murugan, DEEE

K. Srinivasan, ITI

T. Sathishkumar, ITI

S. Vimala, ITI

A. Karunakaran, ITI

S. Muthuraj, ITI

K. Savitha, ITI

M. Karunamoorthi, ITI

N. Syed Ibrahim, ITI

V. Mahendran, ITI, DCE (From 31.12.2014)

S. Balakrishnan, ITI (From 23.01.2014)

Laboratory Assistant

K. Sivaprakasam, VIII Std.

M. Sankaran, MA

G. Raju, VIII Std.

R. Venkatachalam, IX Std.

C. Delhi, upto SSLC

C. Babu, IX Std.

Laboratory Attendant(2)

P. Rani, Upto X Std.

R. Manoharan, VIII Std.

R. Kandiyappan, VIII Std.

B. Suresh Babu, IX Std.

E. Mani, VIII Std.

B. Punitha, Upto V Std.

Laboratory Attendant (1)

S. Eswaran, X Std.

Controller of Administration

Manuel Thomas, B.Sc.

V. Krishna Kumar, B.Com. Master of Vocational Studies in CO&A (till 31.01.2014)

Section Officer

Shikhar Sharma, B.E. (ECE) (till 19.04.2013)

Assistant (General) Gr.I (MACP)

R. Nageswara Rao, B.Com.

R. R. Pillai, M.A(Pub. Admn.)

M. Chitra, B.Sc.

K. Kuppan, M.Com.

Assistant (General) Gr.I

Kalpana Chandrasekar, B.A.

Amod Kumar, B.A.

M. Chandrasekaran, SSLC

V. Chandran, B.Sc.

N. Sudhakar, MA, Ph.D.

S.P. Kalaivani, BSc.

M. Vanijayaleela, B.Sc.

A. Srinivasa Rao, B.Com.

K. Nagajothi, HSC

Assistant (General) Gr.II

P. Priya, M.Com.

N. Hemamalini, M.A.

Controller Finance & Accounts

D. Srinivasa Raghavan, B.Sc.

Section Officer (Finance & Accounts) (NFS)

Karthikai Kannan, T., B.Sc. (Comp. Science), MBA

Section Officer (Finance & Accounts)

K. Mahalakshmi, B.A

Assistant (Finance & Accounts) Gr.I (MACP)

Kamalabai Prabhakaran, M.Com.

Assistant (Finance & Accounts) Gr.I

P. Kanagaraju, PUC

J. Devan, SSLC

J. Uma Maheswari, B.A.

R. Rajalakshmi, M.Com., MBA

T.M. Muhammed Majaz, B Tech. (From 18.12.2013)

Assistant (Finance & Accounts) Gr.II

M. Thulasi, B.Com.

Controller of Stores & Purchase

H.V.Sundar, B.Com., PGDMM.

Section Officer (Stores & Purchase)

C. Jayasingh, B.A.

Assistant (Stores & Purchase) Gr.I (MACP)

M. Palanisamy, B.E.

R. Ramanathan, B.Com

Assistant (Stores & Purchase) Gr.I

J. Govindarajulu, SSLC

A. Basheer Ahamed, M.A.

S. Kannappan, B.Sc., MCA

M. Mohamed Jindha Saffi, B.Sc.

T. Srinivasan, B.A.

Assistant (Stores & Purchase) Gr.II

C. Rajaji, M.A., DCE

Private Secretary(ACP)

S. Vaidyanathan, B.A., Dip. in Industrial Relations & Personnel Management, Labour Law

Private Secretary

B. Subramonia Iyer, M.A.

Senior Stenographer (MACP)

N.V. Kannan, M.A.

Beulah Daisy Williams, AIHSE

R. Gurumurthy, B.A.

Rukmani Raghavan, B.Com.

P.M. Mohandas, B.A.

R. Venkatesan, B.Com.

C. Rebekkal, B.A.

R. Raghuraman, B.A.

Senior Stenographer (ACP)

K. Venkateswari, B.Sc.

Senior Stenographer

S. Jagadhaprabha, B.Com.

S.A. Habeebah, B.Com.

M. Vijayalakshmi, B.Com.

Junior Stenographer (MACP)

M. Niraja Pasupathy, B.Com.

Junior Stenographer (ACP)

S. Shanthi, SSLC, NTC

Senior Technical Officer (2)

D. Parthiban, Dip. in HM & CT

Hindi Officer

M. Vani Satyanarayana, B.Sc., B.Ed., MA (Hindi), M.Phil.

Driver Gr.II(4)

T. Thangam, Upto X Std.

G. Vijayakumar, Upto IX Std.

Cook Gr.II(3)

P. Muthusami, B.Com.

S.T. Pandian, VIII Std.

E. Umachandran, PUC

V. Pichamani, HSC

Security Assistant

R. Ravisankar, B.A.

Receptionist

M. Sangeetha, B.Sc., MBA

Driver Gr.II(3)

K. Jagannathan, Upto SSLC

Record Keeper (MACP)

G. Munirathinam, IX Std.

Guest Room Attendant

C. Sekar, VIII Std.

Driver Gr.II(1)

D. John, SSLC

Peon

B. Reeta Sangeetha, VIII Std.

Bearer(ACP)

J. Gopalakrishnan, IX Std.

MEMBERSHIP OF STAFF IN VARIOUS COMMITTEES OF BUREAU OF INDIAN STANDARDS
(During the year ending 31.03.2014)

Code		Committee/ Sub-Committee	Principal Member	Alternate Member
CEDC		Civil Engineering Division Council	Dr. Nagesh R. Iyer	Dr.K. Ravisankar
CED 2		Cement and Concrete Sectional Committee	Dr. K. Ramanjaneyulu	Dr.P. Srinivasan
	CED 2/P1	Panel for Work relating to ISO/TC 71 & ISO TC 74	Dr.K. Ramanjaneyulu	Shri P. Srinivasan
	CED 2 /P2	Panel for Revision of Handbooks	Dr.K. Ramanjaneyulu	Dr. Jolly Annie Peter
	CED 2:2	Concrete Sub-Committee	Dr. B.H. Bharathkumar	Shri P. Srinivasan
	2:2/P1 (Sub)	Panel for Revision of IS 3370 (Part 1 & 2))	Dr. B.H. Bharathkumar	Shri P. Srinivasan
	CED 2:2/P5	Panel for IS 456 & Revision of IS 1343	Dr.K. Ramanjaneyulu	Dr. B.H. Bharathkumar
	CED 2:2/P7	Panel for revision of Indian Standards on Test Methods for Concrete	Shri P. Srinivasan	Dr. S Bhaskar
CED 7		Structural Engineering and Structural Sections	Dr. G.S. Palani	Dr. Napa Prasad Rao
	7:1	Use of Steel in Overhead line towers and switchyard structures and masts for telecommunication and flood lighting sub-committee	Dr. Napa Prasad Rao	Shri R.P. Rokade
	7:2	Use of structural Steel in general Building Construction sub-committee	Dr. G.S. Palani	Dr. S. Bhaskar
	7:6	Fabrication, Erection and Inspection of Steel Structures in general sub-committee	Dr. Napa Prasad Rao	Dr. G.S. Palani
	7:8	Use of Steel Hollow Section in Structures sub-committee	Dr. Napa Prasad Rao	Dr. G.S. Palani
CED 13		Building Construction Practices including Painting, Varnishing & allied	Dr. Nagesh R. Iyer	Shri P. Srinivasan
CED 37		Structural Safety Sectional Committee	Dr. K. Balaji Rao	Dr M.B. Anoop
	37/P:3	Panels for Load other than Wind Loads	Dr. K. Balaji Rao	Dr. J. Rajasankar
	37/P:4	Panel for Wind Loads	Dr. P. Harikrishna	Dr A. Rama Mohan Rao

Code		Committee/ Sub-Committee	Principal Member	Alternate Member
CED 38		Special Structures Sectional Committee	Dr. J. Rajasankar	Dr. N. Anandavalli
CED 39		Earthquake Engineering Sectional Committee	Dr. N. Gopalakrishnan	Dr. K. Sathishkumar
	39: P/1	Adhoc Panel for Tsunami Resistant Structures	Dr. K. Muthumani	Dr. S. Selvi Rajan
	39:4	Maps Sub-committee	Dr. P. Kamatchi	Dr. K. Balaji Rao
	39:4/P-1	Panel for preparation of Probabilistic Seismic Hazard Map of India	Dr. K. Balaji Rao	Dr. P. Kamatchi
	39:8		Dr. N. Gopalakrishnan	Dr. P. Kamatchi
	39.10	Earthquake Resistant Design of Dams and Embankments Sub-committee	Dr. J. Rajasankar	Dr. N. Gopalakrishnan
CED 43		Soil and Foundation Engineering Sectional Committee	Dr. N. Gopalakrishnan	Dr. J. Rajasankar
CED 46		National Building Code Sectional Committee	Shri P. Srinivasan	Dr. Jolly Annie Peter
	46/P:4	Panel for Loads, Forces and Effects	Dr. J. Rajasankar	Dr. G S. Palani
	46/P:7	Panel for Masonry	Dr. A. Ramachandra Murthy	Smt Smitha Gopinath
	46/P:8	Panel for Plain, Reinforced and Prestressed Concrete	Dr. K. Ramanjaneyulu	Dr. B.H. Bharathkumar
	46/P:9	Panel for Steel	Dr. G.S. Palani	Dr. G. Raghava
	46/P:10	Panel for Prefabrication & Systems Building	Dr. J. Prabakar	Dr. Jolly Annie peter
CED 47		Ports, Harbours and Off shore Installations Sectional Committee	Dr. G. Raghava	Dr. J. Rajasankar
		Environmental data, Design, Offshore Structures	Dr. G. Raghava	Dr. J. Rajasankar
CED 51		Planning, Housing and Prefabricated Construction Sectional Committee	Shri P. Srinivasan	Dr. J. Prabakar
CED 53		Cement Matrix Products Sectional Committee	Shri P. Srinivasan	Dr. B.H. Bharathkumar

Code		Committee/ Sub-Committee	Principal Member	Alternate Member
	53:1	Fibre Reinforced Cement [FRC] Products Sub-committee	Ms P.S. Ambily	Dr. B.H. Bharathkumar
	53:2 (Sub)	Concrete Pipes Sub-committee	Ms P.S. Ambily	Shri S. Sundar Kumar
	53:3 (Sub)	Precast Concrete Products Subcommittee	Dr. J. Prabakar	Dr. S. Bhaskar
CED 54		Concrete Reinforcement Sectional Committee	Dr. B.H. Bharathkumar	Smt Smitha Gopinath
CED 57		Cyclone Resistant Structures Sectional Committee	Dr. S. Selvi Rajan	Shri G. Ramesh Babu

Membership of CSIR-SERC scientists in various committees / academic bodies, etc.

Name of the Scientist	Name of the Committee / Agency
Prof. Nagesh R. Iyer	Fellow of Indian National Academy of Engineering (FNAE) -
	Fellow of Institution of Engineers (India) (Fellow) - Member
	Indian Concrete Institute – Member
	Computer Society of India – Member
	Indian Association of Computational Mechanics (Founder Member) [F-IACM] - Member
	CSIR Transformation Project Initiatives (ICT Project), CSIR - Chairman
	Engineering Apex Committee, CSIR - Chairman
	Governing Board, National Academy of Construction, Hyderabad, A.P. (NAC) - Member
	Governing Council, Institute for Steel Development & Growth (INSDAG), Ministry of Steel, GOI - Member
	Governing Council & Governing Body, National Institute of Ocean Technology (NIOT), Chennai - Member
	Executive Committee, Centre of Research, Anna university, Chennai – Member
	Board of Studies, Vellore Institute of Technology, Vellore - Member
	Advisory Council, Kalasalingam University - Member
	Technical Advisory Committee, Mubarak Mandi Jammu Heritage Society, Jammu - Member
	Technical Advisory Committee (TAC), Governing Council, Central Water & Power Research Station (CWPRS), Pune - Member
	National Steering Committee for Mitigation Project – NDMA - Member
	Research Advisory Council, National Council for Cement and Building Materials - Member
	Research Councils of CSIR-CBRI, Roorkee, CSIR-NAL, Bangalore, CSIR-AMPRI, Bhopal, CSIR-CECRI, Karaikudi - Member
	Management Councils of CSIR-CMERI, Durgapur, CSIR-CLRI, Chennai & CSIR-NAL, Bangalore - Member
	Work Review Committee, B.C. Division, PWD, Chennai - Member
	Supervisor, MS (by Research/Ph. D), Anna University, Chennai – Member
	Advisory Board, Shiv Nadar Univeristy, Noida - Member
	Prize Nomination Council, Board of Trustess, Infosys Science Foundation, Bengaluru - Member
	Academic Advisory Committee, Institute of Technology, Nirma University, Ahmedabad - Member

	Board of Studies, Sri Ramakrishna Institute of Technology, Coimbatore - Member
	Merit Review Panel for Building Energy Efficiency, Indo-US Science & Technology Forum, New Delhi - Member
	Board of Courses & Studies (BOCS), Indian School of Mines, Dhanbad, Jharkhand – Member
	Advisory Committee on Civil & Environmental Engineering, Science and Engineering Research Board(SERC), DST, New Delhi - Member
	5th International Congress on Computational Mechanics and Simulation (ICCMS 2014) - Chairman
	Journal of Structural Engineering – Editor
	Editorial Board, Intl. Journal of Aerospace Sciences and Technologies – Member
Dr. K. Ravisankar	Fellow - Institution of Engineers (India) Life Member – ICI Life Member – Indian Society for NDT Life Member – Instrument Society of India Member - Indian Roads Congress – Instrumentation Committee (G5) Member - Panel of Experts for Selection of Scientists at Ministry of Earth Sciences Chairman, Technical Evaluation Committee for 10 MLD DPR at NIOT, Chennai Member - Panel of Experts for Review, Indian Concrete Journal, Sadhana
Shri T.S. Krishnamoorthy	ICFRC, Madras – Life Member
Dr. K. Muthumani	Institution of Engineers India (IEI) – Fellow Indian Society for Earthquake Technology (ISET) - Member Indian Concrete Institute (ICI) – Member Indian Nuclear Society (INS) – Member Indian Association for Structural Engineering (IASE) – Member Indian Association for Computational Mechanics (IndACM) - Member The Indian Society for Wind Engineering (ISWE) – Member
Dr. Jolly Annie Peter	Technology Advisory Group, BMTPC – Member Doctoral Committee, Vellore Institute of Technology VIT - Member Doctoral Committee, Velammal Institute of Technology, Madurai – Member Doctoral Committee, SRM University – Member
Dr. S.J. Mohan	National sub-committee of CIGRE study committee B2 on overhead lines – Member Steel Long Products and Wires Sub Committee – Member Wrought Steel Products Sectional Committee – Member Institution of Engineers - Member Indian Society for Wind Engineering – Member
Dr. S. Selvi Rajan	Technical Advisory Committee, National Disaster Management Authority, New Delhi – Member Indian Society for Wind Engineering – Member

Dr. P.K.Umesha	Institution of Engineers (India) – Fellow Indian Concrete Institute – Fellow Computer Society of India - Sr. Member Advanced Computing Society – Member Indian Association for Computational Mechanics – Member
Dr. K. Balaji Rao	Indian Society of Wind Engineering – Member Institution of Engineers (India) – Member Indian Concrete Institute – Member Board of Studies, Department of Civil Engineering, Jawaharlal Nehru Technological University, Ananthapur – Member Board of Studies, Department of Civil Engineering, Jawaharlal Nehru Technological University, Kakinada – Member Gnedenko e-Forum, International Group on Reliability – Member IAENG (International Association of Engineers) – Member Society for Reliability & Safety (SRESA) – Member
Dr. A. Rama Mohan Rao	Computer Society of India, Indian Society of Wind Engineering, Instrument Society of India – Member
Dr. K. Ramanjaneyulu	Special Structures Sectional Committee - Member Indian Society for Wind Engineering - Member Institution of Engineers - Member Indian Concrete Institute - Member Indian Institution of Bridge Engineers - Member Computer Society of India – Member
Dr. G. Raghava	Expert Committee for the third Indian Research Station in Antarctica at Larsemann Hills, East Antarctica, National Centre for Antarctic & Ocean Research, Goa – Member Board of Studies of Department of Construction Technology & Management, Sri Jayachamarajendra College of Engineering, Mysore – Member Project Review Board of Offshore Structures Group, National Institute of Ocean Technology, Chennai – Member Ph.D. Doctoral Committees, Anna University, Chennai – Member Institution of Engineers (India) – Member Indian Concrete Institute – Member Indian Society for Non-Destructive Testing – Member Computer Society of India – Member Indian Nuclear Society – Member Instrument Society of India – Member Indian Association for Structural Engineering – Member Indian Association for Computational Mechanics – Member
Dr. P. Sivakumar	Engineering Science Research Committee, CSIR, New Delhi - Member Doctoral Committee, Hindustan University – Member Doctoral Committee, Anna University – Member Doctoral Committee, Thiagarajar College of Engineering, Anna University – Member The Institution of Engineers (India) (FIE) – Fellow Indian Concrete Institute (MICI) – Member Computer Society of India (MCSI) – Member Instrument Society of India (MISI) – Member

Dr. K. Rama Raju	American Society of Civil Engineers (ASCE) - Member
	Earthquake Engineering Research Centre (EERC), University of California, Berkeley - Member
	Institution of Engineers, India (IE) - Fellow
	Computer Society of India (CSI) - Member
	Indian Association for Structural Engineers (IASE) - Member
	Indian Association for Computational Mechanics (IndACM) - Member
	Indian Society for Wind Engineering – Member
Dr. N. Gopalakrishnan	Indian Society for Wind Engineering (ISWE) – Member
	Instrumentation Society of India (ISI) - Member
	Computer Society of India – Member
Shri P. Gandhi	Indian Nuclear Society - Member
	Instrument Society of India - Member
	Indian Association for Structural Engineering - Member
	Indian Association for Computational Mechanics – Member
Dr. G.S. Palani	Open Aerospace Engg. Journal - Editorial Board Member
	Advisory Board of Industry Institute Partnership Cell of Dr Mahalingam College of Engineering Technology, Pollachi – Member
Dr. K. Sathish Kumar	Institution of Engineers India (IEI) - Member
	Institution of Chartered Engineers India (ICEI) - Member
	Indian Society for Earthquake Technology (ISET) - Member
	Indian Concrete Institute (ICI) - Member
	Indian Nuclear Society (INS) - Member
	Indian Association for Structural Engineering (IASE) - Member
	Indian Association for Computational Mechanics (IndACM) - Member
	Indian Society for Wind Engineering (ISWE) – Member
Dr. P. Srinivasan	Life member of
	Indian Concrete Institute, Chennai
	International Centre for Fibre Reinforced Concrete, Chennai.
	Indian Society of Earthquake Technology, Roorkee.
	Society of Structural Engineers, Chennai
	Member of the BIS Committee for some standards
Dr. C. K. Madheswaran	Institution of Engineers India – Member
	Instrumentation Society of India (ISI) – Member
	Computer Society of India – Member
Dr. P. Harikrishna	Indian Society for Wind Engineering - Member
Dr. N. Prasad Rao	Institution of Engineers - Member
	CIGRE-INDIA National, Subcommittee B2, on “Over Head Lines” – Member
	Wrought Steel Products Sectional Committee – Member
	Institution of Engineers – Member
	Indian Society for Wind Engineering – Member
	Institute for Steel Development and Growth (INSDAG) – Member

Dr. V. Srinivas	Indian Society for Wind Engineering - Member Computer Society of India - Member IABSE - Member Institution of Engineers - Member Indian Concrete Institute – Member
Dr. S. Bhaskar	Board of Studies (BoS), Dept. of Civil Engineering, Sri Ramakrishna Engineering College, Coimbatore – Member Life member of Indian concrete institute (ICI); Computer society of India (CSI); Institution of Engineers (India) (IE); Indian society for earthquake technology (ISET); Indian society for construction materials & structures (ISCMS) Indian Society for Non-destructive Testing (ISNT)
Dr. M.B. Anoop	Indian Society of Wind Engineering – Member Gnedenko e-Forum, International Group on Reliability – Member IAENG (International Association of Engineers) – Member Society for Reliability & Safety (SRESA) – Member
Dr. P. Kamatchi	Indian Society for Earthquake Technology – Member Indian Concrete Institute – Member Indian Society for Technical Education – Member Indian Society of Wind Engineering – Member
Smt. R. Sreekala	Indian Society for Earthquake Technology (ISET) – Member Indian Concrete Institute (ICI) – Member
Shri D.M. Pukazhendhi	Institution of Engineers (India) - Member Indian Concrete Institute - Member Indian Society for Non-Destructive Testing - Member Indian Nuclear Society - Member Computer Society of India – Member
Shri R.P. Rokade	Institution of Engineers – Member Indian Concrete Institute – Member India Chapter of ACI – Member Indian Institute of Bridge Engineering – Member Indian Society for Wind Engineering – Member Indian Association for Structural Engineering – Member Indian Association for Computational Mechanics – Member Institute for Steel Development and Growth (INSDAG) – Member
Dr. A. Rama Chandra Murthy	Editorial board member for Advances in Concrete Construction (ACC), An International Journal – Member Board of Studies of the Department of Civil Engineering, Bharath University, Chennai - External expert Doctoral Committee Member, VIT University, Vellore – Member

Shri V. Srinivasan	Institution of Engineers (India) – Associate Member Indian Buildings Congress – Member Indian Concrete Institute – Member Institute of Urban Transport – Member
Dr. R. Manisekar	Indian Roads Congress – Member Indian Institution of Bridge Engineers - Life Member Indian Association for Structural Engineers - Life Member Indian Concrete Institute – Member
Shri R. Balagopal	Indian Society for Wind Engineering – Member Indian Association for Structural Engineering – Member Indian Institution of Engineers – Member Institute for Steel Development and Growth (INSDAG) – Member
Smt. Smitha Gopinath	RILEM - Senior Member ship & Member of two technical committees
Shri S.R. Balasubramanian	Computer Society of India – Member
Dr. S. Vishnuvardhan	Ph.D. Doctoral Committee, Hindustan University, Chennai – Member Ph.D. Doctoral Committees, Anna University, Chennai – Member Ph.D. Doctoral Committee, SRM University, Kattankulathur – Member Institution of Engineers (India) – Member Indian Concrete Institute – Member Indian Society for Technical Education – Member Indian Society of Earthquake Technology – Member
Shri G. V. Rama Rao	Indian Concrete Institute (ICI) – Member
Dr. K.N. Lakshmikandhan	The Institution of Engineers (India) – Member Computer Society of India – Member Structural Engineering Forum, Anna University – Member American Society of Civil Engineers (ASCE) – Member All India Council for Technical Education (AICTE) – Member
Shri M. Saravanan	Indian Society for Technical Education - Member Indian Nuclear Society - Member Indian Association for Structural Engineering - Member Indian Association for Computational Mechanics – Member
Smt. K. Lakshmi	Indian Society of Wind Engineering, Computer Society of India – Member
Ms. C. Bharathi Priya	Indian Society for Wind Engineering (ISWE) - Member

Members of the Research Council

(Upto July 2013)

Dr. N. Rajagopalan	[Professor, IIT (M) (Retd.) & Former Dean, IIT-Madras] Chief Technical Advisor, L&T Ramboll Consulting Engineers Ltd., Chennai New No.1/Old No.13, Vasudeva Nagar Thiruvanmiyur, Chennai – 600 041
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Prof. C. Antony Jeyasehar	Prof. & Head, Dept. of Civil & Structural Engg. Annamalai University, Annamalai Nagar – 608 002
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Ms. Alpa Sheth	Partner, VMS Consultants Pvt. Ltd., 4, Jorawar Bhavan, 93, Maharishi Karve Road Mumbai-400 020
Dr. Shailesh Kr. Agrawal	Executive Director Building Materials & Technology Promotion Council Core 5A, 1st Floor, India Habitat Centre, Lodhi Road, New Delhi – 110 003
Dr. N. Palaniswamy	Chief Scientist and Head, Corrosion Protection Central Electrochemical Research Institute Karaikkudi – 636 006
Prof. S.K. Bhattacharyya	Director CSIR-Central Building Research Institute Roorkee – 247 667
Dr. Gautam Biswas	Director CSIR-Central Mechanical Engineering Research Institute M.G. Avenue, Durgapur-713 209
Dr. Nagesh R. Iyer	Director CSIR-Structural Engineering Research Centre CSIR Campus, Taramani Chennai – 600 113
Dr. Sudeep Kumar (Permanent Invitee) (or his representative)	Head, Planning & Performance Division (PPD) Council of Scientific & Industrial Research Anusandhan Bhawan 2, Rafi Ahmed Kidwai Marg New Delhi – 110 001
Dr. J. Rajasankar	Chief Scientist CSIR - Structural Engineering Research Centre CSIR Campus, Taramani, Chennai – 600 113

Members of the Research Council
(From August 2013)

Dr. N. Rajagopalan	[Professor, IIT (M) (Retd.) & Former Dean, IIT-Madras] Chief Technical Advisor, L&T Ramboll Consulting Engineers Ltd., Chennai New No.1/Old No.13, Vasudeva Nagar Thiruvanmiyur, Chennai – 600 041
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Dr. Shailesh Kr. Agrawal	Executive Director Building Materials & Technology Promotion Council Core 5A, 1st Floor, India Habitat Centre Lodhi Road, New Delhi – 110 003
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Dr. J. Rajasankar	Chief Scientist CSIR - Structural Engineering Research Centre CSIR Campus, Taramani, Chennai – 600 113

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(upto December 2013)

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Head, RPBD Member	CSIR- Structural Engineering Research Centre Chennai – 600 113
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Dr. S. Bhaskar Member	Principal Scientist CSIR- Structural Engineering Research Centre Chennai – 600 113
Dr. A. Rama Chandra Murthy Member	Senior Scientist CSIR- Structural Engineering Research Centre Chennai – 600 113
Dr. T. Hemalatha Member	Scientist CSIR- Structural Engineering Research Centre Chennai – 600 113
Dr. A. Hariharan Member	Principal Technical Officer CSIR- Structural Engineering Research Centre Chennai – 600 113
Dr. A.B. Mandal Member	Director, CSIR -Central Leather Research Institute Chennai - 600020
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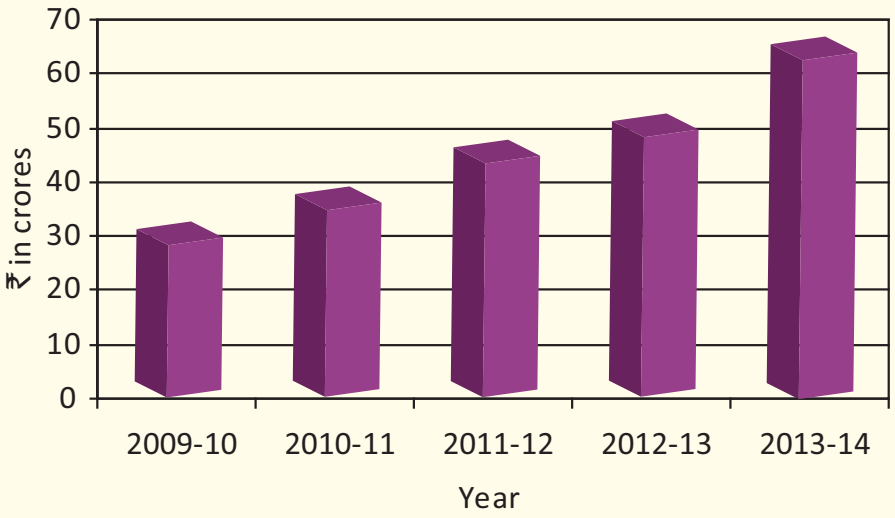
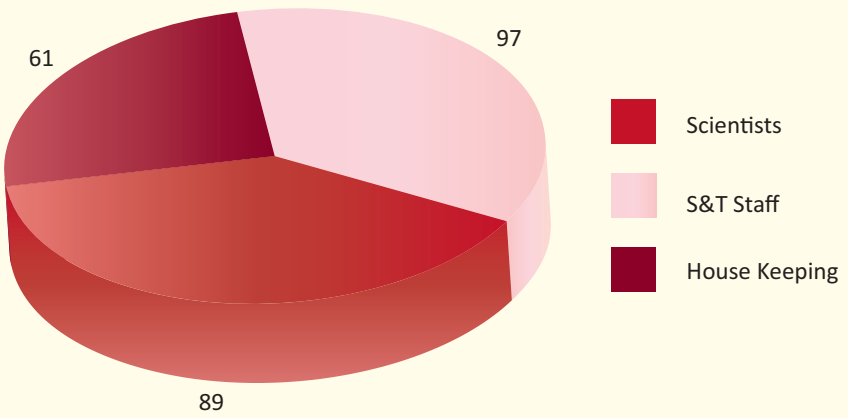
Controller of Finance & Accounts Member	CSIR- Structural Engineering Research Centre Chennai – 600 113
Controller of Admin. / Administrative Officer Member-Secretary	CSIR- Structural Engineering Research Centre Chennai – 600 113

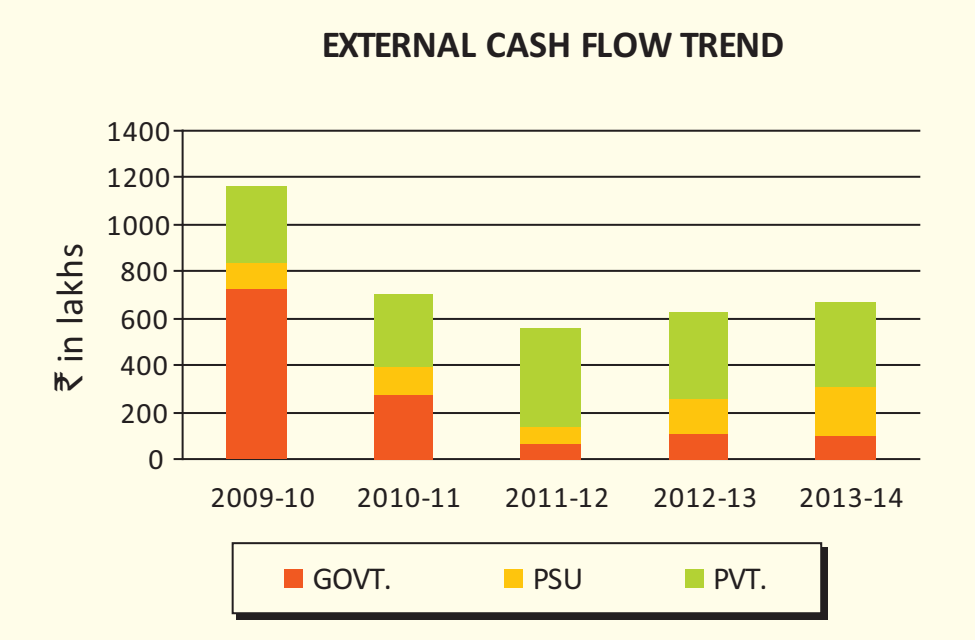
BUDGET

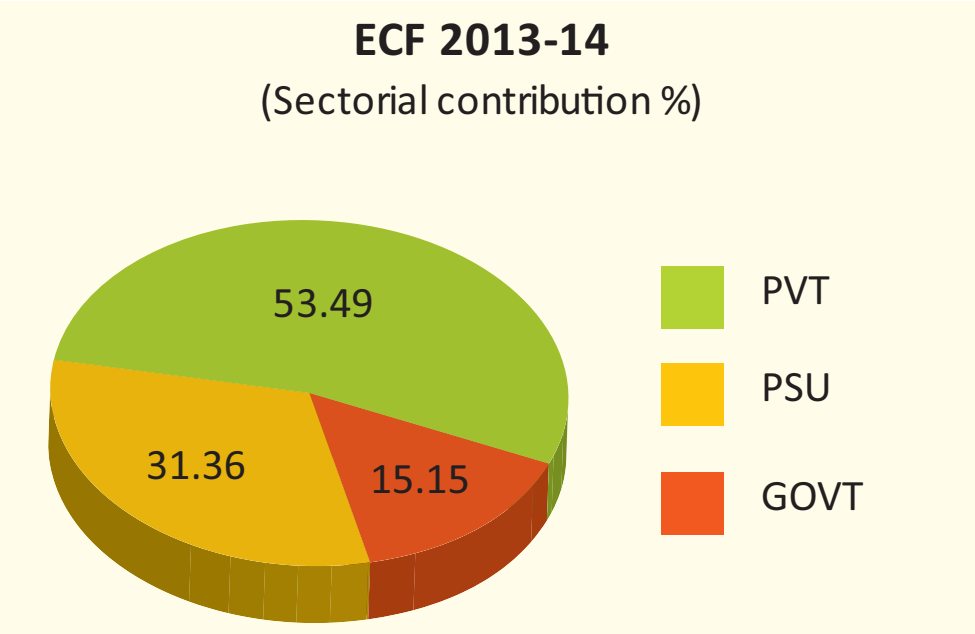


STAFF

(As on 1st April 2014)




EXTERNAL CASH FLOW TREND
₹ in lakhs
1400
1200
1000
800
600
400
200
0
2009-10
2010-11
2011-12
2012-13
2013-14
GOVT.
PSU
PVT.


ECF 2013-14
(Sectorial contribution %)
53.49
31.36
15.15
PVT
PSU
GOVT

CSIR-SERC TEAM COMES TOGETHER ON NEW YEAR DAY

For further information & details
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Participants of advanced course on Seismic Response Control and Damage Mitigation Methodologies for Buildings and Structures visiting ASTaR laboratory

Prof. Herbert Wiggenhauser, BAM, Berlin, Germany, delivering inaugural address during Advanced Course on Sustainable Engineered Concrete (SECON 2014)

Dr. Nagesh R. Iyer welcoming the delegates at the Inaugural Fucntion of the Eighth Asia-Pacific Conference on Wind Engineering (APCWE-VIII)

Prof. M. S. Swaminathan with Dignitaries during National Science Day Celebration on the Dias

Compilation, Editing, Design & Production

Director's Technical Cell & Knowledge Management Division, CSIR - SERC

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