

# Recent Advances in Structural Engineering and Materials

(A TEQIP sponsored winter school)



American Concrete Institute



AMERICAN SOCIETY OF CIVIL ENGINEERS



Department of Civil Engineering

Indian Institute of Technology, Hyderabad

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## Introduction

A two day winter-school was organized on January 14-15, 2015 on “Recent Advances in Structural Engineering and Materials-RAISE 2015” at IIT Hyderabad. The program, which was sponsored through TEQIP, focused on themes including:

- (i) Advances in Sustainable Infrastructure Materials (Materials with Low Carbon Footprint, high performance materials with low quantum consumption, and recycled materials)
- (ii) Advances in Performance Monitoring and Prediction (Structural Health Monitoring of civil infrastructure, Performance Prediction) and
- (iii) Advances in Strengthening Technologies (performance enhancement through innovative materials and strengthening techniques)

Technical sessions were delivered by leading experts from institutes of national importance like the IITs, IISc and eminent faculty from Canadian universities. The schedule of the program was as below:

**Day 1: Wednesday, January 14, 2015 (VENUE: Lecture Hall 3, Main Building, IIT Hyderabad)**

<b>Opening</b>	
8:00-8:30	Registration

<b>Advances in Sustainable Infrastructure Materials (Materials with Low Carbon Footprint, high performance materials with low quantum consumption, and recycled materials)</b>	
9:00-11:15	<b>Advances in developing Consistent Fly Ash based binders</b> Dr. K.V.L. Subramaniam, Professor, IIT Hyderabad
	<b>Innovative Concrete Materials with Low Carbon Footprint</b> Dr. Rishi Gupta, University of Victoria, Canada
	<b>Alternate Binders using Calcined Clay</b> Dr. Shashank Bishnoi, IIT Delhi
	Question and Answer
11:15-11:30	Tea-Break

<b>Advances in Performance Monitoring and Prediction (Structural Health Monitoring of civil infrastructure, Performance Prediction)</b>	
11:30-1:15	<b>Advances in Structural health Monitoring for Ageing Infrastructure</b> Dr. C.S. Manohar, Professor, Department of Civil Engineering, Indian Institute of Science, Bengaluru
	<b>Advances in Seismic Structural Monitoring and Earthquake Warning Systems</b> Dr. Carlos Ventura, Professor of Civil Engineering and Director of Earthquake Engineering Research Center, University of British Columbia
<b>Lunch</b>	
1:15-2:00	Lunch

Advances in Strengthening Technologies (performance enhancement through innovative materials and strengthening techniques)	
2:00-3:30	Advances in Strengthening of non-Engineered Construction Dr. Ananth Ramaswamy, Professor, IISc Bengaluru
	Rehabilitation of Deteriorated Structures using High Performance Fiber Reinforced Shotcrete Dr. Nemy Banthia, Professor and Senior Canada Research Chair, Department of Civil Engineering, University of British Columbia
	Question and Answer
3:30-3:45	Tea-Break

Technology Implementation (Strengthening, health monitoring and smart sensing)	
3:45-5:30	Application of Fibre Reinforced Polymer (FRP) in Infrastructure Repair and Strengthening Dr. Ashutosh Bagchi, Concordia University
	Implementation of Structural Health Monitoring Dr. Abdussamad Siddiqui, Starmass Environmental Technologies
	Field Applications of FRP Strengthening- Case Studies in India Dr. Gopal Rai, R&M International
	Question and Answer

Day 2: Thursday, January 15, 2015 (VENUE: Lecture Hall 3, Main Building, IIT Hyderabad)

Advances in Condition Assessment (Damage Assessment and Fire Performance)	
9:30-11:00	Damage Assessment in Concrete Structures including Fire Effects Dr. K.V.L. Subramaniam, Professor, IIT Hyderabad
11:00 -11:45	Fire Performance Modeling of Structures and Enhancement in Indian Context - Dr. Anil Agarwal, Assistant Professor, IIT Hyderabad

Advances in Strengthening Technologies (performance enhancement through innovative materials and strengthening techniques)	
11:45-1:00	Strengthening of Concrete Structures using External Post-Tensioning- An Overview - Dr. S. Suriya Prakash, Assistant Professor, IIT Hyderabad
<b>Lunch</b>	
1:00-1:30	Lunch

Field Visit- STARMASS Facility/ Visit to Laboratories	
1:30-5:00	Dr. Abdussamad Siddiqui, Starmass Environmental Technologies;

## Day 1: Advances in developing Consistent Fly Ash based binders

Dr. K.V.L. Subramaniam, Professor, Department of Civil Engineering, IIT Hyderabad



Dr.K.V.L. Subramaniam delivered the keynote lecture on alternate cements and low energy binders. He presented a historical overview of binders, detailing their development from roman age till the present modern day cement. The need for alternate low energy binders was put into perspective by presenting data on the embodied energy, the manufacturing process and the consequent environmental impact.

Dr.Subramaniam provided detailed insights into the development of supplementary cementitious materials. He highlighted the use of fly ash as an alternate binder and discussed its chemistry at length.

Prof. Subramaniam concluded his lecture by showing results from his recent research where he highlighted the challenges involved in the development of cement substitutes.

## Day 1: Innovative Concrete Materials with Low Carbon Footprint

Dr. Rishi Gupta, University of Victoria, Canada



Dr. Rishi Gupta presented an interesting talk on innovative concrete materials. He discussed the state of Canadian and global infrastructure and the current deficit. He listed recent initiatives taken in Canada towards sustainable construction and pointed out that the University of Victoria's Civil and Environmental Engineering Program focusses on sustainability.

He presented several examples of civil engineering collapses and discussed reasons for possible failures. He added that material failure could have been the reason in some of the collapses and added that performance of recent materials and technologies was not fully understood.

Dr. Rishi Gupta delved at length on fiber reinforced concrete and discussed its key features of sustainability and durability, by listing several examples from the construction projects in Canada.

## Day 1: Alternate Binders using Calcined Clay

Dr. Shashank Bishnoi, IIT Delhi



Dr. Shashank Bishnoi presented an overview of the worldwide cement production trends and stated that cement production in India is increasing at a very high rate, while it is either reducing or plateauing in all other nations. He then presented details of chemical composition of cement and highlighted that increasing cement production is environmentally unsustainable.

He emphasized that alternate binders must be explored and presented results from his group's research work on analysis and production of alternate binders. He added that further work on identifying and producing alternate binders using calcined clay is being carried out.

Dr. Bishnoi concluded by stating that the encouraging results would encourage construction industry to adopt the new binders.

## **Day 1: Advances in Structural health monitoring for Ageing Infrastructure**

Dr. C.S. Manohar, Professor, Department of Civil Engineering, Indian Institute of Science, Bengaluru



Dr.C.S.Manohar gave an interesting lecture on recent advances in health monitoring of ageing structures and Bayesian model updating. He emphasized the growing need to monitor a structure's health on a regular basis. Aging Structures are plagued by several problems such as fatigue, creep, scour, corrosion, cracking etc. and these effects are not completely understood nor monitored continuously.

The importance of combining mathematical models with experimental models was stressed. As an example, Dr.Manohar presented findings from his studies on condition assessment of railway bridges and stated that imperfection in mathematical and experimental models can be understood by continuous updating of these models, based on real time measurements made available by sensors.

Dr.Manohar concluded that the Bayesian framework presents a unified mathematical framework to tackle problems in model updating.

## Day1: Advances in Seismic Structural Monitoring and Earthquake Warning Systems

Dr. Carlos Ventura, Professor of Civil Engineering and Director of Earthquake Engineering Research Center, University of British Columbia



Dr. Carlos Ventura presented details of the advanced earthquake warning system being used in British Columbia. He explained the background regarding the causes and origin of seismicity along western Canadian border and the necessity to instrument the region to record seismic events.

Dr. Ventura also presented details of the infrastructure monitoring work being done in British Columbia under the auspices of the Ministry of Transport. He stated that the benefits of such a monitoring system are immense and critical information can be obtained in real time. He listed the pros and cons of such systems and added that there is a need to develop control systems to take automatic decisions.



## **Day 1: Advances in Strengthening of Non-Engineered Construction**

Dr. Ananth Ramaswamy, Professor, Department of Civil Engineering, Indian Institute of Science, Bengaluru



Dr. Ananth Ramaswamy discussed the recent developments in the field of strengthening engineered and non-engineered construction. He discussed the IRC and IS codes on rehabilitation of concrete buildings and bridges. He highlighted the general principles for improving seismic performance of structures and presented an example from a recent study on condition assessment of railway bridges.

Dr. Ramaswamy presented details of experiments and finite element analyses carried out at IISc on old masonry structures, fiber reinforced concrete structures and fiber reinforced polymer systems. He also presented details of load deformation characteristics of concrete exposed to high temperatures.

He concluded his lecture by emphasizing the need to study the potential impact of creep and shrinkage on repair techniques for concrete structures.

## **Day 1: Rehabilitation of Deteriorated Structures using High Performance Fiber Reinforced Shotcrete**

**Dr. Nemy Banthia**, Professor, Distinguished University Scholar and Senior Canada Research Chair, Department of Civil Engineering, University of British Columbia



Dr. Nemy Banthia presented a very interesting and thought provoking lecture on the use of shotcrete for repair and rehabilitation of deteriorating structures. He discussed the two common procedures used for preparing shotcrete: the dry process and the wet process. He also elaborated on the material properties, the mix design and the role of compaction.

Dr. Banthia presented details of fiber reinforced shotcrete (FRS) and listed its advantages over normal concrete. He added that the rebound models and penetration resistance models must be carefully studied, in order to fully understand shotcrete.

Dr. Banthia presented examples showing the growing application of shotcrete in areas such as slope stabilization, new construction, and infrastructure rehabilitation and tunnelling.

**Day 1: Application of Fibre Reinforced Polymer (FRP) in Infrastructure Repair and Strengthening**

Dr. Ashutosh Bagchi, Concordia University



Dr. Ashutosh Bagchi highlighted the importance of FRP in strengthening concrete structures. He stressed that FRP is an ideal material for rehabilitation of concrete structures as it is lightweight, corrosion resistant, possesses high strength and is highly versatile for use in different kinds of projects.

He presented design examples from the Canadian code towards application of FRP to strengthen flexural and shear members. As shear is a sudden, brittle failure mode, the applicability of FRP to strengthen structural members against shear failure was emphasized with an example.

In addition, Dr. Bagchi provided information on useful websites for obtaining further information on FRP.

## Day 1: Implementation of Structural Health Monitoring

Dr. Abdussamad Siddiqui, Starmass Environmental Technologies



Dr. Abdusammad Siddiqui presented a very interesting study on the practical application of sensors for structural health monitoring. He stated that sensors have a variety of applications these days, and highlighted several examples from recent industrial successes using these sensors.

In particular, Dr. Siddiqui highlighted application of sensors to monitor stresses in structures at the annual Haj pilgrimage, where stresses due to high footfall were monitored on a real time basis. He gave details of the project by showing project photographs and videos.



Dr.Gopal Rai presented a talk on the field application of fibre reinforced polymer composites. He discussed several structural rehabilitation projects handled by his company, with detailed photographs of the projects (before and after application of FRP).

Dr. Rai stated that proper identification of deterioration in structural members is key and discussed the need to use correct techniques for applying FRP to various structural members. He showed several photographs to emphasize correct application techniques.

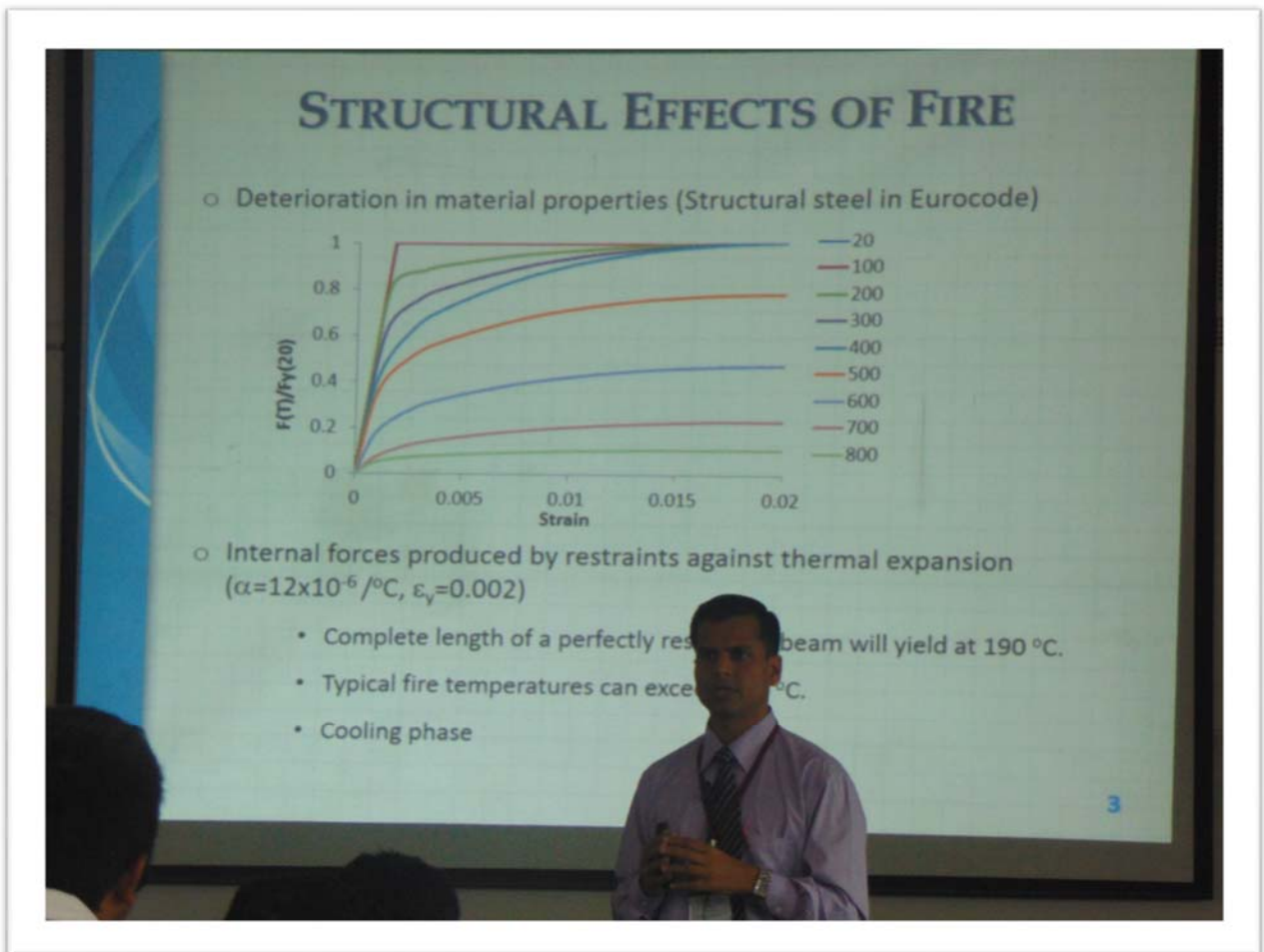
## **Day 2: Damage Assessment in Concrete Structures including Fire Effects**

Dr. K.V.L. Subramaniam, Professor, IIT Hyderabad



Dr.KVL Subramaniam gave an interesting lecture on material damage in concrete. It was emphasized that structural deterioration manifests itself in physical form as scaling, cracking, spalling, cavitation, freeze thaw damage etc. He highlighted the mechanics behind damage to reinforced concrete structures subjected to severe fire. The causes of sulfate attack on concrete and its manifestation, which could lead to progressive loss of strength.

Dr.Subramaniam also discussed the harmful effects of shrinkage. Cracking due to restrained shrinkage was discussed at length with an example of material testing on a cracked bridge deck.



Dr. Anil Agarwal discussed the hazard to structures due to fire. He delved at length on the structural effects of fire and showed examples from past experiences of buildings subjected to fire.

He emphasized that steel structures often need to be protected from fire and listed some common solutions used for the same. He highlighted the current state of practice in India and abroad and stated that current practice is based on codes which are prescriptive in nature and compared it with the new performance based methods which are under development.

Dr. Anil Agarwal also discussed the European Practice in detail and discussed calculations for thermal and structural response. He pointed out deficiencies of current approach and listed possible future areas for development.

**Day 2: Strengthening of Concrete Structures using External Post-Tensioning- An Overview**

Dr. S. Suriya Prakash, Assistant Professor, IIT Hyderabad



Dr. Suriya Prakash presented an overview on strengthening of concrete structures through post tensioning. His presentation mainly focused on types of post tensioning, design of post tensioned members, analysis considerations and their recent applications.

In the introductory part of the presentation, he discussed reasons for strengthening, gave a brief introduction about prestressing, and emphasized more on post tensioning and its types. In later part, he discussed analysis of post tensioned members, design criteria and IS code provisions.

He concluded his talk by showing some recent applications of post tensioning in different domains of structural engineering.

**Group Photo**



At the end of the two day workshop, the participants were asked to provide feedback in oral and written form. A group photo was also taken on the occasion.

