

# CONMAT 2003

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CONSTRUCTION MANAGEMENT AND MATERIALS  
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## Abstracts



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# Abstracts

## Keynote Papers

### 1 **Evaluating Structural Design For Constructability** **Mirosław Skibniewski and Krishan Mathur**

*Constructability is one of the many performance attributes that must be considered during the design process for a building or other constructed facility. Constructability must be analyzed along with all other attributes such as: Structural strength and stability, Level of complexity of structural assembly, Cost of labor, materials and equipment, Lighting performance, Acoustic performance, Maintainability, Durability, Ease of facility operation and others. Design evaluation is a dynamic process. However, constructability analysis should be performed at least at two important stages. One, during the early design stage, and two, during post-tender stage before the actual construction begins. The paper addresses various issues related to evaluation of structural design for constructability.*

### 2 **Long Span Truss Bridges in Seismic Zones** **Issam E. Harik and Wael A. Zatar**

*Bridges over the Ohio River in Western Kentucky are influenced by the seismically active New Madrid Zone. The majority, however, have been constructed prior to the implementation of stringent seismic design codes. This paper reports on the continuous seismic evaluation of highway bridges in Kentucky. The evaluation scheme includes a preliminary three-dimensional (3-D) finite element (FE) modeling, field ambient vibration testing, and calibration of the FE model. The calibrated models are then subjected to projected maximum credible earthquake excitations. The calibrated models may also serve as accurate baseline models for possible utilization in further assessments. As a representative example, generation of the baseline model of the US-51 Bridge on the Ohio River is presented.*

## Part I: Construction Management

### Invited Papers

### 3 **Application of Un-Bonded Post-Tensioning in Infrastructure – (a review on research and development)** **P.R.Chakrabarti and Keith Thornton**

*In this paper, the application and development of un-bonded post-tensioning over last forty years is discussed. The significance of various researches is also discussed. One equation for the calculation of ultimate stress of un-bonded post-tensioning, and another equation for the calculation of deflection of un-bonded post-tensioned beams, advanced by the first author are presented. Several photographs and sketches are added in the appendix.*

#### **4 Soils and Structures under Wave Load Werner Richwien**

*Within this paper some results of large scale tests in the wave flume of Hannover University/Germany on wave loads on dikes and other structures are presented and analysed. The transfer of wave loads into the soil beneath of closed revetments is discussed with respect to densification and pore pressure accumulation. A special problem is the breaker thrust on the outer slope of dikes covered with clay. A limit state equation for the thickness and the strength of the clay layer covering the dike slope is presented.*

#### **5 Construction and Evaluation Of CFRP Prestressed Concrete DT-Girder Nabil F. Grace and George Abdel-Sayed**

*The present study deals with the fabrication, instrumentation, and flexural-testing of a full-scale double-T (DT) concrete girder prestressed using bonded pretensioned carbon fiber reinforced polymer (CFRP) Leadline™ tendons and unbonded carbon fiber composite cable (CFCC) post-tensioning strands. The DT-girder was designed to simulate the performance of the girders used for the construction of the 3-span Bridge Street Bridge, City of Southfield, Michigan. The conducted test focused on measurement of strain distributions along the length and depth of the girder, transfer length, camber/deflection, cracking load, forces in post-tensioned strands, ultimate load carrying capacity, and mode of failure. It was observed that the ultimate failure of the DT girder was initiated by partial separation between the topping and the girder flange, which then led to the crushing of the concrete topping followed by rupture of bottom tendons. It was also observed that the ultimate and cracking loads of the girder were 5.3 and 1.4 times the service load, respectively. The deflection of the girder at the service load was 3.8% of that at the ultimate load.*

#### **6 Supporting Creative Collaboration in A/E/C Through Network-Like, Interleaved Information Technology Yehuda E. Kalay**

*This paper discusses the impact of information technology on creative collaboration in the building industry. It starts by establishing the need for collaboration, which is the result of professional specialization. It then classifies the different types of collaboration—association, team, and collaborative—and discusses the advantages and limitations of each. The habitual means that support collaboration in the building industry are explained, and case is made for network-like, interleaved collaboration, which is the only means capable of supporting creative collaboration.*

#### **7 Retrofit of Concrete Beams Strengthened With FRP Laminates against Impact Loading Taiping Tang and Hamid Saadatmanesh**

*Majority of research conducted on fiber reinforced plastic (FRP) applications in civil engineering so far has concentrated on static and pseudo-dynamic loadings. In engineering practice, there are many situations where structures undergo impact or dynamic loading, such as during an explosion, impact of ice load on pile structures, accidental falling loads, tornado-generated projectiles, etc. The characteristics of impact load are different than those of static and seismic loads. Since the duration of loading is very short, the strain rate becomes significantly higher than that under static and seismic loading. As a result, the behavior of structure will be different than that with a low strain rate. This paper presents the results of an experimental investigation conducted to study the impact effects on concrete beams strengthened with FRP laminates. Two types of composite laminates, Carbon and Kevlar, were bonded to the top and bottom faces of concrete beams with epoxy. A total of twenty-seven concrete beams were tested. The variation of beam stiffness, deflection, reaction force, and crack and failure modes were investigated. The test results revealed that composite laminates significantly increased the capacity of concrete beams to resist impact loads.*

**8 Repairing Corrosion-Damaged Prestressed Piles Using FRP**  
**Rajan Sen and Gray Mullins**

*Fiber reinforced polymers (FRP) are widely used to repair concrete structures. Recently, demonstration studies were undertaken by several state agencies to explore their use in repairing corrosion damage caused by deicing salts. This paper addresses some of the design issues relating to using FRP to repair corrosion-damaged piles driven in tidal waters where they are subjected to wet-dry cycles in salt water. The design of the FRP wrap requires data relating transverse strain due to corrosion to metal loss. Problems associated with their determination are discussed and initial findings presented. Also, results from studies conducted to evaluate the durability of the FRP wrap in a tidal environment are presented.*

**9 Role of Thin walled Prefab Steel Tubular Structural Building Systems for Better Construction Management**  
**Arunendu Banerjee**

*Prefab thin walled tubular structure are useful for large span space frames. It saves steel, labour and essential energy. Historical civilization of man also relates to technological civilizations. Better steel products will also better civil engineering projects. Efficient construction materials can result into timely and economy – efficient project management. Salt lake stadium Roof Cantilever system, are such example of efficient design – material – use to better project, effective project implementation in speed and economy, relevant to 21<sup>st</sup> Century – goal of futuristic Project engineering vision.*

**10 Plasticity Based Assessment of Slab-Girder Bridges**  
**Kiran Akella, Ib Enevoldsen and Finn M. Jensen**

*Slab-girder type superstructure is widely used in bridges. Hence, the aspects of repair and strengthening of these bridges are important. Substantial savings in repair and strengthening costs can be achieved by using analysis methods representative of the structural behaviour at failure condition, without compromising the overall safety requirements of the code. This paper discusses the observations made in this direction from the plasticity-based analysis of the slab-girder type deck in the Storstrom Bridge in Denmark. Observations on the behaviour of the damaged structure and the effects of deterioration of reinforcement on capacity are discussed. The importance of such analysis towards optimal repair and strengthening of slab-girder bridges is highlighted.*

**11 Earthquake Source Model and Estimation of Ground Motion**  
**R. N. Iyengar and S. T. G. Raghu Kanth**

*Success of earthquake resistant design practice critically depends on how accurately the future seismic hazard and the resulting ground motion can be determined at the construction site. Importance of estimating possible strong motion from potential earthquake sources has not been well recognized in India except in the case of nuclear power plants. On the other hand, the recent spate of earthquake related damages to our cities highlights the need to apply better methods, other than just codes, to find seismic forces. The paper discusses about the earthquake sources model and ground motion estimation aspects.*

# Contributory Papers

## Construction Management Aspects

- 12 Assessment of Risk for International Firms in the Chinese Construction Market: A Case Study**  
**Jie Situ, Qingbin Cui and Makarand Hastak**

*With the rapid growth of Chinese economy, the demand for construction and engineering service has steadily increased. China's accession to WTO offers more opportunities of market access for international construction firms. However, before finalizing the decision to expand operation in this new market a through analysis of the risks, benefits, and future market potential of the Chinese construction market is required. The paper presents an International Construction Risk Assessment Model (ICRAM-1) and uses the model to evaluate the risk for international construction firms involved in a high-rise building construction project in China.*

- 13 Investigation Of Constructibility Issues In Building Projects**  
**Reshma R, Koshy Varghese and J. Bhattacharya**

*The need to constructibility as a formal program is apparent. In India, Designers are aware of the operational problems, yet there are lapses in the designs in many projects. These lapses could be arrested if constructibility issues are considered from the planning stage itself, solutions thought off and built into the designs. The prominent reasons for not integrating constructibility into all phases of a project may be attributed to the fact that traditional contractual approaches for completing construction projects separate design and construction. For this study, constructibility issues were collected from four building projects. After proper categorisation, the issues were analysed for finding root causes. Eight management tools have been identified and their suitability in addressing the constructibility issues is analysed.*

- 14 Mitigation of Risks Associated with Construction Equipment**  
**S. S. Pimplikar**

*Use of Reliable Construction Equipment as a minimum necessity for the sustainable development growth of the Indian construction sector in the context of the globalisation and the liberalization of the economy is focused. Various risks associated with the Construction Equipment are identified and assessed for their overall impact on the performance of construction projects. Risk mitigation strategies are explored and the use of the Vorster Sears model as an effective way of managing risks associated with construction equipment is highlighted. As a case study, the impact of the risks associated with the earthmoving equipment used on a dam project is discussed, and the strategy that can be adopted for mitigation of risks associated with construction equipment is projected.*

**15 Risk Analysis in Production Shop Floor Pressure Vessle Unit  
D. Gerard David, V. Manikandan, G. L. Samuel, and A. Mohanakrishnan**

*Hazards are everywhere. Unfortunately, a hazard is not always identified until an accident occurs. It is therefore essential to identify hazard and reduce the risk - which is nothing but probability of occurrence of hazard - well in advance of an accident. This paper presents an in depth analysis and review of many aspects of risk analysis with the help of a study carried out at Bharath Heavy Electricals Limited – Trichy. Various stages in Risk Assessment are discussed with respect to a manufacturing industrial plants such as - Identification of hazards, Estimation of the effects of the hazard, Determination of the probability of occurrence of hazardous events. This paper also presents a new innovative and effective method in finding out the probability, severity, frequency and criticality of the risks. In general this paper gives an easy algorithm to calculate the criticality of the various hazardous event associated with the various operations and thereby helping us to identify the potentiality of the risks, based on their priority so as to take corrective actions at the earliest.*

**16 TLC Analysis In Engineering Industry  
D. Gerard David , S. T. Danier, G. SundarRaj and A. Doraiswamy**

*Total Loss Control (TLC) gives an overall assessment of the factory about the successful implementation of loss control program. It is a macro analysis starting from Management Involvement to advanced analysis in Ergonomics, Security etc., While a detailed safety code has been brought for conducting safety audits , except the material that is available in some form brought by the British Safety Council, we do not have any information. Total Loss Control (TLC) consists of examining 30 key result areas. Each key result area should be administered to factory and to find out how far they have that requirement to prevent loss. James Tye in his book on “Management Introduction” to TLC has given only ten questions on Management Involvement. An attempt has been made to develop similar such questions for all the 30 key result areas. The questions have been compiled by making reference to various standard books, by discussion with people who are in the field of Safety, Health and Environment.(SHE) and management science. The aim is to administer such a well developed criteria measurement to a select group of industries and assess the present status of SHE policies implementation. The inference is that the industry which scores high in the rating should necessarily have launched proactive programmes to entitle them to that status. After such a corroboration, this measuring criteria should be an effective tool to apply to any industry with ease as to know whether their loss prevention activities require 1. Immediate action 2. Short term action 3. Long range action. The questions are developed that they themselves is a way indicating various activities to be carried out.*

**17 Construction Process- An Integrated Approach  
Shailesh Jha, Virendra Kumar and M. M. Prasad**

*“Process Re-engineering” may be described as the rethinking and radical redesigning of construction process of Civil Engineering works to achieve dramatic improvements on critical, contemporary measures of performances such as cost, quality service and speed. The manufacturing industry has seen a lot of mutations during the past few decades, but the same cannot be said for construction Industry. It is a common thinking that re- engineering the construction process is a buzzword and not a reality. Enterprise Resource Planning (ERP), a software to integrate various departments in an industry, and Program Evaluation Review Technique, an old management fundamental adopted by many industries, have become successful in manufacturing industries only and the nexus of these two concepts along with a few changes may put new life in the dying construction industries. PERT along with a new concept of ERP is bound to revolutionize the construction process. In this paper a new re-engineered map for construction process has been drawn. Efforts have been made to add a new dimension in construction management theory and for making the people rethink about construction process re-engineering as a reality and not an illusion.*

**18 Activity Sequencing in Construction Projects Using Dependency Matrix  
J. Uma Maheswari and Koshy Varghese**

*Concurrent Engineering from the construction point of view is a process where the selected activities in the design phase are started simultaneously and are overlapped with the construction phase. It is obvious that assumptions have to be made to enable the simultaneous start and overlapping. These assumptions can lead to numerous problems. One of the challenges is to find the appropriate sequence of activities that will enable the concurrent execution without requiring risky assumptions. The Dependency Matrix has been identified as a powerful tool in solving the sequencing problem. It is used in modeling iterations and also helps in identifying and managing information needs and requirements. The present paper focuses on the activity-sequencing problem in the Engineering – Procurement – Construction domain and the application of Dependency matrix to address the problem.*

**19 Procurement and Institutional Strengthening for Road Development in India  
Bhargab Maitra, J. R. Sarkar and P.K. Sikdar**

*India has now taken a mission to upgrade its road transportation sector through several ambitious road development programmes. The achievements so far in various fronts of road development have been tremendous. However, as modern road infrastructure development has started only recently, there are ample opportunities to improve various aspects. The need, issues and challenges associated with two such aspects: rationalization of procurement process and institutional strengthening, are the focus of the present paper. Due considerations to the issues highlighted in the paper, will be helpful to ensure smooth transformation of know how, quality, economy and efficiency in the process of developing and sustaining a sound road transportation system in India.*

## **Analysis and Design**

**20 Assessment of Coefficient of the Consolidation in Geotechnical Practice  
A. Richwien and N. Meyer**

*One important parameter in soil mechanics is the coefficient of consolidation  $c_v$  and along with the degree of consolidation  $U$ . With the soil mechanical background of Terzaghi's one-dimensional consolidation theory most of the available methods determine  $c_v$  from the laboratory compression test. Of the various methods, Taylor's method and Casagrande's method are the most widely used in the laboratory practice. This paper presents another method to determine the coefficient of consolidation from laboratory consolidation tests, which is rectangular hyperbola method for consolidation analysis. The method can be used for all types of time-settlement curves and the interpretation of the test results based on this approach is more reliable than other classical curve fitting methods.*

**21 Impact in composite concrete panels due to small arms firing  
Major R.K. Mengi and Ashok K. Jain**

*The structures such as field defenses, security pickets, defense installation, ammunition storage bins are highly susceptible to impact loading of projectiles. Due to relatively low tensile strength and fracture energy, impact resistance of concrete is poor. In this paper an attempt has been made to study the impact effect of small arms fire in composite concrete panels made up of SFRC and ferrocement. It was observed that the depth of penetration with 9 mm machine carbine fire in case of 50 mm thick panels was 15 mm and the depth of penetration with 7.62 mm self loading rifle fire and light machine gun fire in case of 75 mm thick and above panels was 35 mm. The minimum thickness for single panels should be at least twice the depth of penetration plus up to 20 mm depending upon the panel thickness. If two 30 mm thick panels are placed at a gap of 15 mm the bullet is able to penetrate through the panel but not through the rear panel.*

**22 Flexural Behaviour of Two Way Reinforced SFRC Slabs**  
**S. Sivaraj, N.Arunachalam and Vengatasalopathy**

*In order to study the behaviour and Ultimate strength of SFRC(Steel Fiber Reinforced Concrete) slabs subjected to central concerted load, eight concrete slabs of dimensions 1m x 1m x 50mm thick were tested to destruction by applying gradually increased central concentrated load. Simply supported edge conditions were maintained for all the slabs. The percentage of steel fiber was varied from 0 to 1.75. The influence of fiber content in the behaviour of the slabs has been studied by measuring the deflection of the slabs and by observing the crack patterns. The ultimate loads obtained by applying the Yield line theory of slabs are compared with the experimental values. The percentage of fibers which results in least deflection of the slabs and maximum load carrying capacity has been identified.*

**23 Tensegrity – an Alternative to Conventional Structures**  
**Akhil Bhutani and Ankit Khanna**

*For years, researchers have worked on methods to improve the serviceability, durability and maintenance of civil structures. These led to the development of an innovative technology for making tensegrity structures which provide effective utilization of available materials, uses locally available materials, are easily built & disposed off and are examples of temporary structures. Such structures are based on the reasoning for knowledge gained through experience, search for effectiveness, learning and planning for such intelligent civil structures. In this review article our aim is to provide a beginner's introduction to this environmentally friendly technology. We have explained the basic concept of tensegrity, shown few standard configurations, applications, properties, recent research developments and introduce appropriate, general methods of analysis.*

**24 Steel–Concrete Composite Structural Systems In Buildings**  
**Mital M Shah, V V Nori and R D Vaswani**

*Internationally, composite construction has proven to be popular in recent years and has largely accounted for the dominance of steel frames in commercial building construction in developed countries. In India too, the use of composite construction is gaining popularity in commercial and hotel buildings. This article gives an overview of the possible types of composite systems for buildings and their application in a building being constructed in Bombay.*

**25 Influence of Berm Width on the Stability of Berm Breakwaters**  
**Subba Rao and Balakrishna Rao K**

*A laboratory investigation was conducted in a two-dimensional wave flume to study the influence of berm width on the stability of berm breakwater. The berm breakwater undergoes reshaping in response to wave action resulting in a stable profile. The changes in berm has been quantified by the two dimensionless parameter: the damage level  $A/(D_{50})^2$  and the eroded berm width  $L/B$ . The model studied consisted of armor stones of size  $D_{50} = 0.018m$ ,  $D_{50} / D_{15} = 1.82$  and  $H/\Delta D_{50}$  value between 2.6 to 5.2. Three different berm widths were studied. The results indicated that for known value of  $H/\Delta D_{50}$  the damage level and eroded berm width decrease with the increase in berm width up to certain limit.*

**26 Hysteritic Response Of Multistorey Reinforced Cement Concrete Infilled Frame**  
**S. Basil Gnanappa and E.B. Perumal Pillai**

*The action of natural wind gusts and other aerodynamic forces will continually buffet a multistorey structure. Although the structure will tend to deflects towards the mean position it will oscillate continuously. Now-a-days hollow concrete blocks are comparatively durable and uniformly stronger than clay bricks and are structurally stable. Also the hollow concrete block have characteristics like thermal insulation, sound absorption and reduction in self-weight due to hollowness. In the present investigation, an attempt has been made to study the behaviour of a two-bay Five storey R.C. frame infilled with concrete hollow blocks under lateral cyclic loads and the experimental results of top storey deflection is compared with that of finite elemental method of analysis by using ANSYS. The experimental and analytical results compare well in the case of top storey deflection of the reinforced concrete frame infilled with concrete hollow block.*

**27 Finite Element Analysis of Ferrocement Roofing Shell Elements**  
**Damodar Maity, Nazrul Imam and U. C. Kalita**

*A finite element code for the analysis of ferrocement roofing shell elements has been developed. The behavior of the ferrocement material is assumed as linear and elastic. The objective of this paper is to simulate deflection and stress behavior of different shell type roofing elements. A comparison of the numerical load-deflection response with the experimental data available shows excellent agreement. An attempt has been made to find out the economic shape of the roofing element on the basis of present results.*

**28 Design Scour Depth at Abutments in Thin Armor-Layers**  
**Subhasish Dey and Abdul Karim Barbhuiya**

*Investigation on local scour at abutments (vertical-wall, 45° wing-wall and semicircular), embedded in a bed of relatively fine noncohesive sediment overlain by a thin armor-layer of coarser sediment, was carried out experimentally for different thickness of armor-layers, bed sediments and flow conditions. The armor-layer and the bed underlain it were composed of different combinations of uniform sediments. In the experiments, the approaching velocities did not exceed the clear water condition with respect to the armor-layer particles. Depth of scour at an abutment with an armor-layer in clear water condition under limiting stability of armor-layer (approaching velocity almost equaling critical velocity of armor-layer particles) is always greater than that without armor-layer for the same bed sediment. The characteristic parameters influencing the maximum scour depth, identified based on the physical reasoning and dimensional analysis, are excess abutment Froude number, normalized flow depth, normalized armor-layer thickness, and ratio of bed sediment to armor particle size. The experimental results in clear water condition under limiting stability of armor-layer were used to determine the equations of maximum scour depth through regression analysis. The estimated scour depths were in good agreement with the experimental scour depths.*

**29 Modular Ratio Analysis of Flexible Pavement Using Falling Weight Deflectometer**  
**R. Srinivasa Kumar, K. S. Reddy, M. Mazumdar and B. B. Pandey**

*The design of granular layer thickness depends on the modular ratio (R-value) of granular layer and subgrade soil. Estimation of R-value plays the significant role in flexible pavements to choose appropriate granular layer modulus based on the subgrade strength and granular layer thickness. An attempt has been made to investigate the applicability of the widely used existing modular ratio prediction models in comparison with the present Falling Weight Deflectometer (FWD) back-calculated pavement layer moduli on a selected stretch of IIT-Kharagpur perimeter road in India.*

**30 Estimation of In-Situ Pavement Layer Moduli Using Falling Weight Deflectometer**  
**R. Srinivasa Kumar, K. S. Reddy, M. Mazumdar and B. B. Pandey**

*Impulse loading tests are being widely used for the evaluation and rehabilitation of pavements because of the shorter test periods and the resulting cost-effectiveness. Back-calculation of pavement layer moduli from measured deflections is a key element of the pavement evaluation systems that use impulse test data. The back-calculated moduli can be used in the analysis of the pavements and in the assessment of the existing condition and remaining life of the pavements. A number of back-calculation models are available at present. Most of these methods operate in an iterative manner and hence require larger computational time. A tool that can carry-out the back-calculation quickly will be very useful for checking the measured deflections on site. Any model that can produce reasonably accurate results without much computational effort can serve as a useful tool for the evaluation and design of pavements. The present paper discusses a model developed for the back-calculation of layer moduli of two and three layer pavement systems. This method is proposed to be used for the Falling Weight Deflectometer (FWD) developed by the Transportation Engineering section IIT, Kharagpur. Non-linear Multiple Regression Analysis Technique has been used for the development of the model. Back-calculated moduli of some field sections using the models developed have also been presented.*

**31 Vibration Analysis of Eccentrically Stiffened Laminated Plates with Cutouts**  
**A.N. Nayak and J. N. Bandyopadhyay**

*The free vibration of eccentrically cross-stiffened laminated square plates with square concentric/eccentric cutouts is investigated using the finite element method. The stiffened plate element is obtained by appropriate combinations of the nine-node doubly curved isoparametric thin shallow shell element with the three-node curved isoparametric beam element assigning very high values for the radii of curvature of both plate and stiffeners. The accuracy of the formulation is validated by comparing the authors' results of specific problems with those available in the literature. The additional problems are taken up for parametric studies to include the effects of boundary condition and number of stiffeners and size and location of cutouts on the free vibration characteristics of eccentrically cross-stiffened laminated plates.*

**32 An Approach For Sustainable Construction**  
**Anil K. Dikshit and Ashok K. Gupta**

*Sustainable construction is all about attempting to minimise the total environmental impacts of construction over the total life cycle of the buildings, from materials manufacturing and transport through construction, use, maintenance and repair followed by dismantling and disposal of wastes. In the present paper, a life cycle based approach has been outlined for ensuring above-mentioned objective with specific reference to construction activities. One case study has been included to demonstrate the application of the approach on a limited scale.*

## Retrofitting of Structures

### 33 **Retrofitting SCR Unit** **Subhamoy Kar**

*The emerging stringency of emission norms in the new millenium across the globe has hit the thermal power sector also like any other industry. For the generating stations already in operation, Owners are to look for “Add-on” units, with minimal disturbance to the various plant systems and operation. To abide by the revised clean air act in US, the power station Owners have resorted to the Selective Catalytic Reduction (SCR) units as the means to curb the NOx emission from coal fired boilers. The design and detail engineering for such SCR units are critical for the varying system parameters of different stations and due to the challenges of retrofitting in on-line boiler. This article is intended to give an account of the SCR system, which is already installed and commissioned in some power stations in US and planned to be installed in many others.*

### 34 **Application of FRP Materials for Repairing and Retrofitting Un-Bonded Post-Tensioned Beams** **P.R.Chakrabarti, M. Samara and S. Widjaja**

*In this paper, a relatively simple repairing and retrofitting method is suggested. Using FRP (Carbon and E-glass in this case) and adhesive materials, within a short time and without any skilled labor, a very effective repairing and retrofitting system has been developed. Two un-bonded, post-tensioned beams were loaded to ultimate load. These beams were then repaired with FRP and adhesives, and loaded again to ultimate stage. The load carrying capacity of these beams and the deflections were compared with the original un-cracked beams. Two other beams were retrofitted with FRP and adhesive materials, and shear patches were place at the load points. The load carrying capacity and the deflections of the retrofitted beams were compared with the original un-cracked beams and the repaired beams. The repaired and retrofitted beams behaved very well. Crack propagation, steel and pre-stressing strain, load and corresponding deflection were recorded. Discussion, conclusion, and recommendations for possible repairing and retrofitting of un-bonded pre-stressed structures are made.*

## Information Technology Applications

### 35 **A Comparative Study On Machine Learning Models for Constructability Analysis** **S V Barai and Rajeev S Nair**

*With the emergence of new computer science areas of artificial intelligence and neural networks, researchers have applied them in construction industry successfully. In this paper, we present comparative studies of two machine learning models namely backpropagation (BP) and Fuzzy ARTMAP based neuro-fuzzy models for handling qualitative fuzzy information of constructability evaluation. The model not only performs like traditional machine algorithm, but also handles well when the missing information is given to such model with better accuracy. Performance evaluation of the network test has been carried out using traditional statistical tests. From study, it was found that Fuzzy ARTMAP model performs much better than BP model.*

**36 Neuro Models For Finding Earthquake & Wind Forces On Building Frames**  
**V. S. Purani and S. C. Patodi**

*An Artificial Neural Network (ANN) based approach is suggested in the present work to evaluate earthquake and wind forces on multi- storied building frames. Lengthy, complicated and computationally expensive procedure of IS code for calculating the lateral forces is stream lined by employing nine Counterpropagation neural network (CPN) models. More than 3400 training patterns are extracted from various charts, tables and figures given in IS: 1893 and IS: 875 for earthquake and wind forces respectively. An interactive graphical user interface is evolved in Visual C++ to facilitate data input and to estimate and display the lateral forces at each floor level of multi storied building frame.*

**37 Feedback System for Designers**  
**Rajendra P. Adhikari**

*Among the various contractual approaches of executing construction works, traditional approach (separate design and construction functions) is the widely followed type particularly for public construction works. One of the major drawbacks of the separation of design and construction functions in traditional contracting method is that many problems are found resulted because of this gap. This paper discusses about the drawbacks of the separation of design and construction functions and proposes a feedback system to make learn and to incorporate learning from the past experience in the design process so that constructability of design can be improved. Incorporation of this feedback system in design will have positive impact in construction economy, method and functionality of the system/structure.*

**38 Probability Assessment Of Project Risks Using Fuzzy - Fault Tree Approach**  
**A. V. Thomas, K. N. Satyanarayana and K. Ananthanarayanan**

*Construction projects are increasingly complex and dynamic in their nature. Probability assessment of project risks is often a difficult task when past data on similar risks are not available. The actual problems are usually ill defined and vague, they require subjective evaluations, which classical risk assessment models cannot handle. A new risk probability assessment based on fuzzy-fault tree approach is proposed. This proposed approach is part of a risk assessment framework developed by authors for the critical risks in Indian BOT road projects. The method includes extensive scenario modelling of critical risks in projects and systematic processing of professional judgement (subjective knowledge) of experts. The module presented in this paper is generic in nature and can be applied to any complex project risk (by suitably modifying the model) where no past data is available for its probability evaluation*

**39 Knowledge Management in Construction Organisations**  
**V. Paul Christopher Charlesraj and Satyanarayana Kalidindi**

*Knowledge Management (KM) is an emerging concept that is gaining wide acceptance and is being implemented in many industries as an enabler of better decision making tool. The amount of information generated during the entire life cycle of construction projects is enormous and this information is not systematically put back into use in future projects, which ultimately leads to loss of knowledge. KM concepts can be implemented to improve the business performance of construction organisations in terms of time, cost, safety, and quality. The concepts of KM are presented in this paper. The research initiatives in developing KM systems for construction organisations are in the preliminary stages. Two research initiatives in Loughborough University, UK and University of Illinois at Urbana & Champaign, USA are presented. There is a significant need to explore KM in construction.*

**40 Knowledge based Expert System for optimizing the decision making process in tender evaluation**  
**Suvojit Bhattacharya and Ramesh Karnam**

*To solve a new problem by remembering a previous similar situation and by reusing information and knowledge of that situation. Using this principle we propose a system, which uses Case Based Reasoning (CBR) and Rule based approach in selecting the best bidder for a construction job in an organization. This selection is based on some expert rules of the domain engineer and on the selection criteria incorporated by the organization in similar past case.*

# Part II: Materials

## Invited Papers

- 41      Role of Fibres in the Flexural and shear Response of Prestressed Concrete Beams**  
**S. K. Padmarajaiah and Ananth Ramaswamy**

*This study presents the results from an experimental, analytical, and finite element analysis of high strength steel fibre reinforced concrete (HSFRC) fully and partially prestressed beams. The experimental program consisted of a set of beams, both fully and partially prestressed, having fibres of varying volume fractions placed in the different zones of the beams and tested in four point bending. The 28-day cube strength of plain concrete in these tests was 65 MPa. Based on these studies, it has been found that fibres contribute significantly to the ductility and enhanced the load carrying capacity substantially. Further, beams having fibres over half the depth in the tensile zone were found to give comparable loads and deformational response with respect to beams having corresponding amounts of fibres over the whole depth. The various deformational characteristics (deflections, curvatures, and strains) reduced as the percentage of fibres increased.*

- 42      High Performance Concrete – Research and Practice**  
**Ashok K. Jain**

*High performance concrete has been developed over the last few decades to provide cost effective solutions for tall buildings, bridges, marine structures, airports, and power plants and to provide superior durability in aggressive environments. However, there is a big gap between the concrete under research and that is produced in practice. Barring some reputed contractors in different parts of the country, a vast majority of the contractors are unable to produce even a satisfactory M20 or M40 concrete. The design and production of HPC is quite different than that of the normal concrete. There is a very complex interaction between the interstitial phases of cement gel of HPC. This paper brings out the general state of concrete production in India and latest changes in the Indian codes. Strict quality assurance and a very strong database are required at each stage of production of HPC.*

- 43      Coarse Recycled Aggregates for More Sustainable Concrete Construction**  
**Mukesh C Limbachiya**

*Concrete is the premier construction material across the world and the most widely used in all types of civil engineering works, including infrastructure, low and high-rise buildings, defence installations, environment protection and local/ domestic developments. This Plenary session paper gives results of studies undertaken to assess suitability of construction demolition as coarse aggregate in new concrete production and thereby assist with the implementation of the sustainable construction strategy. The influence of coarse recycled aggregate on the key fresh, engineering and durability properties of concrete are examined. Moreover, some of the key technical issues, together practical barriers associated with the use of recycled aggregates in new concrete construction are discussed.*

**44 The Difficult Choice of Appropriate Materials and Techniques for Retrofitting in Historic Centres**  
**L. Binda**

*The conservation of a historic patrimony is a very delicate operation which can be adequately carried out provided that a deep knowledge is collected of the building history, of the physical and mechanical characteristics of material and structure, of its state of preservation, of the appropriate way of strengthening and repair. When this attention is not given, non compatible repairs can be carried out with poor results. The paper after describing some examples of failures gives some general guidelines for a methodology of investigation and interpretation of the collected data and for an appropriate choice of the building functions and of the repair and strengthening techniques.*

**45 Deterioration of Concrete**  
**A P Gupta**

*All structures are designed for specified exposure of load but, unfortunately, no designer is comfortable in responding to queries about durability in such specified terms. A study of Indian, American, British, Australian, CEB-FIP codes on reinforced concrete will show that there is no specified expectation either. There are too many uncertainties to contend with -- in material, workmanship, environment and protocol for maintenance. Indeed, the designer is never expected to provide a protocol for maintenance. And yet, the question is legitimate as the cost on maintenance, repair and restoration should be taken into account while considering options in project proposals. The paper addresses issues related to deterioration of concrete.*

**46 Fabrication, Mechanical Testing and Scanning Electron Microscopic Study of Short Carbon Fibre Reinforced Reactive Powder Concrete (CFRPC) with Improved Fibre Dispersion**  
**Gary Jui-Pu Kao, Sri Bandyopadhyay and N. Gowripalan**

*A new type of cement has been developed in Europe and Canada, called Reactive Powder Concrete (RPC), where w/c ratios of 0.1-0.14 fine particles were used. This particular formulation has achieved high compressive and flexural strength. Carbon fibres have been used widely recently due to its long-term durability. Dispersion of short carbon fibres was always a major problem when they were mixed with cement. The present research has concentrated at carbon fibres dispersion in RPC by using two techniques: 1) Mechanical-ultrasound; and 2) Chemical-surfactants., The influences caused by these dispersion techniques on mechanical properties of the RPC were studied. Results show that ultrasound has provided better improvements on dispersing fibres and also enhanced overall mechanical properties. Surfactants have contributed lesser significant effects on the mechanical properties due to possible loss in interfacial bonding caused by the surfactant molecule.*

**47 An Experience In The Development Of Corrosion Resistant Reinforcement Steel**  
**U. K. Chatterjee , K. Banerjee and A. K. Chakrabarti**

*The development of a corrosion resistant low alloy steel to replace the conventional cold twisted reinforcement bars in concrete has been attempted. The experimental steels in the cold twisted condition have shown only a marginal improvement in corrosion performance over the cold twisted plain carbon steel rebars. The much improved corrosion resistance of an experimental steel in annealed or normalized condition demonstrates the deleterious effect of cold twisting. The ductility is also adversely affected on cold twisting. The alloy design with a slight modification appears to be potentially suitable for the production of corrosion resistant steel rebars.*

**48 Energy, Environment and Buildings**  
**K S Jagadish**

*The energy crisis of the seventies forced engineers to look at the energy content of building materials. This becomes important in conserving energy consumption in a world used to profligate use of resources. The awareness of the dangers of global warming, which became apparent in the eighties, focussed also on the annual energy consumption in buildings. It is estimated that about half of CO<sub>2</sub> emissions from human activities come from energy used in buildings in the U.K. It is now clear that there is a need to reduce the embodied energy as well as the maintenance energy consumed by buildings. It is also necessary to point out that the increasing tendency to air condition 'buildings using chlorofluoro carbons' is now known to lead to 'ozone-depletion' in the upper atmosphere. The depletion of ozone leads to transmission of hazardous ultra violet radiation to the earth's surface. Air conditioning loads can be significantly reduced through a combined use of Solar Passive Cooling and use of insulating materials. Such practices become important until refrigerants harmless to the ozone layer come into wider use.*

**49 Recent Advances in Atomistic Simulations of Fracture: A Review**  
**Qiang Lu and Baidurya Bhattacharya**

*This paper reviews atomistic simulation of fracture of solids with emphasis on recent results reported in the literature. Atomistic simulation (also referred to as molecular dynamics simulation or MDS) predicts the motion of a large number of atoms based on appropriate assumption regarding their interactive forces and boundary conditions. Based on the predicted evolution of the material structure at atomic level, relevant properties such as elastic modulus, fracture toughness, geometry of crack tip etc can be computed.*

**50 Recent Developments in Geo-Materials And Construction**  
**Madhira R. Madhav**

*The practice of Geotechnical Engineering has been revolutionized with the concept of reinforcement, the introduction of geosynthetics and engineered ground. Earth structures, e.g. steep slopes or high retaining walls are built economically with the placement of metallic or geosynthetic reinforcements or even scrap tyres. Geosynthetics made of polymers such as polypropylene, polyester, polyethylene, PVC, etc. woven, heat/resin or machine bonded, drawn, to form strips, sheets, nets, grids, membranes, etc. provide functions of drainage, filtration, reinforcement, separation, imperviousness, etc. and have several applications in various facets of civil engineering. With improved understanding of the behavior of soils, ground is engineered to increase its strength, stiffness and/ or to impart either increased or reduced drainage characteristics and increased liquefaction resistance*

# Contributory Papers

## Performance Studies

- 51 Performance Of Pulverised Fuel Ash In Cement Concrete**  
**Md. Kamruzzaman, S. M. Zahurul Islam, S. Md. Nizamud-Doulah and Star Jingkaojai**

*Flyash from coal burning power plants is used in concrete primarily because of its pozzolanic and its cementitious properties. These properties contribute to strength gain and improved durability when used with Portland cement. In addition to economic and ecological benefits, the use of flyash in concrete improves its workability, reduces segregation, bleeding, heat evolution and permeability, inhibits alkali-aggregate reaction, and enhances sulfate resistance. This paper presents the results of an investigation of performance of pulverized fuel ash as a partial replacement of ordinary Portland cement in cement concrete. It is observed from the experimental results that concrete exhibits higher strength, impermeability, lower heat of hydration, better compactability and better workability with strength compensation by such replacement.*

- 52 Static Modulus Of Elasticity Of Flyash-Silica Fume Concrete**  
**Virendra Kumar and M.M. Prasad**

*An experimental investigation on flyash–silica fume concrete has been presented in this paper. A design mix of M20 grade of concrete having proportion 1:1.40:3.40, w/c=0.52 has been used as reference mix. The partial replacement of cement with, a constant 7% by silica fume and a varying 10%, 15%, 20% and 25% by fly ash has been incorporated. The stress–strain curves for flyash–silica fume concrete at 28-day of maturity are plotted. The test results show that the static modulus of elasticity for mix containing up to 22 % fly ash plus silica fume is comparable to that of reference mix.*

- 53 Strength and Flow Characteristics Of High Performance Mortars**  
**P.Rathish Kumar and C.B.K.Rao**

*Reduction in water-cement ratio combined with a refined pore structure increases the compressive strength of mortars in addition to the enhancement of durability characteristics, but the workability decreases. A reasonably workable high performance cement mortar can be obtained by using a high cement content coupled with the use of superplasticizers. These were also found to retain the cohesiveness and check the undesirable bleeding and segregation. An experimental program was conducted to study the functional efficacy of a SNF condensate used as a water reducing superplasticizer. The compressive strength and flow characteristics of the mortars were determined. The parameters included the mix proportions, the grade of cement, age of curing and the dosage of super plasticizer. It was concluded from the study that addition of an optimum dosage of super plasticizer has improved the workability and strength characteristics of silica fume mortars. There was a late gain in the compressive strength of silica fume mortars.*

**54 Materials, Construction Quality Control and Energy Conservation with Special Reference to Cement Concrete Materials**  
**P Krishnamachar and Saroj Rangnekar**

*Energy conservation is an effective energy management strategy needed to be adopted in every activity. Construction materials are energy expensive and need to be judiciously used under strict quality control. The paper looks at quality control measures in construction material management as energy conservation strategies and quantifies energy conservation possibilities in the use of cement, water and aggregate. Reducing water cement ratio to the minimum for machine mixing and placing with vibration can save 50% of cement. Prolonged curing can increase the strength by 38%. Revibration / remixing is detrimental, especially with rapid hardening modern cements. Water, used as an important ingredient of cement mixes as well as curing, is precious, consuming 31.5 kWh of solar energy in its production in nature, and needs to be conserved. Curing water requirement can be cut to 1/60<sup>th</sup> by reducing water cement ratio from 0.6 to 0.38. Quantities of ingredients of concrete can be cut to 40% to 60% by obtaining maximum possible strength by strict quality control.*

**55 Failures in Cohesive Geomaterials Due to Shear Band Formation Siddhartha Sengupta and Aniruddha Sengupta**

*Geomaterials may exhibit both in laboratory experiments and in fields strain accumulations in well defined narrow zones. This phenomenon is called strain localizations or formation of shear band. In such shear band, material behaviour is inelastic, while the remaining zones are elastic, with infinitesimal strains. Typical examples can be found in brittle geomaterials where progressive damage produces strain softening, or in soil as for instance in case of slope stability or foundation failure. Present study aims at finding the failure mechanisms of cohesive geomaterials under plane strain condition. Kaolinite has been used as test material.*

**56 Morphology of Aggregates for Concrete- State of Art Report on Methods of Evaluation**  
**Sanjay Shrinivasrao Jamkar and C. B. Kameswara Rao**

*Aggregates occupy bulk of the volume of concrete. Their grading and morphological characteristics such as size, shape and surface texture have significant influence on the properties of concrete, both in the green and hardened state. The influence of these properties has become more crucial with the increasing use of High Strength and High Performance Concrete. The specifications for size and grading of aggregate are clearer than their shape and surface texture. Therefore, objective measurement of morphological properties of aggregate is essential for good quality control and also for understanding their influence on the behaviour of concrete. The paper presents the state of the art report on the stages of developments in this regard and the significance of these properties on the behaviour of concrete.*

**57 Role of Coarse Aggregate Gradation And Shape Factors in Bituminous Mix Properties**  
**Mohamed Ilyas Anjum and Krishnamurthy**

*The various theories adopted for proportioning of aggregate mix aim at obtaining maximum density. Various agencies have specified the ranges of gradation requirement in the form of gradation tables. The variation in gradation changes not only the proportions of aggregate in the mix but also its shape factors. These changes are likely to affect the properties of the resulting mix. In this study, an attempt has been made to study the effect of variation in aggregate gradation and hence the shape factors on bituminous concrete mix properties and compare the results obtained with those at the proposed optimum gradation. Ten different aggregate samples were collected. Dry density, Marshall stability and Indirect tension tests were carried out on aggregate mixes prepared at low bound, middle bound and high bound gradations using the MOST<sup>(8)</sup> (Ministry of Surface Transport) gradation table for bituminous concrete as well as at the proposed optimum gradation. It was generally observed that the mixes prepared corresponding to the optimum gradation have improved properties. Further the effect of coarse aggregate shape factors could also be considerably reduced.*

**58 Effect of Replacement of Cement by Silica Fume on the Permeability of Silica Fume Concrete**  
**T D Gunneswara Rao and D R Seshu**

*Experimental studies on partial replacement of cement by this silica fume in concrete were reported in this paper. An attempt has been made to study the effect of partial replacement of cement by silica fume particularly, in respect of permeability aspect of concrete. Up to 16% replacement of cement by silica fume, the strength of concrete improved and permeability decreased. Beyond 16% replacement of cement by silica fume reduced the improvement in the strength but reduction in permeability continued. From this investigation, it is concluded that replacement of cement by silica fume up to 16% is beneficial from durability consideration without sacrificing the compressive strength / tensile strength of the mix.*

**59 Fatigue Studies of Bituminous Concrete With Polymer Modified Bitumen**  
**V.S. Punith, M.M.K. Durrani and A. Veeraragavan**

*The current study deals with the investigations on EVA-polymer modified bituminous mixes. Marshall stability tests were carried out on plain and modified bituminous concrete mixes to determine the optimum bitumen content and optimum modifier content. Indirect tensile test was then conducted at test temperatures of 25°C, 30°C, 35°C and 40°C on specimens prepared at the optimum polymer modified bitumen content for bituminous concrete mixes. Laboratory fatigue tests on bituminous concrete and polymer modified bituminous concrete conducted at 25°C, 30°C, 35°C and 40°C at 40% and 50% stress levels under constant stress mode indicated that the fatigue life of the EVA-polymer modified bituminous concrete is significantly higher than that of the plain bituminous concrete.*

**60 Indirect Tensile Tests On Crumb Rubber Modified Bituminous Mixes**  
**M. P. S. Reddy and A. Veeraragavan**

*Laboratory tests were conducted to study the tensile strength of compacted bituminous mixtures with and without crumb rubber as modifier for both Dense Bituminous Macadam (DBM) mix and Bituminous Concrete (BC) mix. Marshall specimens were prepared by adding 8%, 10% and 12% of crumb rubber modifier at optimum bitumen content. The specimens were tested and the indirect tensile strength of the modified bituminous mix was determined before and after soaking the specimens in water as per ASTM D 1559-65 and ASTM D 4123-82. The test results shows that the additive significantly increases the indirect tensile strength of the bituminous mixes and also they exhibit good resistance to soaking.*

**61 Evaluation of hardened concrete properties using non-destructive methods  
Manu Santhanam, Amal Raj, and R. Vikramaditya**

*Non-destructive measurements using the rebound hammer and ultrasonic pulse velocity equipment were performed on hardened concrete specimens from three mixtures – M1 (high w/c), M2 (low w/c), and M3 (high w/c with steel fibres). Apart from through transmission measurement, the pulse velocity equipment was also used for semi-direct and indirect measurements on beam specimens. Results from the study indicate that the rebound hammer tests cannot be used reliably to predict the strength of concrete, and is highly dependent on the surface quality at the time of testing. Ultrasonic pulse velocity test in a through-transmission mode can be used to study the damage at different stress levels in the concrete. Such data can be utilized to ascertain the concrete condition in service and to predict the remaining service life. When access to two sides of the structure is not possible, indirect means of measurement of pulse velocity can be used. The test results show that indirect measurements can be modeled as a linear function of through-transmission measurements.*

**62 Behaviour of Ferrocement Specimens with & without fibres for various span to depth Ratios  
V. Bhaskar Dasai, K. Lakshmi Pathi and P. Krishnaveni**

*This paper presents a study on the behaviour of ferrocement elements in flexure. The results of 70 simply supported beams with out steel fibres and 120 simply supported beams with various %ages of fibres for variable span to depth ratios (a/d) are presented. 70 specimens are tested for various span to depth ratios i.e 2, 4,5,6,8, 10& 11.7 with increasing number of chicken wire mesh layers from one to five layers. 120 specimens are tested with a/d ratios of 4, 8, 10 and 13 with increasing number of chicken wire mesh layers 1, 3 and 5 and increasing percentage of fibres 0, 0.5, 0.75, 1.0 and 1.5. It is observed that ultimate load in flexure is increasing with increasing in number of wire mesh layers and decrease with increasing a/d ratios for the specimens with and without fibres. Also the ultimate load in flexure is found to increase with increase in percentage of fibres. The present study throws some light on the strength properties and deflection characteristics of ferrocement specimens with and without fibres.*

**63 Shear Reinforcement For Brick Work Beams Using Ferrocement  
V. Bhaskar Desai and Ravi Shankar**

*In the present paper behavior of shear reinforced brickwork beams with ferrocement using different types of shear reinforcement such as stirrups, weld mesh and chicken mesh has been presented. Twelve specimens of each series A & B totaling to 24 have been cast & tested. In "A" series two rods of tensile reinforcement are used where as in "B" series four rods of tensile reinforcement are used. The other parameters like spacing of vertical stirrups and number of layers of weld mesh and chicken mesh are same in both the series. The specimens are tested under two point loading. The effect of variation of first crack shear strength, ultimate shear strength versus different types of shear reinforcement, along with the load deflection behavior have been studied.*

**64 Cementitious Materials In Road Construction  
B. B. Pandey**

*Low cost solution is necessary for speedy construction of roads and highways. Application of cementitious materials like Portland cement, lime and fly ash, granulated blast furnace slag etc can bring down the construction cost considerably. This paper describes structural properties of cementitious materials, which may be used as base layer of bituminous pavement. Thickness design method is also presented. It is found that much less thickness of bituminous layer is required if cemented bases are used as compared to the standard granular bases.*

## Alternate Materials

### 65 **The Potential Utilization of phosphogypsum in concrete** **Rajesh B. Thakare, O. P. Bhatia and K. G. Hiraskar**

*Recent revision in Indian Standard (IS: 456 - 2000) opens the new avenue to cement and concrete industries to use variety of mineral admixtures such as fly ash (pulverized fuel ash), silica fume (SF), rice husk ash (RHA), highly reactive metakaolin (HRM), ground granulated blast furnace slag (GGBFS). The ongoing research work and literature survey conducted indicates phosphogypsum (PG) has greater potential in utilizing as admixture than that of some materials specified by the code.*

### 66 **Characterization of GGBFS as Partial Cement Replacement in Concrete** **S C Pal, A. Mukherjee and S.R. Pathak**

*The utilization of Ground Granulated Blast Furnace Slag (GGBFS) as a cement replacement material is gaining importance due to its improved performance characteristics in concrete composites and also due to the economy achieved in the production of cement and cement composites. Separate grinding of slag and its addition as a mineral admixture/ supplementary cementitious material in concrete is often seen as a means of reducing the temperature due to its hydration process. However, the properties of slag may vary significantly depending upon the type of raw material used, method and rate of cooling. This paper presents the characterization of slag in order to investigate which slag can be used economically and effectively to replace cement in high doses.*

### 67 **Phosphogypsum Applications in Cement Concrete** **M.S. Mulla, V.V. Karjinni, V.D. Gundakalle and R.B. Thakare**

*Phosphogypsum (PG) is the waste product of the fertilizer industry, i.e. phosphoric acid production. PG is the third major waste product of India. Typical analysis of phosphogypsum shows that the major constituent of phosphogypsum is gypsum and the other constituents are in minor quantities. At 5 per cent replacement of cement (by weight) with PG there is gain in strength as compared with percentile replacements. In the present investigations carried out compressive strength characteristics, flexural strength characteristics and other parameters have been studied. In the end a Logical Method of mix design using phosphogypsum has been suggested.*

### 68 **Suitability of No-Fines Concrete Short Columns with Glass Fibre Reinforced Plastic (GFRP) Casings** **Prashanth G. Kulkarni, B. R. Patagundi and K.B. Prakash**

*Among the major break throughs in the field of concrete technology are the invention of different types of concretes like high density concrete, light weight concrete, polymer concrete, fibre reinforced concrete etc.. All these special concretes in one or the other way offer many advantages during the construction. In this experimentation an attempt is made to study the behaviour of no-fines concrete short columns with GFRP casings. For the study no-fines concrete short columns are prepared with different proportions like 1:2, 1:3, 1:4, 1:5 and 1:6. These no-fines concrete short columns are wrapped in GFRP casings containing zero layer, 1 layer, 2 layers and 3 layers. The strength aspect of these GFRP encased no-fines concrete short columns are compared.*

**69      Activation of Lime Kiln Dust to Develop a Cementitious Material**  
**V.T.L.Bogahawatta and Hassan Karam**

*Lime kiln dust, an industrial waste generated by the hydrated lime industry in Kuwait, was subjected to mineralogical analysis followed by activation trials and activity enhancement techniques. A series of predetermined firing schedules were performed on the fractionated material. A combination of six firing temperatures and two isothermal holding times were employed. Selected minerals were used as additives. The optimum size fractions and firing schedules appropriate to the material were thus established. Pozzolanic activity of cements was determined as an index. The tests on the specimens indicated an improvement in compressive strength when critical size fractions are heat treated according to a schedule established in the investigation. The resulting cementitious material shows promise in partial replacement of Portland cement in concrete.*

## **Inexpensive Technology**

**70      Behaviour Of Bamboo-Reinforced Flexural Members**  
**Sanjay Kumar and M. M. Prasad**

*Investigations conducted on the strength and deformation characteristics of six beams –three conventional concrete bamboo reinforced beams (CCBRB) and three blended concrete bamboo reinforced beams (BCBRB) of size 125mm x 150mm x 1000mm with bamboo strips as reinforcement in tension zone have been reported. The blended concrete, containing fly ash and blast furnace slag as 15% and 30% replacement of cement and coarse aggregate respectively by weight has been used. All beams have been tested under two-point loading. Test results show that the first-crack load and experimental failure load have been found almost same for both types of beams. The experimental failure loads are 2.72 and 2.54 times their corresponding theoretical failure loads respectively. All beams exhibited large ductility before final failure in flexure.*

**71      Recycling of crushed Rock Dust as fine Aggregate for concrete**  
**K.Kumarasamy , K.Nagamani and R.Ilangovan,**

*All along in India we have been using natural sand. The volume of concrete manufactured in India has not been much, when compared to some advanced countries. The infrastructure development such as express highway projects, power projects, and Industrial developments have started now. Availability of natural sand in that is getting depleted and also it is becoming costly and illegal sand quarrying from river resulted loss of soil, loss of Ground Water, farm land also affect and changes in river course. Concrete industry now will have to go far Recycling of crushed Rock Dust as fine Aggregate in concrete construction. Large-scale use of such crushed Rock dust in making structural grade concrete can lead to economy in the material cost of the projects. This article examines the possibility of using crushed rock dust as fine Aggregate in the place of sand. Also this paper presents the results of experiments conducted on crushed rock dust made concrete cubes with Indian, British and ACI design mix specification in Material Testing Laboratory of RVS College of Engineering, Dindigul, Tamil Nadu. The Test result shows that  $M_{20}$  &  $M_{30}$  made concrete cubes using crushed rock dust as fine aggregate is better than the river sand both strength wise and cost wise.*

**72 Promotion of Appropriate Low-Cost Housing Walling Materials in Rwanda**  
**Kyambadde Benjamin Senyonga and K.K. Singh**

*This paper gives a broad overview of the low-cost housing situation and the common walling materials (their availability, use and constraints of production) in Rwanda. Suggestion is made of strategies to adopt, and the measures to be undertaken by government and other partners in promoting the use of appropriate / cost effective walling materials that could well perform in place of the conventional materials.*

## **Innovative Applications**

**73 Radiation Shielding Concrete With Special Aggregate**  
**Rabindranath De, S. Chakraborty and Tapas Bandopadhyay**

*Concrete is an effective shielding material against nuclear radiation and is extensively used for shielding of nuclear power plants, particle accelerators, reactors etc. It is relatively cheaper with good structural properties and cast into any shape. As it consists of many heavy and light materials, it has got good nuclear properties to attenuate radioactive rays specially neutrons. An effort was made to increase water content with addition of serpentine by partially replacing normal constituents of concrete. Few slabs of varying thickness were cast with ordinary concrete and with serpentine. Neutron attenuation through these slabs were studied using Pu-Be neutron source and NE-213 liquid scintillator along with standard NIM as a detector set up and serpentine concrete is found more effective shield for neutrons after a certain thickness.*

**74 Fly Ash- As An Additive For Stabilization Of Soils**  
**B.A. Mir and N.S. Pandian**

*At present, nearly 100 million tonnes of fly ash is being generated annually in India posing serious health and environmental problems. To control these problems, the most commonly used method is addition of fly ash as a stabilizing agent usually used in combination with soils. In this study, high-calcium and low-calcium fly ashes were used for stabilization of black cotton soil. Fly ashes were added to the black cotton soil and subjected to consistency limits, compaction, consolidation and strength tests. Specimens with fly ash were cured for 7 days and 28 days and subjected to different tests. Based on the favourable results, it was concluded that the fly ash could be successfully used as an effective additive in stabilization of soils.*

**75 Cenospheres: The High Potency Fillers for Specialty Construction Materials**  
**A. Sarkar, A. Kumar, G.Udayabhanu and A.K.Basu**

*Flyash, the coal combustion residue, contains cenospheres apart from many other morphologic classes. Some of the unique properties like high mechanical strength, low thermal conductivity, reduced shrinkage, chemical inertness makes this material highly potent as filler material for use in construction. This paper aims to evolve some of these properties and the potential use of the cenospheres. An attempt has been made to obtain cenosphere enriched floats from flyash. Physico-chemical and morphological characterizations have been carried out for each of the floats. The float obtained from the finest fraction (under pass of sieves of m.s 350 ) is recommended for use in the speciality construction materials as these floats have higher enrichment of cenospheres, low carbon content and high  $Al_2O_3$  /  $SiO_2$  content.*

## **A Survey of Use of Ferrocement as Potential Rehabilitating Material for Various Structures**

**Narendra Arora and C. B. Kameswara Rao**

*Imperfection in construction techniques, misinterpretation of structural design principles, prevailing corrosive environmental conditions, natural disasters, fire and bad maintenance schedules, induces distress in structures. Demolition and reconstruction of such buildings are usually restricted by economical aspects and non availability of services rendered by building for long periods. There are various rehabilitation techniques available to bring back these structures into serviceable conditions. In the past decades, ferrocement has emerged as a very good rehabilitating / re-strengthening material because of it's superior mechanical properties, high in-plane strength, better mouldability, and low cost low technology application. The paper presents, development of this field in past decades.*