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6. To disseminate information in various fields of Structural Engineering, to all members.

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GRAND PAGODA - A WONDER IN MASONRY

M.N. Varma, N.R. Varma, P.N. Varma and V.G. Achwal

Cover page Story

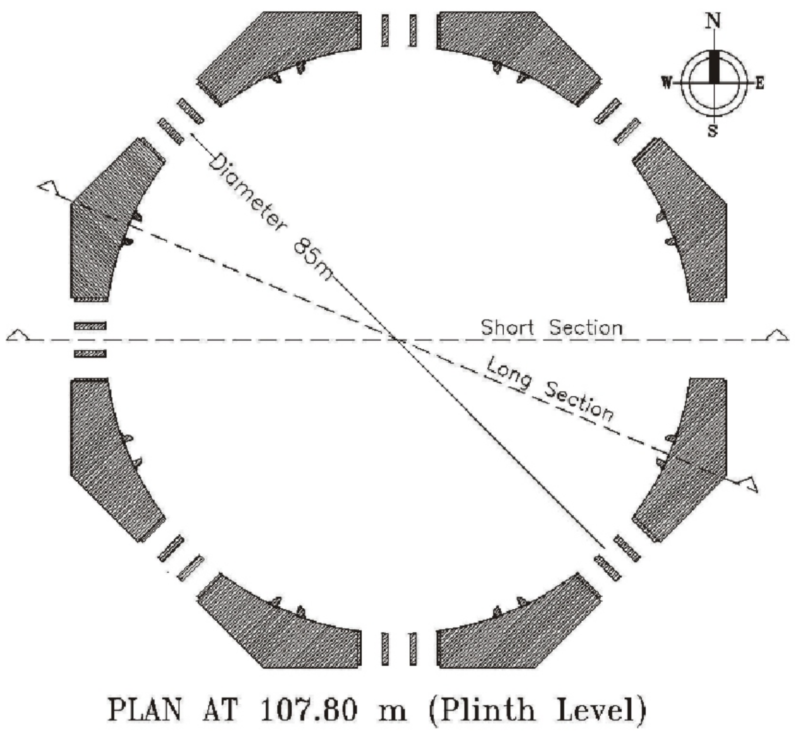
Introduction:

The advances in modern materials in the last few decades have made masonry more as the subject of history of architecture. RCC and steel are used at every place where fast track construction is needed and the trend of modern materials has caused us to ignore the structural use of masonry. Masonry construction techniques for temples, domes, vaults and even the arches do not seem to be in practice these days. In fact, these techniques are not found in our engineering books also. As a result, the use of masonry has become limited to partition walls and non structural elements.

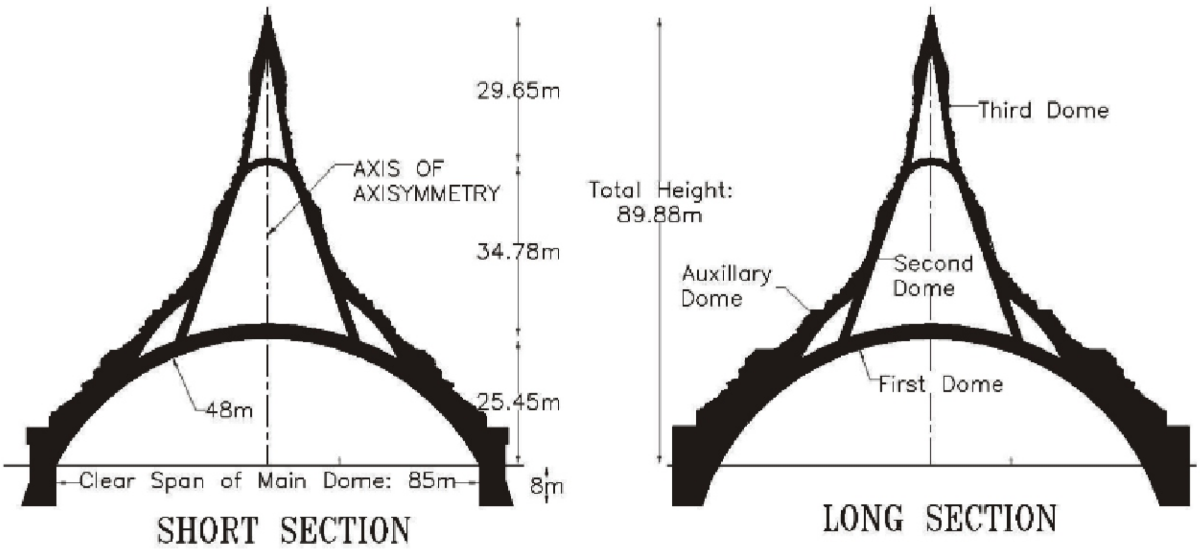
Though RCC construction can be carried out at a faster rate and RCC structures are easy to analyze, the life expectancy of such structures is limited. While the bridges and buildings built using RCC need replacement within 50 years of its construction, the ancient structures built in masonry, in harmony with nature, have been standing for thousands of years and will continue to stand for a few more hundred years before failure. Further, the feeling of holiness and peace which we get in religious structures constructed in masonry can not be achieved by using RCC or steel in structures. In the absence of insight of structural behaviour and techniques of structural analysis and methods of construction of masonry structures, engineers are tend to use RCC even for spiritual or religious structures.

The Grand Pagoda:

Design and construction of the Grand Pagoda near Mumbai is an effort to bring to life the ancient techniques of masonry construction and to blend it with the modern methods of analysis and construction to make structural use of masonry more practicable. The largest span of un-reinforced masonry dome known before this structure was Pantheon (Rome, Italy-123 A.D.) with a span of 43 meters, St. Pietro (Rome, Italy-1590) with span of 42 meters and Gol Gumbaz (Bijapur, India) with span of 42 meter [1,2]. Now the Grand Pagoda (Oct 1997- Nov 2008) is constructed with a dome of clear span of **85 meters** as shown in *Drawing 1* and *Drawing 2*. The seating capacity of the base dome is 8500 persons. The structure has a height of 89 meters and has consumed several lakh tonnes of masonry.



Drawing 1: Plan of Grand Pagoda



Drawing 2: Cross sections of Grand Pagoda

Grand Pagoda is a center for meditation and exhibition for spreading Vipassana technique of meditation. The external profile of Grand Pagoda is the replica of Shwe Dagon Pagoda (Yangon, Myanmar). Shwe Dagon Pagoda is completely a solid structure having no room inside structure, whereas the inner portion of Grand Pagoda is covered with massive dome offering the place for meditation under the dome.

Constructional Details:

Grand Pagoda is constructed in the stone masonry and brick masonry with Lime and Surkhi mortar. The First dome is constructed with fascia in Jodhpur Ashlar stone and core in CRS masonry. The second dome is constructed using fascia in Jodhpur Ashlar stone and core in brick masonry. The third dome has less thickness compared to previous two domes and hence it is built completely in Ashlar stone masonry.

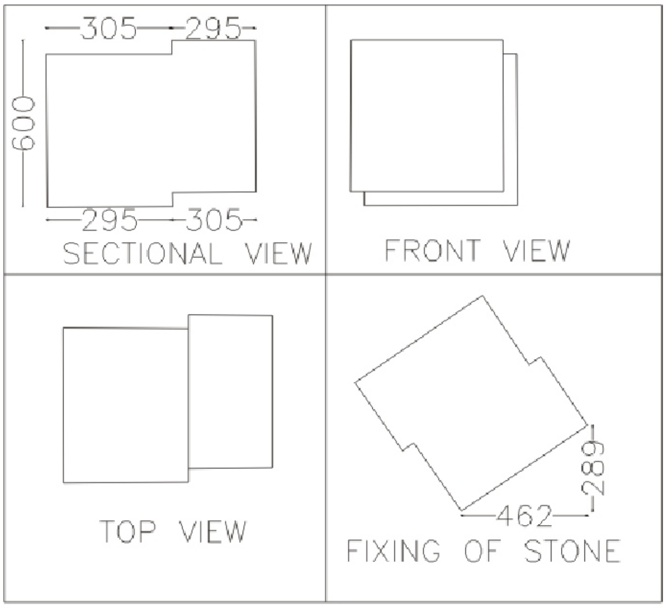
Dome and Arches:

The dome is constructed in ring form. Each stone of the dome is provided with tongue and grove joint as shown in *Photo 1*, and *Drawing 3*. These joints help holding the stone in position till the provision of temporary supports and also provide enhanced shear strength. Once the ring is formed then it does not require any support and remains stable under the hoop compression forces. Controlling the shape of masonry dome was the challenge of execution. The drawing specifies the radius at top of the layer, at bottom of the layer and height of bottom and top of the layer. The templates were prepared to maintain the desired slope in vertical and horizontal plane. Every layer was verified using manual and total station measurement. Any deviation occurring was adjusted in next layer and sometimes the analysis was checked by incorporating the deviation to find the effect of deviation on the stress patterns.

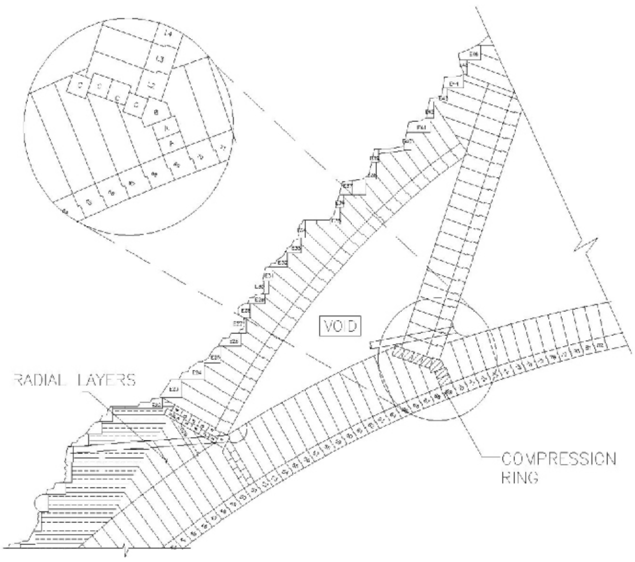
Photo 1: Fixing dome stone

Each inner stone ring of the dome required separate drawing, showing the dimensions and way of positioning. The external stone was a carved stone and was difficult to show in drawing and also to execute. Therefore for execution, 1:1 scale drawings were prepared for all the stones to act as templates. The complete dome is constructed without form work. The arch stones were also designed to allow the construction without centering.

Cranes were used for lifting the stone and mortar; cranes were placed over the structure itself. The execution work was a tremendous challenge, like the carving of the stones, carrying the stones to a height of about 100 meters and fixing with a reasonable accuracy. The execution team took painstaking efforts for a decade to complete this structure.



Drawing 3: Typical Dome Stone Details



Drawing 4: Dome Junction Details

Junctions of Dome:

The masonry shells are designed to carry the membrane stress only and normally have less capacity to resist flexural stress. This poses difficulty in transferring the load from upper dome to lower dome as the flexural stress is induced in lower dome at the junction. To handle this, the concept of compression ring was introduced in the construction of Grand Pagoda. Compression rings have more stiffness in hoop compression, and hence the flexural effect reduces. This was well verified using the finite element analysis (using ANSYS) and the thrust line analysis. Foundation details for the first and second dome junction are shown in *Drawing 4*.

Analysis:

There are two known approaches for analysis of a masonry structure. One is thrust line approach [3-7] and the other is finite element approach [8-13]. The thrust line approach is easy to implement and gives clear understanding of structural stability, but the method is not versatile and is limited to analysis of simple arches and domes. On the other hand Finite element is a highly versatile method but fails to give the stability in simple terms [4].

It was a challenging task for us as structural consultants, to select a methodology for the structural analysis of the

Pagoda. For the structural analysis of the Grand Pagoda, both the approaches were utilized in a balanced manner. Moreover the analytical tool was developed to incorporate the thrust line analysis in finite element analysis itself. The stability was verified using thrust line approach whereas serviceability and requirement of tension ring[14] were checked from the results of the finite element analysis.

Conclusion:

The masonry has a proven life of hundreds of years and moreover it creates the environment of peace and tranquility. But despite that in the last few decades, masonry was seldom used as a structural material. This was probably because of nonavailability of construction knowhow and analytical methods for structural analysis of such structures. The construction of Grand Pagoda is the result of dedicated efforts from the Trust, consultants and the execution team. This structure comprise of a dome with clear span of 85 meters, which is now the largest span in masonry construction in the world. With this success, we should now look forward to construct more structures in masonry to achieve better life expectancy and harmony with nature.

Acknowledgements:

We acknowledge with thanks the support given by the owner of the project, Global Vipassana Foundation. Even though masonry is not a commonly used structural material and the techniques of structural analysis and construction of such large span structures are not readily available, the trusties have shown real courage and foresight in selecting masonry as the structural material and encouraging and supporting the execution team against all odds.

We acknowledge the support given by Professor R.S. Jangid of IIT Bombay who worked as the Proof Consultant and who went beyond his role to support and guide us. We also acknowledge the support by other consultants Mr. Parvez Dhumasia (Architect) and Mr. C.P. Trivedi (Sompura consultant). Last but not least, we would like to acknowledge the painstaking efforts of the execution team under Shri Muthaji; without whom it would not have been possible to convert the dream in reality.

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2. Mr. V.G. Achwal is an advisor to Nandadeep Building Center and a professor at M.I.T. Engineering College, Aurangabad

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FRP IN CONSTRUCTION : THE INDIAN SCENARIO

Ravikant Shrivastava, Uttamasha Gupta and U.B. Choubey

Abstract

Fiber Reinforced Polymer (FRP) is being used worldwide for new construction as well as for retrofitting of existing structures. In India use of FRP is largely confined to repairing and strengthening of structures. FRP offers an advantage over conventional materials and methods of strengthening by virtue of its high strength to weight ratio, minimal impact on the existing structure, speed of installation and its non-corrosive nature. Engineers across the world have used this technology to satisfy their diverse structural requirements in an efficient and economical manner. After discussing advantages and limitations of FRP; this paper illustrates the field, educational and research scenario of FRP in construction in India.

Introduction:

Construction activity contributes in a major way to the development of developing countries including India. This may be in the form of new construction for infrastructure and housing; or maintenance, life enhancement and strengthening of existing structures. Structures deteriorate with time as a result of aging of materials, adverse environment conditions, overloading etc. Structures may also become deficient in strength and durability due to an accident or lapses during the phases of design or construction or due to an act of God. Sometimes strengthening, retrofitting or upgradation may become necessary to make an old structure satisfy the modern requirements specified in revised codes and standards or the higher loading requirements in form of increased service loads, growing traffic volumes etc. There are several methods in practice for repairing or strengthening of structures e.g. guniting, injection grouting, polymer/ epoxy mortars, steel or concrete jacketing, post tensioning, externally bonded steel plates, etc. Then there are the newly developed methods like advanced techniques for corrosion affected RCC and methods of modifying structural properties using active or passive mass damper for high rise buildings[1]. However, use of Fiber Reinforced Polymers (FRP) offers a significant advantage over conventional materials and methods because of their high strength to weight ratio, minimal impact on the existing structure, speed of installation and its non-corrosive nature. Till date, several thousand structures are retrofitted in the world using FRP. In recent years the Southeast Asian region including China and India, has witnessed a rapid growth in the use of external FRP systems for strengthening works. The application of FRP systems in these regions has largely been confined typically to flexural and shears strengthening, as well as seismic strengthening.[2] However, while there are example of use of FRP for new construction in some countries, none could be traced in India. FRP is still considered relatively new in this part of the world.

FRP Composite:

A composite material consists of two or more physically distinct and mechanically separable components which are combined together to form a new material which possesses properties that are remarkably different from those of its individual components. FRP is a composite material. Its components are very strong high performance fibers (such as glass, carbon or aramid) and resin matrix (such as epoxy, polyester). Fibers are placed in resin matrix to form FRP composites. The fiber is the primary load carrying component, while the resin acts as a binder, as environmental protector and stress distribution matrix of the composite. FRP products produced for use in structural engineering can comprise significantly more ingredients than just the primary constituents: fiber and polymer resins.

Advantages and Limitations:

FRP offers the following advantages over conventional materials and techniques of strengthening and retrofitting:

- High tensile strength, light weight and therefore, high strength to weight ratio
- High specific stiffness, good fatigue strength and chemical adhesion
- High corrosion resistance, rot proof, termite proof
- Low thermal conductivity, no electrical and non magnetic conductance
- Good formability and tailorability, reduced joints due to longer lengths available
- Ease and speed of transportation, handling and installation
- Low labour and equipment cost
- Longer life, low maintenance cost
- Minimum service disruption hence less down time

FRP is a superior alternative to many traditional materials and methods for strengthening and retrofitting of RC structures. However, due to a few limitations its use has still not picked up significantly. The major limitations are as follows:

- Very high material cost
- Uncertainty in timely supply of material and difficulty in procuring it in small quantities[3]
- Lack of codal standards and guidelines or formal methods of design
- Unawareness among the construction professionals

However, despite these limitations, FRP can be practical and cost effective in many circumstances.

Indian Scenario:

In India, use of FRP for strengthening and retrofitting of RC structures is increasing over the past few years. After the Gujarat earthquake (2001) this technique has gained some attention. However, the same is still not commensurate with the potential of the FRP. As the material is still considered relatively new in India, most of the works have been carried out in accordance with the available guidelines like ACI 440.2R-02 and other published literature.

There exists enormous potential for use of FRP in India, as India has a huge stock of seismically deficient buildings and has a long coastline and long monsoon season stressing the use of non-corrosive FRP, as an alternative to steel which is very prone to corrosion. FRP can be used for retrofitting of various structures such as residential buildings, hospitals, hotels, refinery buildings, fertilizer plants, petrochemical plants, water tank, silos, flyovers, road/rail over bridges etc using indigenous as well as imported FRP materials.

Field Applications in India:

There are many Indian projects to the credit of FRP systems by various companies like Fyfe (India) Pvt Ltd, Fosroc Chemicals (India) Pvt Ltd, Krishna Conchem Products Pvt Ltd, BASF, Sika India Pvt Ltd etc. Mumbai, New Delhi, Pune, Goa, Ahmedabad, Panipat, Ratnagiri, Rohtak, Bangalore, Udaipur, Rajkot, Surendranagar are among the Indian cities where retrofitting applications have been implemented using FRP. Examples given below illustrate the field scenario in India

1. Some applications of Tyfo Fiberwrap System by Fyfe(India) Pvt Ltd, in buildings:

   Structural strengthening of circular columns & flat slab at Shah House, Worli, Mumbai, slab strengthening at Sudharkar Building, Mumbai (1999). Various MTNL TE buildings at Fountain/ Gamdevi Mumbai, structural strengthening and protection of beams/ columns/ slabs at Voltas Sagar Building, Parel, Mumbai, structural strengthening of peripheral columns due to increased loads (2000). MTNL TE building, Kidwai Bhawan New Delhi, St. Thomas School, New Delhi, Casa Grand Society, Mumbai.- structural strengthening / protection/ corrosion protection of beams/ columns/ slabs, BSNL Staff Quarters, Jamnagar/ BSNL T.E. Building, Amreli/ Laxmi Motors Showroom Gandhidham, Gujarat - structural repairs & strengthening of columns distressed due to earthquake, Phoenix Mills Ltd., Parel, Mumbai - strengthening of masonry walls for structural integrity (2001). Param Plaza Bldg, Juhu, Mumbai -structural strengthening of columns due to additional loads, Reserve Bank of India, Staff Quarters Chakala, Mumbai. (Phase I) -localized strengthening of beam column junctions (2002). Hotel Ramee, Dadar, Mumbai - strengthening of columns for increased loads due to addition of floor; Panchratna Building, Opera House, Mumbai - structural strengthening of beams and columns for ductility enhancement (2003). IT Software Park, Hyderabad- strengthening of columns due to low grade concrete (2004). CST Airport Terminal 1B, Mumbai. (Phase 1) -column/beam joint retrofit (2005)[4]

2. Some applications of Tyfo Fiberwrap System in bridges/ water tanks/ brick walls:

   Road Over-Brigge 235A, KRCL Madgaon, Goa -beam strengthening and corrosion protection (2003). Janak Setu Flyover, Municipal Corp Delhi (1 span) -structural strengthening of bridge girders, BSNL Staff Qtrs, Elevated Water Tank, Ahmedabad.- structural strengthening of water tank staging columns and beams; at Jindal House, New Delhi - seismic retrofit to load bearing brick wall structure (2004)[4]

3. Sangam Complex, Bangalore, which was previously a theatre, was converted into a multi-storeyed shopping complex. To convert the G+2 structure to a G+7 structure, an increase of 90% in load carrying capacity was required. Along with other measures, Nitowrap EP (CF) carbon fibre wrapping system was provided to columns. Potential Consulting Engineering was the consultant for the project which was completed in 2003.[5]

4. The Water treatment plant at Vadakuthu –Veeranam, Tamilnadu, was constructed in 1978 but left unused for nearly 25 years without any maintenance. Due to harsh environmental conditions and lack of maintenance, the whole plant had undergone severe damage. In 2003, rehabilitation of prestressed girders for bridges supporting the pipelines was carried out. A total of seven such bridges were to be rehabilitated. Glass fiber (Nitowrap EP GF) was used to cover the repaired areas. Carbon fiber (Nitowrap EP CF) was used for the soffit of the girder, for the entire length as well as across the girders completely confining the diaphragm portion and also for a width of 500mm from the edge of the bearings. Mecon was the consultant.[5]

5. One of the masonry piers of a major steel plate girder bridge (constructed more than 75 years back for BLML standard loading) on Vijayawada-Visakhapatnam section of South Central Railway- (Bridge No. 220 Down with spans 2x18.3 m+2x16.2m) had vertically cracked along the height. This route has been identified for running Higher Axle Load trains with CC+8+2 t, for which the cracked pier caused serious concerns even with restricted speed. The conventional methods would have been cumbersome, messy, time consuming, labour intensive and would have caused increase in dead weight and reduction in water way. Moreover the river flowing round the year had a history of flash floods. Construction of an alternative bridge on a diversion was also contemplated at a cost of Rs.7 crores. Ultimately, the cracked bridge pier was rehabilitated using Nitowrap CF at a mere cost of Rs. 7 lakh and the entire work was carried out in 40 days. The bridge which was rehabilitated in July 2005 was opened for trains without speed restrictions and has not showed any distress yet.[6]

6. A fertilizer plant in Gujarat which was severely damaged due to earthquake was rehabilitated using Indian FRP (area around 5000 sq.m.) in 45 days. The plant was re-commissioned in 3 months.[7]

7. The vertical portions of RCC cylindrical silos in Mumbai

(constructed before 1972) used to store powdered rock phosphate exhibited severe damage due to carbonation of concrete (M15) and corrosion of reinforcement (mild steel). This damage resulted in reducing the storage capacity to about 60%. In some areas the steel had reduced by about 35%. After taking measures for corrosion protection the silos were strengthened using a single layer fibre-wrap system consisting of specially formulated epoxy resin binders and unidirectional e-glass fibre cloth. Within 50 days the silos were restored to their design performance.[8]

8. National Highway Authority of India adopted FRP system for structural strengthening of a 25 year old, 42 meter long rail over bridge near Chalthan, Surat on NH8 connecting Mumbai to Delhi. Strengthening involved increase in the shear and flexural capacities of the main girders in the each 12 meter long end span to withstand current and future loading conditions. The work was executed during 2005-06, using 700 sq m of MBrace G sheet EU900, Uni-directional E-Glass fiber sheets. Single/ multiple layers of the sheet were used depending upon the requirements. FRP designs and detailing were based on International guidelines.[9]
9. For the Dhirubhai Ambani Life Sciences Centre at Navi Mumbai, a petro-chemical facility containing some old RCC framed structures has been altered. The project was implemented in 2006. The old structure had interiors adoptable to new use but as the change in use demanded the increase in live load from 350 Kg/sqm to 750 Kg/sqm, the whole structure was analyzed accordingly. It was found that the secondary beams warranted strengthening to take extra loading. Again the interior space has limited access, was congested and and the ground floor was already provided with false ceiling containing central air conditioning and air-handling ducts and access to the bottom of the slab/beam was limited. Carbon laminates (MBrace CFK 150/2000) being light weight and easy to handle were selected for the flexural strengthening of the beam bottoms. End anchorage was provided using Carbon sheet (MBrace CF240, 200 gsm) cast in place. Carbon sheets were placed on three sides of the beams by means of U wrapping. Negative bending moment was also considered and strengthening was carried out for at the top of the slab.[10]
10. The project of addition of one more floor to the existing four floor RCC framed structure, in the hotel Airlink Mumbai, was completed in year 2006. The hotel was built in late eighties. To take additional load some of the beams and columns required structural strengthening. MBrace G sheet EU 750 was used for the purpose.[11]
11. During construction of a residential multi-storied tower in Pune, the inferior grade of concrete in some RCC beams was compensated by strengthening them using BASF's MBrace G sheet EU 750. The work was completed in 2006.[12]
12. A road over bridge nearly 40 years old, at Budge located in the Sealdah Division of Eastern Railways was rehabilitated using carbon laminates. The bridge consisted of 7 RC T-beam girders of 10.80 m span. Due to close proximity of the marine atmosphere the structure faced severe corrosion of reinforcement and hence peeling-off of concrete too. Several prior patch repair programs did not give any lasting solution before FRP treatment. The procedure adopted effectively repaired and strengthened the structure to its original strength if not more and enhanced the life of the structure by at least 20 years.[13]
13. For adding two more storeys to the existing five storeyed structure of a well known hospital in Mumbai, GFRP along with epoxy adhesive was used for confinement of columns. Confinement using GFRP enhanced the strength of columns to bear the load coming from additional floors.[13]
14. Due to high degree of corrosion as well as carbonation, load carrying capacity of a multistoried building in Mumbai became inadequate. To increase the load carrying capacity of columns, GFRP and epoxy adhesive was used for confinement of columns.[13]

Education and Research in India:

To study the current trends in the FRP education, a survey of universities around the world was carried out between November 2001 and February 2002. The Editorial Board of the American Society of Civil Engineers Journal of Composites for Construction (Lawrence C. Bank, Editor) sponsored the survey of the civil/structural engineering programs. Among others, 35 universities from Asia were included in the survey, out of 35 only 12 participated in the survey including 4 from China, 3 from Japan, 2 from Thailand, 1 each from Korea and Singapore and 1 from India. i.e.-IIT Bombay. According to the survey, despite a significant number of field applications and laboratory research on FRP, the research results have not yet been fully translated into teaching curricula, and civil engineering graduates for the most part are not sufficiently trained to design or specify FRPs for construction projects[14]. This situation is improving now, however at a very slow pace. In India, IITs, IISc, Structural Engineering Research Center (SERC) Chennai, FRP institute Chennai, Research Design and Standards Organization (RDSO) under the Ministry of Railways at Lucknow, Technology Information Forecasting and Assessment Council (TIFAC) a unit of DST are among others, actively participating in the field of education and research related to FRP in construction.

The Department of Science and Technology, Government of India, in collaboration with the universities, is developing standards for FRP in construction. Focus is placed on the rate of degradation of glass FRP in view of the South Asian environment and the concrete mix typically used in India. The application is targeted at corrosion damaged structures and seismic retrofitting. [2] Technology Information Forecasting and Assessment Council (TIFAC) a unit of DST, New Delhi has been doing great service to Indian Composites industry.[15] Composites Technology Centre (formerly known as Fibre Reinforced Plastics research Centre) was established in 1974 at IITM as an interdisciplinary centre for carrying out teaching, research, design and development in the field of composite materials and their applications. The centre was renamed as Composites Technology Centre in 1997[16]. As for as publication is concerned, FRP Today is a monthly magazine for the composites industry, published in India since the year 2000.

Concluding Remarks:

With their unique advantages, FRP hold significant promise over other materials and methodologies not only in the works of rehabilitation and retrofitting of old structures but also in construction of new structures. However it is necessary to effectively address the limitations listed in this paper.

The application of externally bonded FRP systems in strengthening works is showing upward trend in India. However, many practicing engineers are still unfamiliar to the technology. There is a need to provide proper information through general university education and continuing professional activities. In addition, there is a necessity for agencies and organizations to work towards the establishment of guidelines, standards, or codes of practices that are more suited to local economic, geographical and climatic conditions, as well as construction practices.[2] Despite a significant number of field applications and laboratory research on FRP the research results have not yet been fully translated into teaching curricula. At this moment there are not enough engineers in the general civil engineering market who are knowledgeable enough to design structures with composite materials or to specify them for construction projects. FRP is still considered as a specialty item. To improve this situation, civil engineering and their extension programs must provide sufficient training on unique features of FRPs so that engineers could design or specify them in construction.[14] There is a need for Government-Industry-Institute partnership to exploit full potential of FRP. The increase in use of FRP for retrofitting is inevitable because of its potential.

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A MODEL FOR THE EVALUATION OF ITEM-RATE BIDS

Rupali Joshi and Umesh Dhargalkar

When an Item-Rate tender is floated and bids are received, it often becomes very difficult to find out which one is the best offer. The price bid depends on many parameters and hence the lowest offer may not be the best one. Therefore a model, which can analyze the bids is much desired. In this paper the authors present such a model based on a numerical method, which can be easily modeled on a computer. The methodology presented can be used to analyze the bids, bring out the inconsistencies in them, rationalize the bids and to extract important data from them which can be very useful while short listing the bidders or negotiating with them.

Introduction:

An item-rate offer essentially consists of the quantities of various items and the rates quoted by the contractor. The following are the desired features of such an offer:

- The rates quoted should be *realistic.* This means that they should not be too low or too high as compared with the reference rates. The reference rates may be the market rates/ costs or rates/ costs computed through rate analysis.
- The offer should be fairly *balanced*. This means that the markup provided by the bidder over the costs to cover his overheads and profit should be fairly consistent across the set of items. An offer in which the rates are *consistently* low or *consistently* high may be called a balanced offer, which reflects a conscious and systematic approach on part of the bidder.
- The offer should not have serious or too many arithmetical errors.
- Once the above three conditions are satisfied, the total price should also be competitive.

In this paper, the authors present a numerical method based on the above criteria for relative assessment of the bids received.

The Model:

The model presented here is essentially numerical in nature and is based on the following definitions proposed by the authors:

Markup:

The ratio of the quoted rate to the estimated cost for any item

Minimum Markup:

The markup below which the rates may be unrealistically low

Maximum Markup:

The markup above which the rates may be unrealistically high

Rate-based Variance:

Standard deviation of the markups of rates across all the items within a bid

Volume-based Variance:

Standard deviation of [Markup * Quoted Rate * Tender Quantity] across all the items within a bid

The *Rate-based Balance* and *Volume-based Balance* are defined as inverse measures of the respective variances i.e. more the variance, less is the balance.

The Evaluation Process:

The authors suggest the following methodology for the evaluation of the commercial bids. Wherever used, the subscript 'b' refers to the bid and the subscript 'i' refers to the item under reference.

Preparations:

1. To begin with, exclude items for which rates are invited without specifying quantities.
2. Exclude items, which are confusing, vague or unclear and hence might have been misinterpreted by the bidders while quoting rates. Inclusion of such items may lead to misleading results when subjected to a numerical model.

The quoted rates for both the above types of items should be studied separately.

Formation of the Basis:

1. Input total no. of bids received Nb and total no. of items being studied Ni
2. For each item: input quantity Q(i) and estimated cost per unit quantity Rc(i)
3. Calculate total cost for the bid for all items BidCost = sum [Q(i) * Rc(i)]
4. Decide the minimum and maximum reasonable markups (%) on the costs towards the overheads and profit of the contractor: pmin and pmax
5. Calculate the minimum and maximum reasonable rates for each item:

   Rmin(i) = Rc(i) * (1 + pmin/100)

   Rmax(i) = Rc(i) * (1 + pmax/100)

Analysis of the bids:

For each bid follow these steps:

1. For each item:
   - Input quoted rate Rq(i)
   - Calculate markup for quoted rate:

     ft_{bi} = Rq(i) / Rc(i)
   - Calculate weighted markup for quoted rate:

     $fe_{bi} = ft_{bi}$ * Rq(i) * Q(i)
   - Check whether the quoted rate is unreasonably low i.e. Rq(i) < Rmin(i)
   - If yes, add the item to a list of too low rates: TLRates()
   - Check whether the quoted rate is unreasonably high i.e. Rq(i) > Rmax(i)
   - If yes, add the item to a list of too high rates: THRates()
2. Input total price quoted for the bid: Qprice(b)

3. Calculate total price for the bid:
   Total(b) = sum [Rq(i) * Q(i)]
4. Check if quoted total price = calculated total price
5. Calculate average markup for all items within the bid: ftbar(b) = sum [ft_{bi}] / Ni
   Calculate average weighted markup for all items within the bid: febar(b) = [fe_{bi}] / Ni
6. Calculate rate based variance:
   SDT(b) = Sqr [sum [ft_{bi} ftbar(b)]^2/ Ni]
   Calculate volume based variance:
   SDE(b) = Sqr [sum [fe_{bi} febar(b)]^2/ Ni]
7. Calculate overall effective markup for the bid: p(b) = (Total(b) / BidCost 1) * 100

Results:

a) For each bid the following results can be obtained:
   - Bid Serial No.
     Bidder's Name
   - Total Price Calculated
     Total Price Quoted
     The prices tally? Yes / No
   - No. of items with Unrealistically Low Rates
     List of such items
   - No. of items with Unrealistically High Rates
     List of such items
   - Overall effective Markup on Reference Rates
   - Rate-based Variance wrt Reference Rates
     Volume-based Variance wrt Reference Rates

b) The bids can be sorted in any desired order using a combination of the parameters.

Computer based Applications:

The proposed model is ideally suited for computer applications. A detailed flowchart given in the Appendix can be readily used for developing a computer program.

Advantages:

1. Easy to use numerical method for relative assessment of the commercial bids.
2. A good tool for short listing of contractors.
3. The bids can be sorted as desired.
4. The results can be used during negotiations with the contractors.
5. The too low or too high rates may lead to the early detection of some items, which may be ambiguous and hence prone to misinterpretation.
6. Being a numerical tool, this method can be easily modeled on a computer or web enabled.

Appendix

Glossary of Terms used in the Flowchart

Bid Cost	:	Total cost of bid for all items as estimated by consultant excluding markup for Overheads and Profit
Q(i)	:	Quantity for an item
Rc(i)	:	Unit cost for an item as estimated by consultant (without markup)
Ni	:	No. of items in Tender
pmin	:	Minimum reasonable markup over the cost, below which the rates may not remain workable
pmax	:	Maximum reasonable markup over the cost, above which the rates may be termed as unreasonably high
Rmin(i)	:	Minimum probable rate for an item = Rc(i) * (100 + pmin) / 100
Rmax(i)	:	Maximum probable rate for an item = Rc(i) * (100 + pmax) / 100
Nb	:	Total number of bids received
BidderName(b)	:	Name of the bidder
RACode(b)	:	Flag indicating whether a bid has Arithmetical Errors
Rq(i)	:	Rate as quoted in a bid for an item
ft_{bi}	:	Markup for quoted rate for each item within a bid = Rq(i) / Rc(i)
fe_{bi}	:	Weighted markup for each item within a bid = ft_{bi} * (Rq(i) * Q(i))
NL(b)	:	Number of items for which quoted rate < Rmin
NH(b)	:	Number of items for which quoted rate > Rmax
TLRates(b,n)	:	List of items with unreasonably low rate
THRates(b,n)	:	List of items with unreasonably high rate
Total(b)	:	Total price for all items within a bid = sum of (Rq(i) * Q(i))
ftbar(b)	:	Mean ftb for all items within a bid
febar(b)	:	Mean feb for all items within a bid
QPrice(b)	:	Total price quoted for a bid
p(b)	:	Effective markup charged in the bid = (Total(b) / BidCost - 1) * 100
SDT(b)	:	Rate-based varience
SDE(b)	:	Volume-based variance

SDT(b) : Rate-based varience

$$= \sqrt{\frac{\sum_{i=1}^{Ni} (ft_{bi} - ftbar(b))^2}{Ni}}$$

SDE(b) : Volume-based variance

$$= \sqrt{\frac{\sum_{i=1}^{Ni} (fe_{bi} - febar(b))^2}{Ni}}$$

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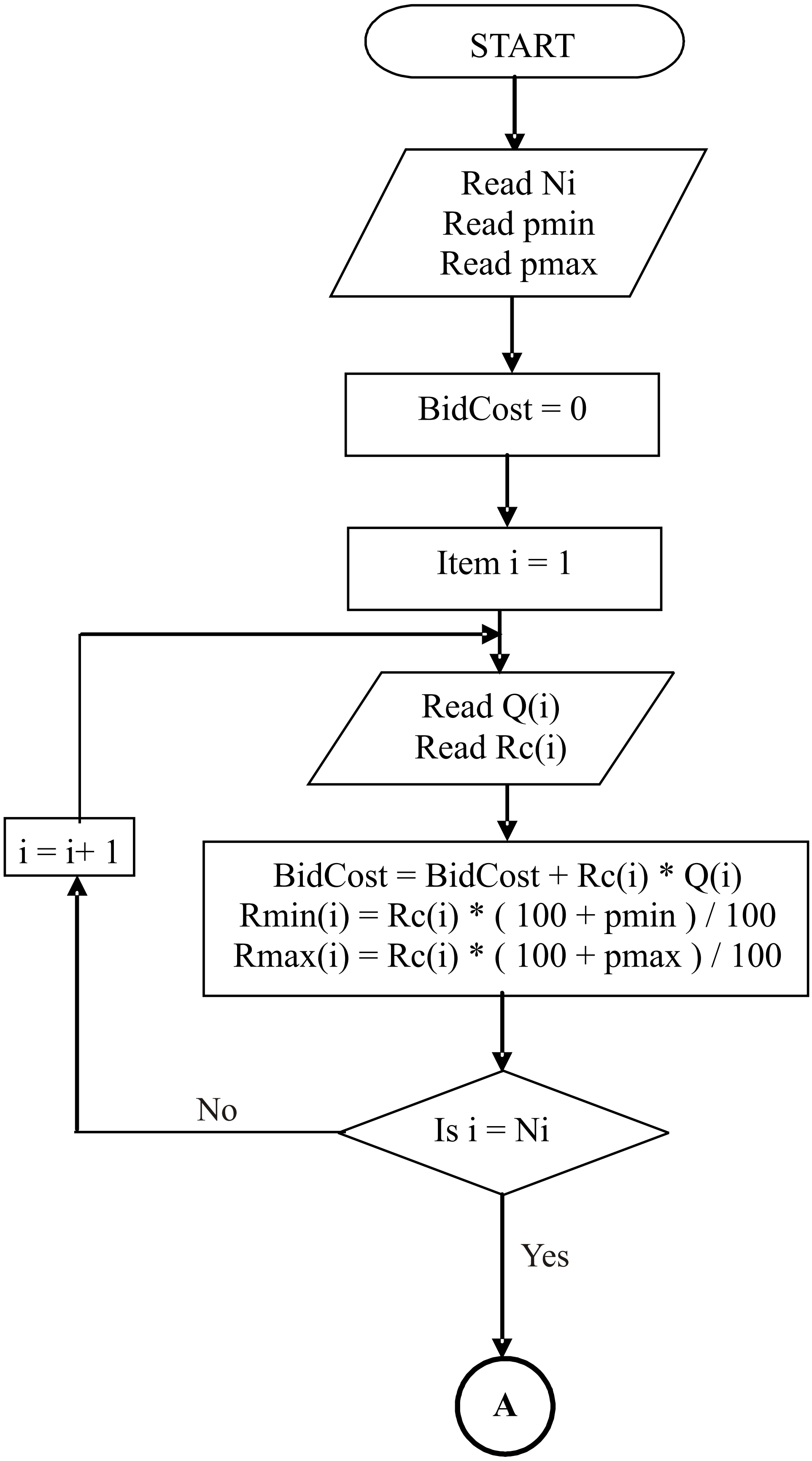
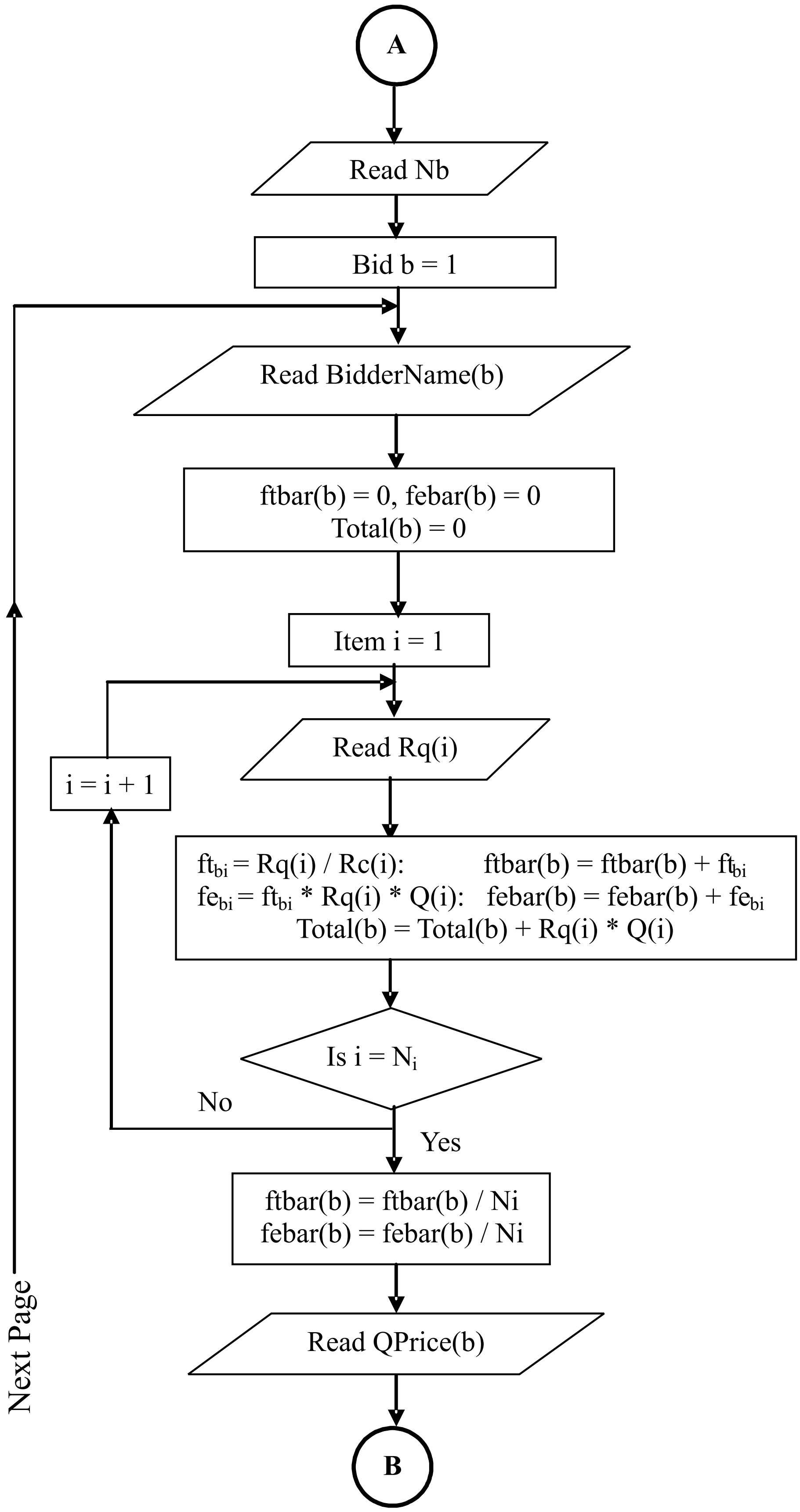
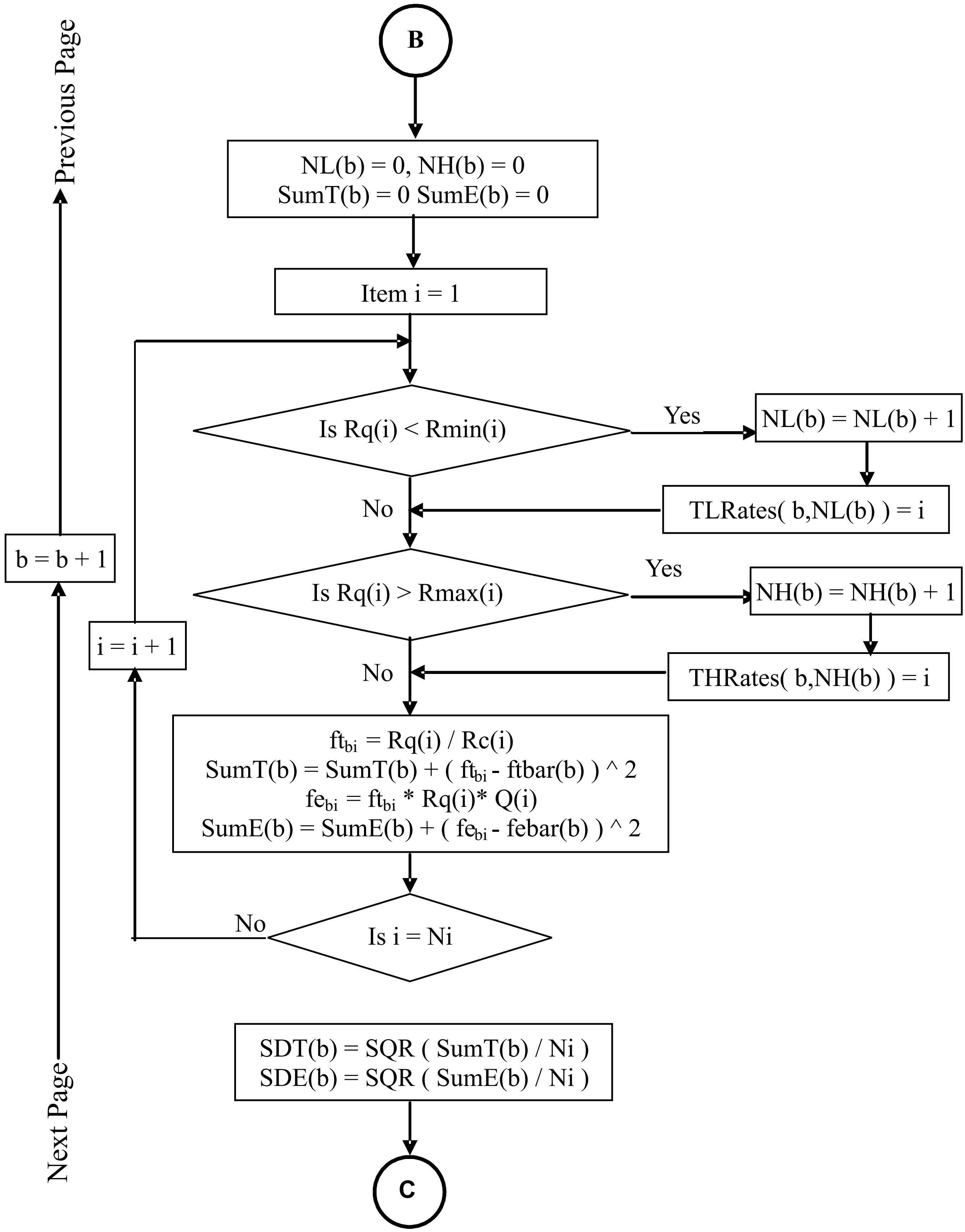
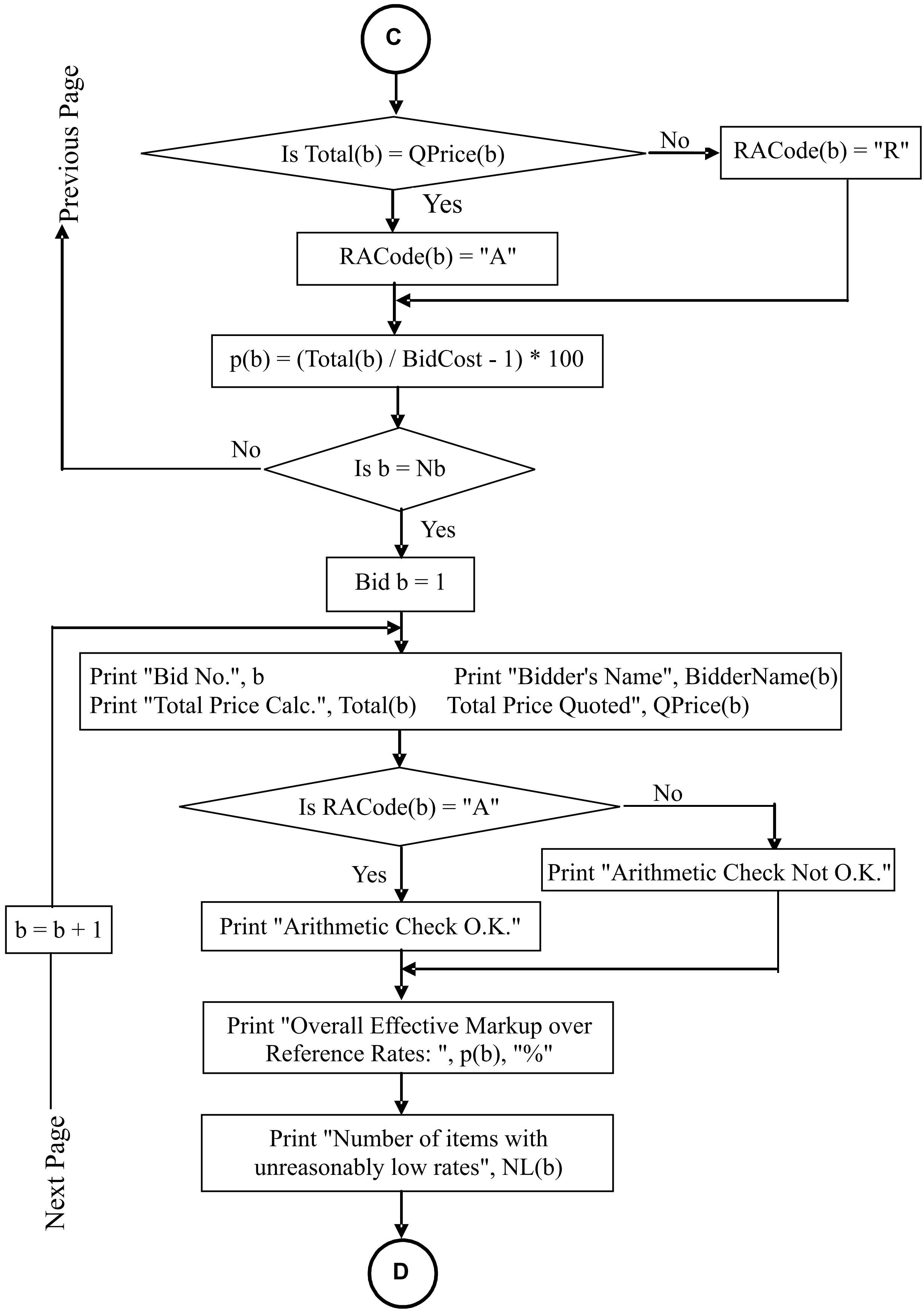
Flow Chart

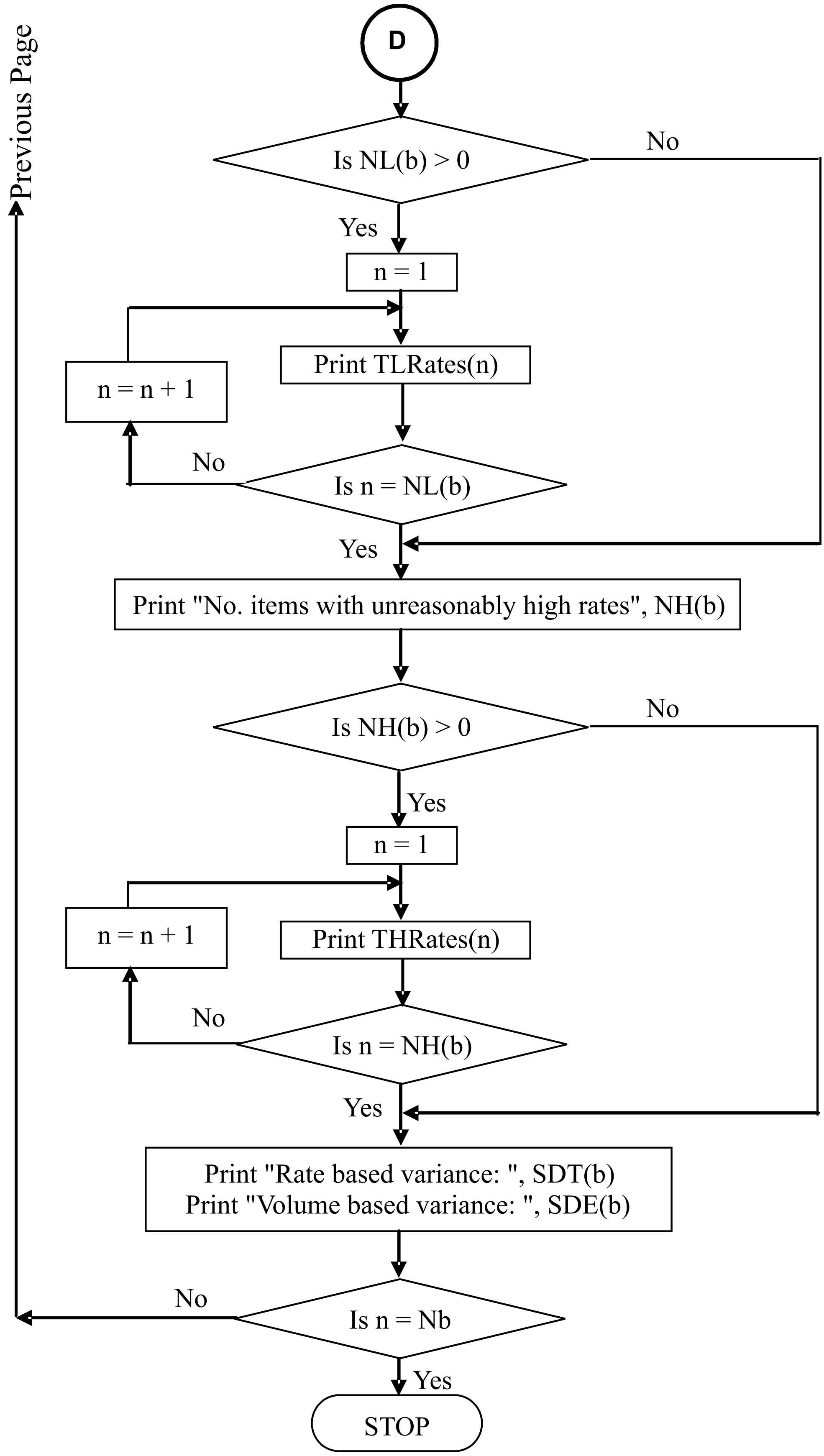

START
Read Ni
Read pmin
Read pmax
BidCost = 0
Item i = 1
Read Q(i)
Read Rc(i)
i = i+ 1
BidCost = BidCost + Rc(i) * Q(i)
Rmin(i) = Rc(i) * (100 + pmin) / 100
Rmax(i) = Rc(i) * (100 + pmax) / 100
No
Is i = Ni
Yes
A


A
Read Nb
Bid b = 1
Read BidderName(b)
ftbar(b) = 0, febar(b) = 0
Total(b) = 0
Item i = 1
Read Rq(i)
i = i + 1
ft$_{bi}$ = Rq(i) / Rc(i): ftbar(b) = ftbar(b) + ft$_{bi}$
fe$_{bi}$ = ft$_{bi}$ * Rq(i) * Q(i): febar(b) = febar(b) + fe$_{bi}$
Total(b) = Total(b) + Rq(i) * Q(i)
Is i = N$_i$
No
Yes
ftbar(b) = ftbar(b) / Ni
febar(b) = febar(b) / Ni
Read QPrice(b)
B
Next Page


B
NL(b) = 0, NH(b) = 0
SumT(b) = 0 SumE(b) = 0
Item i = 1
Is Rq(i) < Rmin(i)
Yes
NL(b) = NL(b) + 1
TLRates(b,NL(b)) = i
No
Is Rq(i) > Rmax(i)
Yes
NH(b) = NH(b) + 1
THRates(b,NH(b)) = i
No
ft_bi = Rq(i) / Rc(i)
SumT(b) = SumT(b) + (ft_bi - ftbar(b)) ^ 2
fe_bi = ft_bi * Rq(i)* Q(i)
SumE(b) = SumE(b) + (fe_bi - febar(b)) ^ 2
Is i = Ni
No
i = i + 1
b = b + 1
Previous Page
Next Page
SDT(b) = SQR (SumT(b) / Ni)
SDE(b) = SQR (SumE(b) / Ni)
C



C
Previous Page
Is Total(b) = QPrice(b)
No
RACode(b) = "R"
Yes
RACode(b) = "A"
p(b) = (Total(b) / BidCost - 1) * 100
No
Is b = Nb
Yes
Bid b = 1
Print "Bid No.", b
Print "Bidder's Name", BidderName(b)
Print "Total Price Calc.", Total(b)
Total Price Quoted", QPrice(b)
Is RACode(b) = "A"
No
Print "Arithmetic Check Not O.K."
Yes
b = b + 1
Print "Arithmetic Check O.K."
Print "Overall Effective Markup over Reference Rates: ", p(b), "%"
Print "Number of items with unreasonably low rates", NL(b)
Next Page
D



Previous Page
D
Is NL(b) > 0
No
Yes
n = 1
Print TLRates(n)
n = n + 1
No
Is n = NL(b)
Yes
Print "No. items with unreasonably high rates", NH(b)
Is NH(b) > 0
No
Yes
n = 1
n = n + 1
Print THRates(n)
No
Is n = NH(b)
Yes
Print "Rate based variance: ", SDT(b)
Print "Volume based variance: ", SDE(b)
No
Is n = Nb
Yes
STOP

SEMINAR ON ADVANCED CAPABILITIES IN STRUCTURAL SOFTWARE

A Report by Rupali Joshi

Indian Society of Structural Engineers (ISSE) organized an evening seminar on "Advanced Capabilities in Structural Software" on 19th September 2008. The seminar was organized in association with the Institution of Engineers (I), MSC and was sponsored by MIDAS R&D Centre, India.

Seminar:

The aim of the seminar was to demonstrate the use of advanced capabilities in structural software for implementing the concepts such as seismic isolation system, effects of column shortening on skyscrapers etc. At the beginning Mr. S.G. Dharmadhikari, President, ISSE gave the welcome address. Thereafter there were three technical sessions. Each session was followed by a questions and answers session. Mr. Umesh Dhargalkar, Advisory Trustee of ISSE conducted the proceedings of the seminar. Mr. Shantilal Jain, Advisory Trustee of ISSE, offered a vote of thanks. The seminar was followed by dinner. About 160 participants attended the seminar.

Technical Sessions:

The first technical session was on "Introduction & theoretical background to base isolation System" conducted by Dr. Jangid (Prof. Dept. of Civil Engg. IITB). He elaborated, in detail, the behavior/ application of Base Isolation System, how this type of earthquake resistant system can add sufficient strength to sustain moderate earthquakes and how the buildings acquire ductility under strong earthquakes. He also displayed many images of buildings affected by earthquake and correlated their failure patterns to the cause of failure and deliberated on the solutions to such failures. One of the important part of his presentation was to stress that base isolation system is not an effective technique for high rise buildings (more than 15 storey) because in such cases the wind load governs the design. He also emphasized that this technique was not very prevalent in India being very expensive.

The second session was on "Building Information Management System" by Mr. Angshuman Pandey, Manager Indian Operations MIDAS India, who was supported by Mr. Nishant Mehta (Structural Software Engineer, MIDAS). He gave a presentation on the time dependent structural behaviour of skyscrapers" i.e. inelastic shortening of columns in high-rise buildings. The presentation covered four topics. In the first topic "Column Shortening & related Issues" he brought out the distinction between elastic shortening & inelastic (time dependent) shortening of columns of a building and the factors that promote the inelastic shortening namely creep/ shrinkage etc. In the second topic "Effects of Column Shortening" various effects on the tall structures were discussed e.g. reverse inclination of drainage piping systems/ breakage of building façade/ deformation of vertical elevator rail/ cracks in infill walls etc. The third topic was "Procedure for Accounting for Column Shortening" wherein various procedures namely pre-analysis data prediction/ site monitoring system and updation during stages etc. were discussed. In the last topic "Project Applications" he exhibited some of the high profile projects completed by the MIDAS IT Co. Ltd. Korea.

The last session was on "Column shortening analysis for High-rises & related issues" conducted by Mr. Subodh Shinde, Application Engineer, MIDAS India. The prime intention of base isolation systems is to increase the time period of the building as a result of which the frequency decreases, the acceleration of the mass decreases and the building approaches a safer mode. This was demonstrated by Mr. Subodh Shinde using their structural design software MIDAS Gen. Two identical frame models were generated in MIDAS Gen, one with fixed base and the other with isolated base connected to the bottom horizontal frame of the building with LRB boundary mode. It was illustrated that the time period of the isolated structure goes up and as a result the lateral seismic forces on the structure are reduced compared to that of one with fixed base system.

Finally two identical 40 storey building models one with ordinary analysis and the other with time dependent analysis were shown. It was observed that for high-rise buildings it is important to carry out the creep / shrinkage calculations as their contributions are enough to create differential shortening of columns which reduces the overall strength of the building system.

WHAT SOIL INVESTIGATIONS DID NOT REVEAL

Part II

V. T. Ganpule

Discussion on Mechanism of Deteriorated Piles:

It is abundantly demonstrated by the case histories that the testing procedure followed to identify the aggressive water while dealing with cast in situ concrete piles is inadequate. The chance discovery of Ryzner Index test has given an new dimension to identify the black sheep and subsequent measuring of Ryzner Index in other sites reported has confirmed that it plays is significant role and can help to identify the culprit.

The revelation emphasized the need of a deep probe in testing procedure and its theoretical basis. The experimental research work taken as a fall out proved beyond doubt that there are some test procedures which can help to mark the black sheep and avoid shock at late stage. The reference to literature on the testing procedure for quality of drinking water and sewage showed that how the parameters of ground water affecting the concrete setting and hardening can be detected.

The concept of saturation indices explained in the literature on quality of water flowing through concrete pipes and boilers plays a significant role in the underwater concrete durability.

Similarly the case history reported in U.S.A. engineering emphasizes the influence of oxygen demanding bacteria's and organic matter in sewage.

- **Calcium Carbonate Saturation:**

  Calcium carbonate ($CaCO_3$) saturation indices commonly are used to evaluate the scale-forming and scale-dissolving tendencies of water. Assessing these tendencies is useful in corrosion control programs and in preventing $CaCO_3$ scaling in piping and equipment such as industrial heat exchangers or domestic water heaters ad sewer lines.

  Waters oversaturated with respect to $CaCO_3$ tend to precipitate $CaCO_3$. Waters undersaturated with respect to $CaCO_3$ tend to dissolve $CaCO_3$. Saturated water, ie. Water in equilibrium with $CaCO_3$ have neither $CaCO_3$ precipitating nor $CaCO_3$ dissolving tendencies saturation represents the dividing line be tween "precipitation likely" and "precipitation not likely".

  Several water quality characteristics must be measured to calculate the $CaCO_3$ saturation indices described here. Minimum requirements are total alkalinity, pH and temperature. The ionic strength also must be calculated or estimated from conductivity or total dissolved solids measurements pH shall be at the system's water temperature using a temperature-compensated pH meter. If pH is measured at a different temperature, for example in the laboratory, correct the measured pH. (In measuring pH and alkalinity, minimize CO_2 exchange between sample and atmosphere. Ideally, seal the sample from the atmosphere during measurements, at a minimum, avoid vigorous stirring of unsealed samples).

  There are two general categories of $CaCO_3$ saturation indices that determine whether a water has a tendency to precipitate $CaCO_3$ (i.e. is oversaturated) or to dissolve $CaCO_3$ (i.e. is undersaturated) and indices that estimate the quantity of $CaCO_3$ that can be precipitated from an oversaturated water and the amount that can be dissolved by an undersaturated water. Indices in the second category generally yield more information but are more difficult to determine.

- **Indices Indicating Tendency of a Water to Precipitate $CaCO_3$ or Dissolve $CaCO_3$**

  Indices that indicate $CaCO_3$ precipitation of dissolution tendencies define whether a water is oversaturated, saturated, or undersaturated with respect to $CaCO_3$. The most widely used indices are the saturation Index (SI) : the relative saturation (RS), also known as the driving Force Index (DFI) ; and the Ryzner Index (RI). The SI is by far the most commonly used and will be described here. The RI has been used for many years. Sometimes with good results, because it is semi-empirical it may be less reliable than the SI.

  Saturation Index by Calculation

  SI is determined from equation 1,

  SI = pH – pH -------------------- (1)

  Where

  pH = measured pH and

  pH = pH of the water if it were in equilibrium with $CaCO_3$ at the existing calcium ion ($Ca_2^{\cdot}$) and bicarbonate ion (HCO_3^{-})

  A positive SI connotes water oversaturated with respect to $CaCO_3$. A negative SI signifies an under saturated water. An SI of zero represents water in equilibrium with $CaCO_3$.

  Analytical solution for pH_s: Determine pHs as follows

  $pH_s = pk_2 – pK_s + p(Ca^{2+}) + P(HCO_3^{\ -}) + 5pf_m$ ... (2)

  Where

  K_2 = second dissociation constant for carbonate acid, at the water temperature.

The methods of finding out saturation Index by experimental determination are described in the 'Standard Methods for the examination of water and waste water manual' recommending the procedure for ground water testing. The procedure for test called 'Heyer's Marble Test' which deals with measuring carbonic acid (CO_2) in mg/litre outlined in DIN 4050 also helps in estimating aggressiveness of water.

- **Effect of free Carbon in Water:**

The other impartial deteriorating action on concrete is the presence of free carbon in ground water. The literature on chemistry of concrete presents invaluable information on these aspects somehow the testing procedure for ground water testing from concrete construction point of view have not paid much attention to it.

Carbon dioxide is present in air to the extent of 0.03 per cent by volume and at atmospheric pressure is soluble in water to the extent of 0.00054 g/L, giving a solution of carbonic acid, which has a pH value of 5.7. Water from deep underground sources in which carbon dioxide has dissolved under pressure may have a higher content and be more acidic, and pH values a low as 3.8 have been recorded. In river waters dissolved carbon dioxide rarely gives rise to pH values below about 5.5, and lower values are often due to the presence of organic acids. The solubility of carbon dioxide under various partial pressures and the pH values of the solutions are shown.

Pure water alone has a solvent action on concrete. It dissolves calcium hydroxide to the extent of 1.2 hg/ L and can leach lime from set cement. This causes gradual deterioration of Portland cement concretes which are subject to water passing through them for length periods. As calcium hydroxide is removed form the cement, the silicates release more to maintain saturation in the pore water, a process which extreme cases of leaching can result in a breakdown of the structure of the cement and a loss of strength of the concrete Alkali metal hydroxides are also readily leached but without adverse effects on the concrete. The alkali metals are adventitious constituents of cement and play no part in its hydration or strength development. They are present in the clinker as sulfates, silicates and aluminates, which dissolve in the mixing water to from alkali hydroxides. The sulfates dissolve rapidly, within a few minutes of mixing, and others more slowly, but all the alkalis are in solution within about 28 days. The alkali hydroxides give the pore water a high pH value, which helps to protect steel reinforcement against corrosion. The content of alkali metals is small, rarely exceeding 1.3 per cent of total alkalis, expressed as equivalent Na_2O. This represents a total alkali hydroxide content of 1.7 per cent, expressed as equivalent NaOH.Portland cements, on the other hand contain an averge of 64.5 percent calcium oxide, of which the greater part is combined in the di- and tricalcium silicates.

The aggressive action of water is increased if it contains carbon dioxide in a free state. The action ceases to be one of solution only but become a serious of chemical reactions. Initially the carbon dioxide reacts with calcium hydroxide to form insoluble calcium carbonate, but on further action the much more soulable calcium hydrogen carbonates is formed. This will not dissolve calcium carbonate and will form more if it reacts with calcium hydroxide,

In considering the carbon dioxide equilibria in water, it is necessary to distinguish between 'free' and 'aggressive' carbon dioxide. The free carbon dioxide is that present over and above the amount which is required to from calcium hydrogen carbonate. Some free carbon dioxide is necessary, however, to stabilize the calcium hydrogen carbonate : this amount is incapable of effecting solution of more calcium carbonate and is therefore not aggressive. Furthermore, the amount this required will increase with the amount of hydrogen carbonate in solution. The aggressive carbon dioxide, capable of dissolving more calcium carbonate, is therefore not the free carbon dioxide present in excess of that required to stabilize the existing hydrogen carbonate equilibrium, but this quantity less that proportion of it which will be required to stabilize additional calcium hydrogen carbonate in the solution. The amount of free carbon dioxide required to maintain the equilibrium for various amounts of calcium hydrogen carbonate in solution and the pH values of the equilibrium solutions.

If the total amounts of free carbon dioxide and calcium hydrogencarbonate in water are determined analytically, then the amount of aggressive carbon dioxide can be derived from the CO_2 – Ca (HCO_3).

$CaCO_3 + H_2CO_3 = Ca(HCO_3)_2$

That for each molecule of free CO_2 consumed, two molecules appear in the hydrogen carbonate. Hence the solution composition must change in this reaction along a line such that the decrease in free CO_2 is half the increase in hydrogen carbonate CO_2. If the free CO_2 is plotted on twice the scale of the hydrogen carbonate CO_2 **(See Figure)** then the path representing the change falls on a line at 45^0 to the axis. Thus if the original composition of a solution of CO_2 and Ca (HCO_3) is represented by the point A and it reacts with solid $CaCO_3$, it will change along the line AB. Reaction ceases at B since this point is on the equilibrium curve. The amount of free CO_2 consumed, i.e. aggressive CO_2 is represented by AC. Thus , of the 100 mg/L of free CO^2 at point A only 22 mg is aggressive. (Refer table)

And more usual, free CO_2 concentrations, or at lower HCO_3 contents in the solution, the proportion of the free CO_2 which is aggressive is higher because of the shape of the equilibrium curve. For such conditions the values can be interpolated from the data. It must be emphasized that these values are only applicable to $CaCO_3$-CO_2 equilibria and will be altered if magnesium hydrogen carbonate or other sales are present.

Carbon dioxide in sea water has also been a cause of damage to concrete. In normal sea water, only small amounts of carbonate and hydrogen carbonate are present, about 10 and 80 mg/L respectively, and a small amount of free dissolved carbon dioxide. The pH value varies between about 7.5 and 8.4, an average value for sea water in equilibrium with the carbon dioxide in the atmosphere being 8.2. In normal sea water some gradual carbonation of set cement occurs, and this may be beneficial by the formation of a protective surface skin, but it is doubtful if the free carbon dioxide plays more than a minor part in the leaching of lime from a concrete. Under exceptional conditions, however sea water can contain abnormal amounts of dissolved carbon dioxide and become very aggressive, since carbonic acid behaves as a much stronger acid in sea water than in fresh water. These conditions can arise in sheltered bays and estuaries if the sea bed is covered by organic matter, which in its decay products carbon dioxide. Unless there is a corresponding increase in the calcium hydrogenarbonates content of the water, aggressive carbon dioxide will be available to attack concrete. Such a case was found in a dock at Newport News. USA, where concrete in the floor of expansion of the concrete by sulfate attack and weakening by leaching. Within 3 years after construction, the concrete below water level has lost as much as 27 per cent of its compressive strength. Analysis of water samples showed pH values ranging from 6.9 to 7.8 free carbon dioxide contents up to 100 mg/ L and aggressive carbon dioxide content up to 60 mg/L. The conclusion reached was that when the pH value of a sea water is above 7.5 there is little likelihood of leaching by carbon dioxide, that at a pH of 7.0 the content of aggressive carbon dioxide may be near the tolerable limit, and that below this pH value the content is almost certain to be excessive and cause damage to Portland cement concretes.

- **Biochemical and Chemical Oxygen Demands of Water:**

The composition of ground water discussed while dealing with sewage disposal scheme refer to chemical and biological oxygen demand. The water testing procedure of under water construction are silent on the biological constituent of water. The organic matter both living and non living play a very significant role in the deterioration of fresh concrete. The terms like BOD and COD are always referred by the waste water treatment experts and engineers.

The wastewater treatment processes, are designed on considering of the BOD and COD of Sewage and natural water. Higher the BOD and COD stronger and more pollutant is the sewage, and a more comprehensive treatment is required. The sewage and natural water are therefore analyzed for BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), and TOC (Total Oxygen Carbon) and another recently developed test TOD (Total Oxygen Demand). From these tests the theoretical oxygen demand is determined from the chemical formula of the organic matter present in the liquid. Determination of these characteristic of liquid is significant in the sewage treatment process and industrial waste water process. The treatment process are then proposed to insure that the oxygen demanded by the sewage or industrial west is made available to the liquid so that the industrial waste water to be disposed reaches the level of non-polutancy as per the environmental norms.

The BOD express the demand of oxygen by the micro organism for the Biochemical oxidation or organic matter while the COD expresses the demand of oxygen for oxidation of organic matter and inorganic matter both. When the ground water level is at the surface i.e. at the atmospheric level the oxygen is available from the atmosphere for completion of oxidation of the organic matter present in the water. There is a small percentage of dissolved oxygen in the surface water which is also consumed for the oxidation. As the depth of striking of ground water increases below the ground level the percentage of dissolved oxygen drops down and also there is no oxygen from atmosphere available for the oxidation process. When the bored cast in situ pile is casted in the such environment with ground water craving for Oxygen for completing the oxidation of organic matter gets an opportunity or opening to complete the oxidation of organic matter on consuming the oxygen available from the concrete constituents. Such activity leads to a chemical reaction like change of the ion aluminum ratio or water saturation of calcium carbonate. The chemical reactions related to the saturation indices as well as effects due to free CO_2 are discussed earlier. But the change of iron aluminum ratio which reduces the resistance to sulphate and oxidation of ion compounds in the cement by the oxygen demand of polluted ground water offers a clear field for sulphate attack on concrete. It is therefore necessary to find out the oxygen demand both BOD and COD to establish the possibility or otherwise of oxygen depleted or non oxygen environment below the ground surface.

Modified Procedure of Water Testing:

The modified procedure shall therefore include these tests along with conventional testing procedure. The injurious properties of water not covered by the conventional procedure for testing of water for underground constructions are summarized below.

a. Degree of saturation of calcium carbonate in water
b. The quantum of free carbon dia oxide aggressive in nature
c. Concentration of carbonic acids and
d. Demand of oxygen in under ground water and soil, (B.O.D., C.O.D. test)

Conclusion And Recommendations :

i) It is abundantly clear that prudent test procedure of testing of water for underground concrete purpose is insufficient. The following tests are proposed in 'Standard methods for the examination of water and waste water manual ' for establishing saturation indices.
   a) Saturation indices evaluated
      i) Ryzner Test
      ii) Marble Test

The test to establish quantum of free carbon must be prerequisite of a testing programme.

ii) To estimate the demand of oxygen in underground water and soil the tests like BOD and COD must be carried out.

iii) The collection of water samples and soil samples during investigation at regular intervals/ change of strata shall be made mandatory.

iv) The concrete cubes freshly casted may be kept for curing in ground water and results compared. Such procedure shall help in verifying performance atleast in top level ground water table.

v) Four piles in four corners of building may be tackled first and exposed up to as much depth possible. Such procedure will above provide the guidelines and suggest the suitable measures.

vi) Polyethylene liner is effectively used at present in aggressive soils in Mumbai. It is recommended to use same for all works. The introduction of liner will deprive the frictional resistance and hence atleast up to 4 to 5 metres below ground or in nor burden the liner shall be introduced. The pile shaft in rock may not be lined with polyethylene liner.

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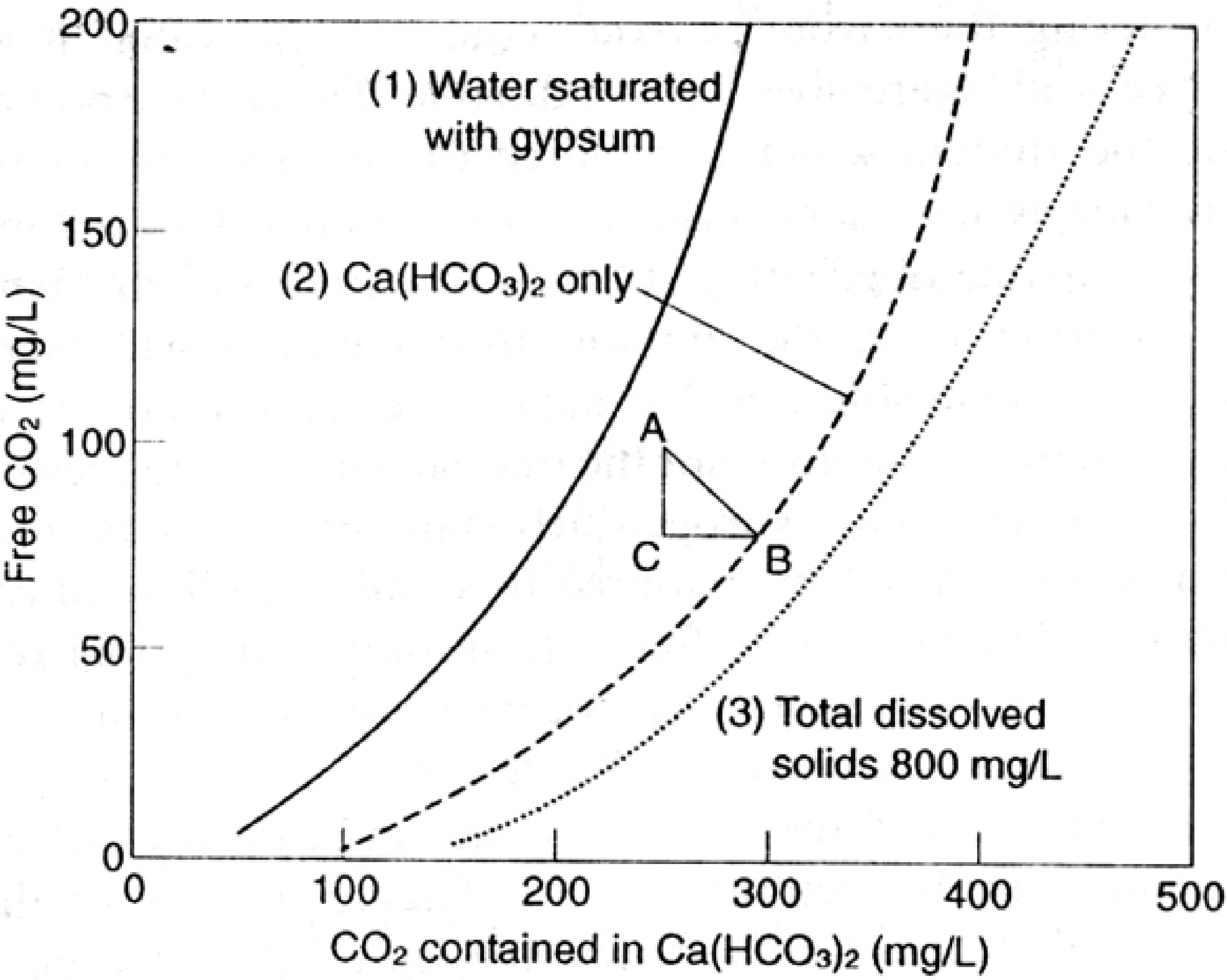
Figure No. 01



Solubility of Carbon dioxide at various partial pressures.

CO_2 content of atmosphere (% Vol)	CO_2 dissolved at 18°C (g/L)	pH value	$CaCO_3$ dissolved (g/L)	pH value
0		—	0.0131	10.23
0.03 Normal air	0.00054	5.72	0.0627	8.48
0.30	0.0054	5.22	0.1380	7.81
1.00	0.19	4.95	0.2106	7.47
10.00	0.18	4.45	0.4689	6.8
100.00 CO_2 at atmospheric pressure	1.8	3.95	1.0577	6.13

Calcium Carbonate-Carbon dioxide equilibria data

Free CO_2 (mg/L)	CO_2 combined in $Ca(HCO_3)_2$ (mg/L)	Aggressive CO_2 (mg/L)	pH value
1	0	1	5.6
	4.4	1	7.2
5	0	5	5.2
	4.4	5	6.5
	8.8	4.9	6.8
	22	4.7	7.2
10	0	9.9	5.1
	4.4	9.9	6.2
	8.8	9.8	6.5
	22	9.5	6.9
30	0	29	4.8
	8.8	29	6.0
	22	28	6.4
	44	27	6.7

WORKSHOP ON NATIONAL BUILDING CODE OF INDIA 2005

A Report by N.D. Patel

BIS and the Institution of Engineers (India), Maharashtra State Centre jointly organized a workshop on NBC 2005 on 18th & 19th October 2008 in Mumbai.

Workshop:

About 250 delegates representing local bodies/ authorities, public sector enterprises, private construction/ property management agencies, consulting organizations, R&D institutions and academic institutions, building material manufacturers/ suppliers and professionals such as architects, engineers, town planners, valuers participated in the workshop.

To begin with, Mr. D.S. Pradhan, Chairman, IE (I) Maharashtra State Centre gave the welcome address. In his welcome address, he presented the background for organizing the Workshop. The Workshop was inaugurated by Mr. S.D. Landge, Director, Town Planning Department, Govt. of Maharashtra. He assured that the revised Building Code, NBC 2005 would be effectively implemented in the State of Maharashtra at the earliest. Mr. N.D. Patel, Principal Co-ordinator of the Workshop informed about the program objectives.

Technical Sessions:

In the technical Sessions, various speakers presented details about different parts and sections of the Code and particularly explained the important modifications made in this revision.

In the first technical session, Mr. Sanjay Pant, Director, BIS and Member-Secretary, BIS technical committee on NBC, gave an overview of NBC 2005 including the application and philosophy of 26 chapters covered under 11 parts and section/subsections thereunder. Mr. V. Suresh, Vice-Chairman of NBC Committee explained the provisions on administration, development control rules and general building requirements which form the main part of the local building byelaws, and explained in detail the implementation aspects of overall provisions of NBC 2005 by the state authorities. Mr. Jose Kurian, Convener of the NBC Panel on Masonry and Chairman of BIS Committee on Cement and Concrete gave a detailed presentation on structural design of buildings for safety. Mr. S. Kanappan, Member of the NBC Panel on Prefabrication and Systems Buildings emphasized the need for adopting prefabricated and pre-engineered buildings for efficient and speedy construction. Dr. Prem C. Jain, Convener of the NBC Panel on Air Conditioning, Heating and Mechanical Ventilation highlighted the important concepts such as need to replace ozone depleting substances by their effective substitutes, sick buildings syndrome etc. Mr. Sandeep Goel explained in detail the provisions on water supply, drainage, sanitation, solid waste management and gas supply given in the revised Code.

Mr. V. Suresh, Guest of Honour, explained the current trend of urbanization in Maharashtra as well as in the country and the need for following the provisions of the Building Code for ensuring safe and orderly development of our burgeoning cities. Mr. M. V. Deshmukh, Director, Maharashtra Fire and Emergency Services, Govt. of Maharashtra advised the professionals and builders of the State to abide by the sound provisions of the Code in all sincerity for ensuring safe, economical and efficient construction. Mr. S.H. Jain, Hon. Secretary, IE (I), Maharashtra State Centre presented a vote of thanks.

In the valedictory Session, it was felt that it is essential to implement the provisions of NBC 2005 in letter and spirit so that the technological developments percolate down to poorest of the poor. The necessity of educational utilization of NBC 2005 and other Indian Standards in Engineering and educational curriculum was also emphasized.

Recommendations:

Recommendations made during the Workshop were as follows:

1. The National workshop was attended by 250 delegates representing all stakeholder groups in the building construction sector and built environment sector, unanimously endorse the adoption of National Building Code of India 2005 (NBC 2005) as an instrument for guiding regulation of planning, design, construction and asset management of all buildings in Maharashtra.
2. The workshop strongly recommends to Government of Maharashtra and all local bodies (urban & rural), development authorities, special and new town development agencies, etc to modify, revise, revamp the existing building byelaws; development control rules; planning standards; town planning rules; special regulations for fire, structural, health, construction, electric and life safety, in line with the NBC 2005 by suitably adopting fully or adapting it with such local variation as may be needed.
3. The workshop recommends to adopt NBC 2005, as the basis for structural design, fire protection, building and plumbing services, building materials and construction practices (and construction safety) by modifying the departmental construction codes/ specifications/ manuals of Govt. construction departments, in line with NBC 2005.

... (Continued page 30)

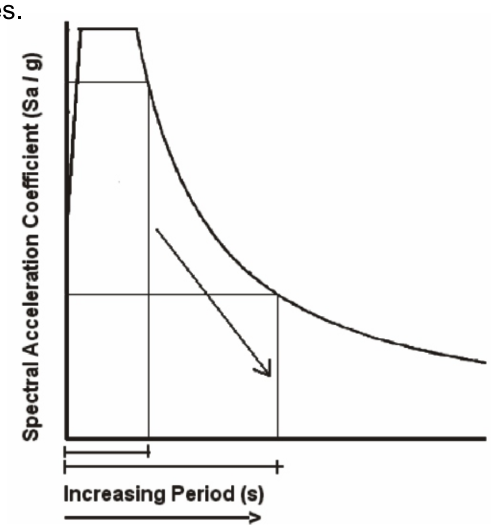
STRUCTURAL ANALYSIS OF BUILDINGS WITH SEISMIC ISOLATORS

Subodh Shinde

Introduction:

Seismic isolation mechanisms leverage the decoupling of a structural system from its foundation for minimizing the lateral vibration of the superstructure from potentially damaging earthquakes or support motion. The decoupling is achieved by increasing the flexibility of the Seismic isolation system, together with providing appropriate damping to it. In many applications, the Seismic Isolation system is mounted beneath the superstructure and is referred to as 'base isolation system'. The most popular technology is the lead rubber bearing (LRB) isolators that decouple the superstructure from the foundation. Other products that have been developed and patented include dampers and sliders, which absorb or dissipate movement. Seismic isolation incorporation costs are in the range of 2 -5% of total construction costs. It is a proven technology that has successfully protected buildings in actual earthquakes in the US and in Japan.

The January 2001 earthquake in the Kutch region of Gujarat affected the middle-class community situated some 300 km from the epicenter. There has been a sustained reaction to this event, in that some residents are considering investing in houses with improved seismic resistance. The first large building with base-isolated system in India is the new 300-bed Bhuj District Hospital, a replacement for the one destroyed in the major Gujarat earthquake of 26 January 2001, Republic Day of India. Members of the Wellington-based Earthquake Engineering NZ business cluster have worked closely with the Indian designers and contractor in developing both the design of the base isolation system for this hospital and the supply of the customized bearings. The hospital is founded on Robinson Seismic Lead Rubber Bearings which will protect the patients and ensure that the hospital will remain operational during the future seismic activities.



Effect on Structural Response:

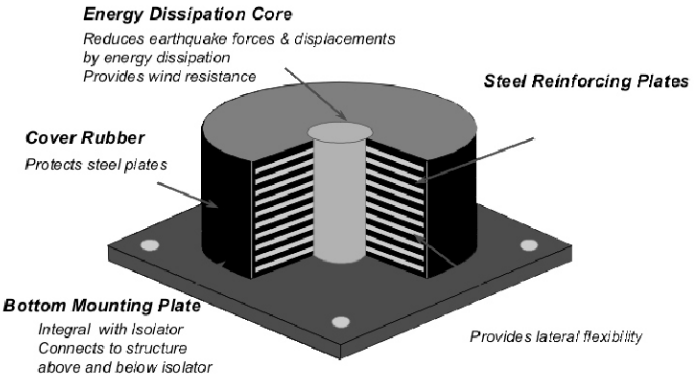
Seismic isolators act as intermediate vibration control devices that prevent transfer of vibration in order to protect the superstructures. Therefore it is installed between the main vibration transfer channel of the superstructure and foundation or between the bridge's pier and superstructure in order to isolate the superstructure from substructure or minimize the transfer of vibration.

The concept of the seismic isolation is that the superstructure is prevented from the horizontal component of ground motion by inserting structural material of low horizontal stiffness between the superstructure and foundations. This makes the isolated superstructures' fundamental period of vibration greater than that of the fixed base structures. The isolated superstructure's 1st mode includes only the seismic isolator's deformation and rigid behavior of the superstructure. From the perspective of dynamics, the structure's natural period of vibration is increased by inserting flexible material in the foundation. Due to increase in time period, the acceleration minimizes (response spectrum), hence the base shear is also minimized.

LRB Isolators:

LRB (Lead Rubber Bearing), the most widely used seismic isolator, is normally made with rubber (Phalanx) vulcanized directly to the top and bottom plates as shown in the figure 1. Or with the top and bottom plates bolted directly to the outer plate inside the bearings. Lead rubber bearing is available with values of damping of the rubber ranging from 5% to 15% (10% being recommended as standard for damping of rubber), lead provides additional 30% damping. LRB seismic isolator's mathematical model has bi-axis plastic that is correlated to 2 of the shear directions. The rest of the four direction's deformation has the characteristics of linear elastic spring that are mutually independent.

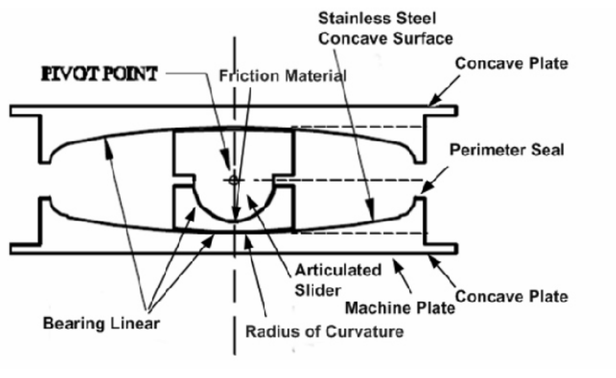
Figure 1. Lead Rubber Bearing (LRB) Seismic Isolator



FPS Isolators:

FPS (Friction Pendulum Systems) isolators, as shown in figure 2, are made up of a dense chrome over steel concave surface in contact with an articulated friction slider and free to slide during lateral displacements. Friction Pendulum Bearings are specially designed for each facility based on the load capacity requirements, earthquake displacement capacity, soil conditions, and the size of the structure being supported. Typically Friction Pendulum bearings measure 3 feet in diameter, 8 inches high, and weigh 2000 pounds. Friction Pendulum System Isolator retains the properties of coupled Biaxial Plasticity for the 2 shear deformations, the nonlinear property of the Gap behavior for the axial deformation and the properties of independent linear elastic springs for the remaining 3 rotational deformations.

Figure2. Friction Pendulum System (FPS) Seismic Isolator



Seismic Isolation Analysis:

The structure includes the non-linear boundary elements (seismic isolators), and the rest of the structural elements & materials are linear & elastic. This type of analysis method is called boundary nonlinear analysis. This prevents the structure from or minimizes the plastic deformation due to design load and is considered to be an appropriate process of boundary nonlinear analysis. In this analysis method, stresses in the structural members need to be checked in order to verify that they are within the elastic range, by reviewing the analysis results. The most important factor in seismic isolator's design and its application is that nonlinear analysis is needed to reflect material nonlinear characteristics. Linear response spectrum analysis that uses equivalent stiffness and equivalent damping ratio can be usefully utilized.

Nonlinear Time History Analysis:

This analysis method is known as the most common method for analyzing the structure installed with seismic isolators. In terms of seismic isolator, the behavior is relatively simpler and many models are verified through experiments. Also, the nonlinear behavior occurs only in these equipments. Therefore the analysis is reasonable and effective considering the elastic behaviour of the rest of the materials.

Illustrative Example:

Boundary nonlinear time history analysis is performed for the 3D frame structure using a structural software having in-built features to handle seismic isolation systems. The example, which was analyzed is shown in figure 3, it is a simple concrete structure designed for wind load and it is assumed that seismic isolator is applied between superstructure and foundation. The seismic isolators (LRB) are placed at the four corner columns and FPS in rest of the columns. The analysis is performed for a structure with seismic isolation system and structure with fixed foundation system (regular analysis models). Behaviour and vibration response of both the structures are compared with each other.

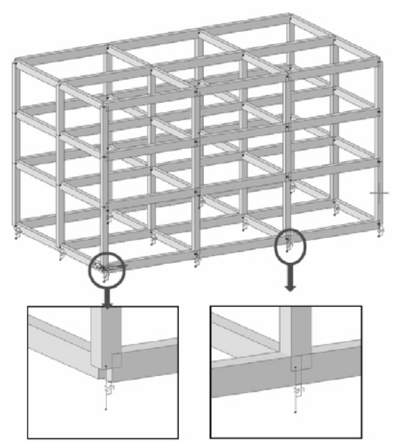
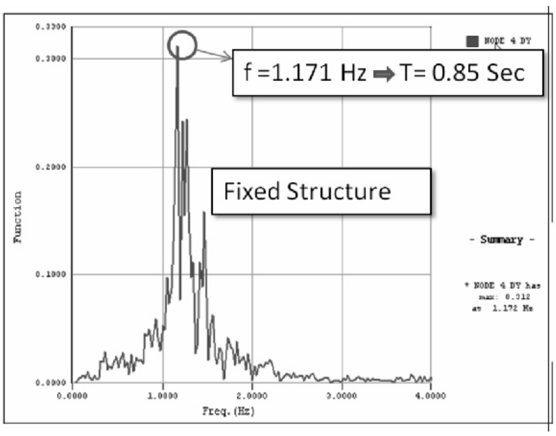


Figure 3. 3-D Frame model with base Isolation system

▪ Material: Concrete(M-30)
▪ Section Size Beam : 500x650 mm Beam : 400x550 mm Column : 500x500 mm
▪ Gravity direction load Dead load: 4 KN/m2 Live load: 2.5 KN/m2
▪ Lateral Load Wind load: wind speed-40m/sec, Terrain Category- Seismic load: El Centro(NS, EW, 1940)
▪ Seismic isolator LRB 4 pieces in edge FPS -8 pieces

El Centro (1940)'s time history is used for seismic load along global X & Y directions. In the nonlinear analysis, the principle of superposition can not be applied and therefore analysis results of static loads and dynamic loads cannot be combined. The software which was used to solve this example is provided with the time function in the form of dynamic seismic load, which is multiplied with static seismic load to consider simultaneous bearing effect of static load and dynamic load. Especially, the module for FPS seismic isolator has an option by which frictional force proportional to the axial load can be considered. Therefore in the boundary nonlinear time history analysis, the gravity direction's static load bearing is necessary as it has great effect on the response for seismic load.

The effect of increase in natural period due to presence of seismic isolator is verified. When the seismic isolators are applied, the structure becomes a nonlinear one hence it does not have set period and eigenvalue analysis is not possible. Therefore the deformation response's time history has to be changed to frequency domain to look for prominent period. It can be directly verified that the period increased from 0.85 sec to 1.78 sec (approximately doubled) by calculating the frequency range that shows the maximum number from the vibration frequency domain response (Figure 4).



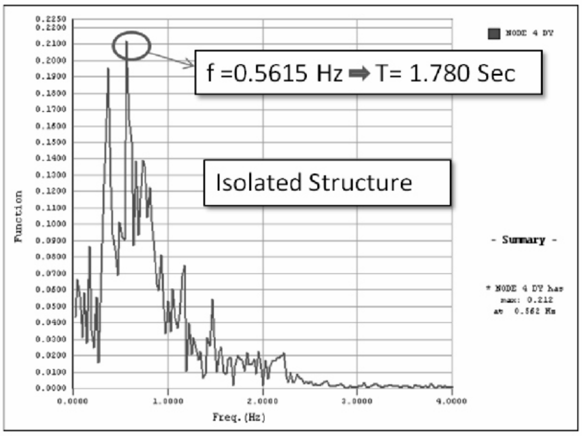


Figure 4. Vibration frequency domain functions for highest story drift time history

Structural Software Used:
The structural software used for solving the illustrative example was “MIDAS Gen”. It contains modules which can perform seismic isolation analysis using LRB and FPS isolators. Time history analysis of the structures can also be performed with seismic isolators by using the boundary non-linear time history analysis function.

Conclusion:
We have seen the characteristic of seismic isolator, vibration response of the building and hysteretic behavior of seismic isolator through the boundary nonlinear time history analysis using MIDAS program. Seismic isolation design increases the time period and damping ratio of the structure which results in minimizing seismic forces and hence saving lives and valuable assets. Even though the initial construction expense may be on higher side compared to that of fixed base structures but the long term gains are much more. Therefore it is an effective measure that can be taken to increase earthquake resistance function.

India consists of strong, moderate and weak earthquake regions. Because of this consideration of vibration analysis in design is of great importance & interest. The seismic isolation analysis method has already received the spotlight in many technologically advanced countries. With tremendously growing average lifestyle, the interest for the safety aspect is also growing. It is well known that earthquake is one of the most unpredictable and destructive natural calamities. However the resulting losses can be minimized by using base isolation systems in today's structures. Such structures with base isolators can be easily analyzed using today's expert structural software.

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REINFORCEMENT DETAILING OF RC STRUCTURES: AN OVERVIEW

Prof. M.D. Mulay

Since concrete is strong in compression but weak in tension, it is necessary to reinforce it in the tension zone by providing adequate reinforcement bars to take full tension developed in the zone and reduce the tensile stress in the concrete, preferably below the cracking strain-level. Tensile stresses are developed due to the shear forces and twisting moments apart from bending moments. Fall of temperature jointly with the shrinkage of concrete can also cause large additional tensile stresses in concrete. Having calculated the amount of reinforcement at a section from the strength angle, it is necessary to provide the reinforcement bars in such a way that the structural members behave in the intended manner and the structure as a whole can resist the loads acting on it without failure. This is called detailing of reinforcement. Following are the guiding principles of reinforcement detailing:

1. **Dense concrete:**

   The concrete provided in the formwork should set into a dense and strong mass, fully bonded to the reinforcement all around and over its full length, suitable plasticizers/ admixtures may be added to achieve the required workability. It is essential that concrete flows easily and smoothly through the reinforcement cage reaching in all corners of the formwork with the use of standard vibrators. All these factors are necessary to make the concrete as impermeable as possible, whereby the life of the structure is increased.

   In this respect, adequate clear distance between the adjacent longitudinal bars in beams / columns as well as the clear distance between transverse reinforcements (stirrups in beams and Links in columns) are the important aspects of detailing of reinforcement in the drawings. Areas such as beam column junction etc, where the probability of congestion of reinforcement would be high, detailing has to be done more carefully and developed in such a way so as to ease the construction work of i) Making formwork, ii) laying of reinforcements, iii) pouring / placement of concrete which can flow smoothly and easily without much obstruction of the reinforcement, using the standard vibrators.

   I.S. 456-2000 is intended to achieve the above-referred aspects in specifying its clauses for detailing. At places, we may need to improve the clauses further so that implementation of dense concrete on site is feasible and can be satisfactorily enforced.

2. **No visible cracks or excessive deflection under working loads:**

   Layout of flexural and shear reinforcement in different regions of any member should be such that under full magnitudes of the possible vertical and horizontal working loads or their critical combinations, the various internal forces that are developed at all critical sections can be resisted adequately without forming any visible crack or excessive deflection or sway displacement. Ideally the crack width should be as small as possible and preferably much less than 0.1 mm so that ingress of moisture, carbon dioxide or aggressive chemicals is well arrested by the dense and almost impermeable concrete thus gaining more life to the structure.

   In this respect, care should be taken to provide extra reinforcement (or the minimum reinforcement as per the code) to take care of the tension developed due to effects of shrinkage and fall of temperature. Apart from this when the plan dimensions of the building are quite long, I.S. Code recommends to make the provision of expansion joints in the building in which clear gap is provided between two parts of the same building or any other alternative measures be included, so that temperature/shrinkage displacement can be mobilized and it relieves the structure form high temperature stress in the members.

3. **Ductile behavior at the stage of failure:**

   In considering the load-combinations including earthquake forces generated by the ground motion, the magnitude of any future earthquake force in a given zone (which depends on the Richter scale of such a future event) is unpredictable. For the purpose of design, earthquake forces are estimated as a fair educated guess recommended in the codal provision of IS1893, which can have some basis depending on intensity of past earthquakes in and around the zone under consideration. However the true value of the earthquake force likely to occur in near future span of say 100 years is not really predictable and can be substantially higher than estimated value.

   Under a severe earthquake, since its magnitude may be many times more than that obtained from codal provisions, a huge loss of human-life can occur. Therefore a concept of ductile detailing of reinforcement in the frame members (especially near the joints) was developed to "safeguard human life". Under ductile detailing, the structure is able to undergo large inelastic deformations at joints due to its ductility and is prevented from total collapse within the short time period of earthquake duration.

If a structure is likely to be struck by an unexpectedly strong earthquake, it needs to be designed for its possible higher ductility in undergoing large inelastic deformations by formation of plastic hinges at the so called rigid-joints of the frame, under the limit values of combination of loads. Such large rotation capacity at the joints of frame members can be achieved by providing special confining reinforcement in form of additional links in column and stirrups and extra compression steel in the beam, so that concrete portion in compression is highly confined. When such special reinforcement is provided, the permissible failure compression-strain in concrete is increased to a very-large extent. It is this aspect, which helps to allow the joint to rotate inelastically under constant value of plastic-capacity of moments at the beam column joint. The redistribution of excess moment takes place from one joint to other adjacent joint to form subsequent hinges in the frame. Such a behavior of framed structure wherein plastic deformations can be mobilized at joints to allow redistribution of moments, is called ductile behaviour. Once the ductile behavior is induced by this special reinforcement provided in all members and their joints, more is the inelastic/plastic deformation (i.e. wider cracks) and more is the number of plastic hinges formed and such a chain action of this continuous process of moment redistribution needs substantial time to undergo associated inelastic deformations and thus absorbs the “Earthquake-Shock” which has a limited time duration of generally much less than a minute. Hence the function of ductile detailing is that the structure is made to sustain over this earthquake duration without total collapse due to the ductility at the joints, even through due to large number of wide-cracks developed at and near the joints, it is then rendered unserviceable. Human life is thus saved and hence this part of design philosophy in which contribution of ductile detailing of reinforcement is emphasized, is referred to as “Survival Condition”, with respect to “Human Life”.

For earthquake forces of magnitude less than the expected codal values, the joints will undergo mainly the elastic deformations and will resist the earthquake loads without the help of any special reinforcement for ductility and will then remain serviceable even after the earthquake shock. The details of the reinforcement required for ductile detailing at the joint and in the Beams/Columns adjacent to the joints are generally specified in I.S. 13920-1993 based also on large experimental research all over world

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4. The workshop recommends the strengthening of all building development and regulating agencies with the right level of professional human resources to deal with proactive responses needed with the building professionals and builders. The professional human resource pooling for contiguously situated human settlements and the related regulating agencies should be attempted, considering the socio-economic and budgetary constrains of smaller level local bodies dealing with building regulation work.
5. The workshop strongly urges the Government of Maharashtra, Directorate of Technical Education, Educational Institutions dealing with architectural, engineering and planning education to upgrade the curricula in line with NBC 2005 so as to ensure proper understanding and training of the provisions of the Building Code right from academic level.
6. The workshop recommends the initiation of continuous orientation and development programmes for creating mass awareness, appreciation and application of NBC 2005 among practicing professionals and the Government, Public and Private Sector; as also capacity building/training of all building professionals and work force involved in building construction activity.
7. The National Workshop on NBC 2005 urges the Government of India - CBDT to provide a level playing field in term of fiscal incentives (excise duty exemption) for use of emerging technology applications for prefabricated/ mechanized construction systems to be competitive and cost effective, considering the needs of speedy and massive mass housing and building construction.

PRODUCT REVIEW

We have now introduced a new section, “Product Review” into the ISSE journal. This is where manufacturers and dealers can introduce their products such as construction materials, chemicals, equipment, software etc, through a technical review. Only one product review may be printed in each issue. A space of up to two pages of the journal may be allocated to this feature.

The main purpose of this feature is to introduce the newer products available in the market to our readers, and therefore, the review should be technically intensive. The manufacturers and dealers can highlight the advantages and uniqueness of the featured products in the review.

The review should cover one or two products only and may include their technical specifications, method of installation/ application, available product range, unique features, advantage, photographs etc. It should not be a direct commercial promotion of the products. However, the contributor may include his contact details at the end of the review. Matter received may be suitably edited and modified in consultation with the contributor.

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