STRUCTURAL ENGINEERING

QUARTERLY JOURNAL OF

INDIAN SOCIETY

OF

STRUCTURAL ENGINEERS

ISSE

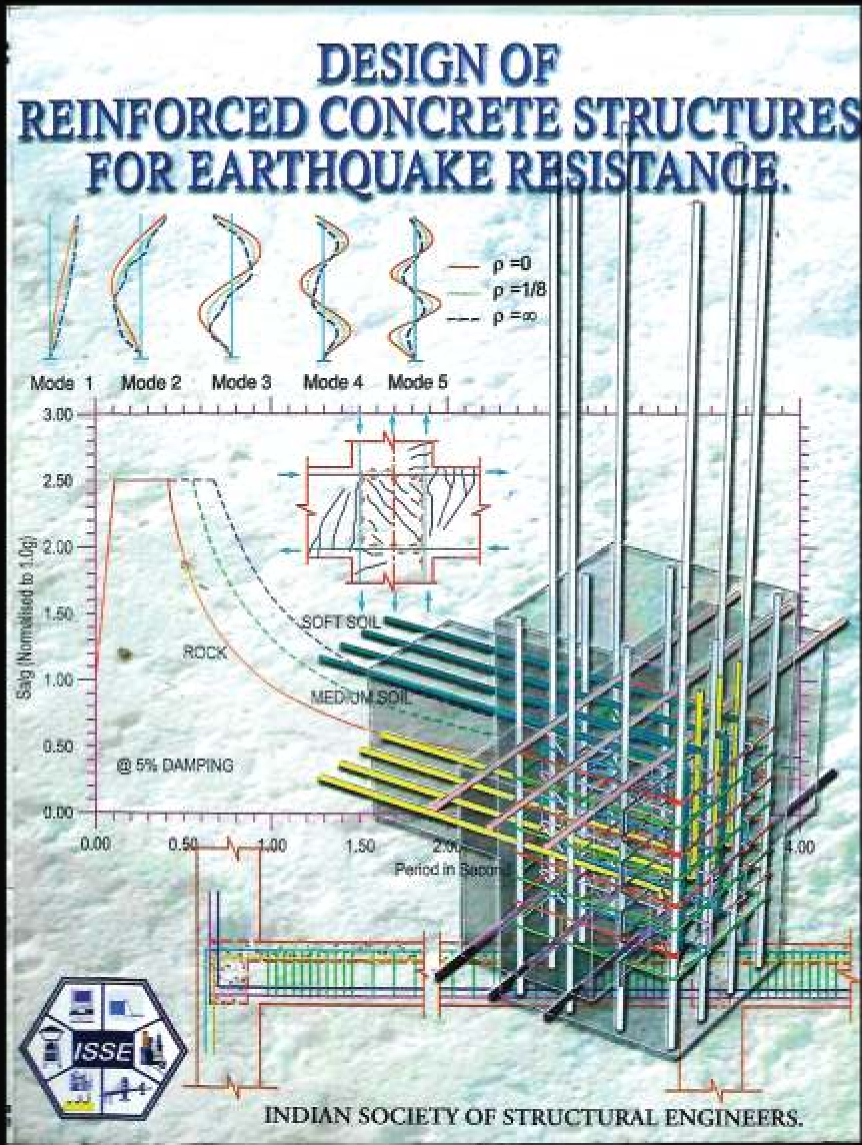
VOLUME 20-1

Jan - Feb - Mar 2018

Gem 15: Dr. Fazlur R. Khan, 'Einstein of Structural Engineering' (Page 3)

News and Events : Lectures on IS16700:2017 (Page 20)

LET US BUILD A STRONG STRUCTURE OF INDIAN SOCIETY



ASSOCIATION OF CONSULTING CIVIL ENGINEERS (INDIA)

CITATION

ACCE - NAGADI AWARD 2004

INSTITUTED BY

NAGADI CONSULTANTS PVT. LTD., NEW DELHI

FOR

BEST PUBLICATION IN CIVIL ENGINEERING

TO

DESIGN OF REINFORCED CONCRETE STRUCTURES FOR EARTHQUAKE RESISTANCE
by Mr. D. S. JOSHI et al, MUMBAI

The book *Design of Reinforced Concrete Structures for Earthquake Resistance* is written by a team consisting of Mr. D. S. Joshi, Mr. R. L. Nene, Mr. M. D. Mulay, Mr. S. Salgaonkar and Mr. N. D. Joshi. It is published by Indian Society of Structural Engineers (ISSE), Mumbai, in the year 2001. All the authors are structural engineers and are members of ISSE committee for Standards and Codes. The team leaders, viz. Prof. D. S. Joshi and Mr. R. L. Nene are highly experienced and eminent structural consultants.

In the 12 sections that the book has, the subject has been dealt with very ably from the point of view of structural consultants and the book aims to provide in a consolidated form, information available in India and abroad. The book discusses mainly the IS codes by pointing to salient features concerning the seismic design with figures, pictures, details and references along with the filtered recommendations by the ISSE as a summary. Starting from a section on causes of earthquakes in the context of Hindu Mythology, the book covers in its various sections, the anatomical aspects of structural framing system, principles for determining design earthquake forces, the clauses in the relevant IS and other codes. Important aspects of ductility, stiffness, strength and capacity design of buildings to resist earthquakes. There is one section called 'open forum' where various questions commonly asked by both public and technical persons on various aspects of earthquake design, have been dealt with explicit answers. There is a noteworthy section which includes a practical designing example of an eleven storey residential RC building, giving step-by-step procedure with explanations, covering all aspects, which would benefit particularly the young design engineers.

The purpose of this book has been to present a logical and practical basis for the design of RC buildings against earthquake forces. The book has more than 300 pages and is enriched with more than 250 coloured figures and photographs (with high quality production and printing) to make it interesting and easily understandable.

The Awards Committee and the Governing Council of ACCE confer the ACCE Nagadi Award 2004 for **Best Publication in Civil Engineering to Design of Reinforced Concrete Structures for Earthquake Resistance by Prof. D. S. Joshi et al. on 17th June 2004.**

Chairman Awards Committee	Secretary General ACCE (I)	President ACCE (I)

STRUCTURAL ENGINEERS
QUARTERLY JOURNAL

INDIAN SOCIETY OF STRUCTURAL ENGINEERS

ISSE

VOLUME 20-1, Jan-Feb-Mar 2018

Head Office : C/O S.G. Dharmadhikari, 24, Pandit Niwas, 3rd Floor, S. K. Bole Road, Dadar (W.), Mumbai 400 028 • Tel. : 91-22 24314423 / 24221015
• E-mail : issemumbai@gmail.com • Website : www.isse.org.in
Regd. Office : The Maharashtra Executor & Trustee Co. Ltd., Bank of Maharashtra, Gadkari Chowk, Gokhale Road (N.), Dadar (W.), Mumbai 400 028.
Charity Commissioner Reg. No. E-17940, Mumbai Donations are exempted from Income Tax under 80-G

Contents

Editor : Hemant Vadalkar

Fraternity News

WELCOME TO NEW MEMBERS

(Oct – Nov – Dec 2017)

M – 1588	T.Anandaraj
M – 1589	Anand Prakash Daftardar
M – 1590	Ashish Madanlal Monga
M – 1591	Gollala Chandrama Motagi
M – 1592	Ajit Sukdev Surwade
M – 1593	Pramod Ganpatrao Powar
M – 1594	Gaurang Pravin Raut
M – 1595	Yash Sanjay Sale
M – 1596	Vijay Ankush Bhandgar
M – 1597	Ankit Manoj Asher
M – 1598	Arati Ramanth Bhat
M – 1599	Ramanth Balkrishna Bhat
M – 1600	Shabir Hussain
M – 1601	Milind Ramdas Kolhe
M – 1602	Ganesh Bharat Baravkar
M – 1603	Ravinder singh Malik
M – 1604	Hemant Kumar Narayan Shinde
M – 1605	Jithin Prem S.
M – 1606	Satheesh Kumar Lakshmanan

Patrons : 36 Organisation Members : 23 Sponsor : 8

Members : 1606 Junior Members : 45 IM : 01

TOTAL STRENGTH 1719

- Structural; Designing & Detailing
- Computer Software
- Materials Technology, Ferrocement
- Teaching, Research % Development
- Rehabilitation of Structures
- Construction Technology & Management
- Geo-Tech & Foundation Engineering
- Environmental Engineering
- Non Destructive Testing
- Bridge Engineering

& Other related branches

1. To restore the desired status to the Structural Engineer in construction industry and to create awareness about the profession.
2. To define Boundaries fo Responsibilities of Structural Engineer, commensurate with remuneration.
3. To get easy registration with Governments, Corporations and similar organizations all over India, for our members.
4. To reformulate Certification Policies adopted by various authorities, to remove anomalies.
5. To convince all Govt. & Semi Govt. Bodies for directly engaging Structural Engineer for his services.
6. To disseminate information in various fields of Structural Engineering, to all members.

Gem 15: Dr. Fazlur R. Khan, 'Einstein of Structural Engineering'

Dr. N. Subramanian
Er. Vivek G. Abhyankar

Dr. Fazlur Rahman Khan (1929-1982)

Bangladeshi-American engineer Dr. Fazlur R. Khan revolutionized the construction of tall building systems during 1960s-1970s, which are followed worldwide to economically construct super tall buildings. He was involved in the design of the then world's tallest structures – notably, Chicago's 110-story Sears Tower, and the John Hancock Center. Khan developed several efficient and economical structural systems including the trussed tube, the tube-in-tube, the bundled tube, and the composite system, and also offered logical frameworks as core ideas for architectural design.

For his contributions to structural engineering, Dr. Khan has been called a "*structural engineer saint*" and "the *Einstein of structural engineering*," as well as received countless other glowing accolades for his professional accomplishments.

EARLY LIFE

Born in Dacca, Bangladesh on 3 April, 1929, Dr. Kahn grew up in the village of Bhandarikandii, in the Faridpur District near Dhaka. His father Abdur Rahman Khan was a high school mathematics teacher and textbook author. He eventually became the Director of Public Instruction in the region of Bengal and after retirement served as Principal of Jagannath College, Dhaka. Due to his father, he acquired a thorough grounding in mathematics and analytical thought in his youth. He discovered the joy of learning, even when he was young which endured throughout his life. Khan attended Armanitola Government High School, in Dhaka. Then he went on to study Civil Engineering in Bengal Engineering and Science University, Shibpur (now called Indian Institute of Engineering Science and Technology, Shibpur), and earned his Bachelor of Civil Engineering degree from Ahsanullah Engineering College, University of Dhaka, (now Bangladesh University of Engineering and Technology), finishing first in his class.

ARRIVAL IN USA

He received the prestigious Fulbright and another Pakistan government scholarship, to do three years of postgraduate studies in the United States in 1952. Working at an unusual pace, Khan was able to acquire three degrees in only three years from the University of Illinois, Champaign-Urbana - a master's in structural engineering, a master's in theoretical applied mechanics, and a Ph.D. in structural engineering (with a thesis on 'Analytical study of relations among various design criteria for rectangular prestressed concrete beams'). His professors reinforced his attitude toward inquiry and strengthened his confidence in innovative thinking. In addition to gaining a firm understanding of materials and principles, he developed an intuitive comprehension of structural behavior, which is important for any structural engineer. Much later in life, he would remark "I put myself in the place of the whole building, and visualize the stresses and twisting a building undergoes" [Khan, 2004]. In 1967, he elected to become a United States citizen.

HIS CAREER

Dr. Fazlur Khan was employed by the architectural firm Skidmore, Owings & Merrill (SOM), in 1955 and he began working in its office at Chicago. He was made a partner of this form in 1966.

Dr. Khan introduced design methods and concepts which resulted in the efficient use of materials in tall building architecture. He first applied his concepts in the seminal, 43-story reinforced concrete, first tubular building, the Chestnut De-Witt apartment building, at Chicago, designed by him and the architect Myron Goldsmith in 1963 (see Fig. 1). In this building, the integration of the tubular structural system and Miesian architecture was complete and seamless-the building behaved as a three-dimensional system much like a solid tube, only partially softened by the openings for windows (Baker, 2001). Because of its great relative strength and stiffness, the tubular form immediately became a standard in high-rise design. Most of Khan's designs were conceived considering pre-fabrication and repetition of components so projects could be quickly built with minimal errors

Fig. 1 The revolutionary framed-tube structural system of Chestnut De-Witt apartment building, at Chicago (Photo: Anuthama Srisailam)

INNOVATIONS

Dr Khan demonstrated through his innovative designs that the rigid frame system, which long dominated tall building design, was not the only system to be used for tall buildings. He was the pioneer to develop several "tube" structural systems for tall buildings, including the framed tube, trussed tube, and bundled tube and shown that these systems resist lateral loads more efficiently than the rigid frame system. The tube system is a three dimensional space structure composed of many frames, braced frames, or shear walls, joined to form a vertical tube-like structural system capable of resisting lateral forces in any direction as a cantilevering perforated hollow tube from the foundation. The small perforations form spaces for windows and hence the normal curtain walling is eliminated (see Fig.1). About half the exterior surface is available for windows. Framed tubes allow fewer interior columns, and so create more usable floor space. Most buildings over 40 stories constructed since the 1960s now use a tube design derived from Khan's structural engineering principles. This system was adopted for the 110 storey Twin World Trade Center Towers in New York, USA (which were destroyed by terrorist attack in 2002) and for the 72 storey First Bank Tower in Toronto, Canada.

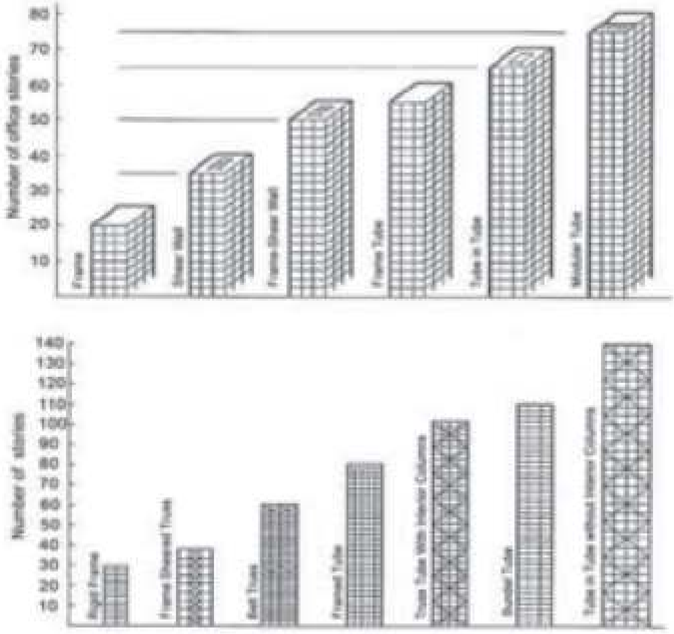


Fig. Classification of Tall Building Frames

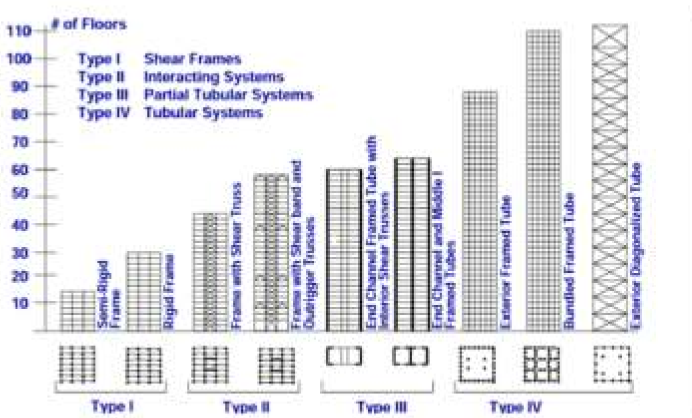


Fig. Evolution of Structural System for Tall Buildings

Trussed Tube and X-bracing

Khan pioneered several other variants of the tube structure design. One of these was the concept of applying X-bracing to the exterior of the tube to form a trussed tube. X-bracing reduces the lateral load on a building by transferring the load into the exterior columns, and the reduced need for interior columns provides a greater usable floor space. Khan first employed exterior X-bracing on his design of the John Hancock Center in 1965, and this can be clearly seen on the building's exterior, making it an architectural icon (see Fig.2). Trussed-tube construction and X-bracing also made buildings more efficient. Due to this system, the John Hancock Center, used only 145 kg/m^2 of steel, whereas the Empire State Building required 206 kg/m^2 and Chase Manhattan Bank Building (1961), required around 275 kg/m^2 of steel. The trussed tube concept was applied to many later skyscrapers, including the Onterie Center (See Fig.3), Citigroup Center and Bank of China Tower.

Fig. 2 John Hancock Center, Chicago, when built, this 100 storey, 334 m tall tower was the second tallest building in the world (Photo: Karthik Muthusamy) and www.Londoni.co

Fig. 3 The Onterie Center in Chicago- use of the trussed-tube structural system in RC construction (Photo: Anuthama Srisailam)

Bundled Tube

Dr. Khan carried the tube concept still further and created the bundled tube, which was used for the 442 m high Sears Tower (now the Willis Tower), One Magnificent Mile (RC building), and the Newport Tower (Jersey City). The Sears tower, built in 1974, is to this day the tallest building in the United States, and the fifth tallest structure in the world. It remained as the World's tallest building for 20 years. In this system, a number of relatively small-framed tubes or diagonally braced tubes are bundled together for great efficiency in resisting lateral forces. Bundled tube was also "innovative in its potential for versatile use of architectural space; the tube-units could take on various shapes and could be bundled together"

Fig. 4 Willis Tower, Chicago introduced the bundled tube structural system (Photo: Karthik Muthusamy)

Tube in Tube

In 1962, while designing the 38-storey, RC Brunswick building in Chicago, he developed methods for using core shear walls and exterior tube interaction to resist lateral loads. Later, he refined this system to come-up with the 'tube-in-tube concept. In this system, the inner tube and outer tube work together to resist gravity loads and lateral loads and to provide additional rigidity to the structure by reducing the deflections at the top considerably. This design was first used in 52 storey One Shell Plaza in Houston. Later buildings to use this structural system include the Petronas Tower.

Outrigger and belt truss

The outrigger and belt truss system is a lateral load

Fig. 5 U.S. Bank Center, in Milwaukee

resisting system in which the tube structure is connected to the central core wall with very stiff outriggers and belt trusses at one or more levels. BHP House was the first building to use this structural system followed by the First Wisconsin Center, since renamed U.S. Bank Center, in Milwaukee. The center rises 183 m, with 42 floors above ground, and three belt trusses at the bottom, middle and top of the building (See Fig. 5) . The exposed belt trusses serve aesthetic and structural purposes. Later buildings to use this include Shanghai World Financial Center.

In the 1970s, computer methods for structural analysis were just beginning to be used on a large scale. SOM was at the center of these new developments, with undeniable contributions from Khan. Although Khan fully embraced this new technology, his cautious and methodical nature was seen in his insistence on laboratory tests at the University of Illinois for a three-span continuous transfer girder, measuring 8 feet wide by 24 feet deep, for the Brunswick Building in Chicago. Khan believed the scale of what he created was still beyond the capacity for which current analytical theory could be trusted.

Hajj Terminal building

Khan's portfolio of notable international structure included the Hajj Terminal building at the Jeddah International Airport in Saudi Arabia, an enormous tent-like roof structure, designed along with Horst Berger of Geiger Berger Associates. This structure covering nearly one square kilometer consists of ten modules, each consisting of 21 'tents' of white colored Teflon-coated fiberglass fabric suspended from pylons, and grouped together into two blocks of five modules and separated by a landscaped mall between the blocks. The Hajj Terminal received the Aga Khan Award for Architecture in 1983. According to the jury, "the brilliant and imaginative design of the roofing system met the awesome challenge of covering this vast space with incomparable elegance and beauty."

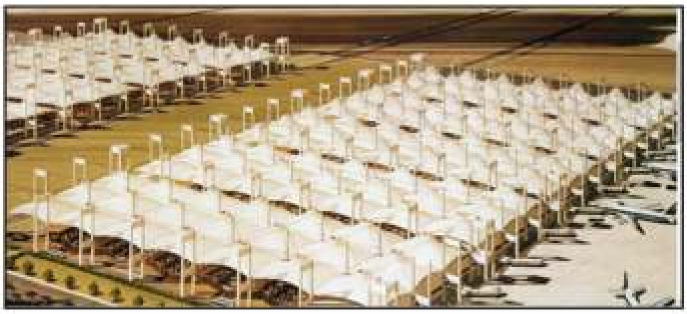


Fig. 6 Hajj Terminal, Jeddah- At 465,000 m², it is estimated to be among the world's largest air terminal

REMEMBERING HIS ROOTS

He never forgot his roots. When Pakistan invaded East Pakistan (now Bangladesh), Khan founded a Chicago based origination, The Bangladesh Emergency Welfare Appeal, to help the people in his homeland. His outstanding compassion was evident in the 1960s and 1970s as he took a lead role in humanitarian relief efforts while Bangladesh struggled to achieve political independence. He founded the Bangladesh Defense League with architect Stanley Tigerman.

In 1971, when selected as "Construction's Man of the Year" by *Engineering News-Record*, he said in a statement refective of his nature and career: "The technical man must not be lost in his own technology; he must be able to appreciate life, and life is art, drama, music, and most importantly, people." This same quotation was later commemorated on a plaque in the Onterie Center (446 E. Ontario, Chicago). Khan himself was an ardent fan of classical music, especially Bach and Brahms. He loved singing Tagore's poetic songs in Bengali with family and friends.

PROFESSIONAL ACCOLADES

List of Notable Buildings

Structures designed by Dr Khan include:

· DeWitt-Chestnut Apartments, Chicago, 1963

· Brunswick Building, Chicago, 1965

· John Hancock Center, Chicago, 1965–1969

· One Shell Square, New Orleans, Louisiana, 1972

· 140 William Street (formerly BHP House), Melbourne, 1972

· Sears Tower, renamed Willis Tower, Chicago, 1970–1973

· First Wisconsin Center, renamed U.S. Bank Center, Milwaukee, 1973

· Hajj Terminal, King Abdulaziz International Airport, Jeddah, 1974–1980

· King Abdulaziz University, Jeddah, 1977–1978

· Hubert H. Humphrey Metrodome, Minneapolis, Minnesota, 1982

· One Magnificent Mile, Chicago, completed 1983

· Onterie Center, Chicago, completed 1986

· United States Air Force Academy, Colorado Springs, Colorado

Awards and chair

Among Khan's other awards and medals include:

· Chicago Junior Chamber of Commerce named him Chicagoan of the Year in Architecture and Engineering in 1970

· The Wason Medal (1971) and Alfred Lindau Award (1973) from the American Concrete Institute (ACI);

· The Thomas Middlebrooks Award (1972) and the Ernest Howard Award (1977) from ASCE;

· The Kimbrough Medal (1973) from the American Institute of Steel Construction;

· The Oscar Faber medal (1973) from the Institution of Structural Engineers, London;

· The International Award of Merit in Structural Engineering (1982) from the International Association for Bridge and Structural Engineering IABSE;

· The Distinguished Service Award from the AIA Chicago Chapter (1982)

· The AIA Institute Honor for Distinguished Achievement (1983) from the American Institute of Architects, Chicago Chapter,

· The Aga Khan Award for Architecture(1983), "for the Structure of the Hajj Terminal, An Outstanding Contribution to Architecture for Muslims,"

· The John Parmer Award (1987) from Structural Engineers Association of Illinois and Illinois Engineering Hall of Fame from Illinois Engineering Council.

· The intersection of Franklin and Jackson Streets, located at the foot of the Sears Tower was named after him as "Fazlur R. Kahn Way", in 1998

· Listed by *Engineering News Re*cord in 1999 as one of the World's top 20 structural Engineers of the last 125 years.

Dr. Khan was cited five times by Engineering News-Record as among those who served the best interests of the construction industry and in 1972 he was honoured with ENR's Man of the Year award. In 1973 he was elected to the National Academy of Engineering. He received Honorary Doctorates from Northwestern University, Lehigh University, and the Swiss Federal Institute of Technology Zürich (ETH Zurich).

The Council on Tall Buildings and Urban Habitat named one of their CTBUH Skyscraper Awards the *Fazlur Khan Lifetime Achievement Medal* after him and other awards have been established in his honour, along with a chair at Lehigh University. Promoting educational activities and research, the Fazlur Rahman Khan Endowed Chair of Structural Engineering and Architecture honours Khan's legacy of engineering advancement and architectural sensibility. Prof. Dan Frangopol is the first holder of the chair.

Khan was mentioned by President Obama in 2009 in his speech in Cairo, Egypt when he cited the achievements of America's Muslim citizens.

Khan was the subject of the Google Doodle on April 3, 2017, marking what would have been his 88th birthday.

LEADERSHIP

Active in several engineering groups, Khan was a leader in many of them. He was the Chairman of the Council on Tall Buildings and Urban Habitat from 1979 until his untimely death. He was also an adjunct professor at Illinois Institute of Technology (IIT), often teaching and working there late at night. For many years, he served on the board of trustees for the condominium development in Chicago where he lived.

DEATH

While on a trip in Jeddah, Saudi Arabia, Khan died of a heart attack on 27 March 1982, at a young age of 52. He was a general partner in SOM, the only engineer holding that high position at that time. His body was returned to the United States and buried in Chicago.

Khan's personal papers, most of which were in his office at the time of his death, are held by the Ryerson & Burnham Libraries at the Art Institute of Chicago. The Fazlur Khan Collection includes manuscripts, sketches, audio cassette tapes, slides and other materials regarding his work.

FAMILY

Kahn and his wife, Liselotte, who emigrated from Austria, had one daughter, born in 1960. A structural engineer like her father, Yasmin Sabina Kahn, wrote an in-depth book celebrating her father and his work: *Engineering Architecture: The Vision of Fazlur R. Khan*, Published in 2004.

References:

1. Baker, W.F., "Building Systems and Concepts-Structural Innovation", *Tall Buildings and Urban Habitat: Cities in the Third Millennium*, Spon Press, New York, 2001, pp. 481–493.

2. Khan, Y. S., *Engineering Architecture: The Vision of Fazlur R. Khan*. New York, W. W. Norton & Company, 2004, 416 pp.

3. Khan, Y.S., "Dr Fazlur R. Khan (1929–1982)", *Structural Engineering International* 3/2004, pp.245-247.

4. Kielar, R. M., *Construction's Man of the Year: Fazlur R. Khan*, Engineering News Record, Vol. 188, 10th Feb.1972, pp. 21-23.

5. https://en.wikipedia.org/wiki/Fazlur_Rahman_Khan

6. Weinegardt, R.G., "Fazlur Rahman Khan, The Einstein of Structural Engineering", *STRUCTURE Magazine*, ASCE, Feb. 2011, pp. 44-46

Authors

Dr. N. Subramanian
Civil / Structural Consultant (USA)
Author of many technical books
Email : drnsmani@yahoo.com

Er. Vivek G. Abhyankar
DGM (Design), L&T TIIC
Email : abhy_vivek@hotmail.com

◆◆◆◆◆◆

IS 16700:2017 Criteria for Structural Safety of Tall Concrete Buildings

Alpa Sheth

1. Introduction

As India experiences rapid development, cities will continue to see huge spurt in the demand for affordable housing and commercial real estate, not just in the metro cities but also in tier 2,3 and 4 cities. In response to this need, the urban development ministries of the states have increased the allowable built up area on land by means of augmenting Floor Area Ratio (FAR or FSI). Most cities now typically have new buildings of 15 storeys and higher (50m+) to consume the available FAR. The structural engineering community across the country was not geared to the sudden increase in building heights and there were gaps in the conceptualisation and design process of tall buildings. Unlike low-rise buildings, design of taller buildings are driven not by gravity loads alone; lateral loads such as wind and earthquake play a defining role in conceptualising the design.

A standardized design protocol to ensure acceptable performance of tall structures in terms of safety and serviceability was needed. Such a Standard Code of Practice did not exist in India for design of tall buildings. Hence a new Standard for Criteria for Structural Safety of Tall Concrete Buildings was developed.

This standard provides prescriptive requirements for design of reinforced concrete tall buildings. The following salient aspects, which are based on the prescriptive approach, are addressed in this standard:

a) Structural systems that can be adopted in tall building;

b) General requirements including;1) height limitations of different structural systems, 2) elevation and plan aspect ratios, 3) lateral drift, 4) storey stiffness and strength, 5) density of buildings,6) modes of vibration, 7) floor systems, 8) materials, and 9) progressive collapse mechanism;

c) Wind and seismic effects:1) load combinations, and 2) acceptable serviceability criteria for lateral accelerations;

d) Methods of structural analysis to be adopted, and section properties (in cracked and uncracked states) of reinforced concrete member to be considered in analysis;

e) Structural design aspects for various applicable structural systems;

f) Issues to be considered in design of foundations; and

g) Systems needed for structural health monitoring.

As another first in the country, this code acknowledges that there will be buildings not will not conform to the requirements of the code and there should be a special review process for such "code-exceeding" buildings. For such buildings, the code has recommended detailed guidelines that may be adopted by local authorities which includes formation of a Review Committee and qualifications of constituent members for such a review committee.

2. Description

2.1 Rationale behind Prescriptive Nature of Code

As can be seen in Figure 1, almost 67% of the slum population in urban India lives in Tier 2 to Tier 4 cities. Under the revised Pradhan Mantri Awas Yojana (Urban) PMAY schemes, a significant section of slum-dwellers are envisaged to be

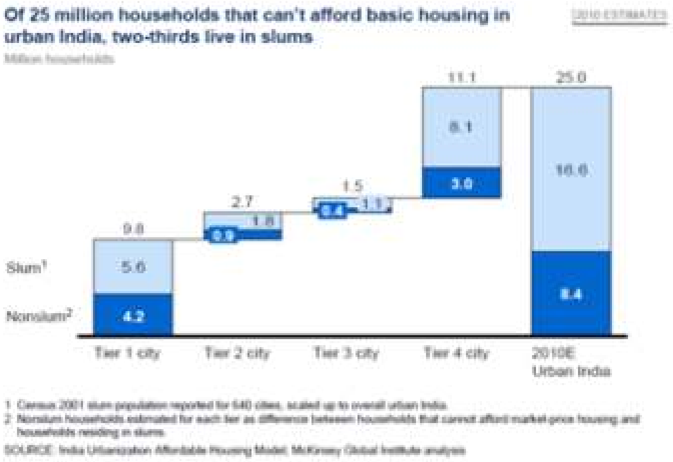


Figure 1. Urban Population in India

rehoused in formal housing. Much of this affordable housing will be of over 50 m height due to constraints of land. The available technical resources for design and construction of high-rises in secondary tier areas is perceived to be limited. The reasons are two-fold. There is limited competent technical manpower available in the country. Secondly, the structural engineering community in India is poorly remunerated and as a result, suffers from a paucity of resources available at the disposal of the structural engineer to adequately invest in a rigorous design process required for performance based design approach. Hence, a prescriptive approach to design of tall buildings was considered more suitable to cater to the needs of the country.

Many iconic or other buildings, however, may not desire to follow the restrictive constraints imposed by the prescriptive approach. Such projects also offer greater resources to the designer to invest in a more rigorous analysis and design approach. For such buildings, the new code has suggested a detailed approval process in the Annexure A which is based on *Performance-Based Design*. Thus the code addresses the two extremes of the spectrum, Prescriptive Design, Performance-based Design, and everything in between.

Another reason for a prescriptive approach is that almost all structural design codes in India are prescriptive. Both the main earthquake code (IS 1893:2017) and the wind Code (IS 875:Part 3: 2015) are also prescriptive. While there is discussion that future revisions of the earthquake code may lean towards displaced-based

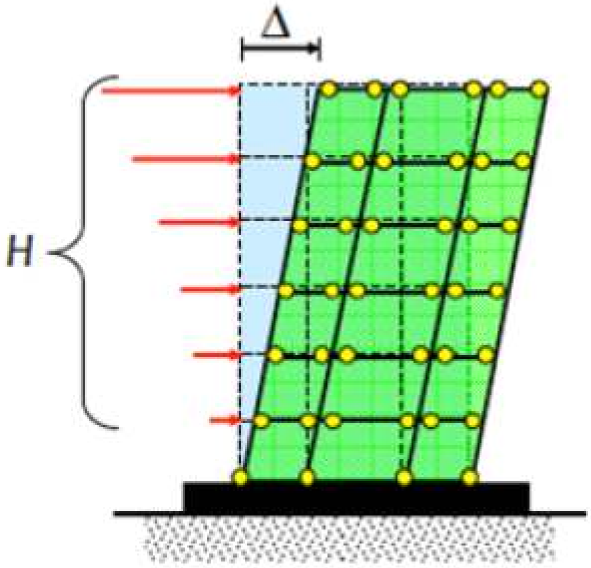


Figure 2. Displacement based Design Approach-Way of Future?

Desirable Collapse Mechanism, and quantifiable Deformation Capacity

design approach, this may take a while to be effected. It was felt prudent, under the circumstances, that the new Concrete Tall Buildings Code (IS 16700) follows, rather than leads, the march towards performance based design for all structures, so that the various design codes in India are more or less in conformance in their philosophy and approach.

2.2 Height Elevation And Plan Aspect Ratios Limitations Of Different Structural Systems

The code restricts the max height of a building for structural systems based on the seismic zone of the site. These restrictions have been historically imposed by other international codes such as ASCE 7 and Chinese Code JGJ-3 Concrete Structures of Tall Buildings and find mention in numerous research journals.

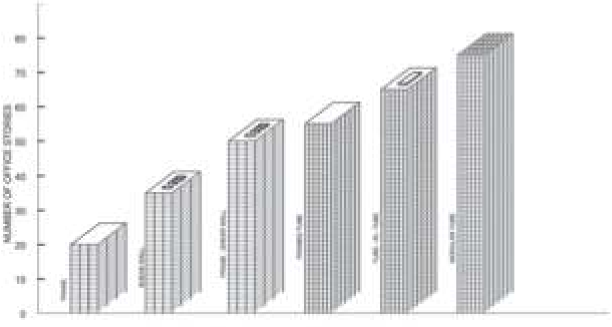


Figure 3[1]. Practical Limits of Lateral Systems

It has been generally found that an aspect ratio H/b (height versus least plan dimension) exceeding 10 results in very slender buildings that may require some damping device to reduce heightened perception of motion (akin to sea or car-sickness). IS 16700 has thus restricted aspect ratio to 10. It may be pertinent to mention that there has been in recent times, a trend, however limited, of super-tall buildings with very high aspect ratio, also called "Pencil Towers". This trend is prevalent in New York and in recent times in cities such as Boston and Melbourne. None of the above mentioned cities have a severe or very severe seismic hazard. Los Angeles (LA) and San Francisco (SF) which have very severe seismic hazard do not have such pencil towers. Buildings in LA and SF that do not follow the prescriptive codes of ASCE 7, ACI 318 and other codes mandated by the local authority are required to follow special, non-prescriptive procedures as mandated by Los Angeles Tall Buildings Structural Design Council (LATBSDC) "An Alternative Procedure For Seismic Analysis And Design Of Tall Buildings Located In The Los Angeles Region" and by SEAONC, 2007, "Recommended Administrative Bulletin on the Seismic Design & Review of Tall Buildings Using Non-Prescriptive Procedures" respectively. The requirements are complex and need a detailed performance based design using non-linear analysis. As noted by F Naeim in his paper "The performance-based alternative procedure requires an in-depth understanding of ground shaking hazards, structural materials behavior, and nonlinear dynamic structural response. In particular, the implementation of this procedure requires proficiency in structural and earthquake engineering including knowledge of: seismic hazard analysis and the selection and scaling of ground motions; nonlinear dynamic behavior of structural and foundation systems; mathematical modeling capable of reliable prediction of nonlinear behavior; capacity design principles; and detailing of elements to resist cyclic inelastic demands, and assessment of element strength, deformation and deterioration under cyclic inelastic loading."

2.3 Building Modes Under Seismic Loads

The IS 16700 code does not allow for torsion irregularity. It stipulates that the first two modes of vibration should be translational modes and the torsion mode cannot be earlier than the third mode of vibration with a mode spacing of at least 10% between consecutive modes. This requirement is in line with the revised IS 1893 code definition of torsional and vertical irregularities. This requirement creates a challenge for buildings symmetrical across both principal axes where the two lateral modes of vibration may be less than 10% apart (even though torsional mode is third mode of vibration) and some variation in stiffness in the two directions would be required to be introduced to avoid this lateral storey (Vertical) irregularity.

2.4 Use of Precast and Historical Experience of its Seismic Performance in the Country

The prescriptive approach of IS 16700 does not cover use of precast elements in tall buildings. It furthers does not allow use precast floor systems without a concrete topping of 75 mm in seismic zones III to V. The performance of precast structures in the 2001 Bhuj earthquake was very poor. A project of building new precast schools, executed from April 1999 to November 2000 and just before the Jan 26 2001 earthquake, proved to be disastrous. About three-fourths of these newly built precast schools either collapsed or were seriously damaged.

	Schoolrooms Damaged	
Type of Damage	Number	% of Total
Type A	48	15.0
Type B	90	28.2
Type C	140	43.9
Type D	30	9.4
No Damage	11	3.5

***Figure 4.* Statistics of damage to precast school buildings in the Kachchh region in 2001 Bhuj Earthquake (See Figure 5 for damage types).**

Figure 14-9. Type A damage — major damage to structure.

Figure 14-10. Type B damage — roof planks slipped.

Figure 14-11. Type C damage — minor dislocation of roof planks.

Figure 14-12. Type D damage — minor opening of grouted joints.

***Figure 5.* Damage Types A to D in 2001 Bhuj Earthquake.**

There has not been adequate documented research in detailing and testing of precast joints subsequent to their catastrophic behaviour in 2001 earthquake as a result of which there is still some scepticism in the academic and research community to allow for unchecked use of precast elements in buildings. Future research, development and rigorous testing in this field may pave the way for review of codal provisions on this subject.

2.4 Openings in Diaphragms

Floors and floor systems including roofs are the key players in distribution of lateral loads (seismic, wind) through their "diaphragm" behaviour, performing as deep beams with very high in-plane stiffness and strength in comparison. They are typically modelled as "rigid" diaphragms ie they have infinite in-plane stiffness. It is thus assumed that there is no in-plane deformation in the floor plate. For such an assumption to be valid, restrictions are required to be imposed on the floor openings as large cut-outs and cut-outs along periphery in the plan of the building do not allow for rigid in-plane behaviour and this results in uneven distribution of the inertia force mobilized at floor levels during earthquake shaking. This distribution and irregular behaviour cannot be captured by simplified "prescriptive" approach to design. Diaphragm opening restrictions are imposed in most international codes using prescriptive approach. Figure 6 displays the results of a study of effect of % openings in diaphragm to incorrectness of rigid diaphragm assumption (measured as ratio of maximum displacement of diaphragm to the average displacement of diaphragm) based on studies conducted by Murty et al .

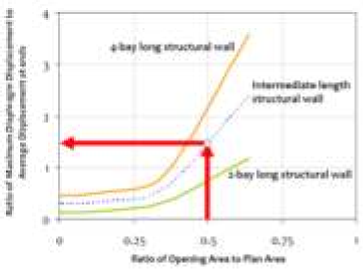


Figure 6[iv]: Effect of Cut-Outs in Diaphragms: Rigid diaphragm action diminishes with openings areas of more than about 25%

2.5 Limits on Concrete Grade

In view of the brittle behaviour of certain types of High Strength concrete, the code has imposed caution in use of concrete grades beyond M70, while not completely disallowing them. Annexure B gives some direction on use of high strength concrete.

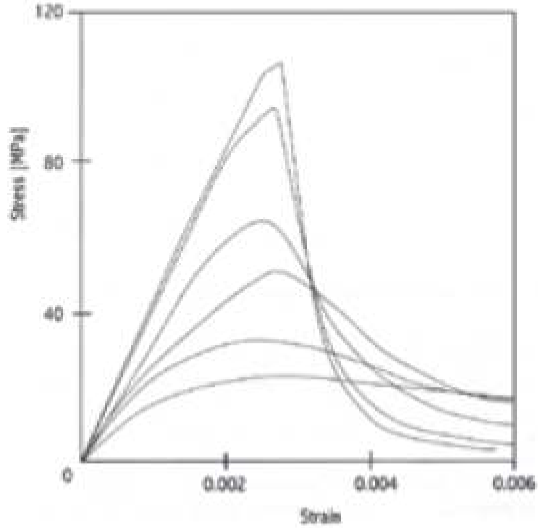


***Figure 7*: Stress-Strain Curves of Concrete with various strength grades (Dahl, 1992)**

2.6 Progressive Collapse Mechanism and Key Elements

The code makes a passing reference to the issue of progressive collapse mechanism and key elements, suggesting the need for redundancy through alternate load path. The intent is to draw the attention of the engineer to important issues of key elements and collapse mechanisms. However, as buildings with transfer systems etc are outside the prescriptive approach of this code, the subject


Needs flashing?
get the world's best flashing range
DEKS
• Superior Design
• High Performance
• Long Life
• Rapid Installation
• Cuts Time/Costs
• Low Profile
20 YEAR WARRANTY
AVAILABLE ONLY AT:
REALM
INTERMEDIATES (P) LTD.
SUITE NO. 19, PLOT NO. 3A
UDYOG NAGAR, GOREGAON (W)
MUMBAI - 400062, MAHARASHTRA, INDIA
TEL +91 22 2876 2876
FAX +91 22 2876 3244
EMAIL hp@realmrx.com
sales@realmrx.com
www.realmindia.com

Designed for connecting concrete reinforcement bars

Spplicetek's traditional method

Spplicetek's new age method

Spplicetek India Pvt. Ltd, is one of the largest manufacturers of the Mechanical Splicing Systems designed for the connection of concrete reinforcement bars.

Spplicetek's Parallel & Taper threaded splicing System ranges from 16mm to 56 mm in thickness. Spplicetek adopt international quality confirming to British & American standard BS 8110 (1997) & ACI 318 (2005). ACI 349, **IS16172 ASME Sec III, Div 2.**

The mechanical splice connection develops, in tension or compression, more than 125% of the specified yield strength of the concrete reinforcement bar.

Our prestigious clients include- TATA TISCON, NPCIL, MCGM, CIDCO, Metro, L & T, Shapoorji pallonji, Indiabulls, etc.

Cutting

Cold Forging

Turning

Threading

Spplicetek™
an honest joint
AN ISO 9001 : 2015 CERTIFIED COMPANY

Office: 202, The Great Eastern Chambers Premises CHS. Ltd., Plot No. 28, Sec.11, CBD Belapur, Navi Mumbai - 400 614
Website: www.spplicetek.com Tel No: +91 22 2756 2962 / 63 Email: admin@spplicetek.com

PRECISE™
CONCHEM PVT.LTD.
The Mark of Excellence

Precise Conchem Pvt. Ltd., a Mumbai-based ISO certified company offers quality solutions for challenges faced by the building construction industries; predominantly cracks, de-bonding of plasters and water leakages & seepages. The company manufactures high quality polymerized Drymix Mortars and Plasters, and markets the same under its flagship brands '**SILICOplast**' and '**SILICOfix**' respectively.

Beginning our projects with '**Imagica**', and there after with Mumbai Monorail, IIT Powai, Government Bodies, Residential & Infrastructural project and so on, our brands - **SILICOplast** and **SILICOfix** have stood the test of time in delivering quality and trust.

SILICO CRETE
RCC Repair Mortar
Strong, Durable, Efficient, Easy

SILICO PLAST
Polymerised Drymix Plaster
Quality Plaster For Quality Builders

SILICO FIX
Block Jointing Mortar
Thinner, Better, Stronger

Eco Friendly

MANUFACTURERS OF POLYMERISED DRYMIX MORTAR, PLASTER AND CONCRETE

Internal & External Plasters | Light Weight Block Jointing Mortars | Polymer Modified RCC Repair Mortars | Micro Concrete

Office: 202, The Great Eastern Chambers Premises CHS. Ltd., Plot No. 28, Sec.11, CBD Belapur, Navi Mumbai - 400 614

Factory: GIDC Panoli, Dist - Bharuch, Gujarat.

Tel No: +91 22 2756 2962 / 63 **Email:** admin@preciseconchem.in **Website:** www.preciseconchem.in

ISSE Website

www.isse.org.in

Search...

Indian Society of Structural Engineers

ISSE

Home | About Us | News & Events | Membership | Publications | Useful Refrences | Payment Options | Contact | Advertise With Us

Home

Main Menu

- Home
- About Us
  - History
  - Formation
  - Aims & Objectives
  - Important Issues
  - Bye Laws
  - Management
  - Our Centers
    - Mumbai Local
    - Pune Center
    - Solapur Center
- News & Events
  - Future Events
  - Latest Happenings
  - Past Events
    - Seminar
    - Workshop
    - Lecture
- Membership
  - Join ISSE
  - Membership Benefits
  - Search Member Directory
- Publications
  - Books
  - Quarterly Journals
  - Standard Certificate
  - Fee Structure
  - Journal Downloads
- Useful Refrences
  - Useful Websites
  - Reference Civil Engg
  - Educational Institutes
  - Professional Bodies
- Payment Options
- Contact
- Advertise With Us

Directory

- Consultants
- Civil Contractors
- Products and services
- Wanted and Available

Members Search

Search by name:

Search

Site Statistics

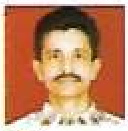
TOTAL VISITS: 151848

Publications

Our Quarterly Journal

Our quarterly journal " Structural Engineering" is published at the end each quarter in months of January, April, July, October. It generally consists of 24 pages plus 4 four colored pages. It contains technical articles from experts in the field. It is in house journal and meant for private circulation only, mainly to our members and the circulation size is about 1200+

Editorial Board of Journal



Editor
Hemant Vadalkar

Publications For Sale

Publications

Sr. No.	Name	Rs
1	Design of Reinforced Concrete Structures for Earthquake Resistance	800/-
2	Professional Services by Structural Design Consultant – Manual for Practice	200/-
Proceedings		
1	National Conference on Computer Controlled Structure in New Millennium	400/-
2	Workshop on ISO 9001 for Construction Industry	200/-
3	Brain Storming Session on Use of Specialty Products in Structures	250/-
4	Workshop on Software Tools for Structural Design of Buildings with CD	600/-
5	Workshop on Structural Audit	200/-
6	Workshop on Seismic Design of Building	200/-
7	Workshop on Effective Use of Structural Software	200/-
8	Workshop on Effective Use of Structural Software CD	100/-
9	Workshop on Shear Walls in Highrise Buildings	200/-
10	Seminar on Innovative Repair materials / Chemicals	200/-
11	Seminar on Foundations for Highrise Buildings	200/-
12	Seminar on structural Detailing in RCC Buildings	250/-
13	Workshop on Pile Foundations	200/-
14	Pre-engineered structures	200/-
15	Any ISSE Journal Copy	50/-

Note : Add Rs. 50 Extra for shipping charges in Mumbai and Rs 100 for out of Mumbai area

Quarterly Journals

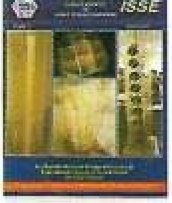
Our quarterly journal " Structural Engineering" is published in months of January, April, July, October. It consists of 24 pages plus 4 four colored pages. It is in house journal and meant for private circulation only, mainly to our members and the circulation size is about 500

Editorial Board of Journal

Editor N K Bhattacharyya
Jr. Editor Hemant Vadalkar

YEAR 2012

Month of Jan-Feb-Mar-12



Contents
1. Fraternity news
2. Report on ISSE 14th Foundation Day Celebration By H. S. Vadalkar
3. Wind Engineering For Design of Structures Fundamentals By K. Suresh Kumar
4. Structural Design of the ICICI Bank Regional Hub, Hyderabad By Girish Dravid
5. Pipe Line Rolling Across Pile Bents for the Tata Power Co. Ltd., Trombay By A. B. Karnik
6. Earthquake Resistant Design of Structure and Experimental Analysis of Scaled Model By Samir Dhuri

Month of Jan-Feb-Mar-12

Contents
1. Fraternity News
2. Effect of grade of steel on load capacity of Composite slabs By Pragnya Shah, Brijesh Pandya & Hansmita Pathak
3. Design and Construction of Wirewound Circular Precast, Prestressed Concrete Tanks By Sanjay Mehta

Login Form

Username

Password

Remember me

Login

Forgot login? Register

Current News & Events

... Approach of Safe Design Practice to Limit Property Losses" on Wednesday, 11th May 2011

Read more

Outstanding Steel Buildings and Structures On Saturday 26th October 2013

Read more

One day workshop on "Wind and Earthquake Loads on Structures"

Advertisements

has not been delved in much detail and will fall within the purview of approval procedures for "code-exceeding buildings".

2.7 Wind Effects

The code has stipulated wind tunnel studies for buildings greater than 150 m in height and those with complexities of shape, topography or are very flexible (T_n>5s). The code requires the building to be designed for the wind tunnel results, subject to minimum of 70% of that derived from the wind code (IS 875: Part3). By this provision, the code is giving the option to the structural engineer to design the structure utilising more realistic wind load and its distribution obtained from boundary layer wind tunnel studies. The lower bound of 70% is to cater for changes in the interference effects due to new developments in the vicinity of the building. Lateral Accelerations have been capped at 0.15% and 0.25% for residential and mercantile buildings respectively. There is paucity of credible data on building movements in existing structures in India. It is hoped that by recommending building monitoring systems, new data on building movements and occupant reception and comfort will emerge, which will inform code writers on this issue in future code revision.

2.7 Earthquake Effects

IS 16700 has made no significant departure in evaluating earthquake loads or in earthquake resistant design. However, the code has relaxed(reduced) the minimum design base shear coefficient to be used for buildings for 200 m in height by 30%. This relaxation is in keeping with the historical seismic data available that has consistently demonstrated the wide spacing between the frequency range of very tall buildings and the frequency range of earthquake shaking.

2.8 Structural Analysis

Use of cracked section properties in earthquake resistant design was initiated by the revised earthquake code IS 1893- Part 1 2016 which stipulated cracked section properties to be used for cracked reinforced concrete structures. IS 16700 has taken this a step further by stipulating separate set of cracked section properties to be used for elastic design (wind loading) in addition to cracked section properties for earthquake resistant design in line with IS 1893.

2.8.1Backstay Effect

The code has a detailed section on backstay effects. The section acknowledges the typology of tall buildings in India and recognises that developers and clients are loathe to provide a seismic joint between the tower and the surrounding podium due to serviceability issues.

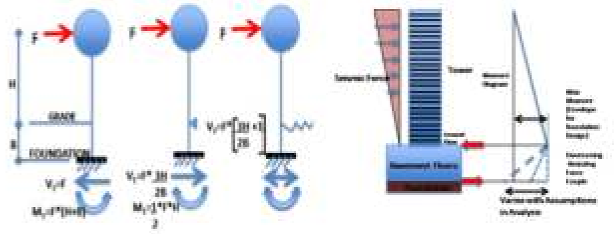


Figure 8a and 8b: Effect of Backstay

As mentioned in the code, "backstays" transfer lateral forces from the tower elements to elements of the podium or basement which are outside tower footprint. This transfer helps the tower in resisting overturning moments. As shown in figure 8a above, this transfer of lateral forces due to additional support from podium/ basement floors can cause a reversal of shear forces.

As part of collapse prevention evaluation, the code requires two sets of backstay sensitivity analyses to be carried out using upper-bound and lower-bound cracked section properties of floor diaphragms. The stiffness parameters for those diaphragms and perimeter walls of podium and below the level of the backstay are given in Figure 9. These analyses are in addition to those required to be carried out using other cracked section properties.

Stiffness Parameters

Sl No.	Stiffness Parameter	Values to be Adopted	
		Upper-Bound	Lower-Bound
(1)	(2)	(3)	(4)
i)	I_{eff} / I_g	0.5	0.15
ii)	A_{cr} / A_g	0.5	0.15

Figure 9- Stiffness Parameters

In estimating backstay effects, the code stipulates that two lateral load paths shall be considered, namely:

1) *Direct load path*, where overturning resistance is provided by the tower elements and foundation directly beneath the tower; and

2) *Backstay load path*, where overturning resistance provided by in-plane forces in the backstay elements (lower floor diaphragm and perimeter walls).

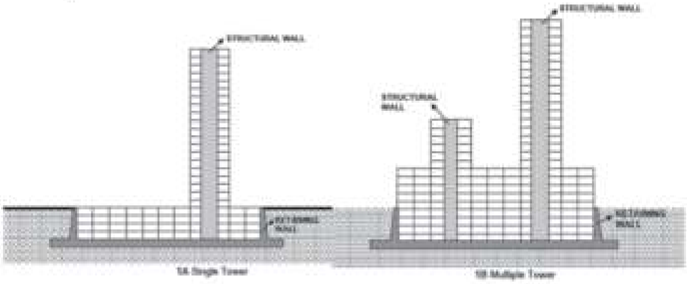


Figure10a and 10b: Tall Buildings with podiums and Basements

They code identifies the different cases when backstay effect will occur and requires the backstay floor diaphragms to be modelled considering their actual inplane and put of plane stiffness. shall be designed for the maximum of forces derived from sensitivity analysis.

For plan irregularity as per Table 5 of IS 1893 (Part 1) of Type i, Type ii and Type iv as well as Type iv of Table 6 (vertical irregularities) seismic forces shall be amplified by a factor of 1.5 in the design of connections of diaphragms to vertical elements and to collectors; and for design of collectors and their connections.

For irregularity of Type iii (diaphragm discontinuity) seismic forces to be amplified by an over-strength factor of 2.5.

Backstay diaphragms have to be designed for maximum forces obtained from sensitivity analysis and must be minimum 150 thick with two layers of steel in each direction and 0.25% reinforcement in each direction.

There are many more detailed requirements provided in the code for design of backstay elements.

2.8.2 Structural Walls

The code has revised minimum thickness of structural walls as 160 mm (200 mm in seismic zones IV and V) to align with fire code requirements (min 2 hours rating). It has further identified cut-out sizes in walls that may be ignored in analysis and design beyond which they will need to be modelled. Minimum reinforcement of 0.4 % in each direction (in two layers) is to be provided .

2.9 Foundations

IS 16700 has made significant changes in design of Foundations for Tall Buildings. It has specified factor of safety of 1.5 for unfactored wind and gravity loads and 2.5 for design earthquake and unfactored gravity loads. Modelling raft foundations will require use of zoned spring constants or zoned modulus of sub-grade reaction for dead load + live load condition. For buildings taller than 150 m, a soil-structure interaction study to conducted

Further the allowable deformation of mats has been relaxed to 125 mm (50 mm in rock) subject to angular distortion being within 1/500. These limits are in keeping with international practice. The depth of foundation is required to be min 1/15 in raft and 1/20 for piled foundations to account for uplift issues. The requirement may be relaxed when there is not net uplift anywhere in the foundation.

The soil investigation requirements are stringent. Minimum 3 boreholes are required in each tower with depth of minimum 1.5 times width of foundation and 30 m in rock. While borehole investigation in rock of 30m may seem excessive, there are regions in India where rock is underlain by soft layers and this 30 m is meant to capture such situation.

2.10 Non-Structural Elements

IS 16700 has detailed design guidelines for securing of non-structural elements. The underpinning rational and design background is available in another document.The discussion of non-structural elements has its genesis in the fact that there is more economic damage in earthquakes and wind conditions from damage to non-structural rather than structural elements.

It is pertinent to be discuss the issue of liability herein. As structural engineers in India typically sign detailed contract for structural design of buildings, and are not remunerated for non-structural element design and performance, the introduction of this topic in a structural code which will be binding to designers will require renegotiation of contracts or special waiver clauses in contracts.

2.11 Monitoring Systems

As mentioned earlier, there is paucity of credible data on building movements in existing structures in India. It is hoped that by recommending building monitoring systems, new data on building movements and occupant reception and comfort will emerge, which will inform code writers on this issue in future code revision. To this effect the code has recommended monitoring of instrumenting top of towers over 150 m height with tri-axial accelerometers for capturing earthquake shaking and anemometers and accelerometers for wind movement. Further, it has recommended monitoring of foundation settlements by means of settlement markers, pressure pads and strain gauges as relevant.

2.12 Annexures

As mentioned herein earlier, Annexure A provides detailed guidelines for setting up an approval process for "code-exceeding" buildings. The onus of forming the necessary review panel (ERP) rests on the local municipal bodies and the Bureau of Indian Standards, the code-making body in India which has published IS 16700 has little role to play in the implementation mechanism of the standards it creates. The setting up of these review panels is a formidable task and there will be many municipal bodies which may not have local resource persons qualified to be members of the panel. It would be recommended that such towns and cities use the services of larger neighbouring cities with such ERPs for buildings which are "code-exceeding" or delay the approval process for code-exceeding buildings until such committees are out in place.

3.0 Concluding Remarks

For the first time in India, a special code for Design of Concrete Tall Buildings has been developed and was released in December 2017. This national code is unique in that other than China, no other country in the world has a separate and dedicated code for Design of Tall Buildings in concrete.

The code prescribes the minimum structural requirements of buildings so as to have a predictable structural behaviour and which allow the building to be designed by simpler, linear elastic (static and dynamic) procedures, eliminating the need for more complex dynamic non-linear analysis. When building configurations, structural systems and other parameters do not satisfy the code, the behaviour of such structures is not easily predictable and in such a case a more rigorous, non-linear analysis procedures would be required. The code has also provided guidelines for the approval process for such buildings.

References

1. John Zils and John Viise: "An Introduction to High-Rise Design", S T R U C T U R E m a g a z i n e • November 2 0 0 3 http://www.structuremag.org/wp-content/uploads/2014/10/highrise.pdf
2. F. Naeim et al: "An Alternative Procedure for Seismic Analysis and Design of Tall Buildings", 15WCEE 2012.
3. Jain S K et al: "Bhuj, India, Earthquake of January 26, 2001, Chapter 14, Hospitals and Schools", Earthquake Spectra 18:Sup A (Jul 2002) http://www.iitk.ac.in/nicee/skj/Research_Papers/2002_spectra_Bhuj_Hospitals & Schools.pdf
4. Murty CVR et al: "Some Concepts in Earthquake Behaviour of Buildings", Gujarat State Disaster Management Authority 2013 http://www.iitk.ac.in/nicee/IITK-GSDMA/EBB_001_30May2013.pdf
5. Murty CVR et al: "Introduction to Earthquake Protection of Non-Strucural Elements" , Gujarat State Disaster Management Authority 2013 http://www.iitk.ac.in/nicee/IITK-GSDMA/NSE_002_31May2013.pdf

Authors

Alpa Sheth
M.D. VMS Consultants Pvt. Ltd., Mumbai.
Email : vmsb@vakilmehtasheth.com

◆◆◆◆◆◆

Problems in Using RCDC for Columns Under Biaxial Bending

by Vasant Kelkar, Ashish Bhangle & Prabhat Pandey

Preamble : Structural engineers are using STAADpro or ETAB for analysis of structures. RCDC is very popular for preparing the RCC drawings and bar bending schedule. Many engineers are using the software without cross checking the results which will be dangerous if there is some bug in some of the versions of software. Some engineers complained about the incorrect results of RCDC for biaxial column design in some of the versions. One such example of column design has been illustrated by Dr. V S Kelkar showing the variation in results with different versions. Structural engineers should not blindly accept the results from any software without validating it .

.... **Editor**

A large number of multistoreyed buildings are being constructed in Mumbai and other cities in India. Columns and shear walls of such buildings are subjected to moments about their major axis mainly due to wind and earthquake loads. They are also subjected to moments about their minor axis due to lateral loads plus minimum eccentricity, slenderness etc. as per IS code. Hence, the columns/walls have to be designed for biaxial bending. For such design and detailing R.C.C. columns and shear walls RCDC software of M/s. S-Cube is very useful and hence is being used by several structural consultants.

When designing columns for compression plus biaxial bending, especially rectangular columns and shear walls having one cross sectional dimension small, it was noticed that reinforcement percentages obtained by RCDC V5 or V6.3a were far too less than those obtained by ETABS and other softwares. However, earlier Version 4 of RCDC did not give such low values of reinforcement percentages. To check this discrepancy and to decide procedure for a safe design of rectangular columns/walls the authors developed their own software for columns with biaxial bending and compared the results with those obtained by other softwares.

Discussions were also held with S-Cube on this subject wherein this discrepancy and the reasons for the same were pointed out to them. But they came out with a new Version 6.3 which gives two options viz: Version 6.3a which apparently still follows same procedure as V5 and Version 6.3b which apparently follows the same procedure as V4. Surprisingly for the same rectangular columns, steel percentages obtained by Version 6.3a are much less than those by Version 6.3b – although they are from two options given in the same software. It is the authors' opinion that results obtained from RCDC V5 and V6.3a especially for shear walls or rectangular columns are apparently incorrect and should be used with caution. This is explained in the following pages.

1) Column is subjected to axial load Pu and moments Mux and Muy about X and Y axis respectively. Refer Fig. 1

   Cl. 39.6 of IS 456 states:
   "The resistance of a member subjected to axial force and biaxial bending shall be obtained on the basis of assumptions given in 39.1 and 39.2 with neutral axis so chosen as to satisfy the equilibrium of load and moments **about two axes**".

Exact solution of this problem becomes very complex. Hence, code also gives a method wherein max. capacities of Mux with Pu and of Muy with Pu are calculated separately treating each case as of axial load with uniaxial bending moment and then satisfying the interaction formula given in Clause 39.6 of IS 456.

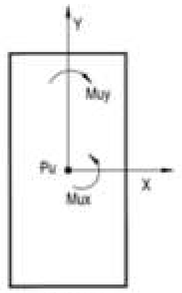


FIG. 1A

COLUMN SUBJECTED TO BIAXIAL BENDING

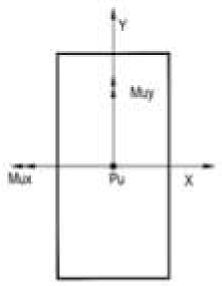


FIG. 1B

VECTOR REPRESENTATION OF Mux , Muy

2) In RCDC Version 4 apparently this interaction formula procedure of code is followed to design columns with biaxial bending.

RCDC Version 6.3 gives in 'Design Settings' under 'Design methods" two alternatives for design:

a) Resultant M (combined action)
b) Interaction Principle (Discrete action)

Version 6.3 b) apparently considers uniaxial moment capacities in each direction and then uses interaction formula of IS code – a procedure similar to V4.

Version 6.3 a) apparently considers resultant of both moments to obtain exact solution.

3) For exact solution of column with biaxial moments the following procedure satisfying equilibrium of axial forces and moments about the two axes, can be followed:

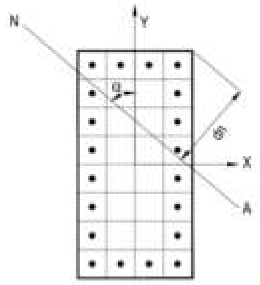


FIG. 2

DIVISION OF COLUMN SECTION INTO ELEMENTS (OR STRIPS)

a) The column section is divided into a no. of strips or elements each of area ΔAi. Refer Fig. 2

b) Under Pu, Mux, Muy, angle 'α' of inclination of N.A. and its depth 'dn' are unknown.

c) Steel percentage 'pt' is assumed and corresponding bar areas calculated – for bars on two or four faces.

d) Then for assumed 'pt', various values angle 'α', and N. A. depth 'dn', values of strains and hence internal stresses σ_i in each element and bar are determined in each case and corresponding capacity Pu, Mux, Muy calculated from the equilibrium equations:

$$Pu - \sum(\sigma_i)(\Delta Ai) = 0$$
$$Mux - \sum(\sigma_i)(\Delta Ai)(Yi) = 0$$
$$Muy - \sum(\sigma_i)(\Delta Ai)(Xi) = 0$$

This is repeated for various values of 'dn' and then of 'α' and then of 'pt'.

e) The lowest steel percentage 'pt' for which the above equations are satisfied gives the correct solution.
This procedure is used in our own software program 1 and also in ETABS.

4) Instead of the above procedure, RCDC Version 5 and version 6.3 a) apparently consider the resultant of the moments Mux and Muy. This resultant moment Muy_1 is about Y_1 axis where Y_1 makes an angle 'Θ' with Y axis. Refer Fig. 3. Moment Mux_1 about X_1 axis is obviously zero. The problem is then considered as of a column subjected to Pu and a uniaxial moment Muy1.

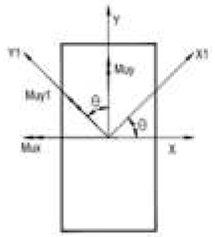


FIG. 3

RESULTANT MOMENT Muy1 AND CORRESPONDING AXES X1 , Y1 AT ANGLE θ

$$Muy1 = \sqrt{Mux^2 + Muy^2}$$
$$Mux = 0$$
$$TAN\,\theta = \frac{Muy}{Mux}$$
$$SIN\,\theta = \frac{Mux}{Muy^1}$$
$$COS\,\theta = \frac{Muy}{Muy^1}$$

For various assumed values of 'pt', various depths 'dn' of N. A. (Parallel to Y_1) are considered and for each case strains and internal stresses in concrete and reinforcement are calculated in each element or strip. Refer Fig. 4.

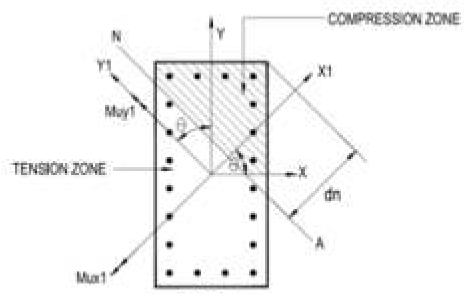


FIG. 4

ASSUMED N.A POSITION AND COMPRESSION / TENSION ZONES

Final location of NA is taken as the one, which satisfies the following equilibrium equations of internal and external forces for the lowest 'pt' value.

$Pu - \sum(\sigma i)(\Delta A_i) = 0$ ...1

$Muy_1 - \sum(\sigma i)(\Delta A_i)(X_{1i}) = 0$ ...2

The third equilibrium equation of moments about X1 axis viz:

$Mux_1 - \sum(\sigma i)(\Delta A_i)(Y_{1i}) = 0$ ...3

is not checked at all – although it should be also satisfied.

5) It is obvious that internal stresses in concrete and steel will also give non zero moment about X_1 axis = $\sum(\sigma_i)(\Delta A_i)(Y_{1i})$

Hence, the solution obtained is valid only if an external moment Mux_1 is also present along with Pu and Muy1, to satisfy equilibrium with moments of internal stresses about X_1 axis.

Thus, the solution obtained by satisfying only two equilibrium equations is actually for external loads Pu, Muy1 and Mux1.

Mux1 direction will be generally as shown in the figure. Then resolving Muy_1 and Mux_1 back to X and Y axis we get

$Muxa = Muy_1 \sin\Theta + Mux_1 \cos\Theta = Mux + Mux_1 \cos\Theta$
and $Muya = Muy_1 \cos\Theta - Mux_1 \sin\Theta = Muy - Mux_1 \sin\Theta$

The first two terms in the above equations are the original design moments Mux and Muy. But the solution obtained is for these moments plus components of Mux_1. It is seen from the above equations that these components increase original Mux but decrease original Muy.

Increase in Mux does not give much higher steel since it is about the major axis of column.

But decrease in moment Muy (which is about the minor axis) reduces steel significantly in rectangular columns and walls.

Thus, solution by RCDC version 5 or 6.3 a) for columns/walls is actually for a slightly higher Mux and much smaller value of Muy and not for given Mux and Muy. This results in substantial reduction of required steel.

6) We ourselves developed a software for columns with biaxial bending by using the exact method above satisfying all three equations of equilibrium (called Program 1) and checked the required reinforcement percentage. We also checked the reinforcement with our own earlier software which is based on interaction formula of IS456 (called Program 2). Given below are reinforcement required for walls of size 1800 x 250 mm, with M30 grade concrete obtained with various softwares.

In all the four examples considered, Pu and Mux were kept the same while Muy was varied. In calculations with ETABS and RCDC the additional moments due to minimum eccentricity and slenderness were not included for comparison with results of other softwares. Reinforcement was considered to be equally placed on two long faces of the column cross section.

Column	Pu KN	Mux KNM	Muy KNM	Required Reinforcement %								STAAD Pro With RDACE 3 option*
				Etabs		RCDC V4	RCDC V5	RCDC V6.3a	RCDC V6.3b	Our Own Program		
				UFL 0.95	UFL 1.0					Program 1	Program 2	
C1	3000	1500	0	0.8 (min)	0.8 (min)	0.34	0.34	0.34	0.34	0.29	0.275	0.65
C2	3000	1500	100	1.07	0.88	0.83	0.34	0.34	0.83	0.86	0.85	0.85
C3	3000	1500	200	2.14	1.89	1.84	0.34	0.34	1.64	1.81	1.7	1.8
C4	3000	1500	300	3.09	2.85	3.19	0.36	0.36	2.88	2.61	2.65	2.9

* STAAD Pro results – Courtesy Mr. Hemant Vadalkar

Notes: Methodology used in the above softwares

- **Our Program 1 and Etabs –** Uses inclined N.A. and satisfies 3 equilibrium equations as per first alternative of Cl. 39.6 of IS456
- **RCDC V4, V6.3b and our Program 2 –** Uses the 2nd approximate alternative of Cl.39.6 of IS456 calculating uniaxial capacities separately in two directions and using the interaction formula of code.
- **RCDC V5 and V6.3a –** Apparently considers uniaxial bending in the direction of resultant moment and satisfies only two equilibrium equations.
- The results of ETABS were also obtained considering Utilization Factor Limit (UFL) = 1.0 for comparison with results of other softwares. Otherwise ETABS considers this factor by default = 0.95 (i.e. it restricts ratio of required capacity to actual capacity to max. 0.95) which results in somewhat higher percentage of steel as seen in table above.
- ETABS gives min. steel as 0.8% irrespective of actual required steel. Hence, ETABS results for C1 show higher steel.

It is seen that reinforcement obtained in our Programs 1 & 2, RCDC V4, and RCDC V6.3b are similar while those obtained by RCDC V5 and RCDC V6.3a are substantially less. This difference is much higher when moment about weak axis Muy is higher for reasons mentioned in 5) above.

Results of ETABS with UFL = 1.0 also match very well with those of our programs 1 and 2, RCDC V4, V 6.3b. ETABS on its own restricts UFL to 0.95 which is not a requirement of IS code and hence shows somewhat higher steel in that case.

Even steel obtained from RCDC V6.3a is much less than that from RCDC V6.3b. How can two alternative options of solution given in Version 6.3 give such completely different results? The reason is obviously as discussed above that RCDC V6.3a (and also V5) apparently gives reinforcement for Pu + a slightly bigger value of Mux + much reduced value of Muy and not for Pu + Mux + Muy and this gives much less steel especially where one dimension of column cross section is small as in shear walls and rectangular columns.

Hence, in our opinion reinforcement obtained from RCDC V5, RCDC V6.3a, is substantially lower than actually required and if so provided can make the column/wall unsafe and hence should be used with caution

NOTE:

Recently version 7.0 of RCDC has been released which also has two options V7.0a and V7.0b similar to the two options V6.3a and V6.3b. They give similar results as those of V6.3a and V6.3b in the above table. So there will be no change in the results and conclusions discussed above even when V7.0 is used.

Author :

Dr. V. S. Kelkar
Director – Dr. Kelkar Designs Pvt. Ltd.
Email Id: vasant.kelkar@kelkardesigns.com

Mr. Ashish Bhangle
Director – Dr. Kelkar Designs Pvt. Ltd.
Email Id: ashish.bhangle@kelkardesigns.com

Mr. Prabhat Pandey
Sr. Associate – Dr. Kelkar Designs Pvt. Ltd.
Email Id: prabhat.pandey@kelkardesigns.com

News and Events during Jan – Mar 2018

22 Feb 2018 : CTBUH meeting on Tall Concrete building code IS16700:2017

Council on Tall Buildings and Urban Habitat (CTBUH) India had arranged a discussion on the clauses of

IS 16700 : 2016 – CRITERIA FOR STRUCTURAL SAFETY OF TALL CONCRETE BUILDINGS with the members of the Code Committee.

Following eminent structural engineers addressed the gathering on the new code provisions.

Alpa Sheth – Practicing Structural Engineer and Member of the Tall Building Code Committee.

Prof. R. S. Jangid – Prof. at IIT Bombay and Member of the Mumbai High Rise Committee

Dr. Suresh Kumar – Wind Engineer and Member of the Tall Building Code Committee

Anil Hira, Practicing Structural Engineer and Member of the Code Committee, Director of CTBUH India.

Ranjith Chandunni – Structural engineer and Member of the Code Committee.

The meeting was attended by structural engineers, architects, developers, academicians and sanctioning authorities from the home city with maximum high rises in the country.

The discussions were moderated by Girish Dravid, Consulting Engineer.

9 March 2018 ISSE and IEI Lecture on Tall Concrete building code IS16700:2017

Indian Society of Structural Engineers in association with the Institution of Engineers, Maharashtra State Centre arranged a lecture on Tall Concrete building code IS16700:2017 by code committee member and eminent Structural consultant Ms Alpa Sheth.

Alpa Sheth discussed the broad outline of the new code provisions which is applicable for buildings of 50m to 250m height across India. This is a prescriptive code providing guidelines to design engineers about the suitable structural systems to be adopted in different zones. Guidelines on various parameters like Height to base width ratio, length to width ratio, allowable drift limits, mode shape limits on torsional mode, cracked section properties for analysis, storey stiffness, floor systems, wind and seismic effects, acceptable serviceability criteria for lateral accelerations, issues related to foundation design and systems needed for structural health monitoring were touched upon.

This lecture created enthusiasm among structural engineers followed by discussions on the clauses during question answer session.

Shantilal Jain introduced the speaker and Hemant Vadalkar conducted the proceedings.

There was huge response and the hall was full to its capacity with more than 170 engineers attending the lecture.

12 Mar 2018 : SEFI eConference on Tall concrete building code

STRUCTURAL ENGINEERING FORUM OF INDIA [SEFI] conducted e-conference on IS16700:2017 between 12 to 19 March 2018. This is a very popular structural engineering online forum in India. www.sefindia.org All the sections of the code were discussed by the members by raising queries and questions. Fellow structural engineers and experts responded to the queries posted on the forum. All the sections of the code like definitions, General requirements, drift limitations, progressive collapse, load combinations, structural analysis with cracked section properties, modelling, construction sequence analysis, single tower and multiple towers with podium, back stay floor diaphragm, sensitivity analysis, structural wall system, depth of embedded of the building, soil modelling for raft, design of non-structural elements, monitoring deformations in buildings, guidelines for approval process for design of code exceeding concrete tall buildings were discussed. There was very good response to the discussions on the subject. The sessions were moderated by Ms Alpa Sheth and Ranjith Chandunni.

23, 24 March 2018 Workshop on Tall Concrete building code IS16700:2017 and Performance based design

Epicons Friends of Concrete In Association with 'Indian Institute of Technology, Roorkee' conducted Workshop No. 73 'Performance Based Design' & 'Provisions of Tall Building code IS 16700:2017' on 23rd & 24th March, 2018 at CIRCOT Auditorium, Matunga, Mumbai.

Ms. Alpa Sheth - Sr. Consulting Engineer & Convener of Code drafting Group presented outline of the new code on Tall concrete buildings. She emphasised that data collection and more research work needs to be carried out in our country so that code provisions can be made based on our data. Since not sufficient data is available, we have to depend on the other country codes. She explained that India is only 2nd country after china to introduce this new code on tall building.

Alpa Sheth mentioned the need for the explanatory code for better understanding of code provisions. This was responded and initiated by ISSE committee member Mr. Hemant Vadalkar by appealing to the audience present to become part of the team to write commentary. Each section of the code can be distributed to the design engineer, or the student who are doing the post-graduation to devote some time in preparation of the Explanatory code for the tall Building IS 16700-2017 and other codes IS1893:2016 and IS13920:2016. Some engineers had shown interest in this work.

Dr. Yogendra Singh , Professor& Head Department of Earthquake Engineering, IIT Roorkee given excellent coverage to 'Provisions of Tall Building code IS 16700:2017 by conducting interactive session covering the code provision clause by clause except for Non-structural elements. Delegates asked very interesting questions, most of them responded by Dr. Yogendra Singh. This interactive session had brought out some of the mis-prints which needs to addressed to the code drafting committee. Dr.Singh elaborated the procedure for Performance based design and how the parameters are worked out for carrying out push over analysis.

Dr. Jaydeep Wagh Geo Technical Consultant & Code Committee Member talked on the geotechnical section of the 'Provisions of Tall Building code IS 16700:2017' which was not so much elaborate but coverup the topic in that section. He emphasis on the interactive report to be prepared by involving structural designer to come to the some of the values in soil report basically the width of the foundation , type of the foundation so on. He also emphasis on the not to use single modulus of subgrade for the design of the raft since raft is acting like saucer. Thus provision of zonal soil springs for central portion, middle and edge part is necessary so that realistic behaviour of the raft can be captured. Also emphasis given in code for the rigorous analysis is required to be carried out for the design of the Tall structures.

Prof. M. G. Gadgil Sr. Structural Consultant discussed actual cases study of a building model which was done in ETAB & designed just before release of this code. He compared the design based on old and new code and clauses affecting his design as per the new provisions. Some changes in design and drawing are required to comply with new code.

Lastly Mr. Ranjith Chandunni Sr. Structural Consultant & Code Committee Member covered the section in the tall building code which deals with non-structural elements like walls, furniture, false ceiling, piping, equipment etc.

There was very good response and about 120 delegates attended the event. Many travelled from long distances. This two days workshop was very successful with lot of discussion on the subject.

BRIHANMUMBAI MAHANAGARPALIKA

No. Dir./E.S.&P./ 658 /TAC dt. 11/12/17

Sub:-To fill the space of cores taken for N.D. Tests

During site inspections of the various dilapidated buildings it was noticed by the TAC members and representatives of TAC, that the core samples were extracted from columns for conducting the core test to assess the insitu structural strength of the concrete columns. However after extracting core samples, the space from where core samples were extracted was left as it is, without grouting with equivalent / higher grade of concrete or any other substitute, which is highly dangerous. Such carelessness is not expected from the structural consultants.

Hence it is advisable for all the structural consultants who have undertaken the structural audit of the respective building to refill/grout the patch from where core sample is extracted with equivalent/higher grade of concrete or any other substitute, so as to maintain integrity and continuity of the structural material within the member/ element and necessary steps should be taken to ensure that load-carrying capacity of such structural members should not to be jeopardized and to avoid any accident due to non-compliance.

In view of above, Dy.Che (B.P)City is directed to inform all the structural consultants those who are registered with MCGM to take necessary measures as required after core test is conducted and core sample is taken out and report the compliance within 15 days.

Director(E.S.&P.)
Chairman
Technical Advisory Committee

Dy.Ch.Eng.(B.P)City

No. Dir./E.S.&P./ 658 /TAC dt. 11/12/17

Copy for information and to take necessary action , please.

Director(E.S.&P.)
Chairman
Technical Advisory Committee

Copy to:- C.E./ Che.Eng(D.P.) / Che.Eng(B.M)

Director (E.S&P.) Chairman Technical Advisory Committee from Municipal Corporation of Greater Mumbai had sent a circular to all Structural Engineers to immediately fill up the holes made for taking concrete cores in RCC structures during NDT. All should take a note and comply for a safety of the structures.

ISSE has sent representation to Municipal Corporation of Greater Mumbai to provide the facility to renew structural licenses and other licenses online and MCGM should not insist on the consultant to personally visit the MCGM office for license renewal. Mr. Shantilal Jain had taken initiative in this regards.

Dr. Kelkar Designs Pvt. Ltd., Mumbai had been awarded " Scroll of Honour " award as Prominent Indian Structural Consultant in UAE by CREDAI (The Confederation of Real Estate Developer's Association of India). This award was presented at a function held in Dubai on 7th December 2017. The aim was to recognize and acknowledge outstanding contributions made by organizations from India and UAE for facilitating and promoting real estate business between the two countries.

Congratulations Dr. V S Kelkar and your team for making India proud!

--------- ISSE TEAM

ISSE local centre at Kolhapur

New ISSE local centre has been inaugurated at Kolhapur, Maharashtra in March 2018. Chairman Mr. Prashant M. Haval, Secretary Mandar Ambekar and Treasurer Mr. Sunil Sutar will look after activities of ISSE in Kolhapur area. ISSE head office will help local centres to conduct technical workshops and seminars in the respective areas.

Congratulations Team Kolhapur !

ISSE Student Chapter at M. H. Saboo Siddik College of Engineering, Mumbai.

ISSE is supporting Engineering colleges to form ISSE Student Chapter in their respective institutes. This will initiate dialogue between industry and academia and help students to understand professional practices. ISSE Student chapter will be formed in M. H. Saboo Siddik College of Engineering along with M. H. Saboo Siddik Polytechnic ,Byculla with 36 students enrolling for the chapter. Faculty members Mrs. Grace Selvarani and Prof. Ashutosh Dabli were instrumental in formation of the chapter. Mr. Hemant Vadalkar from ISSE had taken the lead to from this first student chapter. ISSE will conduct one work shop per semester in the college for the students free of cost and provide set of ISSE publications to student chapter library. It is expected that every year minimum 30 students should be enrolled as ISSE Student members for smooth running of the chapter. ISSE will issue student membership certificates to all student members. All advisory trustee expected that other engineering colleges should be approached to form ISSE student chapter to increase interaction with the educational institutions and future generation of civil engineers.

Edited and published by Hemant Vadalkar for ISSE, C/o S. G. Dharmadhikari, 24, Pandit Niwas, 3rd floor S. K. Bole Road, Dadar(W.), Mumbai 400 028. Tel. +91-22-24314423. e-mail issemubai@gmail.com Web : www.isse.org.in for private circulation and printed by Sudarshan Arts, 10 Wadala Udyog Bhavan, Naigaon Cross Road, Wadala, Mumbai - 400 031.

STRONG LINKS **MAKE STRONG CHAIN**

Don't compromise durability of your structure by using cheap cover blocks.
Use only Internationally acclaimed and tested **ASTRA** Cover Blocks.

World's Best Concrete Cover Blocks™

Test Parameter	Results
Compressive Strength	Not less than 60MPa
Water Absorption	0.45%
Rapid Chloride Penetration Test	Very Low
Sulphate Content	0.23% by mass of cement
Chloride Content	0.12 kg/cubic meter
Water Penetration	0.67 mm
Chloride Migration Coefficient	$2.2 \times 10^{-12} m^2/s$
Alkali Silica Reactivity Test	Harmless
Salt Content	0.003%

ASTRA™
CONCRETE PRODUCTS

Makers of World's Best Concrete Spacers.

Web.: www.astraspacers.com | Email: info@astraspacers.com
Tel.: +91 98904 95751 | +91 96650 15775 | +91 90042 19630

www.thini.in

MEMBER

An ISO 9001:2008 Certified Company

SANRACHANA

SANRACHANA™
Structural Strengthening Pvt. Ltd.

Leaders in Structural Retrofitting

SANRACHANA™
Structural Strengthening Pvt. Ltd.

Specialty Retrofit Contracting Services
- Concrete repairs
- Structural strengthening
- Seismic retrofitting
- Historic restoration

UP GRADE

Improving Performance Of Hardened Concrete
- Specialty monomer & low viscosity grouts
- External wrapping of carbon fiber composite
- Near surface reinforcement & micro jacketing

SHIELD™

Engineering Solutions For Corrosion Damages
- Bipolar penetrating type corrosion inhibition system
- Cathodic protection system
- Execution of corrosion damaged repairs

DATA STRONG

Strengthening Data Centre & Ware Houses
- Post-tension carbon laminates
- Near surface reinforcement
- Steel fabrication
- Span shortening

E-mail:
sanrachana@yahoo.com

Tel:
+91-22-25400203,
+91-22-25440435

Web:
www.sanrachana.in