STRUCTURAL ENGINEERING

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INDIAN SOCIETY

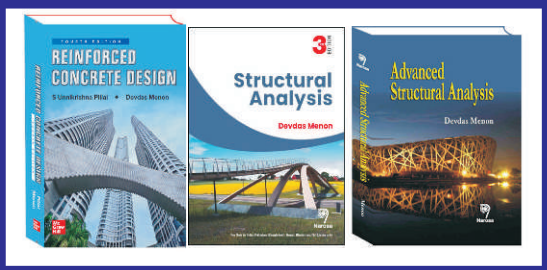
OF

STRUCTURAL ENGINEERS

ISSE

VOLUME 25 - 4

OCT - NOV - DEC 2023



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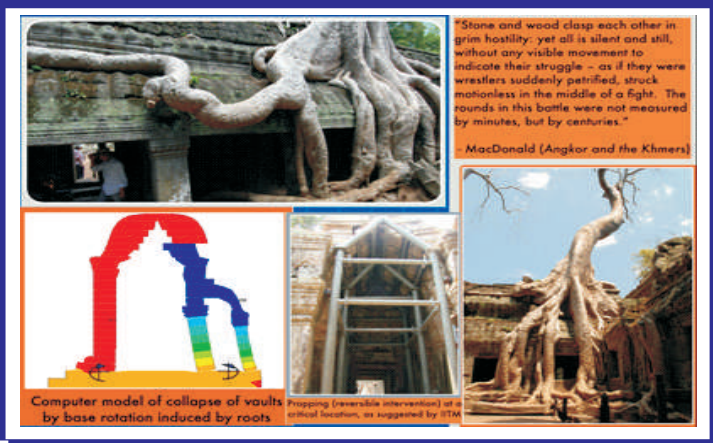

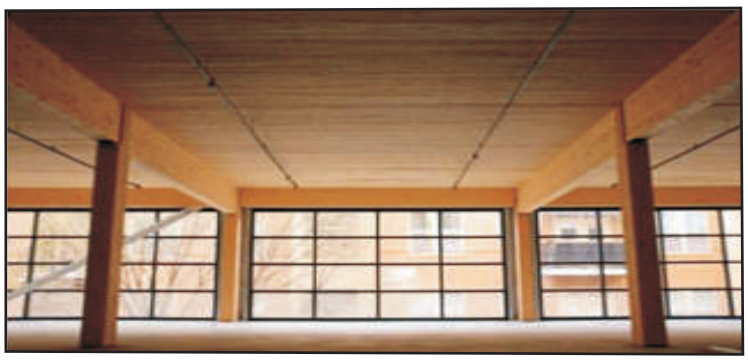

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Correspondence Address : C/O, Maansi Nandgaonkar, 101, Sunflower, Sakharam Keer Road, Shivaji Park, Mahim, Mumbai - 400016

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Editor : Hemant Vadalkar

AIMS & OBJECTIVE OF ISSE

1. To restore the desired status to the Structural Engineer in construction industry and to create awareness about the profession.
2. To define Boundaries of 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.

FIELD OF INTEREST

- 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

Fraternity News

WELCOME TO NEW MEMBERS

(OCT - NOV - DEC 2023)

2371	Hrishikesh Shreeram Mone
2372	Islahuz Jaman Ahmed
2373	P. Rahees
2374	Samim Ahmed
2375	Abhijit Ravindra Kulkarni
2376	Balbir Singh Sahani
2377	Sangeeta Anand Chachadi
2378	Rizwan Quadri Mohammed
2379	Atishay Bajaj Jain
2380	Rajendra Raghunath Borase
2381	Kiran Namdev Johare
2382	Manmath Baswaraj Swami
2383	Vikram Kumar Jangra
2384	Jeetendra Kumar Jha
2385	Nagesh Bhargav Nadiga N R
2386	Ashish Nandkumar Gaikwad
2387	Kushal Padmaraj Patravali
2388	Kalpesh Mhatre
2389	Hemanshu Arun Badgujar
2390	Anant Madhukar Waichal
2391	Krishanrao Marutirao Godbole
2392	Ketan Kiran Kulkarni
2393	Chanrajeet Singh Tumrate
2394	Mahesh Vishnu Chavan
2395	A. N. Lekshmi Priya
2396	Kunal Ravindra Ranjane
2397	Sibin Muhamed B. N.
2398	Satyanarayana Kodavali Veera Venkata
2399	Sameer Sanjay Kumawat
OM 38	AN-ICON ENTISD PVT LTD
JM 75	Yash Sunil Chiraniya

Patrons : 38
Members : 2399
Student Members : 444

Organisation Members : 38
Junior Members : 75

Sponsor : 8
IM : 07

TOTAL STRENGTH : 3,009

GEM 38 : Dr. DEVDAS MENON–INSPIRING ACADEMIC, CONSULTANT, AUTHOR, AND MENTOR

Dr. N. Subramanian, Ph.D., FNAE

Prof. Devdas Menon (1958-)

Dr. Devdas Menon is currently Professor and P. C. Varghese Institute Chair in the Department of Civil Engineering at IIT Madras. He is a very popular teacher, consultant and author who has written several technical books on structural engineering (Reinforced Concrete Design, Structural Analysis, and Advanced Structural Analysis). He has also published a large number of technical papers, and has received several awards. His video lectures, available in NPTEL and YouTube, are widely watched by audiences across the world. He has also guided numerous Ph.D., M.S. and M.Tech. theses.

As a structural consultant, he is known for his expertise in the design of reinforced and prestressed concrete buildings, bridges, stadia, chimneys, towers, liquid retaining structures, etc. He is also known for his innovative research and development in affordable and sustainable building systems for mass housing using glass fibre reinforced gypsum (GFRG) panels. He has also developed biomechanical orthopaedic devices and has two patents to his credit.

He has a special interest in developing codes of practice, and has served as the Chairman of the Bureau of Indian Standards CED 38 Committee on "Special Structures" from 2006 to 2022 – overseeing the standards for the design of RC chimneys (IS 4998), cooling towers (IS 11504), bins (IS 4995), composite structures (IS 11384), shells and folded plates (IS 2210), tall buildings (IS 16700), etc.

What makes Prof. Devdas Menon unique is the fact that he is equally well known for his talks, workshops and writings on finding meaning and fulfilment in life through self-awareness and inner transformation. He is of the view that our modern education is woefully incomplete in terms of its lack of emphasis on inner development, wisdom and compassion – which he sees as the main cause for the widespread inability to deal with increasing distraction and stress, corruption and self-centredness, and lack of enduring fulfilment in life. He points out that even in our best educational institutions (in India and elsewhere), it is practically impossible to conduct any examination without any invigilation, expecting the students to follow 'dharma' and avoid to cheating and copying – despite high institutional metrics and rankings.

Prof. Menon is also well known for his lectures and workshops for students, teachers and corporate organisations. He teaches two uniquely designed and hugely popular 'free elective' courses at IIT Madras, GN5001: Self Awareness and GN6001: Integral Karmayoga, which are open to all interested students and faculty. He has also authored four books on these topics.

EARLY LIFE AND SCHOOLING

Devdas Menon was born and brought up in Kolkata, where his father, Sri MMA Menon, was employed as a senior executive. He had his schooling at St. Xavier's, Kolkata, where he excelled as a student, having additional interests in creative writing and playing hockey. He recalls being attracted to mechanics, and had initially aspired to study mechanical engineering at an IIT. But after completing his Indian School Certificate examination in 1974 with distinction, he settled for a B.Tech. programme in civil engineering at IIT Madras.

Devdas Menon with his mother (Madhavi), sister (Girija) and father (MM Achutha Menon)

ENGINEERING EDUCATION & PROFESSIONAL LIFE

In an interview given to students, he recalls: "Although I did get an opportunity to switch to any branch after completing my first year at IIT Madras, I chose to stay back in civil engineering – the branch that fate had assigned to me when I joined in 1975. I discovered that mechanics could be pursued equally well in structural engineering – a career that opened up for me subsequently. I enjoyed dwelling on the mechanics underlying the analysis and design of various kinds of structures – ranging from small buildings and industrial sheds to tall buildings and towers and long span bridges."

Devdas Menon graduated with distinction in civil engineering from IIT Madras in 1980

He worked in the industry, in structural design consultancy, at New Delhi (1980-'85), and during this time, did a (part-time) post-graduation course in structural engineering at IIT Delhi. He subsequently shifted to Calicut to be with his parents, opting for an academic career, joining as a Lecturer at REC Calicut in 1985. During this time, he continued his education in structural engineering, receiving degrees of M.Sc. (by research) from the University of Calicut in 1989 and Ph.D. from IIT Madras in 1995.

He also ventured to do a post-graduate course in English Literature at the University of Mysore. His academic performance had been consistently top ranking. He later joined the department of civil engineering at IIT Madras as a faculty in 1998, and has been serving as Professor since 2004, engaged in teaching, research and consultancy.

FAMILY

Prof. Devdas Menon is married to Ms Roshni, who teaches History at the school 'Sishya' at Chennai. She has been his companion and support for more than three decades.

Roshni and Devdas Menon

EMPHASIS ON FUNDAMENTAL UNDERSTANDING

Prof. Menon recalls in an interview: "When I first started working (in 1980) as a structural designer, I particularly liked the motto of our company – to design structures that were most efficient, economical, and aesthetic in appearance. Later, when I joined academics, I enjoyed teaching, research and development, as well as consultancy related to various challenges in structural engineering. The challenge for me was to look for simple and elegant solutions based on intuition and simple manual calculations, rather than computationally intensive analysis. This is the approach I advocate for my students and research scholars. It is thoroughly enjoyable."

It is this practical outlook and constant interaction with structural engineering practice that inspired the selection of topics for research by his Ph.D., M.S. and M.Tech. scholars. These comprised wide-ranging topics, such as the analysis and design of PSC sleepers, box girder RC bridges, slender RC

beams, seismic resistance of RC stepped building frames and open ground storey RC framed buildings, wind-induced interference effects on buildings, glass fibre reinforced gypsum walls and composite slabs, probabilistic load modelling of highway bridges, RC bridge pier caps, creep and shrinkage effects on RC walls and PSC girders, etc.

Prof. Devdas Menon is of the view that inspiring and meaningful teaching of structural design is truly possible only if the teacher speaks from first-hand personal experience in design and construction, and not bookish knowledge. He belongs to the old school (and now a vanishing species!) of engineers who would carry out preliminary analysis and design of structures using simple hand calculations, rather than be entirely dependent on computers and software. One of the projects that he sometimes refers to in his design classes is the famous ship-shaped indoor stadium at Kochi, in which he was a key designer. The picture of this beautiful building appeared on the cover page of his first book titled Reinforced Concrete Design by S.U. Pillai and Devdas Menon, published by Tata McGraw-Hill in 1998.

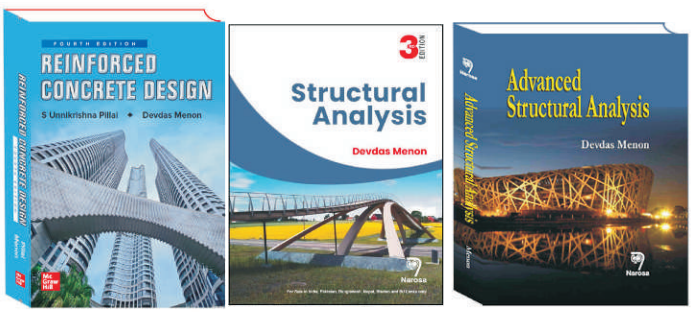
Structural design of a unique ship-shaped indoor GCDA stadium for the Regional Sports Centre, Kochi (1993)

TECHNICAL BOOKS AND PUBLICATIONS

The book on Reinforced Concrete Design has undergone several editions, and its fourth edition was released in 2022. It is widely used as an authoritative reference not only by teachers and students, but also by practising structural engineers. Here is a quote from the book, which reflects the style of writing and emphasis on clear understanding of concepts: The codes are not meant to serve as a substitute for basic understanding and engineering judgement. The student is, therefore, forewarned that he will make a poor designer if he succumbs to the unfortunate (and all-too-common) habit of blindly following the codes. On the contrary, in order to improve his understanding, he must learn to question the code provisions — as, indeed, he must, nearly everything in life!

This basic philosophy has been followed in two other popular textbooks authored by Prof. Devdas Menon: Structural Analysis (Narosa Publications, 3rd Edition) and Advanced Structural Analysis (Narosa Publications, 3rd Edition). In the Preface to his book on Structural Analysis, he has this important insight to offer: Structural Analysis is one of those subjects in engineering that has the potential of awakening a wonderful blend of reason and intuition in the learner. Teachers, who appreciate this, invariably enjoy the classroom experience, because every time, it has some new and refreshing insight to offer. It is a wonderful experience to observe the learning process unfold in ever-new and creative ways in students. He goes on to warn: There is an increasing tendency in modern structural engineers to lean heavily on software packages for everything, and this addiction induces a false sense of knowledge, security and power. The computer is indeed a powerful tool and asset for any structural engineer, for carrying out repetitive work and for generating quick solutions to complex problems. It is dangerous, however, to make the tool one's master, and to make it a convenient substitute for human knowledge, experience and creative thinking.

Prof. Menon has also served as one of the editors of the Handbook on Seismic Retrofit of Buildings (sponsored by CPWD, Indian Building Congress, and IIT Madras).



Popular textbooks authored by Prof. Devdas Menon

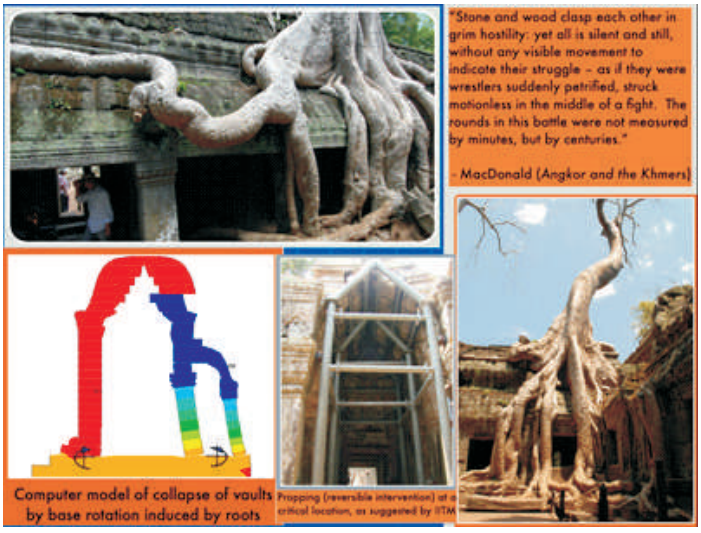
Some of the key technical papers authored or co-authored by Prof. Devdas Menon in the past ten years are listed below:

1. P Mary Williams, Devdas Menon and A Meher Prasad, Experimental study on long-term behaviour of PSC beams", Structures, Vol. 51, pp 560-572, May 2023.
2. Shinto Paul, Aishwarya Shaji, Devdas Menon and A Meher Prasad, Experimental study on glass fibre reinforced concrete floor slab systems", Structures, Vol. 49, pp 415-425, February 2023.
3. N. Harsha, M.N. Shariff and Devdas Menon, "Numerical simulation of nonlinear behaviour of reinforced concrete beam-slab systems", ACI Structural Journal, American Concrete Institute, 119-S142, pp 303-312, November 2022.
4. Gouri Krishna S. R., Devdas Menon and Meher Prasad, A., Lateral load behaviour of Glass Fibre Reinforced Gypsum walls supported on reinforced concrete frames", Structures, Vol. 44, pp 548-565, August 2022.
5. Anurag Singh, Bijily Balakrishnan and Devdas Menon, "Combined beam-slab collapse mechanism in isolated reinforced concrete beam-slabs – strength design and load testing", ACI Structural Journal, American Concrete Institute, 118-S66, pp 223-240, May 2021.
6. Adrija D., InduGeevar, Devdas Menon and Meher Prasad, "Strength assessment of RC deep beams and corbels", Structural Engineering and Mechanics, 77 (2), pp 273-791, 2021.
7. M.N. Shariff and Devdas Menon, "Experimental studies on creep and shrinkage behaviour of reinforced concrete walls", ACI Structural Journal, American Concrete Institute, 117-S66, pp 249-260, May 2020.
8. M Najeeb Shariff, U Saravanan and Devdas Menon, "Time-dependent strains in axially loaded reinforced concrete columns", Journal of Engineering Mechanics, ASCE, 146 (8), May 2020.
9. S Chitra Ganapathy, P Harikrishna and Devdas Menon, "Wind induced interference factor of multirow cooling towers – a glimpse", Engineering Structures, 200(1), pp 1-13, Dec. 2019.
10. Bijily Balakrishnan and Devdas Menon, "Yield line analysis and testing of rectangular slabs with primary and secondary beams", ACI Structural Journal, American Concrete Institute, Vol.116, pp 187-200, Sep. 2019.
11. M Najeeb Shariff, U Saravanan, Devdas Menon and K R Rajagopal, "Analysis of the ASTM C512 spring-loaded creep frame", Journal of Materials in Civil Engineering, ASCE, Vol. 31 (10), July 2019.
12. InduGeevar and Devdas Menon, "Strength of reinforced concrete pier caps – experimental validation of strut-and-tie method", ACI Structural Journal, American Concrete Institute, 116-S24, pp 261-273, Jan. 2019.
13. Bijily Balakrishnan and Devdas Menon, "Collapse load estimation of rectangular reinforced concrete beam-slab systems", ACI Structural Journal, American Concrete Institute, Vol.115, pp 1279-1294, Sep. 2018.
14. Jetson A Ronald, Arun Menon, A Meher Prasad, Devdas Menon and Guido Magenes, "Modelling and analysis of South Indian temple structures under earthquake loading", Sadhana, Springer, 43:24, May 2018.
15. InduGeevar, Bijily Balakrishnan, Habeeb F. and Devdas Menon, "Experimental and numerical assessment of deflections in circular reinforced concrete beams", Structural Concrete, CEB-FIP, Vol. 19 (Issue 6), pp 1633-1648, Feb. 2018.
16. Bijily, B, Shehbaz Hussain and Devdas Menon, "Assessment of shear strength of circular reinforced concrete beams", ACI Structural Journal, American Concrete Institute, 115-S98, pp 1209-1221, Nov./Dec. 2016.
17. Pradip Sarkar, A. Meher Prasad and Devdas Menon, "Seismic evaluation of RC stepped building frames using improved pushover analysis", Earthquakes and Structures, Techno Press, 10 (4), pp. 913-938, 2016.
18. Jiji Anna Varughese, Devdas Menon and A Meher Prasad, "Displacement-based seismic

design of open ground storey buildings", Structural Engineering and Mechanics, Vol. 54, No. 1, pp 19-33, January 2015.
19. Vurugonda Raju and and Devdas Menon, Longitudinal Analysis of Concrete U-Girder Bridge Decks, Bridge Engineering (Proceedings of the ICE), Vol.167, No.2, pp:99-110,June2014.
20. M Janardhana, R Davis, S S Ravichandran, A M Prasad and D Menon,Calibration of hysteretic model for glass fiber reinforced gypsum wall panels, Earthquake Engineering and Engineering Vibration, Vol. 13, No. 2, June 2014, pp: 347-355.

EXAMPLES OF INNOVATIVE RESEARCH AND CONSULTANCY WORK

Among the interesting and innovative consultancy projects handled by Dr Devdas Menon, as a key member of the team from IIT Madras, is the assistance offered to the Archaeological Society of India (ASI) to help restore the Ta Prohm temple at the Angkor Wat complex at Cambodia. during 2008-2014.The structure had been covered and damaged by large trees. But the trees were also a major tourist attraction, and the challenge was to analyse the challenging problem of tree-structure interaction and to find a solution to prop up both the structure and the trees so that tourists could walk through safely.



Understanding and resolving the tree-structure interaction issues at Ta Prohm, Cambodia

Yet another challenging assignment was to restore a lighthouse structure at Little Andaman, which was damaged by the tsunami in 2004. While other consultants had suggested that there was no alternative to building a new lighthouse, Prof. Devdas Menon observed that much of the 45m tall lighthouse was intact, except for the plastic hinge formation at the base, involving yielding of longitudinal steel on one side and crushing of concrete on the other side. Based on his recommendations, the lighthouse was repaired and retrofitted economically, by means of concrete jacketing near the base region, ensuring the verticality of the tower.

Restoring a tsunami-damaged lighthouse at Little Andaman

Prof. Devdas Menon, along with his colleague, Prof. Meher Prasad, have pioneered the design and development of sustainable and economical buildings using glass fibre reinforced gypsum (GFRG) panels, suitable for mass housing in India. They have jointly guided six Ph.D.s in this area, and their R&D efforts have led to the publication of two BIS standards on GFRG panel specifications (IS 17400) as well as design and construction methodology (IS 17401). The first two-storeyed demo GFRG building was constructed in the IIT Madras campus in 2014 and is presently used as quarters for faculty. Subsequently, many such structures have been built in India, notably the four-storeyed hostel buildings at IIT Tirupati.

GFRG demo building at IIT Madras

GFRG hostel buildings at IIT Tirupati

AWARDS AND RECOGNITIONS

Dr Devdas Menon has been conferred several awards, notably the "Distinguished Service to the Institute (2013)" by the IIT Madras Alumni Association, the "Srimathi Marti Annapurna Award for Excellence in Teaching (2014)" by IIT Madras, the "Ultra-Tech Award for the Outstanding Concrete Engineer (2014)" by the Indian Concrete Institute (Chennai Chapter), and the "Guru Shreshta" award (2015) by Rotary Club (Madras NorthWest), "Institute Chair Professor" (2019) and P C Varghese Institute Chair (2021) for distinguished service in education, research and technology development.

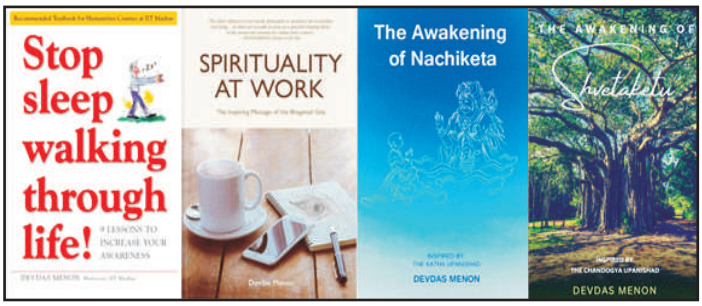
He is also the recipient of The Architectural Engineering Division Gold Medal (1988-89) and Sir Arthur Cotton Memorial Prize (1992-93) of the Institution of Engineers (India) for his innovative research work on low-cost housing using coconut shell composites. He also has two patents to his credit – Patent for Dynamic External Wrist Fixator (filed 1997, awarded 2014) and Patent for External Fixator Assembly for Tibial Fracture (filed 1997, awarded 2014).

Award winning R&D work on low-cost housing

Award winning R&D work on orthopaedic devices

SELF - IMPROVEMENT AND SPIRITUALITY

In the realm of self-improvement and spirituality, Prof. Devdas Menon has also authored books titled, Stop sleepwalking through life! (Published also in Hindi) (1998), The Awakening of Nachiketa (published also in Malayalam), Spirituality at work (on the Bhagavad Gita) (2016), and The Awakening Of Shvetaketu, which are used as texts for the two uniquely designed, popular elective courses at IIT Madras, GN5001: Self Awareness and GN6001: Integral Karmayoga, which are open to all interested students and faculty.



He has been leading a team at IIT Madras, conducting week-long workshops on 'Self Awareness and Higher Goals in Education (SAHGE) at IIT Madras for college teachers across the country since 2012. These workshops are hugely popular.

Prof. Menon taking a class on Self Awareness under the shade of a banyan tree at IIT Madras

Dr. Devdas Menon was initiated into Advaita Vedanta in his youth by Swami Krishnananda (of Rishikesh) and other teachers. Ever since, his approach to spirituality has been to see the 'formless aware presence', the one Divine, in all manifestation, despite the seeming differences in myriad names and forms and beliefs. He seeks to devote the next phase of his life (post-retirement) almost entirely in this direction, and several book projects are in the offing. He will continue to offer courses and workshops at IIT Madras.

In the Amazon web-page of the author, Devdas Menon, it is mentioned: This brief biography of the author is meant for pragmatic purposes: potential readers may be interested. But the deeper truth is that all notions of individual authorship and doer-ship are delusional, and it is important for the apparent doer to recognise this truth — whatever be the inner calling or the role being enacted (writer, teacher, engineer, etc.) in this game of life.

In the same vein, may this write-up on Prof. Devdas Menon serve the pragmatic purpose of inspiring structural engineers to explore and emulate in their own individual ways!

About The Author

Dr. N. Subramanian, Ph.D., FNAE is an award winning Author, Structural Engineering consultant and Mentor, currently based at Maryland, USA, with over 45 years of experience in Industry (including consultancy, research and teaching). He was awarded with a 'Life Time Achievement Award' by the Indian Concrete Institute and many other awards for his contributions towards Structural Engineering. He is the author of 25 books and over 300 papers, including the famous books on 'Design of Steel Structures', 'Design of RC Structures' and 'Principles of Space Structures' and the recent 'Building Materials, Testing and Sustainability'. (email - drnsmani@yahoo.com)

ENVIRONMENTAL SUSTAINABILITY, ENVIRONMENTAL AND ECONOMIC LIFE CYCLE - TIMBER AS SUSTAINABLE CONSTRUCTION MATERIAL.

By Prakash Suthar

The grand vision is to create (1) an environmental life cycle, (2) a sustainable building material and net-zero building life cycle, and (3) an economic life cycle in building construction.

(1) An environmental life cycle for regenerating nature:

Let me share some reality on carbon emissions. The transportation sector generates 19% of carbon emissions, the industry sector generates 33%, and the building civil construction sector generates 40 to 47%. Now which one is the important for us to address immediately for reducing the carbon from the atmosphere while you work to meet the challenges of climate change. I beg of you don't forget nature because today the destruction of nature accounts for more global emissions than all the cars and the trucks and aviation fuel in the world. We can put solar panels on every room, we can turn every car into an electric vehicle but as long as we do not care of the nature we will fail as long as we emit 40 to 47% carbon in construction sector. We are consuming 12% of energy production in iron and steel and cement and concrete generating mainly using fossil fuels. We are generating electricity using coal 64% and more contributes for generation of the electricity.

So, construction material currently under use are highly embodied carbon material.

The Question is:

"What are we going to do with such a huge Development; that we are creating with Greatest ever Climate Risk."

So long as we create "Climate Risk" using highly embodied carbon building construction material, and the reserved forests; Amazon, Sumatra and other great forest are slash and burn, so long as protected lands and tribal people indigenous people are allowed to be encroached upon so long as wetlands and the bouquets are destroyed our climate goals will remain out of reach and we'll be run out of time if we don't stop the destruction of our natural world; if we do not regenerate the forest Woodlands, sustainable farm Agroforestry nothing else will matter; why because protecting and restoring the forest mangroves wetlands, sustainably & professionally managed forest and agroforestry these huge dense carbon sinks represents at least 30% and more of what needed to be done to avoid catastrophic warning. These are currently the only feasible solution for absorbing carbon on a global scale. Simply put if we don't protect nature, we can't protect ourselves then what is the use of GIFT cities and smart cities and the Urban Developments, big infrastructure we are developing if we create a huge climate risk. What is the use of developments of farmlands when they're going to be scarce resources of the water. As a design professionals and engineers this is what we need to do; we need to include nature in our endeavor while we serve our clients for design and engineer the buildings.

Masstimber construction:

Large Wooden Building components are Sustainable Building Material. The timber is resourced from the sustainably managed forest, duly certified timber used in the manufacturing of sustainable building materials.

In a Masstimber construction mainly cross laminated timber (CLT), dowel laminated timber (DLT), glulam columns and beams used for the Masstimber structures. Masstimber components laminated timber are the most appropriate for structural design and most cost-effective use. Inexpensive but resilient softwoods, so highly cost-effective & within the budget uses softwoods for mass timber components.

There is enough sustainable timber grown in the forestry in the world. The overall growth of the sustainable resources takes just 7 Minutes to construct 20 story wooden building, 200,000 square feet of premises. Responsibly grown and harvested species such as spruce, pine, douglas fir, larch and others are used for large masstimber components. The basic cost of import of lamellas are most inexpensive. The cost of making sustainable building material: mass timber panels, and glulam beams as low as in India the labor cost is low and manageable. The factory-made panels and glulam, the most cost effective and ready-to-install for larger and wider spans.

The masstimber components provides design values for structural design and engineering. We will discuss in detail in next Technical Articles.

Masstimber laminated CLT, beams, columns, dowel laminated timber creating values, beauty of the building cost vs. values saves all the cost of interiors.

We are aware, the iron and steel and cement and concrete use 12 percent of electricity that we have produced from coal. “Energy saved is energy generated” Construction sector generates 40 to 47 percent GHG. We gain the cost incurred by reducing embodied carbon involved in material cost vs. values.

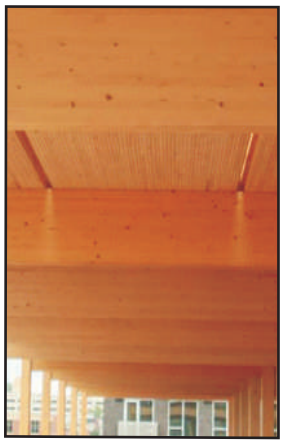
Structural Efficiencies: greater structural efficiency for wider and longer span. Building with masstimber products results in a significantly lighter superstructure than concrete and steel. This reduces foundation sizes and costs, especially associated with difficult ground conditions, or in high seismic zones. Masstimber as a heavy timber element as per the building codes and thus meets the fire rating requirements of heavy timber buildings.

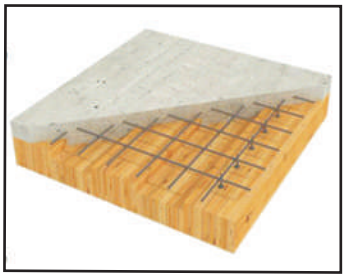
Profile Flexibility and performance products: profile flexibility a wide variety of surface profiles can be integrated inexpensively into the bottom surface of the panel. Masstimber floor panels with the addition of an acoustic mat and concrete topping on site, the DLT / CLT floor panel achieves good thermal and acoustic properties while maintaining the visual warmth of timber from below. The building envelops made of recycle metal panels with glass including the roof factory-made sustainable building material components. Masstimber achieves an acoustic profile noise reduction objective while keeping the wood exposed, dimensionally accurate panel, variety of sealer and stain coatings available to shop-apply at the side of panels.

Masstimber achieves site efficiencies. Is great cost savings, speed of construction: coordinated prefabricated elements, large panels, wide and long, removes the need for intumescent coatings and dropped ceilings beautiful panels can be exposed as a soffit. Masstimber factory made panels less on-site storage and simplified transportation building components are transported as a flat pack, with just-in-time deliveries. It requires smaller crews, quieter site – the reduced impact of construction on the surrounding area by removing wet trades water conservation.

Masstimber are performance products. The structural design of each lamination in a panel is covered by standards and codes. The masstimber panels have proven fire resistance. We will discuss in next articles on Fire and Safety.

Environmental sustainability: an all-wood mass timber product contains only trace amounts of glue due to finger jointing the boards if finger-jointed boards are used (panels >20ft long). • less than 1% of the glue used in masstimber components. No other chemicals, vocs, or metal nails, virtually no site waste, due to optimized offsite prefabrication, healthier indoor air quality with no off gassing. The wood fiber are sourced from sustainably managed forests and locks in carbon dioxide, acting as a carbon sink. ~3650lbs co2 sequestered per ton, wood is the only renewable structural material. Masstimber helps green building PEFC and FSC®, USGBC, Green building council helping achieve LEED and responsible forest management goals.





About the author

Prakash N. Suthar ,

President & Founder of Windsor Housing USA Inc

He has vast experience in tall wooden buildings and wood products for sustainable construction practices.

prakash@prakashsuthar.com

Late Er. N. K. Bhattacharya

8 Dec 2023 : With profound grief and deep sorrow we regret to inform that our beloved Trustee Er. N. K. Bhattacharya left for his heavenly abode on 8 Dec 2023. Er. N. K. Bhattacharya was in military service for longtime. He was posted at various military centres in India. He was expert in solving tricky problems faced during construction work. He guided many engineers during his service.

He was introduced to ISSE by our founder President Late Shri R. L. Nene. He delivered may lectures for ISSE Seminars on various on Technical subjects. He wrote many articles in ISSE Journals. He was Advisory Trustee of ISSE for many years.

He was very punctual to ISSE Meetings and Seminars, giving useful suggestions for ISSE developments. He represented ISSE in Remaking of Mumbai for proper development of Mumbai.

After his retirement, he travelled to many parts of India and military offices for invited technical lectures . Physically very fit person, very co operative to guide juniors and colleagues. Less talkative and humble person. Due to his departure ISSE has lost very dynamic personality. May his soul rest in peace. Om Shanti ! - Er. S. G. Dharmadhikari and Team ISSE

LOCAL BUCKLING WIDTH - TO - THICKNESS LIMITS IN IS 18168:2023

Dr. N. Subramanian, Ph.D. FNAE

ABSTRACT :

Structural steel design specifications worldwide use w/t limits to prevent of local buckling of members on their designs, such that the full cross-section will be effective in resisting the applied forces and moments. In the IS 800:2007 code, the cross-sections are classified as plastic, compact, semi-compact and slender. It was found that in IS 800:2007, just like AISC 360:22, some limiting width-to-thickness ratios of non-compact/slender sections for flexure may not achieve the intended objectives, while all limiting width-to-thickness ratios of compact/non-compact sections for flexure ensure that plastic moment is achieved, but rotation objectives are not consistently implemented. A variety of approaches have been employed to develop w/t limits for design. The most common approach is wholly experimental; in some cases some analytical approaches have been adopted. However, the recently released IS 18168:2023 provides seismic w/t limits to achieve ductile design to ensure adequate inelastic deformation capacities; which are based on the AISC 341-16 code. The w/t limits of IS 800:2007 and IS 18168:2023 code are discussed. Unlike, AISC 341 code, the IS 18168 code gives only one w/t ratio for members, thus allowing only plastic sections. The w/t ratios of the 2022 version of IS 341 code are compared with the 18168 code, and it is seen that there are some variations in the w/t ratios of webs of cross-sections.

INTRODUCTION

The bureau of Indian Standards released a new code IS 18168 in 2023 entitled “Earthquake Resistant Design and Detailing of Steel Buildings-Code of Practice”, to replace Section 12 of the IS 800:2007 code on “General Construction in Steel-Code of Practice”. The Foreword of this IS 18168 notes that the provisions of this code should govern when in conflict with those in Section 12 of the IS 800:2007 code. It is also mentioned that efforts have been made to coordinate with standard and practices prevailing in different countries and particularly from the American codes ANSI/AISC 360-16 and ANSI/AISC 341-16. Although the American codes have been published with commentaries to explain and justify the clauses, the IS 18168:2023 does not have any such commentary. Hence, a few clauses pertaining to the local buckling (width-to-thickness) limits are explained.

It is also very important to note that the IS 18168:2023 code stipulates that in seismic zone V, all steel buildings should be made of eccentrically braced frames only, and special concentrically braced frames should not be used. In addition, it restricts the use of special moment resistant frames in seismic zones VI and V only in buildings with height less than 15m. No such restrictions are found in AISC 341-22. In this connection, it has to be remembered that in the draft IS 1893-Part 1, a new zone, namely zone VI, has been introduced covering the north-eastern states and the extreme northern belt covering Kashmir, Himachal Pradesh, Haryana, part of Uttar Pradesh and Bihar and Gujarat (covering Bhuj area), which were mostly in Zone IV in the 2016 version of IS 1893-Part 1, except Bhuj area (Rahul and Subramanian, 2023).

CROSS-SECTION CLASSIFICATION

Determining the strength of structural steel components requires the designer to consider the cross-sectional behaviour and also the overall member behaviour. Whether in the elastic or inelastic material range, cross-sectional strength and rotation capacity are limited by the effects of local buckling. In the IS: 800:2007 code, cross-sections are categorized into four behavioural classes depending upon the material yield strength, the width-to-thickness ratios of the individual components (e.g. webs and flanges) within the cross-section and the loading arrangement. The

moment-rotation characteristics of these four classes of cross-sections are shown in Fig.1.

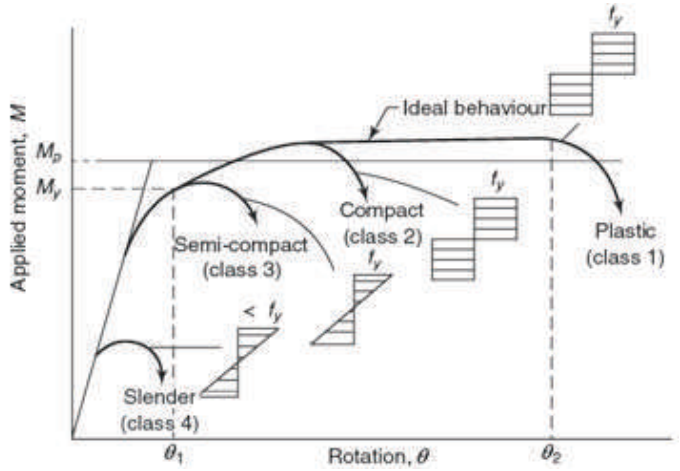


Fig. 1 Moment-rotation behavior of the four classes of cross-sections as per IS 800:2007

a) Plastic or class 1: As seen from this figure, class 1 (plastic) cross-sections are fully effective under pure compression, and capable of reaching and maintaining their full plastic moment in bending and hence used in plastic design. These sections can develop plastic hinges and have sufficient rotation capacity for the failure of the structure by formation of a plastic mechanism. These sections will exhibit sufficient ductility (θ2 > 6 θ1, where θ1 is the rotation at the onset of plasticity and θ2 is the lower limit of rotation for treatment as plastic section).

b) Compact or class 2: These sections are also fully effective in pure compression and can develop their plastic moment of resistance in bending, but have inadequate plastic hinge rotation capacity because of local buckling. These sections have lower deformation capacity and have ductility in the range $\theta 1 < \theta 2 < 6\theta 1$.

c) Semi-compact or class 3: These sections are fully effective in pure compression and the elastically calculated stress in the extreme compression fibre of the steel member, assuming an elastic distribution of stresses, can reach the yield strength. But, local buckling will prevent the development of full plastic limited to the (elastic) yield moment only

d) Slender or class 4: Cross-sections in which local buckling will occur even before the attainment of yield stress in one or more parts of the cross-section. An effective cross-section is therefore defined based on the width-to-thickness ratios of individual plate elements and this is used to determine the resistance of the cross-section.
Majority of the hot-rolled cross-sections will be class 1, 2 or 3 and hence their resistances may be based on gross cross-section properties obtained from section tables (IS: 808:2021).

The design moment capacity Md of each of these four classes of laterally supported sections may be calculated as:

1.	Plastic	$M_d = Z_p f_y/\gamma_{m0}$	(1a)
2.	Compact	$M_d = Z_p f_y/\gamma_{m0}$	(1b)
3.	Semi-compact	$M_d = Z_e f_y/\gamma_{m0}$	(1c)
4.	Slender	$M_d < Z_e f_y/\gamma_{m0}$	(1d)

Where, Z*p* and Z*e* are the plastic and elastic section modulus respectively, and γm0 is the partial factor of safety for material as per IS 800:2007.

Each compressed (or partially compressed) element is assessed individually against the limiting width-to-thickness ratios for class 1, 2 and 3 elements defined in Table 1. If an element fails to meet the class 3 limits, it should be considered as class 4. Different elements of a cross-section can be in different classes. In such cases, the section is classified based on the least favourable classification.

Table 1 Cross-sectional Limits Necessary to Prevent Local Buckling in Members as per IS 800:2007

Type of element	Method of manufacture	Ratio	Limiting proportions for sections		
			Plastic	Compact	Semi-compact
Outstand element of compression flange	Welded	b/t_f	8.4	9.4	13.6
	Rolled	b/t_f	9.4	10.5	15.7
Internal element of compression flange	Welded or rolled	b/t_f	29.3	33.5	42
Web of an I-H or box section	Welded or rolled Neutral axis at mid depth	d/t_w	84	105	126
	Generally if r_1 is negative	d/t_w	$84/(1+r_1)$ but ≤ 42	$105/(1+r_1)$	$126/(1+2r_2)$ but ≤ 42
	If r_1 is positive	d/t_w		$105/(1+1.5\ r_1)$ but ≤ 42	
Web of channel		d/t_w	42	42	42
Angle (both criteria should be satisfied)		b/t and d/t	9.4	10.5	15.7
Stem of a T-section (rolled or cut from a rolled I or H section)		d/t_f	8.4	9.4	18.9
Circular hollow tube subjected to (a) Moment		D/t	42 ε	52 ε	146 ε
(b) Axial compression		D/t	Not applicable		88 ε

Note:
1. The above values should be multiplied by $\varepsilon = (250/f_y)^{0.5}$ if f_y is not equal to 250 MPa
2. The stress ratio r_1 and r_2 are defined as
   r_2 = average axial compressive stress / design compressive stress of web alone
   r_2 = average axial compressive stress / design compressive stress of overall section.
   r_1 and r_2 is negative if axial stress is tensile.

The limiting width-to-thickness ratios are modified by a factor ε, which takes into account the yield strength of the material (For circular hollow section the width-to-thickness ratios are modified by ε2). The factor ε is defined by

$$\varepsilon = (250/f_y)^{0.5}$$

Where, fy is the nominal yield strength of the steel. Note that increasing the nominal yield strength results in stricter classification limits.

The terms internal element, outstanding elements etc., as used in Table 1 are described below:

a) Internal elements: These are elements attached along both longitudinal edges to other elements or to longitudinal stiffeners connected at suitable intervals to transverse stiffeners (e.g. web of I Sections and flange and web of box-sections)

b) Outstanding elements or outstands: these are elements attached along only one of the longitudinal edges to an adjacent element, the other edge being free to displace out of plane (e.g. flange overhang of an I-Section, stem of T-section and leg of angle section)

c) Tapered elements: These elements may be treated as flat elements having average thickness as defined in IS 808.

Compound elements in built-up section:

In case of compound element consisting of two or more elements bolted or welded together as shown in Fig.2 of IS 800:2007, the following width-to-thickness ratios should be considered

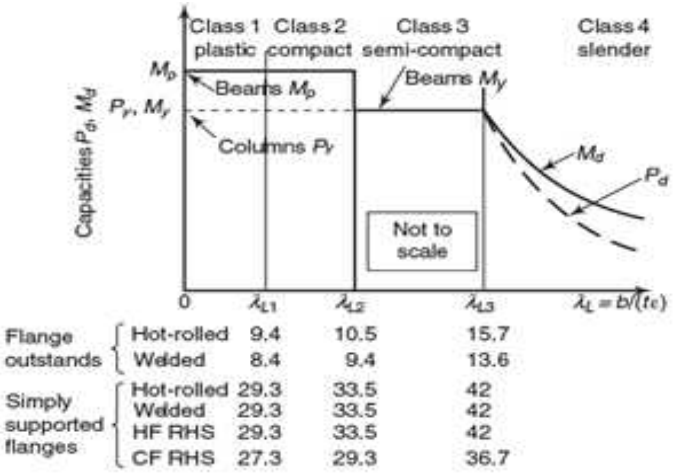
a) Outstand of compound element compared to the thickness of the original element of the rolled section

b) The internal width of each added plate between the lines of welds or fasteners connecting it to the original section compared to its own thickness.

c) Any outstand of the added plates beyond the line of welds or fasteners connecting it to original section compared to its own thickness.

Note that stricter limits are imposed for welded elements in recognition of the weakening effect of the more severe residual stresses present.

The relationship between the moment capacity Mu and the compression flange slenderness b/t indicating the λ limits is shown in Fig.2. In this figure, the value of Mu for semi-compact section is conservatively taken as My. Note that web slenderness d/t is such that its buckling before yielding is prevented. When a beam is subjected to bending, the entire web may not be in uniform compression and if the neutral axis lies at mid depth, half of the web will actually be in tension. In this case, the slenderness limits are somewhat relaxed for the webs.



Flange outstands	Hot-rolled	9.4	10.5	15.7
	Welded	8.4	9.4	13.6
Simply supported flanges	Hot-rolled	29.3	33.5	42
	Welded	29.3	33.5	42
	HF RHS	29.3	33.5	42
	CF RHS	27.3	29.3	36.7

Fig.2 Moment capacities of fully braced beams and columns

As noted earlier, only plastic sections should be used in indeterminate frames forming plastic collapse mechanisms. In elastic design, semi-compact sections may be used with the understanding that the maximum stress reached will be My. Slender sections also have stiffness problems and are not preferable for hot rolled structural steelwork. However they are used extensively in cold-formed members. Plate girders are usually designed based on the tension field approach (which takes into account the post-buckling behaviour of plates) to achieve economy. Since the classification such as plastic, compact, etc. are based on bending, it cannot be used for a compression member. In compression members a criterion is used to find whether the member is slender or not. However, in practice, compact or plastic sections are used for compression members, since they have more stiffness than semi-compact or slender members.

CLASSIFICATION OF SECTIONS FOR DUCTILITY

The Northridge Earthquake in 1994 triggered a new wave of seismic steel research activities, not only for special moment frames (SMFs) but also for other types of seismic force-resisting systems (SFRSs). Since their introduction during 1990 in the AISC Seismic Provisions (AISC 341, 1990), the local buckling (i.e., w/t) requirements have undergone regular revisions. The seismic w/t limits are part of the ductility design requirements to ensure adequate inelastic deformation capacities. In the AISC 341-22 code, members of SFRSs that are anticipated to undergo inelastic deformation have been classified as either moderately ductile members (λmd) or highly ductile members (λhd). During the design earthquake, moderately ductile members may undergo a moderate plastic rotation of approximately 0.02 rad., whereas highly ductile members may withstand a plastic rotation of approximately 0.04 rad. at a post-peak of 0.8Mp, or Mp up to and including strain hardening, Mpe, or high component level strains (10–20εy) and high numbers of component cycles (Schafer et al., 2022). Member rotations result from either flexure or flexural buckling.

But, in the IS 18168:2013 code, only one type of members is allowed, probably the highly ductile members. Obviously, the limiting width-to-thickness ratios in AISC 341:22 and IS 18168:2013 are more stringent than AISC 360:22 and IS 800:2007 respectively. In addition, as per the IS 18168:2013 code, only doubly symmetric parallel flange standard rolled sections, or built-up sections, with flange width-to-thickness ratio (w/t) and web depth-to-thickness ratio (h/t) less than the limits specified in Table 3 should be used as beams (Clause 6.1) or columns (Clause 7.1)or shear links (Clause 11.1). However, clause 10.1 allows standard rolled or built-up sections or closed box sections for structural braces again with the w/t or h/t ratios as per Table 3. The limiting width-to-thickness ratios given in AISC 341:22 and in IS 18168:2023 are compared in Table 3, assuming that the IS 18168:2013 values are applicable for highly ductile members.

Table 3 Limiting width-to-thickness ratios for elements of earthquake resistant structures

Component Section type		Limiting plate slenderness			
		Outstanding flange width-to-thickness ratio		Web depth-to- thickness ratio	
		IS 18168:2023	AISC 341:2022	IS 18168:2023	AISC 341:2022
Beam	Doubly-symmetric rolled or built-up I-section	$\frac{9.0\varepsilon}{\sqrt{R_y}}$	$\frac{8.5\varepsilon}{\sqrt{R_y}}$	$\frac{44.5\varepsilon}{\sqrt{R_y}}$	$\frac{72(1-C_a)^{2.3}}{\sqrt{R_y}}$
Column	Doubly-symmetric rolled or built-up I-section	$\frac{9.0\varepsilon}{\sqrt{R_y}}$	$\frac{8.5\varepsilon}{\sqrt{R_y}}$	$\frac{44.5\varepsilon}{\sqrt{R_y}}$	$\frac{72(1-C_a)^{2.3}}{\sqrt{R_y}}$
Brace	Rolled or built-up I-section	$\frac{11.3\varepsilon}{\sqrt{R_y}}$	$\frac{11\varepsilon}{\sqrt{R_y}}$	$\frac{44.4\varepsilon}{\sqrt{R_y}}$	$\frac{42\varepsilon}{\sqrt{R_y}}$
	Closed box section	$\frac{21.4\varepsilon}{\sqrt{R_y}}$	$\frac{18.4\varepsilon}{\sqrt{R_y}}$	$\frac{21.4\varepsilon}{\sqrt{R_y}}$	$\frac{18.4\varepsilon}{\sqrt{R_y}}$
Links	Doubly-symmetric rolled or built-up I-section	$\frac{11.3\varepsilon}{\sqrt{R_y}}$	$\frac{8.5\varepsilon}{\sqrt{R_y}}$	$\frac{44.4\varepsilon}{\sqrt{R_y}}$	For $C_a \le 0.113$ $\frac{54.6\varepsilon}{\sqrt{R_y}}(1-1.04C_a)$ For $C_a > 0.113$ $\frac{50.4\varepsilon}{\sqrt{R_y}}(1-0.38C_a) \ge \frac{34.8\varepsilon}{\sqrt{R_y}}$
	Closed box section	$\frac{21.4\varepsilon}{\sqrt{R_y}}$	$\frac{15.6\varepsilon}{\sqrt{R_y}}$	$\frac{49.4\varepsilon}{\sqrt{R_y}}$	$\frac{18.1\varepsilon}{\sqrt{R_y}}$
Where $\varepsilon = (250/f_y)^{0.5}$ and $C_a = P_u/(\frac{P_y}{\gamma_{mo}})$					

Width-to-Thickness Limitations of Steel and Composite Sections

Because limiting width-to-thickness ratios are a function of the yield stress, local buckling becomes more of a concern with a higher yield stress. The specified minimum yield stress, fy, had been used in the AISC 360 Code to check local buckling limits. However, recognizing that the actual yield stress may be higher than fy, the 2005 AISC 341 code introduced Ry to express the expected yield stress as Ry fy for capacity design. It has to be noted that the Indian code values were derived based on the 2016 version of AISC 341:2016, and the 2022 code has modified these values slightly, especially for the webs of cross-sections. In addition, the AISC 341:22 provides more cases (18 cases) than the IS 18168:2023.

The limiting width-to-thickness ratios for moderately ductile members of AISC 341:22 generally correspond to λp values in Table B4.1b of AISC 360:22, with the exceptions for round and rectangular hollow structural section (HSS), stems of WTs, and webs in flexure. Although the limiting width-to-thickness ratios for compact compression elements, λp, given in Table B4.1b of AISC 360-22, are sufficient to delay local buckling, from the available test data it was found that these limits are not adequate for the required inelastic performance of highly ductile members in the Seismic force-resisting system (SFRS). The limiting width-to-thickness ratios for highly ductile members, λhd, given in Table D1.1 (some quoted in Table 3 here) are deemed adequate for the large ductility demands to which these members may be subjected to (Sawyer, 1961; Lay, 1965; Kemp, 1986).

For highly ductile members, the limiting width-to-thickness ratios for webs of rolled or built-up I-shaped beams and webs of built-up shapes used as beams or columns were based primarily on research on the effects of web slenderness on ductility under combined bending and axial compression under monotonic loading. In the later editions of AISC 341 the highly ductile limit of the web was expressed in two zones, depending on the value of Pu/Py. The limiting width-to-thickness ratios for webs under combined bending and axial compression have now been modified such that the limit would converge at zero axial loads

.In addition, the h/t value for webs given in 2022 edition of AISC 341 is based on recent studies that included the cyclic effect. These studies also included deeper columns which are often used by the designers to meet the stringent story drift limit in special moment frame (SMF) design. Steel wide-flange columns in SMF are expected to experience flexural yielding and form a plastic hinge at the column base. Because deep columns have h/t ratios that are significantly higher than those of shallow and stocky sections, testing showed that the web was not that effective in stabilizing flanges under cyclic loading. In these tests, the interactive flange-web local buckling occurred earlier than expected and caused significant strength degradation and axial shortening (Wu et al., 2018). Under cyclic loading, lateral-torsional buckling together with local buckling could also occur (Wu et al., 2018, Ozkula et al., 2021). For more discussion on how these w/t values were obtained, refer Commentary to AISC 341:22. A comparison of the limiting width-to-thickness ratios of AISC 360, AISC 341 and Eurocode 3 is provided by Schafer et al., 2022.

In Table 3, Ry is the ratio of the expected yield stress to the characteristic yield stress, and depends on the grade of steel. The value of the same is given in IS 18168 as shown in Table 4. In AISC 341:22, Ry value is provided for different sections (hot rolled structural shapes, hollow structural sections (HSS), plates, strips and sheets, and steel reinforcement), again depending on the steel grade(See Table A 3.2 of AISC 341-22); a few values are provided in Table 4 for comparison. Additional discussion on Ry on the w/t limits is provided by Schafer et al., 2020.

Table 4 Material Strength Uncertainty Factor R_y

Grade of Steel	Value of R_y	
	IS 18168:2023	AISC 341:22
E 250 (B0 or C)	1.4	1.5
E 275 (B0 or C)	1.4	-
E 300 (B0 or C)	1.3	-
E 350 (B0 or C)	1.2	1.2
E 380	-	1.1

A summary of the application of these λhd limits and their intended objective is provided in Table 5 and complete details are provided in Schafer et al. (2020).

Table 5 Intended objectives for application of λ_{hd} limits in AISC 341:22

System	Element	Objective
Special Moment Frames (SMF)	Beam	M_p, 0.04 rad ID @ $0.8M_p$
	Column	M_p, R_y, 0.04 rad
Special truss moment frames (STMF)	Chord and diagonal	3% ID
	Column	3% ID
Special concentrically braced frame (SCBF)	Beam	R_y
	Column	R_y and large θ_p
	Brace	R_y, n cycles, yield at 0.3% ID,10-20ε_y
Multi-Tiered Braced Frames (MT-SCBF)	Column	M_{pc}
	Brace	R_y, n cycles, yield at 0.3% ID,10-20ε_y
Eccentrically braced frames (EBF)	Link	0.02-0.08 rad inelastic rotation
	Column	R_y
Note: R_y = required system strength based on capacity design, ID = Interstory drift, FLB = flange local buckling		

SUMMARY AND CONCLUSIONS

Cross-section width-to-thickness limits are a longstanding and reliable means to ensure behavioral objectives related to the local buckling performance of structural steel members. Establishing the underlying assumptions inherent in current width-to-thickness limits developed over the course of the last 80+ years is critical to the structural steel design using new steels and configurations (Schafer et al, 2022). Existing width-to-thickness limits presented in AISC 360 and IS 800 codes suggest that each limit is unique to each element and loading, while actual limits are based on a small number of targeted, non-dimensional plate slenderness. Seismic width-to-thickness limits provided in AISC 341 and IS 18168 codes are not only to achieve the required strength but also to ensure ductility and avoid premature fracture in a variety of different seismic force-resisting systems. These w/t ratios include Ry, which is the ratio of the expected yield stress to the characteristic yield stress, and depends on the grade of steel. The limiting width-to-thickness ratios given in AISC 341:22 and in IS 18168:2023 are compared and it is found that the values given in AISC 341:22 are slightly different, especially for the webs of sections. A summary of the application of these w/t limits and their intended objective is also provided. Although the AISC 341-22 code allows either moderately ductile members or highly ductile members, IS 18168:2023 seems to allow only highly ductile members.

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About The Author

Dr. N. Subramanian, Ph.D., FNAE, an award-winning author, consultant, and mentor, now living in Maryland, USA, is the former chief executive of Computer Design Consultants, India. A doctorate from IITM, he also worked with the TU Berlin and the University of Bundeswehr, Munich for 2 years as an Alexander von Humboldt Fellow. He has 45 years of professional experience which includes consultancy, research, and teaching in India and abroad. Dr. Subramanian has authored 25 books and 300 technical papers and served as a past vice president of ICI and the ACCE (I). He is a recipient of several awards including the ICI - L&T Life-Time Achievement award of the ICI (2013), Tamil Nadu scientist award (2001), Gourav Award of the ACCE(I) (2021), and the ACCE(I)-Nagadi best book award for three of his books (2000,2011,2013). He has also been in the Editorial Board/Review committee of several Indian and international journals.

CASE STUDY : STRUCTURAL AUDIT OF DETERIORATED INDUSTRIAL RCC CHIMNEY

By Er. R. D. Kalgutkar, Er. Prajakta Bhise, Er. Nilesh Gaikwad

Introduction :

Industrial chimney is a critical structural component of any industrial structure, designed to carry hot flumes from a fireplace to high up in the air.

During structural audits, we observed following typical deterioration of the RCC shell of a chimney : Development of cracks in RCC shell, corrosion of steel reinforcement & spalling of concrete cover.

The reasons behind such deterioration are weathering effects & temperature effects. Construction & design faults like inadequate shell thickness, brick lining, concrete cover & reinforcement add to deterioration.

Case study:

We came across a similar condition of the RCC chimney during structural audit.

This particular chimney was constructed in 2000. The chimney is circular in plan. Height of the chimney above ground level is 60m. It is made up of RCC shell with fire brick lining up to a height of 20m. The thickness of the shell is 300mm upto 20m, 250mm between 30m-40m & 200mm between 40m-60m.

Methodology of structural audit :

1. Data collection (Visual Inspection & NDT)
2. Crack Mapping
3. Analysis of the chimney shell structure in software & compare onsite parameters with design calculations.

1. Data collection :

Visual observations :

The RCC chimney had vertical structural cracks in the concrete shell in the portion between 30m to 60m & corrosion of reinforcement (as seen in photographs below).

Single face steel reinforcement was noticed in the upper portion of the shell where the thickness of the shell provided was less than 300mm. 10mm dia hoop reinforcement was placed inside the main vertical steel.

Photo no.1

Brick lining was provided up to 20m height & the remaining part of the RCC shell was directly exposed to hot fumes.

Photo no.2

NDT :

It was observed that the apparent compressive strength of concrete up to the height of 30m was +M30. Above this level the results were erratic & on the lower side due to formation of cracks in the RCC shell.

The corrosion activity in reinforcement in the RCC shell up to a height of 30m was less than 10%. Above 30m level, corrosion activity was about 50%. Also, the depth of carbonation in the lower portion was up to 20mm & depth of carbonation above 30m was >25mm.

Overall, test results for the upper 30 m portion of the chimney exhibited poor & erratic results for Concrete Hammer Test, Ultrasonic Pulse Velocity Test, Carbonation test & Half Cell Potential Test.

2. Crack Mapping :

Crack mapping was done for the chimney shell. Upper 30 m portion exhibited structural cracks having width >5mm & lengths >20m as shown in figures 1 & 2. Red color shows major cracks having width >5mm, orange color shows moderate cracks having width between 1mm to 5mm & green color shows minor cracks having width less than 1mm.

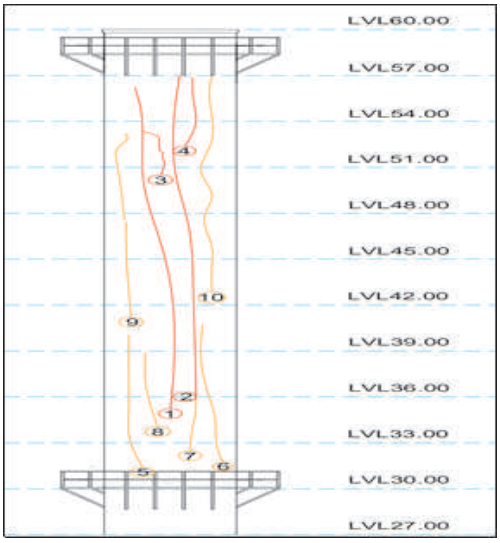


Fig. 1: East Face of Chimney

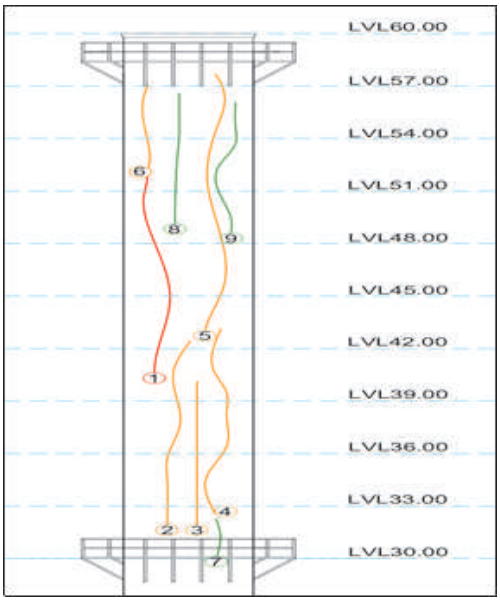


Fig. 2: North Face of Chimney

3. Analysis :

The 60m chimney structure is analyzed using software STAADpro V8i. The stresses & deflection occurred in the chimney for loads (dead, wind & temp.) are shown in the figures 3 & 4.

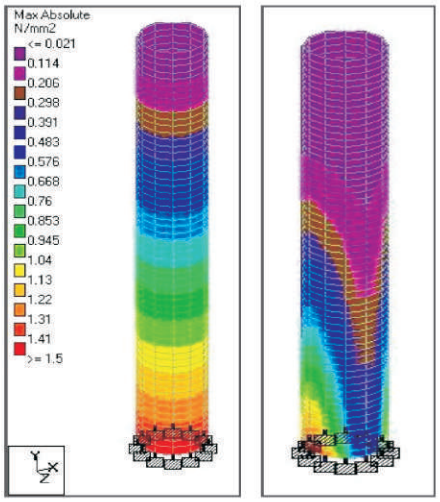


Fig. 3: Stress contour- 1. Dead Load 2. Wind Load

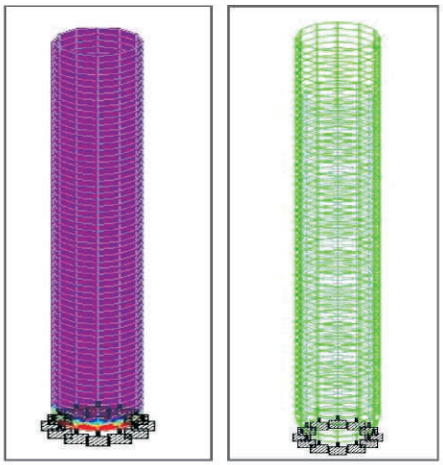


Fig. 4: Stress & deflection due to Temp. Load resp.

Results of analysis are :

I. The minimum thickness required for carrying these stresses is 300mm.

II. Double face steel reinforcement is required throughout the RCC shell.

III. As per analysis, increase in diameter of chimney) due to temperature is up to 14.8 mm, and observed width of existing crack is approximately 15mm.

4. Conclusion :

After extensive study, it was concluded that the portion of the chimney up to 30 m height is structurally sound. However, the portion of the chimney above 30 m height has lost its structural integrity as is seen from 'Crack Mapping' & NDT results.

The main reasons for development of vertical cracks are :

1. Design & construction deficiencies :

(i) As per analysis, the minimum shell thickness required is 300mm & minimum grade of concrete M30. Whereas, provided shell thickness is less than 300mm in portion of shell above 20m. Single layer of steel reinforcement on the outer face is provided instead of the required double layer.

(ii) Steel reinforcement when provided on the inner side, arrests propagation of crack, thereby restricting the width of crack on the outer face.

(iii) Fire brick lining is provided up to 20m height. The fire bricks act as a heat protecting cover to the RCC shells against heat. This has to be provided for length especially where the induced temperature stresses are higher.

(iv) Maximum hoop stresses are developed at the extreme fiber of the shell. Hoop steel should be placed in this zone to resist hoop stresses & to arrest development of tensile cracks. Main vertical steel should be placed inside hoop steel to provide confinement.

Elongation due to wide cracks in the outer face, hoop steel bars reach to a plastic state thereby making it ineffective in resisting hoop stresses.

2. Thermal effect :

Temperature inside the chimney causes expansion of shells into the oval shape. As RCC is a rigid material, expansion in the shell causes development of vertical cracks.

3. Weathering effect :

The depth of carbonation observed in the RCC shell is >25mm. Carbonation decreases the pH of concrete & causes corrosion of steel reinforcement. Corrosion of reinforcement exhibits an increase in reinforcement volume. It causes cracking & spalling of concrete. Cracked concrete & subsequent exposure of reinforcement steel to the atmosphere aggravates corrosion activity.

5. Remedial Measures : (For this particular chimney)

Upper 30m portion of the chimney is structurally not fit for its intended further use. One of the following remedial measures can be adopted.

a) Method I :

Providing external Carbon Fiber Reinforced Polymer (CFRP) Wrapping for the portion above 30m, heat resistant paint from inside to restrict heat transfer for the portion above fire brick lining & steel stiffening frame from inside to avoid internal collapse.

b) Method II :

Removal of cracked portion of the chimney above 30m height & replacing it with steel cylindrical shell.

c) Method III :

Removal of cracked portion of the chimney above 30 m height & replacing it with designed RCC cylindrical shell.

About the author :

Er. R. D. KALGUTKAR.
Completed Master's Degree from IIT Madras. Presently practicing in the field of Structural Design and Structural Auditing through own consulting firm, Shantal Consulting Engineers. Membership of various professional organisations & registrations with concerned government bodies. Expertise in structural audit, retrofitting and repair-remedial solutions to structures.

Name: Er. Prajakta Bhise,
M.Tech.(Structure)
Designation : Str. Engineer,
Shantal Consulting Engineers

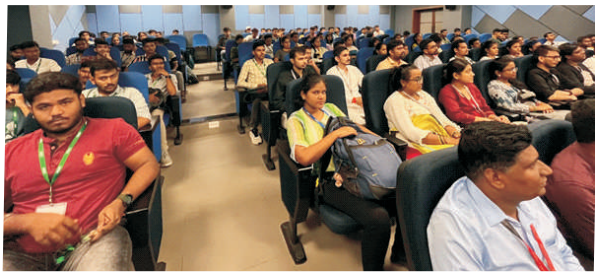
Name: Er. Nilesh Gaikwad,
BE (Civil)
Designation: Sr. Engineer,
Shantal Consulting Engineers

Website : www.shantalconsultingengineers.com
Email id : shantalconsultingengineers@gmail.com

NEWS AND EVENTS DURING OCT – DEC 2023

by Er. Hemant Vadalkar

5 Oct 2023 : Inauguration of ISSE Student chapter at Vidyavardhini College of Engineering, Vasai. This function was supported by ISSE Palghar local centre.



On behalf of Technoesis, I sincerely thank you for extending your valuable support for our CPD Program "Structural Audit and Non-destructive Testing" which was conducted on 14th October 2023 at Mumbai.

You will be happy to note that the Program was a great success. It was attended by 84 participants mainly consisting of consultants, construction professionals, faculty and students who came from more than 20 cities in India. As an extended leg of the one-day Program, we also conducted an online Follow-up Session on 25th October 2023. The purpose of the Follow-up Session was to consolidate and enhance participants' learning experience through additional presentations and a Q&A Session. The feedback was also encouraging.

13 Oct 2023 : CTBUH arranged seminar on" Zero Carbon Ambitions for High-Rises " at Mumbai. Eminent architects and engineers addressed the gathering.

Chairman CTBUH India, Er. Girish Dravid talked about activities of CTBUH for professionals and students.

Architect Raj Patel -A registered American Architect, Raj leads Gensler's Lifestyle Studio in the Middle East focusing on large and intricate architecture projects throughout the region. Raj honestly declared that High rises are not really sustainable. They consume huge amount of energy during its construction and during operations. We can try to minimize the carbon foot print of such structures by certain measures. Shape and form of building is very important which decides façade area of building. Efficient glass façade design with minimum glass % will save carbon emission. Large and multilevel basements below the building can be avoided and converted into podiums which will be more sensible to save on carbon foot print. Efficient use of advanced construction materials will help in reducing the impact on the environment. His talk was very interesting.

Structural Engineer Abhijeet Kulkarni Director Buro-Happold talked on calculations of embodied carbon in various construction material. He emphasised that total costing considering life cycle assessment will provide correct picture and help in making right decision.

Aun Abdullah from Lodha Group discussed their company approach towards sustainability and various mitigation measures taken in that direction.

Vijay Kulkarni – Consultant and Concrete Technologist gave over all perspective of carbon emission by major countries. He showed results of various alternatives for a 40 storey building using different building systems and materials for walls, plaster, main structural frames, different grades of concrete and their carbon foot print comparison. RCC shear walls with AAC block walls shows the lowest carbon footprint. He talked on new research to reduce cement content in the mix design by use of supplementary cementitious materials which will help in reducing the carbon footprint.

Event was moderated by Anil Hira CTBUH Vice Chairman and Nikhil Sanghvi- Director CTBUH.

It was attended by about 100 civil and structural engineers. Event was sponsored by Adani who is the owner of Ambuja and ACC cement.

14 Oct 2023 : Technoesis arranged one day training programme on "Structural Audit and Non-destructive Testing" at Mumbai. It was attended by 84 participants mainly consisting of consultants, construction professionals, faculty and students who came from more than 20 cities in India. As an extended leg of the one-day Program, Technoesis also conducted an online Follow-up Session on 25th October 2023. The purpose of the Follow-up Session was to consolidate and enhance participants' learning experience through additional presentations and a Q&A Session. The feedback was also encouraging.

24-25 Nov 2023 : EFC conducted seminar on revised codes IS1893 and IS16700 at VJTI. Workshop 83 was conducted by Epicons Friends of Concrete successfully at VJTI, Savitribai Phule auditorium on Fri 24th & Sat 25th November 2023. The principal faculty was Prof. (Dr). Yogendra Singh – IIT, Roorkee.

There was a record break attendance - 210 – Senior Professionals, Practicing Engineers, Corporate Consultants, Students and Faculties of Engineering Colleges attended the workshop.

The workshop was inaugurated by Dr. V. N. Gupchup – Retd Pro Vice Chancelor and Ex. Principal of VJTI. Prof. (Dr). K. K. Sangle - Dean and HOD of Structural Eng dept was felicitated for receiving National Award for Technical Education by the hands of President of India.

The principal topic of the workshop was - Revisions of IS 1893 Parts-1 & 2 and IS 16700: Methodological Changes in Seismic Design of Buildings. The entire subject was covered by Pro. (Dr). Yogendra Singh very effectively. The key feature of workshop was QA session, which was not separate but integral part of the workshop. Technical queries of all the participants were answered to the fullest satisfaction there and there itself.

Prof. M. G. Gadgil covered two topics:

1) Back stay Analysis and Design of buildings using ETABS as per provisions of IS 16700 - Tall building code – Day 1

2) Checking Design of PT slab as obtained from PT slab designer using SAFE software.

as a complementary support – Case studies - Day 2.

The interesting remarkable part of the attendees was participation by outstation participants. Total 41 participants attended from various states - Maharashtra, Gujrat, Tamil Nadu, AP, Kerala, MP, Kolkata.

The recording of the entire session is available on Epicons YouTube channel.

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30 Nov 2023 : Association of Consulting Civil engineers (India) ACCE Navi Mumbai centre arranged National seminar on Waterproofing , retrofitting and rehabilitation of Structures at CIDCO convention centre Vashi. Experts in the field delivered lectures on repairs, waterproofing, strengthening of structures. Dr. H. M. Raje, Dr. Gopal Rai, Dr. S. K. Manjrekar, Er. Nilanjan Bose, Er. Amit Barde, Er. Kaizad Engineer, Er. Salil Gadgil and Er. Sunny Surlaker shared their experience and case studies on the subject. The event was supported by ICI, India Chapter of ACI, ISSE,INSTRUCT and CCMA.

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9 Dec 2023 : SEFI is association with BIS arranged a webinar on Tall building code IS16700-2023 Rev1. Code writers Er. Alpa Sheth, Prof. CVR Murty and Ranjith Chandunni shared their thoughts. Panelists President IAStructIE Pradeep Kumar, ISSE President Shantilal Jain, Anil Hira from Buro Happold and Abhishek Pal Secretary BIS CED38 also shared their views on the subject. It was attended by large number of civil and structural engineers.

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9 Dec 2023 : INAE fellowship conferred to Prof T G Sitharam and Prof Deepankar Choudhury at Bhubaneswar along with other stalwarts like Satya Nadella of Microsoft USA, 3 directors of CSIR, IISER, 3 Padmabhusan awardees, Bharti Airtel CEO, TCS CEO , Secretary of ministry of earth science and many others. Heartiest congratulations to both !!!.

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13 to 15 Dec 2023 : Steel construction Expo and Conference was arranged at Jio Convention centre, Mumbai by MX Business Network. This was very informative and attended by large number of delegaes.

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22 Dec 2023 : Ambuja Knowledge centre arranged a lecture on Quality assurance and control in post-tensioning for Precast segments in Mega Project as per FIP recommendations (high speed rail track structure) by L &T Construction QA Head Er. Deepak Gaikwad for MAHSR C6 (Mumbai Ahmedabad high speed rail package C6) .

He described various prestressing operations and components used in prestressing and their specifications and testing as per Japanese consultants tender requirements.

Design Life of structure is 100 years

Concrete of grade M50 has been used. Spans 35 to 40m have been provided with PSC box girders with full span girder and segmental construction is being done.

Components of prestressing systems play important role in performance of system. Wedges (20 Cr Mn Ti) , Anchor cone(SG500/7), bearing plate (EN8), HDPC ducts and low relaxation prestressing strands are the components. FIP guidelines are available for selection of such components.

Grouting of ducts is most critical activity for durability. Grout must pass certain specifications as per contract like fluidity of grout < 25 sec and temperature of 25degree. Minimum pressure of 5kg/cm2 is to be maintained before closing the valve. After grouting “impact echo” test can be conducted to check any voids in the grouted duct to ensure quality.

Concreting of end block zone is very critical due to congestion of reinforcement. Any honeycombing in this area may create problem in anchoring system. Pile foundation was used. Couplers were provided for joining pile cage.

Geotechnical investigation was done at every 100m. Auto Trip hammer to be used for conducting SPT . During pile testing, displacement of pile at top , middle and base was measured by providing a steel tube in pile and SS threaded rods with sensors at three locations. Pile friction along full height was measured using transducers. Testing of 100% piles was done for integrity and some piles for dynamic tests.
In the river, well foundations were used with 10m OD and 7.5m ID. Following tests were done for approving prestressing system and its components
1.Static Load test 2.Load transfer test
3.Dynamic and Fatigue load test (for 2 million cycles) - This set up is available only at IIT Madras
He showed a small film about the project which was very informative. The lecture was very interesting and attended by 50 engineers.

ISRO-made structural analysis software 'FEAST' available for Indian academia, industries.

The Vikram Sarabhai Space Centre (VSSC) of the Indian space agency ISRO, has developed an analysis software that is used to perform Finite Element Analysis (FEA) of various types of structures including rockets, aircraft, satellites, buildings, etc.
FEA is a computerised method for predicting how a component or a structure reacts to real-world forces- like various types of structural loads, thermal conditions and other physical effects that a structure experiences while in operation.
During the design and development phase of a product, FEA is carried out to evaluate how well and safely the structure/component can withstand the various loads, and perform its intended function without any failure.
A Finite Element Analysis of Structures Software(FEAST) developed by ISRO-VSSC is available for free download.. Advanced version offered at nominal cost, compared to foreign options.
"The FEAST software tool is the result of decades-long efforts by generations of scientists and engineers at ISRO's lead centre VSCC, Thiruvananthapuram. We started building this tool for our own internal use and developed considerable expertise in this field. That's when we decided to ensure that our software be shared with the larger FEA user base within India" Dr S Unnikrishnan Nair, Director, VSSC, ISRO, told WION.
He said that FEAST has been made available for Indian academia at a fraction of the price of similar foreign offerings. A free trial of the FEAST software is also available at the ISRO/VSSC website:
https://feast.vssc.gov.in/Software.php
Operable in both Windows and Linux operating systems, the software is capable of running on systems with minimal hardware configurations. FEAST is available in three versions, based on the sophisticating levels and requirements of a broad category of users — academic (for students and educational institutions), premium (for small and medium scale industries) and professional (for general large scale applications).
So far, FEAST has been used by the structural design community in all major ISRO centres across India.
In order to popularise this software among the potential Indian user base, the ISRO has also taken efforts to publish a book targeting the under-graduate and post-graduate students, offering more insights into the fundamentals of FEA method and how FEAST can be used for solving real-world problems.
The book titled 'Introduction to Finite Element Analysis', has been written by practicing structural analysis experts of VSSC and Liquid Propulsion Systems Centre (LPSC) and edited by Dr S Somanath, Chairman, ISRO, Secretary, Department of Space and Dr Unnikrishnan Nair.
Elaborating on the contents of the book, Nair said that it covers the basic concepts and applications of FEA in an easy-to-understand manner. It is specifically aimed at introducing this advanced topic to undergraduate level engineering students and practicing engineers in a lucid style with thrust on how FEAST software developed by VSSC can be understood through worked-out problems and tutorials.

27 Dec 2023 : Industry Excellence Award 2023 by IEI (India) conferred on Epicons Consultants on 27 Dec at Jabalpur. Congratulations Team Epicons !

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VJTI AUDITORIUM, Matunga, Mumbai

SPEAKERS

PROF. CVR MURTY
IIT Madras

PROF. RUPEN GOSWAMI
IIT Madras

PANEL OF EXPERTS

PROF. CVR MURTY
IIT Madras

C V R Murty is Institute Chair Professor at IIT Madras. He has been associated with major revisions of the Indian Seismic Codes for buildings and bridges, and in development of NDMA guidelines towards earthquake for disaster mitigation. He is the Chairman of the Earthquake Engineering Committee of Bureau of Indian Standards, and steering a comprehensive upgrade of the earthquake design standards of India.

PROF. RUPEN GOSWAMI
IIT Madras

Rupen Goswami, is Professor, IIT Madras and is a member of BIS and IRC committees. His research interests are in seismic design of reinforced concrete and steel structures. He has co-authored numerous publications with Prof Murty such as "Earthquake Behaviour of Buildings" and "Introduction to Earthquake Protection of Non-Structural Elements in Buildings".

ER. ALPA SHETH
VMS Consultants Pvt Ltd

Ms Alpa Sheth, is Managing Director of VMS Consultants Pvt. Ltd. Mumbai. She is currently Convenor of the Tall Buildings Sub-Committee of CED 38, Bureau of Indian Standards. She has been Seismic Advisor/Consultant to States of Gujarat, Maharashtra, Delhi, Jammu and Kashmir and undertaken post-earthquake reconnaissance survey studies. She is a Founding Trustee of Structural Engineering Forum of India . She has been involved in design of over 200 tall buildings and holds a post-graduate degree in Structural Engineering from University of California, Berkeley.

ER. ANIL HIRA
Buro Happold

Anil's professional expertise is in tall building design, complex structures and architectural engineering with particular interests in wind and seismic engineering and soil structural interaction. He has been involved in well over 150 tall towers over 200m in height, including 80 towers over 200m worldwide including Australia, New Zealand, South East Asia, Middle East and the Sub-Continent including India. He is recognised as a world expert on structural design of tall buildings.

ABOUT WORKSHOP

ISSE is celebrating its 25th anniversary on Jan 29 and in view of that, ISSE and SEFI are jointly planning a one day in-person workshop on Jan 30 in Mumbai at VJTI AUDITORIUM, Matunga, Mumbai in association with VJTI Alumni association

30 JANUARY, 2024

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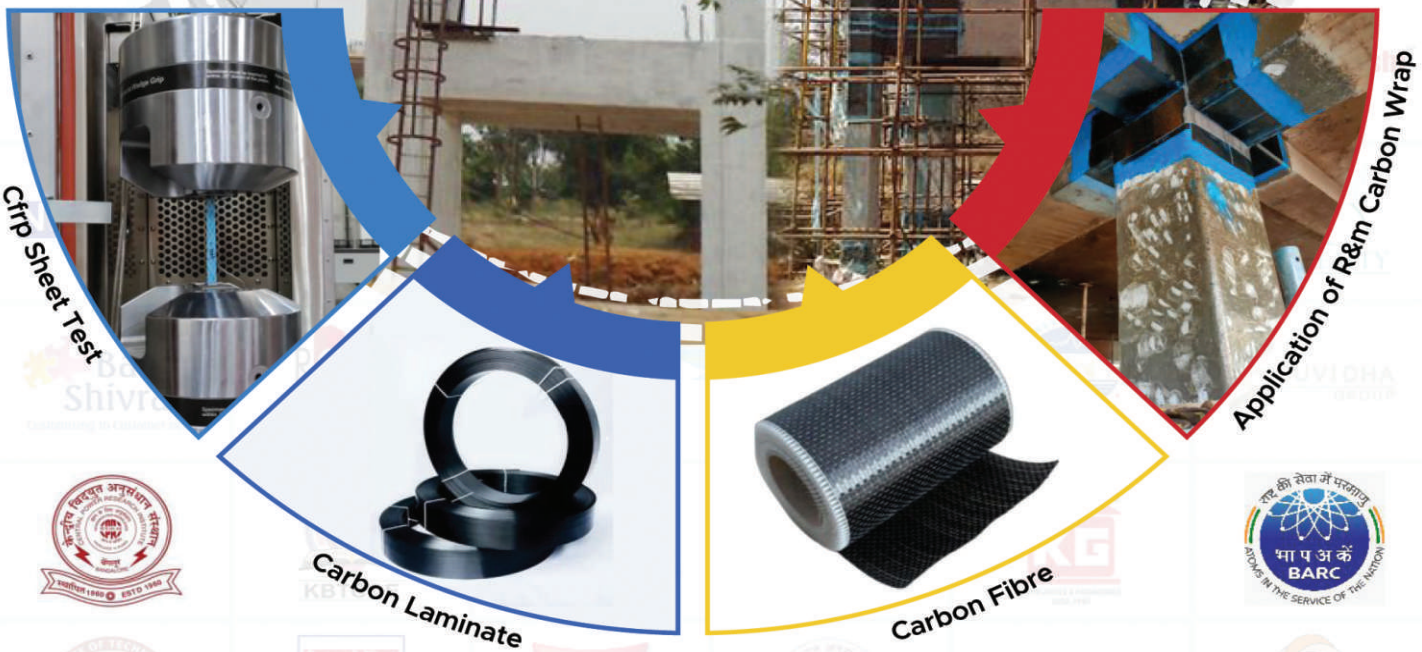

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