STRUCTURAL ENGINEERING



QUARTERLY JOURNAL OF INDIAN SOCIETY OF STRUCTURAL ENGINEERS

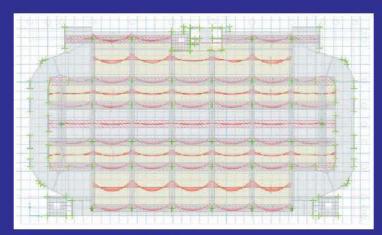


VOLUME 22 - 4 OCT - NOV - DEC. 2020



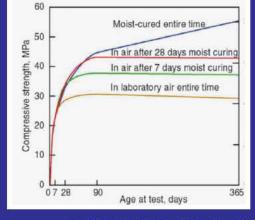


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STRUCTURAL ENGINEERS



INDIAN SOCIETY OF



STRUCTURAL ENGINEERS VOLUME 22 - 4, OCT- NOV- DEC 2020

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ISSE Student Chapter:

M. H. Saboo Siddiq College of Engg., Mumbai MIT WPU, Pune Chameli Devi Group of Institutions, Indore Vivekanand Polytechnic, Mumbai. Walchand College of Engg. Sangli.

Editor: Hemant Vadalkar

By Hemant Vadalkar

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Aurangabad

Kolhapur Navi Mumbai

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.
- 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	Construction Technology & Management
Computer Software	Geo-Tech & Foundation Engineering
Materials Technology, Ferrocement	Environmental Engineering
Teaching, Research % Development	Non Destructive Testing
Rehabilitation of Structures	Bridge Engineering
	& Other related branches

Fraternity News

WELCOME TO NEW MEMBERS

(OCT-NOV-DEC 2020)

01 M	1908	Mummaneni Radhakrishan Venkatrajasekhar	16 M	1923	Rohan Shawkat Shaikh
02 M	1909	Prasham JayeshBhai Vora	17 M	1924	Shahzeb Perwez Azmi
03 M	1910	Paresh Mahesh Gaonkar	18 M	1925	Sohail Saleem Shaikh
04 M	1911	Sujitkumar Parbat Naikwadi	19 M	1926	Rajesh Kumar
05 M	1912	Nikhil Nishikant Mudgal	20 M	1927	Harish Vardhan Malik
06 M	1913	Vaisali Muthirakuzhi Sreekandan	21 M	1928	Pratik Vishnu Borude
07 M	1914	Girish Chintaman Mhatre	22 M	1929	Sanket Dattatray More
08 M	1915	Abhikshek Gopal Dicholkar	23 M	1930	Nishant Dattatray Gaikwad
09 M	1916	Dhiraj Dilip Jain	24 M	1931	Arunkumar S.
10 M	1917	Vishwanand Vitthalrao Gunjal	25 M	1932	Kaushal Bharatbhai Patel
11 M	1918	Ramdas Venkatrao Puranik	26 M	1933	Kanan Ajey Bahekar
12 M	1919	Pramod Bapurao Dethe	27 M	1934	Kedar Girish Sabharanjak
13 M	1920	Anupam Nath	28 M	1935	Yogesh Jalindar Siraskar
14 M	1921	Manasa Shetty	29 M	JM 56	Ronak Dinesh Jain
15 M	1922	Ajay Jagdishkumar Lohia			

Patrons: 38 Organisation Members: 31 Sponsor: 8

Members: 1935 Junior Members: 56 IM: 02

Student Members: 224

TOTAL STRENGTH: 2,294

GEM 26 PROF. N. KRISHNA RAJU – DISTINGUISHED TEACHER, CONSULTANT AND POPULAR AUTHOR OF ENGINEERING BOOKS

by Dr. N. Subramanian



Dr. N. Krishna Raju (b. 1934)

Dr. Naryana Krishna Raju, hails from an illustrious family of Mysore Palace Artist headed by

K. Kesavayya, the disciple of the legendary artist Raja Ravi Verma of Kerala. As a young boy he was groomed by his grand father Kesavayya, who was commissioned by The Maharaja of Mysore, Nalwadi Krishna Raja Wodeyar to prepare several large oil on canavas paintings of the famous Dasara procession held during the Navarathri festival. These paintings are now exhibited at the Ambavilas hall of the famous Mysore palace and attract the attention of the tourists. After his early education in Mysore, he moved to Bangalore to pursue his engineering studies and earned his bachelor's degree in civil engineering. Thereafter he gained practical experience by working at Bhadra Hydro electric project started by Mysore Public Works department. After resigning, he moved to Madras to pursue his post graduate course in structural engineering along with teaching of undergraduates at the college of Engineering, Guindy. From 1962 to 2000 he has served as an engineering teacher, research guide and consultant at various engineering colleges in India and abroad before retiring as emeritus professor at M.S. Ramaiah Institute of technology, Bangalore. Dr. Raju is a Member of the Institution of Structural Engineers (London), Institution of

Engineers (India), Indian Concrete Institute and the Indian Society for Technical Education.

EARLY LIFE AND EDUCATION

Shri. Naryana Krishna Raju was born in 1934 at Mysore and had his lower secondary education at Sharada vilas middle school and his higher secondary school education at Mysore Maharajas High school. After completing his Intermedite examination from the Yuvaraja College in 1953, he moved to Bangalore and completed his Civil Engineering degree at the Government College of Engineering, University of Mysore in the year 1957 with the unique distinction of topping the university during all the four years of his engineering studies. In the Mysore university convocation held in 1958, he was awarded the coveted B.V. Krishna Ivengar and B.B. Garudacharya Gold medals and Sir Bowen Memorial cash prize for topping the university rank list in Civil engineering stream.

JUNIOR ENGINEER – BHADRA DAM & BANGALORE WATER SUPPLY PROJECTS

Soon after graduation, he worked as junior engineer at the work site of Bhadra dam construction site at Lakkavalli and earned practical experience of dam construction and related works during 1957 – 58. He has also worked in the water supply scheme for the city of Bangalore planned by the Mysore Government to bring water from Cauvery and Hemavathi rivers to Bangalore city. In 1959, on deputation from PWD, he joined the College of Engineering, Bangalore as a lecturer. Driven by his intense desire for

higher studies and teaching, he resigned the Mysore P.W.D job, and joined the College of Engineering, Guindy (CEG), Madras after being selected as a Technical Teacher Trainee by the Ministry of Scientific Research and Cultural Affairs of the Government of India (GoI) in 1959.

TECHNICAL TEACHER TRAINING AT COLLEGE OF ENGINEERING, GUINDY, MADRAS

The Gol planned a novel scheme in 1959 to train engineering teaching cadre by selecting top ranking graduates from various universities of India similar to that of B.Ed. and M.Ed. available to the arts and commerce graduates. After selection, they were posted to prestigious engineering institutions at Roorke and Madras for training. These teacher trainees had to teach UGs and also attend PG classes and complete the course in 2 years and the third year was devoted to teach fully the UGs. Krishna Raju successfully completed his master's degree in Structural engineering and the training course by 1962.

As per the contractual obligations with the central government the teacher trainees had to serve as teachers in several regional engineering colleges, started in every state, for a period of three years. Accordingly, Raju served as lecturer in civil engineering at the Regional Engineering College, Calicut, Kerala from 1962 to 1965 before proceeding to join the university of Leeds, U.K as a commonwealth research scholar in September 1965.

DOCTORAL RESEARCH AND TEACHING AT LEEDS AND COVENTRY (U.K)

During 1965-68, Er. Krishna Raju pursued his doctoral research at the civil engineering

department of Leeds University under the guidance of professors E.W. Bennett, R.H. Evans, and A.M. Neville. The well equipped George Earl laboratory in the department helped him to plan experimental research on fatigue of concrete leading to the award of Ph.D degree in 1968. During his stay for 3 years at the Leeds University, he had the opportunity to meet famous professors like A.L.L. Baker, O.C. Zienkiwicz and Fritz Leonhardt during their lecture programs. During 1968-69, he served as lecturer in civil engineering at the College of Technology, Coventry U.K., and returned to India and joined the Indian Institute of Science, Bangalore as pool officer attached to the civil engineering department.

TEACHING & RESEARCH AT KARNATAKA REGIONAL ENGINEERING COLLEGE (KREC), SURATHKAL

In 1969, Dr. Krishna Raju joined the civil engineering department of KREC, Surathkal as assistant professor and in 1974 promoted as professor. During his stay there for a decade, he taught and guided PG students in the Industrial Structures stream. He also developed the laboratory facilities for research and guided number of PG students which resulted in a number of papers in national and international journals. He also actively participated in technical consultancy programs of the department. Prominent among them are (1) Report on Non destructive testing and restoration of structural concrete elements of the Sirisi college buildings, (2) Report on tests on the silos of the Mangalore Fertilizers and Chemicals factory, (3) Design of Prestressed concrete roof trusses for the Mangalore harbour project, and (4) Report on the use of Foamed slag for the manufacture of building blocks for the Bhadravathi Iron and Steel Works.

VISITING PROFESSORSHIP AT UNIVERSITY OF BASRAH, IRAQ

During 1979-82, Dr. Raju served as visiting professor of civil engineering at the University of Basrah, Iraq, when the Iraqi government headed by the military ruler Saddam Hussein started several universities to improve the educational standards of that country. The faculty comprised of professors from Europe, U.K, Egypt and India. The first two years passed of peacefully but in the year 1981-82, war erupted between Iraq and Iran and the city of Basrah being close to the border with Iran suffered extensive bombing raids. By the end of 1982, Dr. Raju returned to India and joined M.S. Ramaiah Institute of Technology in Bangalore.

PROFESSOR AT M.S. RAMAIAH INSTUTUTE OF TECHNOLOGY, BANGALORE

M.S. Ramaiah Institute of Technology was the first private college approved to run a post graduate course in Structural engineering from Bangalore Dr. Raju was invited to join as University. professor to guide PG students and to develop the structural engineering laboratory for undertaking consultancy projects. Accordingly, heavy duty testing facilities for testing of large structural concrete beams and slabs and the associated instrumentation facilities were developed in the laboratory. During his long stay of nearly two decades in the college, he authored several text books useful to the students and the civil engineering faculty. Dr. Raju motivated his colleagues also to jointly author some text books.

Dr. Raju was invited by several engineering institutions to conduct short term courses under the quality improvement program for engineering teachers. He also led structural testing teams

undertaking consultancy projects involving testing and restoration of several distressed structures in Bangalore. After retiring in 1994, he was reappointed as visiting professor and continued his services to the college up to 2000. Thereafter he spent most of his time in revising his monographs and many of his books have seen five to six editions.

AWARDS

During his long innings as professor and consultant, Dr Krishna Raju was bestowed with several awards, which are listed below.

- Garudacharya and Krishna Iyengar Gold Medals, University of Mysore, 1958
- Sir Bowen Memorial Prize, University of Mysore, 1958.
- 3. Institution of Engineers (India) Prize, 1974.
- 4. George Oomen Memorial Prize, Institution of Engineers (India), 1976.
- Best Teacher Award M.S.R.I.T, Bangalore, 1987
- 6. U.P Government National Award, I.S.T.E. 1988
- 7. Birla Super Endowment Award, I.C.I. 1996
- 8. Tor-steel Foundation, Eminent Engineer Award. 2004
- ACCE(I)-Nagadi Award for best book in Civil Engineering for his book Reinforced Concrete Design: Principles and Practice, 2006
- Indian Concrete Institute Life Time Achievement Award, 2009
- Vocational Excellence Award Rotary International, Bangalore, 2019
- Engineer/Teacher Excellence Award Lions Club, Bangalore, 2019

PROMINENT PUBLICATIONS

Papers in Journals and Conferences

During his long professional career as teacher, researcher and consultant, Dr. Raju actively participated in several conferences and published over 100 papers in National and International Journals. A few prominent papers are listed below.

- N.K Raju, "Cumulative Fatigue Damage of Plain Concrete in Compression", Proc. of the International Conference on Structure, Solid mechanics & Engineering design in Civil Engineering Materials, Southampton, U.K, April-1969. John Wiley, 1971, pp. 1089-1102.
- N. Krishna Raju, "Production & Properties of Laterite Aggregate Concrete", Materials & Structures (RILEM), Paris, V.5, No. 29, 1972, pp. 307-314.
- N. K. Raju, "Prediction of the Fatigue Life of Plain Concrete in Compression", Building Science, U.K. Vol. 4, 1969, pp. 99-102.
- N. Krishna Raju et al, "Production and Properties of High density Concrete using Haematite Aggregates", International Symposium on Innovative World of Concrete, 1993, ICI-IWC, Bangalore, India, pp. 3-305 -313.
- N. Krishna Raju, et al, "A Critical Review of the Indian, British and American Methods of Concrete Mix design Procedures", Indian Concrete Journal, V. 63, 1989, pp. 196-201.
- N. Krishna Raju, et al, "Limit State Design of Partially Prestressed Pretensioned Transmission Poles", International Symposium on Prestressed Concrete, Poles, Pipes, Pressure vessels and Sleepers, S.E.R.C. Madras, 1972, pp. 1-13.

Monographs



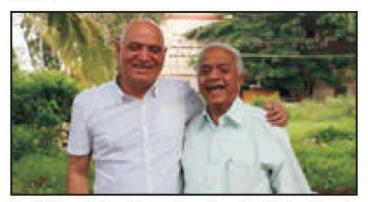
The text books authored by him were popular and adopted in several universities in India and abroad, and are listed below

- Design of Concrete Mixes, C.B.S, New Delhi,
 1st Edition-1974, 5th Edition-2014
- Prestressed Concrete, McGraw-Hill, New Delhi, 1st Edition -1981, 6th Edition -2018 (This book has been translated into Indonesian Language by Suryadi & published by Penerbit Erlanga, Jakarta, Indonesia in 1986)
- Design of Reinforced concrete Structures, C.B.S, New Delhi, 1st Edn-1984, Fourth Edition -2016.
- Advanced Reinforced Concrete Design (IS: 456-2000), C.B.S, New Delhi, 1st Edition 1986, 3rd Edition -2016. (This book has been translated to Arabic by Razia University Press, Iran)
- 5. Design of Bridges, Oxford & I.B.H, New Delhi, 1st Edition-1988, 5th Edition-2017.
- 6. Numerical methods for Engineering Problems, Macmillan, New Delhi, 1989.
- Structural Design and Drawing (R.C.C & Steel), Universities Press, Hyderabad, 3rd Edition - 1992.
- Prestressed Concrete Bridges, C.B.S, New Delhi. 2009.
- Prestressed Concrete (Problems & Solutions)
 C.B.S, New Delhi, 3rd Edition-2015.

- Advanced Mechanics of Solids & Structures, McGraw Hill, New Delhi, 2019.
- Reinforced Concrete Structural Elements (IS, BS & ACI Codes), New Age International, New Delhi, 2003.

EXTRA CURRICULR ACTIVITIES

Dr. Raju being a keen sportsman from his college days, continued playing tennis, shuttle badminton and table tennis throughout his academic career. As a life member of the Vijayanagar club, Bangalore from 1983, he captained the clubs table tennis team to participate in the annual sports competitions conducted by several clubs in Bangalore. In the year 2003, He started the Vijayanagar Senior Citizens Forum for social activities and retired as president in 2019. He also started the Jai Maruthi laughter yoga club in 2003 and serves to date as an anchor and counselor spreading the message of "LAUGH, LOVE & LIVE".



Dr. Krishna Raju with Laughter Guru Dr. Madan Kataria



Dr. Krishna Raju with Spouse Pramila Raju

Dr. Raju is ably assisted by his wife Pramila Raju in typing and formatting of his several books and the couple is blessed with two daughters. His elder daughter K. Sarvamangala an HRD specialist is settled in Freemont, California with her husband Kumar and son Srikanth who are computer engineers. The younger daughter K. Amrutha, a commerce graduate is married to S. Balakrishna Raju, presently serving as Garrison engineer at Port Blair, Andaman Island. The younger couple is blessed with a daughter Lekha Raju now pursuing her degree course in Computer science.

Dr. Raju with his routine activities of Laughter club, Vijayanagar citizen's Forum, Spiritual meetings and indoor sports is enjoying his life as a super senior citizen in Bengaluru.

About The Author



Dr. N. Subramanian is an award winning author, consultant, researcher, 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 26 books, including the famous books on Design of Steel Structures, Design of RC Structures, Principles of Space Structures, and Building Materials, Testing and Sustainability.

Email: drnsmani@yahoo.com

USE OF PRESTRESSED CONCRETE IN BUILDING CONSTRUCTION

By Prof. M G Gadgil

An attempt has been made to focus use of prestressed concrete in building construction. Various aspects have been touched up that are faced by Structural engineers in the design process. The aspects briefs disused are -Introduction with historical background, Materials of construction, Hardware and equipment used, Types of structures under different conditions, RCC v/s pre-stressed concrete, Pre tensioned, post tensioned, bonded and unbounded prestressed concrete, Basic design concepts in prestressed concrete, Loss in pre-stress, Anchorage zone stresses, Permissible stresses, When to use and when not to use PT, Software used in industry for designing pre-stressed concrete structures, Additions and alterations in PT slabs, New trends in PT slab design and construction, Codes of practice Indian and other countries, Role and responsibilities of main RC designer certifying stability of PT components, sample example and Concluding remarks.

1. Introduction and historical background

Prestressed concrete is defined as a concrete in which there have been introduced internal stresses of such magnitude and distribution that the stresses resulting from given external loadings are counteracted to a desired level. Earliest attempt of using this concept was by Mr P H Jackson in 1872 in California USA. He added steel rod into masonry unit and stressed them with a threaded device. The concept he used was correct but the steel of those times were was a very poor by todays standard and hence applied compressive force did not last long. With

development of high grade steel the effective available force increased which led to the development of this concept further by Eugene Freyssenet around 1926-28.

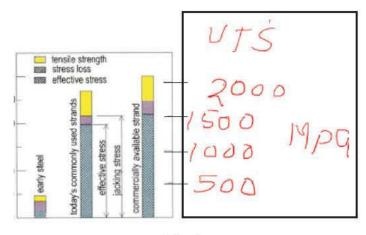


Fig 1

As seen in figure 1, for low grade steel effective stress (after losses) is about 15-20 of UTS while for current high grade steel it is 75 to 80 % of UTS. Freyssenet developed full fledged PT system with its hardware and equipments. By 1950 the building industry in USA started using this concept for flat slab construction. Principal design tools for these applications were developed by T. Y. Lin through the concept of "Load balancing". This concept initially developed for slabs of uniform thickness were later on extended to more complex applications like flat slab with drop panels, beam slab system etc by Alami in 1990, Software tools like ADAPT and PTdata accelerated the use of prestressed concrete to more complex problem of the current era.

2. Materials of construction:

Materials which go into prestressed concrete structures are listed below

- Concrete: generally of grade M35 and above
- High strength Steel: wires/strand with UTS ranging from 1800 to 2000 Mpa
- Non prestressed steel : normal reinforcement of grade Fe 415/Fe500
- Grout for bonded strands : cement sand grout to prevent corrosion of PT strands

3. Hardware and equipment:

Use of pre-stressed concrete requires many specialized hardwares, tools, equipments and sundry items. These specialized items are generally readily available off the shelf and each agency needs to have its own source of procuring the same or manufacturing the same.

- Anchorage devices consisting of anchorage block and wedges, and a device for dead end if stressing is done from one end only
- ii. tendon support rebars or chairs to create design profile for the tendons
- iii. pocket formers at surface of concrete for nose of stressing jack
- iv. stressing jack
- v. grout mixer and pump
- vi. sheathing for bonded cables

4. Types of structures under different conditions:

Prestressed concrete is generally used in following type of structures or structural systems

- Flat slabs with or without drop panels and bad beams
- ii. Edge supported slabs
- iii. Waffle slabs
- iv. Transfer girders, bridge girders
- v. Nuclear containment structures
- vi. Large span shell roofs

5. RCC v/s pre-stressed concrete:

Major differences between the concepts and technologies used in conventional RC structures and more recently introduced prestressed concrete structures are given below

Reinforced concrete

- Concrete can have low strength M20, M25 etc.
- Steel reinforcement is MS, Fe415, Fe 500 etc
- Concrete cracking is acceptable
- Structure can be in compression or tension or flexure
- Structure can have any length
- Unskilled labour can handle it
- Very few specialized equipments are required
- Working cycle is of short duration

Prestressed concrete Concrete shall have high strength M35 and above HT stands of grade 1800 and above

Concrete cracking is controlled structure shall be in tension or flexure

Structure shall have long length highly skilled and competent workers needed special equipments and tools are needed

working cycle is of somewhat longer Duration due to extra activities of laying of cables, stressing of cables and grouting

Pre tensioned, post tensioned, bonded and unbonded pre-stressed concrete

In prestressed concrete construction we have several options of selecting materials and processes depending upon availability of materials and also depending upon type of application. Engineer with enough experience can take decision in these respect depending on the application etc.

In pretensioned systems the cable is stressed before concrete is poured into formwork while in post tensioned systems, cables are stressed after concrete develops sufficient strength usually 0.6fck or more. Pretensioned system is generally adopted for precast prestresseed products lipe precast beams, poles, sleepers etc.

Bonded system of prestressed concrete is the oldest prestressed concrete system developed historically while unbonded system is of more recent origin. Loss of prestress force is more in case of bonded system while it is less in unbonded system

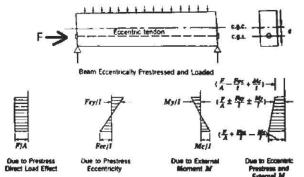
7. Basic design concepts in pre-stressed concrete:

There are three different concepts in the design of pre-stressed concrete structure. These concepts are

- i. Stress concept
- ii. Force concept
- iii. Load Balancing concept

Each of these concepts are explained briefly in the remaining part of this section

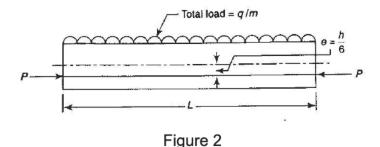
i. Stress concept: In this concept, flexural and axial stresses are calculated in a member due each of the applied forces viz applied prestressing force (with or without eccentricity) and gravity loads (self wt, SDL and live load). Conceptually these stresses are calculated as per the stages given in sketch below



Final stresses, calculated due to application of all forces, are then controlled to a desired level for satisfactory design of the structural element.

ii. Force concept: In any given section of a prestressed concrete beam, the combined effect of the prestressing force and externally applied load will result in a distribution of concrete stresses that can be resolved into a single force applied at some point in the x section. The locus of the point of application of this resultant force in any structure is termed as "the pressure or thrust line". This concept of pressure line is very useful in understanding the internal load carrying mechanism of a prestressed concrete section

In a prestressed concrete members, the location of pressure line depends upon the magnitude and direction of the moment applied at the section and magnitude and distribution of stress due to prestressing force



For the simply supported beam of figure 2 carrying UDL stresses at different points are given in

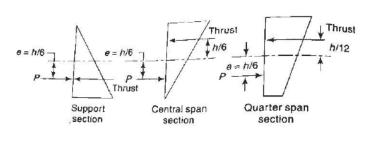
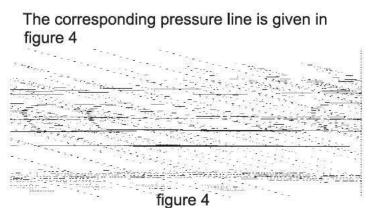


Figure 3



iii. Load balancing concept

In a prestressed member, it is possible to select a proper cable propile such that transverse component of cable force balances the given external loads. This can easily be reasoned by considering free body diagram of concrete with tendon replaced by forces acting on concrete section. Different cable profiles and the equivalent load developed by them are given in figure 5 below

Tendon profile	Equivalent moment or Load	Equivalent loading
c.G.	M = Pe	M M
C.G.	$W = \frac{4Pe}{L}$	
- LIZ + LIZ +	$W = \frac{8 Pe}{L^2}$	14
C.O.	$W = \frac{Pa}{aL}$	al w
	figure 5	<u></u>

The concept of load balancing is useful in deciding profile of the cable inside a beam/slab. Generally the cable profile shall be similar to the Bending moment diagram due to applied loads on beam which the prestress tries to resist.

- 8. Loss in pre-stress: The initial prestress in concrete undergoes a gradual reduction with time from initial stage of stressing and transfer (or at the time of release of jacks at end). There are various causes which are responsible for this loss. Various types of losses are listed below with some explanation appropriate to them.
- i. Elastic shortening of concrete when cables are

stressed successively (one after the other). Length of cable between end anchorages reduce resulting in loss of strain and hence stress

- ii. Creep of concrete: Inherent property of concrete which increases strain of concrete over period of time (at constant stress)results in effect same as i above
- iii. Shrinkage of concrete: Concrete Inherent property of concrete over period of time results into decrease in length of concrete which has same effect as I above
- iv. Relaxation of steel The property of steel which causes molecular adjustment inside body of steel resulting into loss of stress in steel
- v. Slip at anchorage average of 2 to 4 mm: this an unavoidable phenomenon at stressing end of cable where in cable gets locked after the conical wedge moves forward resulting into slippage of cable before it gets locked completely.
- vi. Loss due to bending of member : due to bending of member the distance between end supports slightly reduces resulting into effect similar to l'above
- vii. Loss due to friction between tendon and surrounding sheathing: entire applied force is not

transmitted to cable but some part gets resisted by friction between wall of sheating and cable. For unbounded cables this loss is almost absent.

Quantification of these various losses is given below

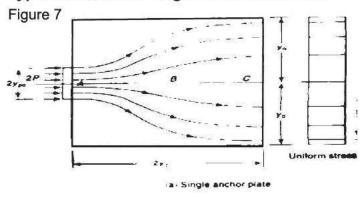
Figure 6

Elastic shortening and bending of	Pretensioning,%	Posttensioning,%
concrete	4	1
Creepof concrete	6	5
Shrinkage of concrete	7	6
Steel relaxation	8	8
Total loss	25	20

Other losses generally contribute to additional loss between 5 to 8 %.

9. Anchorage zone stresses: Due to application of heavy concentrated forces at end anchorages, complex three dimensional state of stress is developed there. This type of transient state of stress exist upto a length equal to depth of beam (approx.) Many researchers have worked on this problem and have suggested several empirical formulae to be used in the design of reinforcement in this length called end zone. To properly resist these high stresses, section of beam is generally increased in this zone and extra reinforcement is provided in all three directions. Several codes have prescribed different formulae for tacling these high stresses in end zone. Some of the important stresses and phenomena are shown in the figures below

Typical stress flow diagram in anchor zone



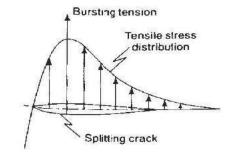


Figure 8

Tensile stresses in transverse direction due to poisson's effect.

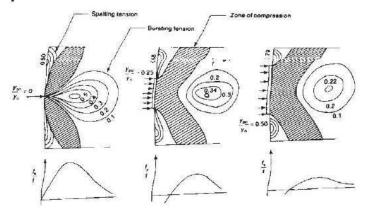


Figure 9-Typical state of stress in end block

10. Permissible stresses: Permissible compressive and tensile stress in concrete at the stage of transfer (of prestress) and service loads are defined in terms of corresponding compressive strength of concrete at that stage. Thus as per IS 1343-2012 the permissible compressive stress in flexure is given by the relation shown in figure 10

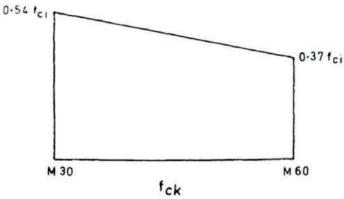


Figure 10. Permissible compressive stress in flexure at transfer

Similarly permissible stresses in compression in concrete at service are given in figure 11

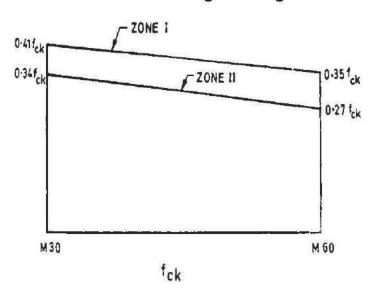


Figure 11 (Taken from IS 1343-2012

- Zone I: It is a section where stress in concrete is NOT LIKELY to increase in service
- Zone II It is a section where stress in concrete is likely to increase in service
 Permissible stress in tension in concrete is related to the type of structure and its exposure condition. Thus as per the code

Type 1 — No tensile stress.

Type 2 — The tensile stress shall not exceed 3 N/mm². However, where part of the service loads is temporary in nature, this value may be exceeded by 1.5 N/mm², provided under the permanent component of the service load the stress remains compressive.

Type 3 — For type 3 members in which cracking is permitted, it may be assumed that the concrete section is uncracked, and that hypothetical tensile stresses exist at the maximum size of cracks. The hypothetical tensile stresses for use in these calculations for members with either pre-tensioned or post-tensioned tendons are given in Table 8, modified by coefficients given in Fig. 6.

TABLE 8 HYPOTHETICAL FLEXURAL TENSILE STRESSES FOR TYPE 3 MEMBERS

TYPE OF TENDONS	LIMITING	97777 (A)				GRADE
(1)	CRACK WIDTH (2)	M 30 (3)	M 35 (4)	M 40 (5)	M 45 (6)	M 50 and above
Pre-tensioned tendons	mm 0.1 0.2	_	_	4.1 5.0	4.4 5.4	4.8 5.8
Grouted post-tensioned tendons	0.1 0.2	3.2 3.8	3.6 4.4	4.1 5.0	4.4 5.4	4.8 5.8
Pre-tensioned tendons distributed in the tensile zone and positioned close to the tension faces of concrete	0.2	Ξ	Ξ	5.3 6.3	5.8 6.8	6.3 7.3

Taken from IS 1343-2012

11. When to use and when not to use PT: For long span structures in concrete it is always advisable to use prestressed concrete as it significantly reduces the self wt and deflection of structure. This concept is valid for both slab and beam. It is true that there are serious requirements while using prestressed concrete as are highlighted in item 5 above.

12. Softwares used in industry for designing pre-stressed concrete structures

Following softwares are popular among PT designers

ADAPT Builder ADAPT corporation

ii. SAFE From CSIiii. RAM From Bentleyiv. RAPT From Australia

13. Additions and alterations in PT slabs :

Addition and alteration in floor slabs is an integral part of construction industry. Few years back it was considered as Taboo and strictly prohibited. However with better understanding of the behaviour of prestressed concrete beams and slabs, now there is virtually no restriction on any addition/alteration, cutting of holes in pt slab or beam. The engineer incharge must properly use

basic principles of structural mechanics and execute such changes as required by the user of the structure.

- 14. New trends in PT slab design and construction: several new trends are now being seen in the field of prestressed concrete. Some of these trends are listed below
- i. Voided pt slabs
- ii. unbounded tendons
- lii. Prestressed foundation rafts
- Iv partial prestressing (allowing large tensile stresses in concrete)

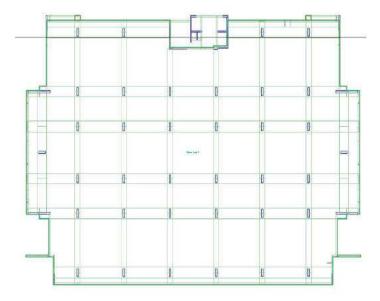
A complete commentary on these trends can be seen in specialized literatures on the topics

15. Codes of practice in India and other countries. A brief list of applicable codes of practice is given below

- IS 1343-2012 Code of Practice for Design of Prestressed Concrete
- ii. ACI 318-2015 Building Code Requirements for Structural Concrete and Commentary
- iii. BS 8110-1997 Structural Use of concrete Part 1 Code of Practice for Design and Construction
- iv. Eurocode EN1992-1-1 Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings
- 16. Role and responsibilities of main RC designer certifying stability of PT components: Prestressed concrete elements like beams, slabs are generally designed by engineer of PT contractor. The data for design, layout, size restrictions etc are generally supplied by the main designer of the structure. Generally these PT elements are designed by the PT contractor for gravity load effects while effects of seismic/wind loads are to be separately added and provided by main designer. For this purpose it

is necessary that main designer should thoroughly check key design parameters and data and satisfy himself about the behaviour of the pt slab as per the PT designer. One important checking which is absolutely essential is to check Dead and live load deflection and BM as obtained by PT designer (who uses more specialized softwares)and by the main designer who uses softwares like ETABS etc. Once this agreement is achieved then effect of lateral load is to be added by the main designer. The stressing data (stress and elongation) is to be properly scrutinized and certified by the main designer. Even the materials (like PT strands, concrete, grout) shall be properly tested and equipments like jack be properly calibrated. The fact of the matter is that main structural is finally responsible for safety of the structure and if the PT designer makes any mistake then apart from him the main structural designer is also held responsible. His licence is at stake. For this reason it is absolutely essential that he understands the intricacies of design of pre-stressed concrete and takes active part in the PT design process. This approach from main structural designer will go a long way in making the structures safer and more reliable.

17. Sample example: Below is shown a specific example of a floor beam slab deck designed using ADAPT software and some preliminary checking of the same being done using SAFE software. This is only a qualitative example just to highlight what kind of outputs are available for comparison.

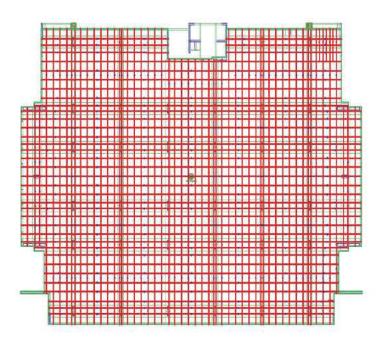


A typical floor plan Modelled in ADAPT software

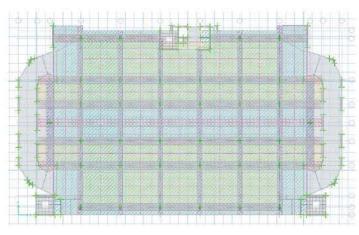
with pt Beams 2000 wide x 400 deep, and 1200 wide x 400 deep, slab 230 thk

And concrete of grade M35

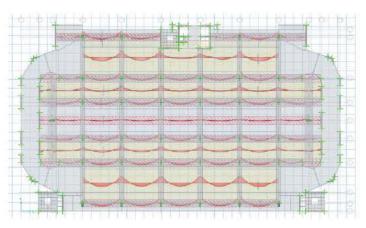
SDL 3 kN/sq m, LL 4 kN/sq m. Grids in x direction are between 10m-11 m while those in y direction are between 6m to 12 m



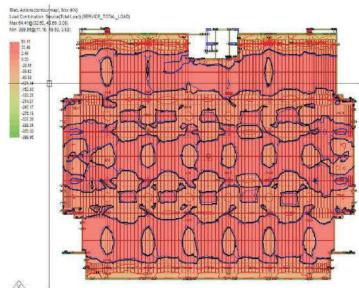
Layout of strands in beams and slab



Same floor modelled in SAFE software



BMD under Dead plus live load from analysis in SAFE software



Slab moment contour under Dead plus live load analysis in ADAPT software

18. Concluding remarks

A brief outline of pre-stressed concrete analysis and design has been presented in this article. It is true that conventional structural designers keep themselves away from the process of design of PT slabs/beams but due to complexities of sharing of responsibilities time has come for them to equip themselves with the intricacies of PT design and at least equip themselves to check whether the PT contractor and his team has done a proper job of designing. Further it is necessary to understand the behaviour of PT beams at ultimate state. The PT strands are not as ductile as conventional HYSD bar (elongation at failure is 14.5% for HYSD bars while it is between 5 to 6 % for PT strands. Further stresses at service state are higher in PT strand (as a percentage of ultimate stress) than the stress level in HYSD bars. All these factors make PT slabs/beams less ductile compared to normal design of RC beams and slabs.

About The Author



Prof. M. G. Gadgil is a retired professor and head Structural Engineering Department, VJTI, Mumbai and independent Consulting Engineer having four decades of experience. He has designed and proof checked variety of steel and concrete structures.

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	"Mandatory Format Of Structural Audit" On 18th Jan ,2020	300/-		
12	Any ISSE Journal Copy	100/-		

Note: Additional courier charges for Mumbai Rs. 50 for outstation Rs. 100).

WHY PERFORM REMAINING-LIFE ANALYSIS FOR BRIDGES & INFRA AND NOT A STRUCTURAL AUDIT

By Dr. Sharvil Alex Faroz

Fear of the Unknown

I am going to assume few things here. You are an infrastructure asset owner or a chief/executive engineer or a minister. You were thinking of the latest bridge collapse and the number of lives lost in it, and the future action plan to avoid such a tragedy. Note, I am using bridges here, but the argument is valid for all critical infrastructures; Power Plants, Ports & Harbours, Dams, etc.

You know how bridges can suddenly collapse prematurely due to deterioration. In fact, after the Gokhale bridge incident at Andheri railway station in 2018, I was involved in a project with Central Railways for the rapid vulnerability assessment of rail bridges. I saw the pain of the officers and engineers very closely in this project; travelling to far off places from home, returning home very late, no time to spend with family, pressure from superiors and ministers, etc. I know how painful it feels being an officer/engineer caught in such a situation.

Imagine the shock and pain you have after your bridge has collapsed and someone or our own loved one is suffering grievously in such an incident. The quick and sudden requirement of funds to treat your family or for rehabilitation of the bridge is unaccounted for and that's why you do not have sufficient money now. Since the Savitri river bridge collapse in 2016, there is atleast one bridge collapse every year in our country. Based on the statistics of national highways (NH) reported in 2017, it is found that, 6551 bridges are structurally deficient and out of these bridges, 86% are below the age of 49 years [3]. This statistic comprises of 5591 minor bridges, 664

major bridges and 296 extra-long bridges [4]. To give you a point of view, the NH bridges are merely 3% of all the bridges in the country; just imagine the vastness of the issue. You don't know beforehand which one of these will collapse first or someone or our own loved-ones become its victim. Is there any salvation? Read on...

Cause of Failure

Leaving aside the deficiency in design and details, "deterioration" is the primary cause of such failures. When the structural performance falls below a specific threshold due to deterioration, is an end of life. Major deteriorations of reinforced concrete (RC) include rebar corrosion due to chloride ingress/carbonation of concrete, loss of concrete strength, loss of prestress and fatigue, etc. You would ask me, "If these are the factors, why bridges still continue to collapse? Can't we control them", Off-course yes! But there is a fundamental block among the engineering fraternity in general...

The Real Cause of Failure

One of the most profound statement I have come across is this, "... RC structures are undergoing deterioration faster, because the mechanism of degradation was not understood well at the time of construction" [5] and was not taken into account in their planning.

In conventional engineering we were not taught to consider deterioration of infrastructures. Remember your 4th year of engineering, we studied 'Design of concrete structures'. We were taught to design for a given distributed load, or a

bending moment, but not taught to design a structure considering, it will corrode in 10 years or how to consider effect of corrosion in design. Thus in essence, the conventional engineers consider the performance of structures as non-degrading over time, see Fig. 1. As such they are unable to handle deterioration at a detailed level. One has to do a detailed study or go for higher education, such as PhD in the subject to understand it.

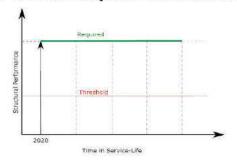


Figure 1: Structural behaviour taught in our engineering
To give you an analogy, suppose you did not
account a particular load in design. What will
happen when that load comes on the bridge — it
fails. Since the engineers did not account
deterioration in design and they are not taught
how to handle it — this is the real reason for

Remaining-Life Analysis

infrastructure failures.

In a common Structural Audit (SA), engineers perform tests on the bridge and evaluate only its instantaneous performance at time t1 (see Fig. 2). They consider the same structural capacity of the previous audit until the consecutive audit is done, at t2. The reason for this is the explanation behind Fig. 1.

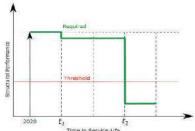


Figure 2: You gain no knowledge about the future from a Structural Audit

It is possible that bridge failure can occur before your next audit (t2) (Fig. 2), because you gain no knowledge about its future behaviour from a conventional structural audit. Mostly the decision to do an audit is initiated based on visual inspection. The New Zealand Transport Agency confirmed that 'visuals can be misleading', because the Sorrell Causeway Bridge suddenly collapsed with no obvious visual distress [6]. This indicates that many, bridges may already be in a severely weakened state while still passing a visual inspection test without detection of damage.

But now, it is possible to tell you just exactly when your bridge is about to fail or when it is due for a major rehabilitation, see Ref. [1, 2]. In a Remaining-Life Analysis (RLA) you are empowered through a deterioration analysis to "see" the behaviour of your bridge in the years to come and inform you proactively when you have a dangerous situation in future, see Fig. 3.

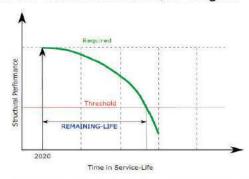


Figure 3: Remaining-Life Analysis proactively prepares you to avoid future calamities

RLA proactively tells you the future behaviour of your structure through strategic data fusion of SHM/NDT and performance model of the structure through Bayesian updating [1]. Both, the SHM/NDT and the performance model cannot stand on their own to analyse the future behaviour of your infra, they must be stochastically combined. Bayesian updating empowers you to realistically analyse the behaviour and lets you account for uncertainties such as design /

execution deficiencies, deteriorations, extreme events and determine the balance life of your project with confidence.

The most important benefits you get from RLA is seen in Fig. 4.

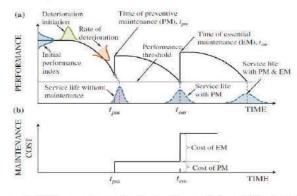


Figure 4: Life-cycle gain from Remaining-Life Analysis, impossible from a Structural Audit

As you already know the behaviour of the bridge in the coming years you are forewarned of its end of life. Usually when there is a sudden collapse you are into panic and might make a hasty decision, unwise for the long run. But because you "see" through RLA you are prepared to combat future rehabilitation by accumulating funds, rather than digging a well when there is fire. Plus you can do a proactive life cycle planning for your bridge (impossible in a structural audit), that can minimise your operation cost, and can achieve a target life extension with confidence. I always say, "Bridges don't demand RLA, they deserve it".

Conclusion

Structural audit is just ok for instantaneous testing, but it cannot provide us confidence about the future performance of the bridge. Remaining-Life Analysis (RLA) is about care and honesty, which can provide confidence and peace of mind to you. It benefits those, who really want to see their Nation as a super power by avoiding its enormous losses from infrastructure failures. There are three

qualifier, to check if RLA is for you: 1) You are wise and knowledgeable, 2) You are proactive, and 3) You don't compromise for the Nation. If you fit in all three criteria, the world is open for you to succeed.

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About The Author



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Email: irms365@gmail.com

ENSURING DURABILITY AT SITE

By Mr. Paresh Unnarkar

Higher Grade of Concrete do not guarantee Durability.

Durability of Concrete can be achieved at site by Ensuring 6C's at Site –

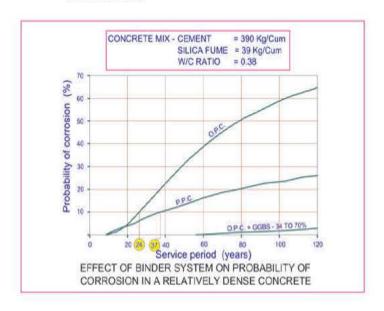
- 1) Cover to Reinforcement
- Cement & Supplementary Cementitious Material
- 3) Concrete Mix Design
- 4) Concrete Mixing, Transporting & Placing
- 5) Compaction
- 6) Curing

1) COVER to Reinforcement -

- Prevent Corrosion of Steel by Carbonation and Penetration of Moisture and Air from the surface
- Give the Reinforcement bar the necessary Embedment to be Stressed without Slipping
- Acts as a Thermal Insulation of Reinforcement bars to protect it from Fire.
- As per IRC 112-2019, Life span of Bridges are 100 years and if want life span of Structure 50 years then just reduce cover by 5mm only. This explains the importance of concrete cover.
- As per BS 7973 Part-1- Minimum Grade of Concrete M50 for Concrete Cover blocks.
- As per BS 7973 Part-1- Concrete Cover Blocks should not be made at site.

2) CEMENT & Supplementary Cementitious Material –

 The overall Durability requirement of the structure should be based on the specification of a certain service period before 10 per cent probability of corrosion is reached.



3) CONCRETE MIX DESIGN-

- In Concrete Use Minimum Amount of Cement + SCM.
- Cement + SCM should be used only for Glue.
- Do not use Cement + SCM as Filler Material
- Well Graded Aggregate shall be used having a Gradation of Particle size that Fairly evenly Spans the size from the Finest to the Coarsest.

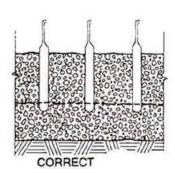
 Use Chemical Admixture to reduce the water content and to give sufficient slump.

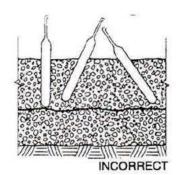
4) Concrete Mixing, Transporting & Placing -

- Use Weigh Batch Mix only.
- Do not use Volumetric Batch Mix
- After all Materials are placed in Drum of Mixer, Mixer should rotate for minimum 90 seconds.
- Concrete should be transported through Wheel Barrow & Hand Cart or through Pumping
- Maximum drop of Concrete should be 1.5m.

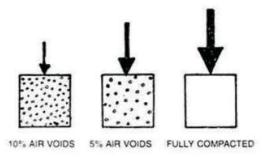
5) Compaction of Concrete -

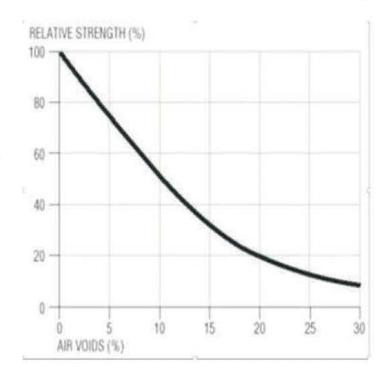
- · Compaction should be done in 2 Stage -
- Stage-1- Liquefaction of the Concrete which allows it to slump and fill the form.
 Time – 3 to 5 seconds
- Stage-2- The Expulsion of Entrapped Air.
 Time 7 to 15 Second.
- · Position of Vibrator





Loss of Strength through Incomplete Compaction

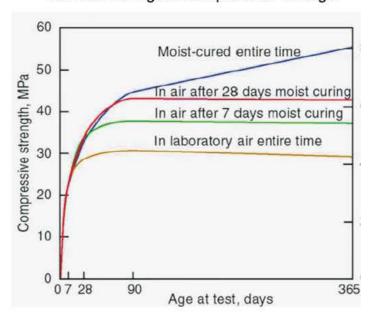




6) CURING-

- · Curing Ensures -
- o Strength
- o Water Tightness
- o Abrasion Resistant
- o Volume Stability
- Start the Curing immediately after the Concrete starts Stiffening/Setting.
- CURING METHOD -1- Sealing of the Mixing Water
- □ Plastic Sheets
- ☐ Membrane-Curing Compounds
 - Waxes, Resins, Chlorinated Rubber etc.
 - Fugitive Dyes, White Pigments.
 - Apply Immediately after final finishing
- CURING METHOD -2-Supply of Additional Water-
- □ Ponding or Immersion
- □ Spraying or Fogging
- □ Saturated Wet Coverings

· Effect of Curing on Compressive Strength



Ensuring 6C's at Site will ensure DURABILITY at Site.

About The Author



Paresh Unnarkar is a Practicing Structural Engineer & Green Concrete Technologist in Vasai Virar region having 30+ years experience.

Email: paresh@unnarkarsgroup.com

Believe it or not



Yes, I am changing my profession as I am getting only 0.3% of the structural cost as consultation fee, and that also not being paid full. With the new profession, I will get minimum 2% of the property cost as fee with least liability, Besides, it can be carried on by my future generations without requiring any technical qualification.

(Courtesy Indian Concrete Journal)

NEWS AND EVENTS DURING OCT – DEC 2020

by Hemant Vadalkar

23 Oct 2020 : ISSE in association with TATA Tubes arranged a knowledge sharing webinar on use of Steel tubes for construction. Mr. Neerajkant Jha from TATA Tubes welcomed all the attendees and set the tone for steel tube discussion. Shantilal Jain President ISSE in his welcome address elaborated use of steel tubes in various infrastructure projects like airports, railway stations, bridges and stadiums. Mr. Hemant Vadalkar, Hon Secretary of ISSE introduced activities of ISSEand appealed to all civil engineers to join ISSE and take active part in knowledge sharing. Prof. M G Gadgil presented various aspects of design of steel structures and tubes in particular. He also elaborated on connection details for tube structures. Mr. Manu Shivananda showed the available products from TATA tube which includes 400x400x20 thick tube and Piles of 610mm diameter in high strength steel are now available. Mr. Murali Krishna shared the available guidelines for connection design and detailing based on CIDECT and Euro code. ISSE and TATA Tubes will jointly come out with reference booklet on steel tube connections. Mr. Viraj Mehta from Maharashtra Pipe Distributors (MPD) thanked all the participants and speakers. The function was attended by more than 90 civil engineers.

28 Oct 2020: "Dr. N. Subramanian, A well known Consultant, award winning author and mentor and also a regular contributor to our journal has recently been elected as a Fellow of the prestigious Indian National Academy of Engineering (INAE). The Academy honours Indian and Foreign nationals who are elected by "peer" committees in recognition of their personal achievements in "Engineering" which are of exceptional merit and demonstrated distinctive eminence in the new and developing fields of

technology. Election to the National Academy of Engineering is among the highest professional distinctions accorded to an engineer. Up to 50 Fellows from Academia, R&D and Industry are elected every year and the total number of Fellows at any one time does not exceed 1000."

7 Nov 2020: IGS Mumbai chapter arranged a webinar on Bearing capacity analysis of Jack up foundation (spudcan) and On bottom stability of offshore jacket platforms. Rupam Mahanta from ONGC made the presentation on the subject covering his work on the subject and some case studies. It was very interesting talk arranged by IGS Mumbai.

9 Nov 2020: Senior Structural Consultant S H Balchandani left for his heavenly abode. He had more than five decades of experience in design of RCC and steel structures. He was very active and attended many seminars arranged by ISSE and IEI. May his soul rest in peace.

2 Dec 2020: Unified development control rules for Maharashtra except Mumbai published and notified. ISSE teams from Pune and Mumbai attended various hearings on those DCPR and submitted suggestions and objections from time to time. A committee to investigate any accident at site can be formed and ISSE local centre member will be on committee. Great achievement for ISSE. Congratulations all active team members!!!

All members should carefully read the duties and responsibility of structural engineer mentioned in the new DCPR apart from design responsibility (adequacy of design as per NBC2016), he has to do many more things. Provide list of tests to be carried out at each stage of work and allow further work after satisfying with the results, verify structural elements at site in compliance with

drawings, document the site visit report mentioning lapses/ deviations if any and inform the same to site engineer. This means, we have to keep record of tests and site visit records for the project which is generally the responsibility of site manager or PMC.

4 Dec 2020: Er. P. M. Deshpande a retired Chief Engineer CIDCO from New Mumbai passed away. Few words about him by Dr. Mohan Dagaonkar. Er. P M Deshpande was not any office bearer of BLC but he was very renowned civil engineer. His contribution to civil engineering is tremendous. As a chief engineer and General Manager (Technical) in CIDCO his work was commendable. He authored many civil engineering books like about' tendering process', 'Romancing with the Soil', Adhyatm and Administration' so on. currently, He was writing on some more topics. He was instrumental in designing, planning Holding Ponds in the City.

He was very humble, polite, compose, soft spoken and always ready to help and guide. He had been on many government assignments after his retirement such as Mihan Airport development, BMC etc. The Institution of Engineers (INDIA) conferred on him Eminent Engineer award in the year 2014 at MSC.

We lost an visionary engineering personality.
Our heartfelt condolences

8 Dec 2020: Madhav Chikodi active technical committee member presented with ISSE memento during a joint site visit by Hemant Vadalkar.



11 Dec 2020 : Joint programme for all Student chapters of ISSE was organized on the web platform. Er. Madhav Chikodi coordinated the event. Senior engineer Vatsal Gokani delivered the lecture on Innovations in the design of high rise buildings. He explained the parameters which are important in the design of high rise buildings such as aspect ratio, framing arrangement, dead load, wind and seismic loads. Deflections under lateral load and vibration control are important aspects for comfort of occupants. He discussed actual design basis report for one 55 storey tall building designed in their office. Students from various colleges from ISSE student chapter attended the program. Students from Walchand College of Engineering managed the web programme. Appeal was made to all students to share their project work synopsis which can be published in ISSE Journal.

28 Dec 2020: ISSE had provided suggestions and comments on published Unified Development control Regulations for Mharashtra as per notification of Govt. related to Structural engineering and civil engineering practices.

Dec 2020: ISSE followed up with Municipal Corporation of Greater Mumbai for simplifying the license renewal process. MCGM had responded positively and the process is simplified. Engineers can renew the license by paying online now. No physical appearance of concerned license holder is required at MCGM Wadala office. These are positive developments. ISSE has also written to various municipal corporations in MMR region to simplify the license renewal process and allow renewal for three years instead of one year.

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Sulphate Content	Less than 1% by MoC in Mix	IS-456:2000 (RA:2016)		
Chloride Content	Less Than 0.5 kg/Cum	IS-456:2000 (RA:2016)		
Water Permeability Test	Less than 6mm	DIN 1048 Part 5:1991		
pH Value	More than 12.6	IS 2720 Part-26:1987 RA 2016		

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