STRUCTURAL ENGINEERING

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INDIAN SOCIETY

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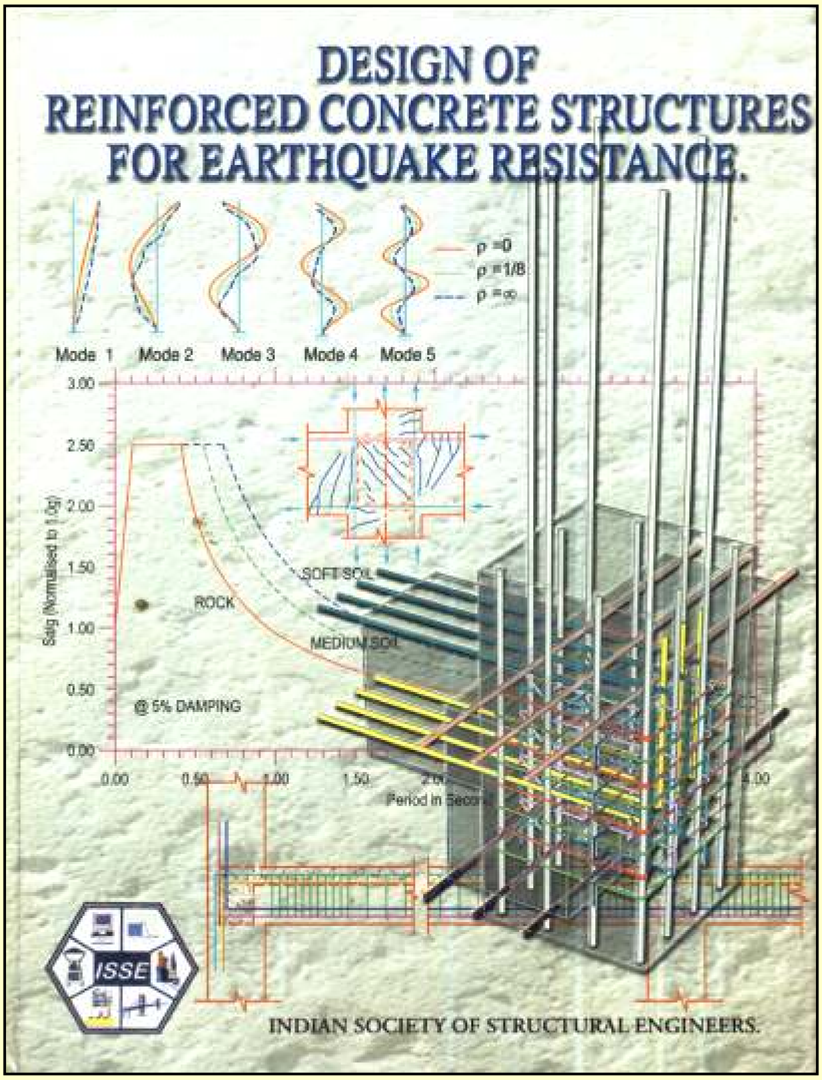
LET US BUILD A STRONG STRUCTURE OF INDIAN SOCIETY

Prof. D S Joshi

We welcome our new President Prof. D S Joshi who is an eminent Structural Engineer having more than 47 years of experience. He has designed variety of structures, done proof checking of many structures, carried out structural inspection of buildings in distress. He has teaching experience. He has published many technical articles and conducted many technical seminars for structural engineers. He is is a good orator.

Shri D. S. Joshi is the principle author of the book "Design Of Reinforced concrete Structures For Earthquake Resistance" published by Indian Society Of Structural Engineers. Mumbai (2001). The book has been awarded ACCE NAGADI AWARD for The Best Publication In Civil Engineering (2004) by ASSOCIATION OF CONSULTING CIVIL ENGINEERS INDIA. "

ISSE will progress under the able guidance of Prof. D S Joshi.
--- All Advisory Trustees of ISSE



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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.

GEMS OF STRUCTURAL ENGINEERING
GEM 5 – JÖRG SCHLAICH

Dr. N. Subramanian & Er. Vivek G. Abhyankar

About this Series of Articles

Dear ISSE members, writing on this series of Gems of Structural Engineering is an immensely joyful experience for both of us. The response by the readers of the Journal is motivating as well as educating to both of us. To give an example, the email by eminent structural engineer and consultant from Mumbai, Dr. V. S. Kelkar was very much inspiring and motivating; he shared his interaction with Prof. S. P. Timoshenko during his M.S degree at Stanford University. Many of you have shared similar valuable experiences with us over emails, phone calls and personal meetings; mentioning all of them here is practically not possible, due to the space constraint, but we whole heartedly thank all of you for boosting our moral to write this series. You may keep communicating your views / suggestions / experiences about these Gems with us and how this article inspired you (especially young members of ISSE).

In this issue, we are presenting to you a living legend, Dr. Jörg Schlaich, a renowned German structural engineer and thinker, internationally known for his ground-breaking work in the creative design of bridges, long-span roofs, and other complex structures. He is a co-founder of the leading firm Schlaich Bergermann & Partner. While we discuss about the work of Dr. Jörg Schlaich, it is very natural to also discuss about the work done by his illustrious son and equally well known structural engineer Dr. Mike Schlaich.

Prof. Jörg Schlaich [1934-]

Introduction, Early life and Education

Mr. Jörg Schlaich was born on Oct. 17, 1934 in Stetten i.R., near Stuttgart, Germany. From 1939-53, he studied in Primary school, high school, and college at Stetten, Heilbronn and Waiblingen (had his apprenticeship as a joiner and carpenter at Stetten). He studied architecture and building engineering from 1953-55 at Stuttgart University. From 1955-59 he studied civil engineering at the Technical University of Berlin. During 1959 he worked as Graduate Assistant at the Institute for Reinforced Concrete with Prof. Dr.Ing. W. Koepke and got his Dipl.-Ing. Degree in Civil Engineering in Feb. 1959. He spent 1959-60 at the Case Institute of Technology in Cleveland, Ohio, USA and obtained his Master of Science degree. From 1959-63, he worked for his Dr.-Ing. Degree in the University of Stuttgart, with Profs. F. Leonhardt and F.E. Bornscheuer, and earned the degree in Sept. 1963. [You may learn more about Prof. Leonhardt from Gem.4 of this series].

Academic Research and Teaching:

From 1967 to 1974 he worked as a Lecturer for reinforced concrete design at the University of Stuttgart; in 1974 he was made Full professor and Director of the Institute for Concrete Structures (Institut für Massivbau) [later called as Institute for Structural Design (für Konstruktion und Entwurf], which post he held till 2000. At the university, he conducted research on a number of subjects which include: wind loads on buildings and bridges, cracking, deformations, plastic design of structural concrete, design of structural concrete using strut-and-tie models, form finding and construction of concrete shells, design and construction of cable and membrane structures, and holistic evaluation of structures.

Consulting and Practice

He started his practice as a Design engineer with Ludwig Bauer, Civil Contractors, Stuttgart, in 1961. After working there for 2 years, he joined his mentor and guide's own consulting office, *Leonhardt and Andrä*, Structural Consulting Engineers, Stuttgart in

1963 as Design engineer and in 1970 rose to become one of the Partners of the company and served there till 1979. In 1980 he established his own consulting firm *Schlaich Bergermann Partner* at Stuttgart along with Dr. Rudolph Bergermann and continues to serve in this firm. This firm now has offices in Berlin, New York, Sao Paulo and Shanghai. Both *Leonhardt and Andrä und Partner* and *Schlaich Bergermann Partner* have given consultancy to numerous important projects all over the world [see www.lap-consult.com and www.sbp.de for details and variety of the projects handled by them]. You may notice that both Prof. Leonhardt and Prof. Schlaich had very successful private consulting practice, while they were holding university positions, as such a practice is allowed in Germany[Many professors in Germany have their own consulting offices also].

Major Projects:

It is not possible to mention all the important projects in which Prof. Schlaich was involved. Hence only a limited number of projects are mentioned here.

Bridges

- Akkar Bridge in Sikkim, India, 1988; cable stayed concrete bridge, spans 77 - 77 m.

Fig. 1 Akkar Bridge, India's first cable stayed bridge-Built by Gammon India, Ltd.

- Kelheim Westtangente Bridge, 1988; P.C. girder, rigidly anchored into abutments with haunches, span 71 m.
- Obere Argen Autobahn Crossing, 1990; cable-stayed/supported steel box deck, A-shaped concrete tower on one side only, span 255 m.
- Evripos Bridge, Greece, 1992; cable-stayed bridge, concrete slab deck for 2 lanes and concrete pylons, length 395 m, main span 215m
- Second Hooghly Bridge, Calcutta, India, 1971-1993; 8-lane cable-stayed bridge, composite deck of 35 m width, length 822 m, main span 457 m.
- Kirchheim Autobahn Overpass, 1993; cable supported concrete slab, spans 18 - 45 – 17 m.
- Macao-Taipa Crossing, 1994; continuous girder with 3 cable-stayed main spans.
- Glacis Bridge across the Danube at Ingolstadt, Germany, 1998; hybrid concrete frame Road Bridge with cable suspension and stress-ribbon pedestrian bridge, length 164 m, main span 105 m.
- Ting Kau Bridge, Hong Kong, 1998; two-span cable-stayed bridge with 448 and 475m main spans, length 1,177 m. 1st prize in "Design und Build" competition with international joint venture of contractors.
- Havel Railway Bridge, Berlin-Spandau, Germany, 1998; A 3-span continuous steel trough bridge with a main span of 72 m.
- Humboldthafen Railroad Bridge, Berlin, Germany, 1999; prestressed concrete structure with tubular steel arch, length 190 m, main span 60 m.
- Bridge over Nesenbach Valley, Stuttgart, Germany, 1999; Jointless concrete slab supported by steel truss and tree-shaped steel pillars, length 151 m, main span 49.5m.
- Railway Bridge Ingolstadt, Germany, 2001; concrete girder reinforced with 'steel sails'.
- Yamuna Bridge Wazirabad, Delhi, 2006; Detailed design of cable-stayed highway bridge with inclined pylon and main span of 250 m, length 575 m.
- About 30 pedestrian bridges of different type (girder, frame, arch, cable suspended, convertible)

Towers

- Communication Towers: Hamburg, 1967; Stuttgart 2, 1970; Mannheim, 1975; Kiel, 1976; Cologne, 1980
- Leipzig Fair Tower, 1995
- Lookout Tower Weil am Rhein with a pedestrian bridge, 1999
- Stuttgart Killesberg Viewing Tower, 2001

Membrane Roofs

- Jeddah Airport Haj Terminal Roofs, 1982
- Riyadh Stadium Roof, 1984
- Nîmes Roman Arena Inflated Roof, 1988
- Montreal Olympic Stadium Retractable Roof, 1989

Fig. 2 Award winning Olympic Stadium, Munich, 1972

- Zaragoza Arena Retractable Roof, 1989
- Stuttgart Gottlieb-Daimler-Stadium Roof, 1993
- Hamburg-Stellingen Ice-Skating Rink Roof, 1994

Fig. 3 Glass roof for the Hippo House at the Berlin Zoo. (Architect: J. Griebl, München)

- Oldenburg Grand Stand Roof, 1996
- NSC Outdoor Stadium Kuala Lumpur, 1997
- NSC Roof over Swimming Pool Kuala Lumpur, Malaysia, 1998
- Tram Station Roof Waldau, Stuttgart, 1998
- Vista Alegre Inflated, Convertible Roof, Madrid, 1999
- Olympic Stadium, Seville, Spain, 1999
- Volkspark Stadium Hamburg, 2000
- Pusan Dome, South Korea, 2001
- Inchon Munhak Stadium, South Korea, 2001
- Vordach Ehrenhof Bundeskanzleramt Berlin, 2001
- Stadium Wolfsburg, 2002

Solar Energy Systems

- Solar Chimney Manzanares, 1982
- Dish/Stirling Systems.

Fig. 4 Gottlieb-Daimler-Stadion, Stuttgart

In his designs, Prof. Schlaich introduced several innovative systems. For example, in the roof of the Gottlieb-Daimler-Stadion (since 2008 Mercedes-Benz-Arena) built in Stuttgart during 1993, Dr. Schlaich introduced the "speichenrad" principle to structural engineering. [Of course, this principle was first employed by the Italian engineer Massimo Majowiecki, in the roof of Olympic Stadium, Rome (built in 1990, three years before the Gottlieb-Daimler-Stadion].

Since then, his company successfully employed it to stadium projects across the globe. In the 40 m tall Killesberg cable-stayed observation tower, at Killesbergpark, Stuttgart, Prof. Schlaich used the cable-stayed bridge technology to construct this unique tower.

Fig. 5 The 40 m tall cable stayed observation tower at Killesbergpark, Stuttgart, Germany.

Another invention of Dr. Schlaich in the year 1980 is the Solar Updraft Tower (popularly known as SUT); In this system, sunshine heats the air beneath a very wide greenhouse-like roofed collector structure surrounding the central base of a very tall chimney tower. The resulting convection causes a hot air updraft in the tower by the chimney effect. This airflow drives wind turbines placed in the chimney updraft or around the chimney base to produce electricity. An experimental plant with a peak output of 50 kW was built in Manzanares, Spain in 1981. For this invension he won the Preis des Deutschen Stahlbau-Verbandes.

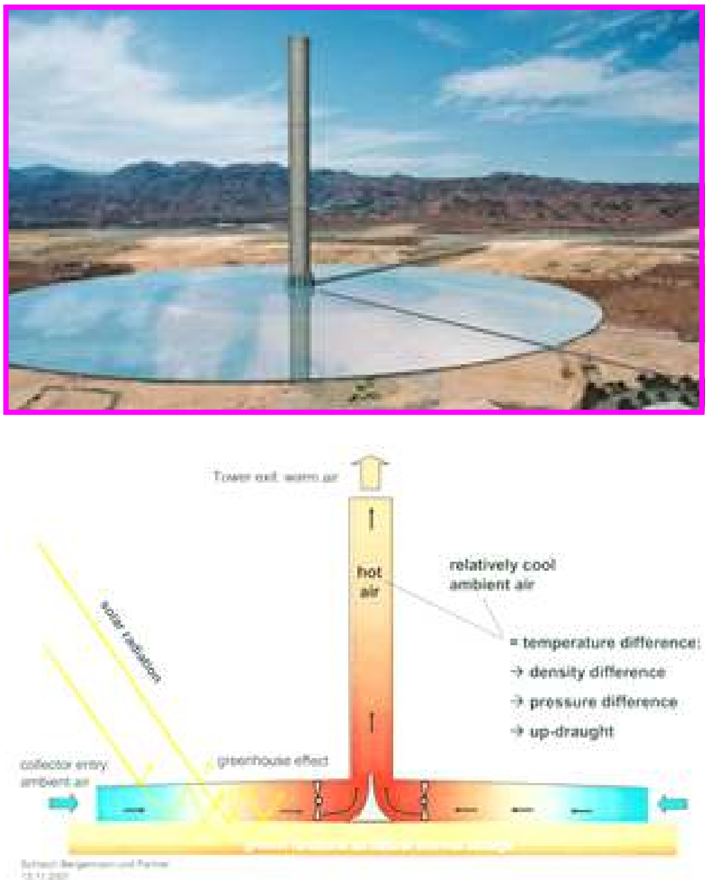
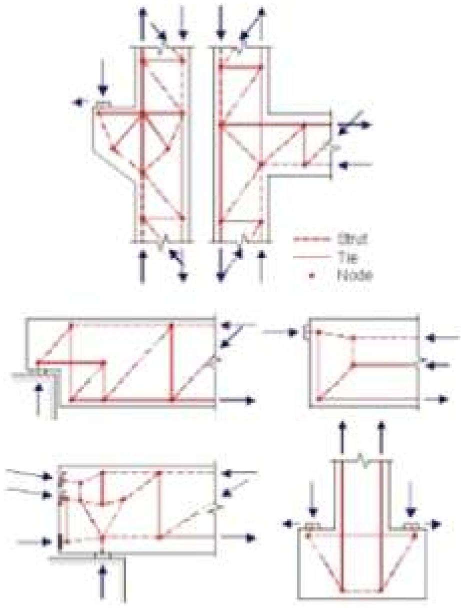
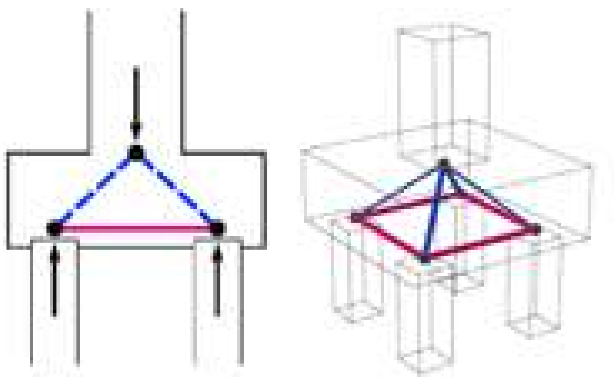


Fig. 6 Solar Updraft Tower (a) in Spain, (b) Principle

He is also credited with advancing the strut- and-tie model for reinforced concrete with his seminal 1987 paper, "Toward a Consistent Design of Structural Concrete" in PCI Journal.



(a)2D – Structure



(b) 3D – Structure

Fig. 7 Typical Strut-and-Tie models for various structural elements

Strut-and-tie models may be used to analyse and design whole members, but the more common application is to use them in "disturbed" regions, known as D-regions. Disturbed regions are assumed to occur at concentrated loads and reactions and at geometric discontinuities. Thus, this extremely useful and simple method can be used in situations where beams have sudden changes in depth, corbels, pile caps, slabs / walls with opening etc. where beam theory can not be applied.

Prof. Schlaich, with the help of his associates, has also designed several breathtaking glass roofs, including free-form shells.

Fig. 8 World Trade Center, Dresden

Membership in Professional Societies

He is a member of many German professional bodies such as VBI,VPI, VDI, DAI, DAfStb, DBV, DASt, DSTV and international associations like IABSE, IASS, FIB and ASCE.

Honorary Membership

Recognizing his contributions to Structural Engineering, he was awarded honorary membership in the following societies:

- Academia de Ingeniería, Madrid (Corresponding Member)
- Indian National Academy of Engineering, New Delhi (Foreign Fellow)
- National Academy of Engineering, Washington (Foreign Associate Member)
- The Royal Academy of Engineering, London (Foreign Member)
- American Concrete Institute (Honorary Member)
- Akademie der Künste, Hamburg
- Akademie der Künste, Berlin

Awards & Honours

He has numerous awards including the following:

- Six honorary doctor's degrees: Hanover, Stockholm, Bratislava, Zurich, Venice, and Lausanne
- Deutscher Stahlbaupreis
- Award of Merit in Structural Engineering of IABSE
- Freyssinet Medal FIP
- Fritz-Leonhardt-Preis
- Fritz-Schumacher-Preis
- Mörsch-Denkmünze des DBV
- Gold Medal, Institute of Structural Engineers, London
- Prix Albert Caquot (French Association of Civil Engineering)
- Swedish Concrete Award
- Werner-von-Siemens-Ring
- Eduardo Torroja Award (IASS)
- Golden Medal Gustave Magnel
- Honorary Professor of HUST, Wuhan
- RIBA Honorary Fellowship, London
- Honorary Professor Tongji University, Shanghai
- The Japan Structural Design Award, Japan Structural Designers Club, Tokyo

Publications

Dr. Schlaich wrote 5 books including:

- Schlaich, J., *Concrete Box Girder Bridges*, IABSE, 1982, 108 pp.
- Schlaich, J., *The Solar Chimney: Electricity from the Sun*, Edition Axel Menges, 1996, 55 pp.
- Schlaich, J., and Hackelsberger, C., *Türme sind Träume*, Avedition GmbH, Ludwigsburg, 2001, 97 pp.
- Schlaich, J., and Bergermann, R., *Leicht Weit (Light Structures)*, Prestel Verlag, 2005, 328 pp.

In addition the following book has been written which describes the works done by him & his team.

Holgate, A., The Art of Structural Engineering: The Work of Jorg Schlaich and his Team, Axel Menges, 1997, 28 pp.

Prof. Schlaich has also contributed over 300 papers in international journals on scientific and practical aspects of structural engineering and delivered numerous lectures at various forums. Some of these lectures delivered by him and his son Dr. Mike Schlaich can be found on website of MIT and Youtube.

Prof. Dr. Mike Schlaich

When we are discussing about Dr. Jörg Schlaich, it is very obvious that we mention about his son, and partner in SBP, who is also an equally renowned Structural Engineer.

Dr. Mike Schlaich-Born 1960 in Cleveland, Ohio

Dr. Mike Schlaich received his Civil Engineering and Doctorate Degrees from the ETH Zürich, Switzerland. In subsequent years, he went to Spain and gained experience in an engineering office in Madrid. From 1993 he worked as a project engineer at SBP GmbH in Stuttgart and in 1999 became one of the partners. He is currently the Managing Director of Schlaich Bergermann and Partner (SBP GmbH), Stuttgart and Professor at the Technical University of Berlin, Faculty VI, Department of Civil Engineering, the Department of Design and Construction - Concrete. In the years before he held temporary positions as lecturer lat ILEK Institute for Lightweight Structures and Conceptual Design at the University of Stuttgart.

He has designed many novel structures under the banner of Schlaich Bergermann und Partner (SBP). He has written many papers about his ideas on light weight structures, cable suspended roofs etc. The well known signature bridge under construction in New Delhi is designed under his capable guidance only.

Fig. 9 Yamuna Signature Bridge Delhi

A specialist in lightweight structures, Mike is a firm believer in a holistic, conceptual design approach, and in engineers' responsibility to contribute more to "baukultur" - that is the concept of producing quality structures to improve quality of life. He also has an enduring interest in creating free, clean, renewable energy by developing solar thermal power plants in the North African desert.

Examples of his remarkable designs can be seen around the world, from the Christian Garden in Berlin, to the Ting Kau cable-stayed bridge in Hong Kong and presently the new Yamuna cable-stayed bridge in New Delhi, India- a single-pylon cable-stayed bridge with a main span of about 250m length will be India's longest-span bridge of this kind. All the projects reflect his belief that engineering should always strive to be elegant.

His award-winning career has brought him in touch with architects like Frank Gehry, the offices of Richard Rogers and Sir Nicholas Grimshaw, engineers like Ted Happold and Fazlur Khan, and even with the artist Christo - on the remarkable Mastaba project.

He received the 2015 Gold Medal by The Institution of Structural Engineers, London, in recognition of his remarkable accomplishments in the field of lightweight structures and the elegant use of concrete, plus his very well known and widely respected engineering publications on footbridges.

His publications include the following book:

Schlaich, M., and Ursula B., *Footbridges-Structure-Design-History*, Birkhäuser Verlag, 2008, 255 pp.

The senior author has met both Jörg and Mike Schlaich and also visited the University of Stuttgart where they worked along with Prof. Leonhardt. He also wishes to thank Prof. J. Schlaich for responding to his article published in *the Indian Concrete Journal* about the status of Civil Engineers in the World.

Acknowledgements

The authors wish to acknowledge that the images used in the article, have been taken from various sources in the Internet.

Reference Literature used for this article :-

- Wikipedia https://en.wikipedia.org/wiki/J%C3%B6rg_Schlaich
- http://www.sbp.de/en
- www.sefiindia.org (Posts published in Engineering Marvels)
- Various youtube videos and MIT website;
- http://video.mit.edu/watch/joerg-schlaich-the-challenge-and-joy-of-structural-engineering-12970/
- Schlaich, Jörg: Glaskonstruktion Hotel Kempinski in München, in: GLAS 2/1995, pp. 30-37.
- Schlaich, J., and Schober, H., Design Principles of Glass Roofs, *Lightweight Structures in Civil Engineering*, *Proceedings of the International Symposium*, Warsaw, Poland, 24-28 June 2002, pp.815-827.
- Schlaich, J., Schober, H. Glaskuppel für die Flußpferde im Zoo Berlin, Der *Stahlbau*, Vol. 67, No. 4, 1998, pp. 3-8.
- Schlaich,J., Bergermann,R., Schiel, W., and Weinrebe, G.,Design of Commercial Solar Updraft Tower Systems – Utilization of Solar Induced Convective Flows for Power Generation, *Journal of Solar Energy Engineering, Transactions of the ASME*, Vol. 127, Feb. 2005, pp.117-124.
- Subramanian, N., Civil Engineering is Noble Too!, *The Indian Concrete Journal*, Vol. 74, No. 9, Sept. 2000, pp. 507-508 (Prof. Schlaich response:http://www.icjonline.com/fo1.htm)

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INTZE - TYPE ELEVATED SERVICE RESERVOIRS – A CASE STUDY

Hemant K. Gor and D. Sarkar

INTRODUCTION

Elevated service reservoirs are important lifelines for a city. Nine Intze-type Elevated Service Reservoirs (ESRs) have been constructed in Ajmer as part of the Rajasthan Urban Infrastructure Development Project (RUIDP) funded by the Asian Development Bank. The ESRs have capacities ranging from 5 lac litres to 15 lac litres. Staging heights vary from 11m to 22m. Reinforced concrete frame-type staging has been adopted. The sizes of the staging circular column and bracing beam sizes have been standardized for all tanks irrespective of capacity and height. The analysis for loads due to earthquakes was performed using the two mass model [2,3].

DESIGN PARAMETERS

The design parameters adopted for the project are listed below:

Grade of Concrete	:M30 (using 43 Grade Cement)
Minimum Cement Content	: 320kg/m^3)
Grade of Steel	: High Yield Deformed Bars, Fe 415
Seismic Zone	: II (IS 1893-2002)
Importance Factor	: 1.5
Wind Pressure	: 1500 N/m^2
Minimum thickness of Water retaining member (specified by owner's consultant)	: 200 mm
Minimum thickness of reinforced concrete member not contact in water	: 150 mm
Clear Cover to reinforcement on face in contact with water	: 45 mm
Clear cover to reinforcement on far face	: 25 mm
Free Board	: 300 mm

General Arrangement of Tanks

Tanks having inner diameter upto 14.5m are provided with a single circular dome roof (see *Fig*. 1). Tanks having inner diameter exceeding 14.5m are provided with a dome of about 14.5 m diameter and an annular slab roof beyond the dome (see *Fig.2)*. The reason for this was that the construction of larger domes at height had practical difficulties. The staging columns with reduced diameter are continued inside tank which supports circular ring beam connecting dome and annular slab. The rise of roof dome is generally $\frac{1}{6}$ to $\frac{1}{7.25}$ of span. The rise of bottom dome is generally $\frac{1}{6}$ to $\frac{1}{5.25}$ of The inclination of conical wall is kept at 40° - 45° with horizontal. These span to rise ratios ensured that hoop tension was not developed in the domes under vertical loads. The staging columns are generally placed on a circle having a diameter of about 0.7 times diameter of tank container. The peripheral walkway, 0.9m wide forms part of middle ring beam.

The diameter of circular staging column is 50cm uniform for all ESRs. The bracing beam size is 30cm x 50cm for all, except the 5 lac litre capacity ESR, for which it is 25 cmx45 cm. The junctions of beams and columns in the staging were provided with haunches of 15 cm x 15 cm. The standardization of the staging column and beam size helped in repetitive use of formwork and faster construction. The tanks are founded on solid circular raft. The depth of foundation was 2.0 m below ground level. The beam column junction reinforcement is detailed confirming to ductile detailing requirements of IS 13920.

Table 2 presents information about locations; staging height, number of staging columns, inner diameter of container, and centreline diameter of staging for nine elevated service reservoirs. The fig. 3, 4 and 6 shows completed view of elevated service reservoirs.

Design Methodology

The tank is designed based on the working stress method confirming to IS 3370 as un-cracked section. The framed staging and the solid raft foundation are designed based on limit state method confirming to IS 456:2000. Table 1 shows load combinations for limit state of collapse for framed staging and foundation.

The tank container is analysed for

i) Membrane forces (Hoop forces and Meridional forces), and

ii) Continuity forces at junctions (bending moment and shear at ends of member).

Analyses were made using a spreadsheet program in

EXCEL. Displacement compatibility conditions were applied at:

1. Junction of main ring beam, bottom dome and conical wall
2. Junction of conical wall, Middle Ring Beam and Cylindrical wall
3. Junction of cylindrical wall, top ring beam and roof dome.

The volume of water inside and self weight of tanks was calculated using mass properties command in AutoCAD. The commands “boundary”, “region”, “revolve” and “massprop” were utilized to calculate volume of concrete in tank and the centre of gravity.

Table 1 Load Combinations for Limit State of Collapse for Staging and Foundation

Combination No	Dead Load	Water Load	Seismic Load / Wind Load			
			X Direction		Y Direction	
			Full	Empty	Full	Empty
1	1.5	1.5	-	-	-	-
2	1.2	1.2	1.2	-	-	-
3	1.2	1.2	-	-	1.2	-
4	1.5	-	-	1.5	-	-
5	1.5	-	-	-	-	1.5
6	0.9	-	-	1.5	-	-
7	0.9	-	-	-	-	1.5

Seismic Analysis to IS 1893:1984

As IS 1893 : 2002 (Part 1) is applicable only to buildings, and Part 2 of the code which will be for elevated structures was not published at the time of the design, IS 1893 : 1984 was adopted for design. The elevated tank staging was treated as a system with single degree of freedom with its mass concentrated at its centre of gravity. The design value of horizontal seismic coefficient (a_h) was computed using response spectrum method. The tank was analysed for two loading cases, tank empty and tank full. The fundamental time period T in seconds is given by the expression

$$T = 2 \cdot p \cdot \sqrt{\frac{m}{K_s}}$$

where

m = mass of single degree of freedom system

= $\frac{1}{3}$ x mass of staging + mass of tank container (for Tank Empty Case)

= $\frac{1}{3}$ x mass of staging + mass of tank container + full mass of water (for Tank full case)

K_s = Staging Stiffness (Force required at seismic mass location for unit deflection at the same location)

The damping in the system was assumed 5% of critical damping for concrete structures and spectral acceleration ($\frac{S_a}{g}$) was read off from Fig. 2 of IS 1893:1984.

$$a_h = b\,I\,F_o \frac{S_a}{g}$$

Seismic Analysis as per Two Mass Model[1,2,3]

The sloshing mass, impulsive mass and sloshing mass stiffness was computed based on geometry of cylindrical tank for tank full case. The elevated tank was regarded as system with two degrees of freedom. The damping for sloshing degree of freedom is 0.5% and for impulsive degree of freedom is 5%. The design value of horizontal seismic coefficient (a_h) is

$$a_h = b\,I\,F_o K \frac{S_a}{g}$$

K = Performance Factor[2,3] =3.0

A comparative study of the magnitude of base shear was performed using following three different procedures,

1. Present IS 1893:1984
2. The two mass model with value of K equal to 3
3. The two mass model with value of K equal to 1

The staging stiffness was calculated based on approximate method[4] and exact analysis. The exact analysis was performed using a 3D frame model in commercial finite element analysis software SAP2000. The seismic base shear results for tank full case are presented in Table 3. The base shear computed was applied at the centre of mass of tank container in 3D frame model shown in Fig 9. The critical column under maximum bending moment is column marked “C” in the figure 3.

Column Reinforcement Requirement

The reinforcement in columns was designed for seismic base shear calculated from IS 1893 : 1984 and two mass model with value of K equal to 3 for seismic zone III (F_0=0.2). The critical load combination for the limit state of collapse was found to be 1.2 x (DL+ Full Water + Earthquake). The reinforcement required with two mass model approach and value of K equal to 3 is about 1.5 to 5.56 times the reinforcement required by IS 1893:1984 (see Table 2). Typical calculation of seismic base shear is presented for the 7.5 lac Litre capacity, 15m staging height ESR.

CONCLUSION

The design of the intze type ESRs with framed staging was standardized for repetitive use of form work and speedy construction. The diameter of staging columns was kept constant for various tanks, and their numbers were varied depending on size of tank. The seismic base shear computed using the two mass model with performance factor value of 3 was found to be 2 to 3 times the value computed using IS 1893:1984 for the tank full case. The seismic base shear using the two mass model with performance factor 1 was found to be 0.62 to 0.9 times the value computed using IS 1893:1984 for the tank full case. The fundamental time period with staging stiffness computed using the approximate method[4] is in close approximation to results from the exact analysis. The reinforcement in columns increases by 1.50 to 5.56 times in the two mass model approach with value of K equal to 3 compared to the present IS 1893:1984 single mass model. The ratio of volume of water to volume of concrete in container was found in the range of 4.62 to 4.82 for intze type tank.

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Credits
Design and Project Management Consultant: STUP Consultants P Ltd
Contractor
: Geo Miller and Company Ltd.

REFERENCES

1. Housner, G.W., "The dynamic behaviour of water tanks", Bulletin of the seismological society of America,1963,53(2),pp. 381-387

2. JAIN, S.K., and MEDHEKAR, P. S., "Proposed provisions for aseismic design of liquid storage tanks: Part I- Codal Provisions", *Journal of Structural Engineering*, 1993, Vol 20, No. 3,pp. 119-128

3. JAIN, S.K., and MEDHEKAR, P. S., "Proposed provisions for aseismic design of liquid storage tanks: Part II – Commentary and Examples", Journal of Structural Engineering, 1993, Vol 20, No.4, pp. 167-175

4. SAJJAD, S. U., AND JAIN, S.K., "Approximate methods for determination of time period of water tank stagings", The Indian Concrete Journal, Dec. 1992

5. Kand, C.V., "Problems of concrete water towers and sump wells", The Indian Concrete Journal, February 1998, pp 91-101

6. Indian Standard Code of Practice for Concrete Structures for the storage of liquids. IS 3370 (Part I-IV):1965. Bureau of Indian Standards

7. Indian Standard Code of Practice for Plain and Reinforced Concrete. IS 456:2000, Bureau of Indian Standards.

8. *Indian Standard* Criteria for the earthquake resistant design of structures. IS 1893:1984, Bureau of Indian Standards.

9. *Indian Standard Code of Practice for Ductile detailing of reinforced concrete subjected to seismic forces.* IS 13920:1993, Bureau of Indian Standards

Location	Kalyanipura	Chaurasiyavas	Foy Sagar	University	Shakti Nagar	Rati Dang	Topdara	Vaishali Nagra	Anted
Capacity(Lac Liter)	5	7.5	7.5	7.5	10	10	12.5	15	15
Staging Height (m)	12	15	12	20	12	13	20	22	12
Tank Internal Diameter (m)	11.5	13.5	13.5	13.5	14.5	14.5	17.0	18.0	18.0
Staging Diameter (m)	8.0	9.4	9.4	9.4	10.15	10.15	10.15	12.6	12.6
Number of Columns(N_c)	10	12	12	12	14	14	16	18	18
Main Ring Beam Size (bxh) (m)	0.5x1.1	.5x1.15	.5x1.15	.5x1.15	0.5x1.2	0.5x1.2	0.5x1.2	0.5x1.2	0.5x1.2
Volume of Concrete (Cu.m) – Tank	107.4	162.3	162.3	162.3	207.5	207.5	269.8	313.0	313.0
Volume of Concrete (Cu.m) – Staging	32.2	51.0	43.4	65.68	44.0	46.6	88.80	106	54.5
Volume of Concrete (Cu.m) – Raft	48	89	89	100	125.6	125.6	296*	142	141
Wall Thickness (Base/Top) (m)	0.2/0.2	0.325/0.2	0.25 / 0.2	0.25/ 0.2	0.325/ 0.2	0.325/ 0.2	0.325/ 0.2	0.350/ 0.2	0.350/0.2
Height of Wall (m)	4.5	4.9	4.650	4.650	5.675	5.675	5.4	5.5	5.5
Number of Tie Beam Levels	2	3	2	5	2	2	5	5	2
Structural Steel Consumption in (MT) – Raft	4.462	6.431	7.137	7.132	9.85	9.466	31.262	10.632	10.632
Structural Steel Consumption in (MT) – Staging	5.569	10.232	8.71	13.099	10.606	11.23	17.89	19.524	13.518
Structural Steel Consumption in (MT) – Tank	12.53	18.939	18.939	18.939	26.113	26.11	51.18	52.771	52.771

Table 2. Detailed Information of Elevated Service Reservoirs for Ajmer * Net SBC is only 7.5t/m^2

Location		Kalyanipura	Chaurasiyavas	Foy Sagar	University	Shakti Nagar	Rati Dang	Topdara	Vaishali Nagra	Anted
Capacity (Lac Liter)		5	7.5	7.5	7.5	10	10	12.5	15	15
Staging Height (m)		12	15	12	20	12	13	20	22	12
Staging Stiffness (kN/m)	Approximate Method	17476	23035	28200	18336	34421	33915	26481.	32216	56987
	Exact Analysis	15693	18172	22573	14401	27189	22173	18997	21603	35373
Time Period (s),IS 1893:1984, Exact analysis		1.43	1.63	1.46	1.85	1.52	1.68	2.08	2.05	1.59
Impulsive mass Time Period (s), Two mass model	K_s(Approximate Method)	1.08	1.14	1.03	1.3	1.07	1.08	1.38	1.27	0.93
	K_s (Exact analysis)	1.14	1.29	1.15	1.49	1.21	1.33	1.63	1.55	1.19
Convective mass time period (s), Two mass model		3.74	4.09	4.09	4.09	4.2	4.2	4.66	4.88	4.88
Base Shear (kN)	Present IS 1893:1984	89.8	171.4	143.2	110.25	187.4	151.52	183.15	203.9	249.4
	Two mass model K=3, approximate method	250.1	354	354.	314	485	482	513	597	630
	Two mass model K=3, Exact method	239.2	322.3	350.3	298.1	442.8	398.3	435.9	493.6	578.6
	Two mass model K=1, Exact method	79.7	107.4	116.8	99.4	147.6	132.7	145.3	164.5	192.9
Column Reinforcement for Z=0.2 (Zone III)	Present IS 1893:1984	8-T12	8-T12	8-T12	8-T12	8-T12	8-T12	8-T12	8-T12	8-T12
	Two mass model K=3, Exact method	8-T20	11-T20	11-T20	12-T12	14-T20	16-T20	14-T20	14-T20	14-T20

Table 3 Seismic Base Shear and Column Reinforcement Comparison

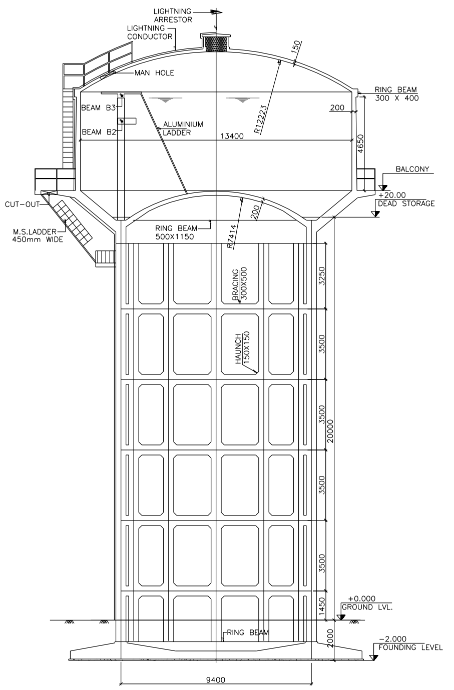

Fig. 1 Typical Arrangement of Tank with Container Diameter <=14.5m

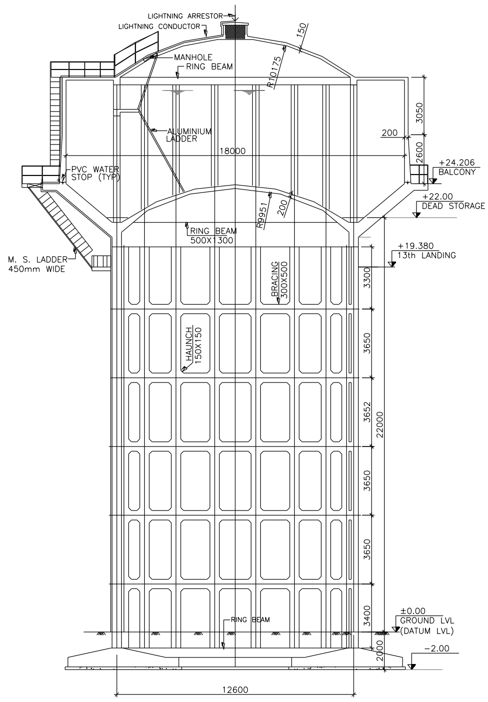

Fig. 2 Typical Arrangement of Tank with Container Diameter exceeding 14.5m

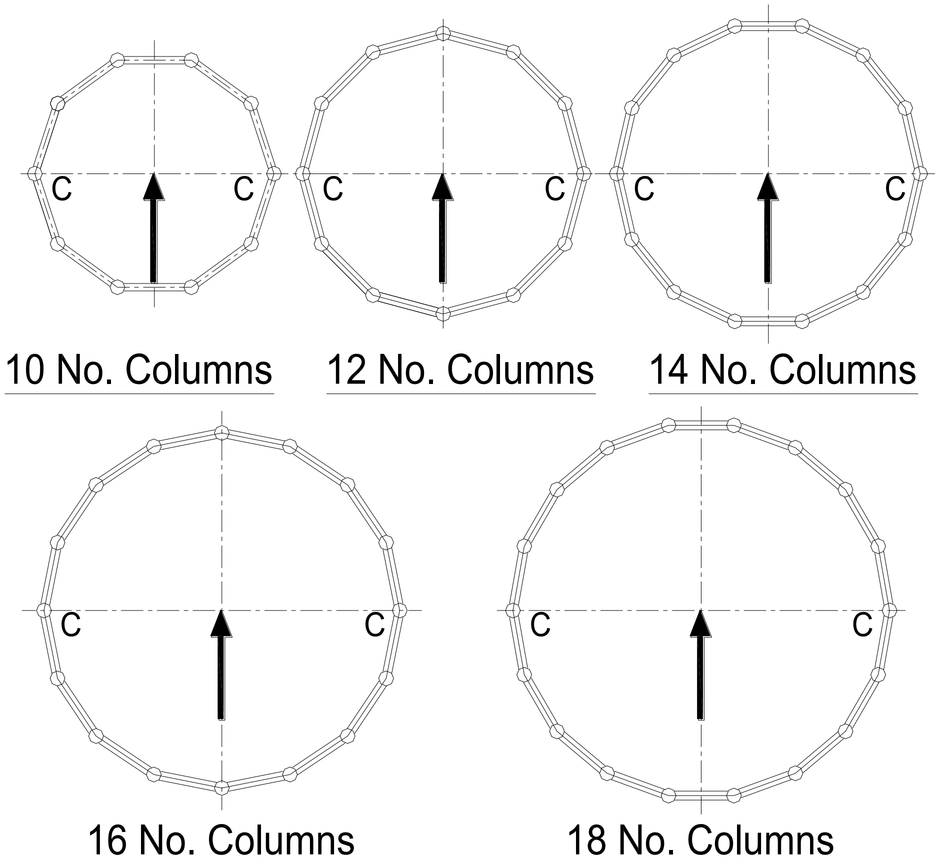

Fig 3 Plan of Staging Showing Direction of Base Shear for Maximum Bending Moment in Column C

Fig. 4- 7.5 Lac. Litre Capacity, Staging height 20m

Fig. 5- 7.5Lac. Litre Capacity, Staging Height 15m

Fig. 6- 10 Lac Litre Capacity, Staging height 13m.

Fig. 7-Conical Wall shuttering Arrangement

Seismic Base Shear Calculation for 750 cu.m capacity, Staging Height 15m ESR

Mass of water in the tank (m)	750t
Height of the tank container	4.9m
Height of water in the tank (h)	4.9m
Radius of the tank container (R)	6.7m
Radius of Staging Column centreline(r)	4.7m
Number of columns (N_c)	12
Mass of the empty tank (m_1)	410t
Mass of the Staging (Beams, Columns and Staircase)(m_2)	128t
CG of the tank mass from base of tank (bottom of centre line of main ring beam)	2.98m

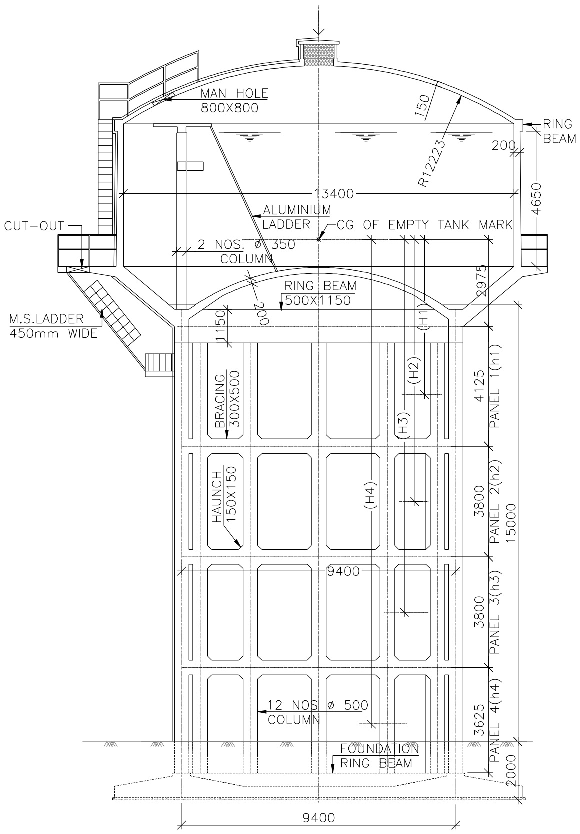

Fig.8 750cu.m capacity ESR

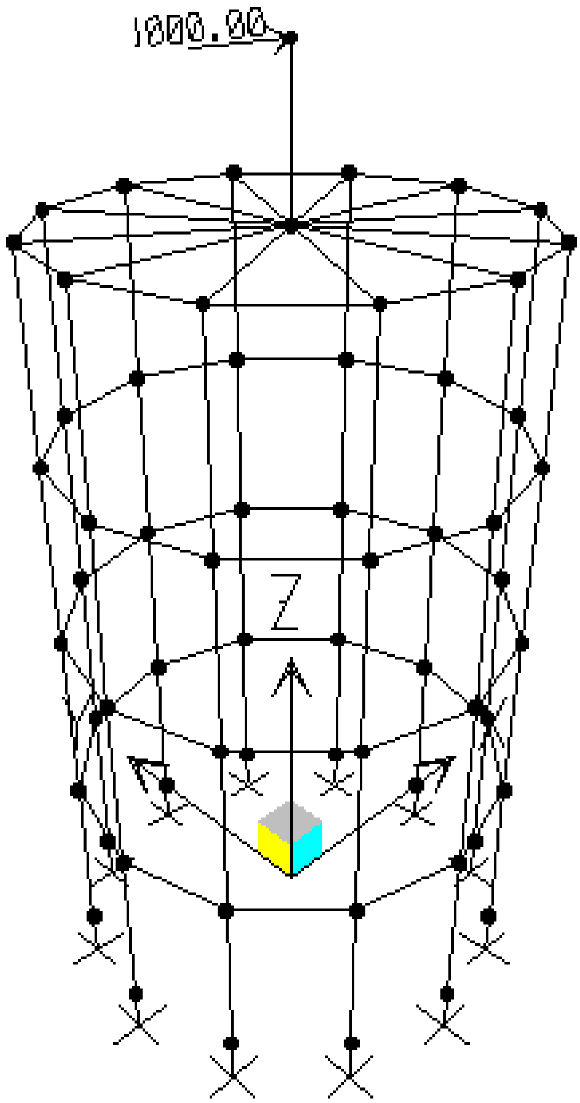

Fig.9 3D Frame Computer Model

A)The Two Mass Model Parameters of Tank

h/R=0.731

g = 1.732 x R/h = 2.368

d = 1.873 x h/R =1.37

Impulsive mass $m_0 = m \cdot \frac{\tanh(g)}{g}$ =311.184t

Convective mass $m_1 = 0.455 \cdot \frac{R}{h} \cdot \tanh(d)$ =409.98t

CG of Impulsive mass above base

$$h_0 = \frac{3}{8} \cdot h \;=1.838\text{m}$$

CG of Impulsive mass above base

$$h_0' = \frac{3}{8} \cdot h\left(1+\frac{4}{3}\left\{\frac{g}{\tanh(g)}-1\right\}\right)$$

CG of Impulsive mass above base

$$h_I = h\left(1-\frac{\cosh(d)-1.0}{d\sinh(d)}\right)=2.773\text{m}$$

CG of Impulsive mass above base

$$h_I' = h\left(1-\frac{\cosh(d)-2.0}{d\sinh(d)}\right)=4.717\text{m}$$

Spring Stiffness of Convective Mode

$$m_I = 0.836 \cdot \frac{m \cdot g}{h} \cdot \tanh^2(d) = 969.104\text{kN/m}$$

B) Calculation of Staging Stiffness

E (Beam and Column Concrete) = 5000x$(f_{ck})^{0.5}$ = 2.5e+07 kN/m^2

Column Diameter (D)=0.5m

Rectangular Beam Dimension = 0.3 m x 0.5m

Moment of Inertia of Column Section

$$I_c = \pi \times \frac{D^4}{64} = 3.067\text{e-}03 \text{ m}^4$$

Cross Sectional Area of Column Section

$$A_c = \pi \times \frac{D^2}{4} = 0.19635 \text{ m}^2$$

Moment of Inertia of Beam Section

$$I_b = \frac{b \cdot d^3}{12} = 3.125\text{e-}03 \text{ m}^4$$

Distance between adjacent Column Centreline (L) = 2xrxsin(180/N_c) =2x4.7xsin(180/12)=2.433m

$$\frac{I_b}{L} = 0.0012844$$

$$\sum \frac{1}{K_{axial}} = \frac{2}{N_c A_c E R^2} \sum H_i^2 h_i$$

$N_c A_c E R^2$ = 1.30e+9 kNm^2

Panel	h_i (m)	Ic/h	$12EI_cN_c/h^3$	alpha	$K_{flexure}$	$1/K_{flexure}$	H_i (m)	$H_i^2 h_i$	$1/K_{axial}$
1	4.125	7.44e-4	247e+3	1	147.575e+3	6.776e-06	5.325	100.66	0.155e-6
2	3.8	8.07e-4	201e+3	2	89.174e+3	11.214e-06	9	307.8	0.473e-6
3	3.8	8.07e-4	201e+3	2	89.174e+3	11.214e-06	12.8	622.59	0.957e-6
4	3.625	8.46e-4	232e+3	1	139.766e+3	7.1548e-06	16.513	988.40	1.520e-6
	14.775				$\sum \frac{1}{K_{flexure}}$=3.962e-05			$\sum \frac{1}{K_{axial}}$=3.1e-6	

$$\sum \frac{1}{K_s} = \sum \frac{1}{K_{flexure}} - \sum \frac{1}{K_{axail}} = 4.27\text{e-}5$$

Staging Stiffness $K_{staging}$ = 2.34e+4 kN/m

The exact staging stiffness is computed using 3D frame computer model on analysis program (Fig. 8). Staging Stiffness $K_{staging}$ Exact Analysis = 1.82e+4 kN/m

C) Calculation of Fundamental Time Period

Tank Empty Case

Mass $(m_3) = m_1 + \frac{m_2}{3} = 452.667t$

Time period (t) = $2 \cdot p \cdot \sqrt{\frac{m_3}{k_s}}$ =0.874s

Tank Full Case

Impulsive Mode Time Period

Impulsive Mode Mass $(m_4) = m_3 + m_0 = 763.851t$

Impulsive Time period (t) = $2 \cdot p \cdot \sqrt{\frac{m_4}{k_s}}$ =1.135s

Convective Mode Period (t_i)= $2 \cdot p \cdot \sqrt{\frac{m_i}{K_i}}$ =4.087s

D) Design Horizontal Seismic Coefficient

Zone Factor (F_0)	0.1(Table 2, IS 1893:1984, Zone II)
Performance Factor (K)	3 (Table 5, Clause 4.2.1.1, IS 1893:1984)
Foundation Interaction Factor (b	1(Table 3, Clause 4.2.1.1, IS 1893:1984)
Importance Factor (I)	1.5 (Table 4,IS 1893:1984, IS 1893:1984)
F_0K b I	0.45

Loading Case		**Time Period (s)**	**Damping**	**S_a /g**	**a_h**	**Base Shear (kN)**	**Design Base Shear (kN)**
Empty		0.84	5%	0.12	0.054	239.8	239.8
Full	Impulsive	1.135	5%	0.1	0.045	337.2	$\sqrt{337.2^2 + 108.6^2}$ = 354.256
	Convective	4.087	0.5%	0.06	0.027	108.6	

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REPORT ON ISSE – LECTURE ON STEEL SHEET PILES 28 APR 2015

By Hemant Vadalkar

Indian Society of Structural Engineers (ISSE) arranged a lectures on Steel sheet piles.

ISSE Secretary P. B. Dandekar welcomed the delegates.

A technical lecture on " Steel Sheet Piles : complete and customised foundation solutions for Urban Infrastructure project" was delivered by Mr. Boris Even , Director- Arcelor Mittal Sheet Piling. He presented case studies of steel sheet piles being used around the world for various applications in urban areas, marine structures, underground construction etc. Application of steel sheet piles was demonstrated for various infrastructure application. Sheet piles can be used as temporary shoring structure which can be removed after the construction. Steel is reusable and green material. Use of steel sheet piles cuts down the construction time as it can be driven and retrieved using mechanical devices. In many applications sheet piles can be used as permanent structures. Underground car park in Kolkata was completed using top down construction and steel sheet piles as permanent structure. Protection of steel sheet piles from corrosion can be achieved by modifying chemical composition and by cathodic protection

Application of sheet pile on rock using toe pinning technique – a case study on signature bridge New Delhi was presented by Mr. E A Khan of L& T Construction. He shared his experience in use of sheet pile in construction of foundations for signature bridege.

The event was sponsored by M/s ArcelorMittal . The program was conducted by Mr. Hemant Vadalkar. Program was well attended by about 120+ engineers.


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" Appeal to ISSE Members "

ISSE is working on updating the Manual of practice for structural engineers. Rationalisation of structural licensing system across the state and certificates to be provided by structural engineers and other agencies are to be worked out. Role and responsibilities of different agencies in building construction field must be defined. Appointment letter of structural engineers is to be standardised. All are requested to share their views and suggestions on this and share their drafts of appoint letter and certificates issued to different agencies in their area of operation like Municipal corporation, CIDCO, MHADA, MIDC, SRA, Collector, Town Planning which will be helpful in compiling the data. Suggestions can be forwarded to issemumbai@gmail.com

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The Trustee,
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