STRUCTURAL ENGINEERING

QUARTERLY JOURNAL OF

INDIAN SOCIETY

OF

STRUCTURAL ENGINEERS

ISSE

VOLUME 19-4

Oct - Nov - Dec 2017

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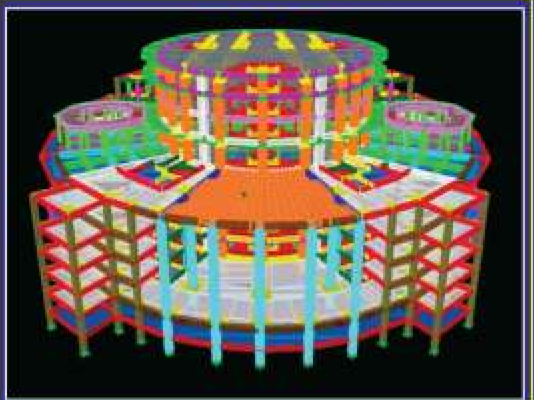

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GEM 14: Prof. T. Y. Lin –The Man who Shaped Prestressed Concrete

Dr. N. Subramanian
Er. Vivek G. Abhyankar

Prof. T.Y. Lin (Nov. 14, 1912 – Nov. 15, 2003)

Based on knowledge domain, Structural Engineering is a noble profession, making it one of the most respected and rewarding professions in our society. Over the past 100 years, there have been several wizards who contributed to our profession and developed various ground-breaking concepts/techniques, which resulted in efficient structures/construction sequence. One such concept is Prestressed Concrete. Eminent structural engineers like Eugene Freyssinet, Fritz Leonhardt, and Tung-Yen (T. Y.) Lin developed this concept and designed and built numerous novel structures. In this issue of GEM, we will discuss about the contributions of Prof. T. Y. Lin.

Prof. T.Y. Lin was a professor emeritus in civil engineering at the University of California, Berkeley (UC Berkeley), in the United States, and a visionary whose pioneering work in prestressed concrete had a profound influence on modern structural design. He lived a long and active life of 91 years.

Preliminary Education and Early Life:

T. Y. Lin was born on 14th November 1912 in Fuzhou, China, as the fourth of eleven children of Supreme Court Judge Ting Chang Lin and Feng-Yi Kuo Link. The family moved to Beijing soon after his birth and he was home-schooled to the age of 12. He completed his pre-collegiate education at Hwei Wen American Methodist School. When he was only 14, he entered Jiao Tong University's Tangshan Engineering College (now Southwest Jiao Tong University) and earned the top score in math and the second best overall score in the college entrance exams. He graduated with a bachelor's degree in civil engineering in 1931. Then he went to the United States, to do his master's degree in civil engineering from the UC Berkeley in 1933. His thesis on direct moment distribution was an important contribution to structural analysis and was subsequently became the first student thesis published by the American Society of Civil Engineers (ASCE).

Start of Professional Career:

After graduation, Lin returned to China and was employed by the Chinese Ministry of Railways. With his dedicated work, he quickly moved up in the ranks to the position of chief bridge engineer of the Chongqing-Chengdu railway at the age of 25, where he had the responsibility to survey, design and construct more than 1,000 bridges throughout China.

In 1941, Lin married Margaret Kao, whom he had known for a decade and whose father was also a Supreme Court justice in China. Five years later, while Lin was working in Taiwan to aid in the transition from Japanese rule to Chinese rule after the end of World War II, he accepted an invitation to join the UC Berkeley as assistant professor of civil engineering. This signaled the beginning of a memorable career of academic and professional accomplishment. During his tenure, he served as Chair of the Division of Structural Engineering and Structural Mechanics and as Director of the Structural Engineering Laboratory from 1960 to 1963. During 1968-69 he was appointed campus-wide Professor of Arts and Science to advance interdisciplinary teaching. From 1969 to 1970, during a turbulent time on campus, Lin chaired UC Berkeley's Board of Educational Development.

Professor Lin introduced new and innovative courses at UC Berkeley, such as the design of long-span bridges and large arenas. He was an exuberant teacher- with his enthusiasm for the subject and new ideas of design; he was able to capture the interest of both engineering and architecture students. He had an untiring willingness to teach students at all levels. Even after his retirement he continued to be a popular lecturer at the University, fascinating and inspiring students.

Work on Prestressed Concrete

During 1946, Prof. Lin began his work to research the practice of prestressed concrete. He did not invent prestressed concrete (the inventor was Eugene Freyssinet of France), but developed it for practical use. In 1957, Prof. Lin conceived the idea of a World Congress on Prestressed Concrete, to be held in San Francisco. An international advisory committee was formed. In a particularly bold move at that time (due to the intense Cold War), the committee invited a delegation from Russia. The week long congress was held at the Fairmont Hotel atop Nob Hill, and was grand success- it was budgeted for an attendance of 500, but 1,200 attended it! In a gesture of reciprocation, the advisory committee of the congress was invited the next year to visit Russia. Prof. Lin was also invited to China and was asked to give five lectures – that number turned into more than 20, in a trip lasting over a month.

Lin retired in 1976 to work full-time at *T.Y. Lin International* (*TYLI*), a firm he founded in 1954. After selling the firm, he left it in 1992 to found another company, *Lin Tung-Yen China*, which oversees engineering projects in China.

Reaching for Excellence:

In the early 1900s, engineers often acted as project architects, but by the late 1940s, this aspect of engineering had been all but forgotten. Lin was saddened by this situation. But, during the last half of the century, particularly in America, construction rushed ahead. Lin fought against the pressures of economy by incorporating more aesthetics into his bridges,developing new techniques that resulted in economy as well as aesthetic beauty. He believed that "(an) engineering approach should be a global vision of the bridge - to fit the environment and to express the structural forces and moments, and nature itself." Attention had to be paid not only to the details of the bridge, but also to the surrounding landscape. Prestressing the concrete allowed Lin to accomplish the goal of incorporating unique shapes without sacrificing the bottom line.

Prof. Lin conceived of a number of brilliant structures, often beyond the state-of-the-art at the time, such as cantilevered and hyperbolic roof spans, tall buildings, and unique bridges. He often sketched the initial concepts on the back of an envelope while flying home from a technical meeting; he then presented them to his organization and also suggested the procedures for analysis and design. Most remarkable of all was his Ruck-a-Chucky Bridge in California, a curved cable-stayed bridge hung from the two mountainsides. Unfortunately, it has not yet been built but it fired the imagination of bridge architects and engineers worldwide. Among his many engineering accomplishments are the Moscone Convention Center in San Francisco, California (Fig. 1), the Kuan Du Bridge in Taiwan (Fig. 2), and the roof of the National Racetrack in Caracas, Venezuela (Fig. 3). He is particularly well known for his groundbreaking research in prestressed concrete, profoundly influencing modern structural design methods and making possible today's high-rise buildings and long span structures. He became so widely known for his work in this area that he is often referred to as "The Father of Prestressed Concrete."

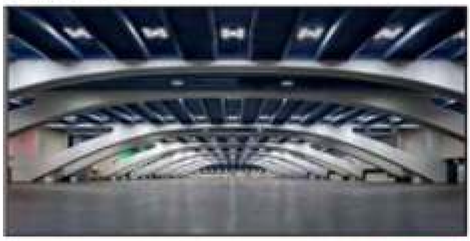
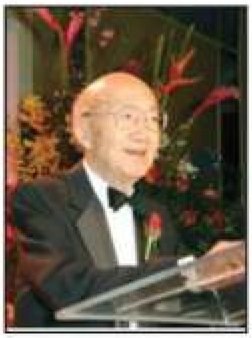


Fig. 1 Moscone Convention Center in San Francisco

Fig.2 Kuan Du Bridge in Taiwan

Fig.3 The Caracas Racetrack in Venezuela (Photo courtesy: Maribel Castillo of T.Y. Lin International)

Lin's legacy is international," said Karl Pister, UC Berkeley professor emeritus of civil and environmental engineering and dean emeritus of the UC Berkeley College of Engineering. "Almost every continent you go to there will be structures with T.Y. Lin's mark on them. He was a one-of-a-kind person of incredible creative vision in structural design." Pister's collaborations with Lin on engineering materials date back to the 1950s.



"There was no way to be around T.Y.Lin and not respond to his remarkable energy, enthusiasm and clarity of mind," said Alex Scordelis, professor emeritus of structural engineering at UC Berkeley and a colleague of Lin's for more than 50 years. "It's what made him a great engineer, a great colleague and one of Berkeley's great teachers."

Lin served as a professor at UC Berkeley from 1946-1976. Seeing himself a teacher first and a practicing engineer second, Lin remained deeply committed to his students, and helping them to solve challenging engineering problems, for 30 years.

Fig.4 Unique Rio Colorado Bridge in Costa Rica 100 m high, 146-m meter span, 1974 (Photo courtesy : Maribel Castillo of T.Y. Lin International)

Awards Galore:

Lin's admiration and respect for the educational community was recognized with several awards and honors. Among the many honors Lin received over his long career and in recognition of his professional achievements are his election to the National Academy of Engineering in 1967, the 1986 National Medal of Science from President Ronald Reagan, National Research Council's Quarter-Century Citation, American Consulting Engineers Council's Award of Merit, Institute Honor Award of the American Institute of Architects, University of California Berkeley Citation, the FIP Freyssinet Medal, and the PCI Medal of Honor. In 1996, he was named the 53rd National Honor Member of Chi Epsilon, the national civil engineering honor society.

In 2000, he was the first recipient of the ASCE Outstanding Lifetime Achievement in Design award. To further honor him, ASCE renamed its annual Prestressed Concrete Award the "T.Y. Lin Award." Professor Lin also holds the distinction of having Honorary Membership in the American Society of Civil Engineers, the American Concrete Institute, American Institute of Architects, and the Prestressed Concrete Institute.

He was also awarded honorary doctorates of law from four universities in the U.S.A and the Far East, and held four honorary professorships in China, including the one from his alma mater, Jiao Tong University.

Beyond his professional contributions, Prof. Lin was an ardent supporter of the Berkeley campus. The Lin family and the T. Y. Lin Foundation endowed the T. Y. and Margaret Lin Chair in Engineering, assisted in the establishment of a structural engineering lecture-demonstration laboratory, and endowed fellowships in both structural engineering and architecture.

Dr. Man-Chung Tang, current Chairman of the Board for TYLI, the firm Lin founded in 1954, met Lin for the first time in 1970 at a meeting to discuss the design of a long-span prestressed concrete bridge. Tang wrote, "Those who were touched by the brilliant mind and boundless energy of T.Y. Lin knew him to be a forward-thinking and joyful person who embraced his work and his people with equal vigor. More than a touchstone for the art and practice of structural engineering, his life exemplifies a passion for service to better the communities of which he was a beloved member."

Fig.5 Professor T.Y. Lin at the Moscone Convention Center in San Francisco, California (Photo courtesy: Maribel Castillo of T.Y. Lin International)

On Nov. 15, 2003, one day after his 91st birthday, T. Y. Lin died at his El Cerrito, Calif. home — the world's first residential structure made of prestressed concrete — after a fall resulting from a mild heart attack. His home also features a 93 m^2 dance floor serving as monument to his favorite pastime - dancing. T. Y. Lin was survived by his wife Margaret, son Paul, daughter Verna, and five grandchildren: Deanna, Katie and Erik Lin and William and Maxim Lin-Yee.

Brief about T. Y. Lin International

T. Y. Lin International (TYLI) is a globally recognized, full-service infrastructure consulting firm. Headquartered in San Francisco, TYLI established its business in the design of long-span bridges and specialty structures.

The firm provides a full range of planning, design, construction and project management services to the Aviation; Bridge; Facilities; Federal; Mobility, Planning, and Management; Ports and Marine; Rail and Transit; and Surface Transportation industries. TYLI operates from more than 50 regional centers across four continents, and employs a professional staff of more than 2,700 engineers, planners, architects and scientists. As leader of T.Y. Lin International, Prof. Lin designed innovative bridges in Costa Rica, Libya, Taipei, Taiwan and the United States. Lin earned a reputation for combining elegance and strength in his designs. Considered one of the greatest structural engineers of his time, Evidence of this can be found worldwide. For example, in San Francisco, he engineered the multiple 100-m arches that support the ceiling of the massive 2044 m^2 Moscone Convention Center, making it the largest underground room in the world at the time of its construction in 1982 (see Fig. 1). He is also well known for daring designs that have yet to be built, including the Intercontinental Peace Bridge that would span the Bering Strait to connect Siberia and Alaska, and the Strait of Gibraltar Bridge with two 4877 m spans.

Fig. 6 San Francisco's Peace Pagoda, designed by T.Y. Lin

1960s–1970s: After establishing the firm in 1954, Prof. Lin expanded his firm's specialty in prestressed concrete to broader consulting services, to include projects involving reinforced concrete, structural steel, masonry, and timber-framed structures. In 1967, he designed the 18-story, Bank of America shear wall building in Managua, Nicaragua. The reinforced concrete tower was one of only two structures left standing after the country's 1972 earthquake. Prof. Lin is also famous for his innovative designs, such as the Rio Colorado Bridge, an upside-down suspension bridge spanning a deep gorge in Costa Rica (see Fig.4). The firm's offices were established in Taiwan and Singapore, during this time.

1980s: New offices were established in Kuala Lumpur. Maine-based Hunter-Bellow Associates merged with TYLI in the U.S. In 1989, TYLI was acquired by the Dar Group, an international network of professional service firms located in 45 countries.

1990s: The Loma Prieta earthquake in California in late 1989, resulted in TYLI developing advanced techniques, engineering tools, and design standards for bridge assessment, seismic retrofit of existing structures, and the design of new bridges. During this period several acquisitions occured, including California-based McDaniel Engineering, Chicago-based BASCOR, Washington State's DGES Consulting Engineering, and New York's DRC Consultants. In addition, a new Asia-Pacific office in Chongqing, China was opened.

2000s: Acquisition of firms in the USE continued with Miami-based H.J. Ross Associates, Inc., Northern California's CCS Planning and Engineering, multi-location FRA Engineering and Architecture, and Medina Consultants on the East Coast. These acquisitions strengthened the firm's services in areas of ITS/traffic engineering and resulted in executing projects such as Miami International Airport's expansion project. In Asia, TYLI designed several major bridges, especially in China, including the Shibanpo Bridge and the Caiyunba Bridge in Chongqing, and the Second Wujiang Bridge in Fulin.

2010s: Twenty five elevated bridges across Taiwan were designed for the island's new High Speed Rail system. In addition, the Hoover Dam Bypass Bridge on the Arizona-Nevada border (2010), the Port Mann Bridge in British Columbia, Canada (2012), and the new Eastern Span of the San Francisco-Oakland Bay Bridge (2013) were also designed.

Fig. 7 The 579 m long Mike O'Callaghan–Pat Tillman Memorial Bridge (Hoover Dam Bypass Bridge)

Books and References, Biographies

Prof. Lin was the author of three acclaimed textbooks as well as more than 100 technical papers: *Design of Prestressed Concrete Structures* (3rd ed. 1981), *Design of Steel Structures* (2nd ed.

1968), and *Structural Concepts and Systems for Architects and Engineers* (2nd ed. 1987). His famous book, *Design of Prestressed Concrete Structures* with N. H. Burns, still remains the most recommended book in universities across the globe.

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- https://www.sefindia.org/forum/viewtopic.php?t=7025
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Acknowledgements: The authors wish to acknowledge that the photos and material used in this article are taken from various sources of the internet. The authors also wish to acknowledge Dr Maribel Castillo, Associate Vice President and Director of Corporate Communications, T.Y. Lin International, 345 California Street, Suite 2300, San Francisco, CA 94104 for editing the manuscript and for adding additional photos and information.

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Overturning Of Buildings a 'Macro' Study

Shishir Dhawade

Modern softwares give us exact idea about 'micro' aspect ..... B.M. ,shear forces at center or at ends of beams , vertical loads and bending in columns at all levels etc. for all kinds of load combinations. But we should not forget the 'macro' aspect. The building instead of studying as combination of numerous columns, slabs and beams etc. should also be studied as a whole single unit. Especially this approach is important while studying overturning of structure due to wind load or earthquake load.

Here I have discussed instability in a building with basement. While designing buildings with **basements** we should always give attention to overturning .A basement can provide 'floating foundation' and increase the allowable safe load bearing capacity (LBC) of soil. But a basement if filled on all sides by water then the structure may become highly unstable. The structure will behave like a ship. If the strata is loose soil susceptible to liquefaction then the structure during high wind or earthquake may behave like an unstable ship. Even in hard soils if there is penetration of water about basement then also the building may behave like a ship. This happened at two of my sites. Building is also subjected to upward buoyancy force and downward self load. Before starting discussions we should refresh our basic knowledge of buoyancy.

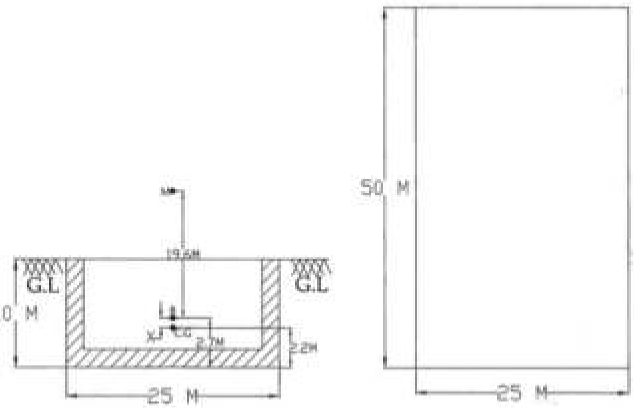
Buoyancy: When a body is immersed partially or fully in a fluid, it is subjected to an upward force. This vertical upward force on a floating body is known as **'Buoyant force'**. This upward buoyant force and downward weight of body creates a couple on body. This disturbing couple is matter of discussion here.

A multistoried building with different stages of construction has been considered. Three cases have been considered.

Note – friction between side walls and soil is neglected. Also neglect weight of beams and bricks.

Study I

Consider a building with two basements



PLAN ELEVATION

Neglect side friction between walls & soil. Also neglect weight of beams and bricks

Weight of building 'W'

W = weight of slabs and raft + weight of side walls

= 33125 Kn

❖ Find out C.G.

Consider all dimensions in cm

15 X 2500 X 5000 X (500+2x) = 40 X 2500 X 5000 (480-x) + 1500 X 30 X 1000(500-x)

X = 280 cm, i.e. 2.2 m from bottom

'B' – Centre of buoyancy; by Archimedes principle,

Buoyancy force = weight of fluid displaced by body

= Total weight body

= 33125 Kn.

Volume of liquid displaced = W/specific weight of liquid

= 3316 c.m

'B.M' = I/V

I = 1/12 (50 X 25^3) = 65104

B.M = 65104/3316 = 19.6 m

Depth of immersion = V/Area in plan

= 3316/(25 X 50)

= 2.7 m

Here; C.G. is below metacentre. The building will float but there will be stable equilibrium. After removing horizontal fore, building will come to its original upright position.

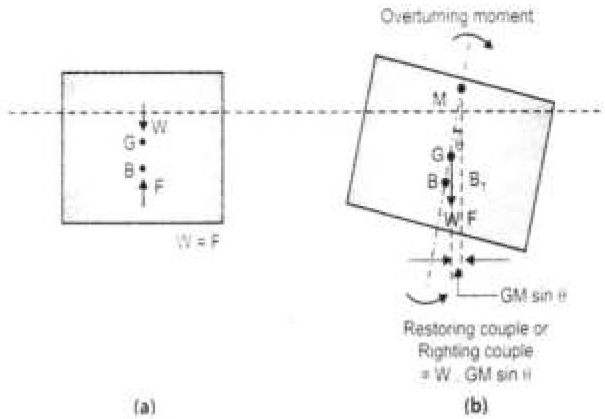


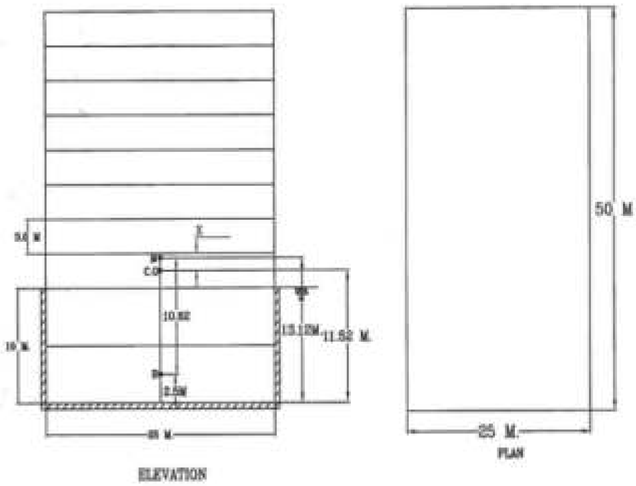
Fig - Stable Equilibrium

Study II

Consider the same building with two basements. Height of each basement is 5 m. Consider 7 slabs above. Thickness of raft: 400 mm, Thickness of all other slabs : 150 mm , Thickness of RCC wall of basement : 300 mm

M – Metacentre,

C.G. – Centre of gravity, B – Centre of Buoyancy



Neglect side friction between walls and soil. Also neglect weight of columns, beams and bricks.

❖Upward force due to water = Area X 100 Kn

= (25 X 50) X 100

= 125000 Kn —— A

❖ Find out weight (W) of building without considering any brickwork. Also for simplicity neglect weight of columns and beams.

W = Weight of slab and rafts + weight of side wall of basement

= (25 X 50) X 25 X 0.4 + (25 X 50) X 25 X 0.15 X 8 +(150 X 10) X 25 X 0.3

= 61250 Kn ——————B

< A. So the building will float.

❖ Find out C.G of entire building. (Already discussed)

❖ Consider all dimension in cm.

15 X 2500 X 5000(4500 + 6x) = 40 X 2500 X 5000(1280 – x) +15 X 2500 X 5000 (1100 – 2x) + 15000 X 30 X 1000(800- x)

x = 148 = 1.48 M i.e. 11.52 M. from bottom of raft.

B – Centre of buoyancy; by Archimedes principle,

Buoyancy force = weight of fluid displaced by body

= Total weight causing displacement

= 61250 Kn

'V' Volume of liquid displaced = w/specific weight of liquid

= 6125 cu.m

'B.M' = I/V

I = 1/12 (50 X 25^3) = 65104

B.M = 65104/6125 = 10.62 M

Depth of immersion = V/Area in plan

= 6125/(25 X 50) = 4.9 M.

OB 2.45 M.; say 2.5 M.

OM = 10.62+ 2.5 = 13.12 M

Distance between C.G. & M = 13.12 – 11.52 = 1.60 M

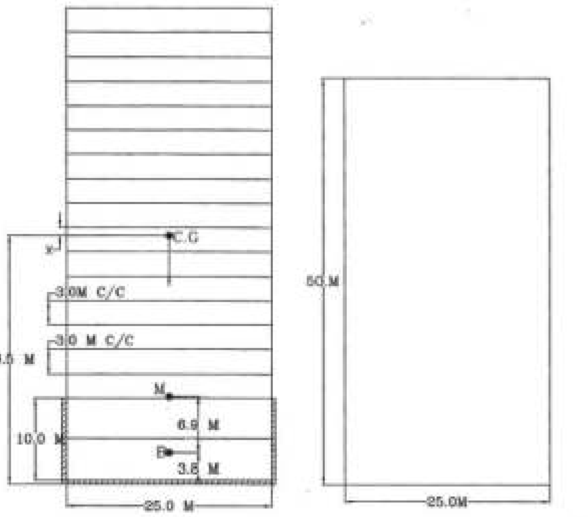
As centre of gravity is above metacentre; the structure is unstable.

A slight lateral force will tilt the building. Upward buoyancy and downward weight of building will form a couple. But it will be an unstable equilibrium. Even after removal of lateral force , the building will go on tilting as the couple will not be balancing each other. See fig. (P) in study III. It represents the building under unstable equilibrium.

Study III

Consider a building with two basements. Height of each basement is 5 M. consider 16 slabs above. Thickness of all slabs: 150 mm.

Thickness of RCC wall of basement: 150 mm.
Size of building in plan : 25 M. X 50 M.
Height of each floor : 3 M.



ELEVATION PLAN

❖ Let us find out upward force due to water

= Area X 100 Kn
= 25 X 50 X 100
= 125000 Kn ———— A

❖ Find out weight (W) of building without considering any brick work. Also for simplicity neglect weight of columns and beams.

W = weight of slabs and raft + weight of side wall of basement

W = (25 X 50)X 0.15 X 25 X 19 + 150 X 10 X 0.15 X 25

W = 94688 Kn. ——— B

< A so, the building will float.

Find out centre of gravity of entire building.

- All dimensions below are in cm.

15 X 2500 X 5000 (16200+10x) = 15 X 2500 X 5000(14100-9x) + 15000 X 15 X 1000(2600-x) x = 50 cm i.e. 30.5 M from bottom raft

❖ B – centre of buoyancy: By Archimedes principle,

Buoyancy force = weight of fluid displaced by body
= Total weight causing displacement
= 94688 Kn.

Volume of liquid **'V'** displaced = 94688/10
= 6469 cu.m.

B.M = I/V,

I = 1/12 (50 X 25^3) = 65104

So, B.M = 65104/9469 = 6.9 M

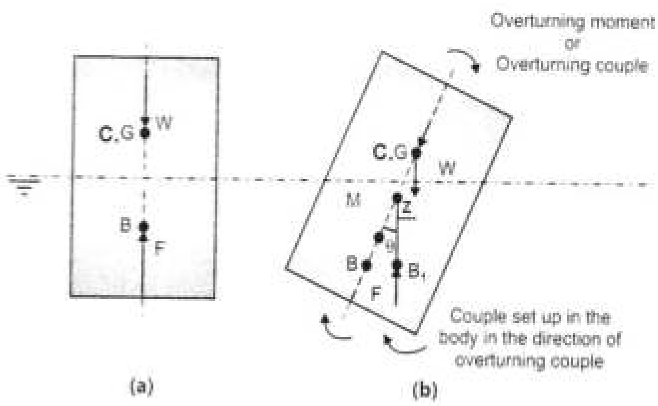
Depth of immersion = V/Area in plan
= 9469/(25 X 50)
= 7.6 M

So , ; 'OB' = 3.8 M. OM = 3.8 + 6.9 = 10.7 M;

Distance between C.G and M = 30.5 – 10.7 = 19.8 M.

As centre of gravity is above metacentre; the structure is unstable.

A slight lateral force will tilt the building. Upward buoyancy and downward weight of building will form a couple. But it will be an unstable equilibrium. Even after removal of lateral force , the building will go on tilting as the couple will not be balancing each other. See fig. (b) below. It represents the building under unstable equilibrium.



Unstable equilibrium for study II and III

FIG 'P'

Fig 'a' shows building without horizontal force. Fig. 'b' shows slight horizontal force will make the building tilt permanently even after removal of lateral force.

❖ **Consider study II and III :**

Lever arm 'z' = (M – C.G.) ϕ

Consider a slight tilt of 1^0 i.e. ∂/(180) Radian

In study II, Z = 1.6 X $\left[\frac{\pi}{180}\right]$ = 0.03 M ———C

In study III, Z 10.7 X = 0.19 M —————D

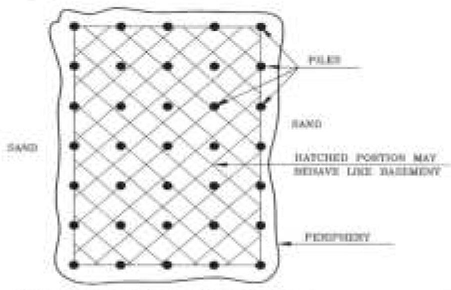
See in study III, Z is 7 times that in study II. Thus as height increases, instability also increases

In case III, Overturning couple = Zw = 0.19 X 94688 = 18000 Kn/m

This couple will produce downward and upward force (18000/(25 X 50) i.e. 14.4 Kn/m along the periphery of building. This force shall be resisted by friction between walls and soil or piles.

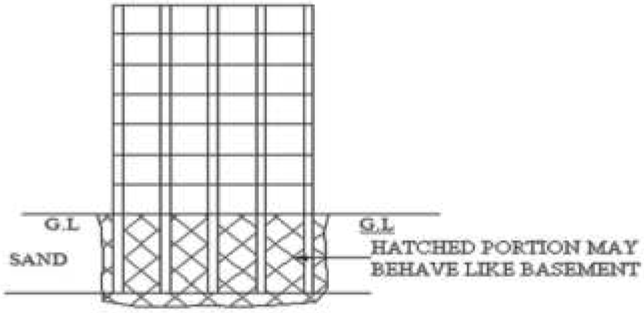
Conclusion:

It is obvious from above discussions that any building with basement shall be analyzed for any disturbing couple due to buoyancy. For various stages of construction weight of building and buoyancy are different. The building with basement may float during earlier stages of construction or even after completing total eighteen slabs as discussed earlier. As height increases, the disturbing couple due to buoyancy increases. The best way to insure building will not float at any stage of construction is to provide sufficient downward weight at basement raft level to balance the upward buoyancy. It can be achieved by thick raft and thick RCC wall of basement. Pile foundation or anchor bolts (in case of hard rock) will also prevent building from floating.



PLAN OF BUILDING AT GROUND LEVEL

Special study to be made by the reader: A building with piles and in loose soil and without basement may behave like a ship. Soil confined in periphery of building in presence of piles will behave in different manner than soil outside periphery. The inner hatched portion may behave like a basement and the building may become unstable.



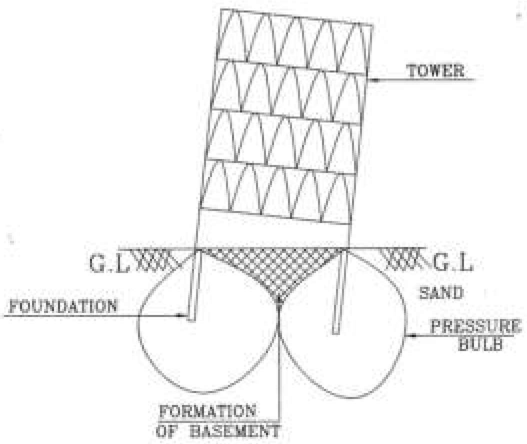
SECTION
FIG (t)

Building without basement on friction piles and in sandy soils may behave like building with basement. Group of piles may create a totally different soil structure on inner periphery of building. This inner periphery may behave like a basement and building may 'float' and be in unstable equilibrium.

This phenomenon may happen for high-rise buildings or towers on sands. Is it the reason for tilting of tower of PISA? Also there was tilting of PETRONAS towers. To arrest tilting the famous glass bridge was introduced. But if the bridge is in 'X' direction; what about 'Y' direction?

In case of PISA, foundation of the tower creates pressure bulb in soil. So the pressure bulb modified properties inside the periphery of tower as shown. The inner hatched portion behaves like a basement.

The tower took about 300 years to built. In this course of time due to consolidation of soil; there was large difference in properties 'outside' and 'inner side' of periphery. This change created a 'basement' inside periphery of tower, and tower became unstable. The outside loose sand behaves like liquid. The unstable equilibrium made the tower tilt permanently.



ELEVATION

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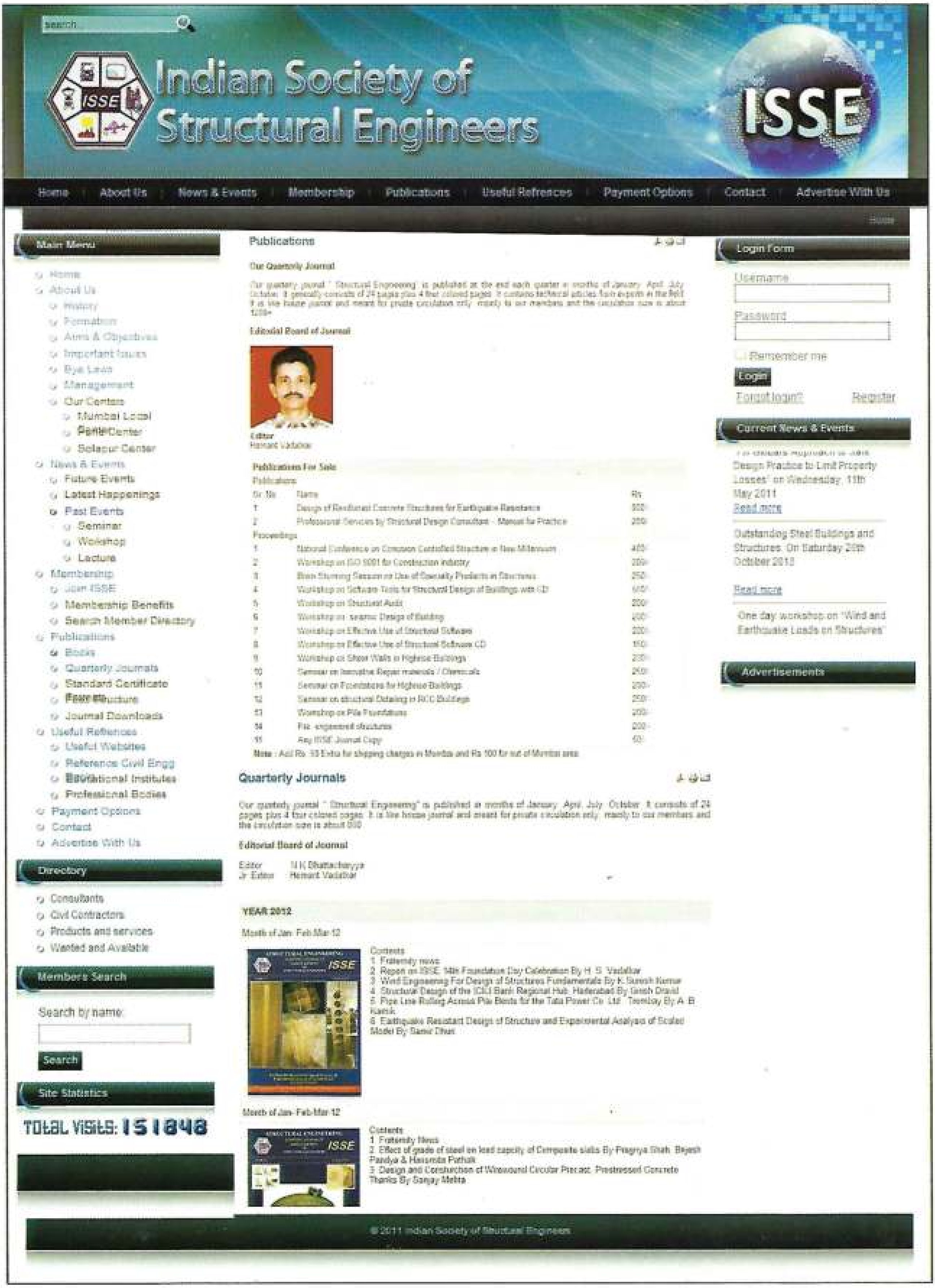


GOOD CONSTRUCTION PRACTICES TO CONSTRUCT DURABLE BUILDINGS (STRUCTURES) PART - 2

By Jaykumar J. Shah

(Continued from Part 1)

18. Waterproofing

Buildings do not have moving parts like those in automobiles and other machineries and very few services are incorporated in common buildings. One of the most important of them is the waterproofing system. The next most important service in the building is plumbing. The owner would want this minimum service to function trouble free from all of us connected with the construction of buildings. It is high time we put our mind to the materials used in the existing conventional system and on the systems as a whole.

(a) Conventional systems

(i) Bituminous system

This has organic material in the system, which decays with age and exposure to sunlight and thus the system becomes ineffective. This has short life span.

(ii) Brick bat coba with or without china mosaic chips

It is projected that china mosaic toppings helps in waterproofing. In fact, they do more harm than good so far as waterproofing is concerned. Due to temperature difference between the day and night, the numerous joints of china mosaic open out and water leaks into the brickbat, which is a porous material and subsequently, water leaks in the RCC frame members and the walls and deteriorates them.

Brick is highly porous material. Brickbats are used to provide slope to the horizontal surface of the terrace slab. Thus, the entire waterproofing depends upon:

⇨ The cement slurry spread over the top

or

⇨ Application of sodium silicate mixed with cement over the terrace top

or

⇨ Application of jaggery mixed with cement over the terrace top

It is informed that the brickbat coba waterproofing system originated long back on the philosophy that it absorbs water and later the water evaporates from it and thus there would be no leakage. Infact brick bat coba works as reservoir of water in places where there is good rain and throws water in top storey flats during monsoon and even later after monsoon.

Even otherwise, when the quality of the material used and the application is excellent, normally it is seen that the maximum life of the system is 10 years.

However, this system helps to insulate the terrace slab from heat.

(iii) Farshi type box-waterproofing:

This has joints and is not monolithic with the main structure.

In all the above conventional waterproofing system, it is observed that:

⇨ They have short span of life.

⇨ They all have some inherent problem in the system.

⇨ They all are time consuming and extend the project time.

(b) Water proofing system advised- Acrylic Polymer Based Flexible Membrane.

This is the best system available as on date. This becomes part and parcel with the structure and is monolithic without any joints. This has generally the same properties (except that this flexible membrane has hairline crack bridging ability) as that of concrete on which it is applied.

Further, it is claimed that this system has chloride resistance, sulphate ion resistance, good carbon-di-oxide diffusion resistance coupled with its waterproofing qualities and, as such, acts further as a protective coating against concrete and re-bar deterioration.

This acrylic polymer based flexible membrane system alone, once understood and mastered, takes care of all areas of waterproofing in a building. for example, basements, service ducts, lift room top slabs, sunken slabs, water tanks, swimming pools, terraces, chajjas, toilet blocks, entrance canopies, stairwell top slabs, damp proof course, flower vases etc.

The application of flexible membrane waterproofing system has to be done by an experienced and trained applicator and this has to be supervised properly, as is necessary for any construction activity. This reduces inventory as only one product is to be arranged for the entire building. Further, it is a repeat job for the entire building and same small group of trained workers continue with the same operation. (Photo 17)

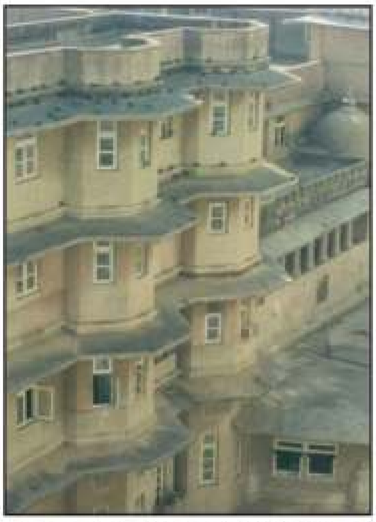
19. Damp proof course

This is generally neglected in majority of the buildings resulting in the sub-soil water rising in the property by capillary action. Provide DPC properly. Provide flexible membrane DPC as advised in para 18 above to use one product in all areas of the building. In fact provide membrane to entire ground floor slab along with DPC location for better results with small increase in the cost which is negligible against the total cost of the building.

20. Chajja tops

In the present day construction, these are horizontal protruding slabs without any slope. These are the locations, which are neither cleaned nor inspected for years. Water stagnates on these slabs, as scrap material is stacked over them, at times, even good usable material is stacked over them in industrial units, and garbage is also thrown over them. Vegetation grows due to bird droppings in the earth accumulated over these slabs from broken plant pots placed over them and brought by wind and finally, as top surface does not have proper slope.

The stagnated water seeps into these slabs, which deteriorates them, and later deteriorates adjoining RCC members, e.g. beams, columns. The author has observed that these are the RCC members that deteriorate first in the buildings. Hence, the author strongly advises that top balcony slabs and chajjas should be sloping RCC slabs only, as illustrated in photo 18 and entrance canopies, stairwell/lift room top slabs should be doubly curved (Photo 3.) or in such other shapes if in RCC or should be lightweight pipe truss with sheets of one's choice so that no material (scrap, usable, debris and garbage) can be stacked over them and that water will not stagnate over them and flow out smoothly. Further, if chajjas are sloping, unit of split air-conditioners cannot be fitted over them for which they are not designed and also not help accumulation of earth and water. We have read in newspapers some instances where people have gathered over the cantilever slabs to see a procession passing by and which have collapsed with casualties.



Surprisingly, chajjas/top balcony slabs provided in old buildings monumental buildings and temples are in-variably sloping. (Photo 18).

Only these days, these are provided horizontal.

21. External Plaster

This should have good bond with masonry. Further plaster has to be impermeable and crackless. Again, we cannot afford to have seven days gap between first coat of plaster and second coat of plaster. Author has developed plaster mix – SHAH PLASTER - which satisfies all above requirements by continuous trials over the years. This is not elaborated here. This is a topic in itself.

22. Anchor Fasteners

Presently M.S. nails are hammered into holes drilled for fixing safety grills and plumbing pipes. At times, M.S. nails are hammered even without drilling holes. This practice needs to be discouraged as crude hammering of M.S. nails develops cracks in the plaster. This invites water leakage. Subsequently, M.S. nails rust and loosens the fixtures and also become the source of leak-age. Provide suitable non-corrosive anchor fasteners only. In fact, as a rule, all fixtures in a building should be fixed by suitable non-corrosive anchor fasteners only.

23. Separation gaps

Gaps between the masonry wall and the RCC beam and column is separation gap. These days, this is the major source of leakage. In olden days, the masonry wall was raised in stages and the gap between the wall and the RCC beam was sealed properly. The separation gaps should be properly sealed by acrylic polymer based cement mortar. (Photo 19)

The present practice of providing mesh at separation gaps is not advised. Reinforcement is recommended only when it is structurally required. Generally decorative grooves are provided at the separation joints in the external face of the building. This becomes the source of leakage. This also is not advised.

24. Important Aspects

Plumbing forms 12% to 20% of the total cost of the building and is one of the major source of leakage. Plumbing/Expansion joints/spouts etc are not covered in this article, which needs special attention for durability considerations.

- Statutory majors

Various Development Control Regulatory Bodies should make it mandatory to incorporate measures to ensure durability of structures. Code provisions also need to be suitably modified to promote durability of the structure.

- Curriculum of Educational Institutions

The students should be equipped with knowledge about measures to be adopted for building durable structures. It is also necessary to inculcate the right attitudes in this respect among the students.

- Role of financing agencies

Finance and other development agencies should insist on adoption of durability measures in the project they finance. In fact they should refuse loan to a project which does not include DURABILITY PARAMETERS.

25. Curing

This has to start as early as possible. Hence, first step is to curtail finishing time. Start curing immediately (say after 30 minutes to one hour or so) after finishing is complete and as soon as bleed water evaporates, initially by sprinkling water and later by usual methods (by hoses, by covering by wet Hessian, by covering with plastic sheets, etc.) throughout the 24 hours of the day, without any interruption continuously for minimum 14 days.

Sir Adam Neville a world-renowned doyen of concrete says:

"Wet curing is specified in majority of construction projects but is rarely achieved. Like batching and mixing, curing requires close supervision, but in my experience not only in the United Kingdom but also in desert countries, curing is left with the man with the water hose or to no one at all. Curing is not an item in the bill of quantities and is not paid separately. In my view, curing should be detached form the general items of concrete placing, and paid for by consumption of water or man-hours, in some other ways".

Author feels that even with curing as a separate item of work in the bill of quantities, it will not be done as specified and as required unless where it is possible to mechanize the same.

Curing at night is something new to building industry.

Hence, curing by the curing compound is the only solution when curing as specified and as required by water is not possible. Horizontal surfaces, round structures and final coat of external plaster which is hardly 12mm to 15mm MUST be cured by CURING COMPOUND as here curing by water as required is not possible.

CONCLUSIONS

Society will not excuse the technical community if they continue to build the RCC structures in the present style. Durability has to be the word from CONCEPT to COMPLETION and has to reach to the grass root levels.

A training and awareness programme is to be taken up on a very big scale and specially for small and medium level builders who are presently in dark about DURABILITY.

Curing has to be taken up seriously and steps are to be taken up for its implementation.

Author feels that a day will come when all the DURABILITY PARAMETERS detailed above will be implemented except CURING. Hence very special attention to CURING is necessary by all concerned in the construction of RCC structures.

"Even one small defect is enough to destroy all accompanying virtues, like the spot on the moon."

-Kumara Sambhava

If the buildings are built with lifecycle cost consideration with sustainable development and with holistic approach, there should be no early deterioration and with regular maintenance, the buildings should last for many more years than the life for which they are designed

Author

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OFFICE BUILDING FOR NAVI MUMBAI MUNICIPAL CORPORATION

by Jitesh Patel and Sachin K C

During the last two decades, the increased urbanization leads to a boost in the construction sector in the metro cities. The development of the town ships and the urban infrastructure was a necessity in these circumstances.

The un-precedent growth opportunity in the sector was a shot in the arm for many professionals working in the industry. But as we know, the success of a project depends largely on the quality of the collaboration between various agencies. The Architect of the project is invariably controlling the design aspects at the planning and developing stage. The project under discussion is a perfect example of the professional collaboration and harmony existed between the various agencies involved in the project.

Introduction:

The NMMC (Navi Mumbai Municipal Corporation) plays an important role in the development of the satellite town of Mumbai known as Navi Mumbai. They were looking to construct their office building and we were appointed as the structural consultants for the project. M/s Hiten Sethi Architects Pvt. Ltd was the Architect for this project.

Location of the project is at sector 15A at CBD, Belapur. The project work started in the year 2009 and completed in the year 2013. Total project cost was of 155crores.

Structure - Geometry:

The total construction area of the project is 2.5 lakh sq. ft. Structure shape is a perfect circle. It has two parts, the inner circle of 43m (141ft) diameter and the outer circle of 92m (300ft). The structure has 7 levels, above the ground floor. The first, second and third floors are having the central atrium portion and so that area is kept as void. It creates a large central area and a person standing at the ground floor lobby gets an astounding view of the circular shaped outer structure with circular columns and the high ceiling of about 25m.

The fourth floor and the fifth floor are having full floor plate including the centre circular area. The roof level is 12.7m above the fifth level and in between there are intermediate part levels. The Main dome projects above the roof level over the inner circular area. The maximum height of the structure is 56m above the ground level.

The circular dome at the roof is in perfect symphony with the shape of the structure. The dome itself is iconic in nature, it covers the central circular area with a diameter of 43m and at the apex, and it hovers 15m above the base level. There are two smaller domes also at a lower level with a diameter of about 15m which together with the upper larger dome define the aesthetic appeal of the building.

There is one basement also for the vehicle parking. The extended basement area is having a maximum size of 160m in length and 150m in width.

Foundation System:

The foundation of the structure is done with Independent footings. The foundations are supported on rocky strata which is 7.5m below the road level. The rock formations are having a bearing capacity of 80t/m2 as recommended by the Geo tech consultant. As the structure is with a single basement, it was a natural choice to have the foundation system on the rocky stratum.

Structure – Framing systems:

For the lateral loading system, combined system of Moment resisting frames and Shear wall were used. The shear walls were taken at the service area and the lift locations. The Horizontal framing system was consisting of normal beam/slab system. Flat slab system with Post Tensioning methods were used also at the office portions where proper column grids are available. Drop panels around the columns were taken to cater for punching shear and added flexural capacity.

A detailed discussion on some of the structural aspects is listed here.

1. Floor slab at the 4th Level:

The size of the central circular floor area is 43m diameter. To support such a huge span, various farming methods using Reinforced concrete and others like structural steel framing and pre-stressed concrete were prepared and compared. Finally Post Tensioned beams with RCC slabs were selected. PT beams with sizes of 800mm width and 1600mm depth were used to effectively transfer the huge floor loads to the supports. These were stressed with bonded post tensioning methodology. Pls. see the images of these beams in the attached Fig

It now holds a record for the maximum span for a pre-stressed concrete beam and **entered in to the Limca book of world records**. Specially designed shuttering systems were used for this floor as it stands at a height of 18.25m from the ground floor level.

2.The circular domes:

The Main dome at the roof level is having a diameter of 43m and the apex point is 15 m high. Such a large size dome was formulated with structural steel framing with GRC sheeting.

This Dome has been recognized as the biggest dome by Limca Book of World records.

3. Major Corbels for the floor supports:

The central circular areas are supported on the corbels taken from the inner ring columns at the 4th and upper levels. These are 1m wide and have a depth of 1.2m- 2.2m. These allow the provision of a separation joint between the outer portion of the building and the inner circular area.Finite element models were done to capture the stress flow patterns and it clearly showed the desired load path as expected from these elements.

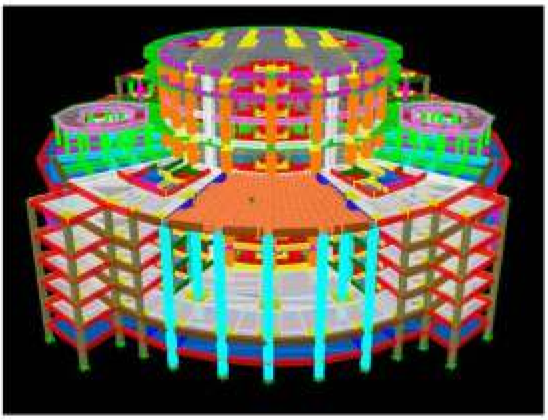
Suitable bearing pads were designed in such a way to allow uniform transfer of load from beams to these corbels. They permit beam rotation at the bearing point, but insulate the floor vibration transferring to the outer structure.

4. Free standing Columns:

There are some columns which are free- standing (without tie at intermediate levels) up to the fourth level slab, ie about 25m height from the fixed base. The sizes of these were fixed by considering the slenderness moments and the buckling aspect.

Structure – Analysis:

3D model of the structure were done using the latest finite element software ETAB.



The Frame analysis of the structure gave the results of various parameters to be checked for the stability and serviceability of the structure like drift, deflection, torsion effects, and soft storey effects etc. 2 Hour fire resistance is adopted as per the NBC guide lines. The foundation and the floor slabs were analyzed and designed using the software SAFE.

Stringent norms were considered in the lateral load design of the structure, especially for seismic forces. The code prescribed values (like seismic zone) were enhanced further, considering the importance of the structure. The detailing is also done to ensure that proper ductility is available for all the main lateral load carrying elements.

Construction sequence analysis is done to capture the non linear behavior of the structure to account for the stage wise casting.

The structural analysis and design were submitted to the proof consulting agency appointed by the client and the site execution is done after getting the approval on the details.

Construction Methodology:

Normal concrete of Grade up to 40 N/mm2 (M40) is used for the structure. The main structure consumed 70000 m3 of concrete and 5500 MT of steel. (Which includes rebars, structural steel and PT cables).

High standard construction methodologies were used throughout the full construction phase of the structure. Stringent quality control norms were also followed. At the super structure, special shuttering methods were adopted for the fourth floor. The erection of the central dome also demanded precision formworks.

Pour sequence for the casting of this structure is also an important aspect because of the parameters like large spans, pre-stressing, corbels, expansion joint etc.

Structural Health Monitoring System (SHM)

Due to the large span of the central floor area, proper monitoring of the structural responses are to be observed for the service life of the structure. Keeping this as objective, strain gauges and penetrometer were planted in the concrete at these levels to check whether any excessive deflection is happening at these levels. Further, it is planned to have much more sophisticated tools to measure the accelerations and vibrations also. These facilities will provide the building management team, the real time information on the building movements and characteristics to effectively service the structure during its life time.

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News and Events during Oct – Dec 2017

6-7 Oct 2017 INTERNATIONAL CONFERENCE ON INNOVATIONS IN CONCRETE FOR INFRASTRUCTURE CHALLENGES At Nagpur (INFRACON-2017)

The INFRACON-2017 conference was inaugurated on 6th October 2017 at 9:30 am by Hon. Shri Nitin Gadkari, Union Minister for Road Transport, Highway and Shipping via Video Conferencing.

Er. Vivek Naik, President (Elect) ICI (Indian Concrete Institute) and Principal Convener ICI briefed about rhetoric way of INFRACON-2017, its conception, progression, and eventually its conduction.

During the conference spanning two days on 6th & 7th Oct'17, Key-Note Addresses were delivered by many renowned academician and a practicing civil engineers, Including

✤ *"Large underground construction for metro station"* by **Er. Mahesh Tandon**, Tandon Consultants Pvt Ltd.

✤ *"Confluence of requirements for sustainable and durable concrete"* by **Dr. A. K. Mullick**, Former Director General, NCB

✤ *"Concrete for tunnel lining"* by **Er. Florian Krenn**, Geoconsult India Pvt. Ltd.

✤ *"Shaping the future of Structural Health Monitoring with IOT sensors"* by **Er. Daman PARSY**, App. Engineer, Berlin, Germany

✤ *"Elevated corridors for road connectivity"* by **Er. Vinay Gupta**, Tandon Consultants

✤ *"Innovative methodology for mixture proportioning of self- compacting concrete with high volume fly ash" by* **Er. Subrato Chowdhury**, Sr. Consultant

These Key-note addresses on various aspects of Civil engineering were highly enriching and useful to the participants.

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11 Oct 2017 Meeting at MCGM with Director Engineering

Municipal Corporation of Greater Mumbai has sent a circular to take action against Structural Engineer if NDT is not conducted during the structural audit.

Considering seriousness of this circular a meeting was arranged with Director(ESP) by ISSE.

In the meeting ISSE was represented by Prof G B Chaudhari (Past president ISSE), Sr structural consultant Shri Satish Dhupeia and Shantilal Jain (ISSE trustee) on 11 th oct at BMC office.

In the meeting ISSE raised the issue with the Director Engineering about the unfair circular issued by MCGM. ISSE explained that use of NDT for structural audit shall not be made mandatory.

Decision regarding conducting any type of test must be left to the competent Structural engineer who is doing structural audit.

For not doing NDT no show-cause shall be issued to structural consultant.

Director Engineering assured that revised circular will be issued by withdrawing this circular.

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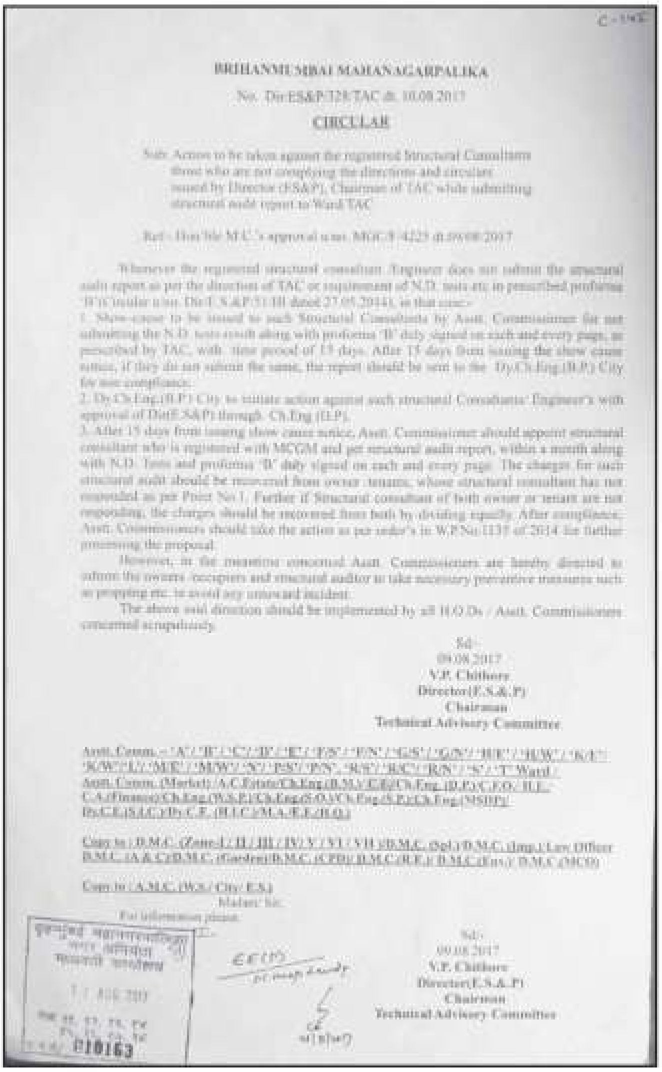
BRIHANMUMBAI MAHANAGARPALIKA

CIRCULAR

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

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Technical Advisory Committee

13 Oct 2017 Lecture by Dr. Suresh Kumar on Wind load on Tall buildings as per IS875-Part 3: 2015

Indian Society of Structural Engineers (ISSE) in association with Department of Civil Engineering Mukesh Patel School of Technology Management and Engineering, NMIMS had arranged a lecture on Wind load on Tall Buildings. Dr. Suresh Kumar from RWDI explained the revised code IS875-Part 3 :2015 clauses and its limitations. He elaborated on along wind and across wind considerations for tall buildings. Conditions stipulated in various standards for " when to carry out wind tunnel test " were discussed. Certain code clauses need further discussion and modification in line with the international standards. He had pointed out certain discrepancies like in fig 4 , force coefficient Cf value is very high for h/b>3 which is not the reality. From testing it has been found that this factor is not more than 1.3.

Also in Figure 10, the peak has been shifted on the left side compared to Australian code which needs correction. He had compared the results with Australian code with some solved examples. There was detail question and answer session for more than one hour where participants raised various queries. The program was well appreciated by the design engineers.

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3 Nov 2017 ACE Tech Alpha Awards at Mumbai

In the Structural Engineering Category, **ACE Alpha Awards** gave **Mr. Kamal Hadker the Lifetime Achievement Award** for his contribution to Structural Engineering and Nation Building.

The Award was presented by **Dr. R. C. Sinha** (IAS Retd.), Advisor to the Government of India, Ministry of Road Transport and Highways and Ministry of Shipping.

SACPL received the "Best Structural Design" Award for design of Navi Mumbai Municipal Corporation Building (NMMC) at Navi Mumbai.

The Award ceremony took place at the Sahara Star in Mumbai on the 3rd of November 2017.

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15 Nov 2017 Steel Day was celebrated by MX Media at Mumbai.

Industry experts were called to share their experience on

High rise structures, bridges and infrastructure, Composite steel v/s steel buildings.

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18 Nov 2017 Lecture on Wind code IS875 Part 3 :2015 by code authors

CTBUH in association with Department of Civil Engineering Mukesh Patel School of Technology Management and Engineering, NMIMS had arranged a lecture meeting with authors of Wind code.

Dr. Selvi Rajan and Dr. Harikrishna, both from SERC, Chennai, started off describing wind actions in a very simple manner and built up the background and theory that have been the basis of the clauses of IS 875 Part 3, 2015. The emphasis was on being conservative, wind being an unpredicted phenomena. The presentations done by both were well structured, highly informative and rich in technical content. The approach taken to explain the philosophy behind each aspects of the code was brilliant and clarified most of the ambiguities faced by the structural engineers in using the code. Much understanding on the wind tunnel studies were also achieved from the presentations.

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24 and 25 Nov 2017 – ACI International conference on Repairs, Retrofitting and Forensic Engineering of built structures.

President ACI Mr. Khaled Awad graced the occasion and made presentation on new code ACI-562:2016 which deals with assessment , repair and rehabilitation of existing concrete structures. We also need some code for carrying out systematic repairs in our country. Various papers on repairs, case studies on repairs, rehabilitation of heritage structures, Non-destructive testing, modern materials for repair and rehabilitation, Forensic Engineering applications in IBMS (Indian Bridge Management System) were presented by experts.

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1st and 2nd Dec 2017 Workshop on IS1893:2016 and IS13920:2016 by Epicons Friends of Concrete at Mumbai

Dr. Yogendra Singh from IIT Roorkee was the expert who discussed the new code clauses and the background for IS1893 and IS13920 revisions. Various questions were raised by the participants and mistakes in the codes were pointed out. Practical difficulty in implementing the code clauses like regular configuration, minimum column dimension, location of lap splice in column, limiting lateral drift to 0.4% considering cracked Moment of Inertia for column and beams, provision of diagonal reinforcement in the coupling beam and placement difficulties , congestion due to special confining reinforcement in beam column junction, limiting stress level to 0.4fck in column, were discussed.

Dr. Singh also discussed the similar provisions in other codes like ACI, EURO code, New Zealand code and need for updating our codes to international standards. He explained the concept of capacity based design and how codes are moving towards that direction.

Some case studies were presented by consulting engineers comparing the provisions of earlier version and latest version for different type of buildings. Some observations from case studies are –

The deflection limit of 0.1% is critical for design of flat slab structures. Column sizes will be bigger as per the provision of new codes. There will be marginal increase in structural cost as per new code guidelines. We have to convince our clients and architects to adopt the new code guidelines for safety of our structures.

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18, 19 and 20 Dec 2017 workshop on Wind Loading

Indian Society of Structural Engineers (ISSE) in association with Department of Civil Engineering Mukesh Patel School of Technology Management and Engineering, NMIMS had arranged a three days workshop on wind engineering.

Fundamentals of fluid dynamics was explained by Dr. Eldoh, Professor, IITB with illustrations and pictures along with the theoretical background.

Use of Computational Fluid Dynamics (CFD) for analysis was discussed with good examples by structural engineer Rajiv Iyer from Tata Consulting Engineers.

Architectural Aerodynamics was described by Mr. Rahul PS from RWDI. Dr. Suresh Kumar explained wind tunnel testing procedure, wind design of structures and IS code provisions for wind loading.

The program was attended by practicing structural engineers and civil engineering students.

20 Dec 2017 Lecture by S. Bhattacharjee from UK

An evening lecture was arranged by ISSE in association with The Institution of Engineers India Maharashtra State Centre. Topic of the lecture was

IMPACT OF GLOBALISATION ON CONSULTING ENGINEERS

By Mr.SAPRAVA BHATTACHARJEE FROM U.K.

Mr. Bhattacharjee urged members of engineering fraternity to become global engineers by getting membership for Institution of Structural Engineers , UK. He also explained the application procedure for getting the membership. He is on the committee for scrutinizing applications from engineers and requested maximum applications from India.

TATA Steel representative made presentation on TATA steel products and cut and bend facility available for re-bars. High strength steel like Fe600 can be used for high rise buildings which will save cost on steel.

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

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