STRUCTURAL ENGINEERING

QUARTERLY JOURNAL OF

INDIAN SOCIETY

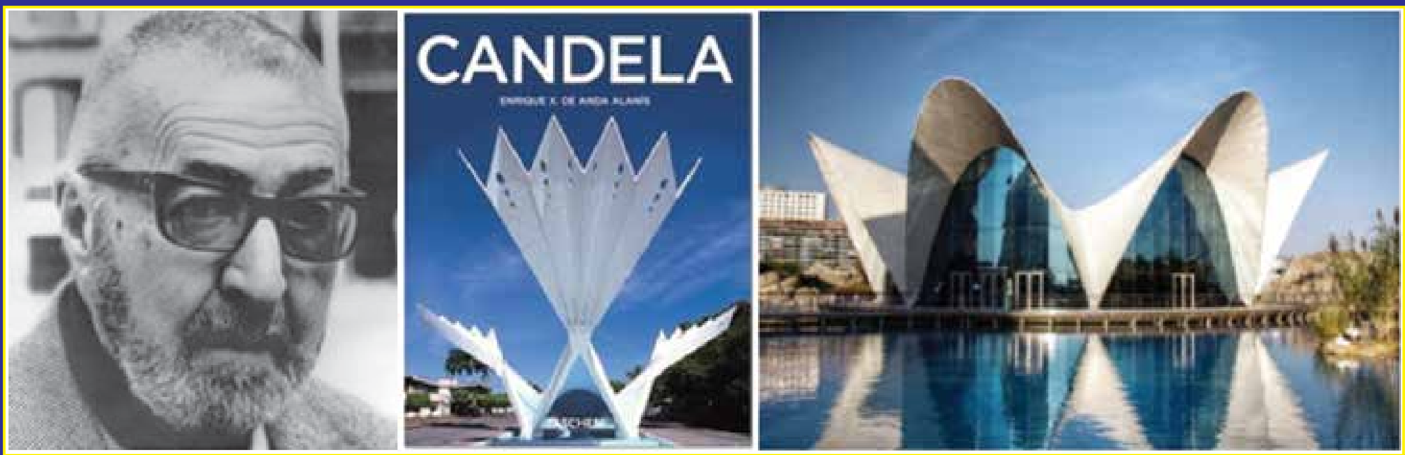
OF

STRUCTURAL ENGINEERS

ISSE

VOLUME 19-3

Jul - Aug - Sep 2017



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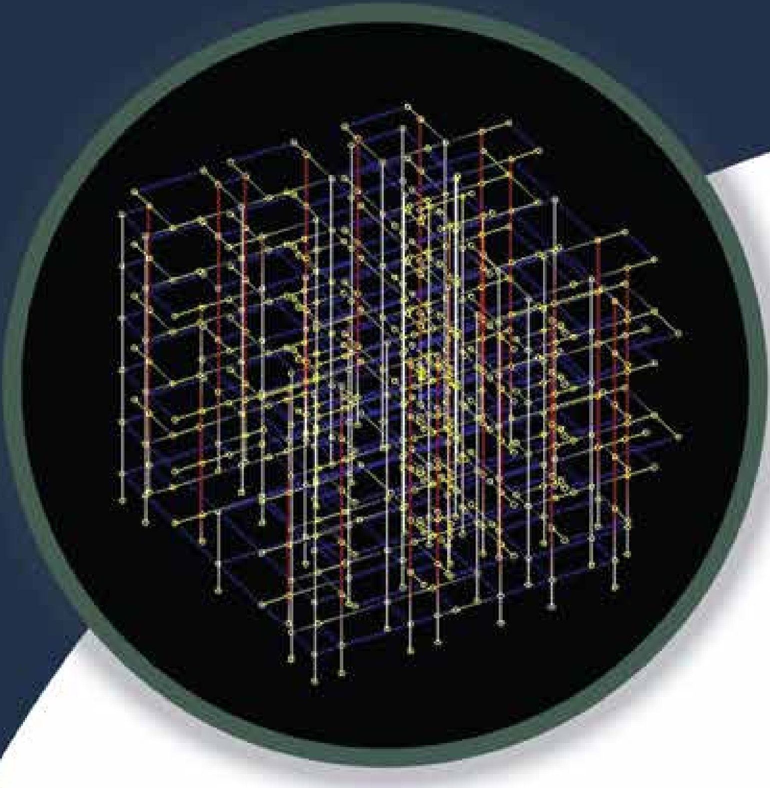
LET US BUILD A STRONG STRUCTURE OF INDIAN SOCIETY



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Patrons : 37	Organisation Members : 23	Sponsor : 8
Members : 1571	Junior Members : 44	IM : 01

TOTAL STRENGTH 1684

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

& Other related branches

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

GEM 13:Felix Candela - Builder of Dreams

Dr. N. Subramanian
Er. Vivek G. Abhyankar

General about series of articles:

About three years are complete, since we wrote the first article in this series of 'Gems of Structural Engineering', about the Life of Prof. S. P. Timoshenko. This was followed by the professional life and achievement/contribution of Sir. Ove Arup, Eugène Freyssinet, Profs. Fritz Leonhardt and Jörg Schlaich, Sir Mokshagundam Visvesvaraya, Profs. Priestley, R. Park and Paulay, and Adam Nevillie, Dr. Blodgett and Buckminster Fuller. Several senior fraternity members, who read these articles, also shared their experiences of working with some these Gems, or how they used their literature during their work. Such constructive comments by readers always boost the morale of authors. A few students sent us comments over email, Whatsapp and phone calls on how the series is inspiring them to achieve greater heights. We are thankful to all these readers. In this 13th article let us study about the inspiring professional biography of a world renowned Structural Artists - Félix Candela.

Félix Candela Outeriño (January 27, 1910 - December 7, 1997) was an internationally renowned architect, structural engineer, and master builder. He is best known for his innovative designs using reinforced thin-shell concrete to create highly efficient hyperbolic paraboloid shapes utilized in his construction of many well-known churches, factories, stadiums, and other buildings, primarily in and around Mexico City in the mid-20th century.

Early life:

Félix Candela was born in Madrid, Spain in 1910. He was an award-winning athlete in his youth. In 1927 Candela enrolled in La Escuela Superior de Arquitectura (Madrid Superior Technical School of Architecture), and graduated in 1935. In his sixth year, he begun to study thin shells thanks to their appearance in architectural and engineering magazines, and to Eduardo Torroja's building of a thin-shell concrete vault, Frontón Recoletos, in Madrid. Although he never took a formal course on thin shells, Candela on his own started to seriously read articles by French and German engineers.

During this period, he developed a special interest on geometry and started teaching other students in private lessons. In his junior year, his visual intelligence and his descriptive geometric and trigonometric talent helped him catch the eye of Prof. Luis Vegas. Prof. Vegas was his professor teaching material strength, and gave Candela the honorary title of "Luis Vegas's Helper". While helping Vegas, Candela entered many architecture competitions and won most of them. Unlike many of his peers, Candela didn't show intellectual or aesthetic efforts in school. He didn't even like pure mathematics. When Candela was a student in Madrid, the schools taught the theory of elasticity. This was a huge problem area for architects, but it didn't faze Candela, who assisted the professors and even tutored other students.

Candela abandoned plans to continue his studies in Germany in 1936 to join the Republican struggle against the Nationalist forces of General Francisco Franco (1892–1975). During the Spanish Civil War, he gained practical construction experience as the Spanish Republic's Captain of Engineers and led projects to renovate old buildings for military use. His work, however, led to his eventual capture and imprisonment in an internment camp in Perpignan, France, until the end of the war in 1939, when he was one of a few hundred prisoners sent by ship to Mexico, where he would start his career.

Candela married Eladia Martin when he moved to

Mexico from Spain; there, they raised a family. In his early life, Felix was active in sports, particularly rugby and skiing.

His Love for Thin Shell Structures:

Candela worked very hard during his life time to prove the potential of reinforced concrete in structural engineering. His work proved that reinforced concrete is extremely efficient in shell structures. As this shape eliminates tensile forces in the concrete, and RC is strong in compression, it resulted in economic and elegant structures. He also solved problems by simplest means. For example, in shell design, he relied on the geometric properties of the shell for analysis, instead of solving complex mathematical equations, as given in any book on shell structures. He seemed to follow the works of Eduardo Torroja in Europe and Guillermo Gonzalez Zuleta in America.

Around 1950, when his company had to design laminar structures, he started researching journals and engineering articles to obtain as much information as possible on these types of structures. From this, he started questioning the behaviour of reinforced concrete with the elastic assumptions and concluded they are in total disagreement with each other (Faber 1963). Candela has said on more than one occasion that the analysis of a structure is a sort of "hobby" to him.

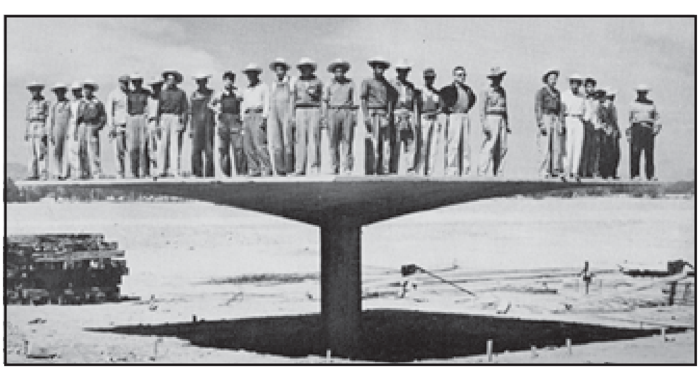
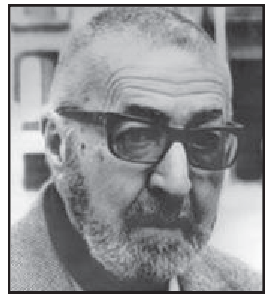


Fig.1 Umbrella shell experiment by Candela, (Faber,1963)

His Practice in Mexico

In 1939, when he was exiled to Mexico, he developed experience working as an architect, an engineer, and a builder of traditional beam and column construction. During the first two years in Mexico, Candela subscribed to engineering and



architectural magazines and journals, through which readings he tried to complete his education as a structural engineer, but, he later admitted, "I still did not seriously dedicate myself to study shells".

Candela did most of his work in Mexico throughout the 1950s and into the late 60s. He was responsible for more than 300 works and 900 projects in this time period. Many of his larger projects were given to him by the Mexican government, such as the Cosmic Rays Pavilion. Thanks to self-education in shell design and construction during 1950 and 1951, by the end of 1951 Candela began to gain international recognition.

Most of his early thin-shell forms during this period were copies, with minor modifications, of those he had read about. They served primarily as full-scale experiments so he was self-taught not only in the analysis of thin shells, but also in their construction. These experimental shells provided him with crucial insight on the practice of building these structures. His earliest thin-shell forms were not of the hyperbolic paraboloid (hypar) form, but of more traditional forms––funicular, conoidal, and cylindrical. It was only when he became confident, based on experience in the design, analysis, and construction of thin shells, that he started to create his art.

Candela also benefited from the budget implemented by Mexican President Adolfo Ruiz Cortines in many construction projects and also the area of education. Candela became a professor in Mexico, which is what he did for the remainder of his career. He also taught of Santiago Calatrava, which highly influenced the style of Calatrava's works (Fig. 2). Felix Candela died at the age of 87 in 1997 in North Carolina, USA.

Fig.2 Félix Candela In different moods with his colleagues (top) and with young engineer Sandiago Calatrava (bottom)

Key Projects :

Candela and his siblings, Antonio and Julia, founded Cubiertas Ala S.A., in 1950, a company dedicated to the construction of reinforced concrete shell and laminar structures. Their first major work, and Candela's first hypar shell (in collaboration with Jorge Gonzáles Reyna) was the Cosmic Rays Pavilion, near Mexico City (see Figs. 3 to 5). The Pavilion was well received by the general public as well as by the architectural and engineering professions, and it was widely published. This RC roof varies in thickness from only 16 mm to 50 mm.

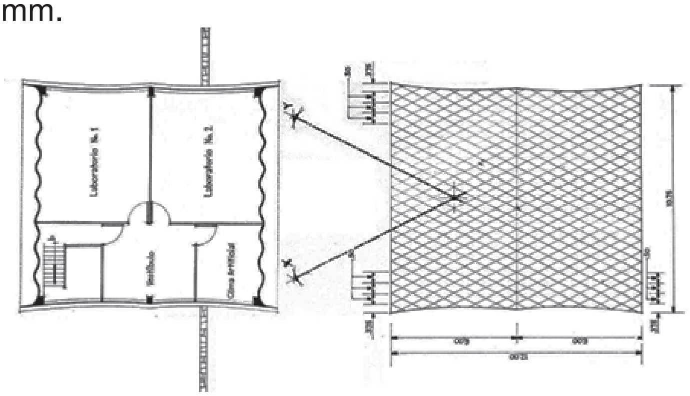


Fig.3 Architectural Plan of Cosmic Ray Pavilion, 1951

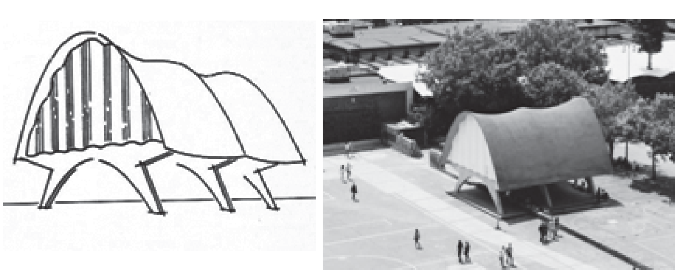


Fig.4 Sketch and Actual Structure - Cosmic Ray Pavilion, 1951

Fig.5 Cosmic Ray Pavilion during construction stage, 1951

Subsequently, Candela built in Mexico City the Church of La Virgen Milagrosa (1953–55; "The Miraculous Virgin"), with a warped roof of reinforced concrete 38 mm thick, and the Church of San Vicente de Paul (1960). In addition to Rio's Warehouse in Mexico City (1955) and other warped-shell industrial buildings, he designed various thin-shell catenary, or barrel-vaulted, factories and warehouses. A concept sketch of paraboloid made by him is shown in Fig.6. On several of his projects he acted as construction foreman.

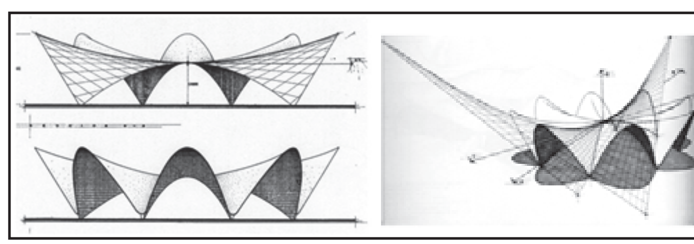


Fig.6 Concept sketch of a Paraboloid by Candela

Other notable projects executed by him are given below:

· 1952, Almacenes de las Aduanas (customs warehouses), Pantaco, Azcapotzalco, Mexico City, with Carlos Recamier

· 1953-1957 Iglesia de la Medalla de la VirgenMilagrosa, Colonia Narvarte, Mexico City

· 1954-1955 Fábrica Celestino Fernández, Colonia Vallejo, Mexico City

· 1955, covering for Mexican Stock Exchange, Mexico City, with Enrique de La Mora Lopez and Fernando Carmona

· 1955-1956 Quiosco de Música, Santa Fe.

· Churches in Mexico City: 1955 El Atillo church, Coyoacán; 1955 San Antonio de las Huertas, Tacuba; 1959 San Vicente de Paul, 1963 Santa Monica Lopez of Carmona; all with Enrique de La Mora y Palomar and Fernando Lopez Carmona

· 1955-56: Municipal markets in Coyoacán, Azcapotzalco and Anáhuac, Mexico City with Pedro Ramirez Vàzquez and Rafael Mijares

· 1956-1957 Nightclub La Jacaranda, Acapulco

· 1958, Los Manatiales restaurant, Xochimilco, Mexico City, with JoaquínÁlvarezOrdóñez

· 1959-1960, Plantaembotelladora Bacardi, Cuautitlán, near Mexico City (Fig. 7)

Fig.7 Bacardi Pavilion (1960)

· 1959, Capilla de Abierta Palmira in Cuernavaca with Rosell and Manuel Guillermo Larrosa (Fig. 8)

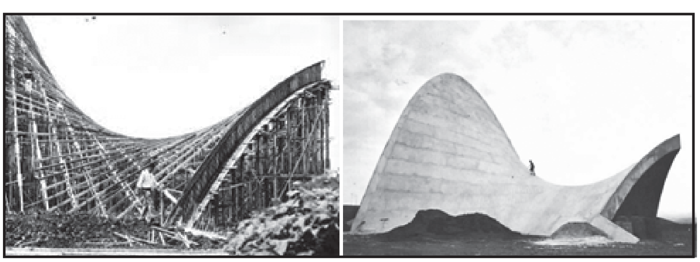


Fig.8 Capilla de Palmira, 1959

· 1959, San José Obrero church Monterrey, with Enrique de La Mora y Palomar and Fernando Lopez Carmona

· 1962, Aula Magna at The Anglo Mexican Foundation, with Enrique de La Mora Colonia San Rafael

· 1962-3, Church of Our Lady of Guadalupe in Madrid, with Enrique de La Mora y Palomar and Fernando Lopez Carmona

· 1966, Parroquia del Señor del Campo Florido, Mexico City

· 1968, Palacio de los Deportes, Mexico City, built for the 1968 Summer Olympics, with A. Peyri and E. Castañeda Tamborell (Fig. 9)

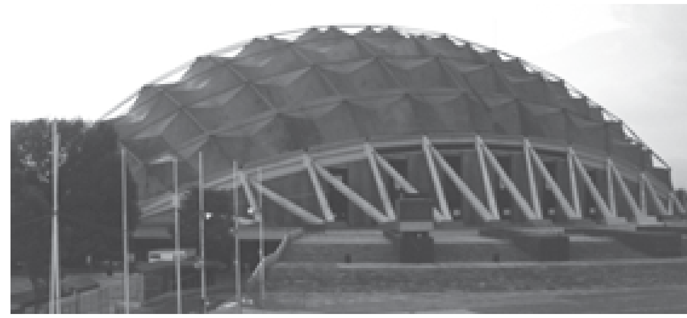


Fig.9 Palace of Sports is an indoor arena located in Mexico City (1968)

· 1969, Mexico City metro stations San Lázaro and Candelaria (Fig. 10 and 11)

Fig.10 San Lázaro Metro Station, Mexico City, 1969

Fig.11 Panoramic view of roof of Candelaria metro station, Mexico City, 1969

· 1994-2002 L'Oceanogràfic, Valencia, Spain (Fig. 12)

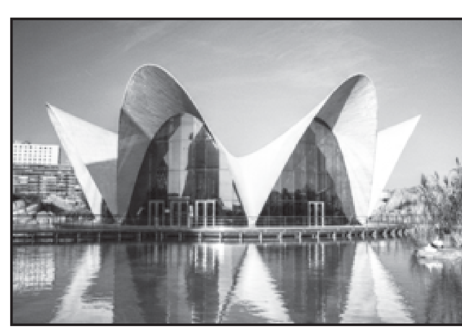
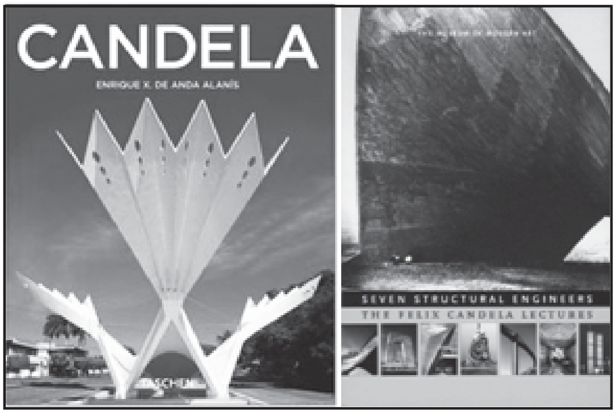


Fig.12'L'Oceanogràfic'an oceanarium, in the east of the city of Valencia, Spain (opened in 2003)

Books and References, Biographies



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2. Seven Structural Engineers – Lectures by Felix Candela

Acknowledgements:

The authors wish to acknowledge the images, used in this contribution, which are extracted from several web resources.

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GOOD CONSTRUCTION PRACTICES TO CONSTRUCT DURABLE BUILDINGS (STRUCTURES) PART - 1

By Jaykumar J. Shah

Mr. Shah was born on 18th April 1934 in a village Umadi in Maharashtra. He did his matriculation in 1950, from Maharashtra High School, Jabalpur, inter-science in 1952, from Ruia College Mumbai. He was awarded Gibbs prize, which goes to a student who ranks first in physics in inter-science in Mumbai University. In 1957 he received bachelor of engineering degree in Civil Engineering from then Victoria Jubilee Technical Institute, Mumbai.

Since May 1957 to September 1990 he worked with Hindustan Construction Company, Mumbai both in India and abroad in various fields but mainly on projects.

Later two years he was United Nations Specialist to government of Jamaica (West Indies). After he returned from Jamaica in December 1992 he has totally devoted himself to Repairs, Rehabilitation and waterproofing of existing RCC buildings and durability of new constructions.

He has written following two books.

'A Handy Guide to Repairs, Rehabilitation and Waterproofing to RCC buildings (structures)- 28th Edition.

'A Handy Guide for Builders, Users/Owners, Civil Engineers and Architects for constructing RCC buildings (structures) Durable and Eco-friendly' on Durability in association with ACC.

He has conducted many in-house training programmes and workshops in the subjects of his expertise, single faculty, for one / two full days and are continuing with great demand.

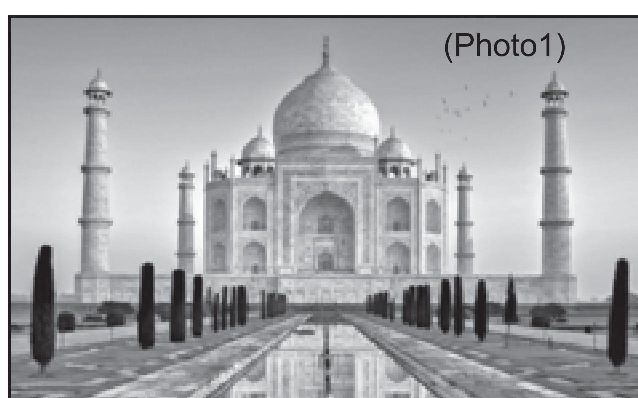
Introduction

Can we not have a sweet home forever? A sweet home to rest peacefully after the day's hard work. A home without any dampness, leakage, seepage and deterioration. Will it be a death trap all along? Certainly everybody would like to have a durable home with long life. How do we achieve this? Who can really bell the cat? What is the ACTION PLAN?

These are the questions, which haunt us day in and day out.

In this article the author has attempted to find a permanent solution to these very pertinent questions. This article is gist of book 'A Handy Guide for Builders, Users/Owners, Civil Engineers and Architects for constructing RCC Buildings (structures), Durable and Eco-Friendly ' by the author.

Construction has very long history in India from the day of Mohen-Jo-Daro Civilization. Even today we have great monumental structures like Dilwada Temples at Mt. Abu, Qutub Minor at New Delhi. The Taj Mahal (Photo1.) considered being the jewel among the monumental buildings was built during 1632 to 1650 AD. All these have stood the vagaries of the nature for years. Some of the outstanding ancient buildings and structures in other parts of the world which have stood the test of the time and standing fine even today are:


(Photo1)

· The Khufu Pyramid in Egypt built around 4700 BC.

· The Anio Novas aqueduct in Italy 89 Km long built by Roman Emperor Caliquda during 52 AD

· The Great Wall of China, 2400 Km long and 9 m high going over mountains and valleys.

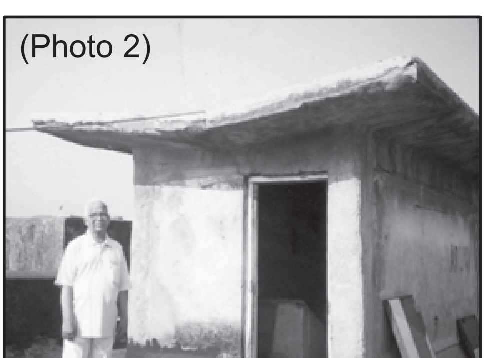
The construction materials and the construction techniques went on changing with the time. The 20th century can rightly be called the century of the reinforced cement concrete structures. RCC was extensively used for the various types of structures due to the ease of the construction and the ability of the concrete to lend any shape. This provided good speed of construction and is economical also. However in the recent years, heavy deterioration of many reinforced cement concrete structures due to the corrosion of the reinforcing steel bars is reported from all over the world. Similar problem is also experienced in India.

Earthquakes in Gujarat, Maharashtra and other states in past destroyed many buildings/structures with heavy loss of human lives. These were not designed to resist the earthquake forces.

The early deterioration of the RCC structures and the early collapses before the lifetime of the structure has sufficiently brought in the awareness to build the RCC structures to the Durability Parameters. The earthquakes has taught us to design the structures to resist the earthquake forces.

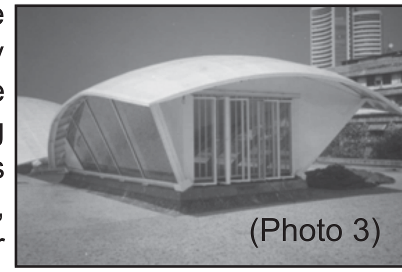
Reasons for early deterioration of RCC structures.

The first major reason for early deterioration is at architectural planning, then in design and finally at construction stage


(Photo 2)

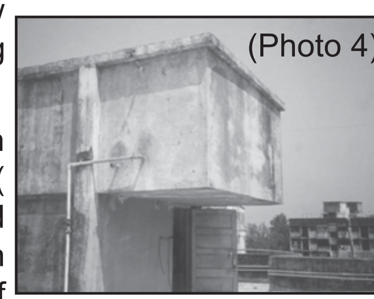
Few main reasons are:

Facade and shapes of different units are such that we experience leakage, seepage and dampness in the building. (as seen in Photo 2. Here the head room slab of stair – case of a building is SAUCER shape which accumulates the rain water and then it percolates in the building whereas the head room slab at PRIENCE of WALES MUSEUM as seen in Photo 3 is doubly curved shape which does not allow rain water to stagnate but flows out easily / smoothly.


(Photo 3)

➪ Plumbing service ducts are invariably not easily accessible for attending leakages from joints of plumbing lines, and for other problems.

➪ Use of 'B ' class GI pipes for drinking water lines, corrode within just 3 to 5 years. 'C' class pipes commonly used so far corrode within 15 years or so. Now UPVC pipes with long life are used.


(Photo 4)

➪ Deficiency in design/bad design. (Cantilever Over Head water tank provided in a building is example of bad design as due to load it is in distress in just few years of construction as seen in Photo 4.)

➪ Specifying nominal concrete mixes such as 1:2:4 with high water to cement ratio.

➪ Use of substandard/ adulterated cement. (This is for existing old buildings.) Now we get good quality world class cement.

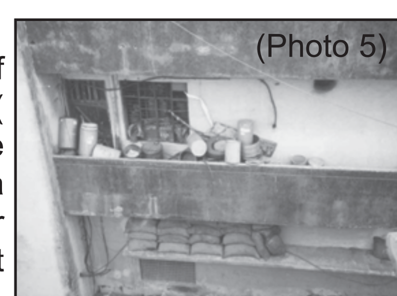
➪ Use of sand with silt content more than permissible limits.

➪ Buildings are not built to durability parameters.

➪ Substandard construction

➪ Lack of supervision during construction.

The second major reason for early deterioration of RCC buildings is its wrong use during its service life, like;


(Photo 5)

➪ Imposition of additional loads (Photo 5 shows fire escape and chajja heavily loaded for which it is not designed)

➯ Improper renovations and tampering of RCC members

➯ Wrong use of structure for which it is not designed (Photo 6 shows beam used for lifting heavy loads for which it is not designed)

The third major reason of early deterioration of RCC buildings is our indifferent attitude to housekeeping and regular maintenance of buildings.


(Photo 6)

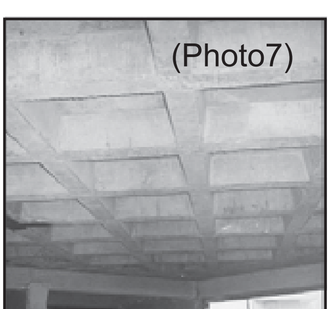
This article does not deal with architectural planning, design, wrong use/housekeeping/ regular maintenance during service life but deals with only good construction practices to construct Durable Buildings (structures).

We need to build RCC buildings/structures DURABLE in TOTALITY from CONCEPT TO COMPLETION. There is sufficient awareness in this regard with all the concerned in the constructions of the buildings but the things have not changed as desired. Why?

This is because:

- Terrible lack of EDUCATION about durability parameters at all levels (users/owners, architects, structural engineers, contractors, contractor's staff and labour)
- Misconception that Durable buildings cost fortune. In fact there is saving of 2% to 5 % in the overall cost and that repairs, if any, in future is delayed.

Thus, DURABLE STRUCTURE will fetch a good price to the builder and will also be in big demand and further establish his name permanently.


(Photo7)

There are many areas, where one saves on cost e.g. omission of plaster to RCC members (Photo 7 shows no plaster provided to slabs at Gitanjali Building)

The author suggests the following 'Action Plan' to build durable buildings.

ACTION PLAN

What is durability of building (structure)?

Many experts from all over the world have defined a DURABLE BUILDING–STRUCTURE. They have generally defined this as ability of a structure to withstand the deterioration, which is caused under the influence of environment throughout its desired life, without the need for undue maintenance.

My simple and straight forward definition of a durable building is – "A Building in

Which there is no LEAKAGE-SEEPAGE-DAMPNESS and that its DUCTS-

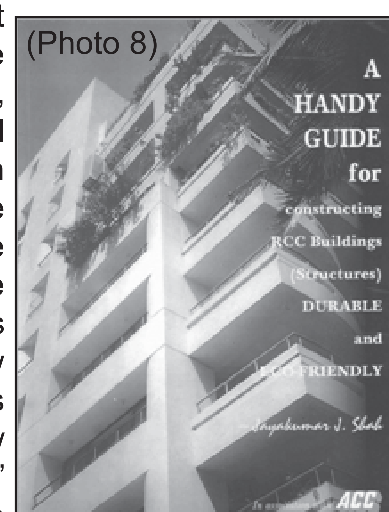
where Plumbing lines are housed are accessible easily for life time of the building for inspection, regular maintenance ,repairs and for total replacement of Plumbing Lines.

1. Appoint Durability Consultant

There cannot be two opinions that the RCC buildings must be built to last long. In other words they must be built to well defined durability standards.

It is the specifying authority; the owner/user who has to take a lead and do it or else it will never happen or will happen in few aspects with no tangible results.

The author suggests that the owner/user must first appoint a DURABILITY CONSULTANT who will take care of the overall DURABILITY aspects right from the conceptual stage to the completion. The durability consultant will coordinate between the architect, the structural designer, the main contractor and the other service agencies to achieve durable building. This is a totally new concept but has worked well on a new building "GITANJALI" (Photo 8 of the



(Photo 8)

building) close to sea-shore in a prestigious locality in South Mumbai at Rungta Lane where the author worked as an associate with an agency which was appointed as DURABILITY CONSULTANTS by the client. Durability consultant on behalf of clients weaves beads (our beads are architects, structural designers, contractors) in a thread to have a good necklace (in our case durable building).

Author thanks the owners of 'Gitanjali' (Apar), who appreciated this concept and appointed Durability consultants, with the result that this totally new concept is put to practice and the building stands a mute witness to such function.

2. Incorporate Durability Parameters in the Tender

All the durability parameters discussed later in this article were incorporated in the TENDER itself for GITANJALI. This is the next important step to achieve durable building. If durability parameters are not specified (in tender) the specifying authority cannot insist and the contractor may not oblige even if few of the suggestions do not have cost implications.

3. Monitor to Implement

The author held weekly meetings at Gitanjali with the client, the contractor, the structural designer and the architect to advise on durability and to monitor implementation.

Durability has to be the Mission of all the concerned in the construction of the building with durability consultant as a ringmaster (on behalf of the client).

Shall we say:
Let us all drink durability.
Let us all eat durability
Let us all talk durability
Let us all think durability

There has to be a continuous thought about durability with all concerned to achieve a dream house.

4. Design

The building structure has to be designed to take care of all the relevant BIS codes including BIS codes on the earthquake. It will be a good precautionary step if the client further gets the design checked from any other agency (Proof consultants) to have a full proof design without any mistakes or omissions. In fact the author suggests that the designers should not restrict themselves to the regulations which are obligatory but should look beyond and take good points from American (ASTM), British and for that matter of fact any good suggestions from any other codes to achieve a DURABLE Structure.

The design of the building should be for a minimum strength of M-30 if not more. This is necessary form durability considerations. However as author specifies free water to cement / binder ratio of 0.4 or less for all concretes, with the present day cement and use of admixture, strengths achieved will be more than M-40 at site.

5. Life Cycle Cost

The concept of life cycle cost needs to be introduced at the time of planning stage itself, looking to the astronomically high cost of restoration later. Of course the life of the building has to be decided depending upon the importance of the building.

Grand Pagoda called Dhama Pattana at Gorai near Esselworld near Mumbai developed by the Global Vipassana Foundation to accommodate 10,000 persons at one time for meditation (without any columns in-between). It is designed with life cycle cost of 500 years.

6. Structure must be Impermeable

The durable buildings have to be impermeable.

a. Water should not stagnate at any location of the building.

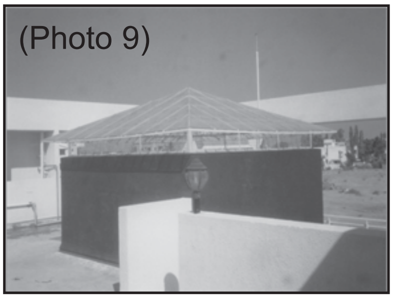
b. Water should not seep into the building from any location.

A RCC building cannot be built without water but ironically water deteriorates the building.

7. Easy Access to every unit of the Structure

Every unit of the building should have easy access for periodic inspection, maintenance and restoration later.

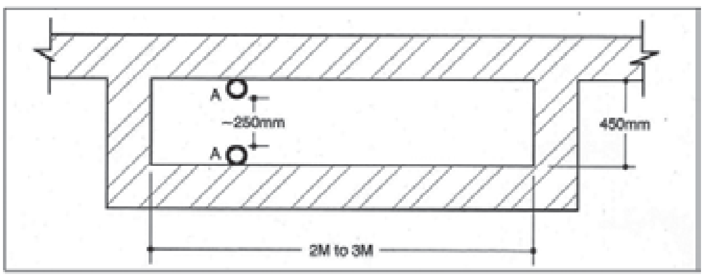
e.g. the duct for the service pipes. The author has come across a building in the prestigious locality of south Mumbai where the size of the service ducts are 450 mm by 2M/2.5M closed on all four sides



(Photo 9)

with RCC slab at ever floor level (from fire hazard consideration and as per IS Code) and also closed at terrace (Photo 9) with access from individual flats. Where two pipes come in front of each other there is hardly any gap for a plumber to attend to damaged leaking and rusted pipes.

(Sketch 10 gives details)



Also, the fourth closing wall is totally not plastered from inside and the existing plaster of other three walls has at many places debonded/cracked. The flat owners are experiencing severe leakages from the ducts but attending to the damaged/leaking service pipes and bad plaster has become a nightmare due to lack of enough working space. Service ducts should be covered as detailed in Photo 9 for good light ventilation and protection from rains.

8. Life of materials should be near about the life of structure

Life of the materials used in the construction should be more that the life for which the structure is planned. Presently we use galvanized iron pipes for circulation of drinking water. Maximum life of C-Class, G.I pipe is around 15 to 17 years. A serious thought needs to be given as deterioration of the structure starts within 15 to 17 years or so of the building due to leakages from the rusted pipes. Alternative suitable material needs to be used for long life.
e.g. Copper / U PVC etc.
Copper pipes are used at GITANJALI Building.
Now, concerned have started using UPVC pipes.

9. Ensure Sustainable development

The 1992 Earth Summit at Rio de Janeiro defined sustainable development as economic activity that is in harmony with the earth's ecosystem. In an ideal world, the best way to ensure sustainable development would be to practice a barter system with the earth's bounty in which humans take as little as possible of the good things and return as little as possible of the bad things.

Let us switch over to the use of blended cements. It is also necessary for us to understand that the increased % of the supplementary material as advocated by world renowned experts like Mr. V.K.Malhotra and many others improves the quality of the cement and uses waste material from power houses/steel plants, etc. and thus the blended cement is environmental friendly (sustainable development).

10. Concrete

(a) Cement
Use blended cement only. Increase the percentage of the supplementary material. This would not only improve the quality of cement but would also utilize the so-called waste material of Thermal Power Plants and Steel Plants (fly ash, slag, etc.). This is environment-friendly cement. Author prefers use of OPC and fly ash as separate ingredients and advises replacement of OPC by fly ash as per following details.

Table below gives blending percentages of cement with fly ash by weight.

Type of work	53 grade OPC	Fly Ash
For all Structural Works like: i. New RCC constructions ii. Rehabilitation of RCC members iii. Repairs to honey combs, Zari in fresh concrete iv. Sealing separation gaps	65%	35%
For all non-Structural Works like: i.Plaster ii. Parapet Coping Concrete Plinth protection Pavement Concrete Mortar for masonry work, Brick-bat coba and IPS work	55% 45%	40% 60%

(b) Concrete Mix Design

The concrete mix has to be designed. Let us forget 1:2:4, 1:3:6 mixes and design the mix. The FIRST most important parameter is free water to binder (cement plus supplementary material) ratio. This has to be 0.4 or less, preferably 0.35 or so.

This will give us dense concrete, which is impermeable. Concrete mix should be cohesive, workable so that no honey combed concrete is produced when vibrated properly.

(c) Sand

Use well graded good quality sand with permissible silt content only.

It may be necessary to replace natural sand by certain percentage of manufactured sand to improve the grading of sand. In case proper natural sand is not available, one has to use 100 % manufactured sand.

(d) Water

Use water suitable for construction work. This must be tasted for chlorides and sulphate contents. These have a major influence on the durability of the concrete.

(e) Tests on concrete

Apart from usual tests like slump test for workability and cube tests for strength-yet another test for concrete on site is must to assess its Durability by in- situ permeability test.

11. Concrete from Ready mix concrete plants or mixers only

At a typical construction site in an urban area using site-mixed concrete, the stored ingredients of concrete, more often than not, spill on the footpaths and roads obstructing pedestrian and vehicular traffic, besides clogging up manholes and drains. Such hazards do not exist on sites using RMC.(Photo 11) A construction site using RMC would generally look neat and clean.


(Photo 11)

Further, the use of RMC enables in reducing the wastage of materials.

At the RMC plant, relevant technology can be used to prevent or minimize dust emissions in accordance with local and national regulations. Plant and vehicle noise can be minimized through appropriate plant design, location and technology. Suitable action can be taken to improve affluent quality and reduce volumes of discharge.

RMC thus is an eco-friendly product, an advantage that is certainly appreciated in the growing environmentally conscious world.

Specify mixing of all concretes and all mortar mixes in RMC plants or in mixers only. Goodbye to hand mixing.

12. Transport, placing and vibration

- Plan proper transportation
- Place the concrete properly in position. Plan this to ensure that no segregation takes place. Take extra care during pouring of sloping roofs. It is generally understood that sloping roofs do not leak. But in practice these leak due to segregation of concrete and due to too many and bad construction joints.
- Vibrate the concrete properly to achieve dense concrete either by:
- Needle vibrator or by external vibrators or by screed vibrators or combination of the above as per the requirement of the structure. Photo 12 shows use of make shift SCREED VIBRATOR for pavement concrete.


(Photo12)

13. No more hacking of freshly placed concrete Hacking develops micro-cracks that help deterioration of structure. Specifying authorities have to make special efforts to stop this practice of hacking, which is practiced since decades. Due

(Photo13)

to ignorance, by hacking freshly placed concrete, we are making the structure to deteriorate from day one. At no stage of the concrete, hacking is advised. The author feels that the present thinking that hacking provides bond to plaster is only psychological.

Any new suggestion receives lot of resistance initially. This needs insistence and proper guidance to make the new suggestion successful. No hacking was done to any RCC members at GITANJALI Building. (Photo 13)

14. Cover, cover blocks and reinforcement

(a) Cover.

This is very often neglected. Reinforcement bars and legs of chairs are observed exposed to atmosphere when slab form is struck. When questioned, the usual answer is that these will be sealed when plaster to the slab is provided and that there is no concern for worry. This is not at all desirous. This attitude has to change. Proper cover must be provided to ensure durability.

Provide sufficient cover to the reinforcement steel. Give special attention and ensure proper cover to the legs of chairs. Cover concrete protects steel reinforcement by providing a dense, strong and impermeable barrier against ingress of moisture, oxygen, chlorides, sulphates, carbon dioxide and other aggressive gases and chemicals and by providing a passive protective coating on steel surface. Due to alkaline nature of concrete, this coating prevents corrosion of steel. Every care should be taken to ensure that the projecting ends of the binding wire do not encroach into the concrete cover.

(b) Cover blocks.

Poor quality mortar/concrete cover blocks cast a day or two before concrete are generally used. They break during concreting resulting in reduction of cover or no cover. Instead of protecting the steel they become a passage for moisture and chemicals

(Photo14)

to enter and cause corrosion and durability problems. At many construction sites, stone chips are used as cover blocks. These often get dislodged during concreting, resulting in steel reinforcement resting directly on the form, leaving little or no cover to the bars. Polypropylene/low density polyethylene cover blocks are a better solution. However, industrially manufactured superior designs and shapes of cover blocks in concrete with comparable strength, durability and porosity to the surrounding concrete is the excellent choice for obvious durability reasons. (Photo 14)

(c) Reinforcement.

This must be sufficiently uncongested to allow concrete to flow freely and definitely around every reinforcement bar. Detailing of reinforcement should be done to facilitate easy pouring of concrete and good compaction.

Protection of reinforcement bars against corrosion will depend upon the importance of the building and one or the combination of the following measures are adopted by the industry.

(i) Specify free water to binder material ratio of 0.4 or less to all RCC members as advised earlier. This gives dense and impermeable concrete and the environment around the reinforcement bars will be alkaline and thus ensures protection of rods against corrosion.

(ii) Coat reinforcing bars with suitable protective coating.

(iii) Protect finished concrete by suitable protective coating.

(iv) Provide stainless steel rods fully or partially depending upon the life cycle cost requirement.

(v) Use corrosion resistant reinforcing bars.

(vi) Protect reinforcing bars against corrosion by providing cathode protection

(vii) Use galvanized steel reinforcement.

(viii) And/or such other measures.

However author agrees with experts that if measure (i) above is adopted then following other measures are not required and that then one can use regular reinforcement bars.

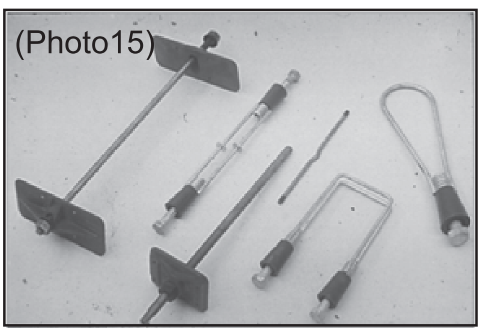
15. Formwork

This must be designed to take the service loads, must be rigid and water tight consistent with the safety of the workers and the safety of the structure.

Plan good quality form and use good quality form oil to achieve good quality form finish. Plaster can be totally omitted to form-finish RCC members

Use only coil-nut with threaded bolt tie-rods. (Photo 15) This is as per international standards. In this system, there is no through and through hole formed in the RCC members and the tie rod reinforcement, which gets embedded, is 50 mm inside from the face the concrete.

(Photo15)

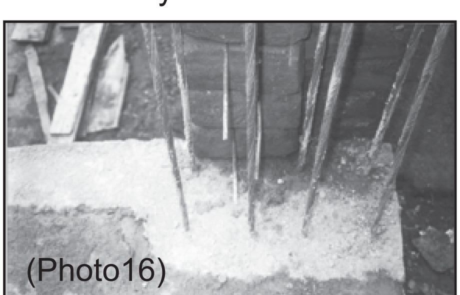


Discourage starter lifts to columns, which are very commonly used in the building industry, which are normally an un-vibrated mortar base and thus absolutely not desirable.

16. Construction joints

These are often neglected. These need proper attention to avoid any leakage form the construction joints.

1. Best and easy method is to remove laitance immediately after two hours or so by light water jet. During this preparation clean the exposed reinforcement rods also. (Photo 16 shows laitance, not removed)



(Photo16)

2. Keep the construction joints as minimum as possible.

3. In case of basement or water tanks the construction joints should not be at the top of bottom slab level but at least 300mm above in the vertical walls.

4. Grout the construction joints with cement slurry with minimum 2.5 liters of acrylic polymer based bonding agent and around 500 ml of naphtha based super plasticiser both together per 50 Kg of cement. The free water to cement ratio should be around 0.6 or so. Nipples for grouting can be placed in position during the construction itself.

17. Foundation Care

Once the concrete has 0.4 or less free water to binder material ratio, no protective coat is necessary. However, as foundations are not available for inspection during the entire lifetime of the building, it is advised to provide suitable protective coat for additional protection. It is advised to coat the foundations with coating advised in next Para waterproofing to have uniformity and only one product for all areas.

(Part2 To be continued in next issue ...)

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MUMBAI METRO LINE-3 (COLABA-BANDRA-SEEPZ) PROJECT

- C.M. Jadhav

1.0 Project Description :

Mumbai Metro Line-3 (Colaba – Bandra – SEEPZ) is an important infrastructure Project being implemented through Mumbai Metro Rail Corporation a special purpose Joint Venture Company of Govt. of India and Govt. of Maharashtra with 50:50% equity. The Project has been approved by the Govt. of India and the Govt. of Maharashtra and will be implemented with the loan assistance of Japan International Cooperation Agency (JICA).

Project brief details are:

a. Project name	: Colaba-Bandra-SEEPZ MRTS corridor (Line-3)
b. Project Length	: 33.5 km
c. No. of Stations	: 26 U/G+ 1 At Grade
d. Car Depot	: Aarey Colony
e. Completion Cost	: Rs. 23,136 Cr.
f. Implementation Agency	: Mumbai Metro Rail Corporation Ltd (MMRC)
g. JICA loan	: Rs.13,235 Cr. (57.2%)

2.0 Metro Line 3 - Project Benefits:

h. Provide high quality public transport system throughout Mumbai city and suburbs within accessible/approach distance of 1 to 2 km.

i. Provide Connectivity: Nariman Point, Cuffe Parade (WTC), Fort, Lower Parel (Senapati Bapat Marg), Worli, Prabhadevi, Shivajipark, Bandra Kurla Complex (BKC), Bandra (Govt.)Colony, MIDC area and SEEPZ.

j. Multimodal integration and Interchange with other Public Transport: Central Railway at Chatrapati Shivaji Terminus (CST), Western Railway at Churchgate, Mumbai Central, Metro Line 1 at Marol Naka and Monorail at Mahalaxmi.

k. Facilitate Airport Connectivity (Domestic & International Terminal T2).

l. Comfort & Reliability : End to End Air Conditioned Travel, Higher Frequency, Reliable & Punctual 100% Time Adherence Eliminate Peak Hour delays, Reduced Travel time

m. Safety & Security :Platform Screen Doors, Closed Door Cars, Women Safety & Security, Continuous Surveillance (24X7), No Trespassing possible

n. Environmental : 35% Reduction in traffic (456,771 less vtpd), Reduced fuel consumption (save 243,390 lpd), Reduced Air & Noise pollution (PM-133.5, Nox-594.2, HC-1,328.8, CO-4,327.4, CO2 – 6,800.2 tonnes/yr)

o. Economic : Repositioning of Mumbai on Worldwide competitiveness, Additional Employment During and After construction, Improved Productivity,

p. Reduced burden on suburban railway (within Mumbai) 25%

q. Reduced demand for road for automobiles and parking; 35%

3.0 Project alignment:

Line 3 Colaba - Bandra - SEEPZ Alignment

4.0 Project Benefits to Mumbai:

a. When completed this will be the longest single underground Metro Line in India (will be one of the 5 longest underground lines in world)

b. The Line will revive Mumbai Island City Economic ativity and business environment.

c. Several Development and Redevelopment projects will come all along the Alignment.

d. This will be first of several Metro lines to be implemented on EPC basis will boost economic activity in Mumbai.

e. Major Civil contracts / sub-contracts / Construction material suppliers

f. Equipment suppliers, TBM / D-Wall machineries, etc.

g. System components – Rolling Stock, E&M services, Traction & Power Supplier, Signalling & Telecommunication, etc.

h. New Employment opportunities (in several thousands)

i. Project will boost skill development/Internship programs

j. Daily ridership is projected as 14 lacs in year 2021 and is expected to rise to 17 lacs in 2031.

5.0 Funding pattern of project:

GOI approved project funding plan is as below:

Source	(Rs Cr)	Percentage
Equity by Centre	2,403	10.4%
Equity by MMRC, State	2,403	10.4%
Sub Debt by Central Govt	1,025	4.4%
Sub Debt by State Govt	1,615	7.0%
Property development + Impact fee	1,000	4.3%
Stakeholder contribution (MIAL)	777	3.4%
ASIDE funding / MMRDA Grant	679	2.9%
JICA loan	13,235	57.2%
Total Project Completion cost	**23,136**	**100.0%**

6.0 Present status of project:

6.1 Consultants: M/s AECOM-PADECO-LBG-Egis Consortium is the General Consultants (GC) for this project.

6.2 Civil Works: Civil work has commenced in all 7 packages. Works of utility shifting, TBM launching shaft, station works are in progress. Casting yard for all 7 packages completed, Segment casting are commissioned.

6.3 Car Depot works: - Car depot civil works are in progress at Aarey colony with completion period 30 months.

7.0 Tunnel Boring Machine

The tunnelling will be done using Tunnel Boring Machines (TBMs). The twin tunnels between stations will be of finished tunnel diameter is 5.8 m each. A total of about 51 km of tunnelling will be carried out for this project. For this about 2.8 lakhs tunnel segments are to be erected.

Some of the statistics related to tunnelling operation is as under:

7.1 The average excavation diameter of TBM is 6.5 m. Average length of a TBM is 110 metres.

7.2 The TBM types to be used in the line 3 project are Earth Pressure Balance (EPB) TBMs, Hard Rock TBMs, Slurry TBMs and Dual Mode TBMs.

7.3 Total 17 TBMs to be used in the entire project for tunnelling, out of which 10TBMs are new and 7 TBMs are refurbished.

7.4 TBMs deployed on this project are manufactured by Herrenknecht (Germany), Robbins (US), STEC (China) and Terratec (Australia).

7.5 Refurbished TBMs are also practically new as all crucial components barring steel parts, are replaced with new ones.

7.6 The two TBMs have already reached at Mumbai.

7.7 The tunnelling is scheduled to be completed within 2 years of commissioning of TBMs in respective packages. This would be followed with installation of Tracks and other systems.

7.8 There are 11 TBM launching shafts in 7 packages. After lowering of machine in shafts, the machine will be assembled. This process takes about 45 days. For assembly of machine, TBM parts such as front shield, middle shield, cutter head, erector, screw conveyor and tail-skin shield shall be lowered in the shaft.

7.9 Other equipment shall initially be assembled on surface, but would be lowered inside the shaft in stages as the TBM moves forward inside ground.

8.0 Project milestones:

a. Commencement of Civil Works (7 U/G Packages) – July, 2016.
b. Commissioning date of Phase1 - June, 2021 (Aarey Depot to BKC)
c. Commissioning date of Phase2 - December, 2021 (BKC to Cuffe Parade)

Author :

C.M. Jadhav
Chief Project Manager,
Mumbai Metrorail Corporation Ltd.

News and Events during July to Sept 2017

31 July 2017 : Discussion on " Impact of Revised Earthquake Design Codes on Buildings " by ISSE Pune centre

The ISSE Pune Center's new managing committee has arranged the technical Panel discussion on " Impact of Revised Earthquake Design Codes on Buildings " on 31st July 2017 at Patrakar Bhavan, Sadshiv Peth, Pune as 1st program for year 2017-18. The program was attended and well appreciated by 215 structural engineers and architects of Pune City.

The program was aimed to educate, share and explain the impact of revised IS 1893 (Part 1) : 2016 Criteria for Earthquake Resistant Design of Structures and IS 13920 : 2016 Ductile Design and Detailing of Reinforced concrete Structures Subjected to Seismic Forces - Code of Practice for the city architects and the structural consultants.

The program begins with welcome and sharing the ISSE calendar by Er. Kishor Jain. ISSE chairman Mr. Dhairyashil Khairepatil in his presentation explained how the code gets revised, objections and recommendation submitted to BIS before these codes gets published. Further he briefed the few major changes suggested in revised codes which architect should consider while doing the planning of the building. In his presentation he explain the architect about the importance of sharing the preliminary plans and sketches with structural engineers before submitting it to sanctioning authority.

The second session of the program was panel discussion in which Ar. Girish Brahme , Ar. Vikas Achalkar , Ar. Shashank Phadke chair as panelist on behalf of IIA, AESA , PACA architectural associations of Pune. Er. Achyut Watve , Er. G. A. Bhilare , Er. Satish Marathe chaired as panelist on behalf of ISSE Pune. The panel discussion was neatly initiated and fully coordinated by Er. Umesh Joshi.

In the panel discussion Er. Umesh Joshi present the revised codal provision clause by clause and the questions are raised to architects and consultants for their views. Few ISSE members from audience took the great participation by cross questioning the panelist. During the discussion the points pertaining to prohibition of floating columns, provision of 2% shear walls in each directions, minimum size of column and beams, minimum % of steel in column and beams, importance factors, irregularity of buildings in plan and elevation, restriction on openings in buildings, strong column weak beam concept, restriction and new provisions for Prestress slabs , minimum grade of concrete, non consideration of shear capacity of concrete,

infill wall consideration, special shear walls from foundation levels, elimination of soft stories by provision of shear walls, column aspect ratio, detailing of shear wall, etc. thoroughly discussed.

In the concluding remark the ISSE decides to follow the revised code and do the necessary changes in the analysis and design for the upcoming projects. It was also decided to conduct the similar kind of program for generating awareness for the developers and builders of Pune city.

Er. Parag Deshpande proposed the vote of thanks.

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4 Aug 2017 R L Nene memorial lecture : Challenges in design and construction of Underground Metro rail by ISSE Mumbai.

R. L. Nene Memorial lecture was organized by ISSE on 4th August 2017 At I.E's hall. Every year ISSE organizes a lecture and arranges a technical informative lectures to remember Late Shri. R. L. Nene, our founder president.

The program was started with offering floral tribute to Late Shri. R. L. Nene, founder president, our guru and guide.

Shri N.K. Bhattacharya remembered Late Shri R.L. Nene about his association, working with Late Shri R.L. Nene. The Methodology, neatness of working, Discipline were virtues of Shri. R.L. Nene with impressed him.

Shri Hemant Vadalkar introduced Speaker C. M.Jadhav, Chief Project Manager, MMRCL.

Er. C. M. Jadhav, explained the planning of Mumbai Metro line 3 which is underground and challenges faced during planning and execution. He gave information on Tunnel boring machines required for underground tunnels and station buildings and general construction method adopted. He explained about difficulties in foundations of nearby structures, services below roads, and how new machine goes below ground up to 20 to 30m where tunnel is created without disturbing near by structures.

Being a very important project from point of view of Mumbai, Lot of Engineers attended the lecture to have proper idea about the project. Actually the project started with Consultants study long back and with their study remarks route was finalized, lot of questions were asked by engineers to satisfy their points.

After this, very informative and educative lecture, by representatives of TATA Steel on new products like steel doors and other steel products was delivered.

This was an ongoing lecture series by ISSE jointly with Tata steel.

Shri Hemant Vadalkar gave vote of thanks. The programme had overwhelming response and more than 150 engineers attended it .

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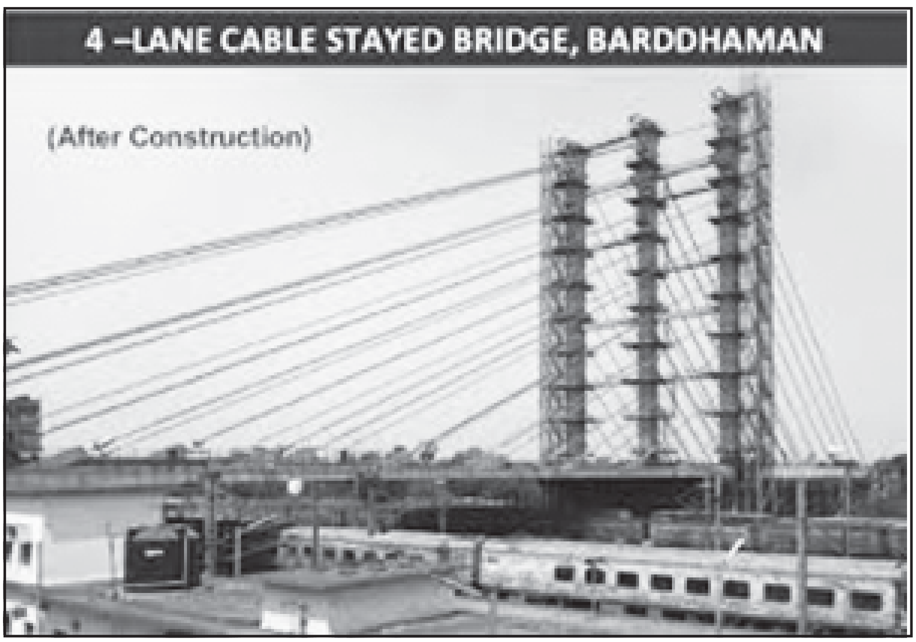
18 Aug 2017 – Technical lecture on Cable stayed bride by IIBE Mumbai



Indian Institute of Bridge Engineers (IIBE) arranged a lecture on Cable stayed bridges. Experts in the field were called to share their experience. R. R. Jaruhar – Member Engineering, Ex Officio Secretary Govt. Of India had given over view of bridge construction practices. Dr. Prem Krishna- former HOD IIT Roorkee presented evolution of cable stayed brides which are being used from 150m span to 1100m span. The advantage of cable stayed bridge over suspension bridges was explained which includes handling small size cables, stiffer and lighter decks, etc.

Mr. Rajesh Prasad , E.D.- Metro, Rail Vikas Nigam Limited, Kolkata, presented case study for cable stayed bridge built at Kolkata in record time with all quality provisions. This has four lane bridge having 124m main span and 64m tie back span. This has three lines of cable and composite construction. Corrosion protection measures were implemented for protecting cables and steel deck members. Life time monitoring system to check the force in the cable has been introduced. The lecture was very interesting. The proceedings were conducted by Dr. Gopal Rai.

1 Sept 2017 Participating in ACETech Connect 2017

Interaction with construction industry, manufacturers of steel, repair chemicals, cement, tiles, natural stones was done at the ISSE stall.

ACETECH CONNECT 2017 was organized by The Economic Times ACETECH in Hotel Sahara Star Mumbai on 1st Sept. 2017.

The platform was for the purpose of direct meeting with Architects, designing firms & Construction house. It was opportunity to meet directly management of top brands.

ISSE participated in ACETECH CONNECT 2017. ISSE representatives Eng. Shri Hemant Vadalkar and P.P. Eng. Shri Suresh Dharmadhikari participated to obtain information from various agencies and to brief them about ISSE.

May companies like Finolex Pipes, Texel, Asian Paints, Aakash Italian marble, my window, Shreeji wood crafts Ltd… and many other companies were cosponsors.

This was organized in many segments. Bath and sanitation, tiles & marble, Decorative lighting, paints, Hardware and fittings, roofing and cladding, steel and concrete, plumbing, Doors and windows, construction chemicals… and many more.

All construction related information was available under one roof.

The arrangement made by organized was very good and all company representatives could reach to all cubicals easily.

A booklet was issued by CONNECT containing information about all participants.

It was a good opportunity for ISSE to project to large segment of construction related companies,

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Certification by Structural engineers

It has been observed that various organisations like MIDC, CIDCO, MHADA, various municipal corporations, special planning authorities and other statutory bodies demand stability certificate from structural engineers. The formats of certification are different for all organisations. Some formats state that " I have checked all the materials at site, work is executed as per approved plans, I am responsible for every thing. ". Architects are also putting pressure on structural engineers to issue the required certificates. Builders are asking structural engineers to issue certificates under RERA which is really not required. Unfortunately our colleagues are issuing any kind of certificates with the fear of losing the project.

Corporations are insisting on issuing structural stability certificate after carrying out structural audit which is also wrong. ISSE has represented to various organisations against this demand. Structural engineers should only issue" Structural inspection certificate" as he is not the original structural designer.

Structural engineer is only responsible for correctness of his structural design based on the current code of practice. Structural engineer is not responsible for quality of material, workmanship, excess construction, alteration / damage by occupants, absence of maintenance by the owners etc.

We appeal to all ISSE members and practicing structural engineers not to issue any certificate which is beyond their scope of work. Please bring such cases to the notice of ISSE. ISSE is working on standard certification formats for structural engineers which can be followed. Recently new NBC2016 has provided draft certificates in section 2 which talks about " Structural design sufficiency certificate "which should be followed by all structural engineers.

- - - - - - - - - - - - Team ISSE and Advisory Trustees

Formats issued by NBC2016

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ANNEX C

(*Clause* 12.2.8)

FORM FOR CERTIFICATE FOR STRUCTURAL DESIGN SUFFICIENCY

With respect to the building work of erection, re-erection or for making alteration in the building No. .... or to .... on/in Plot No. .... in Colony/ Street .... *Mohalla*/*Bazar*/Road ....City ...., we certify that the structural design of the building for which building plans are being submitted for approval shall be done and submitted for approval, to satisfy the structural safety requirements for all situations including natural disasters, as applicable, as stipulated in National Building Code of India and its Part 6 'Structural Design' and other relevant Codes; and the information given therein is factually correct to the best of our knowledge and understanding.

	Signature of owner with date	Signature of the registered engineer/structural engineer[1)] with date and registration No.
Name (in block letters):	....	....
Address :	....	....

ANNEX E

(*Clause* 12.2.9)

FORM FOR SUPERVISION

I hereby certify that the development, erection, re-erection or material alteration in/of building No. .... or the .... on/in Plot No. .... in Colony/Street .... *Mohalla*/*Bazar*/Road .... City .... shall be carried out under my supervision and I certify that all the materials (type and grade) and the workmanship of the work shall be generally in accordance with the general and detailed specifications submitted along with, and that the work shall be carried out according to the sanctioned plans.

Signature of Registered Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/ Urban Designer [1)] ....

Name of Registered Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer [1)] .... (in block letters)

Registration No. of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer [1)] ....

Address of Registered Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer [1)]

....

....

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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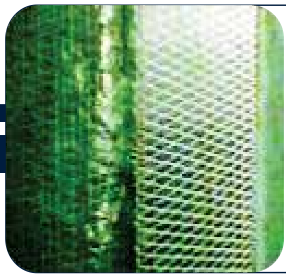

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