STRUCTURAL ENGINEERING

QUARTERLY JOURNAL OF
INDIAN SOCIETY
OF
STRUCTURAL ENGINEERS

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VOLUME 13-3

Jul-Aug-Sept-2011

(See page 12 inside)

(See page 3 inside)

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Contents

Editor : N K Bhattacharyya
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Fraternity News

WELCOME TO NEW MEMBERS

(Jly-Aug-Sep 2011)

LIFE MEMBERS

M- 1108 Mr.Harshad Ajit Kulkarni
M- 1109 Mr. Manish Ravindra Negandhi
M- 1110 Mr. Prabhakar Govinda Vanjari
M- 1111 Mr. Ravi Malaya Pasulla
M- 1112 Mr. Zarir Nowraz Panthaky
M- 1113 Mr. Shashikant Marutirao Jiddimani
M- 1114 Mr. Agnelo Fernades
M- 1115 Mr. Shashikant Bhaskarrao Andurkar
M- 1116 Mr. Kalpeshkumar Goutamchand Maloo
M- 1117 Mr. Rajendrakuamar Tukaram Salve
M- 1118 Mr. Jayant Govindrao Kulkarni
M- 1119 Mr. Shriniwas Ashayya Arakal
M- 1120 Mr. Rajendrakumar Gulabbhai Desai
M- 1121 Mr. Rohit Ramesh Khandelwal
M- 1122 Mr. Nilesh Sakhahari Dighe
M- 1123 Mr. Umesh Madhukar Naik
M- 1124 Mr. Vijay Bharat Awatade
M- 1125 Mr. Nitin Padurang Sonaje
M- 1126 Mr. Channabasava Bapurao Nadagouda
M- 1127 Mr. Sandip Bansilal Javheri
M- 1128 Ms. Kirti Sachin Bhosale
M- 1129 Mr. Atit Shahikant Gandhi
M- 1130 Mr. Aditya Rajan Deshmukh
M- 1131 Mr. Prasad Vaman Dharap
M- 1132 Mangesh Vasant Joshi
M- 1133 Mr. Prashant Vishwanath Dhanshetti
M- 1134 Mr. Prasad Arun Aphale
M- 1135 Mr. Sanjeev D. Shelar
M- 1136 Mr. Naveed Akhtar
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M- 1139 Mr. Gajendra Ramakant Gandhe
M- 1140 Ms. Uma Sopan Dasri
M- 1141 Mr. Pralhad Nanddeepa Kori
M- 1142 Mr. Shirikant Digambar Gaikwad
M- 1143 Mr. Shahikant shantaram Manekari
M- 1144 Mr. Rameez Abdul Rashid Badeghar
M- 1145 Mr. Azhruddin Abdul Quder Preampalli
M- 1146 Mr. Anand Appasheb Mulge
M- 1147 Mr. Manoj Madhukarrao shinde
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- ❄ Construction Technology & Management
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- ❄ Environmental Engineering
- ❄ Non Destructive Testing
- ❄ Bridge Engineering & Other related branches

AIMS & OBJECTIVES

1. To restore the desired status to the Structural Engineer in construction industry and to create awareness about the profession.
2. To define Boundaries of Responsibilities of Structural Engineer, commensurate with remuneration.
3. To get easy registration with Governments, Corporations and similar organisations 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.

INTEGRATION OF CONSTRUCTION ASPECTS AND AESTHETICS IN STRUCTURAL DESIGN

Vasudev V Nori,

Introduction:

Generally structural engineers often derive immense satisfaction from the intricate calculations they perform. Seldom any interest is evinced in construction problems. Certain grades of concrete are specified but the designer engineers are least interested in the design of concrete mixes, method of batching workability and many other practical aspects of construction. The "good for construction drawings" are often in form of tabular schedules. Beam column connections are rarely detailed. It is left to the engineers at site to figure out or imagine such important details of construction. Same thing this true for every aspect of construction such as design of scaffolding, intermediate stages of construction, placing underwater concrete etc. With the availability of a variety of user friendly software design engineers today have virtually very little understanding of structural behaviour and are incapable of performing simple rudimentary calculations. They are totally disinterested in aesthetic aspects of structure they design. Barring a few exceptions most of the bridges that are being built are far from being elegant. How can we loose sight of the fact that structures we design will be judged not by our refined calculations and computer software but rather by the visual impact they make on people who observe these structures ! In what follows we would like to share our experience on benefits of integration of construction and aesthetic aspects in structural design by presenting a few case studies.

Design of concrete mixes by weight apartment buildings 1966-68 :

In those days volumetric mixes were most commonly specified and used. We chose instead to design concrete mixes proportioned by weight. This was achieved by encouraging design engineers to visit the sites at regular intervals. They were trained to design the concrete mix proportions in a site laboratory by carrying out sieve analysis, measuring moisture contents, silt content etc. The actual batching was still done by same wooden boxes but calibrated by weight. A standard weighing machine that is used on railway platforms was used for checking weights. This was preferred to weigh batchers which were not only expensive, but less reliable. For example how does one correct if more sand is added inadvertently into the hopper of the weigh batcher? All cube test results were statistically evaluated on the basis of 5 % failure. We were able to demonstrate that it was possible to achieve M20 grade concrete with quantity of cement that would have been consumed for producing 1:2:4 nominal volumetric mixes. Statistical evaluation was very useful in demonstrating that with good quality control the current margin could be reduced and in fact quality work pays for itself.

Fig-1 GESC Apartment building 1967

M20 was the minimum grade specified (M15 required by I S Code). Also minimum clear cover to slabs was 20 mm (12 mm required by IS Code). Concept of characteristic strength was introduced. These features started appearing in the IS Codes almost 20 years latter.

Most of the shear walls were discontinued at the ground floor and lower basements contributing functional and aesthetic improvement of the structure.

Large panel prefabricated construction for Apartment building 1968-73.

Petit hall apartment buildings constructed during 1968-1973 was the first major application of large panel wall slab construction to multi-storied buildings in India. The moulds for pre casting, casting yard layout evolving optimum sizes of

wall panels. We had also to design the moulds for various elements, the casting yard and erection methodology.

Since this was the first major application of precast concrete technology to a 24 storied building we thought it prudent to test the behaviour of joints on a full scale mock up. We had to design the mock up and subject the same to vertical and horizontal loads of 24 storied building which was achieved with the help of prestressing cables. Indian Institute of Technology (Powai) was involved in recording various measurements. Satisfactory performance of the full scale test and the lessons learnt from the casting procedures formed the basis of design of the actual structure.

Fig-2A Completed view of Petit Hall

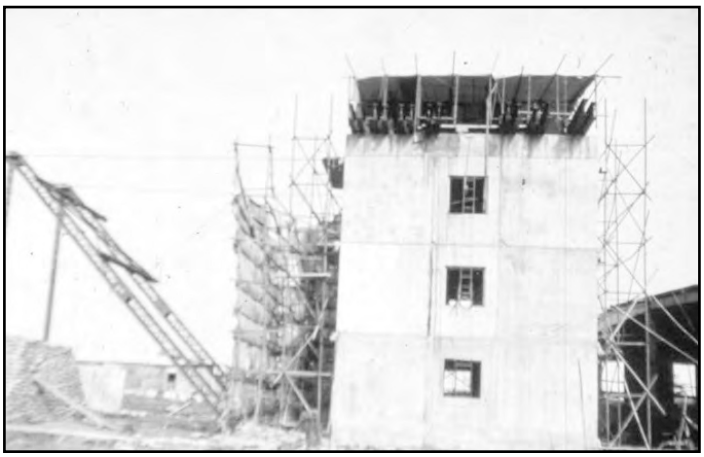


Fig-2B Mock up testing with prestressing cables

Fig-2C Battery moulds for internal walls

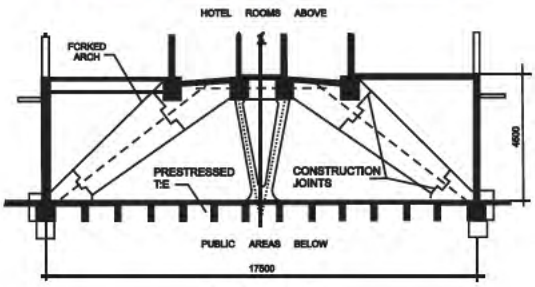
Fig-2D Moulds for external walls with permanent finish on exterior

Problems of soil investigation (1970)

The specialist agency who had carried out the soil investigation for a five star hotel in Chennai (fig 3) recommended that only sulphate resistant cement should be used for pile foundations. A table extracted from British Code CP 110 was included as a part of the report in justification of their recommendations. The fact that sulphate resistant cement was not being manufactured in India in those days did not deter the agency from making such impractical recommendations. That no distress has been observed in buildings resting on pile foundations using Ordinary Portland Cement (OPC) in Chennai did not seem to matter. It was also pointed out that sea water contains high amount of sulphates and all marine structures are being built using OPC. The specialist agency simply refused to reconsider their recommendations. Ultimately it was left to us and we recommended use of a richer mix using Pozzolona Cement that was available from a near by cement plant since it is known that Pozzolana Cements are better in resisting sulphate attack. At about same time a building constructed in Mumbai resting on pile foundations was tilting and it was suspected that this was a case of concrete disintegrating because of chemical attack caused by chemicals in soil. The problem was referred to a professor from IIT. Few concrete

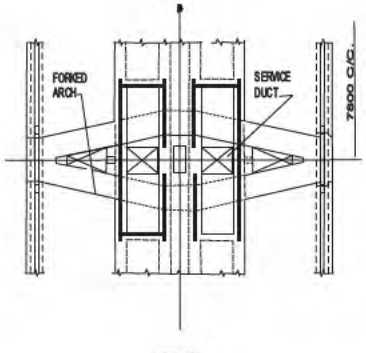
cubes were cast and buried in the same soil and the concrete cubes were inspected and tested at various ages spreading over 12 months. No evidence of concrete disintegration could be found. The settlement of building in this case had in fact occurred due to major construction defects in piles.

Fig-3A Five star Hotel – Chennai completed in 1972. The upper stories are supported on transfer girders with prestressed ties.



ELEVATION

Fig-3B



PLAN

Problems of underwater concreting and defects in cast-in-situ piles (1975)

When use of cast-in-situ bored was introduced in our country only a few contractors with experienced foremen were undertaking piling works. Since boring equipment was quite simple many contactors took up to cast-in-situ piling works. Unfortunately very few were aware of potential defects that could arise in such piles during concreting, withdrawal of casing etc. Lack of awareness of possible potential defects in cast-in-situ bored piles is not restricted to our country alone. For example after completing a seven storied building resting on cast-in-situ bored piles in Canada unacceptable settlements were observed. It was ultimately established that this was caused by major defects in the cast-in-situ piles. There was no choice but to demolish the entire building.

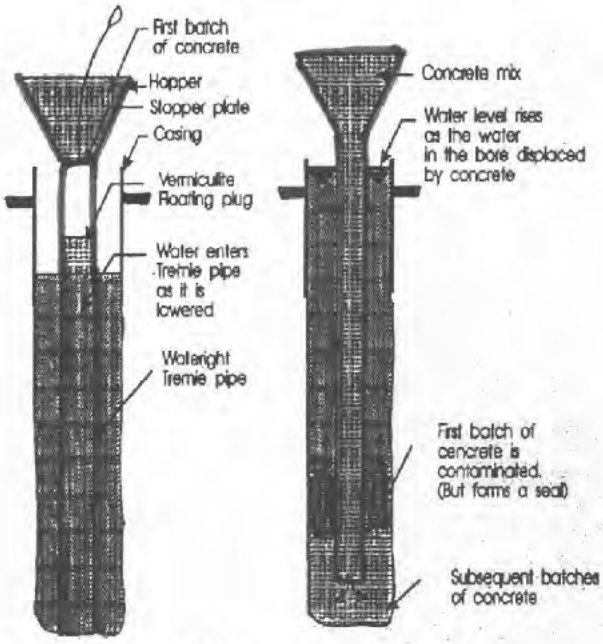


Fig-4 Tremie Concreting

We were singularly fortunate that during a routine visit to one particular site it was observed that concreting of a 1.2 m diameter pile was in progress and the tremie pipe was being raised to facilitate removable of a 1.2 m segment of tremie pipe. This was being done without following customary checks of concrete levels which are mandatory and which were being followed earlier. After a protracted bitter arguments it was decided that the only option that was left was to drill through the piles. Out of four suspect piles selected two piles had major defects. There was no choice but to install additional piles for supporting the superstructure.

The figures below show the structure which is quite complex with transfer girders supporting the superstructure supported by cast-in-situ bored piles.

Fig-5A

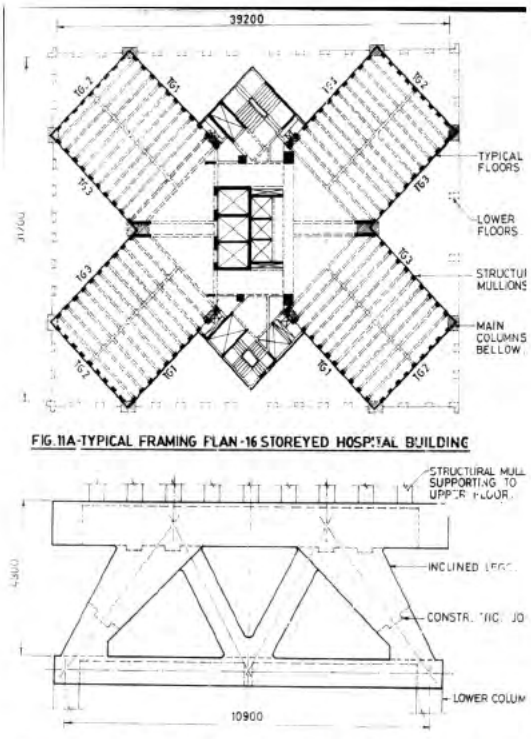


FIG.11A-TYPICAL FRAMING PLAN-16 STOREYED HOSPITAL BUILDING

Fig-5B Typical Elevation of Transfer girder

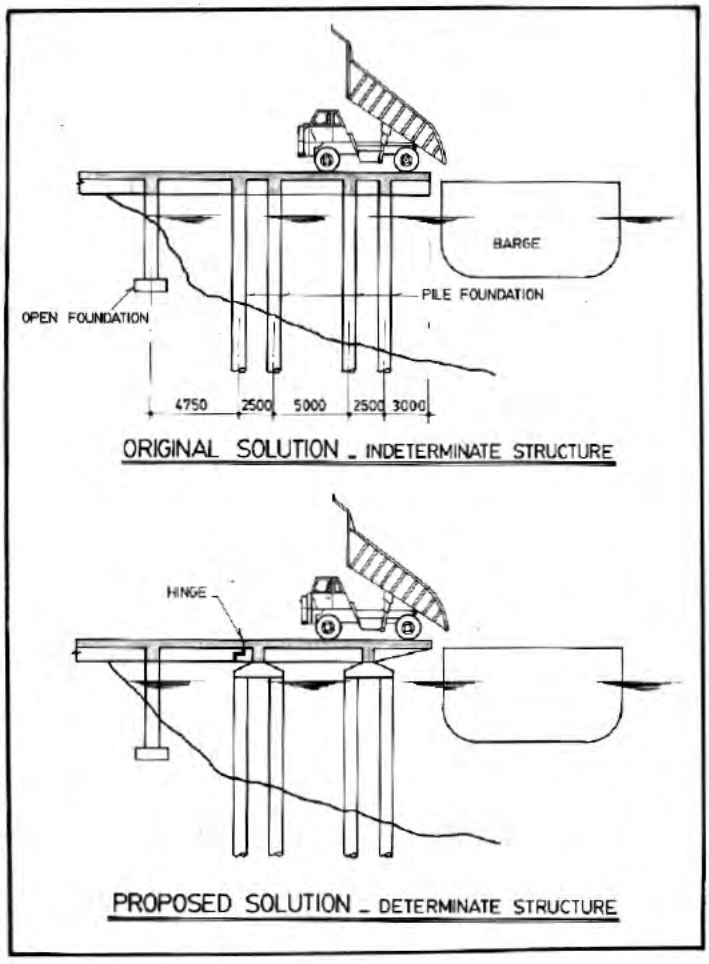


Fig-6

Understanding structural behaviour

This is a structure with modest dimensions and concerns a dumper unloading jetty. After the piles were installed the owner came up with requirement of an increase in the overhang. The contractor was saddled with the problem of overloading of front row of piles. The problem could not be solved by his designer. We were approached by the contactor to find a solution since it was not possible to install additional piles at this stage. With the increase in the cantilever it became quite obvious that front row of piles would be badly over loaded. The structural framing proposed by the designer was also vulnerable to differential settlements because the shore end of the jetty was supported on open foundations with low bearing capacity. With a slight change in structural system overloading of front row of piles was avoided. The structure is no longer sensitive to differential settlement.

Pitfalls of using formulae without understanding their basis.

Floating caissons are commonly used for bridge foundations. The stability of such caissons is usually measured by meta-centric height. However in certain situations this formula cannot be used without corrections.

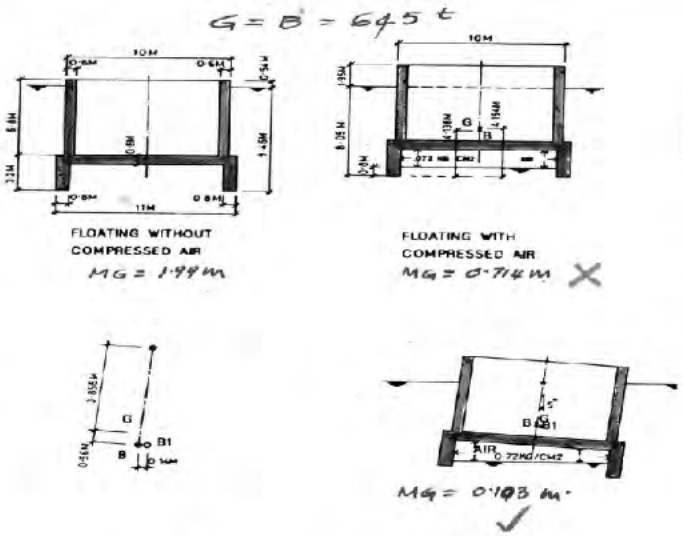


Fig-7 Effect of Compressed air on Stability of Floating Caissons

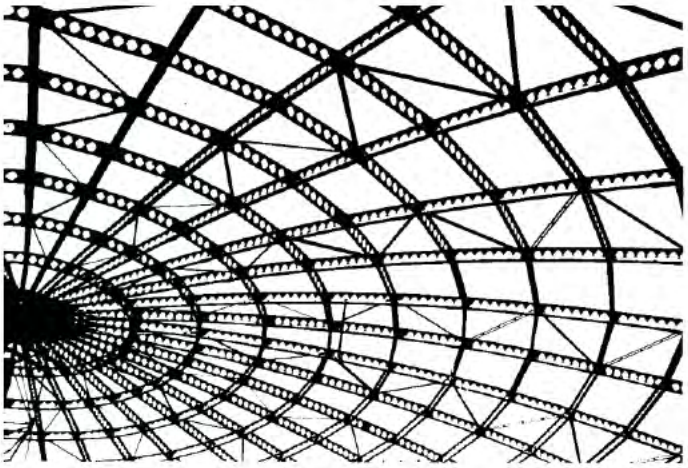


Fig-8A

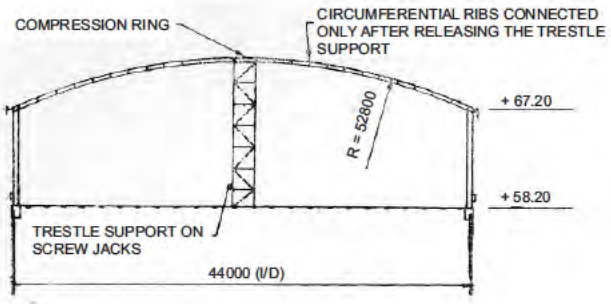
Volumes calculations were submitted for the floating caisson with compressed air trapped below for a major bridge. The calculations were duly approved by the authorities. However a marine engineer in charge of floating and sinking these caissons had apprehensions intuitively about the stability of this type of caisson. The first caisson was cast on floating pontoon ready for launching and nobody took the marine engineer seriously since all the calculations were already approved.

That this structure is not stable can be easily demonstrate by giving a slight tilt and examining its stability. The righting moment is found to smaller than the overturning moment! A prototype model was made since all engineers had implicit in the formula ! When the model was lowered in a water tank it's instability became apparent. One should never use formulae without understanding their limitations. The only solution to the stability problem was attaching buoyancy collars to the caisson.

Importance of understanding intermediate stages of construction

It is very important for design engineers to appreciate Contractor's point of view. The ribs of a 44 m diameter steel dome covering a water tank had a structural depth of 300 mm. In view of the slenderness of the structure temporary supports were suggested at crown as well as at two intermediate locations. However, the steel erector who had considerable practical experience observed that he had erected a dome of 30 m diameter dome with only one central support.

The dome was rechecked with single temporary support. When the support is lowered the structure behaves like a number of three pinned arches inter connected at the center. There will be some stresses that will remain locked in. But the total stresses were still within the permissible limits.



Erection sequence for dome

Fig-8B

Accepting the suggestion made by the erection contractor who was not a qualified engineer greatly simplified the construction of the dome.

It is equally important to adopt the erection methods to suit the equipment easily available with the Contractors. For example a hangar in Bengaluru with plan dimensions of 45.75 m x 91.5 m the roof is a folded plate type roof in structural steel. This structure was fabricated and erected at ground level so that all the welds could be easily made and inspected. The entire roof was raised by about 12 m to it's final position using standard screw type truck jacks that were easily available. The roof was suspended from the top of columns using mild steel channel sections that were reused for the sliding doors after the roof was lifted into position. The entire lifting scheme was designed by us. This was the first time such a roof was erected in this manner in our country. This solution was offered as an alternative design by the Contractor.

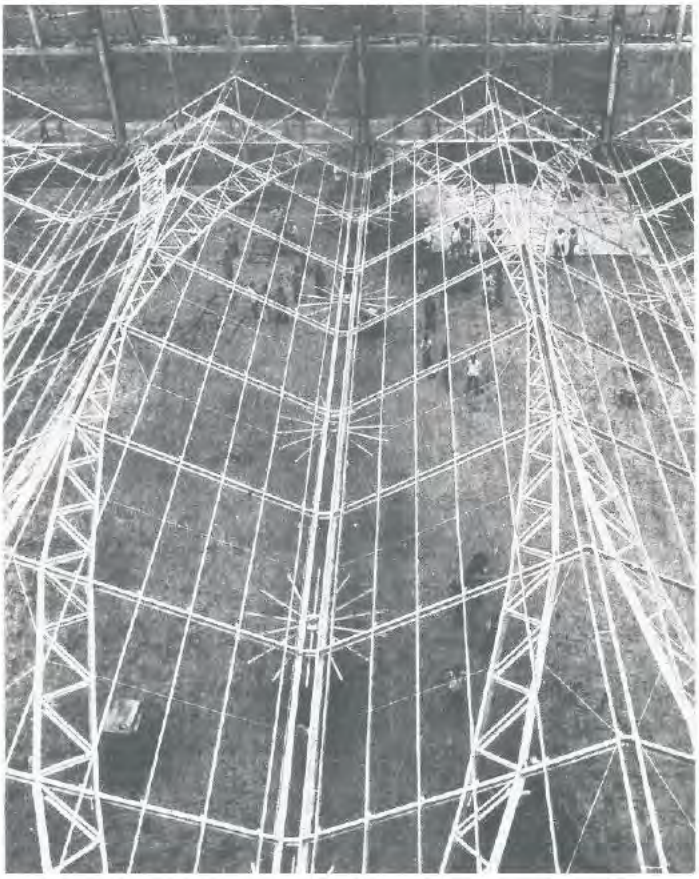


Fig-9A Hangar(1981) steel 29 kg/m2

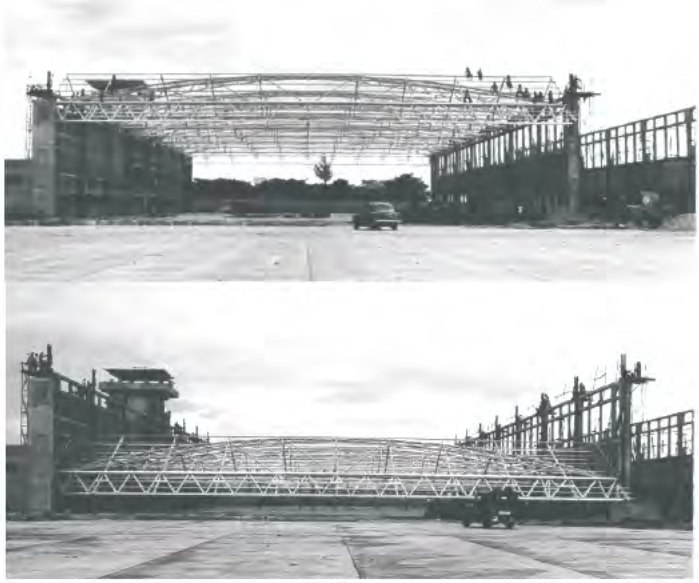


Fig-9B Jacking of 45.75 m x 91.5 m span hangar using simple equipment locally available

Handling of precast elements

It is very important to address all the erection problems in the design office. A workshop building built in 1983 was offered as an alternative design by the Contractor. The original design proposed by design was a standard North Light roof in structural steel. We proposed precast post tensioned funicular trusses spanning 30 m and supporting 50mm thick pretensioned concrete L shaped purlins spanning 12 m and 17.6 m high columns trussed branched columns also in precast concrete. The crane girders are post tensioned I girders. All the elements are very easy to cast since the work is at the ground level. Another notable future is that there are no internal drains for the building with plan dimensions of 84 m x 160 m. The roof gutters cum purlins are pretensioned U shaped elements spanning 12m. The entire roof is drained at the gable ends only.

The tilting and erection methods have to be conceived with great care. Once erected the columns and roof girders are quite sturdy. Because of their slenderness in horizontal plane tilting and erection methodology was designed by us so that the structures could be erected safely.

Fig-10A Precast columns and trusses

Fig-10B Erection of columns and trusses in progress

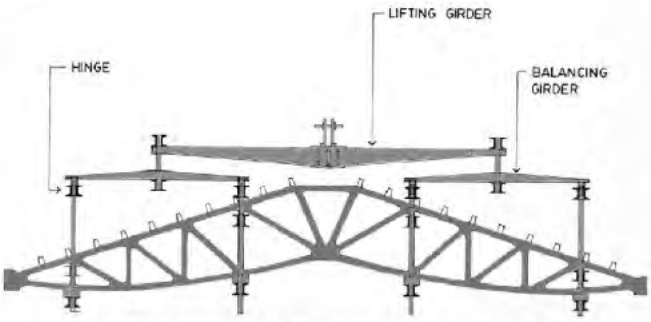


Fig-10C Tilting and lifting arrangement of trusses

Fig-10D Finished view of a 30 m bays (Hyderabad) 1982

Importance of aesthetics

Engineers must learn the aesthetic aspects from architects. Construction of ugly structures leads to hurting the aesthetic sense of the viewer. Engineers have to be very careful when they design bridges and other engineering structures where there an Architect is not involved. Juinagar foot bridge designed by us in 2002 is a good example of appreciation of aesthetics by Engineers. Several railway bridges were designed by us for Konkan Railway Corporation Limited where standard designs could not be adopted. We suggested simple structural forms with monolithic piers which were not only more economical than standard designs but even more elegant in appearance

Fig-11A Juinagar Foot bridge 2002

Fig-11B Berdewadi Nullah railway Bridge

At times aesthetics of simple structural forms needs to be enhanced by fluted surfaces as in the case of a road over bridge or by introducing curves in gusset plates as in the case of crane girders for a rail roach factory. Introducing such shapes for gusset plates also improves the performance of crane girders against fatigue.

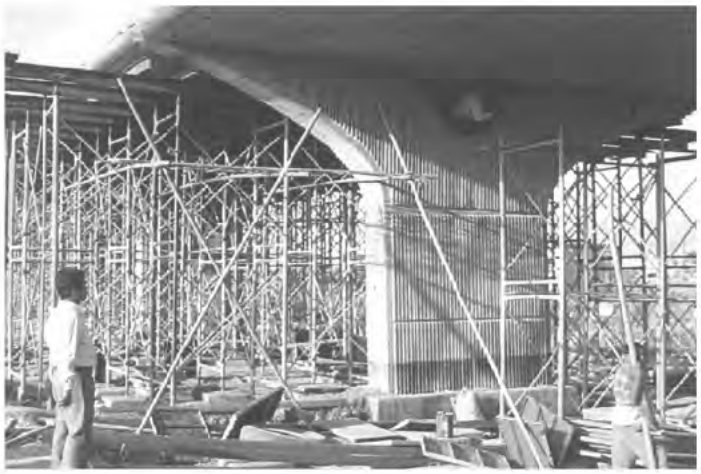


Fig-11C Road over Bridge 2001

IMPORTANCE OF DETAILING

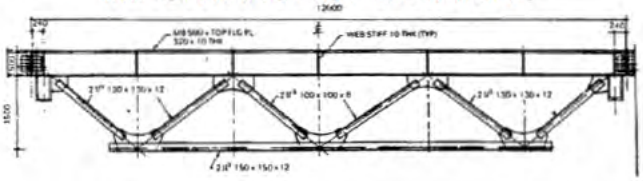


Fig-11D Crane girder rail coach factory 1987

Importance of mutual trust

The importance of mutual trust and cooperation can never be under estimated. The credit for our best projects goes to the entire team including the Client who plays very crucial role in the success of the project.

Larsen and Toubro's Hydraulic Excavator Project (1975) incorporated several innovations. The entire building is in

precast concrete designed for future extensions length wise and widthwise in a simple manner. Since completion, the building has already been extended using the same wall panels which are 2.5 m wide and 14 m high. The roof is very light consuming just 0.097 cum/m for covering a span of 20 m x 20 m.

Fig-12A 50 mm thick pretensioned shells 2.5 m x 20 m being transported

Fig-12B Construction in progress

Engineering Construction Corporation's administrative building is yet another example of excellent team work between the architect the designer and the Contractor who in this case was also the owner.

Fig-13A ECC's administrative building in Chennai was constructed in two phases. The building was occupied in 1984 with two floors complete. Two more additional floors were added in 1991. This building was recipient of most outstanding award in 1994 at the XII FPI Congress held in Washington

Konkan Railway's Panval Nadi viaduct (1994) is another example of importance of mutual trust and cooperation that easily comes to mind. This was first application of incremental launching of prestressed box girder supporting single ballasted broad gauge railway track. The tallest of the piers is about 64 m above foundation level. These are tapered hollow octagonal shaped with a wall thickness of 325 mm. Since incremental launching was being adopted for the first time in India we made it a point to share with the Client's engineers and Contractor's engineers whatever information that was available with us on the subject.

Fig-14A Panval Nadi Viaduct – Incremental launching in progress

Fig-14B View of the completed viaduct

Consideration for long term aspects

There is no doubt that simply supported bridges are not only easier to design but also easier to build. But experience has shown that these structures are difficult to maintain at times needing frequent repairs. Continuous bridges with monolithic piers are more difficult to design but these are certainly more elegant, economical and will be more durable. We have been designing continuous bridges in reinforced concrete and prestressed concrete with monolithic piers for over 25 years now.

6.5 km long viaduct in Dwarka sub-city for Delhi Metro Corporation Limited with full span continuous precast post tensioned girders is longest stretch of integral form of construction in India. 15 road over bridges with post tensioned precast concrete girders and monolithic piers designed by us have been executed by Konkan Railway Corporation Limited demonstrate the versatility of this form of construction.

Fig-15A TEC Trombay flyover 1980

Fig-15B KRCL Road over bridge Madgaon 1995

Fig-15C DMRC 6.5 km long elevated viaduct 2004

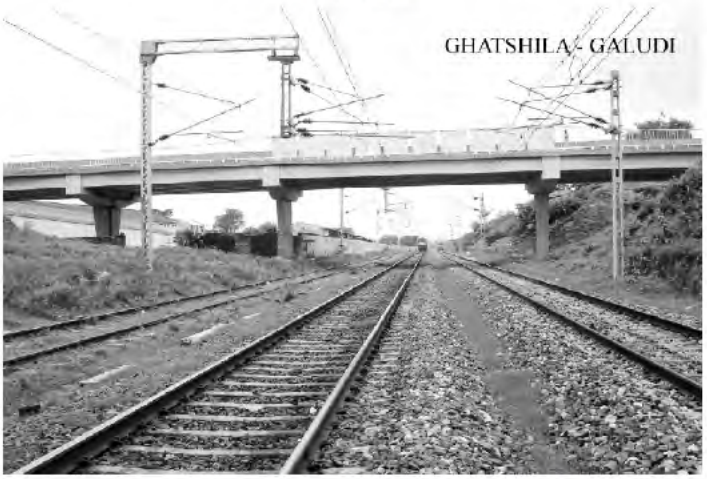


Fig-15D KRCL Ghatshila Road over bridge Jharkhand 2006

Conclusion

It is very important for design engineers to take a keen interest in all aspects that go into the realisation of the project. This will necessarily include soil investigation, construction practices, intermediate stages of construction, enabling structures, aesthetics, durability and maintenance. With such an approach we will can all work together and produce structures that are elegant, durable requiring little maintenance.

Acknowledgments

None of the examples cited in this article would have peen possible without the inspiring and able leadership provided by Mr Shirish B Patel, Chairman Emeritus with whom the author continues to have a patently fruitful relationship.

About the Author

Dr. V. V. Nori is having five decades of experience and is Chairman and M.D. of M/s Shirish Patel & Associates Pvt. Ltd.
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SUNSHINE TOWER – The Tallest Commercial Steel-framed building in India

By Mr. Kamal Hadker

INTRODUCTION:

Until recently, developers in India were rather skeptical about using structural steel on a large scale for their projects and RCC was the preferred choice. However, due to availability of suitable structural steel sections manufactured to international standards and advancement in fabrication / erection facilities, steel-framed buildings are emerging as viable alternatives to RCC structures. One recent example is the construction of Sunshine Tower, the tallest commercial steel-framed building in India – located on Tulsipipe Road, Dadar, Mumbai.

ARCHITECTURAL PLANNING

The plot of land available for construction is about 3000sq. mts of which 15% area is consumed by the narrow approach road itself. The overall dimensions of the tower in plan are 21 m x 27 m with a total height of 161m above the ground and 5 m below. Hence, construction of a very tall and slim building was inevitable. Considering these space constraints, it was decided to minimize "in-situ" work and fabricate most of the building components away from the site. This led to selection of steel-framed building covered with structural glazing and aluminum composite panels. The service core comprises of elevators, fire escape staircases, toilets and air-handling units.

The tower comprises of a basement, Entrance Lobby at the Ground Floor, 5 parking floors and 35 office floors including refuge floors at different levels. The office space, measuring 21 m x 16 m, is completely column free. All the services are accommodated in the basement along with a mechanical car parking facility. The car parking floors above are accessed by a 6 m wide ramp. The entire parking block is designed as an RCC structure, attached to the tower block.

STRUCTURAL SCHEME

The structural scheme comprises of RCC slabs supported on steel beams which in turn span 15.6m from the service core to the peripheral columns. The depth of these beams is restricted to 686mm and they are designed as composite sections utilizing the compressive strength of the concrete slabs. The beams are directly supported on square hollow steel columns (measuring 500mm x 500mm). The plate thicknesses of these sections vary from 36mm at the bottom to 16mm at the top.

Traditionally, the lateral loads due to earthquake and winds are resisted by providing a strong, centrally located service core. However, in this case, the plan dimensions of the RCC core were restricted to 11 m x 21 m only and the core was eccentrically placed. It was too weak to provide lateral stability for this 180m tall building. Hence it was decided to utilize the strength of the steel columns on the periphery of the building. Although 500mm x 500mm steel columns can carry large axial loads, they have very low stiffness to resist lateral loads. Hence, lateral deflections could be brought under control only after the introduction of diagonal bracings. The bracings used are rectangular hollow steel sections of size 500mm x 300mm. The concept of having bracings also appealed to the Architects for its aesthetic advantages and honesty of expressing the structural concept. The six storey high diagonal bracings resist significantly large tensile forces and reduce lateral deflections. Besides, the steel columns are filled with concrete to increase their stiffness as well as to improve their resistance to fire.

In addition to this, the structural framing system at every service floor is specially designed to function as a "Floor Deep" Spandrel Truss along the periphery of the building. Its major contribution is to utilize the axial load carrying capacity of the steel columns on the periphery and further reduce the lateral deflections at the top.

As per the geo-technical report, a suitable strata (offering a Safe Bearing Capacity of 150 T/Sq mt.), was available at a depth of 7 to 8 meters below the natural ground level. As only one basement was required in the building, the option of using Pile Foundation was ruled out. Hence shore piles were provided to facilitate deep excavation without endangering the adjoining buildings.

The roof of the lift-machine room rises more than 6 m above the terrace level. A steel truss of the same height, along the periphery of the building, conceals the façade cleaning system mounted on rails as well as the lift machine room and staircases.

A specially designed architectural feature – resembling a fountain – is supported above the roof of the lift-machine room. This feature is expected to be illuminated at night. This feature is over 15m tall with an upper and lower diameter of 16m and 6m respectively. It was modeled using ETABS software. This feature along with an access ladder and maintenance walkways is fabricated using MS tubular sections. So optimized is the design that the total weight of the whole unit is less than 25 tons.

CONSTRUCTION SEQUENCE

While the contractors were busy excavating for the basement in the restricted plot area, the owners imported all the special steel sections sourced through CORUS from Japan, Taiwan and UK, since they were not rolled in India. These sections were transported directly to Pratibha Industry's modern fabrication facilities in Wada 90 Kms away from Mumbai. The fabrication was carried out with utmost care and accuracy. As soon as the raft foundation was concreted, the lowest sections of the steel columns (complete with 100 mm thick base plates) were brought to the site by special trailers. A heavy duty crane – capable of lifting 5 metric tons at 185 mts height was erected in the north east corner of the tower block. Similarly, to expedite construction of the concrete core, pre engineered aluminium formwork was used. This ensured dimensional accuracy as well as speed.

It must be noted that all the diagonal steel bracings in the tower block are installed in the same plane as the peripheral columns and beams. Thus, eccentric connections were avoided. However, the erection sequence of the columns, beams and diagonal bracings had to be worked out very carefully to avoid delays. The accompanying diagram shows the erection sequence adopted successfully. It can be seen that the junction of columns was staggered specifically to simplify erection and the bolted connections between columns and beams were moved away from the main grids. The diagonals were connected by using single pins and all other joints were “bolted” connections. Thus, welding at site was practically eliminated for obvious reasons.

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INTEGRAL FRAMES FOR MUMBAI MONORAIL GUIDEWAY

Milind Bhoot, Elizer Abrea

Exerpts:

The Mumbai monorail project; India's first; probably the second longest in the world (after Walt Disney Monorail) traces road median through congested roads connecting Chembur with Trombay (Mahul), Anik,Wadala, Antop hills, Matunga and Chinchpokli.

Mumbai Monorail guideway structure uses the most accepted straddle-beam type system; using straddle-tyres to hold the car against overturning. The guideway beam forms the track for the monorail cars; incorporating the complex curve-surface geometry true to the geometric-design and embodies electro-mechanical systems. The structural engineer must correctly understand the lateral forces and overturning reactions caused in this system.

Mumbai Monorail aims 2000 precast beamsof 23 to 27m spans; to be 'stitched' with Y-piers of 12 to 20m height by in-situ concrete joints into integral frames of 3 to 5 bays. Full frame is finally post-tensioned by long continuity tendons; finishing the integral post-tensioned frames to slender aesthetic proportions. Monorail structure is indeed very flexible (framing just two slender-beams on slender pier) in comparison with the road/rail bridges – carrying rigid box / beam deck on just 6 to 8m pier height.

This paper is aimed at fulfilling structural engineer's appetite for design methods; elaborating vital features of monorail guideway frame arrangements; distinguished from conventional bridge-structures. Outline details of Monorail Guideway Structures are published elsewhere[1,2,3,4] and this paper extends the sequel.

Stitch elements are the most vital elements of the guide-way frame transferring beam reactions to the column through just a RC section of 800x1000, half the PSC beam section. The stitch-joints are stiffened with stitch-connector (raised pedestal type extended pier-cap section), enabling the forces disperse to larger section.

The conventional vertical diaphragms of bridges; change to horizontal diaphragms in the monorail frame avoiding side-wheel tracks. Mumbai monorail decided to completely eliminate horizontal diaphragms. These diaphragms have a vital function in limiting the beam-sway (under lateral train-movements) within rider-comfort limits. Mumbai Monorail cautiously eliminated the diaphragms after a simulation run on beam geometry software; incorporating the design-sway computed on structure design models. This reveals yet another structural design interface with system-geometry.

The durability specifications of Mumbai Monorail for 120 years called for specific mix design requirements. In addition this reflected into upgrade of seismic design criteria from Zone 3 to Zone 4; accounting for higher probability of seismic occurrence over extended life-span.

Guide-way Structure design is based upon construction stage analysis on advanced bridge-software; accounting for time-dependent properties. [5,6]After beam launching; refined lifting-shifting-tilting operations perfect the curve geometry of the guide-way using temporary clamping frames supported with inclined supports. As the temporary clamping-frames are released after continuity pre-stress; secondary pre-stressing forces are generated. Hence the pre-conceived erection methods are carefully modeled in the structural designs.

Monorail integral frames appear an opportunity for interesting new skill-sets in architectural and structural designs; stirring remarkable enthuse after Mumbai Monorail. This paper will hopefully add to the useful references; due to publish in the next issue, permitting readers sufficient time for background reading listed below; mostly available online.

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Elizer Abrea, Ph.D., Principal Structural Engineer,

References :

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2. C. Shankarlingam, "Construction Methodologies for Mumbai Monorail Project,"Civil Engineering & Construction Review, December 2010
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DESIGN OF DEEP BEAM USING STRUT & TIE METHOD

Prasad Samant, Mayuri Patil

Introduction: This article is in continuation with the last two articles published, "Fundamentals of strut and tie model" and "Understanding of Stress Flow Pattern Using STM & FEM". We have discussed the basics of STM and stress flow within a structure using Strut & Tie Modeling and Finite Element Method.

Now we will discuss procedure for design and detailing of strut-and-tie modeling. The first step of the STM process is to determine the location of the D-region or disturbed region. This D-region occurs wherever there is a local disruption of the stress flows within a member. The ACI 318-05 Appendix A provisions provide estimations of the strength of the struts of a strut-and-tie model as a fraction of the specified compressive strength of the concrete:

$f_{ce} = 0.85\beta_s f'_c$ Equation A-3 as per ACI-318

Where: β_s = the strut efficiency factor (Table1)
f'_c = the concrete compressive strength
f_{ce} = effective compressive strength

If a particular strut satisfies Equation A-4 in Section A.3.3.1 of ACI 318-05 or the more general provisions of A.3.3, the larger β_s factor of 0.75 may be used. It allows designer to determine the necessary transverse reinforcement for a bottle-shaped strut based on a 2:1 spread of compression. The equation is

$\Sigma((A_{si} \sin\alpha_i)/bs_i) \geq 0.003$ Equation A-4 as per ACI-318

Where: A_{si} = area of surface reinforcement in the i[th] layer crossing a strut.

s_i = spacing of reinforcing bars in the i[th] layer adjacent to the surface of the member.

b = the width of the strut perpendicular to the plane of the reinforcing bars.

α_i = the angle between the axis of the strut and the bars in the i[th] layer of reinforcement crossing that strut.

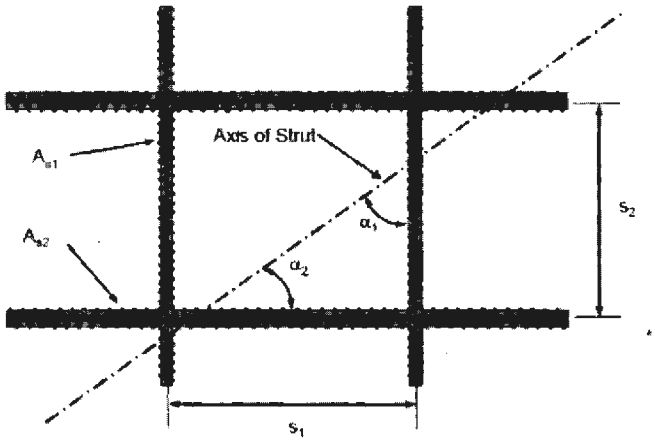


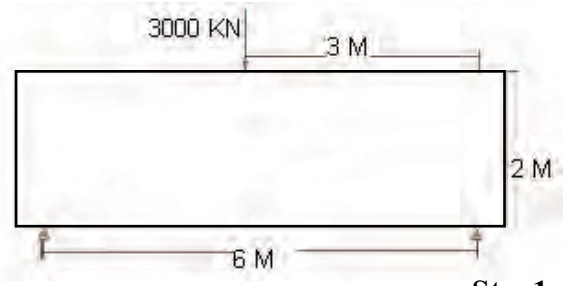
Figure1 Nomenclature for Equation in A.3.3 in ACI -318

The efficiency factor β_s is based on the type of strut. There are five classes of struts listed in Table 1

Table 1: Node and strut efficiency factors

	Strut and Node Efficiencies	ACI 318-05	
		$_s$	
STRUT	* Strut with uniform cross-section over its length	1.00	0.75
	* Bottle-shaped struts with reinforcement satisfying A.3.3	0.75	0.75
	* Bottle-shaped struts without reinforcement satisfying A.3.3	0.60	0.75
	* Struts in tension members	0.40	0.75
	* All other cases	0.60	0.75
NODES	* Nodes bounded by compression or bearing CCC Node	1.00	0.75
	* Nodes anchoring one tie CCT Node	0.80	0.75
	* Nodes anchoring more than one tie CTT and TTT Nodes	0.60	0.75

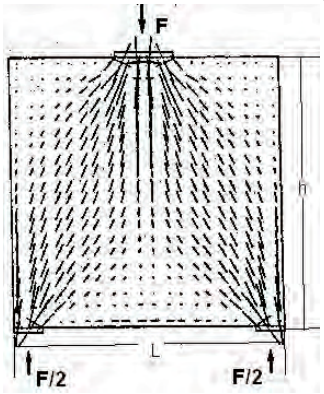
To understand the design with STM, consider one example of deep beam.



Consider a simply supported deep beam having 6M span with depth of 2M and width of 500MM carries concentrated factored load of 3000KN at mid span i.e. 3M from support. f_c= 30 N/mm², f_y= 415 N/mm², All bearing plates are 450mm x 500 mm

Step1 –Determine the D-region

(a)



(b)

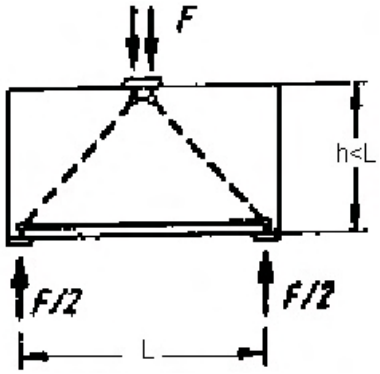


Figure 3 stress diagrams and strut and tie model for disturbed region

Step 2 Select the strut-and-tie model

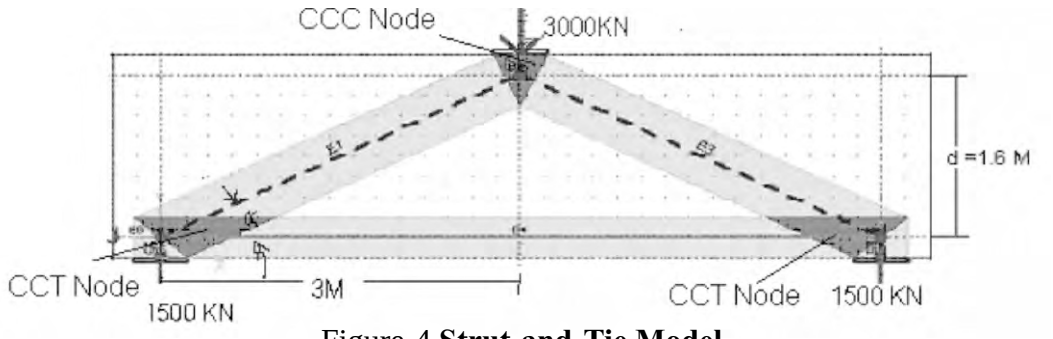


Figure-4 **Strut-and-Tie Model**

Step3 determine required truss forces:

Assumed = 2M – (2 X 0.2M) = 1.6M á = tan $^{-1}$ (1.6M / 3M) = 28.07 ^{o}

Table 2 : Member forces in truss

Member	Force	Behavior
E1, E3 E4	1500 / Sin 28.07 = 3187 KN E1 X Cos 28.07 = 2813 KN	Compression /strut Tension /tie

Table 3 : Bearing stresses at nodes under load & above support

Location Of node	**Type of node**	**effective compressive strength of the node** $f_{cu} = 0.85 \ _n f_c$	**Bearing capacity** f_{cu}	**bearing stresses = load or reaction per mm² of area of bearing plate**
nodal zone beneath the loading locations	all-compression (CCC) node	0.85 X 1 X 30 = 25.5 N/mm²	0.75(25.5) = 19.125 N/mm²	3000000 / (450X500) =13.33 N/mm²
nodal zone over the s upport locations	compression -tension (CCT) node	0.85 X 0.80 X 30 = 20.4 N/mm²	0.75(20.4) = 15.3 N/mm²	1500000 / (450 X500) = 6.67 N/mm²

Step 4 Determine the bearing capacity of strut and tie

Determine the dimension of strut and tie -

To find the width of Tie E4 = force per m depth / bearing capacity

= (2813 X 1000) / (15.3 X 500)

= 367.71 mm (Assume 400 mm)

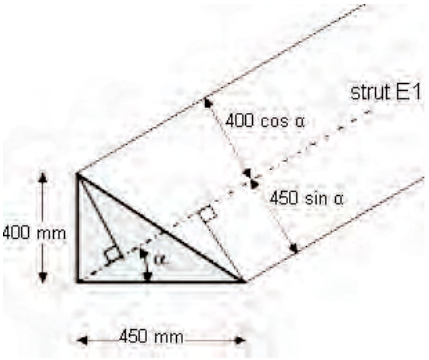


Figure5. Geometry and dimensions of nodes at support.

Width of strut E1 & E3 = 400 Cos (28.07) + 450 Sin (28.07) = 565 mm

Now check the strut capacity = Φf_{cu} **X width of strut X width of member**

= 0.75 X 19.125 X 565 X 500 /1000 = 4052 KN > 3187 KN O.K.

Step -5 Select Reinforcement:

For Tie E4: $\Phi A_s f_y$

A_s (2813 X 1000) / (0.75 X 415) = 9038 mm²

Consider 3 layers of 4 bars each of Ô 32 = (12 X 804 mm²) = 9648 mm²

For design of the nodal zones check the anchorages

The 90° standard hooks are used to anchor tie E4.

The required anchorage length is $L_d = \lambda \left(0.02 f_y d_b / f_c^{0.05}\right)$ As per ACI 12.13.2.2

Where $\lambda = required\ A_{st} / Provided\ A_{st}$ represent the correction factor for excess of reinforcement

d_b= Dia. of bars used. (Inch)

f_y = Steel bar yield strength (psi)

f_c = concrete compressive strength (psi)

L_d = [(9038/9648) X (0.02 X 60000 X 1.28/4000 $^{0.05}$)] = 22.8 in. (580mm)

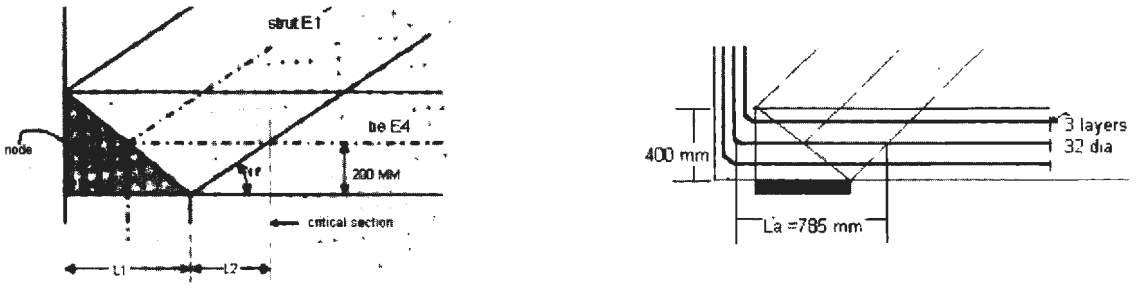


Figure6 anchorage length of node at support

The available anchorage length = L_a = L1 + L2 – cover

Where L2 = 200 / (tan 28.07) = 375 MM

L1 = 450 MM (bearing plate)

Cover = 40 MM

So available anchorage length = 450 +375 - 40 = 785 mm > 580 mm

Calculate the minimum reinforcement required for crack control

Vertical web reinforcement provided must be at least, as per ACI 11.5.5

A_v = 0.0025 X b X s1

And horizontal web reinforcement provided must be at least, as per ACI 11.5.5

A_{vh}=0.0015 X b X s2

Where s1 and s2 are spacing of web reinforcement and cannot exceed d/5 or 12"

(304.8 mm)

For vertical web reinforcement, use 2L Φ16 mm @ 300 mm on each face over entire length, A_v / b s1 = 2(201.062)/(500X300) = 0.0027 > 0.0025

For horizontal web reinforcement, use Φ12 mm @ 300 mm on each face over entire length, A_{vh} / b s2 = 2(113.097)/ (500X300) = 0.0016 > 0.0015

Because β_s factor equal to 0.75 is used to calculate the strength of strut E1, minimum reinforcement provided must also satisfy.

$$\Sigma ((A_s \sin \alpha)/b\ s)$$

(A_v / b s1) sin α1+ (A_{vh}/bs2) sin α 2

= 0.0027 sin 61.97 + 0.0016 sin 28.07 = 0.0032 0.003 .....OK

Where α1 = is the angle between the vertical reinforcement and the axis of strut.

= 90° - 28.07° = 61.97°

Where α 2 = is the angle between the horizontal reinforcement and the axis of strut.

= 28.07° As in figure 1

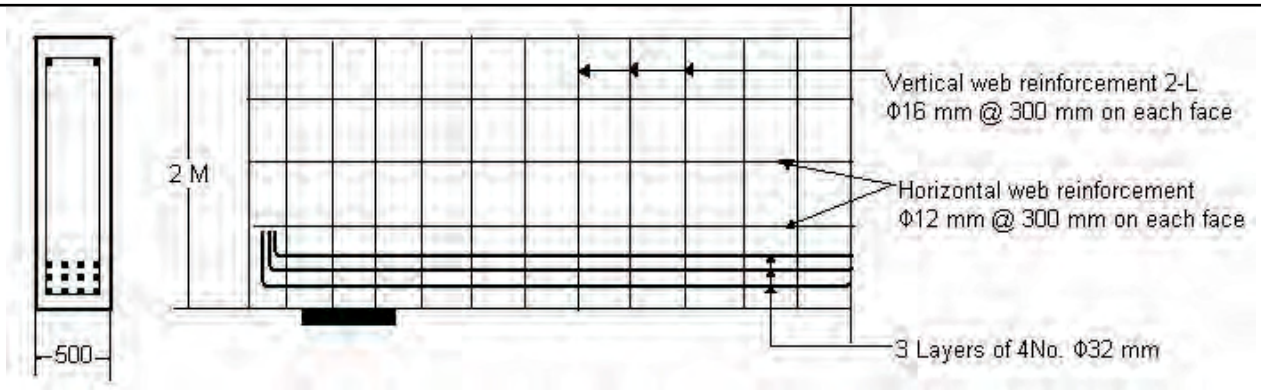


Figure 7 Reinforcement detail

Reference:

ACI 318-2002, Building Code Requirements for Structural Concrete and Commentary, Appendix A, Strut-and-Tie Models. American Concrete Institute.

Schlaich, J., and Schäfer, K.,1991 ,"Design and detailing of structural concrete using strut-and-tie models," The Structural Engineer, Vol. 69, No. 6, pp. 113-120.
http://www.cee.uiuc.edu/kuchma/strut_and_tie

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Mayuri Patil is trainee design Engineer working with Staad Engineers Email id: mayuri.patil90@gmail.com

DRAFT : RECOMMENDED FEE FOR STRUCTURAL CONSULTANTS

- ISSE Committee

Indian Society of Structural Engineers (ISSE) has formulated a draft guideline for minimum fees to be charged by the structural engineers for various assignments. This is based on the feedback received from its members and based on the discussion during the committee meetings. ISSE members are requested to send their feedback and suggestions.

Scope of work for Structural Engineer

A) General scope of work

1) Preliminary Structural Layout Based Architect's requirement.
2) Finalize Structural lay out with Architect and Client.
3) Structural analysis, design, calculation, structural drawing (Excluding fabrication and bar banding schedule). Five sets of drawings will be provided by consultants.
4) Estimate of structural quantity for tender purpose.
5) Site visit during execution of work (two visits during foundation work and one visit per slab). Providing structural stability certificate.

B) Structural Audit and Inspection of Structure –

Study of existing drawings for the building, check for any additions and alteration based on data available, survey the building from inside and outside, mark the observations and distress on the available plans, take photographs during the survey for record, preparation and submission of audit report.

C) Project Management consultancy –

Coordinate with Client, Architect, Various consultants, Contractor. Conduct site meetings at suitable interval and make progress report for the work. Monitor the project by appointing site supervision staff on behalf of the client. Monitor project progress and update the barchart.

D) Peer review –

Overall assumptions, load data, framing plans prepared by main consultants will be reviewed briefly. Sample calculations will be checked along with sample member detailing will be reviewed.Based on the details provided a review report will be submitted indicating the observations and scope of improvement if any can be mentioned. Once the report is submitted ,the scope of peer review ends.

E) Proof checking –

All the design data, assumptions, analysis, design and drawings will be scrutinized in detail by the proof consultant. If required main consultant can be called for discussions and clarifications. Proof consultant may suggest some improvements in the design / drawings. Proof consultant will certify the design and drawing of the main consultant after the necessary revisions in design and drawings

Stages of payment after submitting following details	
1) Appointment	15%
2) Preliminary drawings and tender quantity	25%
3) Foundation	15%
4) Super structure	40%
5) Completion	5%

Note : Fees to be paid after completion of each stage of work or three months, which ever is earlier after submitting the bill, ir-respective of work progress at site.

Recommended minimum fees to be charged by Structural consultant

1)	Residential Buildings	Sq. Ft. Area	Rate Rs./ sq.ft.	Percentage of Total Structural Cost	Minimum	Remark
		Up to 5000	15.0	3%	Rs. 25,000/-	Scope A
		25,000	12.0	2%		
		50,000	10.0	2%		
		1 Lac	9.0	2%		
		2 Lac	8.0	-		
		5 Lac	7.0	-		
		Above 5 Lac	6.0			
		Extra for high rise building & its submission to high rise committee	4.0			

2)	Industrial Structures	B. UP area Sq.ft.	Normal Rs./Sq.ft.	(PEB / Shed) Rs./Sq.ft.	Minimum	Remark
		Up to 50,000	12	6	Rs.50,000/-	Scope A
		1L	10	5	2% of structural lost	
		Above 1L	8	4		

3)	Special Structure / Drawing basis				Minimum	Remark
I)	Per Drawing basis A 1	Rs. 35,000/-			Rs. 50,000/-	Scope A

4)	Fees Based on Man hours	As on 2011	Rs./hour			
I)	Principal Consultant		3000			
II)	Senior Structure Engineer		1500			
III)	Design Engineer		1000			
IV)	Sr. Draft man		750			
V)	Draftsman		500			

5)	Structural Audit				Minimum	Remark
I)	Based on area		Rs. 1.25/sq. ft.		Rs10,000/-	Scope B
II)	Based on Number of Flats		Rs. 750 per flat 2BHK			

6)	Visit Fees By Structural Engineers					
		Within MCGM limit	Out Station up to 150 KM	Long Distance beyond 150 Km		
	Principal Consultant	Rs. 3,500	Rs. 7,000	Rs. 10,000		Visit fees per person per day
	Senior Structural Engineer	Rs. 2,000	Rs. 4,000	Rs. 6,000		
	(Travel AC class, stay and local transport to be arranged by client)					

7)	Project Management Consultant				Minimum	Remark
I)	Based on Project Cost	3% of overall cost	For total project coordination	Supervision site staff to be paid by client.	Rs. 1,00,000/-	Scope C
II)	Man hour spend	Rs. Per hour				
	i) Site in - charge	1,500				
	ii) Site Engineer	1,000				
	iii) Site Supervisor	750				

8)	Inspection and Structural Stability Certificate		Minimum	Remark
I)	For Municipal Corporation	Depending on Area Rs. 1.25 per sq. ft.	Rs1,00,00/-	Scope B
II)	For Factory Inspector	Depending on Area Rs. 1.25 per sq. ft.		
III)	Other	Depends on Area, Spread, Responsibilities		

9)	Marine Structures		Percentage of Total Structural Cost	Minimum	Remark
			3% of cost	Rs. 1,00,000/-	Scope A

10)	Bridge Design:		Percentage of Total Structural Cost	Minimum	Remark
			2% of cost	Rs. 1,00,000/-	Scope A

11)	Peer Review				Minimum	Remark
	(Residential & Commercial Building)	Rs. 2/ per sq. ft.	or	20% of main consultant's fee	Rs25,000/-	Scope D

12)	Proof Checking				Minimum	Remark
	(Residential & Commercial Building)	Rs. 5/- per sq. ft.	or	50% of main consultant's fees	Rs. 50,000/-	Scope E

13)	Fees for repetitions of the design					Remark
		Up to first five repetitions	50% of fees for each repetition			The structure to be repeated must be exactly identical except foundation
		Beyond five repetitions	25% of original fees for every repetition			

14)	Fees for additional work due to changes in the design / layouts					
		Minor changes	15% of original fees			
		Major changes In the layout	50% of original fees			

REPORT ON R L NENE MEMORIAL LECTURE 5 AUG 2011

Indian Society of Structural Engineers (ISSE) in association with The Institution of Engineers India, Maharashtra State Centre (IEI) arranged R. L. Nene memorial lecture on 5th August 2011 at SASMIRA auditorium.

Mr. Dharmadhikari, President, ISSE welcomed the delegates. Hemant Vadalkar, advisory trustee introduced the speaker Dr. V V Nori who is a Chairman and MD , Shirish Patel & Associates Consultants Pvt. Ltd., Mumbai.

Dr Nori, spoke on **"Integration of construction aspects and aesthetics in structural design"**

He shared his experience in planning and design of various engineering projects. He enlightened the audience with the outstanding projects designed by his team. He emphasised on the constructability aspect to be considered during design.

Dr V V Nori is one of the leading and senior structural engineer. He is involved in the design of buildings, bridges and special structures with innovative ideas.
He has designed wide range of structures. Some of the structures were awarded by reputed organisations. Some of the outstanding structures are **Panval Nadi Viaduct – by Incremental launching for Konkan Railway, ECC's administrative building in Chennai, Foot Over bridge at Juinagar and many more. Dr Nori is recipient of many awards like -**

- National Design Award in 1993 from Institution of Engineers (India)
- FIP award for Most Outstanding Structure in 1994 in Washington at XIIth FIP Congress
- Felicitations bestowed in 2003 by Dr Adam Neville for Excellence in Design of Concrete structures - American Concrete Institute - India Chapter
- Indian Concrete Institute – 2005 Outstanding Concrete Technologist Award
- S B Joshi Memorial Award for Excellence in Structural and Bridge Engineering, Pune 2009

In his five decades long engineering career, Dr V V Nori has been exceptionally focussed on innovative thinking and practical approach in his structural designs.
He had published many technical papers and made numerous presentations during seminars and workshops. He is ready to share his ideas with young engineers and motivate them in adopting good engineering practices.

The program was attended by civil engineers in large number. His paper has been printed in this issue.

Edited and published by N K Bhattacharyya for ISSE, C/o S G Dharmadhikari, 24 Pandit Niwas, 3rd floor S K Bole Marg, Dadar (W), Mumbai 400 028. Tel 91-22-24365240, Fax-91-22-24224096, e-mail issemumbai@gmail.com Web (www.isse.org.in) for private circulation and printed by S L Bengali, Bensan Printers, 15, Pandit Niwas, S K Bole Road, Dadar, Mumbai 400 028

PRODUCT REVIEW

We have now introduced a new section, "Product Review" into the ISSE journal. This is where manufacturers and dealers can introduce their products such as construction materials, chemicals, equipment, software etc, through a technical review. Only one product review may be printed in each issue. A space of up to two pages of the journal may be allocated to this feature.

The main purpose of this feature is to introduce the newer products available in the market to our readers, and therefore, the review should be technically intensive. The manufacturers and dealers can highlight the advantages and uniqueness of the featured products in the review.

The review should cover one or two products only and may include their technical specifications, method of installation/ application, available product range, unique features, advantage, photographs etc. It should not be a direct commercial promotion of the products. However, the contributor may include his contact details at the end of the review. Matter received may be suitably edited and modified in consultation with the contributor.

For details please call the editor.

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Note : 10% discount is offered for advance booking of colour advertisement for 4 issues, provided entire payment is made in advance

APPEAL TO ISSE MEMBERS

We appeal to ISSE members to actively participate in all functions and activities of ISSE.
Member can suggest new topics for discussion during the seminars and workshops, contribute in arranging expert lectures on varies civil engineering subjects.
Senior members can share their knowledge and experience through short evening lectures.
We are looking for participation from Engineering Colleges through their faculty and students. Civil Engineering Department can send the interesting projects done by undergraduate and post-graduate students in the form of articles which can be published in our Journal.

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R. L. Nene memorial lecture
5th August 2011

S. G. Dharmadhikari welcoming delegates

Shri. Tambekar offering floral tribute to Late R. L. Nene

H. S. Vadalkar introducing speaker Dr. V. V. Nori

Dignitaries on the dais

Kamal Hadker felicitating Dr. V. V. Nori

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