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(Jan-Feb-Mar)

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1. To restore the desired status to the Structural Engineer in construction industry and to create awareness about the profession.
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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.

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- The matter should be relevant to the subject and should be organized in a logical flow. It may be divided into sections and sub-sections, if necessary.
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ERECTION OF FENDER BLOCK WEIGHING 52 T FOR JETTY AT ENNORE, INDIA

A.B.Karnik

In the construction of marine works like jetty, ship berthing arrangement needs to be provided. During the berthing operation, ship exerts impact force on the structure. To facilitate smooth berthing of the ship and to absorb energy due to impact of the ship, special rubber fender pads are provided at interval along the berthing face. These fender pads are fixed on massive concrete fender blocks attached to the deck slab and beams. Most of the times, pre-cast concrete fender blocks are used. To minimize the weight of fender block during handling, part pre-cast blocks are used. After placing the block in position, remaining part and joints are cast in place with dowels for proper connectivity. The weight of the fender block is 52t in this particular case.

Erection and handling of Pre-cast Concrete Fender Block on the Jetty under construction was a challenge. Floating Crane of the required capacity was not available for the purpose. In sequence, Precast Concrete Fender Block was to be brought closest on the shore and handled on water for transportation to the Jetty site and erected in position as follows.

1. Block was loaded on to the trailer in casting yard by means of yard crane.
2. It was then transported to the nearest location on breakwater.
3. **Erection Gantry I** (sketch SK1 and photograph PH1) was designed to lift block from trailer and load it on to the twin pontoon assembly (designed for the purpose). This Gantry was designed with all clearances required for the rolling of the trailer on breakwater and standing underneath the Gantry comfortably for lifting of the block.
4. **Gantry I** itself thereafter rolls out (photograph PH2) to load block on the pontoon.
5. **Pontoon** (photograph PH3) gets loaded by block and starts out to move towards Jetty for erection.
6. **Gantry II** (sketch,SK2 and photographs PH4, PH5) on Jetty, at the location where block is to be erected unloads the block. Shifting of block from pontoon on to the Jetty is done by shifting winch mounted on top of Gantry.

   Gantry II (photograph PH6 on the cover page) is provided with back anchorage of 18 T as against lifted load of 52 T in front making use of greater lever arm. Thus block gets successfully erected in position and then the junction with floor beam is concreted.

Complete concept, design and detailing in sketch form has been done by the author. Sketches are quite elaborate from execution point of view and were followed on site without any difficulty. Article includes sketches to explain the scheme as well as for young generation of engineers as an example, how the engineer's ideas can be explained to draftsman as well as to oneself for clarity of thinking.

While developing the concept and system, it is very important to look into safety first, then time and money economy. Clarity of mechanical operations and reasonable factor of safety are important aspects to be thoroughly looked into. Full information will not be available for design unless searching questions are asked with satisfactory answers. Mishaps are likely if concept of handling heavy loads and modus operandi is not clearly understood.

Gantry I was designed to facilitate entry of trailer with block underneath for handling. Two pairs of vertical adjacent bracings were possible and other two faces had to be kept open to facilitate entry of trailer and exit on to the pontoon. Apart from design of tall columns and beams for heavy load of 52 T plus impact, plan bracings and vertical bracings are equally important to minimize horizontal sway.

Pontoon Assembly (2 no.) with bridging beams for 52 T plus load had to be checked for buoyancy as well as comfortable metacentre height against toppling. In view of shallow depth of water near breakwater, block had to be elevated over pontoon to avoid the same grazing the bed. All difficulties for navigation are also pointed out here to take care of all of them at one time.

Gantry II design had to take care of lifting of block from pontoon and shift it by overhead winch near pile centre and carefully lower it. Temporary steel column over pile (shown in the sketch) restricts bending moment to the tune of 325 T.M. (including 25 % impact). Gantry tail is anchored behind to grid J pile 18 m away requiring only 18 T of anchorage. Such are the practical ideas used to design safe, sound and economical systems. Gantry II is now free for moving it to next destination. Apart from design of main members for safety, adequate plan and vertical bracings are very essential for sturdy behavior.

Author

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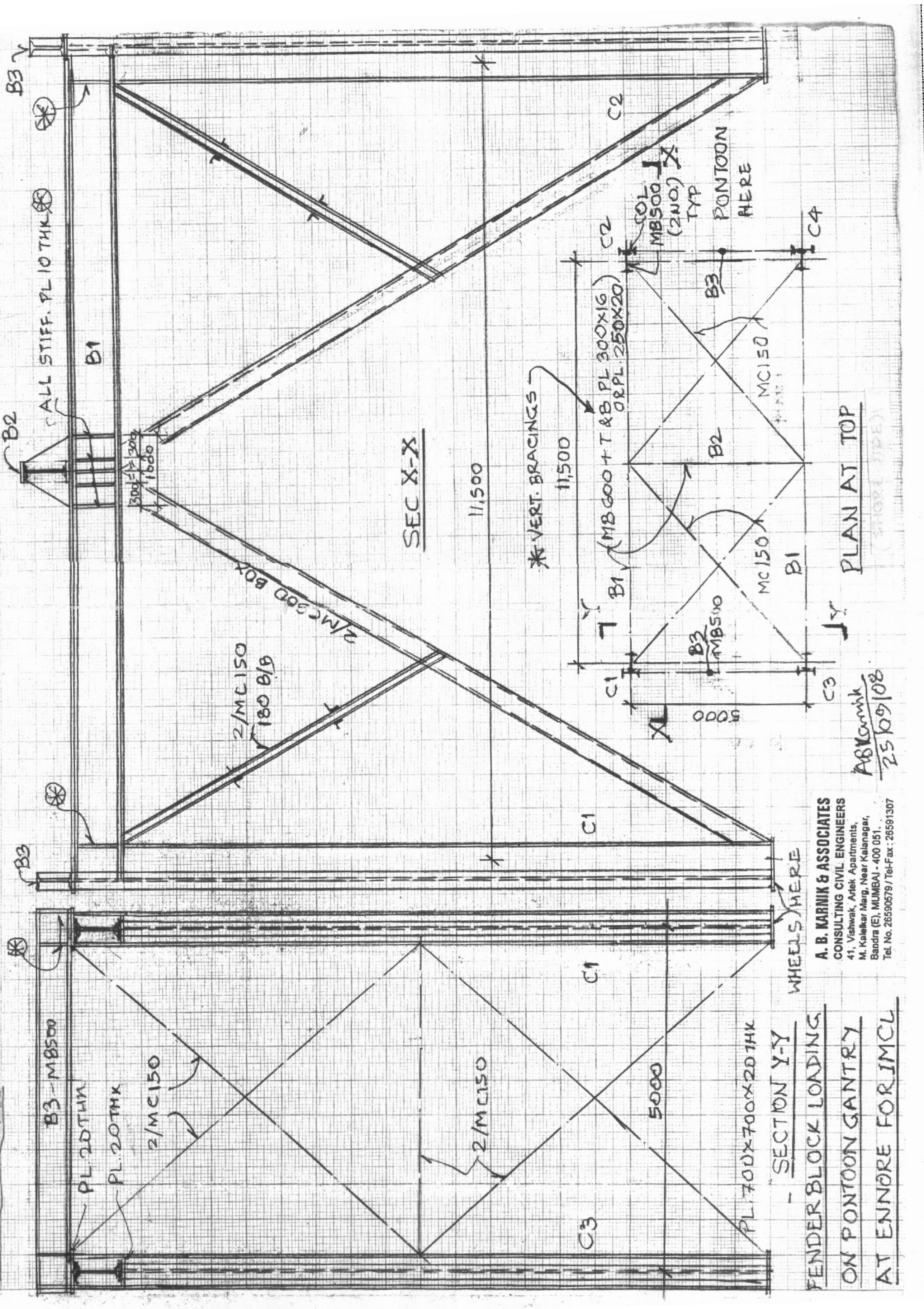
SKETCH SK1


SEC X-X
PLAN AT TOP
SECTION Y-Y
FENDER BLOCK LOADING
ON PONTOON GANTRY
AT ENNORE FOR IMCL
WHEELS HERE
PONTOON HERE
11,500
5000
2/MC150
2/MC150 180 B/B
2/MC300 BOX
ALL STIFF. PL 10 THK
VERT. BRACINGS
MB600 + T & B PL 300X16 OR PL 250X20
COL MB500 (2NO.) TYP
PL 20THK
PL 700X700X20 THK
B3-MB500
MC150
B1
B2
B3
C1
C2
C3
C4
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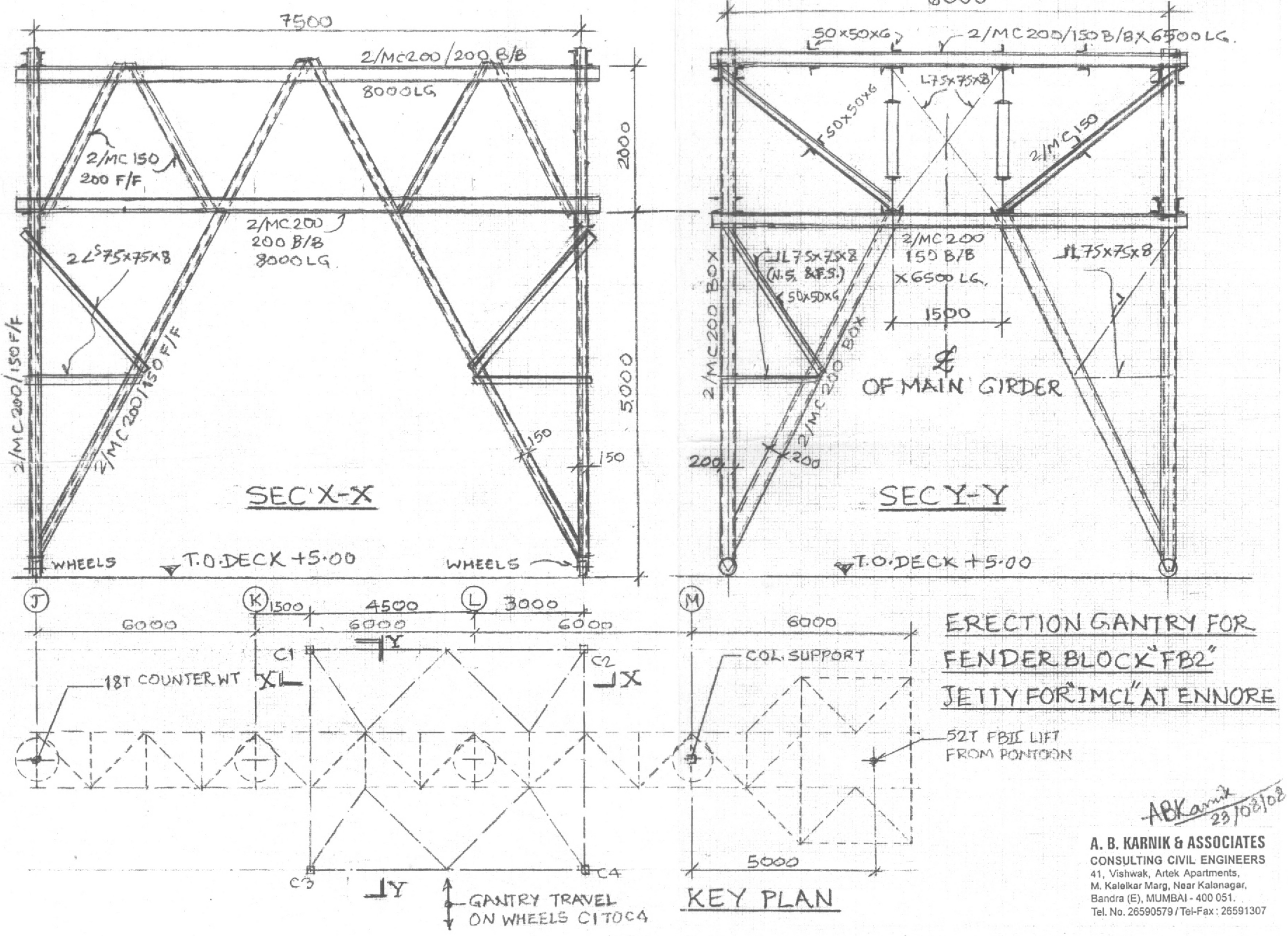
SKETCH SK2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150
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SEC X-X
WHEELS
T.O.DECK +5·00
WHEELS
6000
50x50x6
2/MC200/150 B/B x 6500 LG.
L75x75x8
50x50x6
2/MC150
2/MC200
150 B/B
x 6500 LG.
JL75x75x8
(N.S. & F.S.)
50x50x6
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4500
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6000
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6000
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C1
C2
C3
C4
Y
X
X
Y
18T COUNTER WT
COL. SUPPORT
52T FBII LIFT
FROM PONTOON
5000
GANTRY TRAVEL
ON WHEELS C1 TO C4
KEY PLAN
ERECTION GANTRY FOR
FENDER BLOCK "FB2"
JETTY FOR "IMCL" AT ENNORE
ABKarnik
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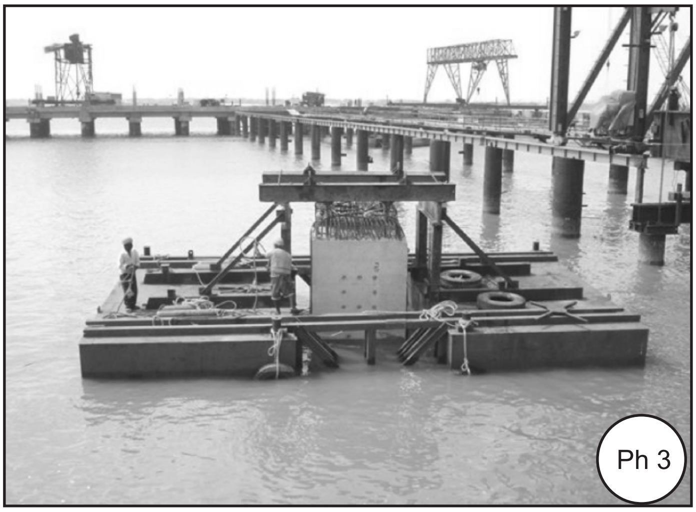
Transportation, handling, lifting and erection of Fender Block


Ph 1


Ph 4


Ph 2


Ph 5


Ph 3


Ph 6

EFFECT OF POSITIONING OF REINFORCED CONCRETE SHEAR WALLS ON SEISMIC PERFORMANCE OF BUILDING HAVING SOFT BOTTOM STOREY

Dr. S. K. Hirde & Ms. S. T. Charjan

ABSTRACT

Large number of reinforced concrete framed buildings with open storey at ground floor level suffered extensive damage and in some cases catastrophic collapse during the past earthquakes. Shear walls improve performance of buildings with soft storey during an earthquake. This paper aims to present a parametric study of multistory medium rise building having soft storey along with shear walls. The effect of positioning of the shear walls on different performance characteristics is presented in this paper. Equivalent static analysis on 3D mathematical models with different locations of shear walls, using software SAP 2000 for seismic zone III, IV and V are given.

Key words: Earthquake analysis, soft storey, shear walls

INTRODUCTION

A soft storey is an unavoidable feature in the construction of a multistoried building not only in India but throughout the world. But during an earthquake, most of the damages of the multistoried building occur at soft bottom storey. In buildings, any type of irregularity causes severe damages during an earthquake. Buildings having simple regular geometry and uniformly distributed mass and stiffness in plan as well as elevation suffer less damage than buildings with irregular configurations. Greater the departure from the regularity or symmetry, greater is the vulnerability of building to earthquake shaking. A soft storey has lateral stiffness less than 70% of that in the storey immediately above, or less than 80% of the combined stiffness of the three storeys above. The stiffness of the soft storey can be increased by providing higher dimensions of column or by introducing shear walls such that center of stiffness of columns and shear walls taken together coincide to avoid development of undue torsion during earthquake.

Every earthquake provides lessons to human society particularly to engineers, architects for improving design and construction practices. It has been observed that major failures occur in soft storeys, floating columns, at places of mass irregularities, poor quality of construction material, and due to faulty construction practices, soil and foundation effect, inconsistent earthquake responses etc.

Performance of a soft storey building of medium rise during an earthquake, is studied for various positions of shear walls using different building models for seismic zone III, IV, V Comparison of different performance characteristics is made to check the performance of the soft storey buildings having various shapes of shear walls.

BUILDING DESCRIPTION:

A residential building having G+6 storeys with open bottom storey and unreinforced brick infill walls in the upper storeys is considered. Details are given in table 1 and plan of building is shown in figure 1.

MODELING AND ANALYSIS OF BUILDING

The building is modeled using the finite element software SAP 2000. Beams and columns are modeled as two noded beam elements with six degree of freedom at each node. Walls are modeled by equivalent strut and wall load is uniformly distributed over beams. The diagonal length and thickness of the strut are taken same as the brick wall diagonal length and thickness. To improve seismic performance of such buildings, different alternatives are proposed without disturbing parking facilities. Five building models having different shapes of shear walls are generated using SAP 2000. In every model, position of wall is decided to keep the building symmetrical about both principal axes to avoid undue torsion. Length of wall in both directions is equal. Number of columns in each case is also same.

Equivalent static analysis done on all models and parameters such as stiffness, storey drift, bending moments are compared for each model. Following models of buildings with or without soft storeys are considered:

Model I:	Without shear wall	… Fig. 2
Model II:	Straight shape shear wall	… Fig. 3
Model III:	L-shape shear wall	… Fig. 4
Model IV:	T- shape shear wall	… Fig. 5
Model V:	Channel shape shear wall	… Fig. 6

RESULTS AND DISCUSSION

Equivalent static analysis is carried out on all models for zone III, IV and V and results are presented in graphical forms.

Storey Stiffness

A bar chart is plotted taking different models on X axis and storey stiffness on Y axis in the longitudinal and transverse direction as shown in figure 7 and 8. It is observed that stiffness of first storey for model I is about 7% of second storey stiffness. Model I represent the realistic situation for earthquake. It is seen that use of reinforced concrete shear walls at some location reduces the stiffness irregularity marginally. In case of model II, stiffness of first storey is increased to 20% of second storey stiffness. The use of L shaped shear wall (Model III) also increases the stiffness of first storey up to 20%. The use of T shaped shear wall (Model

IV) increases the stiffness of first storey up to 22%. The use of C shaped shear wall (Model V) increases the stiffness of first storey up to 20%.

Storey drift for Zone III

A graph is plotted taking floor level as the abscissa and the storey drift in the longitudinal and transverse direction as the ordinate for different models as shown in figure 9 and 10. Abrupt change in stiffness profile results in increase storey drift at first floor i.e. soft storey. From graph it is found that storey drift is maximum for model I. Introduction of different shapes of reinforced concrete shear walls reduces storey drift to about 47-60%. Maximum reduction in storey drift is observed in case of model II i.e. about 60%.

Storey drift for Zone IV

The same graph is plotted for storey drift in zone IV as shown in figure 11 and 12. From graph it is found that storey drift is maximum for model I. Introduction of different shapes of reinforced concrete shear walls reduces storey drift about 45-56%. Maximum reduction in storey drift is observed in case of model II i.e. about 60%.

Storey drift for Zone V

The variation of storey drift for zone V is shown in figure 13 and 14. Storey drift is maximum for model I. Different shapes of reinforced concrete shear walls reduce storey drift up to 35-75%. Maximum reduction is observed in case of model III i.e. about 75%.

Bending moment in columns for Zone III

Maximum bending moments in columns in longitudinal and transverse direction are shown in figure 15 and 16. Bending moment is quite large in first storey columns compared to that in upper storeys. Maximum reduction achieved in bending moments is in case of model II i.e.61% and in all other three models, it is about 45-52%.

Bending moment in columns for Zone IV

Maximum bending moments in columns in longitudinal and transverse directions are shown in figure 17 and 18. Maximum reduction in bending moments is in case of model II i.e. 59% and in other three models, it is about 49-54 %.

Bending moment in columns for Zone V

Maximum bending moments in the columns are shown in figure 19 and 20. Maximum reduction in bending moments is in case of model II i.e. 59%, and in other three models, it is about 39-53 %.

OBSERVATIONS

Increase in stiffness, reduces lateral drift, and hence the stress resultants, on first storey columns if described improving measures are taken. Shear walls are very effective in reducing storey drifts, which are the main causes of failure of buildings during earthquake. Introduction of shear walls can take care of stiffness irregularity. Bending moments in the columns are also reduced.

CONCLUSION

Presence of open ground storey with masonry infill walls in upper storeys causes sudden change in drift profile, because of stiffness irregularity, and makes the building vulnerable to earthquake. But a soft storey is a much required feature in multistory building since there is no alternative for parking of vehicles.

In case of soft storey building i.e. model I, storey drift at soft storey is nearly same for all the three zones for equivalent static analysis. Bending moments in all the models for zone IV are increased to 15-25% and for zone V bending moments increased to 25-50% compared to that in zone III for equivalent static analysis. It is observed that rectangular shape shear wall (Model II), is more effective than other shapes of shear walls in zone IV and V.

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Table 1: Building Parameters

Plane dimensions	21x21 m
Total height of building	23.2 m
Height of each storey	3.1m
Height of parapet	1m
Depth of foundation	1.5m
Size of longitudinal beams	300x500 m
Size of transverse beam	300 x 450 mm
Size of columns	450x450 mm
Thickness of slab	120 mm
Thickness of external walls	230 mm
Thickness of internal walls	115mm
Seismic zone	III
Soil condition	Medium
Response reduction factor	5
Importance factor	1
Floor finishes	1.875 kN/m^2
Live load at all floors	3 kN/m^2
Grade of Concrete	M20
Grade of Steel	Fe415
Density of Concrete	25 kN/m^3
Density of brick masonry	20 kN/m^3

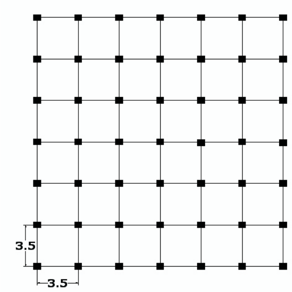

Figure 1: Plan of sample building

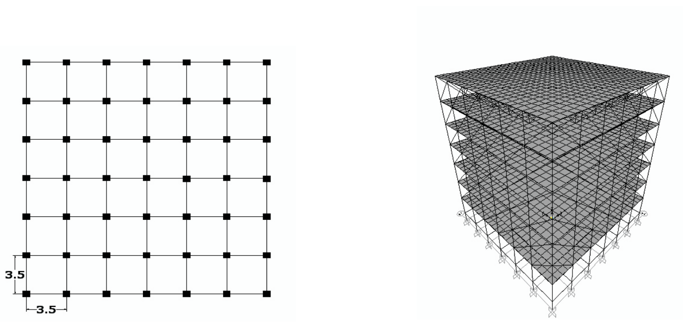

Figure 2: Building with soft storey without shear wall- Model 1

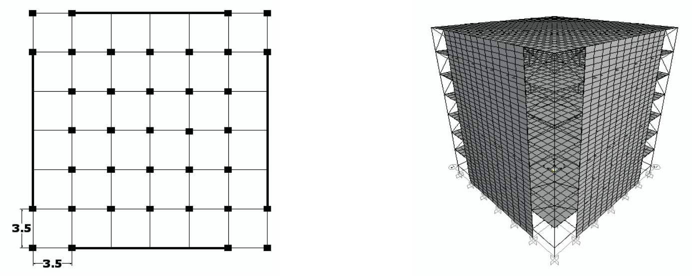

Figure 3: Building with soft storey with rectangular shape shear walls - Model 2

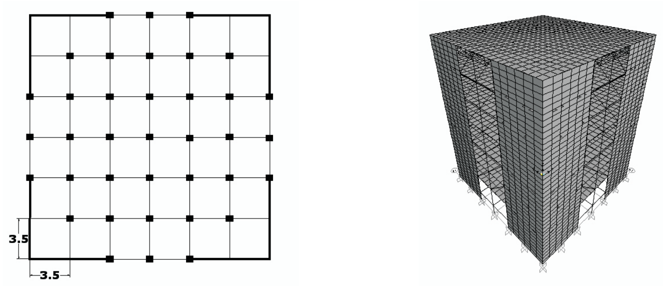

Figure 4: Building with soft storey with L- shape shear walls - Model 3

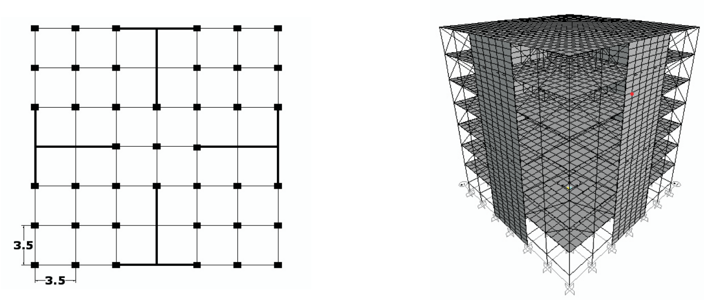

Figure 5: Building with soft storey with T- shape shear walls - Model 4

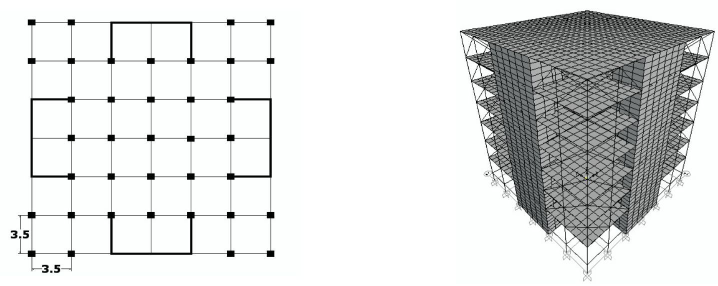

Figure 6: Building with soft storey with C- shape shear walls - Model 5

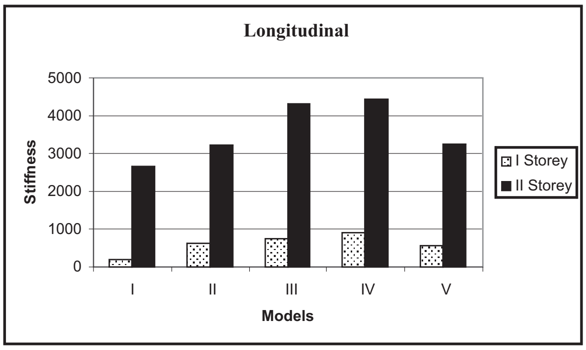

Figure 7: Comparison of stiffness at first and second floor for different models in longitudinal direction

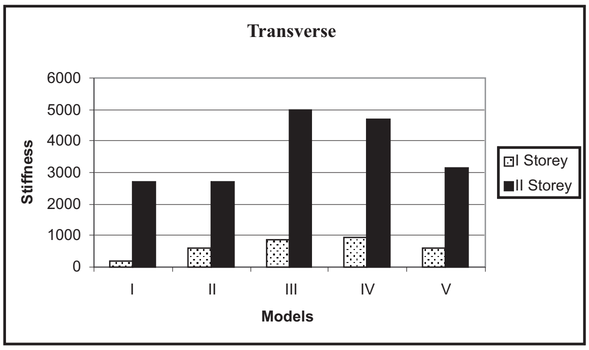

Figure 8: Comparison of stiffness at first and second floor for different models in transverse direction

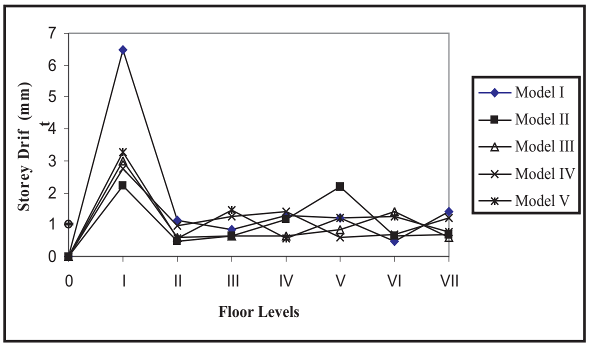

Figure 9: Drift profile in longitudinal direction for zone III (ESA)

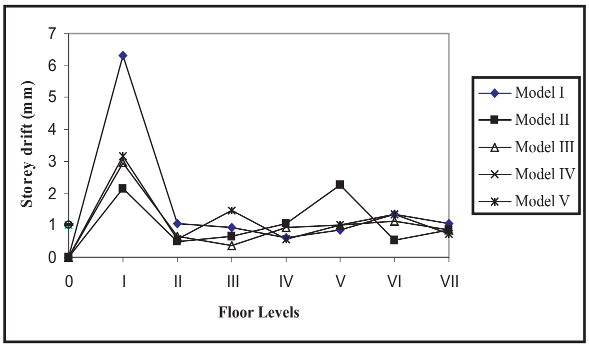

Figure 10 : Drift profile in transverse direction zone III (ESA)

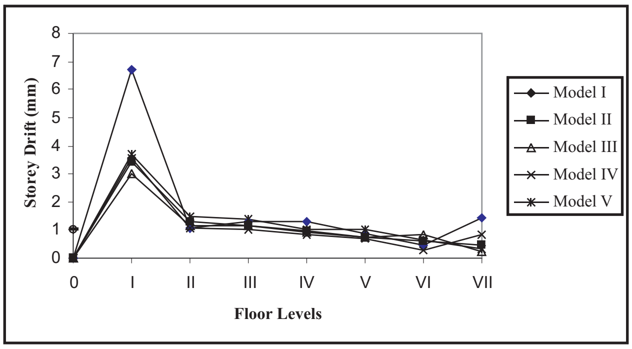

Figure 11: Drift profile in longitudinal direction for zone IV (ESA)

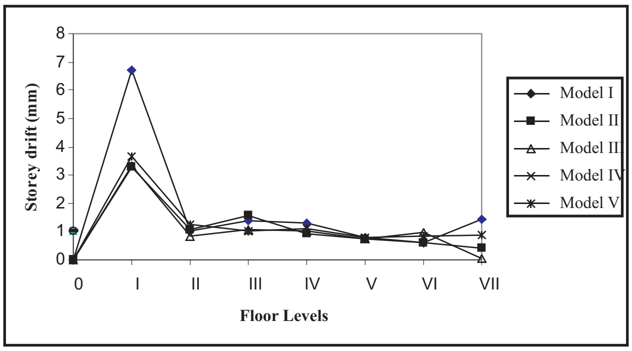

Figure 12: Drift profile in transverse direction for zone IV (ESA)

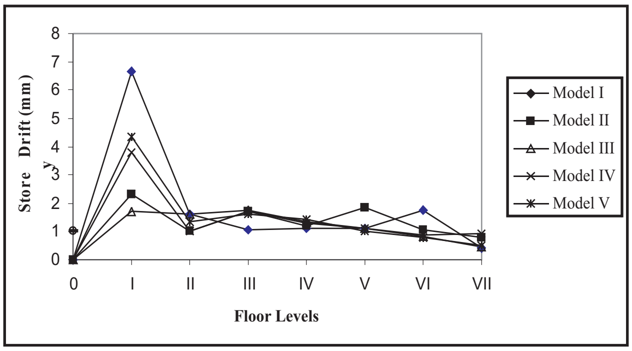

Figure 13: Drift profile in longitudinal direction for zone V (ESA)

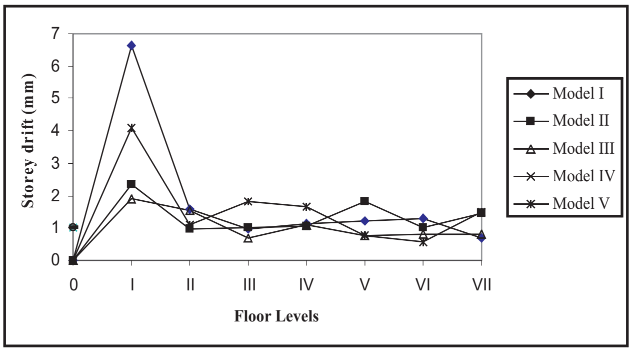

Figure 14: Drift profile in transverse direction for zone V (ESA)

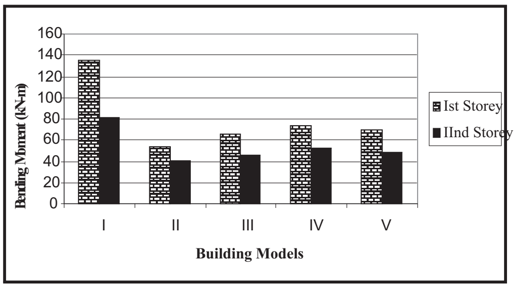

Figure 15: Comparison of maximum bending moment in longitudinal direction for zone III (ESA)

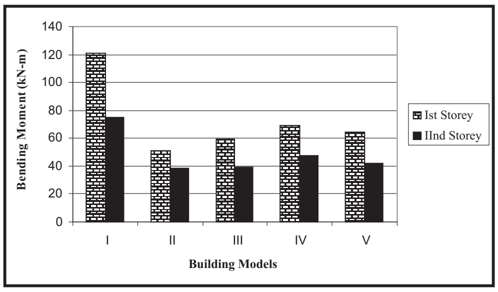

Figure 16: Comparison of maximum bending moment in transverse direction for zone III (ESA)

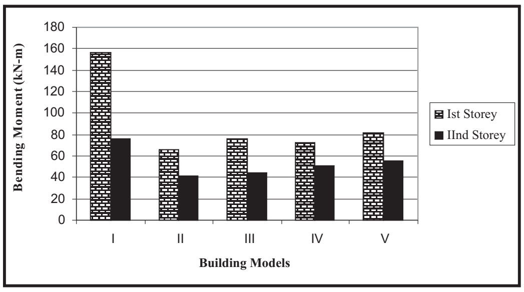

Figure 17: Comparison of maximum bending moment in longitudinal direction for zone IV (ESA)

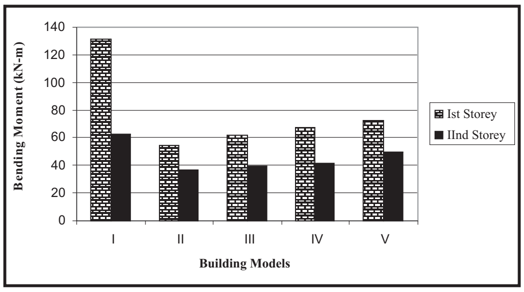

Figure 18: Comparison of maximum bending moment in transverse direction for zone IV(ESA)

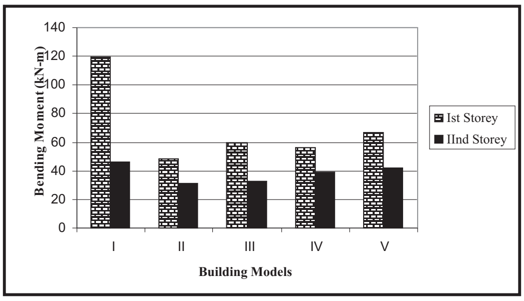

Figure 19: Comparison of maximum bending moment in longitudinal direction for zone V (ESA)

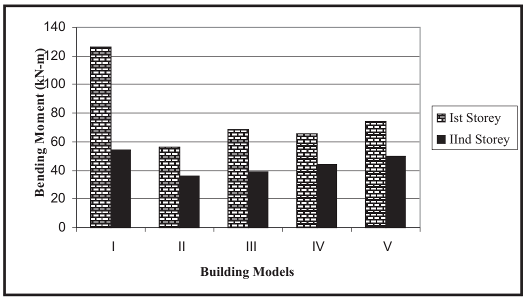

Figure 20: Comparison of maximum bending moment in transverse direction for zone V(ESA)

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USE OF RMC (READY MIX CONCRETE) AND ITS IMPACT ON SQA (STRUCTURAL QUALITY ASSURANCE)

Prof. R. G. Limaye, Devendra Limaye

Abstract

While carrying out non destructive tests (NDT) on structures constructed with ready mix concrete (RMC), large variations in characteristic strength are reported. This paper tries to analyze the cause of such variations, suggest probable methods to overcome them and proposes a techno commercially feasible methodology for early detection and prevention of deviations in quality.

Widespread Use of Ready Mix Concrete

Use of Ready mixed Concrete is increased considerably in last few years. Today's high rise structures demands smaller column sizes, faster construction, prompting use of high grade concrete. Use of Ready Mixed concrete is expected to give better control on quality of concrete compared to site mixed concrete.

Significant variation in in-situ strength

Cubes tested at RMC plant is testing “raw materials” of the “finished product”. The same concrete at site is subjected to varying site conditions during compaction & curing, directly affecting the in-situ strength. Information obtained from many sites using ready mixed concrete indicate that the strength of concrete obtained is lower than that specified. The situation is more serious when higher grades of concrete, M40 and above, are used. Studies show significant variation in strengths from 20% to 100% in samples. This is a cause of serious concern directly affecting structural behaviour.

Current methods and limitations

At site, are cast and tested at seven days and 28 days age after continuous water curing, usually by immersion in water. Some times, these cubes do not reach the specified strength for the grade of concrete. Then non destructive testing like ultrasonic pulse velocity, is carried out at site on structural members like columns, beams etc., followed by drilling cores and testing the same for compressive strength. It is then observed that results of NDT & cores invariably indicate lower quality of concrete.

In some cases, it is noticed that even if the cube test results are satisfactory, NDT on the structural members and cores taken from these members indicate lower strength of concrete. It is necessary to understand the reasons for lower strength so that corrective actions could be taken.

The Compaction Factor

Core test results indicate that the density of concrete in the cores is lower than the theoretical density of concrete based on the mixed proportions as per mix design. From technical literatures and experience, it is known that small percentage of voids in concrete may lead to very large reduction in strength. If the density obtained is 5% lower indicating 5% voids the reduction in strength may be of the order of about 30%. In a typical case e.g. the density of concrete in the core is 2370 kg/cubic meter in stead of 2500kg/cubic meter giving 5% voids. The very definition of fully compacted concrete allows for 1-2% air voids, compared with theoretically assessed compacted concrete as it is very difficult to completely eliminate the last traces of air entrapped in the body of the concrete. Additional voids can be the result of inadequate compaction while casting concrete. It is necessary to have a proper match between the workability of concrete at the time of casting and the method of compaction used. If the workability is lower than that specified compaction may be inadequate resulting in extra voids.

The Curing factor

Guidelines for curing period are provided in IS -456:2000 which are followed at sites with continuous wet curing, for 10 days. In many cases arrangements are made for wrapping concrete members with burlap etc so that the concrete is really kept wet continuously. In other cases, only intermittent spraying of water is used. The surface of concrete in such cases dries up within few minutes of spraying and the real actual period of wet curing is questionable. It has to be appreciated that the development of strength of concrete is only possible when the hydration reaction continues for which presence of water is essential. The reaction stops when the relative vapor pressure in the concrete reduces below 0.8. This problem is more serious for vertical members like columns.

The logic in adopting only ten days of wet curing could probably be that even when spraying of water is stopped, the internal humidity in concrete is still there for hydration reaction to continue. This may not always be true in our conditions when the ambient temperature tend to be relatively higher during the day time for most part of our country.

The Cement factor

The trend these days, especially for higher grade concrete, is to use blended cement with more than 20% pozollanic material like fly ash. Sometimes OPC is used and the pozollanic material is added at the time of mixing concrete. The final result depends on the reactivity of pozollanic material used. Moreover it has to be noted that the pozollanic reaction is secondary hydration and is slower and essentially contributes more at later ages. Therefore, it is all the more essential to ensure that proper continuous curing conditions are maintained over a longer period of time than when OPC is used. It is advisable to continue curing up to 28 days and not stopped at 10 or14 days.

Possible remedial measures

It is possible to improve the strength of concrete in the structural member by;

A) Grouting with Cement slurry
B) Grouting with MMA
C) Extended curing
D) Combination of A, B, & C

Where strength drops are significant, jacketing of columns can also be considered. These measures generally avoid the last resort of demolish and reconstruction of the members. Higher the strength, the more difficult it is to carry out the demolition. Further, there is no guarantee that the newly cast member will have the desired strength, forcing one to repeat the entire exercise all over again.

It is possible to confirm the effectiveness of these treatments by testing at site before and after the treatment. Also, the earlier the treatment begins, the most cost effective it is and lesser time consuming.

After application of these remedial measures, NDT methods are used again to assess effectiveness of these repairs. This is to assure that the strength has actually increased. This also means that a similar methodology can be used not only for new projects but also for rehabilitation projects.

An early detection and prevention methodology

With continuous non destructive testing at 3,7,14 days of casting, across 100% of structural elements on site, co-relation with the strength gain graph of the mix design, an early warning system can be put in place.

With today's sophisticated information technology tools, collection and processing of large scale data is a reality. A customized report highlights the variances in actual and calculated strength. It is essential that this testing be carried out by an independent third party agency (Structural Quality Audit Agency) appointed by the customer.

Adoption of a 3 tier Structural Quality Assurance System.

The execution agency, the project monitoring agency and the structural quality audit (SQA) agency, together form this 3 tier quality control system. With day to day quality monitoring and record with the project management agency, the SQA agency does periodic audit of all records and conducts extensive tests on site. Reporting directly to the customer and structural designer, SQA agency plays a vital role in identifying potential problems and defining methods for its rectification.

Justification of investments in testing.

The Structural Designer is ultimately responsible for issuing the structural stability certificate. When varying results are reported at site for concrete strength, usually the site work is usually stopped by the structural designer. The causes are then analyzed, and rectification measures undertaken. This results in both time loss and excess costs of the project.

Costs involved for large scale continuous testing range between 1-2% of construction costs. This seems even lower when compared to the overall project costs. These are instantly recovered in optimized design (with an assurance of getting the design strength on site) and no wastage of time takes place.

Extending the Study

The problem as discussed above appears to be present at many sites. It is desirable to get authentic information regarding detail of mix design including workability aids used, actual transit time, workability at the time of placement of concrete, results of cube strength, results of NDT carried out if any, and results of cores tested if any, from a large number of sites to understand real extent of the problem. This will be possible only with the kind co-operation of all agencies concerned. Then proper inference could be drawn. It is suggested therefore that the information be made available without mentioning the names of the agencies concerned and resorting to code names. The idea is to arrive at factual information and draw correct inferences.

(Photo of mobile data collection tool)

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ANALYSIS OF BEAMS ON ELASTIC FOUNDATION USING CONCEPT OF STIFFNESS MATRIX

Dr. B. N. Pandya

ABSTRACT: In this present work an attempt has been made to solve beam members resting on elastic foundation by finite element method. The formulation adopts an exact stiffness matrix derived using element of exact shape functions obtained from equation of elastic line. This eliminates the need to discretise members into shorter element to converge to an "exact" solution. Inter-nodal values of deflections and bending moments are obtained by using exact shape functions and trigonometric series. The effects of heavy compressive or tensile axial forces are treated as a linear problem by considering the axial force as a constant parameter affecting the stiffness. A computer program is developed using *object oriented programming language* C++. While calculating element shape function derived from classical theory by Hetenyi[6], it is found that under certain combination of axial force *P* and subgrade modulus *k*, imaginary terms are involved. But due to physical nature of the problem only real terms remain in the solution. However single numerical solution is obtained for every combination of *P* and *k* by using the *algebra of complex numbers.*

Results of numerical problems are compared to that available in the literatures to validate the finite element formulation and the program developed. It is found that the present results are well in agreement to the values available in the respective literatures. Also a parametric study is carried out involving foundation rigidity as a variable parameter. Results are interpreted graphically indicating range of values defining foundation characteristics. This also conforms to the work carried out by various authors. From the present results, it is seen that solution of considerable accuracy can be achieved using minimum number of elements. That is due to use of *exact shape function derived from equation of elastic line*. Also this program eliminates the necessity of superimposing different loadings as required while using classical method, which is quite laborious too.

INTRODUCTION

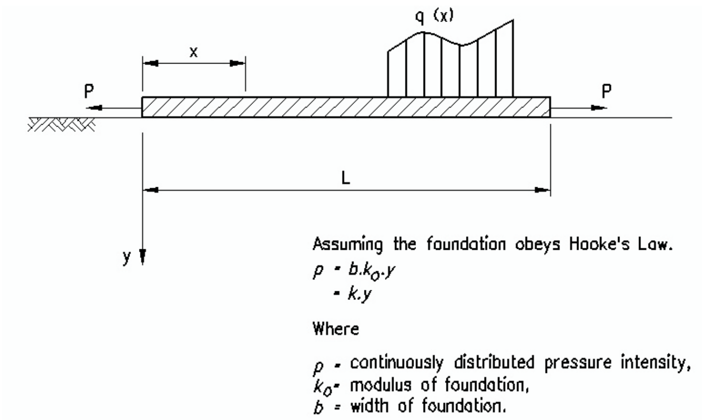
Structural members subjected to transverse loading and continuously supported on Elastic soil is a common occurrence in many Civil Engineering problems. Major part of analysis of such members is carried out on the assumption that the reaction forces of the foundation are uniform and constant or at the most of linearly varying intensity. Though solution achieved was quite well accepted, in some cases it was found to be overestimating bending moments on foundation members.

E. Winkler (1867) first evolved the concept of beams on an elastic foundation. It has since been applied by Terzaghi[9] and many others to geotechnical problems in which the ground or subgrade is the support medium.

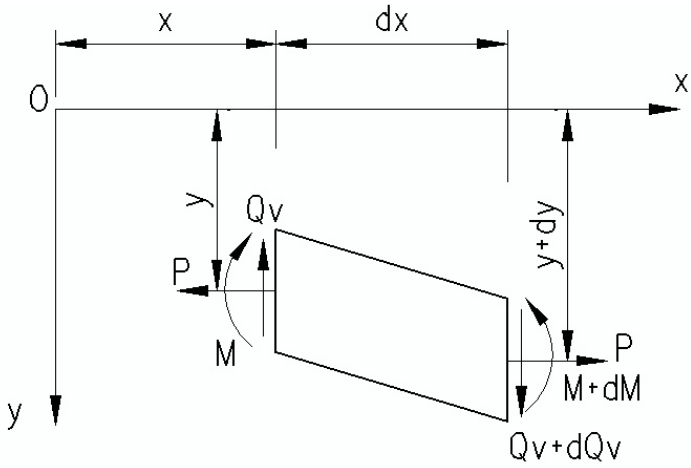
Winkler first introduced the assumption that the reaction forces of the foundation are proportional at every point to the deflection of the beam at that point. This formed the basis of classical work on the analysis of railroad track. Later it was found that there are other fields of applications where Winkler's assumptions get much more rigorously satisfied. It is the physical properties of soil, that have much more complicated nature than that which could be accurately represented by such a simple mathematical relationship as the one assumed by Winkler. Some important points in supporting the application of this theory of soil foundations are brought forward. Firstly under certain circumstances the elasticity of the soil is justified; it can for instance, propagate sound waves. Also the second most debatable part of Winkler's assumption is that foundation deforms only along the portion directly under the loading which has often been found to be true for a large variety of soils. These reasons taken into consideration, implies that Winkler theory, may often just offer more accurate solution by representing the actual conditions existing in soil underneath foundations.

Several authors have treated the problem of a beam on elastic foundation. Hetenyi provided the solution by classical approach by solving equation of elastic line. Finite difference solution has been applied by Beafault and Hoadley[3] to obtain approximate solution that converges to the exact solution when finite difference mesh is refined. Bowles[1] formulates a stiffness matrix by combining a conventional beam element with discrete soil springs at the ends of the beams. The degree of accuracy using this element is highly dependent on the number of elements modelled.

In the present work, an attempt is made to solve beam members resting on elastic foundation by finite element method. The formulation adopts an "exact" stiffness matrix derived using element of exact shape functions obtained from equation of elastic line. This eliminates the need to discretise members into smaller size element to converge to an "exact" solution. Inter-nodal values of deflections and bending moments are obtained by using exact shape functions and trigonometric series. The effects of heavy compressive or tensile axial forces are treated as a linear problem by considering the axial force as a constant parameter affecting the stiffness.



(a) – Typical beams on elastic foundation



(b) – An infinitesimal section cut from the beam

Fig-1.

A t7ypical Beam on Elastic Foundation.

Considering an infinitely small element of the bar, loaded with a distributed load q, bounded by two verticals at a distance dx apart as shown in Fig-1, the governing differential equation of elastic line is obtained as,

$$EI\,(d^4y/dx^4) - P\,(d^2y/dx^2) + ky = q \qquad \text{....(1.1)}$$

It is sufficient to consider only the general solution of eq-1.1, for any transverse loading total solution can be obtained by adding the particular integral part corresponding to *q*.

Shape function

Considering a solution y = e^{mx} for the deflection in the homogeneous part, (1.1) becomes

$$EI.m^4 - P.m^2 + k_s = 0 \qquad \text{....(1.2)}$$

and the roots of the characteristic equation are

$$m_{1.2.3.4} = \pm\ (a\ \pm\ c)$$

Where

$$a = \sqrt{\frac{P}{4EI} - \sqrt{\frac{k_s}{4EI}}}$$

$$b = \sqrt{\frac{P}{4EI} - \sqrt{\frac{k_s}{4EI}}}$$

.....(1.3)

Hence the general solution of (1.1) when $q = 0$.

$$y = p_1 e^{m_1 x} + p_2 e^{m_2 x} + p_3 e^{m_3 x} + p_4 e^{m_4 x}$$

.....(1.4)

In the matrix form,

$$y = [G]\,\{p\}$$

.....(1.5)

Where,

$$[G] + [e^{m_1 x}, e^{m_2 x}, e^{m_3 x}, e^{m_4 x}],$$

$$\text{and } \{p\} = \{p_1, p_2, p_3, p_4\}$$

Applying <u>boundary conditions</u> to obtain four constants p_1, the displacement {*d*} corresponding to the four degrees of freedom are,

$$\{d\} = \left\{ (y)_{x=0},\ \left(\frac{dy}{dx}\right)_{x=0},\ (y)_{x=1}\ \left(\frac{dy}{dx}\right)_{x=0} \right\}$$

....(1.6)

Differentiating (1.5) and substituting in (1.6)

$$\{d\} = [B]\{p\}$$

$$\{d\} = [B]^{-1}\{d\}$$

....(1.7)

Where

$$\{d\} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ m_1 & m_2 & m_3 & m_4 \\ e^{m_1 l} & e^{m_2 l} & e^{m_3 l} & e^{m_4 l} \\ m_1 e^{m_1 l} & m_2 e^{m_2 l} & m_3 e^{m_3 l} & m_4 e^{m_4 l} \end{bmatrix} \begin{Bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{Bmatrix}$$

Substituting (1.7) in (1.5)

$$\{y\} = [G][B]^{-1}\{d\}$$

$$\text{or} \quad \{y\} = [N]\{d\} \qquad \text{....(1.8)}$$

[N[is the one row vector of shape functions.

Element stiffness matrix

The force vector corresponding to the four degrees of freedom is,

$$\{f\} = \{-(V)_{X=0}\ \ (M)_{X=0}\ \ (V)_{X=l}\ \ -(M)_{X=l}\}^T$$

$$= \begin{Bmatrix} \left[EI.\dfrac{d^3y}{dx^3} - P\dfrac{dy}{dx} \right]_{X=0} \\ \left[-EI.\dfrac{d^2y}{dx^2} \right]_{X=0} \\ -\left[EI.\dfrac{d^3y}{dx^3} - P\dfrac{dy}{dx} \right]_{X=1} \\ \left[EI.\dfrac{d^2y}{dx^2} \right]_{X=1} \end{Bmatrix} \qquad .....(1.9)$$

Differentiating y and substituting form eq.3.5,

$$\{f\} = EI.\ [c]\ \{p\} \qquad .....(1.10)$$

Where,

$$c_{1i} = m_1^{\,3} - \left(\frac{P}{EI} \right) m_l$$

$$c_{2i} = -m_i^{\,2}$$

$$c_{2i} = -\ m_1^{\,3} - \left(\frac{P}{EI} \right) m_l\ \ e^{m_i x}$$

$$c_{2i} = -\ m_1^{\,2} e^{m_i x} \qquad for\ \ i = 1.2.3.4.$$

Substituting for $\{p\}$ from (1.7),

$$\{f\} = [S]\{d\} \qquad .....(1.11)$$

Where $[S] = EI.[C]\ [B]^{-1}$ the element stiffness matrix.

Nodal load vector

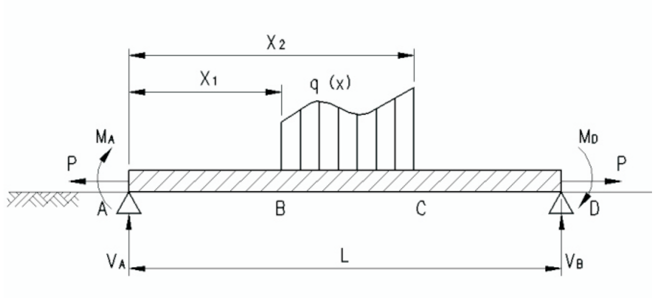


Fig - 2.

Typical Beam on Elastic Foundation with end forces.

For a distributed load q (x) acting transversely the nodal load vector is,

$$\{f\} = \int_{X_2}^{X_2} [N]^T .q(x).\ dx \qquad .....(1.12)$$

When q is distributed uniformly,

$$\{f\} - q\left([B]^{-1} \right)^T \left\{ \left(e^{m_i x_i} / m \right) \right\}_{i=1.2.3.4}$$

For a concentrated load Q, acting at $x = x_Q$

$$\{f\} = Q\ \left([B]^{-1} \right)^T \left\{ e^{m_i x_Q} \right\}_{i=1.2.3.4}$$

NUMERICAL EXAMPLES

Numerical problems are solved to validate the finite element formulation and the developed program. In the example, a beam of uniform flexural stiffness simply resting on elastic foundation is solved using the program. Results are tabulated and compared with the values obtained from several other literatures. This example demonstrates the ease and accuracy of the method developed compared to previously used methods.

Example

The beam analysed by Hetenyi is solved using the computer programme. The input to this problem are given interactive. Boundary conditions for the problem are FREE at both the ends. A single element is used to solve the problem as it is of constant stiffness. Presence of concentrated load in the span does not call for element discretisation. The problem consists of a weightless beam of cross section 10 inches by 8 inches with a concentrated load of 5000 lbs acting at 30 inches from the left end and an UDL of intensity 100 lbs/in acting at 52 inches from left end for a distance of 48 inches. Beam is resting on an elastic foundation with a constant modulus of 200 lbs/in^3. The beam constants are E = 1.5 x 10^6 lbs/in^2 , and Iz = 426.7 in^4 . Figure-3 gives the beam geometry and loading.

Results are plotted and compared with similar literatures.

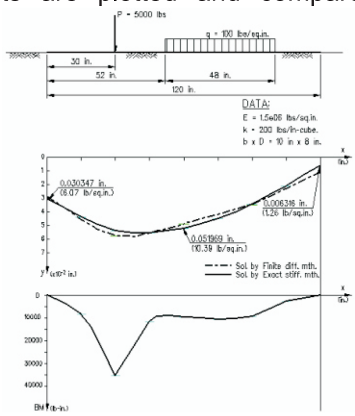


Fig. - 3.

Beam geometry, deflection diagram and Bending moment diagram for example - 1.

Table – 1
Comparison of deflections with the values obtained by applying different methods of solution.

Methods of analysis	x(in)				
	0	30	60	90	120
Newmarks Method	0.021	0.056	0.052	0.034	0.005
Interpolated	0.029	0.057	0.053	0.033	0.007
Rigourous	0.030	-	0.052	-	0.006
Finite Difference	0.029	0.058	0.049	0.035	0.011
By the Present Analysis	0.030	0.054	0.052	0.035	0.006

Values in the braces in the deflection diagram are the base pressures obtained which are exactly the same when compared with those given by Hetenyi.

The Bending moment diagram is compared with that derived by D.Z. Yankelevsky and M. Eisenberger[10] in their paper using the same problem. Maximum bending moment that is occurring below the concentrated load of 5000 lb, as calculated in this example.

M_{max} = 35303.3 lb-in.

In the literature cited above, the analysed results are plotted graphically. Maximum bending moment interpreted from the graph in the previous literature is M_{max} = 35300 lb-in.

Present results are in agreement to results available in the literature.

CONCLUSION

From present results, it is seen that solution of considerable accuracy can be achieved using minimum number of elements. That is due to use of exact shape functions derived from equation of elastic line.

As shown in Example, D.Z. Yankelevsky and M. Eisenberger also solved the same problem. But they used four linear elements to achieve exact solution. Use of complex number in the formulation of shape function and than the trigonometric series that is used to determine bending moments and deflections at intermediate points, helped in solving the same problem only with a single element. Comparison of results show the accuracy of the method.

Other structures, such as walls of circular concrete tanks, thin walled metal pipework, concrete shells and various containment support structures can also be idealised as beams on an elastic foundation. In each case the beam and foundation can be defined explicitly and so the FEM offers an ideal solution to the problem.

APPENDIX

{d}	*Displacements corresponding to degrees of freedom*
EI	*Flextural rigidity*
E_s	*Modulus of elasticity of soil*
f or {f}	*Nodal load vector due to transverse load on the beam*
F	*Concentrated load acting transverse to member axis*
k_0	*Modulus of foundation*
k, k_s, k_r	*Subgrade modulus*
M	*Bending moment*
N or [N]	*Shape functions*
p	*Intensity of base reaction*
P	*Axial load*
q(x)	*Distributed transverse load*
r	*External nodal loads*
S or [S]	*Stiffness matrix*
T or[T]	*Transformation matrix*
V, Q_v	*Shear force*
x	*Distance along member axis*
y	Vertical deflection
y_{sp}	Mean settlement of square plate
y_{cp}	Mean settlement of circular plate
v_s	Poisson's ratio of soil
	Specified nodal displacement

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REPORT OF WORKSHOP ON `NATIONAL BUILDING CODE OF INDIA 2005'

Jointly organized by BIS and IE(I) at Tiruchirappalli on 24 January 2009

As a part of the series of workshops being organized by the Bureau of Indian Standards (BIS) for implementation and dissemination of information about the National Building Code of India 2005, a Workshop on NBC 2005 (19^{th} in the series) was organized jointly by BIS and the Institution of Engineers (India), Tiruchirappalli Local Centre on 24 January 2009 in Tiruchirappalli.

The Workshop was **inaugurated** by **Shri S. Srikumar,** *Airport Director, Airport Authority of India, Tiruchirappalli* who emphasized upon the need for planned infrastructure development in the country utilizing the sound provisions of NBC 2005 whose importance is increasing year after year. He dwelled on the today's scenario of increasing urbanization and urban population and consequent land scarcity. He said, at the same time, under the XIth Five Year Plan lot of emphasis has been laid on proper urban and rural development, which would need expenditure of huge amount by public and private sectors while ensuring international quality levels. He said, this would require multidisciplinary integrated approach in accordance with NBC 2005. Shri Srikumar said that NBC serves as a unifying thread amongst diverse local building bye-laws of different cities and towns throughout the State and provides a sound basis to make appropriate decisions under various situations encountered in the town planning, land development and building construction regulatory process. He hoped that the revised Building Code, NBC 2005 would be effectively implemented in the State of Tamil Nadu and particularly by the Corporation of Tiruchirappalli at the earliest.

Prof M. Chidambaram, *Director, National Institute of Technology, Tiruchirappalli,* who **presided** over the Inaugural Session, said lot of infrastructure development during last five years has resulted in use of large quantity of building materials such as concrete and steel and construction of different types of buildings and complexes including offices, hospitals, institutions and expansion work of airports. He said, these developments would continue, necessitating contribution from all disciplines of engineering and other professions. He said the revised Building Code gives a comprehensive network of information and has been very well written in an attractive manner to provide an easy reference for all the building professionals and others connected with this field. Prof Chidambaram said, the Code should be used as important reference material by students and faculty and assured for immediate proactive measures in this regard at NIT, Trichy. He advised all the delegates to effectively participate in the interactive session of this unique Workshop and go with enriched knowledge about this valuable national publication.

Earlier **Shri R. Kumar**, *Chairman, IE(I) Tiruchirappalli Local Centre*, extended a warm welcome to the dignitaries, speakers and the delegates. He informed about the activities of IE(I) Tiruchirappalli Local Centre, the efforts made by BIS and IE(I) and the background for organizing the Workshop. **Dr G. Swaminathan,** *Convener of the Workshop* while giving the programme objectives emphasized the need for effective implementation of the Code to spread awareness and bring quality culture in construction activities in the State. **Shri Sanjay Pant**, *Director, BIS* gave the framework of the latest revised Code brought out under the leadership of *Padmshri* **Dr. H.C. Visvesvaraya**, *Chairman, NBC technical committee of BIS*. Briefly informing about the genesis of the Code in 1970 at the instance of Planning Commission and subsequent revisions thereof, Shri Pant brought out the important dimension of actual implementation of revised NBC 2005 so that all the improvements and technological developments as reflected in the Code could percolate down to common masses. He suggested following a multi-pronged strategy involving adoption of the revised Code by the local authorities, adoption by Govt construction departments, implementation by private construction agencies, copious use by building professionals, inclusion in engineering and architecture curricula, and organizing a nation-wide awareness and implementation campaign. In this regard, the efforts made by BIS by approaching the Central Government, all the State Governments, Housing Finance Institutions, Academic Institutions, etc for the purpose were also informed. He brought out as to how best our aim of safe and sustainable habitat could be achieved through proper direction and how NBC 2005 could be effectively utilized for the purpose. At the closure of the Inaugural Session, **Shri J. Sankaran**, *Hony. Secretary, The Institution of Engineers (India), Tiruchirappalli Local Centre*, proposed a vote of thanks and highlighted the importance of the role of professional organizations and academic institutions like IE(I) and NITs in achieving the objectives of the Code. He thanked the management of BHEL, Trichy and Director, NIT, Trichy for their unflinching and generous support for the organization of this important Workshop and the support provided by all the sponsors.

In the **Technical Sessions**, the various speakers presented details about different parts and sections of the Code and particularly explained the important modifications made in this revision. **Shri Sanjay Pant**, *Director, BIS and Member-Secretary, BIS technical committee on NBC*, in the first technical session, gave an overview of NBC 2005 including the application and philosophy of 26 chapters covered under 11 parts and section/subsections thereunder. It was explained that NBC 2005 contained latest provisions for planning, design and construction of all types of buildings particularly the techno-legal mechanism for safety against natural and man-made disasters such as earthquakes and fire. It is now for the state authorities such as town and country planning department, development authorities, municipal corporations, other local bodies and fire authorities to implement this Code by revising and revamping the concerned Act and local building byelaws to bring the same in line with NBC 2005. The same thereafter also requires effective implementation. Bringing home the point that it is not the disaster but the badly planned, designed and constructed buildings that kill people, it was explained how the Code could be effectively utilized at state level by the authorities and govt and private construction agencies to help erect safe buildings and protect life and property of our citizens particularly in the event of a natural calamity. **Dr K. Palanichamy**, Prof, Department of Civil Engineering, NIT, Trichy gave a presentation on structural design of buildings for safety against various loads, forces and effects including the natural disasters like earthquake using various material streams. He also highlighted various dos and don'ts and good practices for safe design and construction of buildings. **Dr G. Swaminathan**, Prof, Department of Civil Engineering, NIT, Trichy explained the provisions on water supply, drainage, sanitation, solid waste management and gas supply given in the revised Code. He discussed the various modifications made and basis thereof in the revised Code including those relating to important aspects of recycle and reuse of waste water, rain water harvesting and efficient use of water in general. He also discussed regarding water quality requirements for drinking and other purposes including for making and curing of concrete. **Dr K. Sankaranarayanasamy**, Prof, Department of Mechanical Engineering, NIT, Trichy explained through case studies the provisions on *Fire and Life Safety* and explained how the codal provisions could be utilized to plan and construct buildings which are safe against fire by appropriately implementing the provisions on fire prevention, life safety and fire protection measures given in the Code. He said, these are particularly important for cities of Tamil Nadu, where number of multiplexes and high rise buildings are coming up.

In the **Valedictory Session**, it was felt that it is essential to implement the provisions of NBC 2005 in letter and spirit so that the technological developments percolate down to poorest of the poor. The necessity of educational utilization of NBC 2005 and other Indian Standards in Engineering and educational curriculum was also emphasized. **Shri D. Harsha,** Past Chairman, IE(I), Trichy Local Centre in his Valeditory address dwelt on the importance of dissemination of information and implementation efforts for the Building Code through the effective network available with the IE(I) throughout the country. He also suggested for developing standard typified design of building components and houses to facilitate implementation of the Code. **Shri Sanjay Pant** emphasized on adopting the structured approach enshrined in NBC 2005 for safe and orderly development of our villages, towns and cities. Earlier **Shri R. Dhanuskodi**, Past Hony Sy, IE(I), Trichy Local Centre gave a welcome address, **Dr K. Bhaskar**, Prof, NIT, Trichy summed up the day's proceedings and **Dr G. Swaminathan** spoke as Convener of the Workshop. Also, feedback was given by the delegates representing BHEL, NIT and Grasim Industries Ltd. Finally **Prof K. Palanichamy** gave a formal Vote of thanks. **As the Code contains all the essential provisions for safe design and construction of building in rural as well as the urban areas, the workshop strongly recommended for its effective implementation in the State of Tamil Nadu including in the city of Tiruchirappalli.** The delegates thanked BIS and IE(I) for arranging such a comprehensive exercise of dissemination of information about the revised Building Code.

The recommendations as enclosed were emerged.

Shri R. Kumar and **Shri J. Sankaran**, *Chairman* and *Hony Secretary, Trichy Local Centre* informed that the Institution will follow up with the Govt and other concerned authorities for the early implementation of the above recommendations.

About 100 delegates representing **local bodies/authorities** such as City Corporation of Tiruchirappalli, **govt construction departments/agencies** such as PWD, Govt of Tamil Nadu; **private construction/property management agencies/consulting organizations**; **building professionals** such as architects, engineers, town planners, valuers; **public sector enterprises** such as BHEL; **other important organizations, R&D/academic institutions** such as students and faculties from NIT, Trichy and other engineering institutions and polytechnics and **building material manufacturers/ suppliers** participated in the above successful Workshop.

The Organizers of the Workshop thanked all the dignitaries and the delegates for making it convenient to participate in this important national event and hoped that they would carry forward the message of safe and sustainable developments as enshrined in NBC 2005 to their respective organizations.

RECOMMENDATIONS

1. The National workshop attended by about 100 delegates representing all stakeholder groups in the building construction and built environment sector, unanimously endorse the adoption of National Building Code of India 2005 (NBC 2005) as an instrument for guiding regulation of planning, design, construction and asset management of all buildings in Tamil Nadu.

2. The workshop strongly recommends to Government of Tamil Nadu and all local bodies (urban & rural), development authorities, special and new town development agencies, etc including the Tiruchirappalli Municipal Corporation to modify, revise, revamp the existing building byelaws;

development control rules; planning standards; town planning rules; special regulations for fire, structural, health, construction, electric and life safety, in line with the NBC 2005 by suitably adopting fully or adapting it with such local variation as may be needed.

3. The workshop recommends adopting NBC 2005, as the basis for structural design, firing protection, building and plumbing services, building materials and construction practices (and construction safety) by modifying the departmental construction codes / specifications/manuals of Govt. construction departments, in line with NBC 2005.

4. The workshop recommends the strengthening of all building development and regulating agencies with the right level of professional human resources to deal with proactive responses needed with the building professionals and builders. The professional human resource pooling for contiguously situated human settlements and the related regulating agencies should be attempted, considering the socio-economic and budgetary constrains of smaller level local bodies dealing with building regulation work.

5. The workshop strongly urges the Government of Tamil Nadu, Directorate of Technical Education, Educational Institutions dealing with architectural, engineering and planning education to upgrade the curricula in line with NBC 2005 so as to ensure proper understanding and training of the provisions of the Building Code right from academic level.

6. The workshop recommends the initiation of continuous orientation and development programmes for creating mass awareness, appreciation and application of NBC 2005 among practicing professionals and the Government, Public and Private Sector; as also capacity building/training of all building professionals and work force involved in building construction activity.

7. The National Workshop on NBC 2005 urges the fire services department of the Govt of Tamil Nadu to bring the record of outcome of investigations of instances of building fires, in public domain, so that lessons could be learnt from the same and timely corrective actions ensured by all stakeholders.

Looking Back

List of articles published in the ISSE Journal during the year 2008

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Quality Manual for Ready-mixed Concrete Launched

Ready-mixed Concrete Manufacturers' Association (RMCMA) launched two quality manuals for Ready-mixed Concrete. Quality Manual Part I incorporates an extensive checklist to be used for auditing RMC facility, procedures of audit etc. Quality Manual Part II contains guidelines for QA & QC of concrete, which are based on key provisions in different BIS codes.

In order to develop a self-regulatory framework for quality of ready-mixed concrete, RMCMA formed a sub-committee on quality, consisting of experienced quality personnel from its member companies. Further a committee of national experts was also set up. The quality sub-committee under the guidance of National experts committee, evolved Quality Scheme for RMC in India. The team also finalized procedures of audit and selection criteria of auditors.

Conformity with the Quality Manual Part I through annual external audit of RMC facility is now made mandatory for obtaining an RMCMA certification. Till date nearly 50 RMC facilities have been audited and certified based on these manuals.

You can request for the copies of the two Quality Manuals by writing to RMCMA at info@rmcmaindia.org

Missing You

In the past few months, ISSE journals and other correspondence sent to some of our members have been coming back undelivered. It appears that they have moved to a new address. A list of such members is given below. We are very keen in having their latest contact details with us so that we can reach them in future.

If you know any of these members, please ask them to get in touch with us (Phones: 022-24365240, 24221015) or send an email to isse@vsnl.net or update their contact details through our website www.isse.org.in.

Members

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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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