STRUCTURAL ENGINEERING

QUARTERLY JOURNAL OF
INDIAN SOCIETY
OF
STRUCTURAL ENGINEERS

ISSE

VOLUME 21-2

APR-MAY-JUN 2019

GEM 20 Prof. R. N. SWAMY-DOYEN OF CEMENT AND CONCRETE COMPOSITES

Large Hospital Building Constructed in Record Time

Dandi Memorial

Workshop on Wind Loading

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on 9th August 2019
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CHIEF GUEST : Dr. MOHAN DAGAONKAR (Ex. N.M.M.C.)

Topic : Role & Responsibilities of Structural Auditor

Speaker : Shri. C. V. Khandekar (Ex. M.C.G.M.)

Venue : The Institution of Engineers (India)
15, Haji Ali Park, K. Khadye Marg,
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The Lecture will be followed by Dinner

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STRUCTURAL ENGINEERS

INDIAN SOCIETY OF STRUCTURAL ENGINEERS

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VOLUME 21-2, APR-MAY-JUN 2019

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Regd Office : The Maharashtra Executor & Trustee Co. Ltd., Bank of Maharashtra, Gadkari Chowk, Gokhale Road (N), Dadar (W), Mumbai 400 028.

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5. To convince all Govt. & Semi Govt. bodies for directly engaging Structural Engineer for his services.
6. To disseminate information in various fields of Structural Engineering, to all members.

GEM 20 Prof. R. N. SWAMY-DOYEN OF CEMENT AND CONCRETE COMPOSITES

By Dr. N. Subramanian

Prof. R. N. Swamy
(1st Nov. 1928 -24th Sept. 2018)

Dr. Ramnath Narayan Swamy was Professor Emeritus in the Department of Mechanical Engineering, at the University of Sheffield, England. He was involved in teaching, research, design, and consultancy activities for over forty five years. His research cover a wide range of cement and concrete-related topics, including cement materials, admixtures, microstructure and properties, durability, long-term exposure, and repair and rehabilitation of structures. He had also undertaken significant research on the durability of steel in concrete and protective coatings for steel and concrete.

In all these activities he adopted a "Holistic" approach integrating material characteristics and structural performance with "Design" as a total concept of civil engineering construction. His research activities reflected this approach, and encompass a wide range of inter-related and interdependent topics concerned with concrete materials, concrete structures, their design, and construction, and their interactive performance in real environments,. Professor Swamy has lectured extensively all over the world, especially on topics such as Technology Transfer, Holistic Design and Design for Durability, Environment, and Sustainability.

EARLY LIFE AND EDUCATION

Narayan Swamy was born on 1st November 1928, at Palakkad, Kerala, India to his parents Mr. Ramnath and Mrs. Lakshmi. He obtained his Bachelor in Engineering with Honours, from Annamalai University, India, in 1950. He then went to England and earned his Masters in Engineering from the University Sheffield, in 1956 and subsequently his Doctor of Philosophy degree from the same university in 1959. He had the great honour of becoming President of the Students' Union of the University of Sheffield for the year 1956/1957.

PROFESSIONAL EXPERIENCE

During 1950 to 1952, he worked as an engineer with the Public Works Department, Madras, India . He then joined the Western Railways, Bombay, India, in 1952 and worked as a design engineer till 1954. After earning his postgraduate studies, he taught as Assistant professor at the Ahmadu Bello University, Zaria, Nigeria, from 1959 to 1962, at the University Leicester, England from 1962 to 1967. He joined the University of Sheffield, England in 1967 as lecturer and rose to become a Professor, and then as Professor Emeritus from 1994. He also served as a Visiting professor at the University Calabria, Italy. He was involved in teaching, research and consultancy activities for over forty years. He also served as Member science committee of various international conferences.

RESEARCH

One of the pioneers of concrete education and research in the UK, Professor R Narayan Swamy, worked at the Structural Integrity Research Institute and the Centre for Cement and Concrete, University of Sheffield, England.

Professor Swamy has lectured extensively and has had the privilege to guide and train over 100 research scholars, from all over the world (Japan, China, Taiwan, Malaysia, Sri Lanka, Iraq, Italy, Greece, Brazil, Canada, the USA), for their Ph.D.

Degree, which is a record! He has extensive international research collaboration, and considers Teaching and Research to be interactive and inter-disciplinary activities. This international interaction enabled the Sheffield Group to tackle a much wider range of research topics such as corrosion and corrosion control/protection, punching shear mechanisms, fibre cement composites, environmentally friendly and low energy building materials, use of natural fibres and so on. Such international collaboration made research very exciting and adventurous and gave the team a greater vision and understanding of the problems involved in civil engineering infrastructure development.

Professor Swamy at the University of Sheffield, UK with some students from Japan.

This collaboration also enabled the group to produce sustainable and cost-effective solutions to engineering challenges. It is worth mentioning two such challenging solutions, the group developed. In the first instance, a highway concrete bridge near Sheffield (prestressed in two directions) has been designed for a live load of 100 tonnes, and was required to carry a new live load of 400 tonnes. The simplest solution would have been to demolish and rebuild the bridge to carry the extra load. But the Sheffield group based on extensive research, developed a plate bonding technology of strengthening structures – the first of its kind applied to bridges.

Another challenge was to develop an efficient, reliable and cost-effective protective coating system for concrete to prevent the penetration of air, water, chlorides and other aggressive ions into concrete, thus protecting and rehabilitating structures from further damage and deterioration, and extending their durable service life. The group spent about 25 years of research and developed such a coating system !

For over forty years his published works have been a barometer of the strengths, weaknesses, opportunities and threats in the field of concrete and concrete structures. During the times when research funding for concrete in UK Universities was limited, Prof. Swamy managed to attract a large number of dedicated researchers to work with him at the Department of Civil and Structural Engineering of the University of Sheffield. Although the city of Sheffield is firmly linked with the steel industry, the work of Prof. Swamy at the University made Sheffield one of the established centers of excellence in concrete research.

PUBLICATIONS AND BOOKS

Prof. Swamy along with his research associates has published over 200 refereed papers in International Journals and Conferences. Prof. Swamy has edited a large number of books, including five Concrete Technology and Design Series, several chapters in books, and many international conference proceedings. Some of his research papers may be found at Ref.3.
His books include the following:

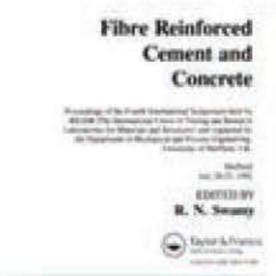
1. Cement Replacement Materials (Concrete Technology & Design)
2. New Concrete Materials (Concrete Technology & Design)
3. New Reinforced Concretes (Concrete Technology & Design)

In addition, he co-authored the following books and proceedings:

1. Developments in Prestressed Concrete, 1978,
2. Developments in Concrete Technology, 1979,
3. Progress in Concrete Technology, 1980,
4. Fracture Mechanics of Concrete, 1983,
5. Alkali-Silica Reaction in Concrete, 1991,
6. Advances in Concrete Technology, 1992.

He also edited the following books/conference proceedings/journals:

1. Concrete Technology and Design, 1983, 1984, 1986, 1988, 1991.
2. Founder, editor: International Journal Cement Composites and Lightweight Concrete, 1979-1989,
3. Journal of Cement and Concrete Composites, 1990—2006.
4. Editor: International conference proceedings, 1978, 1986, 1989, 1991, 1992, 1994, 1999




His research interests include a variety of topics concerned with concrete materials, construction technology with special emphasis to concrete materials, and concrete structures and their interactive performance in real environments, design, and construction. The focus of his research/lecture activities had been technology transfer, education and training of Engineers, and holistic design of materials and structures in relation to environment, sustainability and durability.

International Journal of Cement & Concrete Composites

In 1972 the Construction Press launched two journals specializing in material technology of buildings. Prof. Swamy was the founder-editor and headed the editorial board of both these journals: International Journal of Cement Composites and Lightweight Concrete and the International Journal of Cement and Concrete Composites. It was launched to provide a "unifying forum" for the various composites that had recently emerged on the market, and to "bridge the gap between material scientists, engineers and designers". After just two years the two titles were combined as the International Journal of Cement Composites & Lightweight Concrete (http://www.journals.elsevier.com/cement-and-concrete-composites/editorial-board/).

Dr. Swamy continued as editor. At the end of 2005, Prof. John Bolander (University of California) joined Prof Swamy as joint editor in 2006, until the latter's retirement half way through the year. In his parting editorial of the journal he founded and edited for 27 years, he wrote that "he carried out his work much to the chagrin of some of the then self appointed custodians of cement and concrete"! He continued as Honorary Editor until this his death (Now Prof. N. Banthia of the University of British Columbia, Vancouver, British Columbia, Canada, heads the editorial board).

MEMBERSHIPS AND LEADING ROLES

Prof. Swamy was a Fellow of the Institution of Structural Engineers (IStructE), the Institution of Mechanical Engineers (IMechE), the Institution of Civil Engineers (ICE), the American Concrete Institute (ACI), and the American Society of Civil Engineers (ASCE). He was also a past Chairperson of the Yorkshire sections of the ICE (1980-1981), Concrete Society (chairman Yorkshire and Huberside branch 1972-1973), and chairman- IStructE (1983-1984). As Secretary and then Chairperson, he was closely associated with the work of the RILEM (Paris) Committee on fiber concrete for about two decades (Member technical committee 1971-92 and Chairman 1976-1992).

Member House Secretary's National Advisory Council Race Relations, England, University representative- Sheffield Council Racial Equality, and also Chairperson, member convocation, court, faculty, senate & senate library of the Sheffield University. In addition, he was a Chartered engineer of the Engineering Council of England.

AWARDS

Prof. Swamy has earned many research awards and accolades. He received from the ACI the ACI/Canada Metal (1991), the ACI Concrete Research Council's Robert E. Philleo Award in 1998 (in recognition of outstanding contributions to the Advancement of Concrete Technology), and the ACI Design Practice Award in 2005. In March 1992, Prof. Swamy organized a technical session at the ACI Convention in Washington, DC, that resulted in the publication of ACI SP-165- *Repair and Strengthening of Concrete Members with Adhesive Bonded Plates*. He also received the CANMET/ACI Awards for his contributions to *Durability of Concrete* and the *Use of Supplementary Cementing Materials in Concrete*. His other awards include the ICE (UK) George Stephenson Gold Medal (1975), Construction Institute/ASCE Best Paper Award for developing a new design criterion for plate bonding in 2001, and the Hendry Adams Diploma of the Institution of Structural Engineers in 1981. In addition, he received the Best Paper prize of the Yorkshire branch of IStructE during1971-1972, 1988-1989 and 1992-1993, and Wales branch prize of IStructE in 1986.

He is an Honorary Life Member of the ACI and the "R.N Swamy Symposium" at the 5th CANMET/ACI International Conference is a fitting tribute to his outstanding contributions to concrete technology during his lifelong career in the forefront of concrete research, practice and education. In receiving these Awards, Professor Swamy has always dedicated them to the large number of researchers who have worked with him and to whom he is eternally indebted.

DEATH AND FAMILY

He passed away peacefully on 24th September 2018 and left behind his wife Ms. Enid, whom he married on July 23rd 1960 and two adopted children: Andrea, Julian.

EULOGY

Professor R. Sri Ravindrarajah, of the University of Technology Sydney, Australia, in his eulogy wrote that like many others, he was lucky to carry out his Doctor of Philosophy research from 1974 to 1977 under Prof. Swamy's effective supervision. He admired Prof. Swamy's kindness, self-confidence and belief in hard-working. He wrote that Prof. Swamy was well-known for his pioneering research in fibre-reinforced concrete in 1970s and researched in several aspects of concrete technology and practice. Most importantly, Dr Swamy was a perfect gentleman with kindness and he will be missed by the concrete research world as well as by his family and friends.

Finally to quote from a famous Professor from Leeds University, UK, about Prof. R.N. Swamy "His caring attitude towards research students, his gentlemanly conduct of PhD examinations, his kind comments and encouragement which accompanied reviewer's comments on papers submitted to his journals have been appreciated by many. His warm, friendly personality combined with his words of encouragement is hard to find. He had the rare ability of generating excitement and inspiration in those around him. He had managed this humanistic approach despite the stresses and strains of having to 'climb mountains' time and again against all odds!"

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2. https://prabook.com/web/r.n.swamy/645383
3. https://www.researchgate.net/scientific-contributions/74346691_RN_Swamy

Author :

Dr. N. Subramanian

Dr. N. Subramanian is a Civil/structural consultant and Author, currently based at Maryland, USA, with over 40 years of experience in Industry (including consultancy, research and teaching). He was awarded with a 'Life Time Achievement Award' by the Indian Concrete Institute and many other awards for his contributions towards Structural Engineering. He is the author of 26 books, including the famous books on 'Design of Steel Structures', 'Design of RC Structures' and 'Space Structures' (email - drnsmani@yahoo.com).

SEISMIC DESIGN CONSIDERATIONS FOR FLAT SLABS

by Vatsal Gokani.

Introduction

Current earthquake design practise allows the structural engineer to designate some elements of the building as lateral force resisting elements and other elements as gravity-only load resisting elements. The lateral load resisting elements are proportioned such that they carry the entire seismic loads and the gravity load carrying system is proportioned to carry only the gravity loads; but it must be checked to ensure that the gravity load carrying system continue to carry the gravity loads under ultimate lateral deformation demand under seismic loads.

For structural design it is not always necessary to accurately predict expected response (Moehle 1996). Conventional seismic analysis relies on simplified elastic analysis whose results may not accurately represent the actions of the members during an earthquake. These inaccuracies may be of little consequence in structural systems which have immense ductility built in e.g. beams, columns and shear walls detailed as per ductile design codes etc. However, the same casual approach may be inappropriate for design of gravity systems and other systems with marginal ductility whose performance is critical for life safety. Prevalent seismic analysis methods are oriented towards determining lateral force distributions and required strengths and provide limited information on lateral deformations. To understand the performance of gravity load system, it is necessary to focus on the imposed inelastic lateral drift and the internal forces that result.

Some such gravity systems critical for life safety under a seismic event are beams, columns, flat slab column connections, transfer girders etc.

Brittle punching failure can occur due to the transfer of shearing forces and unbalanced moments between slabs and columns. During an earthquake, the unbalanced moments can produce significant shear stresses in the slab. As a result, many flat slab structures have collapsed by punching shear in past earthquakes (Meghally and Ghali 2002). During the 1985 Mexico earthquake 91 waffle and flat slab buildings collapsed (Meghally and Ghali 2002).

This paper focuses on the seismic behaviour of the flat slab column connections, codal provisions for the same in ACI 318 vis-a-vis the current IS 1893-2016 provisions regarding flat slabs as well as proposed provisions in line with the state of the art.

Lateral Interstory Drift

Flat slab-column frames are very flexible and hence a primary lateral load resisting system in the form of shear walls is generally recommended as well as provided to control side-sway. The column-slab connections should not be used as part of the primary lateral load resisting system(Meghally and Ghali 2002; Moehle 1996). This has been taken care in the newly introduced IS 1893: 2016 which prohibits the use of flat slab as part of the lateral load resisting system: it mandates that shear walls carry the entire lateral seismic loads of the structure and back-up perimeter beam-column frames be provided to resist atleast 25% of the lateral load over and above the 100% lateral load carried by shear walls.

The latter point of back-up perimeter frames in IS 1893: 2016 is added for redundancy (it is present in the ASCE 7 code in the form of structural height limits on pure shear wall structures: pure shear wall structures have lower redundancy as compared to framed structures or dual structures, as the plastic hinge formation is generally at one location i.e. its base, which also may cause detrimental P-Delta effects) and a detailed discussion on the same is not carried out in this paper.

The slab-column connections must have sufficient ductility to undergo thelateral deformations of the primary lateral force resisting system without loss of their ability (due to punching) to carry the gravity loads applied during or after the earthquake.

A solution sometimes is to augment the punching shear resistance by increasing the slab or drop-panel thickness. However, though increased slab or drop panels/shear capitals enhance punching shear capacity of the slabs, they do not improve the ductility and hence the drift or deformation compatibility significantly (Meghally and Ghali 2002). It is also shown that shear capitals do not enhance the punching strength when columns transfer large moments due to this drift or deformation compatibility (Meghally and Ghali 2002).

The ultimate interstory drift will be significantly higher than the elastic interstory drift calculated from elastic analysis using code-based forces. The main reason for this isinelasticity of the concrete system at significantly higher forces (compared to code-based forces used in elastic analysis) on the structure during a seismic event. The ultimateinterstory drift ratio (Du) can be approximated as R (Response Reduction Factor) times the elastic interstory drift ratio (Dy). It has been suggested that the interstory drift ratio Du should be limited to 0.015 for concrete structures(Meghallyand Ghali 2002)which should be provided by the primary lateral load resisting system.

IS 1893: 2016 specifies the upper limit of Dyas 0.004 for regular structures which can be approximated to an upper limit of Du as 0.016 (taking R = 4 for shear wall structures).

However, for flat slab structures IS 1893: 2016 specifies a stringent upper limit of Dy as 0.001 which can be approximated to an upper limit of Du as 0.004 and this is to be provided by the primary lateral load resisting system (shear walls) without the involvement of flat slabs.

The reasons for these stringent drift limits in IS 1893:2016 is discussed in the next section of this paper.

Alternate ways to provide ductility to of column slab connections without penalising the structure to meet stringent drift (Dy 0.001Du 0.004) demands is also discussed in this paper.

Effect of Gravity Load on Lateral Interstory Drift

Figure 1 shows the variation of ultimate interstory drift capacity in a slab-column system with the punching demand to capacity ratio for gravity forces (Meghally and Ghali 2002). This graph is produced from a number of test performed on slab-column connections in the laboratory. V_u is the punching shear force for gravity loads. ϕV_c is the concrete capacity of the slab-column joint against punching shear as per ACI 318. According to ACI 318-14 ϕV_c(in Mpa) isgenerally governed by the following equation (substituting $f_c' = 0.8 f_{ck}$):

$$\Phi Vc = 0.22\ \sqrt{fck}.bo.d$$

The corresponding equation for ΦV_c in IS 456:2000 can be taken as

$$Vc = 0.25\sqrt{fck}.bo.d$$

where d is the effective depth and bo is the shear perimeter at d/2 from the face of the column in both codes.

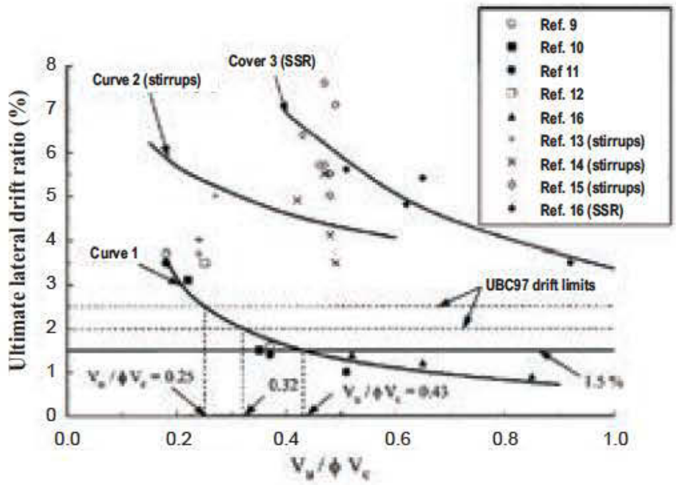

Figure Effect of Gravity Loads on lateral drift capacity of interior slab-column connections (Meghally and Ghali 2002)

Following are the observations from the graph Figure 1:

1. Consider a flat slab structure designed to satisfy the drift requirement as per IS 1893: 2016 for regular structures (Dy 0.4% Du 1.6%). The demand to capacity ratio for punching shear under gravity loads has to be kept as low as 0.35 for the slab-column

connection to not fail under ultimate drift requirements. This would result in very high slab depth at slab column junction and this is sometimes impossible to obtain in real life design situations (Refer Curve 1)

2. IS 1893: 2016 has made the interstory drift requirement more stringent for flat slab structures (Dy 0.1% Du 0.4%). At this reduced drift demand, the demand to capacity ratio for punching shear under gravity loads can even be kept close to 1: the slab-column connection will not fail even at this high value due to the stringent drift control (Refer Curve 1). This is the main reason for the introduction of the stringent drift demand clause in IS 1893: 2016 for flat slab structures. However, this has serious design and economic limitations under real life scenarios as it results in very heavy and stiff lateral framing system.

3. As per Meghally and Ghali 2002, by introducing a shear reinforcement such that

$$Vc = \frac{Av.fy}{bo.s} \geq 0.22\sqrt{fck}$$

introduces significant amount of ductility to the slab-column connection and the flat slab can reach significantly higher drift ratios (above 3.5%) than its demand (refer Curve 2 and Curve 3). Here Av is the shear reinforcement area and s is the shear reinforcement spacing.Infact, as per ACI 318-14, no calculation of induced moments is required if punching shear reinforcement is provided: this is corroborated by the graph above.

Design Recommendations

IS 1893: 2016 has used one of the ways to prevent punching shear of slab-column connections in gravity column-slab systems under seismic effects i.e. to make the interstory drift control stringent (Dy 0.1%).In-addition, this stringent drift control is to be provided only by shearwalls with back-up perimeter frames. However, according to the author (as well as based on provisions in ASCE 7, ACI 318 and above observations), it makes no difference which primary lateral load resisting system provides the drift control as long as slab-column connections are not used as part of the primary lateral load resisting system and sufficient ductility is provided to meet the interstory drift requirements.

Based on the research by Meghally and Ghali 2002, ACI 318-14 provides an equation to introduce ductility and interstory drift capacity in gravity flat slab system by strengthening the slab-column joint with reinforcement given by the following equation:

$$vc = \frac{Av.fy}{bo.s} \geq 0.26\sqrt{fck}$$

The value of $V_s/\phi V_c$ as per ACI 318-14 is approximately 1.2 i.e. shear reinforcement in column-slab joints should be such that the punching shear capacity of stirrups is about 1.2 times the punching shear capacity of concrete to ensure deformation compatibility of the joint. This shear reinforcement is only to be provided based on the criterion illustrated in the graph in Figure 2. In the graph $v_{ug}/\Phi v_c$ is the ratio of the punching shear stress due to axial load due to gravity to the concrete punching shear capacity. As can be seen from the graph, flat slab is permitted to be without punching shear reinforcement only if interstory drift is acceptably low and/or punching shear due to gravity is acceptably low.

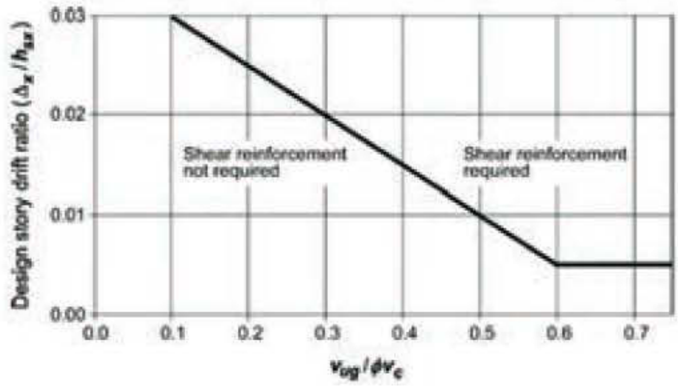

Figure Checking whether shear reinforcement is required in slab-column connections of gravity flat slab system as per ACI 318-14

Based on the above observations, following are the recommendations for slab-column connections of flat slab type gravity system in seismic design to impart ductility without providing stringent drift control introduced IS 1893: 2016:

1) Drift control of (Dy 0.004 i.e. approx. Du 0.016) may be used instead the newly introduced stringent demand (Dy 0.001 i.e. approx. Du 0.004)

2) Drift control may either be provided by primary lateral load resisting system such as shearwalls or moment frames. However, the bending stiffness of the flat slab, slab-column connection and gravity columns should not be used in the elastic analysis. This is to ensure that the entire lateral load and moment is transfer to the primary lateral load resisting system.
3) In addition, to meeting the punching shear provisions of IS 456:2000, shear reinforcement shall be provided in the slab-column connection to impart ductility such that:

$$\tau s = \frac{0.87.Av.fy}{bo.s} \geq 0.3\sqrt{fck}$$

4) The shear reinforcement shall extend four times the slab thickness from the face of the support adjacent to the slab critical section.

Sample Calculation

To illustrate the amount of shear reinforcement required in slab column connections required as per the above equation and discussion, consider the following:

1) Assume a structure with lateral load resisting system as either shear walls or moment frames proportioned to resist the entire lateral load and moments.

2) The gravity system is a flat slab type of system.
   a. 8x8m span
   b. 600x600 columns.
   c. Superimposed Dead Load 1.5 kN/m2. Live Load 3 kN/m2
   d. Drop Cap Depth 350mm
   e. Drop Cap Size 2650mm x 2650mm
   f. Slab Depth 225mm
   g. Concrete Grade : M30; Reinforcement Grade : Fe 500

3) The lateral system meets the drift criteria (Dy 0.004) instead of the stringent drift criteria of (Dy 0.001) provided in the revised IS 1893:2016 for flat slab systems.

An interior column has an axial load and hence punching shear load of 1047 kN (Vu) and unbalanced moment of 65.25 kN.m (Mux) and 65.25 kN.m (Muy). As per IS 456: 2000, no punching shear reinforcement is required. The design to capacity ratio is calculated as 0.82.

To meet the relaxed drift criteria as per the discussion above, shear reinforcement needs to be added in the slab-column junction in addition to the punching shear design as per IS 456: 2000 as per the equation given in the previous section.

This total punching shear reinforcement is calculated as Av = 2458mm2 at 150c/c. If divided equally on all four sides translates to 615mm2 per side; which translates to 6L-T12-150 c/c on all sides of the column, extending 1400mm from the face of the column support.

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About The Author

Vatsal Gokani.

He is a practising structural engineer from Mumbai with 15 years of experience in the industry. He is partner in the structural engineering firm Gokani Consultants and Engineers LLP. He completed his B.E. Civil from VJTI, Mumbai and his M.S. in Structural Engineering with honours from The University of Texas at Austin.
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LARGE HOSPITAL BUILDING CONSTRUCTED IN RECORD TIME

By Vasant S. Kelkar, Ashish Bhangle, Mehga Ghatwal

1.0 Introduction

Alamelu Charitable Foundation (an initiative of Tata Trust) plans to construct Cancer Care Hospitals at various locations in India. One such hospital Mahamana Pandit Madan Mohan Malaviya Cancer Centre (MPMMCC) was recently completed at BHU Varanasi in a record time of 10 months for the construction of about 5,80,000 sq. ft. built up area. This article describes salient features of structural design of this building.

2.0 Details of the Building

The building consists of three wings called IPD, DNT and RT.

IPD Wing has a Basement + Ground Floor + Seven Upper Floors + Terrace.

DNT Wing has a Basement + Ground Floor + Five Upper Floors + Terrace.

The two wings (IPD & DNT) are continuous on lower floors but are separated above first floor but connected by a bridge at fourth and fifth floor levels. These two buildings house OPD and various other departments on various floors.

The third wing called RT is of Ground + Four Upper Floors + Terrace. Its lower two floors also house Linac – which have very thick RCC slabs and walls.

The floor finish was generally of ceramic tiling and the internal walls were of light weight Siporex blocks. In some areas housing CT scan and MRI machines, 150 thick RCC walls were required to be provided.

The total construction area including basements is about 5,80,000 sq. ft. The clients required that construction of the buildings be completed within a period of 10-12 months.

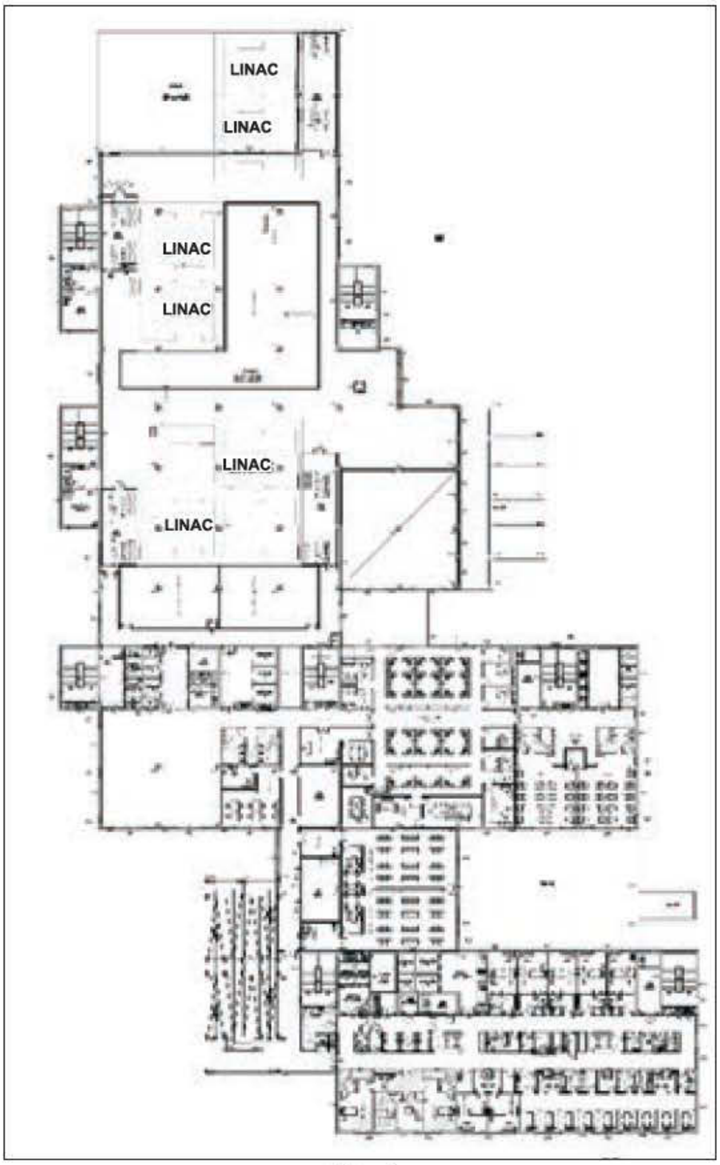

Fig 1.
Architectural Plan of the Building at First Floor Lvl.

3.0 NDMA Guidelines for Structural Design of Hospital Buildings.

The hospital building was required to be designed following "National Disaster Management Guidelines" issued by National Disaster Management Authority (NDMA)[1] besides following the relevant IS codes. NDMA guidelines are much more severe than specifications of IS codes especially for EQ loadings, the reason apparently being that under a very severe EQ even if other buildings have failed the hospitals have to be functional to treat the casualties of the disaster and hence should be designed much more conservatively than other buildings.

NDMA recommendations on the structural design of hospital buildingsprohibit many types of construction such as flat slab floors, floating columns, prestressed floor systems, precast construction etc. The lateral forces due to EQ are specified as:

$V_b = A_h W$

where $A_h = \frac{Z.I}{R}\left[\frac{sa}{g}\right]$ and V_b= Base shear

The formula for A_h above is similar to that in clause 6.4.2 of IS 1893 (Part 1:2016) [2] except that the factor 2 in the denominator in the IS code formula is absent in the above formula. This means that as per NDMA guidelines the building has to be designed for two times the earthquake forces than those obtained for the same building by IS 1893. In addition, with importance factor I=1.5, the lateral earthquake forces for the hospital building become three times those of a similar residential or commercial building.

NDMA also specifies that"The total cross-sectional area of all RC Structural Walls shall be at least 4% of the plinth area of the building (if that based on design is smaller than 4%), along each of the two mutually perpendicular principal plan directions".

This clause seems to be unreasonable considering that as per this clause:

a. In the same earthquake zoneif there are two buildings of different heights, say,one of 10 stories and the other of 20 stories with about the same floor/plinth area, then still for both the buildings the same areas of shear walls haveto be provided = 4% of plinth area although in the second building stresses due to EQ loads will be much higher.

b. If there are two buildings which are very similar in height and plinth area but in two different EQ zones, still for both the buildings minimum shear wall area will have to be the same.

In our opinion this clause in NDMA needs to be amended. We were told by a member of the NDMA committee that they are giving such requirements based on some studies of buildings in EQ Zone IV and then specify them as a general requirement for buildings in any zone. This needs to be changed in amended guidelines.

4.0 Structural Scheme

The columns were placed on a grid of about8.5 x8.5m as per architectural requirement. Flat slabs are not permissible and hence a structural arrangement with R.C.C. slab and beam structure with RCC columns and shear walls was possible. However, considering the stringent time constraint for completion of the building, it was decided to design the main structural elements in structural steel to facilitate speedy construction although it would mean a higher cost compared to a normal RCC structure.

Thus, the floors were designed as RCC slab supported on metal deck and steel beams which spanned between steel columns. The thickness of slab was150mm (90mm flange + 60mm ribs). The secondary steel beams were mainly built up I sections of 460mm depth supported on main beams which varied in sizes but were generally built up I sections of 600mm depth. Some beams were also of lesser or more depths. The slab and beams were connected by steel studs to make them act as composite sections.

The columns were generally built up I sections of 400mm depth and 450 wide flanges. On higher floors the sizes were reduced. They were encased in concrete with steel reinforcement and were designed as composite columns

The RT wing the area housing Linac had walls and slabs more than 1m thick to control radiations,

For lateral load resistance steel diagonal braces inside the building or on its façade were not possible architecturally. Hence, for lateral load resistance shear walls were provided and also many of the main beams were connected to steel columns with moment connections. Thus, the lateral load resisting system consisted of shear walls with steel moment resisting frames. Even though IS code specifies R=5 for a dual system consisting of shear walls + moment frames, R=4 was considered conservatively as it was difficult to design the steel frames to resist minimum 25% of the base shear, considering that lateral forces due to EQ were much too high for this building using NDMA guidelines and importance factor of 1.5.

The concrete grade was M30 for deck slab and M40 for other members. Reinforcement was with Fy = 500N/mm^2. Structural Steel was with Fy = 350 N/mm^2 and for some members even steel with Fy = 450N/mm^2 was used.

The structural layout of the second floor is shown in Fig. 2.

Analysis of the whole structure was done using Etabs software.

The soil report showed that raft foundation with a SBC = 24.5T/m^{2}could be used. Hence, the foundations were designed as a 1200mm thick raft in IPD/DNT building and 1000mm thick raft in RT building. Rafts were analyzed with SAFE software considering soil as springs with stiffness corresponding to modulus of sub grade

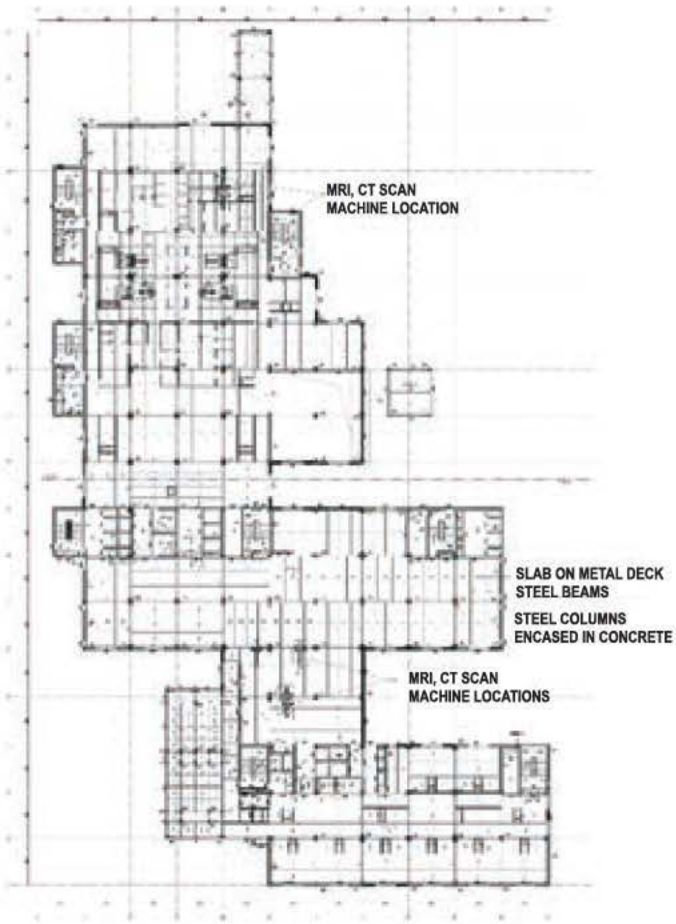

Fig. 2.
Structural Layout of the Second Floor Lvl.

reaction. The water table level at the site was much below the ground level and hence there was no difficulty in carrying out the construction of foundation and retaining walls with open excavation.

For fire resistance the internal steel beams were covered with vermiculite. The beams of facades were encased in concrete.

5.0 Control of Vibrations

5.1 Floors consisting of long span steel beams can lead to uncomfortable vibrations excited due to human activities on the floor such as walking within the rooms or in adjoining corridors. Indeed, such vibrations can be experienced on airport or mall floors with long span steel beams and on foot bridges. Considering that frequency of the forcing function due to human movement is generally between 1.5 to 2.5 Hz it was checked during the design stage that the fundamental frequencies of vibrations of the floors were higher than 3Hz.

However, **after most of the structure was constructed** we were given the limits on velocities and accelerations to be controlled in some bays on the second floor where MRI and CT scan machines were to be installed. The limits were specified by the vendors GE Health supplying the machines.

Hence, further study was done using AISC (American Institute of Steel Construction) Design Guide Services article "Floor Vibrations Due to Human Activity" [4]. The Concrete Society Publication [5] also gives guidelines for calculating footfall induced vibrations.

Operations of a sensitive machine can be affected due to floor vibrations caused by persons walking in the room where the machine is located or in adjoining corridors. Also, vibrations of floors can cause discomfort to persons working in the area.

Natural frequencies of the floor and the resulting vibrations will vary with the actual loads present.Hence,realistic values of SDL = 3KN/m^2 and L.L. = 0.5KN/m^2 (+ machine loads) in the bays where machines were to be located were considered to obtain the natural frequencies of the floor – although design loads were of higher values.

5.2 Vibrations for Human Comfort

i. As per AISC Design Guide [4], for human comfort the peak acceleration when a person of weight 70kg.(157 lbs) is walking should be less than 0.5%g.

The Concrete Society Publication [5] and ISO 2631-2, 1989 give threshold values of RMS accelerations for human perception. AISC guide considers peak accelerations as multiple of RMS values. The multiplying factor varies for residences, malls or footbridges etc. and is taken as 10 for residential and office areas.

ii. For consideration of human comfort, values of peak acceleration due to a person walking are calculated at the center of a bay.

As per AISC guide peak acceleration due to walking can be estimated by the formula

$$\frac{a_p}{g} = \frac{P_o e(-0.35fn)}{\beta W}$$

Where a_p = estimated peak acceleration,
g = gravity acceleration,
f_n = natural frequency of the floor structure,
β = damping ratio. Damping associated with floor systems is recommended = 0.03 for floors with small demountable partitions as in typical modular offices and = 0.05 for floors with full height partitions between floors,
P_o = a constant force = 0.29 KN for floors and 0.41KN for bridges, for a person of 70 Kg weight walking on the floor,
W = Effective weight of the floor (in the area under consideration).

In the present case, there are walls of full floor height and hence damping was considered = 0.05. Value of floor frequency was obtained from ETABS analysis which gives different values for different mode shapes of floor structure. The value which shows a fundamental mode in the bay under consideration was used as f_n. The peak accelerations thus obtained were within limits.

Since the floors were already constructed (although without partition walls etc.) few tests were done at site by having persons walk at different speeds on the floor and check if any uncomfortable vibrations were felt by other persons. No such uncomfortable vibrations were felt.

5.3 Vibrations for Smooth Operation of Sensitive Machines

Machines like CT scan and MRI are very sensitive and give improper images if subjected to vibrations from floor. It is desirable that they are placed on the ground floor (without basement). But in the present building they were located on the second floor.

As per AISC guidelines [4]:

i. The values of acceleration and velocities on the floor are considered due to a person weighing 84kg walking at a) fast pace (100 steps/min.), b) moderate pace (75 steps/min.) and c) slow pace (50 steps/min.),

ii. For movement of persons within the room where a sensitive machine is located, the walking speed will be that of slow pace. Only in any corridors near the locations of the machines the walking speed could be considered as fast, as per AISC.

AISC Guide gives criteria for limiting vibration velocity for different types of equipment such as Computer Systems, Bench Microscopes, Microsurgery Equipment, Electron Microscopes etc. The vendor in the present hospital had given the limitations for smooth operation of the CT scan, MRI machines as:

max. acceleration = 25mm/sec^2= 0.025g (as against 0.5g for human comfort) and max. velocity = 40mm/sec (micrometer / sec) which was similar to that given for Bench microscopes, optical and other precision balances etc. in AISC guide.

AISC Guide gives max. displacement as

$$X_{max} = \frac{Fm\Delta p}{2} \left(\frac{fo^2}{fn^2}\right)$$

Where F_m is a footfall impulse parameter taken as 1.4, 1.25 and 1.1 KN respectively for fast, moderate and slow walking conditions for a walking person of 84 kg weight. Corresponding f_o values are given in AISC guide as 5.0, 2.5 and 1.4 Hz respectively.

Δ_p is the deflection of the structure at the location of the machine under a unit load which were obtained from analysis of the floor structure. After calculating X_{max} from above, max. velocity V max and max acceleration a_p are obtained by the relations:

$$Vmax = 2(\Pi)f_n X_{max}$$
$$ap = 4(\Pi)^2 f_n X_{max}$$

Using the above equations, it was found that under slow walking condition the acceleration and velocity were within allowable limits. But there were long corridors adjoining various rooms in which the machines were to be placed. Hence, vibrations due to brisk walking of persons in the long corridors had to be considered.

It was found that for brisk walking of persons in the corridors, the maximum velocity and accelerations were beyond the specified limits.

5.4 Remedial Action

To reduce vibrations of a floor, AISC guide also suggests remedial measures such as stiffening of steel beams by adding cover plates at bottom or adding below it queen post type truss members, addition of columns etc.

In the present case the following changes were made:

i) The locations of the machines (not yet installed)were shifted to be on stiffer main girders and as close to columns as possible instead of in the center of bays. This reduces values of Δ_p in the above equation and hence X_{max}. The architects changed the room plans accordingly.

ii) In addition, A type steel bracings were proposed below the girders supporting the machines so as to minimize value of Δ_p to almost zero in the above equation thereby reducing V_{max} and a_p. Since the floor below was a service floor, provision of bracings was possible.

iii) For minimizing brisk walking in the corridors AISC Guide also recommends creating obstacles such as reception tables etc. in the corridors to reduce brisk walking. But this was not practical in the present case and hence not done.

After these changes it is expected that the machineswhen installed will operate smoothly as desired.

It was, however,not possible to check vibrations of the floors in the areas of the machines due to operation of hospital power plants, ac units, pumps/motors, elevators etc.

6.0 The construction of the building was started with excavation for foundations in the first week of April 2018 and completed by end of Feb 2019. It was inaugurated by P.M. Narendra Modi on 19.02.2019. The total design and construction time was unusually small for construction of a building with such large area.

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Biswaroop Roy Chowdhury
Chief Editor
India Book of Records

Issued on: February 18, 2019

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Structural Consultants	:	Dr. Kelkar Designs Pvt. Ltd.
MEP Consultants	:	Bluestar India Ltd.
PMC	:	Clancy Global
Main Contractor	:	Capacite Infraprojects Ltd.
Structural Steel Fabrication, Design and Erection	:	JSW Severfield Structures Ltd.

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2. IS 1893 (Part 1): 2016 Criteria for Earthquake Resistant Design of Structures.
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NATIONAL SALT SATYAGRAHA MEMORIAL AT DANDI, GUJARAT

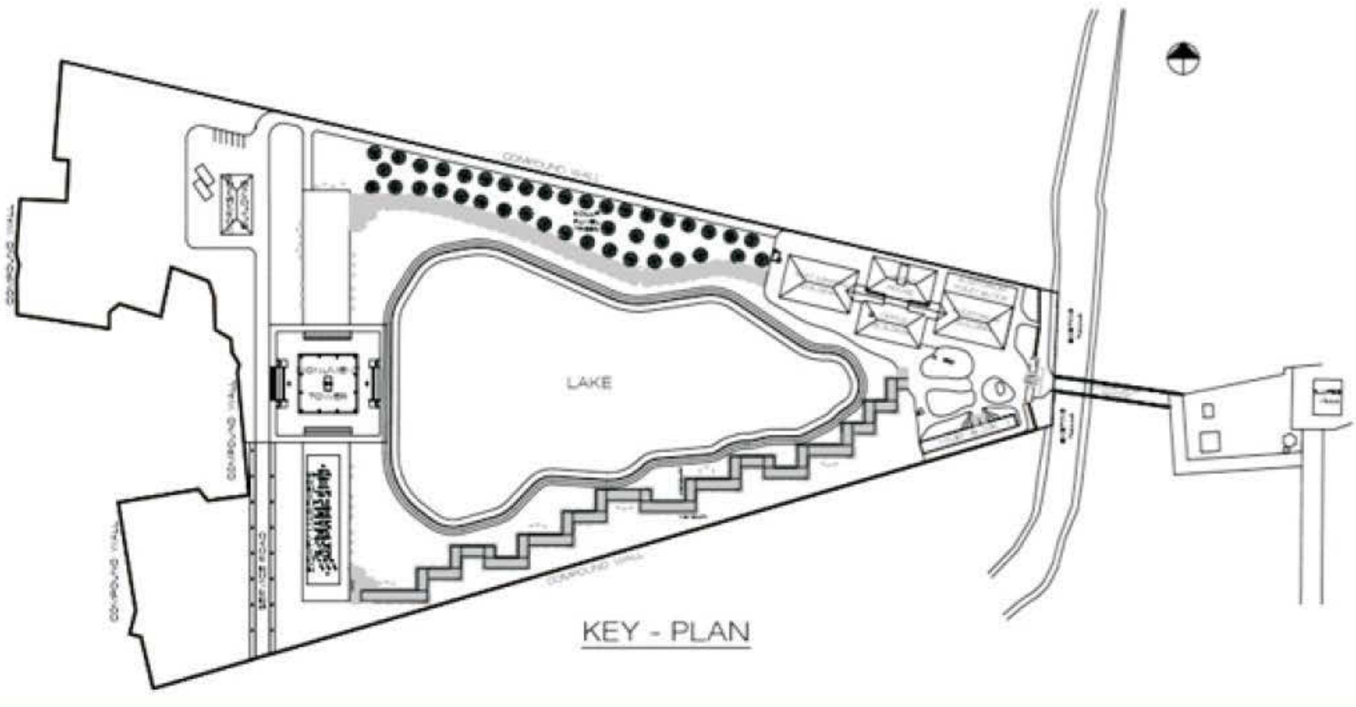
by **Kamal Hadker, S B Malekar**

This Memorial celebrates the spirit of the Salt Satyagraha which took place in 1930, in Dandi, on the west coast of Gujarat. The Memorial is envisioned to recreate the spirit and the energy of the Dandi march and the 241 mile journey that Gandhiji undertook from Sabarmati to Dandi. The architectural planning aims to revive the spirit of Dandi March through the planning of the complex, the landscape, museum buildings and monuments.

This was an initiative by the Central Government which appointed CPWD for implementation of the project. CPWD appointedthe Design cell of IITMumbai to conceptualize the memorial. IIT appointed architects Sandeep Shikre and Associates(SSA) for preparing a master plan for the entire development – this included an artificial lake, a pathway leading to the main monument, landscape, museum, workshop, library, solar trees and the 15' tall pedestal to support the statue of Mahatma Gandhi.

SSA invited Sterling to join the team of consultants to come up with the most appropriate structural design for the monument to represent Gandhian philosophy of simplicity. Being a monument of National importance, it was expected to last for the next 300 years. Sterling came up with the design of a 40 meter tall elegant, economical "A Frame" structure. Sterling recommended the use of appropriate grade of stainless steel to prevent corrosion in the aggressive environment of Dandi. An aerodynamic cross-section was specially designed to minimize the wind pressure on the frame. It comprised of a rhombus shaped tapering tube - varying from 800mm x 2000mm at the base to 400mm x 800mm at the top. It provided an excellent artistic support to the symbolic "Salt Crystal" made of glass weighing about 2.5 tons which was installed at the apex of the frame.

Special aerodynamic checks were made by carrying out wind tunnel tests in IIT Kanpur. This slim structure was checked for vibrations and fatigue. Design calculations and computer



KEY - PLAN

analysis for the entire structure were scrutinized and approved by IIT Mumbai. This A framed structure, was also analysed for special loading conditions during erection. Temporary bracings were installed to prevent distortion during the construction stage.

As the subsoil conditions were poor, precast concrete piles of 450mm x 450mm were driven up to 14 meters depth for supporting the columns of all the buildings as well as the monument.

The site is raised by about 2m from the original ground level. The complex is approached through a 6m wide pedestrian bridge crossing an existing canal. The entire Bridge structure consists of steel beams and girders which in turn are supported on a framework of concrete pile caps and tie beams.

Welcome Centre Buildings:

Visitors to the monument, enter a Welcome Centre Complex which consists of a Reception, Guest Rooms, Auditorium, toilet block, Library, A.V. Rooms, and a workshop to demonstrate Salt Making. All the buildings except the Guest House are single storey with Mangalore tiled roof supported on steel trusses and concrete columns. All the buildings are founded on Precast Driven Piles.

The special features of this memorial are – the murals along the pathway leading to the main statue, the statues of the 81 marchers, 41 Solar trees and a large artificial lake.

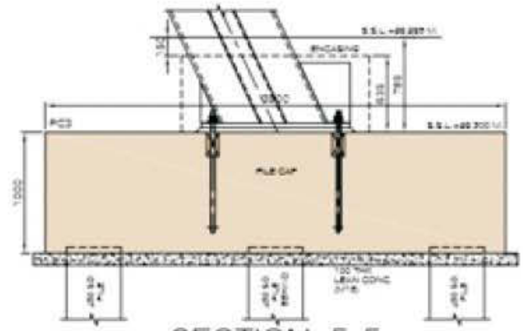
Murals and Pathway:The murals are designed to make the visitors appreciate the struggle of the Satyagrahis. The pathway leading to the memorial goes around the lake and is dotted by large murals. Each mural depicts the events and scenes during the night halts that Gandhiji took along his journey. Sterling had to furnish the design of the foundations and fixing details of the murals to the concrete walls which are 3 meter tall and 2.1 meter wide.

Statues of 81 Marchers:Life size statues of the 81 marchers, were specially sculpted for this memorial and represent the 80 people who joined Gandhiji on this historic route. These are arranged in rows along the pathway, creating a feelingof walking in an organised group. Each statue is secured firmly on a raft foundation.

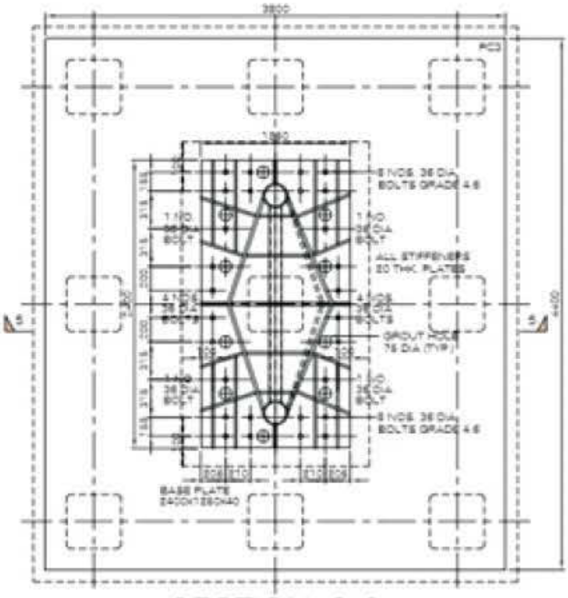
Artificial Lake: In the centre of the complex is a large artificial water body which is 1.25 m deep, created over an area of almost 12,500 sq m. This signifies the sea along the route to Dandi. A waterproof, flexible membrane lining was used to make it impervious and prevent loss of water by percolation.

Pyramid of Light :

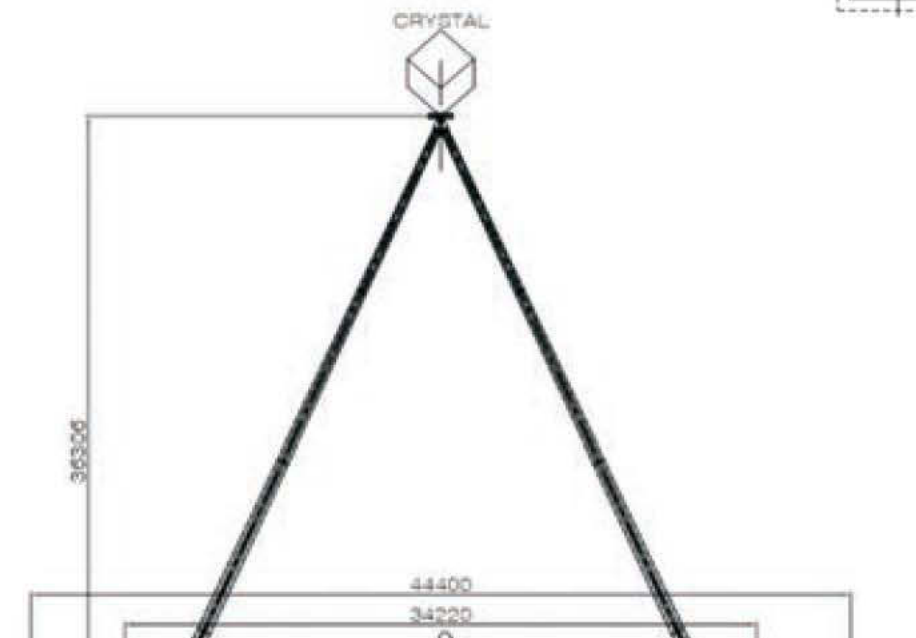
The main A Frame Monument is referred to as the Pyramid of Light. The A Frame Tower supports a large glass Crystal. The anatomy of the saddle which supports and houses the crystal was very complex and Sterling provided the necessary details during erection.The 34 meter wide 'A' Frame is 36 meters tall, designed to support a 2.4 x 2.4 x 2.4 m glass cube with SS cage weighing 2500 kg at its apex. The cross-section of this frame ensures minimal exposure to wind and earthquake forces.



SECTION 5-5



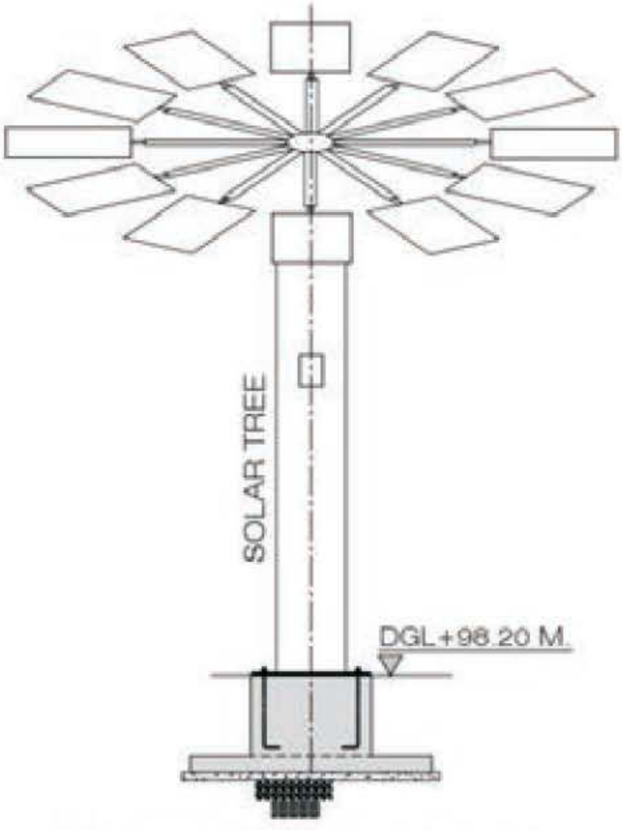
SECTION 2-2



Main Statue: A Courtyard of 44.4 m X 44.4 m was created around the central 15 feet tall statue of Gandhiji. This statue is supported on a 12 feet high Pedestal that rests on a RCC grade slab with a granular sub base.

The Workshop Building:
This is a single storey closed structure and houses the battery back-up of the Solar Power and for the maintenance of the entire complex. The roof consists of steel trusses supported on RCC columns. Mangalore roof tiles are used as roofing.

Solar Trees: There are 41 solar trees placed adjacent to the lake. Each tree has 12 solar panels (1.7 m x 1.0 m) arranged on a circular plane which is 8.38 m in diameter. The central height of the solar panel tree is about 4.5 m. The super-structure is in steel. The tree is supported on a RCC pedestal 1.5 m x 1.5 m x 1.0 m with a 3 m x 3 m x 0.2 m thick RCC pad under it which acts like an isolated footing.



SECTION OF SOLAR TREES

Seismic Loads :

As per this code, Surat lies in Zone III with zone factor Z = 0.16

The Design Base Shear is given by

$$V_b = Z/2 \times I/R \times S_a/g \times W$$

As all the structures and buildings are of National importance, the Importance factor I was taken as 1.5.

Structural Analysis

The buildings are mainly R.C.C column and beam slab frame structures at floor level with steel trusses at the top.

After preliminary sizing of various structural members, a computer model of the structural frame of the building was generated on ETABS for carrying out computer analysis for the effects of vertical and lateral load that are likely to be imposed on the structure.

The computer analysis evaluated individual internal member forces, reactions at foundation level and deflection pattern of the entire structure. This data was used to verify adequacy of the member sizes adopted and after further iterations the engineers arrived at the most appropriate design of the structural members. Some re-runs of the analysis program were undertaken for arriving at the optimum structural space frame characteristics that satisfied the strength and stability criteria in all respects.

Space frame analysis was carried out for gravity loads, wind loads and seismic loads.

As a monument of national importance, the Memorial was designed to have minimum impact on the natural environment with a durability of over 100 years.

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News and Events during April – June 2019

by Editor Hemant Vadalkar

27 April 2019 : One day workshop on "Insight into Wind Loading using IS875 Part 3 : 2015" was arranged by ISSE HQ in association with Mukesh Patel School of Technology Management and Engineering.Dr. Tanuja Bandivadekar from MPSTME welcomed all participants and introduced Dr. Suresh Kumar. Mr. Hemant vadalkar briefed about aims of ISSE & their activities.

Dr. K Suresh Kumar Principal RWDI and renowned international expert on the subject enlightened design engineers on the subject. He talked on Fundamentals of Wind Engineering, new changes in IS code on Wind loading along with sample wind load calculations on tall buildings. He also explained the code provisions in Australian code AS1170-2:2011 and how it has been co-related to our code. Hemant Vadalkar explained Gust factor calculations with live example shared by Vatsal Gokani and demonstrated the effect of natural frequency of structure on Gust factor calculations. Around 40 engineers registered for the workshop. ISSE will be publishing a workshop proceedings with the data shared by Dr. K Sureshkumar.

8 May 2019 : ISSE Pune and ISSE HQ provided suggestions and objections on the published DCR2017 for rest of Maharashtra except Mumbai. ISSE Pune team led by Dhairyashil Khairepatil attended the hearing in Pune for the said Development Control Regulations and submitted comments and suggested corrections in the draft. Mainly the certification formats to be given by structural engineer, site supervisor and geotechnical engineer based on NBC2016 guideline were suggested by ISSE.

13 May 2019

ISSE wrote letters to Prime Minister's Office, Chief Minister's office, Chief Justice of Mumbai High court, Secretary Urban Development Department. The subject of letter was " Suggestions by ISSE Technical committee to minimize the collapse of structures and Views on Structural audit " in the light of Collapse of CSMT Foot over bridge collapse in Mumbai on 14 March 2019. Copy of our ISSE journal 21-1 Jan-Mar2019 was also attached with the letter which talks about Structural Engineer's View point on CSMT bridge collapse and on the issue of " Stability certificate". Reply to our letter was received from PMO dated 28-5-2019 directing the respective department for necessary action.

15 May 2019 : Hearing on unified DCR2017 for rest of Maharashtra except Mumbai was held at Konkan Bhavan, New Mumbai. ISSE team members Hemant Vadalkar, Dhairyashil Khairepatil, Ranganath Satam, Ashutosh Dabli presented ISSE views and submitted the suggestions. Most of the suggestions were noted by the authorities on the draft copy and are likely to be accepted.

ISSE Team congratulates members of ISSE family for their accomplishment !

Sr. No.	Name	Achievement	Subject	Photo
1.	Vedang Hemant Vadalkar	MS from Stanford University 16 Jun 2019	Sustainable Design and Construction	
2.	Nishad Madhav Chikodi	MS from University of Houston, US.May 2019	Civil (Structural) Engineering	
3.	Dr. Vishal Thombre	PhD IIT Bombay in 2017	Analysis evaluation design and construction of Thin White Topping for Habitation of Flexible Pavement	
4.	Dr. Shashank Mehendale	PhD VJTI in 2019 Civil Engineering with Specialization in Structural Engineering.	Analytical Modelling of Reinforced Masonry Beam with Experimental Validation	
5.	Needhi Kotoky	Post Doctoral Fellow, IIT Bombay. The interdisciplinary scientific board of Technical University of Munich (TUM), April 2019	Selected to participate in the fully funded Research Opportunities Week (ROW 2019), (TUM)	
6.	H.G.Naikar	1. Ph.D Visvesvaraya Technological University (Belgaum) 2019. 2. Award.	1. Doctor Of Philosophy In Faculty Of Civil Engineering Science. 2. Award Of ACCE (I) Shirode Yashodeep Award 2019	
7.	Smt. Raana Pathak	Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal. Ph.D. 2019	"Seismic Vulnerability of RC Shell and Spatial Structures."	

Edited and published by Hemant Vadalkar for ISSE, C/o S G Dharmadhikari, 24, Pandit Niwas, 3rd floor S K Bole Marg, Dadar (W), Mumbai 400 028. Tel 022-2431 4423. e-mail issehq@hotmail.com Web : www.isse.org.in for private circulation and printed by S. L. Bengali, 15, Pandit Niwas, S K Bole Road, Dadar, Mumbai 400 028.


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