SEISMIC ANALYSIS AND DESIGN OF HOSPITAL BUILDING BY EQUIVALENT STATIC ANALYSIS

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CERTIFICATE

This is to certify that this thesis entitled "**SEISMIC ANALYSIS AND DESIGN OF HOSPITAL BUILDING BY EQUIVALENT STATIC ANALYSIS** "submitted by **Mohammad Naser (111CE0562)** in partial fulfillment for the award of the degree of Bachelor of Technology in Civil Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision.

To the best of my knowledge, the matter embodied in this report has not been submitted to any other university/institute for the award of any degree or diploma.

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ABSTRACT

Structural design is the primary aspect of civil engineering. The foremost basic in structural engineering is the design of simple basic components and members of building viz., slabs, beams, columns and footings. The first step in any design is to decide the plan of the particular building. The location of beams and columns are decided. Then the vertical loads like dead and live loads are calculated. Once the loads are obtained, the component which takes the load first i.e. the slabs can be designed. From the slabs, the loads are transferred to the beams. The loads coming from the slabs onto the beam may be trapezoidal or triangular. Depending on this, the beam may be designed. The loads (mainly shear) from the beams are then transferred to the columns. For designing columns, it is necessary to know the moments they are subjected to. For this purpose, frame analysis is done by Moment Distribution Method. Most of the columns designed in this project were considered to be axially loaded with uniaxial bending. Finally, the footings are designed based on the loading from the column and also the soil bearing capacity value for that particular area. All component parts are checked for strength and stability.

The building was initially designed as per IS 456: 2000 without considering earthquake loads using STAAD.pro software. Then the building was analyzed for earthquake loads as per Equivalent static analysis method and after obtaining the base shear as per IS1893: 2002, again detailing has been obtained using ETABs.

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NOTATION AND ABBREVIATIONS

Abbreviation

IS = Indian Standard

LSA = Linear Static Analysis

RC = Reinforced Concrete

STAAD Pro. = Structural analysis and design for professional

2D = Two-dimension

3D = Three-dimension

E_c = Modulus of elasticity of concrete (MPa)

E_s = Modulus of elasticity of steel (MPa)

F_c = Compressive strength of concrete (MPa)

F_y = Yield strength of steel (MPa)

F_u = Tensile strength of steel (MPa)

G_c = Shear modulus of concrete (MPa)

G_s = Shear modulus of steel (MPa)

g = Acceleration due to gravity (m/s^2)

x = Longitudinal direction

z = Transverse direction

α_c = Thermal coefficient of concrete

α_s = Thermal coefficient of steel

γ_c = Unit weight of concrete (kN/m^3)

γ_s = Unit weight of steel (KN/m^3)

ν_c = Poisson ratio of concrete

ν_s = Poisson ratio of steel

ξ_c = Damping ratio of concrete (%)

p_u = axial load

CHAPTER 1

1.0 INTRUDUCTION

- Earthquake is the result of a sudden release of energy in the earth's crust that creates seismic waves. The seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time.

A list of natural and man-made earthquake sources

Seismic Sources	
Natural Source	Man-made Source
• Tectonic Earthquakes • Volcanic Earthquakes • Rock Falls/Collapse of Cavity • Microseism	• Controlled Sources (Explosives) • Reservoir Induced Earthquakes • Mining Induced Earthquakes • Cultural noise (Industry, Traffic, etc)

- Buildings are subjected to ground motion. PGA (Peak Ground Acceleration), PGV (Peak Ground Velocity), PGD (Peak Ground Displacement), Frequency Content, and Duration play predominant rule in studying the behaviour of buildings under seismic loads.

- The new hospital block is located at the province of Mazar-e-Sharif, Afghanistan. The total built up area of the hospital building is 611.2 square meters and has five floors (Ground floor +5). The Hospital building consists of various divisions like Ortho ward, Orthopedic ward, Opthamology ward, ENT ward, major and minor operation theaters, outpatient ward, seminar halls for medical students, scanning and X-ray Centre and medicine store room, etc. The building is located in seismic prone zone (zone factor III). Since hospitals are very important buildings and need to remain standing after the earthquake, the design of such buildings needs to be done as per earthquake design considerations.

The present study deals with seismic analysis using Equivalent static analysis of (G+5) story RC buildings using Structural Analysis and Design (STAAD Pro.) software.

1.1 General

Structural analysis is the backbone of civil engineering. During recent years, there has been a growing emphasis on using computer aided software and tools to analyze the structures. There has also been advancement in finite element analysis of structures using Finite Element Analysis methods or matrix analysis. These developments are most welcome, as they relieve the engineer of the often lengthy calculations and procedures required to be followed while large or complicated structures are analyzed using classical methods. But not all the time such detailed analysis are necessary to be performed i.e. sometimes, just approximate analysis could suffice our requirements as in case of preparing the rough estimates and participating in the bidding process for a tender. Now-a-days, high rise buildings and multi-bay-multi-story buildings are very common in metropolitan cities. The analysis of frames of multistoried buildings proves to be rather cumbersome as the frames have a large number of joints which are free to move. Even if the commonly used Moment distribution method is applied to all the joints, the work involved shall be tremendous. However, with certain assumptions, applying the substitute analysis methods like substitute frame method, portal method, cantilever method or factor method, the structures can be analyzed approximately.

1.2 Geometry of the Hospital

The plan of the Hospital building is regular. It has a story height of H = 4.0m where all stories are of the same height. The Hospital building consist of five stories, it is six stories including ground floor. The Hospital building length is 31.75m and width is 19.25m so the area is 611.1875m^2. The building consist of square columns with cross-section (0.5 x 0.5)m, rectangular beams with cross- section (0.6 x 0.3)m and slab thickness of 150mm. The size of column is constant for all stories. In each storey, the size of the beam is constant. The elastic rigidity of outer beams and columns are half that of interior ones and elastic rigidity of corner columns is one fourth that of interior ones.

1.4 Objective and Scope

Since hospital is the most important place during a disaster to give humanitarian aid and medical treatment, it is important to make sure that the hospital building can withstand the earthquake. The objective of this study is to make comparisons of analysis and design of a (G+5) story hospital building. Several cases of seismic loads will be applied to the building.

In Afghanistan there is no particular seismic analysis code for buildings, therefore Indian Standard Code (IS 1893-2002) will be used for this study. The building will be designed according to the Earthquake resistant considerations. The present study deals with an Equivalent Static Analysis of 6 story RCC hospital building using Structural Analysis and Design (STAAD Pro.) software.

1.5 Methodology

- Review the existing literature and Indian design code provision for analysis and design of the earthquake resistant building.
- The different types of structures are selected.
- The selected structures are modelled.
- Performing linear analysis for selected building for both gravity load, and earthquake loads and then a comparative study of both is obtained from the analysis.
- Also design the building manually for design and analysis results obtained and compare with the area of steel of the models obtained.
- Using structural analysis and design Software ETABS and STAAD Pro and comparing both results.
- Observation of results and discussions.

CHAPTER 2

2.0 History of Structural Analysis

A structure refers to a system of two or more connected parts used to support a load. It may be considered as an assembly of two or more basic components connected to each other so that they carry the design loads safely without causing any serviceability failure. Once a preliminary design of a structure is fixed, the structure then must be *analyzed* to make sure that it has its required strength and rigidity. The loadings are supposed to be taken from respective design codes and local specifications, if any. The forces in the members and the displacements of the joints are found using the theory of structural analysis. The whole structural system and its loading conditions might be of complex nature, so to make the analysis simpler, certain simplifying assumptions related to the material quality, member geometry, nature of applied loads, their distribution, the type of connections at the joints and the support conditions are used. This shall help making the process of structural analysis simpler to quite an extent.

2.1 Methods of structural analysis

When the number of unknown reactions or the number of internal forces exceeds the number of equilibrium equations available for the purpose of analysis, the structure is called a statically indeterminate structure. Many structures are statically indeterminate. This indeterminacy may be as a_result of added supports or extra members, or by the general form of the structure. While analyzing any indeterminate structure, it is essential to satisfy equilibrium, compatibility, and force-displacement conditions for the structure. The fundamental methods to analyze the statically indeterminate structures are discussed below.

2.1.1 Force method

The force method developed first by James Clerk Maxwell and further developed later by Otto Mohr and Heinrich Muller-Breslau was one of the first methods available for analysis of statically indeterminate structures. This method is also called *compatibility method* or the *method of consistent displacements.* In this method, the compatibility and force displacement requirements for the given structure are first defined in order to determine the redundant forces. Once these forces are determined, the remaining reactive forces on the given structure are found out by satisfying the equilibrium requirements.

2.1.2 Displacement method

In the displacement method, first load-displacement relations for the members of the structure are written and then the equilibrium requirements for the same are satisfied. The unknowns in the equations are displacements. Unknown displacements are written in terms of the loads or forces by using the load-displacement relations and then these equations are solved to determine the displacements. As the displacements are determined, the loads are found out from the compatibility and load- displacement equations. Some classical techniques used to apply the displacement method are discussed.

2.1.3 Slope deflection method

This method was first devised by Heinrich Manderla and Otto Mohr to study the secondary stresses in trusses and was further developed by G. A. Maney in order to extend its application to analyze indeterminate beams and framed structures. The basic assumption of this method is to consider the deformations caused only by bending moments. It is assumed that the effects of shear force or axial force deformations are negligible in indeterminate beams or frames. The fundamental slope-deflection equation expresses the moment at the end of a member as the superposition of the end moments caused due to the external loads on the member, with the ends being assumed as restrained, and the end moments caused by the displacements and actual end rotations. Slope-deflection equations are applied to each of the members of the structure. Using appropriate equations of equilibrium for the joints along with the slope-deflection equations of each member, a set of simultaneous equations with unknowns as the displacements are obtained. Once the values of these displacements are found, the end moments are found using the slope-deflection equations.

2.1.4 Moment distribution method

This method of analyzing beams and multi-storey frames using moment distribution was introduced by Prof. Hardy Cross in 1930, and is also sometimes referred to as Hardy Cross method. It is an iterative method. Initially all the joints are temporarily restrained against rotation and fixed end moments for all the members are written down. Each joint is then released one by one in succession and the unbalanced moment is distributed to the ends of the members in the ratio of their distribution factors. These distributed moments are then carried over to the far ends of the joints. Again the joint is temporarily restrained before moving on to the next joint. Same set of operations are performed at each joint till all the joints are completed and the results obtained are up to desired accuracy. The method does not involve solving a number of simultaneous equations, which may get quite complicated while dealing with large structures, and is therefore preferred over the slope-deflection method.

2.1.5 Kani's method

This method was first developed by Prof. Gasper Kani of Germany in the year 1947. This is an indirect extension of slope deflection method. This is an efficient method due to simplicity of moment distribution. The method offers an iterative scheme for applying slope deflection method of structural analysis. Whereas the moment distribution method reduces the number of linear simultaneous equations and such equations needed are equal to the number of translator displacements, the number of equations needed is zero in case of the Kani's method.

CHAPTER 3

3. LITERATURE REVIEW

3.1 General

Valmundsson and Nau(1997) studied the earthquake response of 5-, 10-, and 20-story framed structures with non-uniform mass, stiffness, and strength distributions. The object of the study was to investigate the conditions for which a structure can be considered regular.

Das (2000) found that the structures designed by ELF method performed reasonably well. He concluded that capacity based criteria must be suitably applied in the vicinity of the irregularity.

Sadjadi et al. (2007) presented an analytical approach for seismic assessment of RC frames using nonlinear time history analysis and push-over analysis. The results from analytical models were validated against available experimental results. He observed that ductile and less ductile frames behaved very well under the earthquake considered.

Adiyanto (2008) analyzed a 3-storey hospital building using STAAD Pro. Seismic loads were applied to the building. The dead loads and live loads were taken from BS6399:1997 and seismic loads intensity is based on equivalent static force procedure in UBC1994. Result showed that the building can withstand any intensity of earthquake. It means that the buildings were suitable to be built in any area located near the epicenter of the earthquake.

Kim and Elnashai (2009) observed that buildings for which seismic design was done using contemporary codes survived the earthquake loads. However the vertical motion significantly reduced the shear capacity in vertical members.

Griffith and Pinto (2009) investigated a 4-storey, 3-bay reinforced concrete frame test structure with unreinforced brick masonry (URM) infill walls for its weaknesses with regard to seismic loading. The concrete frame was shown to be essentially a "weak-column strong-beam frame" which was likely to exhibit poor post yield hysteretic behavior.

Di Sarno and Elnashai (2011) assessed the seismic performance of a 9-storey steel perimeter MRF (moment resisting frame) using the three types of bracings: special concentrically braces (SCBFs), buckling-restrained braces (BRBFs) and mega-braces (MBFs). Local (member rotations) and global (inter-storey and roof drifts) deformations were employed to compare the inelastic response of the retrofitted frames. MBFs were found to be the most cost-effective bracing system with the least storey drifts.

Kumar et al (2011) experimentally investigated the behavior of retrofitted FRP (fiber reinforced polymer) wrapped exterior beam-column joint of a G+4 building in Salem. The test specimen was taken to be one fifth model of beam column joint from the prototype specimen and was evaluated in terms of load displacement relation, ductility, stiffness, load ratio and cracking pattern. On comparing the test results with the analytical modeling of the joint on ANSYS and STAAD Pro, it was found that such external confinement of concrete increased the load carrying capacity of the control specimen by 60% and energy absorption capacity by 30-60%.

Agrawal (2012) did seismic evaluation of an old institute building. Agrawal evaluated the member for seismic loads by determining the Demand Capacity Ratio (DCR) for beams and columns. Being an old building, the reinforcement details of the building were not available. Hence Design-1 was done applying only DEAD and LIVE loads according to IS 456:2000 to estimate the reinforcement present in the building and assuming that this much reinforcement was present. In Design-2, seismic loads were applied and for this demand obtained from design-2 and capacity from design -1, the DCR was calculated.

Poonam et al. **(2012)** concluded that any storey must not be softer than the storeys above or below. Irregularity in mass distribution contributed to the increased response of the buildings.

Rajeeva and Tesfamariam (2012) studied the Fragility based seismic vulnerability of structures considering soft -storey and quality of construction. Their study was demonstrated on three, five, and nine storey RC building frames designed prior to 1970s. Probabilistic seismic demand model was developed using non-linear finite element analysis considering the interactions between soft -storey and quality of construction. Their study showed the sensitivity of the model parameter to the interaction of soft -storey and quality of construction.

Aslam (2014) analysed a (G+5) storey Hospital building in Agartala as one the projects undertaken by L&T. The seismic analysis of the proposed building was done in the software ETABS, version- 9.7, which is one of the most advanced software in the structural design field. The loads applied on the structure were based on IS:875(part I) 1987[dead load],IS:875(part II)-1987[live load], IS:875(part III)-1987[wind load], IS:1893-2002 [Earthquake load]. Scale factor was calculated from the design base shear. Once the analysis was completed, all the structural components were designed according to Indian standard code IS:456-2000. This included footings, columns, beams, slabs, staircases and shear walls.

Moehle (2014) found that standard limit analysis and static inelastic analysis provide good measures of strength and deformation characteristics under strong earthquake motions.

Yen-Po Wang (2014) introduced the fundamentals of seismic base isolation as an effective technique for seismic design of structures. Spring-like isolation bearings reduced earthquake forces by changing the fundamental time period of the structure so as to avoid resonance. Sliding-type isolation bearings filter out the earthquake forces via discontinuous sliding interfaces and forces were prevented from getting transmitted to the superstructure because of the friction. The design of the base isolation system included finding out the base shear, bearing displacement etc. in accordance with site-specific conditions.

3.2 Summary of literature Review

The present study aims to design a Hospital building in Afghanistan using Equivalent Static analysis method. The base shear is calculated on the basis of mass and fundamental period of vibration and mode shape. The base shear is distributed along the height of structure in terms of forces according to IS 1893 (2002) Code formula. No similar code for design is available in Afghanistan. The Equivalent Static method is usually used for low, medium height buildings. This method is simple and accurate enough to use.

CHAPTER 4

4. STRUCTURAL MODELLING

4.1 Overview

In this chapter, Hospital building description is presented. In section 4.2 six story regular reinforced concrete building is explained. Next in section 4.3 materials properties of both steel and concrete are shown. In section 4.4 Gravity loads, dead load, live load as well as combination loads are presented and the end structural elements are introduced.

4.2 Irregular RC Building

Six story regular reinforced concrete building is considered. The beam length in (x) transverse direction are 3m (four numbers), 6.75m (two numbers), and 6.25m and beams in (z) longitudinal direction are 3 x 3m (three numbers), 2m (two numbers), and 6.25m. Figure 4.1 shows the plan of the six story Hospital building having 7 bays in x-direction and six bays in z-direction. Story height of each building is assumed 4m. Figure 4.2 shows the frame (A-A) and (01-01) of six story RC Hospital building. Beam cross section is 300x600 mm and Column cross section is 500x500 mm.

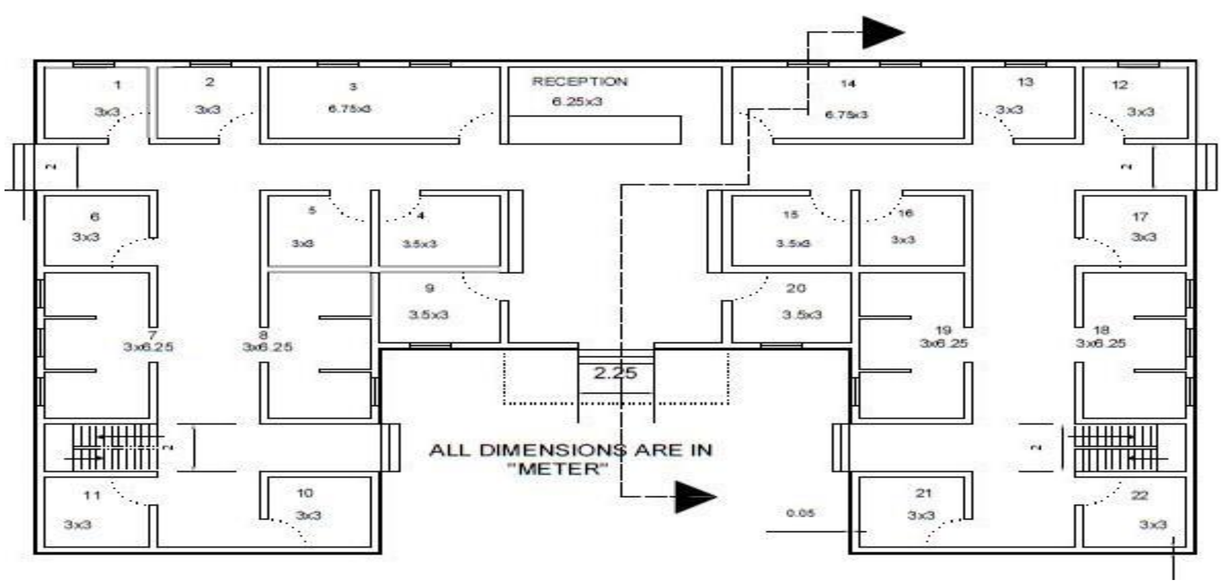
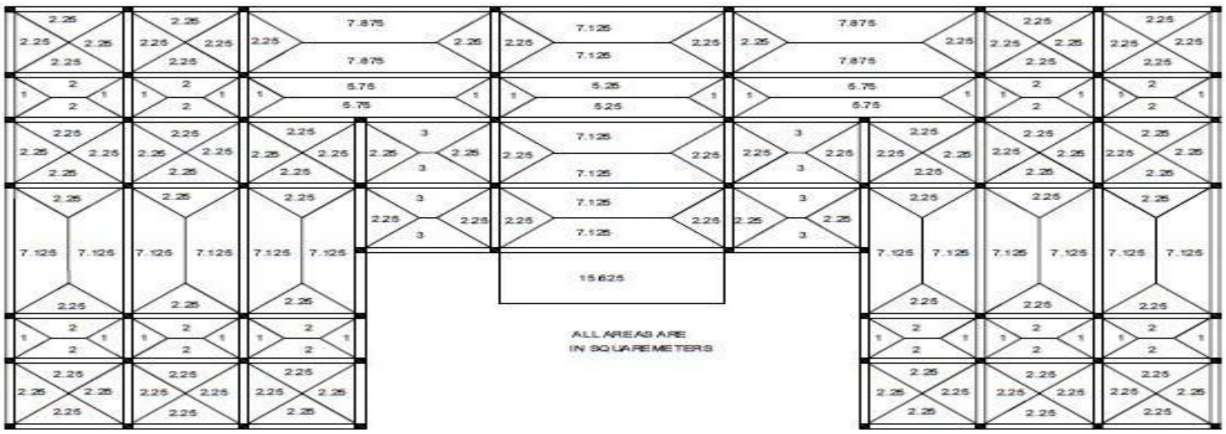
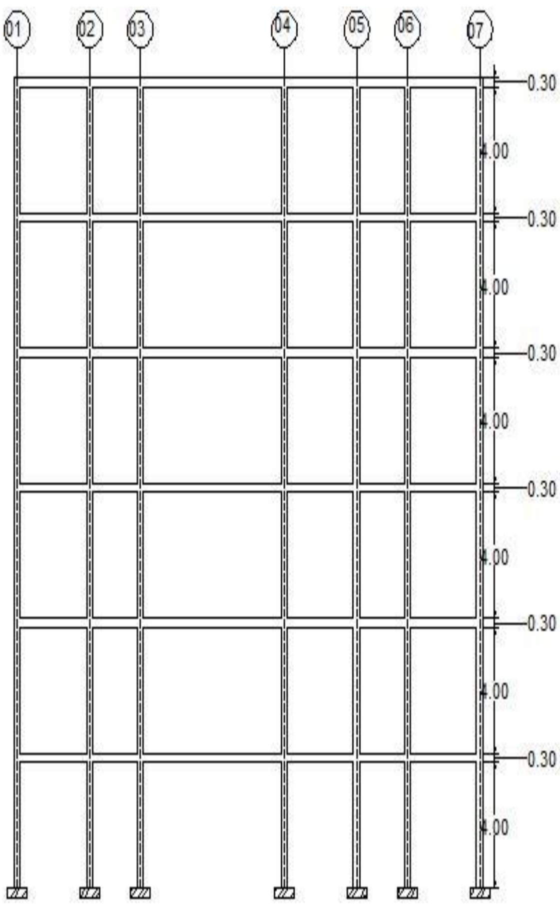
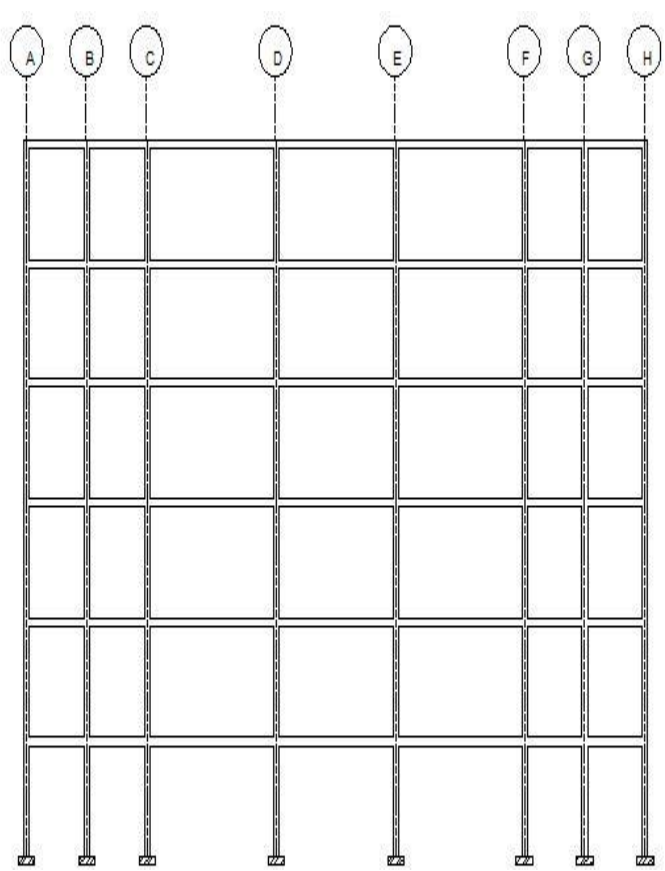


Figure 4.1 Plan of six- story RC building (all dimensions are in mm)



Plan by determination of columns and beams





Frame (A-A) Frame (01-01)

Figure 4.2 Frame (A-A) and (01-01) of six – story RC building (all dimensions are in mm)

4.3 Calculation Load

4.3.1 General Data

Structure	= G + 5
Floor height (First Floor to Fifth Floor)	= 4.0m
Grade of concrete (for all structural elements)	= M25
Unit weight of concrete	= 25kN/m^3
Unit weight of cement mortar	= 24kN/m^3
Unit weight of water	= 10kN/m^3
Unit weight of Brick	= 20kN

A slab load of 3.75 KN/m^2 is considered for analysis. The wall load is taken as 20 KN/m. A floor finish load of 1.5 kN/m^2 is applied on all beams of the RC building as per IS 875 (part1) [8]. A live load of 4 KN/m^2 is provided as per IS 875 (part2) [9]. Table 4.1 shows the gravity loads taken for the building.

4.4 Gravity Load

Table 4.1: Load values for building

Dead and live loads	**Value**
Slab load (dead load)	3.75kN/m^2
Wall load (dead load)	16.6kN/m
Floor finish (dead load)	1.5kN/m^2
Live load	4kN/m^2

The structure is analyzed and designed for live load, seismic load as per IS-1893-2002 and dead load consisting of self-weight of beams, columns and slabs. The following figures show the different loads acting on the building.

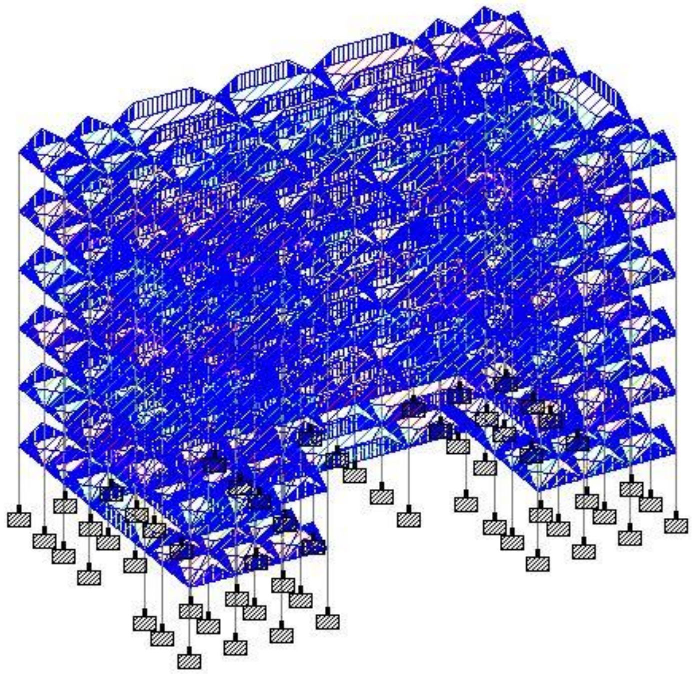


Figure 4.3 the live load acting on the structure

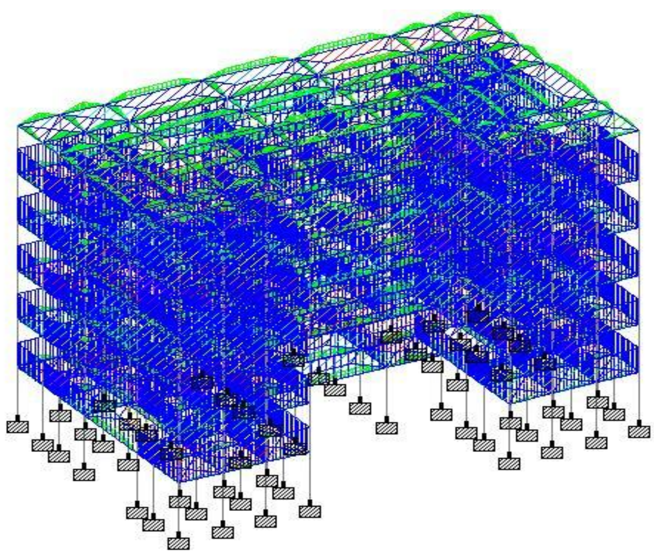


Figure 4.4 Brick load acting on the structure

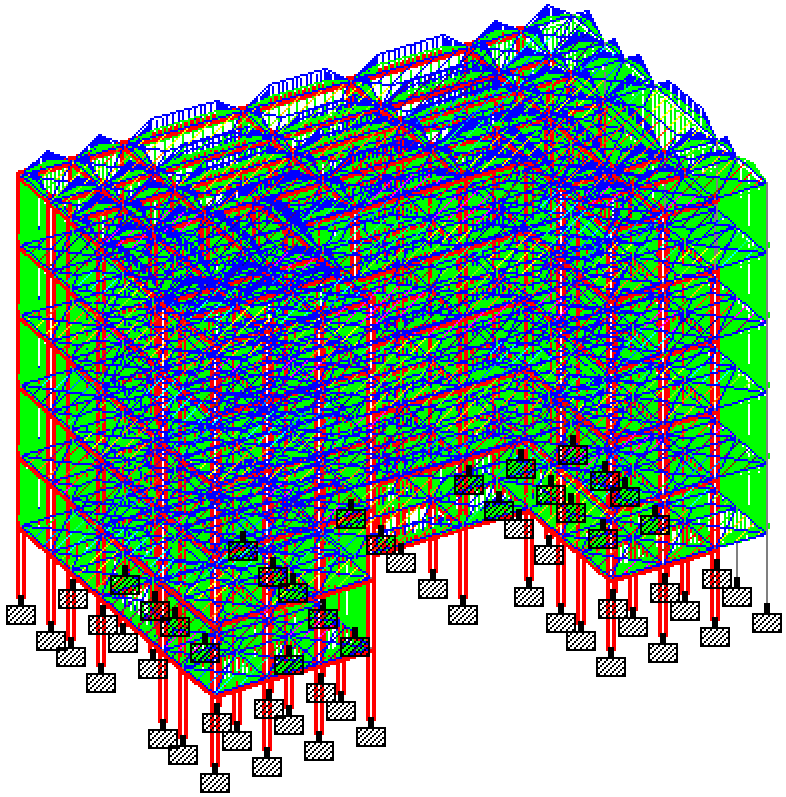


Figure 4.5 Floor load of the structure

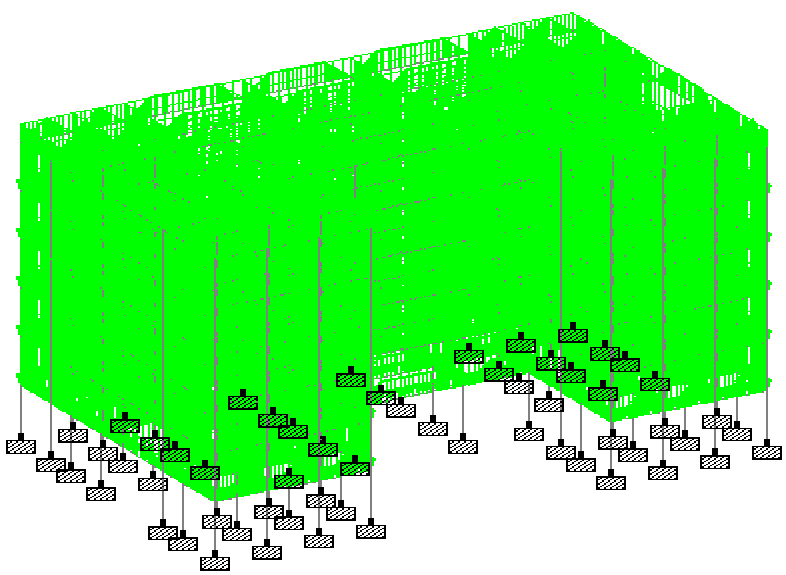


Figure 4.6 Combination load of the structure

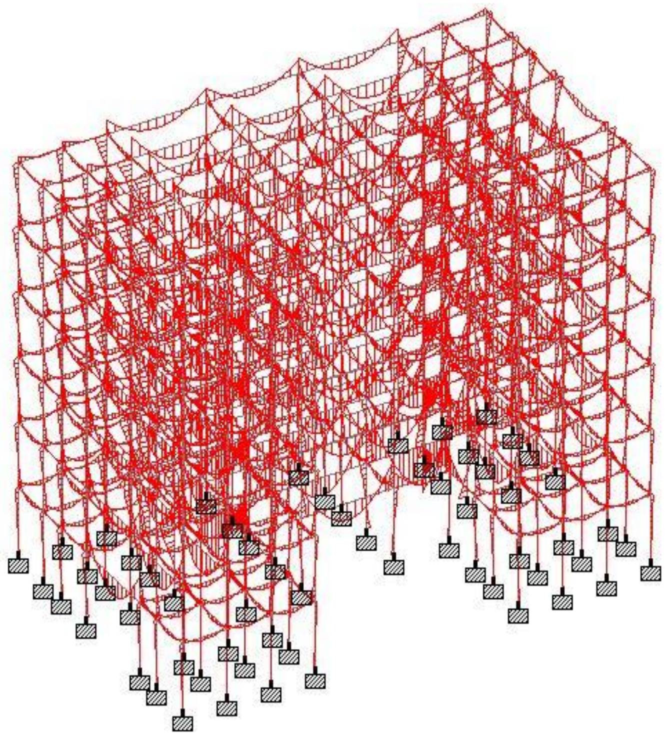


Figure 4.7 Bending moment diagram of the building

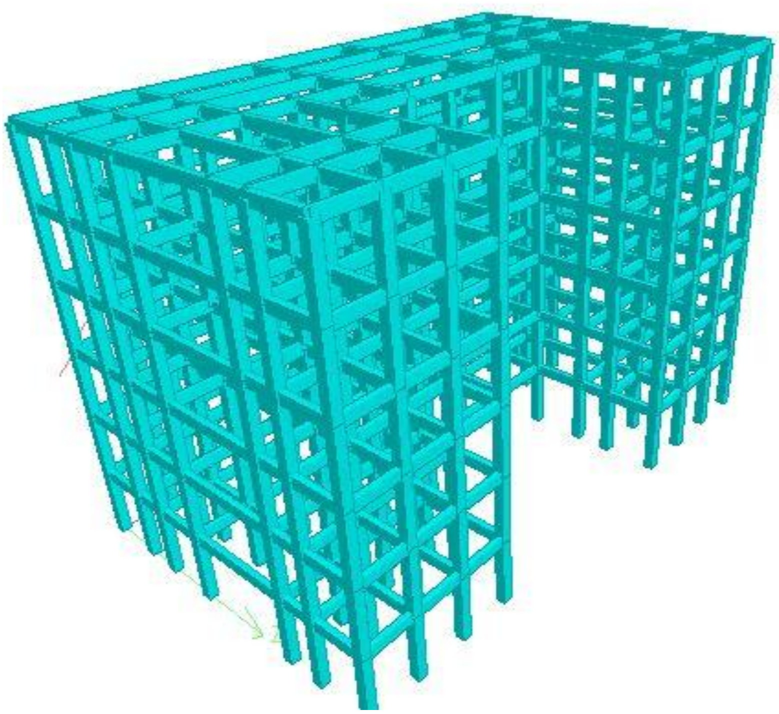


Figure 4.7 3D form of the building

4.5 Material Properties

Table 4.2 shows the assumed properties of concrete and steel bar taken as per IS 456.

Table 4.2: Properties of Concrete and Steel bar as per IS 456[7]

Concrete Properties		Steel Bar Properties	
Unit weight (γ_c)	25 kN/m^3	Unit weight (γ_s)	76.33kN/m^3
Modulus of elasticity	21718.8MPa	Modulus of elasticity	2x10^{5}MPa
Poisson ratio (ν_c)	0.17	Poisson ratio (ν_s)	0.3
Thermal coefficient (α_c)	1x10^{-5}	Thermal coefficient(α_s)	1.2x10^{-5}
Shear modulus (ς_c)	9316.95MPa	Shear modulus (ς_s)	76.8195MPa
Damping ratio (ς_c)	5%	Yield strength	415MPa
Compressive strength (F_c)	25MPa	Compressive strength (F_s)	485MPa

4.6 Structural Elements

The six story irregular reinforced concrete Hospital building was analyzed for gravity loads in STAAD Pro. For the comparative study, beam and column dimensions are assumed 300mm x 600mm and 500mm x 500mm. Height of the story is 4m and beam length in longitudinal direction is taken 3m, 6.75m, and 6.25m and in transverse direction is taken 3m, 2m, and 6.25m.These dimensions and cross sections are summarized in **Table 4.3:** Beam and column length and cross section dimension.

Structural Element	**Cross section** (mm x mm)	**Length (m)**
Beam in (x) longitudinal direction	300 x 600	3m (four numbers) 6.75m (two numbers) 6.25m
Beam in (z) transverse direction	300 x 600	3m (three numbers) 2m (two numbers)

		6.25m
columns	500 x 500	4m

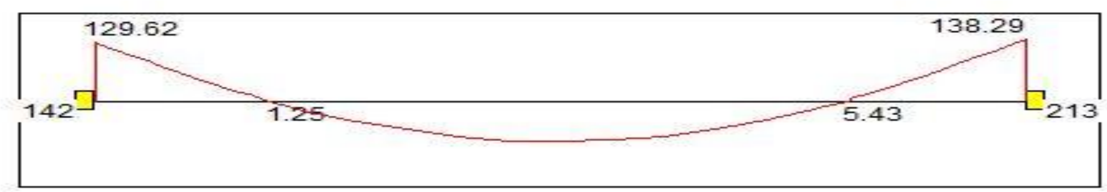
CHAPTER 5

5. Reinforced Structural design

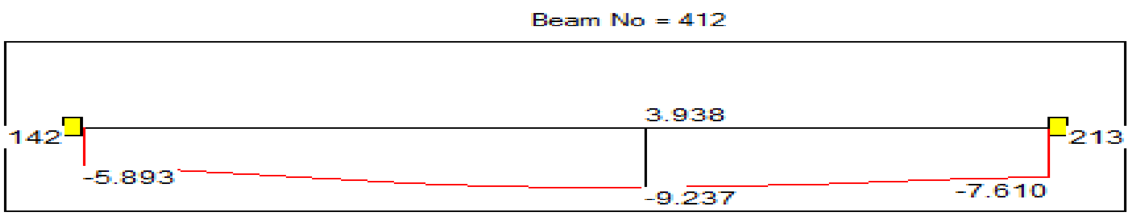
Having decided on a plan of the building and having obtained the beam and column dimensions and decided on the loads as per the relevant IS codes, the next steps in the project are the analysis and determining of the maximum moments, thrust and shears in beams, design of section and reinforcement arrangements for slab, beam, columns and walls and detail drawings and bar schedules.

5.1 Designing of beam

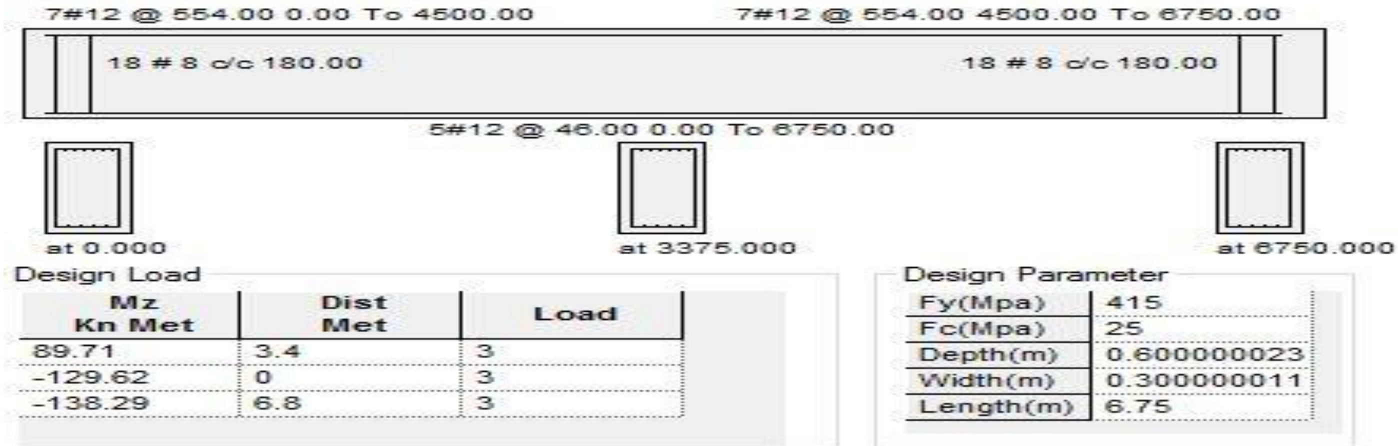
A reinforced concrete beam is designed to resist tensile, compressive and shear stresses caused by the loads on the beam. The beam is analyzed first in order to calculate bending Moment and shear force. The breadth of the beam is taken considering the thickness of the wall and the width of the column so that effective transfer of the load from beam to column is achieved. The depth of the beam is from one-tenth to one-sixth of the length of the beam. In the present design, all beams are of rectangular shape, with breadth and depth of the beam as 300mm and 600mm respectively and total number of beams is 370.



Bending moment diagram of beam No.412



Deflection diagram of beam No.412

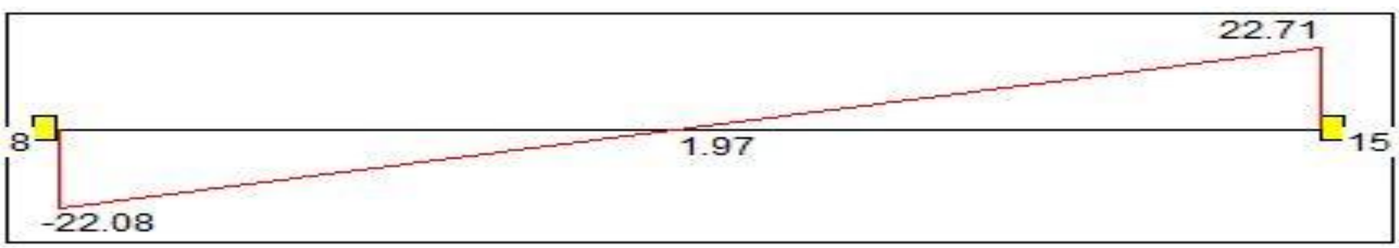


Reinforcement details for beam No.412 in STAAD Pro. using design code IS- 456:2000

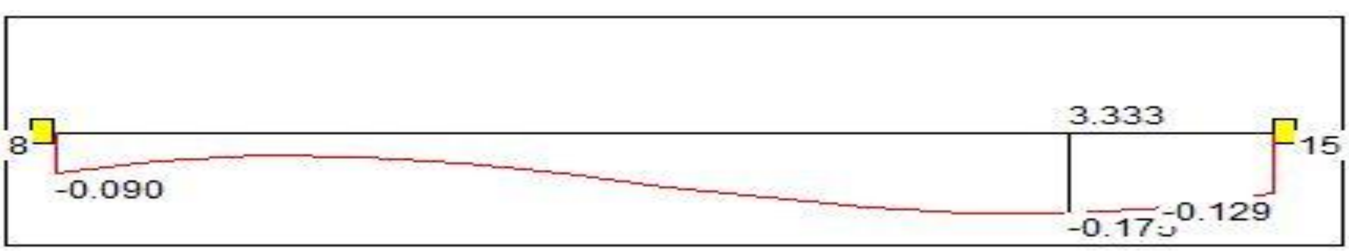
Figure 5.1 Bending moment, Deflection diagram and concrete design by details

5.2 Designing of Columns

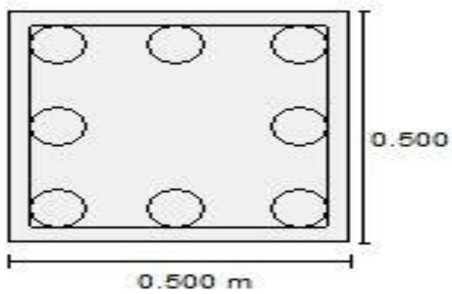
A column is a member carrying direct axial load which causes compressive stresses. All columns are designed separately. The columns are subjected to bending moment and axial loads. The column section is designed just below the beam column joint and just above the beam column joint and larger of the two reinforcements is adopted. The numbers of columns are 606. The design moment is obtained from IS456:2000 code.



Bending moment diagram of column No. 14



Deflection diagram of column No. 14



Design Load

Load	3
Location	End 1
Pu(Kns)	921.23
Mz(Kns-Mt)	22.08
My(Kns-Mt)	24.32

Design Parameter

Fy(Mpa)	415
Fc(Mpa)	25
As Reqd(mm²)	661
As (%)	0.36
Bar Size	12
Bar No	8

Reinforcement details of column No.14 in STAAD Pro. Using design code IS- 456:2000

Figure 5.2 Column deflection, shear force and concrete design by details

5.3 Designing of foundation

In the present study it is assumed that the site is located in granite rock which is suitable for strong foundation. It is assumed that the safe bearing capacity of soil is 180kN/M^2 at a depth of 1.8m and that the same soil exists at a depth of 1.5 times the width of footing below the base of footing. Isolated square footings of M-25 mix and reinforced with HYSD bars of Fe-415 is designed as per IS: 786-1985. The footing is designed for flexure, punching or two-way shear, and flexural or one-way shear. The size of the footing is based on the allowable soil bearing pressure. The depth of the footing is based on punching shear.

Footing design in Mathcad software

Footing ID=F1 Pu = 210 kN

Column size a1 = 0.5m b1 = 0.5m f_{ck} = 25 N/mm^2 Fe = 415 N/mm^2

S_{BC} = 180 kN/m^2

Soil bearing capacity

Load footing P = (P_u + 0.1 P_u) P = 231 kN Adding 10% extra load for self

Weight of footing

Area of footing $a = P/S_{BC}$ $a = 1.283m^2$

Length = $\sqrt{\ }$ length = 1.133m breath = 1.133m

Let provide Len = Round (length, 0.1) Len = 1.1 Len = len+0.05 Len = 1.15m

And Wid = Round (length, 0.1) Wid = 1.1 Width = Wid+0.05 Width = 1.15m

Net upward pressure $P_o = P_u$/Len width $P_o = 158.79$ kN/m^2

Moment calculation:

Mu = P_o x Width $(Len\text{-}a1)^2/8$ $M_u = 9.644$ kNm

Depth d= d = 50.071mm

Let provide overall depth D = 350mm

D_{eff} = (D-cc—12) d_{eff} = 298mm

Area of Steel

A_{st} = 0.5fck x width x 1000 x d_{eff}/fe [1-]

$A_{st} = 90.072mm^2$

But minimum A_{st}, $A_{st}min = 0.0012 \times width \times 10^3 \times D$ $A_{st}min = 483mm^2$

If $(A_{st}>A_{st},A_{st}min,A_{st}) = 483mm^2$

Using 10mm bar, No of Bar = $A_{st}min/ (3.141 \times 10^2/4)$ = 6.15

Bar = Round (No fo Bar, 1) Bar = 6 Bar = Bar + 1 Bar provide, Bar = 7

Spacing = width x 1000/Bar = 164.286mm Provide spacing = 160mm

Percentage of Steel:

Pt = ———————— Pt = 0.16

Check for one way shear:

SF = Po x Width [(Len-a1/2)-deff/1000] SF = 4.93 kN

From table 19 IS 456:2000

Tuc = 0.29 N/mm^2

Tuv = SF x 1000/ (Width x 1000 x deff) Tuv = 0.014 N/mm^2

If (Tuc>Tuv,Tuv,Tuc) = 0.014 Hence safe.

Check for two way shear:

Preimeter of punching shear

Peri = 2 x [(a1+deff/1000) + (b1+deff/1000)]

Or peri = 3.192m

Area of punching shear

Area = (a1+ deff/1000) x (b1 + deff/1000)

Area = 0.637 m^2

Punching shear:

SP = Po x (width x Len- area) SP = 108.882 kN

Tuvp = (SP x 1000/ (peri x 1000 x deff) Tuvp = 0.114 N/mm^2

Punching shear stress:

Bitac = a1/b1,   Ks = 0.5 + Bitac   Ks = 1.5

But Ks Shear b<=1   Kss = Floor (Ks)

Tucp = (0.25 $\overline{\quad}$)   Tucp = 1.25 N/mm^2

tucp = Tucp x Kss

tucp = 1.25 N/mm^2

tucp>Tuvp   hence (ok)

<u>Development length</u>

Ld = (0.87 x fck x 10)/ (4 x 1.6 x 1.4)   Tudb = 1.4   10mm bar

Ld = 402.958mm

Length available,   Lavail = 0.5 (width – b1) x 100-40   40mm clear cover

Lavail = 285mm   Hence (ok)

<u>Load Transfer from Footing to column:</u>

Bearing Stress in the column

Sigma = ————————   sigma = 0.84 N/mm^2

Allowable Bearing Stress = 0.45 x fck x $\frac{\quad}{\quad}$

A1 = [b1 x 10^3 + 2 x (2 x deff)]^2 A1 = 2.863 x 10^6

A2 = a1 x 10^3 x b1 x 10^3 A2 = 2.5 x 10^5

$\frac{\quad}{\quad}$ = 3.384   But this $\frac{\quad}{\quad}$ max value is = 2

Sigma Allowable

SigAllowable = 0.45 fck +2

SigAllowable = 22.5 N/mm^2

SigAllowable>Sigma

Hence column load can carry by bearing alone.

Hence no need of Dowel Bar.

Isolated Footing 1

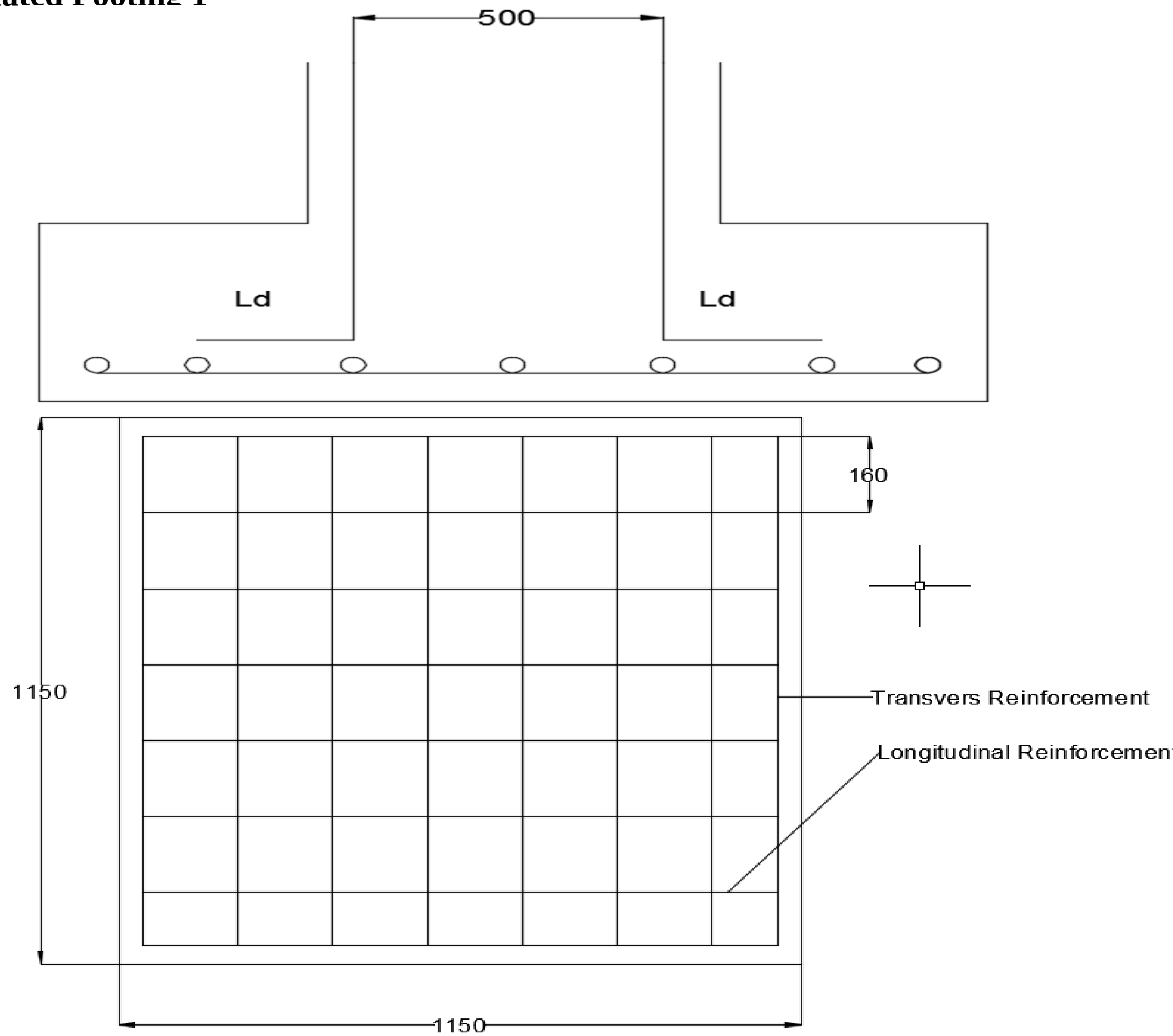


Figure 5.3 Elevation, plan of isolated footing and 3D form, all dims are in (mm)

Design parameters considered for footing design Concrete and Rebar properties							
Unit weight of concrete	Strength of concrete	Yield strength of steel	Max^{m} Bar size	Min^{m} Bar size	Max^{m} Bar spacing	Min^{m} Bar spacing	Footing Clear Cover (F, CL)
25.000 kN/m^3	25.000 N/mm^2	415.000 N/mm^2	32mm	8mm	300mm	75mm	40mm

Table 5.1: Concrete and bar Properties

Footing Geometry:

Footing thickness (F_t): 350mm

Footing length-X (F_l): 1150mm

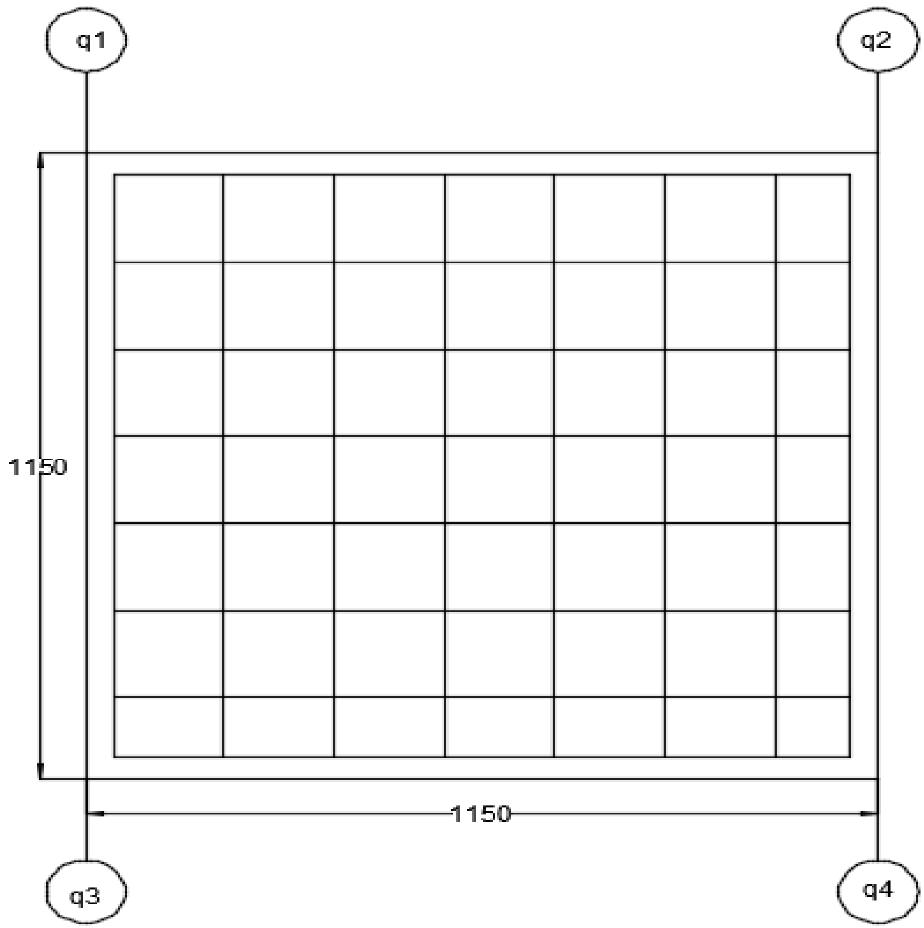
Footing width-Z (F_w): 1150mm

Table 5.2: Soil Properties

Soil properties					
Soil type	Unit weight	Soil bearing capacity	Coefficient of friction	Factor safety against of sliding	Factor of safety against of overturning
Drained	22.00 kN/m^3	180.00 kN/m^2	0.50	1.5	1.5

Table 5.3: Pressure at the four corners

Combination	**Pressure at corner 1 (q_1) (kN/m^2)**	**Pressure at corner 2 (q_2) (kN/m^2)**	**Pressure at corner 3 (q_3) (kN/m^2)**	**Pressure at corner 4 (q_4) (kN/m^2)**
Load Case (3)	97.1952	96.0358	98.7456	99.9050



CHAPTER 6

6. SEISMIC LOAD CALCULATION

During an earthquake, ground motions are developed both horizontally and vertically in all directions and radiating from the epicenter. Due to these ground motions, the structure vibrates inducing inertial forces on them. Hence structures located in seismic zones are designed and detailed to ensure strength, serviceability and stability with acceptable levels of safety under seismic forces.

Many structures are now being suitably designed to withstand earthquakes. This can be seen from the satisfactory performance of a large number of reinforced concrete structures subject to severe earthquake in various parts of the world.

The Indian standard codes IS: 1893-1984 and IS: 13920-1993 have specified the minimum design requirements of earthquake resistant design, probability of occurrence of earthquakes, the characteristics of the structure and the foundation and the acceptable magnitude of damage.

Determination of design earthquake forces is computed by the following methods,

1) Equivalent static lateral loading.

2) Dynamic Analysis.

In the first method, different partial safety factors are applied to dead, live, wind and earthquake forces to arrive at the design ultimate load. In the IS: 456-2000 code, while considering earthquake effects, wind loads are also taken into account, assuming that both severe wind and earthquake do not act simultaneously. The American and Australian code recommendations are similar but with different partial safety factors.

The dynamic analysis involves the rigorous analysis of the structural system by studying the dynamic response of the structure by considering the total response in terms of component modal responses.

6.1 ZONE FACTOR (Z):

- The values of peak ground acceleration given in units 'g' for the maximum considered earthquake.
- The value of (Z/2) corresponds to design basis earthquake damage control in limit state.
- Based on history of seismic activities, the entire country has been divided into four zones. The zone factor from table 2(IS 1893:2002)

Table 6.1: Zone factor values

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

Zone Factor Values

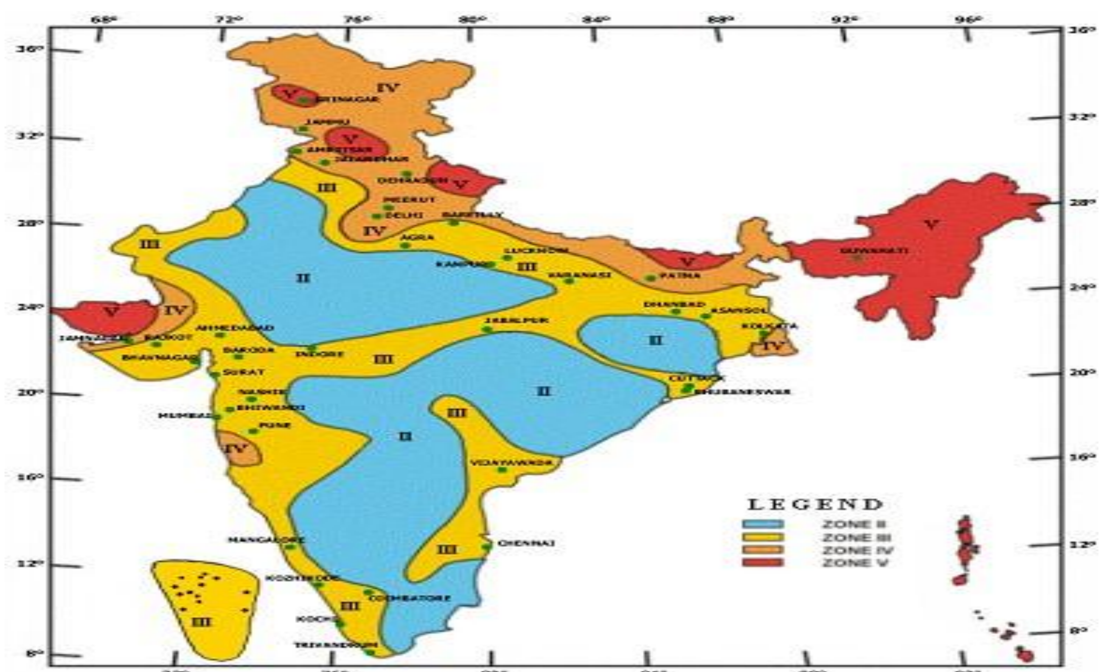


Figure 6.1: Seismic Map of India 2002

6.2 RESPONSE REDUCTION FACTOR (R):

- R is the response reduction factor and controls the permitted damage in design basis earthquake.
- The minimum value of R is 3 and maximum is 5, however to use higher values of R, special ductile detailing requirements are a must and the designer is accepting more damages but in the controlled manner. The Response reduction factor is obtained from table 7(IS 1893:2002).

6.3 IMPORTANCE FACTOR (I):

- I is the importance factor and permitted damage could be reduced by setting the value of I more than '1'.
- For the buildings like **'HOSPITALS'**, communication and community buildings the value is 1.5 from table 6 (IS 1893:2002).

6.4 SEISMIC WEIGHT (W):

- Seismic weight of the building is measured in Kilo Newton. Seismic weight includes the dead loads (that of floor, slabs, finishes, columns, beams)
- Seismic weight includes only a part of Imposed loads, for example 25% to 50% of imposed loads for buildings from table 8 (IS 1893:2002).

6.5 SOIL CLASSIFICATION:

- S_a/g is the lateral acceleration to be established in m/s^2. For 5 % of damping three different types of curves are recommended in IS 1893:2002 for different stiffness of supporting media-Rock, Medium soil and Soft soil.

- The classification of soil is based on the average shear velocity for 30m of rock or soil layers or based on average Standard Penetration Test (SPT) values for top 30m.

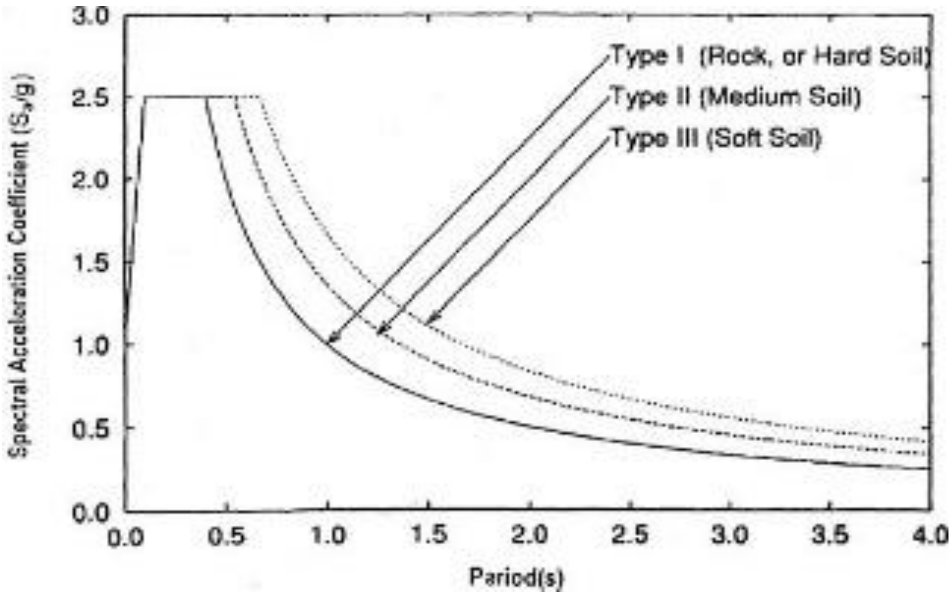


Figure 6.2: Classification of Soil Graph

Zone factor of the building (Z) = 0.16 (Zone III)

Importance of the building (I) = 1.5 (Post Earth quake service needed)

Response reduction factor (R) = 5 (Ductile shear walls with SMRF)

Average response acceleration coefficient (Sa/g) = 2.5

Soil type = Medium soil

Width of building in X-direction = 31.17m

Width of building in Y-direction = 19.25m

Height of the building = 24m

Seismic weight of the building = 75935.75 kN

Table 6.2: showing the dimension and other details

Beams Size	300mm x 600mm
Column size	500mm x 500mm
Slab thickness	150mm
Concrete Grade	M25
Brick infill thickness	250mm
Brick masonry unit weight	$20kN/m^3$
Unit weight of concrete	$25kN/m^3$
Live Load	$4kN/m^2$

6.6 SEISMIC LOAD CALCULATION FOR 6 STORY BUILDING

1) Slab load = (31.75 x19.25-13.75 x 8.125) x 0.15 x 25 = 1873kN

2) Floor finish = (31.75 x 19.25 -13.75 x 8.125) x 1.5 = 749kN

3) Weight of all beams = {(4 x31.75+6 x9+1x13.75) +6 x19.25+2 x14.25)} x0.6x0.3x25

=1524.375kN

4) Weight of Columns in floors = 64 x4 x0.5 x0.5x25 = 1600kN

5) Weight of brick infill in floors = {(4 x31.75+6 x9+1x13.75) +6 x19.25+2 x14.25)}

x 4 x 0.25 x 20 =6775 kN

According to IS1893-2002 Table (8) if the live load is up to and including $3KN/m^2$, the percentage of live load is 25% and more than $3KN/m^2$, then 50% of it will be lumped on floors.

Live load in a typical floor = (31.75x19.25-13.75 x 8.125) x 4 x 0.5=999 kN

The live load is taken zero at roof.

Seismic weight calculation of the structure,

W=W1+W2+W3+W4+W5+W6

W1, W2, W3, W4 and W5 are the seismic weights respectively in each floor.

Table 6.3: Calculation of Seismic of weight of the 6 story building

i	Wi (KN)	Wi (KN)
1	1873+749+1524.375+1600+6775+999	13520.375
2	1873+749+1524.375+1600+6775+999	13520.375
3	1873+749+1524.375+1600+6775+999	13520.375
4	1873+749+1524.375+1600+6775+999	13520.375
5	1873+749+1524.375+1600+6775+999	13520.375
6	1873+749+1524.375+(1600/2)+(6775/2)	8333.875
$\sum$		= 75935.75 kN

Seismic weight is found to be equal to 75935.75 kN

6.7 SEISMIC BASE SHEAR CALCULATION

The design of base shear is the sum of lateral forces applied at all levels that are finally transferred to the ground.

$$V_b = A_h \times W$$

$$A_h = (ZI/2R)\,(S_a/\,g)$$

The fundamental natural period for buildings are in IS 1893(part 1) 2002 Class 7.6.

$T_a = 0.075h^{075}$ for moment resisting RC frame building without brick infill walls

$T_a = 0.085h^{0.75}$ for moment resisting steel frame building without brick infill walls

$T_a = 0.09h/\sqrt{d}$ for all other buildings including moment resisting RC frame building with brick infill walls.

Fundamental natural period for buildings with brick infill walls

$T_a = 0.09h/\sqrt{d}$

$Z = 0.16$

$I = 1.5$

$R = 5$

$S_a/g = 2.5$

$A_h = (ZI/2R)(S_a/g)$

$V_b = A_h \times W$

The fundamental periods on both x and z directions are respectively given below:

T_x=0.383 Sec, T_z=0.492 Sec. From figure 2 of IS 1893, S_a/g is found to be 2.5 for both the periods, so the design horizontal seismic coefficient (A_h) will be same which will result in producing the same amount of base shear in both the directions.

$A_h = (ZI/2R)(S_a/g) = (0.16x1.5/2x5) \times (2.5) = 0.06$

$V_b = A_h \times W = 0.06 \times 75935.75$ kN = 4556.145 kN

So the base shear for 6 story building is found to be equal to 4556.145 kN

Now the base shear is laterally distributed as per IS-1893-2002,

$Q_i = ((W_i h_i^2)/(\Sigma W_i h_i^2)) \times V_b$

Table 6.4: lateral distribution of base shear force

i	W_i (kN)	h_i (m)	$W_ih_i^2$ (kNm^2)	Q_i(kN)
1	13520.375	4	216326	59.02
2	13520.375	8	865304	234.1
3	13520.375	12	1946934	531.22
4	13520.375	16	3461216	944.4
5	13520.375	20	5408150	1475.62
6	8333.875	24	4800312	1309.77
$\sum$	75935.75		16698242	4554.13

These lateral forces (Q_i) are obtained and applied to the building laterally considering the center of mass and the response is obtained using equivalent static analysis.

6.8 ANALYSIS

Based on the external loads, structural materials and structural model, there are different types of analysis process such as linear static analysis, linear dynamic analysis, nonlinear static analysis and nonlinear dynamic analysis.

The analysis options are set before analysis. The analysis is performed with a scale factor 1. The number of modes is initially set as 1.5 after analysis. If the cumulative mass participation factor is less than 95 percentage, then it is modified accordingly with base shear values obtained for the earthquake load case, the new scale factor is calculated and again the model is analyzed for the new scale factor. It can be observed that the base shear value calculated from the code and by the software with the new scale factor are the same.

And the combination load is applied in Staad Pro by using formula which are given bellow.

1) 1.5(DL+IL)

2) 1.2(DL+IL+-EL)

3) 1.5(DL+ - EL)

4) 0.9DL+ - 1.5EL

Table 6.5: showing primary load cases and combination load case

Primary Load Cases

Number	Name	Type
1	SEISMIC LOAD +X	Seismic
2	SESIMIC +Z	Seismic
3	DL	Dead
4	LL	Live

Combination Load Cases

Comb.	Combination L/C Name	Primary	Primary L/C Name	Factor
5	COMBINATION LOAD CASE 5	3	DL	1.50
		4	LL	1.50
6	COMBINATION LOAD CASE 6	3	DL	1.20
		4	LL	1.20
		1	SEISMIC LOAD +X	1.20
7	COMBINATION LOAD CASE 7	3	DL	1.20
		4	LL	1.20
		1	SEISMIC LOAD +X	-1.20
8	COMBINATION LOAD CASE 8	3	DL	1.50
		1	SEISMIC LOAD +X	1.50
9	COMBINATION LOAD CASE 9	3	DL	1.50
		1	SEISMIC LOAD +X	-1.50
10	COMBINATION LOAD CASE 10	3	DL	0.90
		1	SEISMIC LOAD +X	1.50
11	COMBINATION LOAD CASE 11	3	DL	0.90
		1	SEISMIC LOAD +X	-1.50

The result below is after analyzing by using Staad Pro.

Table 6.6 shows the base shear in T_x and T_z

```
*********************************************************
*                                                       *
* TIME PERIOD FOR X 1893 LOADING =     0.38300 SEC      *
* SA/G PER 1893=     2.500, LOAD FACTOR= 1.000          *
* VB PER 1893=     0.0600 X     74365.16=     4461.91 KN  *
*                                                       *
*********************************************************
*                                                       *
* TIME PERIOD FOR Z 1893 LOADING =     0.49200 SEC      *
* SA/G PER 1893=     2.500, LOAD FACTOR= 1.000          *
* VB PER 1893=     0.0600 X     74365.16=     4461.91 KN  *
*                                                       *
*********************************************************
```

Manually the calculation of base shear = 4556.145 kN and software calculation = 4461.91kN

4461.91kN <4556.145 kN so it is safe

Table 6.7 showing the base shear force laterally distributed by Staad Pro analysis

i	h_i(m)	Q_i (KN)
1	4	61.189
2	8	245.189
3	12	551.676
4	16	980.757
5	20	1647.06
6	24	976.039
∑		= 4461.91

Beam and Column Design for Seismic Load Combination

Beam:

According to clause 6.3.1.2 of IS 1893 (part 1):2002 partially safety factors for limit state design of reinforced concrete.

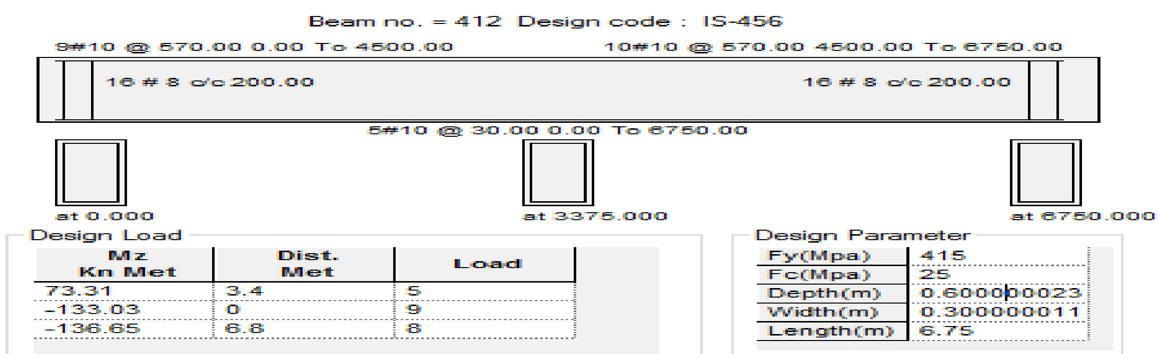
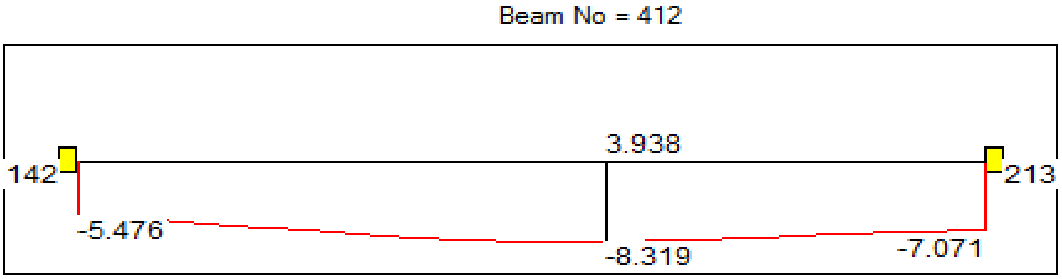
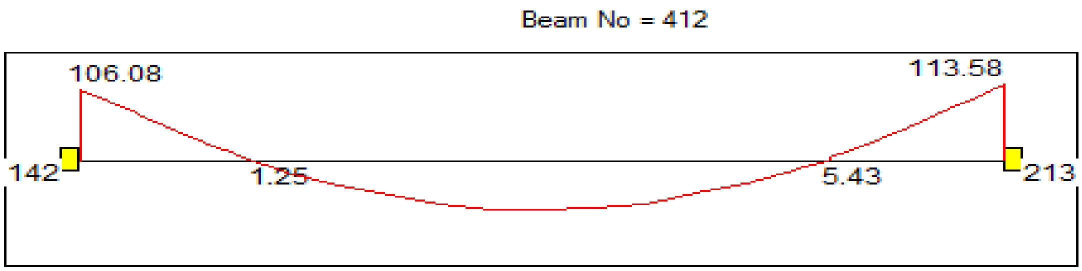


Fig 6.3: Shows the details of beam due to Seismic load combination



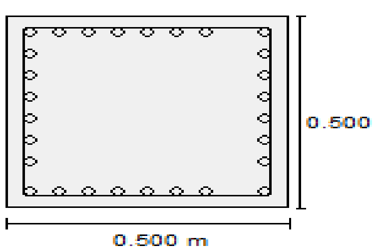
Beam deflection due to seismic combination load



Bending moment due to seismic combination load

Column:

Beam no. = 14 Design code : IS-456



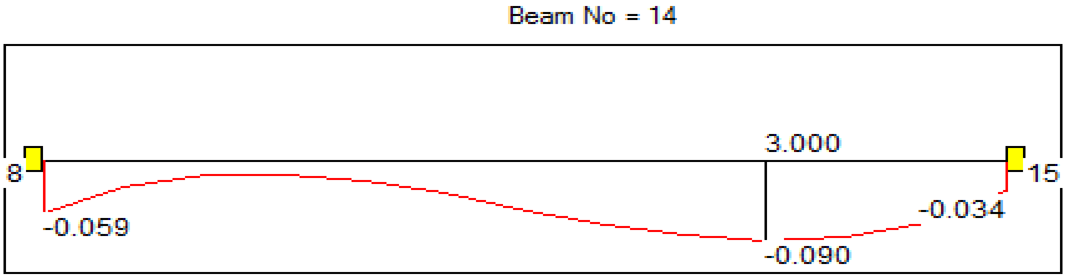
Design Load

Load	10
Location	End 1
Pu(Kns)	-113.83
Mz(Kns-Mt)	166.69
My(Kns-Mt)	19.26

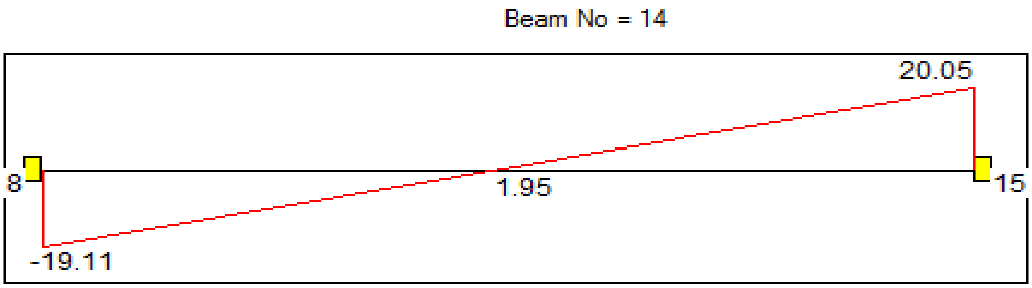
Design Parameter

Fy(Mpa)	415
Fc(Mpa)	25
As Reqd(mm²)	2800
As (%)	1.26
Bar Size	12
Bar No	28

Fig 6.4: Shows the Column details due to Seismic Load Combination



Column deflection due to seismic load combination



Column bending moment due to seismic load combination

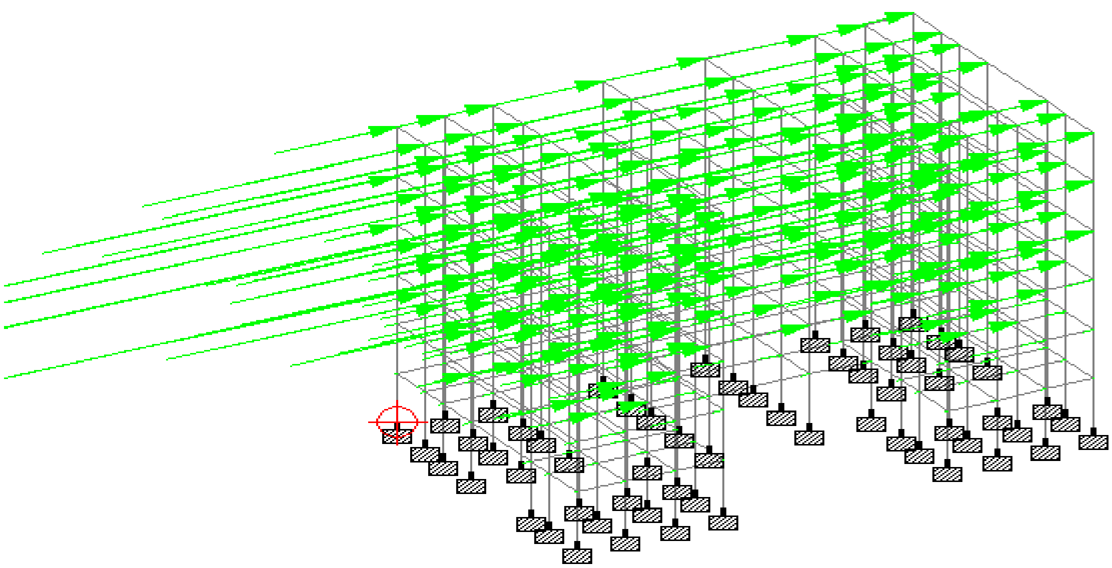


Figure 6.5: showing the seismic load acting from +x direction (Isometric view)

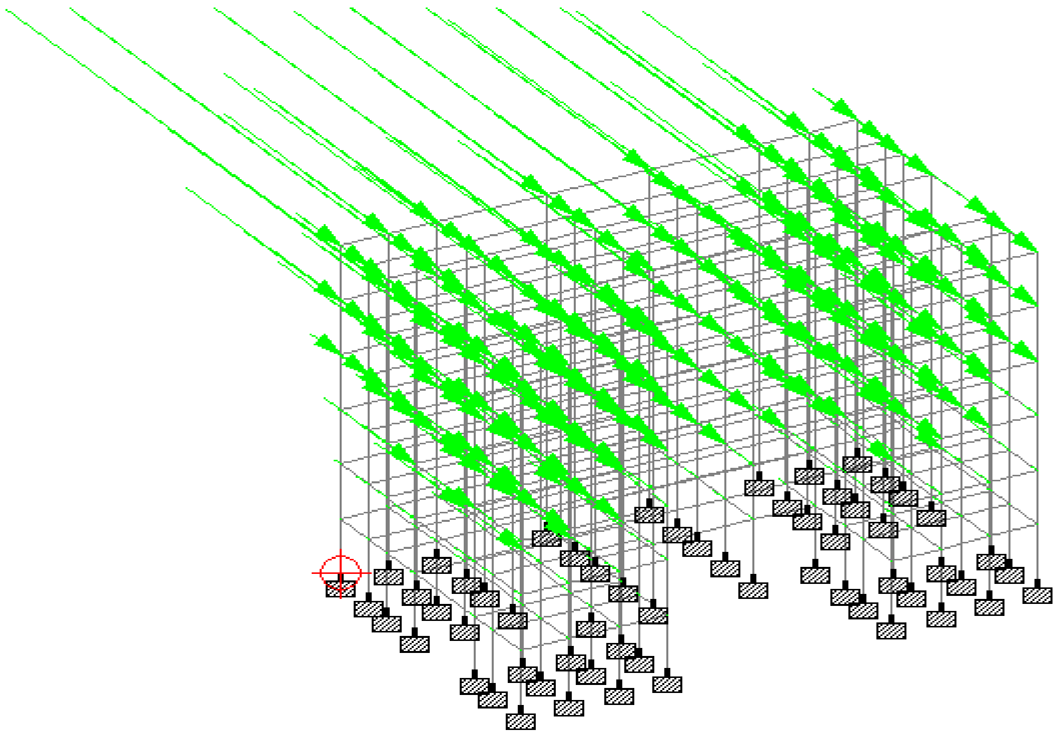


Figure 6.6: showing seismic load acting from +z direction (Isometric view)

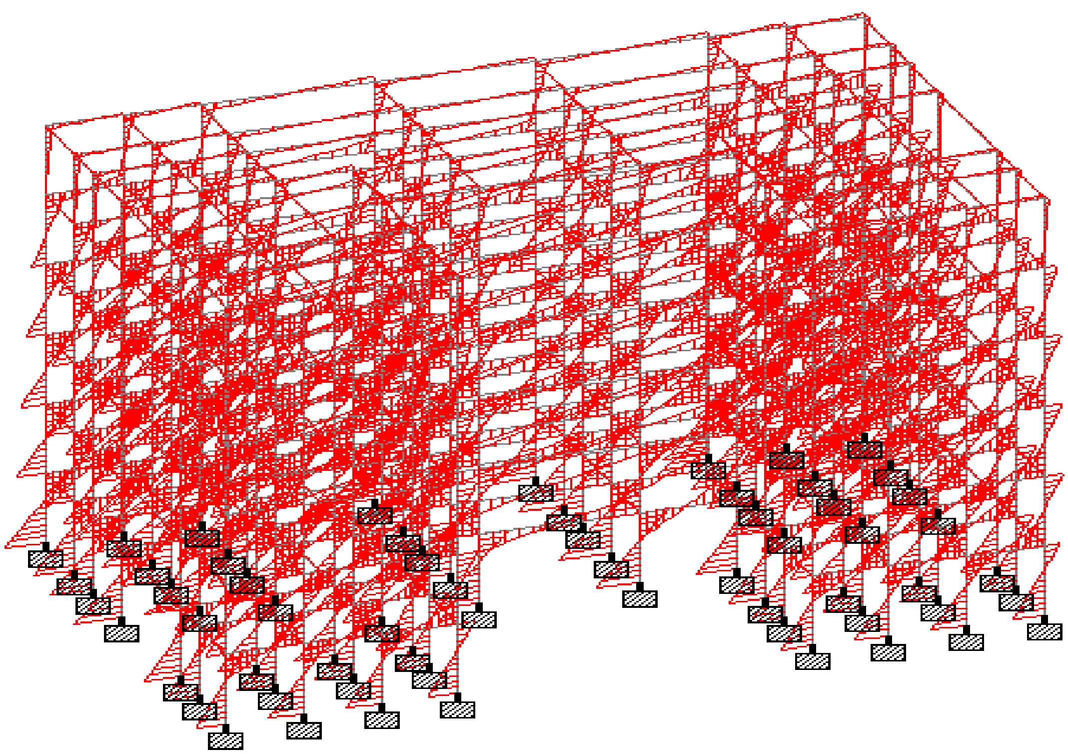


Figure 6.7: Bending moment diagram due to seismic force from +x direction

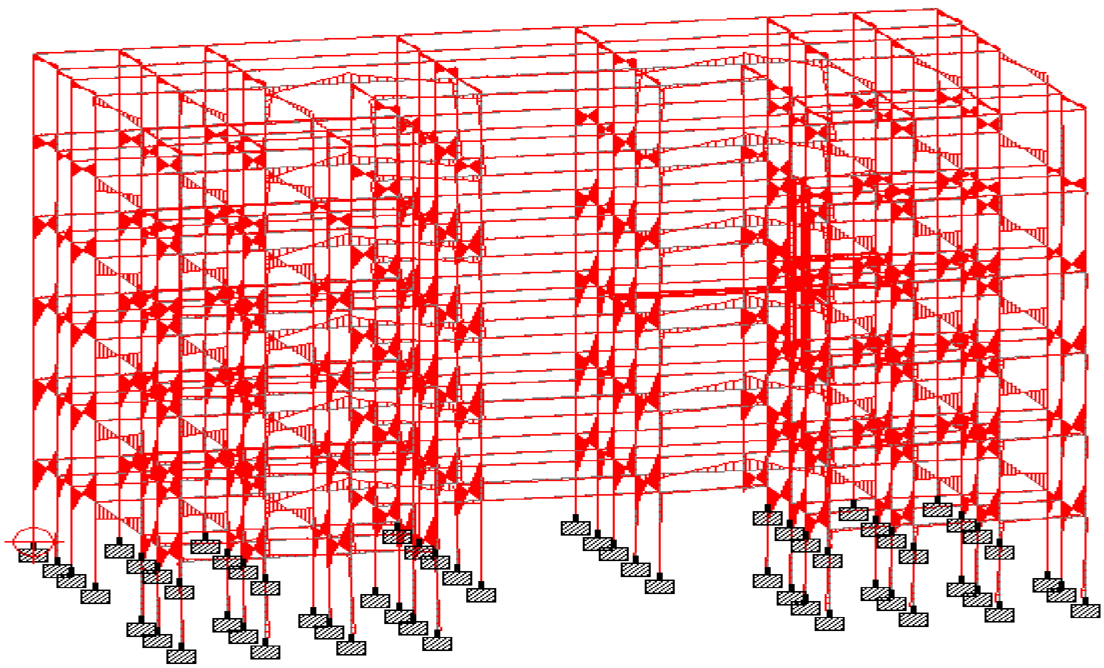


Figure 6.8: Bending moment due to seismic force from +z direction

Conclusion

In the present study, G+5 Hospital building has been drawn in Auto CAD software and designed (Beams, Columns, Footings and Seismic load analysis by using Equivalent Static method) using STAAD Pro software. The dead load, live load and earthquake loads are calculated using IS: 456-2000 and IS 1893: 2002. Concrete grade M25 and HYSD bars Fe415 as per IS: 1786-1985 are used.

Originally, the building was designed without earthquake loads as per IS456:2000. Then building is designed considering the earthquake loads as per IS1893: 2002. The detailing has been done as per both approaches. Since Afghanistan does not have any earthquake code, Indian Standard codes have been used in the analysis and design.

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