“ANALYSIS AND DESIGN OF A COMPOSITE STRUCTURE AGAINST RCC/STEEL STRUCTURE”

A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree of

MASTERS OF TECHNOLOGY

IN

CIVIL ENGINEERING

With specialization in

STRUCTURAL ENGINEERING

Under the supervision of

Dr. Ashok Kumar Gupta (Professor & Head of Department)

&

Mr. Lav Singh (Assistant Professor)

By

Abhijeet Singh (142658)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT SOLAN – 173234

HIMACHAL PRADESH INDIA

JUNE, 2016

CERTIFICATE

This is to certify that the work which is being presented in the project title **“ANALYSIS , AND DESIGN OF A COMPOSITE STRUCTURE AGAINST RCC/STEEL STRUCTURE”** in partial fulfilment of the requirements for the award of the degree of Bachelor of technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Abhijeet Singh (142658)** during a period from July 2015 to June 2016 under the supervision of **Mr Lav Singh (Assistant Professor)** and **Dr. Ashok Kumar Gupta (Professor and Head Department of Civil Engineering)** Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date:……………..

Dr Ashok Kumar Gupta	Mr. Lav Singh	External Examiner
Professor & Head of Department	Assistant Professor	
Department Of Civil Engineering	Department Of Civil Engineering	
JUIT Waknaghat	JUIT Waknaghat	

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ABHIJEET SINGH

M.TECH STRUCTURES (142658)

ABSTRACT

Steel-concrete composite construction means steel section encased in concrete for columns & the concrete slab or profiled deck slab is connected to the steel beam with the help of mechanical shear connectors so that they act as a single unit. In this project, steel-concrete composite with R.C.C. and Steel options are considered for comparative study of G+4 storey residential building which is situated in earthquake zone IV. Equivalent Static Method of Analysis is used. For modeling of Composite & R.C.C. structures, STAADPro.V8i software is used and the results are compared; and it is found that composite structure are more economical.

The use of Steel in construction industry is very low in India compared to many developing countries. Experiences of other countries indicate that this is not due to the lack of economy of Steel as a construction material. There is a great potential for increasing the volume of Steel in construction, especially the current development needs in India. exploring Steel as an alternative construction material and not using it where it is economical is a heavy loss for the country. Also, it is evident that now-a-days, the composite sections using Steel encased with Concrete are economic, cost and time effective solution in major civil structures such as bridges and high rise buildings.

Keywords :- *Composite RCC, Steel, Cost Analysis, STAADProV8i*

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO COMPOSITE CONSTRUCTION

A composite member is defined as consisting of a rolled or a built-up structural steel shape that is filled with concrete, encased by reinforced concrete or structurally connected to a reinforced concrete slab. Composite members are constructed such that the structural steel shapes and the concrete act together to resist axial compression and /or bending.

When a steel component, like an I-section beam, is attached to a concrete component such that there is a transfer of forces and moments between them, such as a bridge or a floor slab, then a composite member is formed. Here it is very important to note that both the materials are used to fullest of their capabilities and give an efficient and economical construction which is an added advantage.

Thermal expansion (coefficient of thermal expansion) of both, concrete and steel being nearly the same. Therefore, there is no induction of different thermal stresses in the section under variation of temperature.

1.2 ADVANTAGES OF COMPOSITE CONSTRUCTION

There are many advantages associated with steel-concrete composite construction. Some of these are listed below:

- The most effective utilization of steel and concrete is achieved.
- Keeping the span and loading unaltered, a more economical steel section (in terms of depth and weight) is achievable in composite construction compared with conventional non-composite construction.
- As the depth of beam reduces, the construction depth reduces, resulting in enhanced headroom.
- Because of its larger stiffness, composite beams have less deflection than steel beams.

- Composite construction is amenable to “fast-track” construction because of using rolled steel and pre-fabricated components, rather than case-in-situ concrete. Encased steel beam sections have improved fire resistance and corrosion. Considerable flexibility in design, pre-fabrication and construction scheduling in congested areas.

There is quite a vertical spread of construction activity carried out simultaneously at any one time, with numerous trades working simultaneously. For example

- One group of workers can be erecting the steel beams and columns for one or two storey at the top of frame.
- Two or three storey below, another group of workers may be fixing the metal decking for the floors.
- A few storey below, another group may be concreting the floors.
- As we go down the building, another group may be tying the column reinforcing bars in cases.
- Yet another group below them may be fixing the formwork, placing the concrete into the column moulds etc.

1.3. ELEMENTS OF COMPOSITE STRUCTURE

1.3.1 SHEAR CONNECTORS

The total shear force at the interface between a concrete slab and steel beam is approximately eight times the total load carried by the beam. Therefore, mechanical shear connectors are required at the steel-concrete interface. These connectors are designed to (a) transmit longitudinal shear along the interface and, (b) prevent separation of steel beam and concrete slab at the interface.

Thus, mechanical shear connectors are provided to transmit the horizontal shear between the steel beam and the concrete slab, ignoring the effect of any bond between the two. It also resists uplift force acting at the steel interface. Commonly used types of shear connectors as per IS: 11384 –1985: Code of practice for composite construction in structural steel and concrete.

There are three main types of shear connectors;

- Rigid shear connectors,
- Flexible shear connectors
- Anchorage shear connectors.

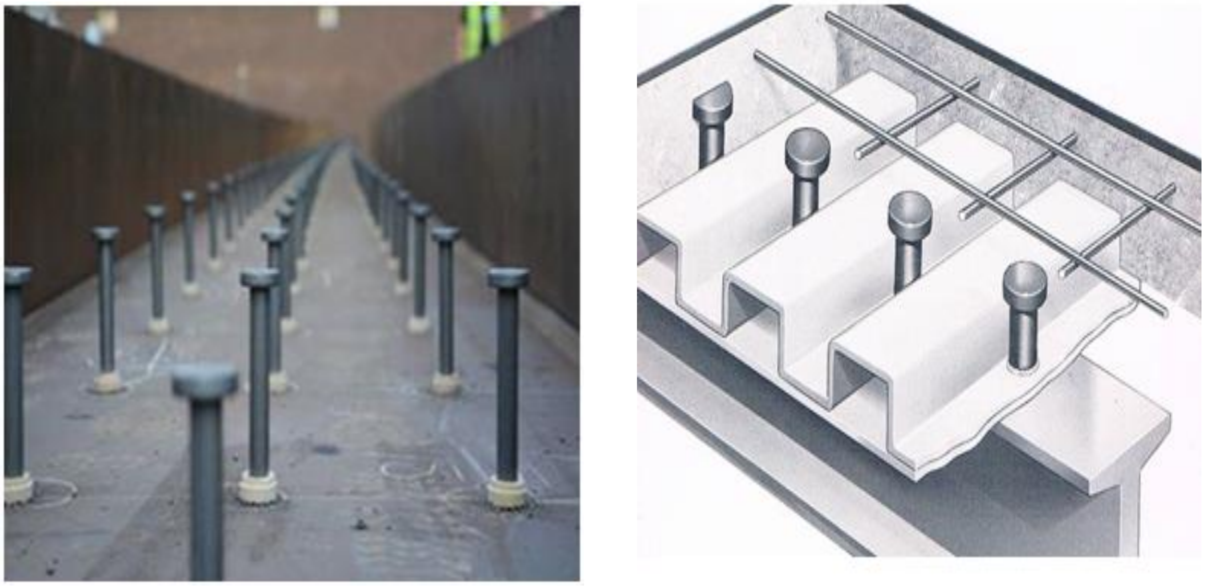


Figure 1 Shear Connectors and their Arrangement

1.3.2 PROFILED DECK

Composite floors using profiled sheet decking have become very popular in the West for high-rise buildings. Composite deck slabs are generally competitive where the concrete floor has to be completed quickly and where medium level of fire protection to steel work is sufficient.

There is presently no Indian standard covering the design of composite floor systems using profiled sheeting.

In composite floors, the structural behaviour is similar to a reinforced concrete slab, with the steel sheeting acting as the tension reinforcement. The main structural and other benefits of using composite floors with profiled steel decking are:

- Savings in steel weight are typically 30% to 50% over non-composite construction.
- Greater stiffness of composite beams results in shallower depths for the same span. Hence lower stored heights are adequate resulting in savings in classing costs, reduction in wind loading and savings in foundation costs Faster rate of construction.

  The steel decking performs a number of roles, such as:
- It supports loads during construction and acts as a working platform.
- It develops adequate composite action with concrete to resist the imposed loading.
- It transfers in-plane loading by diaphragm action to vertical bracing or shear walls.
- It stabilizes the volume of concrete in tension zone.
- It distributes shrinkage strains, thus preventing serious cracking of concrete.

Excessive ponding in long span composite floors shall be avoided by providing required propping. Otherwise, the profiled sheet deflects considerably requiring additional concrete at the centre that may add to the concreting cost.

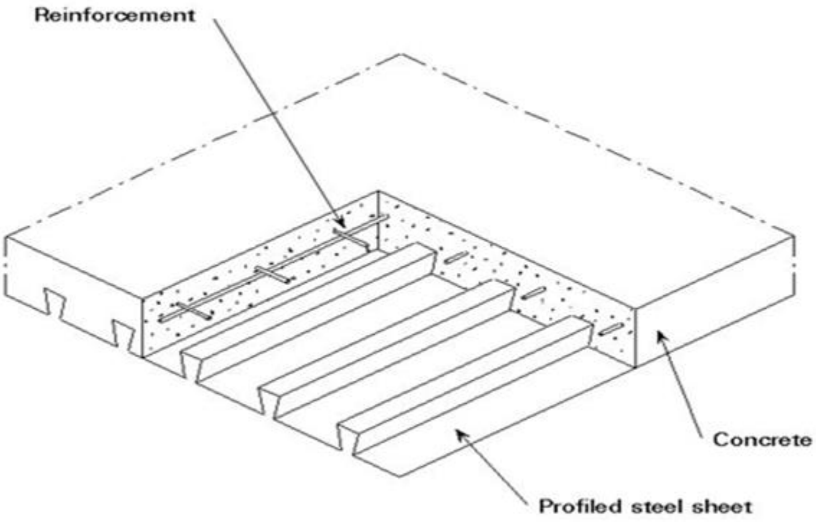


Figure 2.a Profiled Composite Slab elements

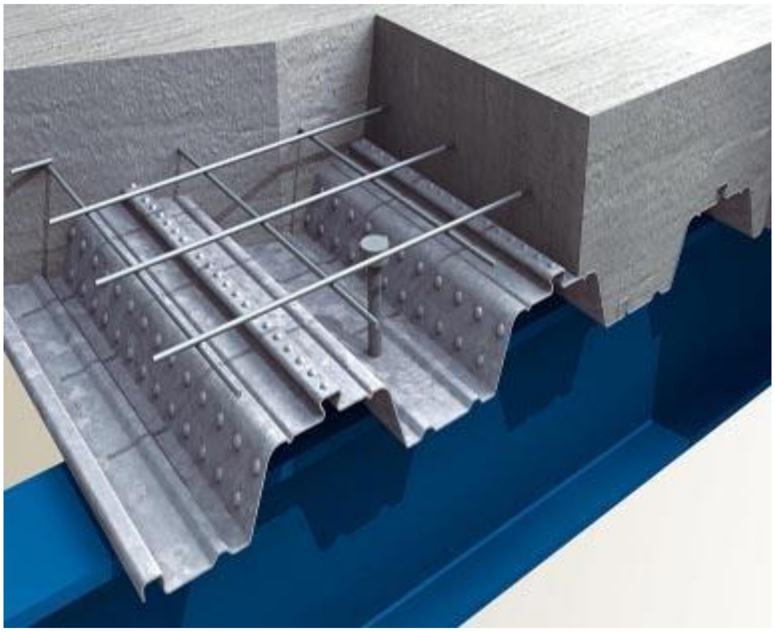


Figure 2.b Profiled Composite Slab

1.3.3 COMPOSITE BEAMS

Composite beams, subjected mainly to bending, consist of steel section acting compositely with flange of reinforced concrete. To act together, mechanical shear connectors are provided to transmit the horizontal shear between the steel beam and the concrete slab, ignoring the effect of any bond between the two materials. These also resist uplift force acting at the steel concrete interface.

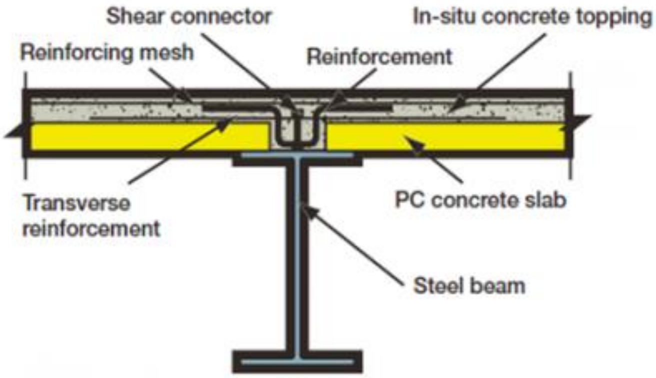


Figure 3.a Elements of Composite Beam

Figure 3.b Composite Beam

1.3.4 ENCASED COLUMNS

A composite member subjected mainly to compression and bending is called as composite column. In a composition column both the steel and concrete would resists the external loading by interacting together by bond and friction. Additional reinforcement in the concrete encasement prevents excessive spalling of concrete both under normal load and fire conditions.

Apart from speed and economy, the following other important advantages can be achieved.

- Increased strength for a given cross sectional dimension.
- Increased stiffness, leading to reduced slenderness and increased buckling resistance
- Fire resistance in the case of concrete encased columns in much better.
- Identical cross sections with different load and moment resistances can be produced by varying steel thickness. the concrete strength and reinforcement. This allows the outer dimensions of a column to be held constant over a number of floors in a building, thus simplifying the construction and architectural detailing.
- Erection of high rise building in an extremely efficient manner.
- Formwork is not required for concrete filled tubular sections.

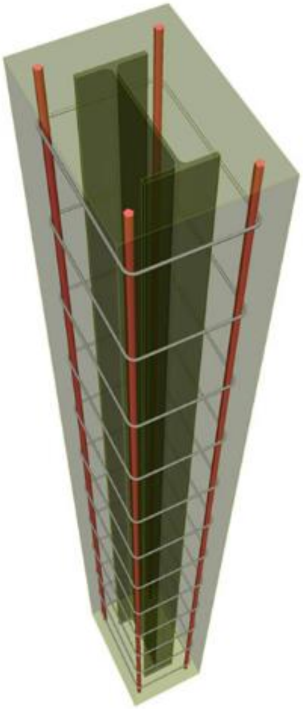


Figure 4.a Encased Composite Column

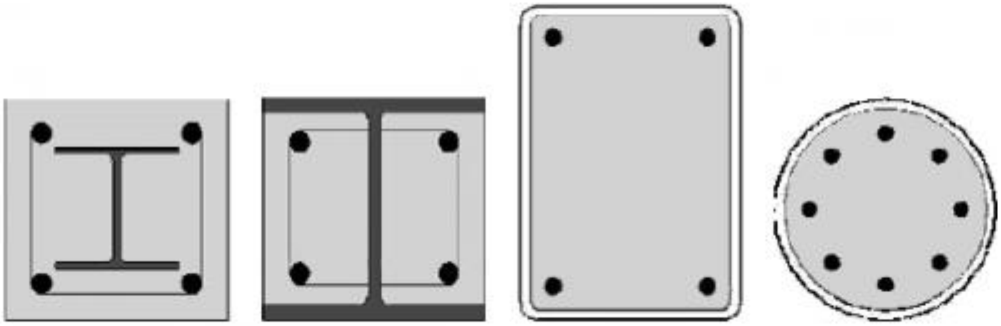


Figure 4.b Common Composite Column Plans

CHAPTER 2

REVIEW OF LITERATURE

Anamika Tedia and Dr. Savita Maru "Cost, Analysis and Design of Steel-Concrete Composite Structure RCC Structure"

Inference:-

The cost comparison reveals hat Steel-Concrete composite design structure is more costly, reduction in direct costs of steel-composite structure resulting from speedy erection will make Steel-concrete Composite structure economically viable. Further, under earthquake considerations because of the inherent ductility characteristics, Steel-Concrete structure will perform better than a conventional R.C.C. structure.

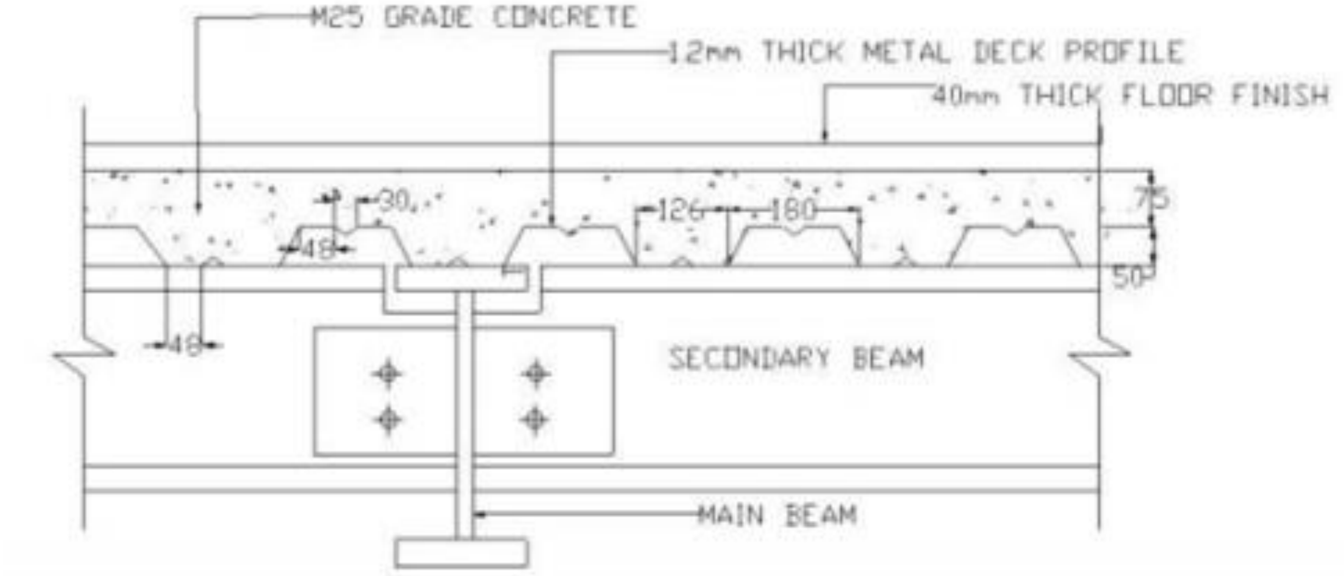


Figure 5 Profiled Decking

Anish N. Shah and Dr. P.S. Pajgade "Comparision Of R.C.C. And Comosite Multistoried Buildings"

Inference:-

Analysis and design results of G+15 storied building with composite columns and R.C.C. columns is given in chapter 6. The comparison of results of composite column building and R.C.C. column building shows that:-

1) The deflection & storey drift in composite structure is nearly double than that of R.C.C. Structure but the deflection is within the permissible limit.
2) Axial Force & Shear force in R.C.C. structure is on higher side than that of composite structure.
3) Max. bending moment in beams of composite structure is slightly on higher side in some storey's than R.C.C. Structure.Composite structures are more economical than that of R.C.C. structure.
4) Speedy construction facilitates quicker return on the invested capital & benefit in terms of rent.
5) Weight of composite structure is quite low as compared to R.C.C. structure which helps in reducing the foundation cost.

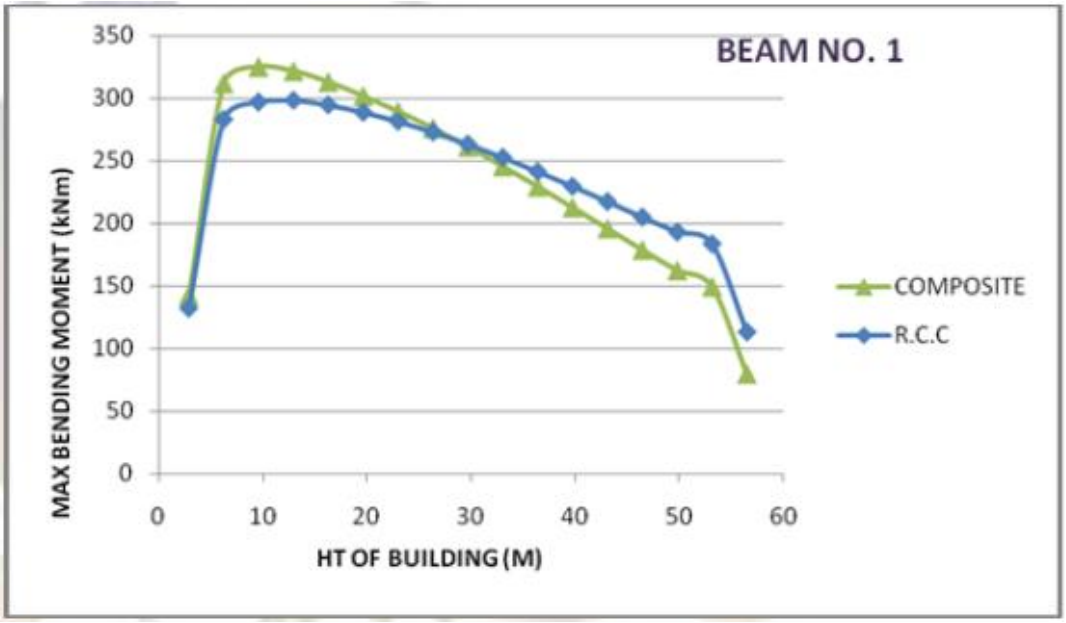


Figure 6 Comparison Of Bending Moment

Yogesh R. Suryavanshi , Prashant S. Patil Deshmukh Siddheshwar Shrikant ,Gaikwad Amol Ramrao, Inamdar Firoj Najmoddin Puri Sujay Uttam "Comparative Study On Analysis, Design And Cost Of R.C.C. And Steel-Composite Structure"

Inference:-

1) The cost comparison reveals that steel-composite design structure is somewhat same as R.C.C. structure. But reduction in direct cost of steel-composite structure resulting from speedy erection will make steel-composite structure economically viable.
2) Further under earthquake consideration because of the inherent ductility characteristics, steel-concrete structure will perform than conventional R.C.C. structure.
3) The axial forces, bending moment and deflections in R.C.C. are somewhat more as compared to the Steel-composite structure.
4) The seismic forces are also not very harmful to the Steel composite structure as compared to the R.C.C. structure, due to low dead weight.
5) There is the reduction in cost of steel structure as compared to R.C.C. structure due to reduction in dimensions of elements.
6) As the result shows steel composite option is better than R.C.C. Because composite option for high rise building is best suited. Weight of composite structure is low as compared to R.C.C. structure which helps in reducing the foundation cost.
7) As the dead weight of the steel composite structure is less as compared to R.C.C. structure, it is subjected to fewer amounts of forces induced due to the earthquake.
8) Composite structures are more economical than that of R.C.C. structure. Composite structures are the best solution for high rise structure as compared to R.C.C. structure. Speedy construction facilitates quicker return on the invested capital and benefits in terms of rent.
9) To avoid the temperature increase in these steel elements, it is necessary to make them fire resistant using various insulators.

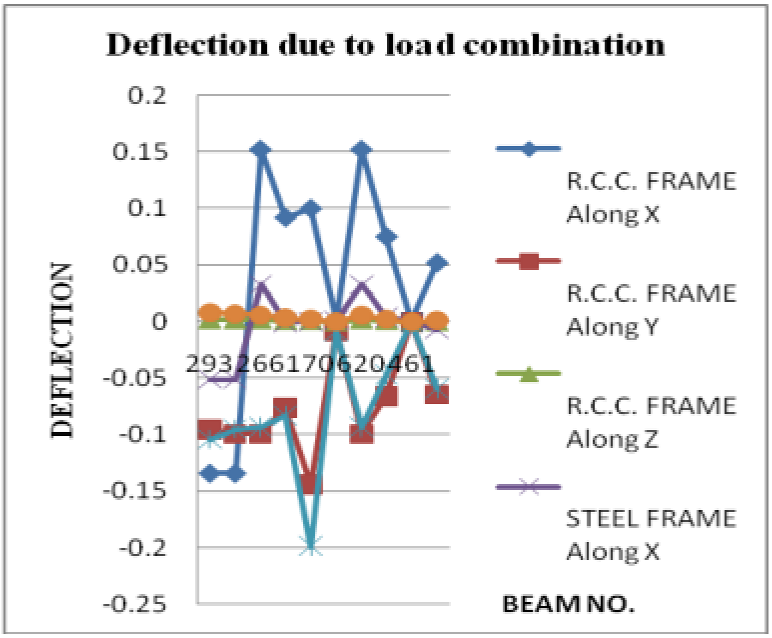


Figure 7 Deflection Due to load combination (Steel Composite Frame)

Josef Hegger, Professor Dr.-Ing "High Performance Steel And High Performance Concrete In Composite Structures"

Inference:-

1)The necessity of a reduction factor for a plastic design where High Performance Concrete (HPC) is being used.

2)Standard push-out tests have indicated a special behaviour of shear studs in high-strength concrete.

Dan Dubinia "Seismic response of composite structures including actual behaviour of beam to column joints"

Inference:-

Partial strength joints may lead to more uniform distribution of dissipated energy without requiring a large rotation capacity to classify the structure into high ductility.

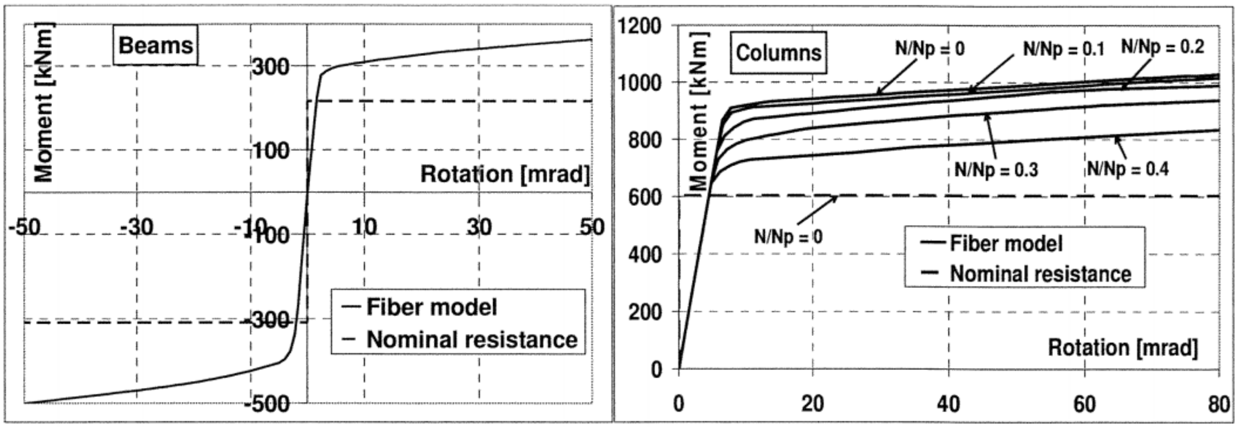


Figure 8 Resulting Moment Distribution Curves of Beams And Columns

Dr.-Ing. B. Hoffmeister "High Strength Materials In Composite Structures"

Inference:-

The paper presents a method to extend experimental pilot investigation by applying numerical methods calibrated on the test results. The evaluation of the results shows that the existing rules of Eurocode 4 may be extended to high strength materials when some modifications are considered.

Wolfgang Kurz, Christopher Kessler, "Evaluation of adhesive bonded steel concrete composite structures"

Inference:-

Composite beams with a span of 7.0 m were tested in 4 point bending test set-up.The results showed a high load capacity for these connections. Failure of concrete and adhesive failure between steel and adhesive could be observed.

Figure 9 Composite Beam During Test

Figure 10 Failure Pattern Of Composite Beams

Roberto Arroyo Matus "A High Seismic Performance Shear Connector For Composite Steel-Concrete Structures Subjected To Strong Earthquakes"

Inference:-

Under seismic solicitation, shear connectors can be affected by strong reversal loads. numerical and experimental results show that the ITW-SPIT shear connector can undergo cyclic stresses exceeding the yielding strength. Large stable deformation can be also obtained. Under static loading, ITW-SPIT shear connectors are stiffer and more resistant than in cyclic loading. ITW-SPIT connector behaviour can resist, without failure, large deformation rates.

Sabine Rauscher and Josef Hegger "Modern Composite Structures Made Of High Performance Materials"

Inference:-

Continuous shear connectors are capable of transferring high shear forces in UHPC. Due to its symmetry, the puzzle strip is a very appropriate shear connector. Depending on the thickness of the shear connector a rigid shear connection can be established with the puzzle strip. Arranging transverse reinforcement in the puzzle recesses and between the shear connectors and the concrete surface leads to an increase in ultimate load of up to 30 % and an improved ductility. In UHPC the ultimate load of the puzzle strip is doubled compared to HSC.

Shweta A. Wagh*, Dr. U. P. Waghe "Comparative Study of R.C.C and Steel Concrete Composite Structures"

Inference:-

Analysis and design of four various building can be done and comparison can be made between them and from that result conclusions can be drawn-out are as follows:-

1). In case of a composite structural system because of the lesser magnitude of the beam end forces and moments compared to an R.C.C system, one can use lighter section in a composite structure. Thus, it is reduces the self-weight and cost of the structural components.

2). Downward reaction (Fy) and bending moment in other two direction for composite structural system is less. Thus one can use smaller size foundation in case of composite construction compared to an R.C.C construction.

3). Under earthquake consideration because of inherent ductility characteristics, steel-concrete composite structure perform better than a R.C.C structure.

4). In the cost estimation for building structure no savings in the construction time for the erection of the composite structure is included. As compared to RCC structures, composite structures require less construction time due to the quick erection of the steel frame and ease of formwork for concrete. Including the construction period as a function of total cost in the cost estimation will certainly result in increased economy for the composite structure.

5). The cost comparison reveals that steel-concrete composite design structure is more economical in case of high rise buildings and construction is speedy.

CHAPTER 3

OBJECTIVES AND SCOPE OF THE PROJECT

The use of Steel in construction industry is very low in India compared to many developing countries. Experiences of other countries indicate that this is not due to the lack of economy of Steel as a construction material. There is a great potential for increasing the volume of Steel in construction, especially in the current development needs in India. Not exploring Steel as an alternative construction material and not using it where it is economical is a heavy loss for the country. Also, it is evident that now-a-days, the composite sections using Steel encased with Concrete are economic, cost and time effective solution in major civil structures such as bridges and high rise buildings. In due consideration of the above fact, this project has been envisaged which consists of

- Design of a G+4 Building as a RCC Framed Structure with symmetric plan of the building and floor height of 3.2m

- Analysis of the RCC Structure On StaadPRO.V8i for its response when subjected to Wind Loads and Seismic Loads

- Design of a G+4 Building as a Steel Framed Structure with symmetric plan of the building and floor height of 3.2m

- Analysis was done for the load combinations given below:

1. Dead load + live load

2. Dead load + live load + wind load in (+ve) x – direction

3. Dead load + live load + wind load in (- ve) x – direction

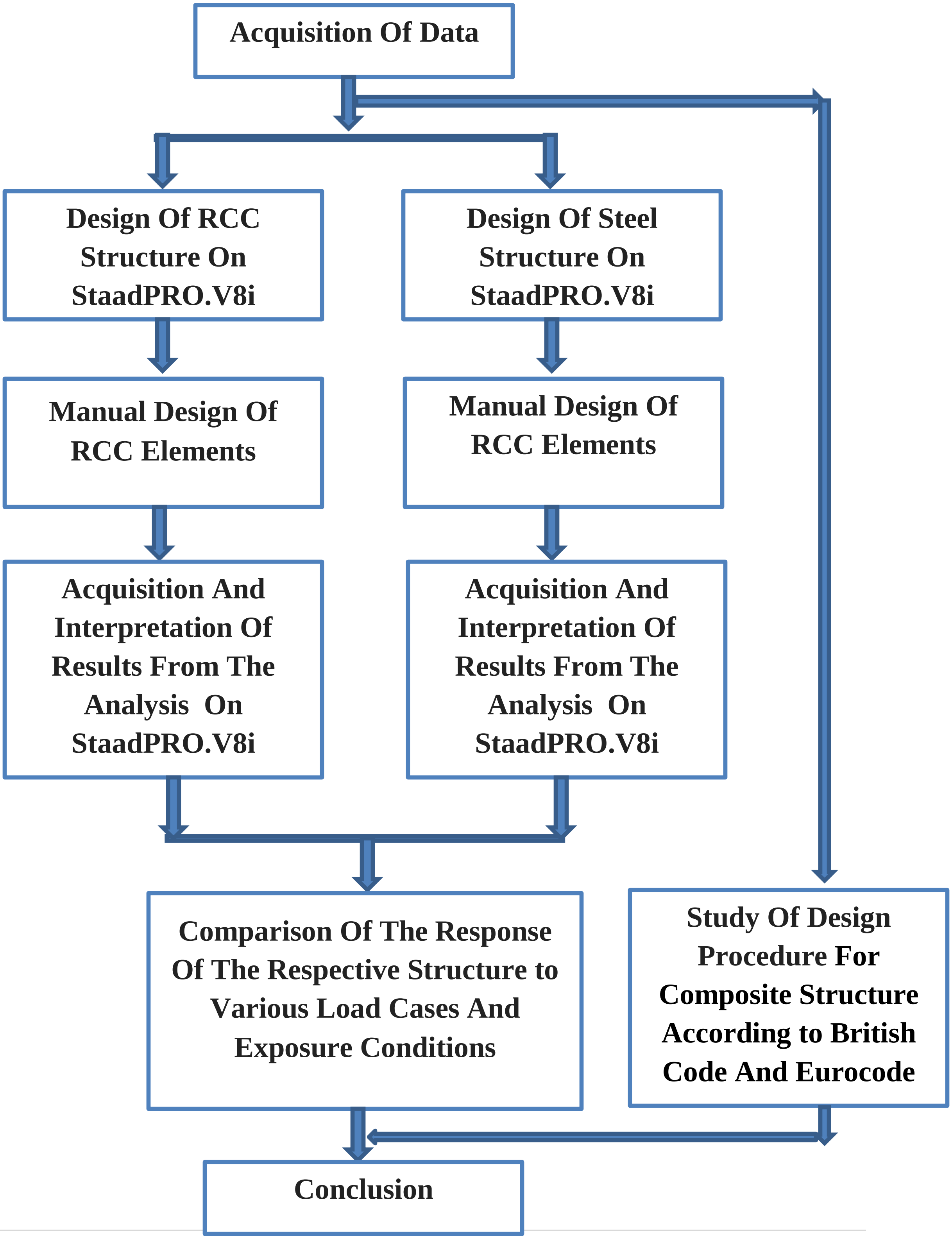
4. Dead load + live load +earthquake load in (+ ve) x – direction

5. Dead load + live load +earthquake load in (- ve) x – direction

- Analysis of the Steel Structure on StaadPRO.V8i for its response when subjected to Wind Loads and Seismic Loads.
- Study of the Results from the analysis done and comparison of the responses of the individual structure to the exposed conditions and load cases.
- Study of Design Procedure for Composite Structure elements in accordance to British and Eurocode.

CHAPTER 4

METHODOLOGY



4.1 DATA FOR DESIGN AND ANALYSIS OF FRAMED STRUCTURE

S.NO	PARTICULARS	DIMENTION/SIZE/VALUE
1.	Model	G+4
2.	Seismic Zone Factor	0.24 (Zone IV)
3.	Floor Height	3.2m
4.	Depth Of Foundation	1.5m
5.	Building Height	16m
6.	Plan Size	12m*12m
7.	Total Area	144 Sq.m
8.	Earthquake Load	As per IS-1893-2002
9.	Type Of Soil	Type -II, Medium soil as per IS-1893
10.	E_c	5000√fck N/ mm2(E_c is short term static modulus of elasticity in N/ mm^2)
11.	F_{ck}	0.7√fc k N/ mm2(F_{ck} is characteristic cube strength of concrete in N/ mm^2
12.	Live Load	2 kN/ m^2 as per IS : 875 (Part II)-1987
13.	Floor Finish	1.00kN/ m^2
14.	Specific Weight Of RCC	25.00 kN/ m^2
15.	Specific Weight Of Infill	20.00 kN/ m^2
16.	Material Used	Concrete M-30and Reinforcement Fe-415(HYSD Confirming to IS-1786)
17.	Reinforcement Used	High strength deformed steel Confirming to IS-786. It is having modulus of Elasticity as 200 kN/ mm^2
18.	Static Analysis	Equivalent static lateral force method.
19.	Software Used	STAAD-Pro for static analysis, MS Excel For Excel Sheets
20.	Specified Characteristics	Compressive strength of 150mm cube at 28 days for M-30grade concrete-30N/ mm^2
21.	Importance Factor	1
22.	Fundamental Naural Time Period Of Building	Ta = 0.075 h0.75 for moment resisting RC frame building without infill's Ta = 0 .09 h/√d for all other building i/c moment resisting RC frame building with brick infill walls Where h = height of building d = base dimension of building at plinth level in m along the considered direction of lateral forces.

Table 1 Design Data For Framed Structure

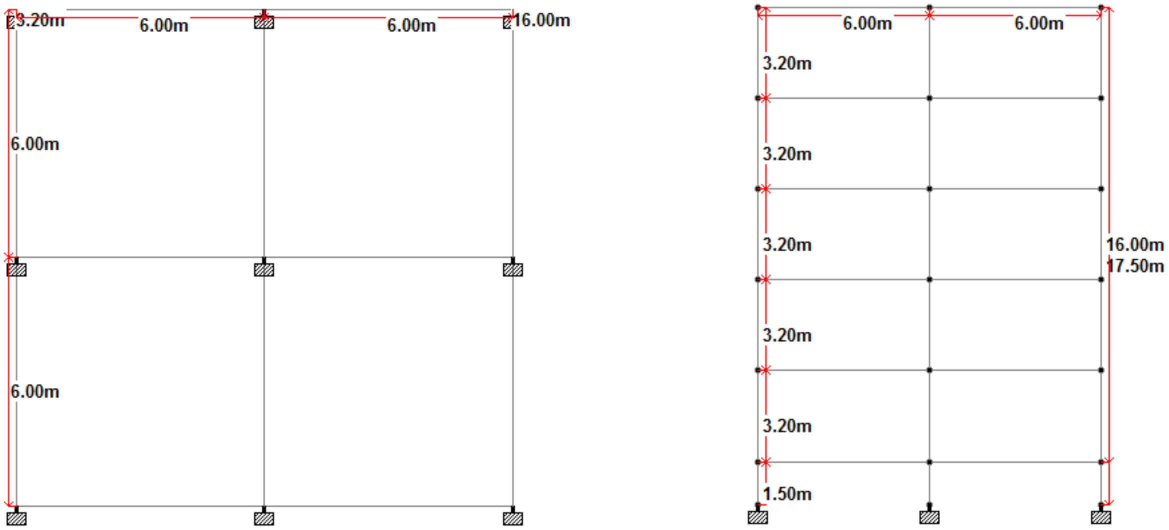


Figure 11 Plan and Elevation of the Structure

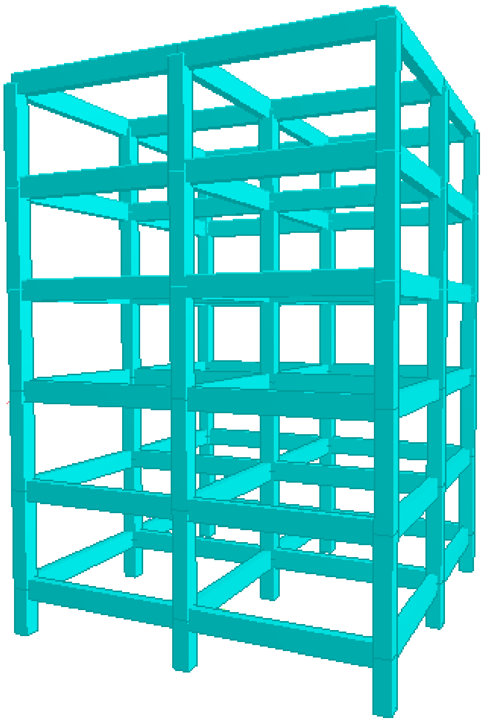


Figure 12 3-D Rendered view of structure.

4.2 DESIGN LOAD DETAILS :-

4.2.1 Dead Load and Live Load :-

At Any Floor Level :-

Load Type	**Intensity (kN/m^2)**
Load From Slab	4.75
Floor Finish	1
Total Dead Load(IS 875 (Part I)-1987)	5.75
Live Load(IS : 875 (Part II)-1987)	2
Total Load	7.75
Total Factored Load	11.65

Table 2 Dead Load and Live Load At Any Floor Level

At Roof Of Top Floor Level :-

Load Type	**Intensity (kN/m^2)**
Load From Slab	4.75
Floor Finish	1
Total Dead Load(IS : 875 (Part II)-1987)	5.75
Live Load(IS 875 (Part I)-1987)	1
Total Load	6.75
Total Factored Load	10.12

Table 3 Dead Load and Live Load At Roof Of Top Floor Level

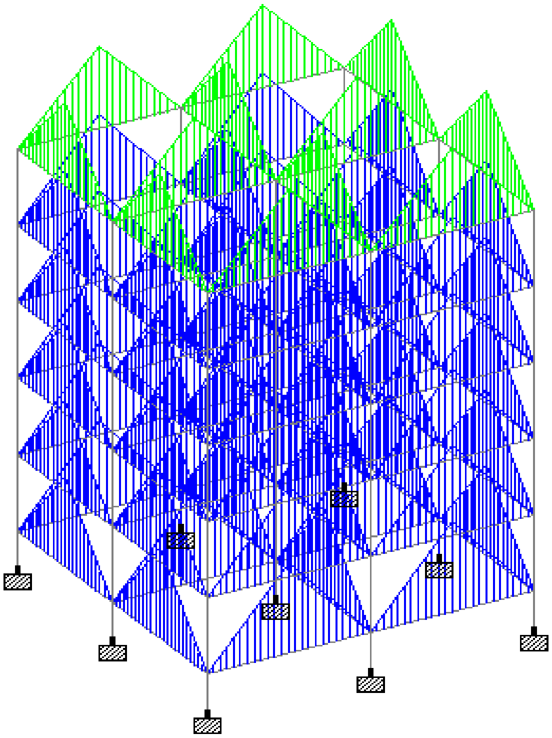


Figure 13 Dead load on Structure

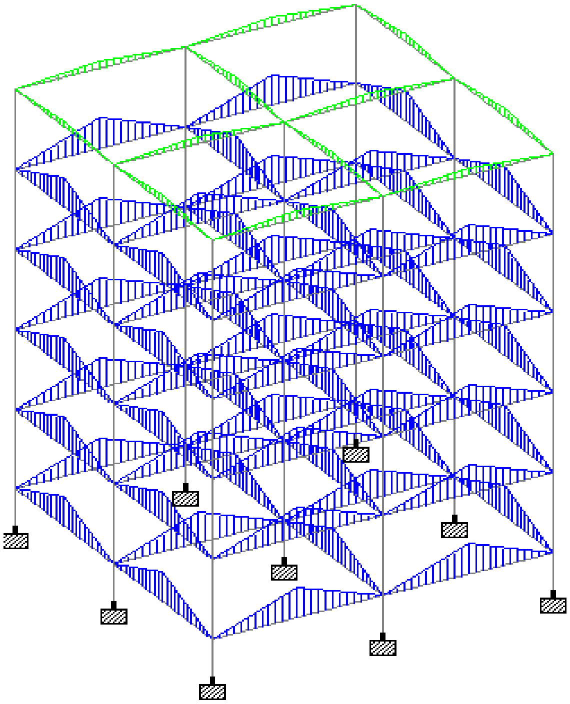


Figure 14 Live load on Structure

4.2.2 Wind Load (IS 875 (Part I)-1987):-

Location	Chandigarh
Basic Wind Speed (V_b)	47 m/s
Design Life	50 Years
Risk Factor (K_1)	1.0
Terrain Type	Category 3
Topography Factor (K_3)	1.0
Upwind Slope	<3 (Assumed)
Height Of Structure	16m

Table 4 Wind Load Parameters

Design Wind Speed ($V_{z)}$= $V_b * K_1 * K_2 * K_3$

Design Wind Pressure (P_z)= $0.6* V_z^2$

<u>Wind Loads-Parallel To Either Direction :-</u>

Height (m)	**K_2**	**V_z (m/s)**	**P_z (kM/m^2)**
1-10	0.91	43.19	1.12
11	0.92	43.76	1.15
12	0.93	44.33	1.18
13	0.95	44.90	1.20
14	0.96	45.47	1.24
15	0.97	46.04	1.27
16	1.01	47.94	1.38
17	1.05	9.84	1.50
18	1.09	51.74	1.60

Table 5 Wind Loads-Parallel To Either Direction

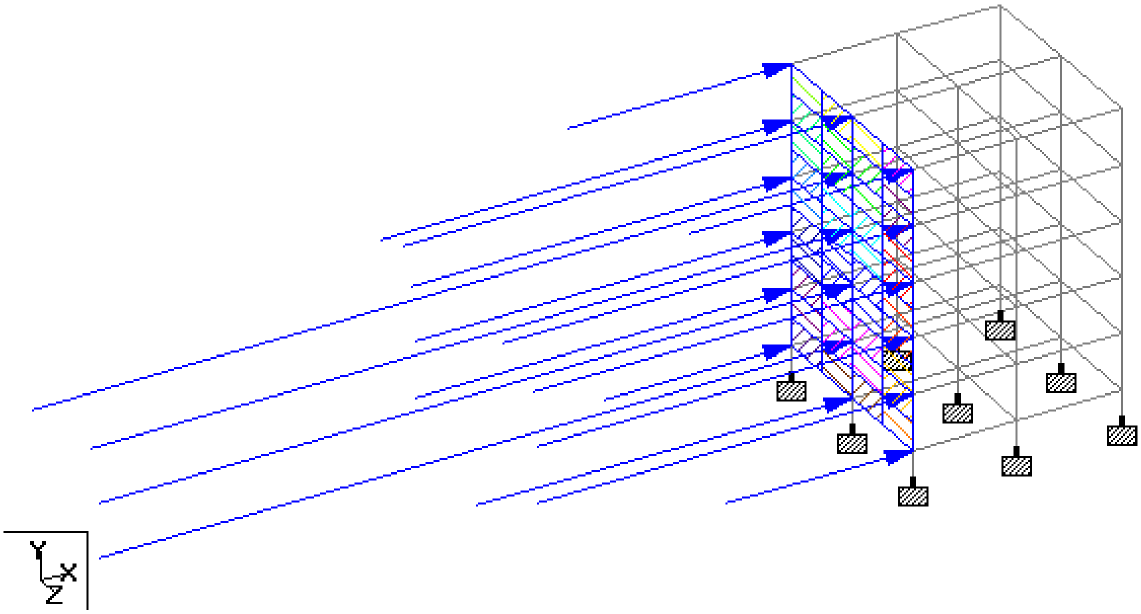


Figure 15 Wind Load On Structure parallel to x direction

4.2.3 Seismic Load (IS:1893(Part I) : 2002):-

1. The city of Chandigarh falls under Zone IV

Zone Factor (Z) = 0.24

Importance Factor (I) = 1.0

Approximate Fundamental Period = $0.09 * H / D^{1/2}$

$= 0.09 * 16 / 12^{1/2}$

$= 0.45$ s

2. Base Shear

$$V_B = K C\alpha W$$

V_B = Base shear

Performance Factor = 1.3

C = a coefficient which depends upon the fundamental time periods

β = A factor depending upon the soil foundation system = 1.2

Basic horizontal seismic coefficient (α_0) = 0.04

Design seismic Coefficient (α_h) = $\beta\ \alpha_0$ I =0.072

Total Load on any floor = 1075.5 kN

Total load on the roof = 1003.5 kN

Total Load = 6205.5 kN

V_B = 582.44 kN

3. Calculation of Lateral Forces

$$Q_i = V_B\ W_{ihi}^2 / \sum W_{ihi}^2$$

Q_i = Lateral Force at floor i

W_i = Load on the floor i

h_i = Height measured from the base of the building to the floor i

<u>Calculation Of Lateral Forces:-</u>

Floor	**h_i (m)**	**w_i (kN)**	**w_i*h_i^2**	**Q_i**
Ground	3.2	1075.5	11013.12	10.58
1	6.4	1075.5	44052.48	42.35
2	9.6	1075.5	99118.08	95.30
3	12.8	1075.5	176209.92	169.4
4	16	1003.5	275328	264.7
			∑= 605721.6	∑=582.375

Table 6 Calculation Of Lateral Forces

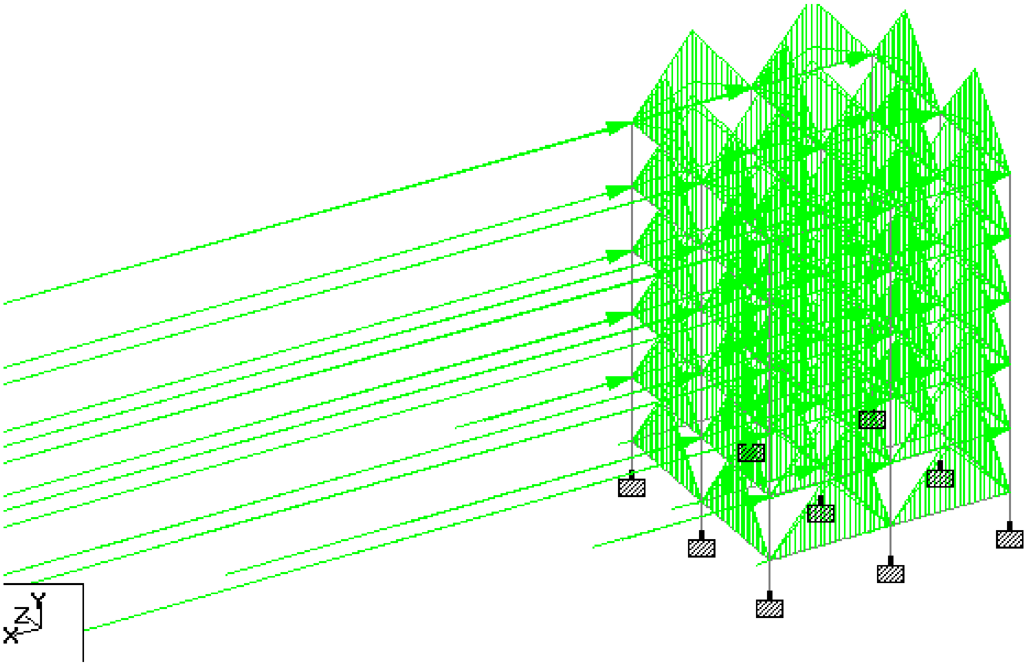


Figure 16 Seismic Loads on Structure parallel to x direction

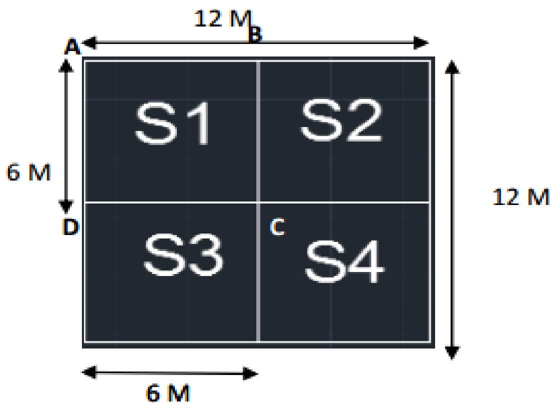
Chapter 5

DESIGN ELEMENTS OF STRUCTURES

5.1 DESIGN OF RCC ELEMENTS.

5.1.1 Design For RCC Slab(Top Floor):-

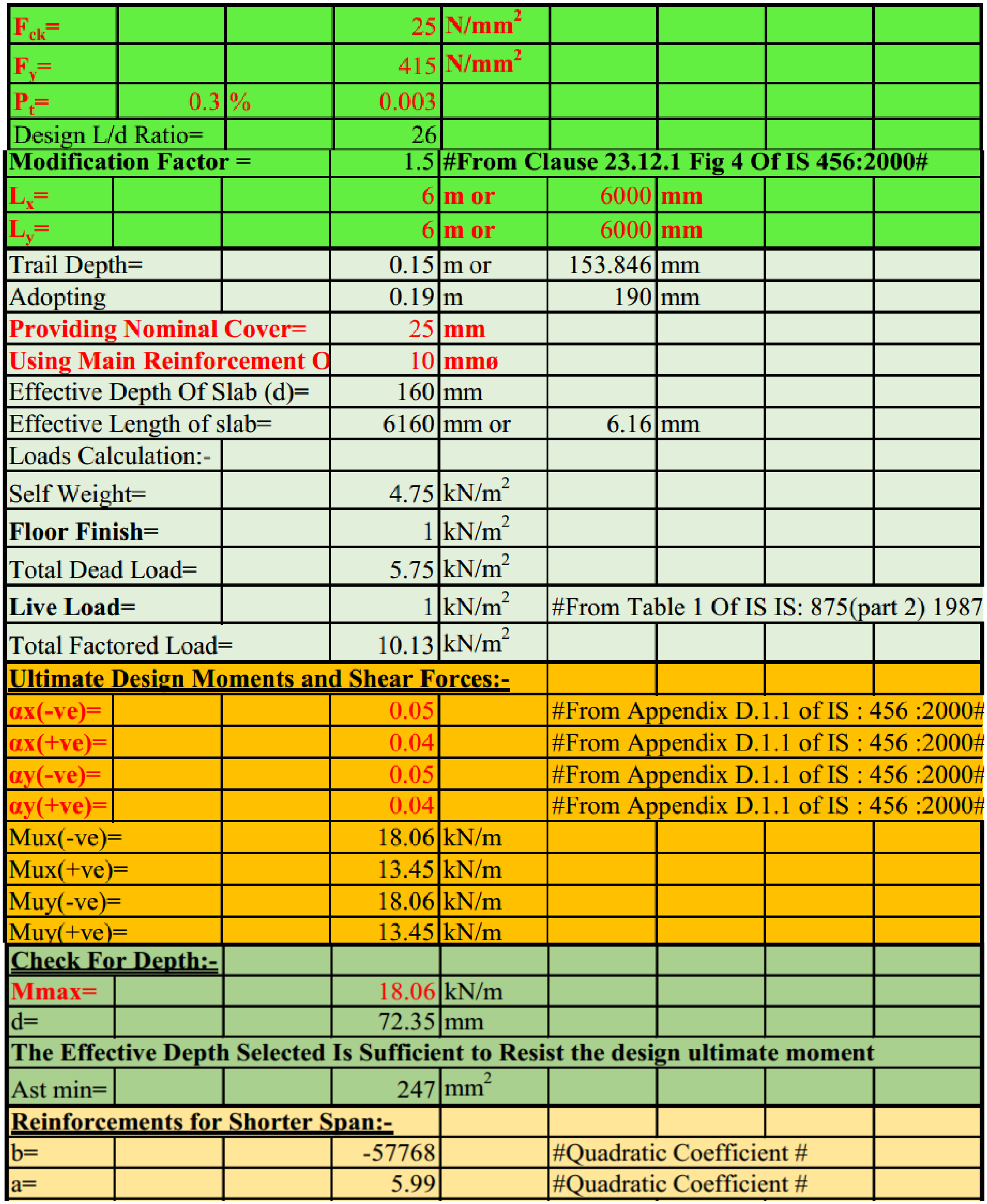
Design Of Two Way Slab Supported On Beams (For Top Floor)



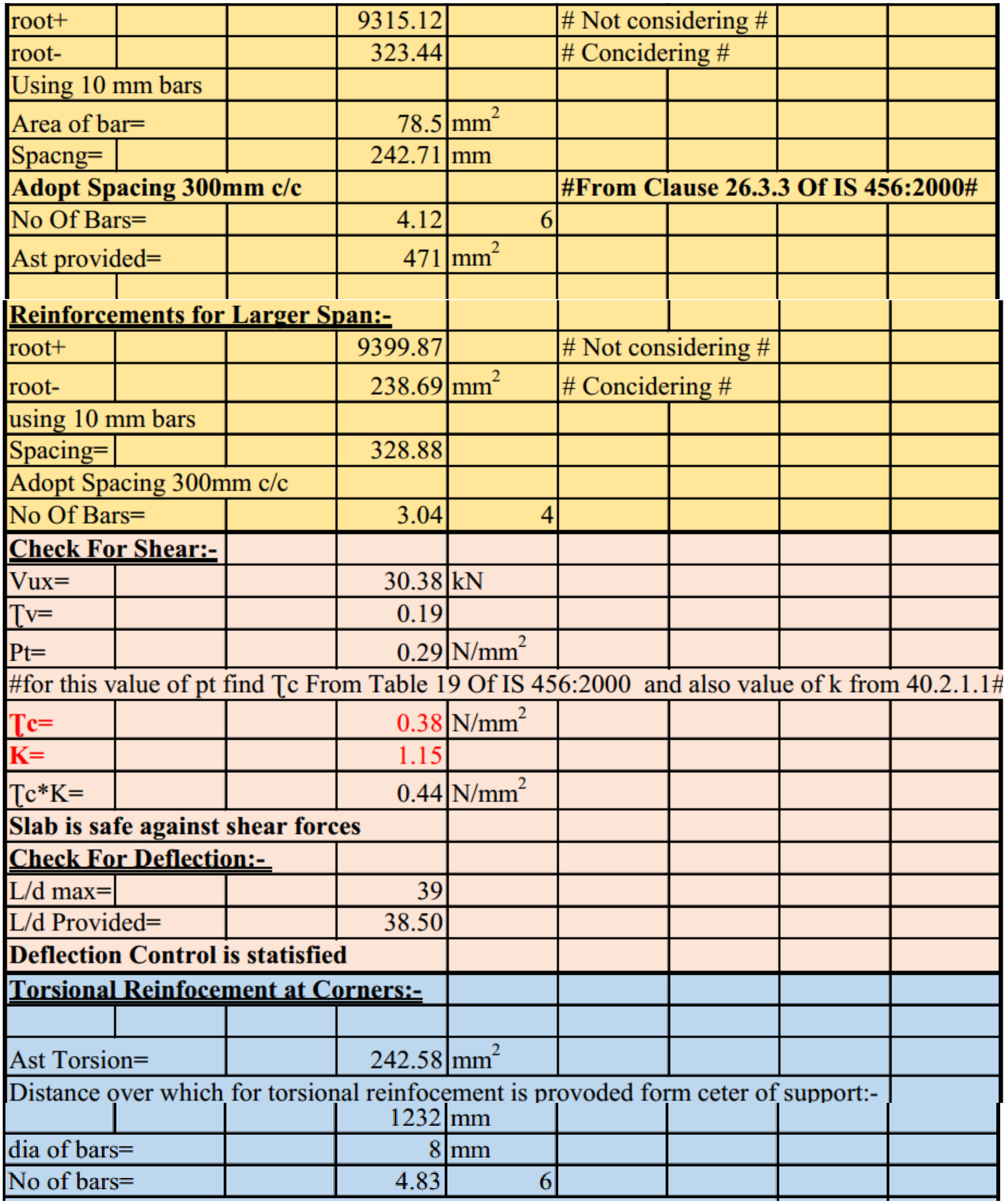
List Of Symbols:-

F_{ck} :-	Characteristic Compressive Strength Of Concrete
F_y :-	Characteristic Strength Of Steel
L_x :-	Length Of Shorter Side Of Slab
L_y :-	Length Of Longer Side Of Slab
αx(-ve) :-	Moment Coefficient
αx(+ve) :-	Moment Coefficient
αy(-ve) :-	Moment Coefficient
αy(+ve) :-	Moment Coefficient
M_{ux}(+ve) :-	max +ve moment on the strip of unit width spanning in shorter span
M_{ux}(-ve) :-	max -ve moment on the strip of unit width spanning in shorter span
M_{uy}(+ve) :-	max +ve moment on the strip of unit width spanning in larger span
M_{uy}(-ve) :-	max -ve moment on the strip of unit width spanning in larger span
M_{max} :-	Max bending moment on Slab
Ast_{min} :-	Min value of reinforement
V_{ux} :-	Max Shear Force
τ_v :-	Max shear Stress
P_t :-	Percentage OF steel
τ_c :-	Permissible shear Stress
K :-	Modification Factor

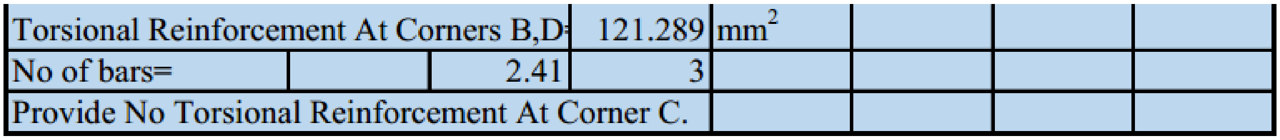
 # As the Ly/Lx Ratio is Less Than 2 Therefore Slab (Slab Mark S1) Is To Be Designed As Two As Two Way Slab Also The Load Dirtribution Pattern Is Traingular For All 4 Sides #



F_{ck}=			25	N/mm^2				
F_y=			415	N/mm^2				
P_t=	0.3	%	0.003					
Design L/d Ratio=			26					
Modification Factor =			1.5	**#From Clause 23.12.1 Fig 4 Of IS 456:2000#**				
L_x=			6	**m or**	6000	**mm**		
L_y=			6	**m or**	6000	**mm**		
Trail Depth=			0.15	m or	153.846	mm		
Adopting			0.19	m	190	mm		
Providing Nominal Cover=			25	**mm**				
Using Main Reinforcement O			10	**mmø**				
Effective Depth Of Slab (d)=			160	mm				
Effective Length of slab=			6160	mm or	6.16	mm		
Loads Calculation:-								
Self Weight=			4.75	kN/m^2				
Floor Finish=			1	kN/m^2				
Total Dead Load=			5.75	kN/m^2				
Live Load=			1	kN/m^2	#From Table 1 Of IS IS: 875(part 2) 1987			
Total Factored Load=			10.13	kN/m^2				
Ultimate Design Moments and Shear Forces:-								
αx(-ve)=			0.05		#From Appendix D.1.1 of IS : 456 :2000#			
αx(+ve)=			0.04		#From Appendix D.1.1 of IS : 456 :2000#			
αy(-ve)=			0.05		#From Appendix D.1.1 of IS : 456 :2000#			
αy(+ve)=			0.04		#From Appendix D.1.1 of IS : 456 :2000#			
Mux(-ve)=			18.06	kN/m				
Mux(+ve)=			13.45	kN/m				
Muy(-ve)=			18.06	kN/m				
Muy(+ve)=			13.45	kN/m				
Check For Depth:-								
Mmax=			18.06	kN/m				
d=			72.35	mm				
The Effective Depth Selected Is Sufficient to Resist the design ultimate moment								
Ast min=			247	mm^2				
Reinforcements for Shorter Span:-								
b=			-57768		#Quadratic Coefficient #			
a=			5.99		#Quadratic Coefficient #			



root+			9315.12		# Not considering #			
root-			323.44		# Concidering #			
Using 10 mm bars								
Area of bar=			78.5	mm^2				
Spacng=			242.71	mm				
Adopt Spacing 300mm c/c					**#From Clause 26.3.3 Of IS 456:2000#**			
No Of Bars=			4.12	6				
Ast provided=			471	mm^2				
Reinforcements for Larger Span:-								
root+			9399.87		# Not considering #			
root-			238.69	mm^2	# Concidering #			
using 10 mm bars								
Spacing=			328.88					
Adopt Spacing 300mm c/c								
No Of Bars=			3.04	4				
Check For Shear:-								
Vux=			30.38	kN				
Ʈv=			0.19					
Pt=			0.29	N/mm^2				
#for this value of pt find Ʈc From Table 19 Of IS 456:2000 and also value of k from 40.2.1.1#								
Ʈc=			0.38	N/mm^2				
K=			1.15					
Ʈc*K=			0.44	N/mm^2				
Slab is safe against shear forces								
Check For Deflection:-								
L/d max=			39					
L/d Provided=			38.50					
Deflection Control is statisfied								
Torsional Reinfocement at Corners:-								
Ast Torsion=			242.58	mm^2				
Distance over which for torsional reinfocement is provoded form ceter of support:-								
			1232	mm				
dia of bars=			8	mm				
No of bars=			4.83	6				



Torsional Reinforcement At Corners B,D=			121.289	mm^2			
No of bars=		2.41	3				
Provide No Torsional Reinforcement At Corner C.							

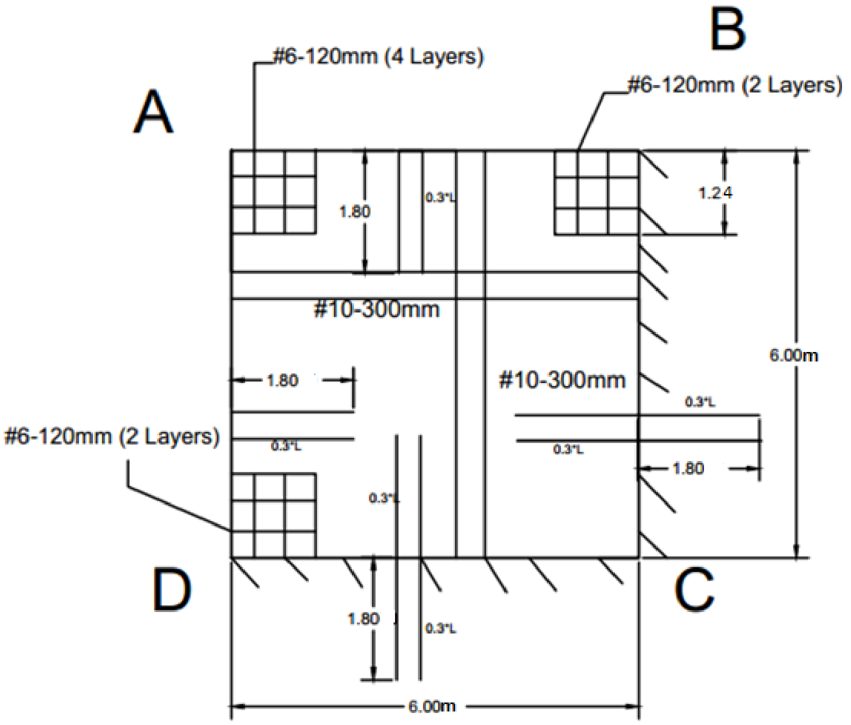


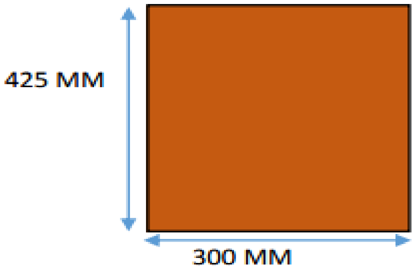
Figure 17 Reinforcement Details Of Top Floor Slab

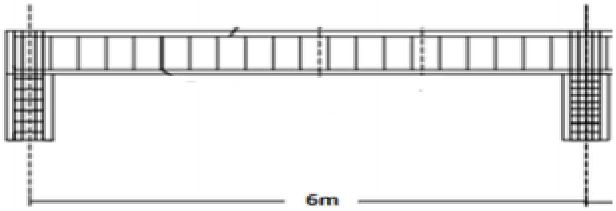
Main Reinforcement	10mm—5 Bars @ 300mm c/c Along Lx. 10mm—5 Bars @ 300mm c/c Along Ly.
Torsional Reinforcement	**Corner A**--6mm—6 Bars @ 120mm c/c In 4 Layers. Provided Till Distance of 1238mm From The Center Of Support. **Corner B,D--** 6mm—3 Bars @ 120mm c/c In 2 Layers. Provided Till Distance of 1238mm From The Center Of Support.

. **Table 7** Reinforcement Details Of Top Floor Slab

5.1.2 Design For RCC Beam:-

Design Of Exterior Beam (For TOP FLOOR)



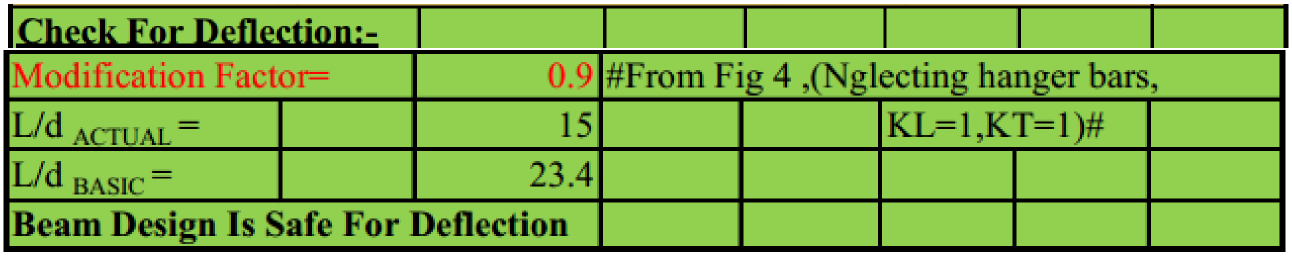


List Of Symbols:-

F_{ck} :-	Characteristic Compressive Strength Of Concrete
F_y :-	Characteristic Strength Of Steel
$M_{u\ (-ve)}$:-	Negative B.M at Interior Support
$M_{u\ (+ve)}$:-	Psitive B.M at Centre Of Span
V_u :-	Maximum Shear Force At Support
M_{uLim} :-	Limiting Moment Of Resistence
A_{st} :-	Area Of Steel
T_v :_	Shear Stress In Section
T_c :-	Permissible Shear Stress
P_t :-	Percentage Of Steel
V_{us} :-	Total Shear Stress

F_{ck}=			25	N/mm^2	**#Char comp strength of concrete#**			
F_y=			415	N/mm^2	**#Charactristic strength ofSteel#**			
Design L/d Ratio=			15		#From Clause 23.12.1 Of IS 456:20			
Effective Length Of Beam			6000	mm or	6	m		
Cross Sectional Dimentions:-								
Effective depth=			400	mm or	0.4	m		
Clear Cover =			25	mm or	0.025	m		
Overall Depth=			425	mm or	0.425	m		
Widh Of Beam=			300	mm or	0.3	m		
Laods Calculation:-								
Self Weight=			3.19	kN/m^2				

Imposed Wall Load=			1.91	kN/m^2				
Total Factord Dead Load=			7.65	kN/m^2				
Live Load=			19.13	kN/m^2				
Bending Moment and Shear Forces:-								
Negative B.M at Interior Support:-								
$M_{u\ (-ve)}$ =			156.04	kN/m				
Psitive B.M at Centre Of Span:-								
$M_{u\ (+ve)}$ =			137.68	kN/m				
Maximum Shear Force At Support:-								
V_u=			144.56	kN				
Limiting Moment Of Resistence:-								
$M_u$lim=			165.6	kN				
The Section Is UnderReinforced								
Main Reinforcements (-ve):-								
b=			-144420		# Quadratic Coefficients#			
a=			19.98		# Quadratic Coefficients#			
Ast=			1322.35	mm^2				
Using	25	mm Bars						
Number Of Bars=			2.70	3	bars			
Ast Provided =			1471.875	mm^2				
Reinforcements at the mid span (+ve):-								
Ast=			1129.99	mm^2				
Using	20	mm Bars						
Number Of Bars=			3.60	4	bars			
Ast Provided =			1256	mm^2				
Shear Reinforcements:-								
τ_v=			1.20	N/mm^2				
Pt=			1.23					
Tc=			0.70	#From table 19 Permissible Shear Stress#				
Shear Reinforcements Are to be Designed								
$V_{us=}$			61.16	kN				
Using	8	mm ø Two Legged Stirrups						
Spacing=			355.87	mm				
Provide Two Legged Stirrups at 300mm Spacing Throughout the beam								



Check For Deflection:-							
Modification Factor=		0.9	#From Fig 4 ,(Nglecting hanger bars,				
L/d $_{\text{ACTUAL}}$ =		15			KL=1,KT=1)#		
L/d $_{\text{BASIC}}$ =		23.4					
Beam Design Is Safe For Deflection							

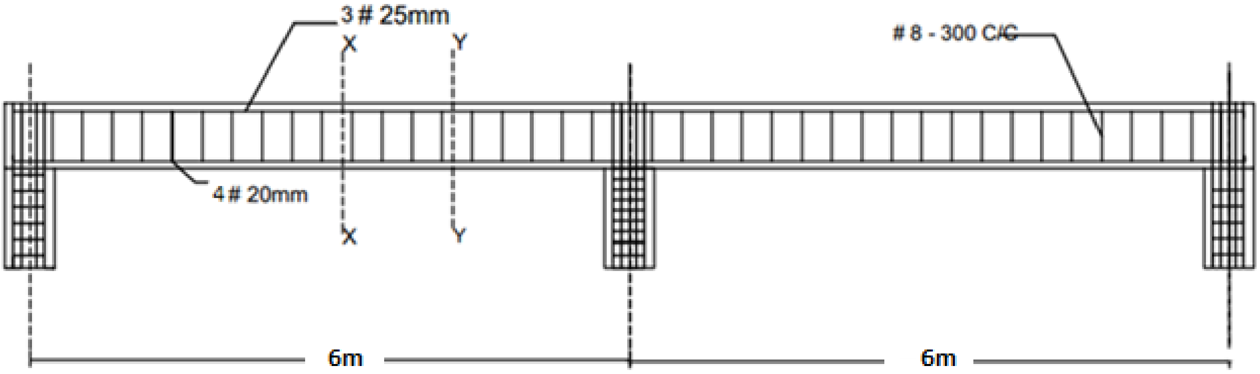


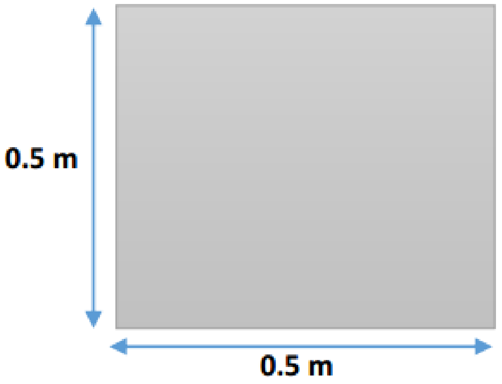
Figure 18 Reinforcement Details Of Continuous Beam (Exterior Top Floor)

Reinforcements Near Support	3—25mm Bars @ 100mm c/c
Reinforcements At Mid Span	4—20mm Bars @ 67mm c/c
Shear Reinforcements	8mm 2 Legged Stirrups @ 300mm c/c Throughout Beam.

Table 8 Reinforcement Details Of Continuous Beam (Exterior Top Floor)

5.1.3 Design For RCC Column:-

Design Of Column For Ground Floor



List Of Symbols:-

F_{ck} :-	Characteristic Compressive Strength Of Concrete
F_y :-	Characteristic Strength Of Steel
b:-	Shorter Dimention Of Column
D:-	Larger Dimention Of Column
d' :-	Depth Of Compression Reinforcemnt From Highly Compressed Face
P_u :-	Designed Axial Load (Factored)
M_{ux} :-	Design Moment About XX-Axis
M_{uy} :-	Design Moment About YY-Axis
M_{ux1} :-	Max Uniaxial Capacity Of Section with Axial Load, Bending Moment about XX-Axis
M_{uy1} :-	Max Uniaxial Capacity Of Section with Axial Load, Bending Moment about YY-Axis
A_s :-	Area Of Steel
A_c :-	Area Of Cross Section
P :-	Percentage Of Steel
α_n :-	Cofficient

#There Are Three Types Of Columns To Be Designed For A Single Storey i.e Axial, Uniaxial, Biaxial. Threfore Designing A Single Column For All Columns Of The Single Floor With Max

Bending Moment And Max Axial Load Of All The Columns On A Perticular Story For Worse Case Senario #

Design Data :-								
b=			500	mm				
D=			500	mm				

d'=			50	mm				
F_{ck} =			25	N/mm^2				
F_y =			415	N/mm^2				
P_u =			3262.52	kN				
M_{ux} =			70.82	kNm				
M_{uy}=			70.82	kNm				
d'/D=			0.1					
Calculation Of Reinforcements:-								
Assuming % Of Steel =			1.5	%				
A_s =			3750	mm^2				
Dia Of Bars Used=			20	mm				
No Of Bars=			11.94	12				
Area Of Steel Provided=			3768	mm^2				
Check For Design:-								
p=			1.507					
p/F_{ck} =			0.06		#Non-Dimentional Parameter#			
$P_u/(F_{ck}*b*d)$=			0.52		#Non-Dimentional Parameter#			
# Refer Chart 44 Of IS SP 16 TO Calculate a non-Dimentional Parameter "$M_{ux1}/(F_{ck}*b*D^{2)}$"								
Corresponding to the Ratio $P_u/(F_{ck}*b*d)$ and d'/D and p/F_{ck} #								
$M_{ux1}/(F_{ck}*b*D^2)$=			0.07					
M_{ux1}=			218.75	kNm				
d'/b=			0.1					
#Refer Chart 44 Of IS SP 16 TO Calculate a non-Dimentional Parameter "$M_{uy1}/(F_{ck}*b*D^{2)}$"#								
Corresponding to the Ratio $P_u/(F_{ck}*b*d)$ and d'/D and p/F_{ck} #								
$M_{uy1}/(F_{ck}*b*D^2)$=			0.07					
M_{uy1} =			218.75	kNm				
A_c =			250000	mm^2				
P_{uz} =			3942.9	kN				
Ratio=			0.83					
α_n=			2	#Calculate α_n Corresponding to ratio P_u/P_{uz} #				
Design Ratio=			0.21					
Design Is Safe								

Details Of Ties Provided:-			
Tie Diameter=		5	mm
Using Diameter=		6	mm
Provide 6 mm Diameter @ 300 mm c/c Stirrups			

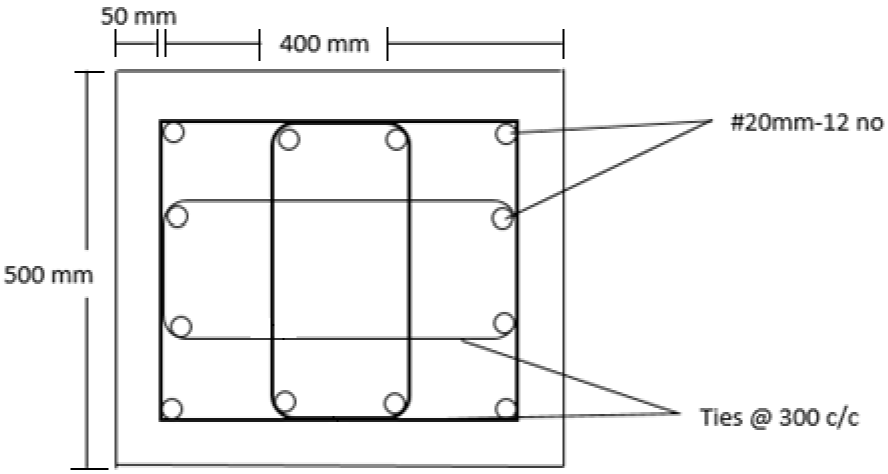


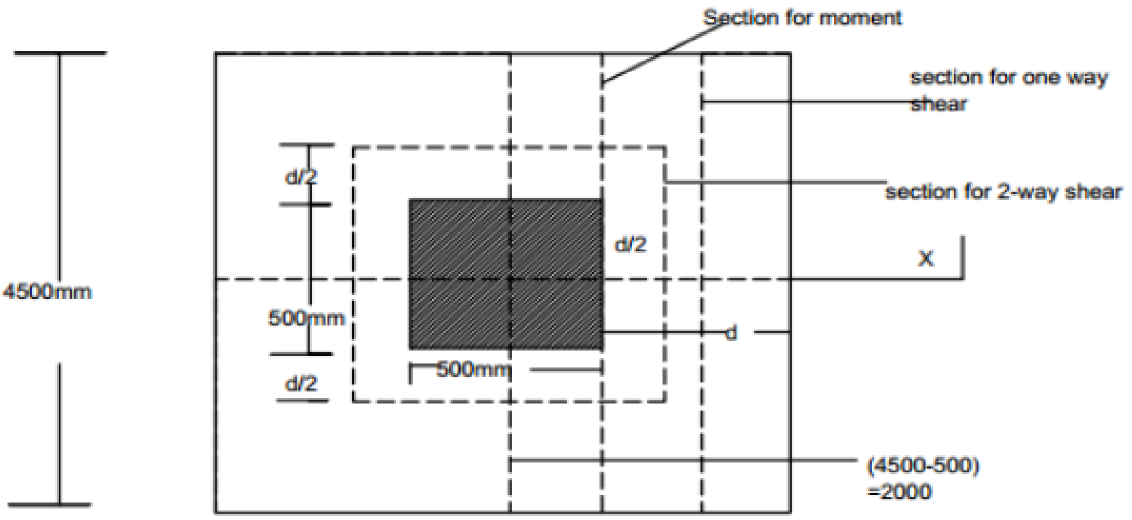
Figure 19 Reinforcement Details Of Column (Ground Floor)

Longitudinal Reinforcement	12—20mm (Four On Each Face)
Shear Reinforcement	6mm Stirrups @ c/c mm Throughout The Column

Table 9 Reinforcement Details Of Column (Ground Floor)

5.1.4 Design For Foundation Of RCC Structure:-

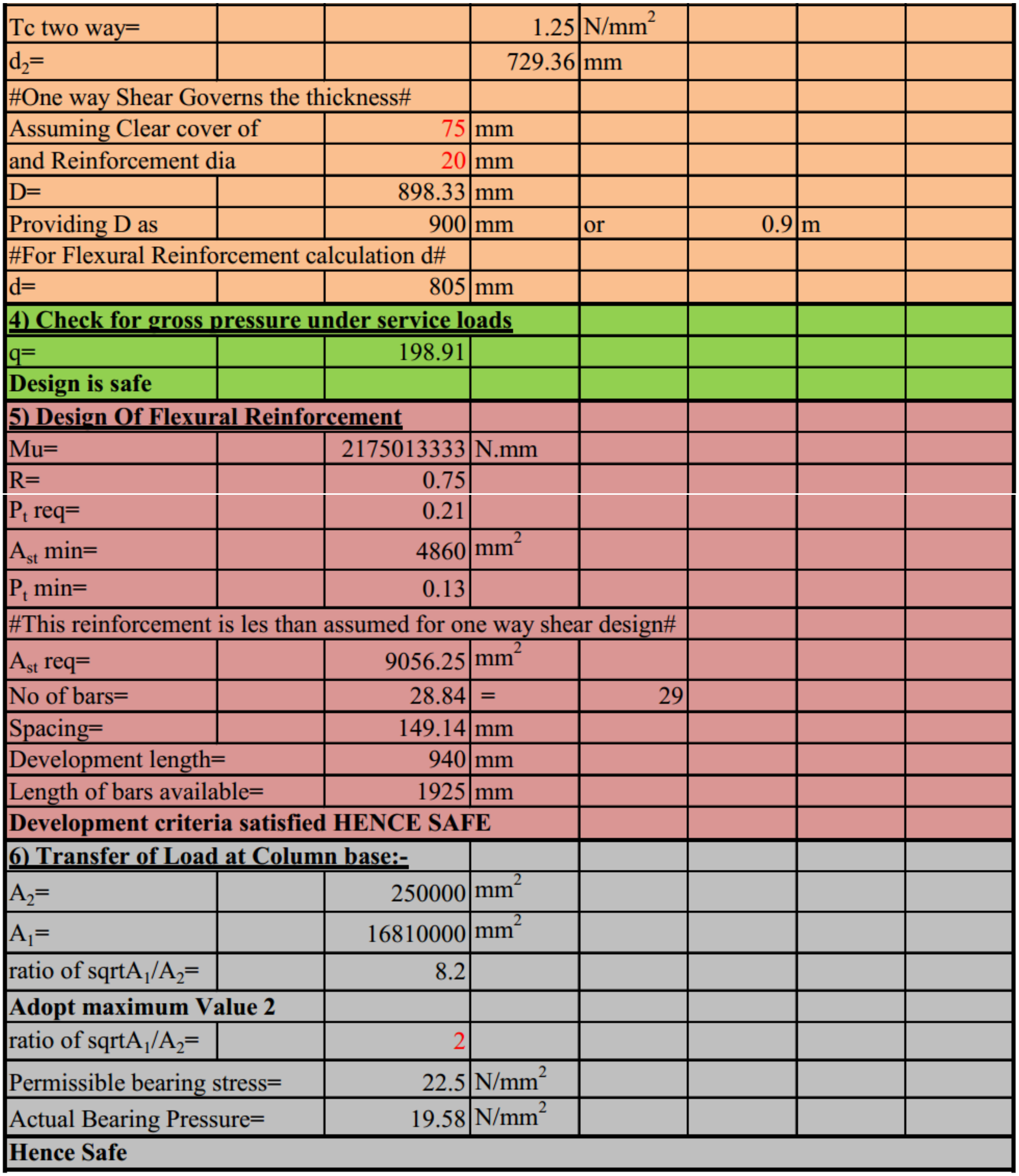
Design Of Footing For Middle Column



List Of Symbols Used:-

f_y :-	Characteristic Strength of Steel
f_{ck} footing:-	Characteristic compressive Strength of Concrete
fck column:-	Characteristic compressive Strength of Concrete
Bc:-	Dimention of column
h:-	Depth of foundation below the ground
q_a:-	Safe bearing capacity
q_u:-	Net soil pressure at ultimate load
d_1:-	Thickness of footing by one way shear
d_2:-	Thickness of footing by two way shear
d:-	resulting thickness of footing
V_{u2}:-	Factored shear Force due to two way shear
D:-	Total depth of footing
q:-	Actual gross pressure at base of footing
M_u:-	Factored moment at column face
A_{st} min:-	Minimum reinforcement required
A_{st} req:-	Required area of reinforcement
P_t min:-	minmum percentage of stel
S:-	Spacing between bars

Design Data :-							
Tc one way=			0.36	N/mm^2			
K$_s$(square column)=			1	#refer	Cl. 31.6.3.1 of the Code#		
wt of concrete=			24				
wt of soil=			18	kN/m^2			
f$_y$=			415	N/mm^2			
percentage of steel assumed=			25.00%	%			
B$_c$ =			500	mm			
Dia Of Col Reinforcement=			20	mm			
No of Bars in Col Reinforcement=			12				
Service Axial Load=			3262.52	kN			
h=			1500	mm	or	1.5	mm
q$_a$ =			200	kN/m^2			
F$_{ck}$ (column)=			25	N/mm^2			
F$_{ck}$ (Footing) =			25	N/mm^2			
1) Size Of Footing:-							
#Assuming 10% weight of the backfill#							
Base Area Required=			17.94	m^2			
min size of square footing=			4.24	m			
#Taking Dimentions of footing base			**4500**	**mm**	**or**	**4.5**	m
2) Calculation of footing slab based on Shear							
#Net Soil Pressure ai ultimate load(Load Factor 1.5)#							
q$_u$=			241.67	kN/m^2	or	0.242	N/m^2
2) Calculation of footing slab based on Shear							
#Net Soil Pressure ai ultimate load(Load Factor 1.5)#							
q$_u$=			241.67	kN/m^2	or	0.242	N/m^2
3) Calculation of Thickness of footing							
#ONE WAY SHEAR							
critical section is at a distance 'd' from the column face #							
Location of one way shear plane=			2000	mm			
#Equating Factored shear force with one way shear resistance#							
d$_1$ =			803.33	mm			
#TWO WAY SHEAR							
critical section is at d/2 from periphery of column #							
V$_{u2}$=			4483268	N/mm^2			



Tc two way=			1.25	N/mm^2			
d_2=			729.36	mm			
#One way Shear Governs the thickness#							
Assuming Clear cover of		75	mm				
and Reinforcement dia		20	mm				
D=		898.33	mm				
Providing D as		900	mm	or	0.9	m	
#For Flexural Reinforcement calculation d#							
d=		805	mm				
4) Check for gross pressure under service loads							
q=		198.91					
Design is safe							
5) Design Of Flexural Reinforcement							
Mu=		2175013333	N.mm				
R=		0.75					
P_t req=		0.21					
A_{st} min=		4860	mm^2				
P_t min=		0.13					
#This reinforcement is les than assumed for one way shear design#							
A_{st} req=		9056.25	mm^2				
No of bars=		28.84	=	29			
Spacing=		149.14	mm				
Development length=		940	mm				
Length of bars available=		1925	mm				
Development criteria satisfied HENCE SAFE							
6) Transfer of Load at Column base:-							
A_2=		250000	mm^2				
A_1=		16810000	mm^2				
ratio of sqrtA_1/A_2=		8.2					
Adopt maximum Value 2							
ratio of sqrtA_1/A_2=		2					
Permissible bearing stress=		22.5	N/mm^2				
Actual Bearing Pressure=		19.58	N/mm^2				
Hence Safe							

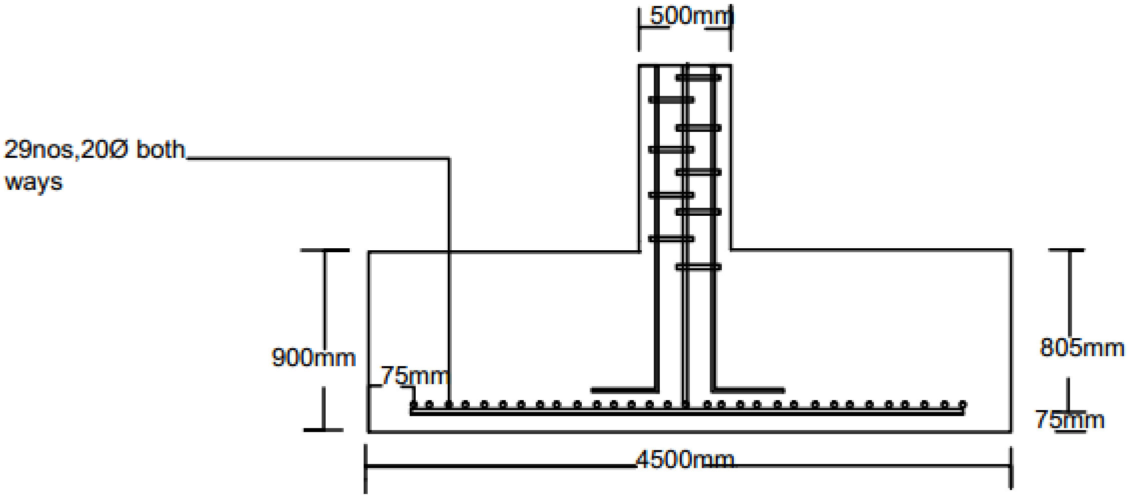


Figure 20 Reinforcement Details Of Foundation Of Middle Column of RCC

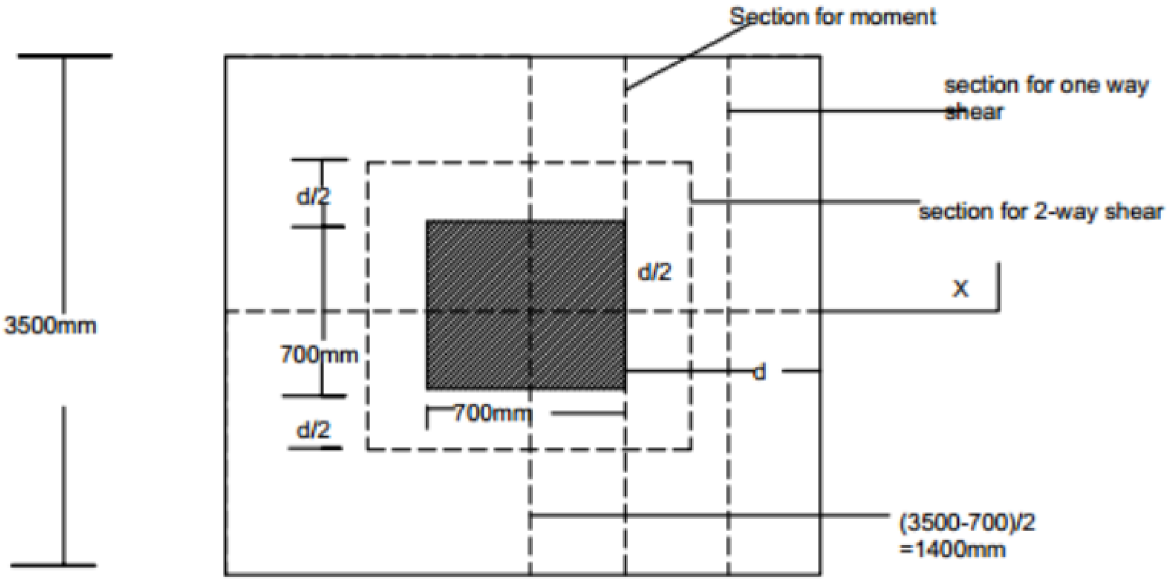
Reinforcement	29 no ,20mm Bars in Both ways @ spacing of 150mm c/c

Table 10 Reinforcement Details Of Foundation Of Middle Column

5.2 DESIGN ELEMENTS OF STEEL STRUCTURE:-

5.2.1 Design For Foundation Of Steel Structure:-

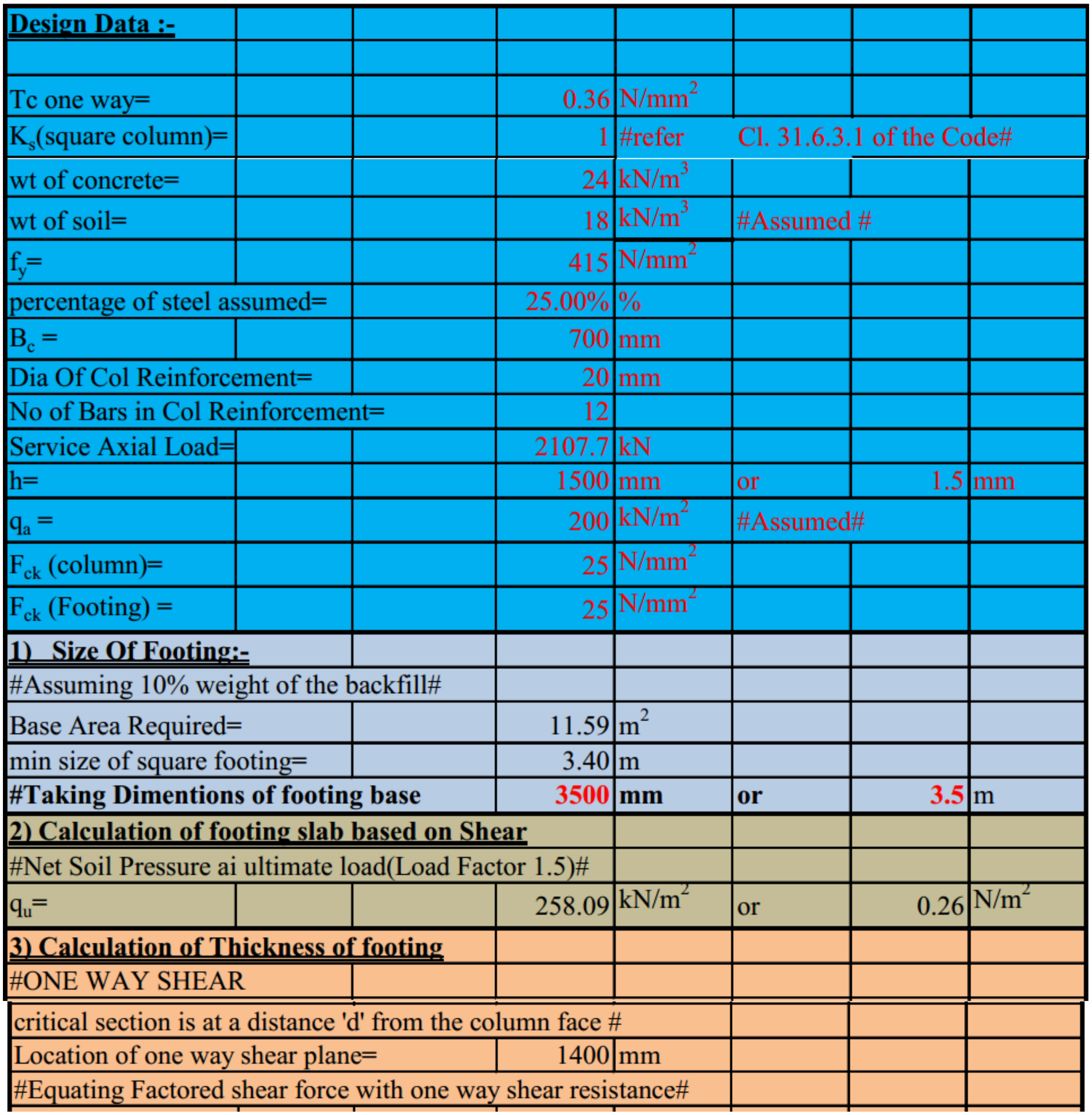
Design Of Footing For Middle Column



List Of Symbols Used:-

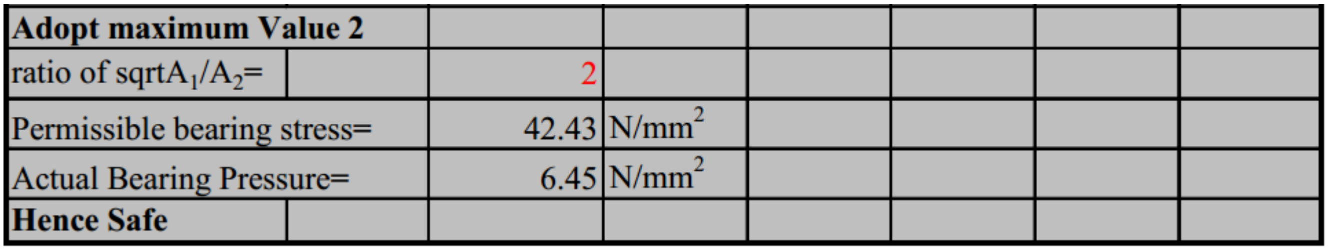
f_y :-	Characteristic Strength of Steel
f_{ck} footing:-	Characteristic compressive Strength of Concrete
fck column:-	Characteristic compressive Strength of Concrete
Bc:-	Dimention of Pedestal
h:-	Depth of foundation below the ground
q_a:-	Safe bearing capacity
q_u:-	Net soil pressure at ultimate load
d_1:-	Thickness of footing by one way shear
d_2:-	Thickness of footing by two way shear
d:-	resulting thickness of footing
V_{u2}:-	Factored shear Force due to two way shear
D:-	Total depth of footing
q:-	Actual gross pressure at base of footing
M_u:-	Factored moment at column face
A_{st} min:-	Minimum reinforcement required
A_{st} req:-	Required area of reinforcement

P_t min:-	minmum percentage of stel
S:-	Spacing between bars
Ld:-	Development length
T_c one way:-	Shear stress in concrete in one way shear
T_c two way:-	Shear stress in concrete in two way shear



Design Data :-							
Tc one way=			0.36	N/mm^2			
K_s(square column)=			1	#refer	Cl. 31.6.3.1 of the Code#		
wt of concrete=			24	kN/m^3			
wt of soil=			18	kN/m^3	#Assumed #		
f_y=			415	N/mm^2			
percentage of steel assumed=			25.00%	%			
B_c =			700	mm			
Dia Of Col Reinforcement=			20	mm			
No of Bars in Col Reinforcement=			12				
Service Axial Load=			2107.7	kN			
h=			1500	mm	or	1.5	mm
q_a =			200	kN/m^2	#Assumed#		
F_{ck} (column)=			25	N/mm^2			
F_{ck} (Footing) =			25	N/mm^2			
1) Size Of Footing:-							
#Assuming 10% weight of the backfill#							
Base Area Required=			11.59	m^2			
min size of square footing=			3.40	m			
#Taking Dimentions of footing base			**3500**	**mm**	**or**	**3.5**	m
2) Calculation of footing slab based on Shear							
#Net Soil Pressure ai ultimate load(Load Factor 1.5)#							
q_u=			258.09	kN/m^2	or	0.26	N/m^2
3) Calculation of Thickness of footing							
#ONE WAY SHEAR							
critical section is at a distance 'd' from the column face #							
Location of one way shear plane=			1400	mm			
#Equating Factored shear force with one way shear resistance#							

critical section is at a distance 'd' from the column face #							
Location of one way shear plane=			1400	mm			
#Equating Factored shear force with one way shear resistance#							
d_1 =			584.58	mm			
#TWO WAY SHEAR							
critical section is at d/2 from periphery of column #							
V_{u2}=			2735672	N/mm^2			
Tc two way=			1.25	N/mm^2			
d_2=			468.31	mm			
#One way Shear Governs the thickness#							
Assuming Clear cover of		55	mm				
and Reinforcement dia		20	mm				
D=		659.58	mm				
Providing D as		660	mm	or	0.66	m	
#For Flexural Reinforcement calculation d#							
d=		585	mm				
4) Check for gross pressure under service loads							
q=		199.78					
Design is safe							
5) Design Of Flexural Reinforcement							
Mu=		885234000	N.mm				
R=		0.74					
P_t req=		0.21					
A_{st} min=		2772	mm^2				
P_t min=		0.14					
#This reinforcement is les than assumed for one way shear design#							
A_{st} req=		6581.25	mm^2				
No of bars=		20.96	=	23			
Spacing=		146.30	mm				
Development length=		940	mm				
Length of bars available=		1345	mm				
Development criteria satisfied HENCE SAFE							
6) Tranfer Of Load at Column base							
A_2=		490000	mm^2				
A_1=		6970300	mm^2				
ratio of sqrtA_1/A_2=		3.77					
Adopt maximum Value 2							
ratio of sqrtA_1/A_2=		2					



Adopt maximum Value 2							
ratio of sqrtA_1/A_2=		2					
Permissible bearing stress=		42.43	N/mm^2				
Actual Bearing Pressure=		6.45	N/mm^2				
Hence Safe							

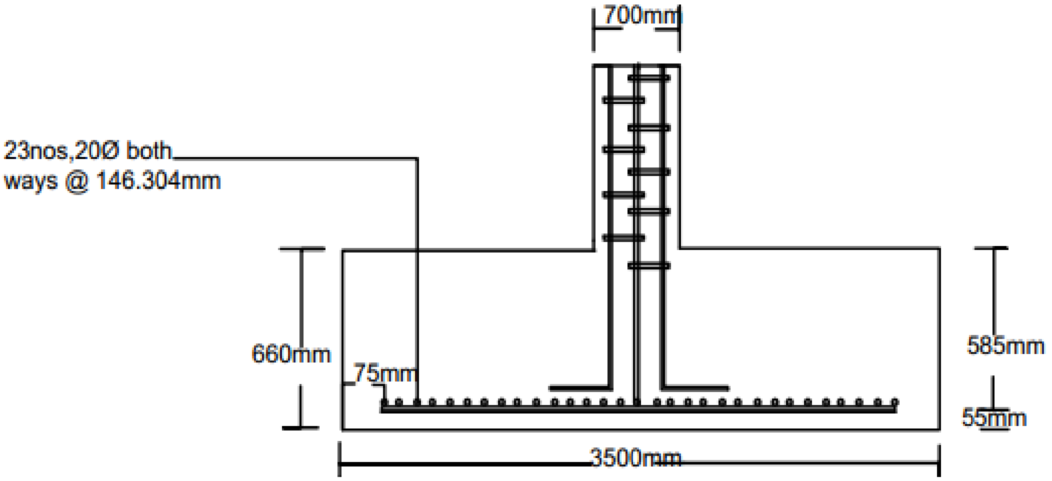


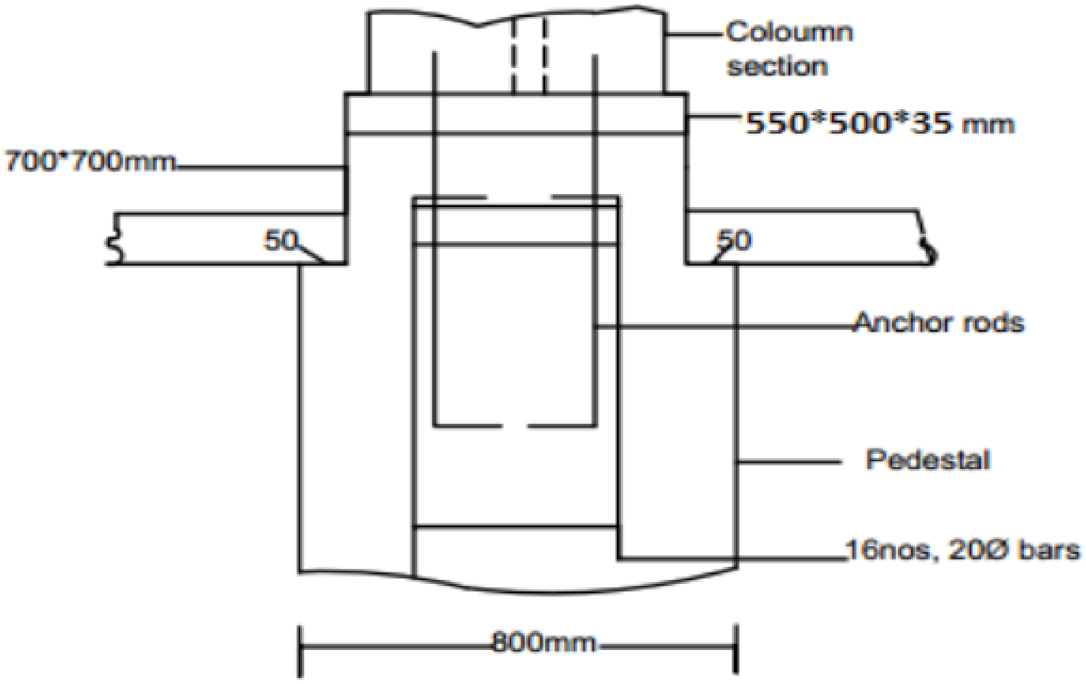
Figure 21 Reinforcement Details Of Foundation Of Middle Column

Reinforcement	23 no ,20mm Bars in Both ways @ spacing of 146mm c/c

Table 11 Reinforcement Details Of Foundation Of Middle Column

5.2.2 Design For Pedestal And Base Plate Of Steel Structure:-

Design Of Pedestal And Base Plate



List Of Symbols Used:-

P:- Axial loads on column

d:- Depth of column section

b_f:- width of flange

f_c:- characteristic compressive strength of concrete

q_a:- Bearing capacity of soil

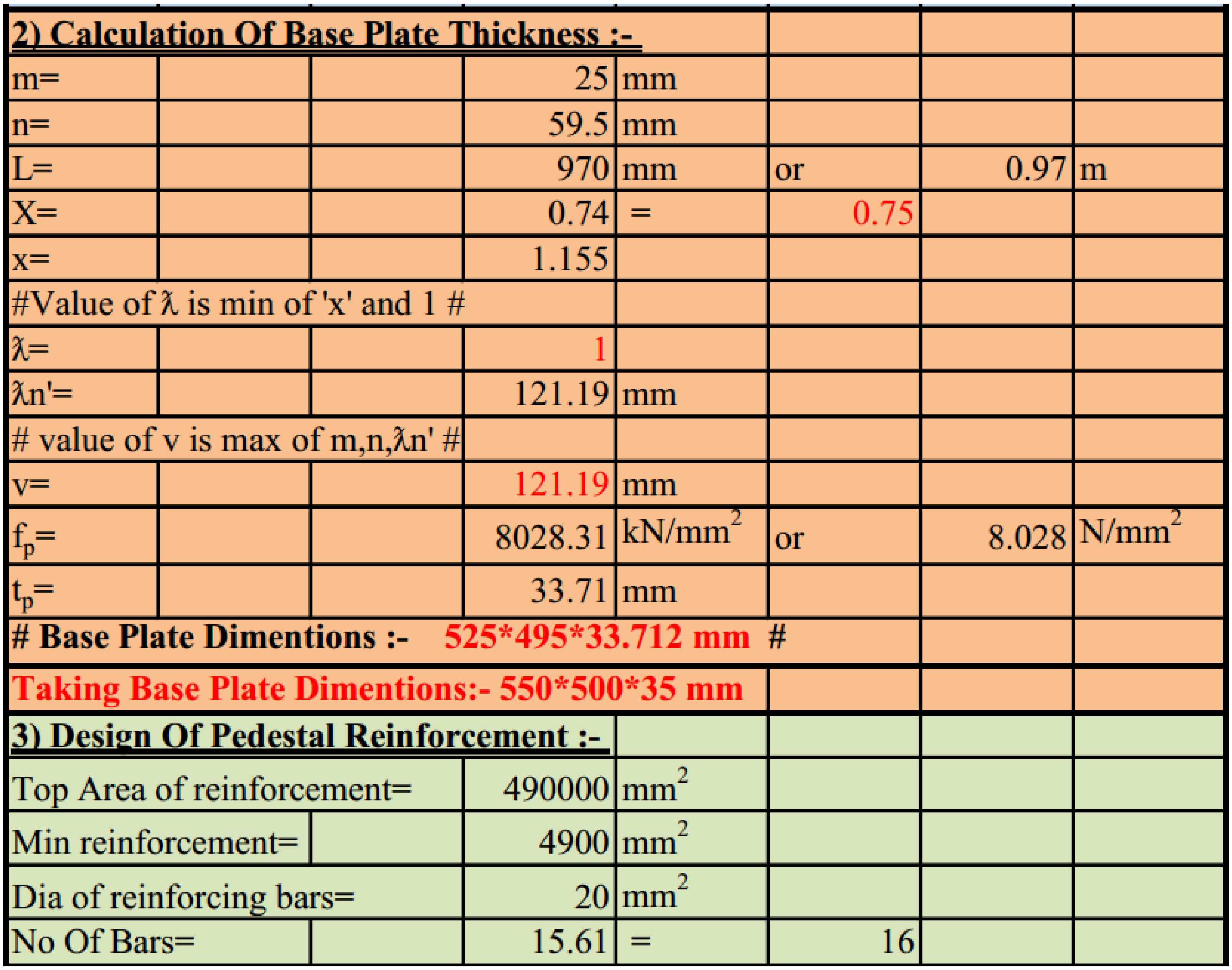
A_2:- Area of pedestal

A_1:- Area of plate

B:- Length of plate
C:- Width of plate
F_p:-
t_p:- Thickness of plate
B_P:- length and width of pedestal

#The design is performed according to the guidelines of ACI ,Article 7.3 , 318.1#

Design Data:-							
P=			2086.36	kN			
d=			500	mm			
b_f=			470	mm			
f_y=			415	N/mm^2			
f_c=			25	N/mm^2			
q_a=			200	kN/mm^2	#Assumed Value#		
1) Initial Dimentions :-							
A_2=			0.48	m^2			
A_1=			0.12	m^2			
# Use Plate area greater than			0.12	m^2	#		
#Use Pedestal area greater than			0.48	m^2			
B_P=			0.69	mm			
Let Use B_p as			**0.7**	**m**			
A_2=			0.49	mm			
# trail base plate area #							
C=			525	mm	or	0.53	m
B=			495	mm	or	0.50	m
Base Plate area=			0.26	m^2			
F_p=			12.02				
Design is Safe							
A_1*F_p=			3122.40				
OK							



2) Calculation Of Base Plate Thickness :-							
m=			25	mm			
n=			59.5	mm			
L=			970	mm	or	0.97	m
X=			0.74	=	0.75		
x=			1.155				
#Value of ƛ is min of 'x' and 1 #							
ƛ=			1				
ƛn'=			121.19	mm			
# value of v is max of m,n,ƛn' #							
v=			121.19	mm			
f_p=			8028.31	kN/mm^2	or	8.028	N/mm^2
t_p=			33.71	mm			
# Base Plate Dimentions :- 525*495*33.712 mm #							
Taking Base Plate Dimentions:- 550*500*35 mm							
3) Design Of Pedestal Reinforcement :-							
Top Area of reinforcement=			490000	mm^2			
Min reinforcement=			4900	mm^2			
Dia of reinforcing bars=			20	mm^2			
No Of Bars=			15.61	=	16		

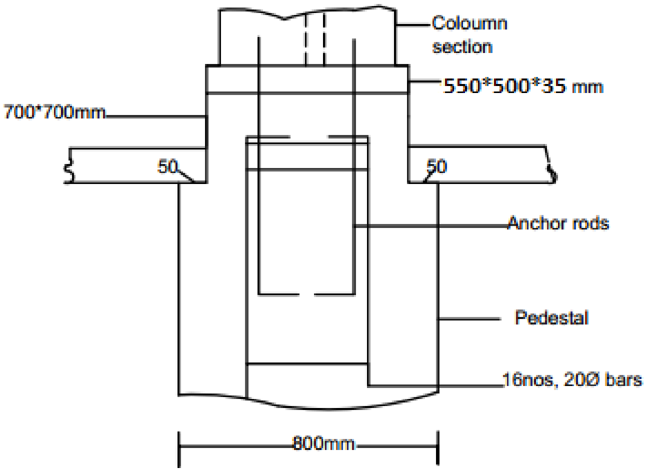


Figure 22.a Reinforcement Details Pedestal and Base Plate Middle Column

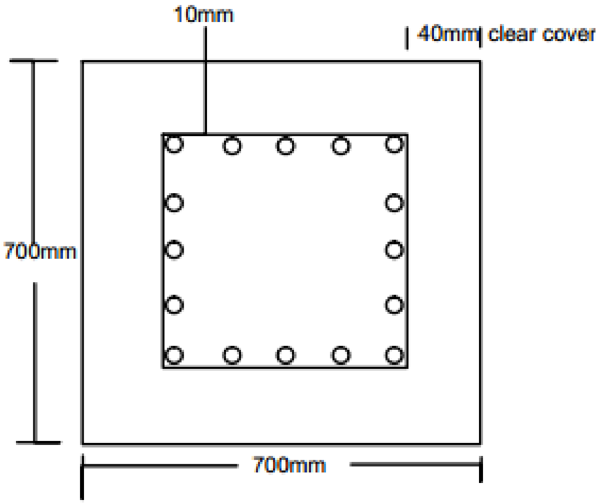


Figure 22.b Reinforcement Details Pedestal and Base Plate Middle Column

Longitudinal Reinforcement	16 no , 20ϕ Bars
Transverse Reinforcement	Providing 10mm Bars @150mm c/c Spacing
Base Plate Dimentions	550*500*35 mm

Table 12 Reinforcement Details Pedestal and Base Plate Middle Column

Chapter 6

ANALYSIS AND RESULTS

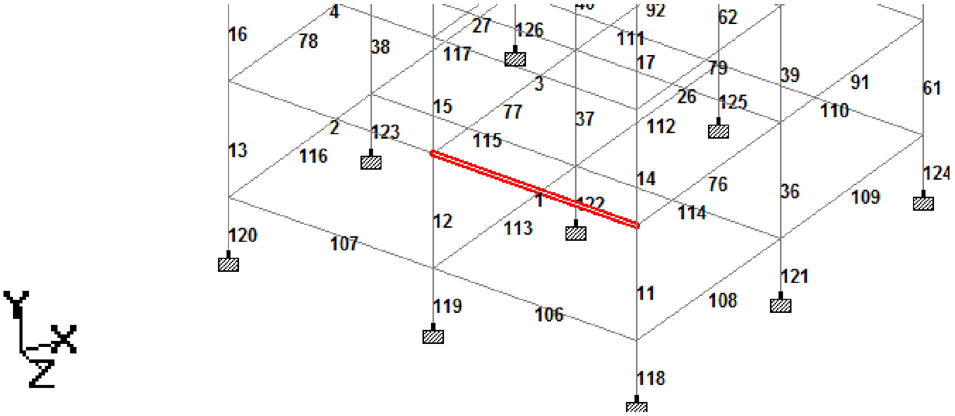
- Analysis was done using STAAD-Pro V8i.
- Footing was idealized as fixed support.
- The load cases adopted are dead load and live load, wind load and the seismic load
- Analysis was done for the load combinations given below:

1. Dead load + live load
2. Dead load + live load + wind load in (+ve) x – direction
3. Dead load + live load + wind load in (- ve) x – direction
4. Dead load + live load +earthquake load in (+ ve) x – direction
5. Dead load + live load +earthquake load in (- ve) x – direction

6.1 COMPARISON OF DESIGN RESULTS OF RCC AND STEEL STRUCTURE.

6.1.1 Bending moments in Column and Beams

Bending moment about Z axis in In Beam 1:-



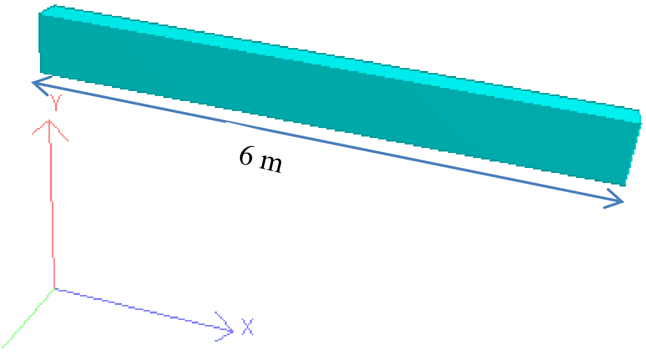


Figure 23 Beam 1 (material property- concrete)

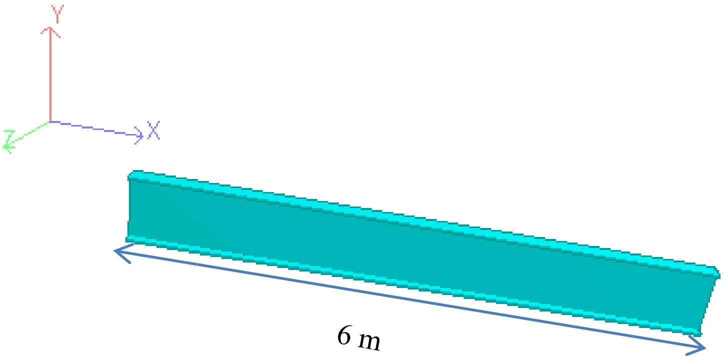


Figure 24 Beam 1 (material property- Steel)

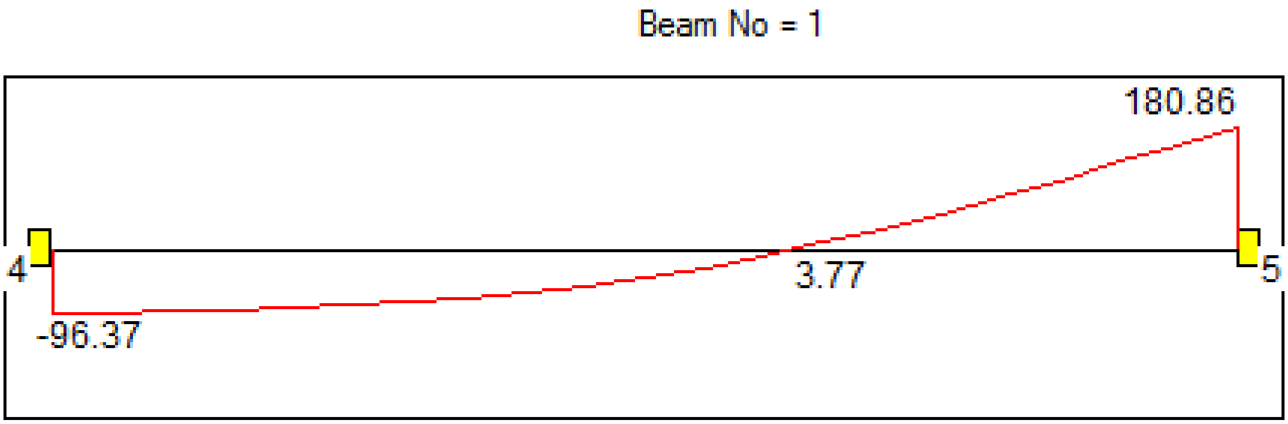


Figure 25 Mz in Beam 1 of RCC Structure

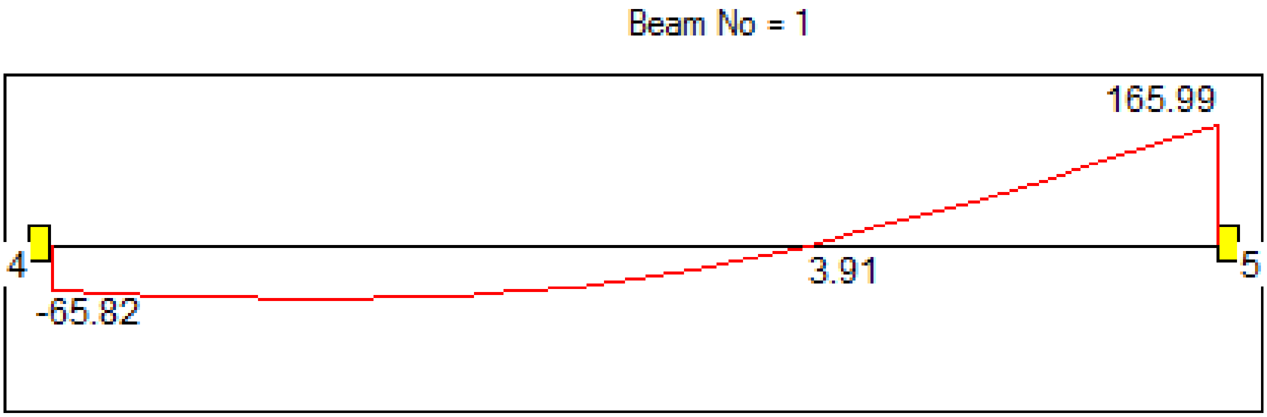
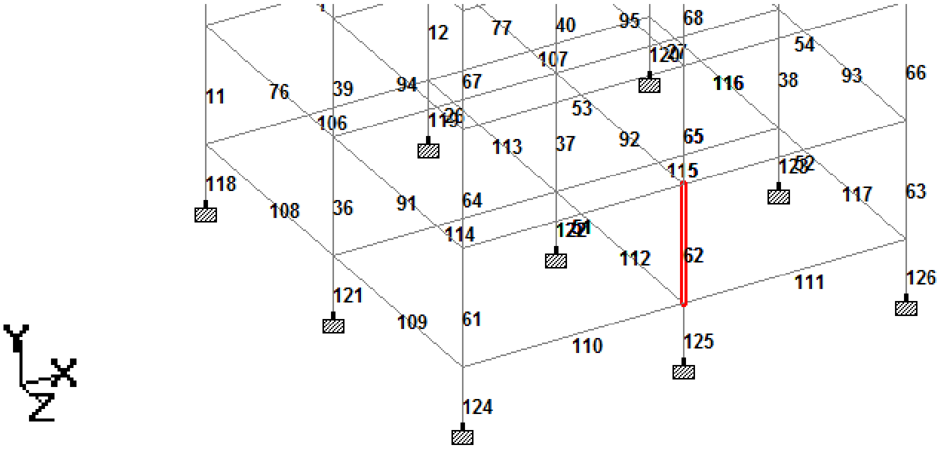


Figure 26 Mz in Beam 1 of Steel Structure

Bending moment about Z axis in Column (member 62):-



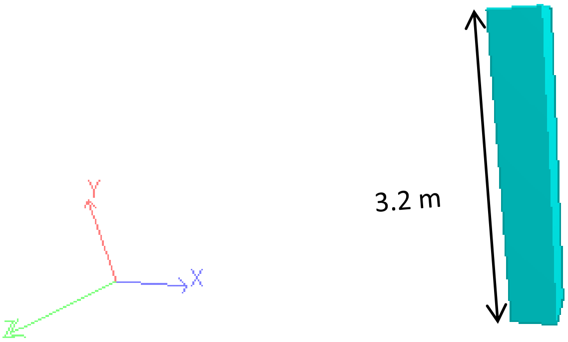


Figure 27 Column (Member no 62 with material property Concrete)

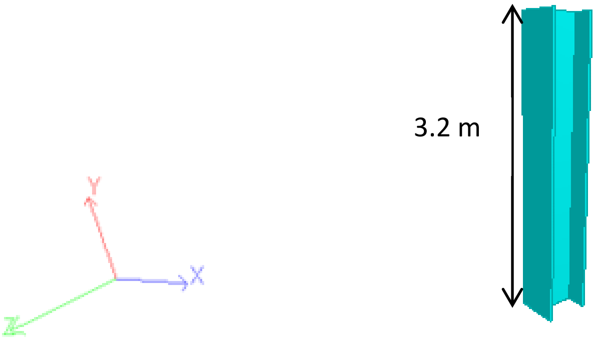


Figure 28 Column (Member no 62 with material property Steel)

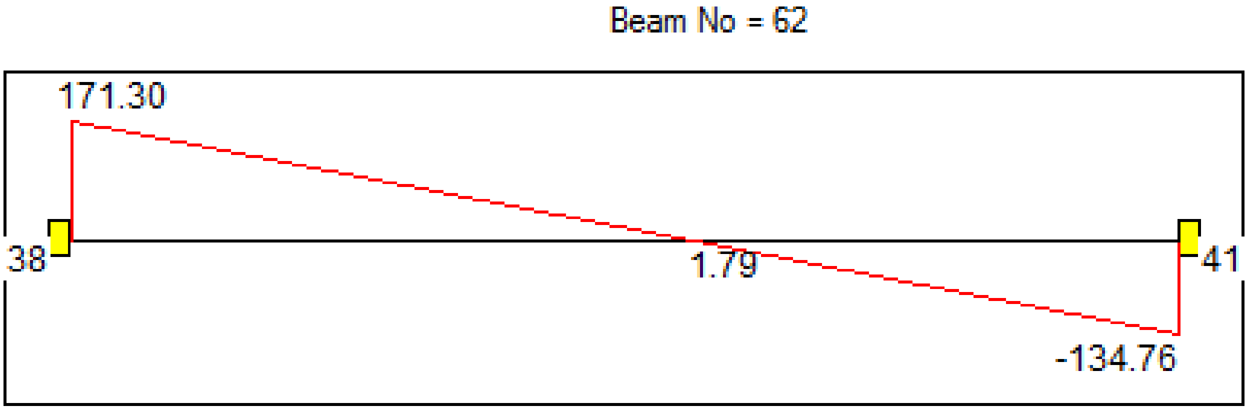


Figure 29 Bending moment about Z axis in Column (member 62) Of RCC

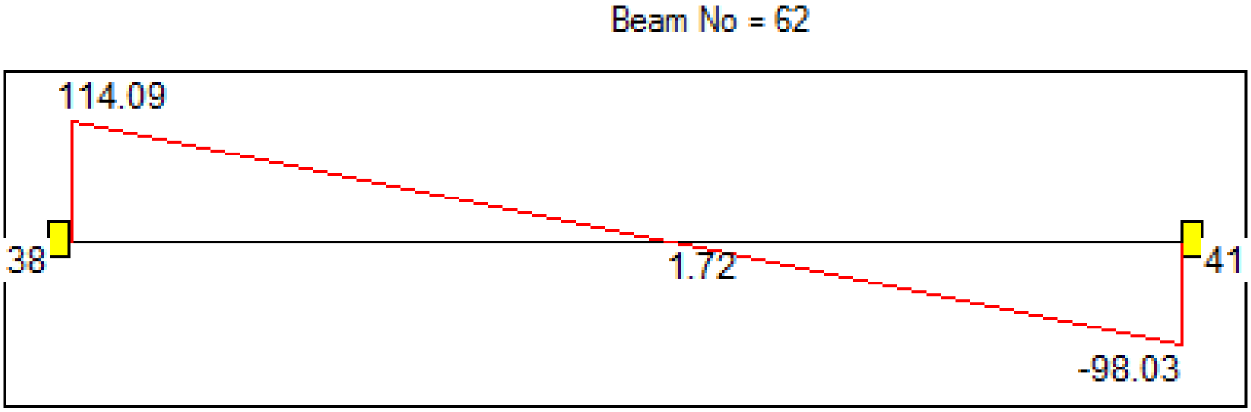


Figure 30 Bending moment about Z axis in Column (member 62) Of Steel

6.1.2 Maximum Shear Force and Bending Moment in column (member 62)

	RCC (kN)	**Steel (kN)**
F_x	56.4	55.2
F_y	115	110
F_z	78.6	72.4

Table 13 Maximum Shear Force and Bending Moment in column (member 62)

6.1.3 Maximum Axial Forces On Column Base Of The Structure:-

Maximum Axial Force on Colum base due to Dead load + live load +earthquake load in (-ve) x – direction

Column	**RCC Structure (kN)**	**Steel Structure (kN)**
Centre Column	2330	1787
Exterior Middle Column	1450	1098
Corner Column	779	658

Table 14 Maximum Axial Load On Column base Of The Structure

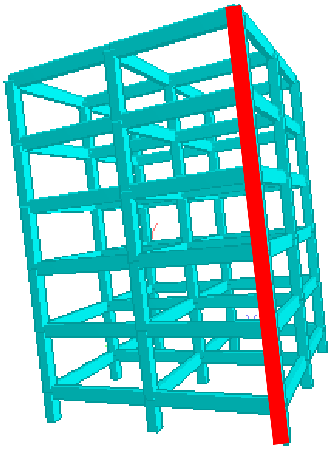


Figure 31 Corner Column

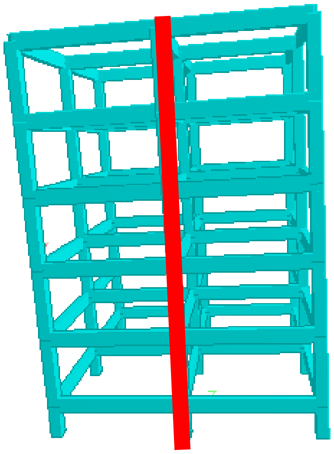


Figure 32 Exterior Middle Column

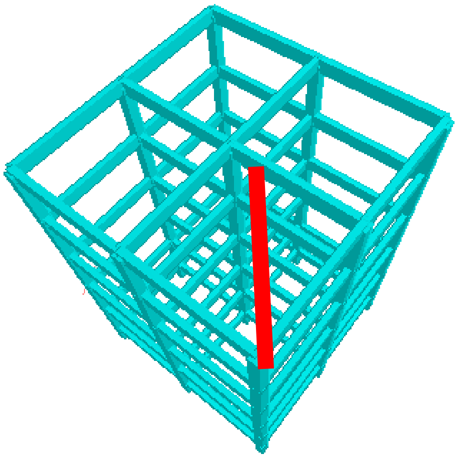


Figure 33 Centre Column

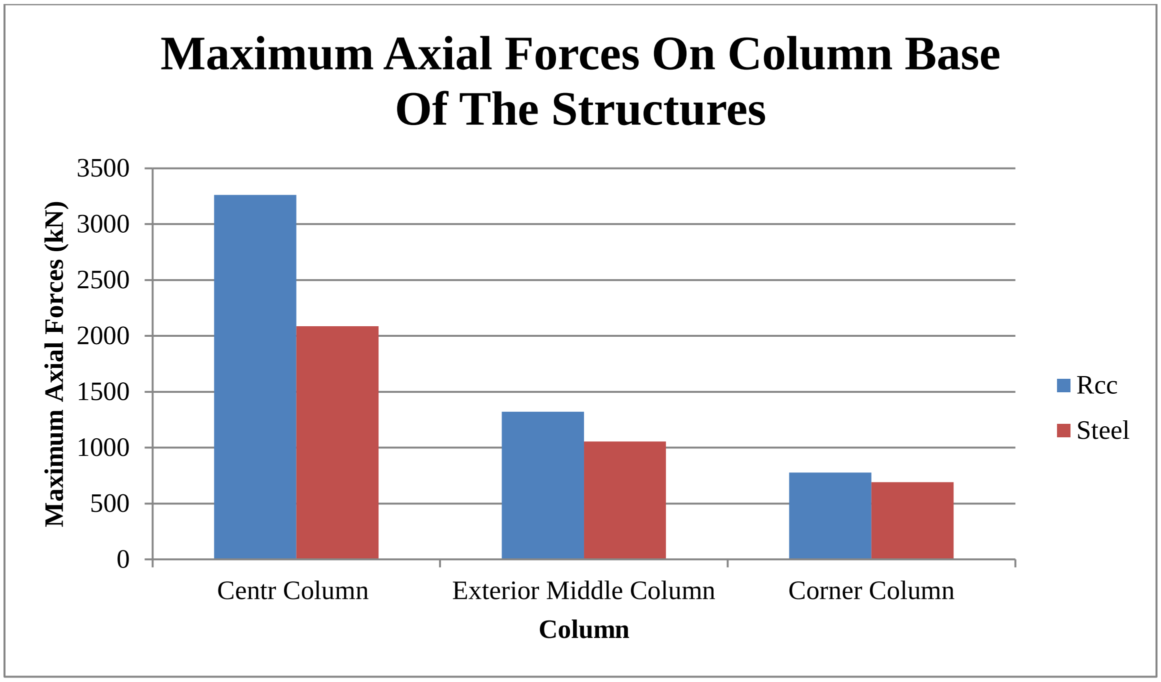


Figure 34 Maximum Axial Forces On Column Base Of The Structure

6.1.4 Maximum Storey Drift:-

Maximum Axial Force on Colum base due to Dead load + live load +earthquake load in (-ve) x – direction

Height (m)	RCC (mm)	Steel (mm)
0.00	0.05	0.10
3.2	0.31	0.75
6.40	0.61	1.47
9.60	0.88	2.14
12.80	1.09	2.65
16	1.21	2.95

Table 15 Maximum Storey Drift In RCC And Steel Structure

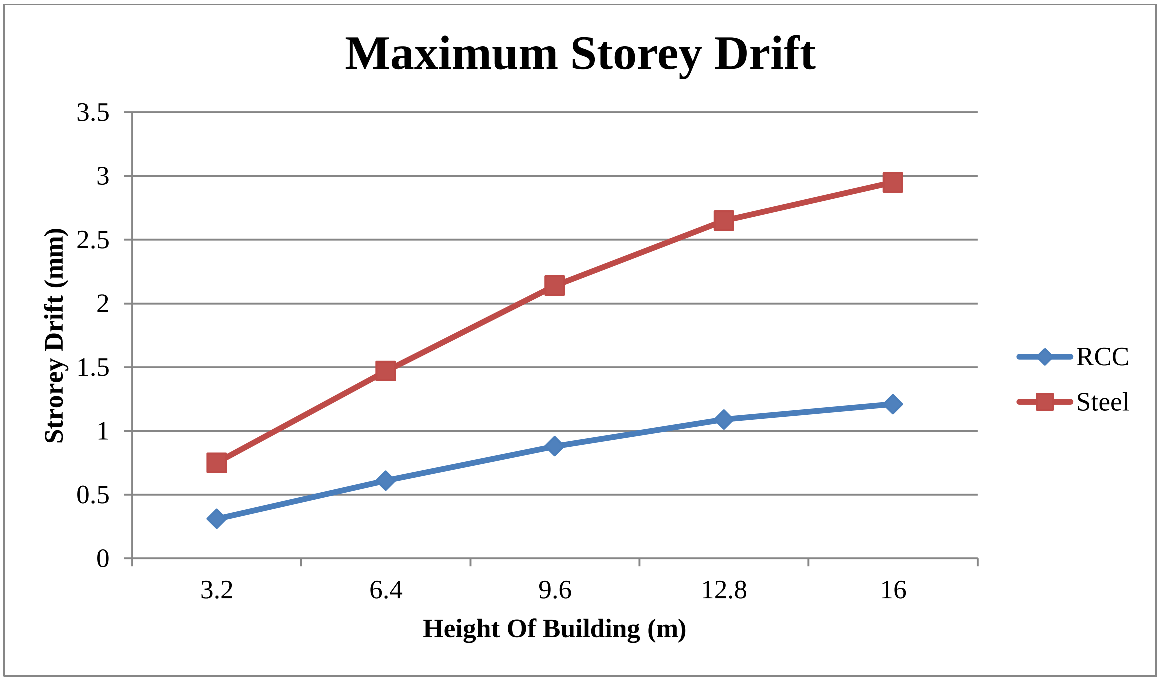


Figure 35 Maximum Storey Drift In RCC And Steel Structure

6.1.5 Maximum Shear Force (Fx) In Exterior Middle Column:-

Maximum Axial Force on Colum base due to Dead load + live load +earthquake load in (-ve) x – direction

Floor Level	**RCC (kN)**	**Steel (kN)**
56	56.4	55.2
1st	58.2	57.2
2nd	52	50.6
3rd	39.8	38.5
4th	22.4	21.5

Table 16 Maximum Shear Force (Fx) In Exterior Middle Column

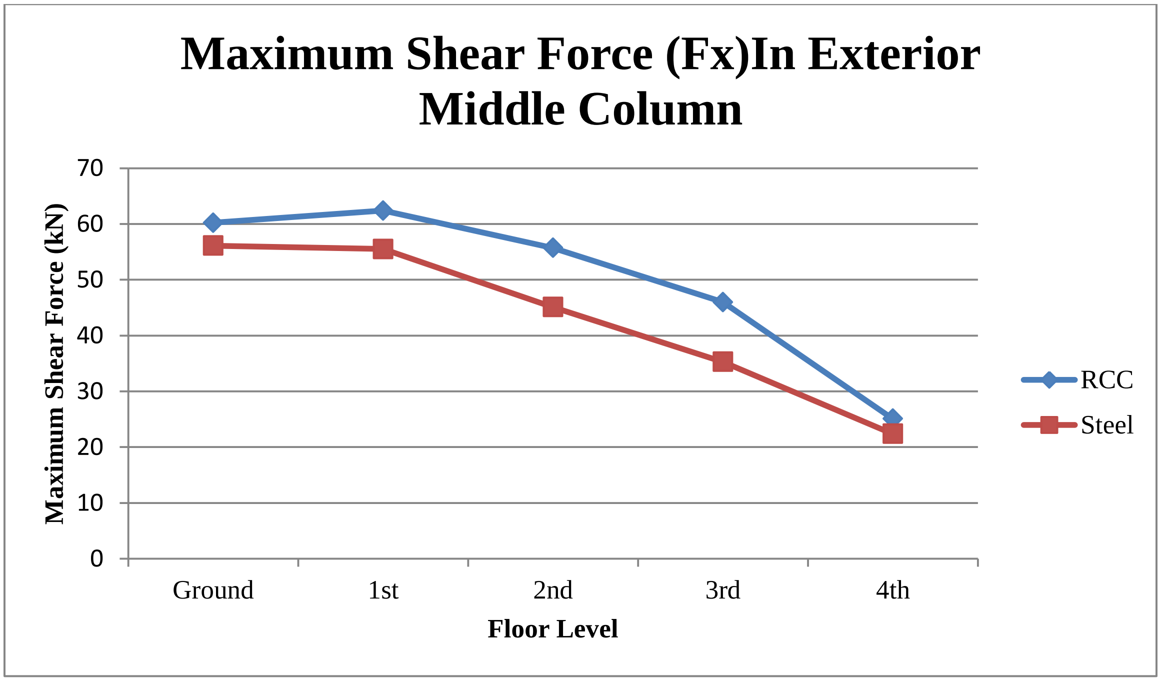


Figure 36 Maximum Shear Force (Fx) In Exterior Middle Column

6.1.6 Maximum Shear Force (Fz)In Exterior Middle Column:-

Maximum Axial Force on Colum base due to Dead load + live load +earthquake load in (-ve) x – direction

Floor Level	**RCC (kN)**	**Steel (kN)**
Ground	115	110
1st	82.9	79.6
2nd	51.5	49.5
3rd	25.4	24.5
4th	8.12	7.61

Table 17 Maximum Shear Force (Fz) In Exterior Middle Column

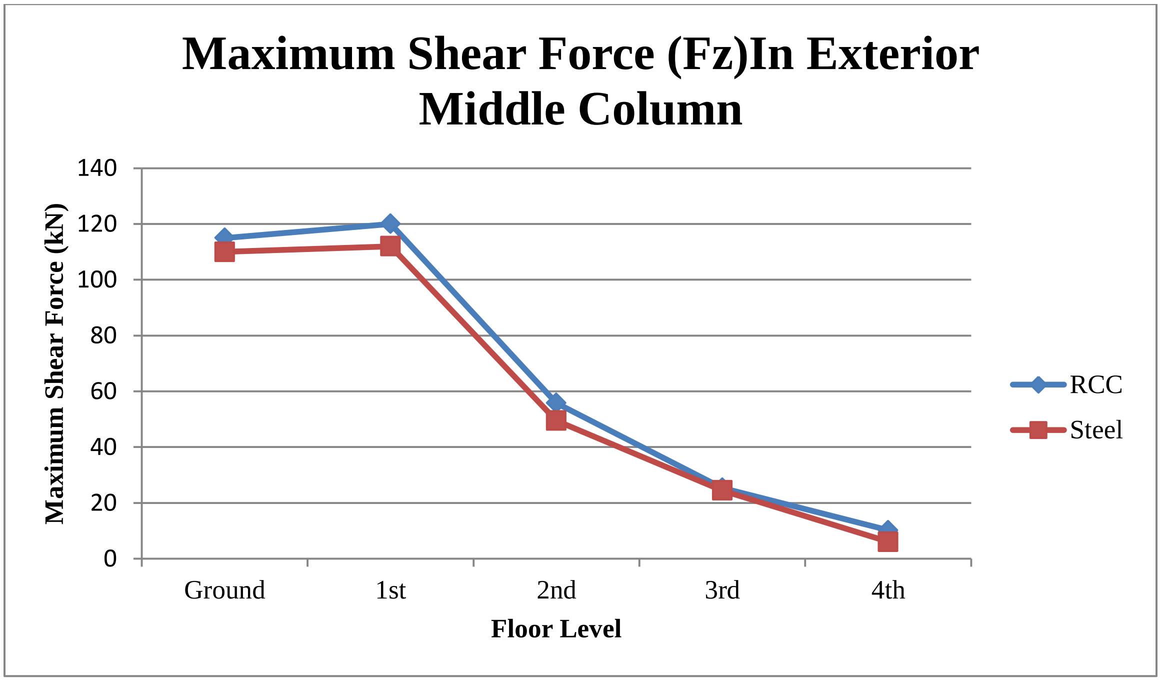


Figure 37 Maximum Shear Force (Fz) In Exterior Middle Column

6.1.7 Maximum Deflection In Exterior Middle Column:-

Maximum Axial Force on Colum base due to Dead load + live load +earthquake load in (-ve) x – direction

Floor Level	RCC (kN)	Steel (kN)
Ground	1.5	3.33
1st	2.92	6.56
2nd	4.23	9.5
3rd	5.27	11.75
4th	5.90	13.06

Table 18 Maximum Deflection In Exterior Middle Column

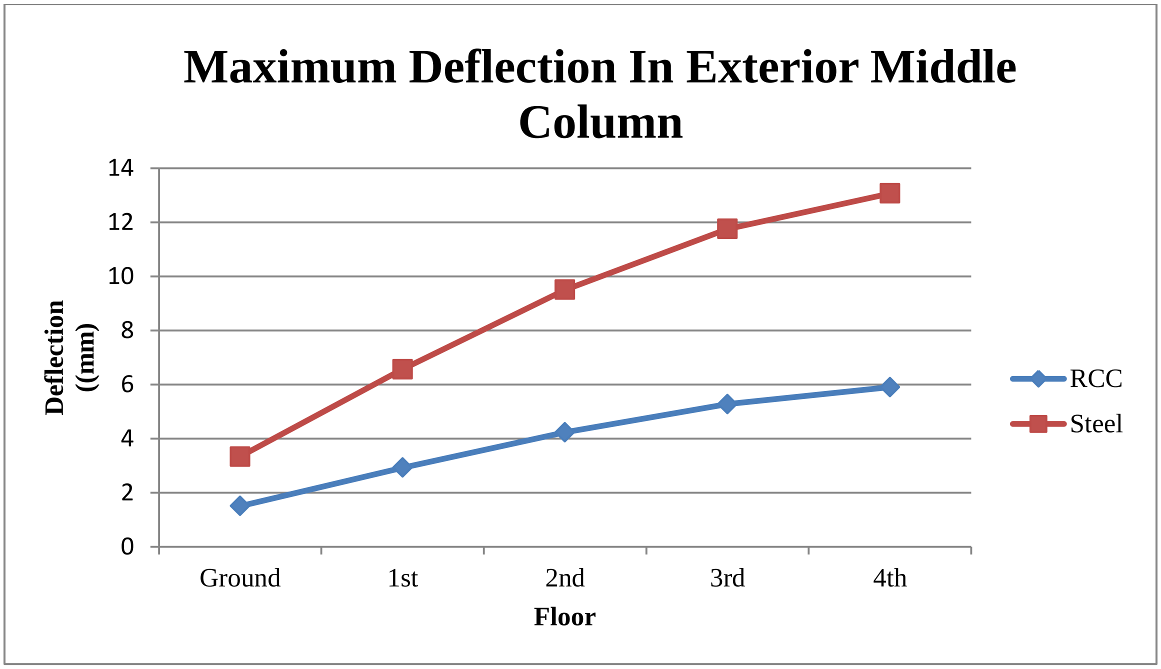


Figure 38 Maximum Deflection In Exterior Middle Column

6.1.8 Differences in Foundation Size and Reinforcement Requirements:-

Property	**RCC Structure**	**Steel Structure**
Centre Column		
Size:-	4500*4500*900 mm	3500*3500*660 mm
Reinforcement:-	9106 mm^2	7222 mm^2
Exterior Middle Column		
Size:-	2900*2900*600 mm	2800*2800*560 mm
Reinforcement:-	5966 mm^2	5652 mm^2
Corner Column		
Size:-	2250*2250*450 mm	2100*2100*430 mm
Reinforcement:-	4220.11 mm^2	4103.6 mm^2

Table 19 Difference in Foundation Size and Reinforcement Requirements

Chapter 7

DESIGN STEPS FOR COMPOSITE STRUCTURE

7.1 COMPOSITE SLAB

a) Stage 1. Profiled steel sheeting as formwork. The assessment of commercially available shapes of profiled steel sheets, used as formwork to support wet concrete. This includes checking the load carrying capacity, the deflection and the effects of using props (Section 5 BS:5950 : Part 4).

b) Stage 2. Composite slab. Composite action between the profiled steel sheets and the structural concrete slab. This includes checking the load carrying capacity and the deflection(Section 6 BS:5950 : Part 4)

In composite slabs there are three possible modes of behaviour based on the level of interaction between the concrete and the steel decking:

Zero interaction And there are also three likely collapse mechanisms depending on the characteristics of the slab:

- Failure type 1: applied moment exceeds moment resistance.
- Failure type 2: ultimate load resistance is governed by the steel concrete interface.
- Failure type 3: applied vertical shear exceeds shear resistance.

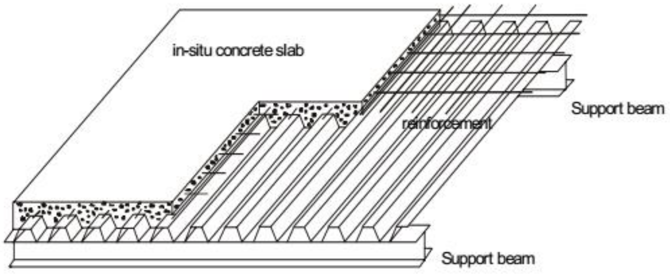


Figure 39 Composite Slab

7.1.1 DESIGN METHODOLOGY

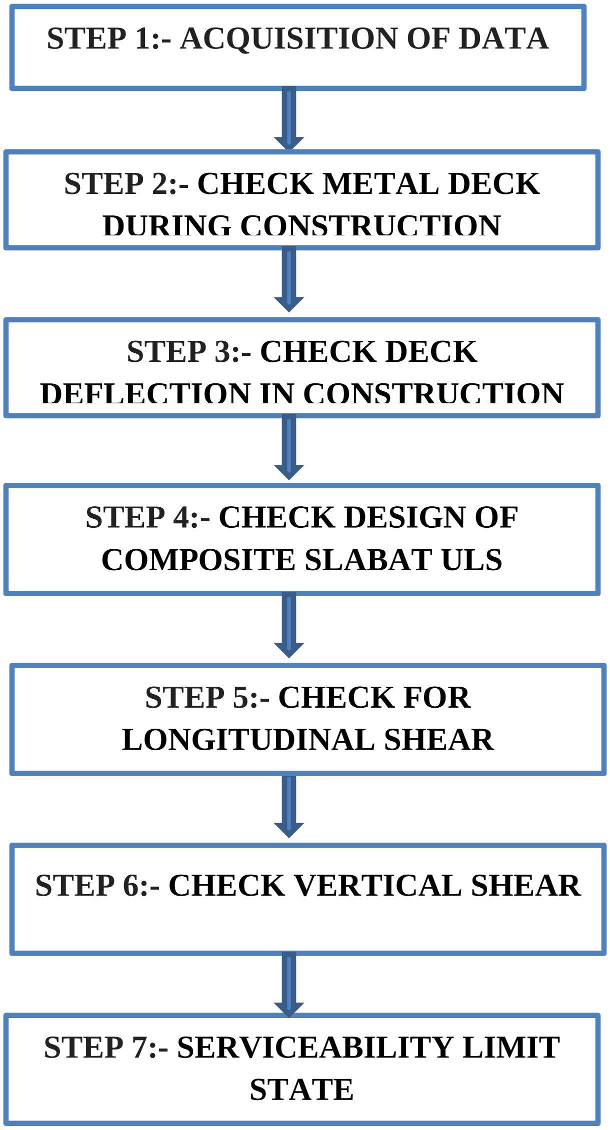


Figure 40 Flowchart for Design Composite Slab

The following stages should be considered in the design of composite slabs.

Step 1:- Check metal deck during construction

Consider the self-weight of the deck and the wet concrete, and these loads have to be over all the deck. Consider the construction loads and distribute them to have the more unfavourable situation for both, maximum sagging bending moment, and maximum hogging bending moment (positive and negative moments). They have to be less than the moment resistance of the deck $M_{p.Rd}^{+}$and$M_{p.Rd}^{-}$.

Step 2:- Check deck deflection in construction

$$\delta = k \times \frac{5}{384} \times p \times L^4 \times \frac{1}{E \times I_{eff}}$$

k=1.0 for simply supported decking

k=0.41 with two equal spans (3 supports)

k=0.52 with three equal spans **k**=0.49 with four equal spans

Ieff is the second moment of area of the effective section

Limit: L/180 or 20 mm (4.2

Step 3:- Check design of composite slab – at ULS

Assume that slab acts as a series of simply supported beams. The moment resistance of the slab has to be greater than the applied moment.

- Design bending moment:

$$M_{Sd} = \frac{\left[\gamma_G \times G + \gamma_Q \times Q\right] \times L^2}{8}$$

- Position of plastic neutral axis: **X**

$$X = \frac{A_p \times f_{yp} / \gamma_{ap}}{0.85 \times B \times f_{ck} / \gamma_c}$$

Where:-

A_p is the area of the deck (mm^2/m)

B width took as 1000 mm

f_{yp} is the tensile strength of the deck

γ_{ap} = 1.10 is the partial safety factor of the deck

z = d_p-0.5*X

d_p is the total depth of the slab without half of the deck height plus the deck thickness.

- Moment resistance of the slab:

$$M_{ps,Rd} = A_p \times \frac{f_{yp}}{\gamma_{ap}} \times z$$

<u>Step 4:- Check for longitudinal Shear</u>

Design shear force:

$$V_{sd} = \frac{\lfloor \gamma_G \times G + \gamma_Q \times Q \rfloor \times L}{2}$$

- Longitudinal resistance is:

$$v_{L,Rd} = B \times d_p \times \left(m \times \frac{A_p}{B \times L_s} + k \right) \times \frac{1}{\gamma_{vs}}$$

Direct relationship is established with the longitudinal shear load capacity of the sheeting. L_s depend on the type of loading. Uniform load applied to the entire span L simply supported beam, L_s = L/4.

γvs = is the partial safety factor of longitudinal shear

Step 5:- Check vertical shear

- Design shear force:

$$V_{sd} = \frac{\left[\gamma_G \times G + \gamma_Q \times Q\right] \times L}{2}$$

- Vertical shear resistance is:

$$V_{v.Rd} = b_o \times d_p \times k_1 \times k_2 \times \tau_{Rd}$$

Where:

bo is the average concrete rib width (over 1 m)

k_1 = $1.6 - d_p$

k_2 = $1.2 + 40 \times \rho$

$$\rho = \frac{A_p}{b_o \times d_p}$$

$$\tau_{Rd} = 0.25 \frac{f_{ck}}{\gamma_c}$$

Step 6:- Serviceability limit state

Calculation of the deflections with the average second moment of composite slab. Deflections would not be design criteria for slabs that satisfy span-to-depth ratio limits.

$$\delta = \frac{5FL^3}{384 E_a I_{xx}}$$

	NWC	**LWC**
Single Spans	30	25
End Spans	35	30
Internal Spans	38	33

Table 20 Maximum span-to-depth ratios

7.2 COMPOSITE BEAM

Composite beam has to be design to support the construction conditions. In unpropped construction, the steel beam is sized to support the self weight of the concrete slab and other construction loads. The difference presented in propped construction at this stage, is that the span of the beam considered is the distance between two consecutive supports which can be props or edge supports, and not the total span of the beam.

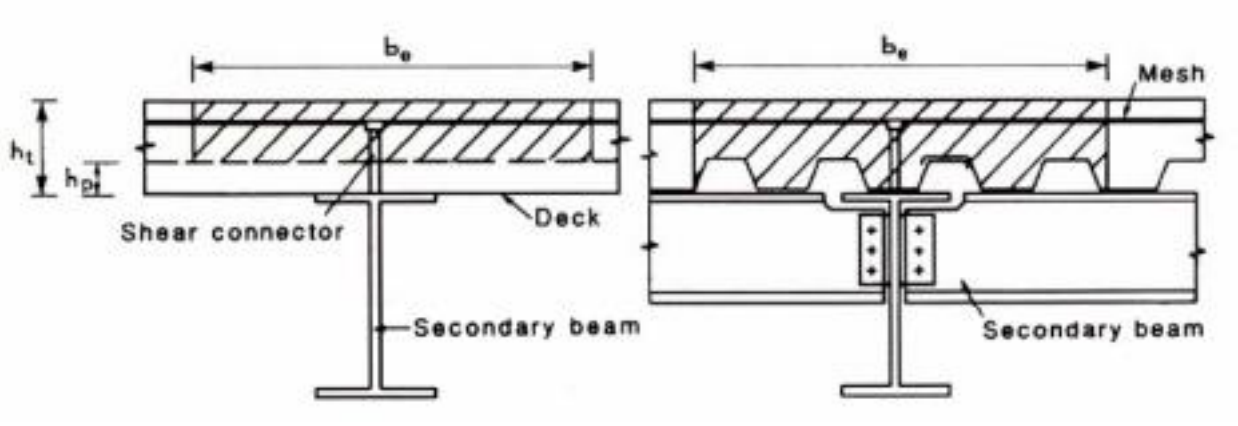


Figure 41 Composite Beam

7.2.1 DESIGN METHODOLOGY

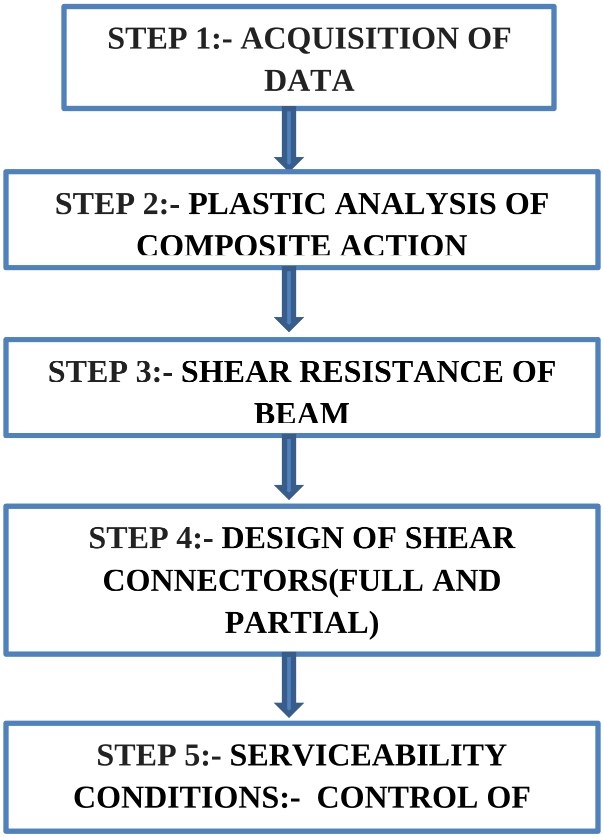


Figure 42 Flowchart for Design Composite Beam

The following stages should be considered in the design of Beams

Step 1:- Serviceability limit state

Not the whole slab is considered for the design; there is an effective breadth of slab. For compatibility between designs at ULS and SLS the effective breadth is taken as L/8 on each side of the secondary beam, being L the span length. This results in L/4, but not exceeding the actual slab width acting with each beam. Effective breadth is represented by $b_{eff..}$

Step 2:- Plastic Analysis Of Composite Action

Materials strengths to be used in the plastic analysis are:

Concrete: 0.85 f_{ck}/γ_c (γ_c=1.5)

0.57fck or 0.45fcu

fck ≈ 0.8 fcu

Steel: fy/γa (γa= 1.05)

0.95fy

- Compressive resistance of the concrete slab

$$R_c = \frac{0{,}85 f_{ck}}{\gamma_c} \times b_{eff} \times h_c$$
$$R_c = 0.57 \times f_{ck} \times b_{eff} \times h_c$$

where

h_c is the depth of the concrete slab above the profiled decking.

- Tensile resistance of the steel section:

$$R_s = \frac{A_a \times f_y}{\gamma_a}$$
$$R_s = 0.95 \times f_y \times A_a$$

where

Aa is the area of the steel beam

- Moment resistance: **$M_{pl.Rd}$:**

a) Plastic neutral axis (PNA) in concrete slab: $R_c \geq R_s$

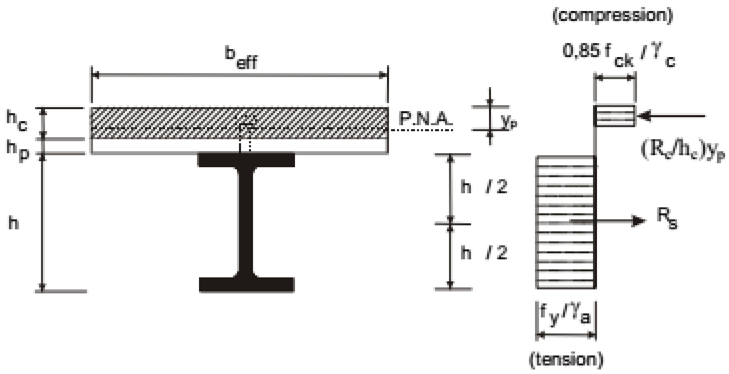


Figure 43 Plastic stress blocks when PNA lies in concrete slab

$$M_{pl,Rd} = R_s\left[\frac{h}{2} + h_c + h_p - \frac{R_s}{R_c} \times \frac{h_c}{2}\right]$$

$$y_p = \frac{R_s \times h_c}{R_c} \qquad \text{from} \qquad \frac{R_c}{h_c} \times y_p = R_s$$

where

h_c is the height of concrete slab above the deck h

p is the depth of the profiled decking h is the depth of the steel section yp is the depth of PNA since the upper surface of the slab.

b) Plastic neutral axis in flange of steel beam: $R_c \leq R_s$ and $R_c > R_w$

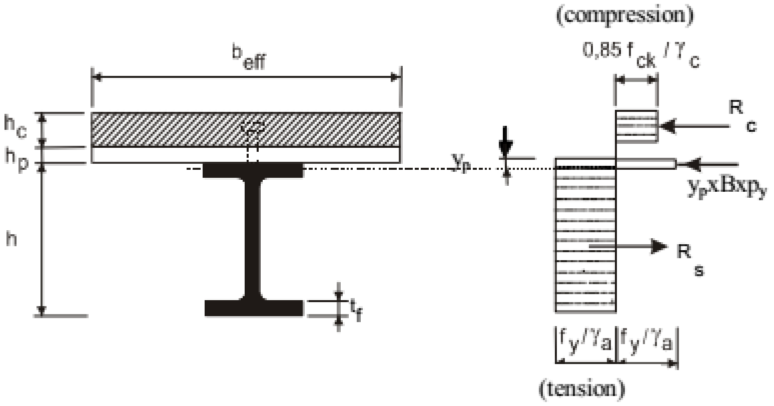


Figure 44 Plastic stress blocks when PNA lies in flange of steel beam

R_w is the tensile resistance of the web of beam:

$$R_w = 0.95 \times f_y \times t_w \times (h - 2t_f)$$

Where

t_w is the web thickness

t_f is the flange thickness The depth of web in compression should not exceed $38t_w\varepsilon$ to be treated as "Class 2".

Where

$$\varepsilon = \sqrt{\left(\frac{235}{f_y}\right)}$$

y_p is the part of the steel flange which is in compression:

$$2 \times B \times p_y \times y_p = R_s - R_c \quad \rightarrow \quad y_p = \frac{R_s - R_c}{2 \times B \times p_y}$$

And the compression force in the steel flange is:

$$y_p \times B \times p_y = \frac{R_s - R_c}{2}$$

Where

$$p_y = \frac{f_y}{\gamma_a}$$

- Moment respect the upper fibre of the top flange:

$$M_{pl,Rd} = R_c\left(\frac{h_c}{2} + h_p\right) + R_s\frac{h}{2} - \left[2 \times \frac{R_s - R_c}{2} \times \frac{R_s - R_c}{2Bp_y} \times \frac{1}{2}\right]$$

$$M_{pl,Rd} = R_c\left(\frac{h_c}{2} + h_p\right) + R_s\frac{h}{2} - \frac{(R_s - R_c)^2}{4Bp_y}$$

c) Plastic neutral axis within web: $R_c \leq R_s$ and $R_c < R_w$

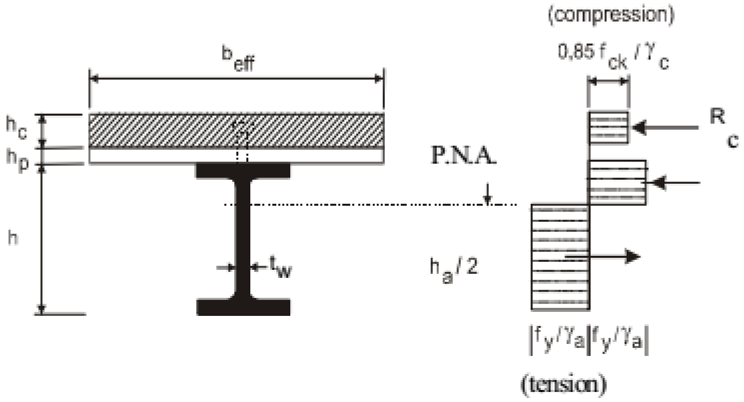


Figure 45 Plastic stress blocks when PNA lies within the web

- Moment relation respect to the centre of gravity of the steel beam:

$$M_{pl,Rd} = M_{apl,Rd} + R_c\left[\frac{h_c + 2h_p + h}{2}\right] - \frac{R_c^2}{R_w} \times \frac{h}{4}$$

where

M$_{pl,Rd}$ is the plastic moment resistance of the steel section alone.

Step 3:- Shear Resistance Of Beam

- Pure shear: the shear resistance of the web is taken as shown below:

$$V_{pl,Rd} = \frac{f_y}{\sqrt{3}\gamma_a} \times A_v = 0{,}58 f_y \frac{A_v}{\gamma_a}$$

where

A$_v$ is the shear area of the section

- Combined bending and shear: the interaction equation used to consider at the same time the bending moment and the shear is:

$$M_{sd} \leq M_{fRd} + \left(M_{Rd} - M_{fRd}\right)\left[1 - \left(\frac{2V_{sd}}{V_{plRd} - 1}\right)^{2}\right]$$

Where

$M_{f,Rd}$ is the moment resistance of the section considering only the flanges M_{Sd} and V_{Sd} are the applied moment and shear force respectively at the cross section considered.

If $V_{Sd} \leq 0{,}5\ V_{pl,Rd}$ no reduction to the moment resistance is made.

<u>Step 4:- Design of Shear Connectors(Full And Partial)</u>

There are two design equations to cover the different possibilities of failure:

1. Failure of the concrete:

$$P_{Rd}^{a} = 0{,}29\alpha d^{2}\sqrt{f_{ck}\frac{E_{c}}{\gamma_{v}}}$$

2. Shear failure of the stud, at its weld collar:

$$P_{Rd}^{b} = 0{,}8 f_{u}\frac{\pi d^{2}}{4\gamma_{v}}$$

P_{Rd} = smaller $(P_{Rd\,a} ; P_{Rd\,b})$

where

f_u is the ultimate tensile strength of the steel used in the studs (normally 500 N/mm^2)

$$\alpha = 0{,}2\left(\frac{h}{d} + 1\right) \leq 1{,}0$$

For the height and diameter of the stud.

γ_v = 1.25 is the partial safety factor at the ultimate limit state.

These formulae apply for stud diameters smaller than 22 mm.

- Degree of shear connection

In the plastic design of composite beams, the longitudinal shear force to be transferred between the points of zero and maximum moment should be the smaller of R_c or R_s. If so, full shear connection is provided.

If less shear connectors than the number required for full shear connection are provided it is not possible to develop the full plastic moment resistance of the composite section. In this case the degree of shear connection may be defined as:

$$\frac{N}{N_f} = \frac{R_q}{R_s} \text{ for } R_s < R_c$$

$$\frac{N}{N_f} = \frac{R_q}{R_c} \text{ for } R_c < R_s$$

where

R_q is the total shear force transferred by the shear connectors between the points of zero and maximum moment.

N_f is the number of shear connectors for full shear connection

N is the number of shear connectors provided over the relevant part of the span.

- Moment resistance of a composite section with partial shear connection

When R_q, resistance of shear connection, is less than both R_c and R_s there is no full shear connection and the moment resistance is reduced.

$$R_q = N_a \times Q_p$$

$$M_{Rd} = M_{apl,Rd} + \frac{N}{N_f}\left(M_{pl,Rd} - M_{apl,Rd}\right)$$

where

$M_{pl,Rd}$ is the moment resistance of the composite section for full shear connection $M_{apl,Rd}$ is the moment resistance of the steel section.

- Minimum degree of shear connection

The general limits on the degree of shear connection for a composite slab (with $b_o/h_p \geq 2$ and h p $\leq$ 60mm):

$$L \leq 25\ m\ N/N_f \geq 1-(355/f_y)\ (1-0{,}04\ L_e) \geq 0{,}4$$

$$L > 25\ m\ N/N_f \geq 1.0$$

Where L is the beam span.

Step 5:- Serviceability Conditions:- Control Of Deflection

Deflections are calculated using the second moment of area of the composite section based on elastic properties. So first of all the second moment of area has to be calculated. Under positive moment the concrete may be assumed to be uncracked. To calculate the second moment of area, the composite section is considered as a transformed steel section. The second moment of area of the composite section, expressed as a transformed steel section, is:

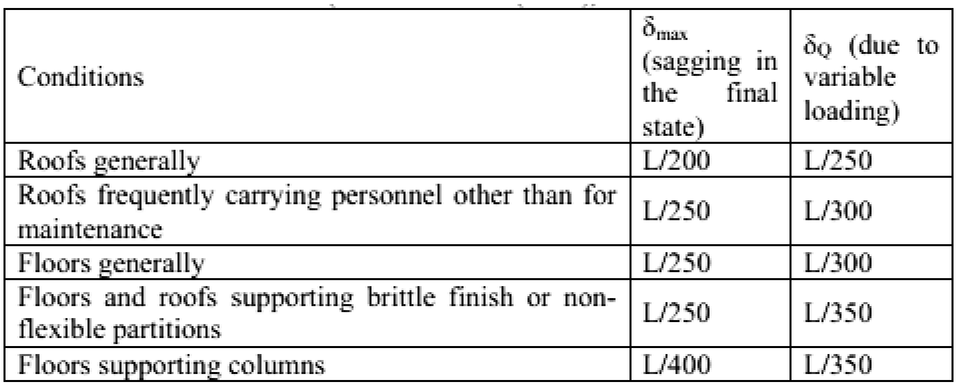
$$I_c = \frac{A_a\left(h_c + 2h_p + h\right)^2}{4\left(1 + nr\right)} + \frac{b_{eff}\, h_c^3}{12n} + I_{ay}$$

Where

n is the ratio of the elastic moduli of steel to concrete, taking into account the creep of the concrete when it is relevant r is the ratio of the cross-sectional area of the steel section relative to the concrete section I.

a_y is the second moment of area of the steel section The common value of the ratio I_c/I_{ay} is in the range of 2.5 to 4.0. These values indicate that one of the main benefits we can get with the composite action is in terms of reduction of deflections.

$$\delta = \frac{5FL^3}{384E_a I_{xx}}$$



Conditions	δ_{max} (sagging in the final state)	δ_Q (due to variable loading)
Roofs generally	L/200	L/250
Roofs frequently carrying personnel other than for maintenance	L/250	L/300
Floors generally	L/250	L/300
Floors and roofs supporting brittle finish or non-flexible partitions	L/250	L/350
Floors supporting columns	L/400	L/350

Table 21 Deflection limits For Composite Beams

7.3 COMPOSITE COLUMN

For the design of a composite column under combined compression and bi-axial bending, the axial resistance of the column in the presence of bending moment for each axis has to be evaluated separately. Thereafter the moment resistance of the composite column is checked in the presence of applied moment about each axis, with the relevant non dimensional slenderness of the composite column. Imperfections have to be considered only for that axis along which the failure is more likely. If it is not evident which plane is more critical, checks should be made for both the axes.

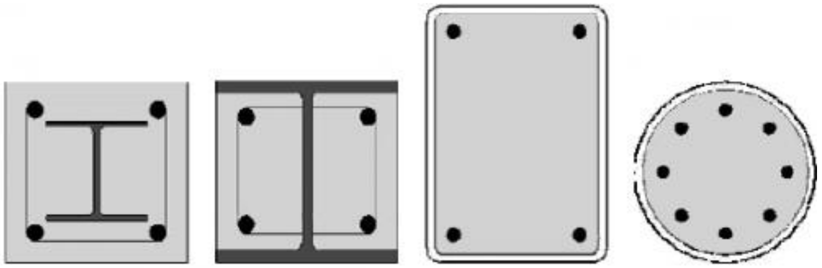


Figure 46 Various Types Of Composite Column Plans

7.3.1 DESIGN METHODOLOGY

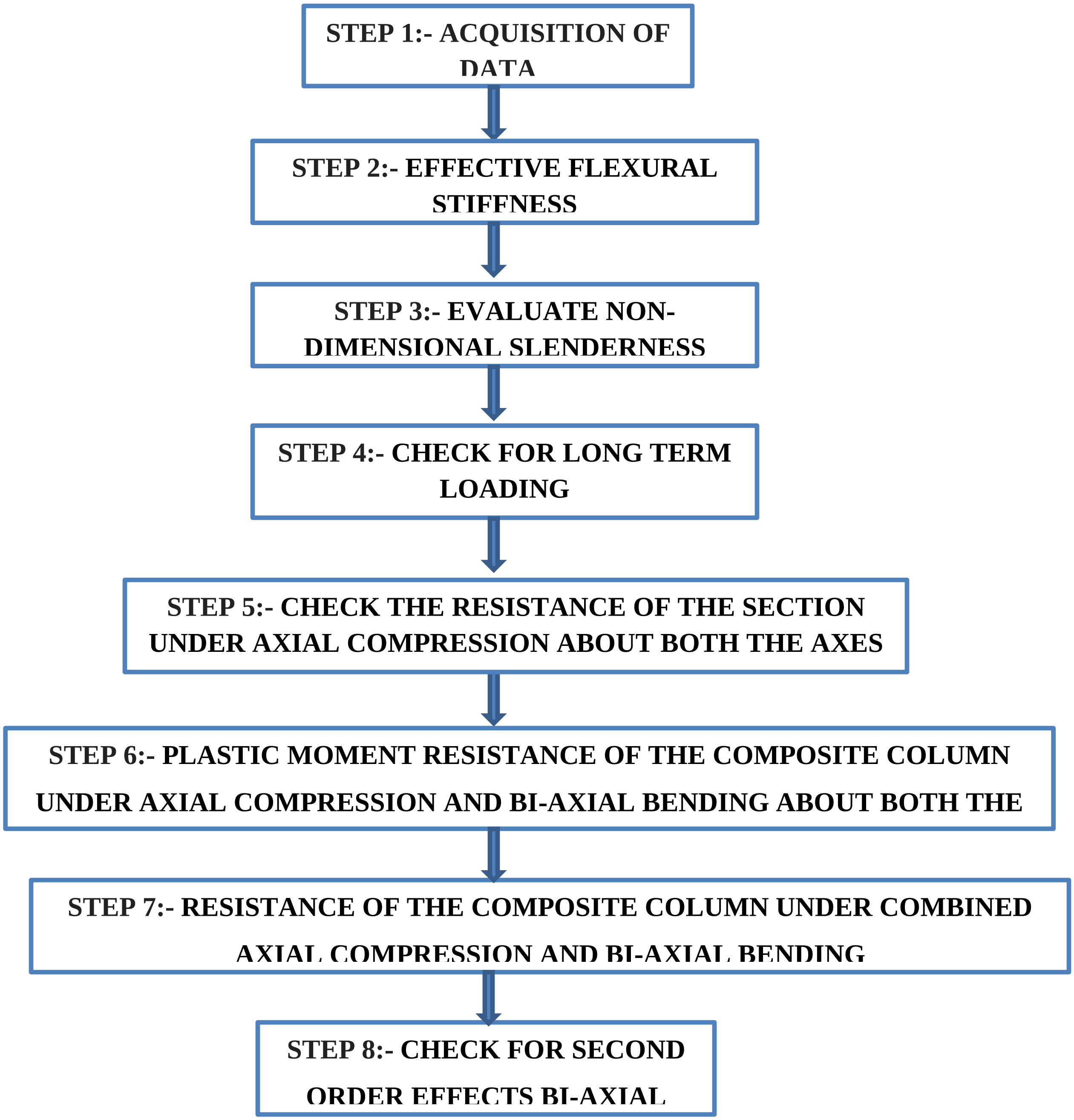


Figure 47 Flowchart for Design Composite Column

The following stages should be considered in the design of Column

Step 1:- List the Properties

- List the composite column specifications and the design values of forces and moments
- List material properties such as f_y, f_{sk}, $(f_{ck})_{cy}$, E_a, E_s, $E_{c.}$
- List section properties A_a, A_s, A_c, I_a, I_s, I_c of the selected section.

Step 2:- Effective flexural stiffness

- Plastic resistance, P_p of the cross-section from equation

$$P_p = A_a f_y / \gamma_a + \alpha_c A_c (f_{ck})_{cy} / \gamma_c + A_s f_{sk} / \gamma_s$$

- Evaluate effective flexural stiffness, *(EI)ex* and *(EI)ey*, of the cross- section for short term loading from equation,

$$(EI)_{ex} = E_a I_{ax} + 0.8\, E_{cd} I_{cx} + E_s I_{sx}$$

$$(EI)_{ey} = E_a I_{ay} + 0.8\, E_{cd} I_{cy} + E_s I_{sy}$$

Step 3:- Evaluate non-dimensional slenderness

$$\bar{\lambda}_x = \left(\frac{P_{pu}}{(P_{cr})_x} \right)^{\frac{1}{2}}$$

$$\bar{\lambda}_y = \left(\frac{P_{pu}}{(P_{cr})_y} \right)^{\frac{1}{2}}$$

Where

$$P_{pu} = A_a f_y + \alpha_c A_c (f_{ck})_{cy} + A_s f_{sk}$$

Note:

P_{pu} is the plastic resistance of the section with $J_a = J_c = J_s = 1.0$

$$(P_{cr})_x = \frac{\pi^2 (EI)_{ex}}{\ell^2}$$

$$(P_{cr})_y = \frac{\pi^2 (EI)_{ey}}{\ell^2}$$

Step 3:- Check for long term loading

The effect of long-term loading can be neglected if following conditions are satisfied:

Eccentricity, e given by

$$\begin{aligned} &e = M / P \geq 2 \\ &e_x \ \geq 2b_c \\ &\text{and } e_y \geq 2h_c \end{aligned}$$

Step 4:- Check the resistance of the section under axial compression about both the axes

Design against axial compression is satisfied if following conditions are satisfied:

$$P < \chi_x P_p$$

$$P < \chi_y P_p$$

Where

$$\chi_x = \frac{1}{\left(\phi_x + \left\{\phi_x^{\,2} - \overline{\lambda}_x^{\,2}\right\}^{\frac{1}{2}}\right)}$$

$$\phi_x = 0.5\left[1 + \alpha_x\left(\overline{\lambda}_x - 0.2\right) + \overline{\lambda}_x^{\,2}\right]$$

$$\chi_y = \frac{1}{\left(\phi_y + \left\{\phi_y^2 - \bar{\lambda}_y^2\right\}^{\frac{1}{2}}\right)}$$

$$\phi_y = 0.5\left[1 + \alpha_y\left(\bar{\lambda}_y - 0.2\right) + \bar{\lambda}_y^2\right]$$

<u>Step 5:- Plastic moment resistance of the composite column under axial compression and bi-axial bending about both the axes.</u>

Evaluate plastic moment resistance of the composite column under axial compression and bi-axial bending about both the axes.

- About x-x axis

$$M_{px} = [p_y\ (Z_{pa}-Z_{pan}) + 0.5\ p_{ck}\ (Z_{pc}-Z_{pcn}) + p_{sk}\ (Z_{ps}-Z_{psn})\ ]_x$$

Where

M_{px} plastic moment resistance about x-x axis

Z_{psx}, Z_{pax}, and Z_{pcx} are plastic section modulus of the reinforcement, steel section, and concrete about their own axes in x direction respectively.

Z_{psn}, Z_{pan}, and Z_{pcn} are plastic section modulus of the reinforcement, steel section, and concrete about neutral axis in x direction respectively.

- About y-y axis

$$M_{py} = [\ p_y\ (Z_{pay}-Z_{pan}) + 0.5\ p_{ck}\ (Z_{pcy}-Z_{pcn}) + p_{sk}\ (Z_{psy}-Z_{psn})\ ]_y$$

Where

M_{py} plastic moment resistance about y-y axis

$\mathbf{Z_{psy}}$, $\mathbf{Z_{pay}}$, and $\mathbf{Z_{pcy}}$ are plastic section moduli of the reinforcement, steel section, and concrete about their own axes in y direction respectively.

$\mathbf{Z_{psn}}$, $\mathbf{Z_{pan}}$, and $\mathbf{Z_{pcn}}$ are plastic section modulus of the reinforcement, steel section, and concrete about neutral axis in y direction respectively.

Step 6:- resistance of the composite column under combined axial compression and bi-axial bending

The design against combined compression and bi-axial bending is adequate if following conditions are satisfied:

$$M_x \leq 0.9\, \mu_x\, M_{Px}$$

$$M_y \leq 0.9\, \mu_y\, M_{Py}$$

$$\frac{M_x}{\mu_x M_{px}} + \frac{M_y}{\mu_y M_{py}} \leq 1.0$$

Where μ_x and μ_y are the moment resistance ratios in the *x* and *y* directions respectively.

Step 7:- Check for Second Order Effects

Isolated non – sway columns need not be checked for second order effects if:

$P / (P_{cr})_x <= 0.1$ for bending about x-x axis

$P / (P_{cr})_y <= 0.1$ for bending about y-y axis

CHAPTER 8

CONCLUSION

- Sufficient Study of literature on Composite Structure has been done to understand behaviour of the composite elements.(Refer **Chapter 2**)
- Design loads and Exposure Conditions are taken as prescribed by IS Codes(Refer **Chapter 4**)
- A G+4 RCC structure of plan dimensions 12mx12m has been analysed, designed and cost per unit quantities worked out.
- An equivalent Steel. structure has also been analysed, designed ,under earthquake considerations because of the inherent ductility characteristics, Steel structure will perform better than a conventional R.C.C. structure.
- For analysis, STAADPro-V8i software has been used.
- Manual design has been carried out for R.C.C. structure(Refer **Chapter 5,Sec 5.1**)
- Dimentions of the structure elements and reinforcements are provided in kkeping economy of the structure in consideration.
- Sufficient insight into the design of Steel-Concrete composite structure which is an emerging area has been gained. (Refer **Chapter 7,Sec 7.1**)
- Foundation size and reinforcement requirements are less in steel structure as compared to RCC Structure. (Refer **Chapter 6,Sec 6.1.8**)
- Bending moment in Steel Member are much less than in RCC members. (Refer **Chapter 6,Sec 6.1.1**)
- Stresses generated in Steel members of the structure are less than stresses generated in RCC member of The RCC Structure Because of more ductility of the steel structure. (Refer **Chapter 6,Sec 6.1.5**)
- Storey Drifts in Steel Structure is more than Concrete Structure. (Refer **Chapter 6,Sec 6.1.4**)
- As the steel structure is more ductile than RCC therefore it has better response to the various load types thus is more reliable.

- Overall Steel Structure has safer response when subjected to Wind and Seismic forces. (Refer **Chapter 6**)
- Sufficient Study Of BS 5950 and Eurocode 4 has been carried out for understanding designing procedure for steel concrete composite structure has been carried out. (Refer **Chapter 7**)
- Immense confidence has been gained in the analysis and design of a multi-storeyed structure using STAAD Pro 2003 software which will benefit us as we step out of the portals of the college

CHAPTER 9

FURTHER SCOPE OF WORK

- Presently Analysis and design of a G+4 Structure has been carried out , further Analysis of a G+10 or above structure can be done to get the responses of the high rise structure when subjected to similar loading combinations and exposure conditions.
- The plan of the structure in the present study is symmetric about both X and Z axis, for further study ,plan of the structure can be changed to more unsymmetrical as per analysis requirements.
- The analysis carried out in the present study is limited to Static analysis for more responses further dynamic analysis can be carried out like, pushover analysis, time history analysis etc.
- In the present work Study of design of Composite Structures according to British Code And Eurocode has been done , further Analysis and design of the Steel-Composite structure can be done and the results of the response of the structure can be compared to the responses of the Steel and RCC Structure.

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