Design and Analysis of G+15 Office Building by Using Hybrid Pre-Engineered Construction.

PULAPARTHI TIRUMALA SRINIVAS[1], SUSANTA KUMAR SETHY[2], A N SHANKAR[3]

[1]P.G. STUDENT DEPARTMENT OF STRUCTURAL ENGINEERING, UPES, DEHRADUN, UTTARAKHAND, INDIA1
[2]ASSOCIATE PROFFERSOR, DEPARTMENT OF HSE & CIVIL ENGINEERING, UPES, DEHRADUN, UTTARAKHAND, INDIA2
[3]ASSOCIATE PROFFERSOR, DEPARTMENT OF HSE & CIVIL ENGINEERING, UPES, DEHRADUN, UTTARAKHAND, INDIA3

---***---

Abstract - *This paper summarizes the design and analysis of High-Rise Hybrid PE structure, Hybrid structures are currently developing and widely using in recent years. Hybrid structure is the combination to different type of structural elements, in general Structural steel members are used as frame members and reinforcement concrete used for slab (Deck slabs) in the construction of hybrid structure etc., likewise in this design work Hollow core slabs (Pre-cast slabs) are used as a replacement for the traditional cast in-situ concrete slabs. the crucial part in this design process is Connections, connection play's major key role in transferring the load acting on slab to frame members. By introducing Hollow core slabs will accelerate the ease of construction, decreases the work force on site and cost of construction of hollow core slabs are significantly lesser than the cast in-situ concrete slabs which is ultimately reducing the cost of construction.*

***Key Words*: Hybrid Structure, Hollow Core Slabs, Deck slabs, High Rise Structures, Connections and Staad Pro Advance connect edition etc.,**

1. INTRODUCTION

The need of concrete structures is rapidly increasing. it can be a residential, commercial and institutional buildings. Which is ultimately increase the usage of cement in construction, as we all know that carbon dioxide is the by-product in chemical conversion of cement production which is not concerned with relation of living organisms. in recent days numerous practices are carrying out to avoid the traditional construction practices in civil engineering to gradually dimmish the usage of cement in the construction to make it more ecological, we can observe in current days there is a lot of advancement is taking place in civil engineering. To make the design and construction of the structures effortlessly and secure. Like pre cast structures and steel structures, A new tier of advancements are taken place in design and construction of structure, it is the combination of Pre-engineered structures and pre cast structures which is known as hybrid structures has come into usage. Hybrid structures amplifies the structural and architectural points of interest of consolidating parts of various materials to accomplish better manageability and guarantee fast construction, all of which convert into considerable reserve funds and better nature of the design. By utilizing pre-cast concrete slabs (hollow-core slabs) a role as instructing material in development lessens the utilization of wet cement on site. Pre-cast concrete increase flexibility of construction and time saving process without intruding any characteristic properties of it. Comparing with traditional reinforced concrete (RC) system, hybrid structure continues to use RC core walls, and introduces steel beams and columns instead of RC beams and columns. So, Hybrid Structure is good at decreasing self-weight, reducing sizes of structural members by comparing to the RCC structure's, and fastens the construction progress. proper design of the hybrid structure has well seismic performance. As we all known, super high-rise building is complex in designing, which involving beauty, safety, and economy.

Advantages of Hybrid structures:

- Hybrid structure increases the scope of serviceability and adaptability.
- Hybrid structures are significantly increase the functionality of the stricture aesthetics properties of the structure.
- Maintenance of the structure is ease which reflects in minimal maintenance.

- Hybrid structures are environment efficient due to minimal use of concrete in the structure.
- The versatility of the structure is better in hybrid structures.

1.1 Objectives:

- To Plan a Hybrid Pre-Engineer Structure G+15, (Built-Up Area :10200sft).
- To Analyse the Hybrid Pre-Engineer Structure using Staad Pro Software.
- To Design the Hybrid Pre-Engineering Structure Based on Indian Standards.
- To Design the Joint between PE Structure and Pre cast slab.

2. Literature Review:

1. Robert E. Englekirk. The construction of this innovative project flowed smoothly and was completed on schedule. The credit for this achievement lies with the Pankow project management team. Assembly procedures were developed in the pre casting yard and carefully documented, as were the procedures for ensuring high quality. an even wider use of precast components is possible. The floor systems, for example, could have been constructed using pre topped hollow-core slabs or double tees. All that is really required is imagination, team work, and careful planning. From a design perspective, the performance and the assembly advantage associated with the development of yielding precast concrete frame systems is clear. The emphasis to date, insofar as code development is concerned, has been on emulative assemblies where precast concrete is assembled so as to perform as though it were cast-in place concrete. The codification process must strive to encourage the yielding approach and avoid the restrictive provisions that dominate current codes

2. M.J. Nigel Priestley, S. Sritharan, James R. Conley. A large scale Five story precast concrete building constructed to 60 percent scale was tested under simulated seismic loading as the culmination of the 10-year PRESSS (Precast Seismic Structural Systems) research program. The building comprised four different ductile structural frame systems in one direction of response and a jointed structural wall system in the orthogonal direction. The test structure was subjected to seismic input levels equivalent to at least 50% higher than those required for UBC Seismic Zone 4.

3. A.M. Mwafy, A.S. Elnashai. The Applicability and Accuracy of inelastic static push-over analysis in predicting the seismic response of RC Buildings are investigated. Twelve RC buildings with various characteristics, incremental dynamic analysis employing eight natural and artificial records, static pushover analysis using three lateral load distributions and local and global limit state criteria are utilised based on the large amount of information obtained.

4. Erol Kalkan, Sashi K. Kunnath. The advancement of performance-based procedure in Seismic design relies greatly on advancements in analytical methods to predict inelastic dynamic response of Building structures. Since Nonlinear time-history analyses are associated with greater uncertainties stemming from the choice of modelling parameter to the selection of ground motions, engineers are more likely to adopt static approaches before finally transitioning to time history methods.

3. METHODOLOGY

1. Planning of G+15 Steel Structural Building.
2. Analysis of Structures using Staad Pro Connect Edition.
3. Designing the Steel structures and Connections according to IS Code.
4. Optimization of the structure.
5. Results and Discussion.

4. Results and Discussion.

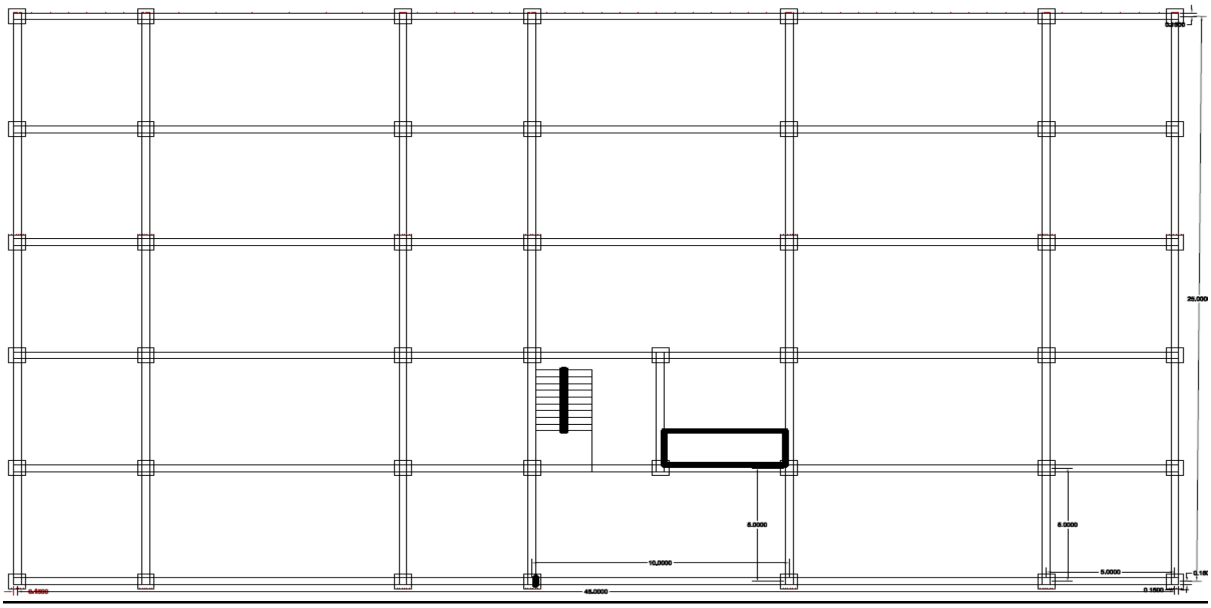


FIG:1 PLAN

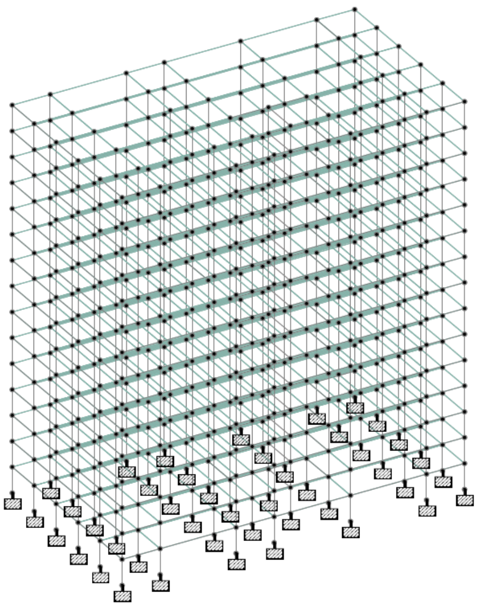


FIG 2: ISOLATED VIEW OF THE STRUCTURE.

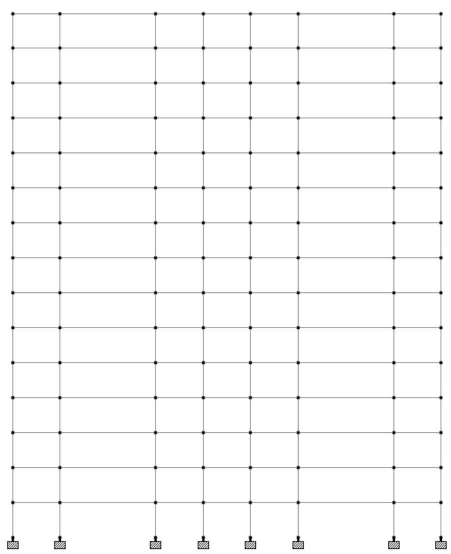


FIG 3: FRONT VIEW OF THE STRUCTURE.

4.1 Structure profile:

- Type of Building: Office Building.
- Construction Area: Hyderabad.
- Built up area: 12110S_{ft}
- Structure dimensions: 45*25M @ 3.5M height of each Storey.
- Total height of building: 52.5M
- Clear Spacing b/w Column: 1. 05*05M
- Clear Spacing b/w Column: 2. 10*05M

4.1.1 Section profile used in design:

Column: for columns we taken Star Column Built up Section to take care of both Longitudinal and Lateral Moments of the structure. the dimension of column will be varied @ 4sotery interval to avoid unnecessary loads and to make the design more economical.

Column1:

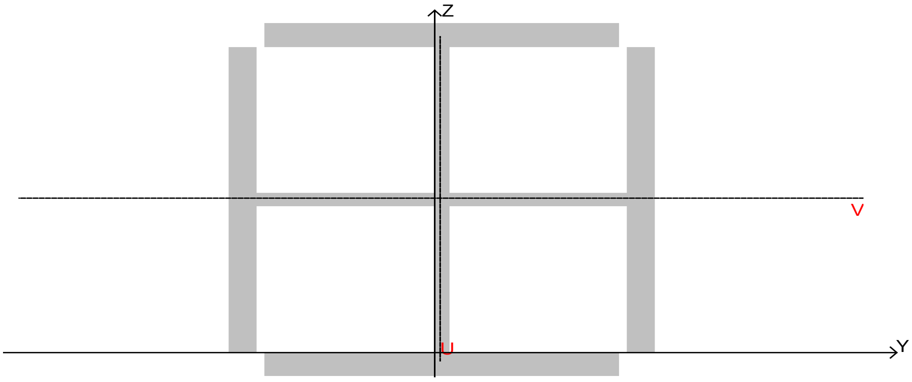


Fig 4: Section Cross- section

Section element	Rotation angle	Mirror	Material	E (kN/mm^2)
Sheet 320 x 14	90.0		Steel	205.0
Sheet 160 x 14			Steel	205.0
Sheet 160 x 14			Steel	205.0
Sheet 320 x 25			Steel	205.0
Sheet 320 x 25			Steel	205.0
Sheet 320 x 25	90.0		Steel	205.0
Sheet 320 x 25	90.0		Steel	205.0

- The overall dimensions of the section are 384 x 370 mm

Basic geometry of the section:

	Parameter	Value	
A	Cross sectional area	40960.0	mm^2
a	Angle between Y-Z and U-V axes	-90.0	deg
I_y	Moment of inertia about axis parallel to Y passing through centroid	651769173.33	^{4}
I_z	Moment of inertia about axis parallel to Z passing through centroid	696430293.33	^{4}
I_t	Torsional moment of inertia (St. Venant)	6811062.81	mm^4
i_y	Radius of gyration about axis parallel to Y passing through centroid	126.14	mm
i_z	Radius of gyration about axis parallel to Z passing through centroid	130.39	mm
W_{u+}	Elastic modulus about U-axis (+ve extreme)	3627241.11	mm^3
W_{u-}	Elastic modulus about U-axis (-ve extreme)	3627241.11	mm^3

W_{v+}	Elastic modulus about V-axis (+ve extreme)	3523076.61	mm^3
W_{v-}	Elastic modulus about V-axis (-ve extreme)	3523076.61	mm^3
$W_{pl,u}$	Plastic modulus about axis parallel to U-axis	4555368.84	mm^3
$W_{pl,v}$	Plastic modulus about axis parallel to V-axis	4416614.84	mm^3
I_u	Moment of inertia about U-axis	696430293.33	^{4}
I_v	Moment of inertia about V-axis	651769173.33	^{4}
i_u	Radius of gyration about U-axis	130.39	Mm
i_v	Radius of gyration about V-axis	126.14	mm
a_{u+}	Centroid to edge of compression zone along +ve U-axis	86.01	mm
a_{u-}	Centroid to edge of compression zone along -ve U-axis	86.01	mm
a_{v+}	Centroid to edge of compression zone along +ve V-axis	88.56	mm
a_{v-}	Centroid to edge of compression zone along -ve V-axis	88.56	mm
y_M	Distance to centroid along Y-axis	7.0	mm
z_M	Distance to centroid along Z-axis	160.0	mm
y_P	Distance to equal area axis along Y-axis	7.12	mm
z_P	Distance to equal area axis along Z-axis	159.9	mm
I_{yz}	Moment of inertia Iyz in the user coordinates	0.0	mm^4
u_P	Distance to equal area axis along U-axis	-0.1	mm
v_P	Distance to equal area axis along V-axis	-0.12	mm

4.1.2. Beam Profile:

In Beams we taken built up section. By considering the point of placing pre-cast slabs and allowable stress in the member. We take Two Different type of section in the design

Section-I properties:

1. depth of the section: 600mm.
2. Width of top flange: 300mm
3. Width of Bottom flange: 200mm
4. Thickness of web: 8mm
5. Thickness of Flange: 12mm

Section-II properties:

1. depth of the section: 600mm.
2. Width of top flange: 300mm
3. Width of Bottom flange: 200mm
4. Thickness of web: 12mm
5. Thickness of Flange: 18mm.

4.2 Wind Load Calculation:

According to the IS 456: Part III the wind load calculations are calculated, Instead Defining Wind Load Definition, Manual Calculations are made and applied on nodal direction on columns for absolute results and total 8 no of Wind Load Cases are defined in the wind load applications.

- Wind zone: Zone II, V_b: 44m/s
- K_1: 1.07, K_3: 1, K_4: 1, K_2: 1-1.1735.
- $V_z = Vb*K_1*K_2*K_3*K_4$
- $P_z = 0.6Vz*Vz$
- $P_d = P_z*Ka*K_d*Kc$
- $F=(Cpe-Cpi) *A*P_d$

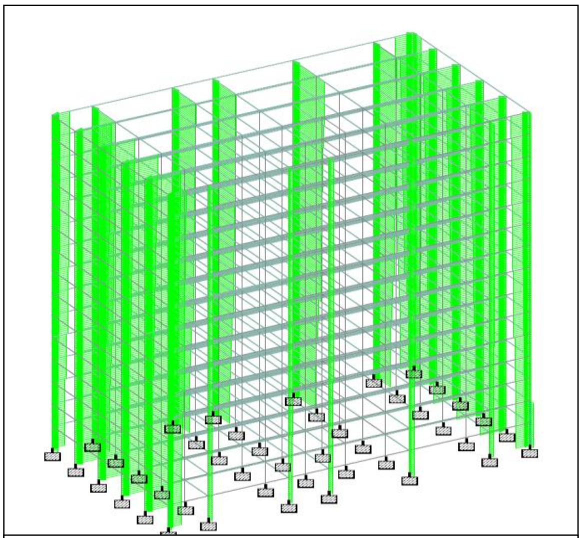


Fig 5: Wind load application

For 1st floor

(A)

- V_Z = 44*1*1.1735*1*1= 47.08 m/s
- P_Z = 0.6*47.08*47.08 = 1329.9N/mm^2
- P_d = 1.323*0.8*09*1 = 0.956 Kn/m^2
- F = (0.7-0.5) * 2.5*0.956 =0.478 Kn/m^2

(B)

- V_Z = 44*1*1.1735*1*1= 47.08 m/s
- P_Z = 0.6*47.08*47.08 = 1329.9N/mm^2
- P_d = 1.323*0.8*09*1 = 0.956 Kn/m^2
- F = (-0.4-0.5) *7.5*0.956 =-6.45 Kn/m^2

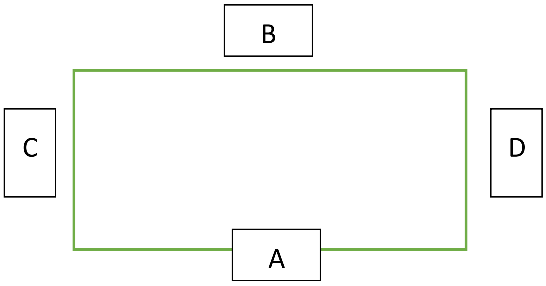


Fig-6 wind load notation.

(C)

- V_Z = 44*1*1.1735*1*1= 47.08 m/s
- P_Z = 0.6*47.08*47.08 = 1329.9N/mm^2
- P_d = 1.323*0.8*09*1 = 0.956 Kn/m^2
- F = (-0.7-0.5) * 2.5*0.956 =-2.86 Kn/m^2

(D)

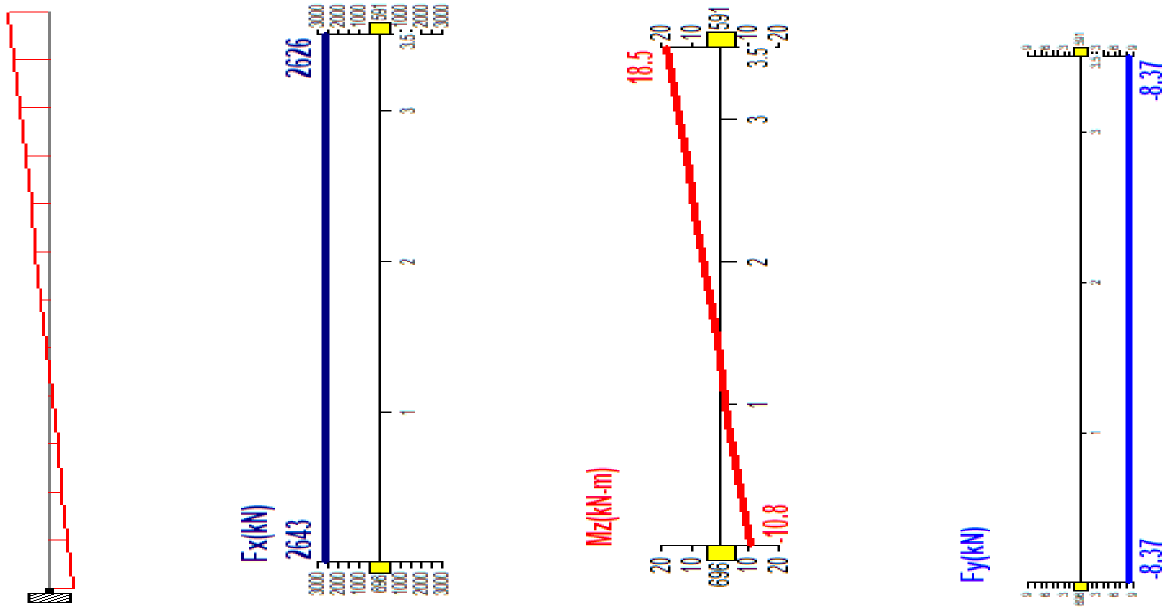
- V_Z = 44*1*1.1735*1*1= 47.08 m/s
- P_Z = 0.6*47.08*47.08 = 1329.9N/mm^2
- P_d = 1.323*0.8*09*1 = 0.956 Kn/m^2
- F = (-0.7-0.5) * 2.5*0.956 =-2.86 Kn/m^2

4.3 Seismic Load Calculation:

According to the IS 1893:2002 seismic load definition is defined in Staad pro.

- Zone: II
- Response reduction factor: 5
- Importance factor:1.5
- Period in X- direction: 0.704
- Period in Y- direction: 0.954

4.4 Staad pro Results:



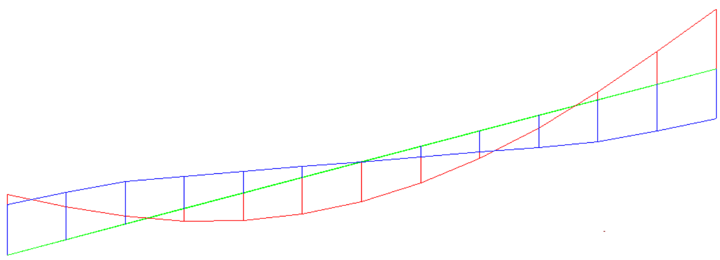
Column Axial Force Bending Moment Shear Force

Fig:7 Column Axial Force, Bending Moment, Shear Force Diagrams.

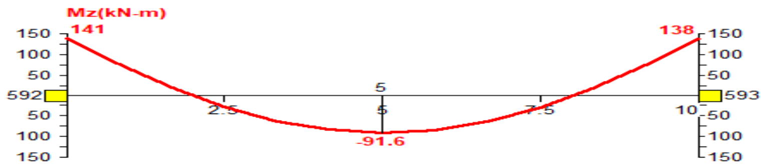
S.NO	COLUMN	AXIAL LOAD(Kn)	BENDING MOMENT (Kn-m)	SHEAR FORCE(Kn)
1	1066	2643	10.5	8.37
2	94	5646	55.6	23.9
3	290	10463	1.66	1.01

Table:1 value of Axial Forces, BM, SF.

The above tabulated values are results of Bending moment, Axial load and Shear Force values of various columns as numbered which show the least, intermediate and highest values in it.

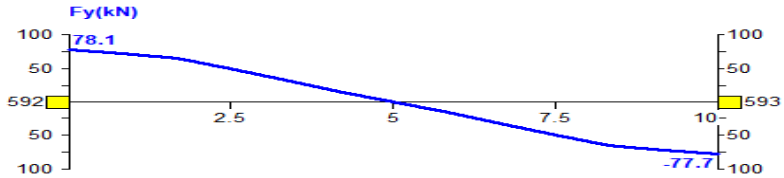


Beam with Axial, Shear Force and Bending Moment Diagram

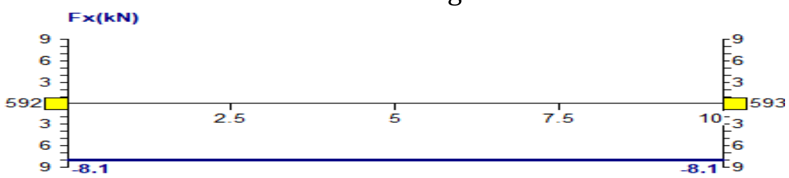


Bending Moment Diagram

She



Shear Force Diagram



Axial Force Diagram

Fig:8 Beam with Axial, Shear Force and Bending Moment

S.NO	Beam type -1	AXIAL LOAD(Kn)	BENDING MOMENT (Kn-m)	SHEAR FORCE(Kn)
1	979	12.3	204-232	114-120
2	587	15.3	383-381	209-209
3	200	14.1	422-374	214-205

Table 2 Beam Type-1 Axial load, BM, SF.

S.NO	Beam type -2	AXIAL LOAD(Kn)	BENDING MOMENT (Kn-m)	SHEAR FORCE(Kn)
1	1591	2.63	32.9-42.4	39.6-42.4
2	1592	1.53	52.9-80	65.9-76.8
3	783	4.33	138-72.3	87.5-61.2

Table 3 Beam Type-2 Axial load, BM, SF.

The above tabulated values are results of Bending moment, Axial load and Shear Force values of various Beams as numbered which show the least, intermediate and highest values in it.

4.4.1 Connections and Base Plate Design:

- Load P: 2653 Kn
- Yield strength of steel FY: 345 N/mm2
- Characteristic strength of concrete Fck: 40N/mm2
- Bearing stress of Concrete: 0.45*40 =18 N/mm2
- Required Area of plate: 2320*10^3/18 =360*360mm (Provided plate area: 600*520)
- Bearing Pressure of Concrete: 2320*10^3/ (600*520) = 8.47 N/mm2
- design shear strength of the bolt (Vdsb) =Vnsb/γmb
- Nominal Shear Capacity of Bolt (Vnsb)= fu/3*(nn*Anb+ns*Asb) =167.16Kn
- Vdsb=Vnsb/γmb =133.72kn
- Design Tensile capacity of the Bolt (Tdb)= Tnb/γmb
- Nominal Tensile Capacity of Bolt (Tnb)= 0.9*fub*A=260.58Kn
- Tdb: Tnb/γmb=208.47Kn
- Max Bending moment in the plate (Ma)= P*g/4 =7.10625kn-m
- thickness of plate required (t): √6*Ma*γmo/(1.2*fy*p) =28mm
- Thickness of plate with web stiffeners: 22mm

- Bolt Diameter: 24 mm
- Length of bolt: 1400mm

4.4.2 BEAM CONNECTIONS:

SHEAR FORCE (FX)	KN	114	120
AXIAL FORCE (FY)	KN	12.3	12.3
Moment (Mz)	Kn-m	204	232
WEB DEPTH	mm	600	
FLANGE DEPTH	mm	300	
BOLT DIA	mm	16	
NO OF BOITS(n)		8	
PLATE THICKNESS (t)	mm	20	
PITCH (p)	mm	100	
GUAGE (g)	mm	100	

web Depth	600
Plate length	700
plate width	400

Shear Capacity of Bolt	Dia: 16mm	
design shear strength of the bolt (Vdsb)	Vnsb/γmb	
Partial safety factor (γmb)	1.25	
Ultimate tensile strength of bolt (fu)	420	N/mm^2
no. of shear Planes with threads(nn)	1	
no. of shear planes without threads (ns)	0	
nominal plain shank area of Bolt (Asb)	201.06	mm^2
Net area of the Bolt at thread (Anb)	156.82	mm^2
Nominal Shear Capacity of Bolt (Vnsb)	fu/3*(nn*Anb+ns*Asb)	
	38.028	Kn
Vdsb : Vnsb/γmb	30.42	Kn

Tension Capacity of Bolt		
design tensile capacity of the Bolt (Tdb)	Tnb/γmb	
Nominal Tensile Capacity of Bolt (Tnb)	0.9*fub*An	
	59.28	Kn
Tdb Tnb/γmb	47.42	Kn

check for Bolt Size		
forces in the bolts	Actual	Allowable

tension due to Axial Force (Fy/n) (up lift)	43	47.42		TRUE
Shear in Each bolt (Fx/n)	15	30.42		TRUE
Check for Plate thickness				
Max Bending moment in the plate (Ma)	P*g/4			
	1.075		Kn-m	
thickness of plate required (t)	√6*Ma*γmo/(1.2*fy*p)			
	13.09		<	20
check for combined tension and shear				

$$\left(\frac{\text{Actual tension}}{\text{Allowable Tension}}\right)^{2} (+) \ \frac{\text{Actual Shear}^{2}}{\text{Allowable Shear}} <1.0$$

1.065	<1.0	TRUE

4.4.3 Pre-Cast Slab:

- Total Moment =20kn/m
- Dia of HT Wire: 8mm @18000 mpa
- Thickness of Slab: 110mm
- Spacing of wires: 150mm

The connections between Pre-Cast slab and structural members are formed by shear studs designed to the shear force from the slab and taken Dia of 12mm shear studs and placed along the Gap between slab and steel member and the HT wires are tied to the studs and designed mix concrete or a GP2 Concrete mix is used as a filler material of joint filling or Gap filling.

4.4.4 Foundation Design:

- Type of Foundation: Raft Foundation
- Dimensions of the Foundations: 46M*26M*0.800M
- Area of Steel Provided in Foundation: 2150mm^2 per Meter width.
- Depth of the foundation is based on Soil test taken: 2.5M
- Safe Bearing Capacity of the soil is 250KN/m^2.

5. Conclusion:

It seems the application of Pre-Cast slabs can be used in the steel structure building. which Results in the Cost Saving in the projects and also it will be very help full in decreasing the time lapse of the project. It also Provides the ease of maintenance in the structure and also offers the option in ease of replacement.

6. Future Scope:

Introducing of Pre cast slabs in Hybrid Structures instead of concrete slabs may decrease time lapse and the workmanship of the construction which simultaneously results in cost cutting of the project without disturbing any characteristic properties actually needed, designing of connection between Hybrid structure and Pre cast slab will be crucial part which acts as medium to transfer the loads.

REFERENCES

[1] Robert E. Englekirk (2002), "Design-construction of the paramount-A 39-Story Precast Prestressed Concrete Apartment Building". PCI Journal, August 2002.

[2] M.J. Nigel Priestley, S. Sritharan, James R. Conley (2002), "Preliminary Results and Conclusions from the PRESSS Five-Story Precast Concrete Test Building". PCI Journal, December 2002.

[3] A.M. Mwafy, A.S. Elnashai (2001), "Static Pushover versus Dynamic Collapse Analysis of RC buildings". ELSEVIER, Engineering Structures 2001.

[4] Erol Kalkan, Sashi k. Kunnath (2006), "Adaptive Modal Combination Procedure for Non-Linear Static Analysis of Building Structures". ASCE,2006.

[5] D.R Panchal and P.M. Marathe (2011), "Comparative Study of RCC, Steel and Composite (G+30 Storey) Building". Institute of Technology, NIRMA University, Ahmedabad 2011.

[6] Jan N. J. A. Vambersky (2004), "High-Rise Building in the Netherlands: Hybrid Structures and precast Concrete". CTBUH 2004 Seoul Conference.

[7] Syed Firoz[1] (2012), "Design Concept of PRE-ENGINEERED Building". International Journal of Engineering Research and Applications (IJERA), Vol.2, PP. 267-272.

[8] Anamika Tedia, (2014), "Cost, Analysis and Design of Steel-Concrete Composite Structure RCC Structure". IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume II, PP 54-59.