e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

SEISMIC ANALYSIS AND DESIGN OF A G+5 STOREY RC FRAME WITH FLOATING COLUMNS

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ABSTRACT

In the present scenario, people are interested to construct a building with spacious rooms and parking places and in the same way investors are coming forward to construct commercial complex with huge space to install commercial elements in different stories of a building, where it became difficult due to the interruption of heavy and medium-sized columns in between the parking places, stories, rooms etc., in such places the importance of floating columns comes into point. Floating column is a vertical element through which the load transfers to a beam instead of column or a foundation. This paper focused on the seismic analysis and design of G+5 storey building with floating columns under low seismic zone parameters and compared the results with same G+5 storey building without floating columns (conventional structure)adopting Equivalent Static analysis of structure using IS code provisions and software toolssuch as STAAD PRO CONNECT EDITION, RCDC which will develop the structural drawings for site execution. The analysis results were evaluated in terms of lateral displacement, maximum storey displacement, storey drifts and overall response of the structures.

Keywords: Seismic Analysis, Floating Column, Hanging Column, Storey Drift, Transfer Beam.

I. INTRODUCTION

The behavior of a RC structure during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the soil. Seismic forces are developed at different floor levels in a RC frame need to be brought down along the height to the ground by the shortest path, any deviations in this load transfer path results in poor performance of the structure. Buildings with vertical setbacks causes a sudden jump in seismic forces at the level of discontinuity in the RC frame. Buildings with least number of supports usually collapse under low loading conditions. Many RC frames with an open ground storey for parking collapsed in Gujarat during 2001 Bhuj earthquake is the best example for the above statement. Floating column or hanging column is a vertical compressive member which rests on a transfer beam but doesn't transfers the load directly to the footings. These columns may begin at any floor of the structure based on the purpose of the floor. Usually, floating column rests on a transfer beam, the mechanism refers that the beam which supports the column acts as a load carrying element and transfers to the main columns, which is called as a "Transfer beam". It is widely used in high storied buildings for both commercial and residential purpose. It helps in altering the plan of the top floors to our convenience. So, a special design has to be adopted.

Figure 1: Floating column structure

Scope and objectives

Scope of the present work is limited to a G+5 storey building with floating columns and without floating column structures with plan area of 484 m^2 (22 m X 22 m). Structure is analyzed under low seismic zone conditions i.e.,

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Zone II using Equivalent Static Method (Linear static analysis) where IS 1893:2016 is strictly followed andIS 13920:2016 is used for ductile detailing of structure.

Objectives of this work are as listed below, (i) To study the behavior of both the structures, (ii) To suggest perfect positioning of structure in order to enhance the load carrying capacity of floating column structure, (iii) Finally, to compare the analysis results between both the models.

II. METHODOLOGY

Methodology of this paper involves simple steps in evaluating the structural behavior. Those are, Modeling of the structures using STAAD PRO with the assumed section properties and location details, then assigning of the load properties to analyze the structure using "Equivalent static method of seismic analysis" on both the models and then review on analysis results by comparing the results between the models and then designing the structures.

III. MODELING AND ANALYSIS

In this paper for comparative studies, two models have been considered in which one is G+5 storey building with floating columns (where columns are removed along the periphery of the structure) as Model-I and another one is G+5 storey building without floating columns (conventional building) as Model-II and its considered respective parameters are mentioned below,

Table 1. General parameters of Model-I and Model-II

Model name	Model-I and Model-II		
Plan area	22 m X 22 m		484 m^2
Floor to floorheight	3 m	Location -	Hyderabad, Telangana, India

Table 2. Assumed Section properties of Model-I

Structural element	Dimension (B X D) in mm
Columns up to 3m height from GL	500 X 800 mm
Hanging Columns (above 3m level)	400 X 500 mm
Transfer beams (at 3m level)	500 X 500 mm
Beams	300 X 400 mm
Slab thickness	125 mm
Support condition	Rigid fixed support

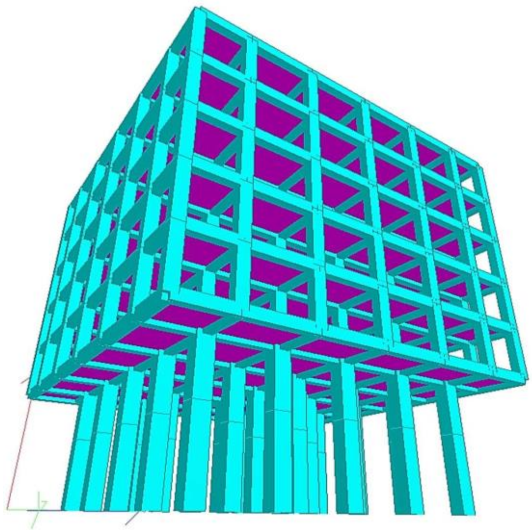

Figure 2: 3D view of Model-I

Table 3. Assumed Section properties of Model-II

Structural element	Dimension (B X D) in mm
Columns	300 X 450 mm
Beams	300 X 300 mm
Slab thickness	125 mm
Support condition	Rigid fixed support

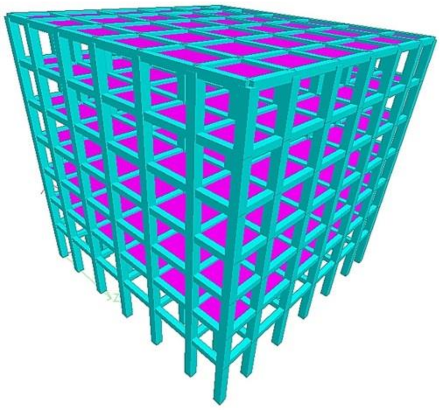

Figure 3: 3D view of Model-II

Load case details

In this paper loading conditions are considered same in both the models i.e., Model-1 & Model-2 Load cases assumed in this work are as follows,

1. Seismic loads
2. Dead load
3. Live load
4. Combination of loads

Seismic load

In both the models, seismic loads are computed based on IS 1893(1):2016 codal provisions.

In this paper seismic analysis is done by adopting "Equivalent static method" of seismic analysis following IS codes. In order to assign seismic loads in STAAD PRO, first seismic definitions are to be entered in STAAD PRO. Seismic definitions are framed in STAAD as follows,

Table 4. Assumed Seismic parameters for Model-I and Model-II

Parameter	Value
Location	**Hyderabad**
Zone	II
Zone factor	0.1
Response reduction factor (RF)	5
Importance factor (I)	1.2
Rock & soil site factor (SS)	Hard rock soil
Type of structure (ST)	RCSMRF
Damping ratio (DM)	0.05
Period in X direction (PX)	0.39 sec
Period in Z direction (PZ)	0.39 sec
Depth of foundation	4 m

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Note - RCSMRF indicates "RC special Moment Resisting Frame structure"

Table 5. Calculated load details of Model-I and Model-II

Type of Load	Model-I	Model-II
Seismic floor weight	3.125 KN/m²	3.125 KN/m²
Seismic member weight	9.25 KN/m²	2.25 KN/m²
Wall loads	11.04 KN/m²	11.04 KN/m²
Floor and floor finish loads	4 KN/m²	4 KN/m²
Live load	3 KN/m²	3 KN/m²

IV. ANALYSIS RESULTS AND DISCUSSION

Analysis results of Model-I and Model-II

For Model -I :

Mass and Base shear values in all directions are,Mass = 43903.02734 KN

Base shear V_b calculated = 1237.914 KN Base shear V_b minimum = 307.3211 KN Base shear V_b Final = 1237.9146 KN

A_h = 0.028

For Model-II :

Base shear in seismic X direction,

Mass = 28692.81836 KN

Base shear V_b calculated = 485.4 KNBase shear V_b minimum = 200.84 KNBase shear V_b Final = 485.423 KN

A_h = 0.0169

Comparative results of Model-I and Model-II

1. Storey drift :

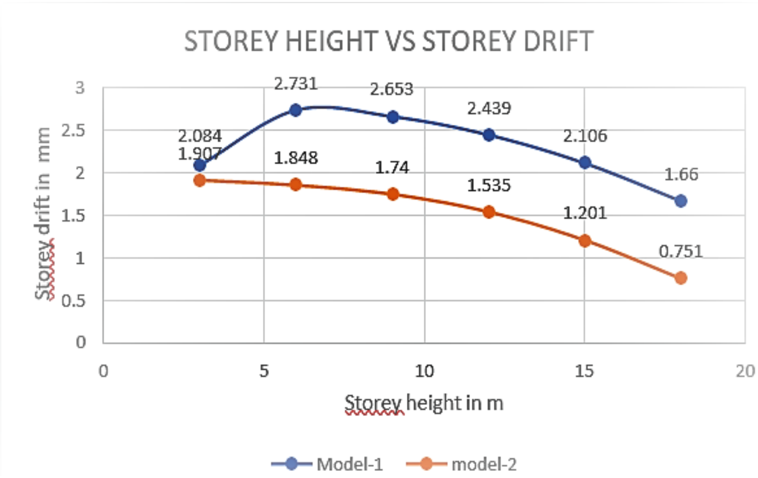

Figure 4: Graph representing Storey drift of RC frames

2. Base shear :

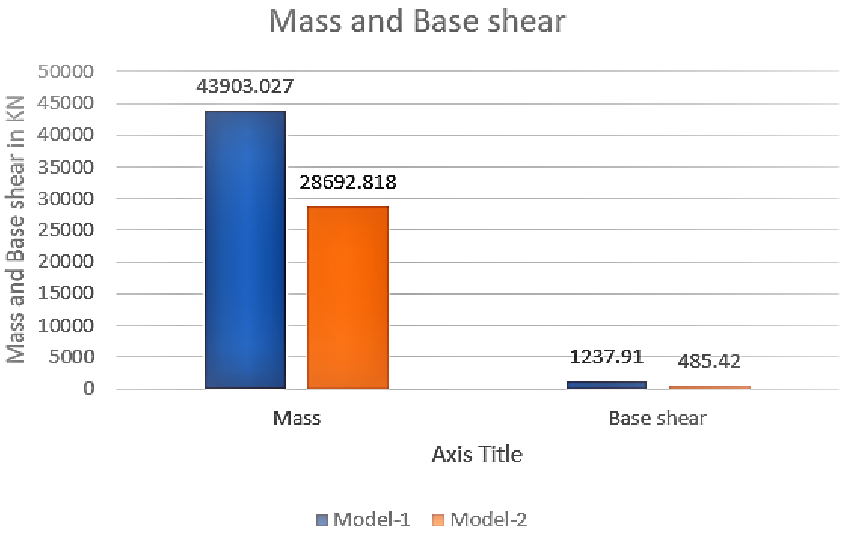

Figure 5: Graph representing Mass vs base shear of both the models

3. Maximum displacements :

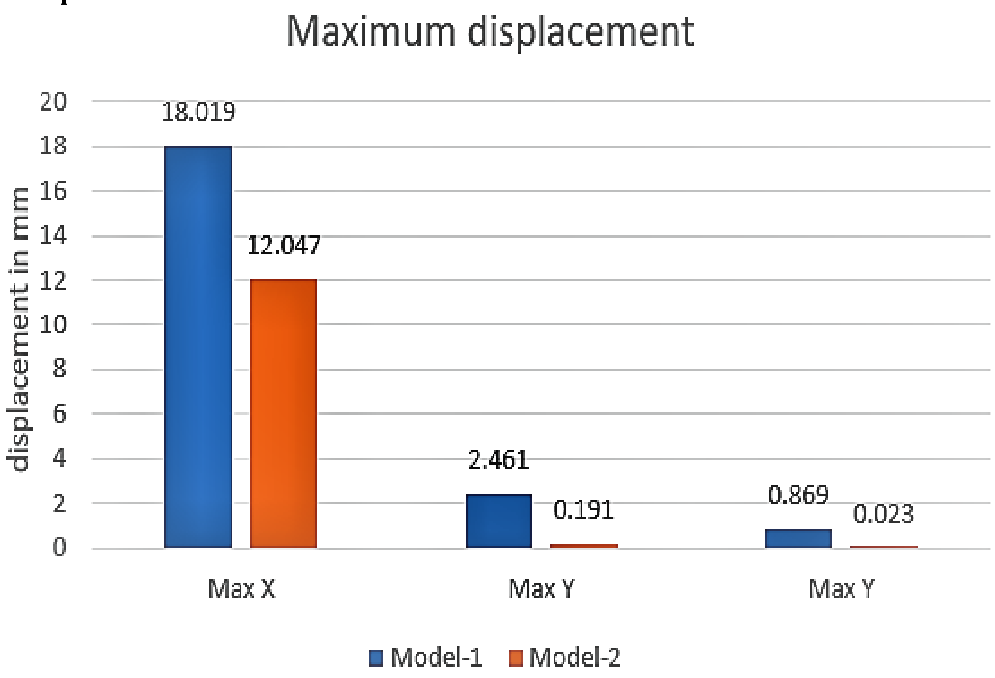

Figure 6: Graph representing maximum displacements of both the models

Model-I is observed with more Storey Drift value at 6m level compared to other floors as this happened mainly due to existence of hanging columns from 3m level onwards and its Storey drift value reduced after 3m level till roof, which says that top levels transfers the load acting on it to the first floor which has transfer beams. Maximum displacement in Model-I is more compared to Model-II, this is because Model-II has morestructural supports than Model-I and IS 1893(1):2016 says that Structure with Floating column is not recommendable since it deflects more under Lateral loads. Orientation of floating columns plays a crucial role in it as its position effects in safe load transferto the main load carrying structural elements.

V. DESIGN OF STRUCTURAL MEMBERS

Based on the obtained analysis results, designing of structural members are done using IS 456:2000 and IS 13920:2016.

Details of structural designed detailing of Model-I

Table 6. Design properties of Main column

Column Size (mm)	Material	P (KN)	Mx (KNm)	My (KNm)	Pt (%)	Interaction ratio	Main Reinforcement	Links
500 X 800	M35 ; Fe500	3871.8	-282.25	-5.53	1.13	0.32	8-T20 + 10-T16	T8@75mm + T8@250mm

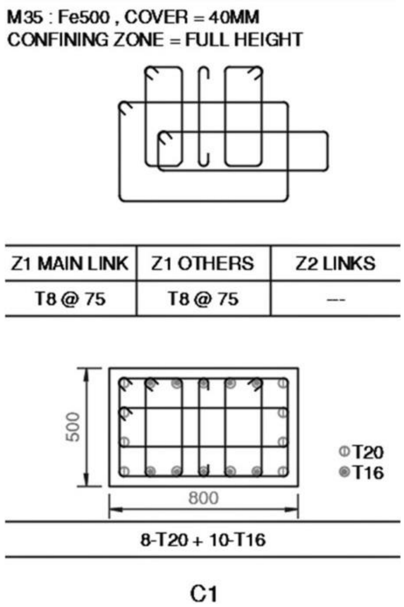

Figure 7: Sectional details of Main column

Table 7. Design properties of Floating column

ColumnSize (mm)	Material	P (KN)	Mx (KNm)	My (KNm)	Pt (%)	Interaction ratio	Main Reinforcement	Links
500 X 500	M30 ; Fe500	6.87	89.5	97.46	1.79	0.38	4-T25 + 8-T20	T8@100mm + T8@250mm

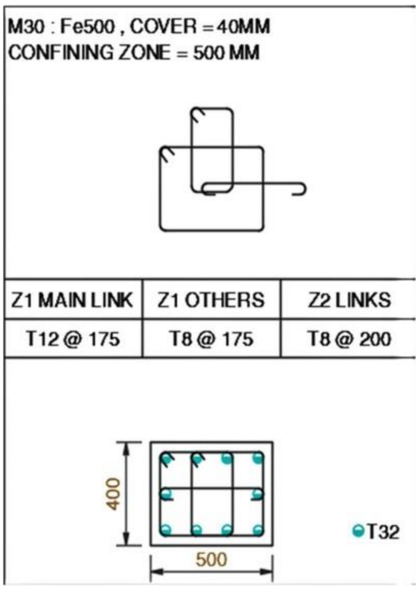

Figure 8: Sectional details of Floating column

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Table 8. Design properties of Transfer beam

	Left	Middle	Right
Vu (KN)	184.5	165.14	159.28
Asv Pr (mm2)	718.14	670.27	693.38
Reinforcement	2L-T8@140mm	2L-T8@150mm	2L-T8@145mm

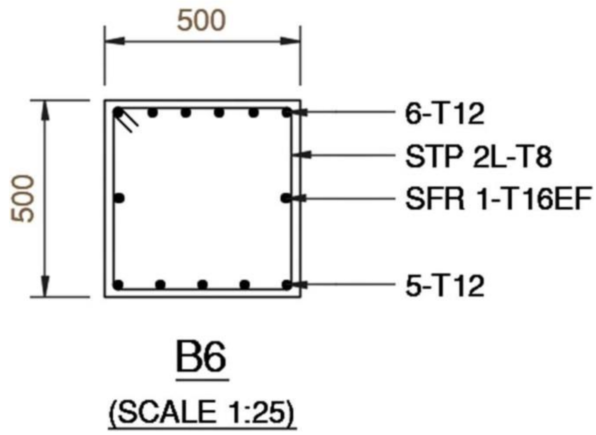

Figure 9: Sectional details of a transfer beam

Table 9. Design properties of a beam

	Left	Middle	Right
Vu (KN)	41.82	27.06	23.1
Asv Pr (mm2)	1340.53	591.41	1340.53
Reinforcement	2L-T8@75mm	2L-T8@170mm	2L-T8@75mm

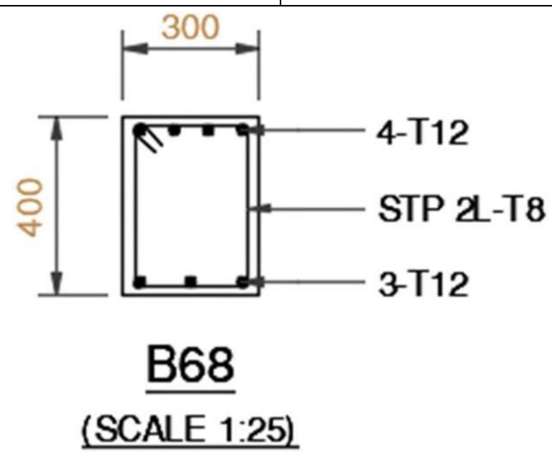

Figure 10: Sectional details of a beam

Table 10. Design properties of a slab

Bottom SS	Bottom LS	Top SS	Top LS	Distribution
T10 @ 300mm	T10 @ 300mm	T10 @ 300mm	T10 @ 300mm	T10 @ 300mm

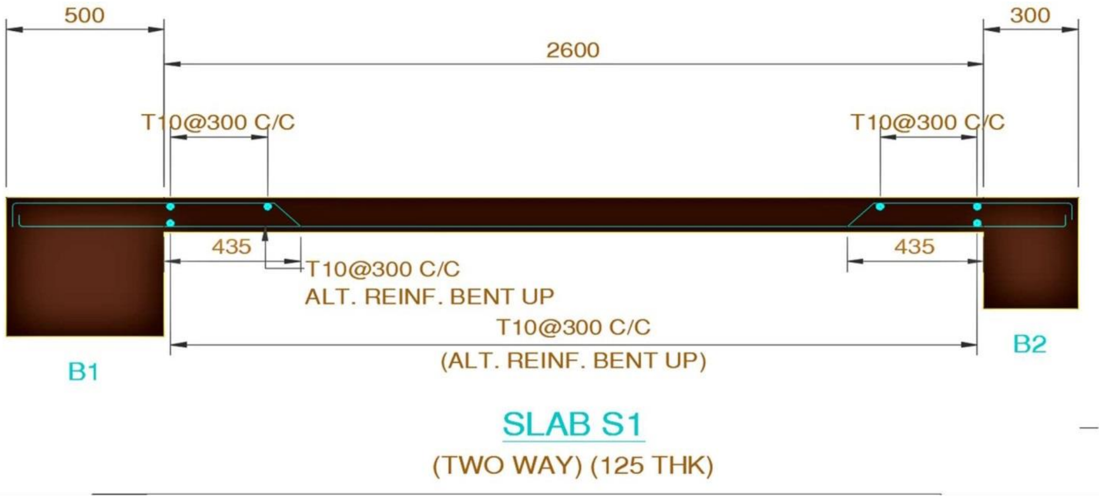

Figure 11: Sectional details of a slab

Details of structural designed detailing of Model-II

Table 11. Design properties of a column

ColumnSize (mm)	Material	P (KN)	Mx (KNm)	My (KNm)	Pt (%)	Interaction ratio	Main Reinforcement	Links
300 X 450	M25 ; Fe415	171.54	-25.75	-0.72	0.84	0.27	10-T12	T10@50mm + T8@150mm

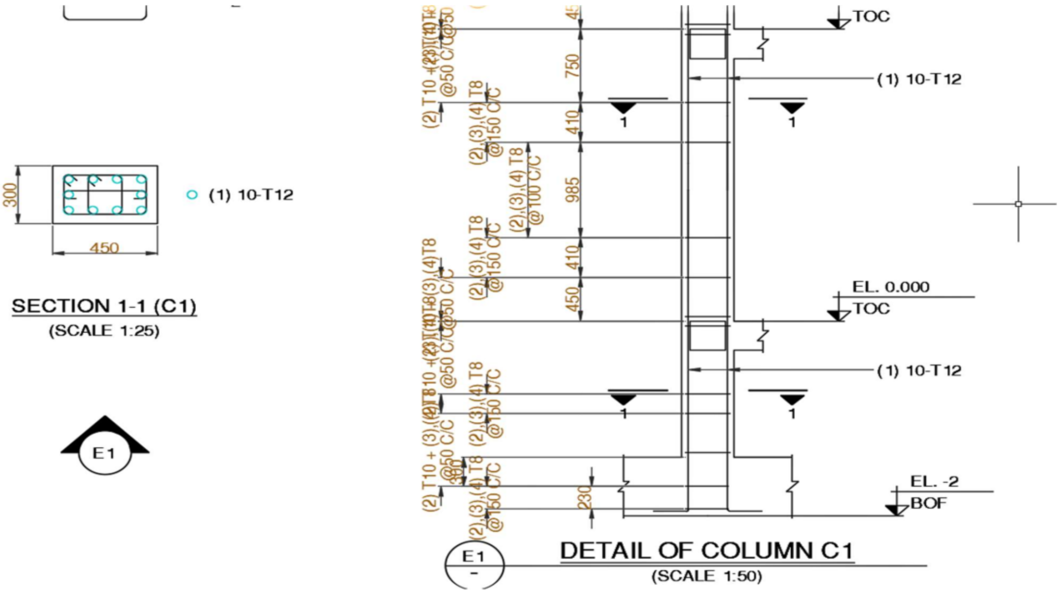

Figure 12: Sectional details of a column

Table 12. Design properties of a beam

	Beam Bottom			**Beam Top**		
	Left	**Mid**	**Right**	**Left**	**Mid**	**Right**
Ast Prv(sqmm)	339.3	339.3	339.3	339.3	339.3	339.3
Reinforcement	3-T12	3-T12	3-T12	3-T12	3-T12	3-T12

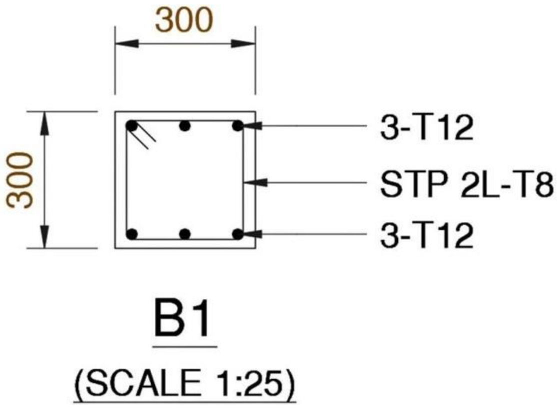

Figure 13: Sectional details of a beam

Table 13. Design properties of a slab

Bottom SS	Bottom LS	Top SS	Top LS	Distribution
T8 @ 300	T8 @ 300	T8 @ 300	T8 @ 300	T8 @ 300

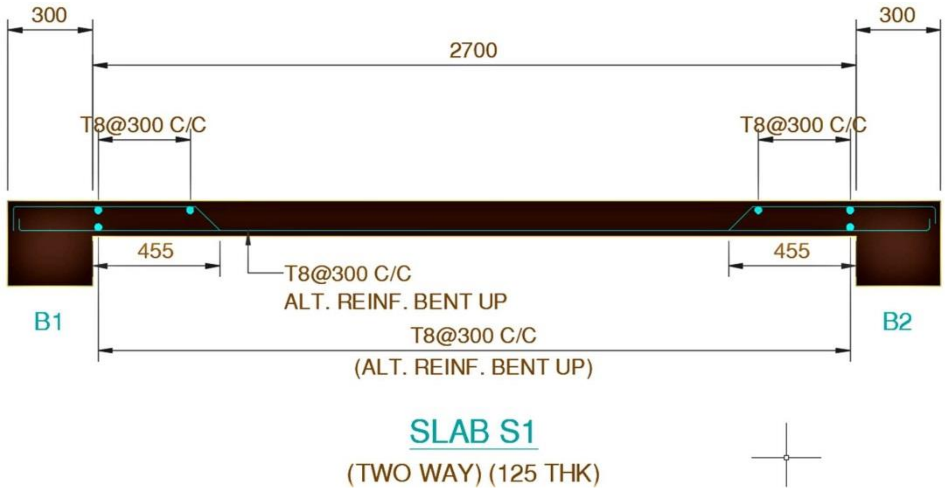

Figure 14: Sectional details of a slab

VI. CONCLUSION

Inferences Drawn from the study:

1. In Model 1 (structure with floating column), it is observed that storey Drift value is maximum in at6m level compared to other floors as this happened mainly due to existence of hanging columns from First floor onwards.
2. And also its storey drift value reduced after First floor till roof, which says that top levels transfersthe load acting on it to the first floor which has transfer beams.
3. Model 1 has More storey drift as compared to Model 2.
4. Maximum displacement in Model 1 is more compared to Model 2, this is because Model 2 has morestructural supports than Model 1 and IS 1893(1):2016 says that Structure with Floating column is not recommendable since it deflects more under Lateral loads.
5. Base Shear in Model 1 is more compared to Model 2.
6. Obtained Base shear of Model 1 done with manual calculations is approximately equal to Base shear generated by STAAD PRO.
7. Orientation of floating columns also plays crucial role in it as its position effects in safe load transferto the main load carrying structural elements.
8. Column sections got failed in Model -1 due to steel stress in crack width check failure, jointshear failure, axial failure, for which its properties have been modified with increasing cross section , which indirectly

increases the cost of construction

9. Material properties have been changed in Model-1 when the section got failed, where materialcost increases more compared to Model-2
10. Due to seismic excitation floating columns at the outer periphery got failed due axial forcesmode of failure
11. It is observed that displacements in model-1 got reduced upon increasing material elasticproperties, such as Young's modulus of concrete
12. Upon increasing section properties of columns in model-1, displacements in member can bereduced up to 32%
13. Since the structure with floating columns are only preferrable for the locations under vertical loads and very low seismic loading conditions. IS 1893-2016 doesn't recommend floating column structure under seismic zone due to structural irregularities.

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