DESIGN OF (G+20) COMMERCIAL STRUCTURE WITH CONSTRUCTION SEQUENCE ANALYSIS

Submitted in partial fulfilment of the requirements

for the degree of

Bachelor of Engineering

by

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Mohd Asim Mohd Salim (15CE31)

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Under the guidance of

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New Panvel, Navi Mumbai-410206

2019

A Project Report on

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CERTIFICATE

This is to certify that the project entitled **"Design of (G+20) commercial structure with Construction Sequence Analysis"** is a bonafide work of **Saif AltafHussain Tickley (15CE57),Khan Mohd Sahil Sarfaraz Ahmed (13CE28),Mohd Asim Mohd Salim (15CE31),Shaikh Nadeem Afroz (15CE48)**submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Undergraduate" in "Civil Engineering"

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APPROVAL SHEET

This dissertation report entitled **"Design of (G+20) commercial structure with Construction Sequence Analysis" by Saif AltafHussain Tickley (15CE57), Khan Mohd Sahil Sarfaraz Ahmed (13CE28), Mohd Asim Mohd Salim (15CE31), Shaikh Nadeem Afroz (15CE48)** is approved for the degree of "Civil Engineering"

Examiners

1. …………………………

2. …………………………

Supervisors:

1. …………………………

2. …………………………

Date:

Place: Panvel

DECLARATION

We declare that this written submission represents my ideas in our own words and where others ideas or words have been included ,we have adequately cited and referenced the original sources. We also declare that, we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Khan Mohd Sahil (13CE28) ………..

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ABSTRACT

Multi-storied buildings have been analysed for years on the assumption that whole of the load is applied on the complete frame. Looking in to the mode of incidence of the load, it is evident that part of the load is applied in stages as the construction of the frame proceeds, whereas remaining part of it is imposed on completion of the frame. Due to architectural requirements some of the column are designed as floating column and ground floor is kept open for car parking. It is important to study the effects of loads due to construction sequence on critical members, such as floating column and other critical members to avoid global failure of the building. It is also important to check the deflections due to sequential load application as it may lead to catastrophic failure of structural or non-structural elements, if the deflection due to sequential load is exceeding permissible limits. In this study we are considering cycle time for floor to floor construction and non-linear behaviour of materials to design a (G+20) commercial structure with floating column and open ground storey by using ETABS.

Keywords: Construction Sequence Analysis , Floating Column , Open Ground Storey, IS 1893:2016, ETABS

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ABBREVIATION NOTATION AND NOMENCLATURE

CSA Construction Sequence Analysis

FC Floating Column

OGS Open Ground Storey

MF Modification Factor

Chapter 1

INTRODUCTION

1.1 General

Construction Sequence Analysis allows defining a sequence of stages wherein one can add or remove portions of the structure, selectively apply load to portions of the structure, and to consider time-dependent material behaviour such as aging, creep, and shrinkage. Staged construction is variously known as incremental construction, sequential construction, or segmental construction.

Recent earthquakes have pointed out that buildings with Open Ground Storey are prone to earthquake collapse than a regular building. At the same time, they may undergo excessive deformations during construction due to stress concentration. The practice of constructing buildings with open ground storey has been very common in the metro cities which may lead to tragic loss of life and property, if they are not analysed in more realistic manner. The current study aims at understanding the behaviour of commercial structure with floating column subjected to seismic loads as per revised IS 1893-2016 and construction sequence to provide more insights for a designer to deal with these structures in a more realistic manner.

1.2 Recent earthquakes in India

Following table presents the recent earthquakes in India. It is quite evident that minor to medium intensity earthquakes are striking Indian subcontinent quite frequently. Under such circumstances, it is important to study the effects of floating columns on the behaviour of structure and effect of sequential construction on forces and deflections of such critical member.

Table 1.1 Recent earthquakes in India

DATE	TIME	LOCATION	LATITUDE	LONGITUDE	DEATH	MAGNITUDE
April, 2019	01:45 IST	Arunanchal pradesh	28°N	95°E	16	5.9
Sept 12 2018	10:30 IST	West Bengal and Bihar	22.4°N	75.25°N	3	5.5
Feb 6 2017	22.33 IST	Uttarakhand	32.5°N	89.55°E	0	5.1
Oct 25 2016	03:30 IST	Nicobar Island	11.7401°N	92.6586°N	0	4.7
Oct 23 2016	21:27 IST	Assam	26.1359°N	89.9253°E	0	4.7
Jan 03 2016	04:35 IST	North East India	24.8°N	93.6"E	11 Dead , 200 Injured in Manipur and Assam	6.7

1.3 Need of the project

Multi-storeyed buildings are quite common in metro cities due to lack of space. For a commercial building it is very important to understand the realistic behaviour of the building as it is a shelter for a large population for most of its occupied time. Though recent revision of IS 1893 advises to avoid use of floating columns, many commercial projects are having floating column due to functional constraints. It is therefore required to study the effects of forces on floating column and understand the behaviour of the building.

1.4 Organization of the report

The introductory chapter i.e. Chapter 1 gives brief introduction to the importance of the design of RCC structure by using Construction Sequence Analysis with floating column and Open Ground Storey. Chapter 2 presents the Review of Literature on Construction Sequence Analysis with floating column along with the objectives, methodology, Aim, Scope of the proposed work. Chapter 3 presents the mathematical modelling followed by results and discussion in chapter 4. Chapter 5 presents the conclusions of the present study.

Chapter 2

Literature Review

2.1 General

The performance of a structure with various loads applied in single step differ significantly from that of when the load are applied in stages. In order to simulate the actual conditions during the construction of the frame, construction sequence analysis is used. In this chapter literature pertaining to behaviour of structures under construction sequence, open ground storey buildings and structures with floating columns has been reviewed to form a reference for further analysis.

2.2 Technical papers

Shambhu Nath Mandal(May 2013) studied the seismic analysis of open ground storey building as nowadays parking area is provided in most of the buildings. This type of building shows comparatively a higher tendency to collapse during earthquake because of the soft storey effect. As the structure consist of an open ground large lateral displacements get induced at the first floor level of such buildings.The bending moments and shear forces in these columns also gets magnified accordingly as compared to a normal frame building.During earthquake massive energy release which can affect the columns of the buildings and can create plastic deformations which can lead to failure of the strucutre.The construction of open ground storey is very dangerous if not designed suitably and with proper care.

Figure 2.1 Building with open ground storey[1]

Modern seismic codes just tends to neglect the effects of non-structural infill walls during analysis. Conventional practice neglects the effect of infill stiffness by assuming that this would give some themconservative results. However this is not true in the case of columns present in the open ground storey. Many codes (e.g., IS 1893- 2002) recommended a factor to take care for the magnification of bending moments and shear forces.For this a procedure requires the analysis of OGS framed building by modelling it with the infill walls considering their stiffness. The proposed multiplication factor ranges from 1.86 to 3.28 as the number of storey increases from six to twenty. They observed that the bending of the columns in the more infilled storey (first storey of OGS building) under the lateral load is in an opposing direction to that of the less infilled storey (ground storey). Based on this observation, an alternate capacity design rule was proposed for the beams present at the top (first floor level) of the less infilled storey i.e. ground storey. According to this rule, the demand on the beams in the first floor should also be increased, depending on the capacity of the columns in the first storey.

IS 1893-2002 recommends a factor 2.5 accounting for the magnification of the forces in the ground storey of an OGS building. According to the clause, the shear forces and bending moments in the ground storey columns, obtained from the normal frame analysis are to be multiplied by a factor 2.5. The factor is used to take care for the increase in the forces in the ground floor columns due to the presence of an open ground structure.There are many such open ground storey buildings existing in the India which have been designed with earlier codes. Such buildings are designed only for gravity load condition. But as per the present code, both seismic lateral loads and the magnification factor shall be considered while designing any building.

The presence of infill walls in the upper storeys of the OGS building increases the stiffness of the building. Due to increase in the stiffness, the base shear on the building increases while in the case of typical infilled frame building, the increased base shear is shared by both the frames and infill walls in all the storeys. In OGS buildings, where the infill walls are not present in the ground storey, the increased base shear is resisted entirely by the columns of the ground storey, without the possibility of any load sharing by the adjoining infill walls. The increased shear forces in the ground storey columns will induce increase in the bending moments at the first floor level. The large lateral deflections further results in the bending moments due to the P-Δ effect. Plastic hinges gets developed at the top and bottom ends of the ground storey columns. The upper storeys remain undamaged and move almost like a rigid body. The damage mostly occurs in the ground storey columns which is termed as typical 'soft-storey collapse'. This is also called a 'storey-mechanism' or 'column mechanism' in the ground storey.

Finally He Concluded that :

- Base shear Capacity of a bare framed structure with fixed support designed with MF 3.0 & 2.5 is about 27% more than that of a building that is designed with MF 1.0. & the deflection that can undergo is up to 85 mm whereas that with MF 1.0 can go up to only 35 mm.

- Strong infill framed structure with hinged support has almost 25 % more shear strength than that of weak infill and can withstand 53 mm of deflection when loaded whereas later can take only 38 mm.

- Strong infill framed with fixed support can take 3 times more load than that with weak infill whereas the deflection being almost same about 66 mm for both the cases.

- The frame almost follows the same path but that designed with fixed support has 24% more strength than that with hinged support also the former one can undergo deflection up to 11 mm whereas the later only up to 8.5 mm.

SaleemAkhtar et.al (February 14) researched on the sseismicrresponseevaluation of RC frame building with floating column. He studied that in the upper storey of the structure, the columns of the ground storey are discontinued and floating columns are provided.This floating column rest at of the taper overhanging beams without considering the increased vulnerability of the lateral load resisting system due to vertical discontinuity. This type of construction does not create any problem under vertical loading condition but during an earthquake a clear load path is not available for transferring the lateral forces to the foundation. Lateral forces accumulated in upper floors during the earthquake have to be transmitted by the projected cantilever beams. Overturning forces thus developed overwhelm the columns of the ground floor. Under this situation the columns begin to deform & buckle, resulting in total collapse. He finally concluded that floating columns is more critical at corners

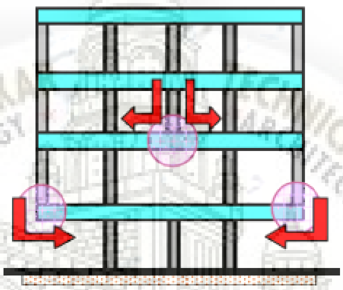


Figure 2.2 Floating Column in a structure[2]

KeerthiGowda B.S (May 14) researched on providing floating columns in earthquake prone zones. He found out that floating columns are highly undesirable in buildings built in seismically active area. He created models of the frame multi-storey RC buildings with and without floating columns to carry out comparative study of structural parameters such as time period, base shear, and horizontal displacement. Results obtained depicts that the alternative measure of providing lateral bracing to decrease the lateral deformation, should be taken. The RC building with floating column after providing lateral bracing is analysed. A comparative study of the results obtained is carried out. The building with floating columns after providing bracings showed improved seismic performance. The study he carried out had an adverse effect of perimeter frame discontinuity on seismic response of RC buildings suggesting that the reliability of slab around the perimeter frame is to be checked. This type of construction does not create any problem under vertical loading condition, but during an earthquake a clear load path is not available for transferring the lateral forces to the foundation. Under this situation the columns begins to deform and buckle, resulting in total collapse. This is because of primary deficiency in the strength of ground floor columns, projected cantilever beams & ductility of beam- column joints.

The eleven storey symmetric RC building without floating columns, with floating columns and RC building with floating columns after providing bracing are modelled in ETABS. All the model details are considered as mentioned in the following table:

The details of the building model are as follows:

Table 2.1 Details of the building model.

1	Type of structure	Multi-storey rigid jointed plane frame
2	Seismic zone	V
3	Number of stories	Eleven (G+10)
4	Floor height bottom	3.5m, Other-3m
5	Size of beam	200mm X 450mm
6	Size of columns	200mm X 600mm; 200mm X 750mm
7	Depth of slab	150mm
8	Live load	4 kN/m2
9	Floor finishing	1 kN/m2
10	Material	M25 Grade concrete; Fe415 Steel
11	Damping in structure	5%
12	Importance factor	1.0
13	Type of soil medium	Type-II

He got the following observations:

Figure 2.3 Variation of Storey Drifts floor levels (before and after providing bracing)[2]

He concluded that Storey drift for building with floating columns is 5.87 % more than that of normal building. After providing bracings, storey drift of building with floating columns was reduced by 18.28 %.

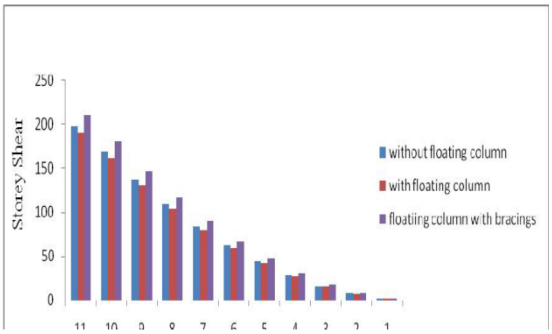


Figure 2.4 Variation of Storey Shear with Floor levels(2)

He depicted the variation of storey shear along the height of the models. The storey shear value of normal building in comparison to building with floating columns is higher by 4.11 %. After providing bracings, the storey shear of building with floating has increased by 31.78%.

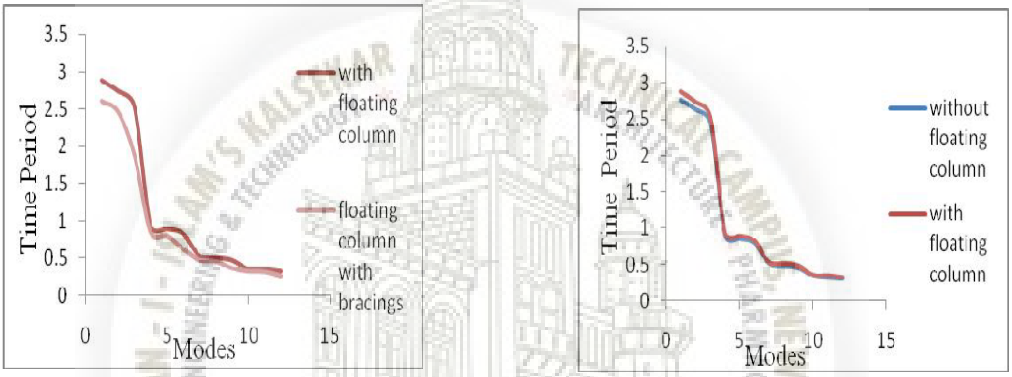


Figure 2.5 Variation of Time Period with different modes (before and after bracing)(2)

Both the figures depicts the variation of time period of various modes of frame. Time period value for building with floating column is 4.04 % more than that of normal building. After providing bracings, the Time Period value for building with floating column has reduced by 10.94%.

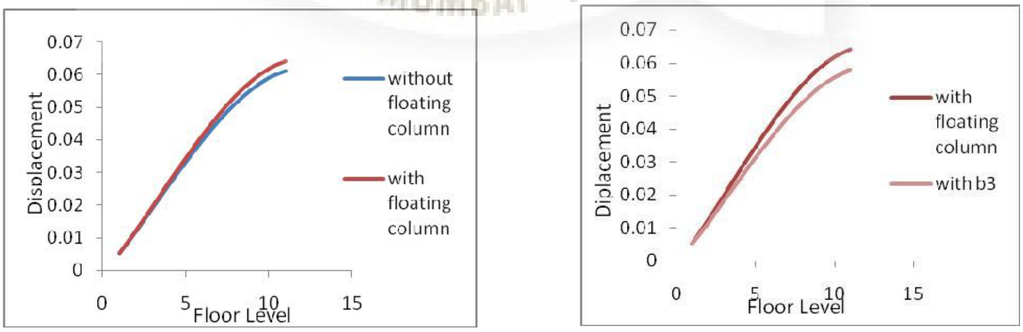


Figure 2.6 Variation of Displacement floor levels (before and after bracings)(2)

Both the figures depicts the variation of displacement along the height of the structure. The displacement of building with floating columns is 4.74 % more than that of normal building. The displacement of building with floating columns is reduced by 9.83%.

He finally found that the multi-storey buildings with floating columns performed poorly under seismic load. Thus to improve seismic performance of the multi-storey RC building, lateral bracings were provided.These bracings improved seismic performance of multi-storey building considerably as different parameters such as storey drift, storey shear, time period and displacement improved upto 10% to 30%.

R.Pranayet.al (July2014) studied and compared construction sequence analysis with conventional lumped analysisusing ETABS. They briefly studied and compared the variation in deformations and forces for the floating column. The building was analyzed and designed using Etabs software.

They assumed staged construction which allowed him defining a sequence of stages wherein one can add or remove portions of the structure, selectively apply load to portions of the structure, and to consider time-dependent material behaviour such as aging, creep, and shrinkage.

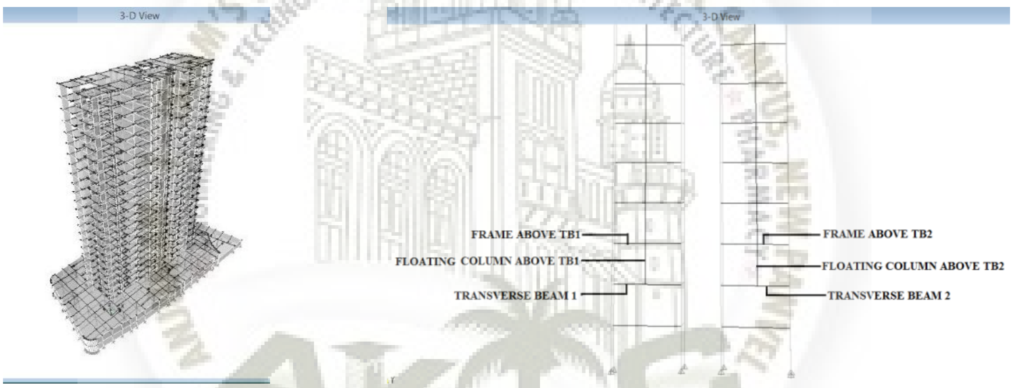


Figure 2.7 3D view of ETABS model Transverse beams and floating column[2]

They assumed the following load combinations

a) Static load cases

b) Unfactored load combinations

c) Factored load combinations

Finally by comparing the results of analysis they concluded staged construction analysis leads to considerable variations in deformations and design forces compared to the ones obtained by conventional one step analysis. It is, therefore necessary that for Multistoreyed building frames with transfer girders and floating columns system, the construction sequence effect shall be taken into consideration.

Ratnesh Kumar et.al (December 14) studied on various effects of staged construction analysis on seismic design and performance of RC building. They assumed Four buildings with identical plan but with different heights i.e. 13.5 m, 31.5 m, 46.5 m and 61.5 m were considered. Initially, bending moments and axial loads for models with and without considering the effect of construction sequence were compared.

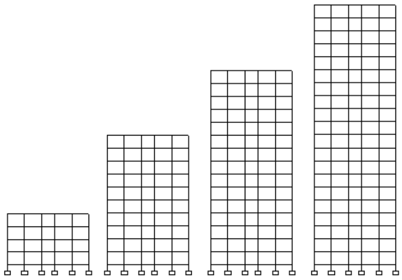


Figure 2.8 The increasing numbers of storey of the buildings[3]

They obtain the ratio of internal actions for a column viz. axial force, moment, moment for dead load. Also the ratio of design column reinforcement has been obtained for the four building models of 4 storey, 10 storey, 15 storey and 20 storey. The pattern of variation of axial forces, bending moments and required reinforcements for four and twenty storey building based on Ratio = Internal Action considering CSA divide by Internal Action without considering CSA

From analysis following observations have been made:

- The variation of the ratio for axial force was negligible and was not more than 5 percent in any of the building models. The variation in the column moments for dead load was significantly high. For the 4 storied building the variation of column moments is up to a maximum of 50 percent. For the 10 and 15 storied building the variation of column moments is up to a maximum of 75 percent and for 20 storied building goes up to 100 percent.

- The effect of CSA is observed for the corner column corner and for the inner column.The seismic loads effects more on the corner columns as compared to the inner columns.Also the effect was seen to be maximum for the lower three storeys and it diminishes for the rest of the storeys.

- In case of column design the variation in the design reinforcement was up to a maximum of 10 percent for 4 storey, 6 percent for 10 storey, 3 percent for 15 storey and 25 percent for 20 storey building.

- Effect of CSA reduces as the storey level increases.

- The increase in the percentage of moment due to CSA is upto a maximum of 100, 50 and 50 percent at left end, right end and mid span sections respectively.

Yousuf Dinar et.al (December2014) studied on construction sequence effects on reinforced concrete and steel buildings. To observe the effects of nonlinear static analysis over linear static analysis finite element were formed using Etabs where construction simulation analysis is included along with linear static analysis. To meet the objective, all loads and sections for both two cases and two separate analysis procedure were designed. The time-dependent effects of creep, shrinkage, the variation of concrete stiffness with time, sequential loading and foundation settlement were accounted for by analyzing 12 separate three-dimensional finite-element analysis models, of which six represent the sequential analysis while remaining six represent the linear static analysis.

At each point in time, for each model, only the increasing loads occurring in that specific time-step were applied. The structural responses occurring at each time-step were accounted and added in a database to allow studying the predicted time-dependent response of the structure. To develop construction sequential effects in rigid joint structure six different story cases is taken where story variation starts from story 5 to story 30.Storycases are: 5, 10, 15, 20, 25 and 30. Each of the story case is performed Linear Static and sequential analysis separately. Each story is 3 meter in height makes Story 5, Story 10, Story 15, Story 20, Story and Story 30 in total height of 15 m, 30 m, 45 m, 60 m, 75 m and 90 m.As story increases so does the slenderness increases. The lateral load seismic is considered in both directions of the structure.

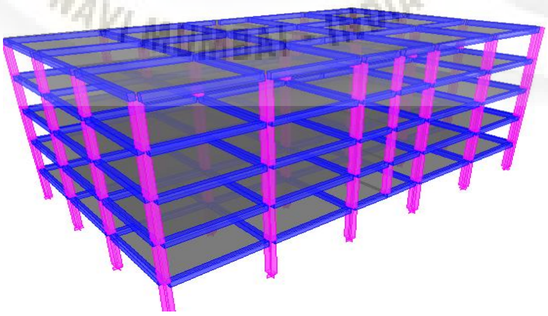


Figure 2.9 Three dimensional model of 5 storey building(4)

Displacement in critical beam: The displacement of RCC structures under sequential analysis for story 5 to story 30 in 5 story intervals was found to be varying from 5.7 to 19.7 mm for this types of structures where it varies only 2.5 to 20 mm during linear static analysis. As steel structures has a minimum displacement than the concrete structures it could be a better option to use steel structures for long term construction.When this types of structures are made by steel they may show displacement from 1.1 to 4.3 mm and 0.69 to 3.8 mm under sequential and linear static analysis respectively, for the same structure.

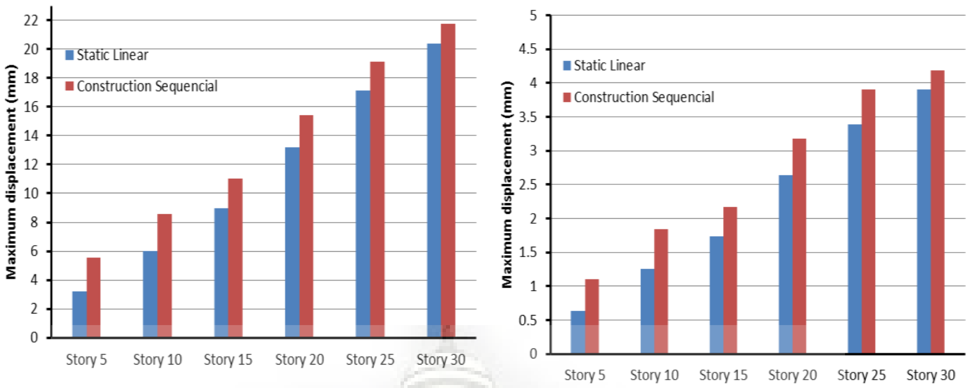


Figure 2.10 Maximum displacement of structures of RCC and Steel[5]

Axial load in column near critical beam: Axial load in exterior column has significant effects of both vertical and lateral load.Steel structures differ significantly from RCC structures. Steel structures are found bearing much loads than RCC.

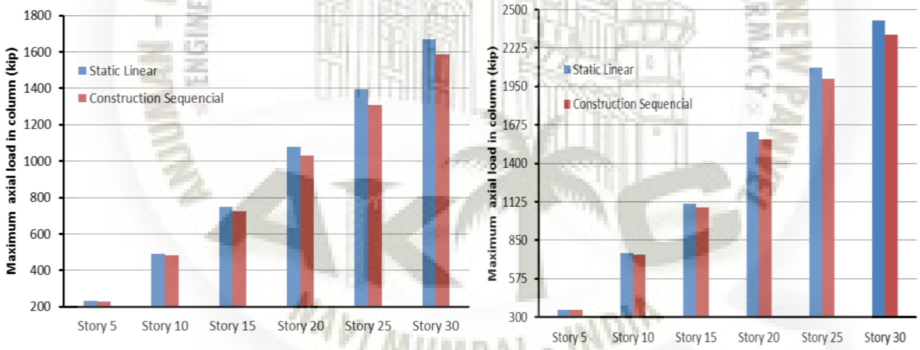


Figure 2.11 Maximum axial load in an exterior column for RCC and steel[5]

Moment in critical beam: Construction sequence increases the moment as once the structure is being constructed effects of nonlinear factors i.e. creep, shrinkage and time dependent load govern. Moments in supporting beam are subjected to much more load under sequential analysis than the liner static analysis.

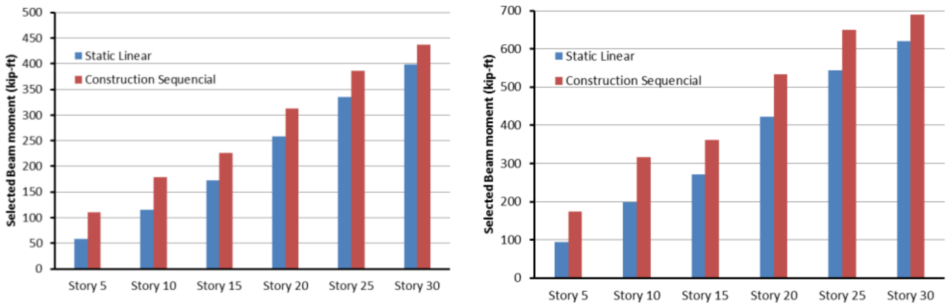


Figure 2.12 Maximum moment in an exterior column for RCC and steel[(5)]

The study reveals the necessity of performing nonlinear static analysis becomes important with increasing slenderness while the each additional floor creates a significant load upon the columns. Construction sequence analysis in structures of both Steel and RCC is necessary to improve the analysis accuracy in terms of displacement, axial, moment and shear force for the whole the structure overall. Moments and shear in supporting beam are higher in sequential analysis which must be considered during manual or computer aided design in the design phase for avoiding cracking of beam and column due to sequence effects. Construction sequential analysis also draws a preference of steel structures over the RCC structures for long term loading effects. In summary construction sequential analysis is an attempt to make finite element model more realistic by taking time dependent nonlinear characteristics of material into consideration which happen in the site of the construction of the structures.

Sagupta R. Amin (July 15) studied and analyzed on multistoried RCC Building for construction sequence analysis. She dealt with construction sequence analysis on different storey's considering earthquake and wind forces and a comparative study between linear and sequence analysis. A Building wasanalyzed for self-weight using linear static method and construction sequence method using Etabs.The size of beam considered was 500mm x 300mm and size of column was 450mm x 300mm .The building was been analyzed for M30 grade concrete and Fe415 steel. All models wasanalyzed for an earthquake forces in both the direction providing coefficients in accordance with IS 1893(Part 1)-2002 and wind coefficients with accordance to IS 875(Part 3)-1987.

In case of multi-storey buildings, importance of construction stage analysis can be understood from following facts:

1. The assumption that all loads are applied simultaneously is not valid in a real construction sequence because a building is constructed floor by floor and dead load acts sequentially.
2. For a building where wind could be a part of critical load combination for the complete frame, earthquake could turn out to be part of critical load combination for staged construction case.
3. CSA should be performed for all structures where there is a change in support conditions, loading and varying material properties.

She concluded that as the construction of building proceeds, the structure members are added in stages & thus their dead load is carried by part of the structure completed till that time.Therefore, the correct distribution of displacements and stresses can be obtained by accumulating the results of analysis at each stage. Linear static analysis accounts the total effect of final stage of construction without considering step by step nonlinear effects for sequential construction, which cannot be a reliable output for high rise structures. Therefore, it becomes necessary to perform construction sequence analysis for high rise structures. Otherwise the results lead to inappropriate deign which may leads to collapse of the structure.

P.J.Salunke (Oct 15) researched on earthquake resistant design of open ground storey building.

His objectives were:

1. To study the applicability of the Multiplication Factor of 2.5 as given by IS Code 1893 Part- 1(2002), for Low Rise and Medium Rise Open ground storey Building.
2. To study the effect of infill strength and stiffness under seismic analysis of Open ground storey building.

He considered 4 models:

Model-A :

Case 1: (G+4) storey building in which Ground storey is open and other stories are having infill wall.

Case 2: (G+4) storey building in which all stories are open (Bare framed Building).

Model-B :

Case 1: (G+7) storey building in which Ground storey is open and other stories are having infill wall.

Case 2: (G+7) storey building in which all stories are open .

Model-C :

Case 1: (G+10) storey building in which Ground storey is open and other stories are having infill wall.

Case 2: (G+10) storey building in which all stories are open.

Table 2.2 Details of the Building

Details of building models : Type of structure	Multi-storey rigid jointed plane frame.
Seismic zone	V
Number of stories	G+10 (34.2m), G+7 (25.6m), and G+4 (16.2m)

Floor height	Ground floor=4.2m, Intermediate floors=3m
Wall	230mm outer external wall, 120mm Internal wall, 150mm Parapet wall
Type of soil	Medium
Size of column	G+10-(230x800)mm G+7-(230x700)mm G+4-(230x600)mm
Size of beam	230mm x 600 mm
Depth of slab	125 mm
Materials of concrete	Column and Beam: M30 Slab:M25
Damping of structure	5%
Modulus of elasticity of concrete	M30-27386 N/mm2 M25-25000 N/mm2

He also considered the following loads:

1. Wall load: unit weight of brick wall = 20 KN/m2

a) External 230mm = 11.02KN/m2

b) Internal wall 120mm =5.76 KN/m2

c) Parapet wall 150mm = 3KN/m2

2. Live Load:

a) Intermediate floors = 2KN/m2

b) Terrace =1.5 KN/m2

3. Floor Finish :

a) For intermediate floors: FF =1 KN/m2

b) For terrace floors: FF=1.5 KN/m2

To obtain results he compared the base shear in which the base shear which was in case of Response Spectrum analysis is compared between bare frame model and Infill model to See the difference between them and also to get the multiplication factor. He also compared the ESA and RSA results for conclusion.

From the results he got he got the following conclusions:

- Linear analysis shows that column forces at the ground storey increase for the presence of infill wall in upper storeys. But design force Multiplication factor found to be much less than 2.5.

- Seismic analysis of bare frame structure leads to under estimation of base shear. Under estimation of base shear leads to collapse of structure during earthquake. Therefore its important to consider the infill walls in the seismic analysis of structure.

Haran Pragalath D.C. (December2015) studied on the reliability based on the seismic design of open ground storey framed buildings. He studied on the Open Ground Storey (OGS) framed buildings in which the ground storey is kept open without providing any infill walls and mainly used for parking, which are increasingly common in urban areas. Vulnerability of this type of buildings has been exposed in the past earthquakes.OGS buildings are conventionally designed considering a bare frame analysis, ignoring the stiffness of the infill walls present in the upper storeys, which under-estimates the force demand in the ground storey columns. To compensate this, a multiplication factor (MF) is introduced by various international codes while calculating the design forces (bending moments and shear forces) in the ground storey column. Present study focuses on the evaluation of seismic performances of OGS buildings designed with alternative MFs.According to Indian Standard IS 1893 (2002) they recommends a factor to magnify the forces in ground storey columns. This factor is referred as 'multiplication factor (MF)' in this study. IS 1893 (2002) states: "The columns of the OGS (soft-storey) are to be designed for 2.5 times the storey shears and moments calculated under seismic loads of bare frame".

He had the following objectives:

i) To establish limit state capacities of each storey of framed building for various performance levels.

ii) To develop probabilistic seismic demand model (PSDM) for OGS framed buildings designed with various schemes of MF.

iii) To develop reliability index for OGS framed buildings designed with various schemes of MF.

iv) To propose appropriate schemes of MF for the design of OGS buildings based on the observation

From his research, he concluded the following:

i) OGS frames designed without any MF always found to have maximum probability of exceedance indicating vulnerability of these frames.

ii) In case of two storey frames, the application of MF only in ground storey columns improves the building performance. However, for building with more than two storeys, application of MF only in the ground storey makes the adjacent storey vulnerable. This shows that the scheme of MF applying in ground storey alone recommended by most of the international codes is not an effective solution.

iii) In general, an MF of magnitude less than 2.0 does not meet the acceptable degree of reliability.

Ms.Waykule S.B (August 2016)studied on the behaviour of floating column for seismic analysis of multi-storey RCC building. He studied about the analysis of G+5 Building with and without floating column in highly seismic zone V. He created three models with floating column at 1st, 2nd, and 3rd floor buildings and without floating column building. Linear static analysis was carried out of all the four models and from linear static analysis compare all the of models result was obtained in the form of seismic parameter such as time period, base shear ,storey displacement ,storey drift.

For analysis purpose he considered three models namely as:

Model1- Building without floating column

Model2-Building in which floating column located at 1st floor.

Model 3-Building in which floating column located at 2nd floor

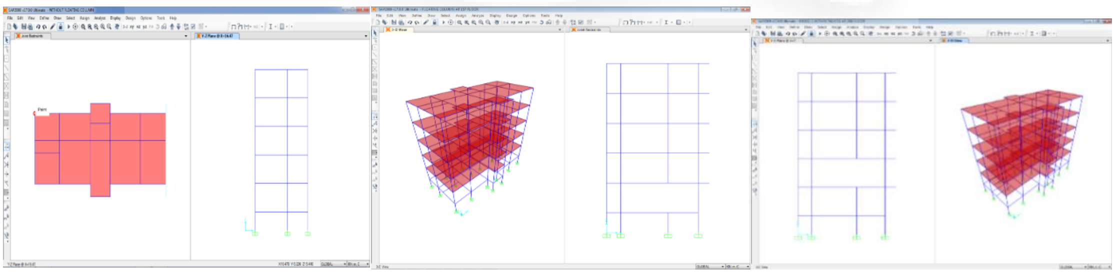


Figure 2.13 Representing the models created for analysis[8]

He studied the comparison of seismic response parameter such as time period ,base shear, storey displacement, storey drift by varying the location of floating column floor wise by using linear static and time history analysis. Result are compared in tabular and graphically for the analysis of building with and without floating column.

Table 2.3 Comparison of time period in sec after the analysis

Mode	RCC building without floating column (Model1)	RCC building with floating column at 1st floor (Model2)	RCC building with floating column at 2ndfloor (Model3)
1	0.8423	0.8614	0.8572
2	0.6475	0.6493	0.6487
3	0.5604	0.5706	0.5685
4	0.2776	0.2816	0.2774
5	0.2124	0.2128	0.2124
6	0.1799	0.1822	0.1798
7	0.1648	0.1657	0.1666
8	0.1246	0.1247	0.1248
9	0.1211	0.1212	0.1236
10	0.1016	0.1036	0.1038
11	0.1010	0.1022	0.1026
12	0.0889	0.1010	0.1016

He also studied on the variation of base shear. He studied that the base shear is the horizontal reaction at the base against horizontal earthquake load. This base shear is acting at the base or supports of the structure or wherever structure is fixed. The variation in base shear due to different location of floating column floor wise.

The base shear decreases by 5-10% for floating column building as compared to without floating column building.

Table 2.4 Shows the comparison of base shear on all the models

Model No.	Base shear in KN
Model 1	631.704

Model 2	617.074
Model 3	619.687

He also studied about the storey displacements. The results variation of storey displacement due to different location of floating column floor wise.

The storey displacement increases 5-10% for floating column building as compared to building without floating column

Table 2.5 The comparison of storey displacement

	Model 1	Model 2	Model 3
Floor6	18.088	18.232	18.291
Floor5	16.162	16.342	16.389
Floor4	13.103	13.345	13.374
Floor3	9.353	9.671	9.671
Floor2	5.287	5.674	5.187
Floor1	1.224	1.041	1.206
Base	0	0	0

Finally he concluded on the following points:

1 .It was observed that in building with floating column has more time period as compared to building without floating columns.

2. It was also observed that shifting of floating column towards top of the building results in increasing time period which is majorly because of decreased lateral stiffness of the building

3. It was observed that in building with floating column has less base shear as compared to building without floating column

4. It was also observed that shifting of floating column from 1st storey towards top storey of the building results in increasing base shear.

5. It was observed that displacement in floating column building is more as compared to building without floating column.

6. It was also observed that shifting of floating column from 1st storey towards top storey of the building results in increasing storey displacement.

7. It was observed that building with floating column has more storey drift as compared to building without floating column.

8. It was also observed that shifting of floating column from 1st storey towards top storey of the building results in increasing storey drift.

Dr.Praseeda K.I (September 16) studied and compared the method of conventional and construction stage analysis of a RCC building. According to him during construction freshly placed concrete floor is supported by previously cast floor by formwork. Thus, the loads assumed in conventional analysis will vary.Hence, results obtained by the traditional analysis will be unsuitable. Therefore, the frame should be analyzed at every construction stage taking into account variation in loads. The phenomenon known as Construction Stage Analysis considers these uncertainties precisely. The present study provides a comparison of conventional analysis with construction stage analysis for a commercial building using Etabs.

In the structural analysis of multistory buildings, there are two important factors that have very significant effects on the accuracy of the analysis but are usually ignored in practice. They are: (1) the effect of sequential application of dead loads due to the sequential nature of construction as discussed above; and (2) differential column shortening due to the different tributary areas that the exterior and interior columns support.

In this study construction stage analysis and conventional analysis is performed for a commercial building of 2B+G+6. A comparison of bending moment, displacement and shear force is done for both analysis. In conventional analysis dead loads, live loads, wind loads and seismic loads are applied simultaneously to the entire complete structure. In construction stage analysis, dead loads are applied in a sequential manner. The case study building is modeled in Etabs for construction stage analysis. The deformation, bending moment and shear force are considered in the study for comparison between conventional analysis and construction stage analysis.

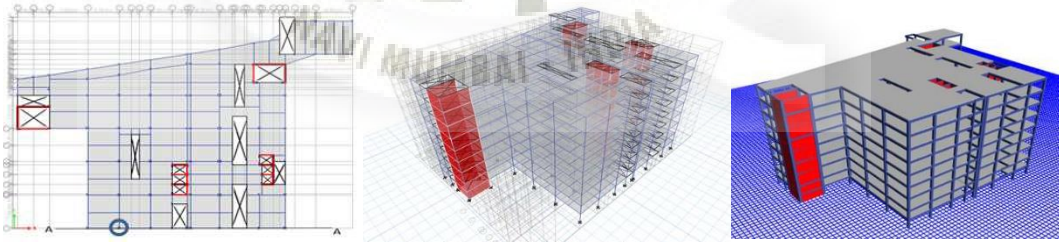


Figure 2.14 Plan from ETABS,3D view of the building and rendered view[9]

In conventional analysis dead loads, live loads, wind loads and seismic loads are applied to the entire structure after complete modeling. But in reality live load, wind load and seismic loads are applied at once to the entire complete structure whereas in case of dead loads, it is a type of sequential loading.

Beams of concrete M25 and steel Fe415 and columns of concrete M35 and steel Fe500 are used in the structure. The thickness of the slab used is 100 mm. M 25 concrete and Fe 500 steel is used for modeling the structure.

After the analysis of the structure he concluded that in conventional analysis the load is applied only after modelling the entire structure. But the dead loads are of sequential nature in reality. So from this we can conclude that conventional analysis is not enough to find out the actual behaviour of structure. In actual case a building, bridge or any kind of structure is constructed in a sequence of stages. So the load applied on the structure will be different at each stage. The analysis considering these sequential nature of application of load is known as construction stage analysis. This type of analysis is essential to ensure the stability of the structure throughout the construction period. An existing commercial building was chosen to study the difference in construction stage analysis from conventional analysis. Deformation, bending moment and shear force is selected as the parameters to compare conventional analysis with construction stage analysis. From the comparison results it is found that for conventional analysis the deformation, bending moment and shear force are underestimated for the bottom floors and the same are over estimated in the upper floors when compared with construction stage analysis. The column shortening for exterior and interior columns for a particular section is also find out for conventional analysis and construction stage analysis. From the results it is found that the value of column shortening is over estimated for upper floors and under estimated for lower floors in case of conventional analysis. So for high rise buildings in order to provide column shortening compensation, accurate values of column shortening can be find out from construction stage analysis.

Radha Krishna Amritraj et.al (February2017) analyzed a building frame with floating column under wind and seismic load. In his paper he stated that in recent years, to enhance the aesthetic view various architects have started using floating columns in their designs. The rigidity of the structure is discontinuous at the soft storey level due to variation in the floor height. This discontinuity may lead to structural failure of buildings under the effects of wind loads and seismic load. In this study, equivalent static analysis of 3-D building frames of G+7 storeys along with floating columns as well as soft storey effects have been carried out. A total of 73 cases was considered from which 8 cases had central floating columns on any one of the storey, while 64 other cases had the floating columns at a particular storey with the soft storey being varied right from ground storey to G+7 storey. Nine load combinations was considered. StaadPro software was used for analysis purpose. Results are collected in terms of maximum displacements, maximum moments, maximum shear force, maximum axial force and maximum storey drift. Results were analyzed to draw technical conclusions.

Following notable conclusions was made:

1. Under the defined loading conditions, maximum bending moment increases 2.54 times as soon as floating columns are introduced at ground storey level with reference to a normal building under same loads but without any floating columns.
2. The presence of floating columns at the top most storey increases the maximum nodal displacement resultant for a non-soft storey building.
3. There are marginal fluctuations in value of design wind pressure till height range of around 15 m.
4. There is general decrease in the value of maximum shear force among various cases
5. The value of maximum axial force is less when both the central floating columns and soft storey are located at ground.

Kiran Y. Naxane(July 17) studied on the construction sequence analysis of multistoried RCC building. Recording and investigating the variation of responses, of a particular point from starting step of sequential analysis to the last one, exhibit how construction sequence has a well impact over the design of the structures. Afterward the comparison between the construction sequential analysis and linear static analysis will explain the importance of considering sequential effects during design and eventually meet the objectives of this study. She considered the following:

Table 2.6 The structured considered for the analysis

Sr. no.	Number of stories	7 Storey
1	Plan dimensions	14 m X 21 m
2	Total height of building	15.5 m
3	Frame type	OMRF
4	Soil condition	Medium
5	Response reduction factor	5
6	Seismic zone	II
7	Importance factor	1.5
8	Zone factor	0.1
9	Grade of concrete	M30
10	Grade of Steel	Fe 415
11	Inner beam 1	150 mm X 250 mm

12	Inner beam 2	150 mm X 300 mm
13	Outer beam 3	230 mm X 250 mm
14	Outer beam 4	230 mm X 300 mm
15	Inner column	300 mm X 300 mm
16	Outer column	300 mm X 400 mm
17	Corner column	300 mm X 400 mm
18	Internal wall	115 mm
19	External wall	230 mm
20	Height of each storey	1-2Storey-4 m, 2-7 Storey-3.5m

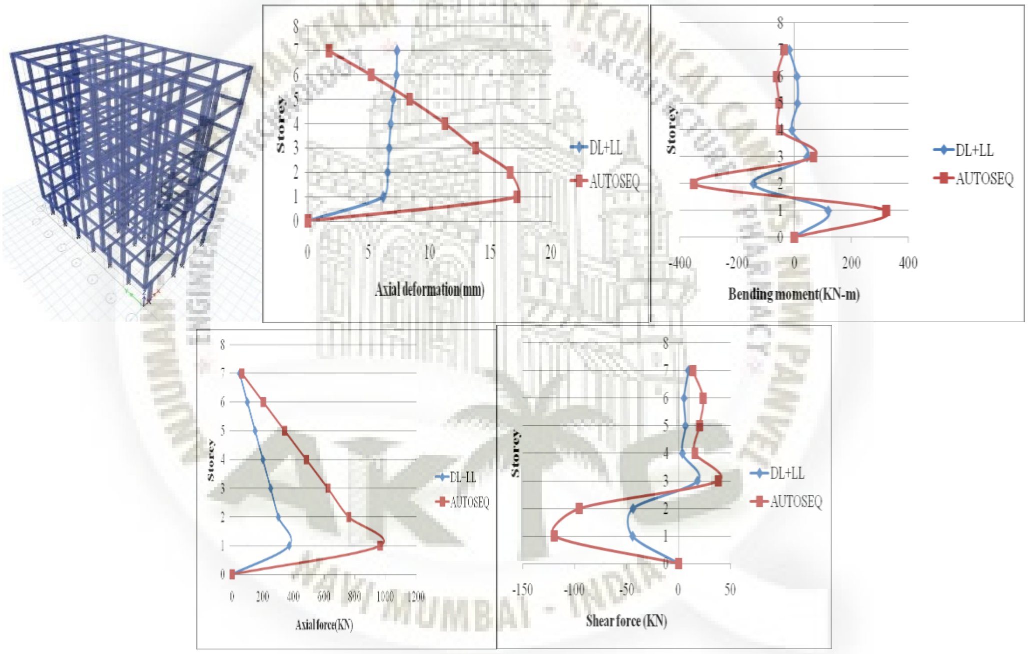


Figure 2.15 3-D View of axial deformation,bending moment,axial force and shear force[11]

Finally she concluded from the results that the axial deformation in the construction sequence analysis is more in supporting beam and it is going to be less in supporting beam of top storey compare to linear static analysis.The axial deformation is more in top and less in bottom.The axial force in exterior columns is more in construction sequence analysis compare to linear static analysis. The Moment developed in sequential analysis is more in column compared to linear static analysis. Shear force in columns in sequential analysis is high compared to linear static analysis. This is possibly because of stage wise construction.

It can be concluded from all the above observations that

1.Construction sequence analysis in structures of RCC is necessary to improve the analysis accuracy in terms of displacement, axial, moment and shear force in supporting beam and column near of it and also for the whole the structure overall.

2.Inclusion of sequential load case in the analysis of multistoried RCC structure provides more realistic design than the conventional design.

KapilDev Mishra(February 2018) comparatively studied on the floating and non-floating column of plaza building subjected to seismic loading. He tried to study on a multi storied plaza building of story (G+2+3) having different position of floating columns at different height of building at two different zones (ZONE III and ZONE IV) was considered for analysis. The plan area of building he considered was up to second floor is 30m×30m and above this floor area is reduced to 20m×20m.Height up to second floor of the building is used for parking or commercial shops having floor height of 4m and above this it is used for residential and office purpose. Different combinations of office and residential floors were considered. Floating columns was provided at office floor. These are the following consideration where comparison is done based on results from the software, Support reaction at the base, maximum moment at the joint.

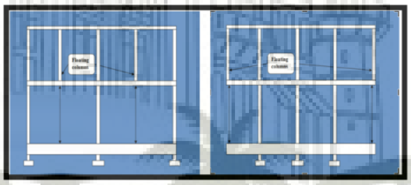


Figure 2.16 Floating column of a structure[12]

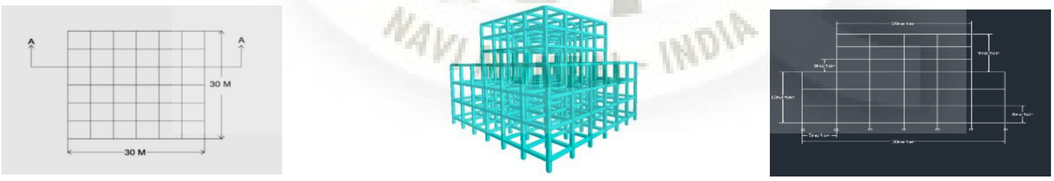


Figure 2.17 Plan,elevation and the rendered isometric view of Framed model[12]

Following sequence has been followed to analyze them using Etabs :-

Step-1 Start the Etabs and designing the types of structures and unit.

Step-2 Preparing the model structure.

Step-3 Defining the support for the structure

Step-4 Defining the seismic load and other parameters related to seismic analysis.

Step-5 Structural analysis of the structure.

Step-6 Comparative analysis of results in terms of bending moment, maximum reaction.

Step-7 Critical study of results.

On the basis of the results of study, he made the following conclusions;

1. Maximum Bending Moments as well as Maximum Support Reaction for the structures having floating columns are higher than that of structures without floating columns.
2. Maximum Bending Moments at seismic Zone IV are greater than that of Zone III.
3. Structures having floating column constructed in Zone IV are more affected by earthquake than Zone III.

Prof. B.S Tyagi (May 2018) did the seismic analysis of multi-storey building with floating column. The objectives of his studies were**:**

1. Analysis of a high rise storey building with and without use of floating column.

2. Design of building with floating column

3. Finding out the effect on different design parameters under seismic effects due to the presence of floating column

4. To compare the benefits of providing floating column

5. To compare the results of all the models as obtained.

Eight Model were considered among which 4 were being analyzed as rectangular building and 4 were analyzed as square buildings.

Four building models are created and analyzed for following data:

Table 2.7 Design of models considered

Plan Area	600 m2
Exterior Beam	M20 230x550 mm
Interior Beam	M20 230x500 mm
Column 1	M35 1.1mx1.1m
Column 2	M35 500x500mm
Slab	M20 125mm
Live Load	3KN/m2
Roof live	1.5 KN/m2
Floor Height	3 m

Structure models used for analysis:

Model 1 - Rectangular building without any floating column

Model 2 - Rectangular building with floating column at ground floor

Model 3 - Rectangular building with floating column at first floor

Model 4 - Rectangular building with floating column at second flood

Model 5 - Square building without floating column

Model 6 - Square building with floating column at ground floor

Model 7 - Square building with floating column at first floor

Model 8 - Square building with floating column at second floor

This research is to analyze the behavior of a multi-storey building with respect to providing or not providing floating column and change in the position of the floating column.

Model 1 is a simple G+11 residential building having rectangular geometry (plan area = 600m2) without any floating column.

Model 2 is a G+10 residential building having rectangular geometry (plan area =600m2) with floating column at ground floor provided at y=10m

Model 3 is a G+10 residential building having rectangular geometry (plan area =600m2) with floating column at first floor provided

Model 4 is a G+10 residential building having rectangular geometry (plan area =600m2) with floating column at second floor provided

Model 5 is a G+10 residential building having square geometry (plan area = 625m2) without floating column

Model 6 is a G+10 residential building having square geometry (plan area = 625m2) with floating column at ground floor

Model 7 is a G+10 residential building having square geometry (plan area = 625m2) with floating column at first floor.

Model 8 is a G+10 residential building having square geometry (plan area = 625m2) with floating column at second floor.

The following results were obtained from the analysis:

1. Behaviour of these models is compared on the basis of the storey displacement and storey drift.

2. Storey displacement is the lateral movement of the structure caused by lateral force.The deflected shape of a structure is most important and most clearly visible point of comparison for any structure. No other parameter of comparison can give a better idea of behavior of the structure than comparison of storey displacement.

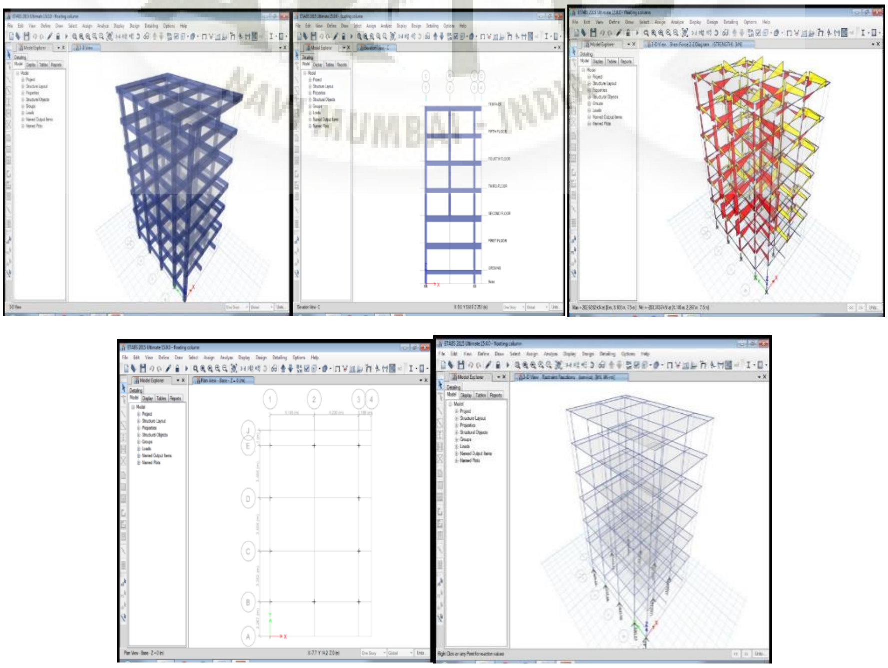
3. Storey drift is the relative displacement of the floor and calculated as the difference of deflections of the floors at the top and bottom of the story under a difference of deflections of the floors at the top and bottom of the story under consideration

Finally he concluded that the studies of various research and analyzing the studies mentioned above, it can be concluded that the use of floating column in the modern buildings are increasing vastly. The unavoidable requirements of space at the time of its shortage can be fulfilled by floating column leading to increase in their demand within residential building as well as commercial building. Building provided with floating column shows more storey drift and storey displacement as compared to building without floating column in seismic prone area.

Chekkara Sai Direddy (June 2018) studied on seismic analysis of multi – storied building with floating column. He assumed the following Load Calculation:

1. Dead load calculation: Main wall load should be the cross sectional area of the wall multiplied by unit weight of the brick. (Unit weight of brick is taken as 19.2 kN/m^3). Slab load should be combination of slab load plus floor finishes. Slab load can be calculated as the thickness of slab multiplied by unit weight of concrete (according to IS-code unit weight of concrete is taken as 25 kN/m^3).and floor finishes taken as .1.5 kN/m^2

2. Live load calculation: Live load is applied all over the super structure except the plinth .generally live load varies according to the types of building. For residential building live load is taken as 2 kN/m^2 on each floor and 2 kN/m^{2}on roof.



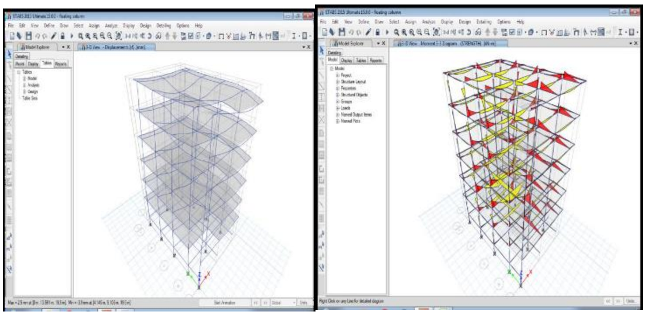


Figure 2.18 3D View, Elevation, Shear Force of the structure(14)

From the following calculations and analysis he concluded that the amount of axial load on the columns is reduced to a larger extent, not only axial load but also the moments i.e. internal stress also reduced to a larger extent in floating columns. Taking into account the technological advance, this project has been dealt with using the latest design software.

2.3 Critical comments on literature

- Behaviour of buildings under one step loading and sequential loading is considerably different.
- In reality, loads are applied sequentially, hence it is important to consider the sequential loading effects in the design of structure.
- It is important to consider deflections of the girder supporting floating column under sequential loading. If this is ignored, it can result in serious underestimation of deflections of the girder.
- Building provided with floating column shows more storey drift and storey displacement as compared to building without floating column in seismic prone area.
- In the conventional analysis the deformation, bending moment and shear force are underestimated for the bottom floors and the same are over estimated in the upper floors when compared with construction stage analysis.

2.4 Problem definition

It is proposed to design a structure using Construction Sequence Analysis using ETABS and revised IS 1893.

2.5 Aim

The project aims at understanding the construction sequence analysis for a building with floating column and compare the same with regular one step analysis This study will form a reference for a practicing engineer to design the structures with sequential loading.

2.6 Scope

The Study is confined of regular RCC structure with floating columns using both construction sequence analysis and linear analysis. No soil-structure interaction will be considered in the analysis.

2.7 Methodolgy

In order to achieve the objectives of our project following methodology will be used:

1. Study of fundamentals of Construction Sequence Analysis.
2. Review of existing literature pertaining to design of structures with Open Ground storey and Floating Column.
3. Selection and design of structure and its modelling in ETABS.
4. Analysis and Design of the RCC structure with Construction Sequence Analysis.

2.8 Objectives

- To design a (G+20) RCC structure with floating column considering seismic load.
- To find out the behaviour of structure with construction sequential analysis.
- To find out the effect of on various parameters of the structure such as shear force, axial force, displacements and bending moments.
- To compare various structural aspect like bending moment, deflection, shear force and axial force in one step and construction sequence analysis.

Chapter 3

Materials and Methodology

3.1 General

To perform any sort of analysis i.e linear/non-linear, static/dynamic as well as construction sequence analysis necessary to develop a computational model with floating column. Hence in this chapter we will discuss the parameters defining the computational models and geometry of the selected building considered for this study. The whole chapters describes about the properties of the materials used for the designing, the modeling procedure followed, calculation based shear as per IS code and obtained RCC design and finally summarize the whole structures.

3.2 Description of the Structure

The dimensions of the building are: 27.23 m X 17.73m. In elevation building has G+20 floors with each floor having height of 3m. Hence total height of building 63m. The plan of the building is as follows. The building is located in Mumbai which means it has seismic zone III ad zone factor = 0.16. It is for the commercial purpose and thus importance factor is 1.

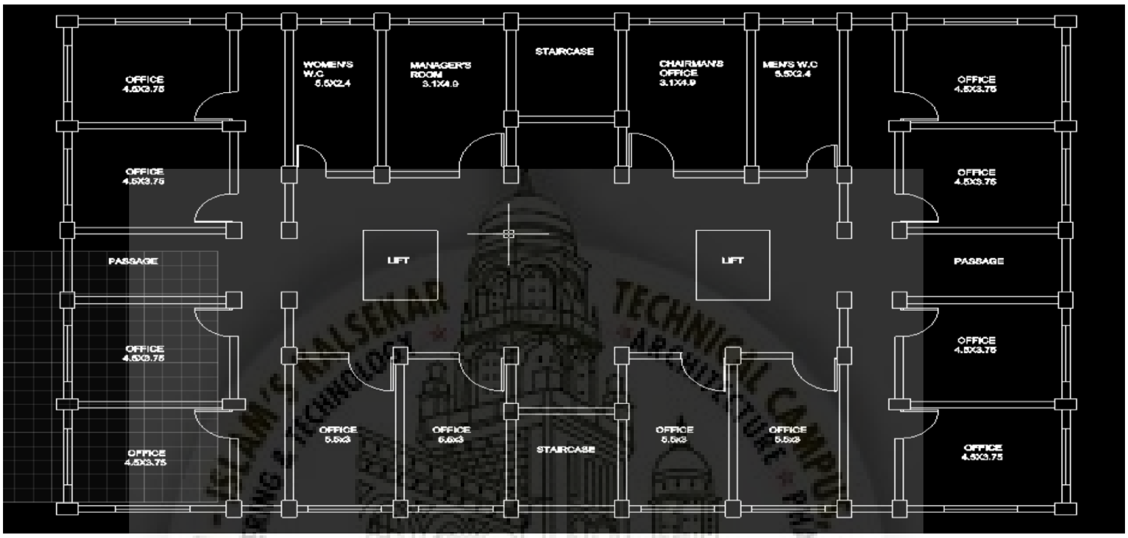


Figure 3.1Architectural Plan View

3.2.1 Structural Elements

The dimension of the element of the structure are:

1. Beam: 300mm X 600mm of M30 concrete
2. Transverse Girder Beam: 500mm X 800mm of M30 concrete
3. Column: 400mm X 800mm of M30 concrete
4. Slab Thickness : 150mm, for One way and Two way M30
5. Staircase slab thickness: 150mm One way M30
6. Diaphragm: Rigid D1

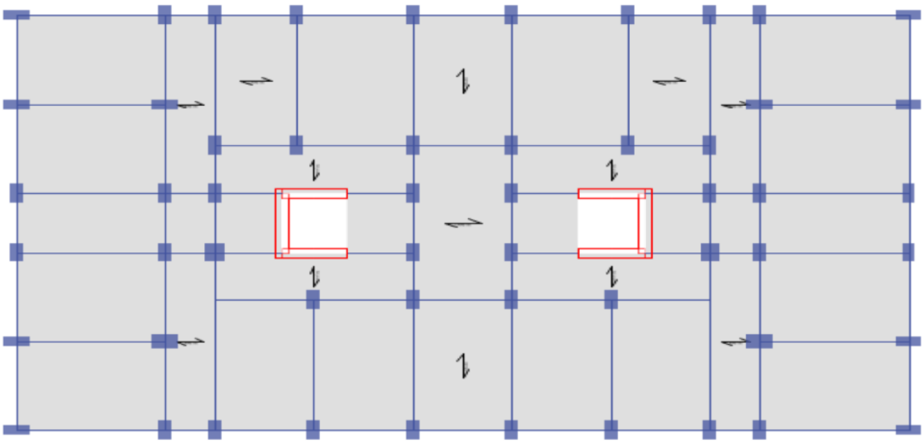


Figure 3.2 Mathematical Model in ETABS

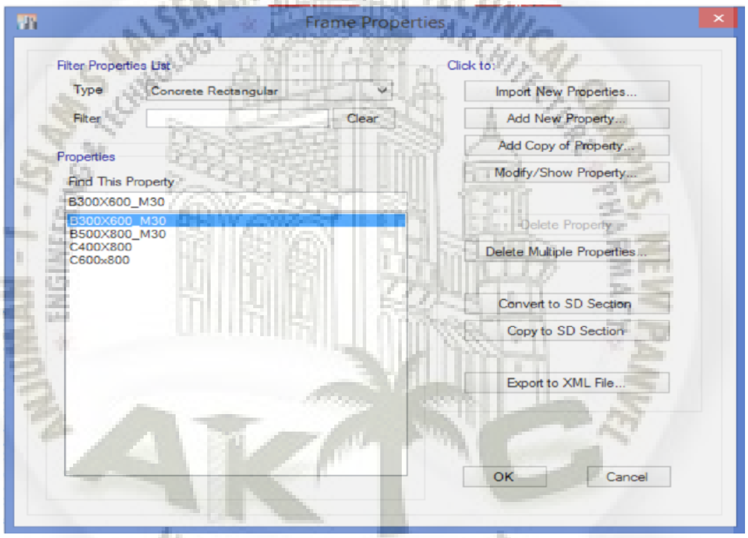


Figure 3.3Frame Section

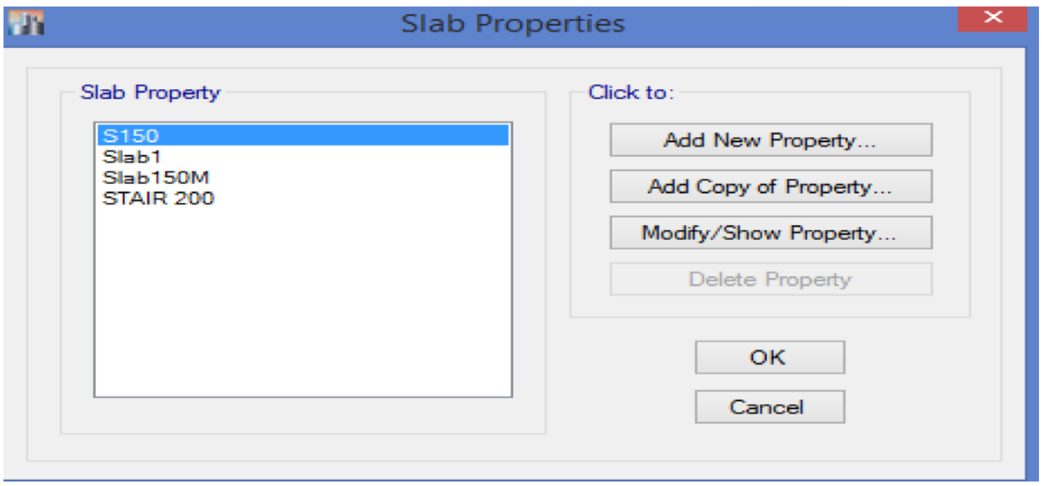


Figure 3.4Slab Sections

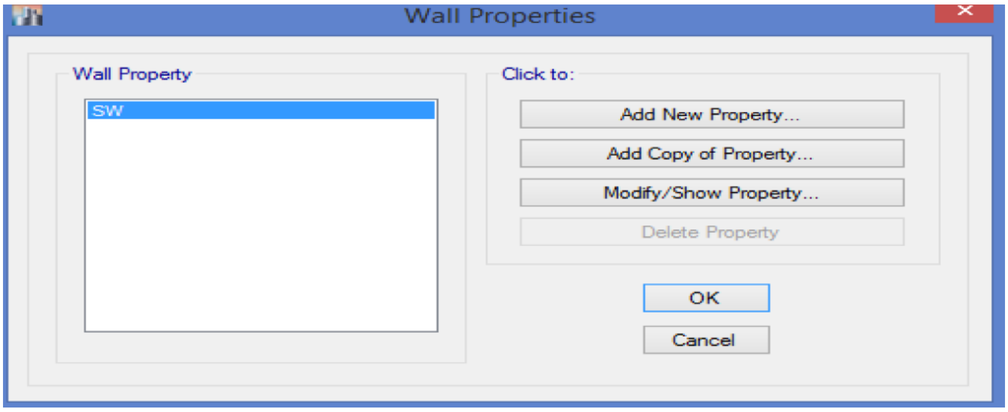


Figure 3.5 Wall Sections

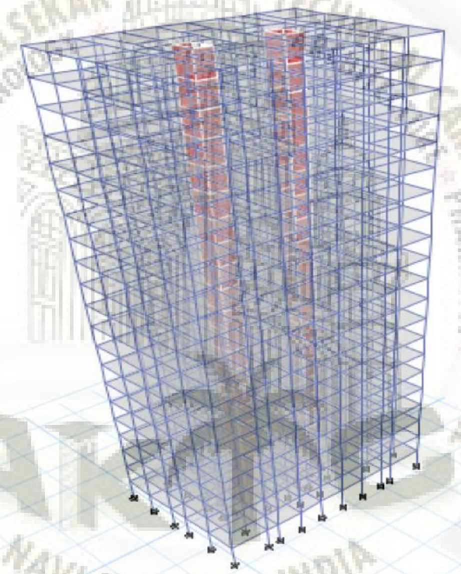


Figure 3.6 3D Model

3.3 Seismic Design Data

The behavior of building during earthquake depends on various parameters which govern the intensity of earthquake. Before analysis it is necessary to assume a certain values of these parameters to make study more coherent. Since the building is located in Mumbai, the seismic zone is III as per IS 1893

Table 3-1 Seismic Design Data

Design Parameters		
Sr. No.	Design Parameter	Value
1	Seismic Zone	III
2	Zone factor	0.16
3	Response reduction factor	3
4	Importance factor	1
5	Soil type	Medium
6	Damping Ratio	5%
7	Frame type	Dual System

Table 3-2 Material Properties

Material Properties		
Sr. No.	Design Parameter	Value
1	Unit weight of concrete	25 kN/m^3
2	Characteristic Strength of concrete	30 MPa
4	Characteristic Strength of Steel	500MPa
6	Damping ratio	5%

TABLE: Story Response

Story	Elevation	Location	X-Dir	Y-Dir
	m		kN	kN
Story21	63	Top	527.8228	0
Story20	60	Top	761.7975	0
Story19	57	Top	687.5223	0
Story18	54	Top	617.056	0
Story17	51	Top	550.3987	0
Story16	48	Top	487.5504	0
Story15	45	Top	428.5111	0
Story14	42	Top	373.2808	0
Story13	39	Top	321.8595	0
Story12	36	Top	274.2471	0
Story11	33	Top	230.4438	0
Story10	30	Top	190.4494	0
Story9	27	Top	154.264	0
Story8	24	Top	121.8876	0
Story7	21	Top	93.3202	0
Story6	18	Top	68.5618	0
Story5	15	Top	47.6123	0
Story4	12	Top	30.4719	0
Story3	9	Top	17.1404	0
Story2	6	Top	7.6269	0
Story1	3	Top	1.913	0
Base	0	Top	0	0

TABLE: Story Response

Story	Elevation	Location	X-Dir	Y-Dir
	m		kN	kN
Story21	63	Top	0	424.985
Story20	60	Top	0	613.3735
Story19	57	Top	0	553.5696
Story18	54	Top	0	496.8325
Story17	51	Top	0	443.1624
Story16	48	Top	0	392.5591
Story15	45	Top	0	345.0226
Story14	42	Top	0	300.553
Story13	39	Top	0	259.1503
Story12	36	Top	0	220.8145
Story11	33	Top	0	185.5455
Story10	30	Top	0	153.3434
Story9	27	Top	0	124.2081
Story8	24	Top	0	98.1398
Story7	21	Top	0	75.1383
Story6	18	Top	0	55.2036
Story5	15	Top	0	38.3358
Story4	12	Top	0	24.5349
Story3	9	Top	0	13.8009
Story2	6	Top	0	6.1409
Story1	3	Top	0	1.5403
Base	0	Top	0	0

Figure 3.7 Story Shears for Equivalent Static Analysis.

3.4 Auto-Sequence Case in ETABS

ETABS gives the flexibility to model the structure with construction sequence with the option of replacing the dead load with the auto-sequence dead loads. This feature is very advantageous to model a complicated structure, like structure with floating column to predict the structural response in a realistic manner.

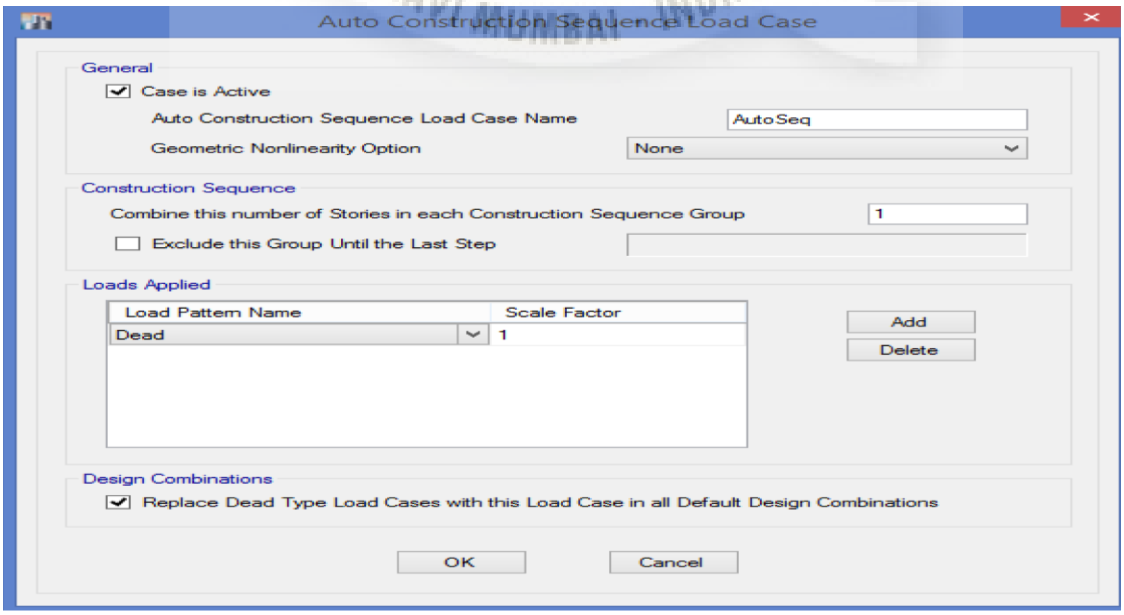


Figure 3.8 Definition of Construction Sequence Case in ETABS

Chapter 4

Result and Discussion

4.1 General

This chapter presents the results from the current study. The structural design is in consistence with IS 456-2000 and IS 1893. The members are designed as ordinary members. The difference in the behaviour in single step and construction sequence is compared in this chapter.

4.2 Design Results

In this section design as per IS codes is presented for various structural members.

4.2.1 Design of Beams

All the beams are designed as for two different cases. In one case dead load in all load combinations is considered while in other case, the dead load is replaced with Auto-Sequence load for design. Beams are designed as per the combinations given in IS code.

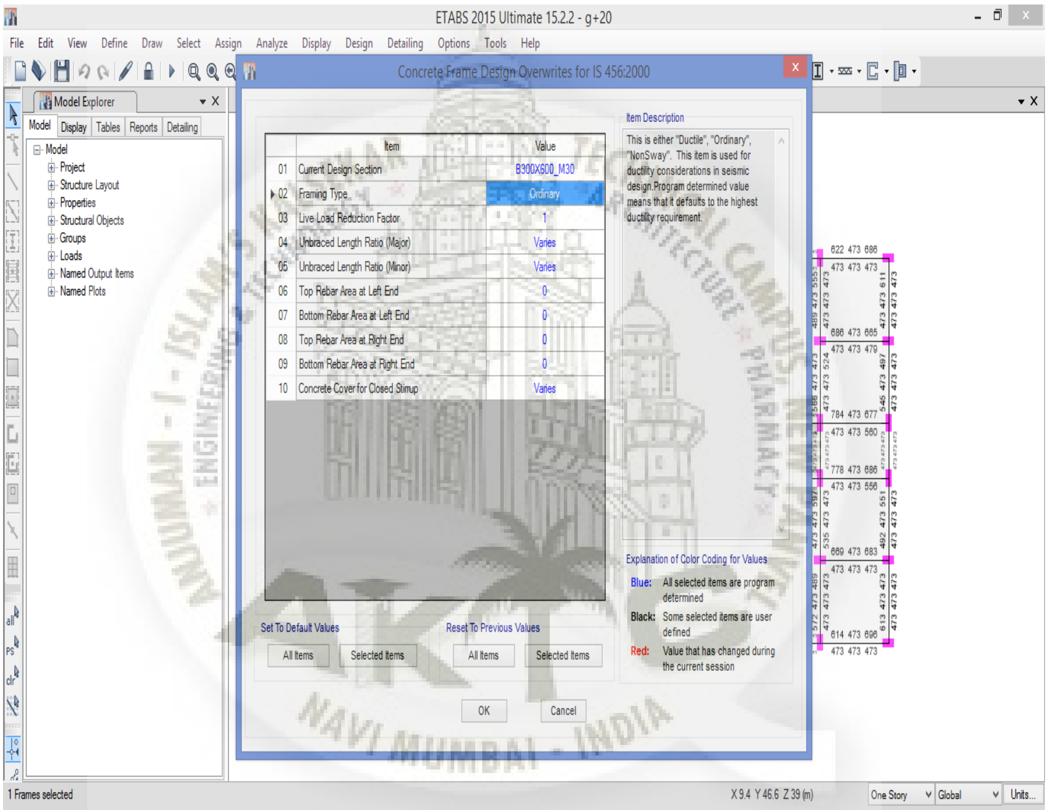


Figure 4.1 Beam Design Overwrites

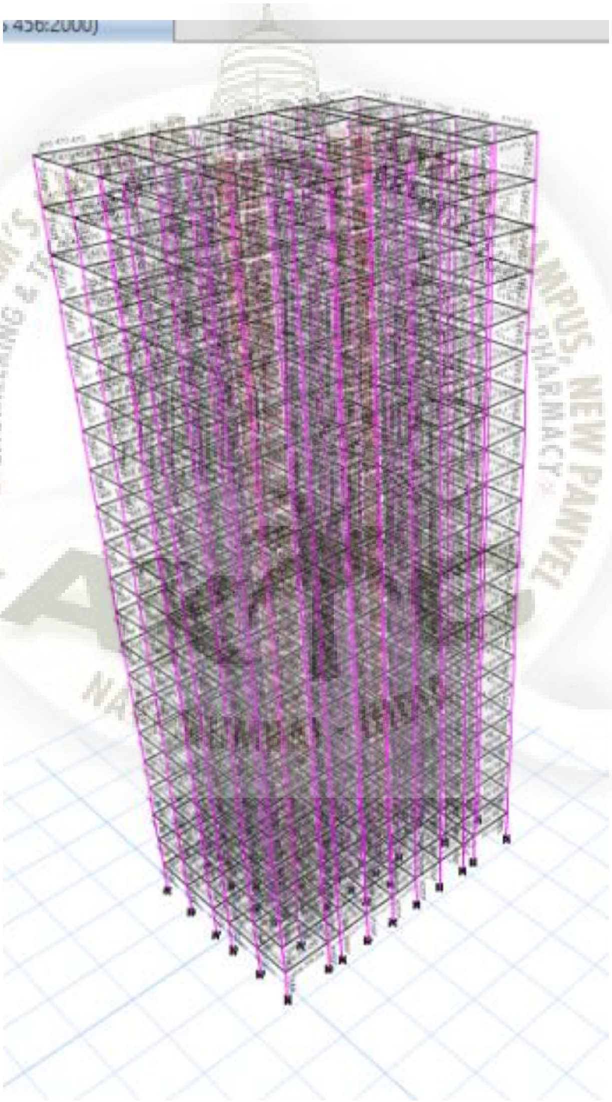


Figure 4.2 Design of Beams using Dead Load in combination

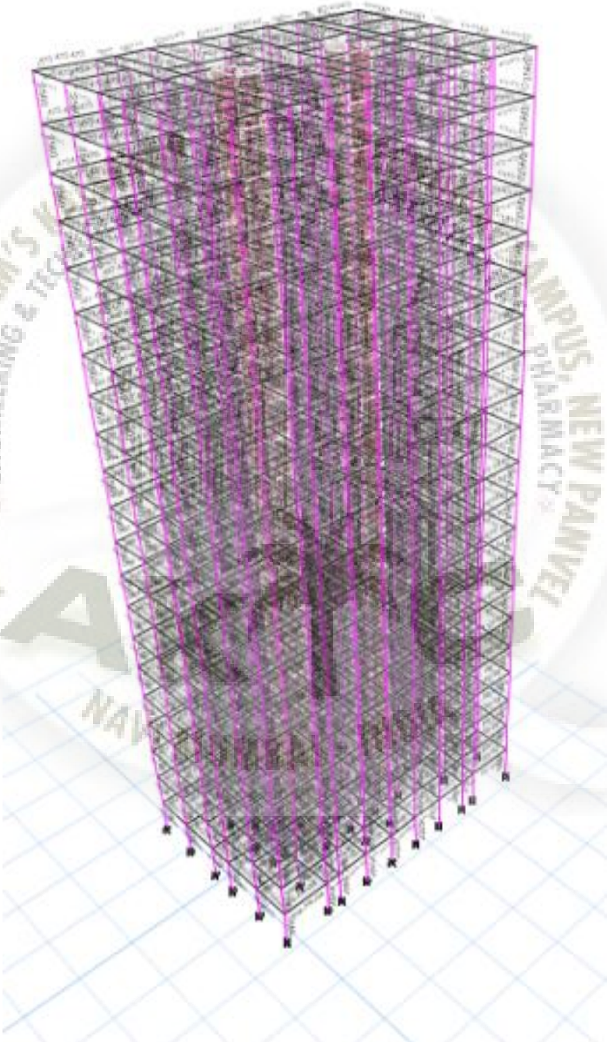


Figure 4.3 Design of Beams Replacing Dead Load with Auto-Sequence in combination

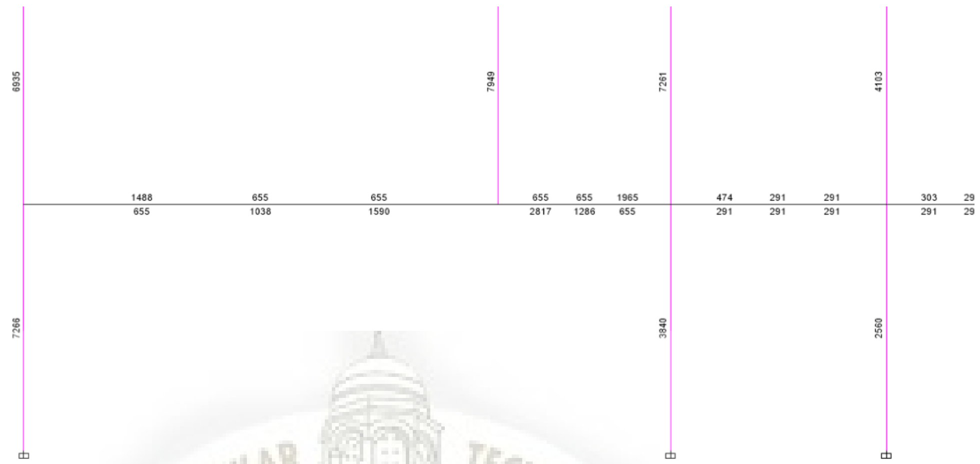


Figure 4.4 Reinforcement in Transfer girder using Dead Load in combination

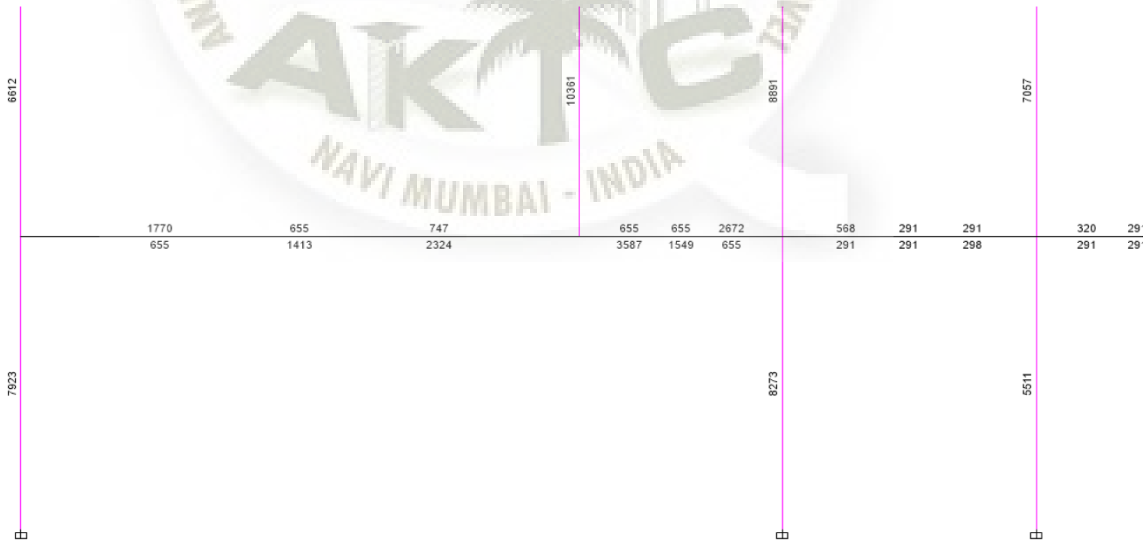


Figure 4.5 Reinforcement in Transfer girder Replacing Dead Load with Auto-Sequence in combination

4.2.2 Design of Columns

Columns are designed as biaxial columns as per IS 456-2000. Ductile detailing is ignored as the frame is designed as ordinary frame. All the columns passed the design checks.

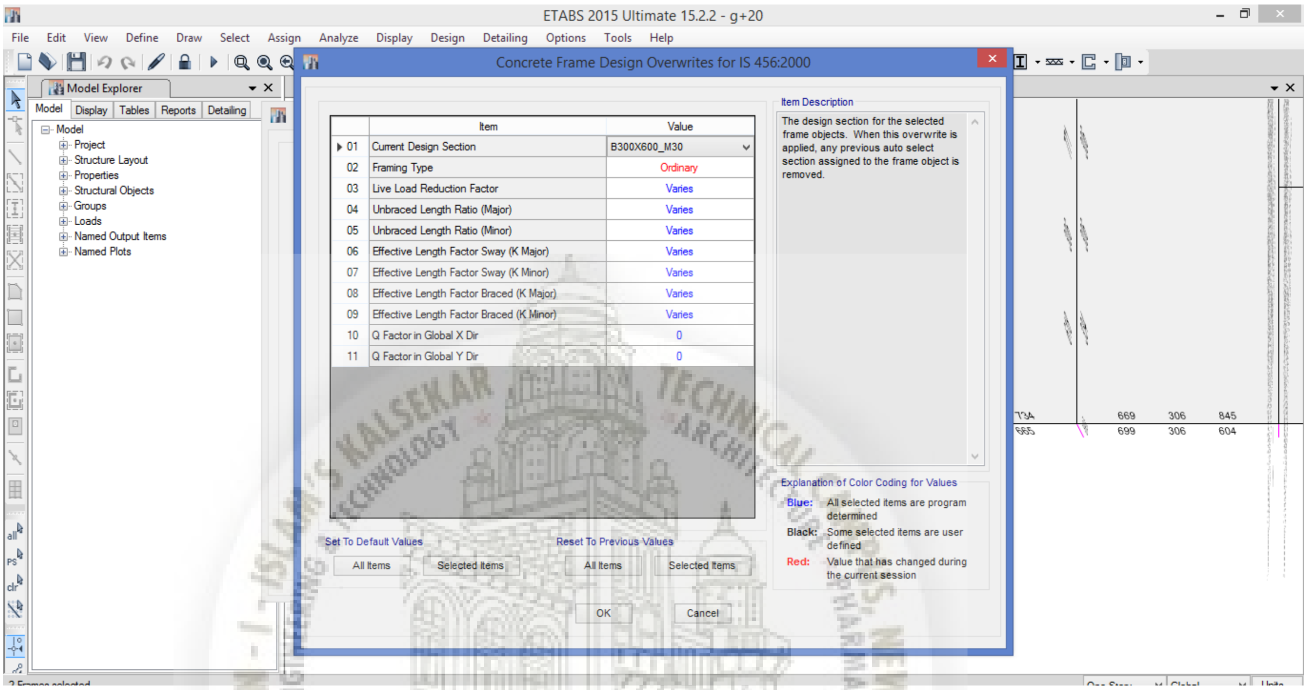


Figure 4.6 Column Design Overwrites

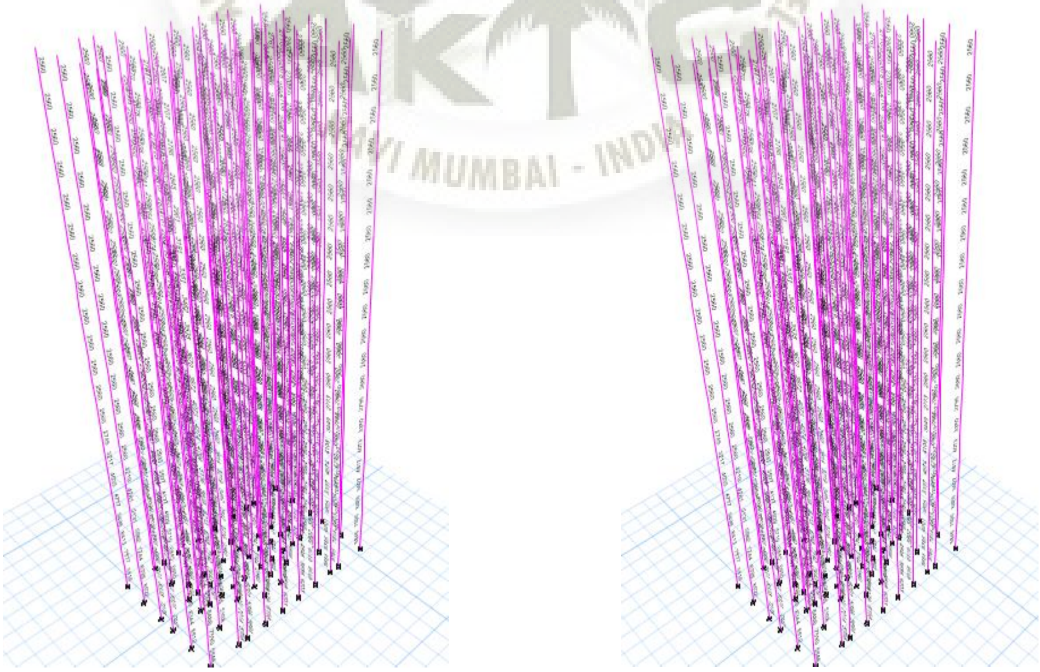


Figure 4.7 Column Design Due To Dead Load and Auto-Sequence in load combination.

4.2.3 Design of Shear Walls

Shear walls are designed as per the guidelines of the IS code. All walls passed design checks.

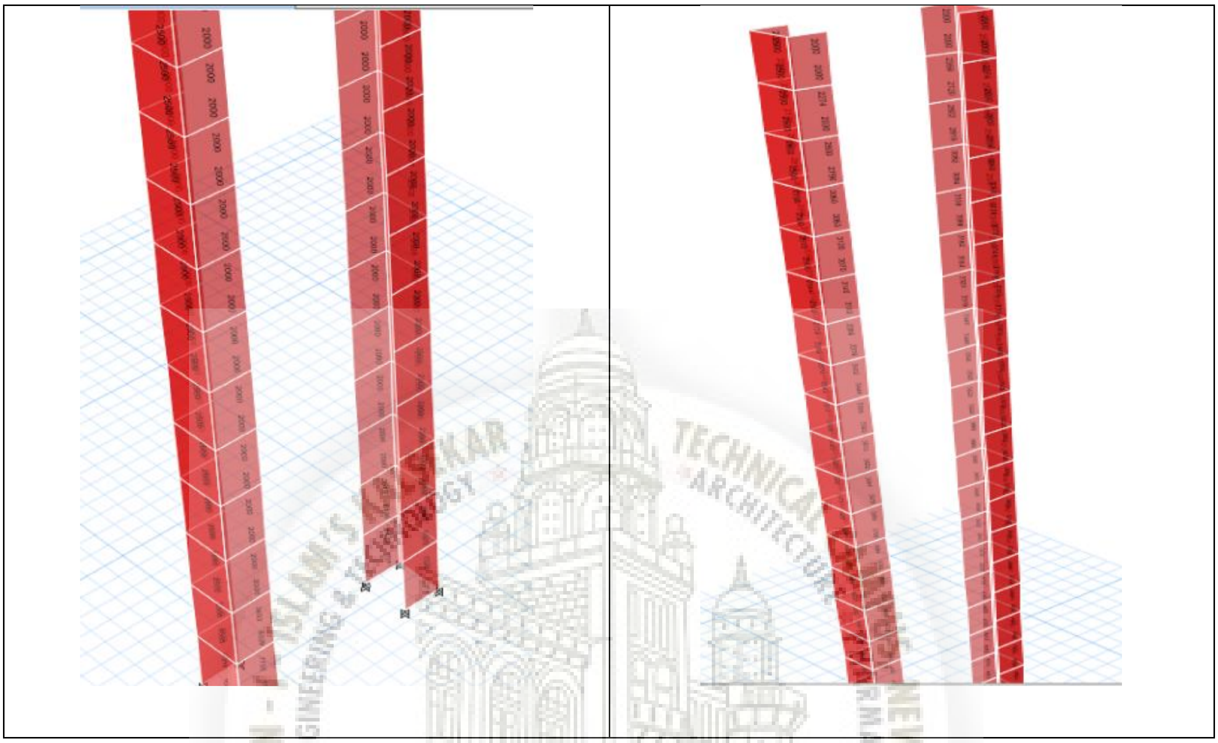


Figure 4.8 Shear Wall Design Due To Dead Load and Auto-Sequence in load combination

4.3 Discussion

The response of the structure is compared and the discussion on results in presented in the following subtopics.

4.3.1 Forces due to One-Step and Auto-Sequence analysis

There is considerable difference in the forces in transfer girder due to construction sequence and one step analysis.

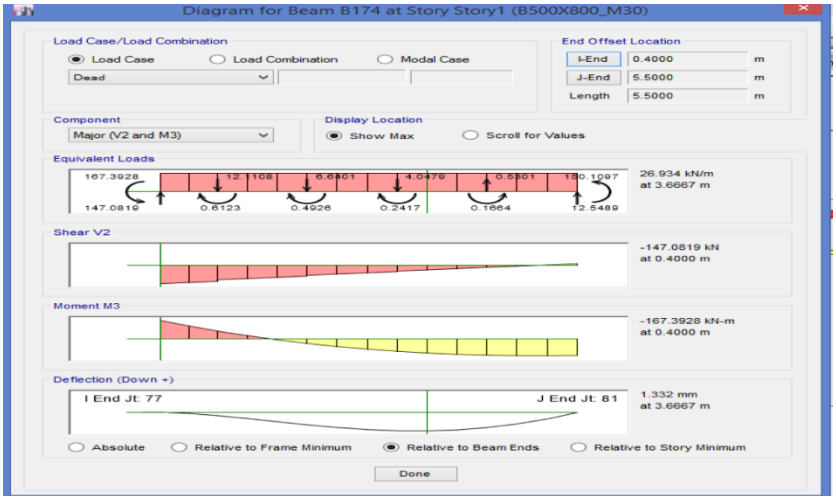


Figure 4.9 Forces in transfer girder due to dead load.

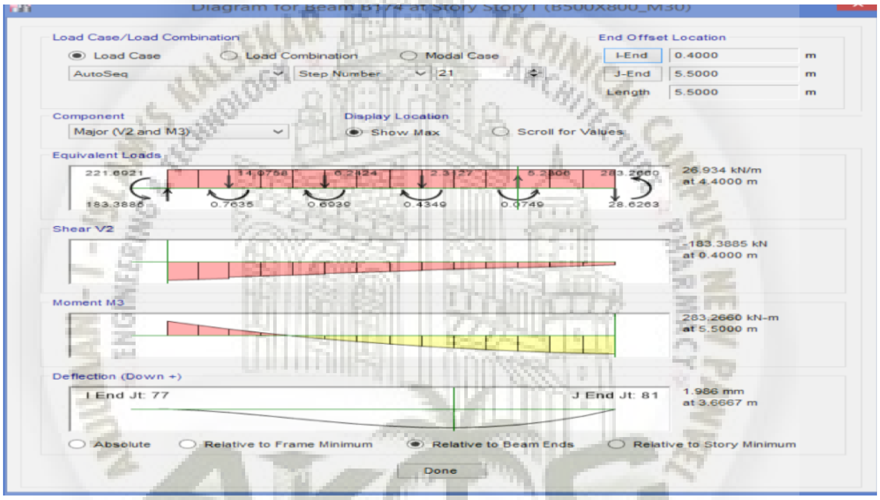


Figure 4.10 Forces in transfer girder due to Auto-Sequence.

4.3.2 Deflection due to One-Step and Auto-Sequence analysis

There is considerable difference in the deflection of the transfer girder in one step and sequential loading. It is very important to consider the deflection due to sequential loading as it may affect the serviceability aspect and subsequently the safety aspect of the structure. Following figures shows the difference between the deflections in both cases.

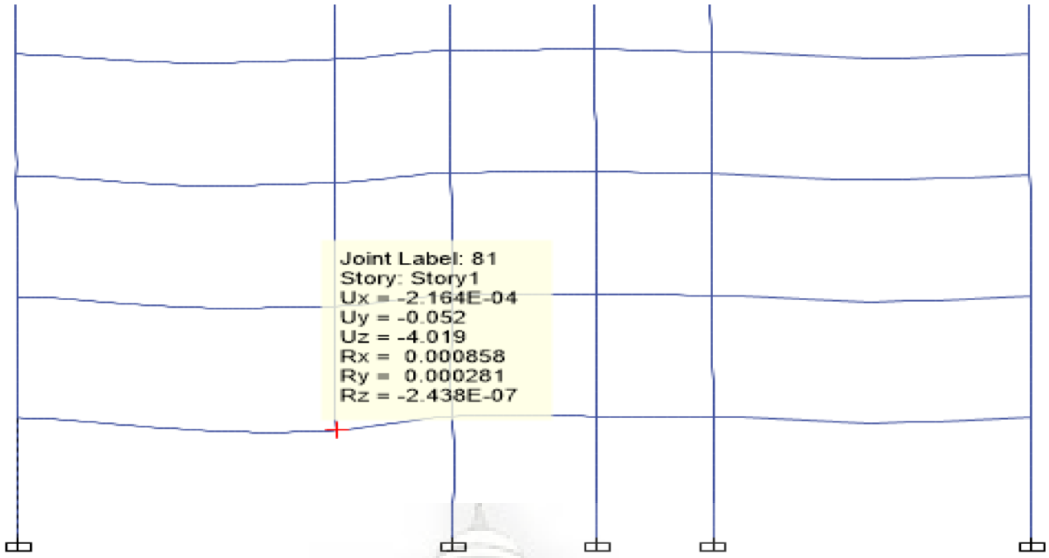


Figure 4.11 Deflection in transfer girder due to Dead load case

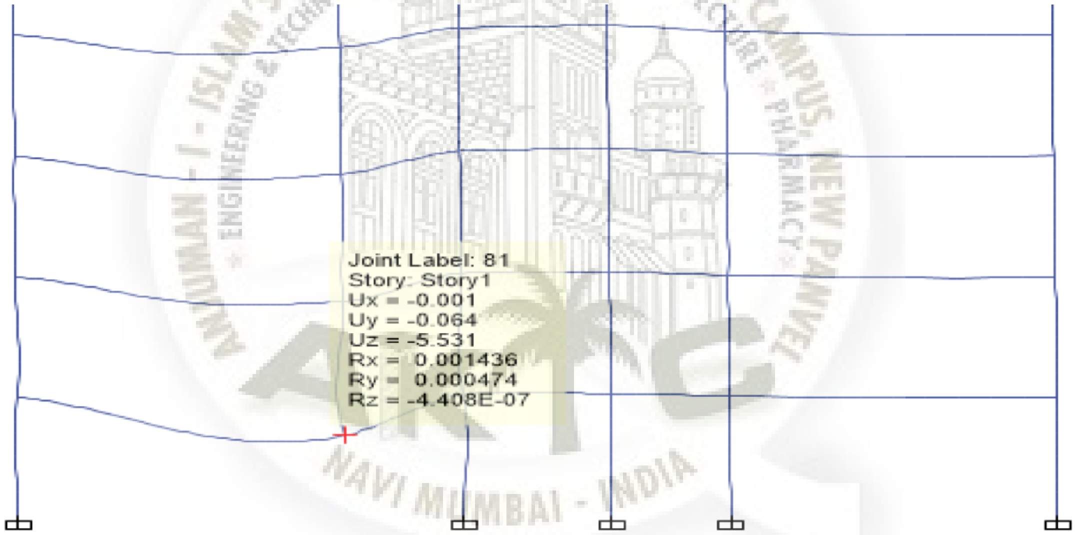


Figure 4.12 Deflection in transfer girder due to Auto-Sequence load case

4.3.3 Displacement

The structure has fairly regular configuration in plan hence the displacement in either direction is more in equivalent static analysis. Following graphs present the comparison of displacements due to static and dynamic loads.

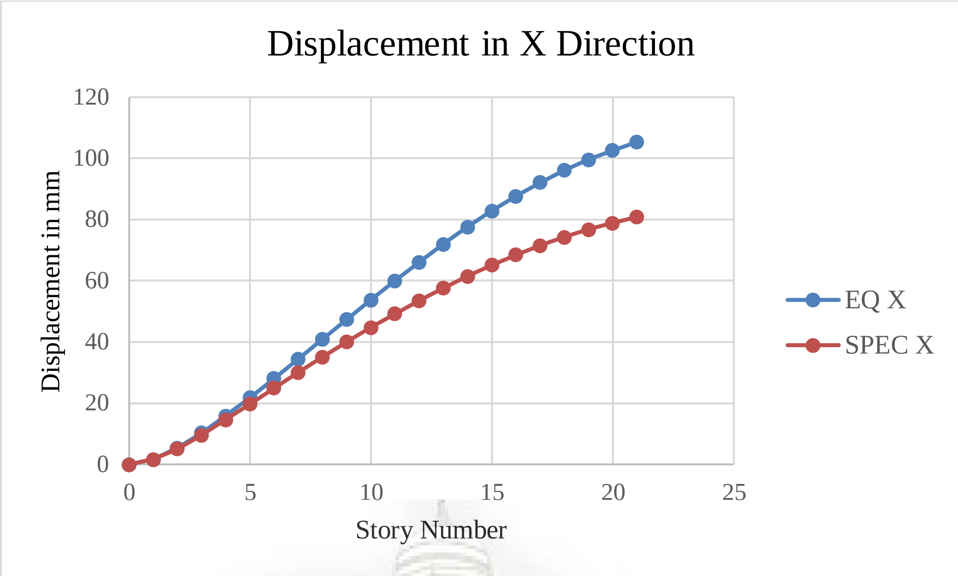


Figure 4.13 Displacement in X Direction

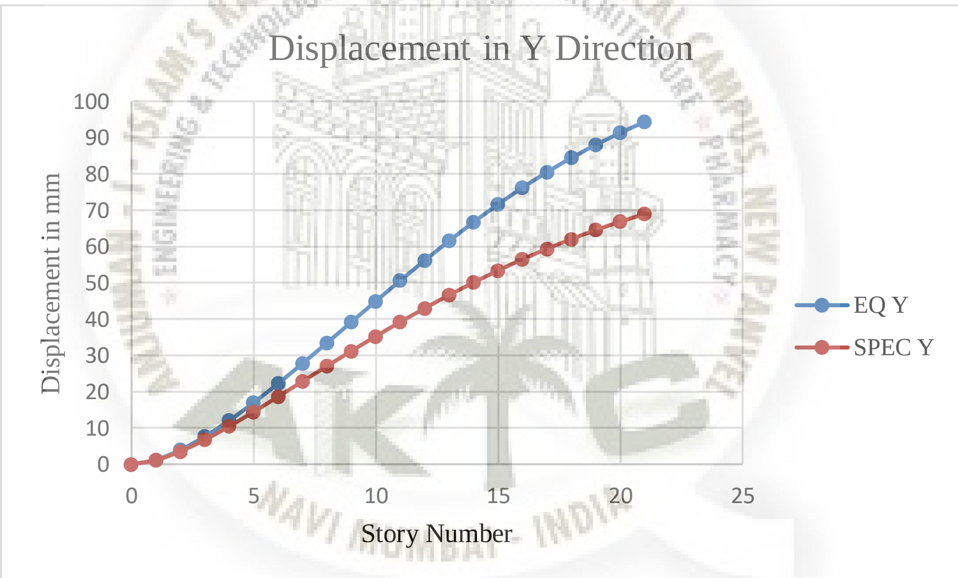


Figure 4.14 Displacement in Y Direction

Chapter 5

Conclusion

5.1 General

Conclusions from the current study are presented in this section. Structural design has satisfied all the IS code checks.

5.2 Conclusions

Following conclusions are derived from the present study.

As per new code of seismic design, IS 1893-2016, floating column structures are not advised to be a part of primary load resisting system.

There is considerable difference in the structural response of the structural elements in one step analysis and construction sequence analysis.

The response of supporting girder to the floating column is even more critical and one step analysis may underestimate the forces and displacements in the member.

It is essential to perform the construction sequence analysis to emulate the real construction loading and corresponding response of the structure for design of structure, this is particularly critical for commercial buildings which may have floating columns.

Structural response of the building with floating column is critical under seismic loading. Supporting girder must be designed with extreme care by using guidelines given by the code and engineer's judgement.

5.3 Future Scope

Current study was confined to linear analysis without addressing the issue of creep and shrinkage. Material non-linearity and P-delta effects are not considered in this study. The long term serviceability analysis and non-linear analysis forms the future scope of the present study.

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