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Study and Comparison of Conventional Analysis with Construction Sequence Analysis using ETABS

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***Abstract*— Some of the columns in multistorey buildings are designed to be floating columns with transfer girder support. These columns are being analysed in a single step under the presumption that the frame will be subjected to design loads. This is necessary because architectural requirements dictate that certain columns be designed as floating columns. In point of fact, loads are applied at various points during the construction process as the frames of the building are built storey by storey. Within the scope of this study, we have looked at two different instances. Whereas in Case 1 the multistoreyed building with floating columns and transfer girder with 16 stories will be analysed as a whole for the subjected loading, in Case 2 the multistoreyed building with floating columns and transfer girder with 16 stories will be analysed with reference to the construction sequence or staged construction. Both cases involve a multistorey building with floating columns and transfer girders. For the purpose of illustrating the floating column on girders, a comprehensive analysis and comparison of the change in deformations, bending moment, shear force, and axial force will be shown for the transfer girders. The ETABS software is used for both the analysis of the building**

Keywords—Floating columns; Construction sequence analysis; Conventional analysis; Staged construction; ETABS

I. INTRODUCTION

The multistorey building frames have been studied for a very long time under the presumption that the entire load is applied to the finished frame structure with all loads acting on the building—self-weight, superimposed load, live load, and lateral loads—applied on the finished frame at a specific instant as a single step analysis. But in reality, when the building structure is built storey by storey in a sequential manner, the dead load owing to each structural component and finishing item is imposed separately. When different loads are imposed all at once, a building structure performs quite differently than when the stresses are applied gradually. Construction sequence analysis refers to the process of analysing a structure in accordance with real construction methods (CSA). Construction sequence analysis, commonly referred to as staged construction analysis, is a static non-linear method of analysis that takes the idea of incremental loading into consideration.

One of the topics that has drawn a lot of engineering research efforts and designers' attention is the structural analysis of multistorey structures. However, there is one area that has received little attention from earlier researchers: the implications of building sequence analysis in a multistorey frame. The structural components are added gradually while a building is constructed, and as a result, their dead load is supported by the portion of the structure that is complete at the time of their installation. As a result, the qualities of the members that have not yet been built have no impact on how displacement and stresses are distributed within a given story. By adding together, the outcomes of the study of each step of the building frame structure, it is possible to determine the right distribution of the displacement and stresses of every part.

Construction sequence analysis is becoming a crucial component of analysis since so many well-known analysis software packages now incorporate this feature. However, due to a lack of understanding of its value and use, nonlinear static analysis is not as well known. Construction sequence analysis, like many other analyses, had a role throughout the structure's design phase. As was already noted, it deals with nonlinear behaviour under static loads in the form of sequential load increase and how it affects structures when structural elements begin to respond to loads before the entire system is complete. ETABS (Extended 3D analysis of building systems), one of the top analysis programmes, is used for finite element analysis. All displacement outcomes are recorded in meters, whereas moments and axial loads are quantified in KN-m and KN, respectively

II. OBJECTIVES

- To use construction sequence analysis to get an analytical understanding of the behaviour of the high-rise building during the construction process at its various stages.
- To study of the similarities and differences between the conventional method and the Construction Sequence analysis.
- To Determine the percentage of change in deflection, bending moments, shear force, and axial force, of the structural elements using the Conventional analysis and the construction sequence analysis

III. METHODOLOGY

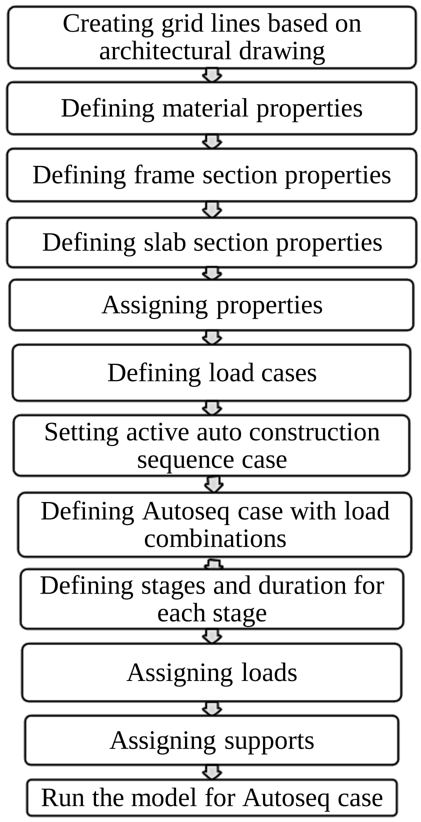
In conventional design, all of the design assessments, including those for strength, stability, and deflection, are carried out by taking into consideration the application of loads in a single step. But in practice, the behaviour of the structure is not the same since the deflection of the components is not the same because of the self-weight, which operates in a sequential manner. The structural self-weight, external loads, boundary conditions, and materials are all dependent on phases of the building process; yet, their fluctuations are neglected in conventional design, which is nothing more than a restriction of the traditional design approach. It is necessary to develop a non-linear static load case in order to carry out an analysis of the structure in a sequential fashion, which depicts said load scenario. During the analysis process, grouping of each narrative is taken into consideration so that the program may determine the total number of steps necessary to finish the task. An analysis that is carried out step by step, taking into account the nonlinear behaviour of the materials analyzed in the prior stage, guarantees that the building sequence effects are accurately reflected in the research.

A. Procedure

1. Creating models:
   Two models of G+15 storied RC frame are created in ETABS v.16. One model for conventional lumped analysis and another for Construction Sequence Analysis. Steps for creating a model are as follows:
   a. Creating grid lines taking reference from an architectural drawing
   b. Defining material properties
   c. Defining frame section properties
   d. Defining slab section properties
   e. Assigning properties

2. Assignment of loads:
   a. Defining load cases
   b. For Conventional Analysis:
      i. Defining load combinations
      ii. Assigning of loads and supports
   c. For Construction sequence Analysis:
      i. Setting Auto construction sequence load case to be active
      ii. Defining Auto construction sequence load case with combination of defined loads
      iii. Defining stages and duration for each stage
      iv. Assigning of loads and supports
3. Analysis:
   a. Run the model for set load cases for conventional lumped analysis
   b. Run the model for Auto construction sequence case for construction sequence analysis
4. Comparison of results:
   The results obtained for parameters such as bending moment, shear force, deformation and axial force from both conventional analysis and construction sequence analysis are tabulated and compared with each other and the changes in results are observed. Percentage increase in the parameters is calculated and the conclusion is drawn.

B. Flow chart for construction sequence analysis



IV. PROBLEM STATEMENT

In this study we have considered a G+15 storey building with floating column. The effects of staged construction have been simulated by setting the auto construction sequence case active in ETABS software. This enables us to define stages of construction and give time duration for all the stages. Here in this study, the building is analyzed for both conventional load combinations mentioned further in this section and auto construction sequence case and for this, each storey is defined as a stage and time duration is not considered and defined as zero. The details of the building are discussed further.

A. Structural details

The details such as loads considered, details of the building and load combinations are discussed in this section.

1) Loads considered

Table 1: Loads considered

Material/Load	Load/Density
Density of Concrete	25 KN/m^2
Floor Finish	1 KN/m^2
Partition wall load	8.39 KN/m
External wall load	16 KN/m
Live load on floor	2.5 KN/m^2
Earthquake load	1.25 KN/m^2
Wind pressure	0.8 windward

2) Details of the structure

Table 2: Structural details

Sl. No.	Contents	Values
1	Number of Stories	16
2	Plan Dimensions	16 m × 20 m
3	Total Height of Building	53 m
4	Height of Each Storey	Base to Storey1 2.7 m Storey 1-16 3.35 m
5	Grade of Concrete	M 40
6	Grade of Steel	Fe 500
7	Beam 1	230 mm × 610 mm
8	Beam 2	230 mm × 305 mm
9	Column 1 and Floating Column	230 mm × 610 mm
10	Transfer Column	600 mm × 900 mm
11	Transfer Beam	600 mm × 900 mm
12	Slab 1 Thickness	152 mm
13	Partition wall	120 mm
14	External wall	230 mm
15	Seismic Zone	II
16	Importance Factor	1
17	Seismic Zone Factor	0.36

3) Load combinations

The load combinations defined and used are as follows

Table 3: Load combinations

Comb 1	1.5(DL+LL)
Comb 2	1.2(DL+LL+EX)
Comb 3	1.2(DL+LL+EY)
Comb 4	1.2(DL+LL+WX)
Comb 5	1.2(DL+LL+WY)

Note 1: DL= Dead load, LL= live load, EX and EY= Seismic force in X and Y direction respectively, WX and WY= Wind Pressure along X and Y direction in windward direction.
Note 2: Only Comb1 is used for comparison of parameters.

B. Plan and elevation

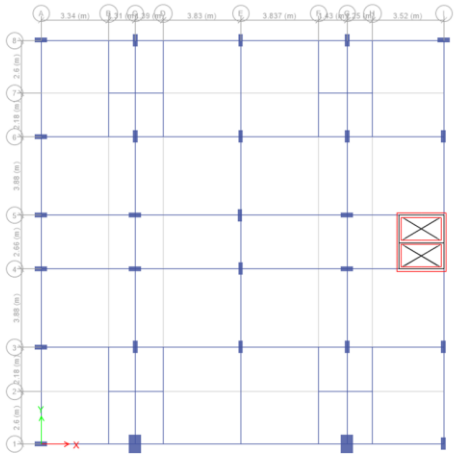


Fig 1: Plan of the building

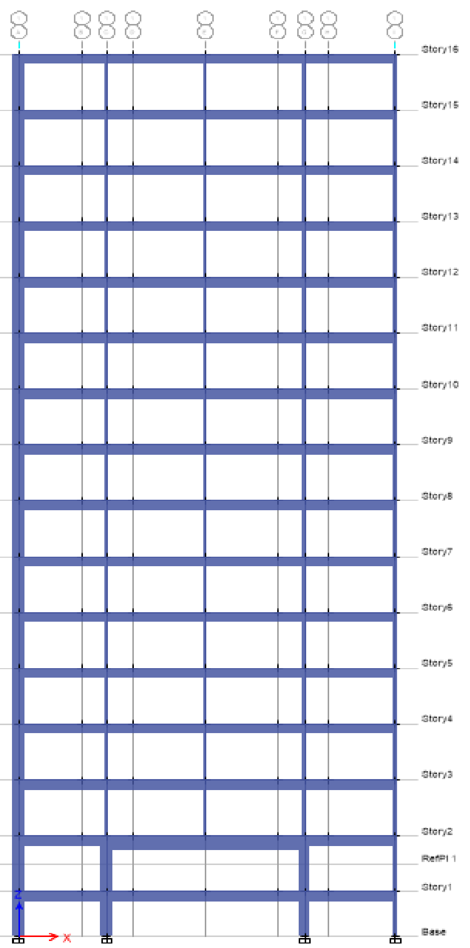


Fig 2: Elevation of building

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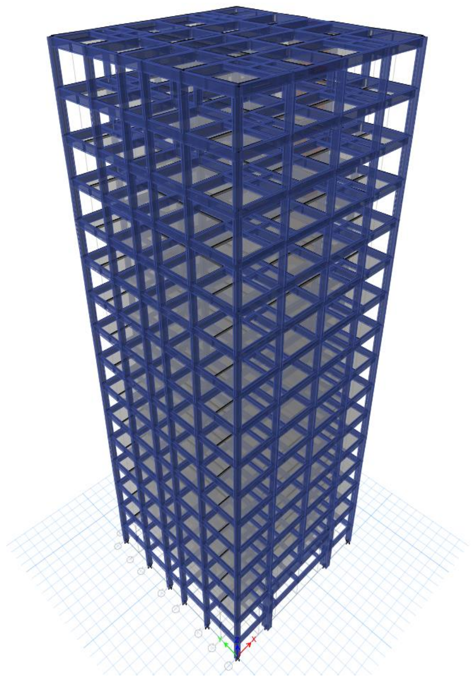

Fig 3: 3D Model

V. RESULTS

The structure has been analyzed and studied for parameters axial force, bending moment, shear force and deflection for conventional method and compared with Construction Sequence Analysis. The comparisons are represented graphically as follows.

A. Comparison of parameters in TB

In construction sequence analysis the parameters vary in each and every stage and goes on increasing as the stages are added and gives a higher value in TB when all the stages are added. On the contrary, in conventional analysis as all the loads are added in single step there is no variation in parameters in TB and the value is also low.

1) Deformation

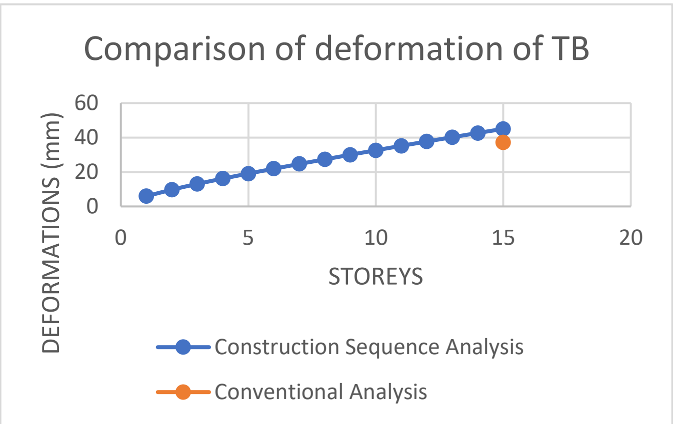

Fig 4: Comparison of deformation in TB

2) Bending moment

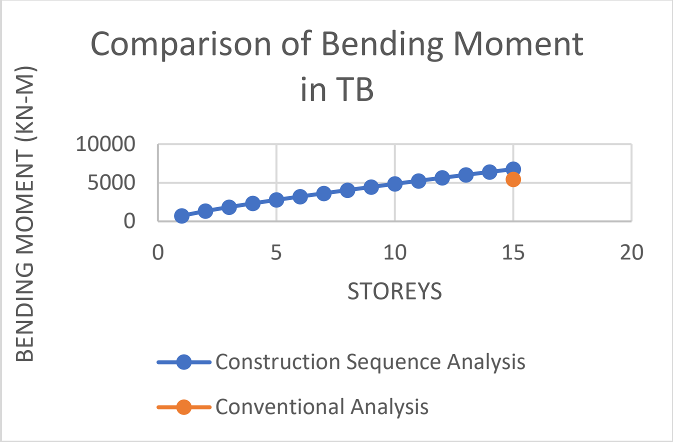

Fig 5: Comparison of bending moment in TB

3) Shear force

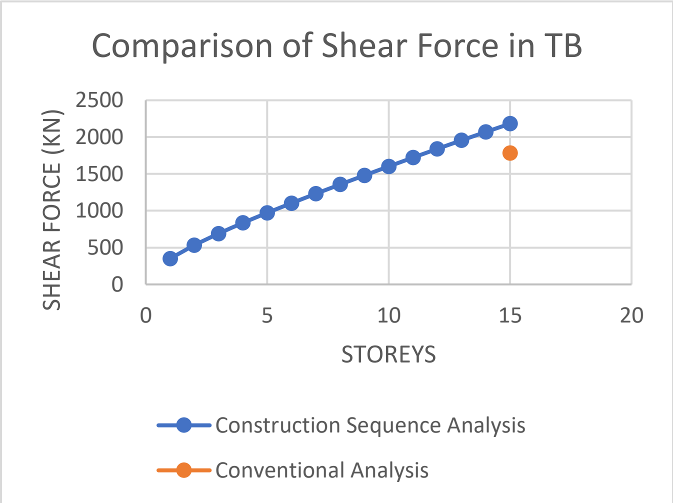

Fig 6: Comparison of shear force in TB

4) Axial force

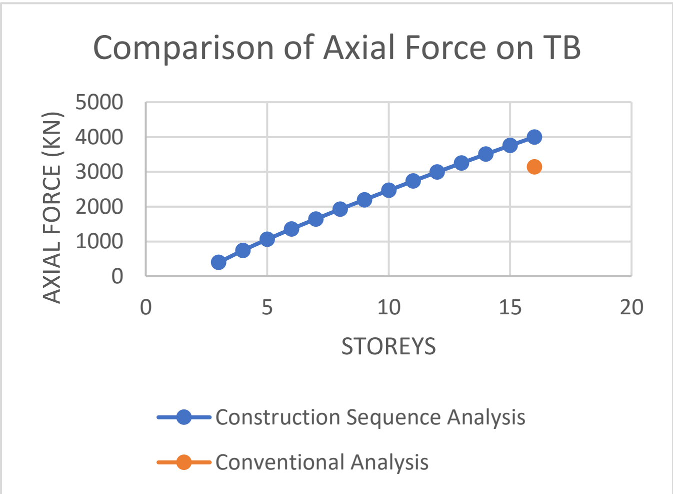

Fig 5: Comparison of Axial force on TB

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B. Storey-wise comparison of parameters

In this section we are comparing the change in parameters, storey-wise at section 1, where the transfer beam and floating column are present and clearly visible.

Here we can see that the parameters in construction sequence analysis are generally higher in TB level and get lower in the stories above TB. On the contrary, in conventional analysis the values are lower in TB level and go up for the stories above.

1) Deformation

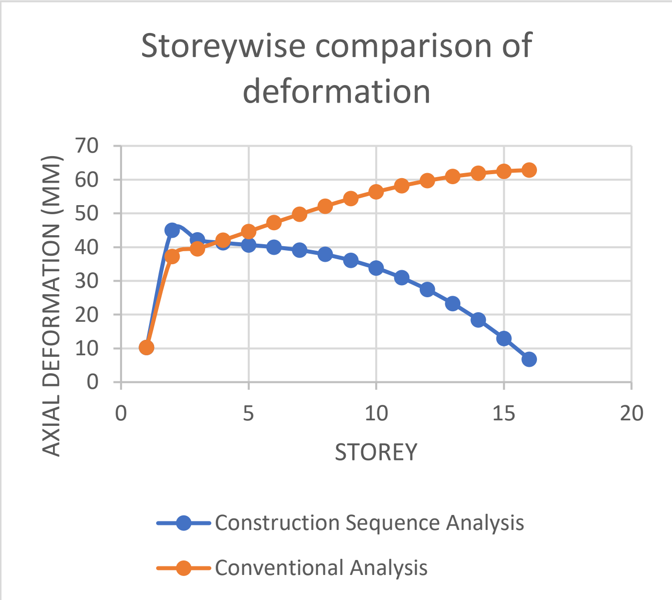


Fig 6: Storey-wise comparison of deformation

2) Bending moment

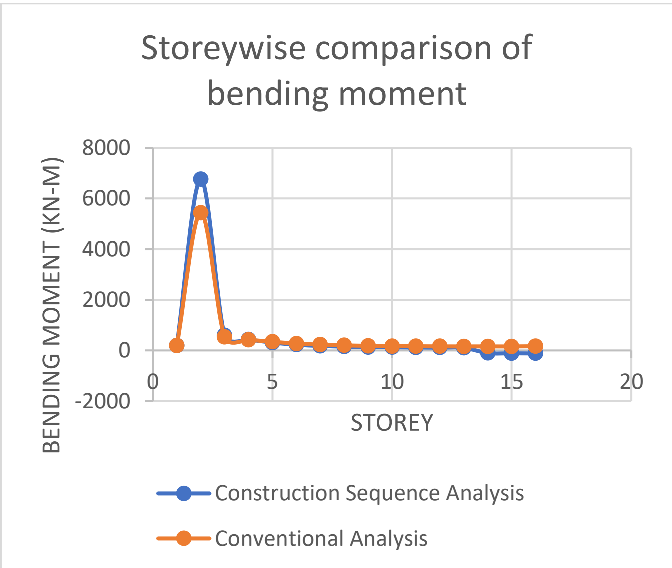


Fig 7: Storey-wise comparison of bending moment

3) Shear force

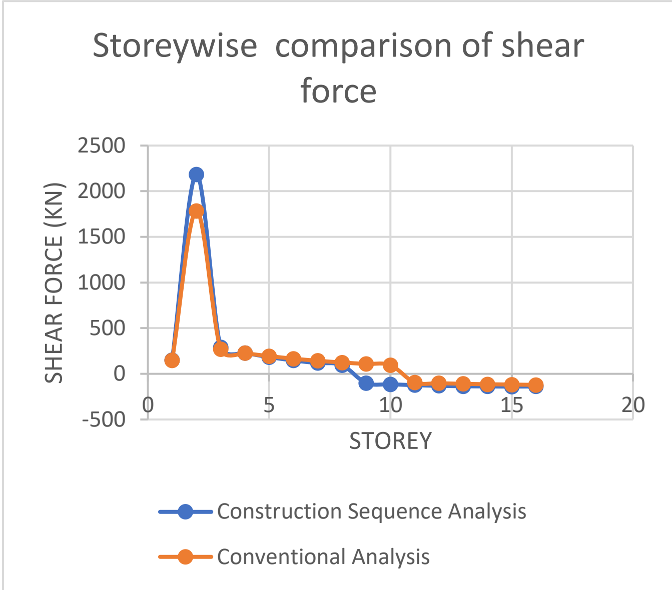
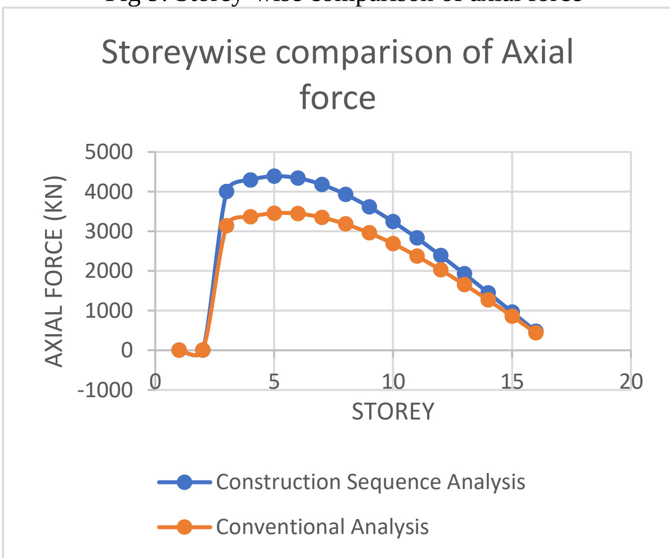


Fig 8: Storey-wise comparison of shear force

4) Axial force

Fig 9: Storey-wise comparison of axial force



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C. Percentage variations in parameters

The parameters vary for certain percentage in construction sequence analysis than in conventional analysis. Here, the variations of the parameters for TB are shown in graphical manner.

1) Deformation

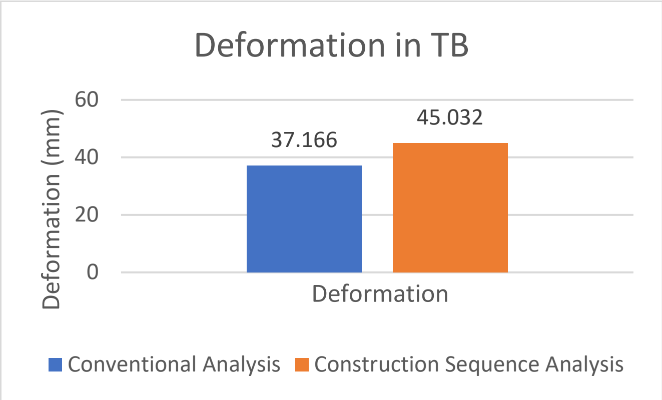

Fig 10: Variation of deformation in TB

2) Bending moment

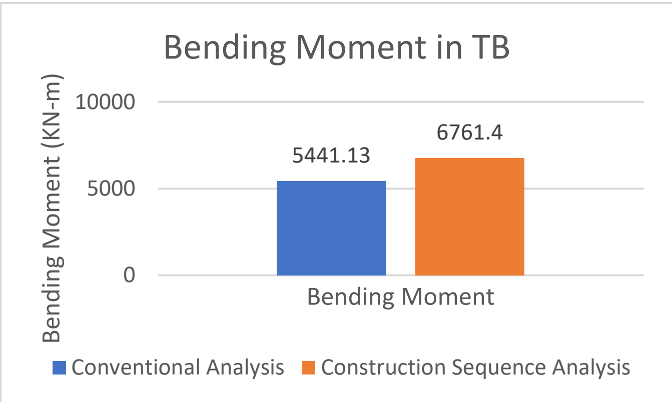

Fig 11: Variation of bending moment in TB

3) Shear force

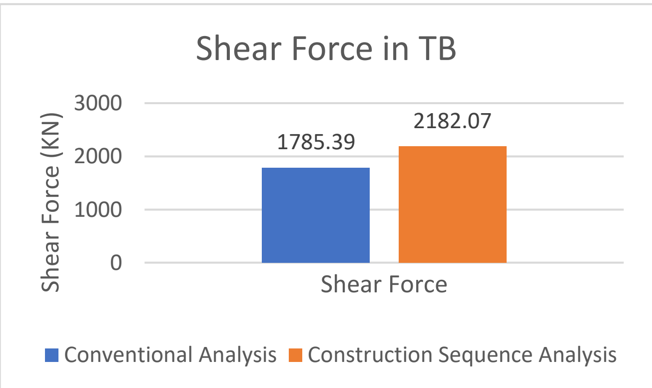

Fig 12: Variation of shear force in TB

4) Axial force

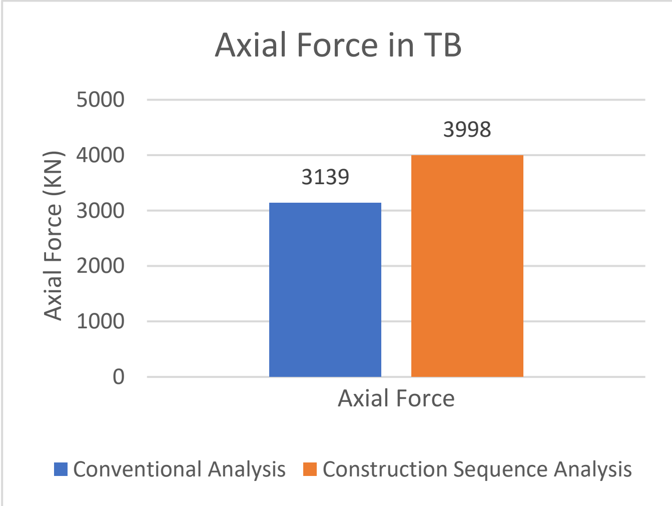

Fig 13: Variation of axial force on TB

5) Percentage increase in parameters

Table 4: Percentage increase in parameters

Contents	**Conventional Analysis**	**Construction Sequence Analysis**	**% Increase**
Deformation of TB (mm)	37.166	45.03	21.16%
Bending Moment of TB (KN-m)	5441.13	6761.4	24.26%
Shear Force of TB (KN)	1785.39	2182.07	22.24%
Axial Force on TB	3139	3998	27.36%

VI. CONCLUSION

Within the scope of this study, a finite model with variable height has been taken into consideration. Analysis has been carried out using both the traditional and construction sequences. When compared to the linear static analysis, which shows that the axial deformation is greater in the top storey and less in the bottom storey, the results of the construction sequence analysis show that the axial deformation is greater in the supporting beams. This is in contrast to the linear static analysis, which shows that the axial deformation is greater in the top and less in the bottom. When compared to linear static analysis, building sequence analysis reveals that external columns experience significantly higher axial forces. In comparison to linear static analysis, the Moment that is created using sequential analysis consists of more columns. When compared to linear static analysis, shear force in columns

during sequential analysis is significantly higher. It's possible that this is due to the building being done in stages.
Following all of the preceding observations, the following is the conclusion that can be drawn:

- Construction sequence analysis in structures made of RCC is required in order to improve the analysis accuracy in terms of displacement, axial, moment, and shear force in supporting beams and columns that are close to it, as well as for the structure as a whole.

- When doing a study of a multistoried RCC structure, using a sequential load case results in a design that is more realistic than the standard design.

- There is a considerable increase in the values of parameters of about 23% on an average when construction sequence is considered.

- Therefore, when we design the structure for these higher parameters obtained from construction sequence analysis, the structure gets safer.

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