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Comparative Study of Construction Sequence Analysis with Conventional Analysis of RC Structures with Floating Columns Using Etabs

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ABSTRACT—

Increasing incidents of failure of structures during the creation phase is a rising concern in India. The failure of various structural elements like slabs, beams, columns, and shear walls is significant. While analyzing a multi storey building frame, conventionally all the probable loads are applied after modelling the entire building frame. But in practice the frame is constructed in various stages. Accordingly, the stability of frame varies at every construction stage. Even during construction freshly placed concrete floor is supported by previously cast floor by formwork. Construction sequence analysis (CSA) helps in analysing the building in a new manner. The aim of this study is to investigate the change in values of numerous structural parameters namely axial force, shear force, and bending moment during and after construction and after a life of 50 years with creep effect. Using construction sequence analysis, this study analysed the behaviour of structural parameters of a G+10 storied building located in low prone earthquake zone with floating columns resting on transfer girder and measured these results against the response spectrum analysis of the building. In previous studies, the values of deflection and shear forces found in CSA are more than dynamic analysis. This study gives an idea regarding the failure of buildings during the construction phase. The present study provides a comparison of conventional analysis with construction stage analysis for RC building after the construction and the life of 50 years using ETABS software.

***Keywords**: Construction Sequence Analysis (CSA), Conventional Analysis, RC Structure, Displacement, Shear, ETabs .*

1.1 Introduction -

The effect of the sequential application of dead load due to the sequential nature of construction is an important factor to be considered in the multi-storey frame analysis. Unfortunately, however, this effect has been ignored by many engineers in practice in the past. One of the ways to include this effect properly in the analysis is to carry out the analysis through step-by-step procedures in accordance with the sequential application of dead loads as the construction proceeds. For bridges and high rise buildings, time dependent effects make analyses even more complex. The effects develop at the early stages of the construction process and continue to evolve considerably after the structures are built. Depending on the construction method, the time dependent effects can appear and induce important stress redistribution in the structures like bridges. To obtain real behaviour of concrete bridges and high rise buildings, segment ally construction stage analysis using time dependent material properties and geometric nonlinearity should be considered, because construction period continue along time and loads may change during this period and after.

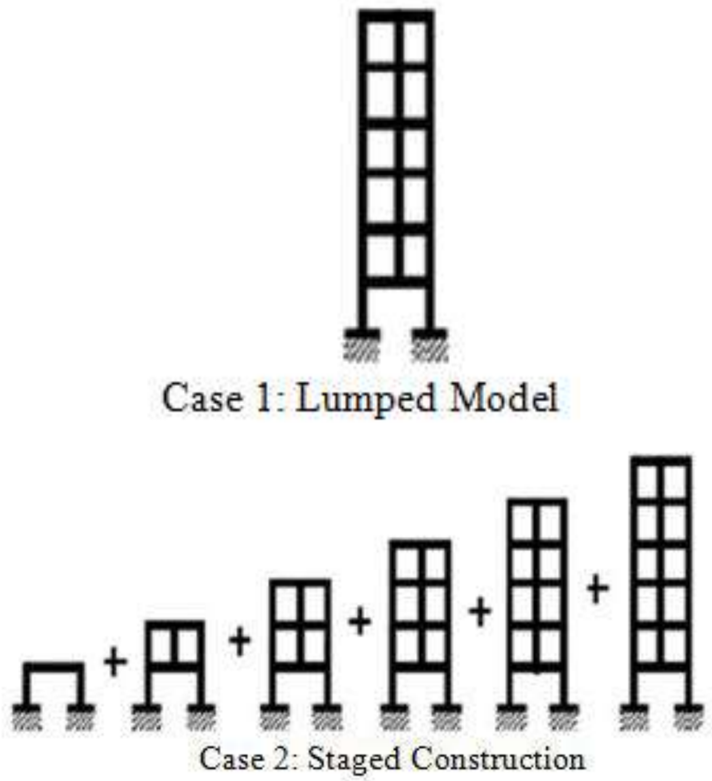
In the structural analysis of multi-storey buildings, there are two important factors that have very significant effects on the accuracy of the analysis but are usually ignored in practice. They are: (1) the effect of sequential application of dead loads due to the sequential nature of construction as discussed above; and (2) differential column shortening due to the different tributary areas that the exterior and interior columns support. The exterior column in a building is loaded with roughly one-half of the gravity load to which the interior column is subjected. In many design practices, however, there is a tendency to design the exterior columns so as to have cross-sectional areas nearly equal to the interior ones, since additional cross-sections are required in the exterior columns to resist the forces induced by overturning moments due to lateral loads such as winds and earthquakes. Therefore, there exists a substantial inequality between the ratio of the applied dead load to the cross-sectional area of an exterior column and that of an interior one. This inequality may cause a differential shortening between the exterior and interior columns in the frame. Moreover, this differential shortening is enlarged in RC frame structures since additional time-dependent deformations of concrete, which have a magnitude of more than two times the elastic deformation, are accompanied.

Multi-storeyed 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 the remaining part of it is imposed on completion of the frame. The main factors affecting the limit state of serviceability of building are

- Creep and shrinkage
- Span and cross section of the structural members
- Cycle time for floor to floor construction and strength of concrete

1.2 Sequential Analysis

Staged construction 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. Staged construction is considered a type of non linear static analysis because the structure may undergo changes during the course of the analysis. However, consideration of material and geometric nonlinearity is optional. For each nonlinear staged-construction analysis case, analysis sequence shall be defined by mentioning the variables like construction cycle, grade of concrete, strength of concrete at the stage of casting for below floors and number of cycles based on the computational effort requirements.

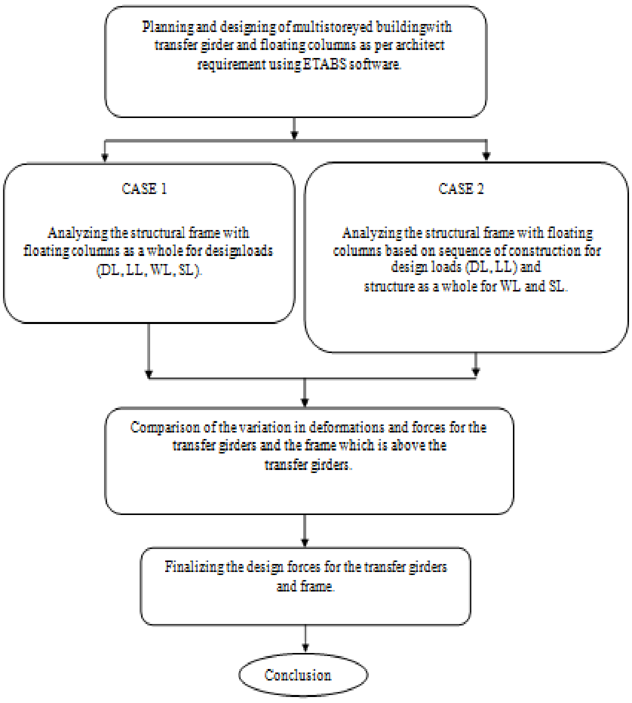


Example of conventional and staged construction model (MULAMREDDY SIVAREDDY)

2. METHODOLOGY

In this study, a residential building located in Indore with G+10 stories and plan dimensions 25 x 25 m is analysed. The modelling of the building is done in ETABS (Extended Three- Dimensional Analysis of Building System) software. The software is capable of analysing multi-storied frame structures both with and without stimulation of construction sequence. The building is analysed using two methods viz. conventional and construction sequence analysis. In conventional analysis, the building is analysed using the single-step method. In this method, it is assumed that the structure is completed and the loads are applied only after the construction is completed. Then the building is analysed by using a construction sequence. In this method, the building is analysed at each story and the loads are applied to each story as the construction progresses by simulating the actual behaviour of the structure. To finish, the results of axial forces, shear forces, and bending moments of both methods were compared.

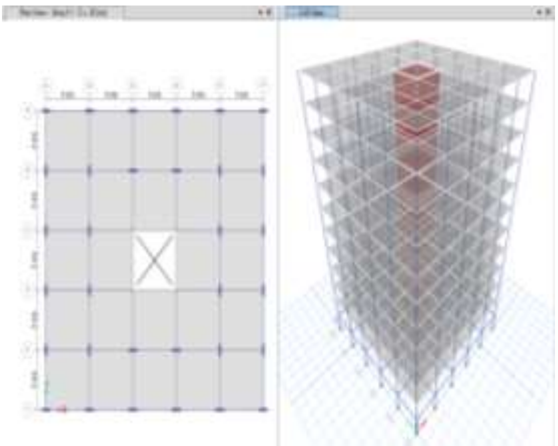
From the review of literature it has been observed that the construction sequence analysis is required to assess the behaviour of structure. The methodology adopted in the study is given below:



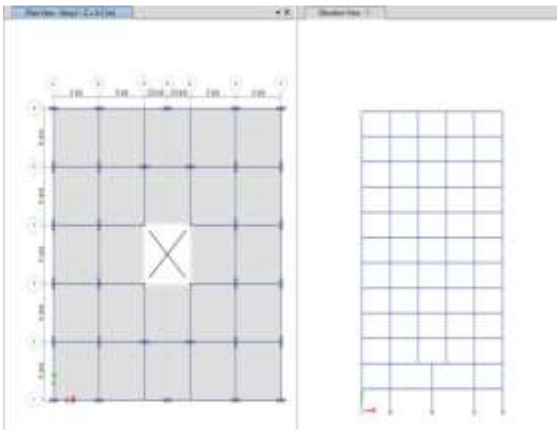
FLOW CHART OF THE STUDY

Model Details –

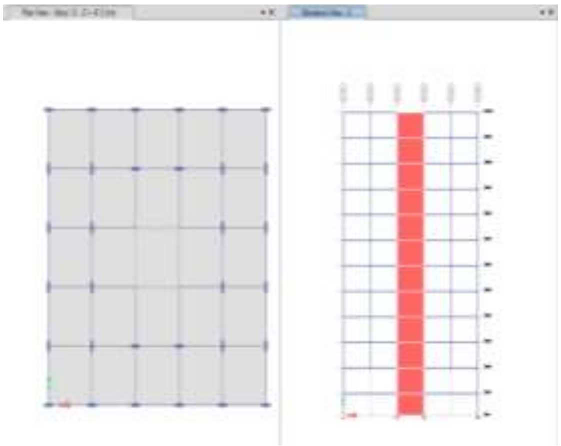
Model 1 : G+10 RC Square Building (Conventional Analysis)



Model 2 : G+10 RC Square Building with outer floating columns resting on transfer girder (Conventional Analysis)



Model 3 : G+10 RC Square Building with inner core floating columns resting on transfer girder (Conventional Analysis)



Sequential Analysis Details –

Stage 1 – After the completion of five floors

Stage 2 – After the completion of Ten floors

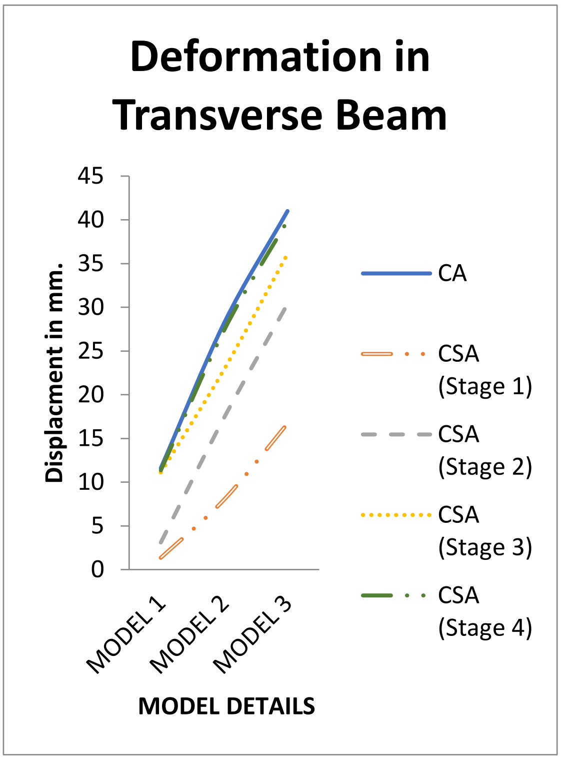
Stage 3 – After the Construction of whole building

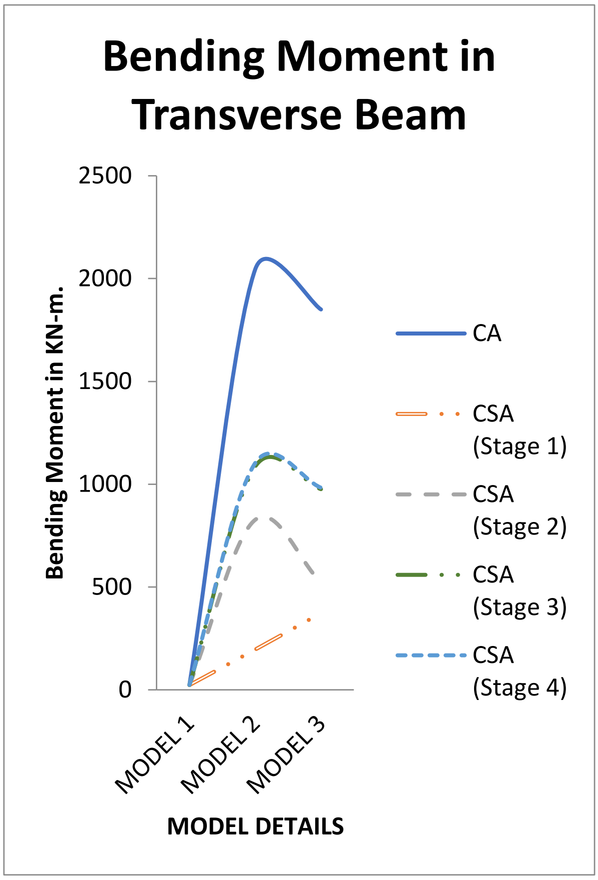
Stage 4 – After the Life of 50 Years including creep effect

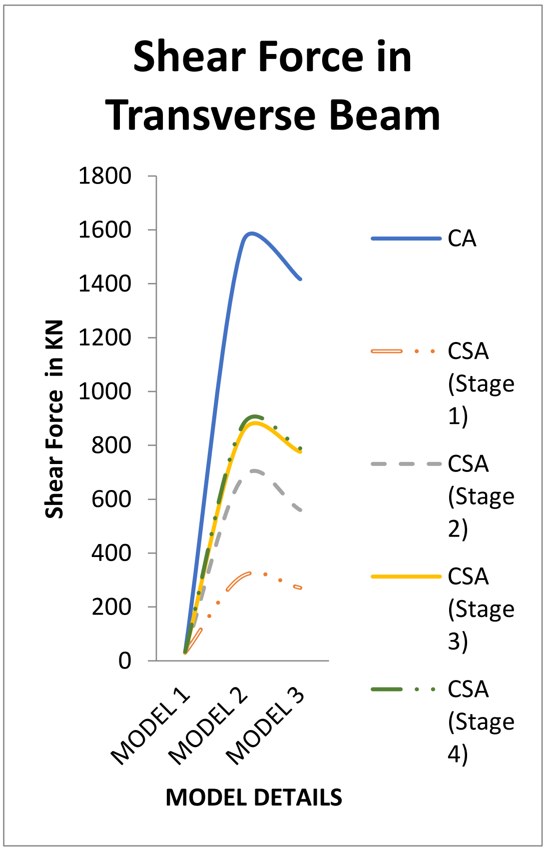
Building General Parameters

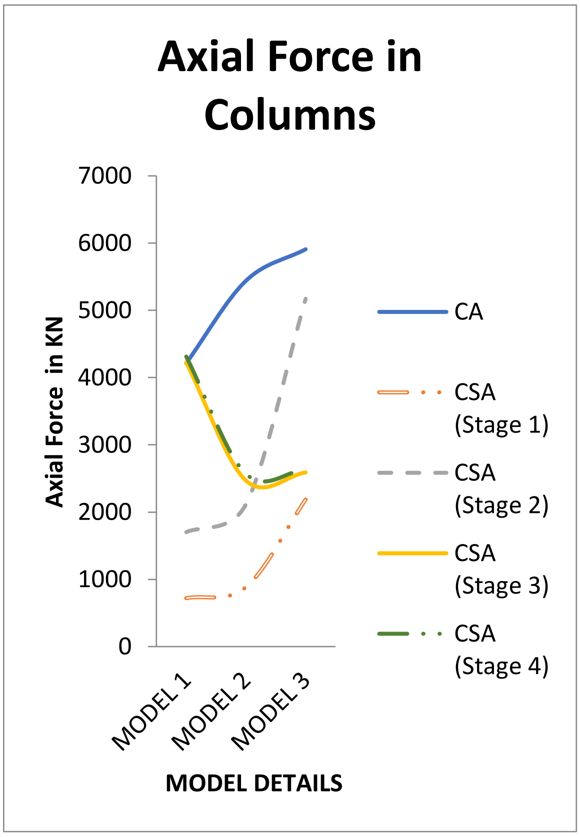
General Properties	
Location of Building	Indore, India
No. of storeys	G+10
Typical Storey Height	3.6 m.
Size of Column	300 mm x 1000 mm
Size of Beam	300 mm x 600 mm
Size of Transfer Girder	600 mm x 750 mm
Thickness of Slab	150 mm.
Thickness of Wall	230 mm.
Thickness of RC Wall	300 mm
Material Properties	
Grade of Concrete	M40
Grade of HYSD Bars	Fe500
Type of Loading	
Wall Load	15 KN/m
Live Load	3 KN/m^2
Floor Finishing	1.5 KN/m^2
Seismic Details (IS 1893:2016)	
Seismic Zone	II
Zone Factor	0.1
Importance Factor	1
Type of Soil	II – Medium
Building Type (R)	5 (SMRF)
Wind Details (IS 875:2015)	
Wind Speed	39 m/s
Terrain Category	II
Risk Coefficient	1
Topography Factor	1
Importance Factor	1

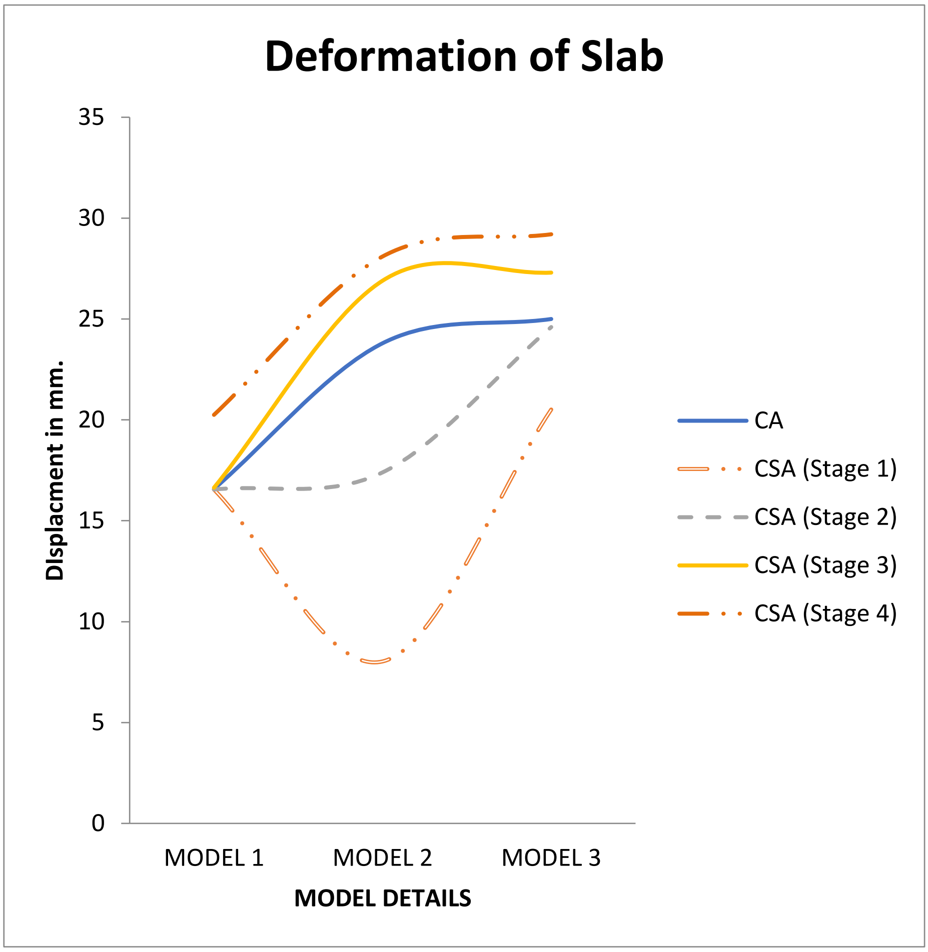
3. RESULTS


Deformation in Transverse Beam
Displacment in mm.
45
40
35
30
25
20
15
10
5
0
MODEL 1
MODEL 2
MODEL 3
MODEL DETAILS
CA
CSA (Stage 1)
CSA (Stage 2)
CSA (Stage 3)
CSA (Stage 4)


Bending Moment in Transverse Beam
Bending Moment in KN-m.
2500
2000
1500
1000
500
0
MODEL 1
MODEL 2
MODEL 3
MODEL DETAILS
CA
CSA (Stage 1)
CSA (Stage 2)
CSA (Stage 3)
CSA (Stage 4)

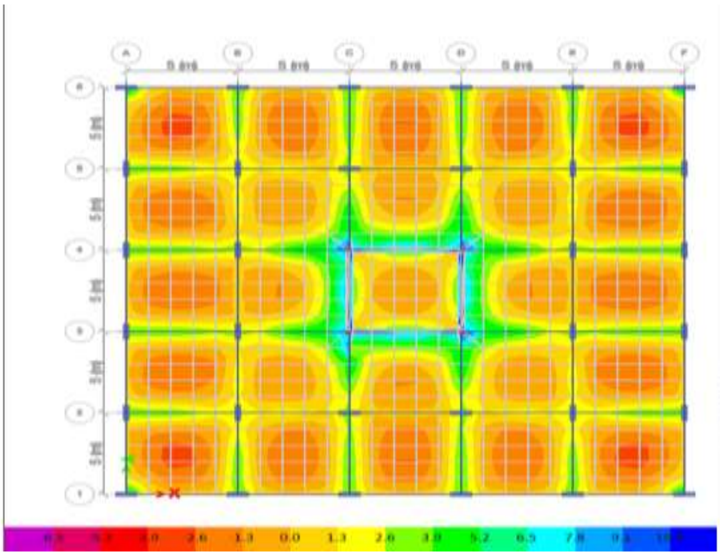

Shear Force in Transverse Beam
Shear Force in KN
1800
1600
1400
1200
1000
800
600
400
200
0
MODEL 1
MODEL 2
MODEL 3
MODEL DETAILS
CA
CSA (Stage 1)
CSA (Stage 2)
CSA (Stage 3)
CSA (Stage 4)


Axial Force in Columns
Axial Force in KN
7000
6000
5000
4000
3000
2000
1000
0
MODEL 1
MODEL 2
MODEL 3
MODEL DETAILS
CA
CSA (Stage 1)
CSA (Stage 2)
CSA (Stage 3)
CSA (Stage 4)

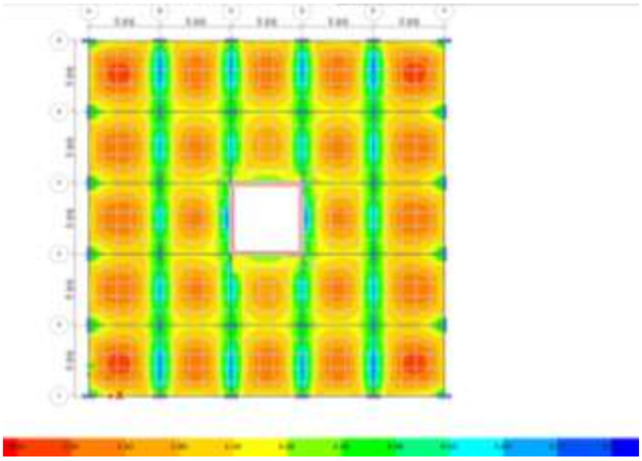


Stress Results in Slab –

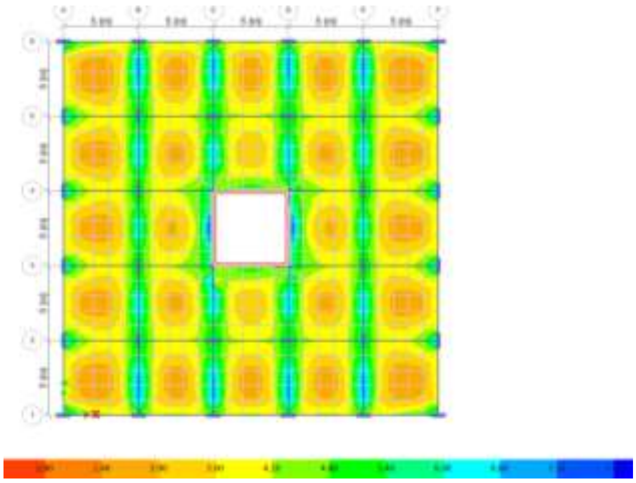
Model 1 (CONVETIONAL ANALYSIS) –



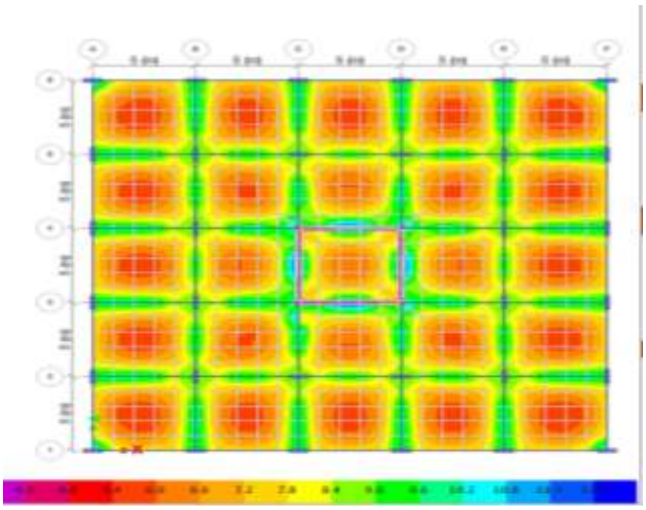
MODEL 1 (CONSTRUCTION SEQUENCE ANALYSIS) AFTER CONSTRUCTION (STAGE 1) –



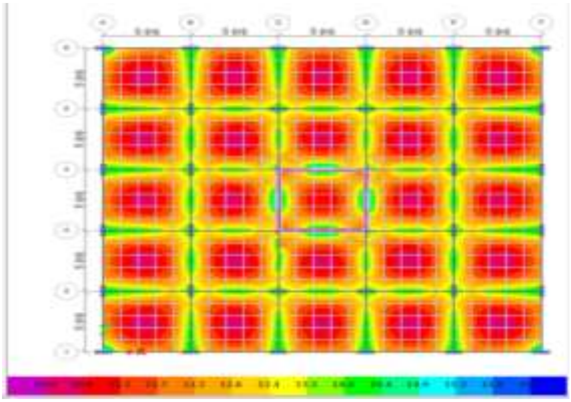
MODEL 1 (CONSTRUCTION SEQUENCE ANALYSIS) AFTER CONSTRUCTION (STAGE 2) –



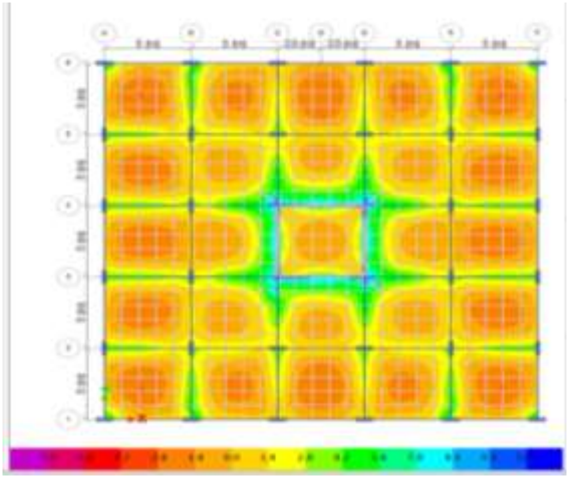
MODEL 1 (CONSTRUCTION SEQUENCE ANALYSIS) AFTER CONSTRUCTION (STAGE 3) –



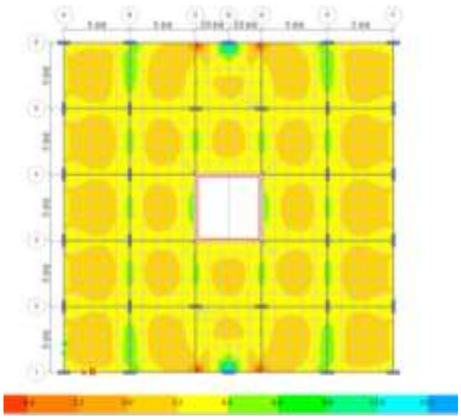
MODEL 1 – (CONSTRUCTION SEQUENCE ANALYSIS) AFTER 50 YEARS (STAGE 4) –



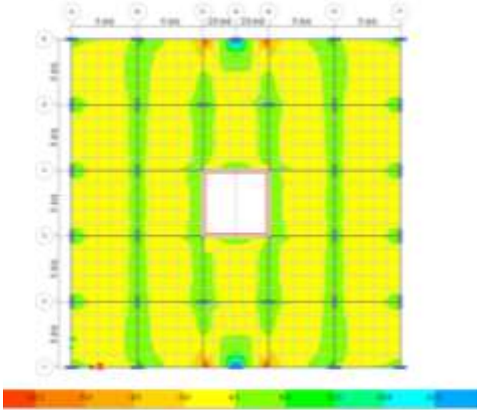
MODEL 2 CONVENTIONAL ANALYSIS–



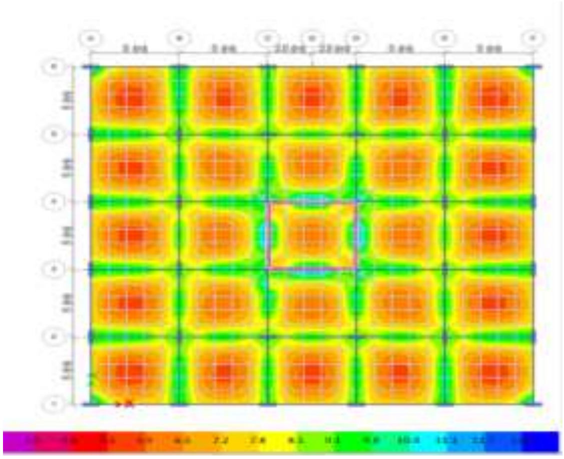
MODEL2 (CONSTRUCTION SEQUENCE ANALYSIS) AFTER CONSTRUCTION (STAGE 1) –



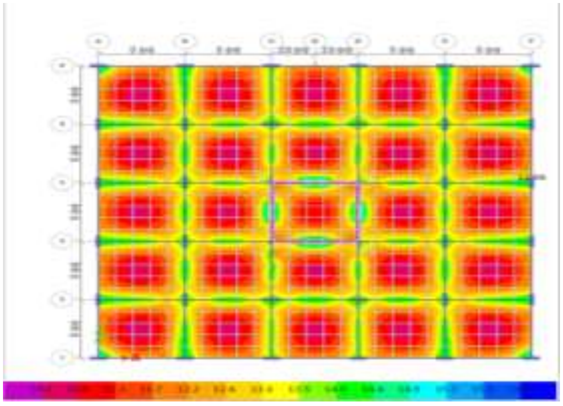
MODEL2 (CONSTRUCTION SEQUENCE ANALYSIS) AFTER CONSTRUCTION (STAGE 2) –



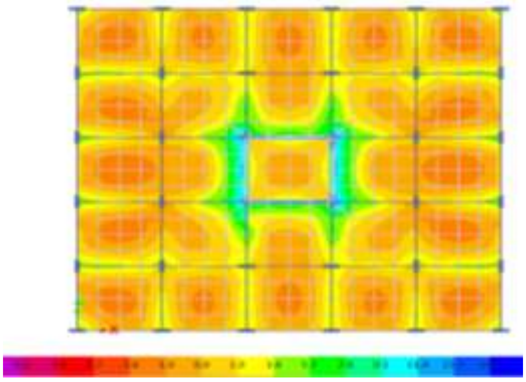
MODEL2 (CONSTRUCTION SEQUENCE ANALYSIS) AFTER CONSTRUCTION (STAGE 3) –



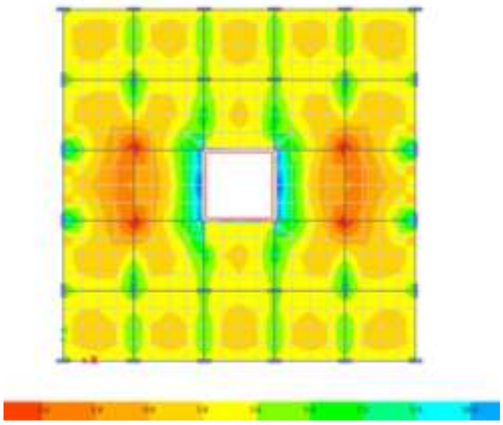
MODEL 2 – (CONSTRUCTION SEQUENCE ANALYSIS) AFTER 50 YEARS (STAGE 4) –



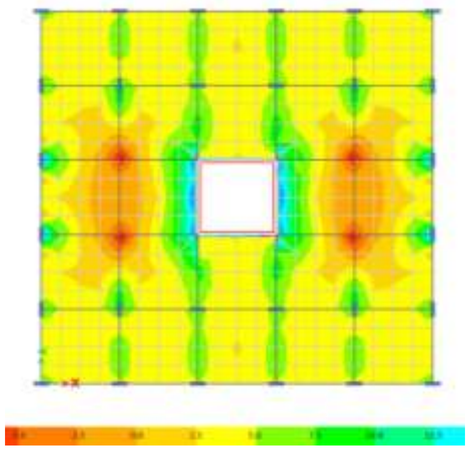
MODEL 3 CONVENTIONAL ANALYSIS –



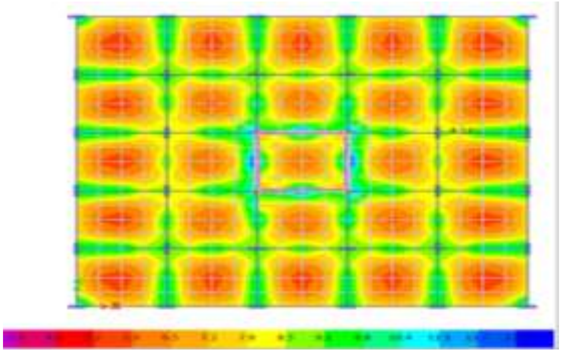
MODEL 3 – (CONSTRUCTION SEQUENCE ANALYSIS) AFTER CONSTRUCTION (STAGE 1) –



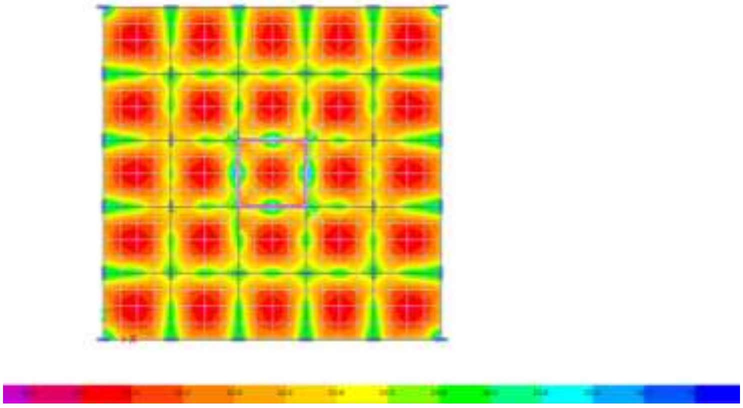
MODEL 3 – (CONSTRUCTION SEQUENCE ANALYSIS) AFTER CONSTRUCTION (STAGE 2) –



MODEL 3 – (CONSTRUCTION SEQUENCE ANALYSIS) AFTER CONSTRUCTION (STAGE 3) –



MODEL 9 – (CONSTRUCTION SEQUENCE ANALYSIS) AFTER 50 YEARS (STAGE 4) –



4. CONCLUSION

It is evident that the simulation of sequence of construction in the analysis leads to considerable variations in deformations and design forces obtained when compared with conventional analysis. Due to changes in deformation and design forces of transverse girder in construction sequence analysis it effects the above beams and floating columns, so this variation has to be taken into consideration for the design of the building. As there is no separate code for design of transverse girders and floating columns, these elements should be designed for worst case and analysed by using construction sequence analysis. It is, therefore necessary that for Multi storeyed building frames with transfer girders and floating columns system, the construction sequence effect shall be taken into consideration and has to be analysed by using construction sequence analysis. Following points have been concluded on this -

- The values of shear force and bending moment are markedly different in conventional and construction sequence analysis for the structures having floating columns. The bending moment increases up to 7% in CSA as compared to conventional analysis while the axial force also decreases up to 20% for floating column case. Hence, the results also clearly state that in high-rise buildings CSA is necessary due to considerable difference in the values for slabs, beams and columns.
- It is found that the change in values of structural parameters is caused due to the incomplete truss, which causes uneven load transfer for the concept of floating columns.
- The deformation in slab shows 15% higher values for construction sequence analysis. In this manner, column shortening for exterior and interior columns for a particular section is also considered for conventional analysis and construction stage analysis.
- The stresses in the slab also increases up to 10 % with respect to time which one needs to considered for the actual behaviour of structure for its entire life of design.
- In conventional analysis, the staging of construction is neglected due to which the values are different from real-world values.
- Beams are more vulnerable to sequential loading as compared to columns.
- The structural members must be designed for the higher values of axial force, shear force, and bending moment between the two methods.

CONCLUDING REMARK –

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 this 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 or after the life of 50 years. And it is also recommended to use the floating columns resting on transfer girder at the exterior part of the building than located it in interior core part.

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