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

[1]Gagan Choudhary, [2]Dr J N Vyas

[1]PG Student, [2]Professor
[1,2]Department of Civil Engineering
[1,2]Mahakal Institute of Technology and Management, Ujjain

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 understand the behaviour by changing 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. In previous studies, the values of deflection and shear forces found in CSA are more than dynamic analysis and it also gives an idea regarding the failure of buildings during the construction phase.

***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.

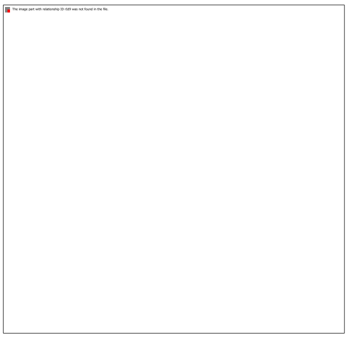
Multi-storeyed buildings have been analysed for years on the assumption that whole of the load is applied on the complete frame. Looking in to the mode of incidence of the load, it is evident that part of the load is applied in stages as the construction of the frame proceeds, whereas the remaining part 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. LITERATURE REVIEW

To obtain the actual response of a structure construction stage analysis is important especially for structures like high rise buildings and bridges for which the construction period continue a long time. The loading will be different at different stages. So analyzing the structure in conventional manner will not be reasonable for these kinds of structures. An extensive literature review is carried out and it is observed that bending moment, shear force and displacement in the structural members are much greater in case of construction stage analysis when compared with conventional analysis.

Kwak, H.G., & Kim, J.K. (2006) Time-dependent Analysis of RC Frame Structures Considering Construction Sequence, Building and Environment, 41, 1423-1434. The impact of CSA on RC buildings inferred that dead load applied as a sequence produced only minimum additional effects compared to conventional analysis (Nayak et al., 2015*)*. The Time-Dependent analysis was performed on RC framed structures using construction sequences and found that there were additional column shortening and bending moments when time-dependent effects were included in the construction sequence analysis.

Vafai, A., Ghabdian, M., Estekanchi, H.E., & Desai, C.S. (2009) Calculation of Creep and Shrinkage in Tall Concrete Buildings using Nonlinear Staged Construction Analysis, Asian Journal of Civil Engineering, 10(4), 409-426.The long-term effects namely creep and shrinkage in the concrete building using CSA were analyzed and found that CSA time-dependent effects produced the concave-shaped storey displacement plot.

Kim, H.S., & Shin, S.H. (2011). Column Shortening Analysis with Lumped Construction Sequences. Procedia Engineering, 14, 1791-1798. In tall buildings consists of short columns subjected to the shortening effect were analyzed using lumped construction sequences approach. It was inferred that the above approach was much helpful for correcting the errors during the design phase of tall structures.

Taehun, H., & Sungho, L. (2013) Advanced Construction Stage Analysis of High-rise Building Considering Creep and Shrinkage of Concrete. Proceedings of Advances in Structural Engineering and Mechanics (ASEM13), 2139-2147. The RC building translations were analyzed using Advanced Staged Analysis Program (ASAP), found to be feasible and beneficial for very high-rise RC buildings.

Mathew, S.A., Parivalla, S. Ravisankar, K., & Kesavan, K. (2014) Elemental Modal Strain Energy for Damage Identification of a Space Frame: A Numerical Approach. International Journal of Applied Engineering Research, 9(17), 3723-3732. The damage study was performed for the space frame by the modal strain energy method using the FEA tool. It was inferred that the different types of damages could be assessed by the MSE technique.

Pranay, R., Sreevallli, I.Y., & Thota, S.K. (2015). Study and Comparison of Construction Sequence Analysis with Conventional Lumped Analysis using ETABS. Civil Engineering Systems and Sustainable Innovations, 220-228. Using CSA in multi-storeyed buildings with the designed floating columns by the support of deep beams found significant variations in analytical results namely, axial forces, shear forces, moments and deformations

Kiran, Y.N., Laxmikant, V., & Gitadevi, B.B. (2017) Construction Sequence Analysis of Multistory RCC Building, International Research Journal of Engineering and Technology, 4(7), 785-790. Using CSA for the multi-storey buildings analysis and design has shown accurate results were inferred

Viji, R.K., & Binol, V. (2017) - Effect of Construction Sequence Analysis along with P-Delta and Material Non Linearity of Floating Column Structure. International Research Journal of Engineering and Technology, 4(5), 1946-1949. The effect of CSA along with P-Delta effects had higher values of displacement, shear force and moment in CSA with P-Delta than in the conventional analysis.

Pattar, A.N., & Muranal, S.M. (2017). P-Delta Effect on Multi-Storey Buildings. i-Manager's Journal on Structural Engineering, 6(3), 8-18. The effect of P-delta analysis in RC framed structures more than 20 storeys could be analyzed and designed, beyond say 30 storeys had increased moments and displacements were noticed.

Mohammad, J.A., Ali, K., & Majid, G. (2017) Simplified Sequential Construction Analysis of Buildings with the New Proposed Method, Structural Engineering and Mechanics, 63(1), 77-88. Four different methods were compared with the adopted method to validate the performed structural analyses of three structures. It was found that in the proposed method, the correction factor for column shortening and the CSA was adopted.

Michele, F.G., Giuseppe, L., Antonino, R., & Marcello, A. (2018) Construction sequence analysis of long-span cable-stayed bridges, Engineering Structures, 174, 267-281. The CSA was also applied for long-span cable-stayed bridges where the structural behavior was simulated by the cable stresses and geometric properties that could reduce the errors in real-time scenarios

Somil, K., & Muthumani, K. (2018) Seismic Performance of High Rise Building, International Journal of Civil Engineering and Technology, 9(3), 878-886.Also in the high-rise buildings, the comparison was made between ASCE 7-16 and IS 1893 (2016) code provisions got similar parametric results. It was reported that the stiffness was highly influenced by the floor plan arrangements.

Chakrabarti, S.C., Nayak, G.C., &Agarwala, S.K. (2019) - Effect of Sequence of Construction in the Analysis of Multistoried Building Frame, Building and Environment, 13(1), 1-6. The effects of construction sequence were analyzed for a multi-storey building frame and examined that there were considerable variations in the design moments obtained between conventional one-step analysis and construction sequence analysis.

Santosh, P., Vikram, P., Madan, S.H., & Sonagouda, T. (2019) Importance of Construction Sequence Analysis in design of High Rise Building, International Journal of Innovative Science, Engineering & Technology, 6(4), 1-9.In high-rise buildings, the influence of CSA has caused an increase in the envelope forces, shear force, bending moment and deflection than the conventional method.

Nyein, N.T., & Tin, Y.K. (2019). Study on the Effect of Response Spectrum Analysis and Construction Sequence Analysis on Setback Steel Structure. International Journal of Trend in Scientific Research and Development, 3(4), 1349-1355 The CSA was performed on setback steel structure and detected that the bottom storey had suffered the most due to loading due to construction sequence compared to lumped loading analyzed.

Vishal, N., Ramesh, K.M., & Keerthika, L. (2020) Sesimic Analysis of Multi-Storey Irregular Building with Different Structural Systems, International Journal of Recent Technology and Engineering, 8(6), 3146-3155. For an irregular geometry of setback building, the structural components were analyzed for the response spectrum method with/ without CSA was performed. The functional analysis parameters namely shear forces and bending moments were increased with the CSA approach concerning the storey levels.

Ying, H., Haiyan, X., Vahan, H., & Ioannis, B. (2022) A graph-based approach for unpacking construction sequence analysis to evaluate schedules, Advanced Engineering Informatics, 52, 101625. The graph-based comparison was made between the construction sequences adopted in the previous project's case studies with the actual and planned ones. It was reported that this sequential approach to the construction schedule could impart quality construction and enhance the project performance.

From the review of literature, it was inferred that very few analysis and design was carried out using CSA and then compared with the conventional analysis & design of the same developed model. In the present analytical research, the CSA was adopted for the conventional/ parent load combinations of dead, live, wind and earthquake loads with the replacement of DL by CSL as sub-combinations as an innovative cum novel approach by carrying out with/ without P-delta and time-dependent effects. The output namely, stories drift and stories displacement of worst load combinations was compared with CSA and the conventional method of analysis (parent loads). The critical section was designed for the reinforcement of the beam and column.

In the present research, a 10-storey building frame was considered for analysis and design. Since gravity loads, seismic loads and wind loads were the primary loads considered to configure the load combinations could lead to large axial and lateral displacements. Hence for the above-combined gravity and lateral load effects, CSA analysis would be preferred. This would lead to an increase in the structural geometrical configurations for fulfilling the transferred load capacity requirements.

3. CONCLUSION

It is evident from previous studies that the simulation of sequence of construction in the analysis leads to considerable variations in deformations and design forces obtained when compared with conventional lumped mass 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.

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