Impact Factor Value 4.046 e-ISSN: 2456-3463
International Journal of Innovations in Engineering and Science, Vol. 3, No.3, 2018
www.ijies.net

Analysis of Multi-Storey Structures Using Sequential Analysis – A Review

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Abstract –*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. Thus, the loads assumed in conventional analysis will vary in transient situation. The structural analysis of multi-storeyed buildings is one of the areas that have attracted a no. of engineering researchers and designers attention. There is one area, however, which has been ignored by many previous investigators, i.e., the effects of construction sequence in a multi-storey frame analysis. Present review deals with study of previous literatures done with respect to sequential analysis.*

Key Words: deformations, design forces, conventional analysis, sequential analysis

1. INTRODUCTION

Generally engineers, researcher and decision makers have determined the behaviour of structures using linear static elastic finite element analysis including summations of vertical column loads. While building height increases in construction phase, the structural responses, i.e. axial loads, bending moments and displacements, of such typical analysis may increasingly diverge from actual behaviour. Time-dependent, long-term, deformations in response to construction sequence can cause redistribution of responses that would not be computed and considered by conventional methods. This analysis was complex in nature and so many parameters have to be taken into account during analysis. But now advancement of finite element modelling and simulation has made nonlinear analysis easy, well managed and popular among engineers, researchers and decision makers which accelerate proper design of structures especially high-rise. Construction sequential analysis is becoming an essential part during analysis as many well recognized analysis software included this facility in their analysis and design package. 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. This paper is an attempt to summarize the work that has been already done pertaining to the comparison of conventional analysis and sequential analysis.

2. REVIEW OF PREVIOUS STUDIES ON SEQUENTIAL ANALYSIS

Sequential analysis which is the subject of research of some researchers among the world is important while analysis of building. Some researchers have analyzed building considering irregularity of structure while some have analyzed without considering irregularity of structure. Following is a brief review of work that has been done in previous studies of sequential analysis.

Das and Praseeda [1] studied construction stage analysis and conventional analysis for a commercial building of 2B+G+6. The case study building is modelled 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. 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, Since the difference exists only in the application of dead load. So only dead load and live load conditions were considered in this study. It is found from comparison results that the deformation, bending moment and shear force are underestimated for the bottom floors for conventional analysis and the same are over estimated in the upper floors when compared with construction stage analysis.

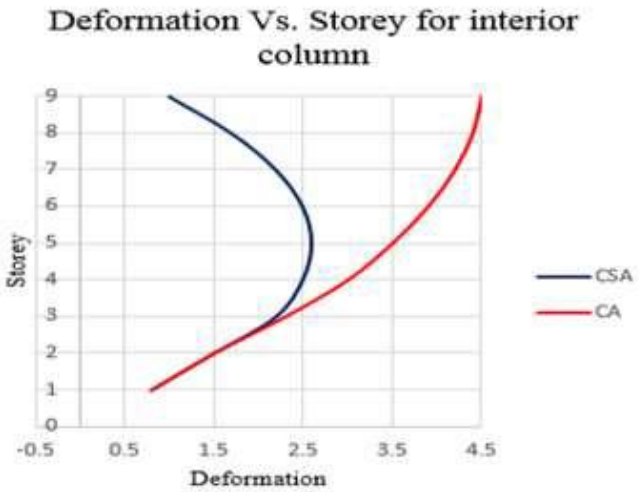

Fig 02: Deformation Vs. Storey for interior column

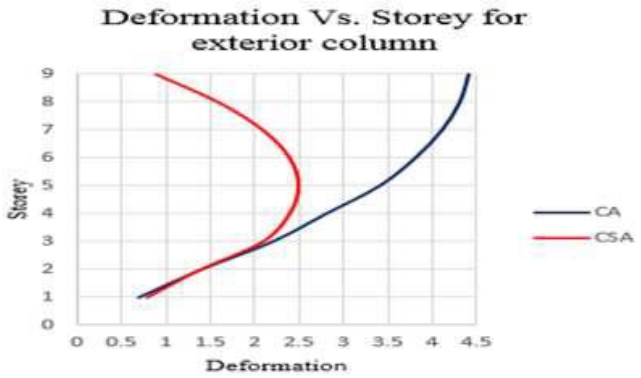

Fig 03: Deformation Vs. Storey for interior column

The effect of column shortening is a major consideration in the design and construction of tall buildings, especially in concrete and composite structural systems. In this study the column shortening due to applied load is calculated. The column shortening values of exterior and interior columns shown in fig 02 & fig 03 is found for section for both conventional analysis and construction stage analysis.

Rao et al. [2] compared results of conventional analysis and sequential analysis of LB+UB G+22 storeyed building situated in zone III. Main factor considered in present study is Cycle time for floor to floor construction and strength of concrete. Analysis is compared for transfer girder and the frame above transfer girder. It is concluded that there is considerable increment in loads and deformations by sequential analysis than conventional analysis.

Shirhatti and Vanakudre [3] studied the effects of linear static analysis, time dependent and construction sequential analysis for two construction materials RCC and steel. Three dimensional modeling for 30 storey building of concrete and steel is done and the analysis results are taken for the same.

For the seismic analysis zone factor for zone IV and hard soil type is considered according to IS: 1893 (part1)-2002. Therefore the analysis result helps to comprehend the structural responses against load variations for linear static analysis, time dependent and sequential analysis.

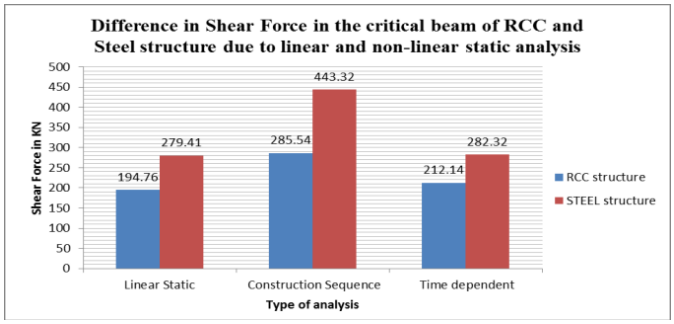

Fig 04: Comparison of Shear Force in beam of RCC and Steel structure

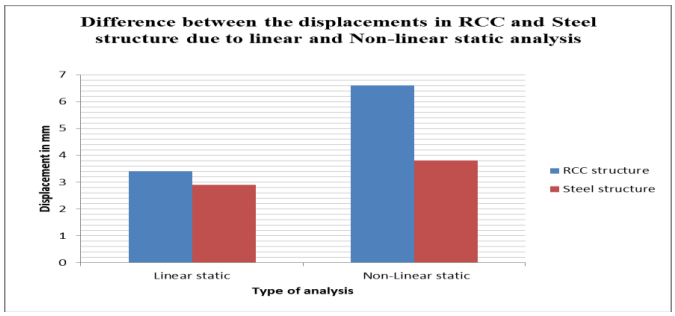

Fig 05: Comparison of Displacements in RCC and Steel structure

Finally, a relative study of shear forces(Fig 04), bending moments and displacements(Fig 05) was done at every story for conventional model and construction sequence model for two construction materials RCC and steel respectively using the finite element analysis software “ETABS version 13”.

Pathan et al. [4] analyzed several numbers of ultistory reinforced concrete building frames of different bay width and length, storey height and number of stories using STAAD.pro, followed by the construction stage analysis of each model. Also all full frame models are analyzed for earthquake forces in Zone – II (IS 1893: 2002). Finally, a comparative study of Axial forces, Bending moments, Shear forces and Twisting moments was done at every storey for full frame model (without earthquake forces) and construction stage model (without earthquake forces).

Pranay et al. [5] studied two cases, in case 1 the multistoreyed building (22 storied) with floating columns and transfer girder were analysed as a whole for the subjected loading and in case 2 the multistoreyed building (22 storied) with floating columns and transfer girder were analysed with reference to the construction sequence or staged construction. A detailed study and comparison of the variation in deformations and forces was presented for the

transfer girders, for the floating column on girders and for the frames which is above transfer girders. The building is analysed and designed using ETABS software.

Chang-koon Choi et al. [6] dealt with the bending moments and shear forces that induces in the members of the frame by the differential column shortening, taking into account the construction sequence and the sequential application of dead weight in the analysis. 57-story building (Republic Bank Center, Korea) is used for analysis purpose. The entire frame is analyzed by "one substructure at a time" approach in the reverse order of construction. Numerical examples of two high-rise buildings clearly show the significance of the differential column shortening effects. The results obtained in this study have shown that the differential column shortening and the bending moments induced by it in the gravity analysis of entire frame are very significant and should not be neglected in the analysis of the high-rise buildings.

Yousuf Dinar et al. [7] have analysed rigid frame structures of both concrete and steel model of different configurations for sequential analysis. 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. Study of results (Fig 05) concluded that with the increasing story the variation decreases with the structures constructed with RCC where Steel does not follow any identical order in nonlinear analysis which is shown in fig 06.

	Material	Construction Sequential analysis					Linear Static analysis
		Step 1	Step 2	Step 3	Step 4	Step 5/ Final Stage	
Moment (kip-ft)	RCC	42.5	67.69	85.4	99.12	112.22	60
	Steel	58.74	106.55	129.62	153	174.4	94.79
Shear (kip)	RCC	8.6	13.26	16.47	19.10	21.46	12.22
	Steel	14.89	22.67	28.07	32.48	36.39	22.14
Displacement (mm)	RCC	2.17	3.28	4.15	4.87	5.54	3.22
	Steel	1.37	1.89	2.59	2.97	3.67	1.63

Fig 05: Structural responses of critical beam

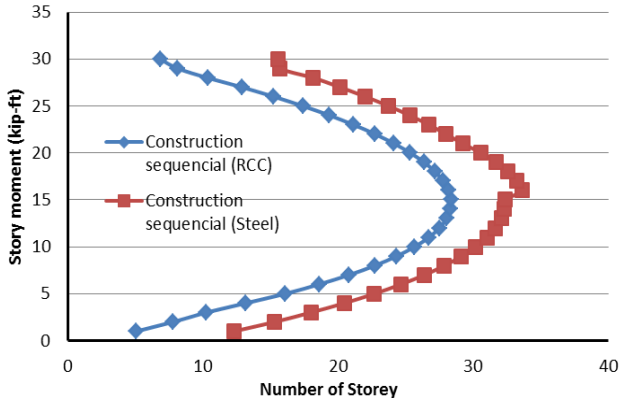

Fig 06: Story moment under Construction sequential analysis

Sagupta R. Amin and S. K. Mahajan [8] carried out study of effect of construction sequence analysis on the multistoried building. A 5, 7, 9 Storey Building has been analyzed for self weight using Linear Static Method and Construction Sequence Method using ETABS. The parameters such as moment, axial load, displacement, shear etc. have been studied under earthquake forces and wind forces, with and without CSA. From the study it is found that while analyzing, Construction Sequence Analysis is proved to be critical for columns and beams.

CONCLUSIONS

From the above discussion, it can be concluded that a large number of research studies have addressed sequential analysis as an important factor to be considered while designing the structure. Majority study have found the results related to displacements, base shear, moments of the structure while load is applied.

Some researchers have considered the vertical irregularity of structure by designing a floating column and creating a transfer girder. From the comparison results it is found that for conventional analysis results are underestimated for the bottom floors and the same are over estimated in the upper floors when compared with construction stage analysis. From the results of column shortening it is found that the value of it is over estimated for upper floors and under estimated for lower floors in case of conventional analysis.[1]

Some researchers have analysed both RCC and Steel strucutres while some have analysed only RCC buidings and from their study it was found that RCC structure in case of sequential analysis follow an identical order i.e. with the increasing story the variation decreases but steel structure does not follow any identical order.[7]

Thus, from all studies it is concluded that construction sequential analysis gives better results as compared to conventional analysis and therefore it should not be neglected while designing any structure.

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