Construction Sequence Analysis of Multistoried RCC Building

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Abstract - Most of the Building frames are analyzed as single step using linear static analysis on the assumption that the frame is subjected to the full load once the whole structure are constructed completely. But in practice dead load due to the each frame components are imposed in separate stages as the frame is constructed story by story. Accordingly, the stability of frame varies from every construction stage. Even a freshly placed concrete floor is supported by previously cast floor by formwork. Hence, difference in the theoretical analysis and the actual construction practice leads to the variation in the performance of the structure. Therefore, the frame should be analyzed at every construction stage taking into account variation in loads, phenomenon is known as Construction Stage Analysis.

In this paper the effect of sequential construction has been studied on rigid RC frame of different configurations. These structures have been analysed for sequential loading and the analysed results have been compared with the single step analysis for structure having same configuration. The variation in axial deformation, axial force, Bending moments and Shear forces were calculated.

Key Words: Non linear analysis, Construction sequence analysis, multi-storeyed building, floating column, ETABS.

1. INTRODUCTION

Over a long period of time the multistoried building frame have been analysed on the assumption that whole of the load is applied to the completed frame structure with all the loads acting on the building that is self-weight, superimposed load, live load and lateral loads which are applied on the completed frame at a given instant as a single step analysis. But in actual practice the dead load due to each structural component and finishing items are imposed in separate stages as the building frame is constructed story by story in a sequential order. The performance of a building structure with the various load applied in a single step differ significantly from that when the loads are applied in stages. Hence, in order to analyse the structure according to the actual construction practices this is known as construction sequence analysis (CSA). Construction sequence analysis is also known as staged construction analysis which is a non-linear static form of analysis which takes into account the concept of incremental loading.

The structural analysis of multistory buildings is one of the areas that have attracted a great deal of engineering research efforts and designers attention. There is one area; however which has been ignored by many previous investigators, i.e. the effects of construction sequence analysis in a multistory frame. The structural members are added in stages as the construction of a building proceeds and hence there dead load is carried by the part of the structure completed at the stage of their installation. Therefore, the distribution of displacement and stresses in a particular story does not depend on the properties of the members which are yet to be constructed. The correct distribution of the displacement and stresses of any member can be obtained by accumulating the results of analysis of each stage of building frame structure.

Construction sequential analysis is becoming an essential part during analysis as much well recognized analysis software included this facility in their analysis and design package. However this nonlinear static analysis is not so popular because of lack of knowledge about its necessity and scope. Like so many other analysis, construction sequential analysis had specific purposes in design phase of the structures. As it is mentioned earlier, it deals with nonlinear behavior under static loads in the form of sequential load increment and its effects on structure considering the structural members are started to react against load prior of completing the whole structure. For finite element analysis one of the leading analysis software "ETABS (Extended 3D analysis of building systems)" is used and all displacement outcomes are measured in meter while moment and axial load are measured in KN-m and KN respectively.

2. RESEARCH METHODOLOGY

In conventional design all the design checks such as strength, stability and deflection are performed by considering the application of loading in single step. But in reality the behavior of structure is different as the deflection of the components is different due to the self-weight which acts sequentially. The structural self-weight, external loads, boundary conditions and materials are depended on stages during the construction process and their variations are overlooked in conventional design which is nothing but a limitation of conventional design procedure. Non-linear static load case has to be generated to analyse the structure step by step which represents the sequential load case. Grouping of each story is considered during analysis so that software can identify its total steps required for completing the procedure. Step by step analysis, considering nonlinear behavior of materials from previous step, ensures that the construction sequence effects are properly represented in the study. 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 findings of 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.

3. Depiction of construction sequence analysis

The traditional analysis procedure is a linear static analysis in which structure is analysed in a single step, as shown in Fig. 1.However, to simulate more realistic analysis, non-linear static construction sequence analysis has been used. In this the structure is analysed storey by storey, as shown in Fig. 2. A comprehensive sequential analysis involves some essential steps which are not generally performed during linear static analysis. In order to get the sequential effects manually using software, each story should be analyzed with its prior stories assigning the vertical and lateral loads till that floor from bottom of whole structure. Eventually outcomes will represent the structural response of building till that floor. Once each story follows the same procedure the complete sequential effects could be visualized. Now-a-days analysis softwares are sufficiently developed to auto perform the sequential analysis easily. In actual structure due to cracking and other effects, the nature of the material is not linear as assumed in our conventional analysis. In the analysis of sequential loading, the non-linear behavior of material is considered which certifies more correct result.

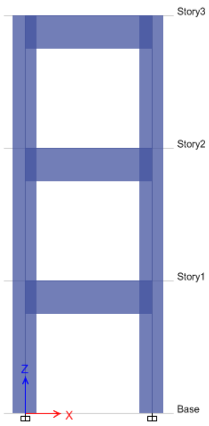
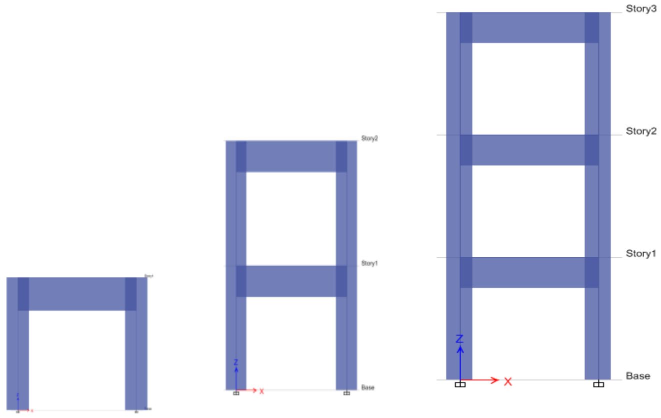


Fig. 1 Single Step



(a) First Step (b) Second Step (c) Final Step

Fig. 2 Simulation of sequential effect

4. Finite element model for analysis

To find out the effect of non-linear staged construction sequence analysis over the conventional single step linear static analysis, using ETAB 2015 ultimate 15.2.2.Finite element model having different storey height are taken. All the loading, material properties and sections are provided to the models. The sequential load case is simulated for the dead load and live load. To carry out the study, the finite element model is analysed sequentially and conventionally.

The plan is shown in fig. 3. 3-D model of floating column is shown in fig. 4. The numbers of stories in the model are 7. Each of the story case is performed Linear Static and sequential analysis separately with appropriate command. The floor thickness is taken as 125 millimeter. The structure is designed considering earthquake loading. The values of different dead loads and live loads are taken according IS 875-Part I (1987) and IS 875-Part II (1987) respectively, shown in Table 1.

Table -1: List of Load Considered

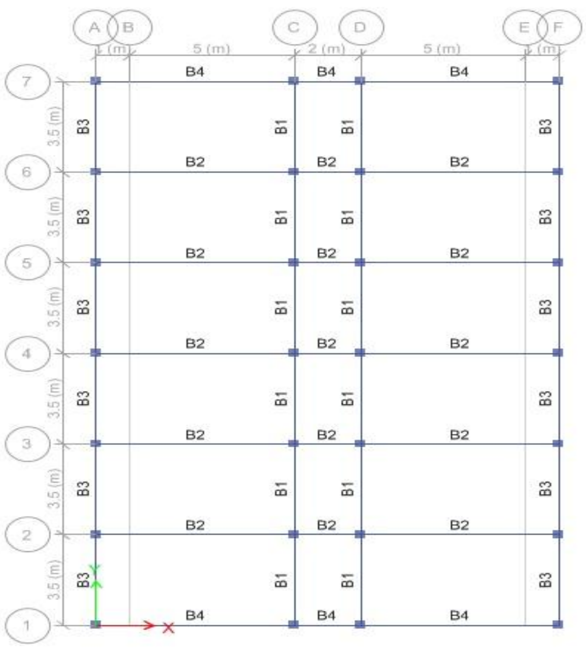
Material/Load	Intensity/Density
Density of concrete	25 KN/m^2
Floor finish	1 KN/m^2
Roof treatment	1 KN/m^2
Internal wall load	9 KN/m
External wall load	13 KN/m
Parapet wall load	4.6 KN/m
Live load on floor	3 KN/m^2
Live load on roof	0.75 KN/m^2

Before conducting the analysis few considerations has been taken (a) Applying wall load on model, (b) Results for construction sequence should be saved at the end of construction of each story, (c) Structure is assumed to be on medium soil in Zone II, with importance factor 1 and response reduction factor of 5, (d) For lateral loading equivalent static analysis is according to IS-1893, part-I (2002).Structural details of 7 storey building is shown in table 2.

Table 2: Structural Details

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-3.5 m

5. PLAN AND 3-D VIEW OF BUILDING



(All dimensions are in meter)
Fig. 3 Plan of building

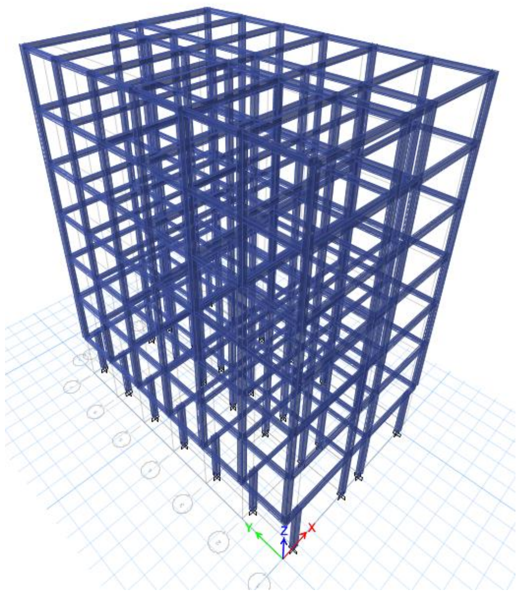


Fig. 4 3-D View

6. Effect of construction sequence analysis with single step analysis on RCC floating column building

Table 6.1 Comparison of axial deformation

Storey	DL+LL(mm)	AUTOSEQ(mm)
0	0	0
1	5.988	17.204
2	6.332	16.637
3	6.665	13.783
4	6.93	11.279
5	7.127	8.379
6	7.257	5.206
7	7.317	1.742

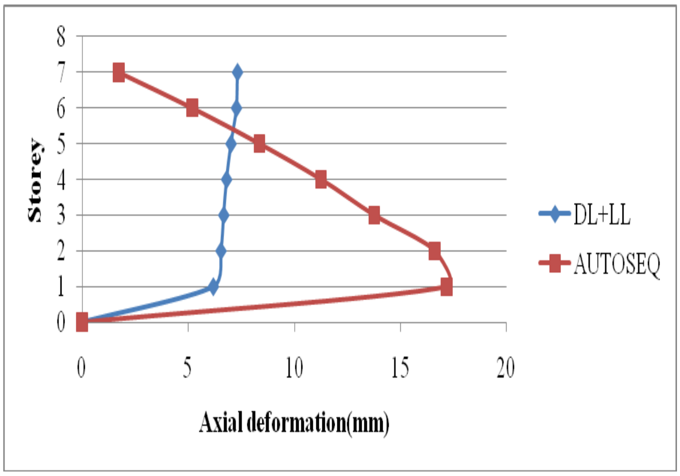


Fig. 5 Axial deformation

The axial deformation in the construction sequence analysis is more at first story which is 17.204 mm in supporting beam and it is going to be decreased as the story level increases hence at the end of total height the story the value is 1.742 mm. The axial deformation in linear static analysis is less as compared to construction sequence analysis which is 5.988 mm at first story and increased at top story having deformation value 7.317 mm. From these results it is found that the deformation is more in support when RC frame is analysed by construction sequence manner than linear static manner. Hence construction sequence analysis should take in consideration.

Table 6.2 Comparison of axial force

STOREY	DL+LL(KN)	AUTOSEQ(KN)
0	0	0
1	358.2113	964.85
2	288.21	759.83
3	238.8206	624.427
4	190.6578	483.923
5	142.8357	344.232
6	94.923	204.359
7	46.6436	64.964

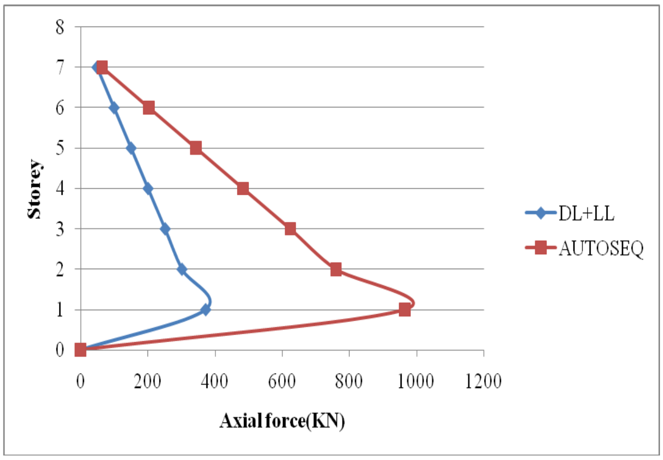


Fig. 6 Axial force

The axial force in the construction sequence analysis is more at first story which is 964.85 KN in external column and it is going to be decreased as the story level increases hence at the end of total height the story the value is 64.964 KN. The axial force in linear static analysis is less as compared to construction sequence analysis which is 358.2113 KN at first story and then decreased at top story having axial force 46.6436 KN. From these results it is found that the axial force is also more in support when RC frame is analysed by construction sequence manner than linear static manner. Hence construction sequence analysis should take in consideration.

Table 6.3 Comparison of bending moment

Storey	DL+LL(KN-m)	AUTOSEQ(KN-m)
0	0	0
1	114.9895	322.132
2	-135.4141	-350.9907
3	28.7377	67.5731
4	-7.8113	-50.9505
5	10.9639	-52.7939
6	9.7013	-61.2319
7	-15.8139	-35.1156

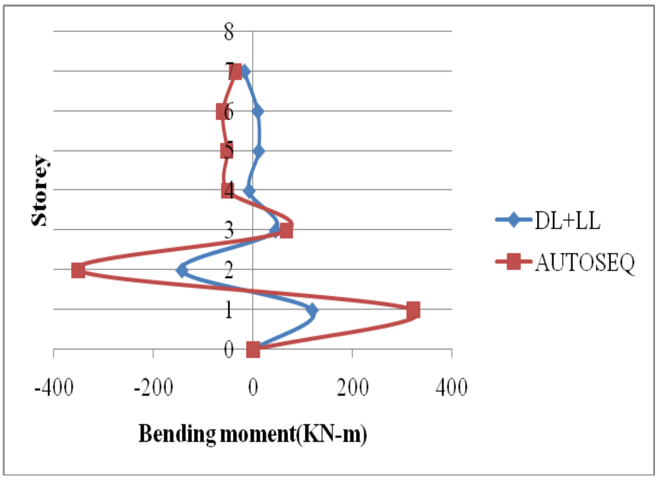


Fig. 7 Bending moment

Bending moment in the construction sequence analysis is more at first story which is 322.132 KN-m in external column and it is going to be decreased as the story level increases hence at the end of total height the story the value is -35.1156 KN-m. The bending moment in linear static analysis is less as compared to construction sequence analysis which is 114.9895 KN-m at first story and decreased at top story having bending moment -15.8139 KN-m. From these results it is found that the bending moment is also more in support when RC frame is analysed by construction sequence manner than linear static manner. Hence construction sequence analysis should take in consideration.

Table 6.4 Comparison of shear force

Storey	DL+LL(KN)	AUTOSEQ(KN)
0	0	0
1	-42.7955	-119.81
2	-38.5028	-95.575
3	12.5583	38.1962
4	4.5455	15.5632
5	6.2129	20.056
6	5.2131	23.6408
7	8.8875	13.7538

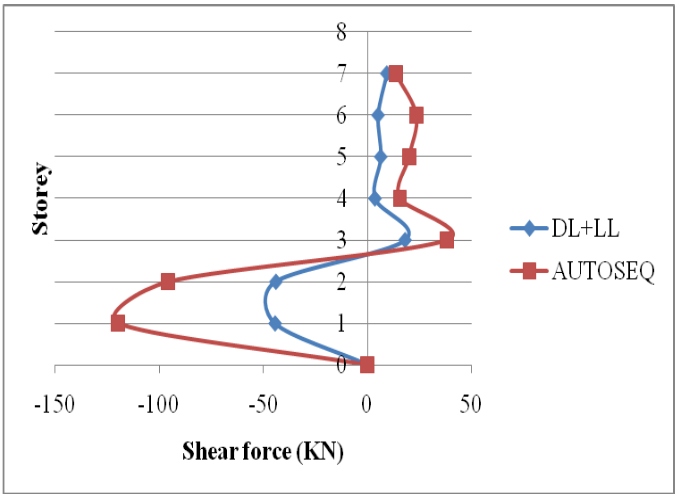


Fig. 8 Shear force

Shear force in the construction sequence analysis at first story which is -119.81 KN in external column and it is going to be increased as the story level increases hence at the end of total height the story the value is 13.7538 KN. The shear force in linear static analysis is less as compared to construction sequence analysis which is -42.7955 KN at first story and increased at top story having shear force 8.8875 KN. From these results it is found that the shear force is also more in support and at top when RC frame is analysed by construction sequence manner than linear static manner. Hence construction sequence analysis should take in consideration for shear force also.

7. CONCLUSIONS

In this paper, the finite model with varying height has been considered. Analysis with conventional as well as construction sequence has been carried out. As it is observed 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, were 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. Regarding displacement results, structure considered sequential effects shows the worst part than that of structure.
3. Inclusion of sequential load case in the analysis of multistoried RCC structure provides more realistic design than the conventional design.

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