

Effect of Construction Sequence Analysis with Creep and Shrinkage on a 4 Storey Building

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ABSTRACT: In this study the effect of construction sequence analysis with effect of creep and shrinkage for a 4-storey building has been outlined. With increasing height of buildings importance of time dependent shortening of columns become more critical due to cumulative nature of shortening. Even creep and shrinkage have similar effect as they cause length shortening. The length of construction time has pronounced effect on amount of creep while shrinkage proceeds independent of construction time.

KEYWORDS: Creep, Shrinkage, Column Shortening, Construction sequence analysis.

I. INTRODUCTION

The conventional method of analysis of tall buildings includes simultaneous application of all design loads and then the responses are obtained. But in actual practice the buildings are constructed stage wise, floor by floor and once the frame is ready then walls are erected. It means we generally neglect the effect of sequential construction of the buildings. But in actual practice loads are applied sequentially, storey by storey. The very significant aspects to be considered for the accurate structural analysis of tall building are:

- i. The effects of staged application of loads due to practical construction sequence.
- ii. Differential shortening of columns.
- iii. The effects of creep and shrinkage on tall structures

Non mechanical deformations and stresses are also induced in the RCC members due to change in construction sequence. 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 designers.

II. CONSTRUCTION SEQUENCE ANALYSIS

Construction sequence analysis (CSA) is a non-linear method of analysis which takes into account concept of incremental loading to simulate the actual effect of construction. Construction sequence analysis (CSA) is more accurate and practical as it reflects the sequence of loading and deformations caused with time. It is also known as staged construction analysis. In normal design practices we use linear static method for design of multi storey buildings. In this method the whole buildings is assumed to be erected at once and all loads are applied simultaneously. But in actual practice of construction building is erected storey wise and then brickwork and internal finishing is done, there is specific sequence through which a member is subjected to various loads. This sequence of application of loads is related with construction sequence. Creep is deformation under sustained loading, this phenomenon is discovered by Hatt in 1907. The volumetric



changes of concrete structures due to the loss of moisture by evaporation is known as concrete shrinkage or shrinkage of concrete. It is a time-dependent deformation which reduces the volume of concrete without the impact of external forces.

With increasing height of buildings importance of time dependent shortening of columns become more critical due to cumulative nature of shortening. Even creep and shrinkage have similar as they cause length shortening. During the initial period the rate of creep and shrinkage is significant. It diminishes as time progresses. In the present study total deformations in columns with creep and shrinkage at the end of 5 years of building age are studied, Considerable studies have been conducted on CSA, however in most of the studies effect of CSA with creep and shrinkage have not studies in detail. The simulation of construction sequence studies by Chakrabarti et.al (1978) for multi-storey frames leads to considerable variation of design moments as compared to obtain by conventional analysis. They used the concept of incremental load in the analysis by computer program based on kani’s method. Shrikar S. Nayak et.al (2016) studied effect of staged construction analysis on seismic design and performance of RC buildings, effect of construction sequence analysis has been outlined for four buildings with identical plan but with different heights. Vafai et.al (2009) attempted attempts to calculate column shortening and differential shortening between columns and walls in concrete frames using combined creep and nonlinear staged construction analysis. Zou et.al (2014) predicted importance of effect of evaluating the time-dependent effects on the structural Performance of concrete structures. They concluded that the rate of shrinkage development of concrete is both size and shape dependent of the buildings. Plan of the considered 20-Storey building is similar as that of Shrikar S. Nayak et.al (2016). Modelling was done in ETABS v17.0.1 and Indian standard codes are followed for design. For introducing effect of time dependent properties ACI209R-92 method is followed. CSA is done for dead load case. Twenty five Load combinations are used for traditional method. Later for comparison dead load (DL) is replaced with by CSA (ATUO-SEQ) and CSA with creep and shrinkage (STAGED). Thus three building models were analyzed, designed and compared separately. The plan of buildings shown in Fig.1 is 19 m x 13 m in dimensions, and height of 4-storey building is 12m.

TABLE I
STRUCTURAL DATA CONSIDERED

Type of structure	RCC framed structure
Grade of concrete	Grade M 40
Grade of steel	Fe 415
Floors	4 storeys
Height of each storey	3m
External wall	230mm
Internal wall	110mm
Beam in X direction	230mm×400mm
Beam in Y direction	300mm×500mm

TABLE II
WIND LOAD DATA CONSIDERED AS PER IS 875:2016 (PARTII)

City	Guwahati
Basic Wind Speed	50 m/s
Terrain Category	3
Class	B
City	Guwahati
Basic Wind Speed	50 m/s
Terrain Category	3
Class	B

TABLE III
LIST OF DEAD LOAD CONSIDERED AS PER IS 875:1987 (PART III)

Material/Load	Intensity/Density
Density of concrete	25 kN/m ³
Floor Finish	1 kN/m ³
Roof treatment	1 kN/m
Internal wall load	9 kN/m ³
External wall load	13 kN/m ³
Parapet wall load	4.6 kN/m
Live load on floor	3 kN/m

TABLE IV
EARTHQUAKE LOAD DATA CONSIDERED AS PER IS 1893:2016 (PART I)

Soil type	Medium (II)
Zone factor	0.36
Importance factor	1.2
Response reduction factor	5
Damping	5%

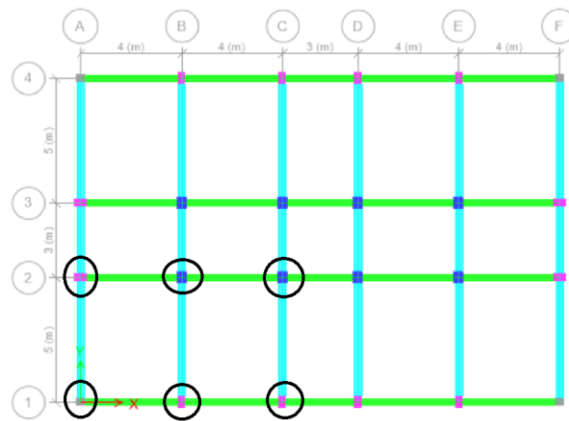


Fig. 1. Plan of the considered building

III. EFFECT OF CSA ON RESPONSE QUANTITIES

1. Axial shortening of columns

Storey wise deformation of columns is studied for the twenty storey building is plotted for the six column encircled in Fig.

1

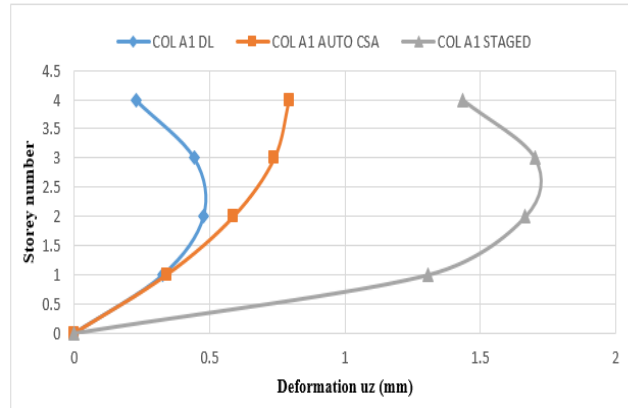


Fig. 2. Storey wise axial shortening of column A1

- i. DL: Response considering dead load case only as in conventional method
- ii. AUTO-SEQ: CSA which ETABS take automatically without time dependent properties of material
- iii. STAGED: CSA with time dependent properties of material and effect of creep and shrinkage

In Fig.2 it has been found that effect of CSA and Staged construction with creep and shrinkage follows same pattern of deflection for a column. While creep and shrinkage caused to significant increase in deformation response for bottom columns, and this increase in response is dominant up to middle storeys as shown in Fig.3 and Fig. 4.

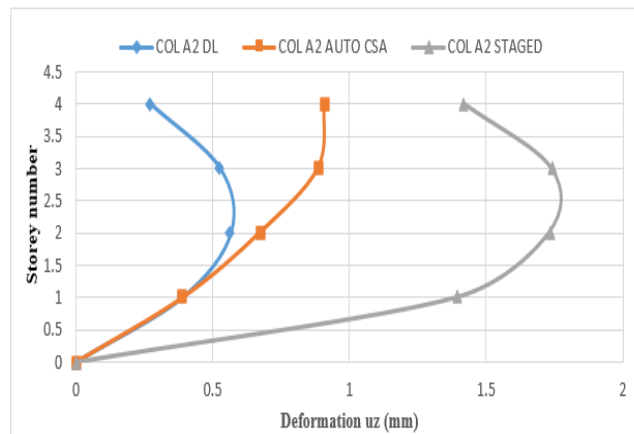


Fig. 3. Storey wise axial shortening of column A2

Fig. 5, Fig. 6, Fig. 7 shows that time dependent shortening is significant in inner columns due to higher intensity of loading. Hence Deformation in STAGED case is much higher than AUTO-SEQ and DL case

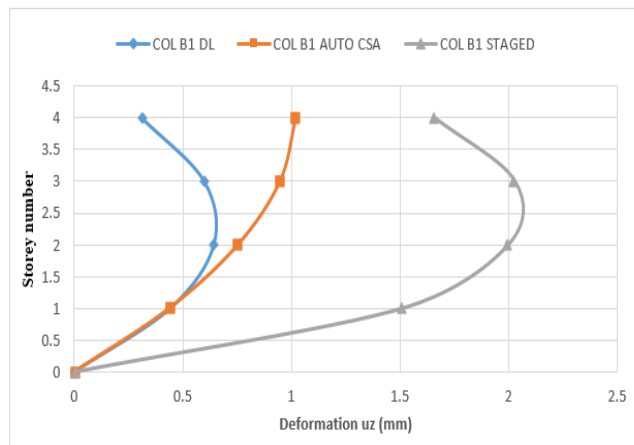


Fig. 4. Storey wise axial shortening of column B1

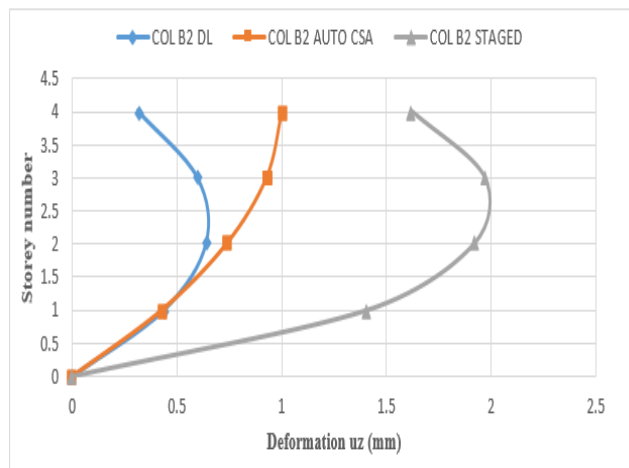


Fig. 5. Storey wise axial shortening of column B2

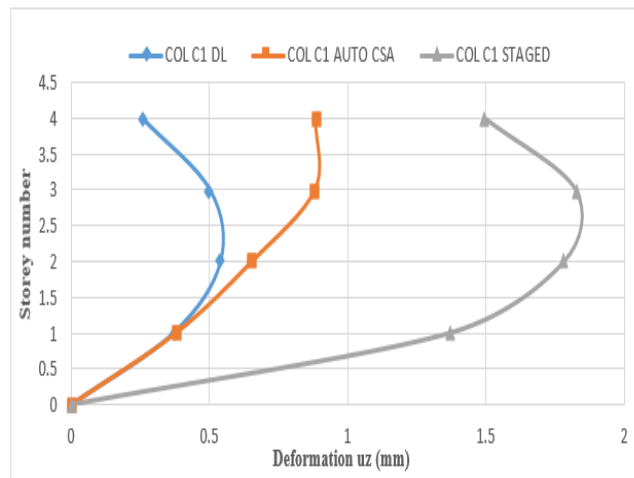


Fig. 6. Storey wise axial shortening of column C1

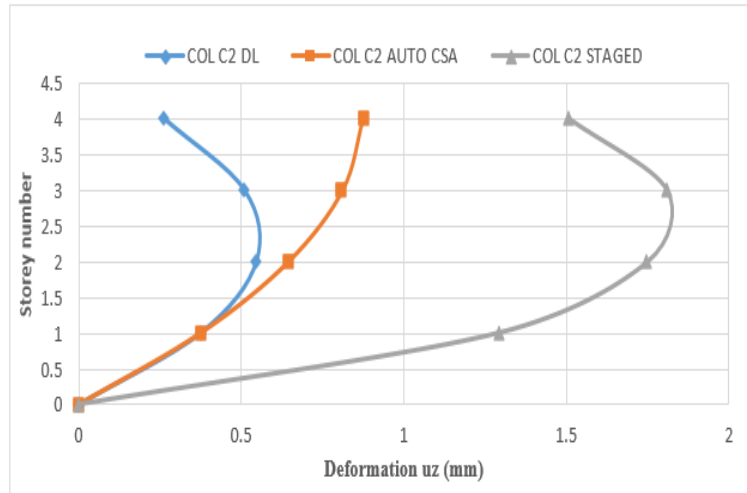


Fig. 7. Storey wise axial shortening of column C2

2. Longitudinal rebar percentage in columns

The deviation in axial shortening response among these three cases has caused to produce variation in column end moments also which is reflected in final design of the column. As we all know designed reinforcement are calculated from envelope of various load combinations. Between Auto-CSA and conventional analysis, values of design reinforcement are almost similar while taking into account the effect of creep and shrinkage convincing difference in steel is obtained. Hence effect of creep and shrinkage in CSA cannot be neglected.

Fig. 8 shows that for upper storeys in corner and exterior columns almost similar amount of design reinforcement was found in all the three cases, where the variation is about 40% to 50% but differences were seen for bottom storeys where variation in design reinforcement is found in the range of 80%. Effect of CSA with creep and shrinkage is more in columns in lower storeys, in most of the cases the bottom storeys columns was turned into overstressed state which were found safe during conventional analysis and normal CSA (AUTO-SEQ) case.

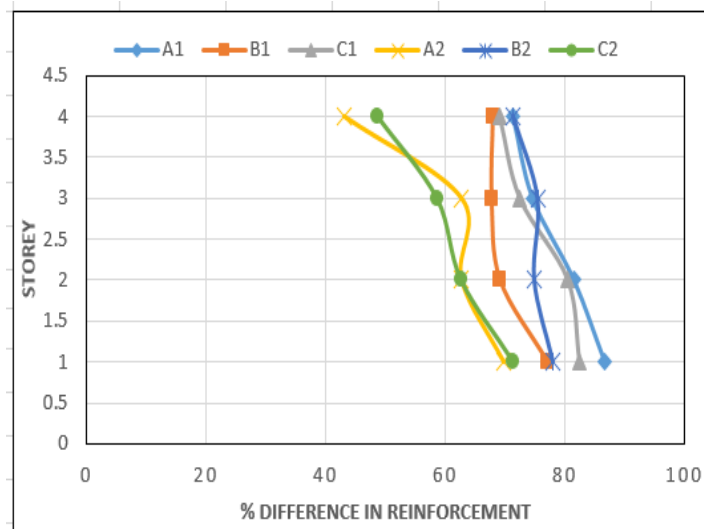


Fig. 8. Variation in Percentage reinforcement in columns



IV. CONCLUSION

1. After performing nonlinear Construction sequence analysis, axial force does not show any variation on comparison with conventional method.
2. Variation in column shortening has direct impact on column end moments and which in turn affects the final design reinforcement.
3. Effect of creep and shrinkage in CSA cannot be neglected for tall building, as time dependent shortening is almost two to three times that of elastic shortening of bottom columns.
4. Design reinforcement was unaffected when AUTO-SEQ was compared with DL case, but the time dependent shortening reflected its effect of increase in percentage reinforcement which is seen in STAGED case
5. Effect of CSA is maximum for top storeys and it attenuates for top storeys

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