DEFINING SEQUENTIAL CONSTRUCTION ANALYSIS FOR BUILDINGS IN ETABS 2016 AND SAP2000 V19

I. Overview

Since the past, multi-storey building frames have been analyzed in a single step as a complete frame with all the loads acting on the building namely self-weight, super-imposed dead loads, live loads, and the lateral loads being applied on the frame at a given instant when the construction of the whole frame is completed. In actual, the dead load due to each structural components and finishing items are imposed in separate stages as the structures are constructed storey by storey.

The performance of a structure with the various loads applied in a single step differs significantly from that when the loads are applied in stages. Hence, in order to simulate the actual condition during the construction of the frame, the frame should be analyzed at every construction stage taking into account variation of loads. The phenomenon known as Sequential Construction Analysis is used to analyze the structure at each storey.

Sequential construction analysis is a nonlinear static analysis which takes into account the concept of incremental loading. Buildings with transfer beams or transfer slabs are vulnerable to the effect of sequential construction this is because when sequential construction is ignored, the analysis assumes that the entire loads are carried by the entire structure, i.e. vierendeel truss action. Sequential construction is also important on analysis of high rise buildings where creep and shrinkage must be considered.

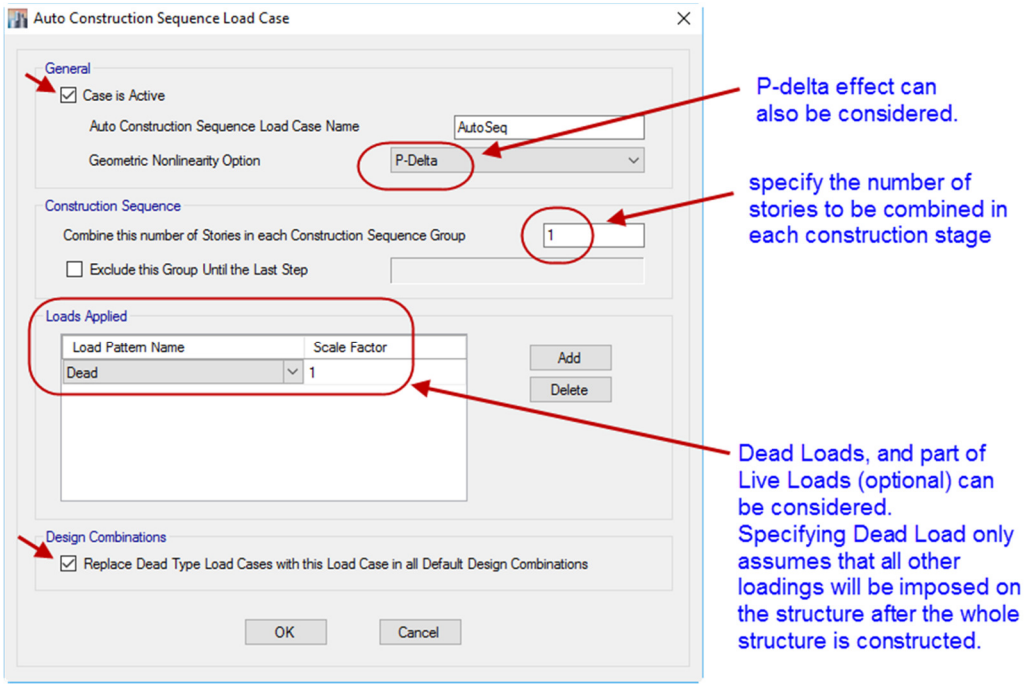
Sequential construction in ETABS 2016 and SAP2000 v19 allows you to easily define a sequence of stages wherein you can add or remove portions of the structure, selectively apply load to portions of the structure. The sequence of stages can be matched on how the building will be built. Time-dependent material behavior such as aging, creep, and shrinkage can also be considered.

This technical note discusses on how to use the built-in Nonlinear Staged Construction Analysis (Auto-generated or Manual) in ETABS 2016 / SAP2000 v19. This technical note will also briefly show the difference on the results between a normal linear elastic analysis and sequential construction analysis.

II. Activating Auto Generated Staged Construction Analysis

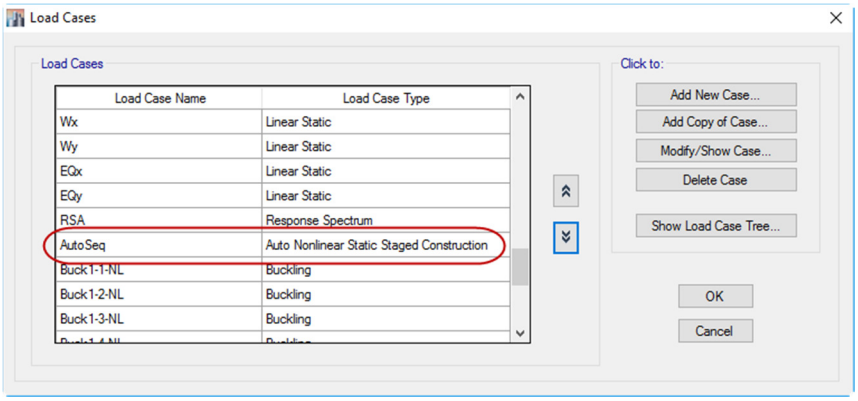
ETABS 2016 and SAP2000 v19 has built-in Auto Construction Sequence tool that can be used to account for sequential construction effect.

Click on to **Define>Auto Construction Sequence Case…** tick "Case is Active" in the dialogue box that will appear.

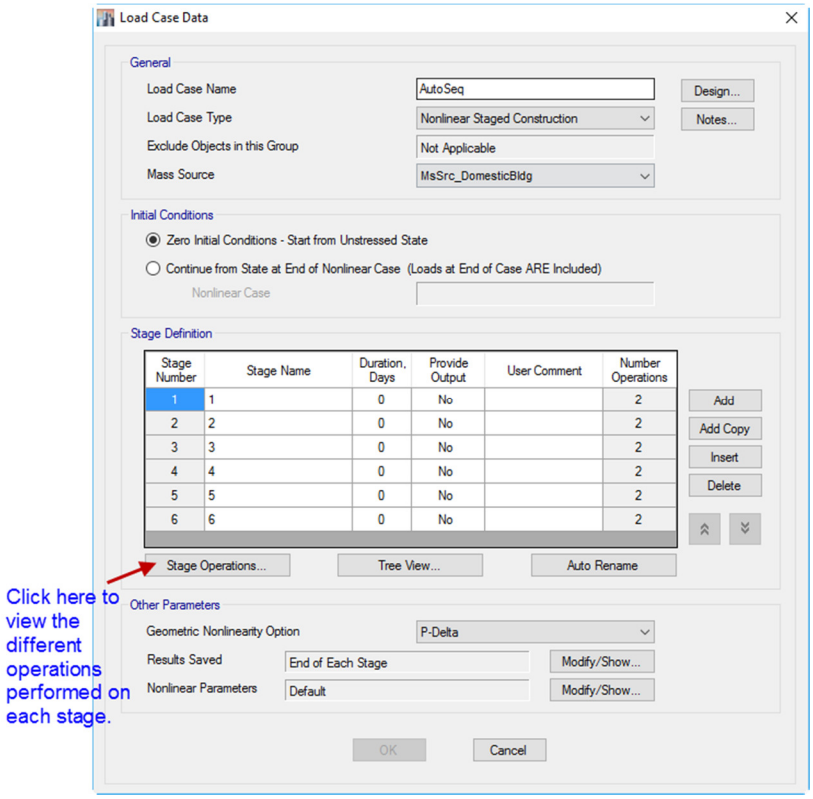


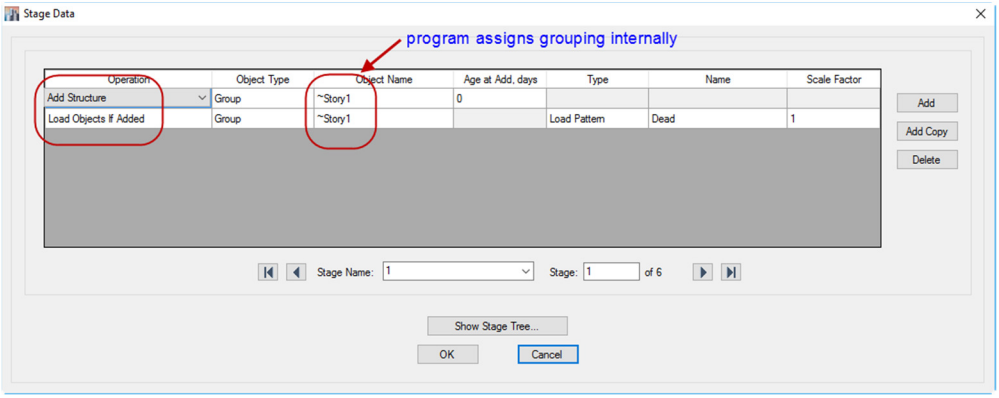
Loads to be applied are typically the Dead Loads, and part of Live Loads (optional).

A new Auto Nonlinear Static Staged Construction load case will be generated. This load case cannot be modified.



In the generated Auto Nonlinear Static Staged Construction load case, the number of stages and number of operations on each stage corresponds to the grouping of stories specified in the Auto Sequential Construction setting.

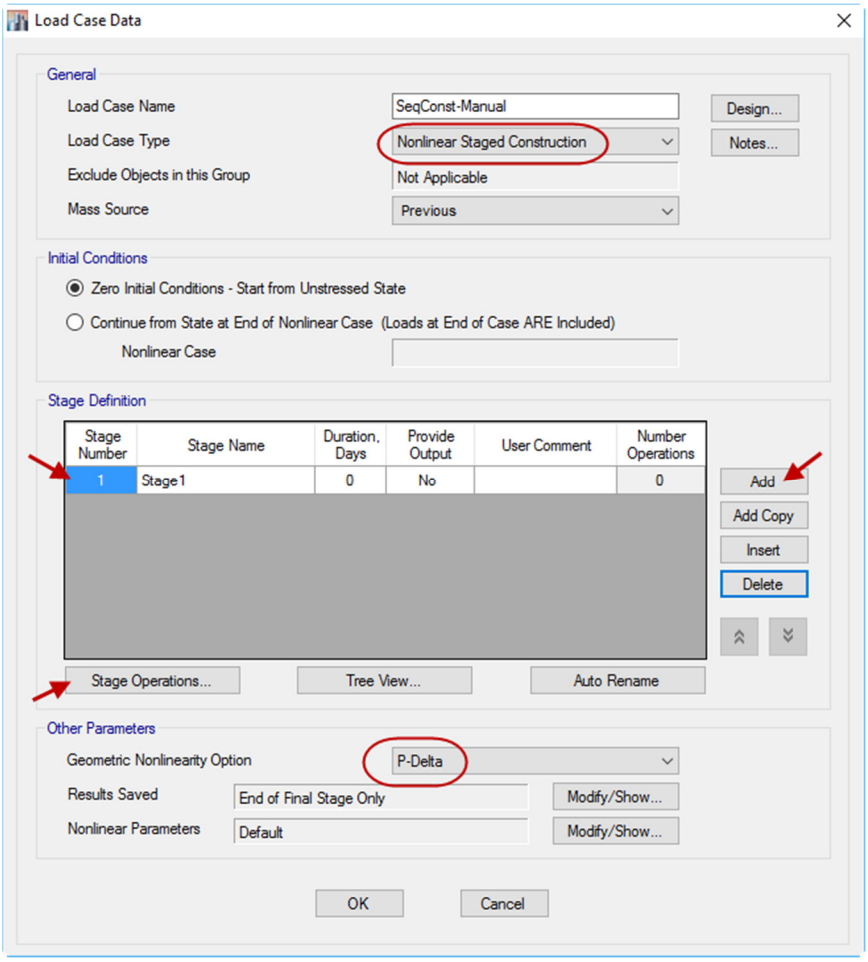


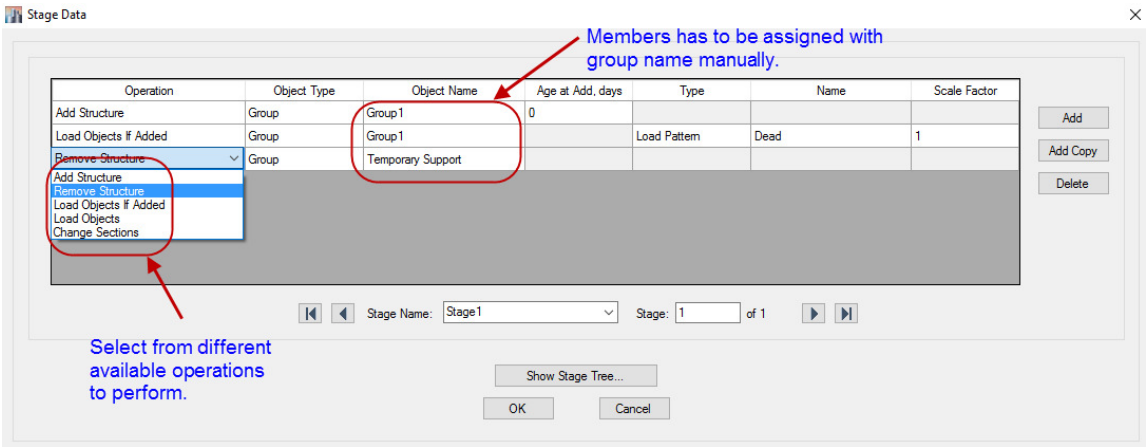


Looking at the above operation, the program's first operation is to add structure, and then followed by operation to load the objects that has just been added with the Dead Load pattern with scale factor of 1 just as previously specified. The operation for all the stages can also be viewed using the "Tree View" button.

A sequential construction load case can also be added manually in ETABS 2016 and SAP2000 v19.

Click on to **Define>Load Cases…** add a new load case and select “Nonlinear Staged Construction” as Load Case Type.





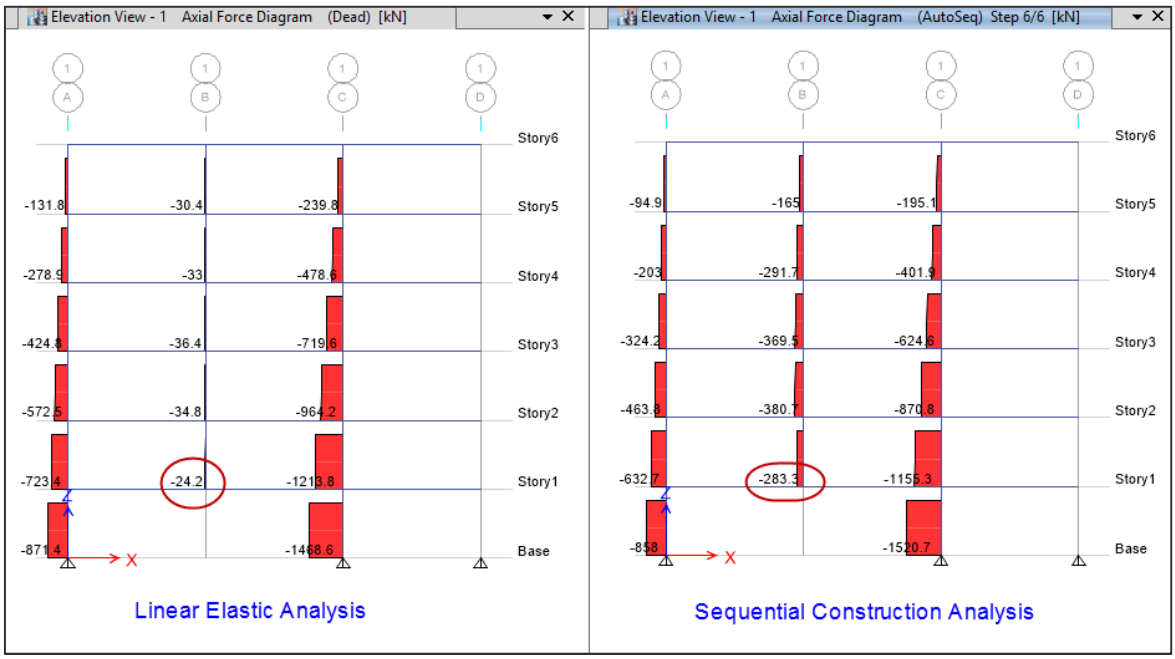
III. Linear Elastic Analysis vs. Sequential Analysis

A 6-storey model below has been analyzed for both Linear Elastic Analysis and Sequential Construction Analysis for dead load case. The 6-storey model involves a transfer beam at Storey 1 along gridline 1.

Two different cases were also considered: (1) all beams with same size; and (2) the transfer beam has bigger size.

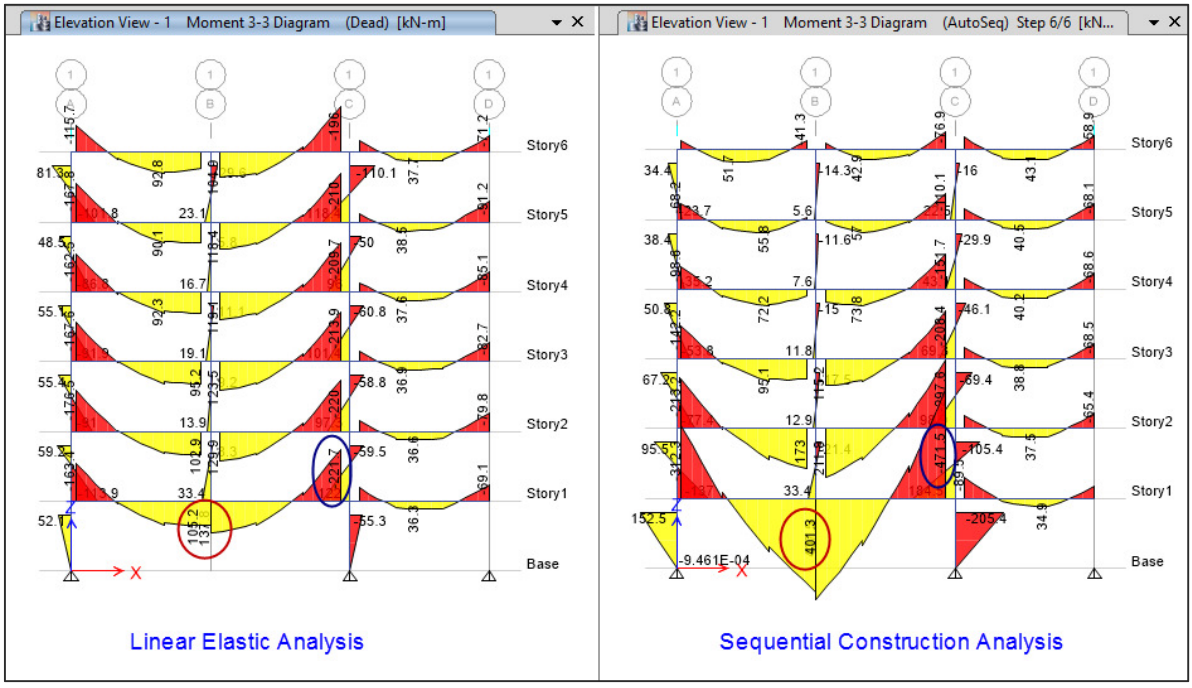
(Case 1) All the beams, including the transfer beam, have the same size of 600(D) x 300(W).

Axial force on the column that is supported by the transfer beam:



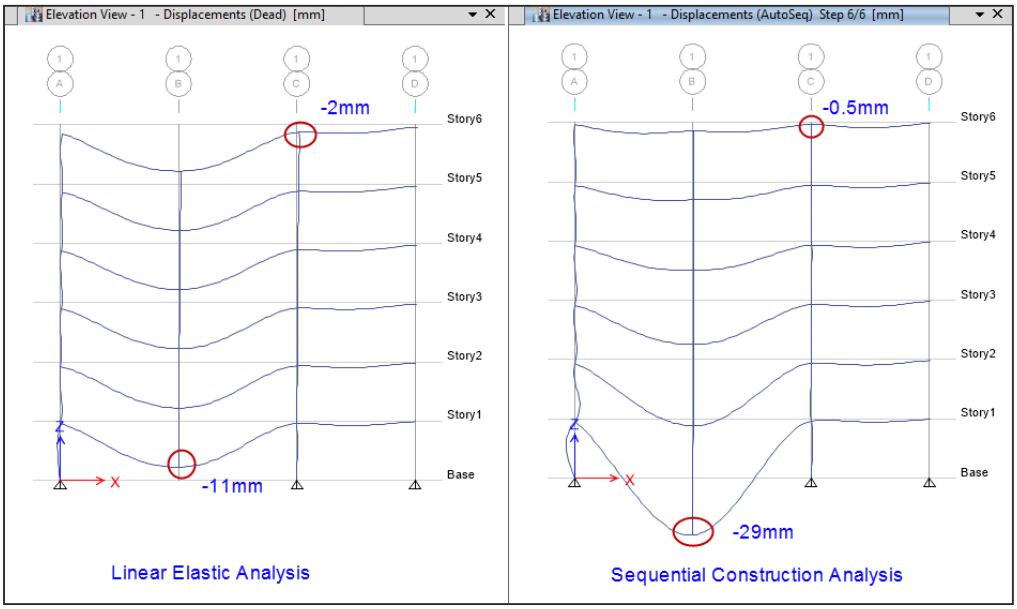
The axial force on the column from Sequential Construction Analysis is about (10) times larger than in Linear Elastic Analysis.

B. Bending moment on transfer beam:



The bending moment on the transfer beam from Sequential Construction Analysis is about (3) times larger than in Linear Elastic Analysis.

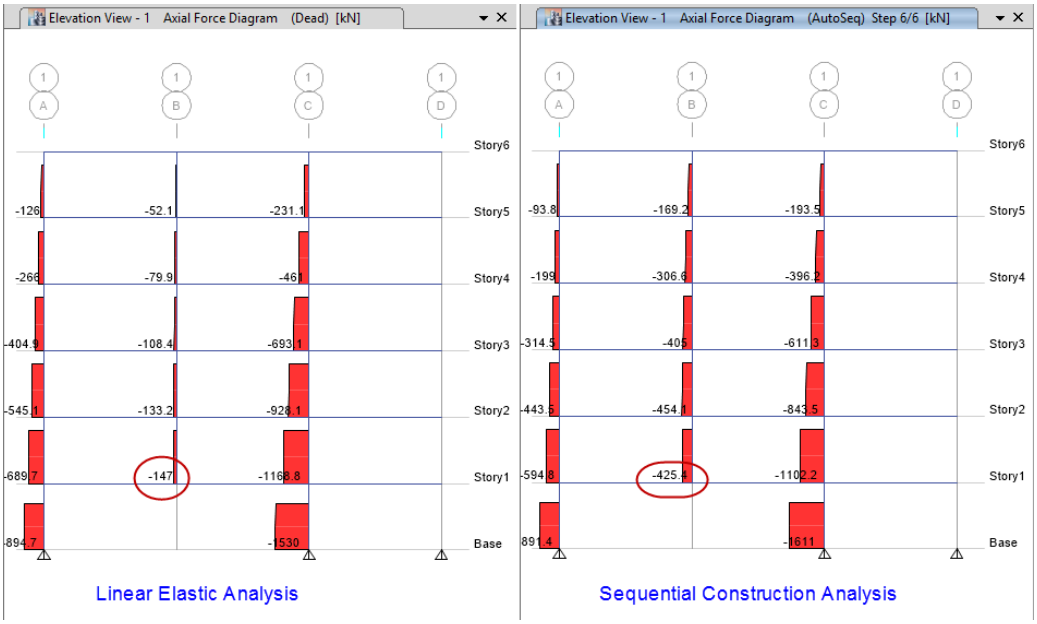
C. Displacement:



The midspan displacement on the transfer beam from Sequential Construction Analysis is about (2.5) times larger than in Linear Elastic Analysis. In contrast, the displacement on top of columns are smaller Sequential Construction Analysis. This is because in Sequential Construction Analysis, the bottom of the columns of the next stage is inserted at the undeformed state of that joint and neglecting the joint displacements from the lower floors as it is assumed that the floor will leveled prior to construction of the next floor.

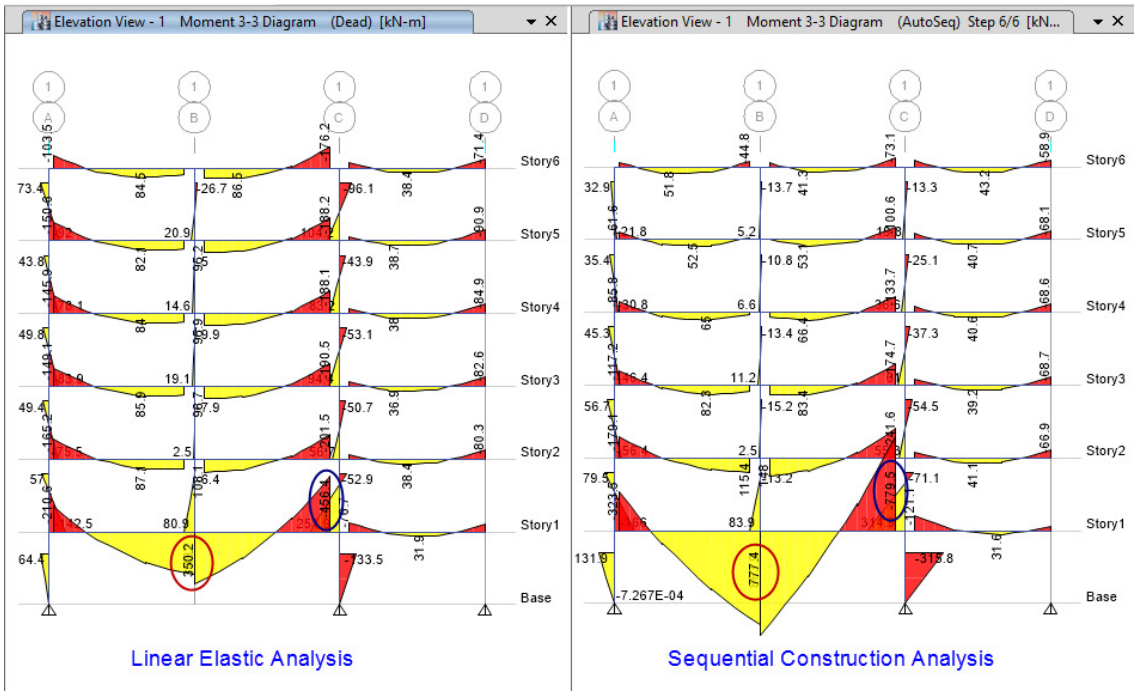
(Case 2) The transfer beam is enlarged to 900(D) x 300(W), all other beams have the same size of 600(D) x 300(W).

Axial force on the column that is supported by the transfer beam:



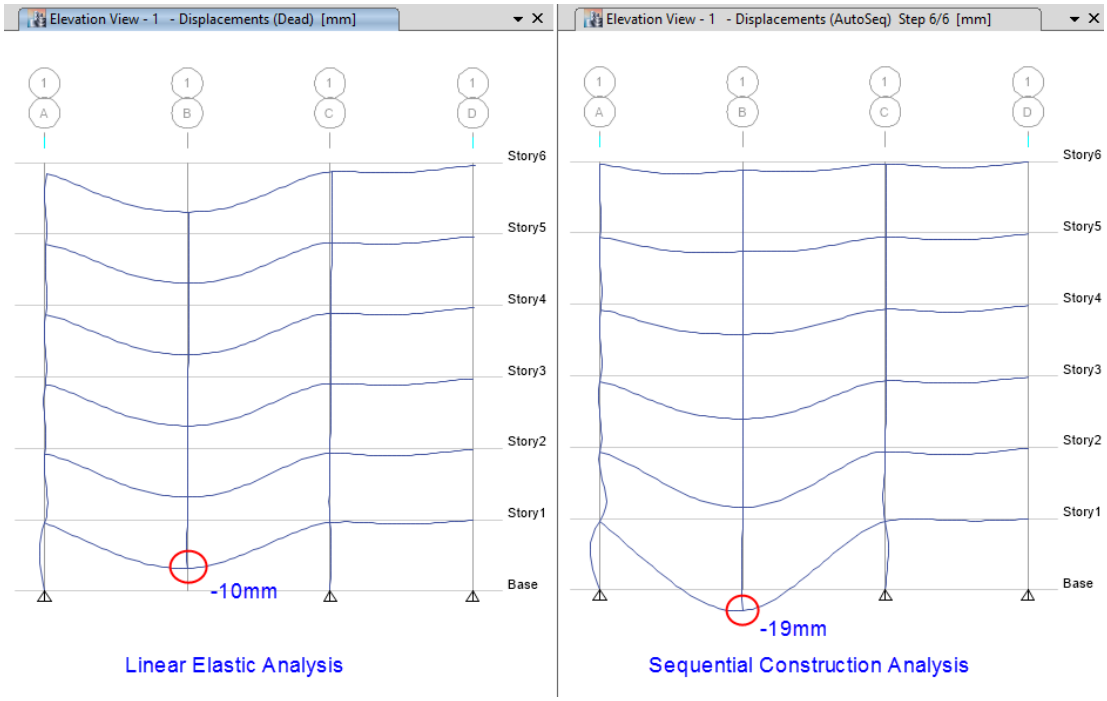
The axial force on the column from Sequential Construction Analysis is still about (3) times larger than in Linear Elastic Analysis.

B. Bending moment on transfer beam:



The bending moment on the transfer beam from Sequential Construction Analysis is about (2) times larger than in Linear Elastic Analysis.

C. Displacement:



The midspan displacement on the transfer beam from Sequential Construction Analysis is about (2) times larger than in Linear Elastic Analysis.

The result from the two cases above shows the sensitiveness of sequential construction effects on transfer structures and thus should not be neglected.