# Staged construction of a five-story column

**Test Problem**

| Name: | Staged construction of a five-story column |
|---|---|
| Description: | Creep application, addition of nodes to deformed configuration, and verification against manual calculations are given for the staged construction of a five-story column. |
| Program: | SAP2000 |
| Version: | 18.0.1 |
| Model ID: | 594 |
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**On this page:**

## Overview and purpose

This test problem demonstrates the formulation of staged-construction analysis, as applied using various modeling procedures. Time-dependent behavior is considered, new joints are placed within deformed and undeformed locations, and a description of how users may interpret output is included.

A five-story column is modeled with five construction stages which ascend vertically. At each stage, a frame object is assigned to represent a 3.7m column segment. A load of 500kN is applied in the gravity direction at the top of each segment. Five load cases are defined to illustrate the process and to evaluate construction scenario. These load cases include:

- LOAD: new joints placed in **undeformed** position; load applied without considering creep.

- (DEF) LOAD: new joints placed in **deformed** position using the ghost structure concept; load applied without considering creep.

- LOAD+CR: new joints placed in **undeformed** position; load applied and **creep is considered**.

- (DEF1) LOAD+CR: new joints placed in **deformed** position using a ghost structure with change modifiers; load applied and **creep is considered**.

- (DEF2) LOAD+CR: new joints placed in **deformed** position using a parallel ghost structure with change modifiers; load applied and **creep is considered**.

Each load case is described more fully in the sections below. Further, the attached PDF provides additional sketches. Results for each load case are independently verified by the spreadsheet calculations in the attached Excel file.

## Modeling and staged-construction sequences

A sketch of the construction sequence and associated loading is presented in Figure 1:
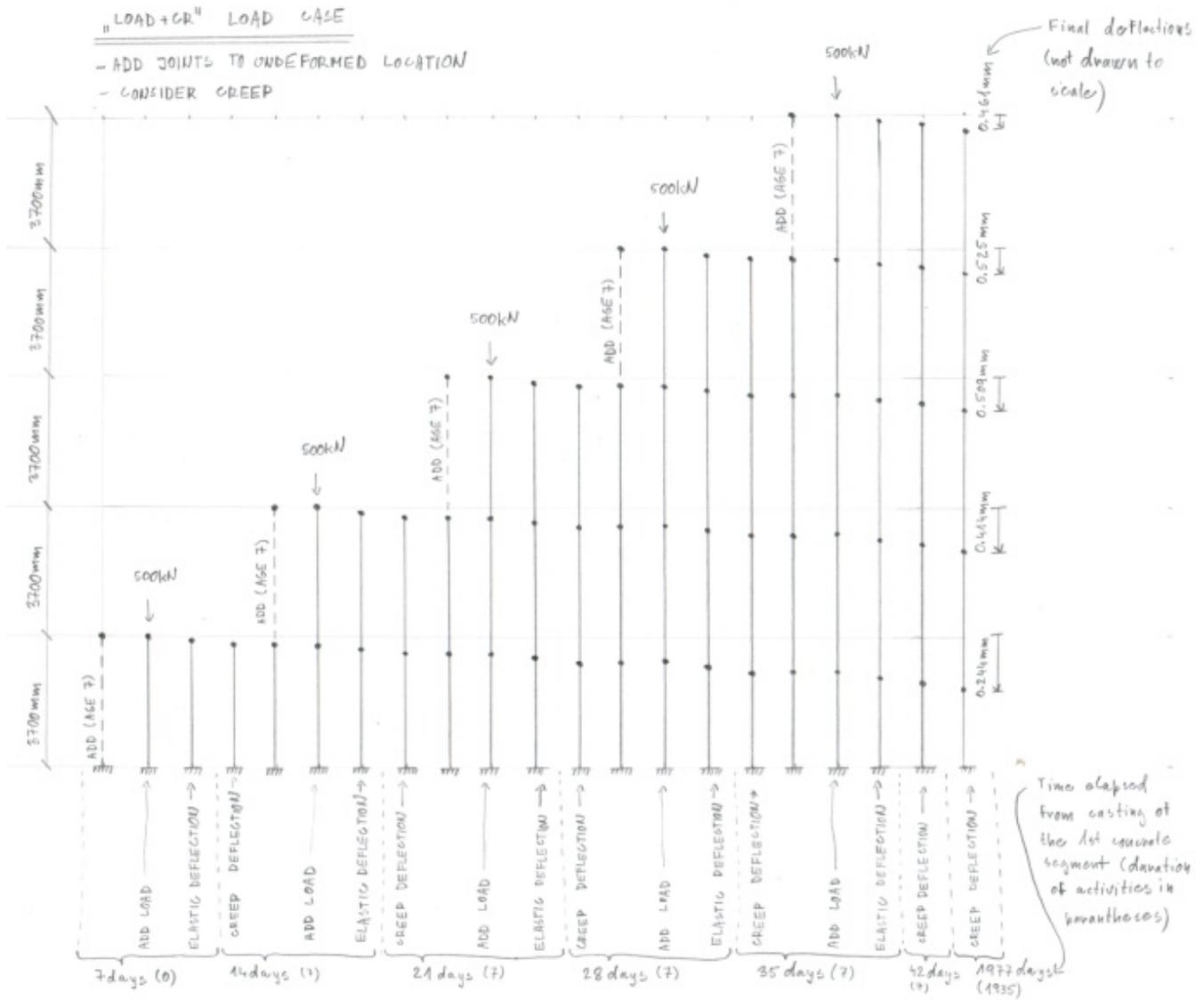
Figure 1 - Column model and sequence

A high resolution image of Figure 1 is presented in the attached PDF .

# Summary of deflection results

Analysis generates the deflection results which follow:

Story Top Joint Deflection [mm], showing 6 decimal places

| | Time since beginning of erection → | T = 7 | T = 14 | T = 21 | T = 28 | T = 35 | T = 1970 | |
|---|---|---|---|---|---|---|---|---|
| | Comment → | erect 1st story, apply load, wait 7 days | erect 2nd story, apply load, wait 7 days | erect 3rd story, apply load, wait 7 days | erect 4th story, apply load, wait 7 days | erect 5th story, apply load, wait 7 days | wait 1935 days | |
| Staged Construction Load Case | Top joint of which story? | | | | | | | |
| ↓ | ↓ | 1 | 2 | 3 | 4 | 5 | 6 | <- step no |
| LOAD | 5 | - | - | - | - | -0.103035 | -0.103035 | |
| (place new joints in undeformed | 4 | - | - | - | -0.082428 | -0.164857 | -0.164857 | |
| position) | 3 | - | - | -0.061821 | -0.123642 | -0.185464 | -0.185464 | |
| | 2 | - | -0.041214 | -0.082428 | -0.123642 | -0.164857 | -0.164857 | |
| | 1 | -0.020607 | -0.041214 | -0.061821 | -0.082428 | -0.103035 | -0.103035 | |
| | | 3 | 4 | 5 | 6 | 7 | 8 | <- step no |
| (DEF) LOAD | 5 | - | - | - | - | -0.309106 | -0.309106 | |
| (place new joints in deformed | 4 | - | - | - | -0.206071 | -0.288499 | -0.288499 | |
| position) | 3 | - | - | -0.123642 | -0.185464 | -0.247285 | -0.247285 | |
| | 2 | - | -0.061821 | -0.103035 | -0.14425 | -0.185464 | -0.185464 | |
| | 1 | -0.020607 | -0.041214 | -0.061821 | -0.082428 | -0.103035 | -0.103035 | |
| | | 2 | 4 | 6 | 8 | 10 | 12 | <- step no |
| LOAD+CR | 5 | - | - | - | - | -0.149574 | -0.460785 | |
| (place new joints in undeformed | 4 | - | - | - | -0.118831 | -0.239698 | -0.525321 | |
| position, creep included) | 3 | - | - | -0.088371 | -0.178496 | -0.26979 | -0.509204 | |
| | 2 | - | -0.058279 | -0.117944 | -0.178496 | -0.239698 | -0.414975 | |
| | 1 | -0.028706 | -0.058279 | -0.088371 | -0.118831 | -0.149574 | -0.244595 | |
| | | 4 | 6 | 8 | 10 | 12 | 14 | <- step no |
| (DEF) LOAD+CR | 5 | - | - | - | - | -0.431511 | -0.712322 | |
| (place new joints in deformed | 4 | - | - | - | -0.287216 | -0.40493 | -0.666864 | |
| position, creep included) | 3 | - | - | -0.172099 | -0.260375 | -0.350078 | -0.574858 | |
| | 2 | - | -0.085996 | -0.144908 | -0.204834 | -0.265493 | -0.434835 | |
| | 1 | -0.028706 | -0.058279 | -0.088371 | -0.118831 | -0.149574 | -0.244595 | |

Note: The age of all frame elements is counted from the first stage when the entire ghost structure was erected.
Make sure that this is consistent with the modeling intention.

| | | 6 | 10 | 14 | 18 | 22 | 24 | <- step no |
|---|---|---|---|---|---|---|---|---|
| (DEF2) LOAD+CR | 5 | - | - | - | - | -0.443761 | -0.754973 | |
| (place new joints in deformed | 4 | - | - | - | -0.294188 | -0.415055 | -0.700677 | |
| position, creep included) | 3 | - | - | -0.17536 | -0.265485 | -0.356779 | -0.596193 | |
| | 2 | - | -0.086999 | -0.146664 | -0.207216 | -0.268418 | -0.443695 | |
| | 1 | -0.028706 | -0.058279 | -0.088371 | -0.118831 | -0.149574 | -0.244595 | |

Figure 2 - Deflection summary



Final Joint Displacements

Legend: LOAD, (DEF) LOAD, LOAD+CR, (DEF1) LOAD+CR, (DEF2) LOAD+CR

Y-axis: Joint displacement [mm]
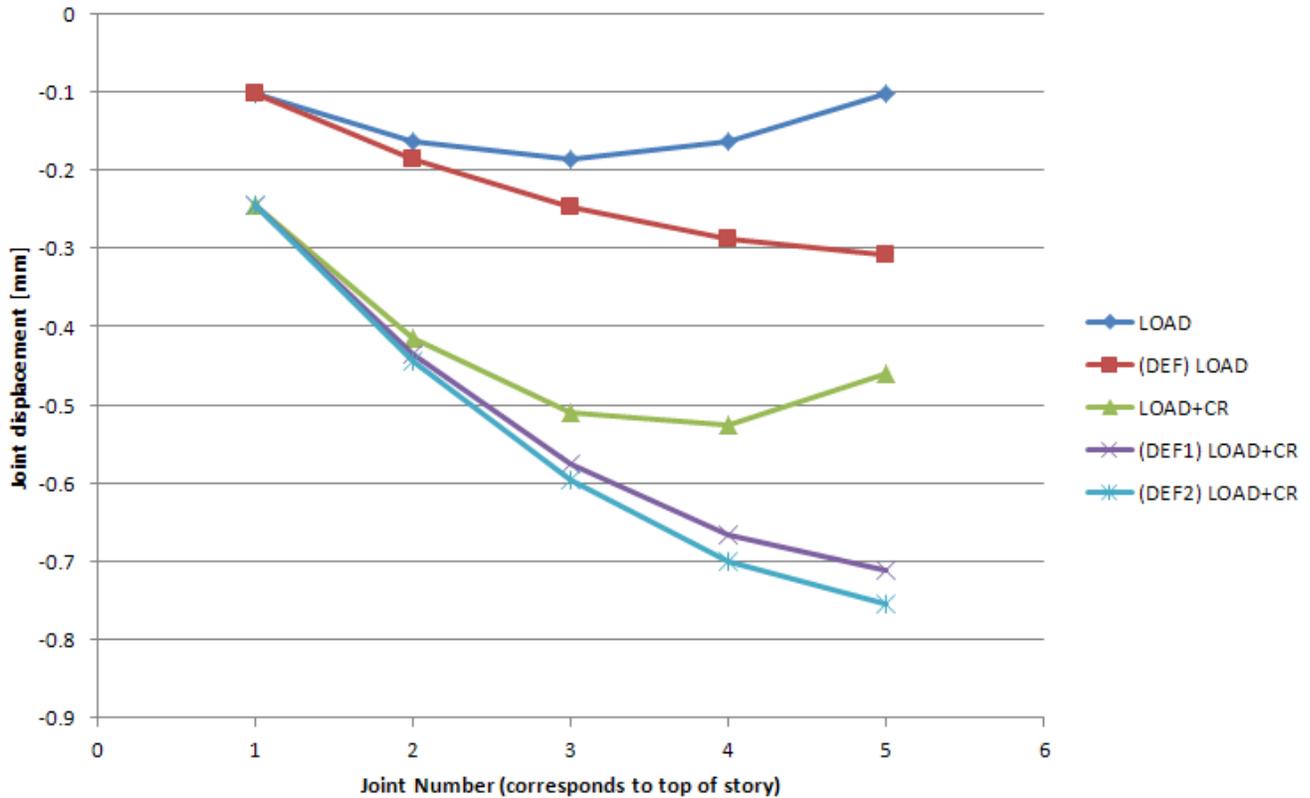X-axis: Joint Number (corresponds to top of story)

Figure 3 - Graph of final joint deflections

A full resolution image of Figure 2 is attached in the Excel spreadsheet .

# Discussion of modeling and results for individual load cases

Modeling and results for individual load cases are discussed as follows:

## LOAD

- Following the default procedure, newly added joints are placed in undeformed locations. This corresponds to a situation in which concrete is cast-in-place up to the desired elevation.

- Leaving the Time-Dependent Material Properties option unchecked in the Nonlinear Parameters menu keeps creep from being considered in analysis.

- In each construction stage, one story is added, and then loaded.

## (DEF) LOAD - using ghost structure

- An auxiliary ghost structure is used to add new joints to deformed locations. This is a manual staged-construction process which requires additional stages to setup and utilize the ghost structure. This method may be applicable when fixed-length precast-column segments are erected one by one.

- Creep is not considered.

- Staged construction consists of the following stages:

    - To create the ghost structure, the entire structure is first added.
    - Frame property modifiers equal to 0.0001 are applied to the entire structure to make it very flexible.
    - Stories are added one-by-one in subsequent stages by first assigning unit property modifiers to the story that is being erected. This effectively assigns the actual stiffness and activates the member before load is then applied.

## LOAD+CR

- Newly added joints are placed in undeformed locations.

- Creep is considered.

- Construction stages are similar to those of the LOAD load case. Please note that nonzero stage duration causes creep deformation.

## (DEF1) LOAD+CR - using ghost structure

- Newly added joints are placed in deformed locations.

- Creep is considered.

- Construction stages are similar to those of the (DEF) LOAD load case, but nonzero stage duration leads to creep deformation in this case.

- Please note that the **age of all elements is counted from the time the entire (ghost) structure is added** in the first step. The upper-story columns are activated, by changing their modifiers from GHOST to FULL, at an older age than the lower-story columns. This may underestimate the creep deformation when compared to the case in which all members are activated at the same (young) age of seven days.

## (DEF2) LOAD+CR - using parallel ghost structure

- Newly added joints are placed in deformed locations.

- Creep is considered.

- Staged construction is slightly modified from the (DEF1) LOAD+CR load case to model **all elements being activated at the age of seven days**. This is achieved by first adding the entire ghost structure and then by then adding the real structure, story-by-story, with an actual age of seven days.

- Another approach which simulates the activation of elements at the age of seven days is to remove the ghost elements and then add the real elements in a subsequent stage. This procedure is illustrated in the DEF3 LOAD+CR load case within the model.

# See Also

- Staged construction in buildings test problem

# Attachments

- SAP2000 V18.0.1 model (zipped SDB file)
- Hand calculations and sketches (PDF)
- Spreadsheet calculations to verify SAP2000 results (zipped Excel file)
- Tabulated summary of SAP2000 results (zipped Excel file)