Staged construction of a five-story column

Name:	Staged construction of a five-story column
Descripti on:	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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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:

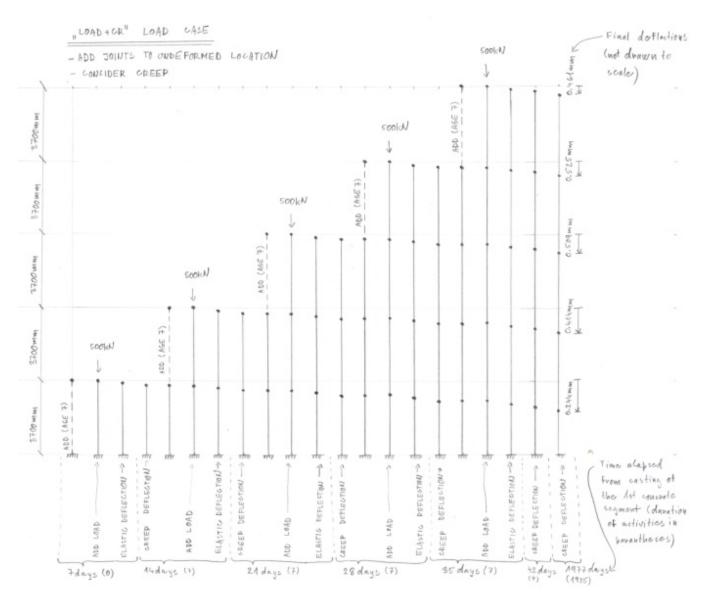


Figure 1 - Column model and sequence

A high resolution image of Figure 1 is presented in the attached $\ensuremath{\mathsf{PDF}}$.

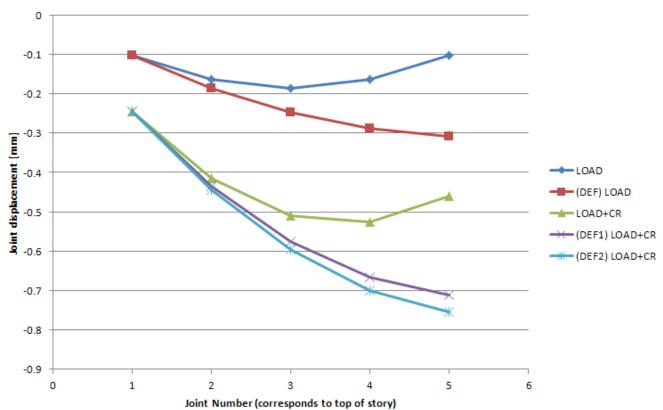
Summary of deflection results

Analysis generates the deflection results which follow:

			Ot T I-!-t D-#t!	formal about a O de desert	-1				
			Story Top Joint Deflection	i [mm], snowing 6 decimal	piaces				_
	Time since		T = 7	T = 14	T = 21	T = 28	T = 35	T = 1970	_
	beginning of	\longrightarrow							
	erection								1
	Comment		erect 1st story, apply	erect 2nd story, apply	erect 3rd story, apply	erect 4th story, apply	erect 5th story, apply	wait 1935 days	
		_	load, wait 7 days	load, wait 7 days	load, wait 7 days	load, wait 7 days	load, wait 7 days		_
Staged Construction Load Case	Top joint of which								
ctaged construction 25ad case	story?								
+	\perp		4	2	3	4	5	6	<- step n
LOAD	5		- :			4	-0.103035	-0.103035	<- step n
(place new joints in undeformed	4		-	-	-	-0.082428	-0.103035 -0.164857	-0.103035 -0.164857	<u> </u>
position)	3			-	-0.061821	-0.123642	-0.185464	-0.164857 -0.185464	I
- positio(1)	2			-0.041214	-0.061821	-0.123642 -0.123642	-0.185464 -0.164857	-0.185464 -0.164857	
┥ ㅏ	1		-0.020607	-0.041214	-0.082428	-0.123642 -0.082428	-0.103035	-0.103035	
	- '		-0.020001	-0.041214	-0.001021	-0.002420	-0.103033	·U.103033	_
			3	4	5	6	7	8	<- step ne
(DEF) LOAD	5		-	-	-	-	-0.309106	-0.309106	~ step in
(place new joints in deformed	4			-	- :	-0.206071	-0.288499	-0.288499	
position)	3		-		-0.123642	-0.185464	-0.247285	-0.247285	
position	2		_	-0.061821	-0.103035	-0.14425	-0.185464	-0.185464	
-	1		-0.020607	-0.041214	-0.061821	-0.082428	-0.103434	-0.103035	
			0.020001	0.011211	5.551521	0.002120	0.100000	0.100000	_
			2	4	6	8	10	12	<- step ne
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	
7 ' ' '	2		-	-0.058279	-0.117944	-0.178496	-0.239698	-0.414975	
7	1		-0.028706	-0.058279	-0.088371	-0.118831	-0.149574	-0.244595	
			4	6	8	10	12	14	<- step n
(DEF) LOAD+CR	5		-	-	-	-	-0.431511	-0.712322	
(place new joints in deformed	4		-		-	-0.287216	-0.40493	-0.666864	
position, creep included)	3		-	1	-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 o	onsistent with the modeling	g intention.				
			6	10	14	18	22	24	<- step n
(DEF2) LOAD+CR	5		-	-	-	-	-0.443761	-0.754973	- 3top II
(place new joints in deformed	4			-	- :	-0.294188	-0.445761	-0.700677	
position, creep included)	3		-	-	-0.17536	-0.265485	-0.415055	-0.596193	<u> </u>
position, croop included)	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



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)