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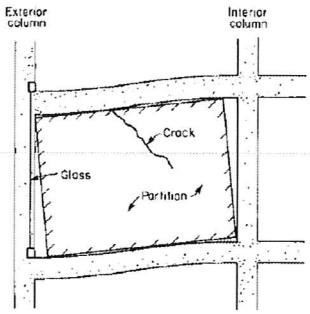
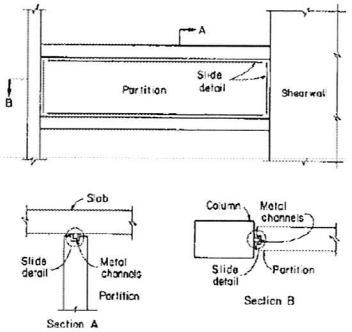
Differential Axial Shortening of Vertical Members

- DAS causes serviceability related problems: unacceptable cracking and deflection of floor plates, beams and secondary structural components, damage to facades, claddings, finishes, mechanical and plumbing installations and other non-structural walls can occur;

- In addition, common effects on structural elements are sloping of floor plates, secondary bending moments and shear forces in framing beams.





-The key building components that control axial shortening are the shear cores, internal columns and perimeter columns that are subjected to axial compression;

- Axial shortening is cumulative over the height of a structure so that detrimental effects due to differential axial shortening become more pronounced with increasing building height.

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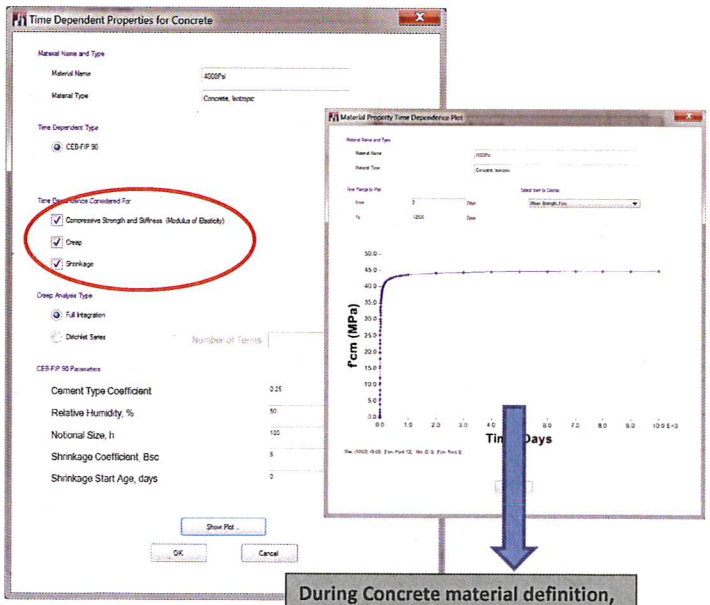
- Accurate prediction and management of differential axial shortening in buildings help to minimize the referenced problems;

- ETABS allows to account for:

1) load time histories associated with the construction process;

2) time varying values of Young's Modules of concrete;

3) creep and shrinkage;



During Concrete material definition, the user is allowed to activate the time dependent properties, to use during staged construction analysis.

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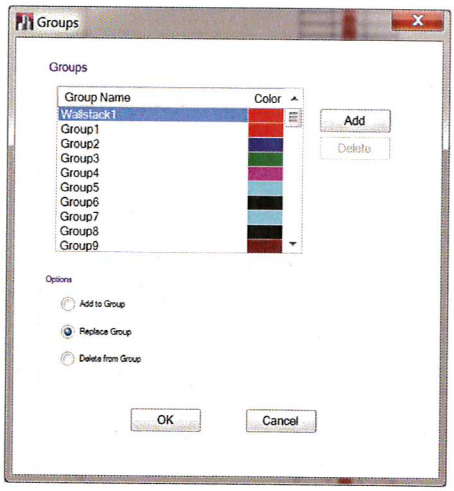
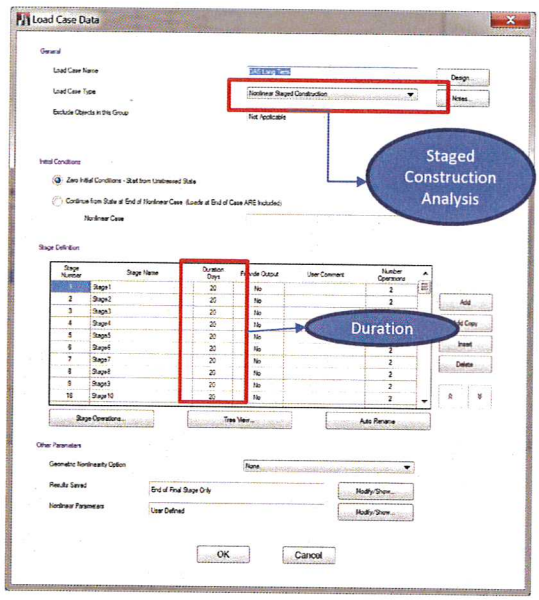
- To prepare the staged construction analysis, ETABS uses the groups concept: each floors is a different group of elements (a 3D view in Elevation XZ is useful to select the elements for each group). To create the groups, use the Assign > Assign Objects to Group command.



- Use the Define > Load Cases to Create a Staged Construction analysis; start by creating the different stages of analysis; notice that if you are considering creep effects, the duration of each stage should have less days (around 20 days) for the first stages, to allow the program to interpolate right the creep function;



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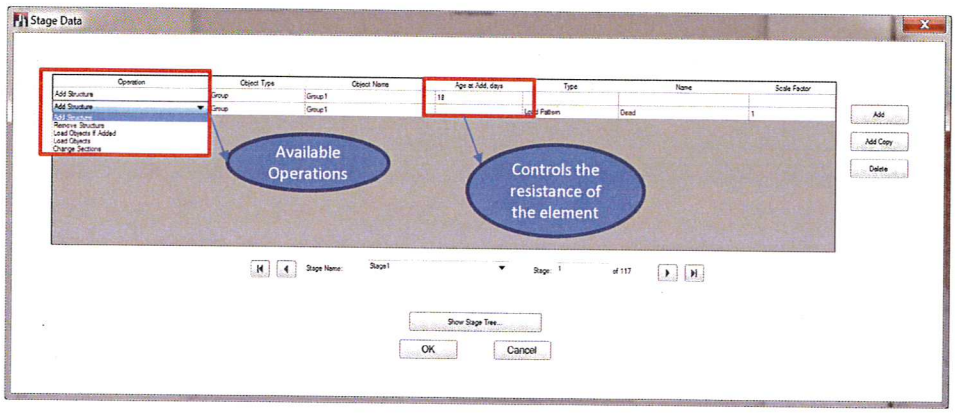
- Each stage consists on a set of operations. Here we prepared the analysis using 2 operations per stage: first adding the group with the elements for each floor and then loading that group with its dead load.



NOTE: another option to perform the same analysis would be adding the complete structure, prepare some "dummy" elements with zero properties and use the "Change Sections" operation to add each group at a different stage. This is actually the most accurate procedure to model the geometry control during construction.

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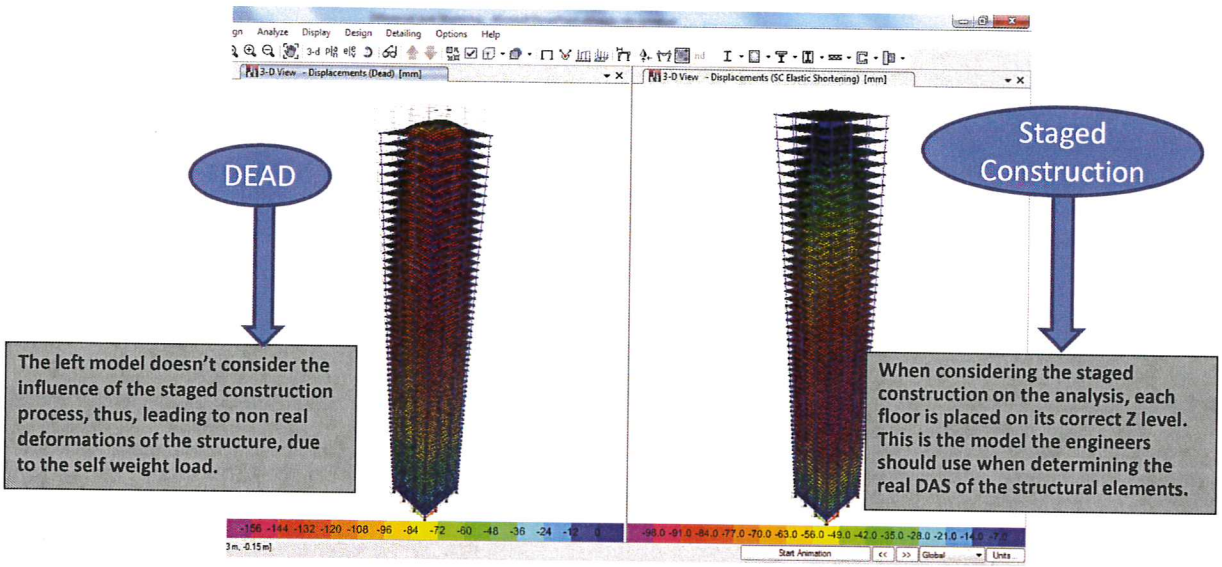
Differential Axial Shortening of Vertical Members

- The differential axial shortening is responsible for the development of shear and bending moments on the horizontal elements; the forces from the horizontal elements lead to a redistribution of the applied loads on the vertical members, with more loads applied on the elements that suffer less shortening effect (cores).



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Differential Axial Shortening of Vertical Members

First, we'd like to point out the difference on the results we get by considering or not the staged construction analysis. To accomplish that, we start by analyzing the stresses we get on a perimeter column and on the core, when considering just the DEAD load and when considering the Staged Construction analysis with time dependent effects (Long Term = 50 years).

Section Cut Results Table for 60 Floor Core

TABLE: Section Cut Forces - Design

Section Cut	Load Case/Combo	P	V2	V3	T	M2	M3	X	Y	Z
		kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
Wall 60	Dead	2099.1928	41.7268	-40.1839	115.6239	1809.5344	213.1837	11.9	11.38	177
Wall 60	DAS Long Term	1171.4135	-10.34	-19.9523	39.0139	984.3557	83.1476	11.9	11.38	177

Frame Forces for Column C1 (Perimeter Column)

TABLE: Column Forces

Story	Column	Load Case/Combo	Station	P	V2	V3	T	M2	M3
Story60	C1	Dead	2.5	-98.5585	-10.4718	27.6045	0.1496	-30.6673	12.1394
Story60	C1	DAS Long Term Min	2.5	-105.0501	-31.5749	-22.6649	0.0402	33.9627	44.951

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Differential Axial Shortening of Vertical Members

- In high rise buildings, perimeter columns tend to be more heavily stressed compared to shear walls of internal core. These perimeter columns thereby tend to deform axially at higher rates compared to shear walls. This leads to differential axial shortening (DAS) between the columns and shear walls.

In order to evaluate the error committed by neglecting the staged construction analysis, please refer to the stresses we get for the core and for Column 1 perimeter column (0,0,Z).

Stress Core DEAD = $N_{long\ Term}/A_{Core}$ = 2099.19/6.21 = 338.04 kN/m2
Stress C1 DEAD = N_{Dead}/A_{C1} = 98.55/0.14063 = 700.77 kN/m2

Stress Core Staged Construction DAS Long Term = $N_{long\ Term}/A_{Core}$ = 1171.41/6.21 = 188 kN/m2
Stress C1 Staged Construction DAS Long Term = 105.05/0.14063 = 700.77 kN/m2 = 746.99 kN/m2

2 Conclusions become evident here:

- When neglecting the staged construction correction, the stress on the base of the core for floor 60 is 338 kN/m2, when in reality, the stress that should be considered is 188 kN/m2, which represents an error of almost 80%; remember that this effect increases with height;
- The stress for the perimeter columns is 4x the stress on the core, thus leading to considerable differential axial shortening effects;

TABLE: Joint Displacements

	Story	Label	Load Case/Combo	UZ mm
Joints of Columns	Story60	1	DAS Long Term Max	-107.7
	Story60	2	DAS Long Term Max	-102.8
	Story60	3	DAS Long Term Max	-101.6
	Story60	4	DAS Long Term Max	-104.8
	Story60	5	DAS Long Term Max	-110.8
	Story60	6	DAS Long Term Max	-75
	Story60	7	DAS Long Term Max	-72.5
	Story60	8	DAS Long Term Max	-106.4
	Story60	9	DAS Long Term Max	-112.8
	Story60	10	DAS Long Term Max	-73.3
	Story60	11	DAS Long Term Max	-72.6
	Story60	12	DAS Long Term Max	-106.5
	Story60	13	DAS Long Term Max	-110.2
	Story60	14	DAS Long Term Max	-106.8
	Story60	15	DAS Long Term Max	-103.2
	Story60	16	DAS Long Term Max	-105
Joints of Core	Story60	40	DAS Long Term Max	-59.4
	Story60	41	DAS Long Term Max	-59.2
	Story60	44	DAS Long Term Max	-59
	Story60	45	DAS Long Term Max	-58.9
	Story60	48	DAS Long Term Max	-58.7
	Story60	50	DAS Long Term Max	-59.4
	Story60	52	DAS Long Term Max	-59.3
	Story60	54	DAS Long Term Max	-59.1
	Story60	56	DAS Long Term Max	-59
	Story60	58	DAS Long Term Max	-59.4
	Story60	59	DAS Long Term Max	-58.9

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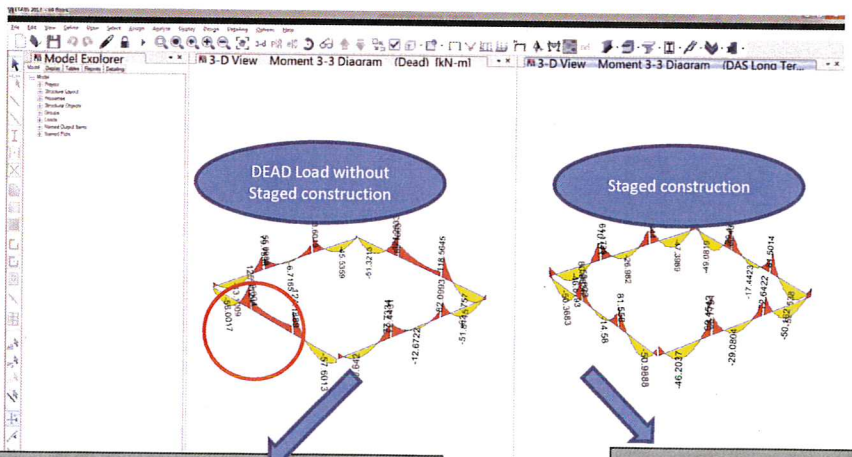
Differential Axial Shortening of Vertical Members

- The differential axial shortening is responsible for the development of shear and bending moments on the horizontal elements; in an extreme case, the differential axial shortening can lead to an inversion on the moment diagram. This can be noticed for the DEAD load case, where the staged construction was not considered.



When the staged construction is not considered, the axial shortening is so relevant that in some cases leads to inversion of the moment diagram. These results are overestimated, when comparing to the expected ones, that come from the Staged Construction analysis.

Though the effect of DAS is relevant, after long term effects the model doesn't present inversion on the moment diagram for the beams.