Accounting for deformed shape in staged construction

Several methods are available to **account for structural deformation during staged construction**. These methods, which involve adding joints to displaced configuration, are discussed as follows:

On this page:

Modify undeformed geometry

In many cases, the most useful approach to account for structural deformation is to start with coordinates which represent the desired final deflected configuration. After running staged construction analysis, select Analyze > Modify Undeformed Geometry to modify joint coordinates such that the deflected shape at the end of staged construction matches the geometry initially specified. A few iterations may be necessary for coordinates to converge to the desired shape.

This approach automatically provides the joint location desired at the time a joint is added to the structure. Deflected shape is therefore meaningful. Another benefit is that bridge camber is calculated automatically.

Implement a ghost structure

Another method which accounts for structural deformation during staged construction is the implementation of a ghost structure, which is done as follows:

1. Define two Frame (or Shell) Modifiers named property sets through Define > Named Property Sets. The first may be named Ghost, and the second, Full. In the named property set Ghost, set all stiffness modifiers to a small value, perhaps 1e-4, and set mass and weight modifiers to zero. In the named property set Full, set all modifiers to 1.0.
2. In the first construction stage, add the whole structure and apply the named property set Full to all objects which are present at the beginning of staged construction. Load these objects, then apply named property set Ghost to the rest of the structure.
3. In subsequent stages, apply the named property set Full to objects which are added to the structure, then load this set of objects.

At each stage, the entire structure will deflect while only objects of the named property set Full will contribute to stiffness. As a result, joints are activated in meaningful displaced locations. This approach may be modified through consideration of partial or multiple ghost structures.

An alternative approach is to change sections instead of modifiers. For example, deck shells may be modeled using plywood sections which are later changed to concrete slab sections.

A discussion of ghost structure application using both sections and modifiers is available in the CSI *Analysis Reference Manual* (Chapter XXIII Nonlinear Static Analysis, Staged Construction).

Implement a ghost structure with two parallel structures

Another approach is to develop the actual structure in parallel with the ghost structure. The color of objects within the ghost structure may be modified to better visualize the staged-construction process. This method also enables better control over the age at which objects are added, improving the simulation of time-dependent effects. The Staged construction of a five-story column test problem demonstrates the development of actual and ghost structures in parallel.

Manually modify joint coordinates

Initial joint coordinates may be retrieved manually by running multiple analyses to gauge the structural behavior of unusual staged construction applications. Begin with a model which has preliminary joint coordinates, then run the first stage of construction. Modify the coordinates of joints which will be added in the second stage such that they are in the correct location relative to the deflected shape of the first stage. Run analysis again for these two stages, locate the joints for the third stage, then continue this process recursively until all joints in the model are located.

See Also

- Staged construction of a five-story column test problem on ghost and parallel ghost structures
- Camber article
- Cable section
- Fabric structure DRAFT