DEVELOPMENT OF A SOFTWARE FOR NONLINEAR STATIC ANALYSIS OF REINFORCED CONCRETE FRAMES AND WALLS

DOCUMENTATION

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1. INPUT PARAMETERS

1. The user should define nodes of the structure with node IDs and co-ordinates referring the global coordinate system

2. Section definition

   The user should define the different section types to be used in the structure for each element

   Section ID
   Section shape (Rectangular, circular)
   Number of uniaxial concrete fibers
   Details about each steel layer in the section (Layer area, distance from the middle)
   Material model selection for steel and concrete.

3. Element definition
   The user should define how elements are located in the nodes defined in 1

   Element ID
   Starting node
   Ending node
   Section level force convergence tolerance
   Relevant section ID to the element

4. Boundary conditions

   The degrees of freedom of a node can be labelled by the relevant node ID and 1 (Global X translation), 2 (Global Y translation), 3 (Global Z rotation anti-clockwise)

   Example- 1 1 represents node 1 global X direction degree of freedom

   5 3 represents node 5 global Z rotation in anti-clockwise direction

   The user should input the degrees of freedom that he plan to restrain

5. Details about the structure level iterations

Convergence criteria (Force, Displacement or energy convergence criteria)
Tolerance
Maximum iterations

6. Load or displacement controlling degree of freedoms

7. The user should decide whether the analysis is “Force controlled “or “Displacement controlled”.

   Step size
   Number of steps
   Reference load vector

8. Details about the other external loads applied
   Applied degrees of freedom and magnitudes
   Force step size and number of steps

   Initially the analysis for other external loads should be carried out using the force step and number of steps specified by the user and force, deformation states of the structure, element, section and fiber should be saved. Then the pushover analysis can be carried out for the controlling degree of freedom

2. FORMULATION

For the easiness of coding the whole formulation can be discretized in to three major parts

1. Structure state determination

The user has the option of deciding the method of structure state determination, Force control or displacement control.

<u>Force control method</u>

- Assume that you are given the initial structure stiffness matrix. $[K]_{i=0}$

- Apply boundary conditions to the Structure stiffness matrix by deleting the rows and columns corresponding to the restrained degrees of freedom (boundary conditions)

- Find the inverse of the boundary condition applied structure stiffness matrix

- Prepare a force increment vector, without the rows corresponding to the restrained degrees of freedom. (The resulting increment vector is known, with one or several non-zero elements. If there is only one non-zero element, load is controlled only at one degree of freedom, else load is controlled in several degrees of freedom)

- Multiply the inverse of the boundary condition applied structure stiffness matrix with the above force increment vector and obtain displacement increments of unrestrained degrees of freedom.

- Complete the structure deformation increment vector by adding zeros to the relevant degrees of freedom that are restrained. ($\Delta U_{i=1}$)

- Update the deformation increment vector for the load step

$$\Delta U_{for\ the\ load\ step} = \{\Delta U_{i=1}\}$$

- Assume that you have the updated structure stiffness matrix for the above deformation increment.
- Calculate the resisting force for the structure deformation increment

$$\{R_{i=1}\} = [K]_{i=1}\{\Delta U_{i=1}\}$$

- In $\{R_{i=1}\}$, delete rows corresponding to restrained degrees of freedom. Then calculate unbalanced force. Here when $i=1$, $O_{i=1-1}$ is the applied load vector without restrained degrees of freedom.

$$\{O_{i=1}\} = \{O_{i=1-1}\} - \{R_{i=1\,reduced}\}$$

- The deformation correction for the above unbalanced force can be calculated as follows. Here, boundary conditions are applied to the updated structure stiffness matrix and it has been inverted.

$$\{\Delta U_{i=2}\} = [K]_{i=1}^{-1}\{O_{i=1}\}$$

- Update the deformation increment vector for the load step

$\Delta U_{\text{for the load step}} = \Delta U_{\text{for the load step}} + \{\Delta U_{i=2}\}$

- The user has been given a chance to decide the convergence check criteria

Force convergence check $|(\{O_{i=1}\})| < \text{Structure level iteration tolerance}$

Displacement convergence check $|(\{U_{i=1}\})| < \text{Structure level iteration tolerance}$

Energy convergence check

$0.5 * (\text{Transpose of force vector increment}) * (\text{Displacement vector increment}) < \text{Structure level iteration tolerance}$

If the convergence check is not satisfied,

- Assume that you have the updated structure stiffness matrix for the above structure deformation increment.
- Calculate resisting force, unbalanced force and deformation correction as before.

$$\{R_{i=2}\} = [K]_{i=2}\{\Delta U_{i=2}\}$$

$$\{O_{i=2}\} = \{O_{i=2-1}\} - \{R_{i=2\,reduced}\}$$

- Please note that boundary conditions are applied to the updated structure stiffness matrix and it has been inverted.

$\{\Delta U_{i=3}\} = [K]_{i=2}^{-1}\{O_{i=2}\}$

- Update the deformation increment vector for the load step

$\Delta U_{\text{for the load step}} = \Delta U_{\text{for the load step}} + \{\Delta U_{i=3}\}$

- Perform the user specified convergence check. If satisfied, $\Delta U_{\text{for the load step}}$ is the displacement increment for the load step applied.

Displacement control method

- Assume that you are given the initial structure stiffness matrix. $[K]_{i=0}$
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