Nonlinear analysis – Assignment 3

**Part A: The Newton Raphson method, applied to a linear material with a non-linear geometric behaviour**

The same method used in assignment 2 is used.

However, the geometric behaviour of the bars is non-linear, therefore the length of the bars varies over time. At each iteration, each length is calculated according to the displacements.

Furthermore, the resisting force in each bar is calculated differently as the strain of a bar subjected to a change in length L-L0 is: Wint=0.5\*k\*(L-L0)², with k=E\*A0/E0. The resisting force is the derivative of Wint with respect to the displacements.

As the geometric behaviour is non-linear, the tangent stiffness matrix is the sum of the material tangent stiffness (same as the one calculated for a linear geometric behaviour) and the geometric tangent stiffness.

**Part B: Displacements linear geometric behaviour and non-linear geometric behaviour**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Load | Displacements [mm] | | | |
| Linear Geometric Behaviour | | Non linear geometric behaviour | |
| U1 | U2 | U1 | U2 |
| 107 N | 0.326 | 19.71 | 0.556 | 19.53 |
| 108 N | 3.255 | 192.13 | 21.946 | 182.58 |
| 109 N | 32.55 | 1971.3 | 666.63\* | 1489.5\* |

\* Approximative results, with a large tolerance considered in order to have convergence of the Newton-Raphson method. If not, the results do not converge in reasonable computational times.

**Graphical comparisons considering linear and non-linear geometric behaviour, with linear element properties:**

For load 107 N:

**Une image contenant texte, ligne, Tracé, diagramme

Description générée automatiquementUne image contenant texte, ligne, Tracé, diagramme

Description générée automatiquement**

**Une image contenant texte, Tracé, ligne, capture d’écran

Description générée automatiquement**

For load 108 N:

**Une image contenant texte, ligne, Tracé, diagramme

Description générée automatiquementUne image contenant texte, Tracé, ligne, capture d’écran

Description générée automatiquement**

**Une image contenant texte, ligne, Tracé, diagramme

Description générée automatiquement**

For load 109 N:

**Add graphs**

**Part C: Comparison between linear geometric behaviour and non-linear geometric behaviour**

The **relative change** is computed as following:

With the maximal linear deformation and the maximal non-linear deformation.

The relative change indicate the change applied to the linear displacements when considering the non-linear geometric behaviour.

|  |  |  |
| --- | --- | --- |
| Load | Relative change between largest displacements [%] | |
| U1 | U2 |
| 107 N | 70.92 | - 0.92 |
| 108 N | 574.14 | - 7.38 |
| 109 N | 1947.82\* | - 24.44\* |

\* Approximative results, with a large tolerance considered in order to have convergence of the Newton-Raphson method. If not, the results do not converge in reasonable computational times.

Another good indicator of changes is the **percentage difference**, computed as following:

With the maximal linear deformation and the maximal non-linear deformation.

The percentage difference compare the displacement for each case relative to the mean of the displacements.

|  |  |  |
| --- | --- | --- |
| Load | Percentage difference between largest displacements [%] | |
| U1 | U2 |
| 107 N | 26.18 | 0.46 |
| 108 N | 74.16 | 3.83 |
| 109 N | 90.69\* | 13.92\* |

\* Approximative results, with a large tolerance considered in order to have convergence of the Newton-Raphson method. If not, the results do not converge in reasonable computational times.

What is the percentage difference between largest displacements? What is the influence of the geometric nonlinearity on the displacement magnitude? Would you trust the results for the 3rd load case