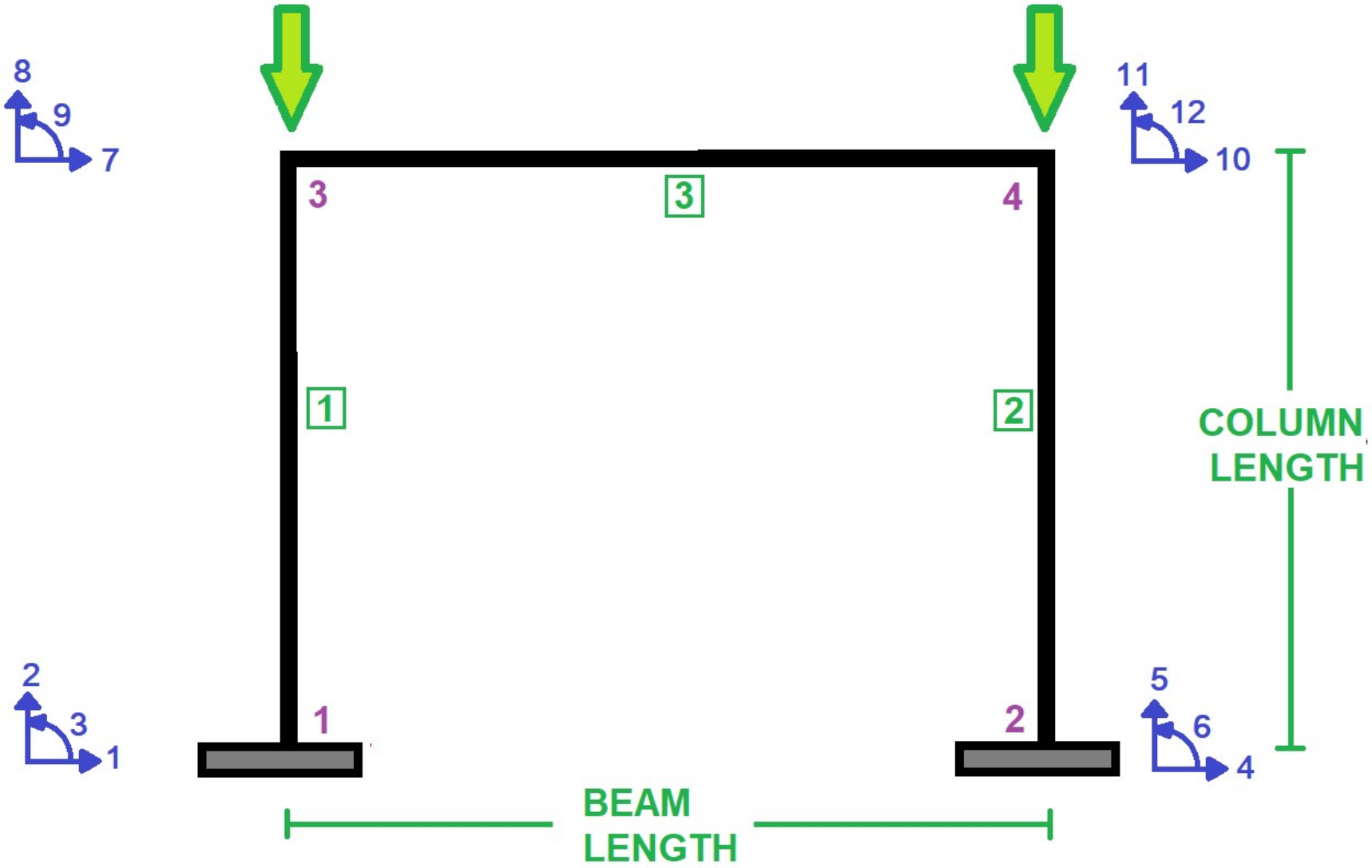
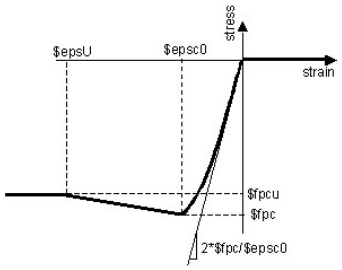
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

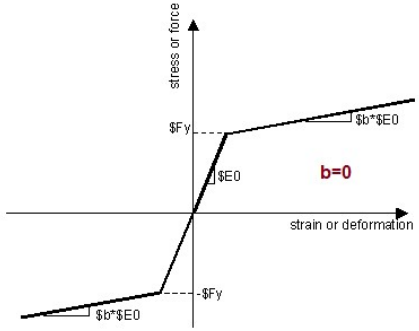
POST-BUCKLING ANALYSIS OF CONCRETE FRAME. EVALUATING STRAIN HARDENING AND ULTIMATE STRAIN CRITERIA USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

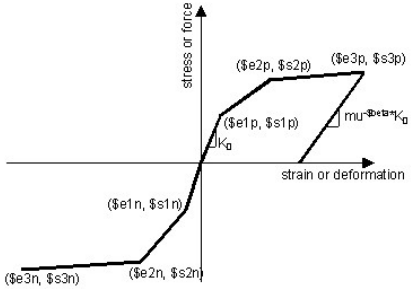

8
9
7
11
12
10
3
3
4
1
2
COLUMN
LENGTH
2
3
1
1
2
5
6
4
BEAM
LENGTH



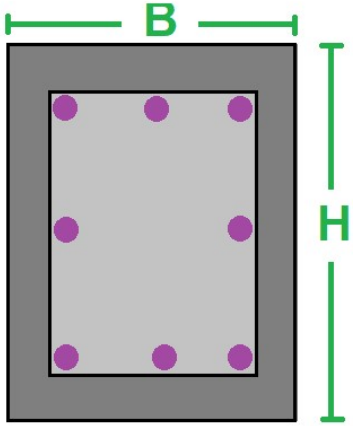
CORE AND COVER CONCRETE RELATION



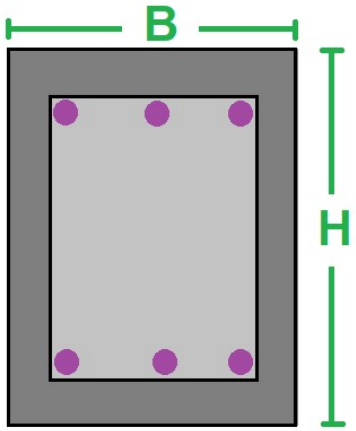
WITHOUT HARDENING AND ULTIMATE STRAIN



WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

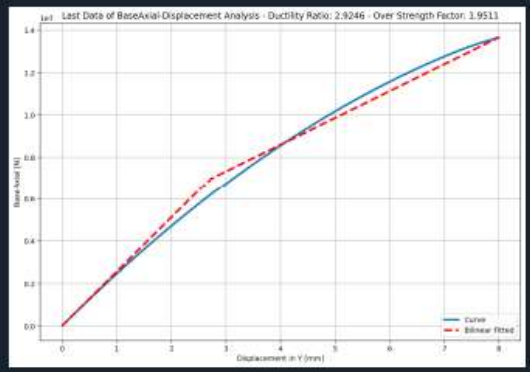
...esktop\OPENSEES_FILES\CONCRETE_FRAME_EXAMPLES\POST_BUCKLING

C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...LES\POST_BUCKLING\CONCRETE_FRAME_POST_BUCKLING.py

CONCRETE_FRAME_SEN...TY_REBAR_Cdepth.py | CONCRETE_FRAME_PUSHOVER.py | CONCRETE_FRAME_POST_BUCKLING.py

```
1  ##########################################################################################################
2  #                          >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
3  # POST-BUCKLING ANALYSIS OF CONCRETE FRAME. EVALUATING STRAIN HARDENING AND ULTIMATE STRAIN CRITERIA USING
4  #--------------------------------------------------------------------------------------------------------
5  #                                THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
6  #                                        EMAIL: salar.d.ghashghaei@gmail.com
7  ##########################################################################################################
8  """
9   This Python code performs a sophisticated nonlinear static pushover analysis
10  on a 2D reinforced concrete frame, evaluating the effects of strain hardening and
11  ultimate strain criteria on structural behavior.
12  Key engineering aspects include:
13
14  1. Imperfection Modeling: The analysis incorporates initial geometric imperfections
15   in columns using a half-sine wave pattern (ε = 0.1% of column length) to trigger realistic buckling behavi
16
17  2. Material Nonlinearity:
18     - Concrete is modeled with confined (core) and unconfined (cover) properties using Concrete01 material
19     - Steel reinforcement is analyzed both with (Hysteretic) and without (Steel01) strain hardening effects
20
21  3. Section Modeling:
22     - Fiber sections are created for both columns (500x500mm) and beams (300x500mm)
23     - Confinement effects are properly considered in the core concrete regions
24
25  4. Advanced Analysis Features:
26     - Corotational geometric transformation captures large displacement effects
27     - Displacement-controlled analysis with convergence safeguards
28     - 100 elements per column for detailed buckling pattern resolution
29
30  5. Performance Evaluation:
31     - Computes key structural parameters: ductility ratio, overstrength factors
32     - Derives structural behavior coefficients (R factors) per modern seismic codes
33     - Tracks stiffness degradation in three domains: axial, shear, and rotational
34
```

23 %



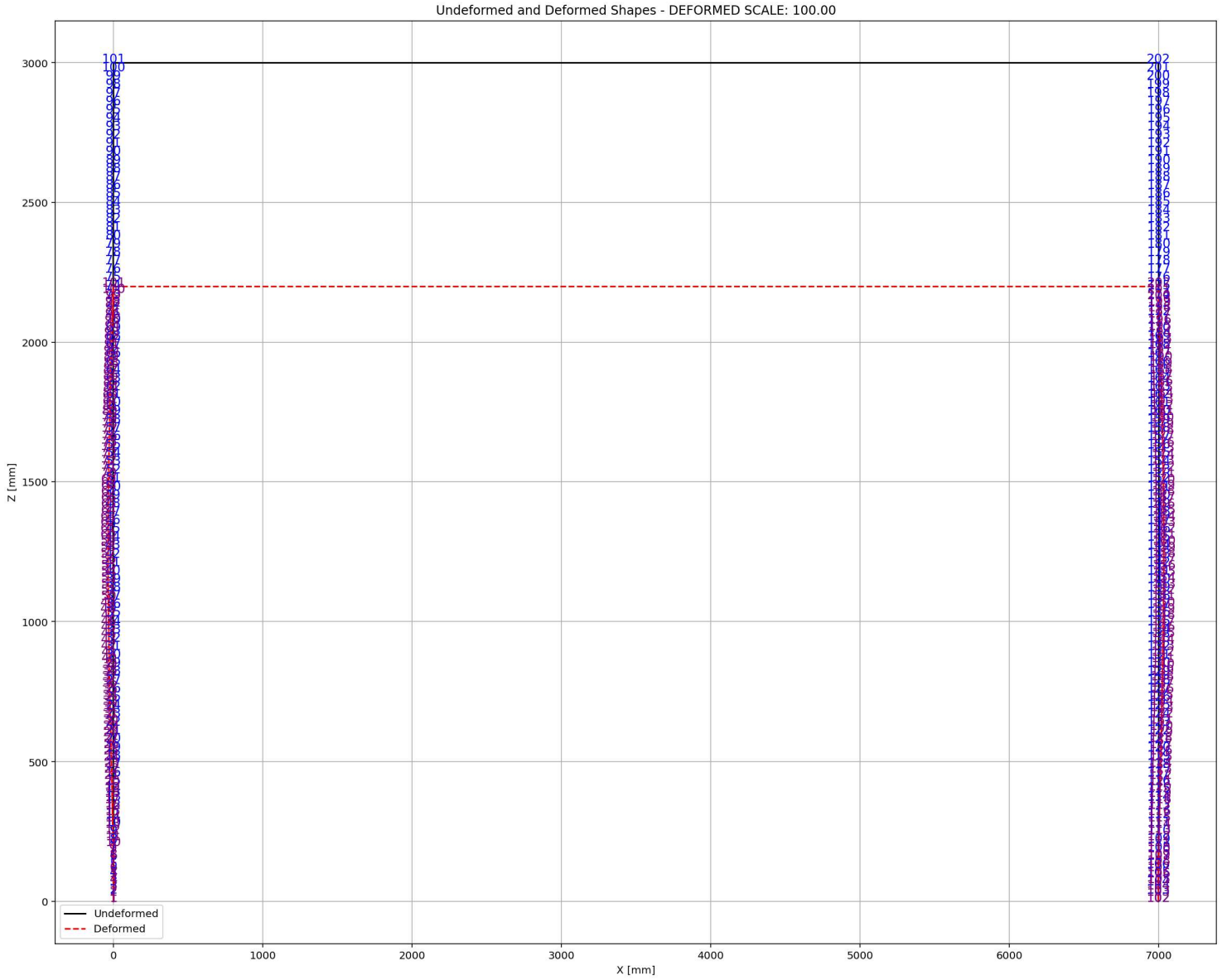
Help | Variable Explorer | Debugger | Plots | Files

Console 1/A

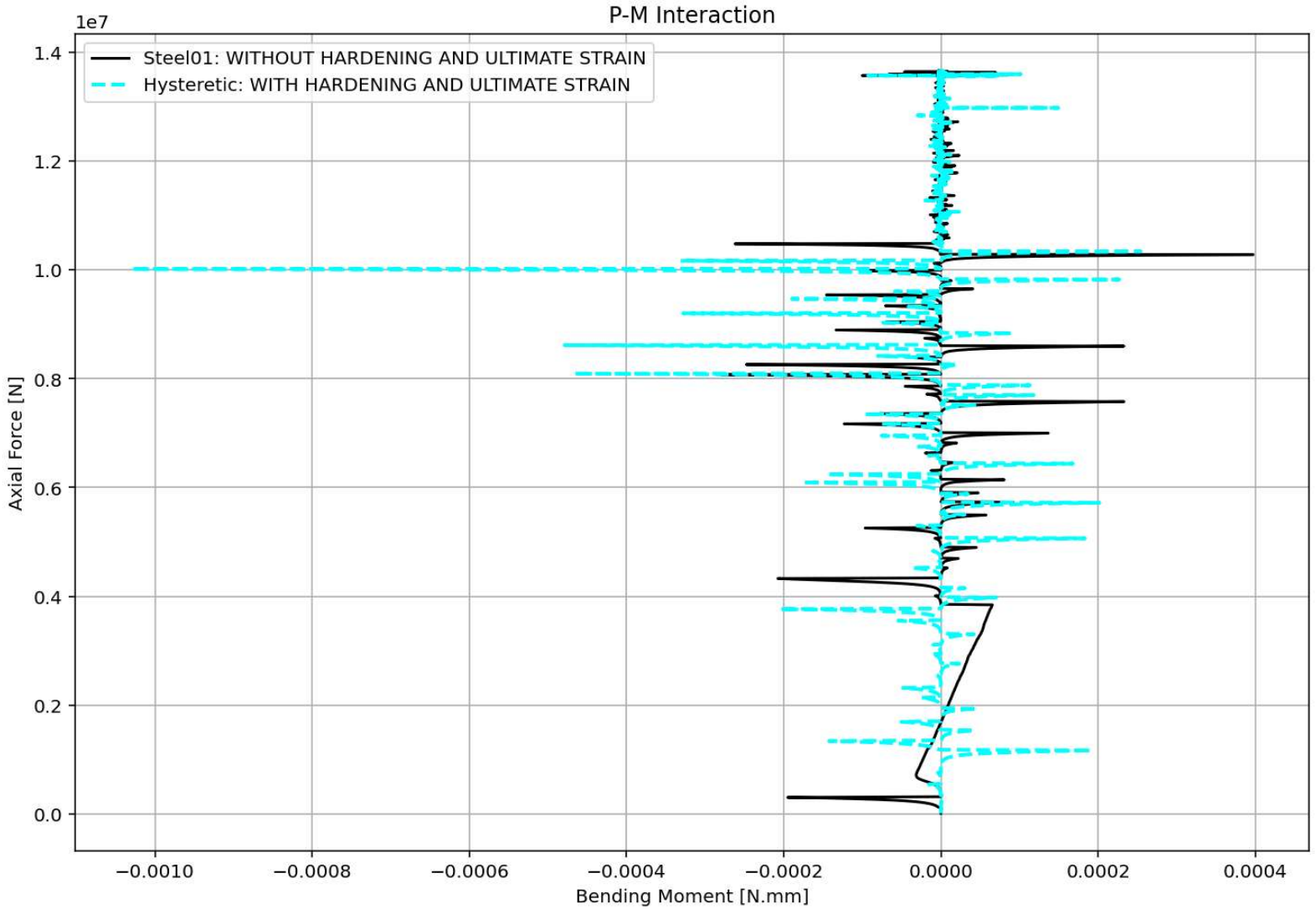
```
Ductility Coefficient (Rμ):          0.6538
Structural Behavior Coefficient (R): 0.0417
+============================+
=   Analysis curve fitted =
     Disp       Baser Shear
----------------------------
[[0.00000000e+00 0.00000000e+00]
 [2.73541850e+00 7.00029388e+06]
 [8.00000000e+00 1.36582941e+07]]
+============================+
+-----------------------------------------------------+
```

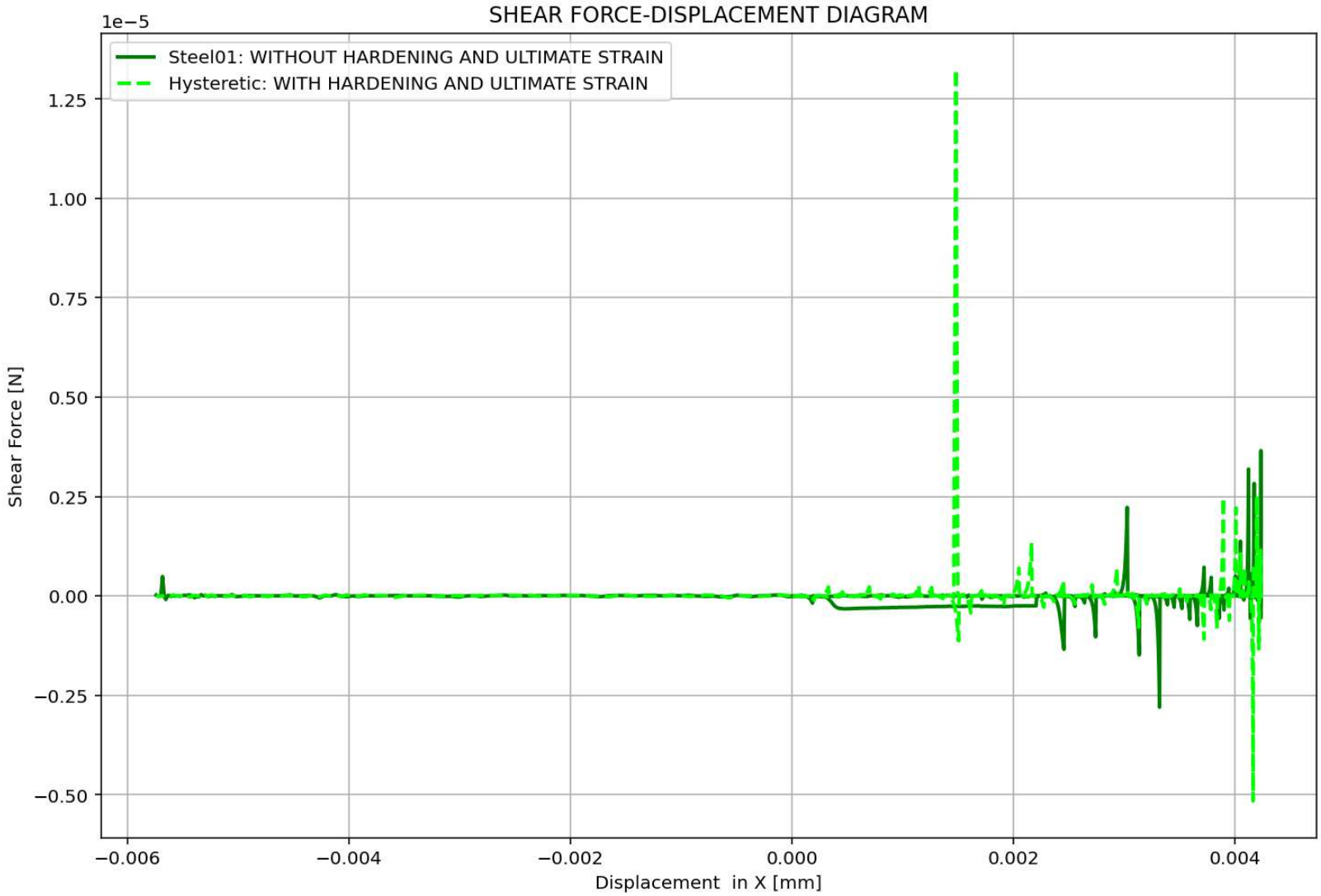
IPython Console | History

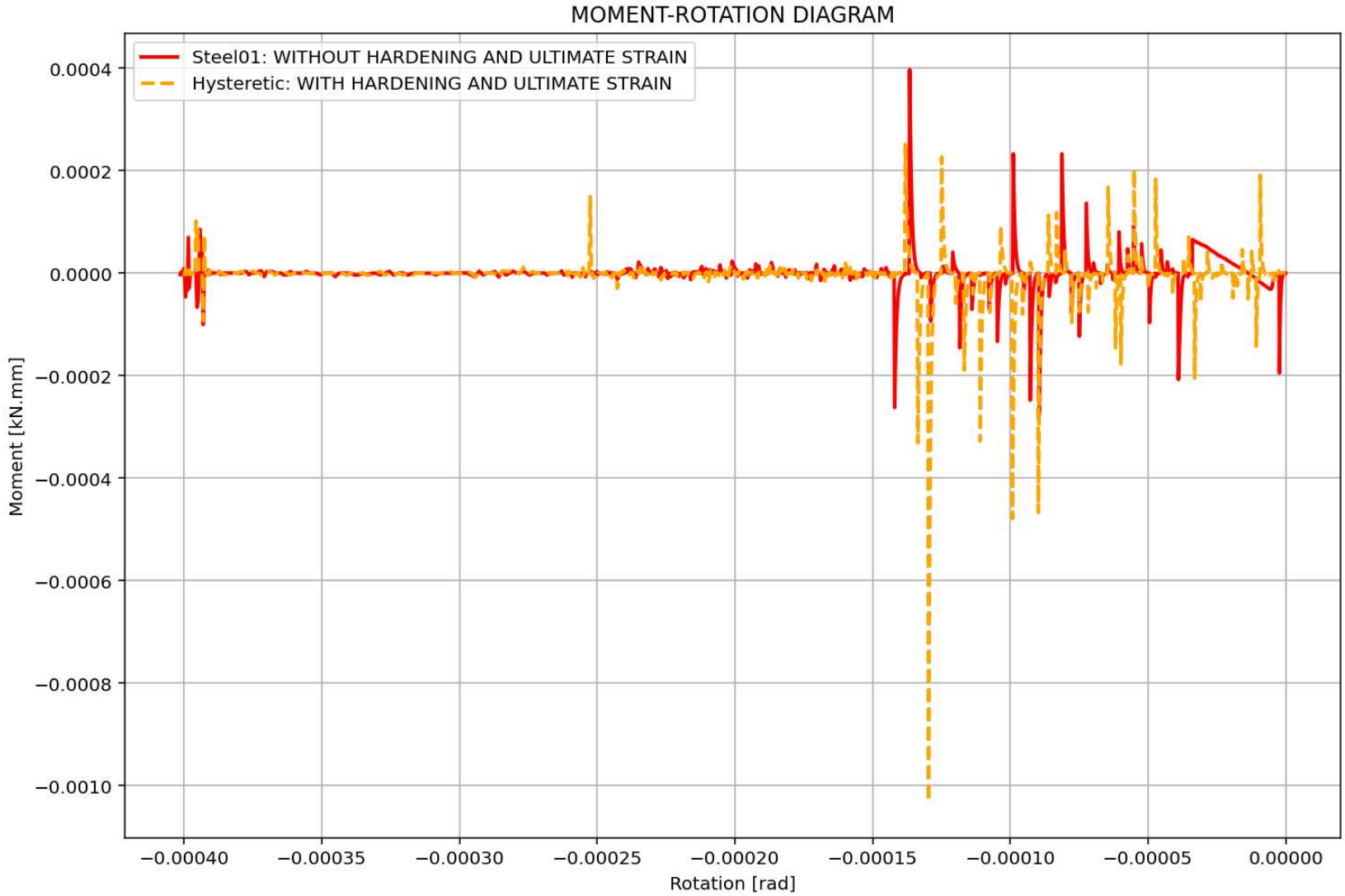
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 119, Col 14 UTF-8 CRLF RW Mem 40%

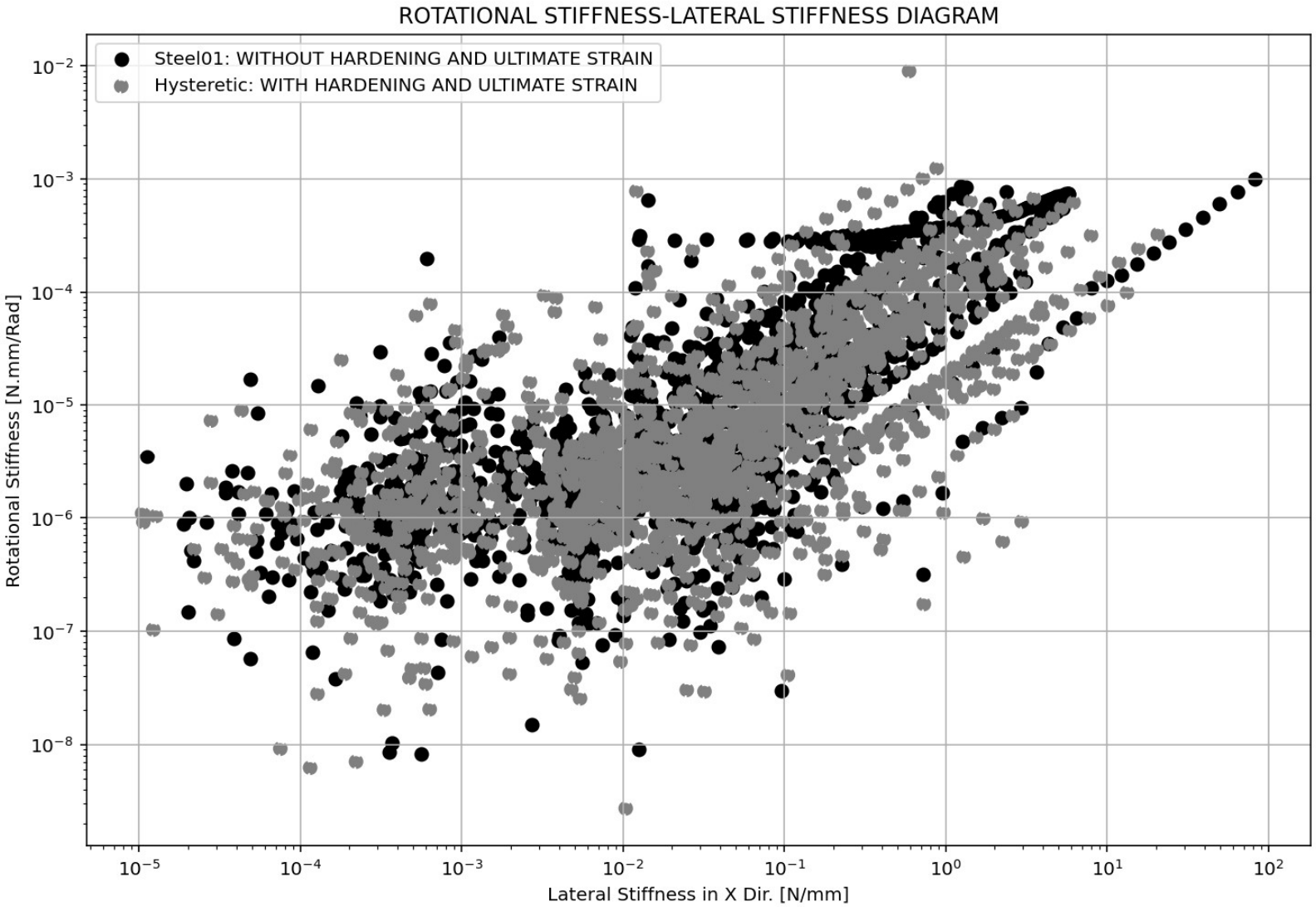

Undeformed and Deformed Shapes - DEFORMED SCALE: 100.00
Z [mm]
X [mm]
Undeformed
Deformed
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000

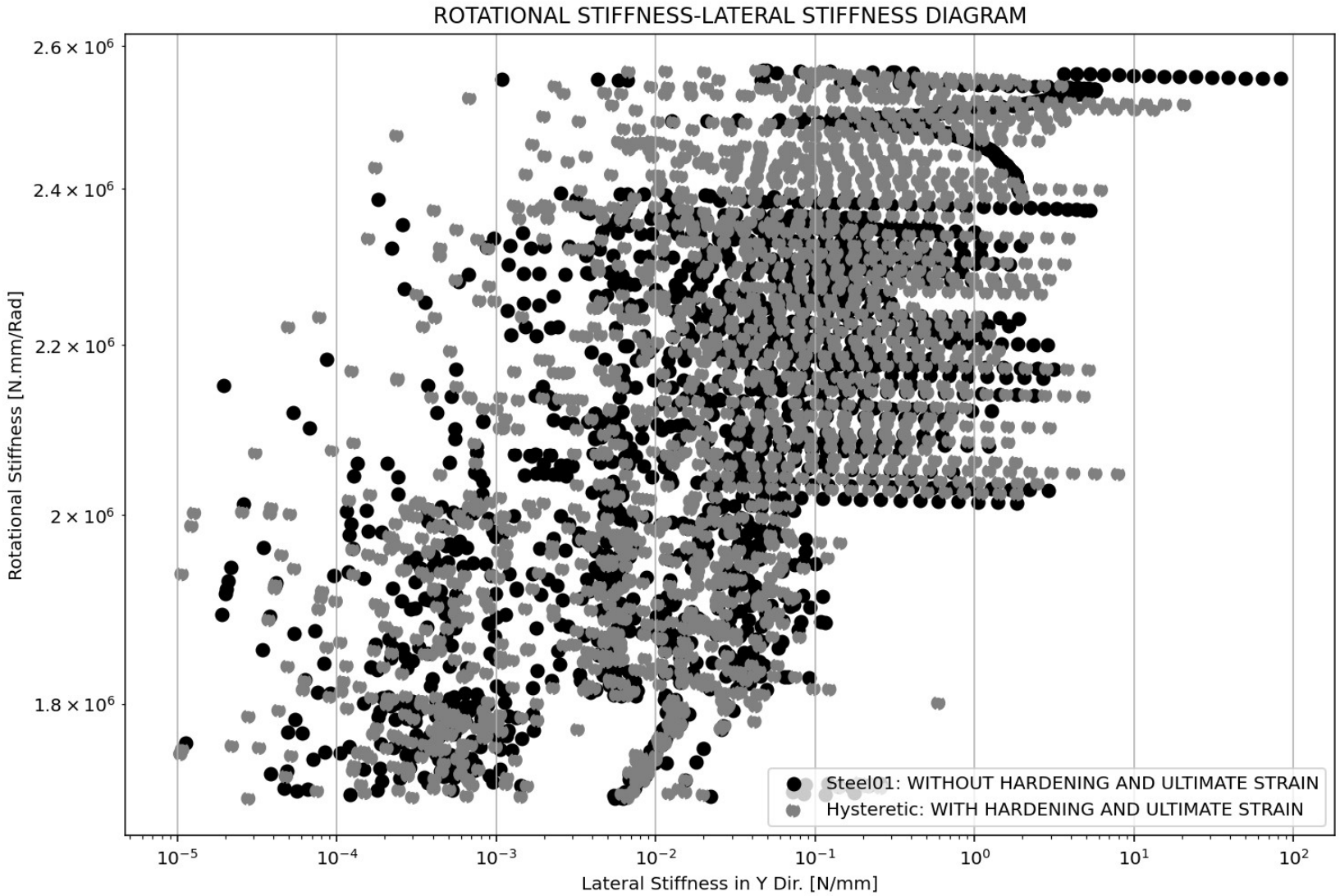
POST-BUCKLING ANALYSIS (PUSHOVER)

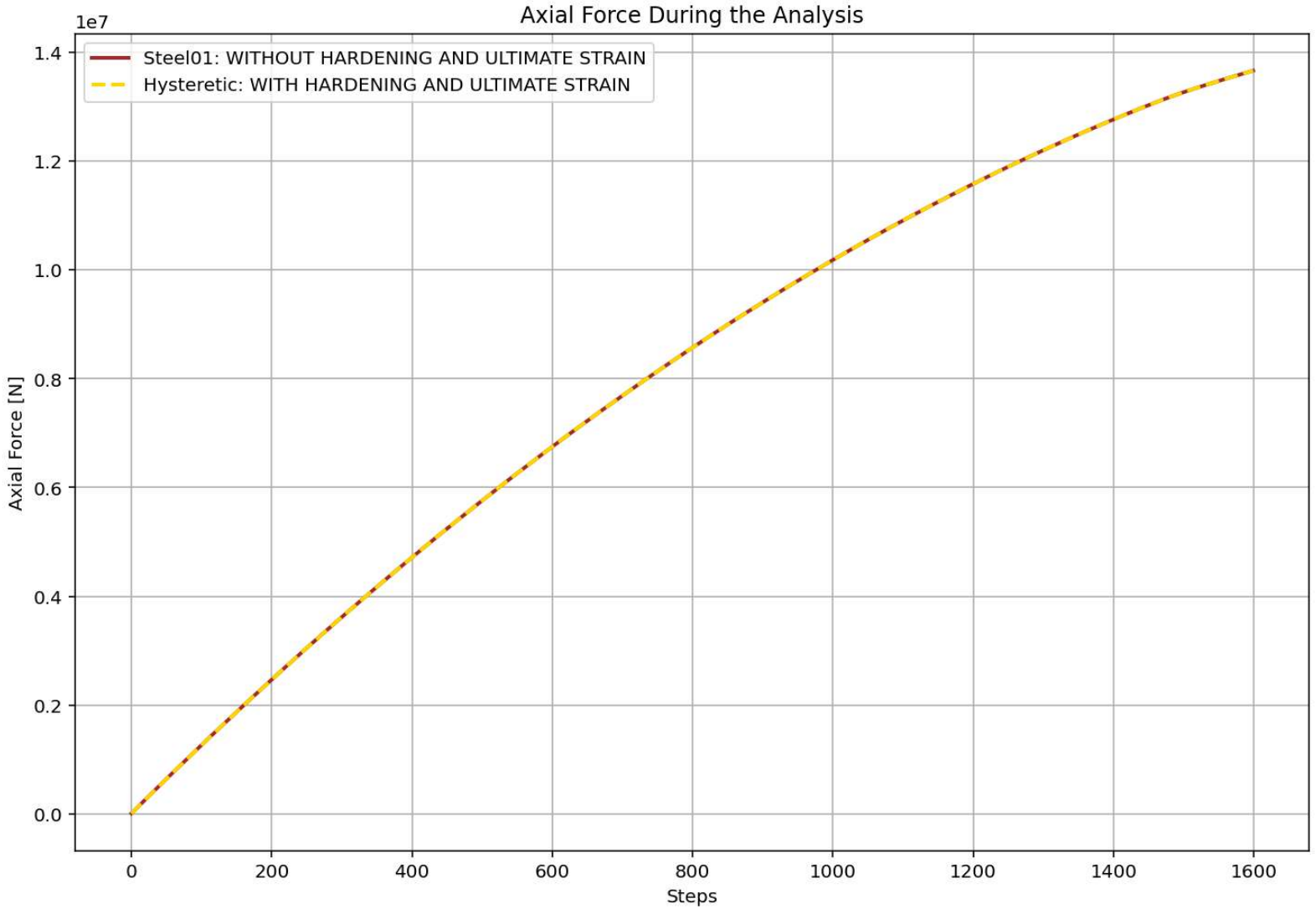

P-M Interaction
1e7
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Axial Force [N]
Bending Moment [N.mm]
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.0010
−0.0008
−0.0006
−0.0004
−0.0002
0.0000
0.0002
0.0004

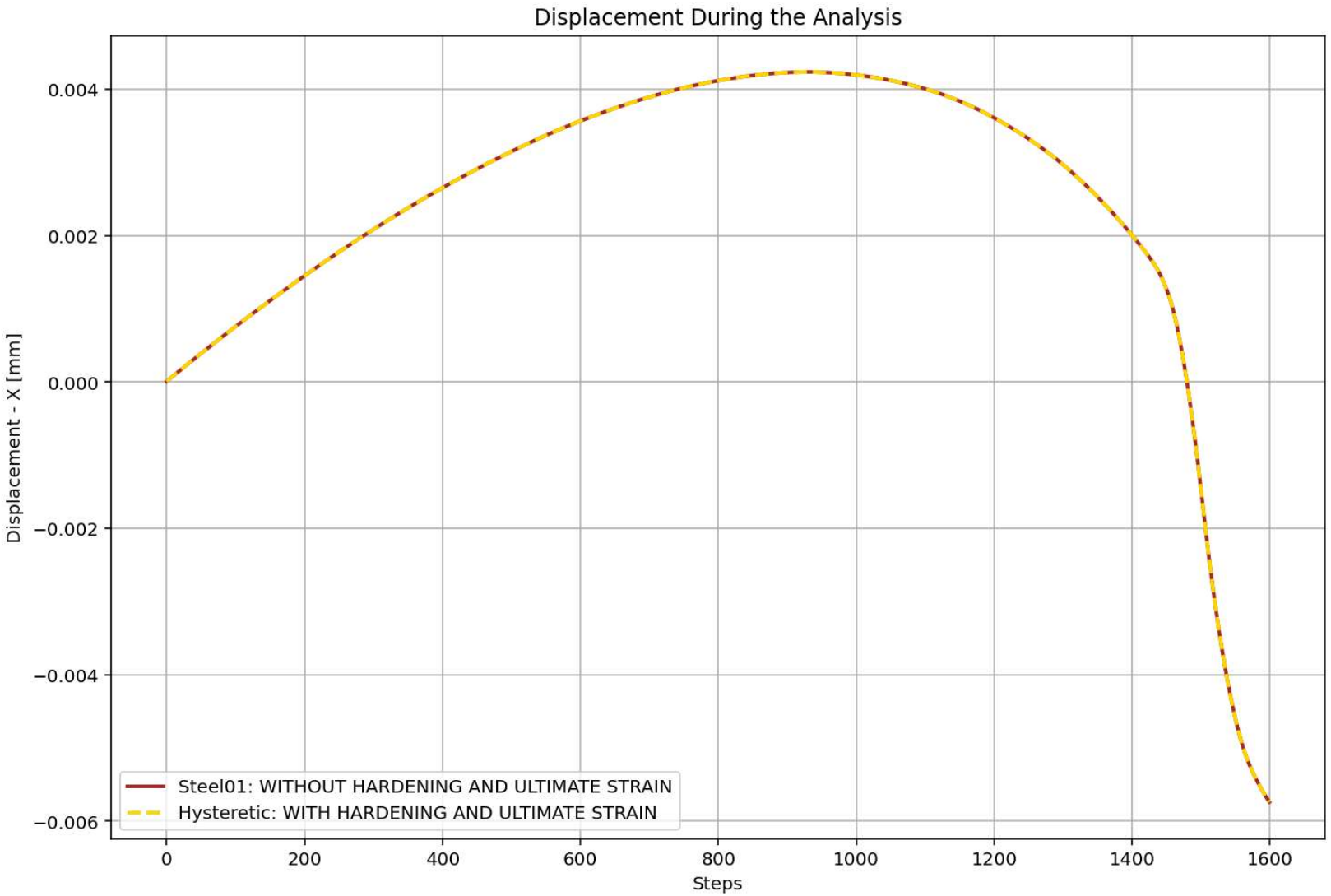

SHEAR FORCE-DISPLACEMENT DIAGRAM
1e−5
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
1.25
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
Shear Force [N]
−0.006
−0.004
−0.002
0.000
0.002
0.004
Displacement in X [mm]

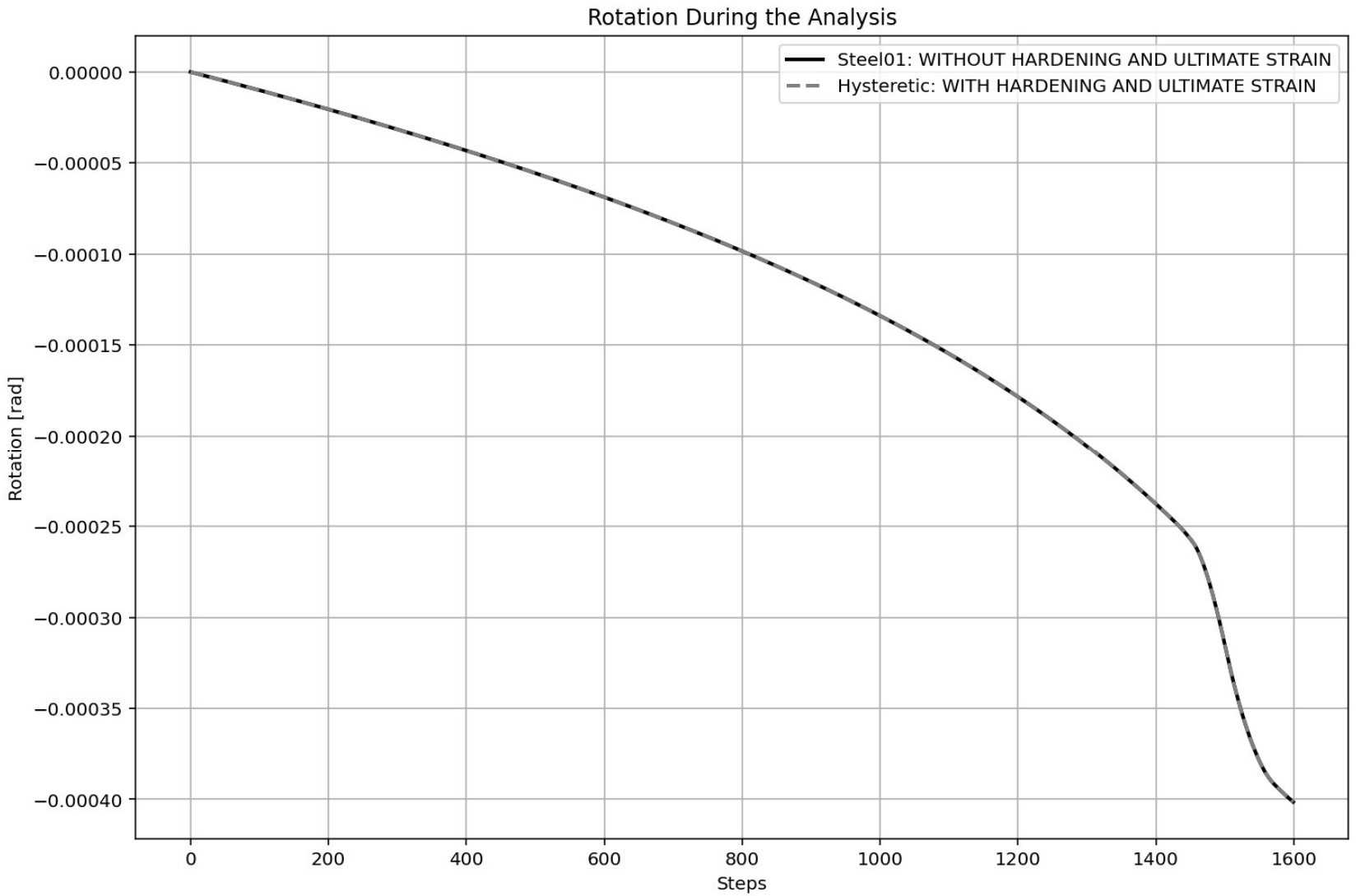

MOMENT-ROTATION DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
0.0004
0.0002
0.0000
−0.0002
−0.0004
−0.0006
−0.0008
−0.0010
Moment [kN.mm]
−0.00040
−0.00035
−0.00030
−0.00025
−0.00020
−0.00015
−0.00010
−0.00005
0.00000
Rotation [rad]

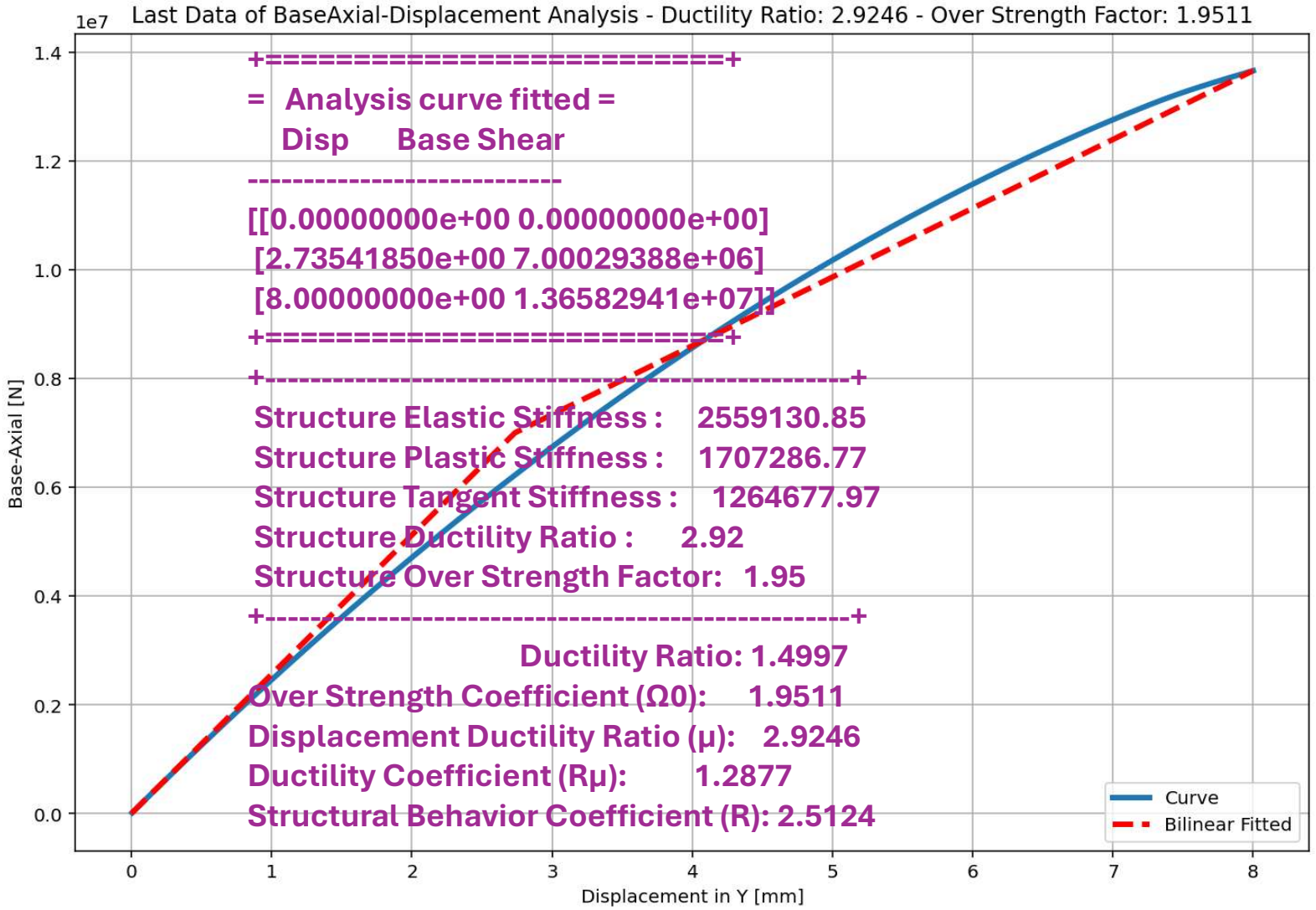

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in X Dir. [N/mm]
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}


ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Rotational Stiffness [N.mm/Rad]
2.6 × 10^6
2.4 × 10^6
2.2 × 10^6
2 × 10^6
1.8 × 10^6
10^−5
10^−4
10^−3
10^−2
10^−1
10^0
10^1
10^2
Lateral Stiffness in Y Dir. [N/mm]
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN


Axial Force During the Analysis
1e7
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Axial Force [N]
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1000
1200
1400
1600
Steps


Displacement During the Analysis
Displacement - X [mm]
0.004
0.002
0.000
−0.002
−0.004
−0.006
0
200
400
600
800
1000
1200
1400
1600
Steps
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN


Rotation During the Analysis
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Rotation [rad]
0.00000
−0.00005
−0.00010
−0.00015
−0.00020
−0.00025
−0.00030
−0.00035
−0.00040
0
200
400
600
800
1000
1200
1400
1600
Steps


Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 2.9246 - Over Strength Factor: 1.9511
1e7
Base-Axial [N]
Displacement in Y [mm]
+============================+
= Analysis curve fitted =
Disp Base Shear

[[0.00000000e+00 0.00000000e+00]
[2.73541850e+00 7.00029388e+06]
[8.00000000e+00 1.36582941e+07]]
+============================+
+---+
Structure Elastic Stiffness : 2559130.85
Structure Plastic Stiffness : 1707286.77
Structure Tangent Stiffness : 1264677.97
Structure Ductility Ratio : 2.92
Structure Over Strength Factor: 1.95
+---+
Ductility Ratio: 1.4997
Over Strength Coefficient (Ω0): 1.9511
Displacement Ductility Ratio (μ): 2.9246
Ductility Coefficient (Rμ): 1.2877
Structural Behavior Coefficient (R): 2.5124
Curve
Bilinear Fitted