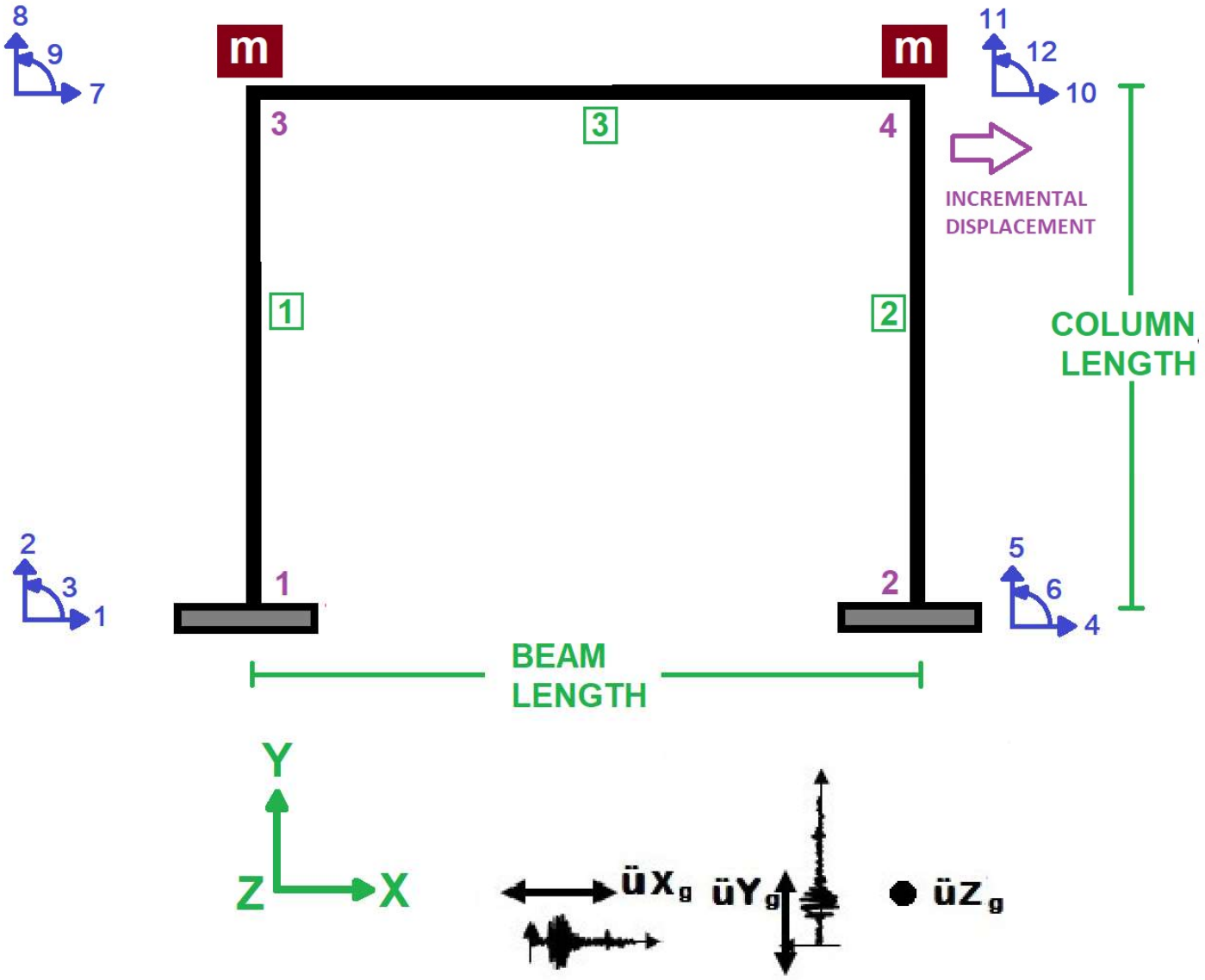
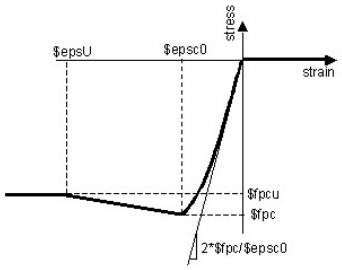
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

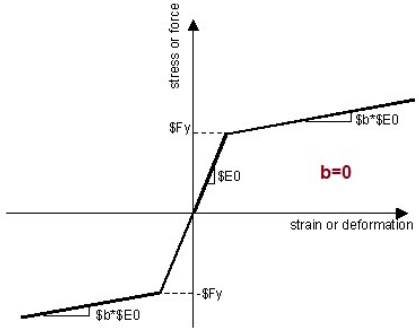
PUSHOVER ANALYSIS OF CONCRETE FRAME. EVALUATING STRAIN HARDENING AND ULTIMATE STRAIN CRITERIA USING OPENSEES AND CALCULATE STRUCTURAL BEHAVIOR COEFFICIENT

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

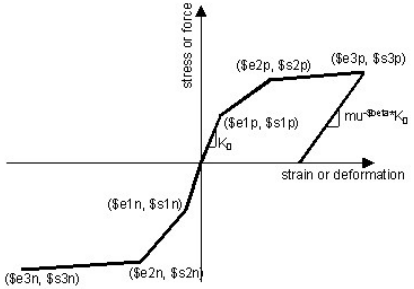

8
9
7
m
m
11
12
10
3
3
4
INCREMENTAL
DISPLACEMENT
1
2
COLUMN
LENGTH
2
3
1
1
2
5
6
4
BEAM
LENGTH
Y
Z
X
üX g
üY g
üZ g



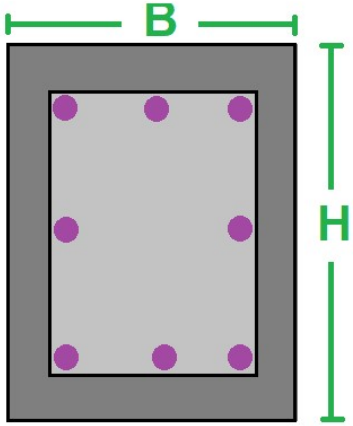
CORE AND COVER CONCRETE RELATION



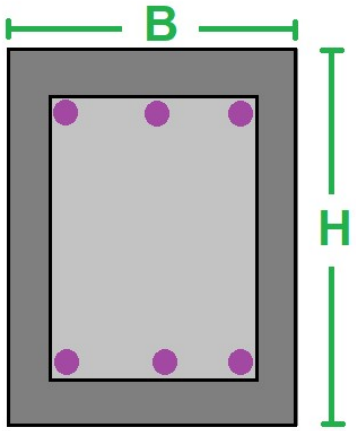
WITHOUT HARDENING AND ULTIMATE STRAIN



WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION

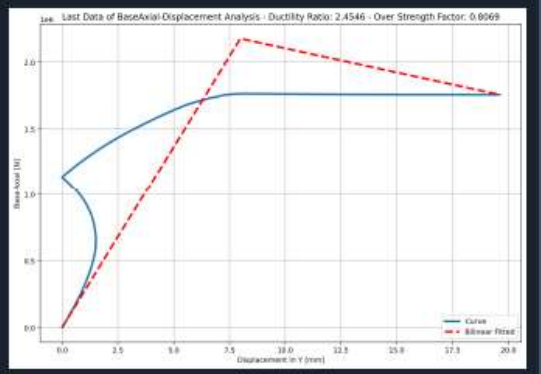
Spyder (Python 3.12)

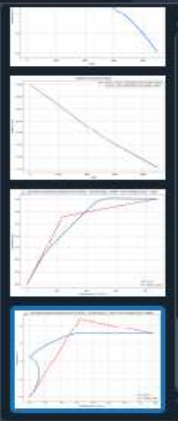
File Edit Search Source Run Debug Consoles Projects Tools View Help

C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRAME_EXAMPLES\PUSHOVER\CONCRETE_FRAME_PUSHOVER.py

CONCRETE_FRAME_PUSHOVER.py

```
#########################################################################################################
#                          >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
# PUSHOVER ANALYSIS OF CONCRETE FRAME. EVALUATING STRAIN HARDENING AND ULTIMATE STRAIN CRITERIA USING OPENS
#                                  AND CALCULATE STRUCTURAL BEHAVIOR COEFFICIENT
#---------------------------------------------------------------------------------------------------------
#                              THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                       EMAIL: salar.d.ghashghaei@gmail.com
#########################################################################################################
"""
1. The analysis compares nonlinear rotational behavior of concrete beam-column
 elements under pushover lateral displacements using OpenSees.
2. Two material models—*Steel01* (bilinear without degradation) and *Hysteretic*
 (tri-linear with pinching and strength/stiffness degradation)—are used.
3. Both models are subjected to identical loading protocols to investigate pushover
 response under increasing drift demands.
4. The *Steel01* model exhibits stable hysteresis loops with no degradation, reflecting
 idealized elastic-plastic behavior.
5. In contrast, the *Hysteretic* model shows strength and stiffness degradation, capturing
 post-peak deterioration and pinching effects.
6. Element rotation histories reveal increasing divergence as inelastic demand accumulates
 across cycles.
7. The *Hysteretic* model produces reduced energy dissipation capacity due to pinching and
cumulative damage.
8. Peak rotation capacity is reduced in the *Hysteretic* model, indicating realistic modeling
 of damage and failure modes.
9. The comparison highlights the limitations of bilinear idealizations in capturing cyclic
 degradation in seismic applications.
10. Advanced modeling with calibrated degradation parameters is essential for accurate
 seismic performance prediction and collapse assessment.
"""
import openseespy.opensees as ops
import matplotlib.pyplot as plt
import numpy as np
import time as TI
```





Help Variable Explorer Debugger Plots Files

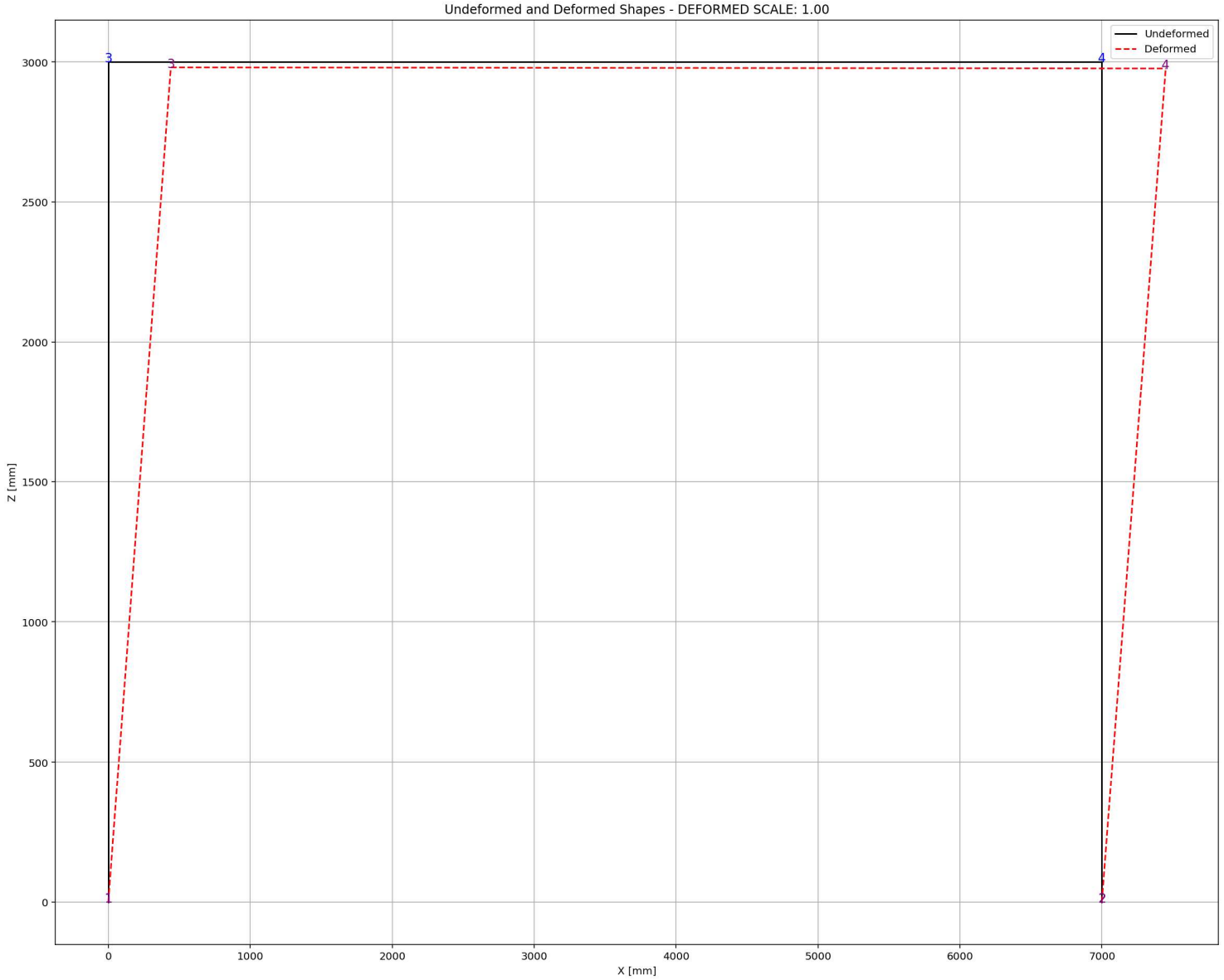
Console 1/A

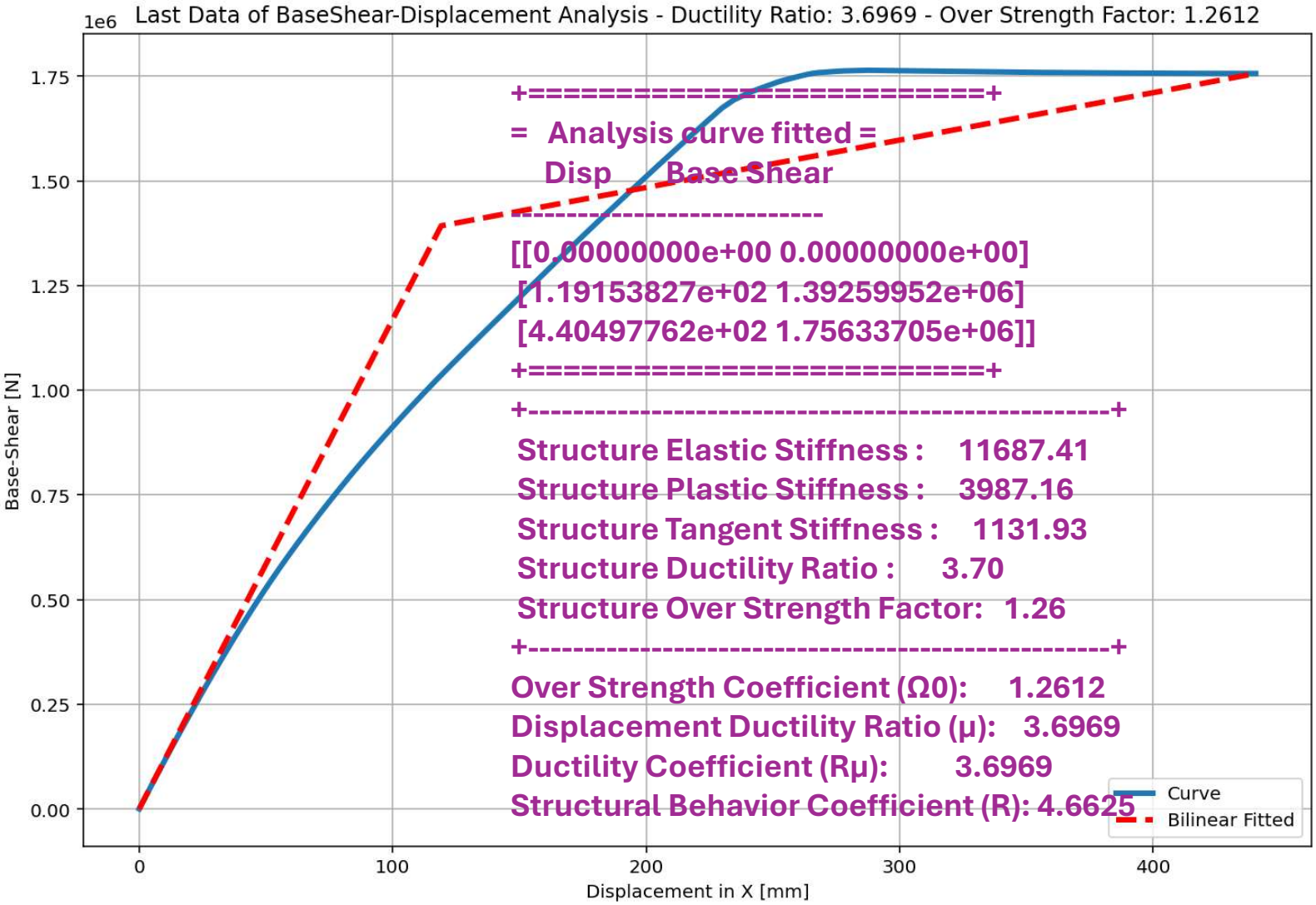
```
Displacement Ductility Ratio (μ):    3.6969
Ductility Coefficient (Rμ):          3.6969
Structural Behavior Coefficient (R): 4.6625
+==========================+
=   Analysis curve fitted =
     Disp        Base Shear
----------------------------
[[0.00000000e+00 0.00000000e+00]
 [7.98659734e+00 2.17669541e+06]
 [1.96042295e+01 1.75633705e+06]]
+==========================+
+----------------------------------------------------------+
```

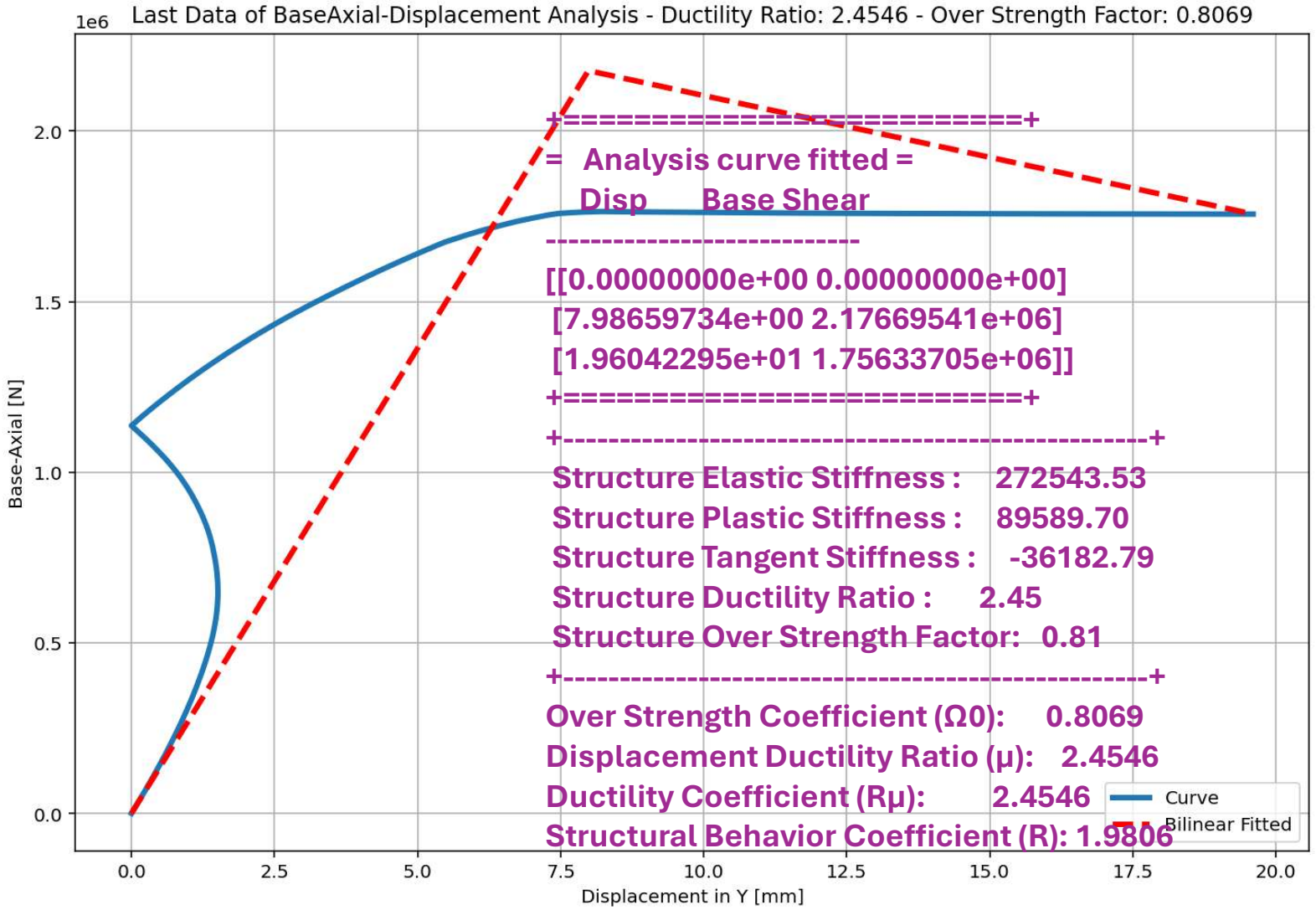
IPython Console History

Conda: anaconda3 (Python 3.12.7) LSP: Python Line 209, Col 1 UTF-8 CRLF R/W Mem 43%

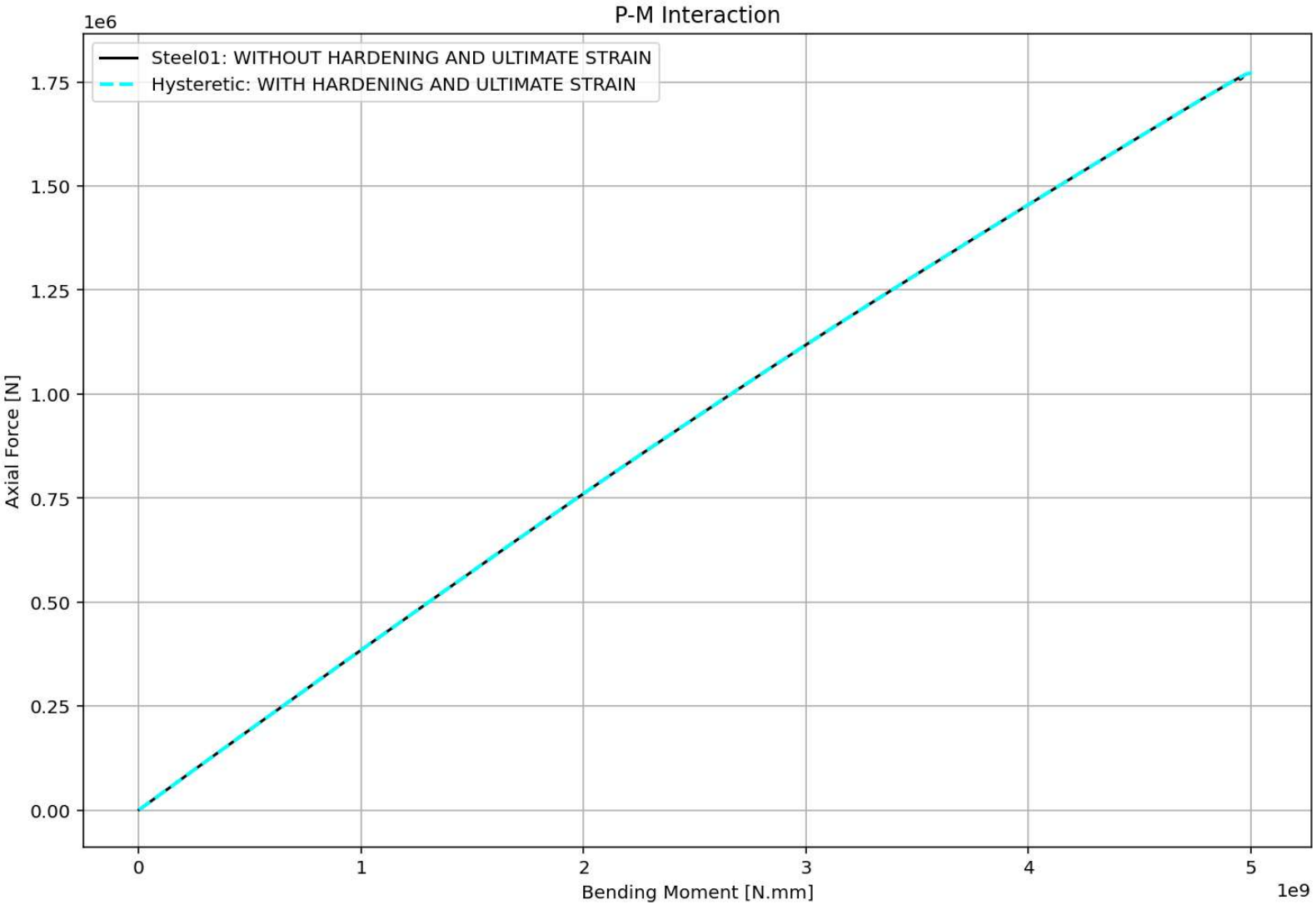
NONLINEAR STATIC ANALYSIS (PUSHOVER)

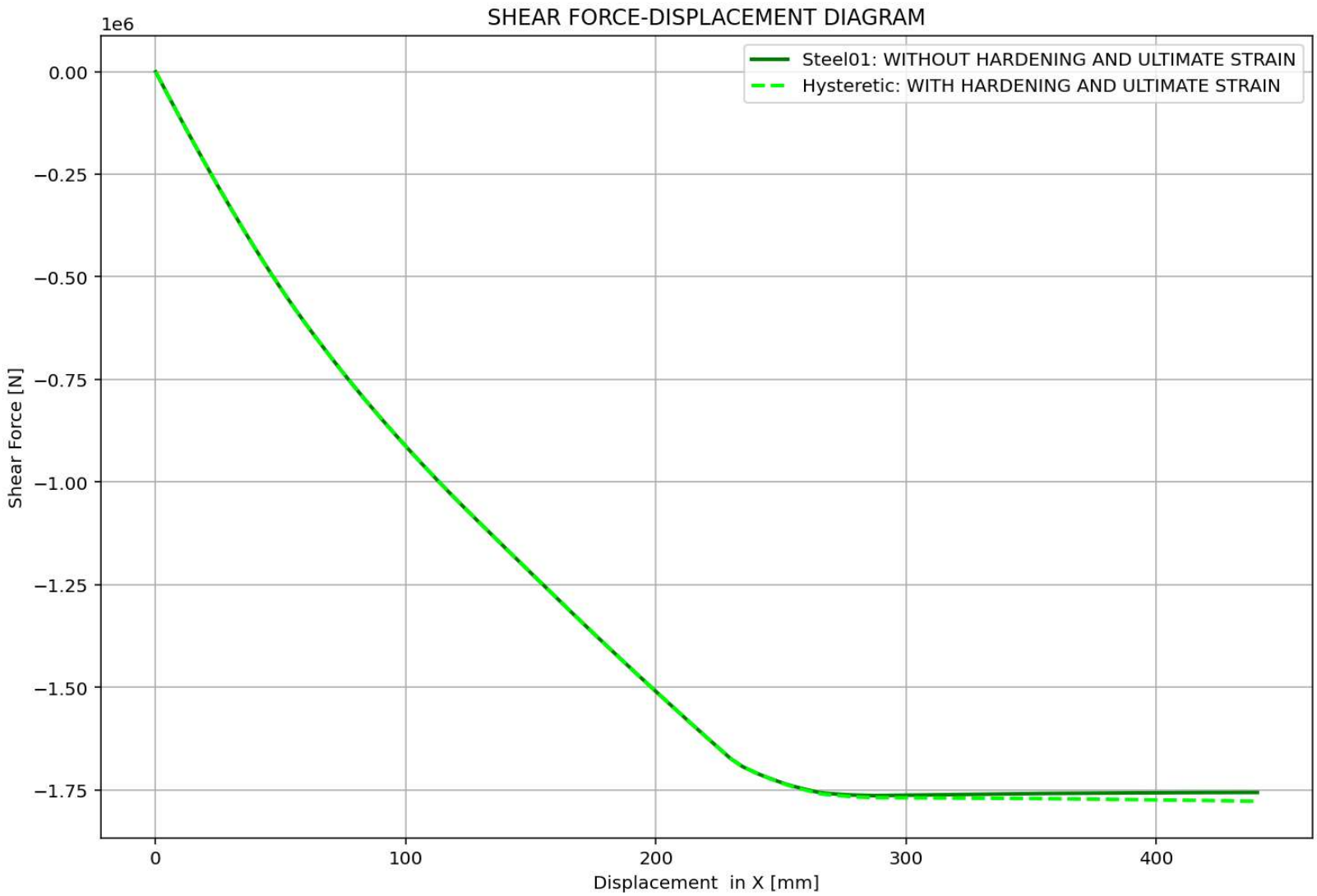

Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
1
2
3
3
4
4

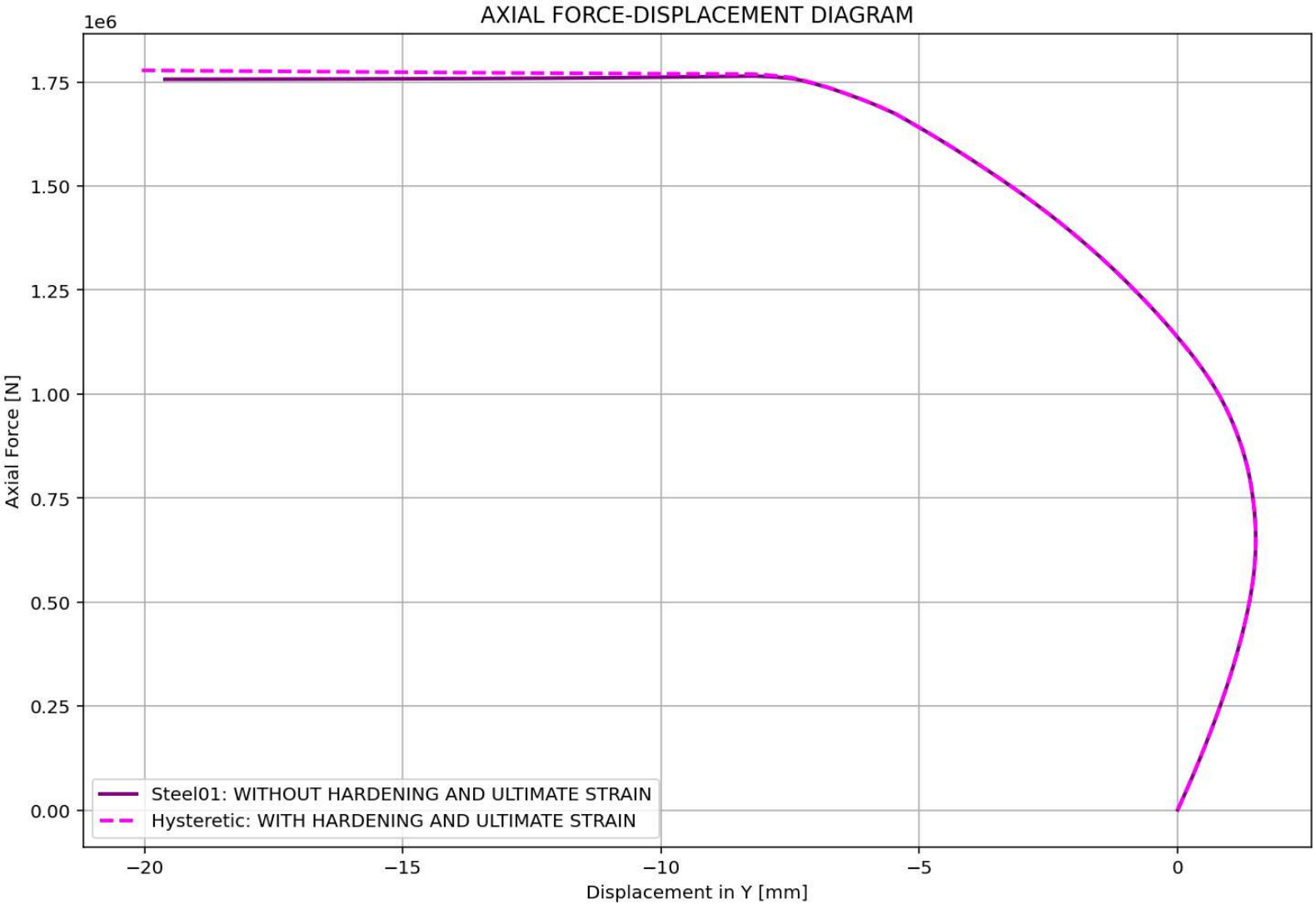

Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 3.6969 - Over Strength Factor: 1.2612
1e6
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Base-Shear [N]
0
100
200
300
400
Displacement in X [mm]
+==========================+
= Analysis curve fitted =
Disp Base Shear
[[0.00000000e+00 0.00000000e+00]
[1.19153827e+02 1.39259952e+06]
[4.40497762e+02 1.75633705e+06]]
+==========================+
+--+
Structure Elastic Stiffness : 11687.41
Structure Plastic Stiffness : 3987.16
Structure Tangent Stiffness : 1131.93
Structure Ductility Ratio : 3.70
Structure Over Strength Factor: 1.26
+--+
Over Strength Coefficient (Ω0): 1.2612
Displacement Ductility Ratio (μ): 3.6969
Ductility Coefficient (Rμ): 3.6969
Structural Behavior Coefficient (R): 4.6625
Curve
Bilinear Fitted

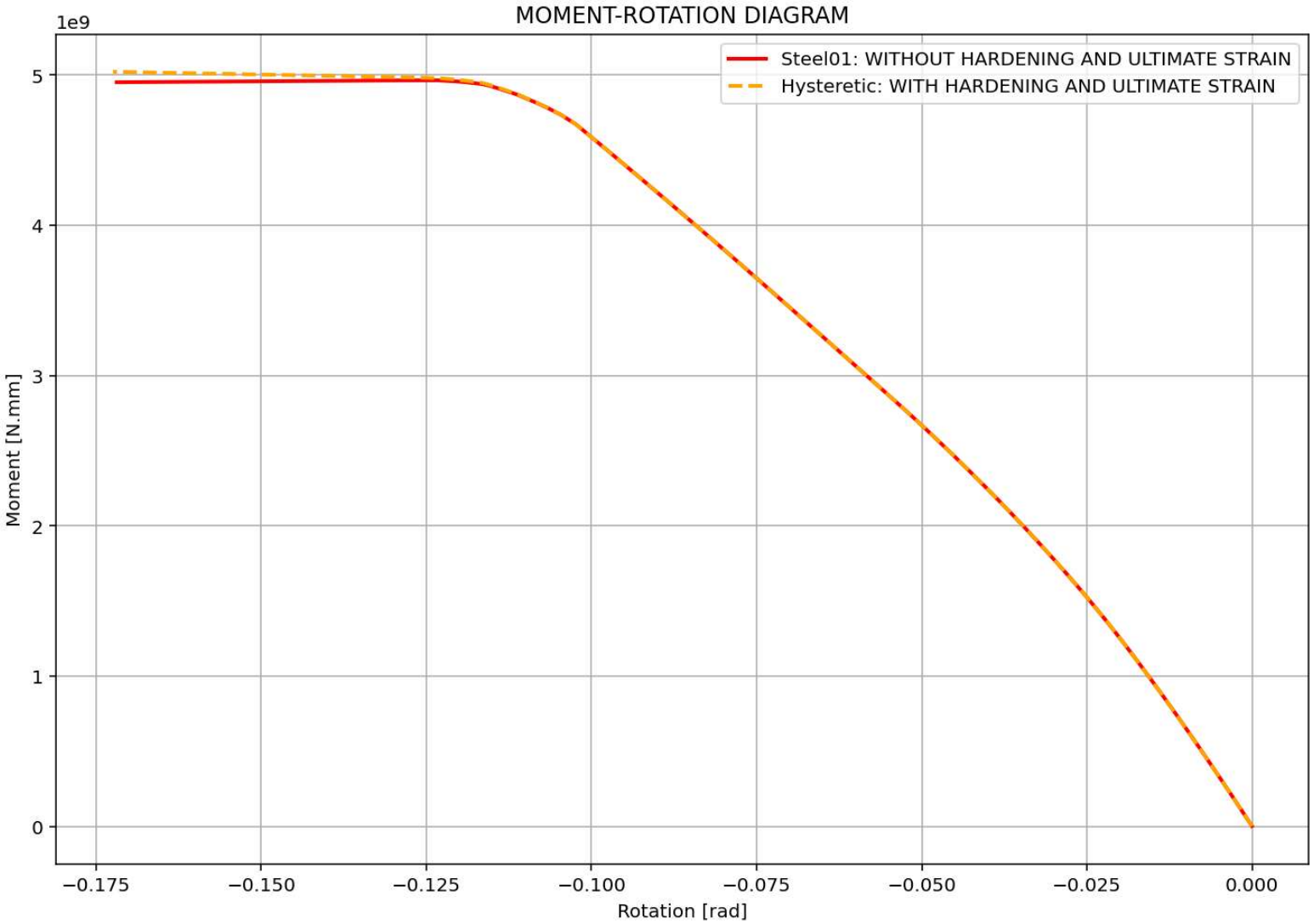

Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 2.4546 - Over Strength Factor: 0.8069
1e6
Base-Axial [N]
Displacement in Y [mm]
0.0
0.5
1.0
1.5
2.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
+============================+
= Analysis curve fitted =
Disp Base Shear

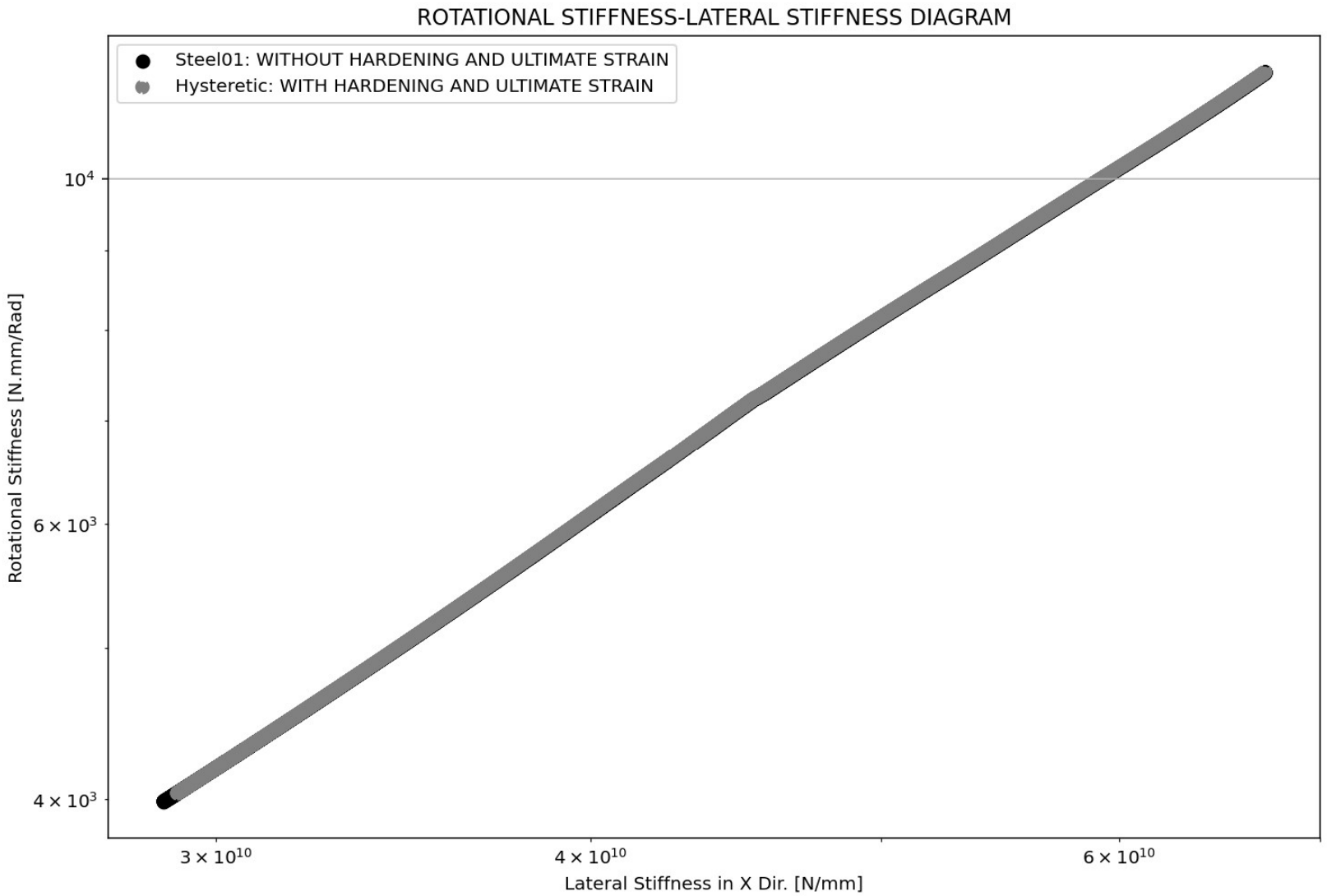
[[0.00000000e+00 0.00000000e+00]
[7.98659734e+00 2.17669541e+06]
[1.96042295e+01 1.75633705e+06]]
+============================+
+---+
Structure Elastic Stiffness : 272543.53
Structure Plastic Stiffness : 89589.70
Structure Tangent Stiffness : -36182.79
Structure Ductility Ratio : 2.45
Structure Over Strength Factor: 0.81
+---+
Over Strength Coefficient (Ω0): 0.8069
Displacement Ductility Ratio (μ): 2.4546
Ductility Coefficient (Rμ): 2.4546
Structural Behavior Coefficient (R): 1.9806
Curve
Bilinear Fitted

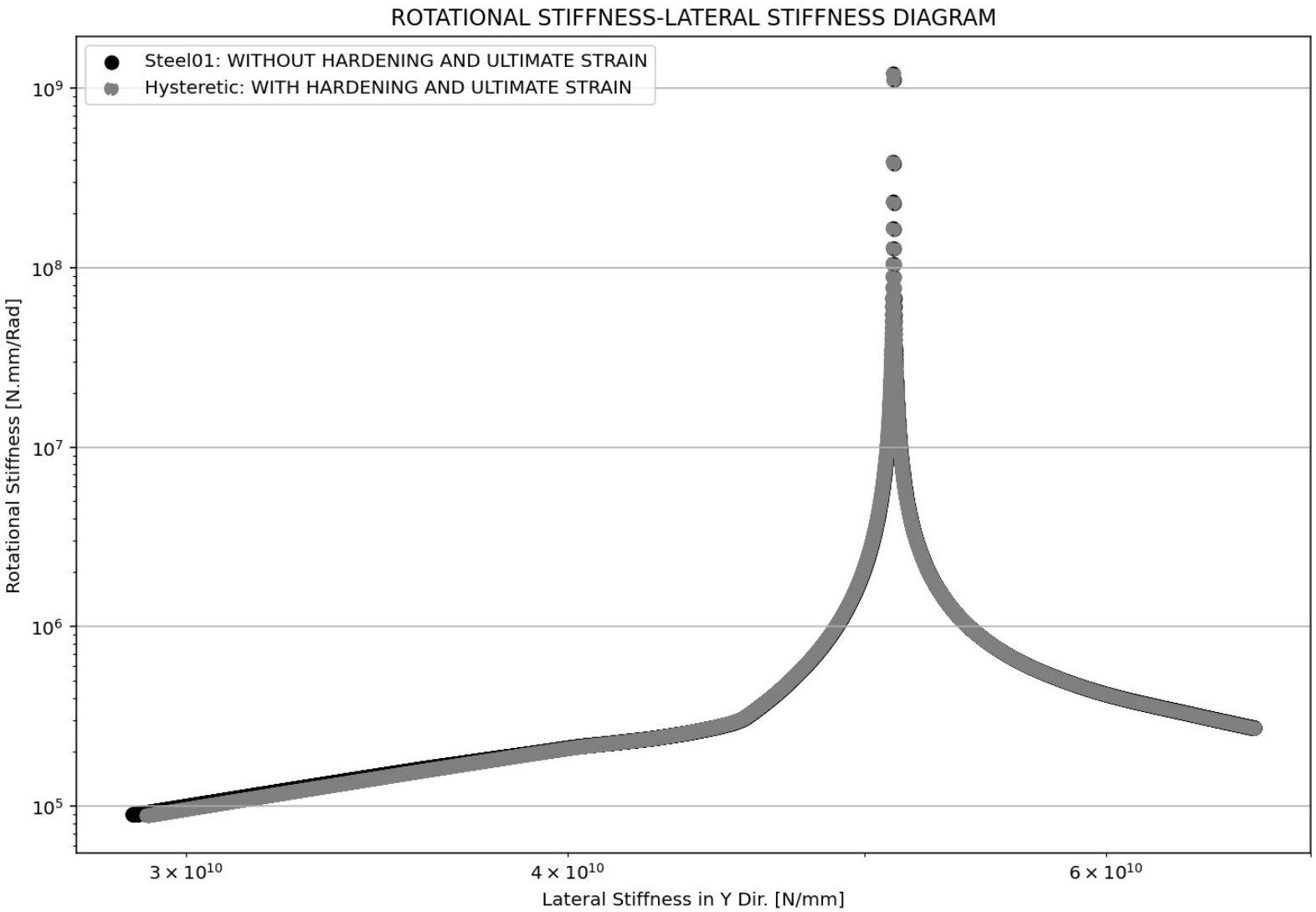

P-M Interaction
1e6
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Axial Force [N]
0
1
2
3
4
5
1e9
Bending Moment [N.mm]


SHEAR FORCE-DISPLACEMENT DIAGRAM
1e6
0.00
−0.25
−0.50
−0.75
−1.00
−1.25
−1.50
−1.75
Shear Force [N]
0
100
200
300
400
Displacement in X [mm]
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN


AXIAL FORCE-DISPLACEMENT DIAGRAM
1e6
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Axial Force [N]
−20
−15
−10
−5
0
Displacement in Y [mm]
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN


MOMENT-ROTATION DIAGRAM
1e9
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Moment [N.mm]
Rotation [rad]
5
4
3
2
1
0
−0.175
−0.150
−0.125
−0.100
−0.075
−0.050
−0.025
0.000


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


ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
10^9
10^8
10^7
10^6
10^5
Rotational Stiffness [N.mm/Rad]
3×10^{10}
4×10^{10}
6×10^{10}
Lateral Stiffness in Y Dir. [N/mm]