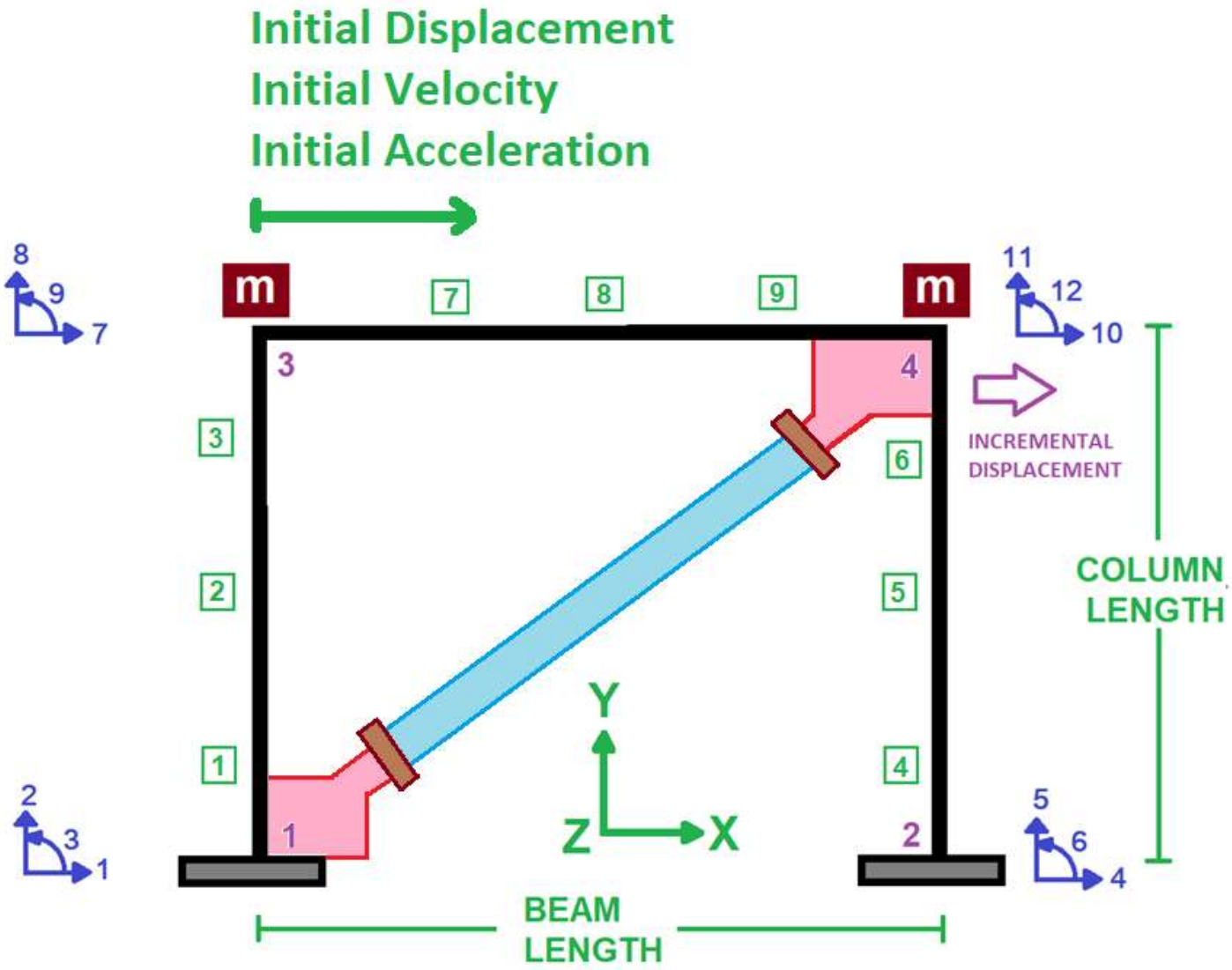
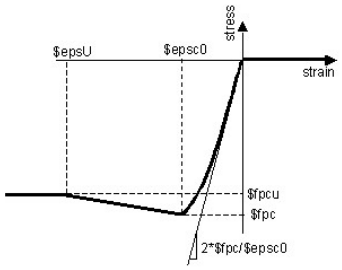
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

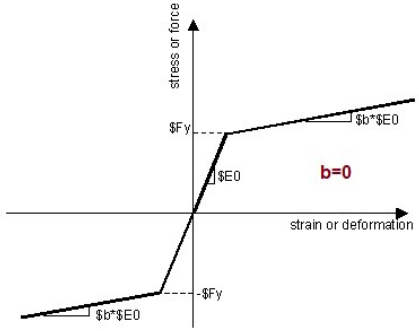
COMPARATIVE STUDY OF ELASTIC AND INELASTIC STRUCTURAL BEHAVIOR THROUGH PUSHOVER DYNAMIC ANALYSIS. FREE-VIBRATION ANALYSIS OF CONCRETE FRAME WITH VISCOUS DAMPER USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

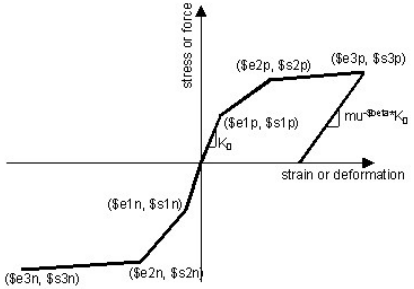

Initial Displacement
Initial Velocity
Initial Acceleration
m
m
7
8
9
3
4
6
5
1
2
INCREMENTAL
DISPLACEMENT
COLUMN
LENGTH
Y
Z
X
BEAM
LENGTH
8
9
7
11
12
10
2
3
1
5
6
4



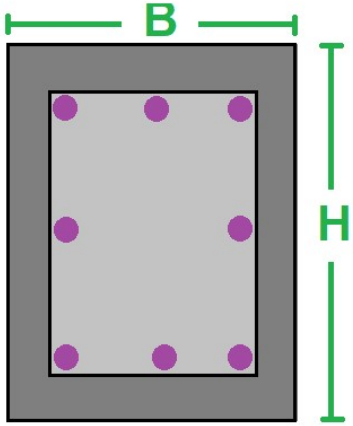
CORE AND COVER CONCRETE RELATION



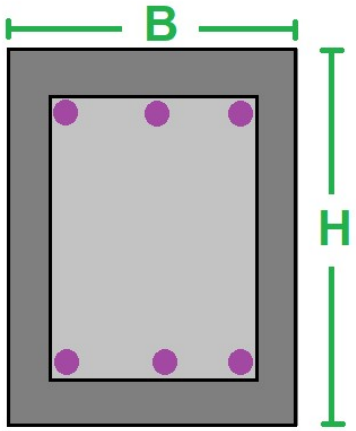
WITHOUT HARDENING AND ULTIMATE STRAIN



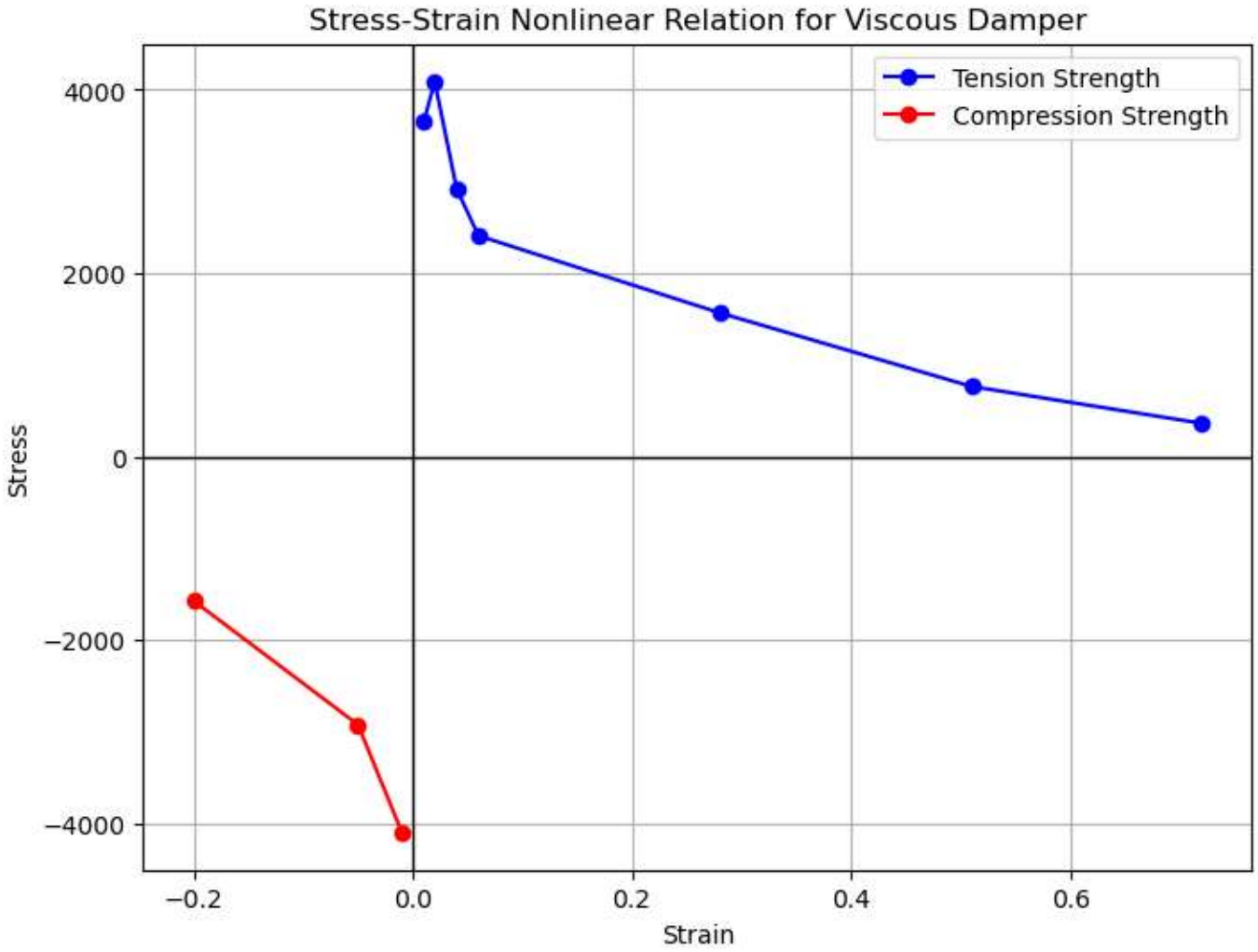
WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION


Stress-Strain Nonlinear Relation for Viscous Damper
Tension Strength
Compression Strength
Stress
Strain
4000
2000
0
−2000
−4000
−0.2
0.0
0.2
0.4
0.6

Spyder (Python 3.12)

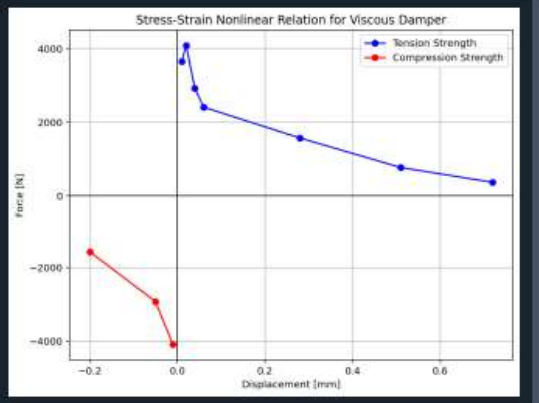
File Edit Search Source Run Debug Consoles Projects Tools View Help

...AME_EXAMPLES\VISCOUS_DAMPER\VISCOUS_DAMPER_FREE_VIBRATION

C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA..._INELASTIC_FRAME_FREE_VIBRATION_VISCOUS_DAMPER.py

CONFINEMENT_NONCON..._VISCOUS_DAMPER.py

```
##########################################################################################################
#                          >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
#                    COMPARATIVE STUDY OF ELASTIC AND INELASTIC STRUCTURAL BEHAVIOR THROUGH PUSHOVER
#                FREE-VIBRATION ANALYSIS USING OPENSEES ANALYSIS OF CONCRETE FRAME WITH VISCOUS DAMPER.
#----------------------------------------------------------------------------------------------------------
#                                THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                          EMAIL: salar.d.ghashghaei@gmail.com
##########################################################################################################
"""
1. The script performs a comparative study of elastic and inelastic structural behavior using pushover and d
2. It models a 2D reinforced concrete frame with columns (500x500mm) and beams (500x300mm) using nonlinear b
3. Material definitions include confined/unconfined concrete (fc=25MPa) and bilinear steel reinforcement (wi
4. Two analysis types are implemented: static pushover (displacement-controlled) and dynamic time-history an
5. Rayleigh damping is calculated based on initial modal periods and target damping ratios (5%).
6. The pushover analysis applies incremental displacements up to 675mm, recording base reactions and drifts.
7. Dynamic analysis uses Newmark integration with ground motion inputs scaled by 0.01g (El Centro records in
8. Key outputs include force-displacement curves, moment-rotation relationships, and stiffness degradation p
9. Eigenvalue analysis tracks period elongation due to inelasticity during dynamic events.
10. Damage indices are computed for ductility assessment using bilinear curve fitting.
11. Overstrength factors (Ω), ductility ratios (μ), and R-factors are quantified for seismic performance eva
12. Real-time monitoring of base shear, axial forces, and interstory drifts is implemented.
13. The script includes advanced convergence controls (Newton-Raphson, 1e-6 tolerance).
14. Confinement effects are modeled with variable enhancement ratios (Kc=1.25 for columns).
15. Results are exported to Excel, including displacements, forces, stiffness, and period data.
16. Visualization includes deformed shapes, hysteresis loops, and cumulative response envelopes.
17. Damping ratios are estimated from free vibration decay in dynamic analyses.
18. Both geometric nonlinearities (P-Delta/Corotational) and material nonlinearities are considered.
19. The code supports parametric studies by varying steel models (with/without hardening) and element types.
20. Comprehensive plotting functions enable side-by-side comparison of elastic vs. inelastic responses for d

-----------------------------------------------------------------
Viscous Dampers:

Definition:
```



32 %

Help Variable Explorer Debugger Plots Files

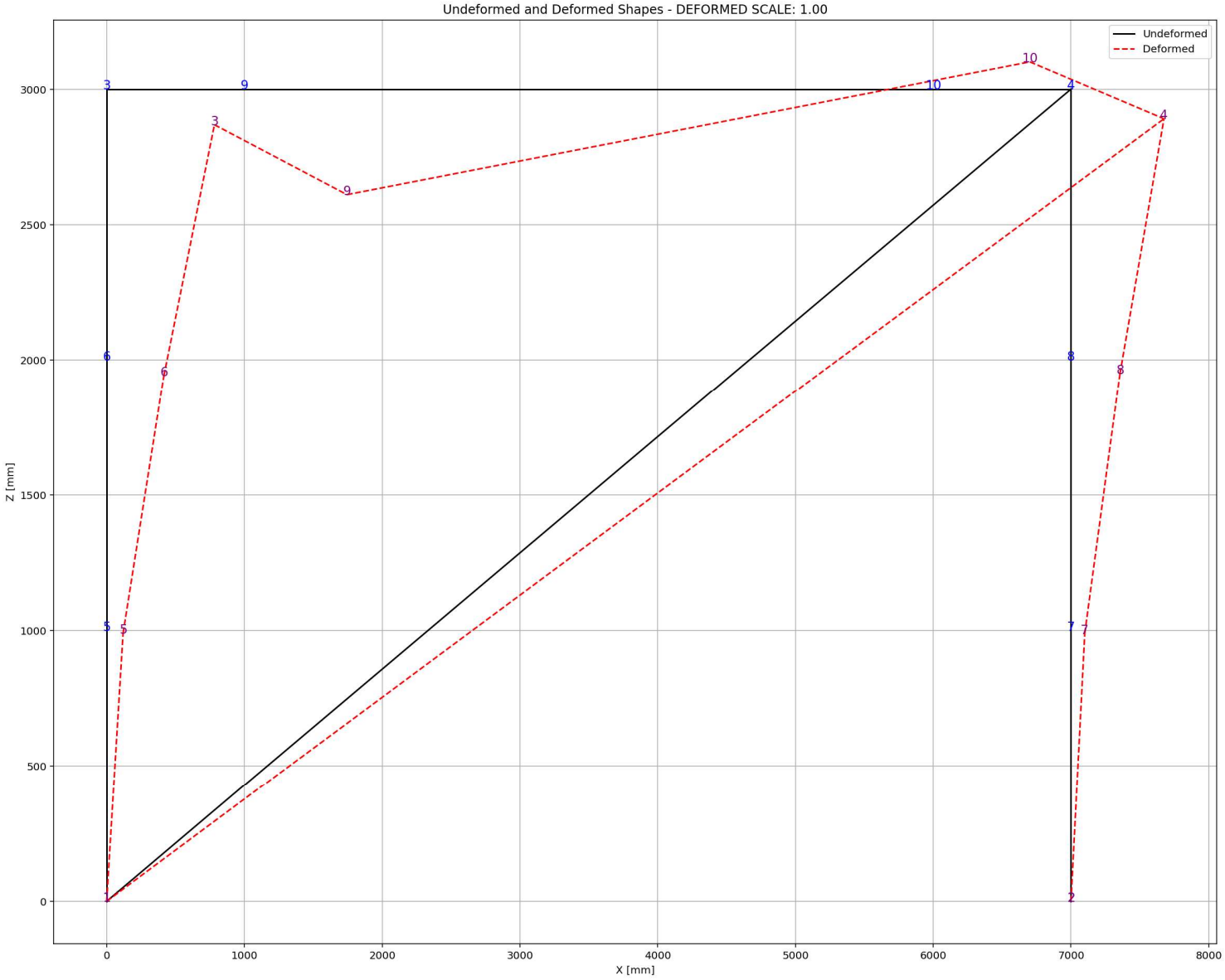
Console 1/A

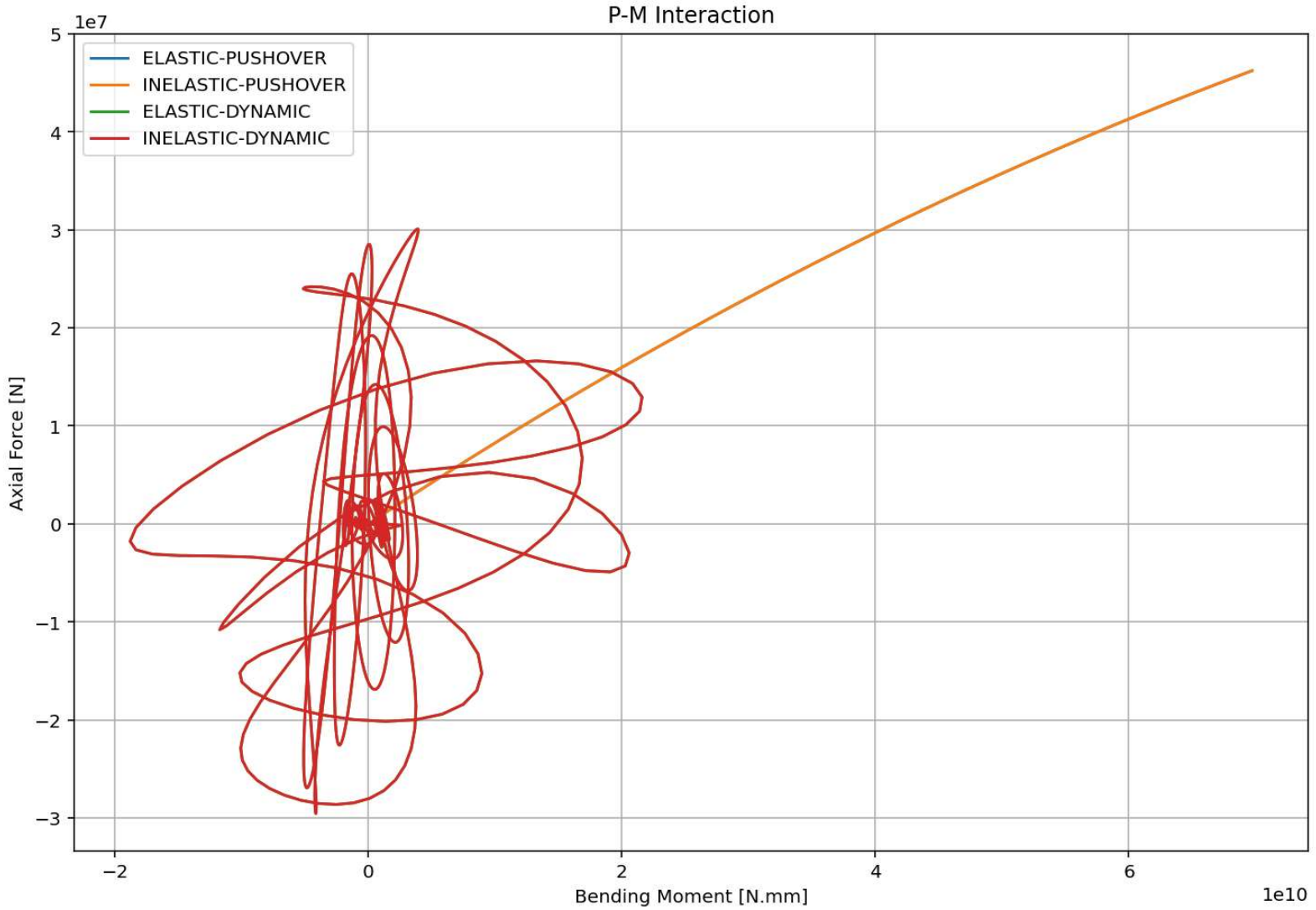
```
    End 2 Forces (P V M): 3559.61 14208.3 7.69877e+06

ElasticBeam2d: 3
    Connected Nodes: 6 3
    CoordTransf: 1
    mass density:  6.25, cMass: 0
    release code:  0
    End 1 Forces (P V M): -3480.79 -12105.9 -7.69877e+06
    End 2 Forces (P V M): 3480.79 12105.9 -4.40715e+06

In [6]:
```

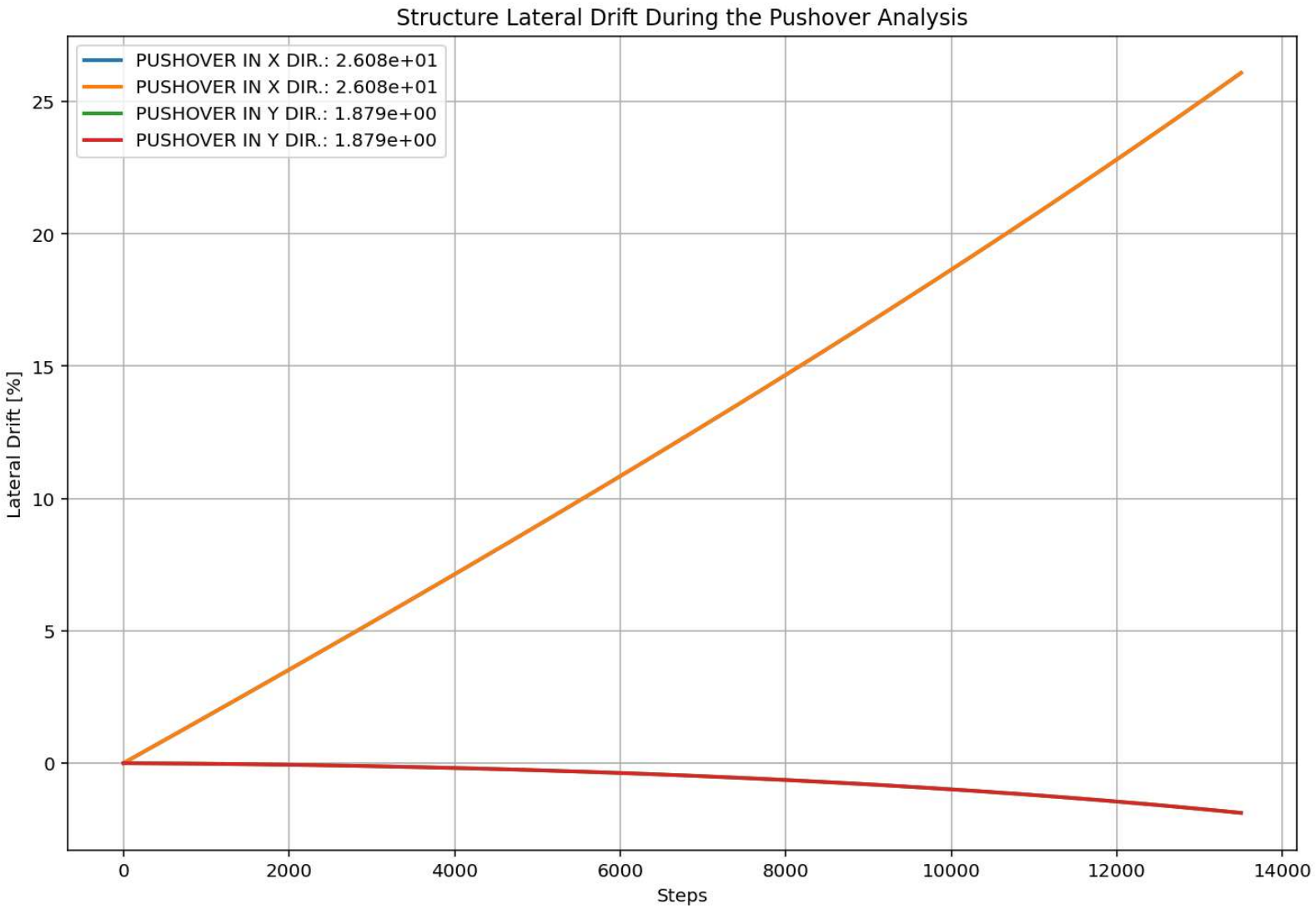
IPython Console History

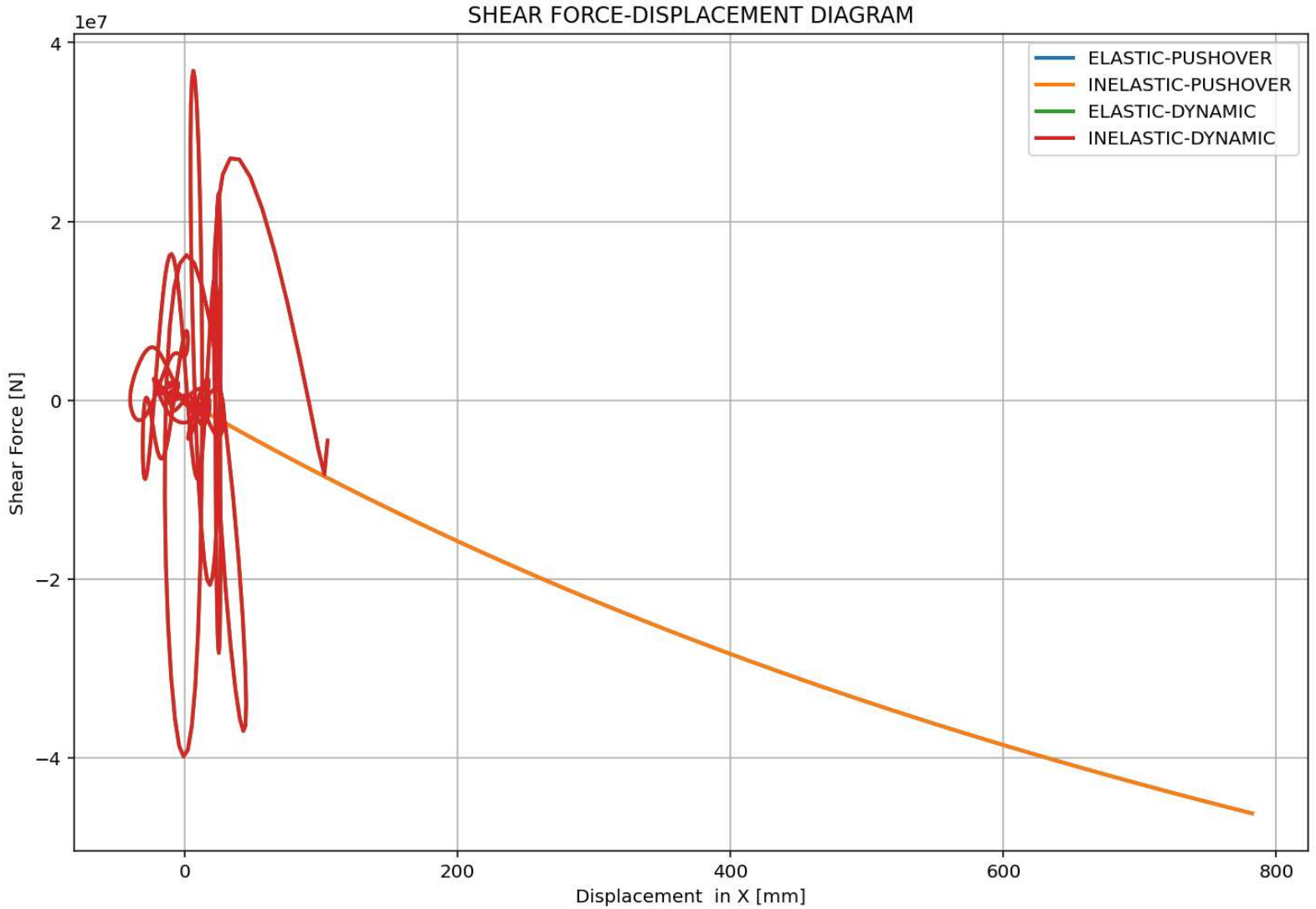
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 226, Col 17 UTF-8 CRLF RW Mem 40%

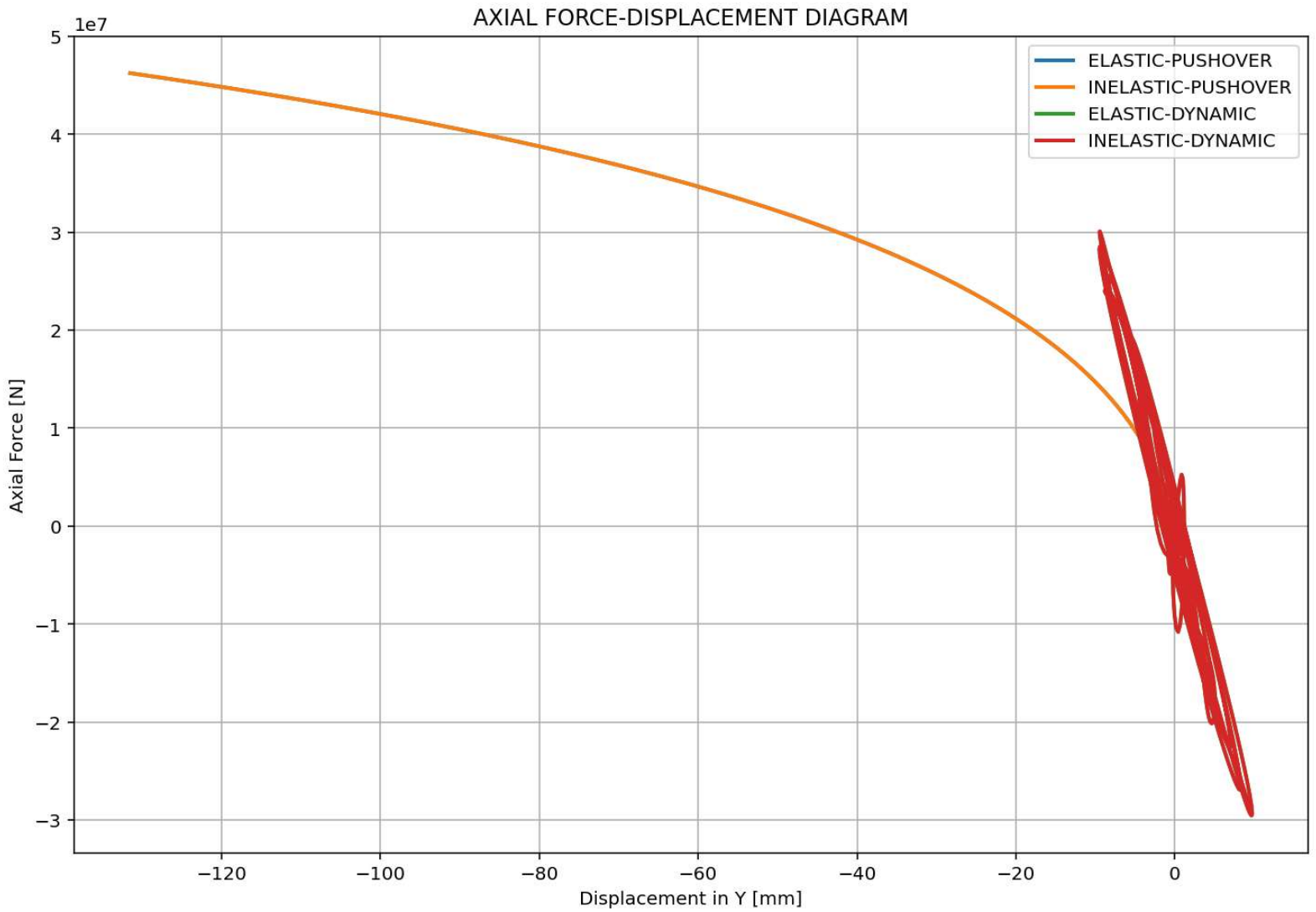
ELASTIC AND INELASTIC STATIC ANALYSIS (PUSHOVER)

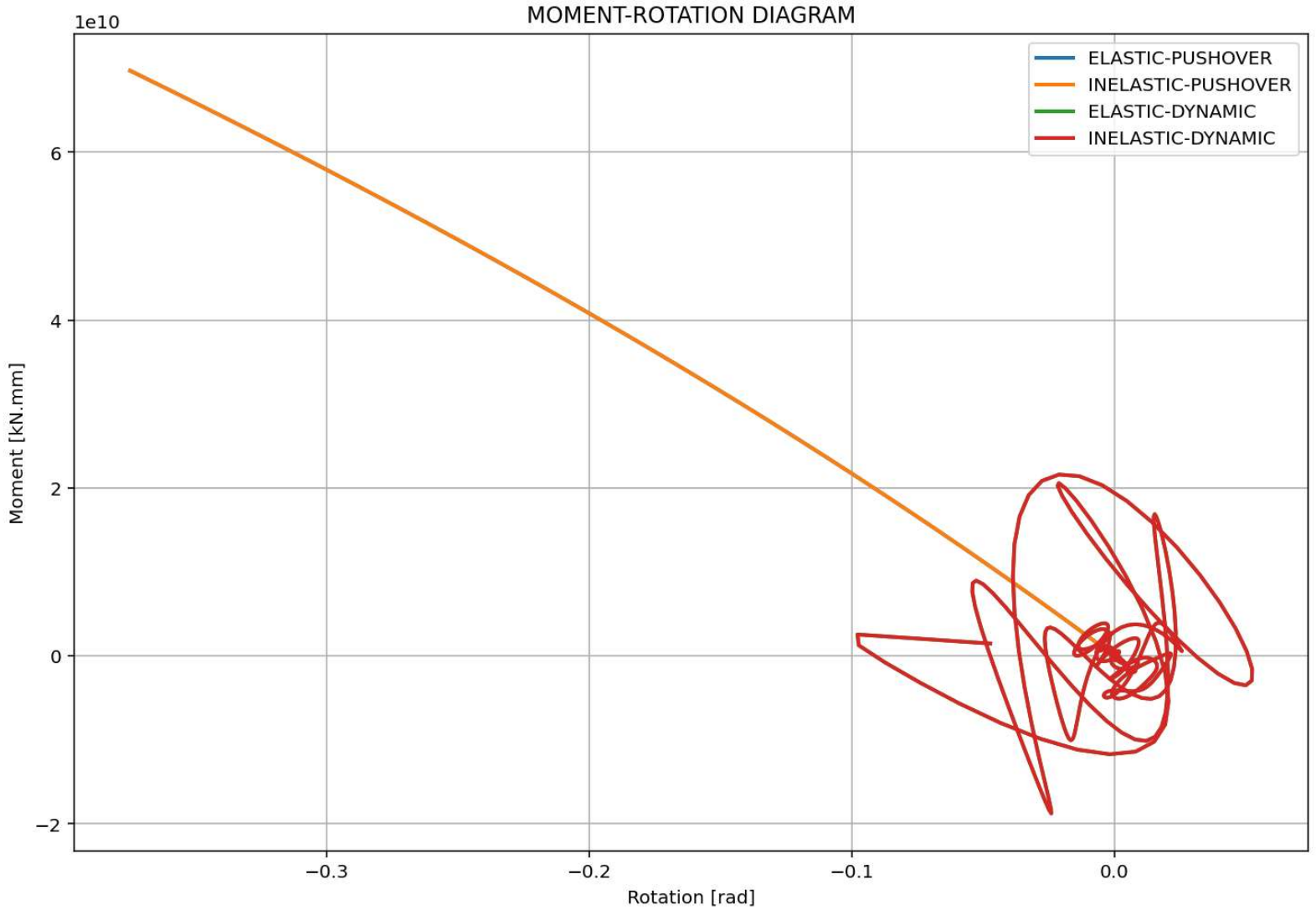

Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
8000
1
2
3
4
5
6
7
8
9
10

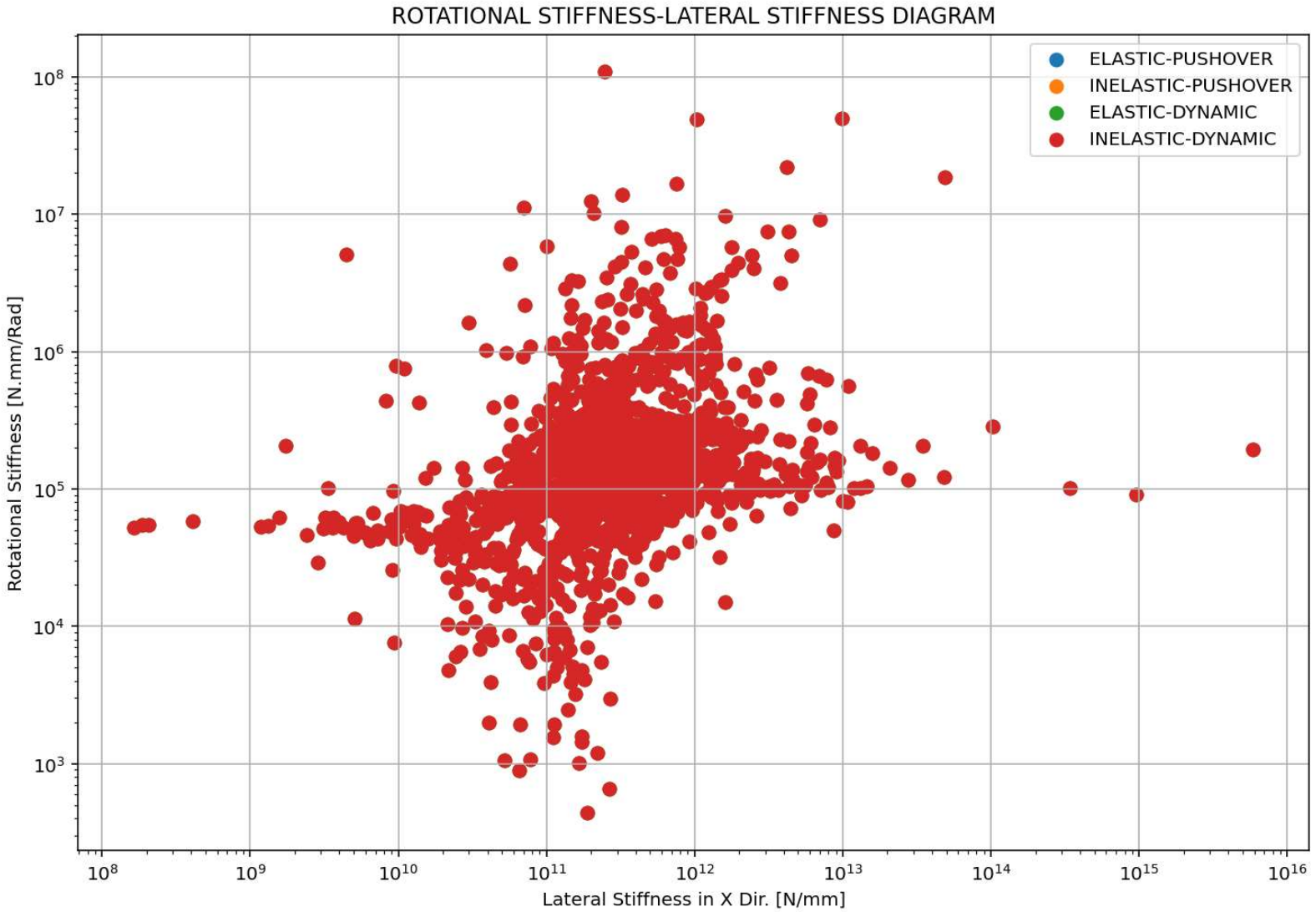

P-M Interaction
1e7
5
4
3
2
1
0
−1
−2
−3
Axial Force [N]
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
−2
0
2
4
6
Bending Moment [N.mm]
1e10

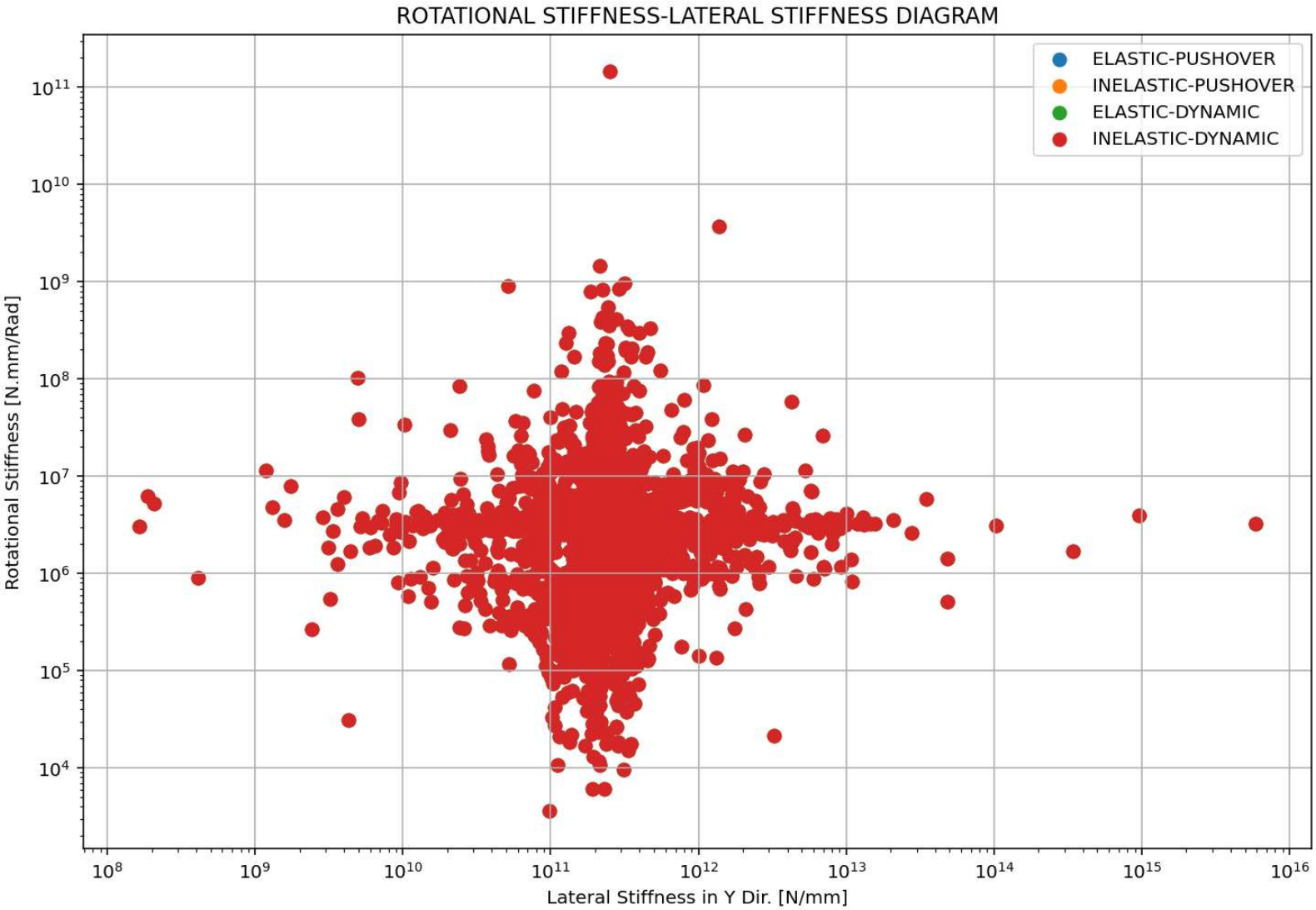

Structure Lateral Drift During the Pushover Analysis
PUSHOVER IN X DIR.: 2.608e+01
PUSHOVER IN X DIR.: 2.608e+01
PUSHOVER IN Y DIR.: 1.879e+00
PUSHOVER IN Y DIR.: 1.879e+00
Lateral Drift [%]
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
12000
14000
Steps

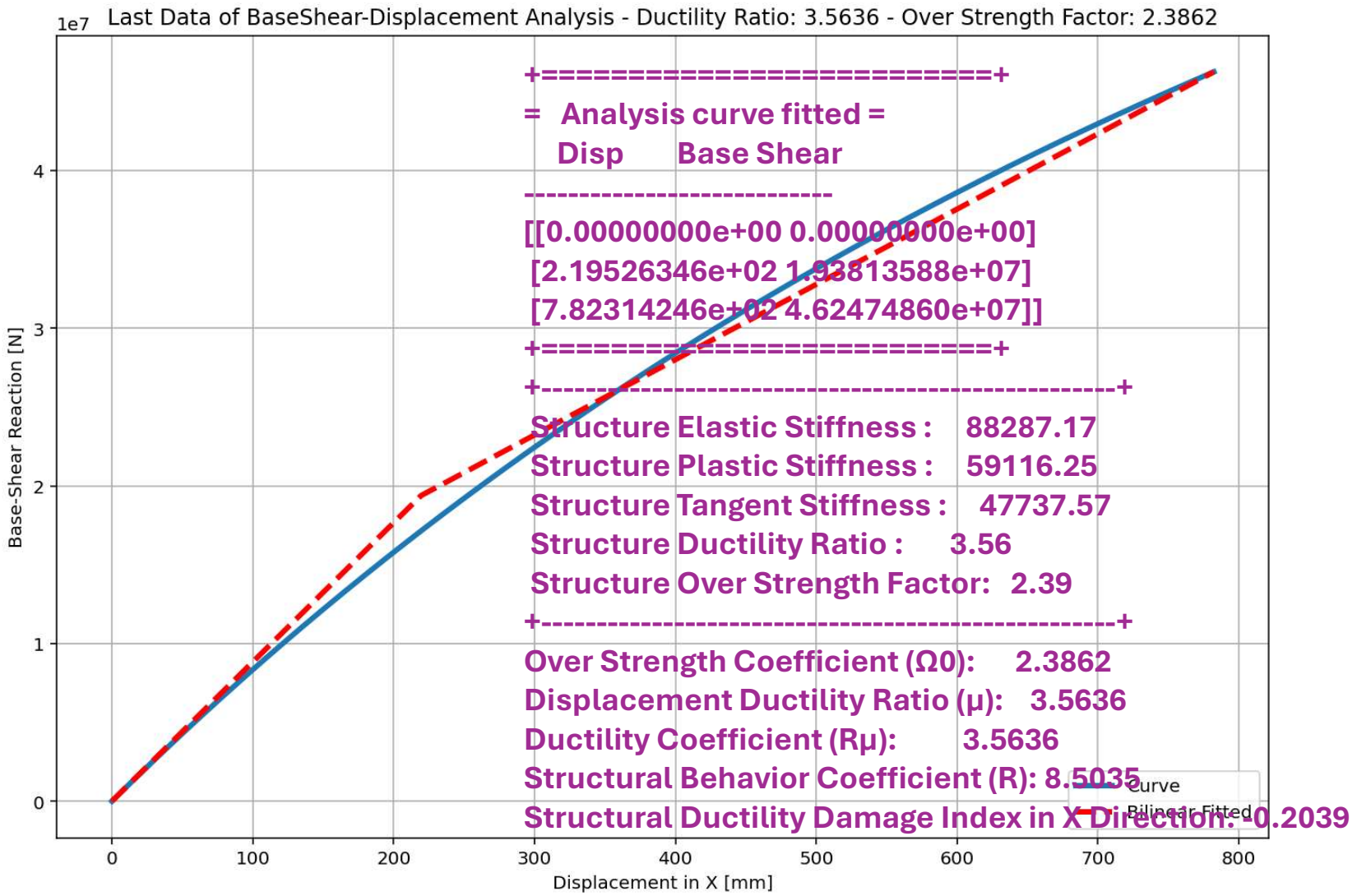

SHEAR FORCE-DISPLACEMENT DIAGRAM
1e7
4
2
0
−2
−4
Shear Force [N]
0
200
400
600
800
Displacement in X [mm]
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC


AXIAL FORCE-DISPLACEMENT DIAGRAM
1e7
5
4
3
2
1
0
−1
−2
−3
Axial Force [N]
−120
−100
−80
−60
−40
−20
0
Displacement in Y [mm]
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC

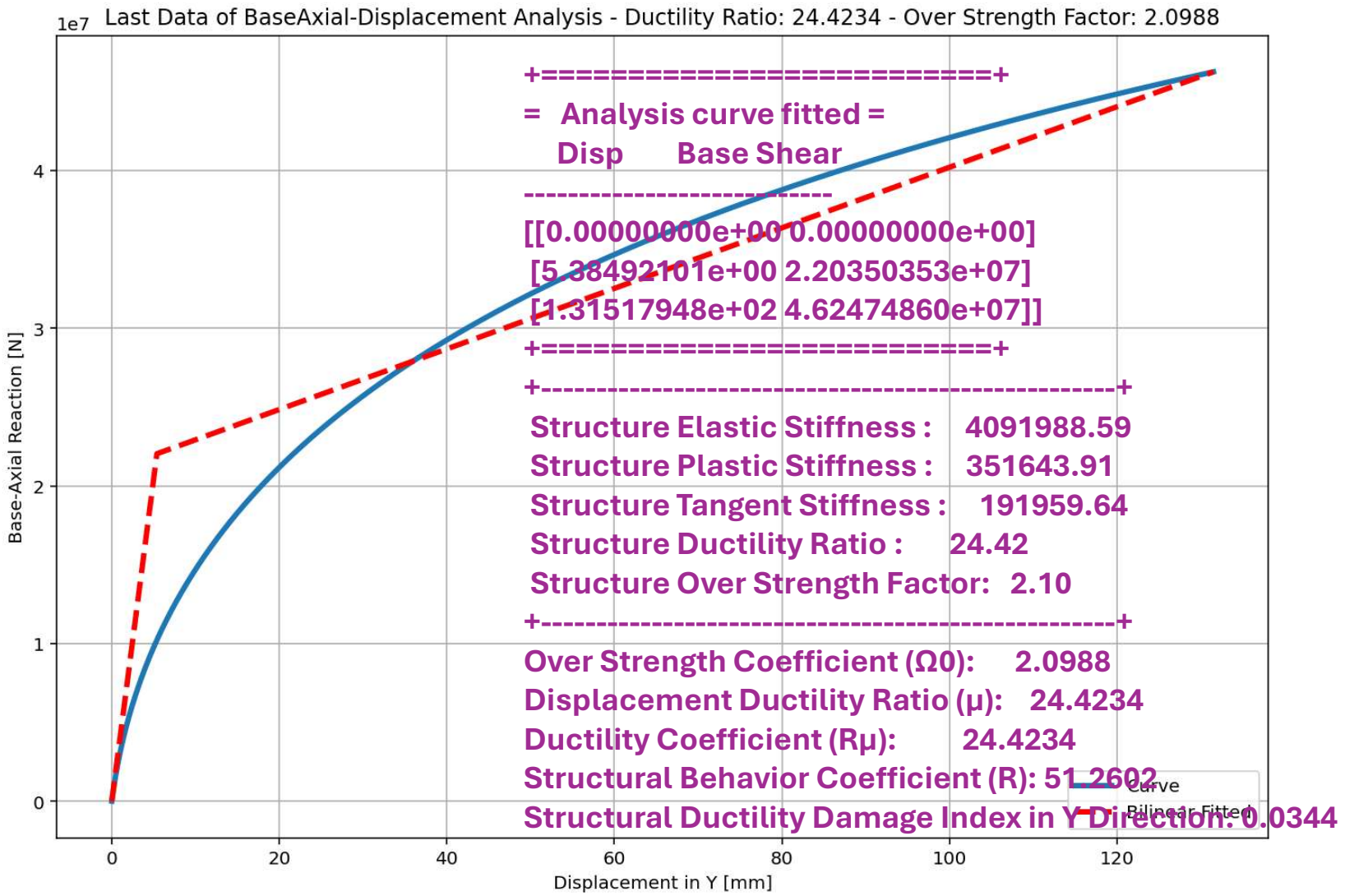

MOMENT-ROTATION DIAGRAM
1e10
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
Moment [kN.mm]
6
4
2
0
−2
−0.3
−0.2
−0.1
0.0
Rotation [rad]


ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in X Dir. [N/mm]
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}


ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in Y Dir. [N/mm]
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}

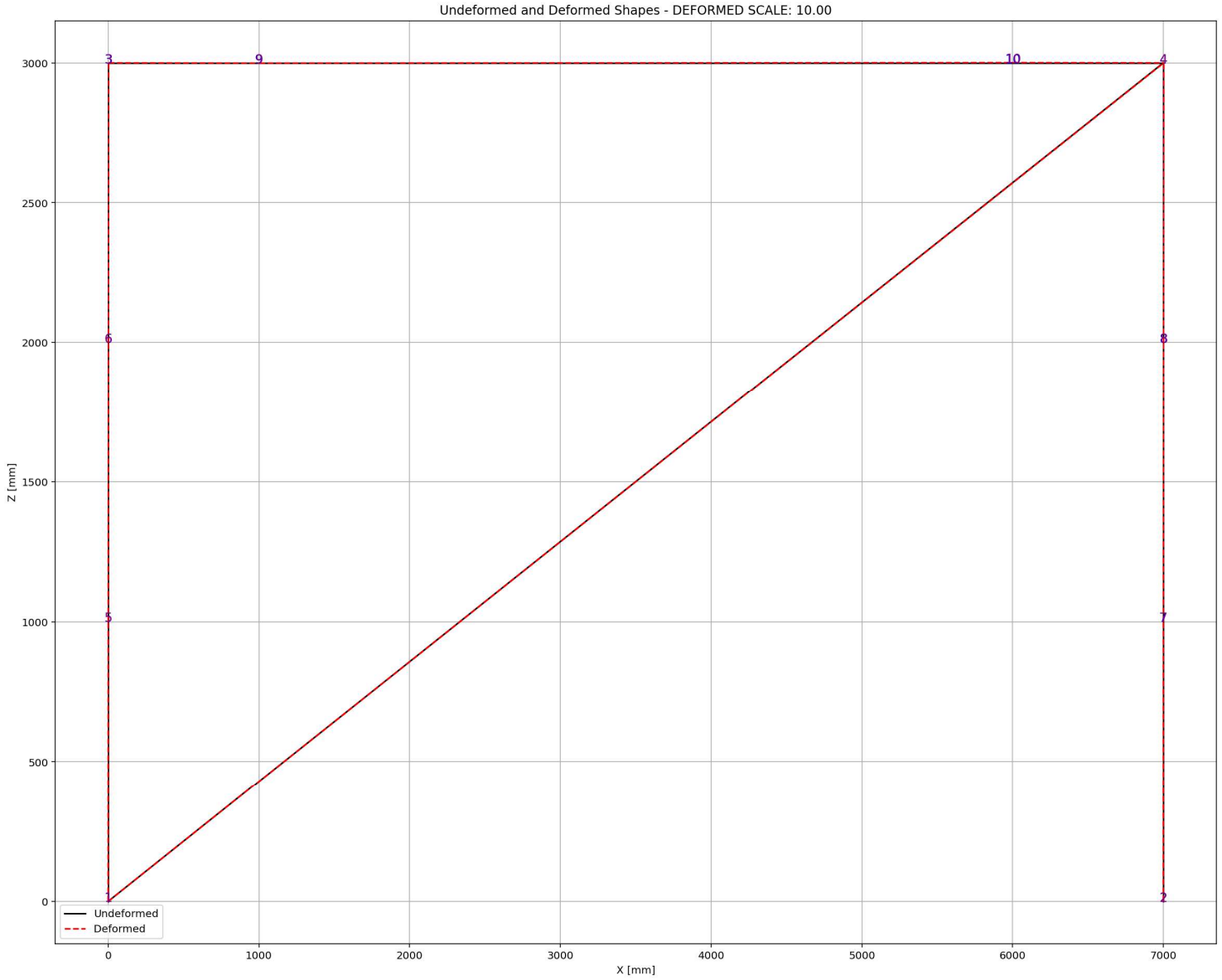

Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 3.5636 - Over Strength Factor: 2.3862
1e7
Base-Shear Reaction [N]
Displacement in X [mm]
0
1
2
3
4
0
100
200
300
400
500
600
700
800
+============================+
= Analysis curve fitted =
Disp Base Shear

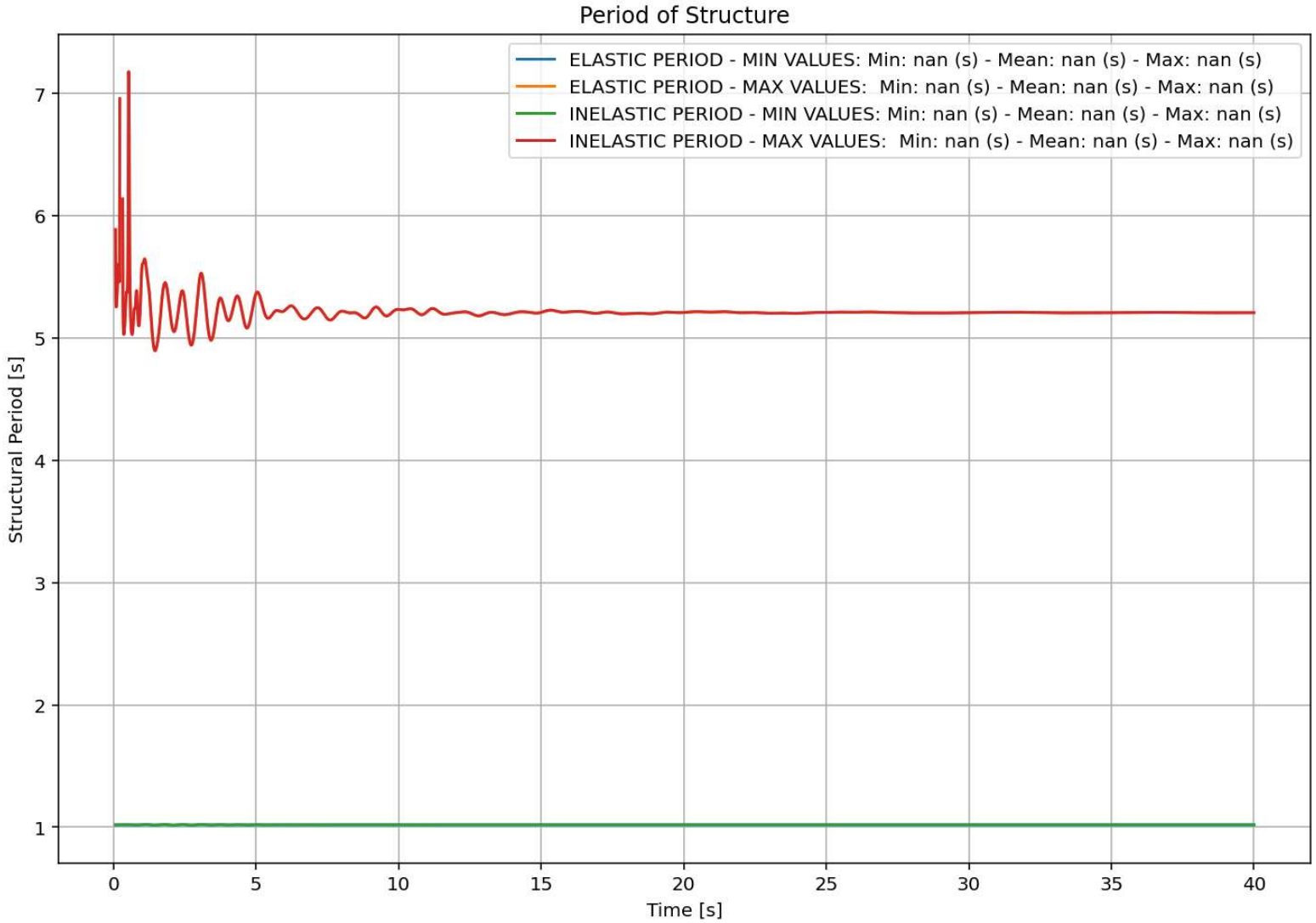
[[0.00000000e+00 0.00000000e+00]
[2.19526346e+02 1.03813588e+07]
[7.82314246e+02 4.62474860e+07]]
+============================+
+---+
Structure Elastic Stiffness : 88287.17
Structure Plastic Stiffness : 59116.25
Structure Tangent Stiffness : 47737.57
Structure Ductility Ratio : 3.56
Structure Over Strength Factor: 2.39
+---+
Over Strength Coefficient (Ω0): 2.3862
Displacement Ductility Ratio (μ): 3.5636
Ductility Coefficient (Rμ): 3.5636
Structural Behavior Coefficient (R): 8.5035
Structural Ductility Damage Index in X Direction: -0.2039
Curve
Bilinear Fitted

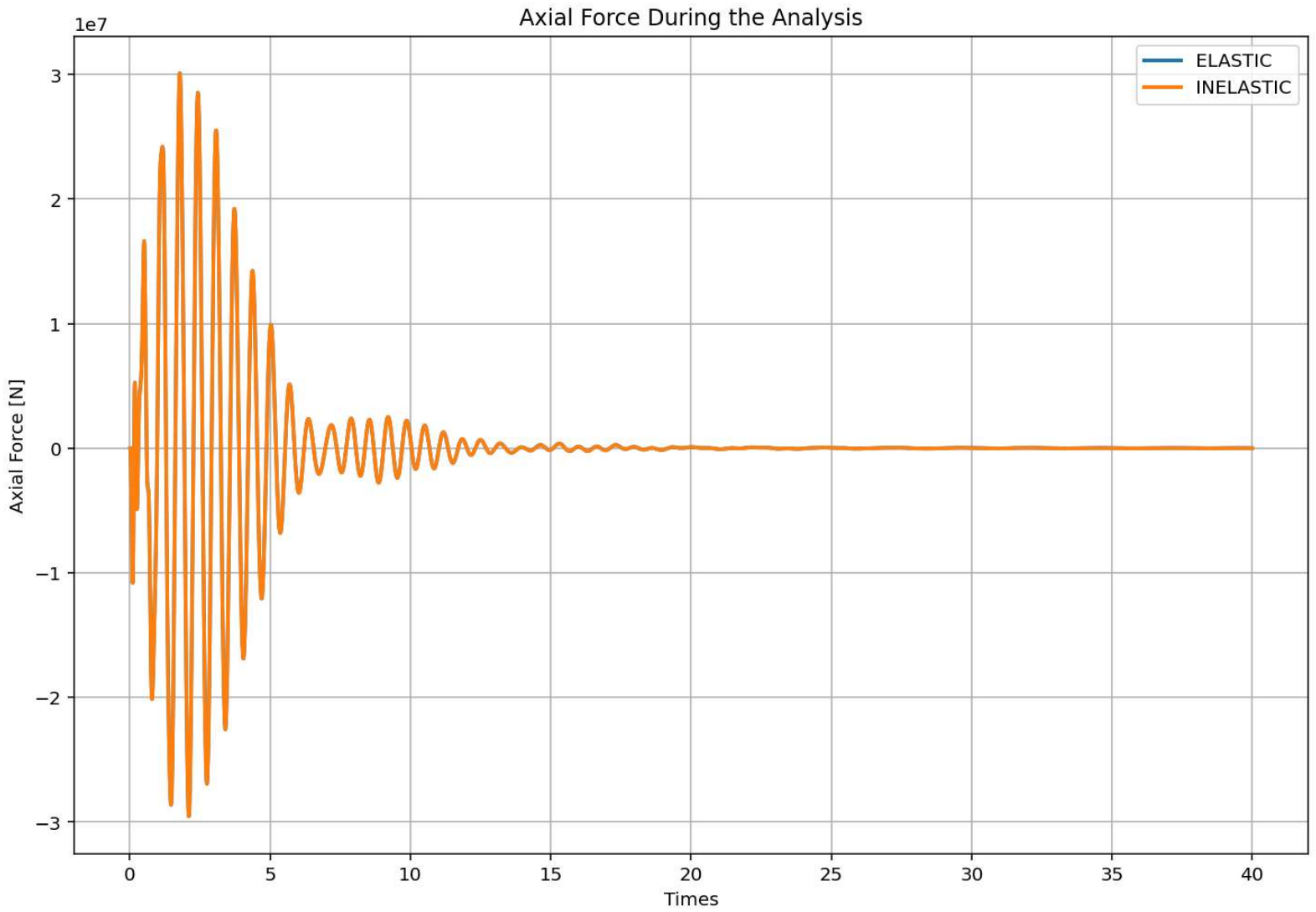

Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 24.4234 - Over Strength Factor: 2.0988
1e7
Base-Axial Reaction [N]
Displacement in Y [mm]
0
1
2
3
4
0
20
40
60
80
100
120
+============================+
= Analysis curve fitted =
Disp Base Shear

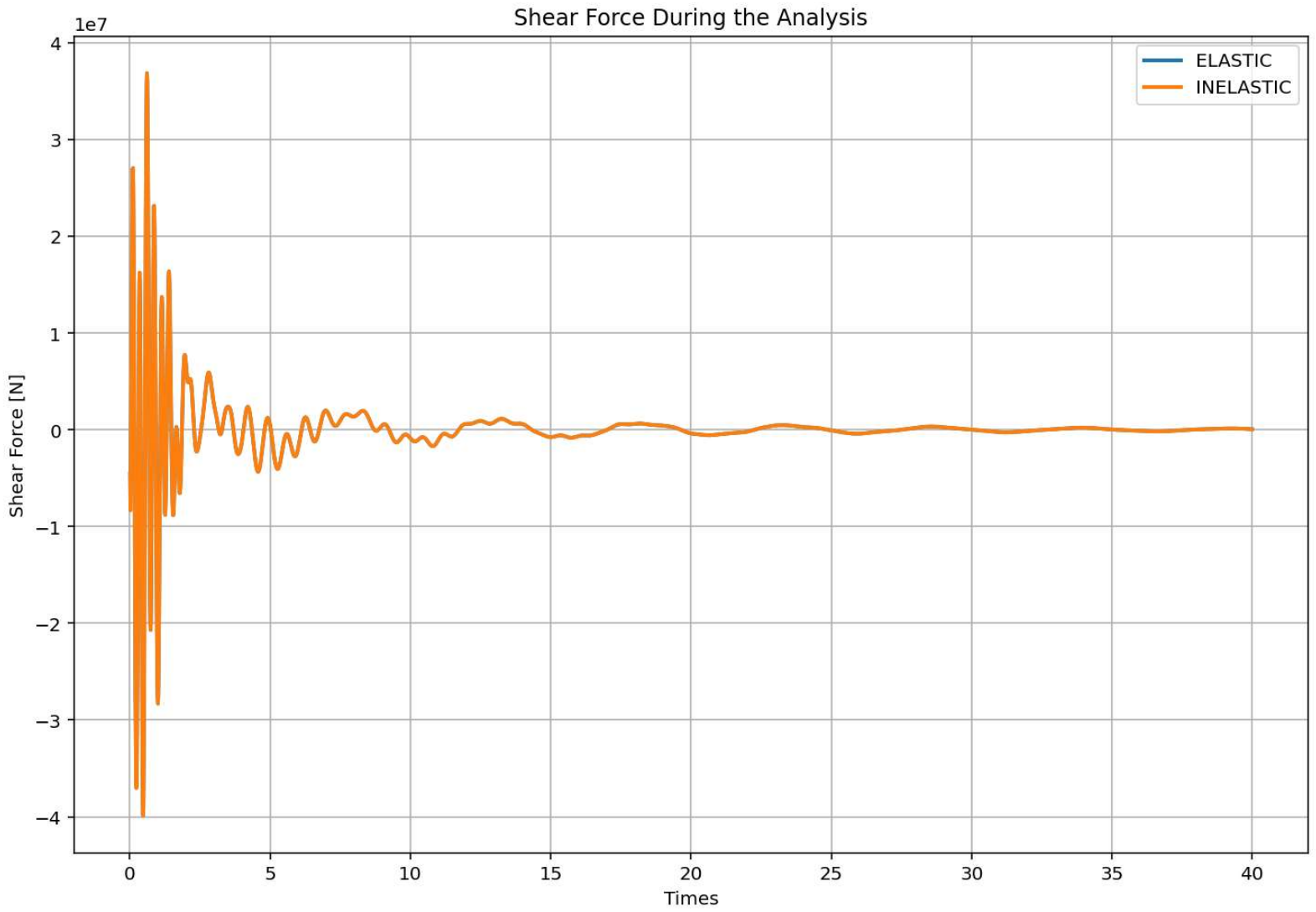
[[0.00000000e+00 0.00000000e+00]
[5.38492101e+00 2.20350353e+07]
[1.31517948e+02 4.62474860e+07]]
+============================+
+---+
Structure Elastic Stiffness : 4091988.59
Structure Plastic Stiffness : 351643.91
Structure Tangent Stiffness : 191959.64
Structure Ductility Ratio : 24.42
Structure Over Strength Factor: 2.10
+---+
Over Strength Coefficient (Ω0): 2.0988
Displacement Ductility Ratio (μ): 24.4234
Ductility Coefficient (Rμ): 24.4234
Structural Behavior Coefficient (R): 51.2602
Structural Ductility Damage Index in Y Direction: 0.0344
Curve
Bilinear Fitted

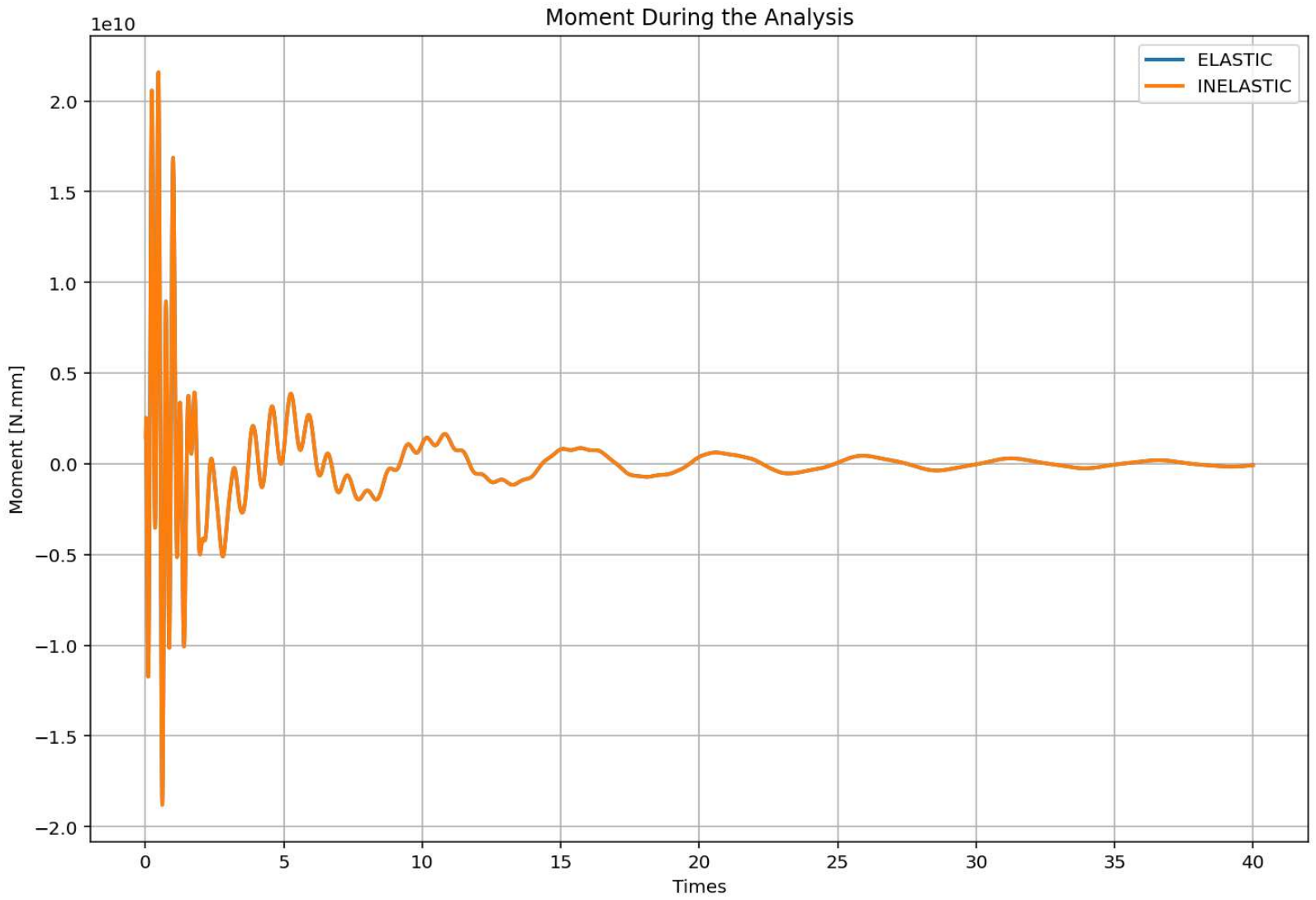
ELASTIC AND INELASTIC DYNAMIC ANALYSIS

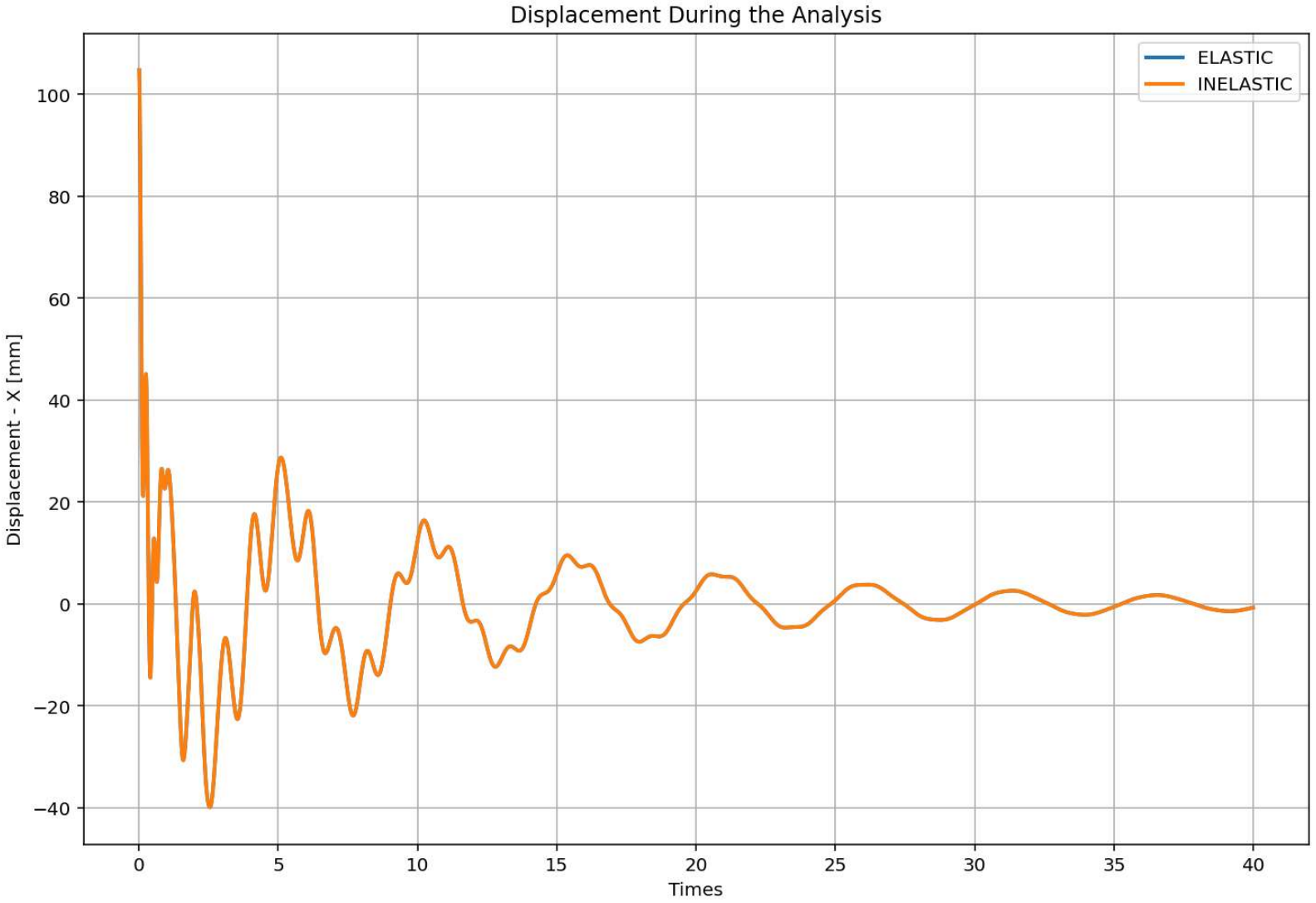

Undeformed and Deformed Shapes - DEFORMED SCALE: 10.00
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
1
2
3
4
5
6
7
8
9
10
Undeformed
Deformed

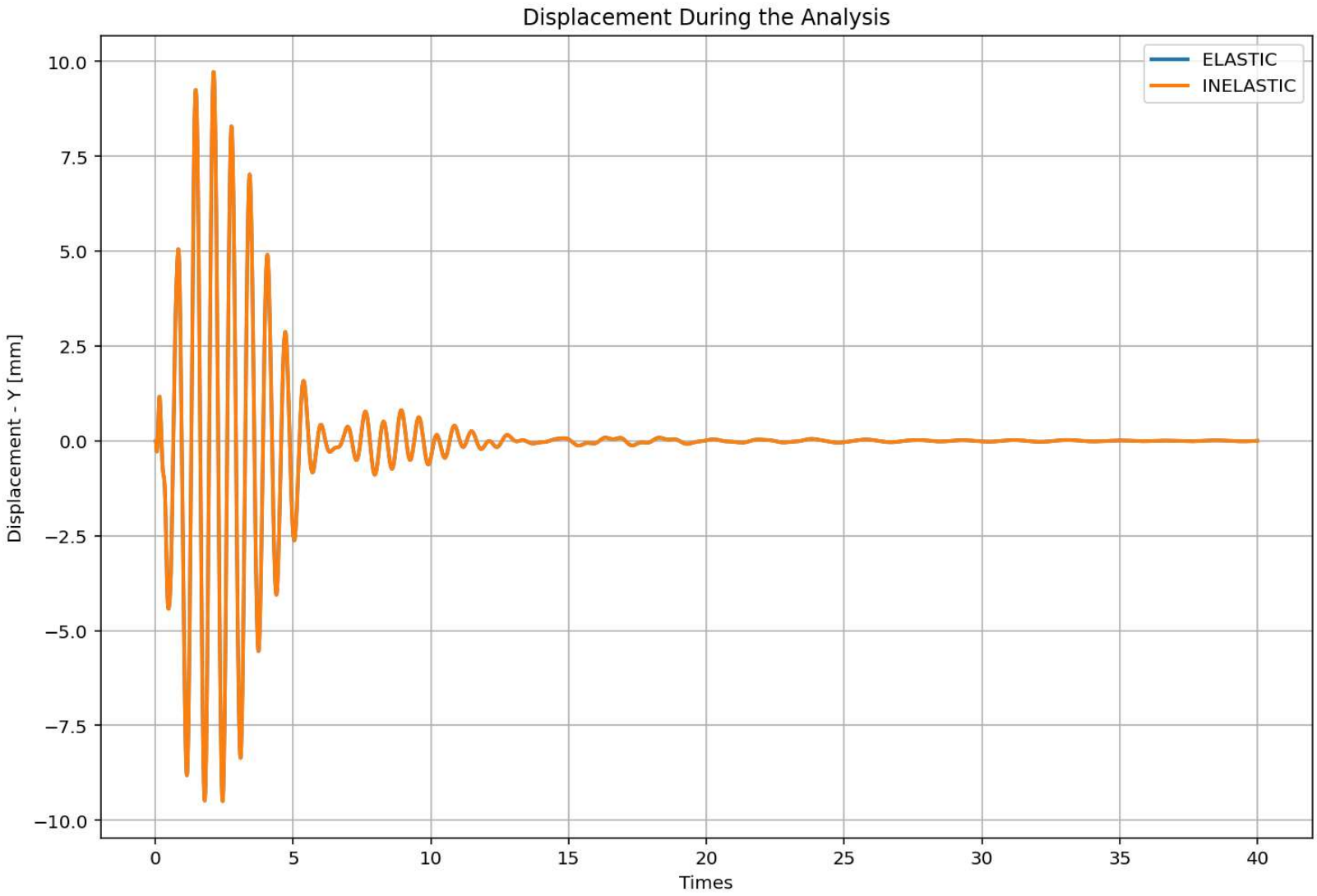

Period of Structure
ELASTIC PERIOD - MIN VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
ELASTIC PERIOD - MAX VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
INELASTIC PERIOD - MIN VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
INELASTIC PERIOD - MAX VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
Structural Period [s]
Time [s]
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40

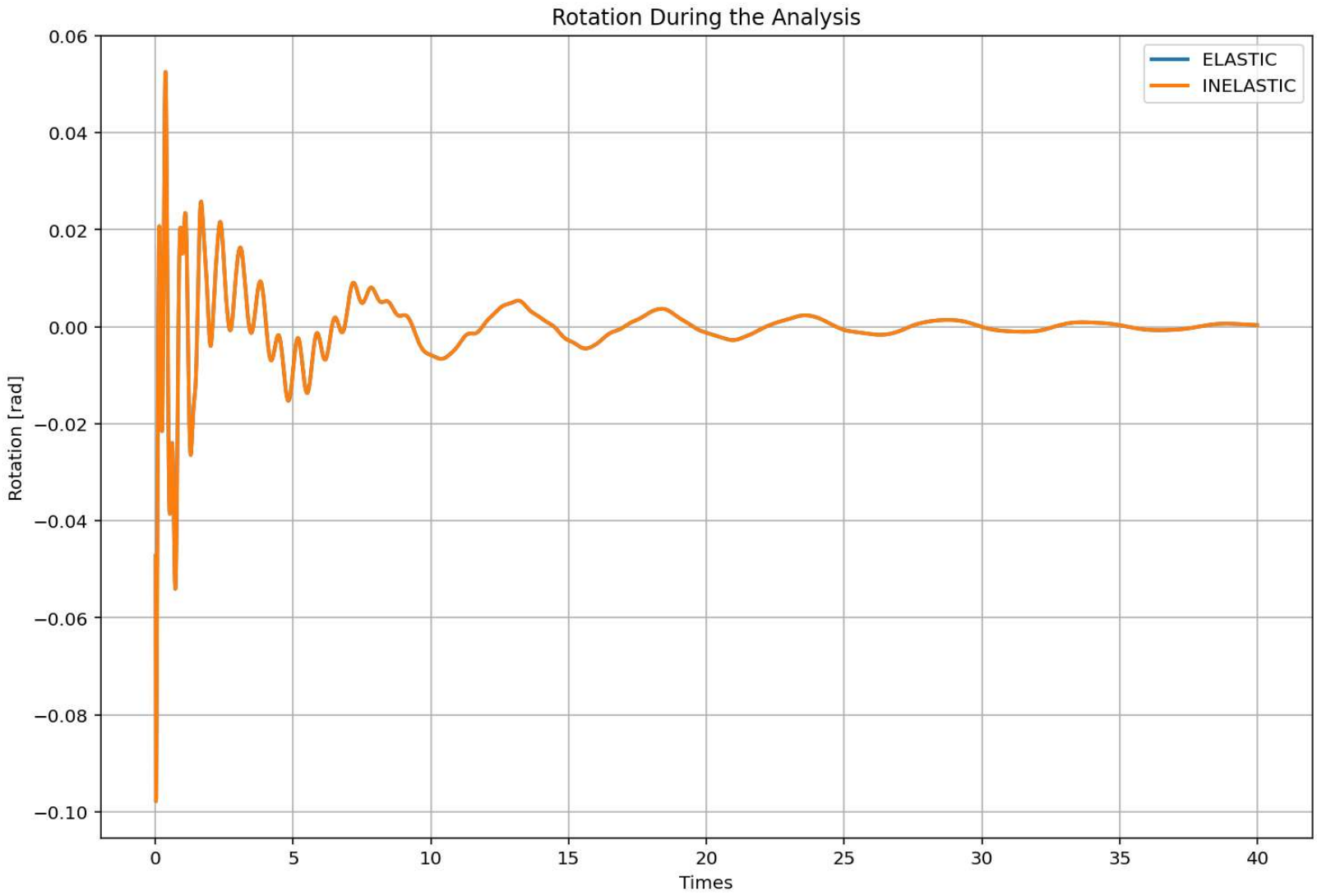

Axial Force During the Analysis
1e7
3
2
1
0
−1
−2
−3
Axial Force [N]
0
5
10
15
20
25
30
35
40
Times
ELASTIC
INELASTIC

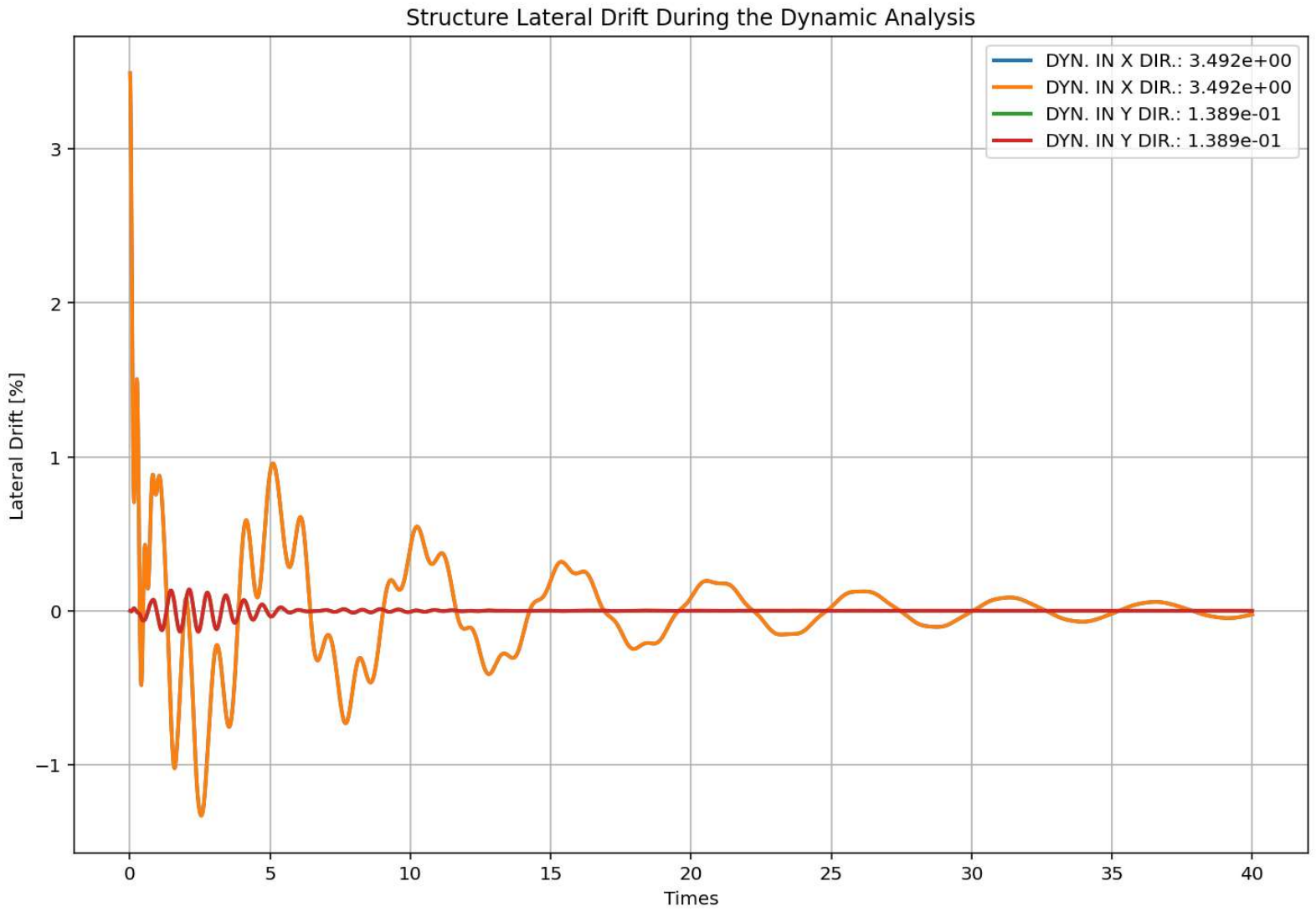

Shear Force During the Analysis
1e7
4
3
2
1
0
−1
−2
−3
−4
Shear Force [N]
0
5
10
15
20
25
30
35
40
Times
ELASTIC
INELASTIC

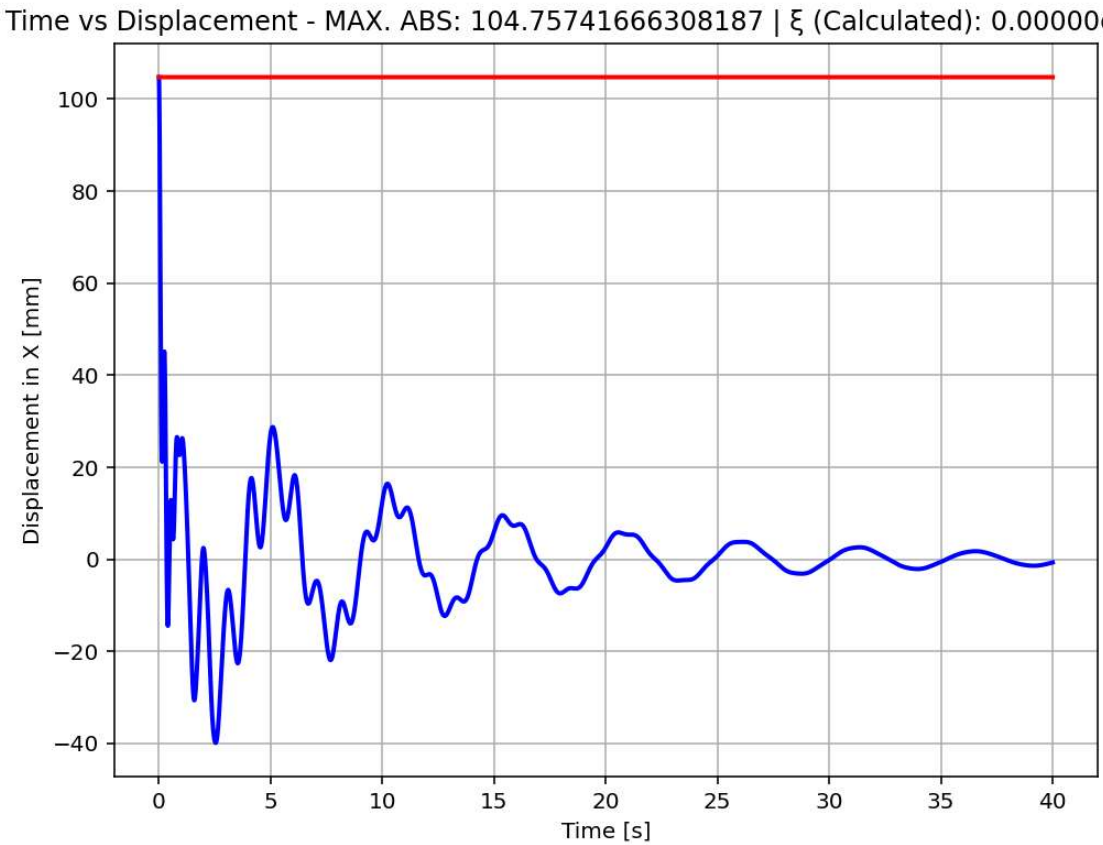

Moment During the Analysis
1e10
ELASTIC
INELASTIC
Moment [N.mm]
Times
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
5
10
15
20
25
30
35
40

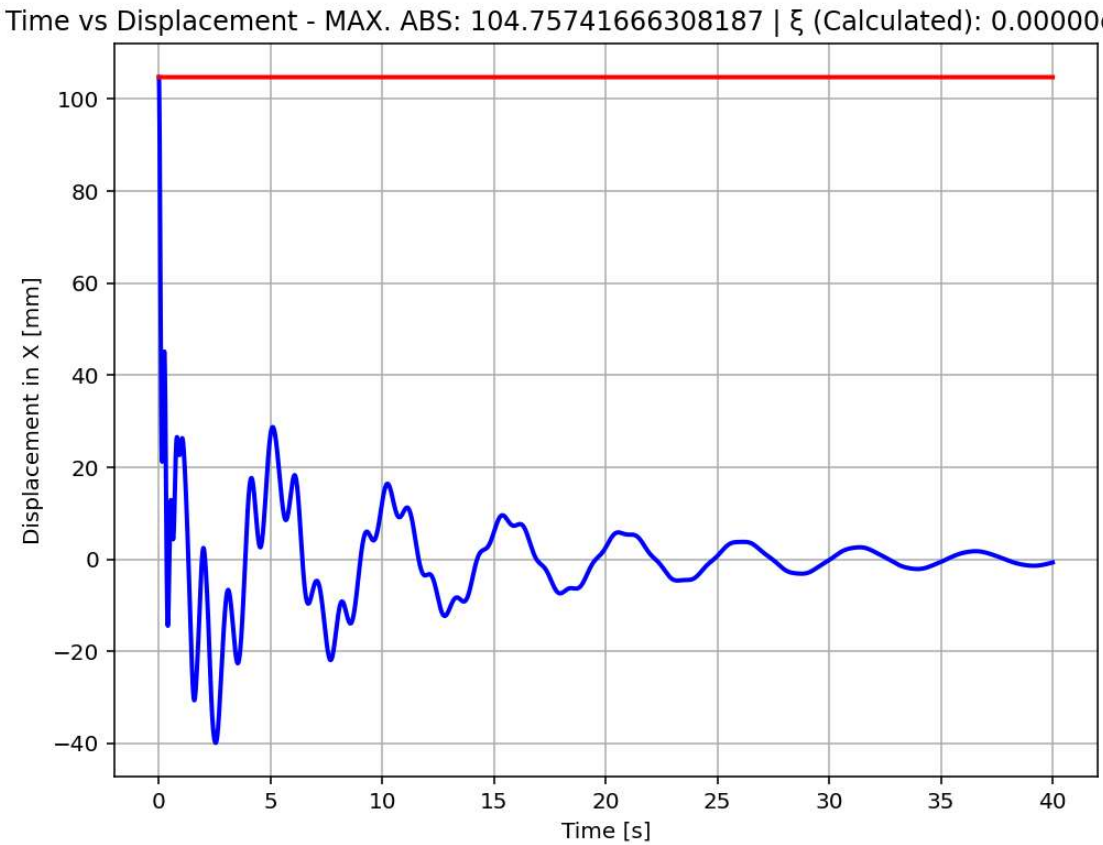

Displacement During the Analysis
ELASTIC
INELASTIC
Displacement - X [mm]
100
80
60
40
20
0
−20
−40
0
5
10
15
20
25
30
35
40
Times

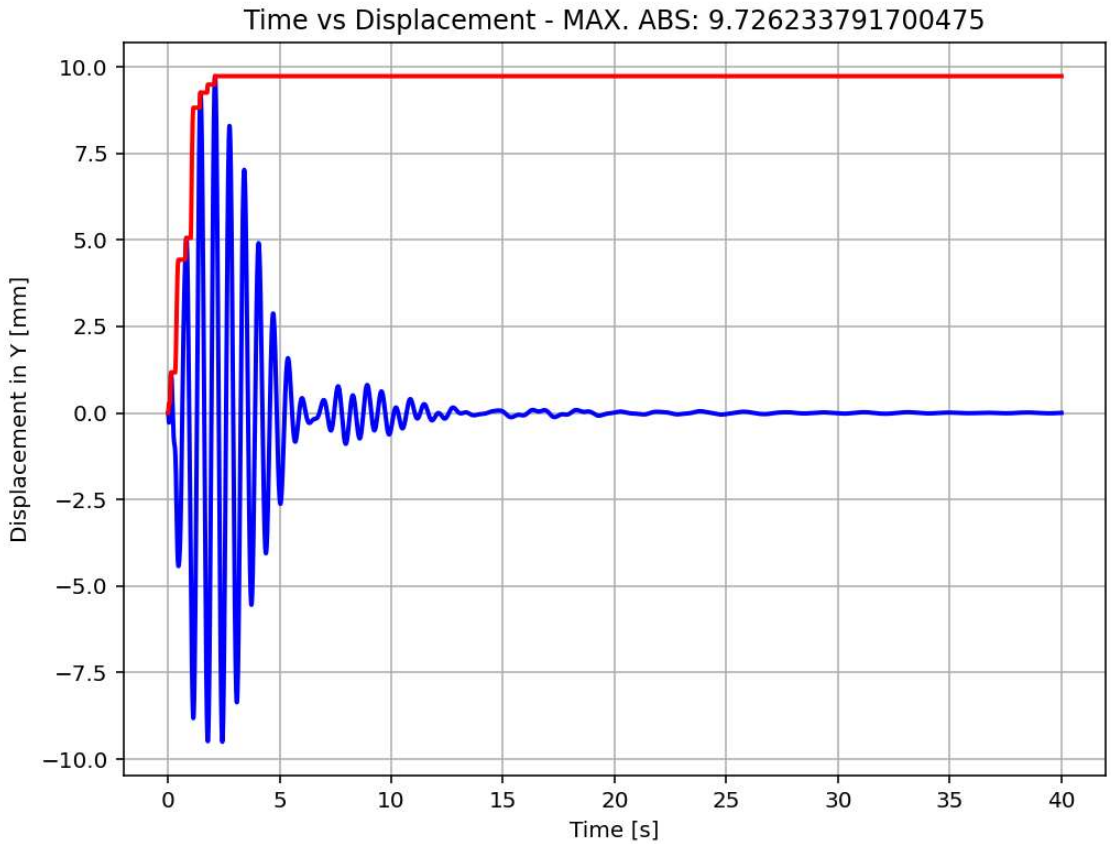

Displacement During the Analysis
ELASTIC
INELASTIC
Displacement - Y [mm]
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
0
5
10
15
20
25
30
35
40
Times

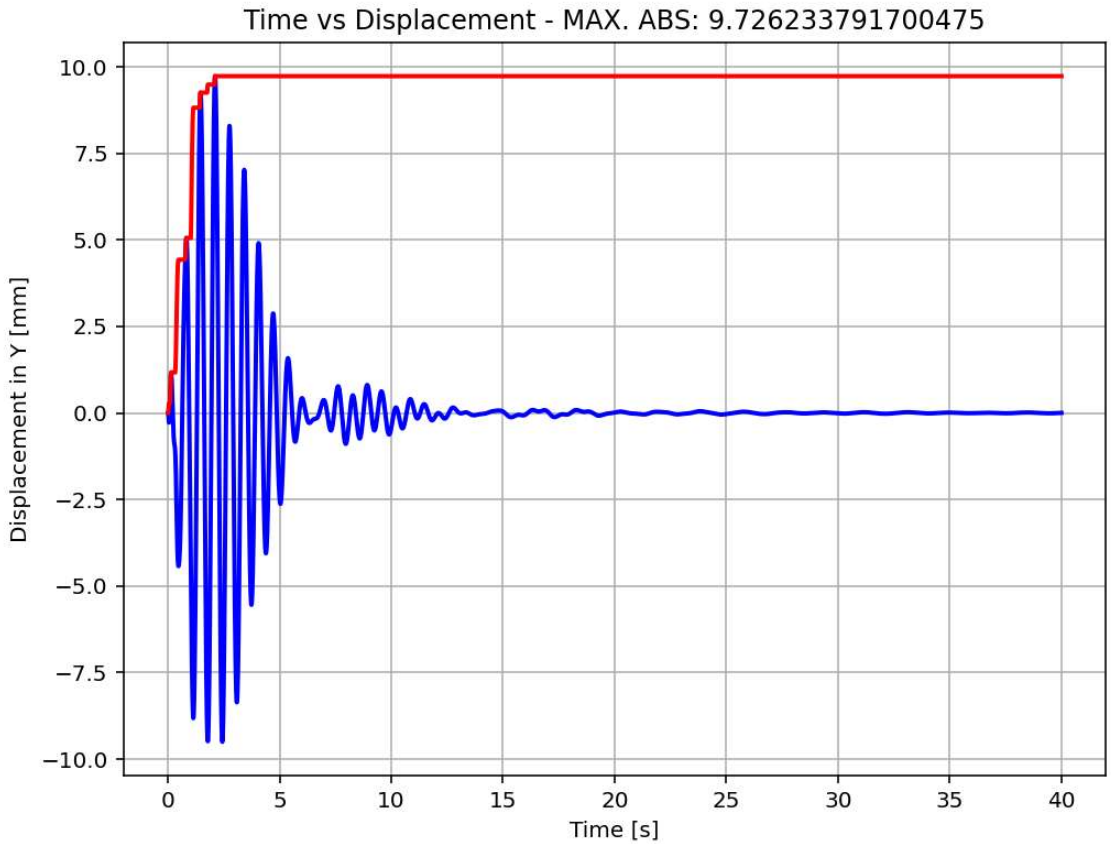

Rotation During the Analysis
ELASTIC
INELASTIC
Rotation [rad]
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
0
5
10
15
20
25
30
35
40
Times

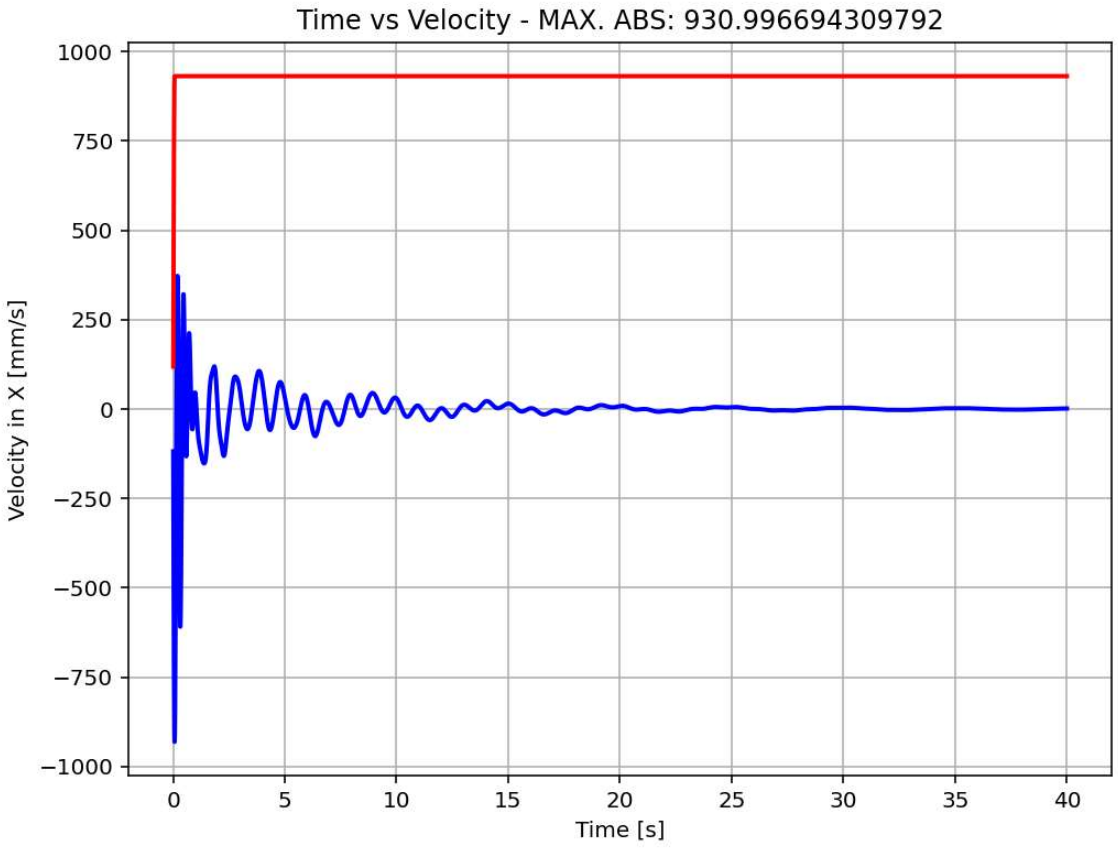

Structure Lateral Drift During the Dynamic Analysis
DYN. IN X DIR.: 3.492e+00
DYN. IN X DIR.: 3.492e+00
DYN. IN Y DIR.: 1.389e-01
DYN. IN Y DIR.: 1.389e-01
Lateral Drift [%]
3
2
1
0
−1
0
5
10
15
20
25
30
35
40
Times

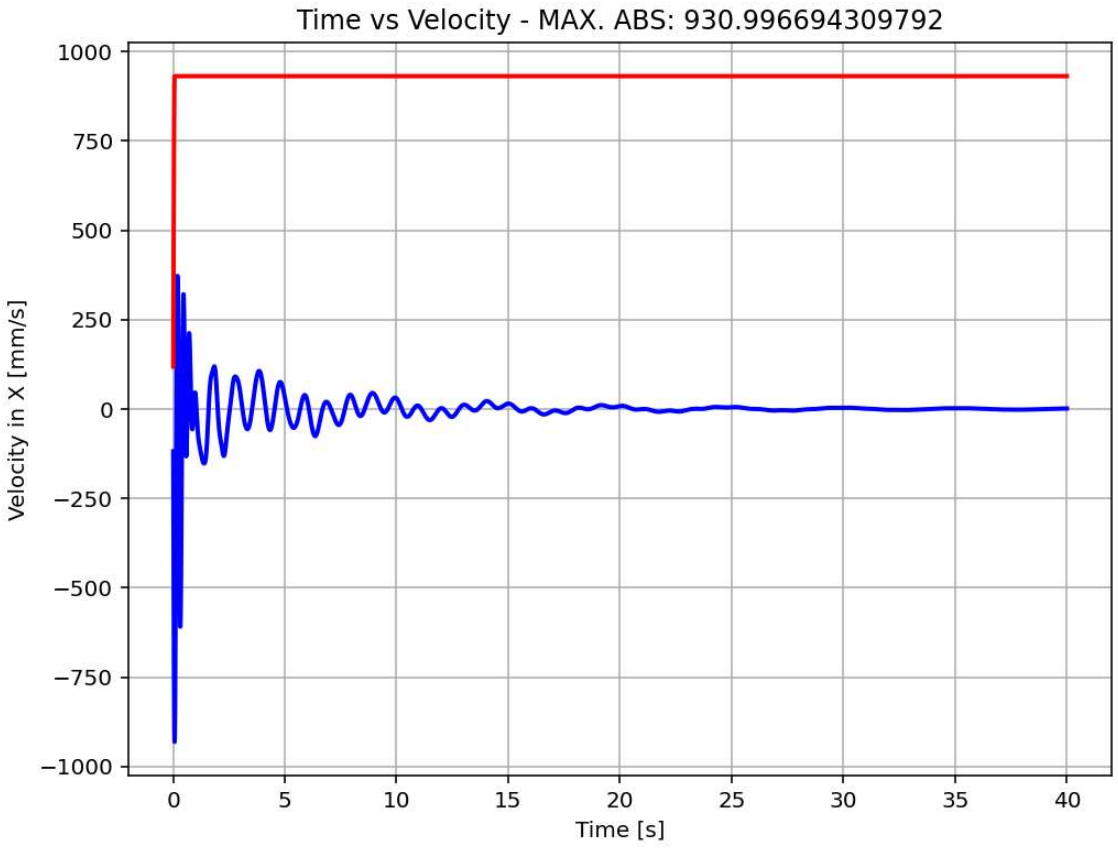

Time vs Displacement - MAX. ABS: 104.75741666308187 | ξ (Calculated): 0.00000e+00 %
Displacement in X [mm]
Time [s]
100
80
60
40
20
0
−20
−40
0
5
10
15
20
25
30
35
40

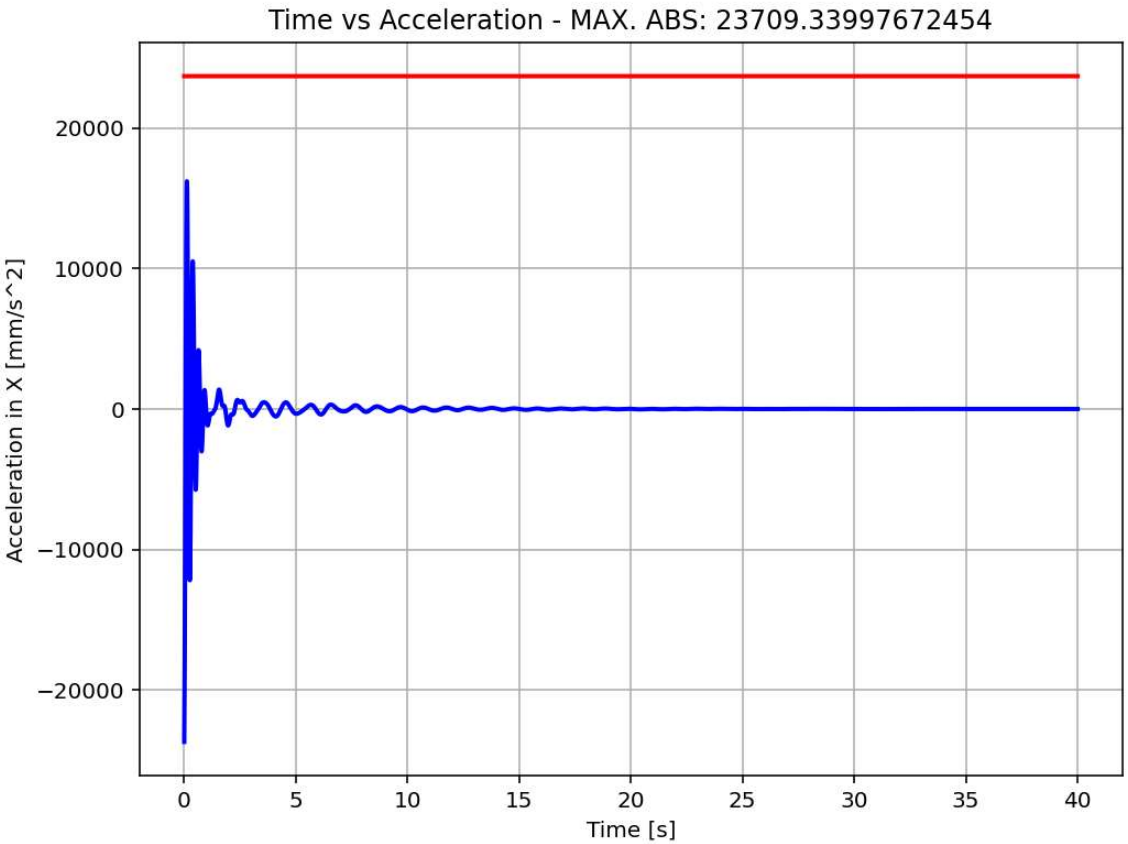

Time vs Displacement - MAX. ABS: 104.75741666308187 | ξ (Calculated): 0.00000e+00 %
Displacement in X [mm]
Time [s]
100
80
60
40
20
0
−20
−40
0
5
10
15
20
25
30
35
40

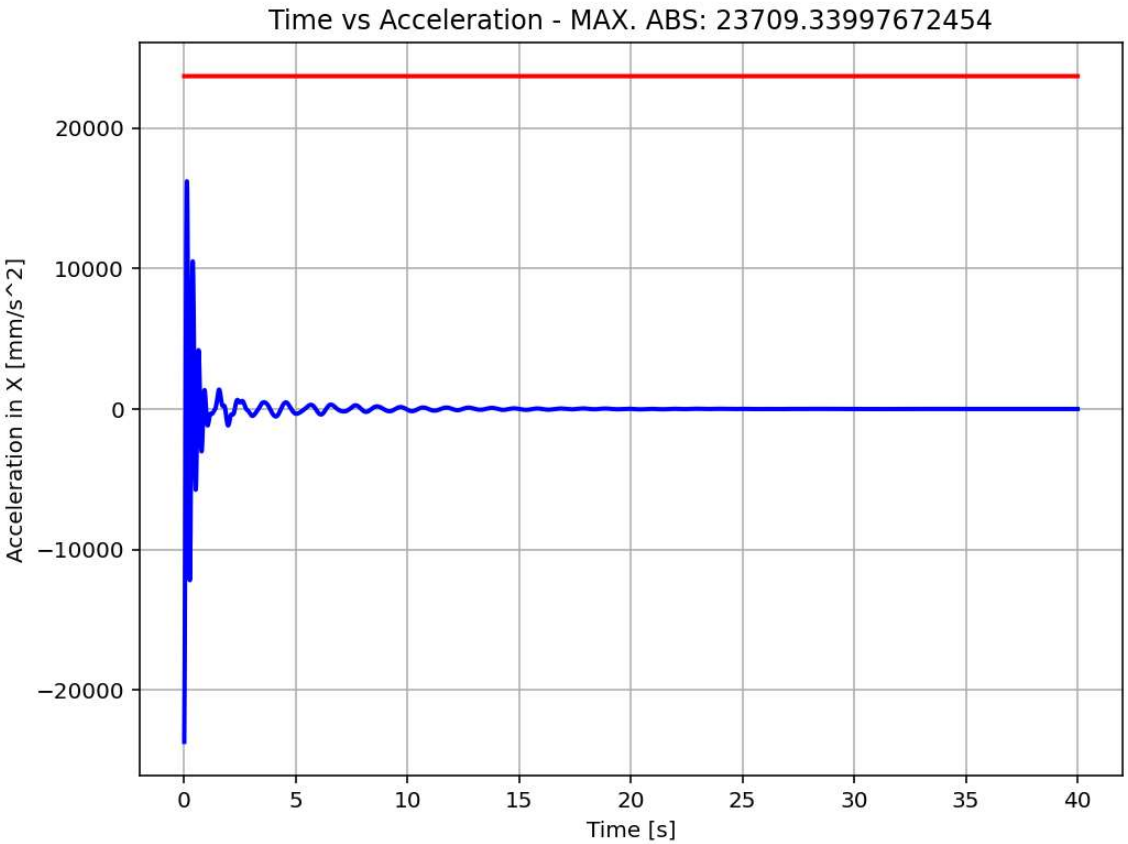

Time vs Displacement - MAX. ABS: 9.726233791700475
Displacement in Y [mm]
Time [s]
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
0
5
10
15
20
25
30
35
40

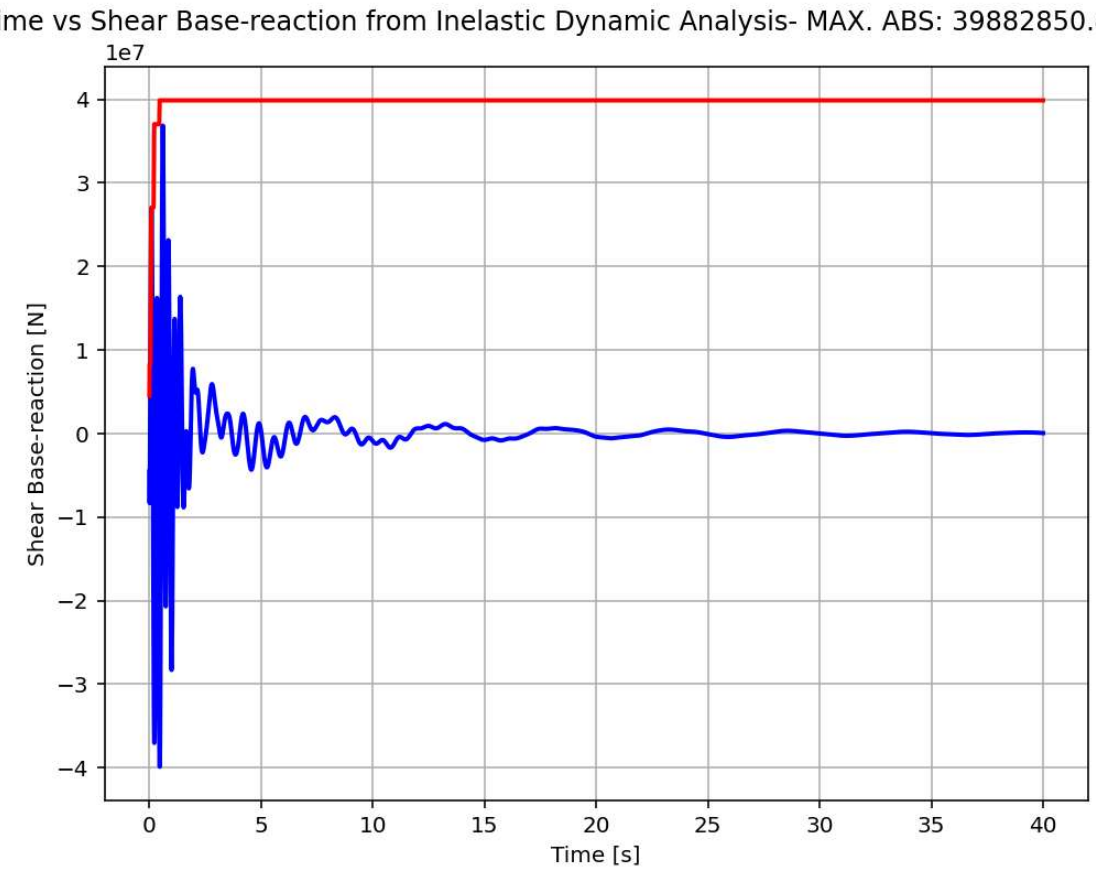

Time vs Displacement - MAX. ABS: 9.726233791700475
Displacement in Y [mm]
Time [s]
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
0
5
10
15
20
25
30
35
40

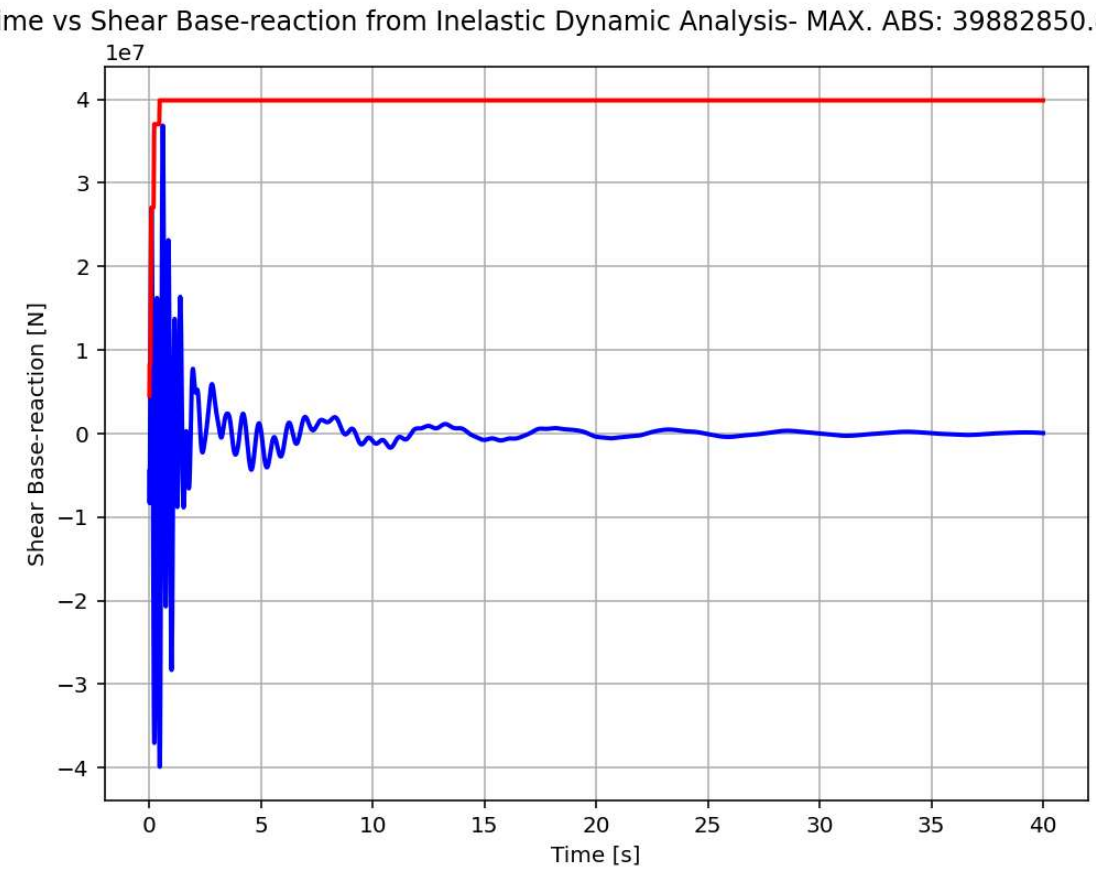

Time vs Velocity - MAX. ABS: 930.996694309792
Velocity in X [mm/s]
Time [s]
1000
750
500
250
0
−250
−500
−750
−1000
0
5
10
15
20
25
30
35
40

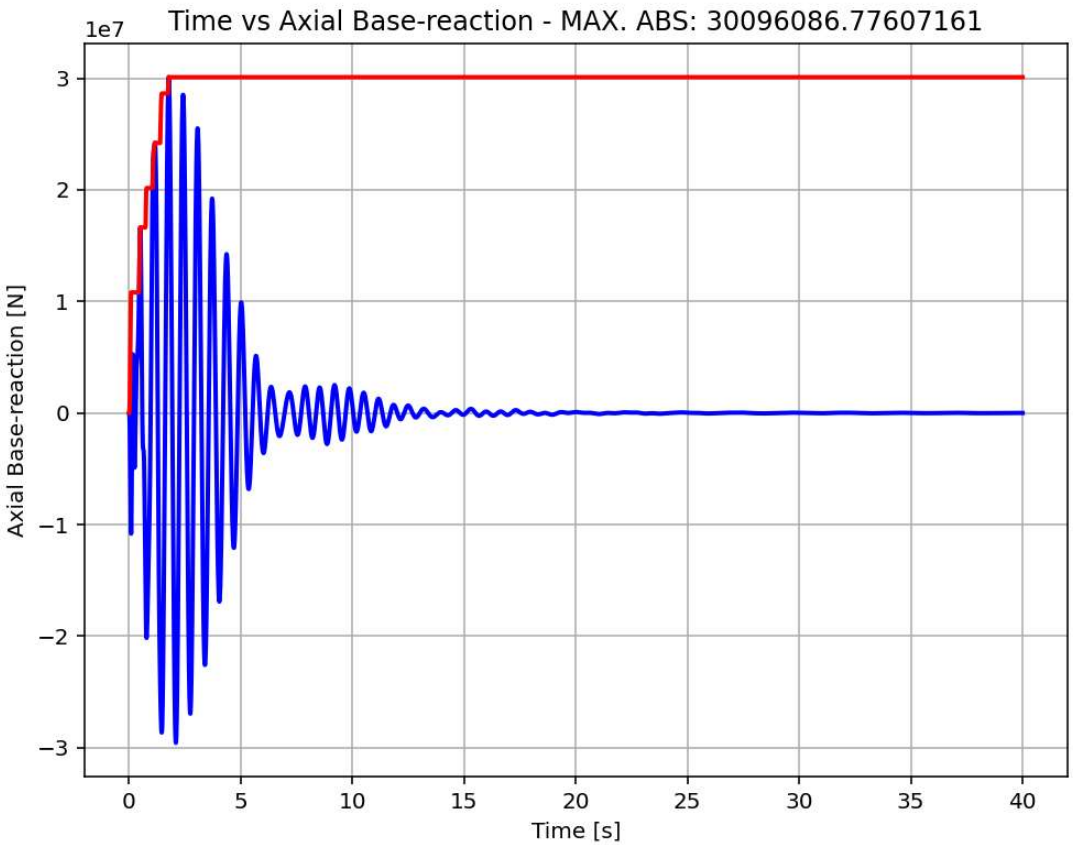

Time vs Velocity - MAX. ABS: 930.996694309792
Velocity in X [mm/s]
Time [s]
1000
750
500
250
0
−250
−500
−750
−1000
0
5
10
15
20
25
30
35
40

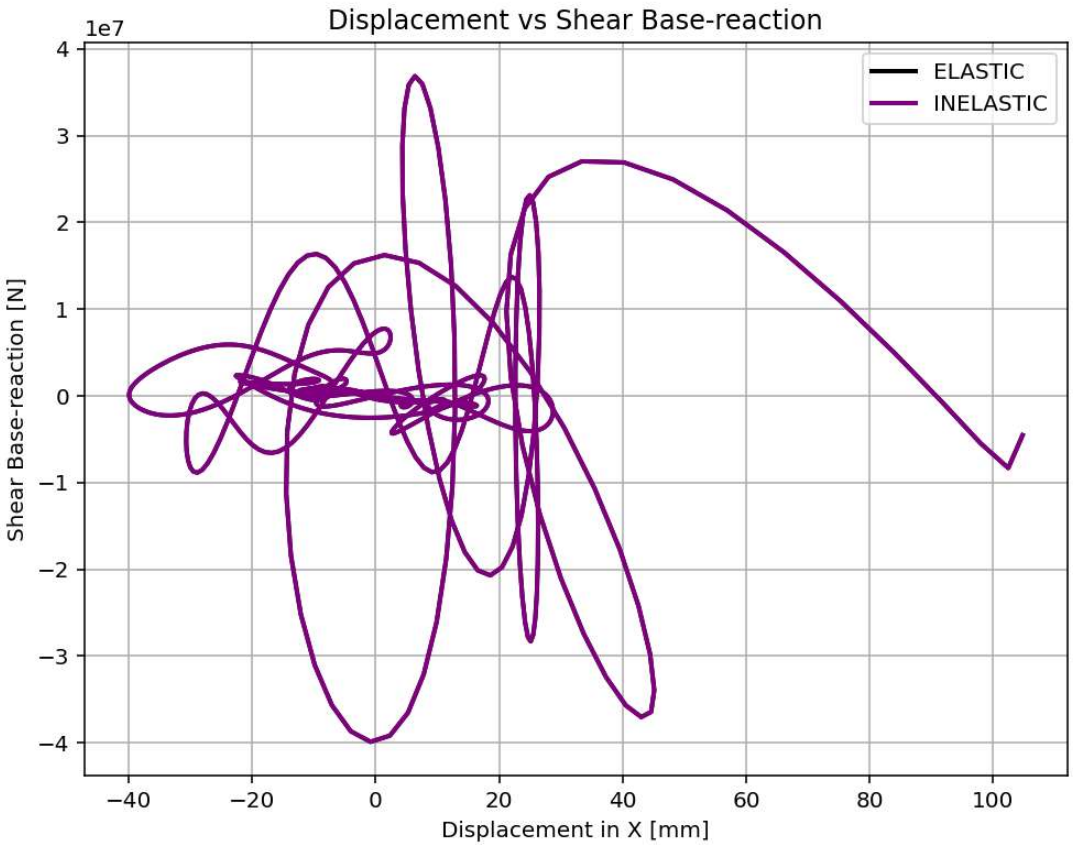

Time vs Acceleration - MAX. ABS: 23709.33997672454
Acceleration in X [mm/s^2]
20000
10000
0
−10000
−20000
0
5
10
15
20
25
30
35
40
Time [s]

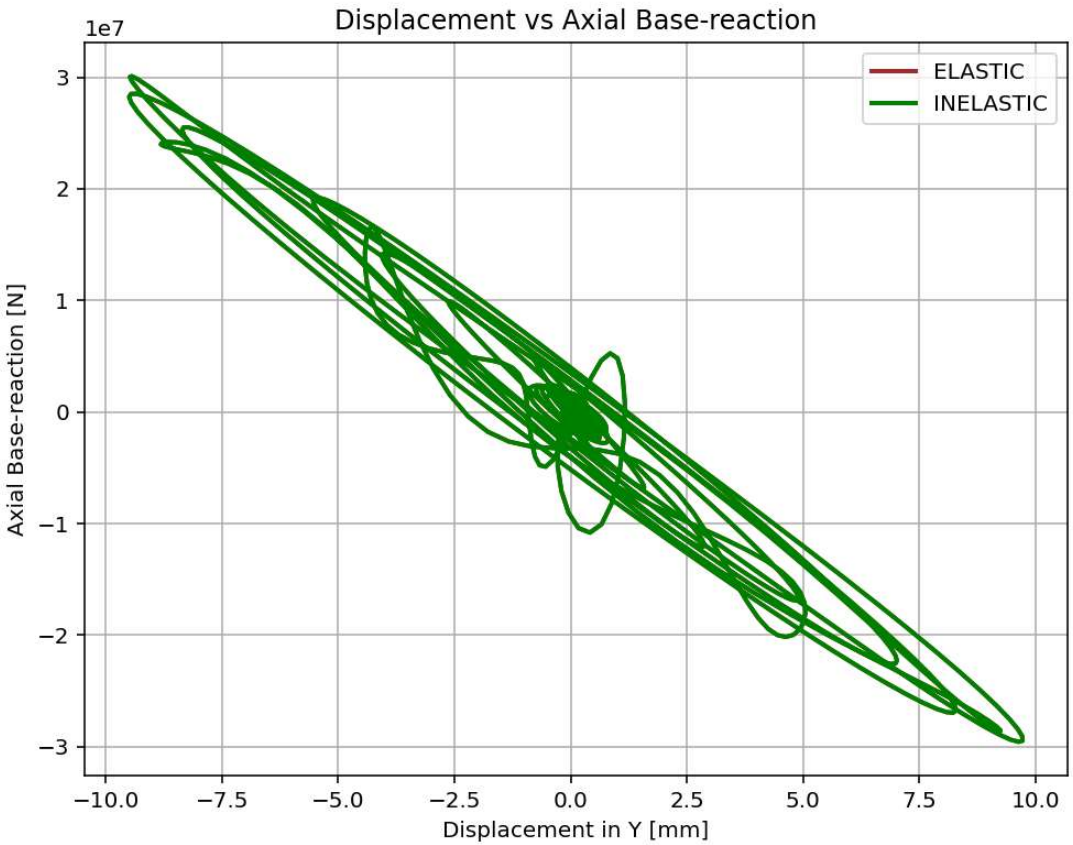

Time vs Acceleration - MAX. ABS: 23709.33997672454
Acceleration in X [mm/s^2]
20000
10000
0
−10000
−20000
0
5
10
15
20
25
30
35
40
Time [s]

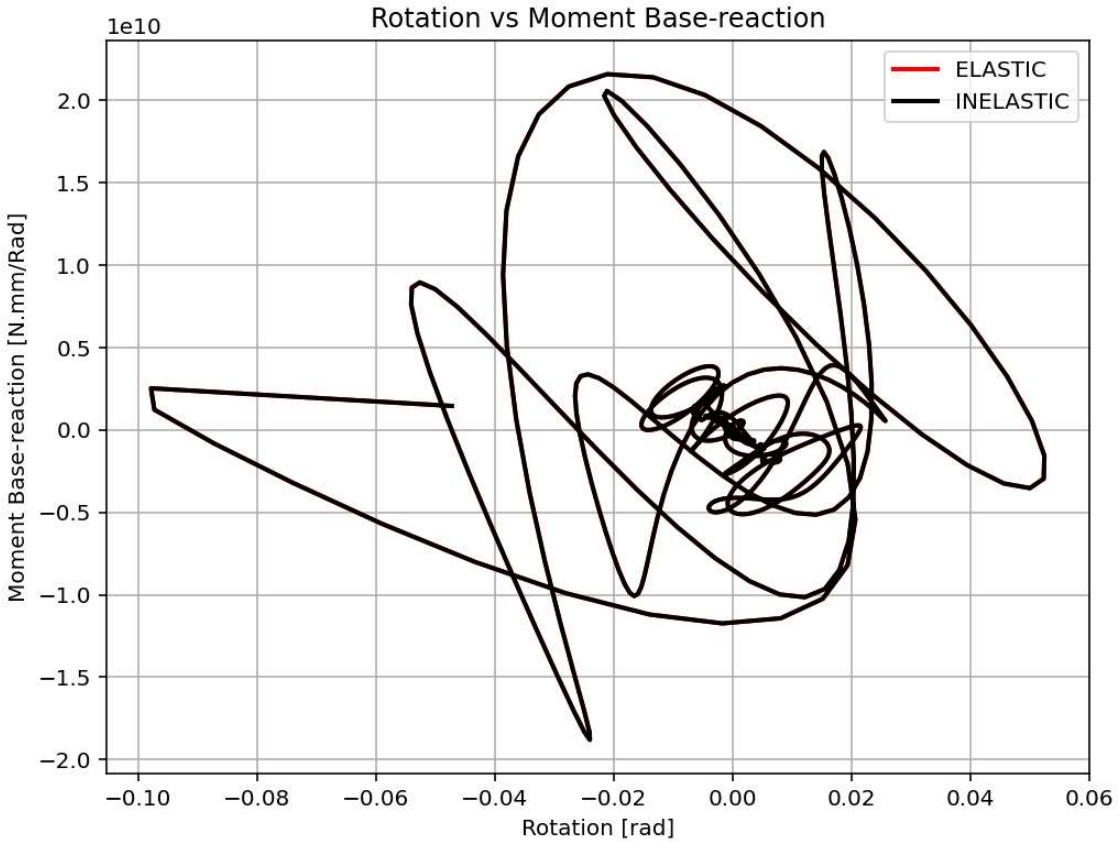

Time vs Shear Base-reaction from Inelastic Dynamic Analysis- MAX. ABS: 39882850.4321066
1e7
4
3
2
1
0
−1
−2
−3
−4
Shear Base-reaction [N]
0
5
10
15
20
25
30
35
40
Time [s]


Time vs Shear Base-reaction from Inelastic Dynamic Analysis- MAX. ABS: 39882850.4321066
1e7
4
3
2
1
0
−1
−2
−3
−4
Shear Base-reaction [N]
0
5
10
15
20
25
30
35
40
Time [s]


Time vs Axial Base-reaction - MAX. ABS: 30096086.77607161
1e7
3
2
1
0
−1
−2
−3
Axial Base-reaction [N]
0
5
10
15
20
25
30
35
40
Time [s]


Displacement vs Shear Base-reaction
1e7
ELASTIC
INELASTIC
Shear Base-reaction [N]
Displacement in X [mm]
4
3
2
1
0
−1
−2
−3
−4
−40
−20
0
20
40
60
80
100


Displacement vs Axial Base-reaction
1e7
ELASTIC
INELASTIC
Axial Base-reaction [N]
Displacement in Y [mm]
3
2
1
0
−1
−2
−3
−10.0
−7.5
−5.0
−2.5
0.0
2.5
5.0
7.5
10.0


Rotation vs Moment Base-reaction
1e10
ELASTIC
INELASTIC
Moment Base-reaction [N.mm/Rad]
Rotation [rad]
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−0.10
−0.08
−0.06
−0.04
−0.02
0.00
0.02
0.04
0.06