COMPARATIVE STUDY OF ELASTIC AND INELASTIC STRUCTURAL BEHAVIOR THROUGH PUSHOVER DYNAMIC ANALYSIS. HARMONIC IMPACT LOADING ANALYSIS OF CONCRETE FRAME WITH VISCOUS DAMPER USING OPENSEES
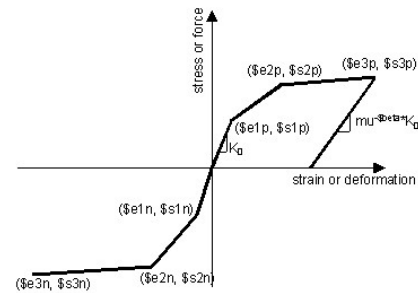
WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
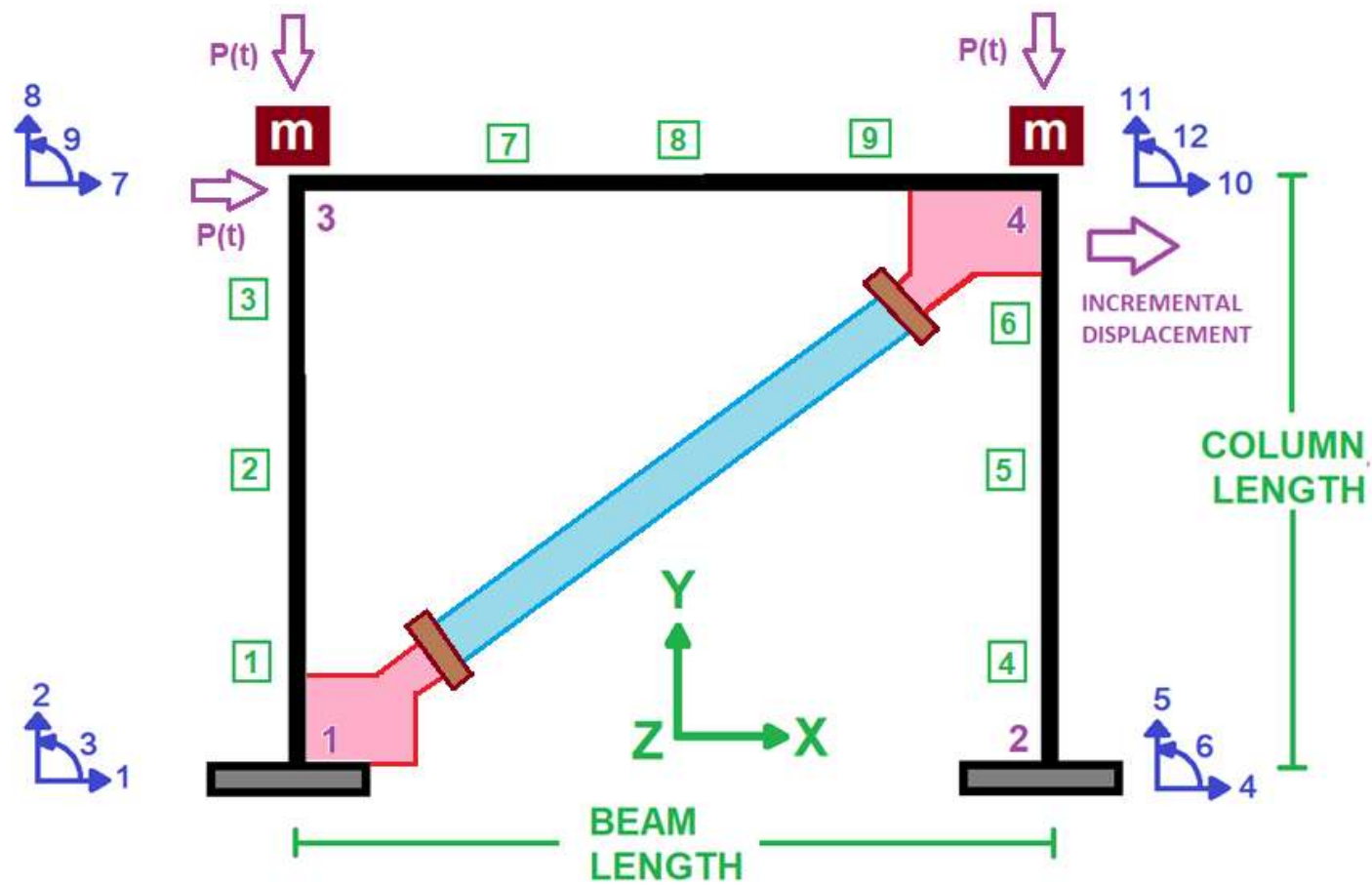
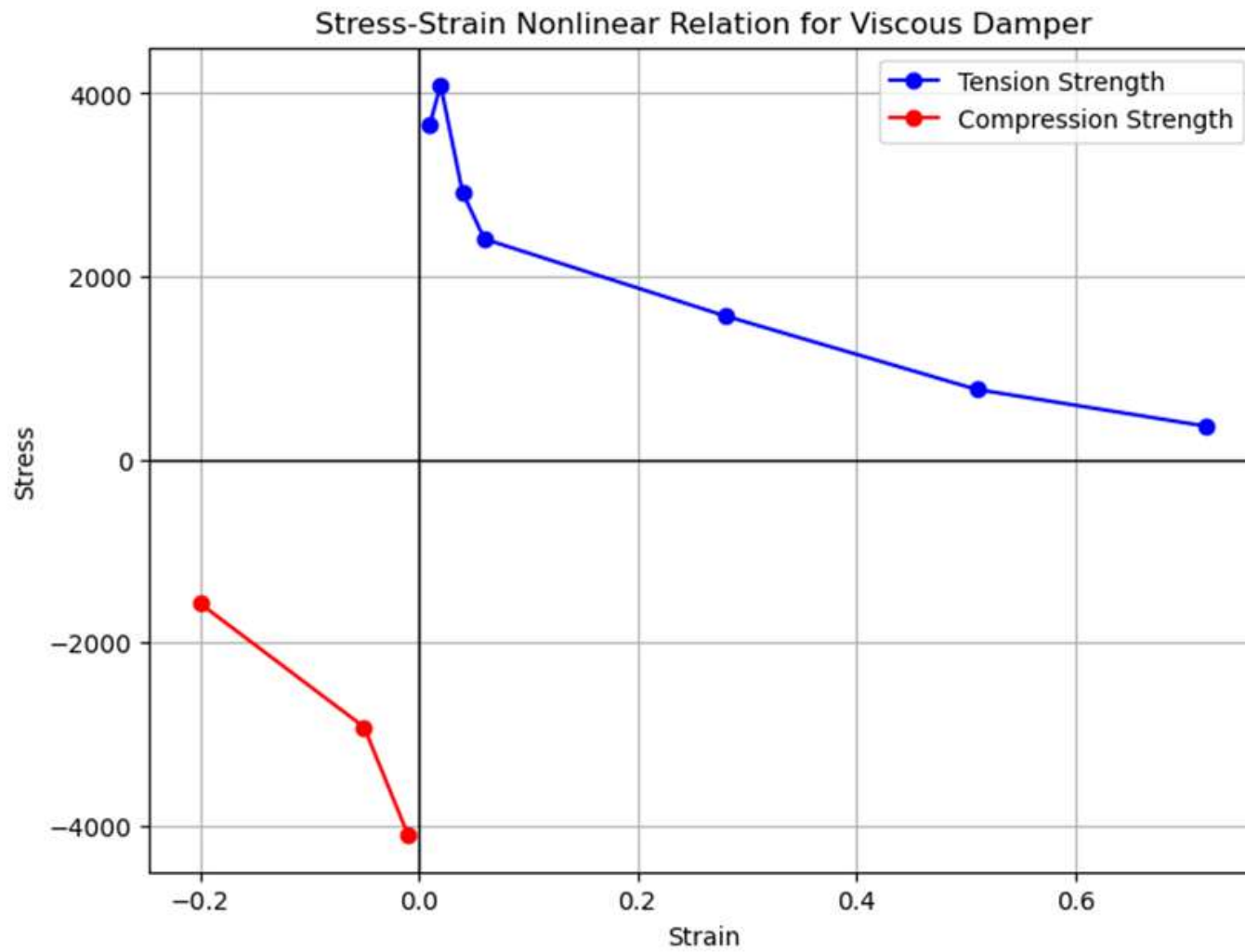CORE AND COVER CONCRETE RELATION

WITHOUT HARDENING AND ULTIMATE STRAIN

WITH HARDENING AND ULTIMATE STRAIN

COLUMN SECTION

BEAM SECTION

Stress-Strain Nonlinear Relation for Viscous Damper

Spyder (Python 3.12)

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...ANT_ELASTIC_OR_INELASTIC_FRAME_IMPACT_LOAD_VISCOUS_DAMPER

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

CONFINEMENT_NONCON..._VISCOUS_DAMPER.py

```
1   ####################################################################################
2   #                  >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
3   #   COMPARATIVE STUDY OF ELASTIC AND INELASTIC STRUCTURAL BEHAVIOR THROUGH PUSHOVER DYNAMIC ANALY
4   #                  HARMONIC IMPACT LOADING ANALYSIS OF CONCRETE FRAME WITH VISCOUS DAMPER
5   #----------------------------------------------------------------------------------
6   #                  THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
7   #                          EMAIL: salar.d.ghashghaei@gmail.com
8   ####################################################################################
9   """
10  1. The script performs a comparative study of elastic and inelastic structural behavior using pu
11  2. It models a 2D reinforced concrete frame with columns (500x500mm) and beams (500x300mm) using
12  3. Material definitions include confined/unconfined concrete (fc=25MPa) and bilinear steel reinf
13  4. Two analysis types are implemented: static pushover (displacement-controlled) and dynamic tim
14  5. Rayleigh damping is calculated based on initial modal periods and target damping ratios (5%).
15  6. The pushover analysis applies incremental displacements up to 675mm, recording base reactions
16  7. Dynamic analysis uses Newmark integration with ground motion inputs scaled by 0.01g (El Centr
17  8. Key outputs include force-displacement curves, moment-rotation relationships, and stiffness d
18  9. Eigenvalue analysis tracks period elongation due to inelasticity during dynamic events.
19  10. Damage indices are computed for ductility assessment using bilinear curve fitting.
20  11. Overstrength factors (Ω), ductility ratios (μ), and R-factors are quantified for seismic per
21  12. Real-time monitoring of base shear, axial forces, and interstory drifts is implemented.
22  13. The script includes advanced convergence controls (Newton-Raphson, 1e-6 tolerance).
23  14. Confinement effects are modeled with variable enhancement ratios (Kc=1.25 for columns).
24  15. Results are exported to Excel, including displacements, forces, stiffness, and period data.
25  16. Visualization includes deformed shapes, hysteresis loops, and cumulative response envelopes.
26  17. Damping ratios are estimated from free vibration decay in dynamic analyses.
27  18. Both geometric nonlinearities (P-Delta/Corotational) and material nonlinearities are conside
28  19. The code supports parametric studies by varying steel models (with/without hardening) and el
29  20. Comprehensive plotting functions enable side-by-side comparison of elastic vs. inelastic res
30
31  -----------------------------------------------------------------
32  Viscous Dampers:
33
34  Definition:
```

32 %

Displacement vs Shear Base-reaction

Help   Variable Explorer   Debugger   Plots   Files

Console 1/A

```
    End 2 Forces (P V M): -515.761 -7445.96 -3.08585e+06

ElasticBeam2d: 3
    Connected Nodes: 6 3
    CoordTransf: 1
    mass density:  6.25, cMass: 0
    release code:  0
    End 1 Forces (P V M): 513.596 5765.31 3.08585e+06
    End 2 Forces (P V M): -513.596 -5765.31 2.67946e+06

In [2]:
```
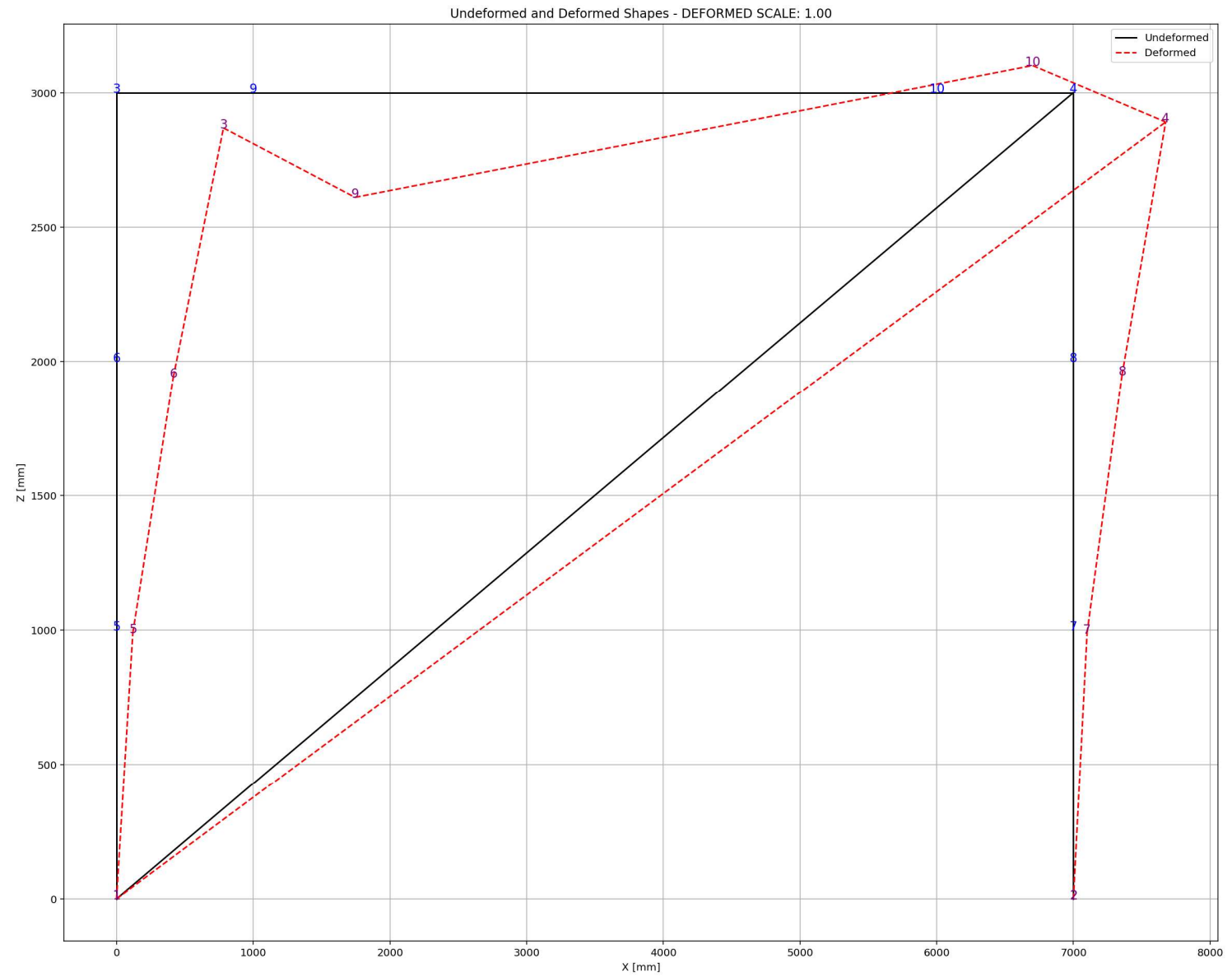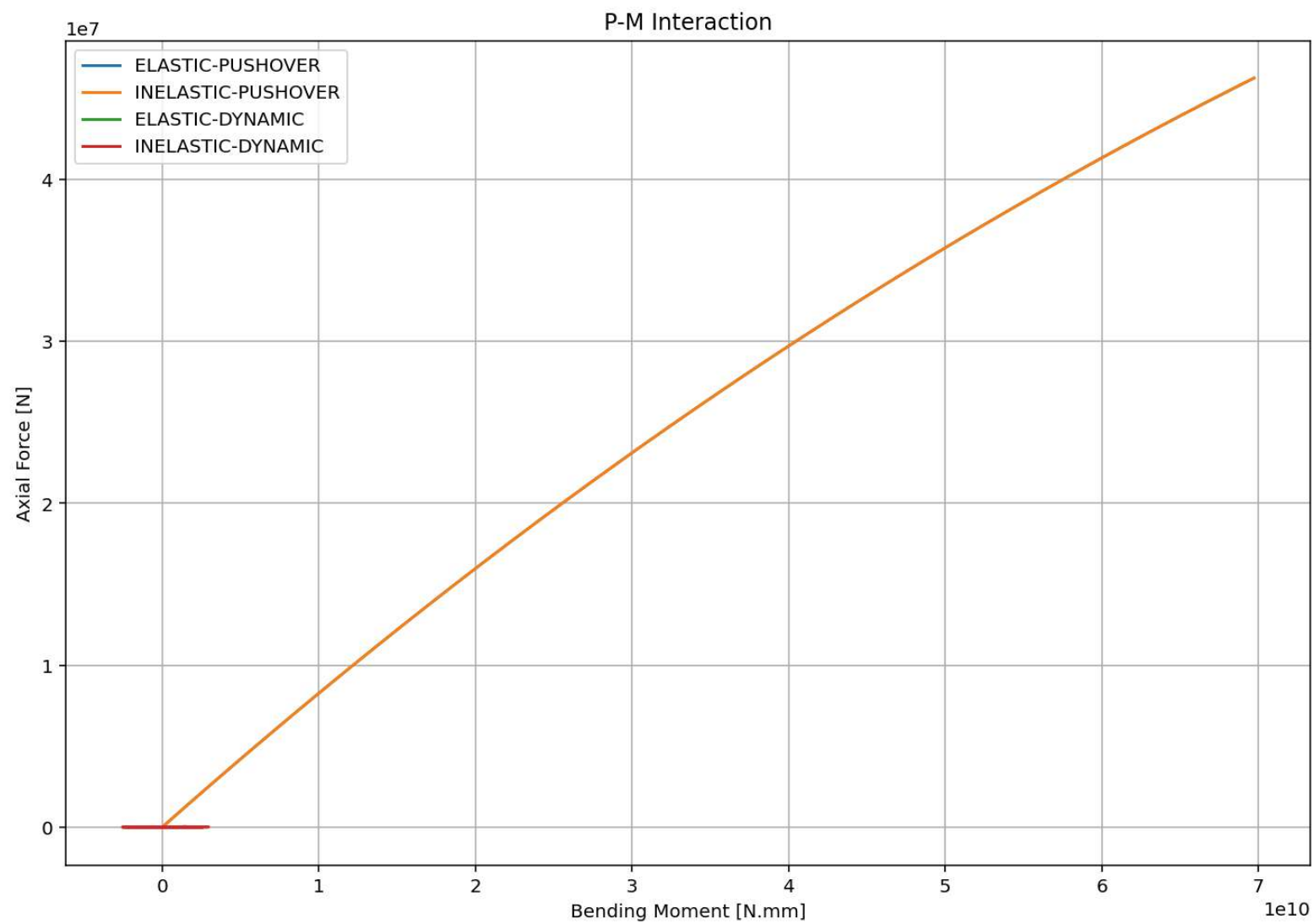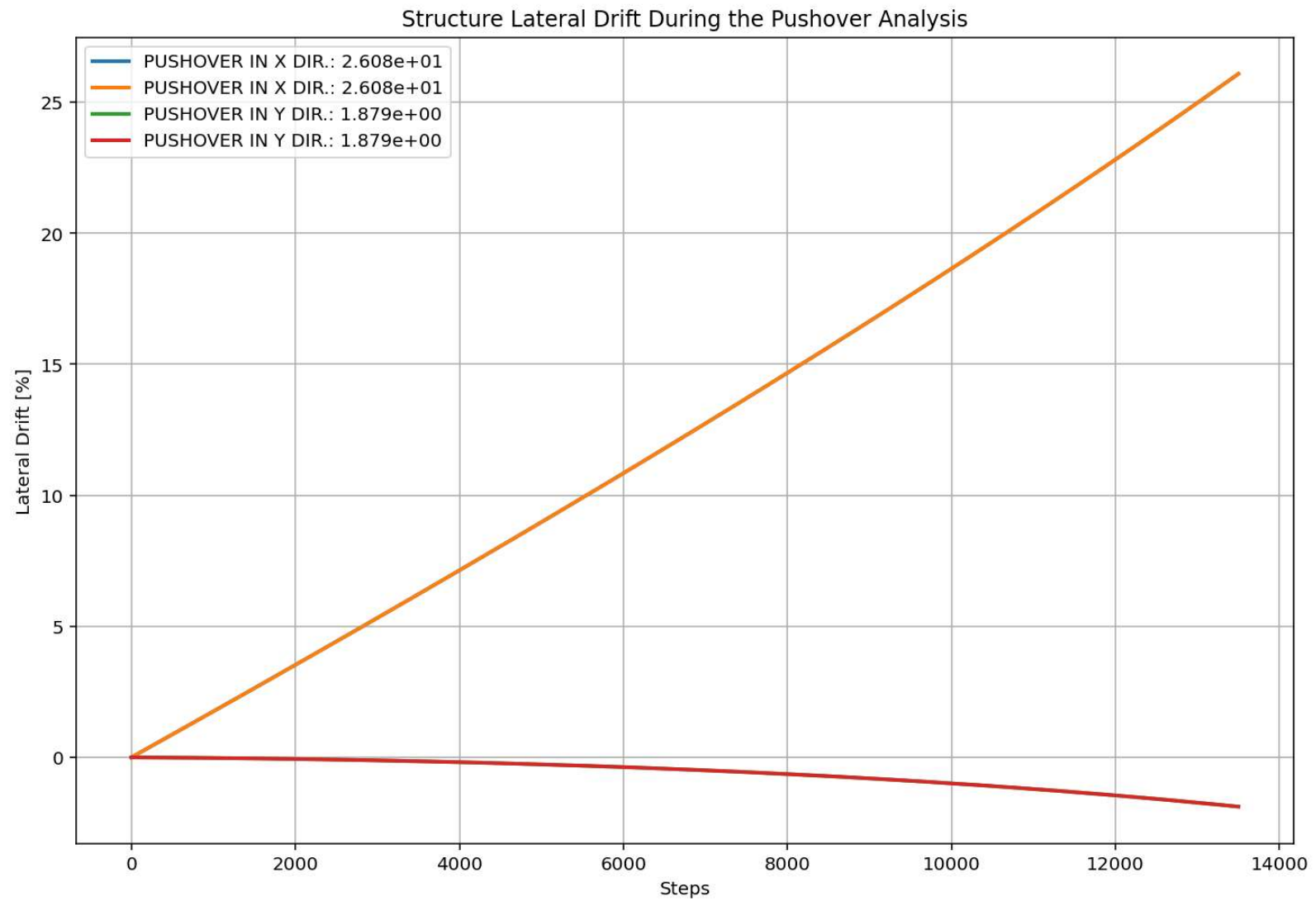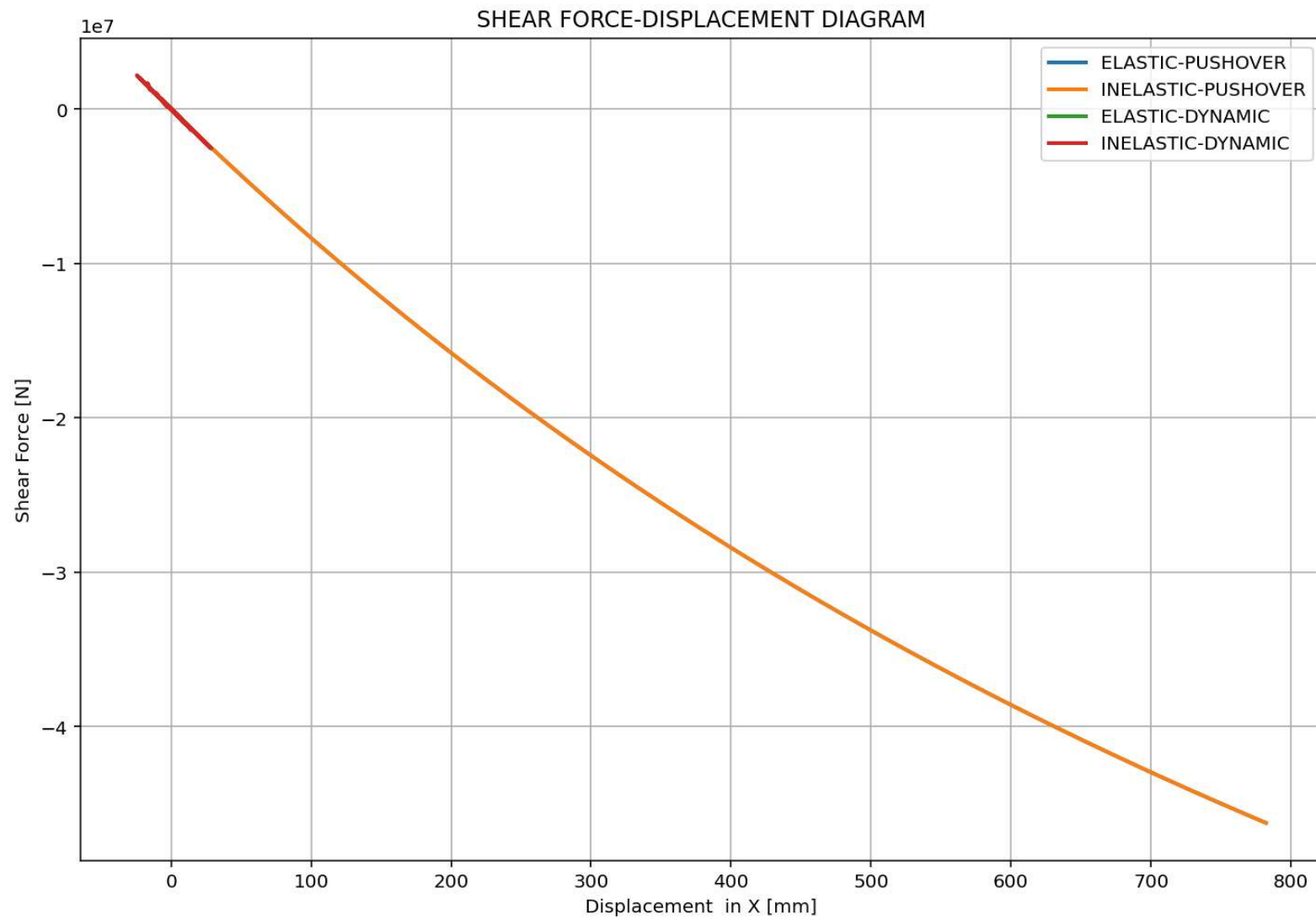
IPython Console   History

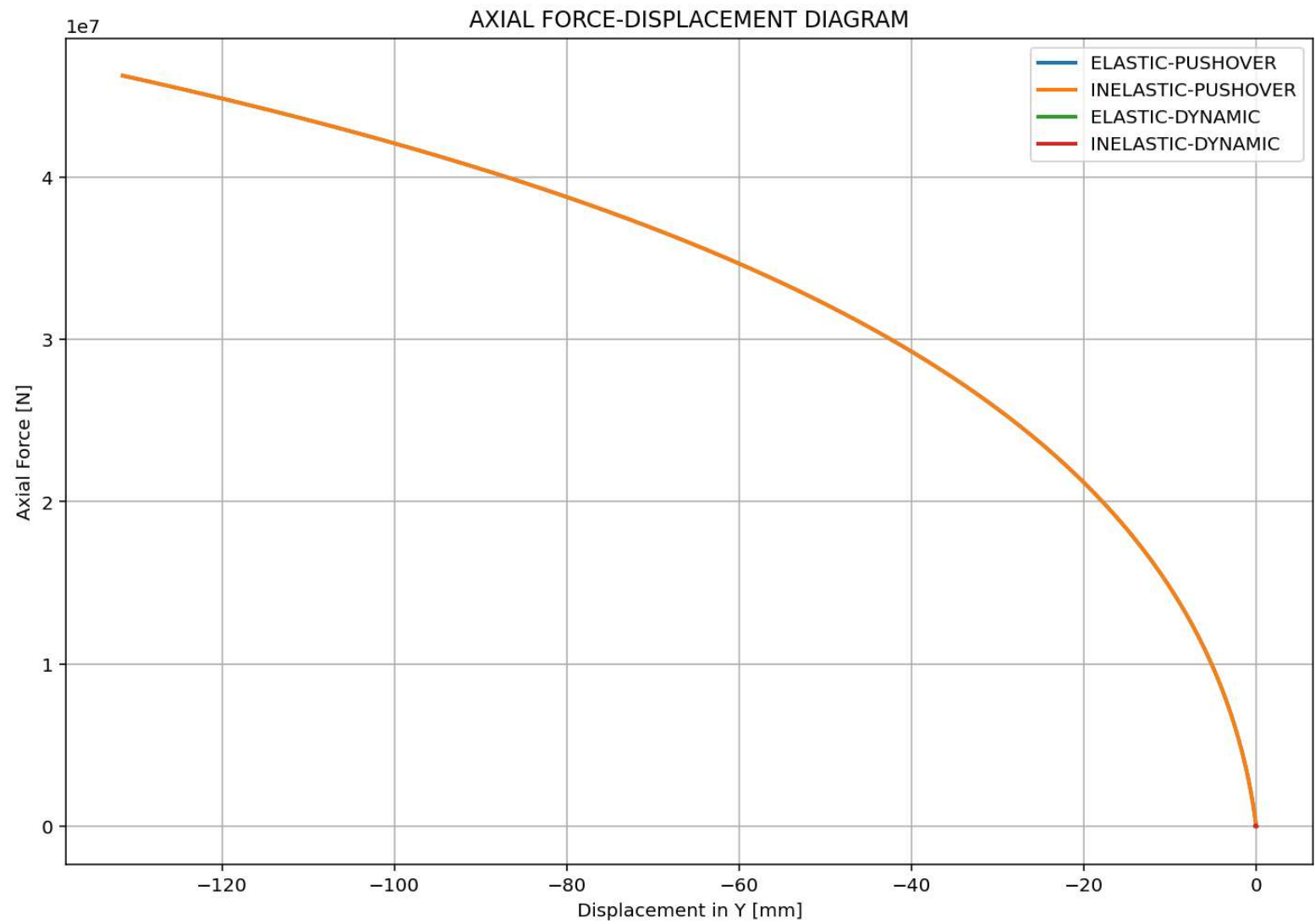Inline   Conda: anaconda3 (Python 3.12.7)   ✓ LSP: Python   Line 966, Col 112   UTF-8   CRLF   RW   Mem 31%
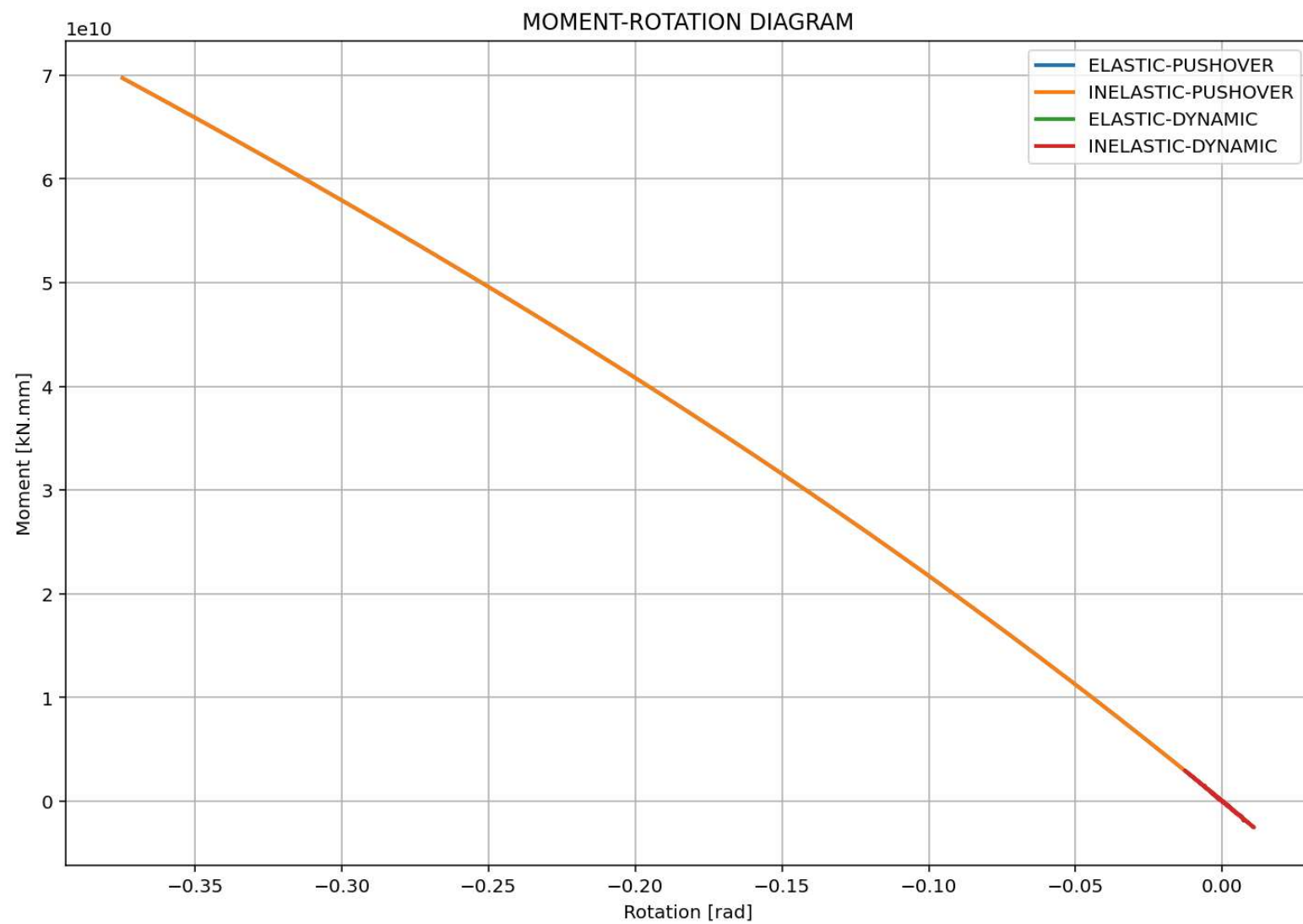
ELASTIC AND INELASTIC STATIC ANALYSIS (PUSHOVER)

Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00

P-M Interaction

Structure Lateral Drift During the Pushover Analysis

SHEAR FORCE-DISPLACEMENT DIAGRAM
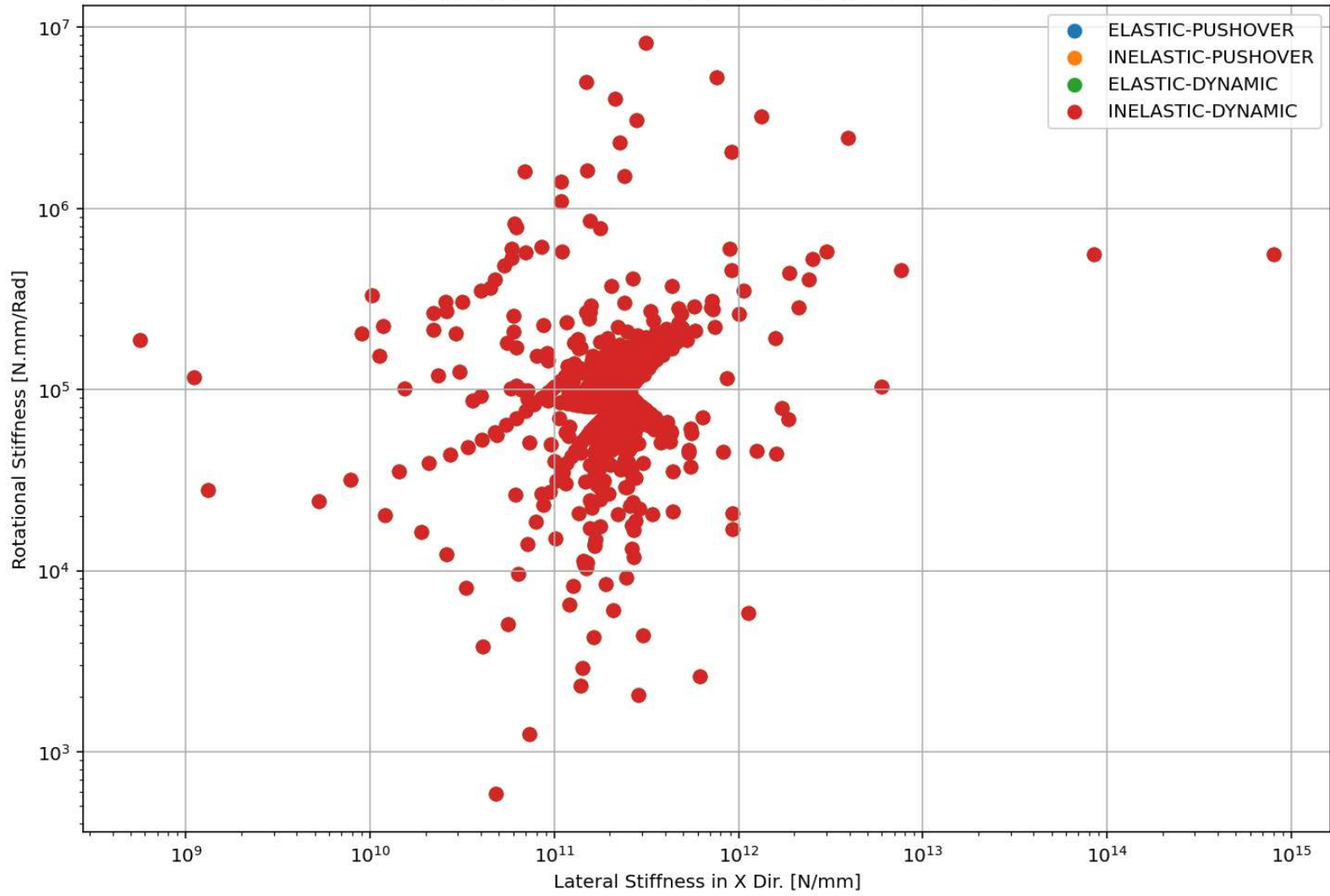
AXIAL FORCE-DISPLACEMENT DIAGRAM
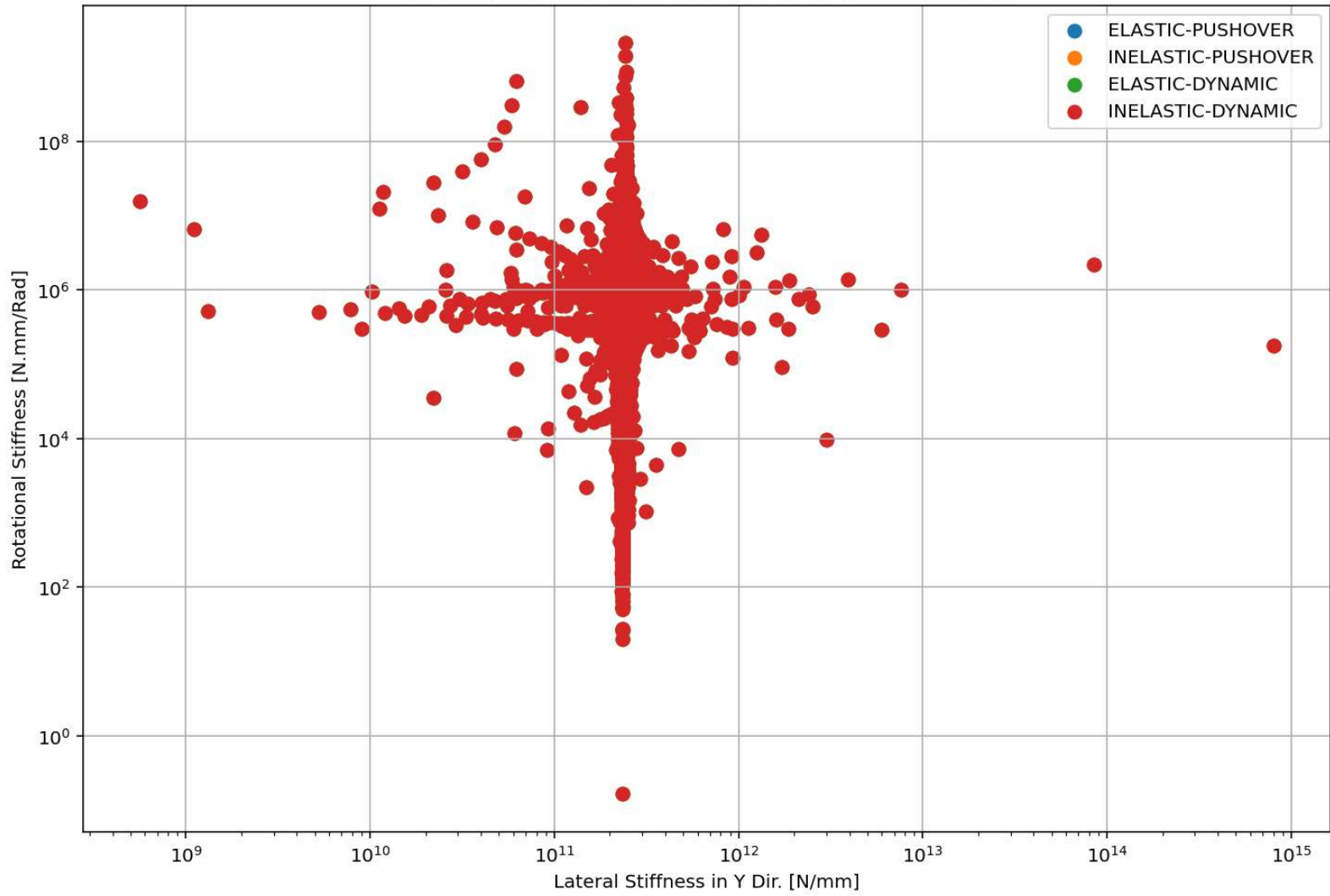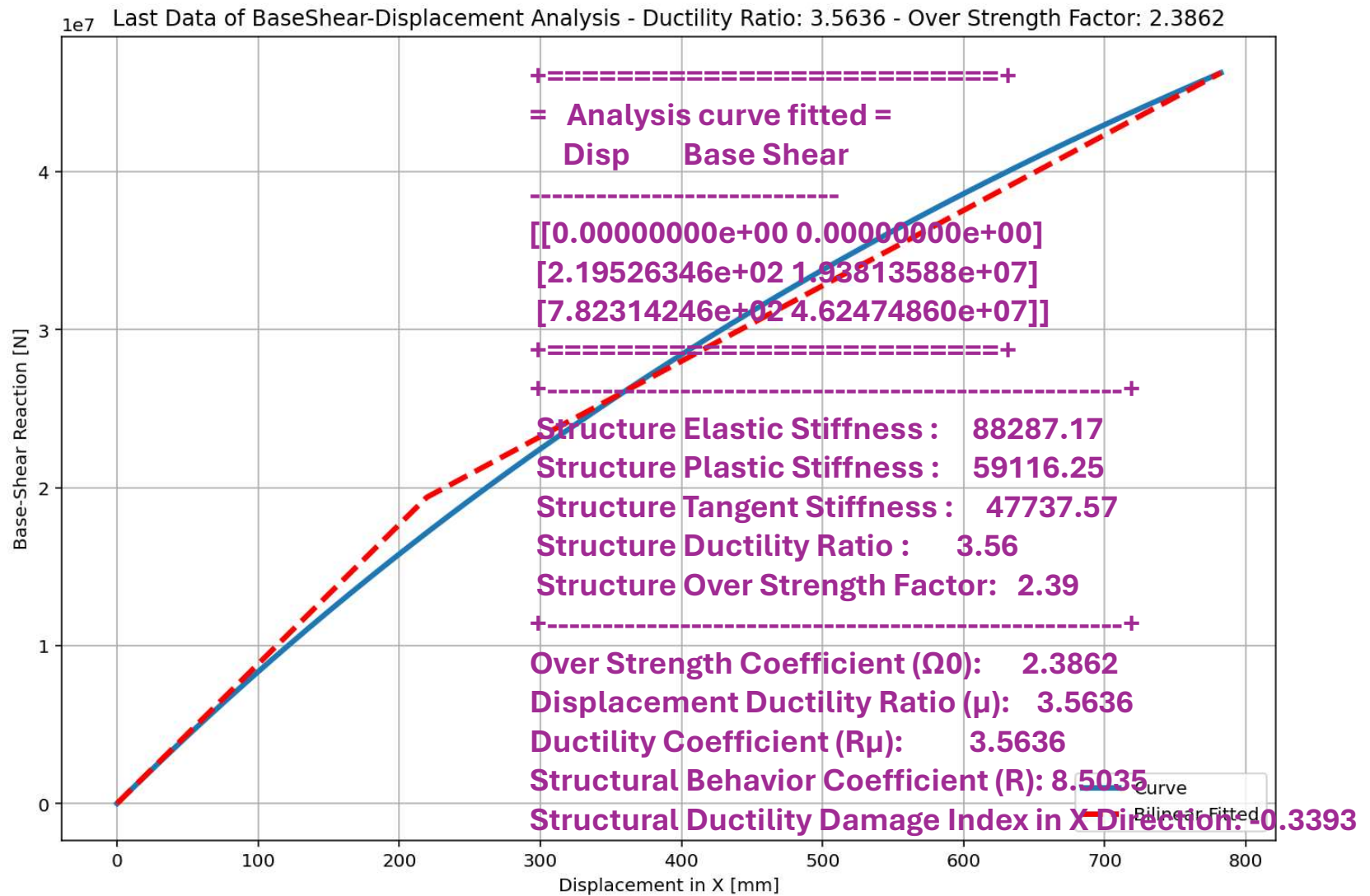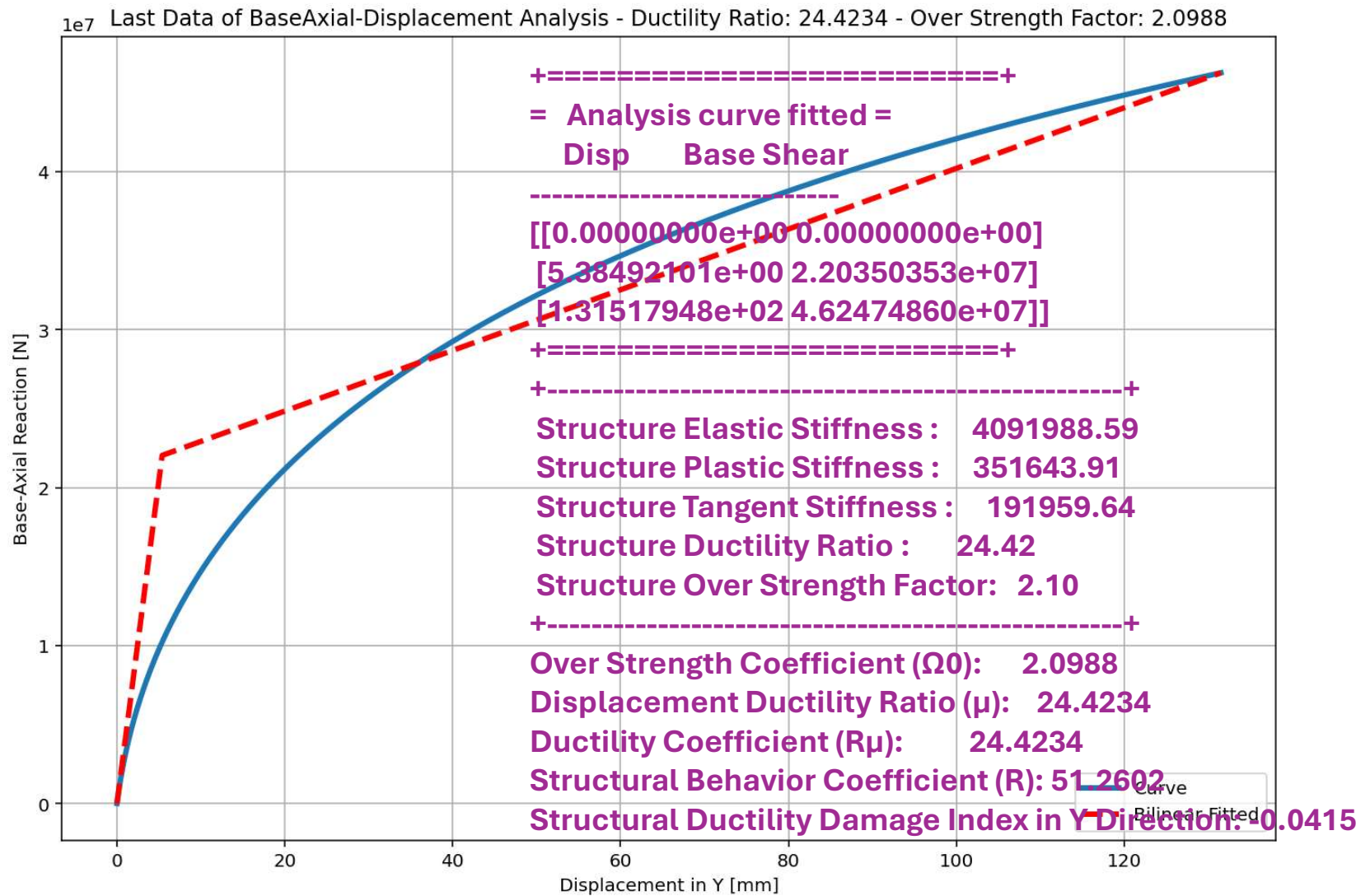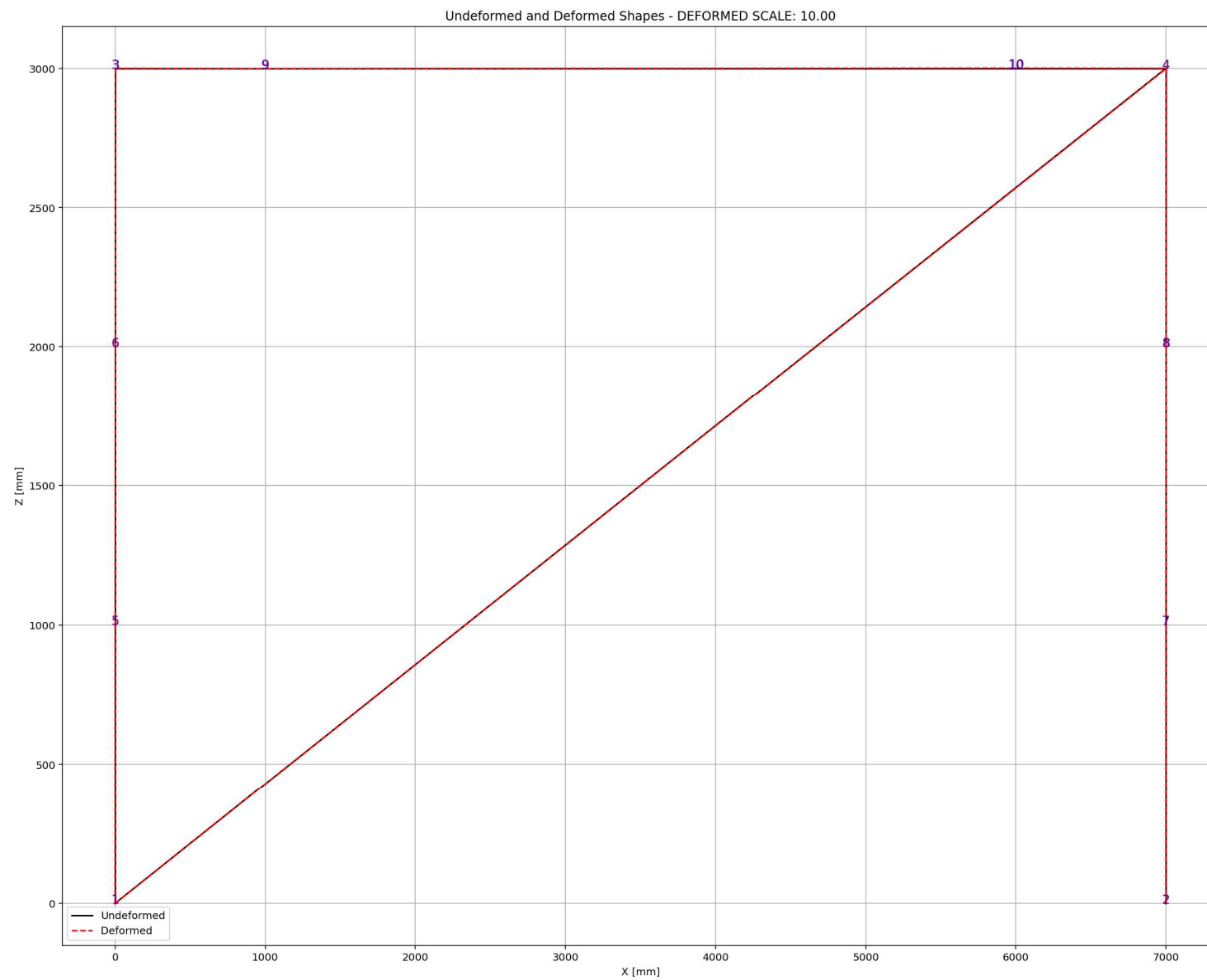
MOMENT-ROTATION DIAGRAM

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM

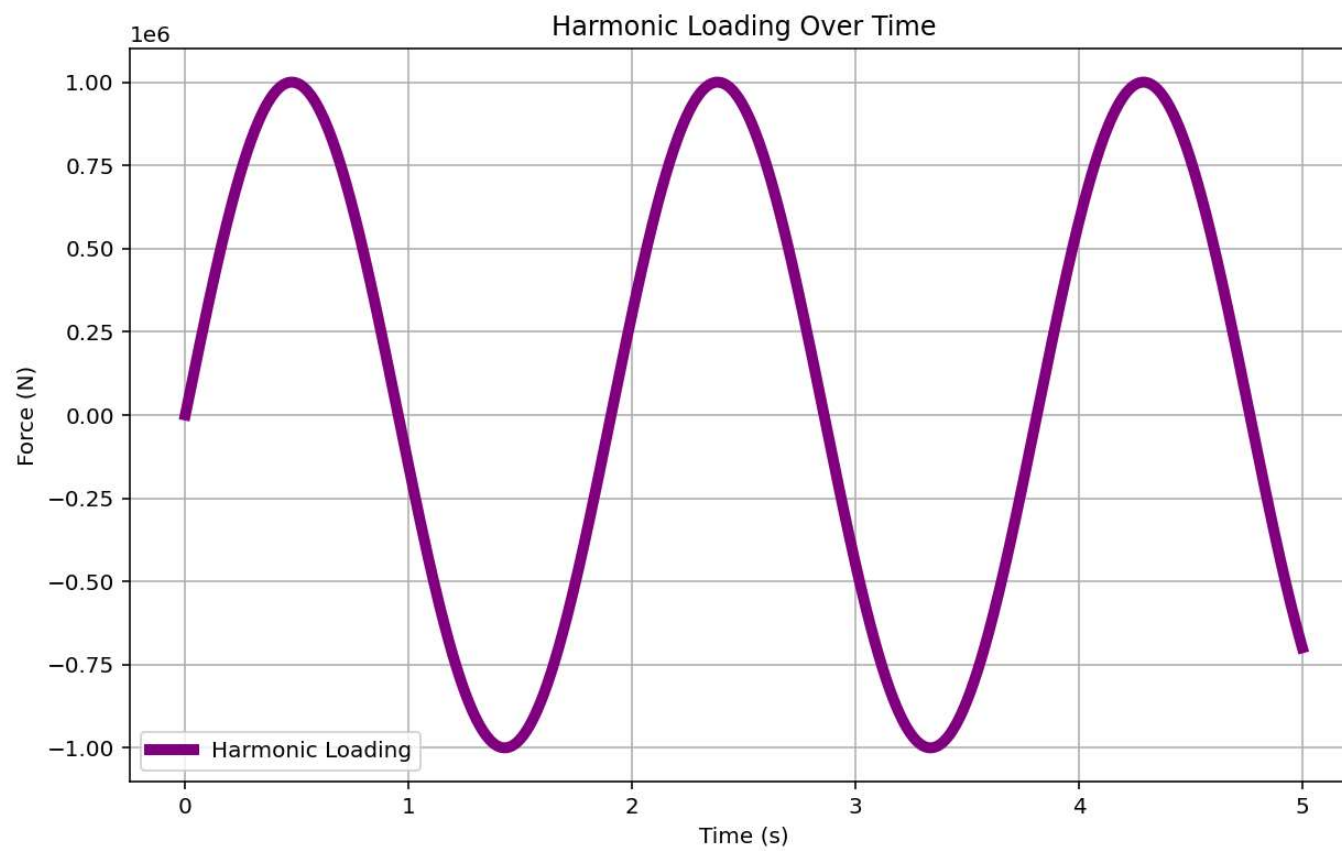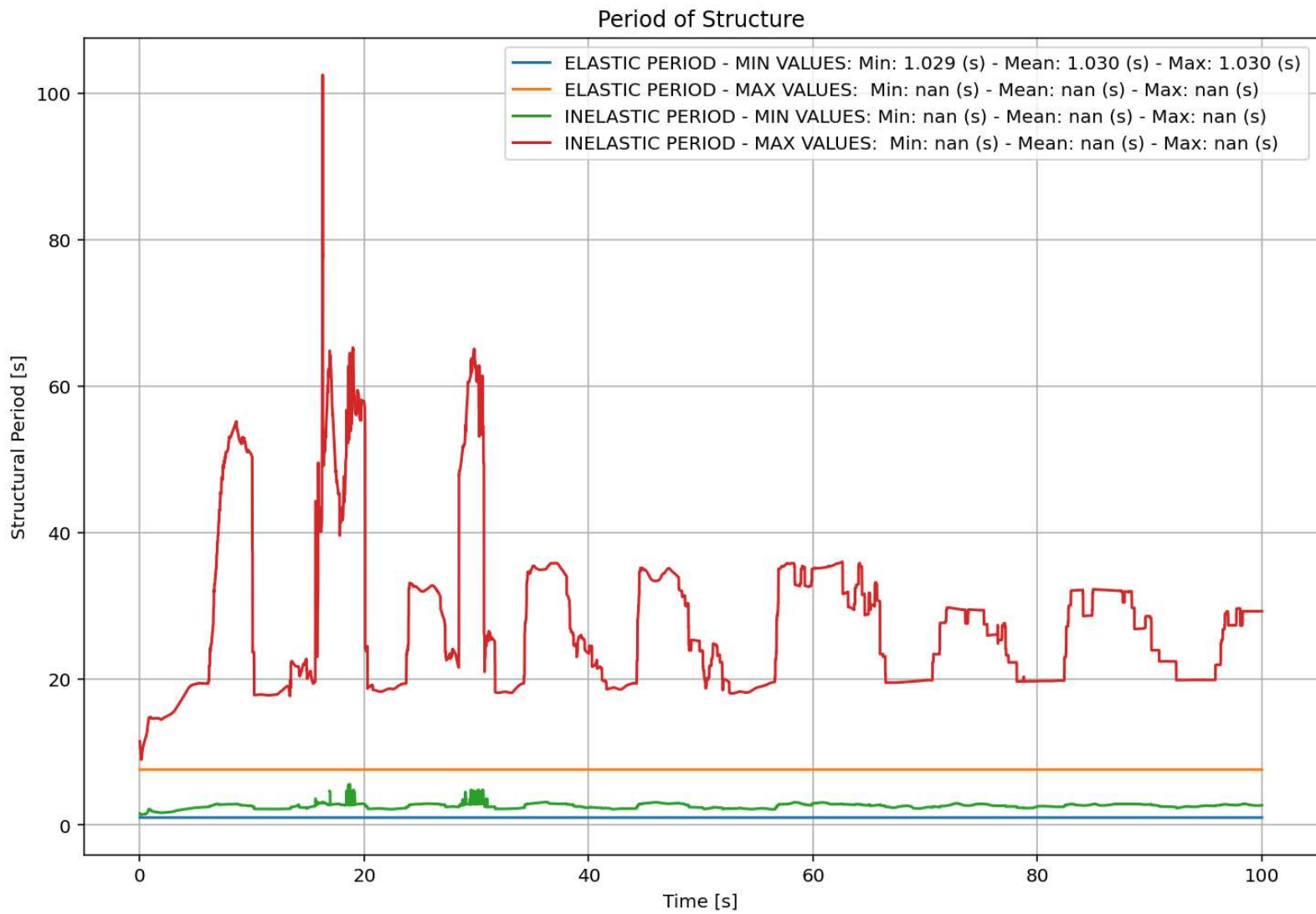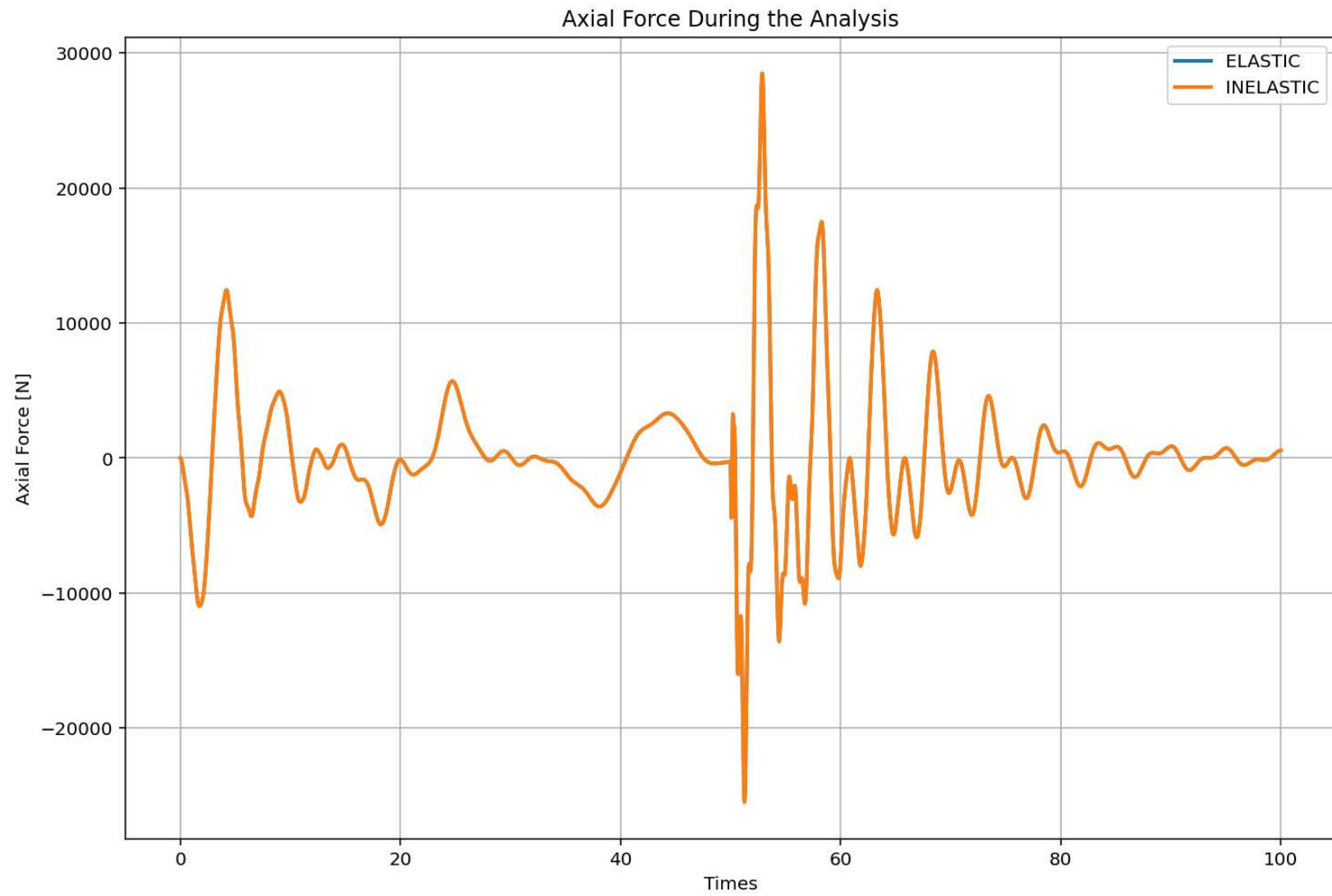ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM

Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 3.5636 - Over Strength Factor: 2.3862

+=========================+
= Analysis curve fitted =
  Disp   Base Shear

[[0.00000000e+00 0.00000000e+00]
 [2.19526346e+02 1.93813588e+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: -0.3393

Base-Shear Reaction [N]

Displacement in X [mm]

Curve
Bilinear Fitted

Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 24.4234 - Over Strength Factor: 2.0988

+===========================+
=   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
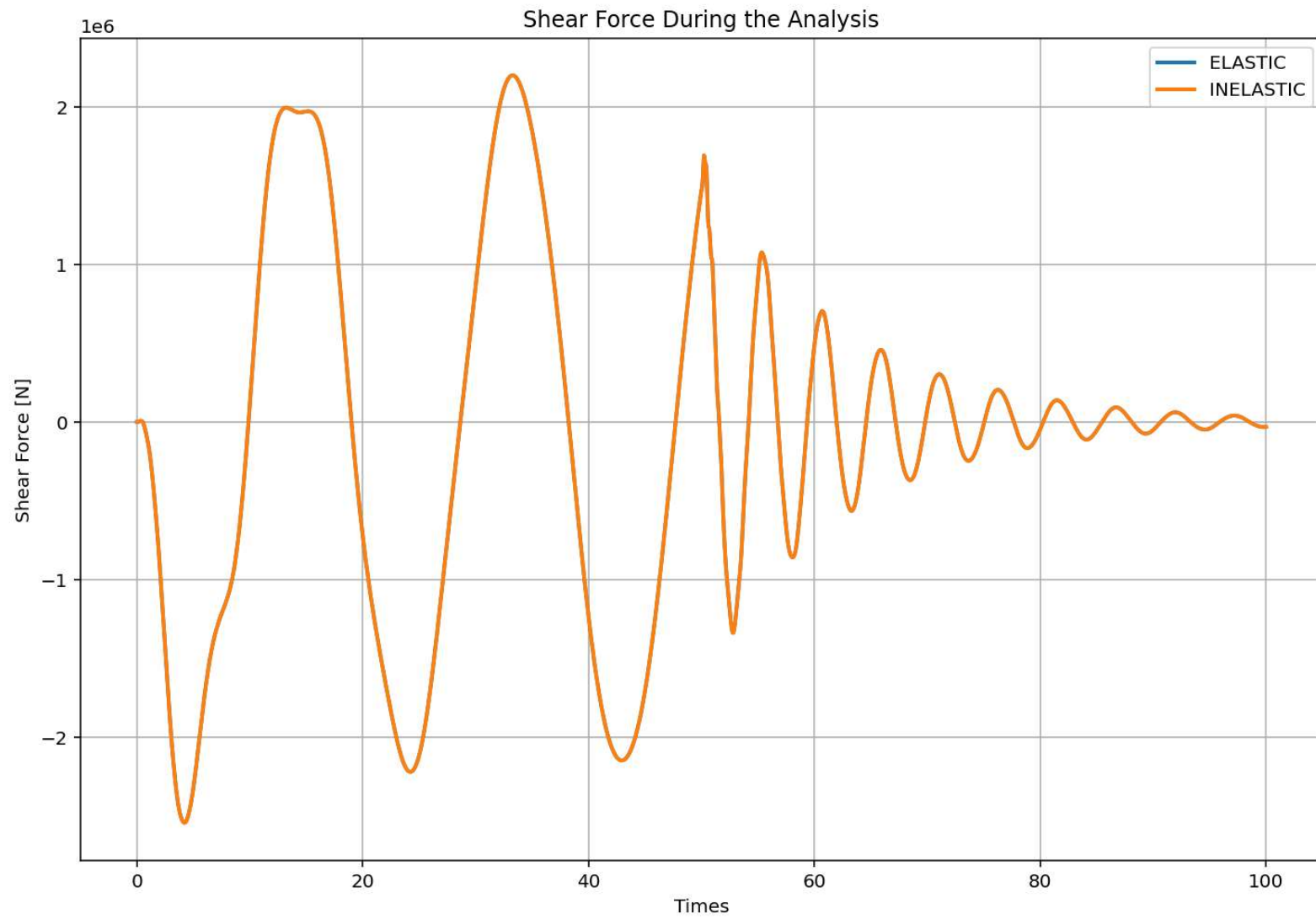Structural Behavior Coefficient (R): 51.2602
Structural Ductility Damage Index in Y Direction: 0.0415

ELASTIC AND INELASTIC DYNAMIC ANALYSIS

Undeformed and Deformed Shapes - DEFORMED SCALE: 10.00

Harmonic Loading Over Time

Period of Structure

ELASTIC PERIOD - MIN VALUES: Min: 1.029 (s) - Mean: 1.030 (s) - Max: 1.030 (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)

Axial Force During the Analysis

Moment During the Analysis

Displacement During the Analysis
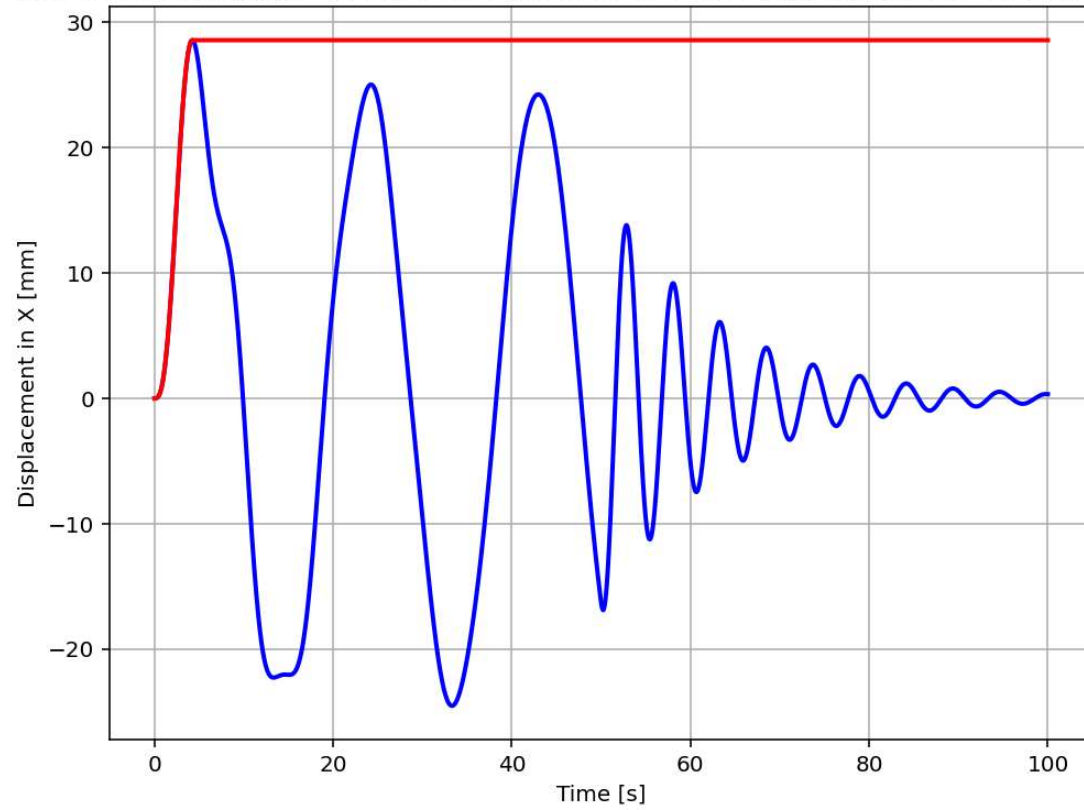
Displacement During the Analysis
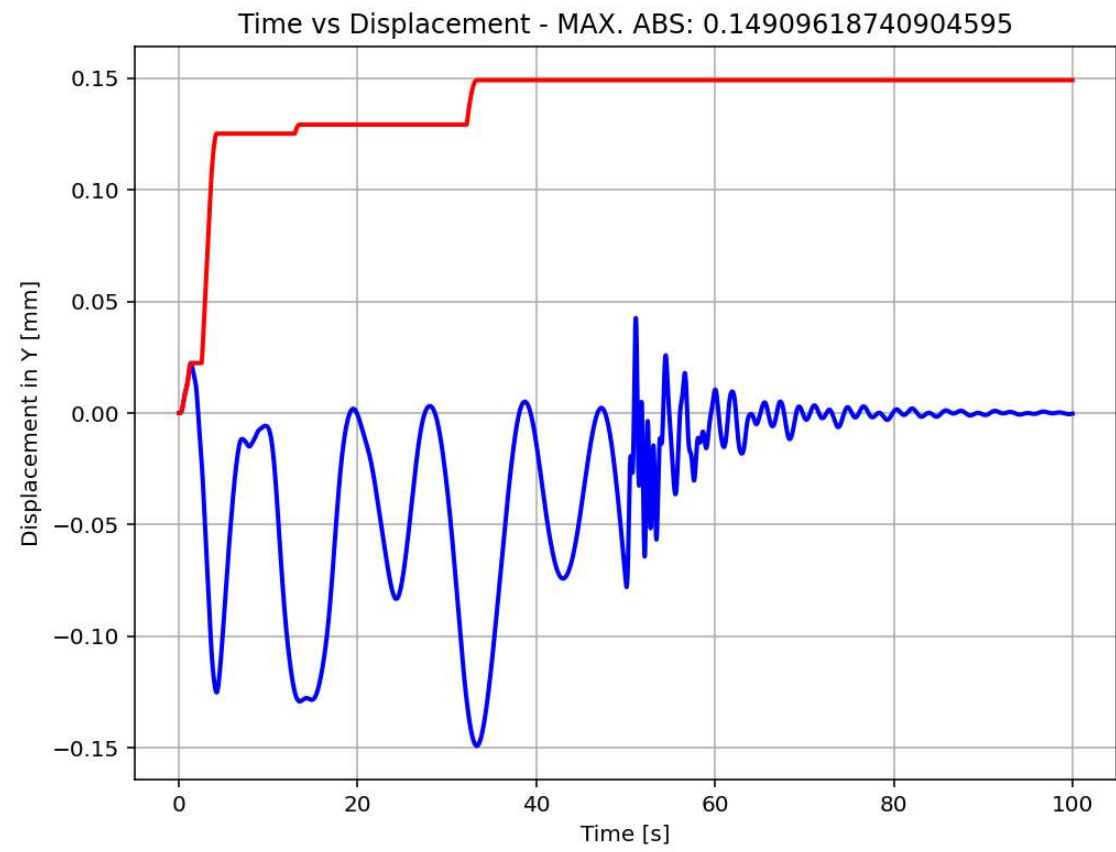
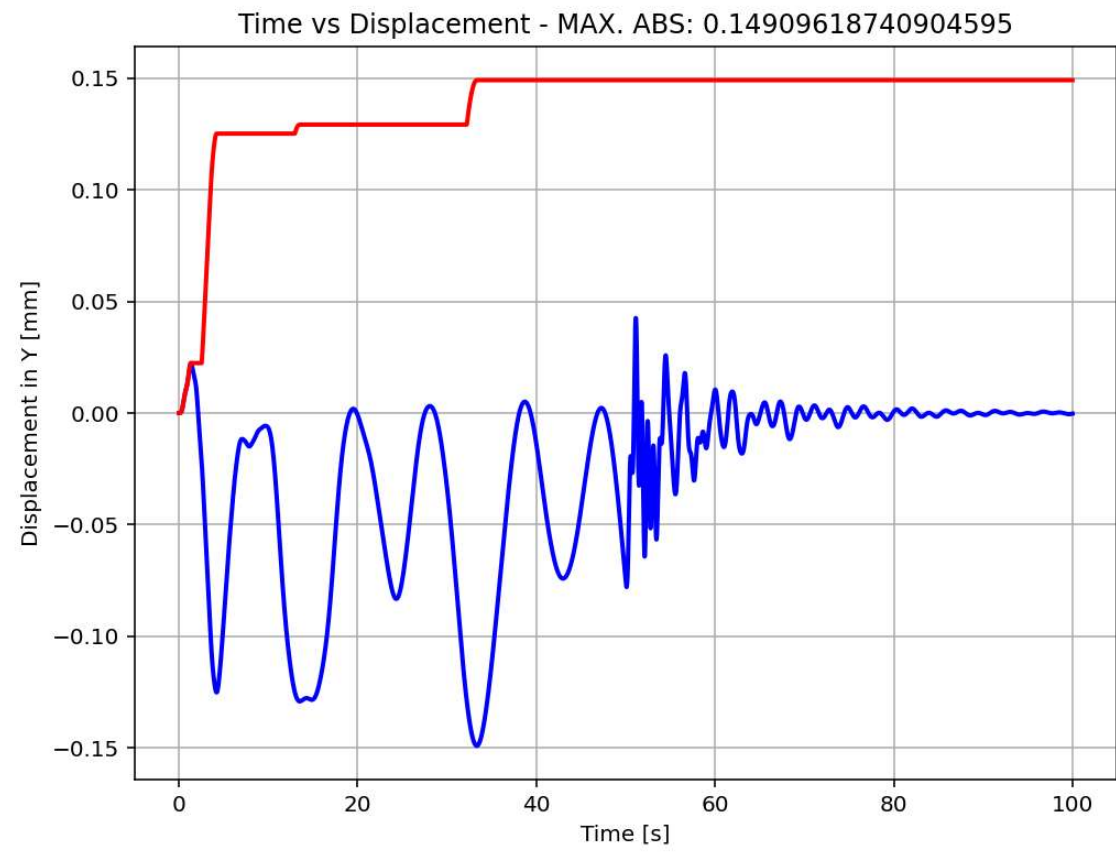Structure Lateral Drift During the Dynamic Analysis

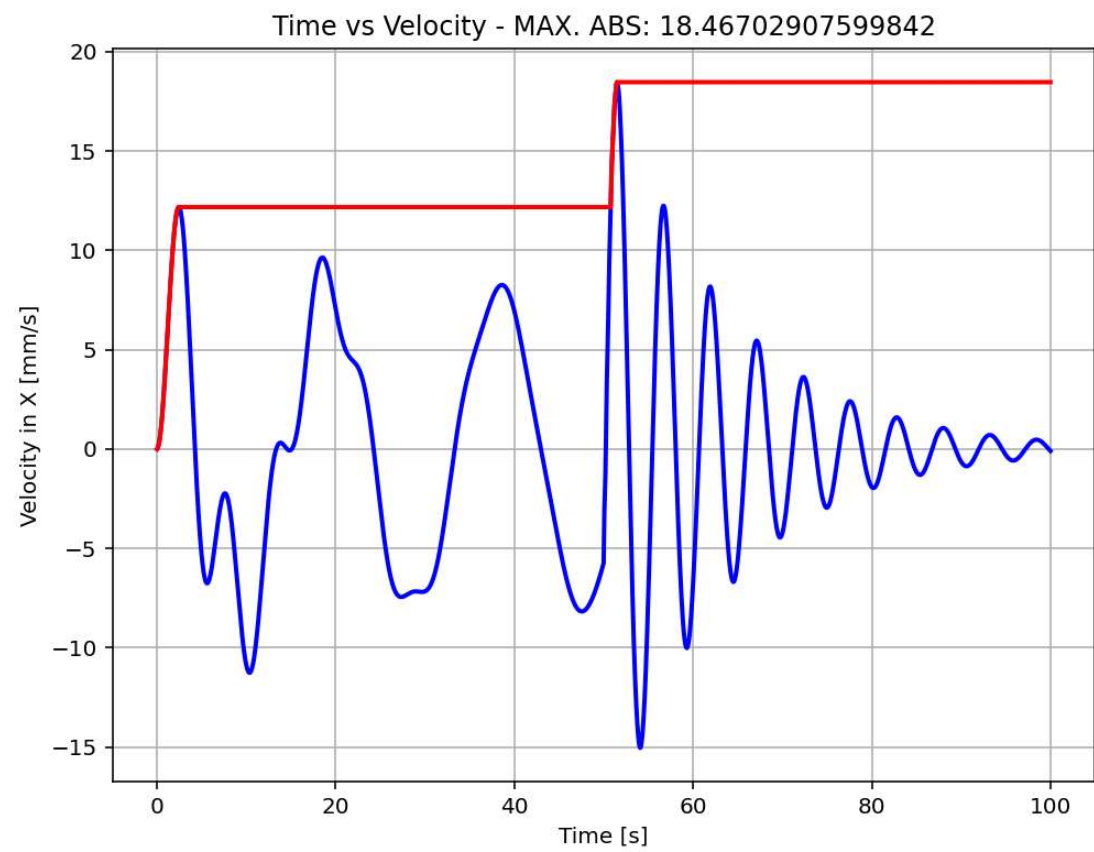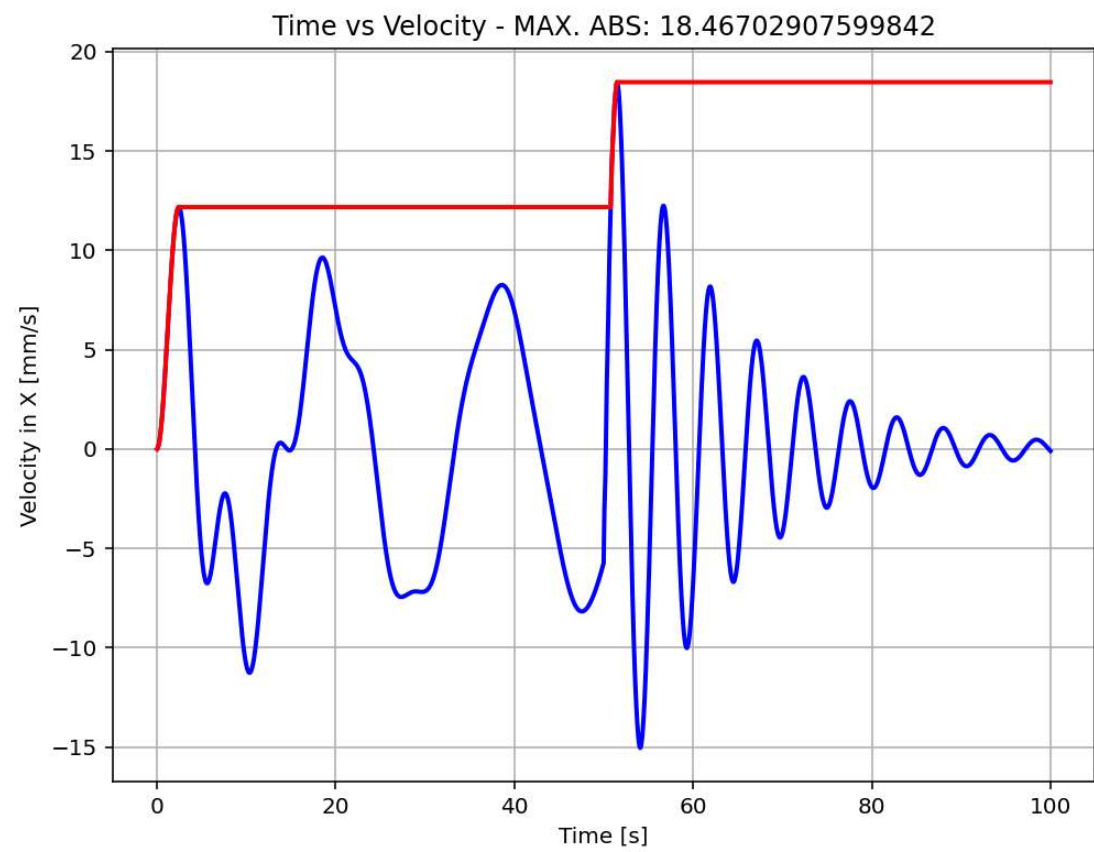Time vs Displacement - MAX. ABS: 28.57909434666904 | ξ (Calculated): 0.00000e+00 %

Time vs Displacement - MAX. ABS: 28.57909434666904 | ξ (Calculated): 0.00000e+00 %

Time vs Displacement - MAX. ABS: 0.14909618740904595

Time vs Displacement - MAX. ABS: 0.14909618740904595

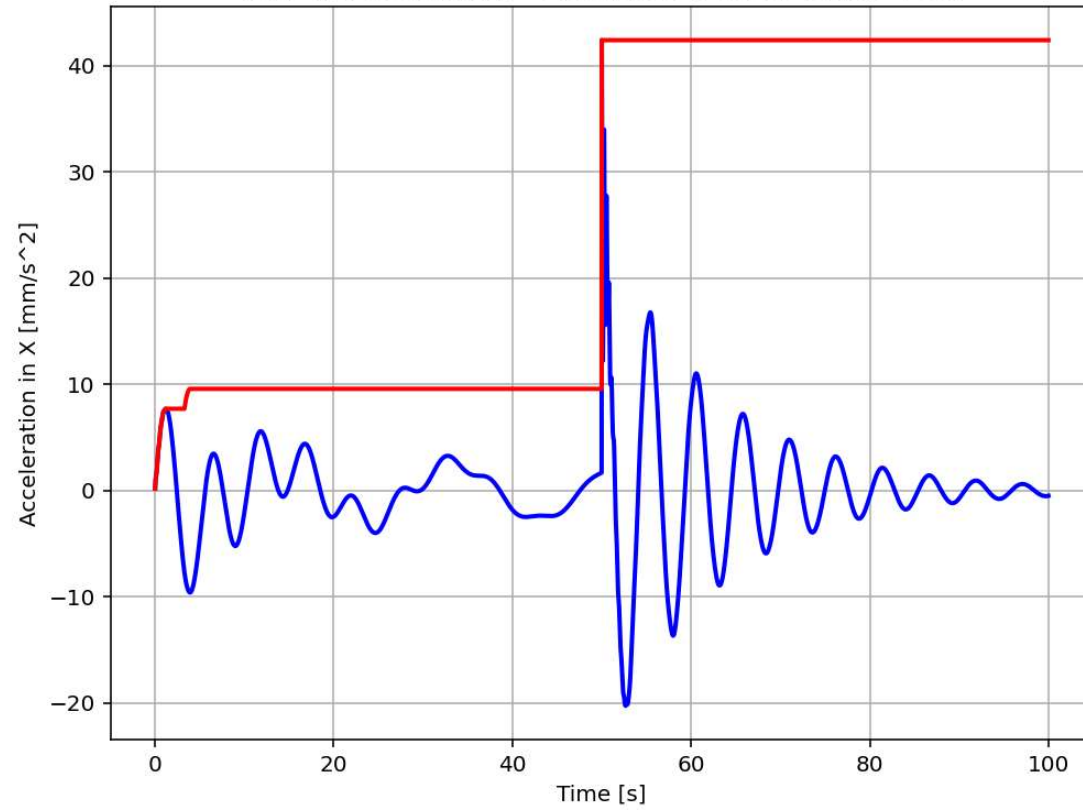Time vs Velocity - MAX. ABS: 18.46702907599842

Time vs Acceleration - MAX. ABS: 42.41814924538691

Time vs Acceleration - MAX. ABS: 42.41814924538691

Time vs Base-reaction - MAX. ABS: 2543718.8123660795

Time vs Axial Base-reaction - MAX. ABS: 28478.1975364222

Displacement vs Shear Base-reaction

Displacement vs Axial Base-reaction

Rotation vs Moment Base-reaction