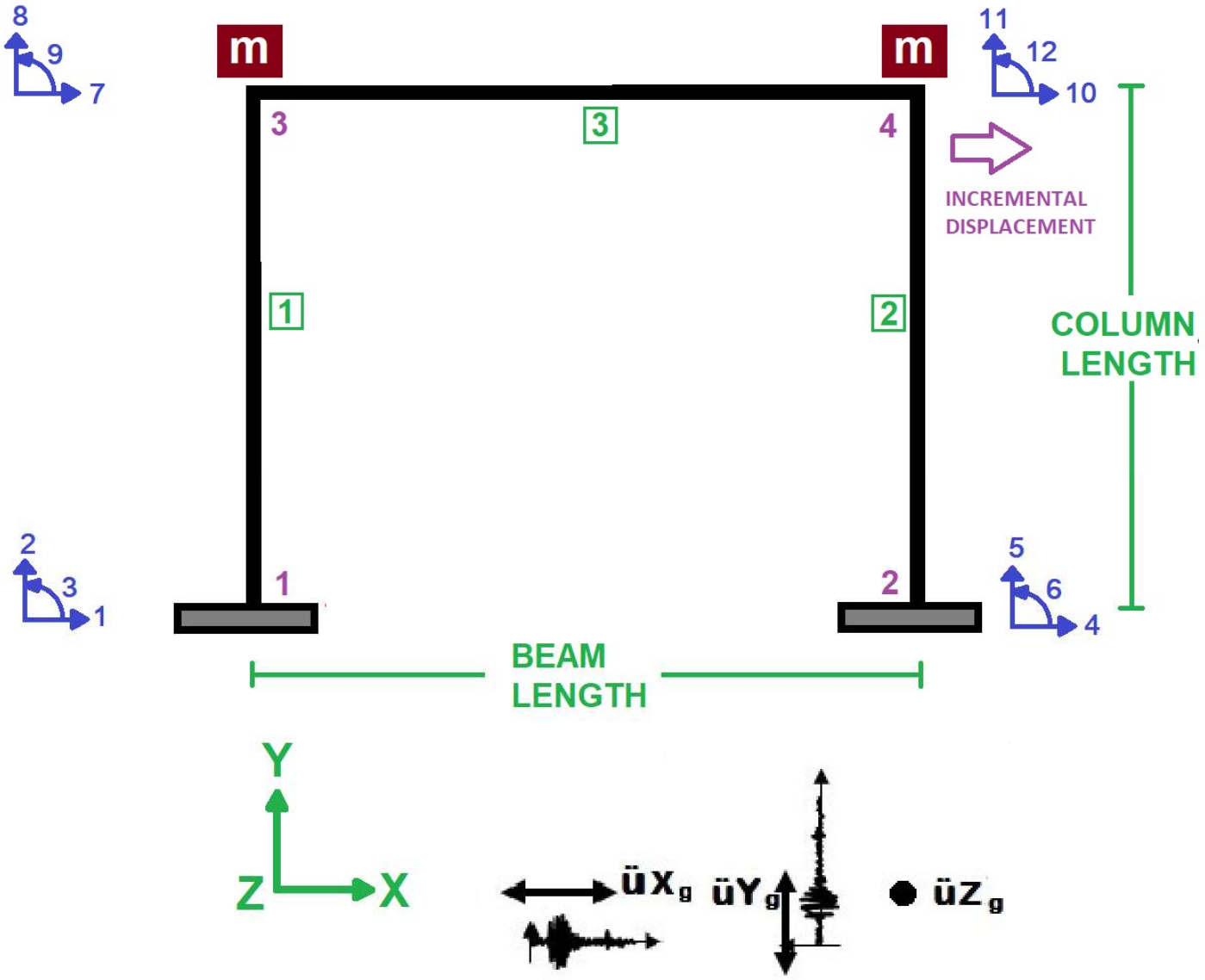
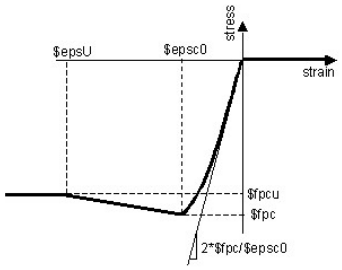
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

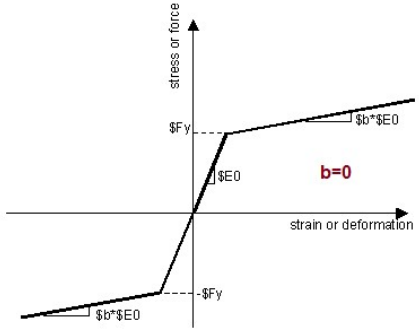
ASSESSMENTS OF THE STRUCTURAL DUCTILITY DAMAGE INDEX OF CONCRETE FRAME USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

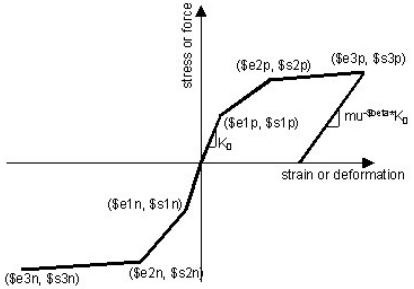

8
9
7
m
m
11
12
10
3
3
4
INCREMENTAL
DISPLACEMENT
1
2
COLUMN
LENGTH
2
3
1
1
2
5
6
4
BEAM
LENGTH
Y
Z
X
üX g
üY g
üZ g



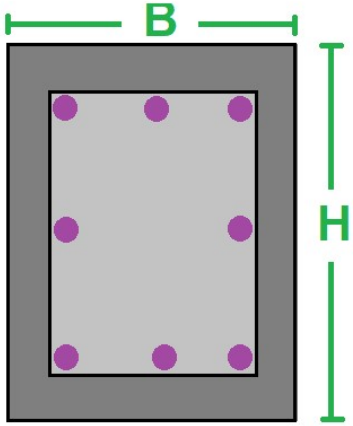
CORE AND COVER CONCRETE RELATION



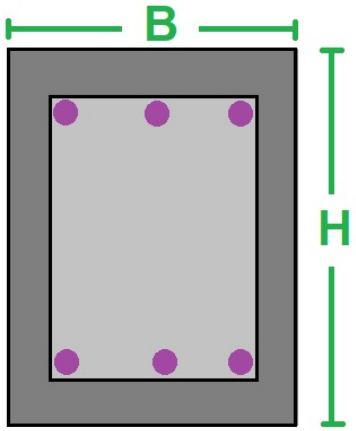
WITHOUT HARDENING AND ULTIMATE STRAIN



WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

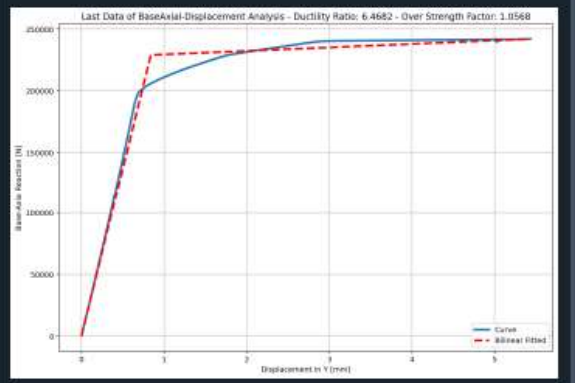
C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...GE_INDEX\CONCRETE_FRAME_DUCTILITY_DAMAGE_INDEX.py

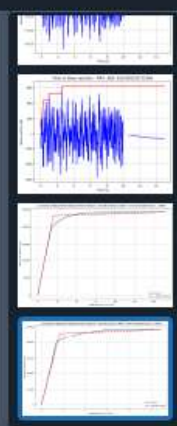
CONCRETE_FRAME_DUCTILITY_DAMAGE_INDEX.py

```
#########################################################################################################
#                                          IN THE NAME OF ALLAH
#                  ASSESSMENTS OF THE STRUCTURAL DUCTILITY DAMAGE INDEX OF CONCRETE FRAME USING OPENSEES
#-------------------------------------------------------------------------------------------------------
#                               THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                        EMAIL: salar.d.ghashghaei@gmail.com
#########################################################################################################
"""
[1] Nonlinear Frame Modeling: 2D RC frame with distributed plasticity (fiber sections) using `nonlinearB
[2] Material Laws:
   - *Concrete*: `Concrete01` with confined (core) and unconfined (cover) properties.
   - *Steel*: `Hysteretic` model with pinching, hardening, and cyclic degradation.
[3] Seismic Loads:
   - Pushover: Displacement-controlled lateral loading to failure.
   - Dynamic: Uniform excitation with user-defined ground motions (X/Y components).
[4] Damping: Rayleigh damping (a0, a1) calibrated via eigenvalue analysis (modes 1-2).
[5] Performance Metrics:
   - Ductility Ratio (μ): Derived from bilinearized pushover curves.
   - Overstrength (Ω₀): Yield vs. ultimate capacity.
   - Damage Index (DI): Normalized displacement demand/capacity.
[6] Advanced Solver: HHT-α integrator (unconditionally stable) with Newton-Raphson iterations.
[7] Outputs:
   - Hysteretic responses (P-M, V-Δ, M-θ).
   - Time-history plots (displacement, base shear).
   - Stiffness degradation tracking.
[8] Validation: Logarithmic decrement method for damping ratio verification.
[9] Ductility Damage Index (DDI) Implementation:
    DDI quantifies structural damage via normalized displacement demand.
    # After bilinear fit (X[1] = Δ_y, X[2] = Δ_u):
    Dd = max(abs(DISP_Xd))  # Max dynamic displacement demand
    DI = (Dd - Dy) / (Du - Dy)  # Ductility Damage Index (X-dir)
    DI ≈ 0: Elastic response (no damage).
    DI ≥ 1: Collapse (demand ≥ ultimate capacity).
Key Innovations:
```

...NSEES_FILES\CONCRETE_FRAME_EXAMPLES\DUCTILITY_DAMAGE_INDEX

24 %





Help Variable Explorer Debugger Plots Files

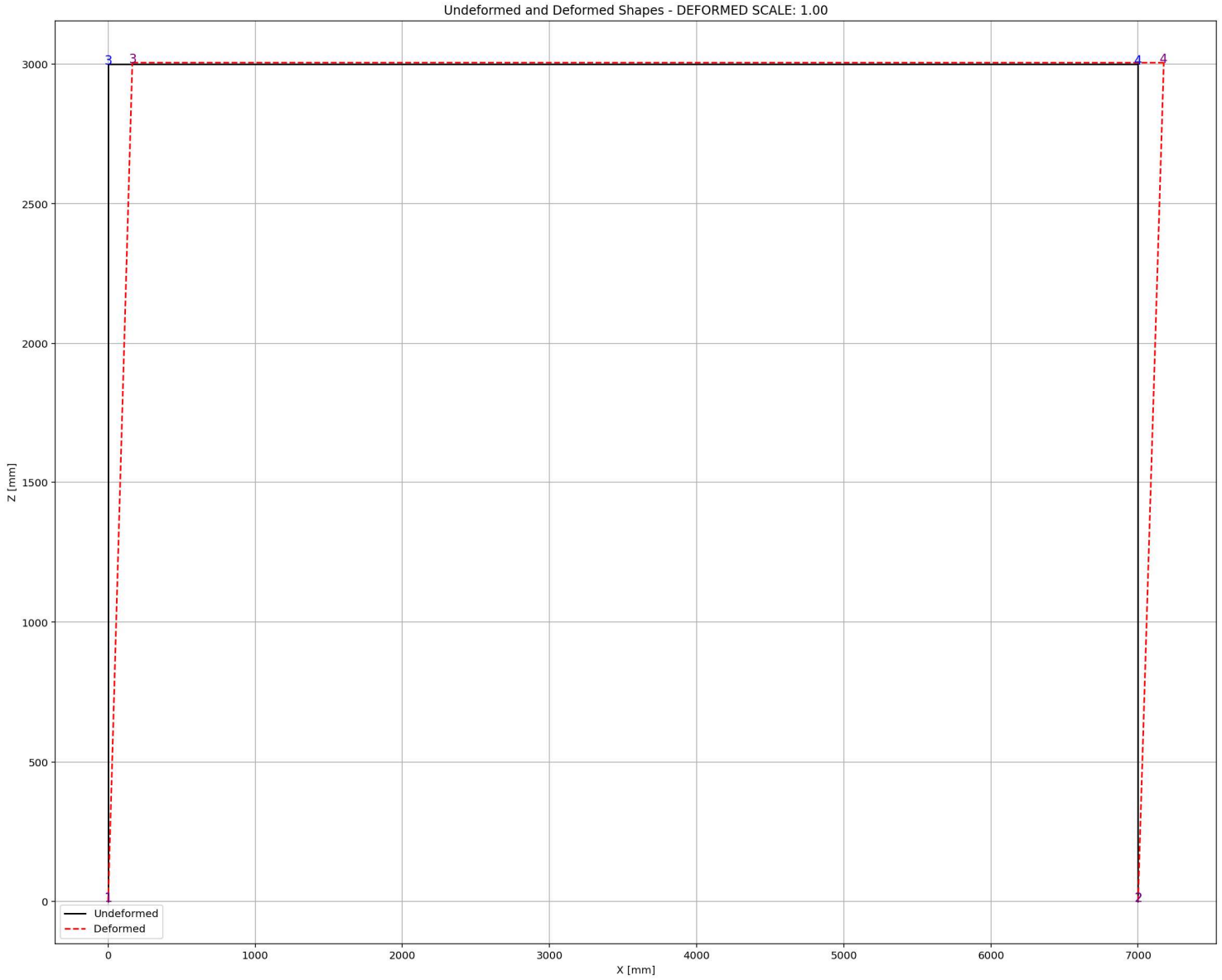
Console 1/A

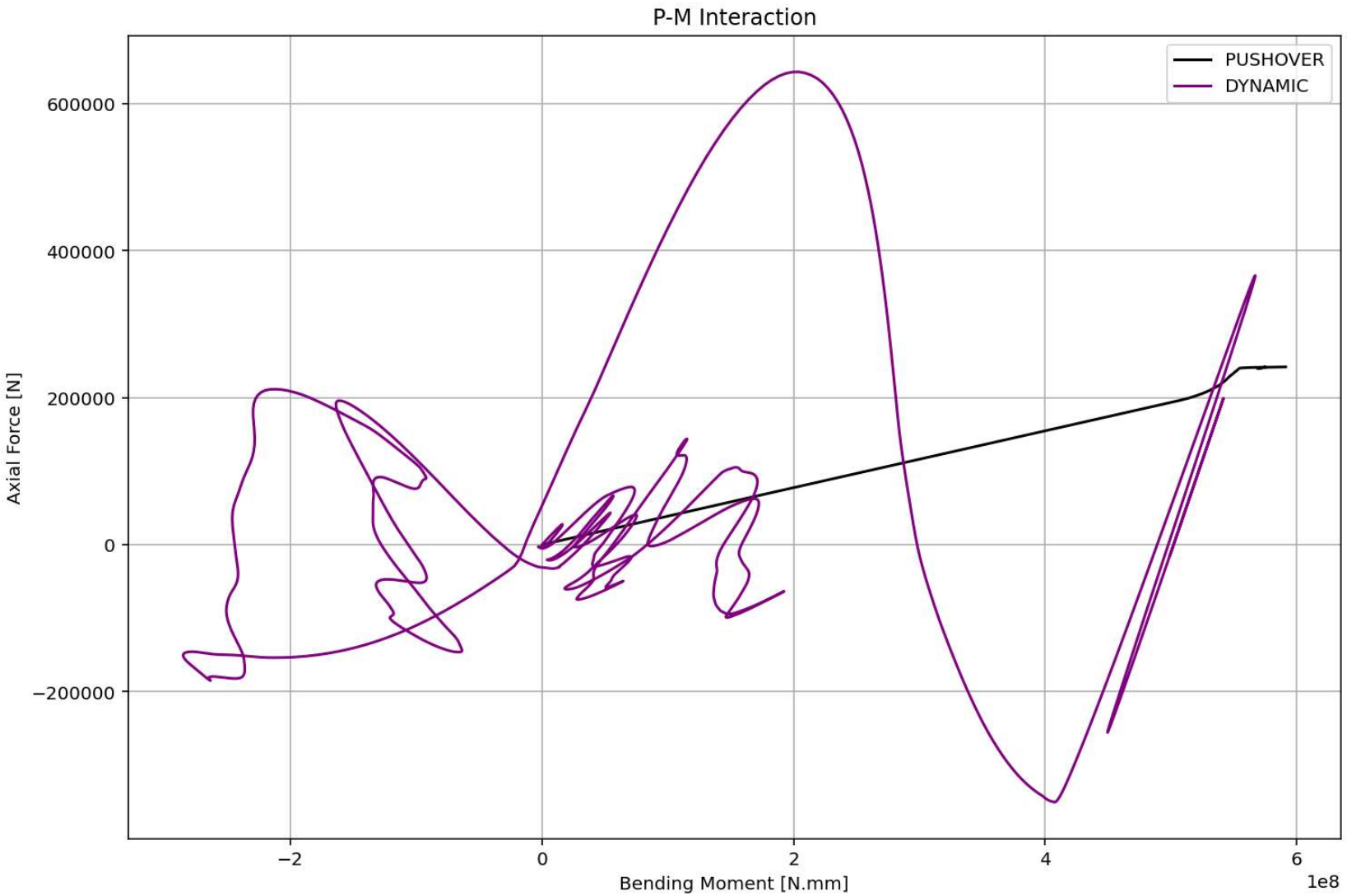
```
+-----------------------------------------------------+
Over Strength Coefficient (Ω0):      1.0568
Displacement Ductility Ratio (μ):    6.4682
Ductility Coefficient (Rμ):          6.4682
Structural Behavior Coefficient (R): 6.8357
Structural Ductility Damage Index in Y Direction: -0.1828

 Node: 3
    Coordinates  : 0 3000
    Disps: 0.00629225 0.000347875 -2.82838e-06
    Velocities   : -0.000316897 -2.73216e-05 1.07006e-07
```

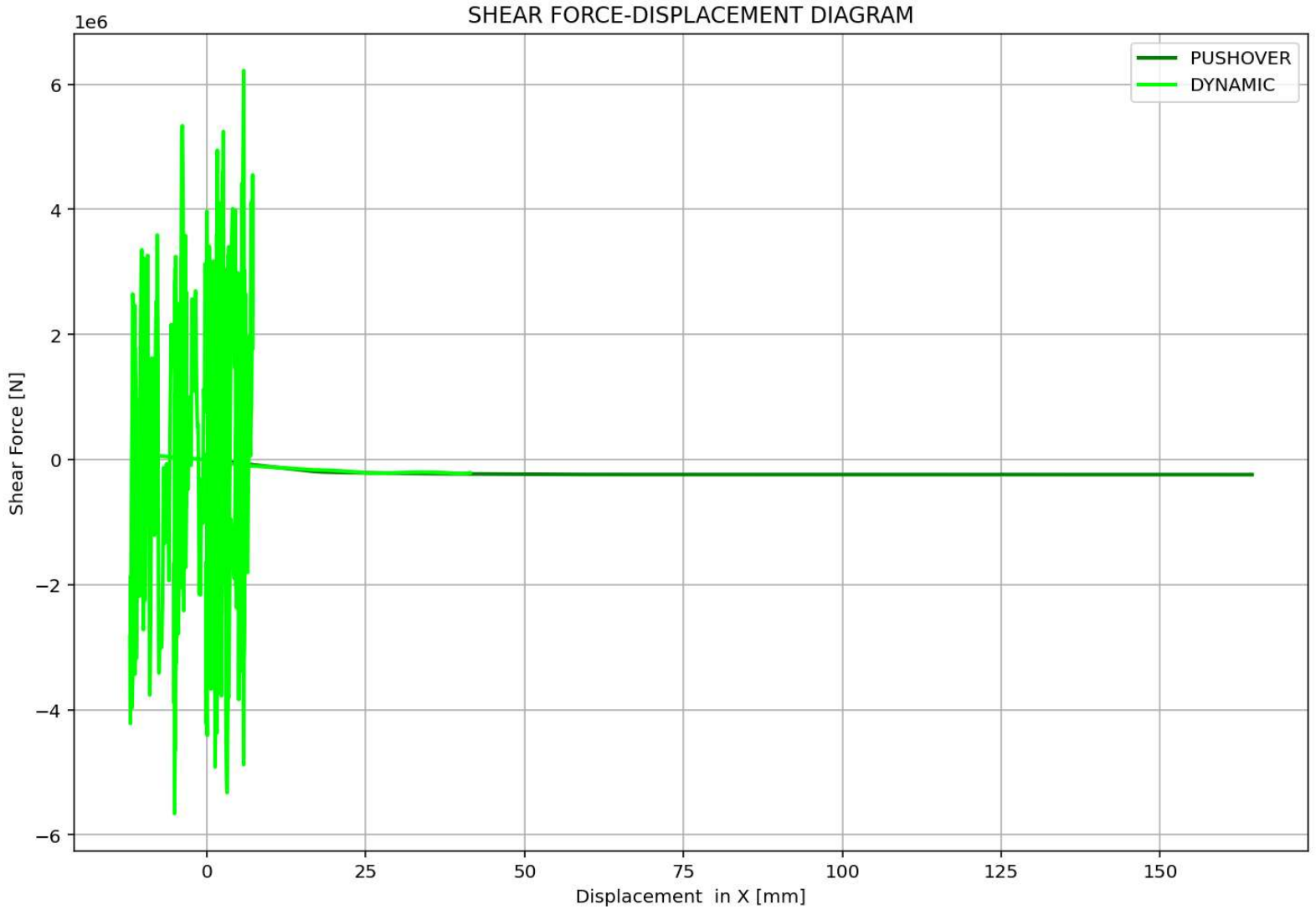
IPython Console History

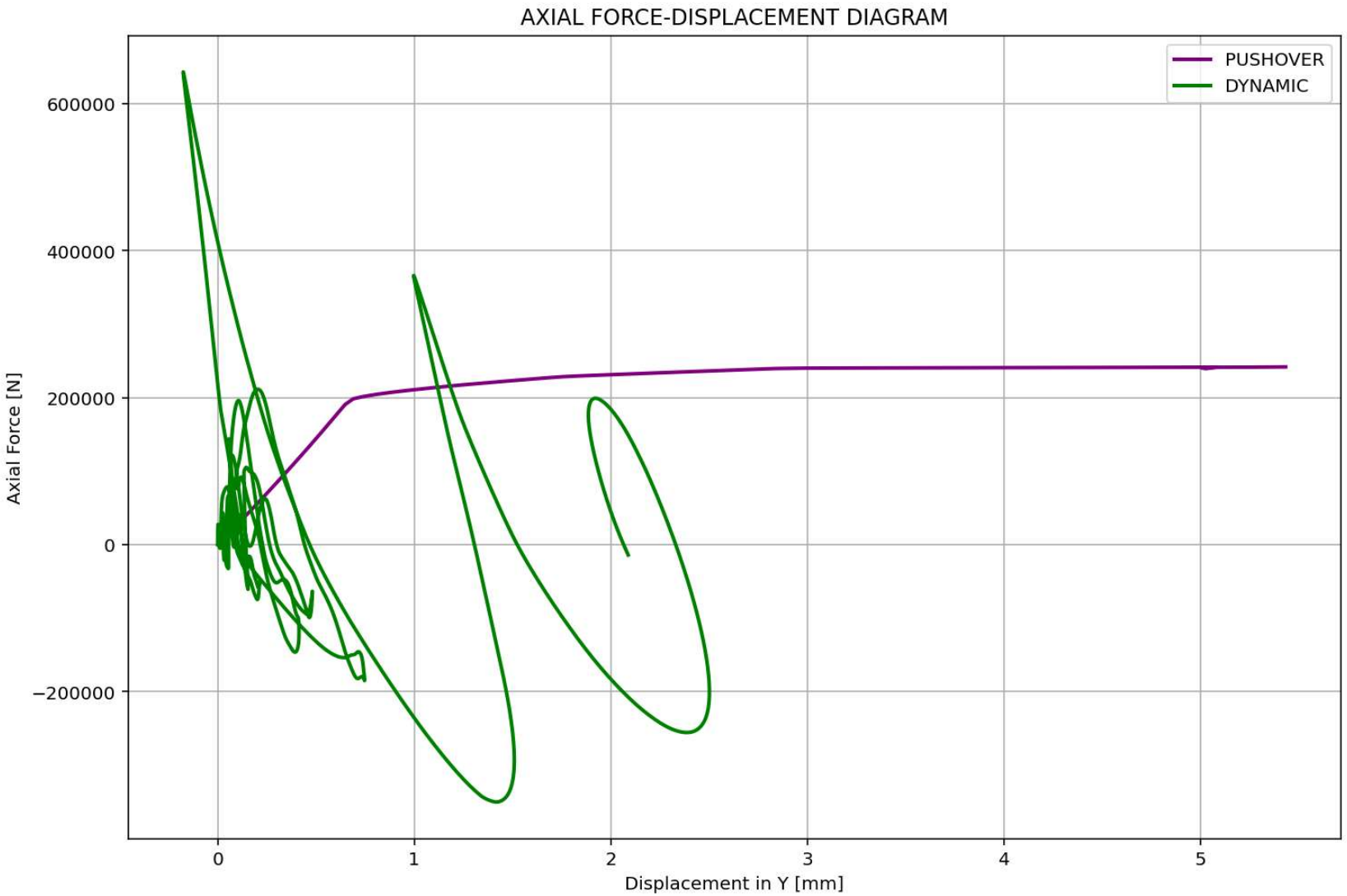
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 45, Col 84 UTF-8 CRLF RW Mem 40%

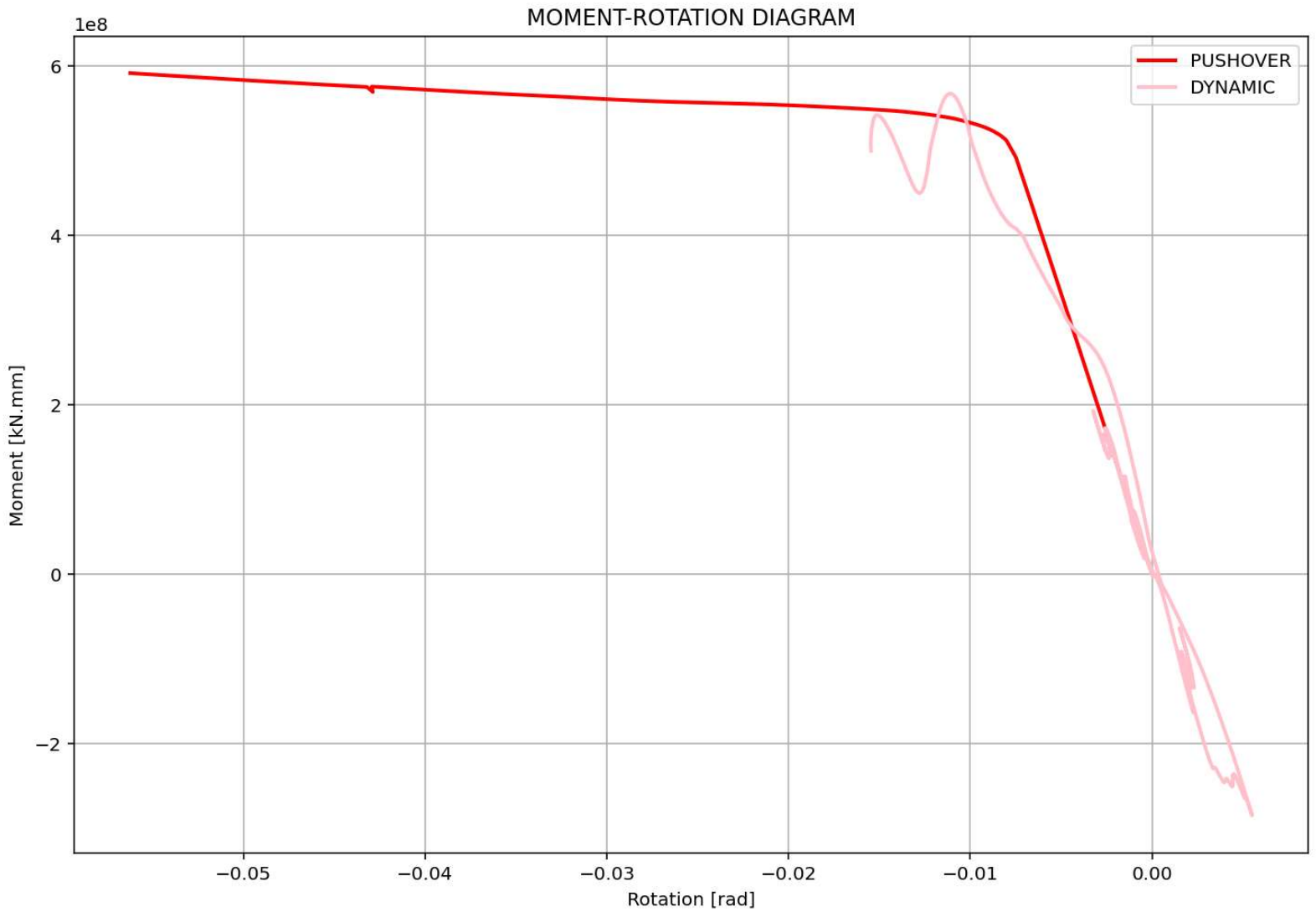
NONLINEAR STATIC ANALYSIS (PUSHOVER)

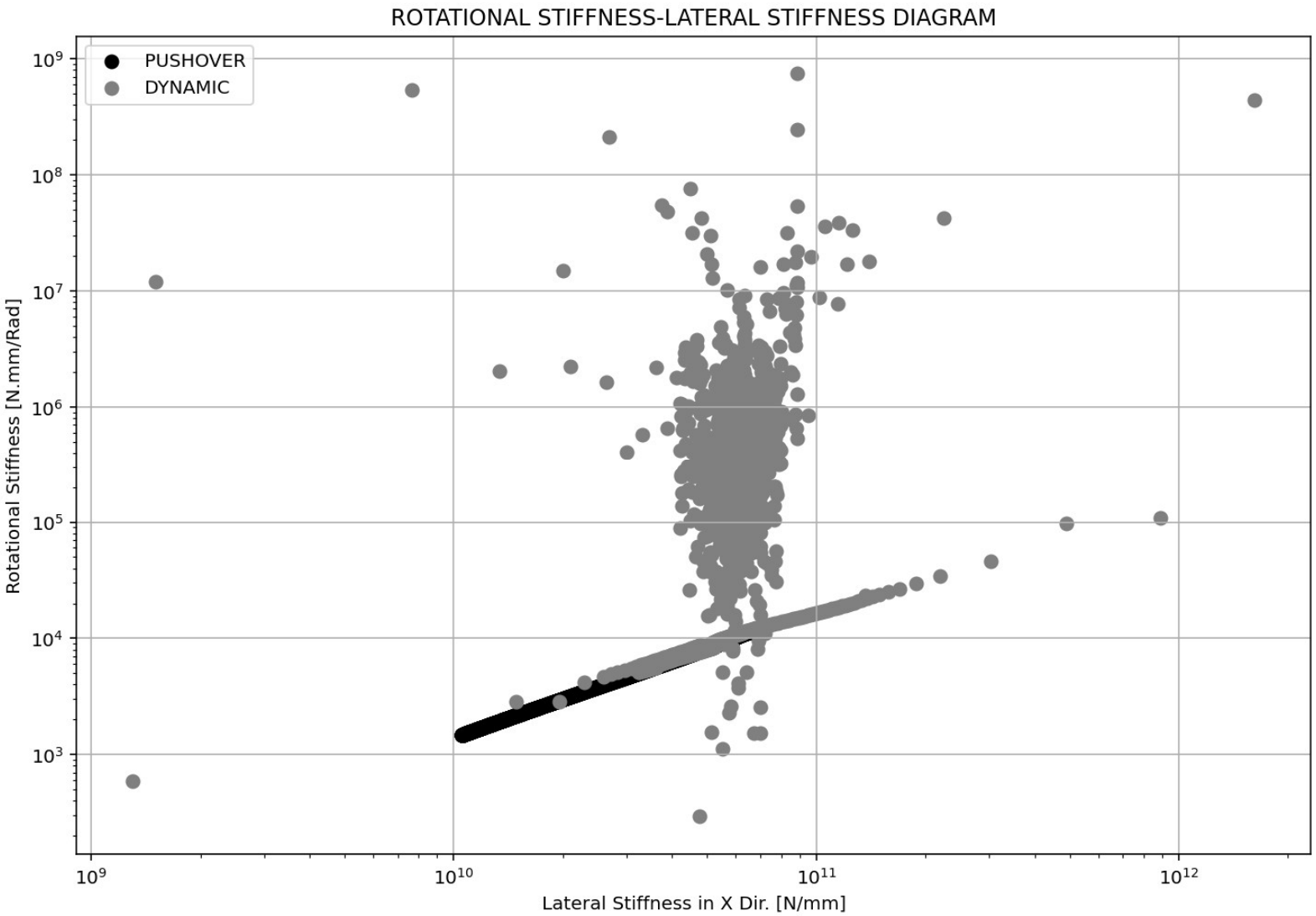

Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
1
2
3
3
4
4
Undeformed
Deformed

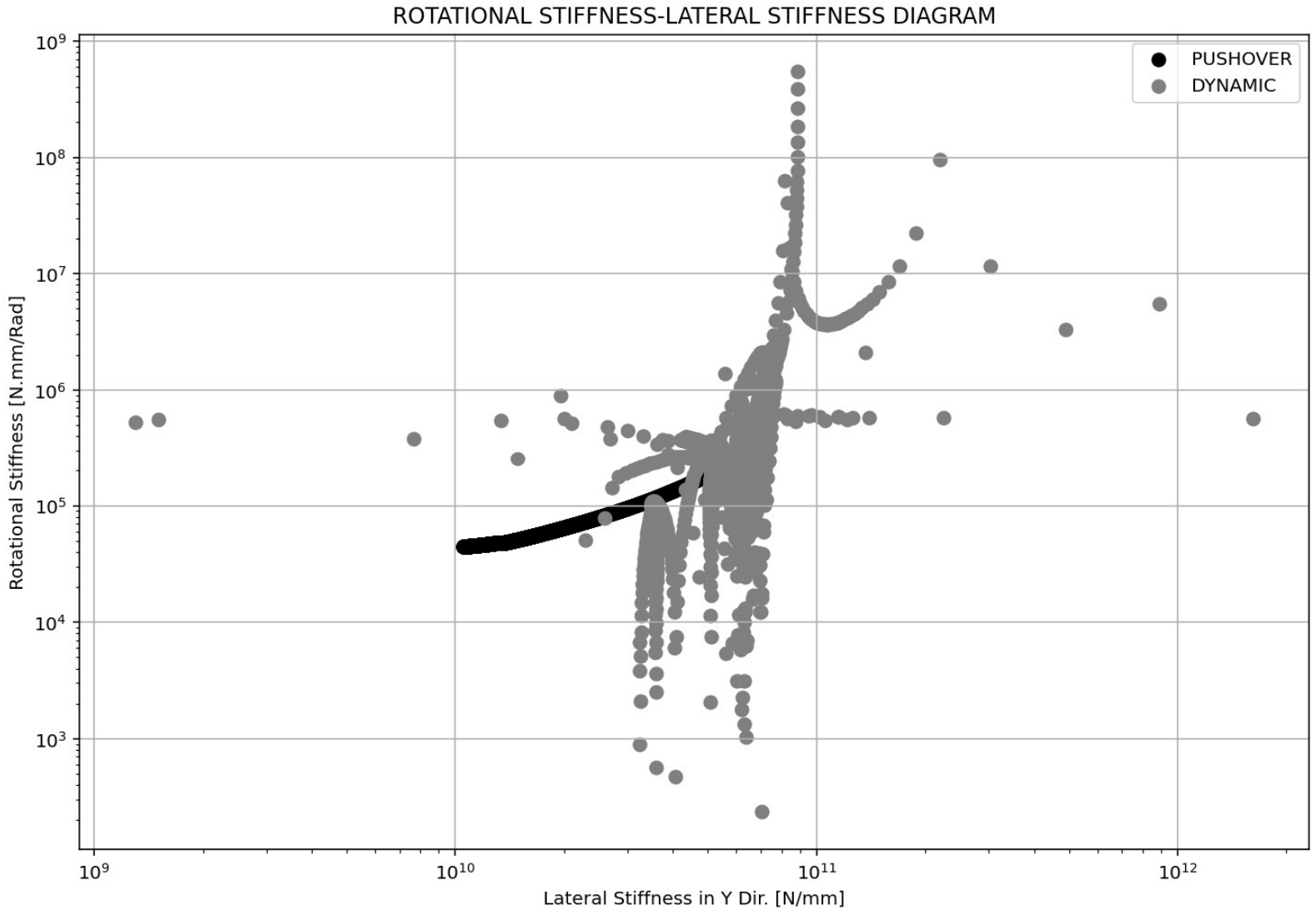

P-M Interaction
PUSHOVER
DYNAMIC
600000
400000
200000
0
−200000
Axial Force [N]
−2
0
2
4
6
1e8
Bending Moment [N.mm]


SHEAR FORCE-DISPLACEMENT DIAGRAM
1e6
6
4
2
0
−2
−4
−6
Shear Force [N]
0
25
50
75
100
125
150
Displacement in X [mm]
PUSHOVER
DYNAMIC

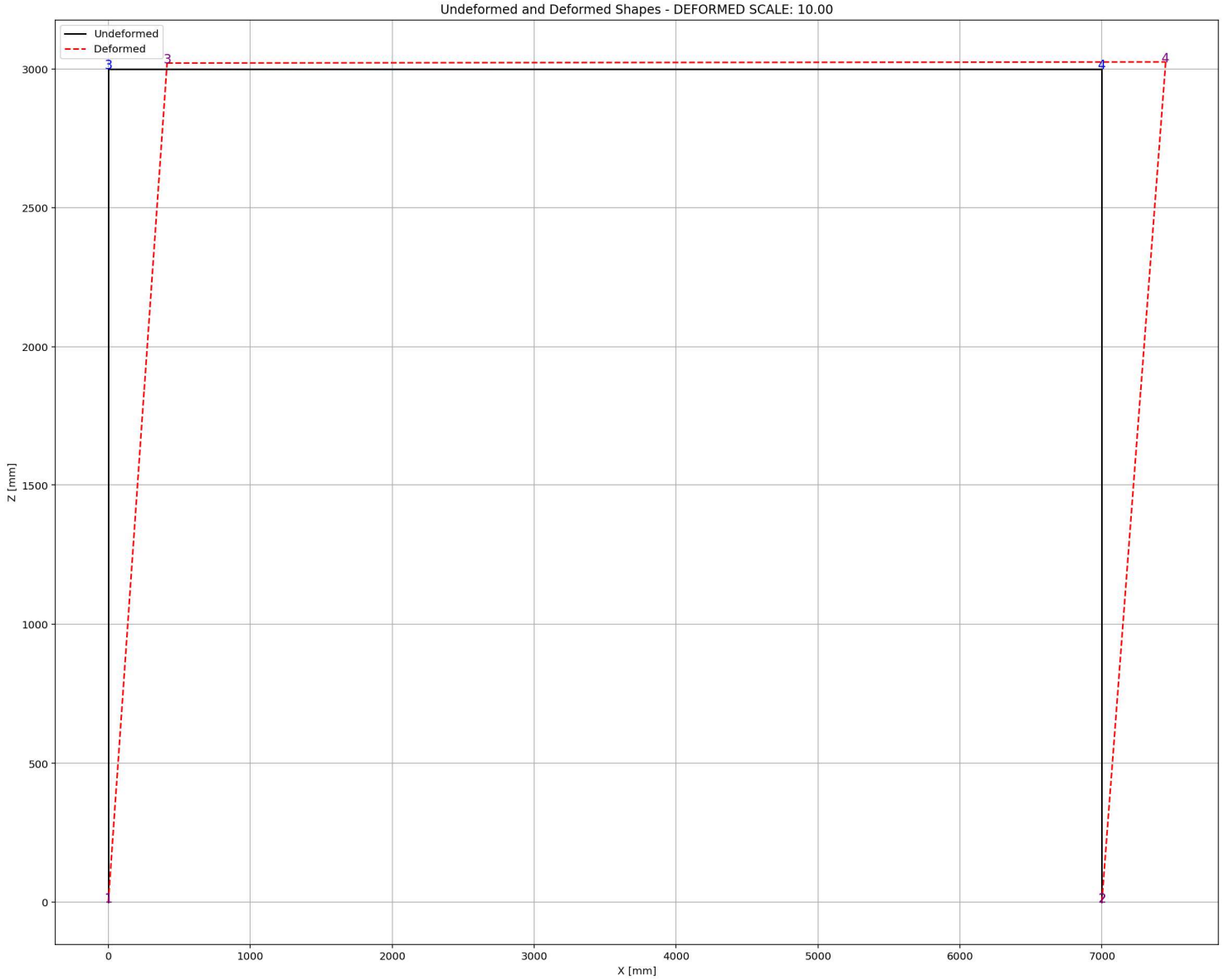

AXIAL FORCE-DISPLACEMENT DIAGRAM
PUSHOVER
DYNAMIC
600000
400000
200000
0
−200000
Axial Force [N]
0
1
2
3
4
5
Displacement in Y [mm]

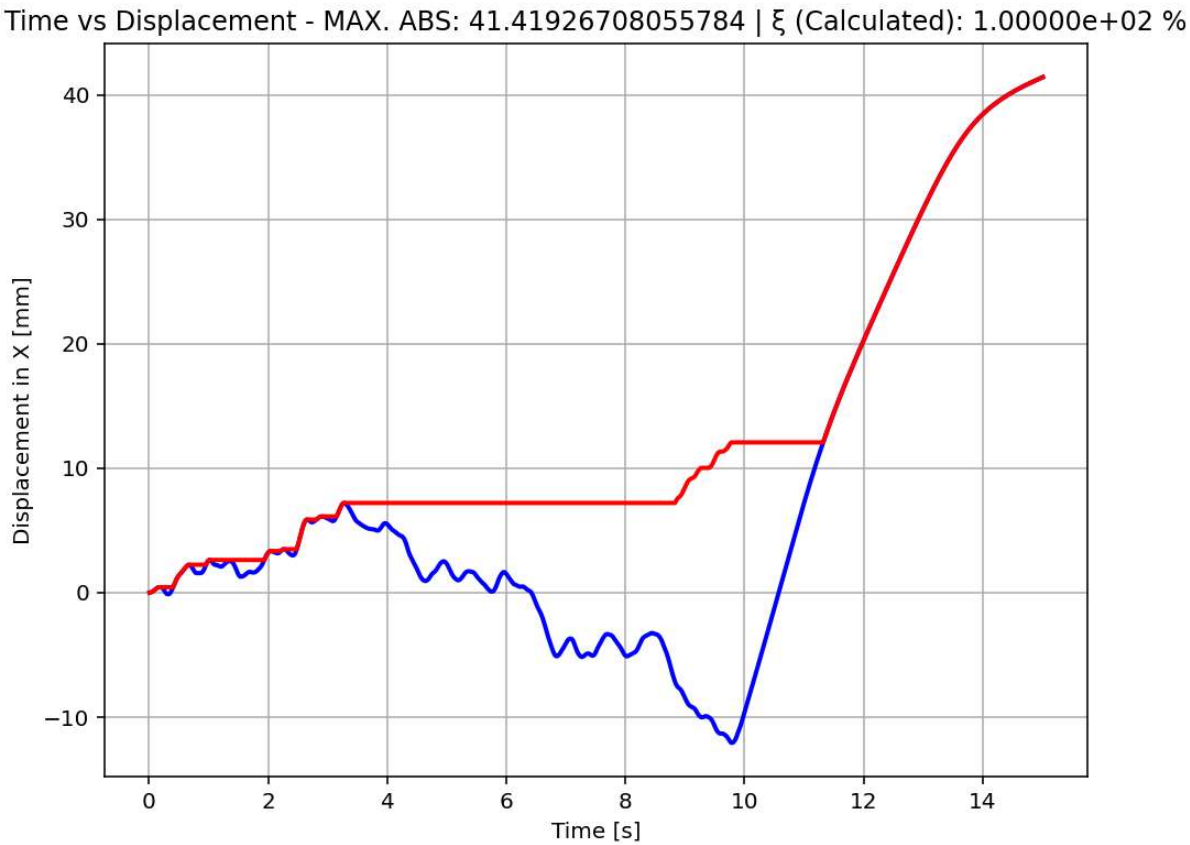

MOMENT-ROTATION DIAGRAM
1e8
6
4
2
0
−2
Moment [kN.mm]
−0.05
−0.04
−0.03
−0.02
−0.01
0.00
Rotation [rad]
PUSHOVER
DYNAMIC

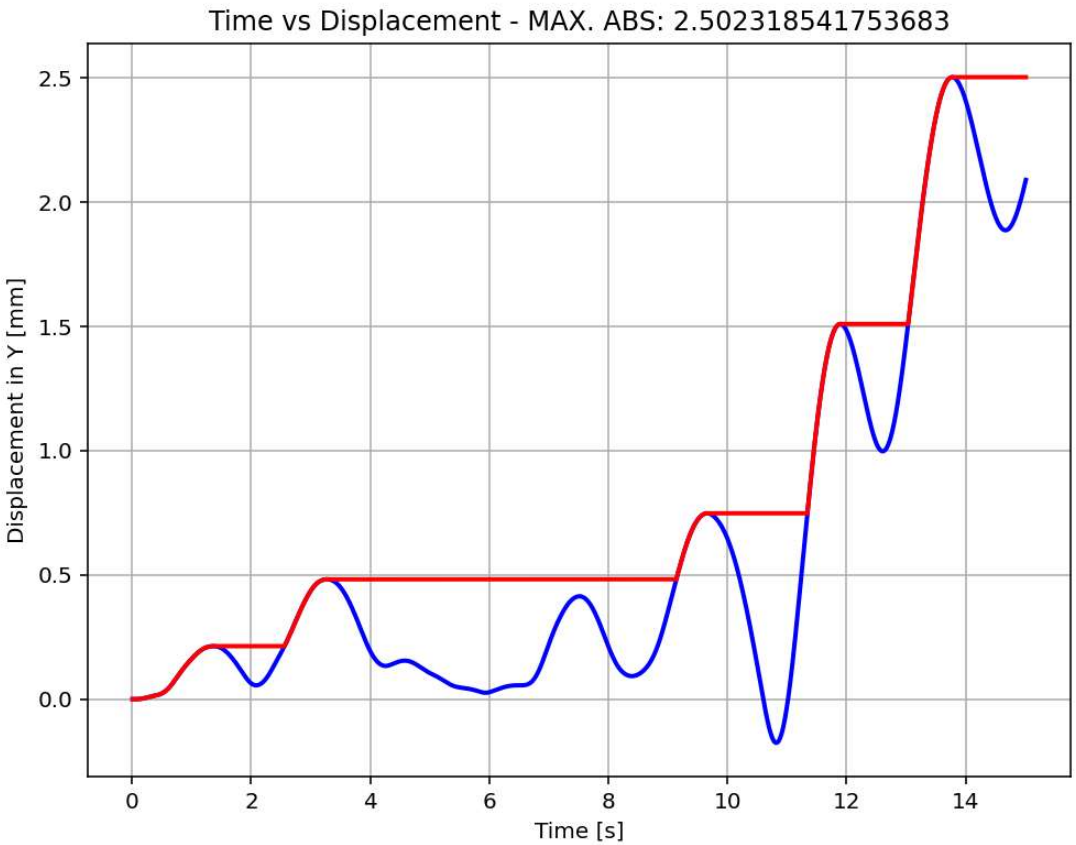

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
PUSHOVER
DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in X Dir. [N/mm]
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{9}
10^{10}
10^{11}
10^{12}

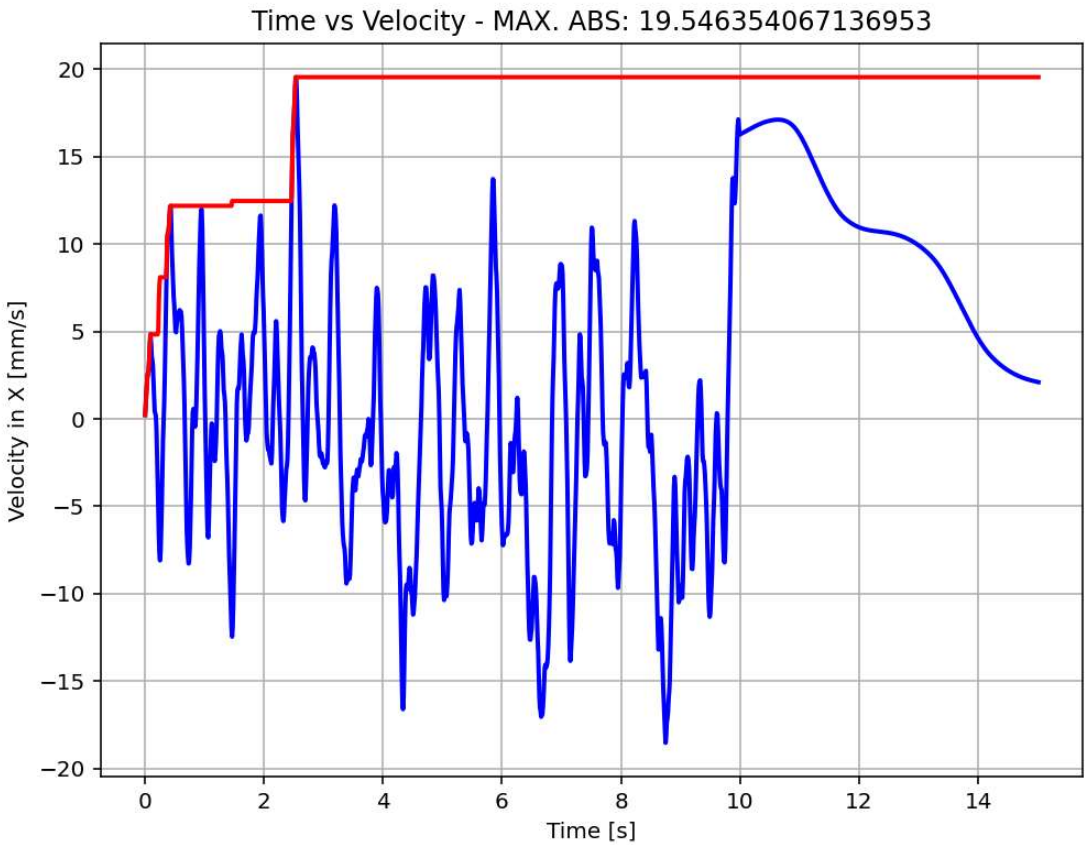

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
PUSHOVER
DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in Y Dir. [N/mm]
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{9}
10^{10}
10^{11}
10^{12}

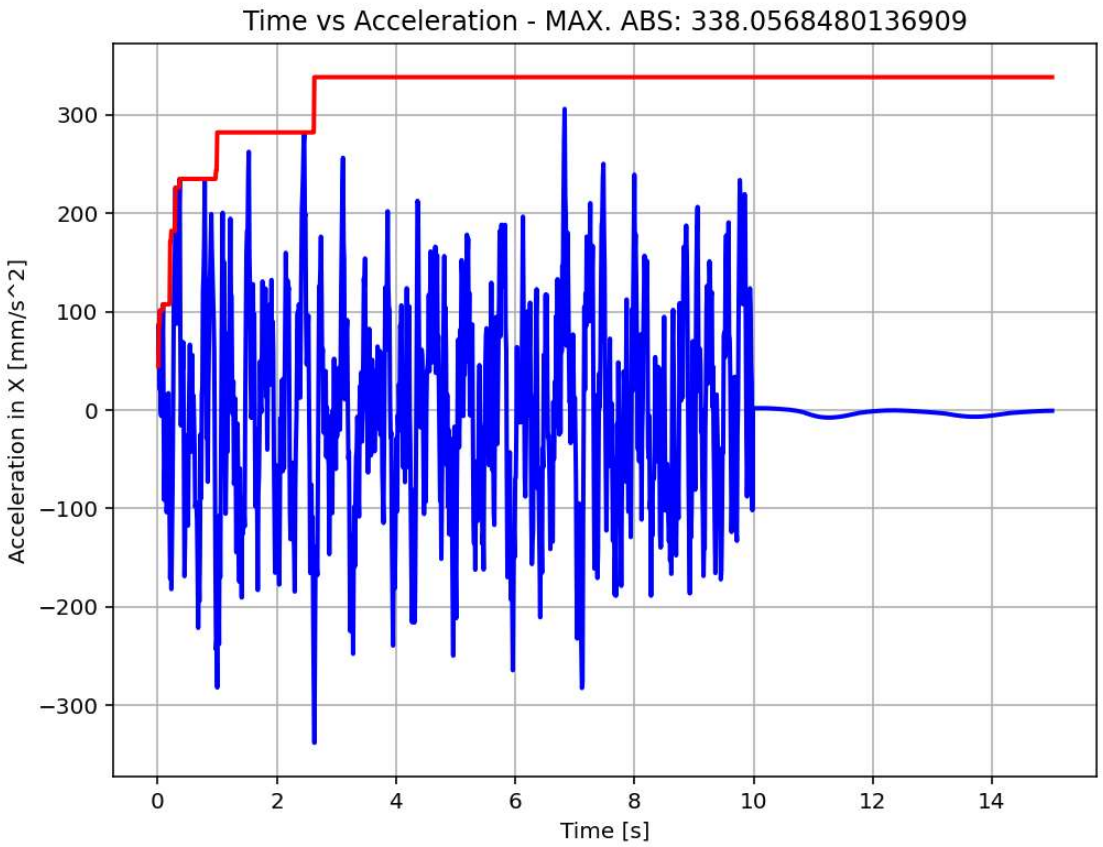
NONLINEAR DYNAMIC ANALYSIS

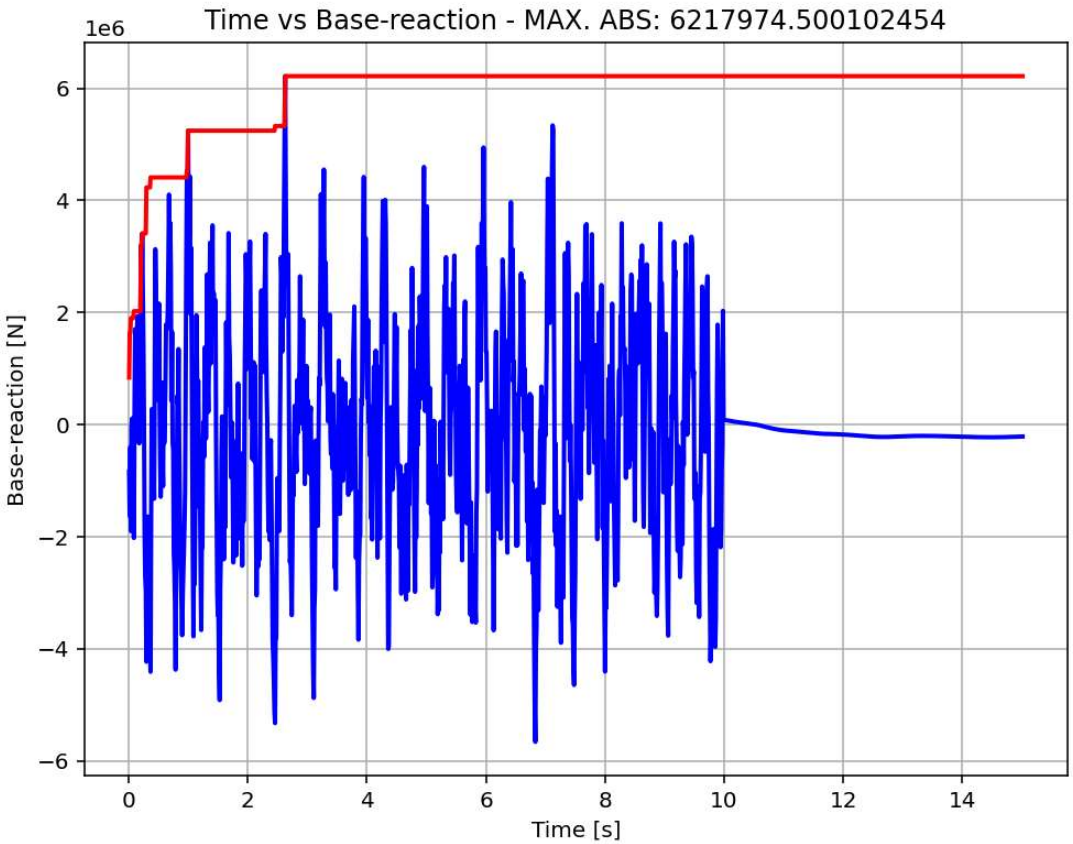

Undeformed and Deformed Shapes - DEFORMED SCALE: 10.00
Undeformed
Deformed
3
3
4
4
1
2
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000

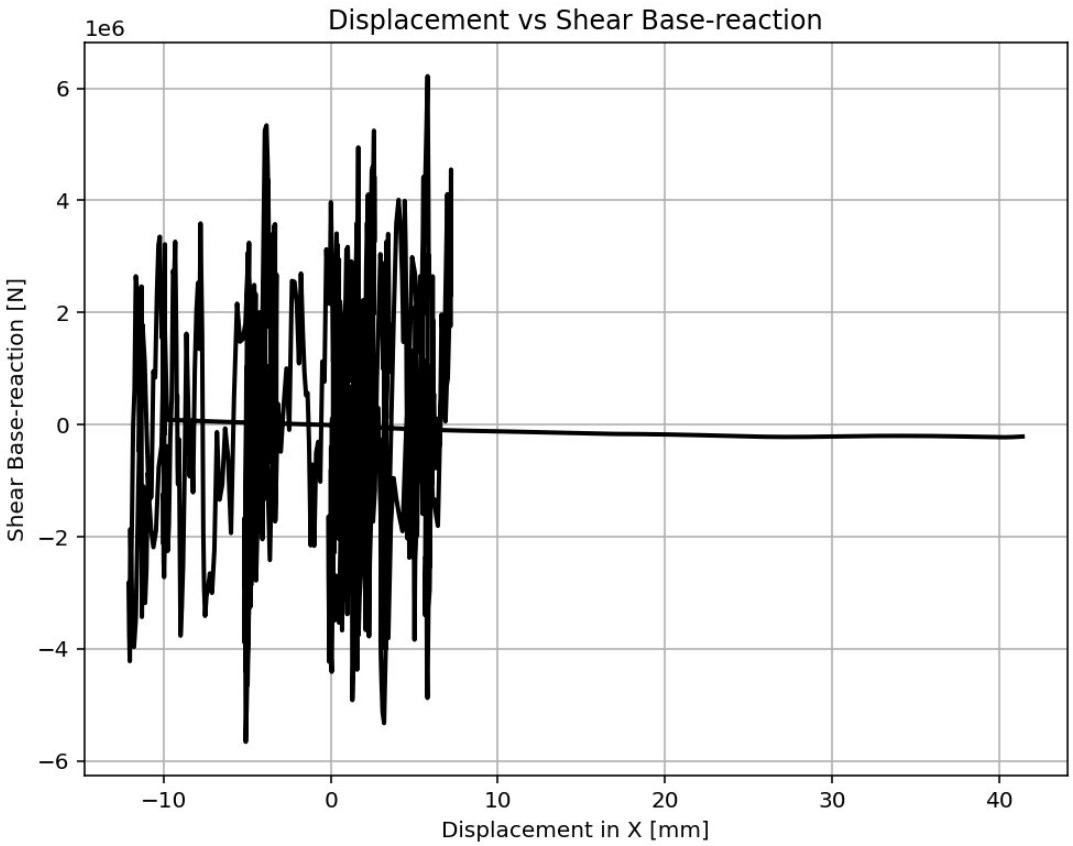

Time vs Displacement - MAX. ABS: 41.41926708055784 | ξ (Calculated): 1.00000e+02 %
Displacement in X [mm]
Time [s]
40
30
20
10
0
−10
0
2
4
6
8
10
12
14

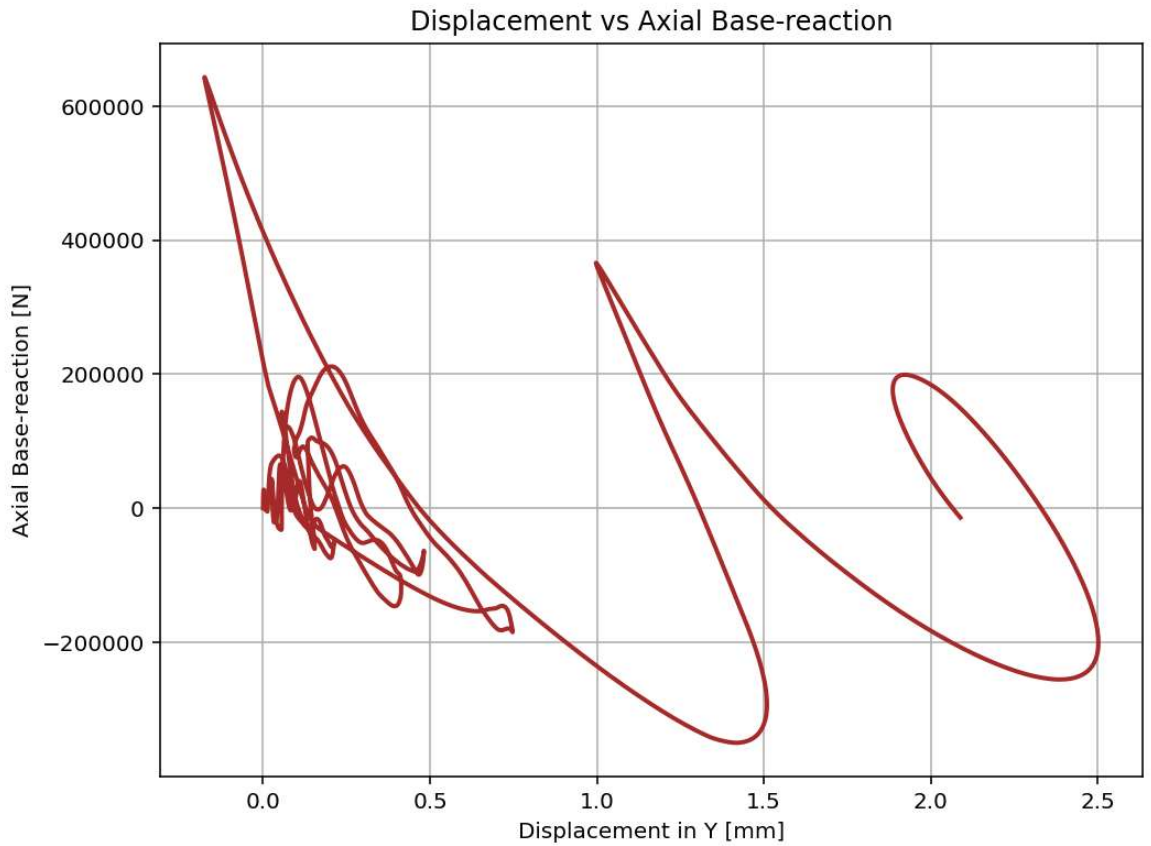

Time vs Displacement - MAX. ABS: 2.502318541753683
Displacement in Y [mm]
Time [s]
0.0
0.5
1.0
1.5
2.0
2.5
0
2
4
6
8
10
12
14

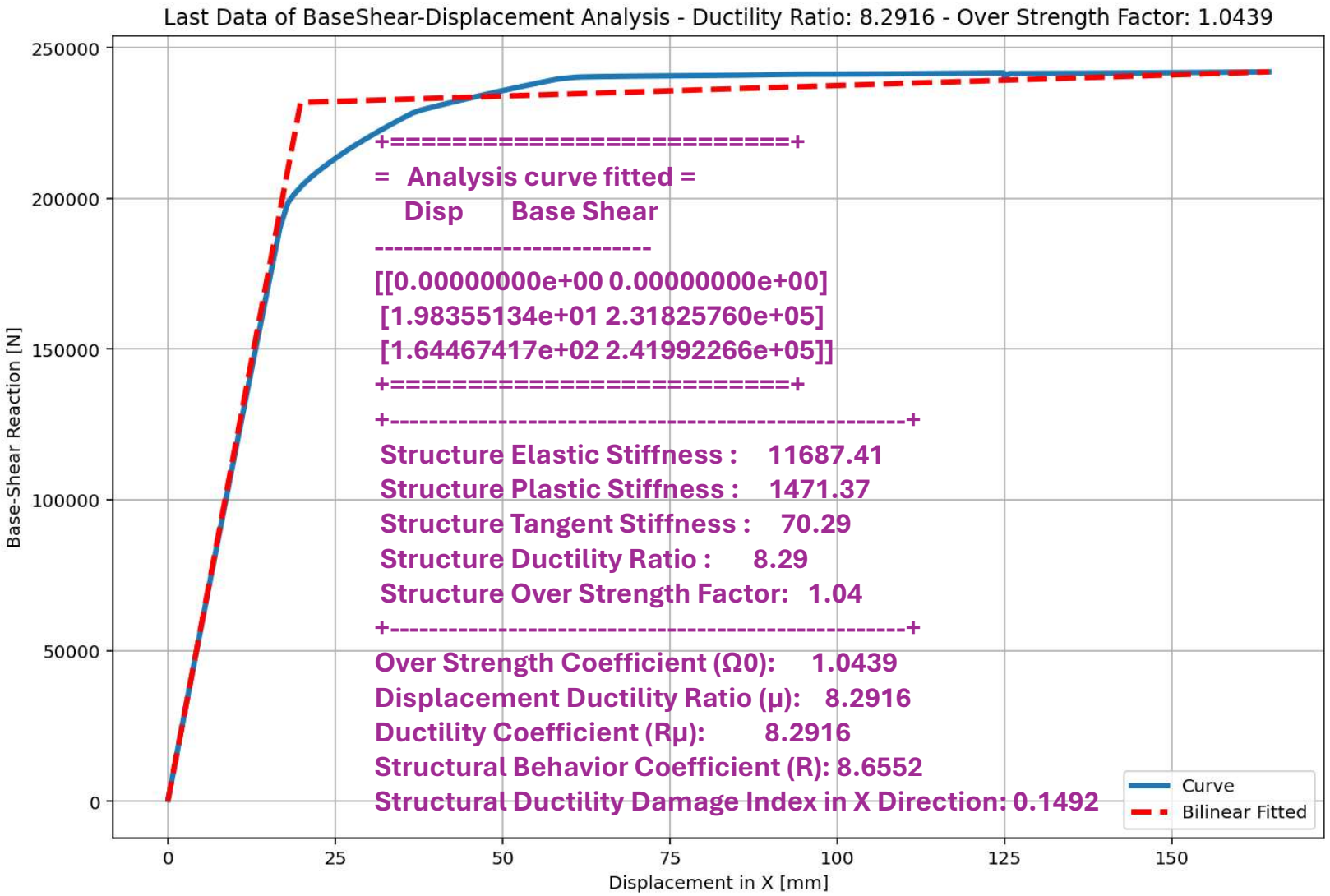

Time vs Velocity - MAX. ABS: 19.546354067136953
Velocity in X [mm/s]
Time [s]
20
15
10
5
0
−5
−10
−15
−20
0
2
4
6
8
10
12
14


Time vs Acceleration - MAX. ABS: 338.0568480136909
Acceleration in X [mm/s^2]
300
200
100
0
−100
−200
−300
0
2
4
6
8
10
12
14
Time [s]

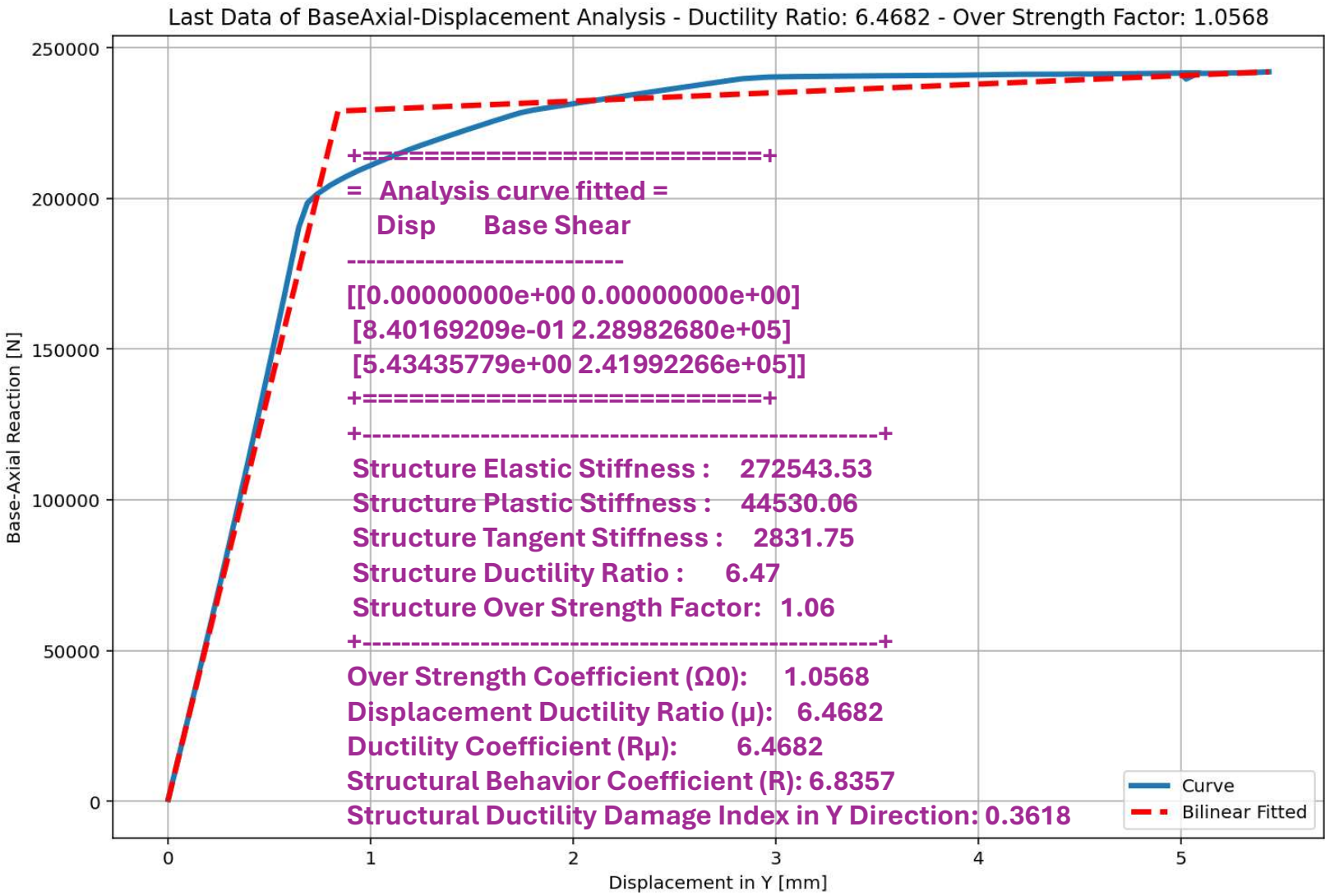

Time vs Base-reaction - MAX. ABS: 6217974.500102454
1e6
6
4
2
0
−2
−4
−6
Base-reaction [N]
0
2
4
6
8
10
12
14
Time [s]


Displacement vs Shear Base-reaction
1e6
6
4
2
0
−2
−4
−6
Shear Base-reaction [N]
−10
0
10
20
30
40
Displacement in X [mm]


Displacement vs Axial Base-reaction
600000
400000
200000
0
−200000
Axial Base-reaction [N]
0.0
0.5
1.0
1.5
2.0
2.5
Displacement in Y [mm]


Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 8.2916 - Over Strength Factor: 1.0439
Base-Shear Reaction [N]
Displacement in X [mm]
250000
200000
150000
100000
50000
0
0
25
50
75
100
125
150
+==========================+
= Analysis curve fitted =
Disp Base Shear

[[0.00000000e+00 0.00000000e+00]
[1.98355134e+01 2.31825760e+05]
[1.64467417e+02 2.41992266e+05]]
+==========================+
+----------+
Structure Elastic Stiffness : 11687.41
Structure Plastic Stiffness : 1471.37
Structure Tangent Stiffness : 70.29
Structure Ductility Ratio : 8.29
Structure Over Strength Factor: 1.04
+----------+
Over Strength Coefficient (Ω0): 1.0439
Displacement Ductility Ratio (μ): 8.2916
Ductility Coefficient (Rμ): 8.2916
Structural Behavior Coefficient (R): 8.6552
Structural Ductility Damage Index in X Direction: 0.1492
Curve
Bilinear Fitted


Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 6.4682 - Over Strength Factor: 1.0568
Base-Axial Reaction [N]
Displacement in Y [mm]
250000
200000
150000
100000
50000
0
0
1
2
3
4
5
+============================+
= Analysis curve fitted =
Disp Base Shear

[[0.00000000e+00 0.00000000e+00]
[8.40169209e-01 2.28982680e+05]
[5.43435779e+00 2.41992266e+05]]
+============================+
+--+
Structure Elastic Stiffness : 272543.53
Structure Plastic Stiffness : 44530.06
Structure Tangent Stiffness : 2831.75
Structure Ductility Ratio : 6.47
Structure Over Strength Factor: 1.06
+--+
Over Strength Coefficient (Ω0): 1.0568
Displacement Ductility Ratio (μ): 6.4682
Ductility Coefficient (Rμ): 6.4682
Structural Behavior Coefficient (R): 6.8357
Structural Ductility Damage Index in Y Direction: 0.3618
Curve
Bilinear Fitted