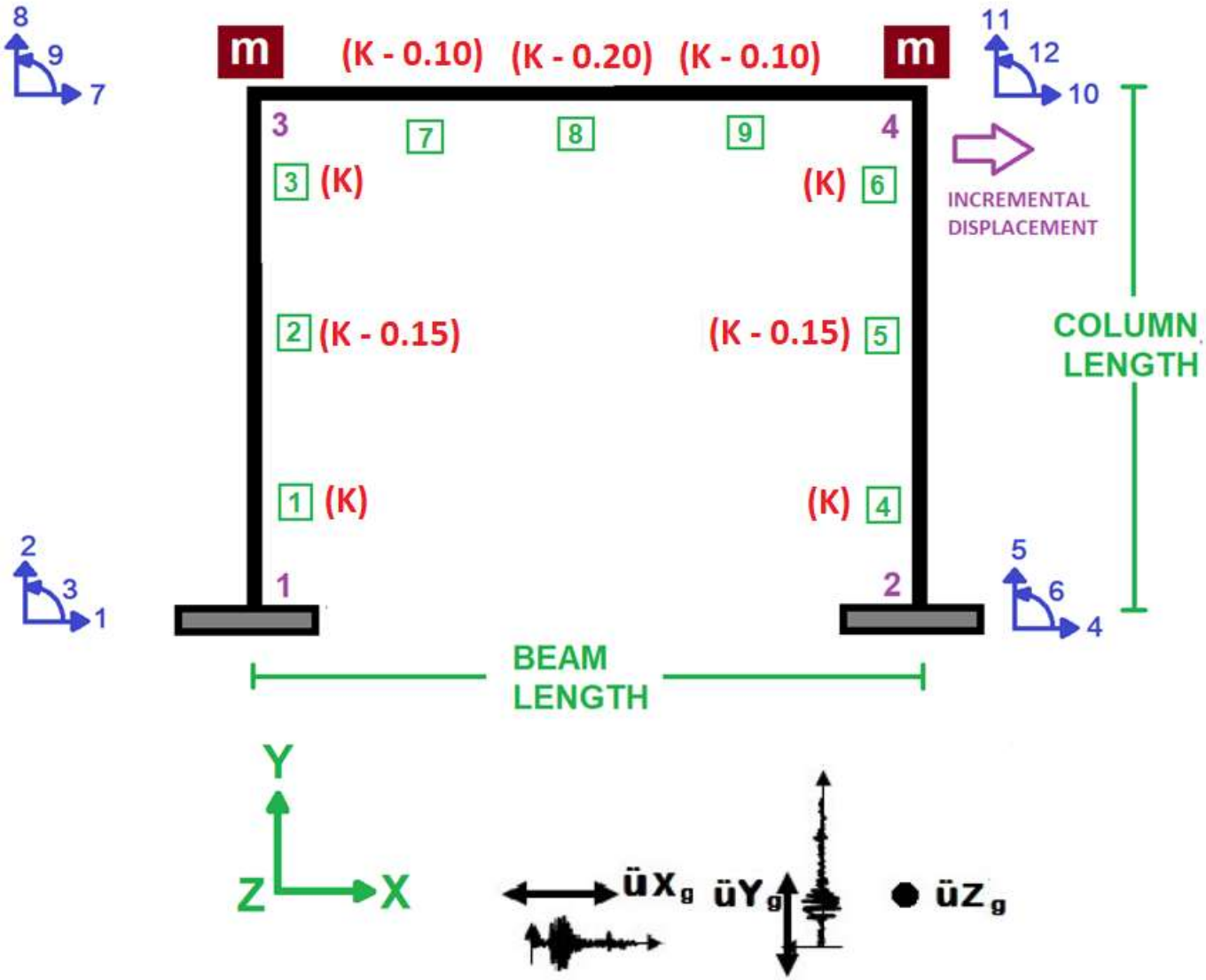
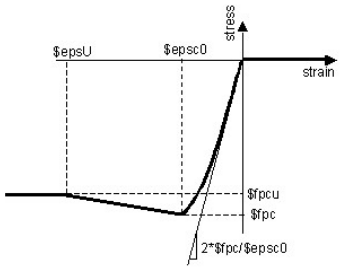
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

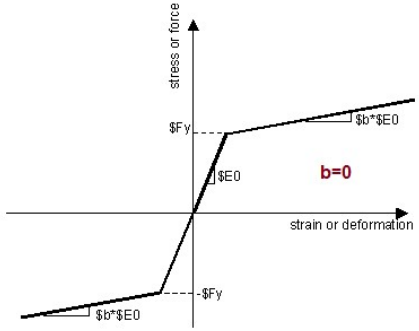
ASSESSMENTS OF THE STRUCTURAL DUCTILITY DAMAGE INDEX WITH DIFFERENT CONFINEMENT ENHANCEMENT RATIO OF CONCRETE FRAME USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

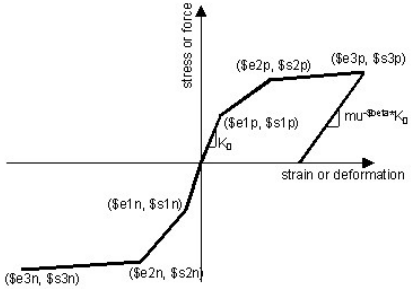

8
9
7
m
(K - 0.10)
(K - 0.20)
(K - 0.10)
m
11
12
10
3
7
8
9
4
3
(K)
(K)
6
INCREMENTAL
DISPLACEMENT
2
(K - 0.15)
(K - 0.15)
5
COLUMN
LENGTH
1
(K)
(K)
4
2
3
1
1
2
5
6
4
BEAM
LENGTH
Y
Z
X
üX g
üY g
üZ g



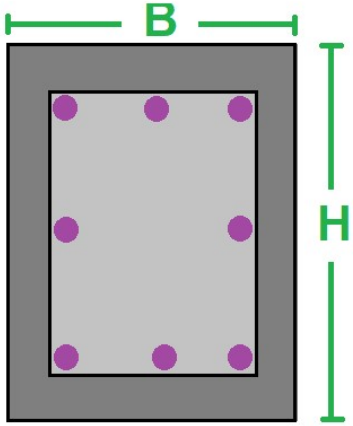
CORE AND COVER CONCRETE RELATION



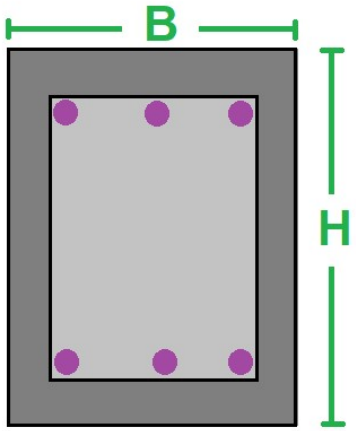
WITHOUT HARDENING AND ULTIMATE STRAIN



WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION

Spyder (Python 3.12)

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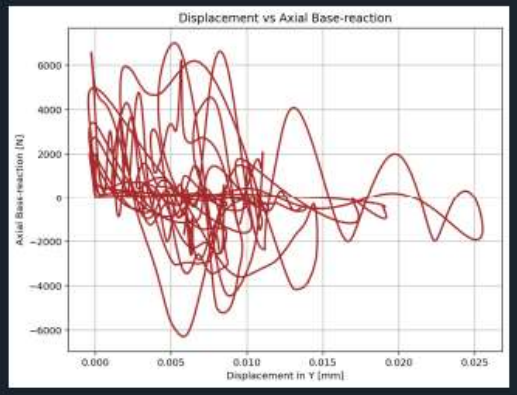
...ATIO\DUCTILITY_DAMAGE_INDEX_CONFINEMENT_ENHANCEMENT_RATIO

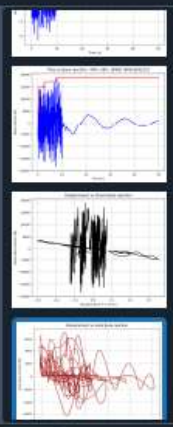
C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...ITY_DAMAGE_INDEX_CONFINEMENT_ENHANCEMENT_RATIO.py

CONCRETE_FRAME_DUC...HANCEMENT_RATIO.py

```
1  ##########################################################################################################################
2  #                              >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
3  #                             ASSESSMENTS OF THE STRUCTURAL DUCTILITY DAMAGE INDEX WITH DIFFERENT
4  #                  CONFINEMENT ENHANCEMENT RATIO OF CONCRETE FRAME ELEMENTS LIKE BEAM AND COLUMNS USING OPENSEES
5  #--------------------------------------------------------------------------------------------------------------------------
6  #                                 THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
7  #                                          EMAIL: salar.d.ghashghaei@gmail.com
8  ##########################################################################################################################
9  """
10 [1] Nonlinear Frame Modeling: 2D RC frame with distributed plasticity (fiber sections) using `nonlinearBeamC
11 [2] Material Laws:
12    - *Concrete*: `Concrete01` with confined (core) and unconfined (cover) properties.
13    - *Steel*: `Hysteretic` model with pinching, hardening, and cyclic degradation.
14 [3] Seismic Loads:
15    - Pushover: Displacement-controlled lateral loading to failure.
16    - Dynamic: Uniform excitation with user-defined ground motions (X/Y components).
17 [4] Damping: Rayleigh damping (a0, a1) calibrated via eigenvalue analysis (modes 1-2).
18 [5] Performance Metrics:
19    - Ductility Ratio (μ): Derived from bilinearized pushover curves.
20    - Overstrength (Ω₀): Yield vs. ultimate capacity.
21    - Damage Index (DI): Normalized displacement demand/capacity.
22 [6] Advanced Solver: HHT-α integrator (unconditionally stable) with Newton-Raphson iterations.
23 [7] Outputs:
24    - Hysteretic responses (P-M, V-Δ, M-ϑ).
25    - Time-history plots (displacement, base shear).
26    - Stiffness degradation tracking.
27 [8] Validation: Logarithmic decrement method for damping ratio verification.
28 [9] Ductility Damage Index (DDI) Implementation:
29     DDI quantifies structural damage via normalized displacement demand.
30     # After bilinear fit (X[1] = Δ_y, X[2] = Δ_u):
31     Dd = max(abs(DISP_Xd))  # Max dynamic displacement demand
32     DI = (Dd - Dy) / (Du - Dy)  # Ductility Damage Index (X-dir)
33     DI ≈ 0: Elastic response (no damage).
34     DI ≥ 1: Collapse (demand ≥ ultimate capacity).
```

31 %





Help Variable Explorer Debugger Plots Files

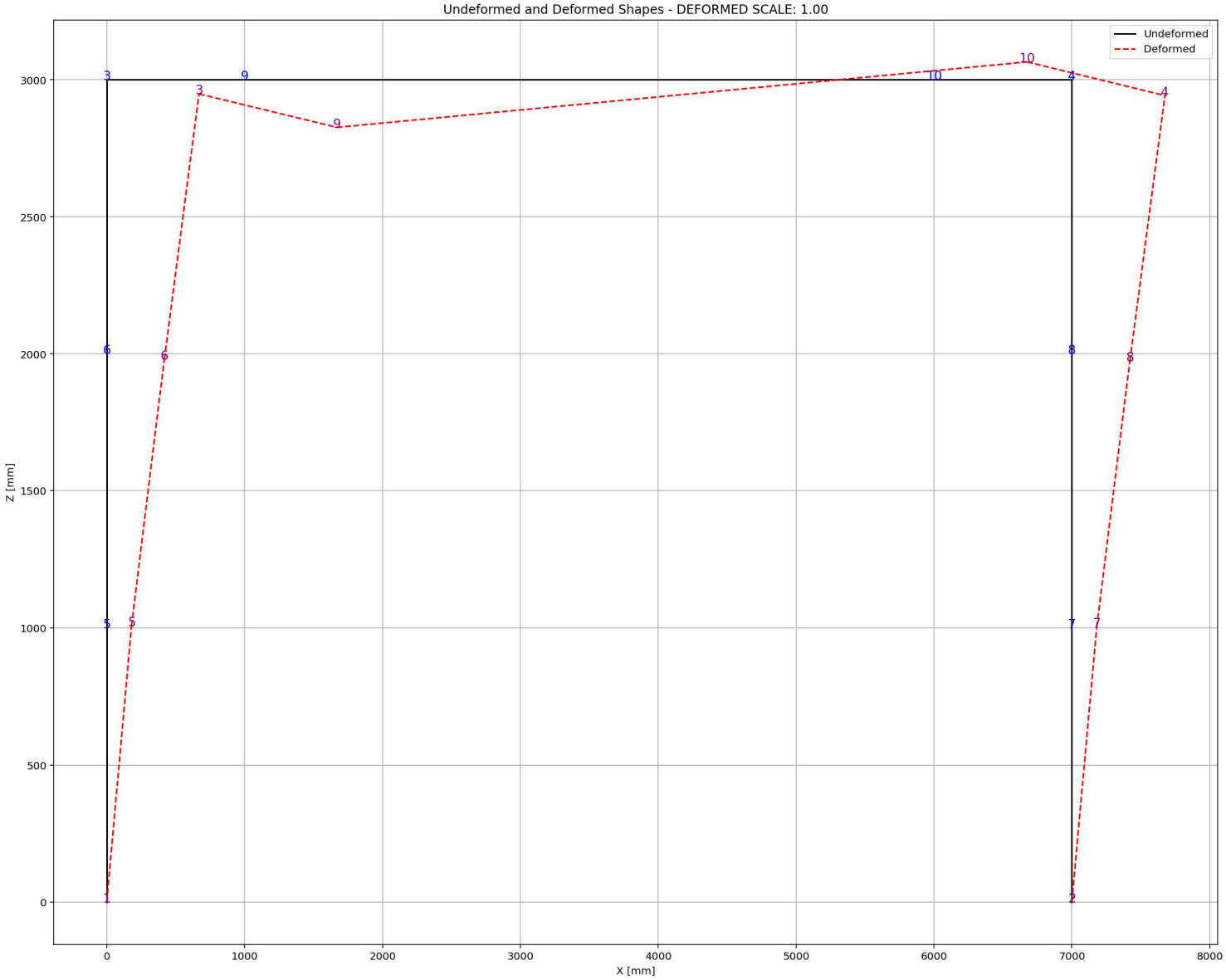
Console 1/A

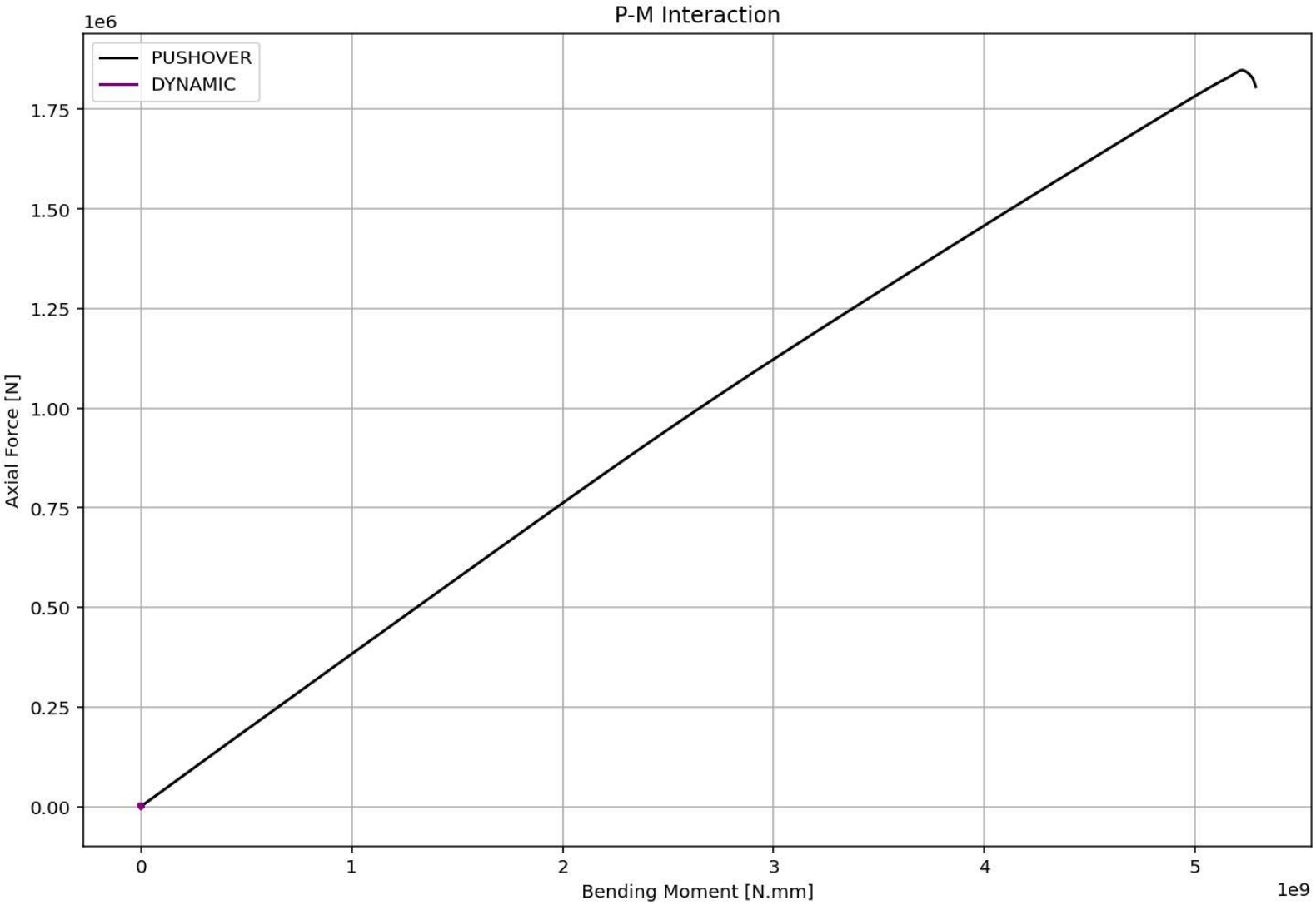
```
Lobatto
    End 1 Forces (P V M): 31.8152 -491.043 -831018
    End 2 Forces (P V M): -31.8152 491.043 339975

Element: 3 Type: ForceBeamColumn2d  Connected Nodes: 6 3
    Number of Sections: 10  Mass density: 6.25
Lobatto
    End 1 Forces (P V M): 9.2331 -482.525 -339975
    End 2 Forces (P V M): -9.2331 482.525 -142550

In [2]:
```

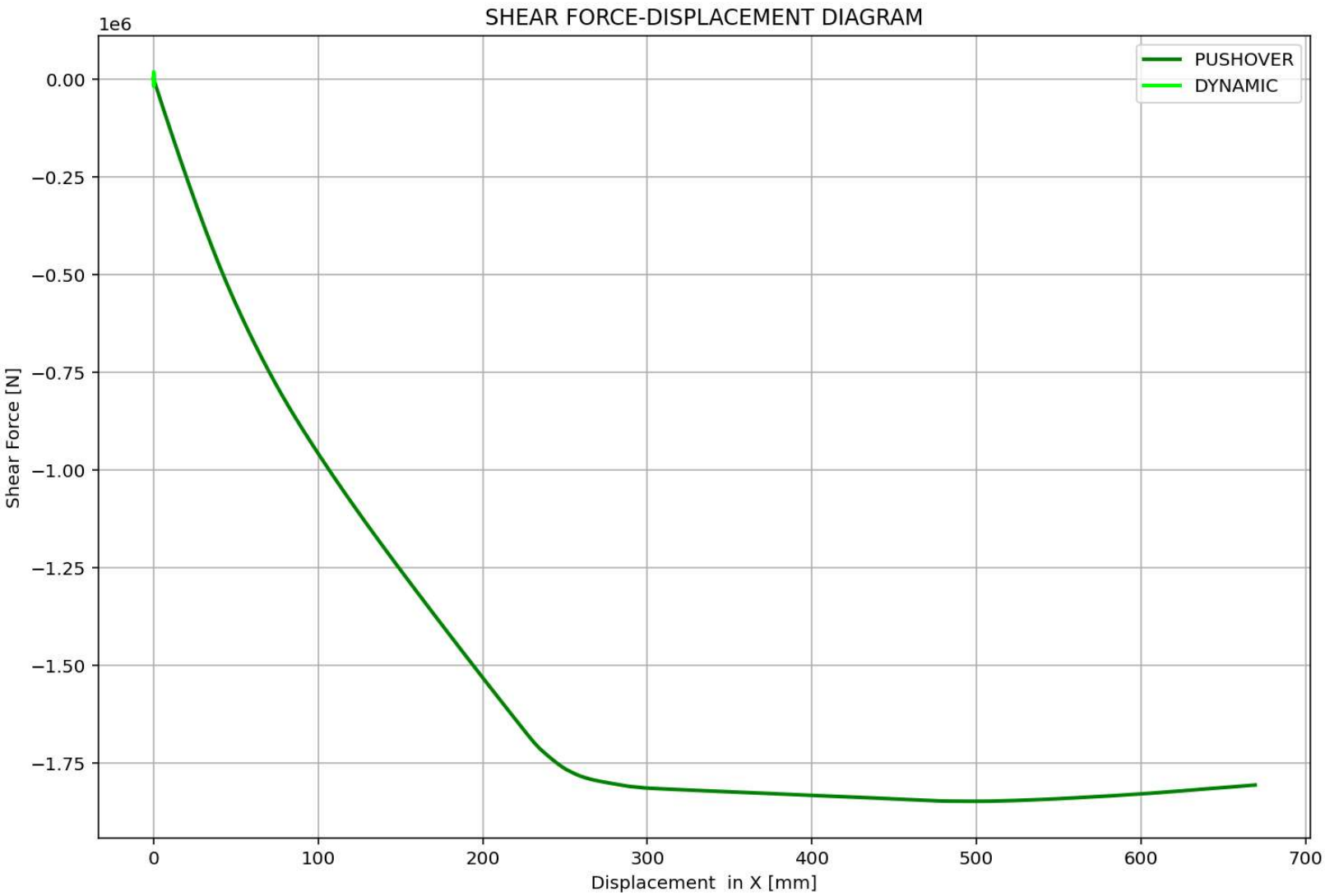
IPython Console History

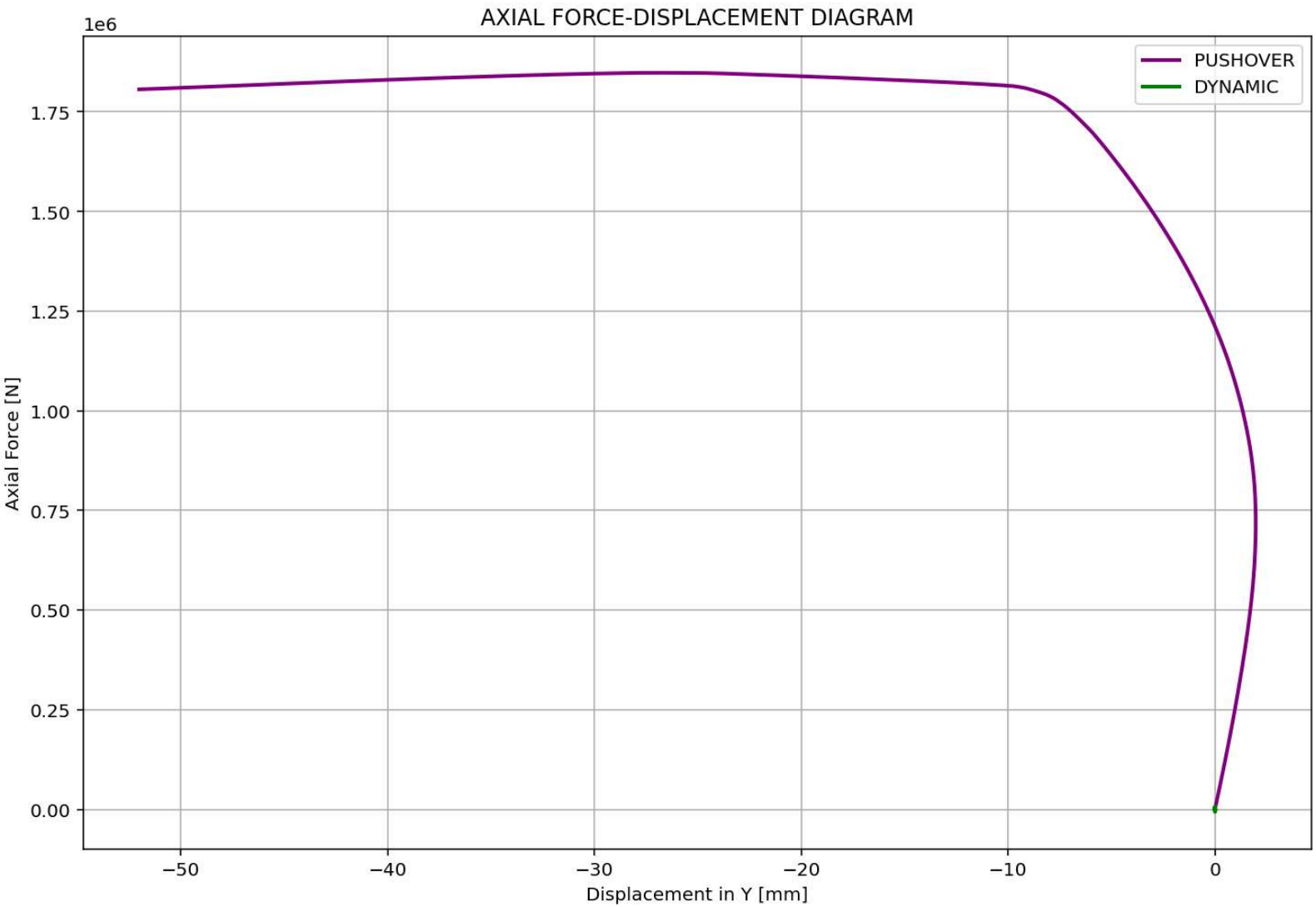
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 4, Col 118 UTF-8 CRLF RW Mem 41%

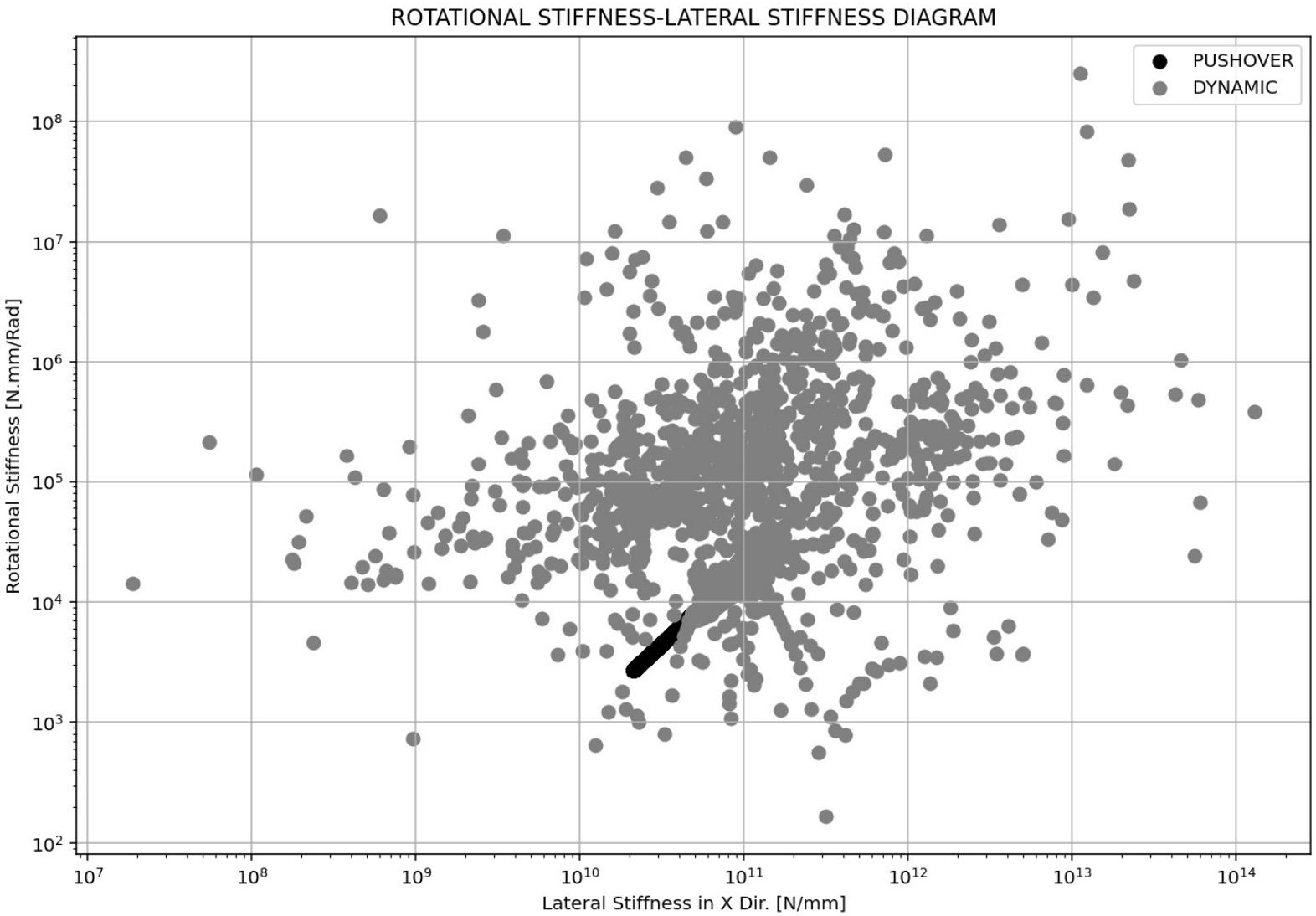
NONLINEAR STATIC ANALYSIS (PUSHOVER)

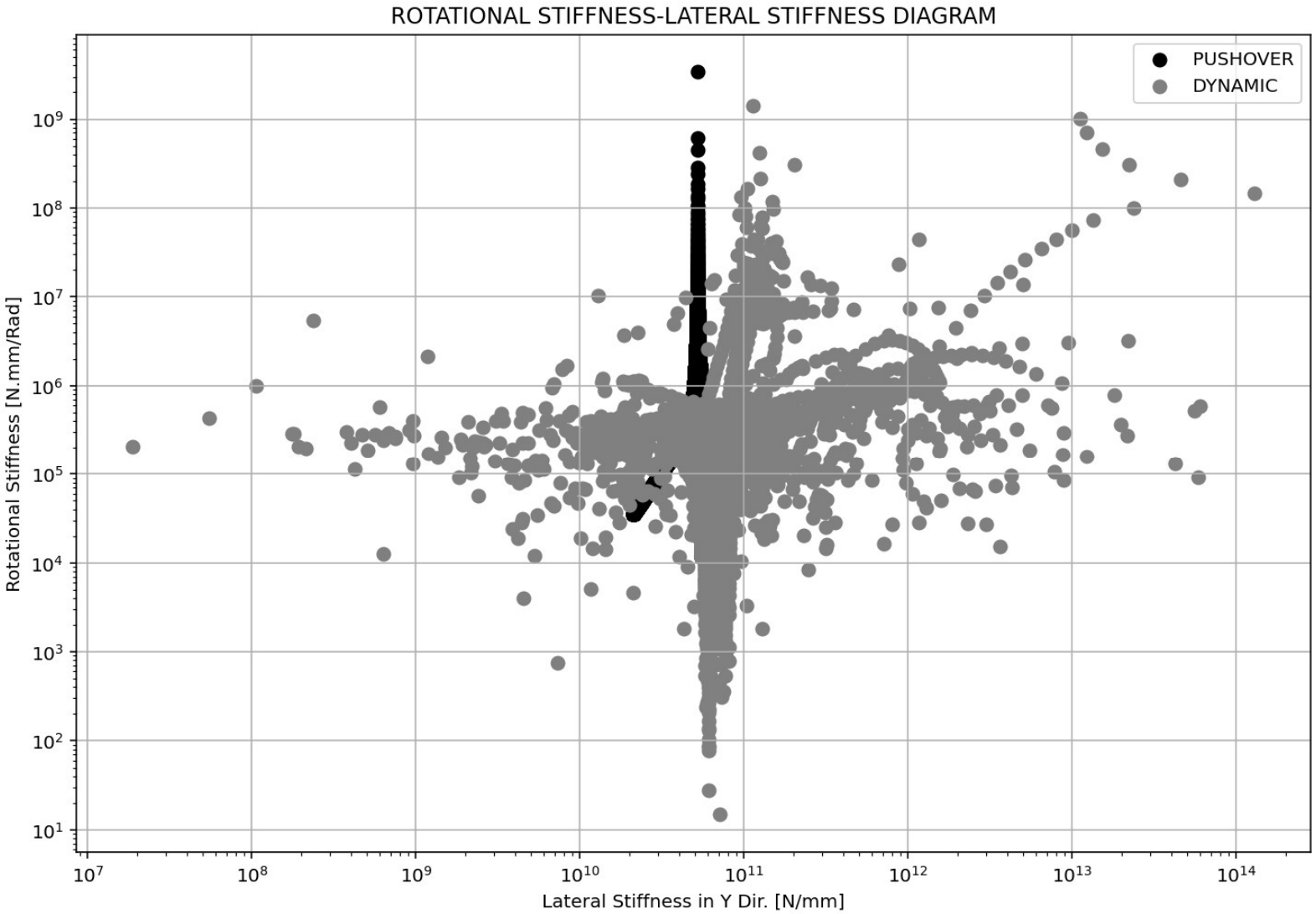

Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
8000
1
2
3
4
5
6
7
8
9
10

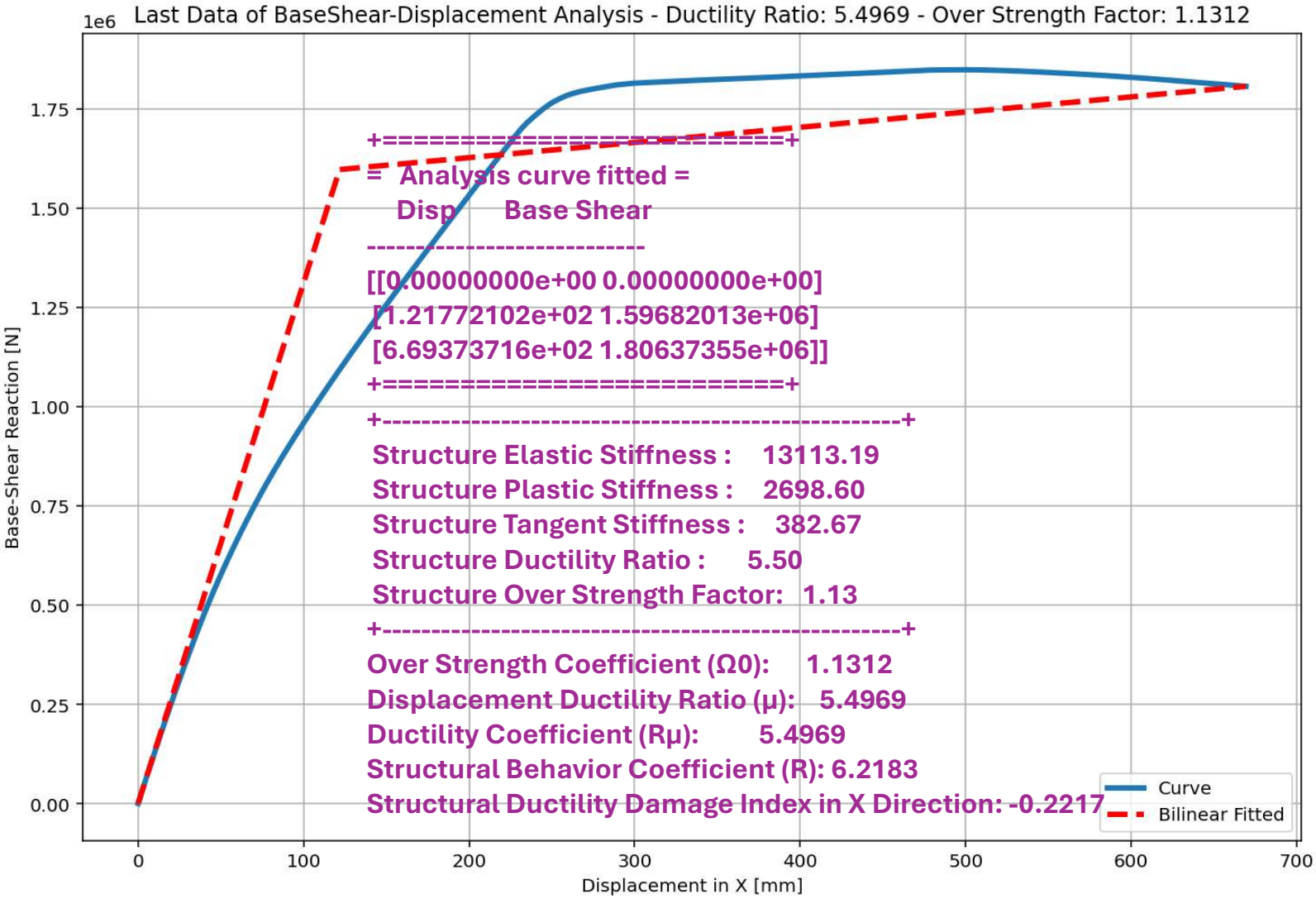

P-M Interaction
1e6
PUSHOVER
DYNAMIC
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Axial Force [N]
0
1
2
3
4
5
Bending Moment [N.mm]
1e9


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
500
600
700
Displacement in X [mm]
PUSHOVER
DYNAMIC

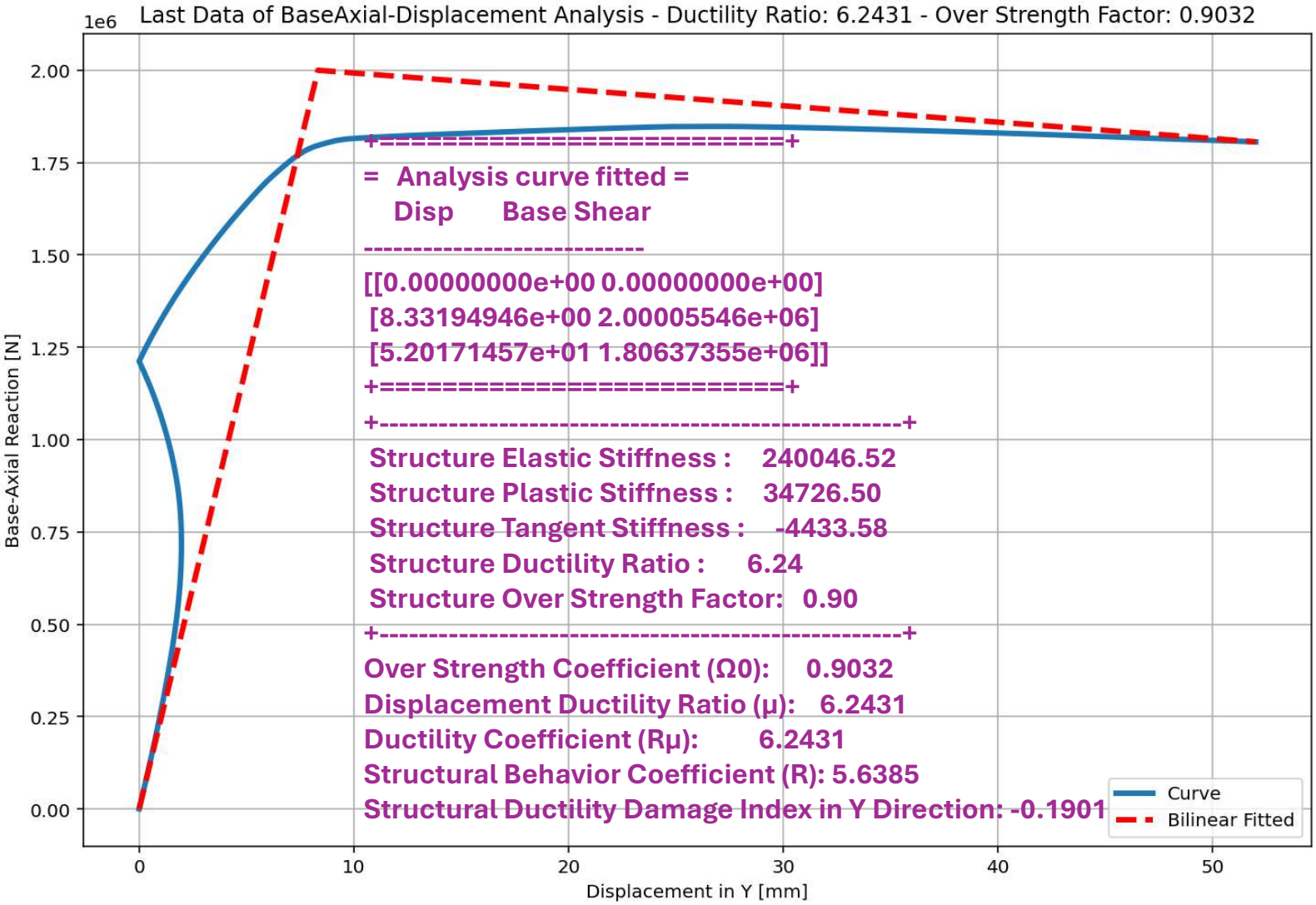

AXIAL FORCE-DISPLACEMENT DIAGRAM
1e6
PUSHOVER
DYNAMIC
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Axial Force [N]
−50
−40
−30
−20
−10
0
Displacement in Y [mm]


ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
PUSHOVER
DYNAMIC
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^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}


ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
PUSHOVER
DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in Y Dir. [N/mm]
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
10^{9}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}

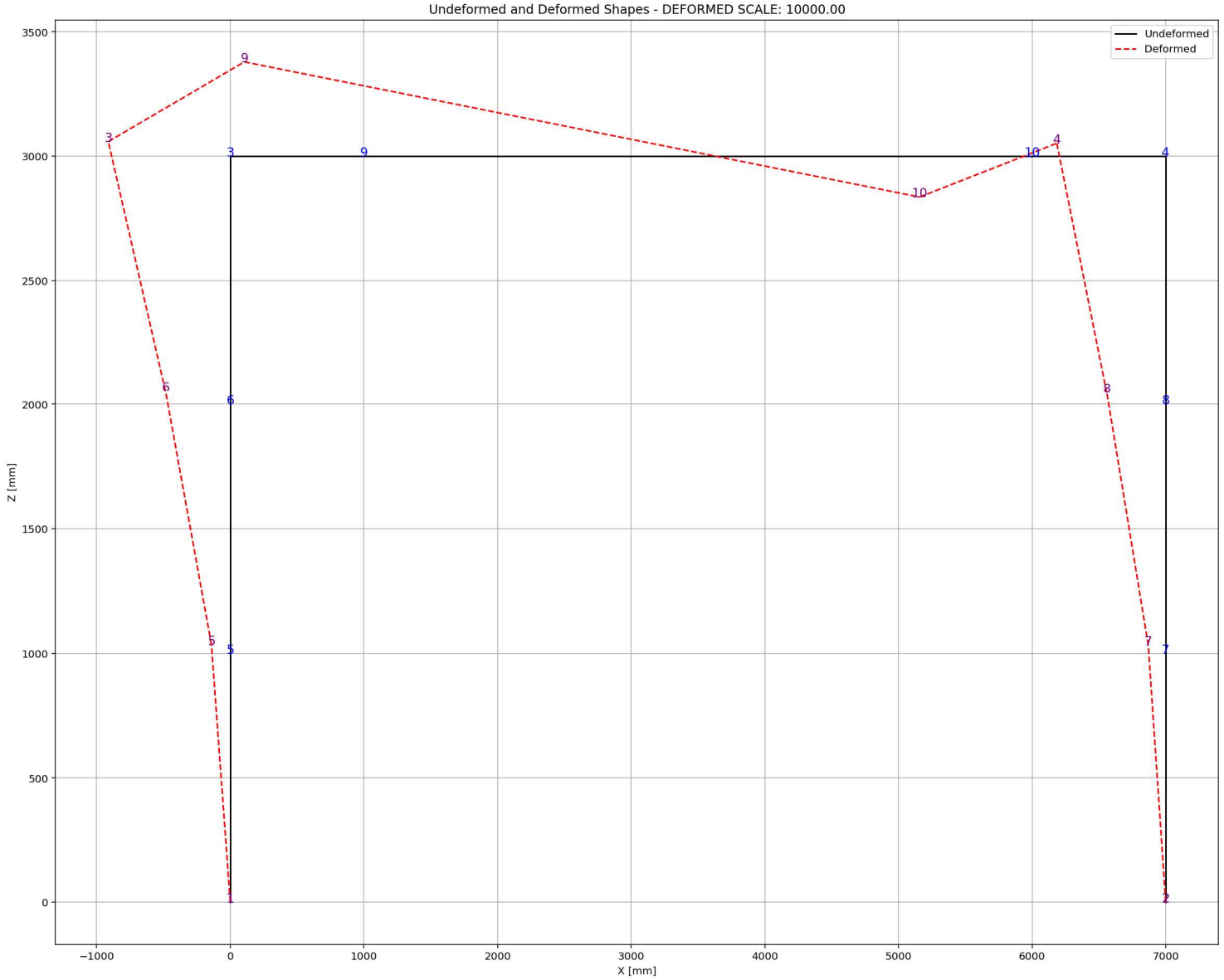

Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 5.4969 - Over Strength Factor: 1.1312
1e6
Base-Shear Reaction [N]
Displacement in X [mm]
+==========================+
= Analysis curve fitted =
Disp Base Shear

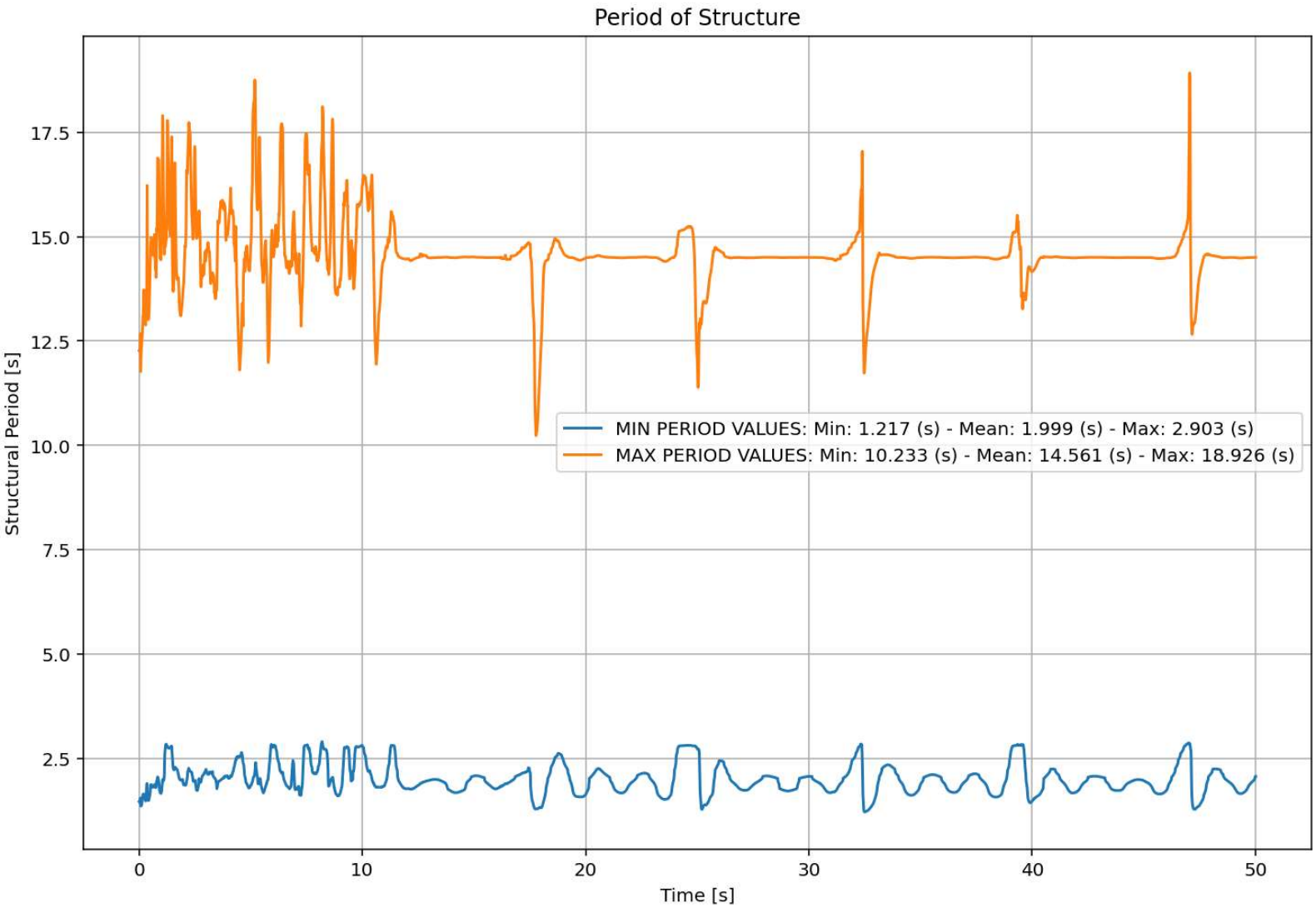
[[0.00000000e+00 0.00000000e+00]
[1.21772102e+02 1.59682013e+06]
[6.69373716e+02 1.80637355e+06]]
+==========================+
+--+
Structure Elastic Stiffness : 13113.19
Structure Plastic Stiffness : 2698.60
Structure Tangent Stiffness : 382.67
Structure Ductility Ratio : 5.50
Structure Over Strength Factor: 1.13
+--+
Over Strength Coefficient (Ω0): 1.1312
Displacement Ductility Ratio (μ): 5.4969
Ductility Coefficient (Rμ): 5.4969
Structural Behavior Coefficient (R): 6.2183
Structural Ductility Damage Index in X Direction: -0.2217
Curve
Bilinear Fitted

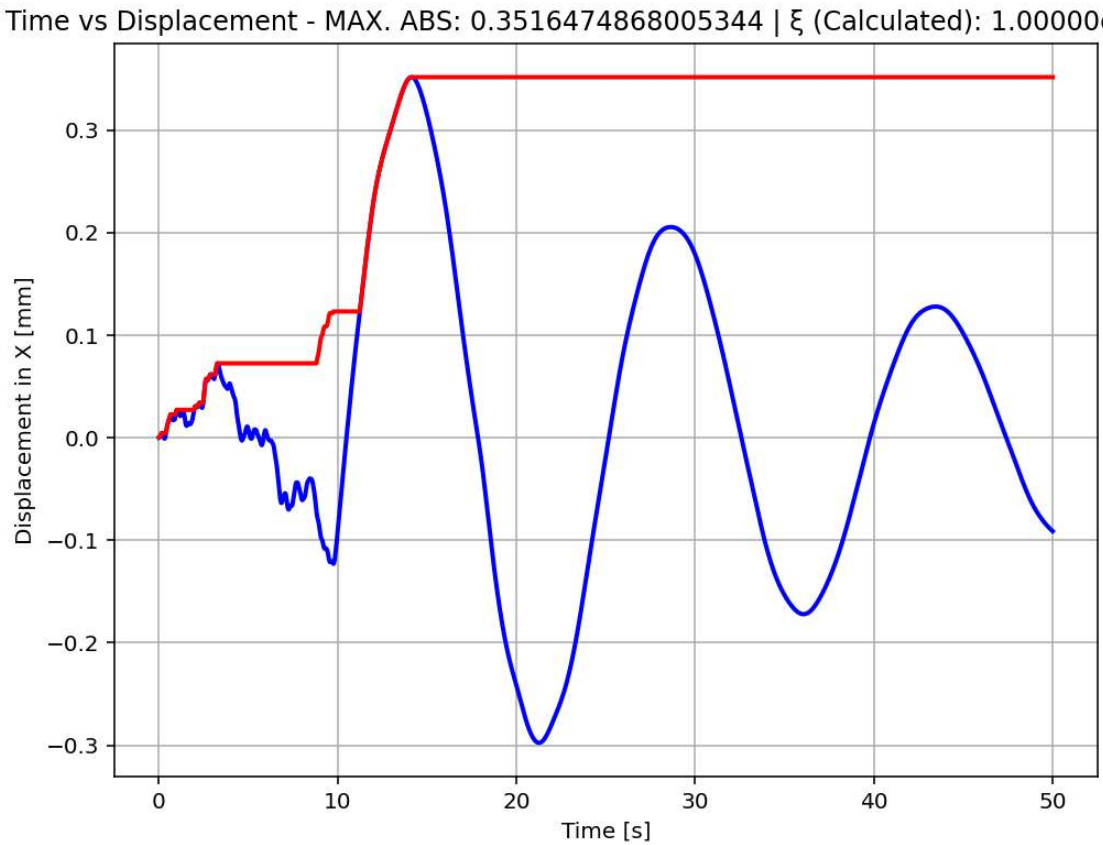

Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 6.2431 - Over Strength Factor: 0.9032
1e6
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Base-Axial Reaction [N]
0
10
20
30
40
50
Displacement in Y [mm]
+============================+
= Analysis curve fitted =
Disp Base Shear

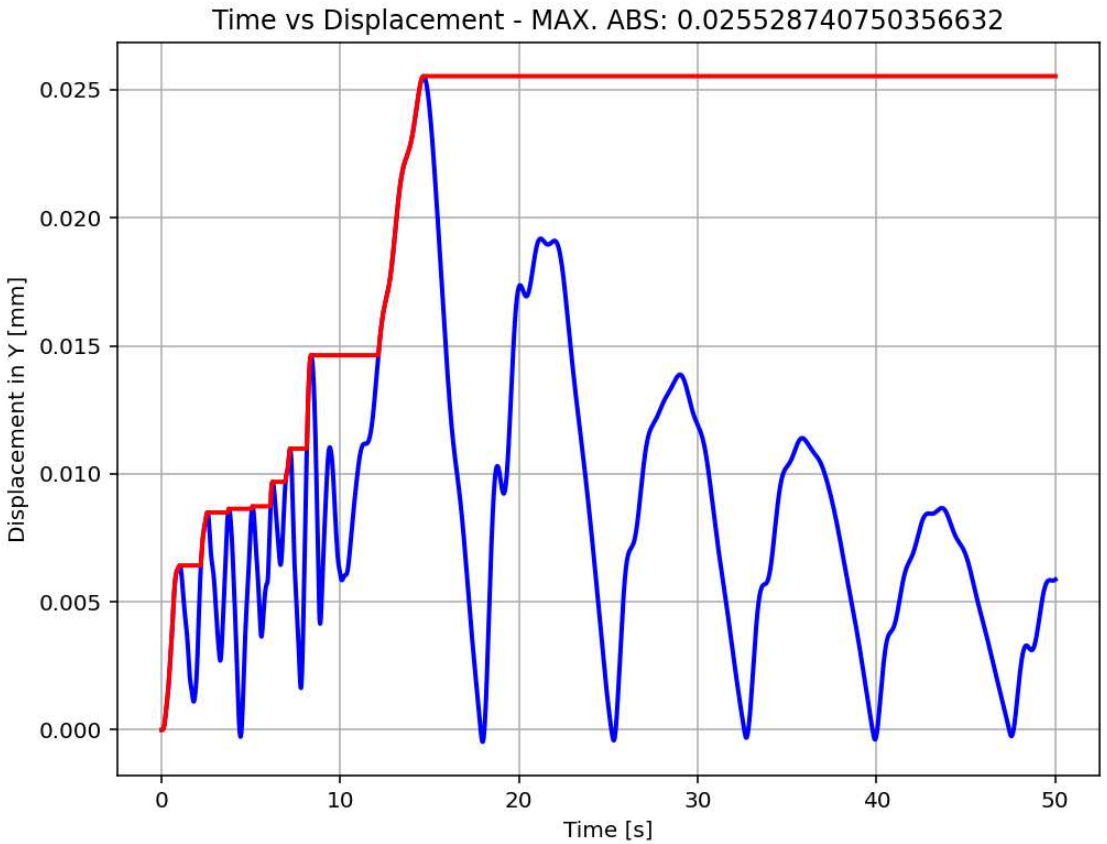
[[0.00000000e+00 0.00000000e+00]
[8.33194946e+00 2.00005546e+06]
[5.20171457e+01 1.80637355e+06]]
+============================+
+---+
Structure Elastic Stiffness : 240046.52
Structure Plastic Stiffness : 34726.50
Structure Tangent Stiffness : -4433.58
Structure Ductility Ratio : 6.24
Structure Over Strength Factor: 0.90
+---+
Over Strength Coefficient (Ω0): 0.9032
Displacement Ductility Ratio (μ): 6.2431
Ductility Coefficient (Rμ): 6.2431
Structural Behavior Coefficient (R): 5.6385
Structural Ductility Damage Index in Y Direction: -0.1901
Curve
Bilinear Fitted

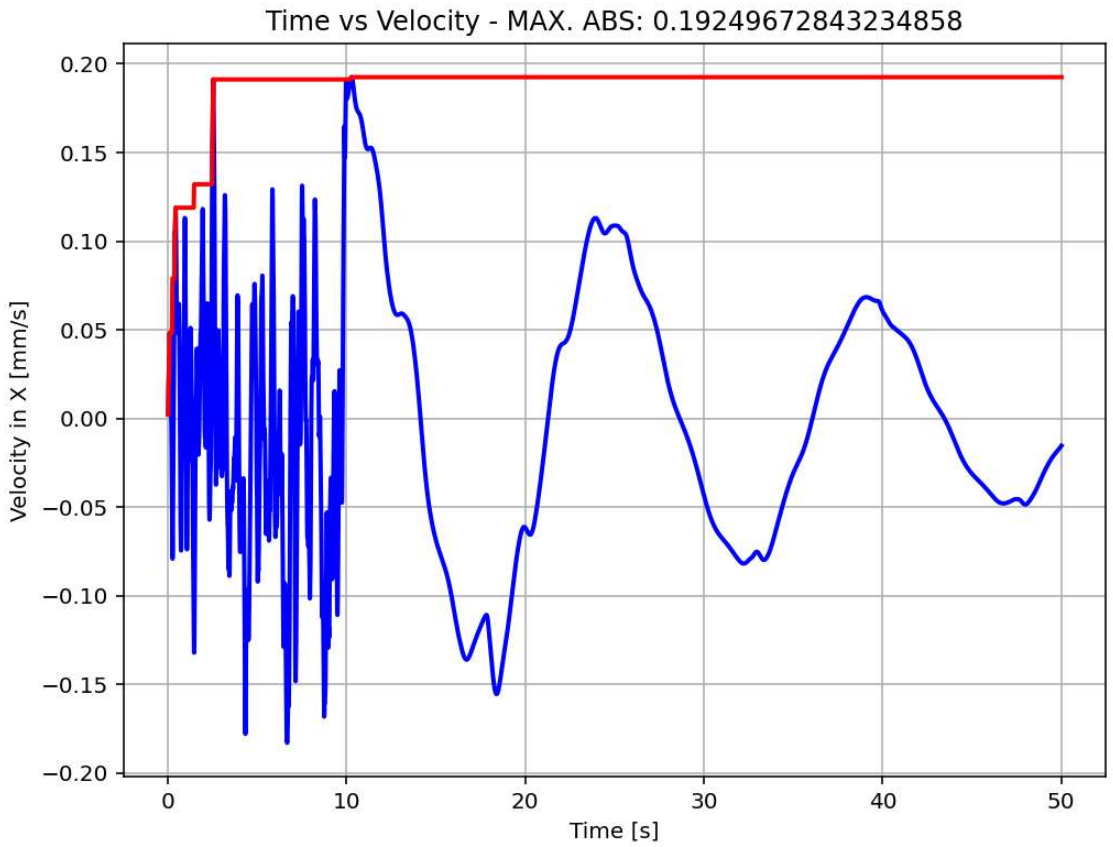
NONLINEAR DYNAMIC ANALYSIS

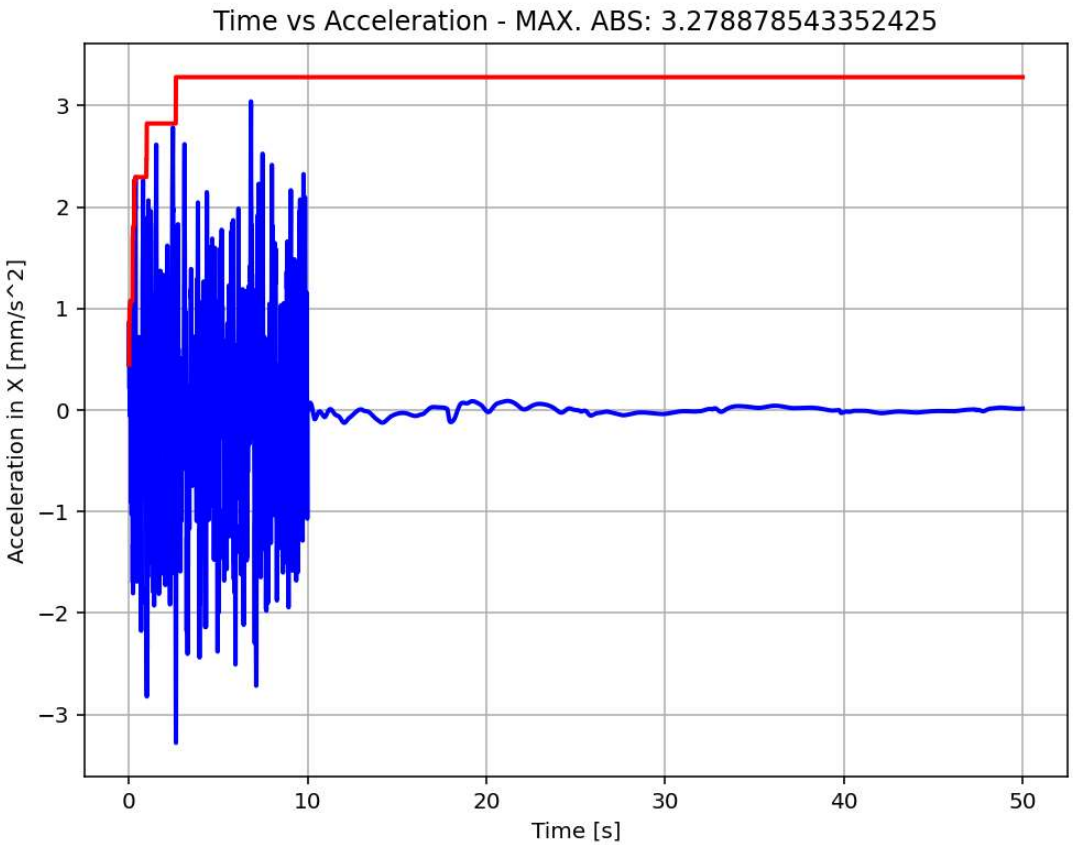

Undeformed and Deformed Shapes - DEFORMED SCALE: 10000.00
Undeformed
Deformed
Z [mm]
X [mm]
3500
3000
2500
2000
1500
1000
500
0
−1000
0
1000
2000
3000
4000
5000
6000
7000
9
3
3
9
10
4
10
4
6
6
8
8
5
5
7
7
1
2

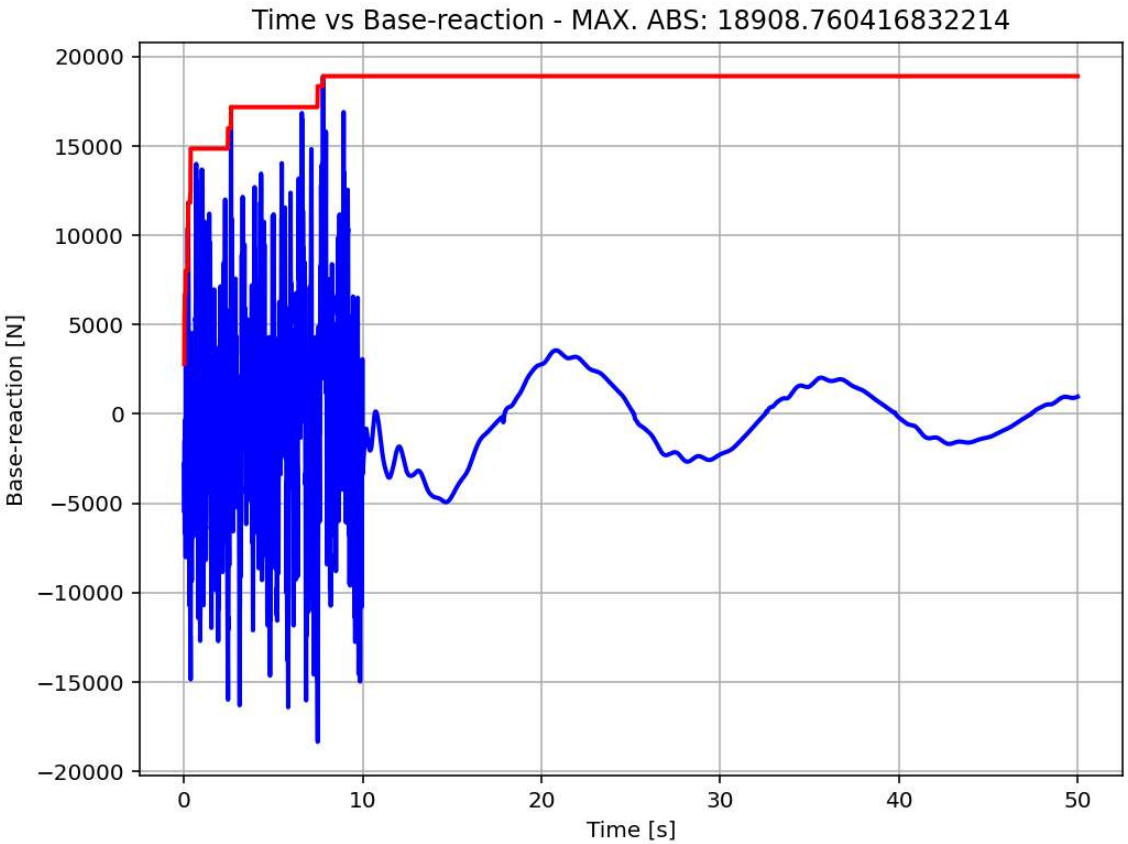

Period of Structure
Structural Period [s]
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
10
20
30
40
50
Time [s]
MIN PERIOD VALUES: Min: 1.217 (s) - Mean: 1.999 (s) - Max: 2.903 (s)
MAX PERIOD VALUES: Min: 10.233 (s) - Mean: 14.561 (s) - Max: 18.926 (s)

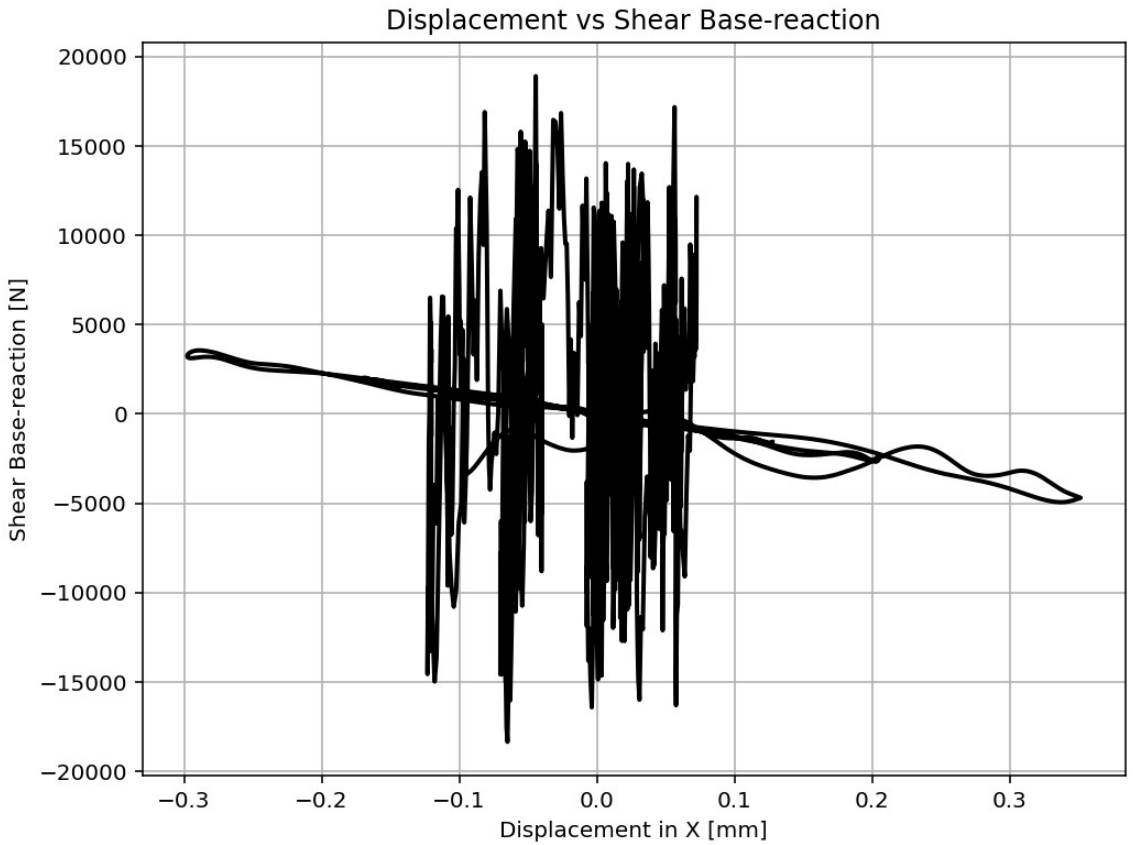

Time vs Displacement - MAX. ABS: 0.3516474868005344 | ξ (Calculated): 1.00000e+02 %
Displacement in X [mm]
Time [s]
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0
10
20
30
40
50

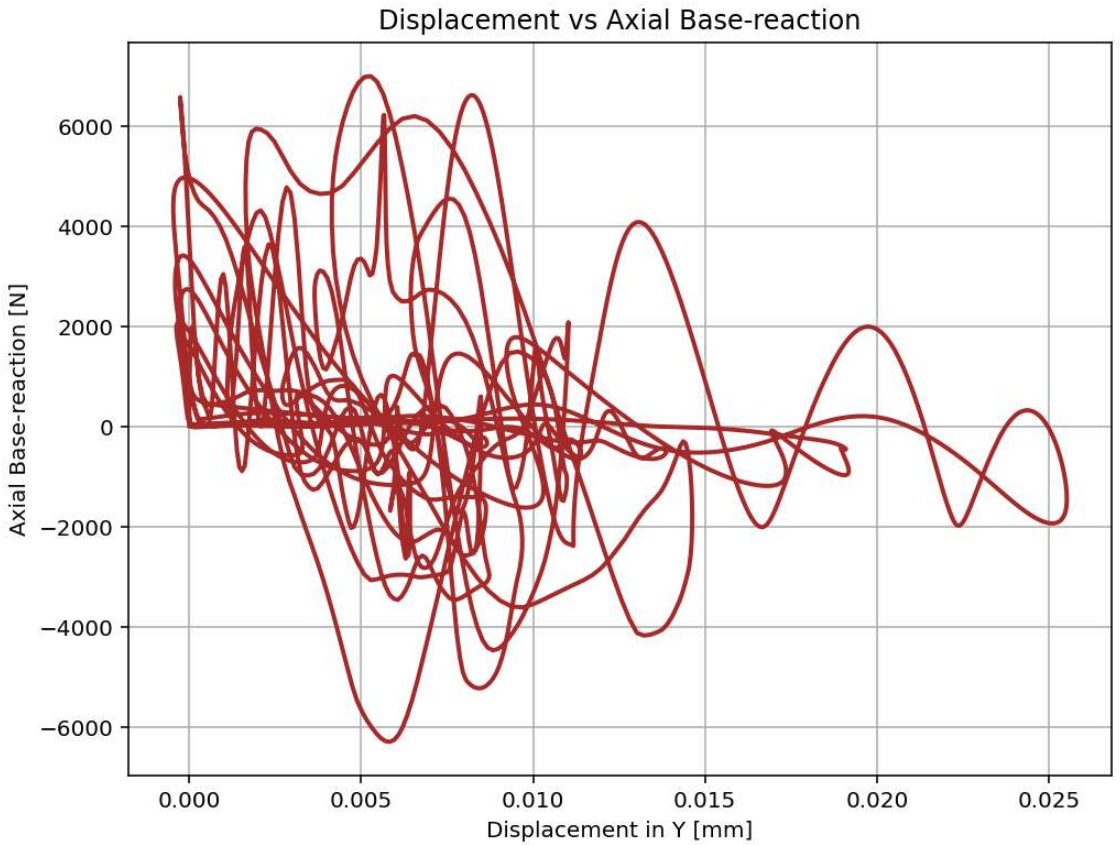

Time vs Displacement - MAX. ABS: 0.025528740750356632
Displacement in Y [mm]
0.025
0.020
0.015
0.010
0.005
0.000
0
10
20
30
40
50
Time [s]

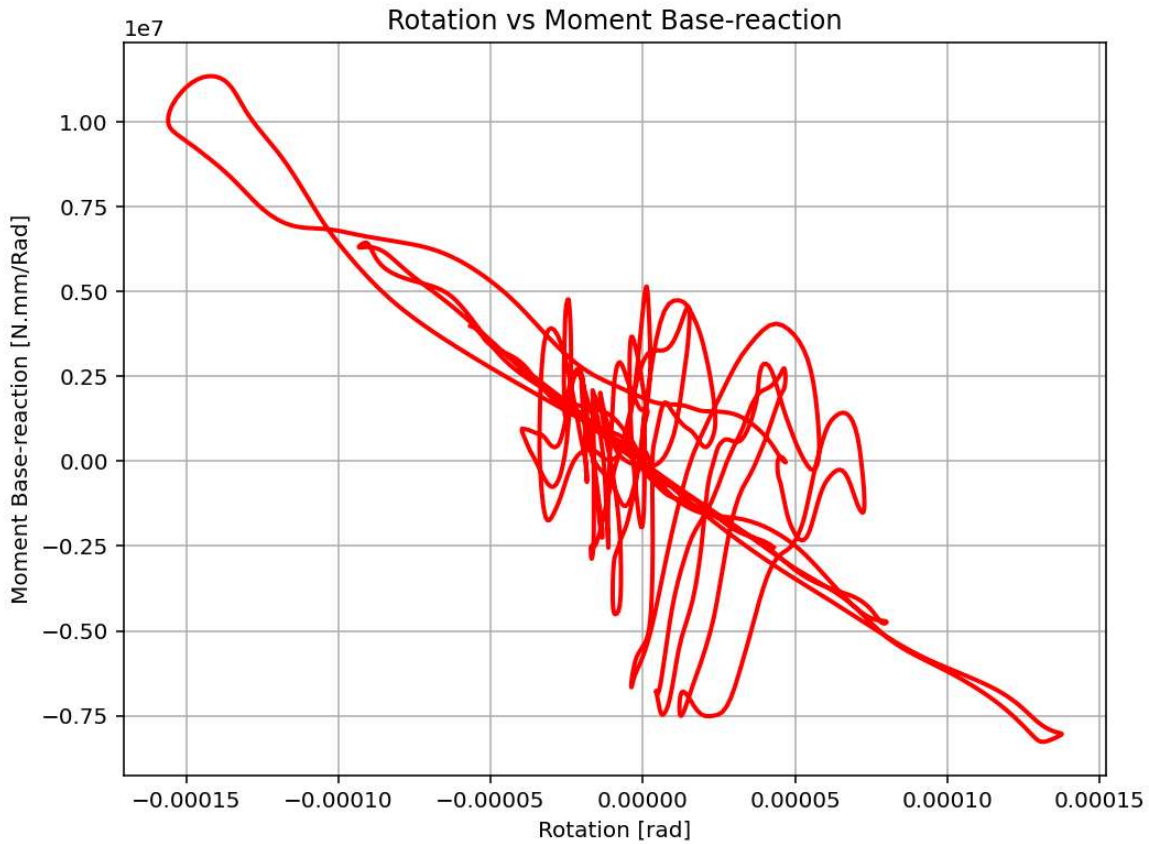

Time vs Velocity - MAX. ABS: 0.19249672843234858
Velocity in X [mm/s]
Time [s]
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
0
10
20
30
40
50


Time vs Acceleration - MAX. ABS: 3.278878543352425
Acceleration in X [mm/s^2]
Time [s]
3
2
1
0
−1
−2
−3
0
10
20
30
40
50


Time vs Base-reaction - MAX. ABS: 18908.760416832214
Base-reaction [N]
Time [s]
20000
15000
10000
5000
0
−5000
−10000
−15000
−20000
0
10
20
30
40
50


Displacement vs Shear Base-reaction
Shear Base-reaction [N]
20000
15000
10000
5000
0
−5000
−10000
−15000
−20000
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
Displacement in X [mm]


Displacement vs Axial Base-reaction
Axial Base-reaction [N]
6000
4000
2000
0
−2000
−4000
−6000
0.000
0.005
0.010
0.015
0.020
0.025
Displacement in Y [mm]


Rotation vs Moment Base-reaction
1e7
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
Moment Base-reaction [N.mm/Rad]
−0.00015
−0.00010
−0.00005
0.00000
0.00005
0.00010
0.00015
Rotation [rad]