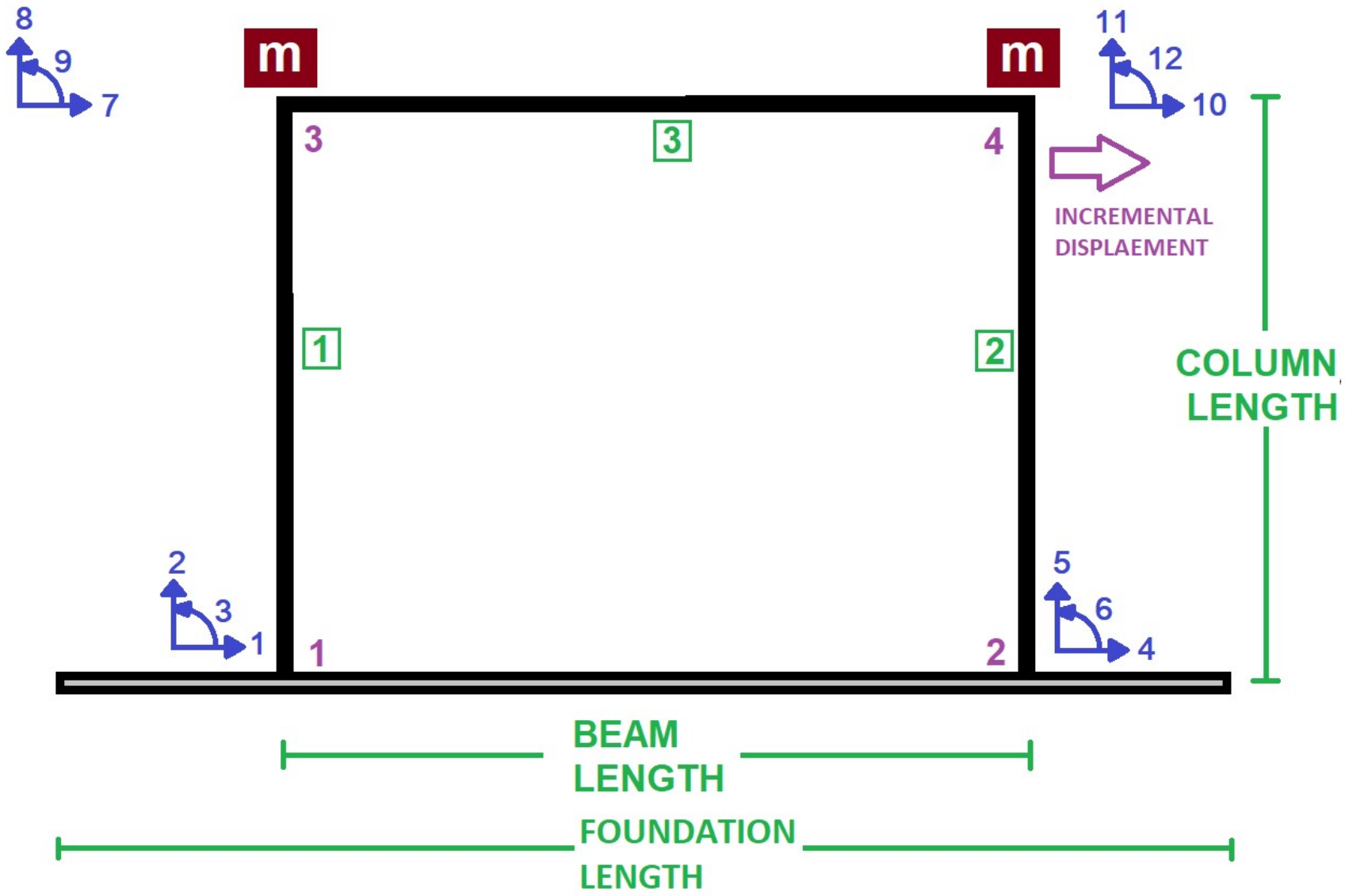
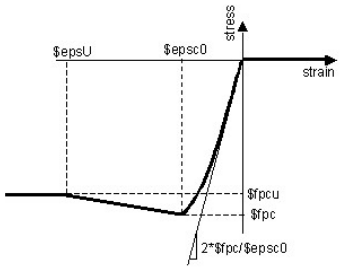
IN THE NAME OF ALLAH

SOIL-FOUNDATION-STRUCTURE INTERACTION USING OPENSEES

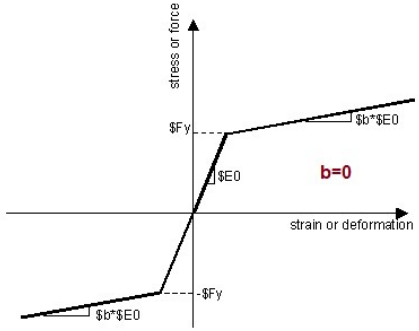
SOIL SIMULATED WITH SIMPLE SPRINGS AND THE SOIL SPRINGS VALUES IS NOT EXACT.

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

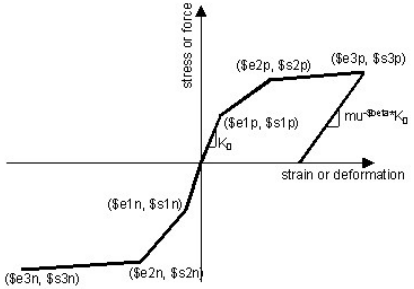

8
9
7
m
m
11
12
10
3
3
4
INCREMENTAL
DISPLAEMENT
1
2
COLUMN
LENGTH
2
3
1
1
2
5
6
4
BEAM
LENGTH
FOUNDATION
LENGTH



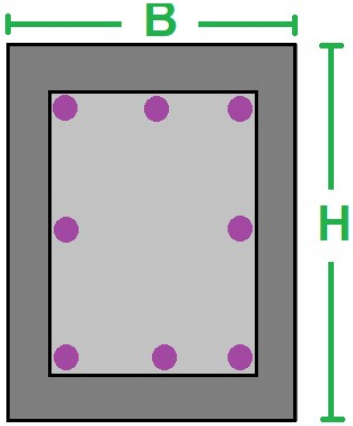
CORE AND COVER CONCRETE RELATION



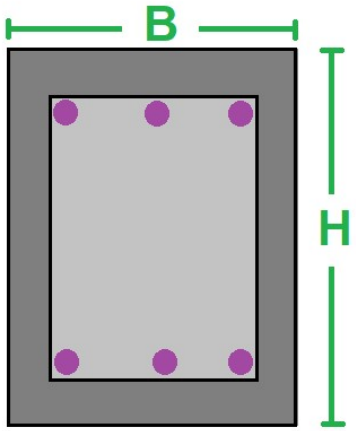
WITHOUT HARDENING AND ULTIMATE STRAIN



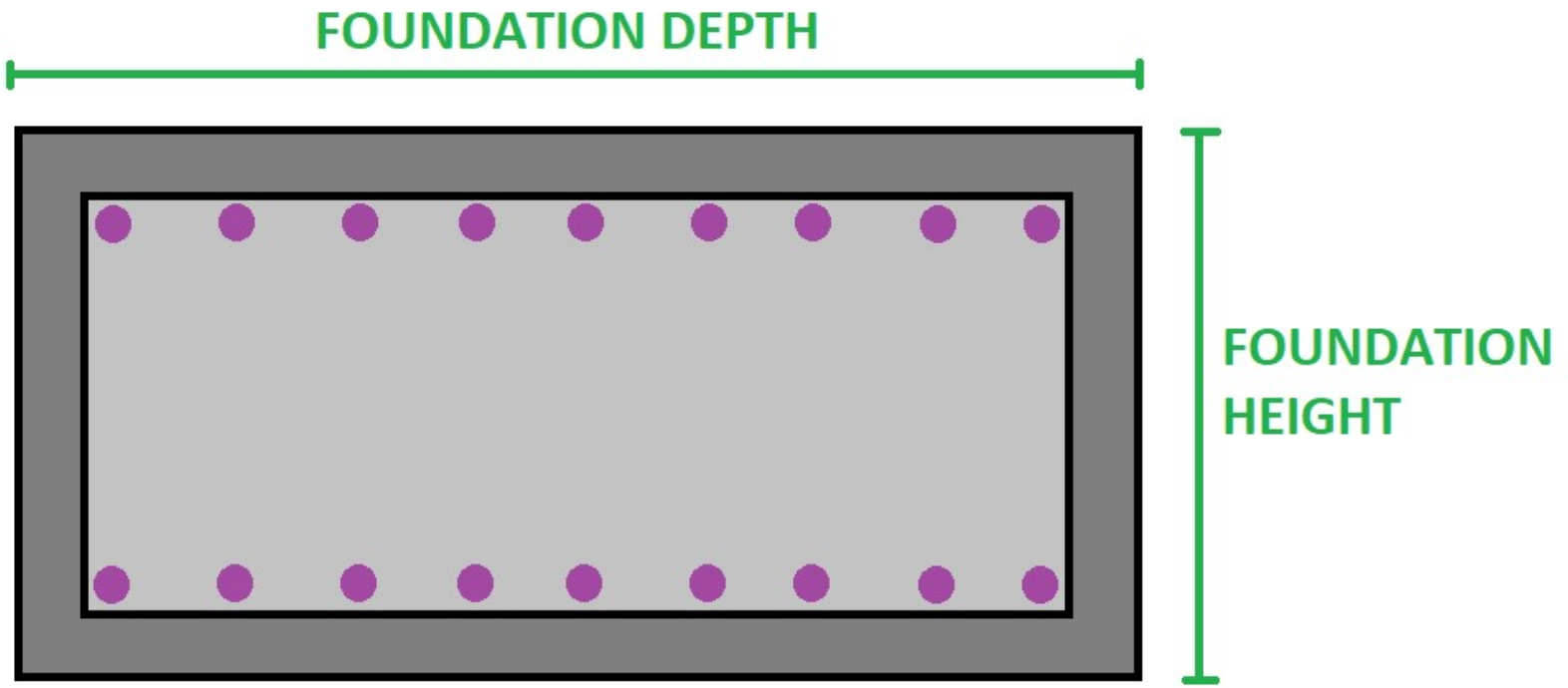
WITH HARDENING AND ULTIMATE STRAIN



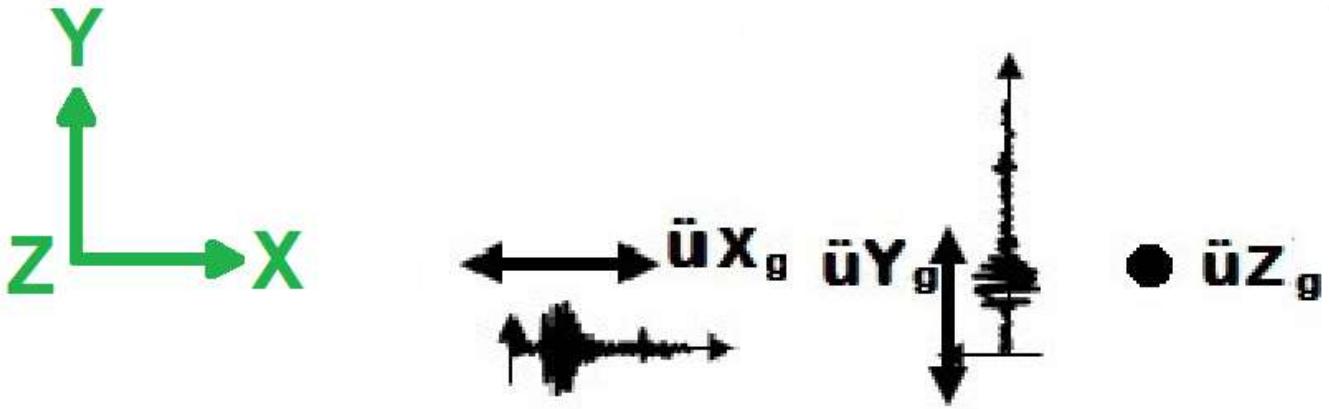
COLUMN SECTION



BEAM SECTION



FOUNDATION SECTION

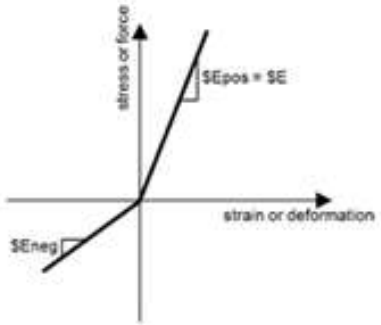


$$Structure\ Ductility\ Damage\ Index = \frac{\Delta_d - \Delta_y}{\Delta_u - \Delta_y}$$

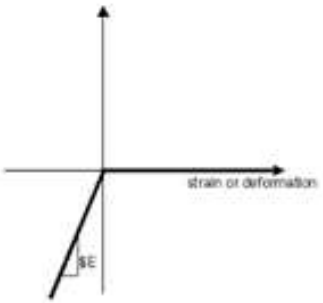
$$\Delta_d = Lateral\ Displaement\ from\ Dynamic\ Analysis$$

$$\Delta_y = Lateral\ Yield\ Displaement\ from\ Pushover\ Analysis$$

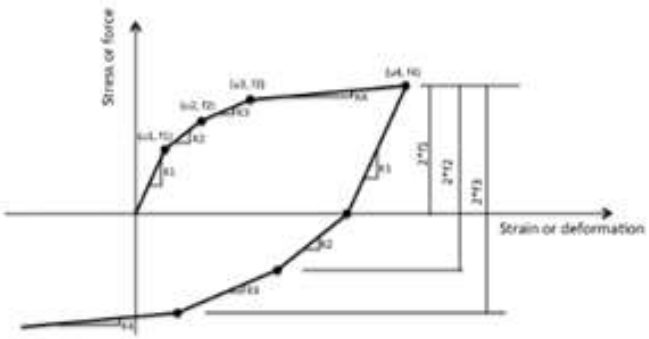
$$\Delta_u = Lateral\ Ultimate\ Displaement\ from\ Pushover\ Analysis$$



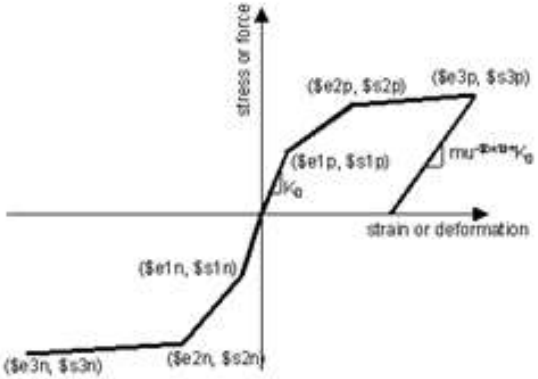
Elastic Uniaxial Material



Elastic-No Tension Material



MultiLinear Material



Hysteretic Material

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

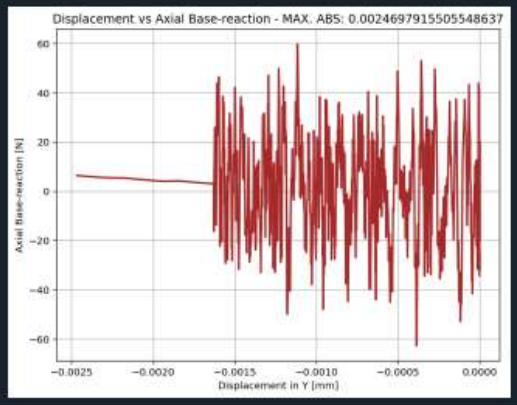
C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...02\CONCRETE_FRAME_SOIL-FOUNDATION-STRUCTURE_02.py

CONCRETE_FRAME_SOI...ON-STRUCTURE_02.py

```
##########################################################################################################
                                        IN THE NAME OF ALLAH
                                SOIL-FOUNDATION-STRUCTURE INTERACTION USING OPENSEES
----------------------------------------------------------------------------------------------------------
                                        EXAMPLE 02:
                        SOIL SIMULATED WITH SIMPLE SPRINGS AND THE  SOIL SPRINGS VALUES IS NOT EXACT.
----------------------------------------------------------------------------------------------------------
                                THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
                                        EMAIL: salar.d.ghashghaei@gmail.com
##########################################################################################################
"
] Nonlinear Frame Modeling: 2D RC frame with distributed plasticity (fiber sections) using `nonlinearBe
] Material Laws:
 - *Concrete*: `Concrete01` with confined (core) and unconfined (cover) properties.
 - *Steel*: `Hysteretic` model with pinching, hardening, and cyclic degradation.
] Seismic Loads:
 - Pushover: Displacement-controlled lateral loading to failure.
 - Dynamic: Uniform excitation with user-defined ground motions (X/Y components).
] Damping: Rayleigh damping (a0, a1) calibrated via eigenvalue analysis (modes 1-2).
] Performance Metrics:
 - Ductility Ratio (μ): Derived from bilinearized pushover curves.
 - Overstrength (Ω₀): Yield vs. ultimate capacity.
 - Damage Index (DI): Normalized displacement demand/capacity.
] Advanced Solver: HHT-α integrator (unconditionally stable) with Newton-Raphson iterations.
] Outputs:
 - Hysteretic responses (P-M, V-Δ, M-θ).
 - Time-history plots (displacement, base shear).
 - Stiffness degradation tracking.
] Validation: Logarithmic decrement method for damping ratio verification.
] 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)
```

..RAME_EXAMPLES\SOIL-FOUNDATION\SOIL-FOUNDATION-STRUCTURE_02

32 %



Help Variable Explorer Debugger Plots Files

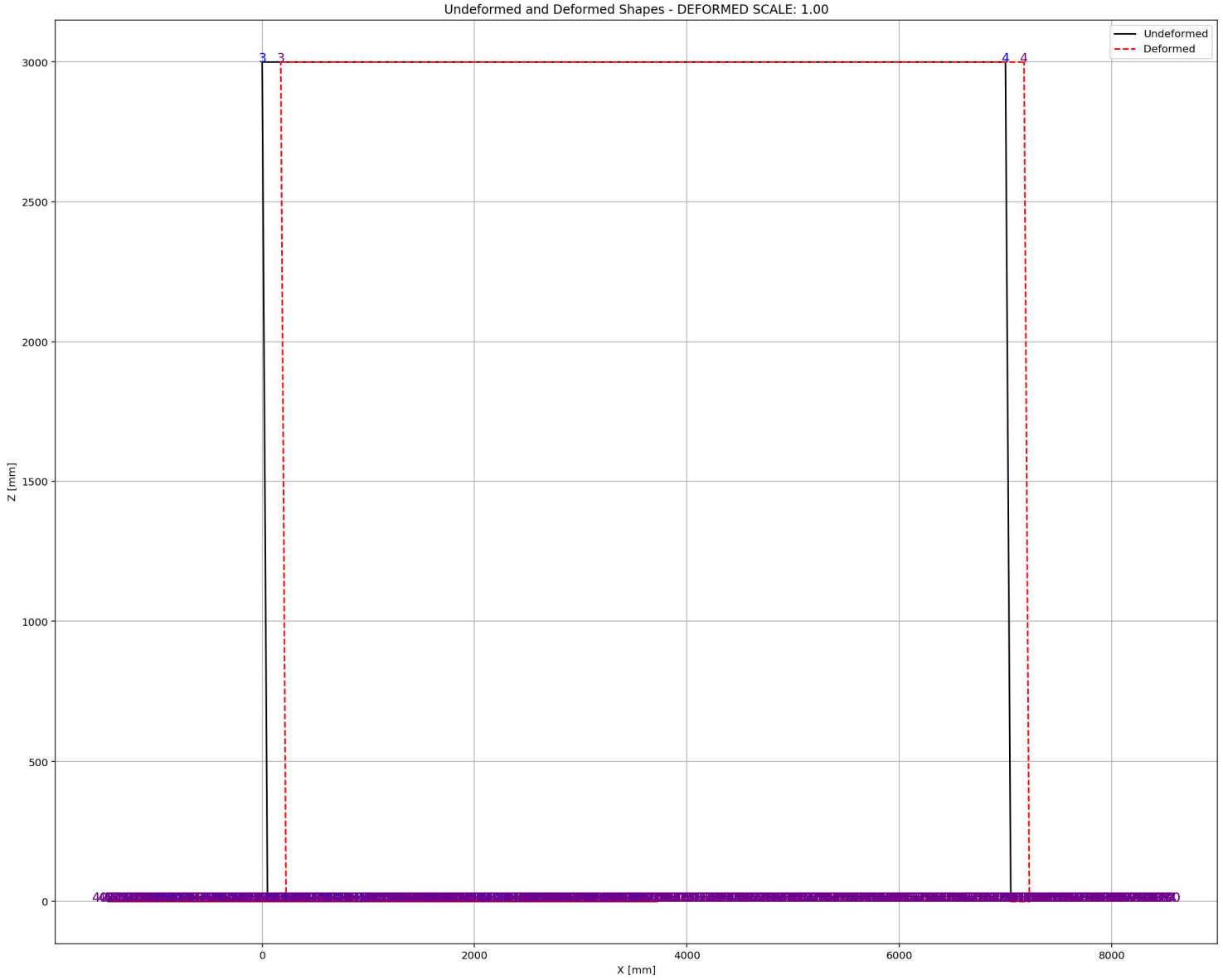
Console 1/A

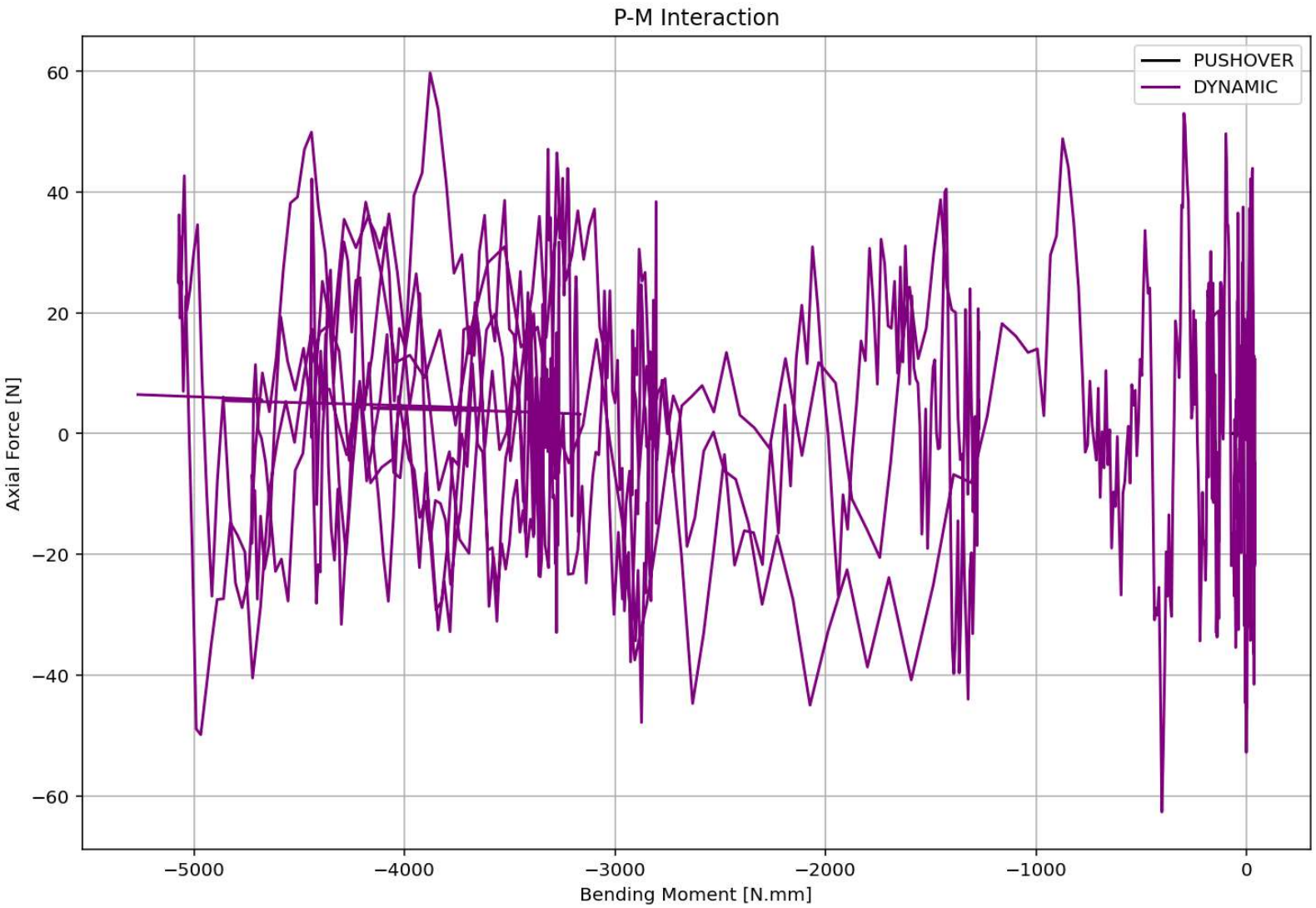
```
Lobatto
    End 1 Forces (P V M): 2.45202 2.88952 0.120247
    End 2 Forces (P V M): -2.45202 -2.88952 8669.64

Element: 3 Type: ForceBeamColumn2d  Connected Nodes: 3 4
    Number of Sections: 5   Mass density: 3.75
Lobatto
    End 1 Forces (P V M): 0.361746 -2.0028 -5349.95
    End 2 Forces (P V M): -0.361746 2.0028 -8669.64

In [2]:
```

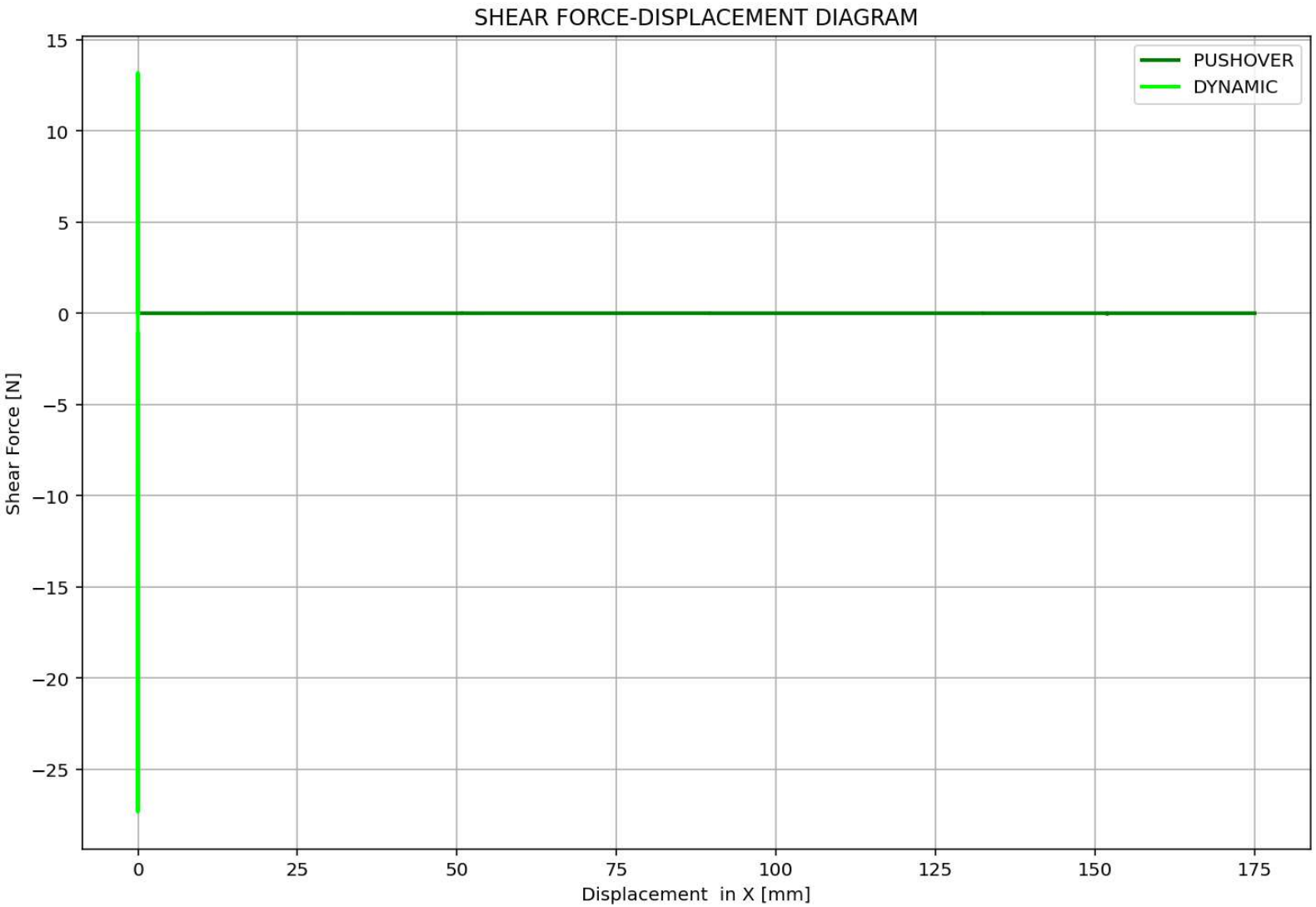
IPython Console History

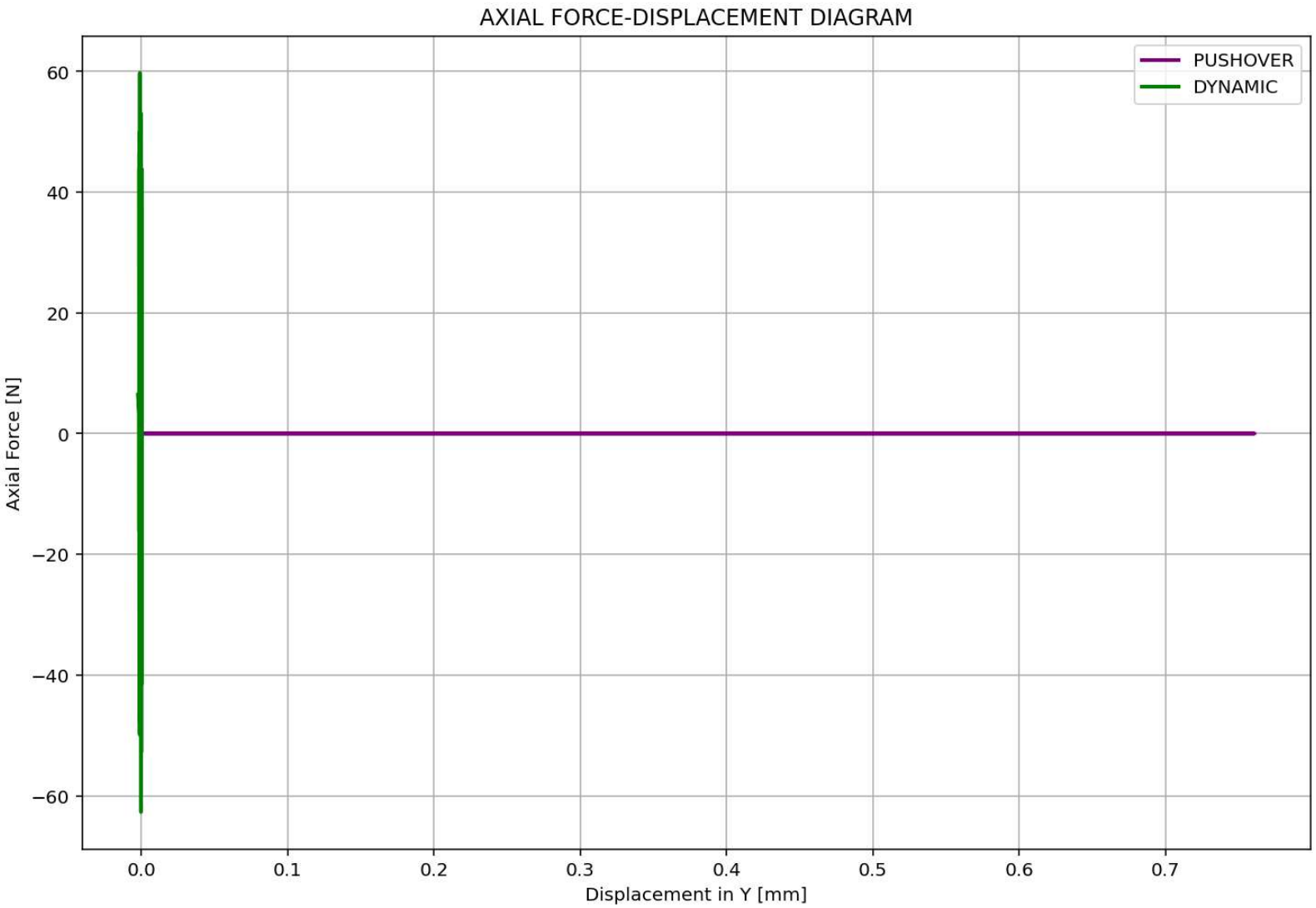
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 26, Col 33 UTF-8 CRLF RW Mem 44%

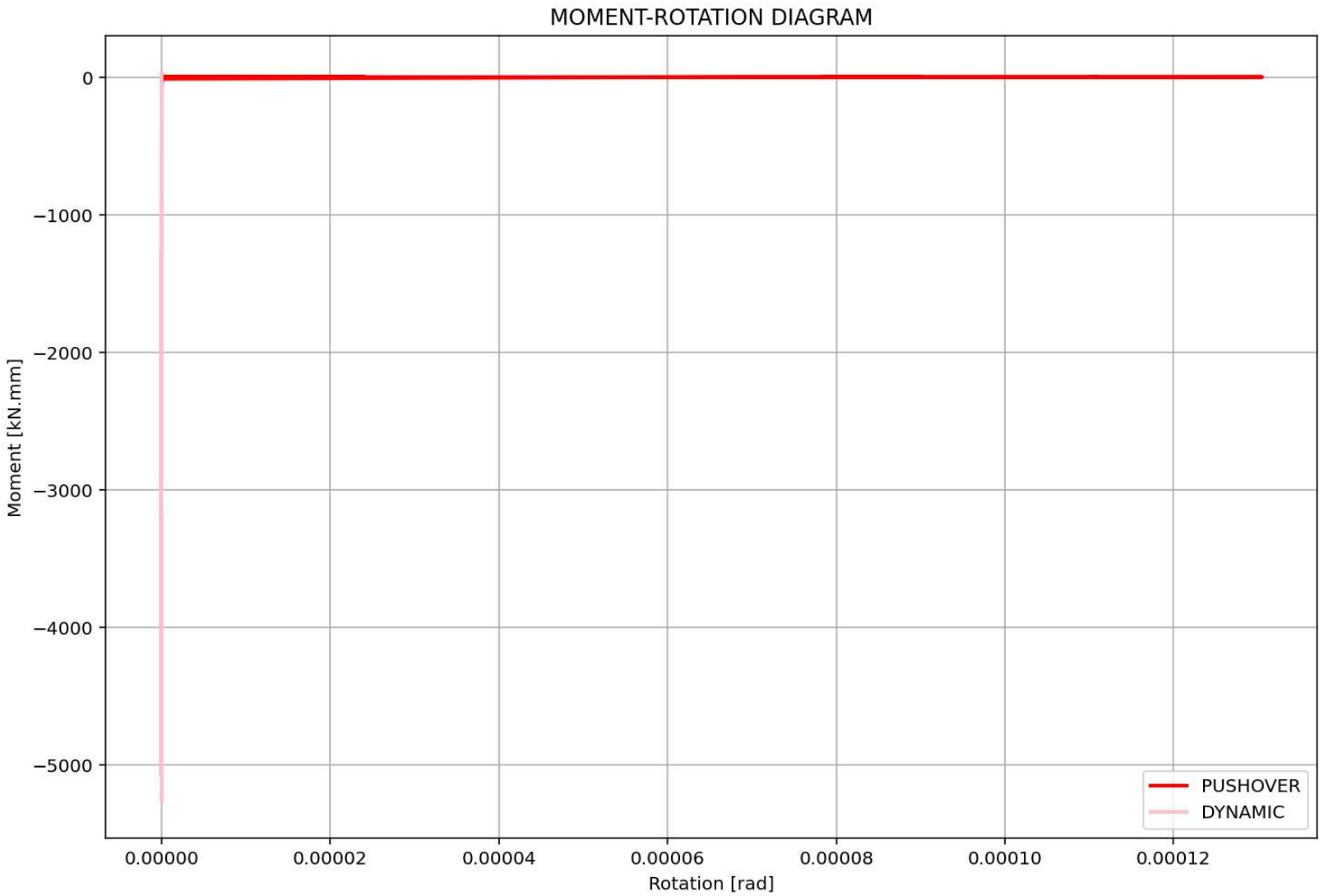
NONLINEAR STATIC ANALYSIS (PUSHOVER)

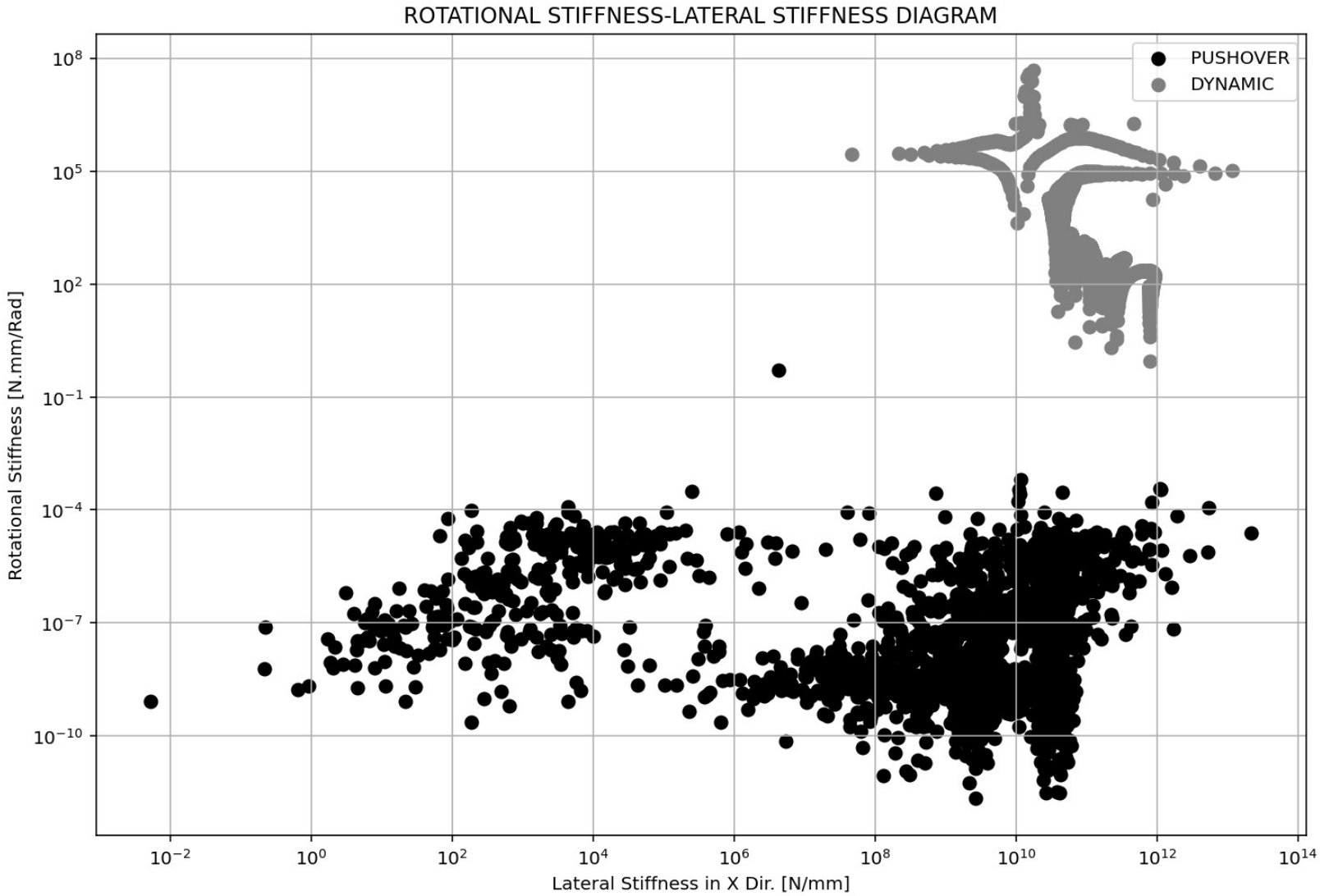

Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
3
3
4
4
40
0
Z [mm]
X [mm]
3000
2500
2000
1500
1000
500
0
0
2000
4000
6000
8000

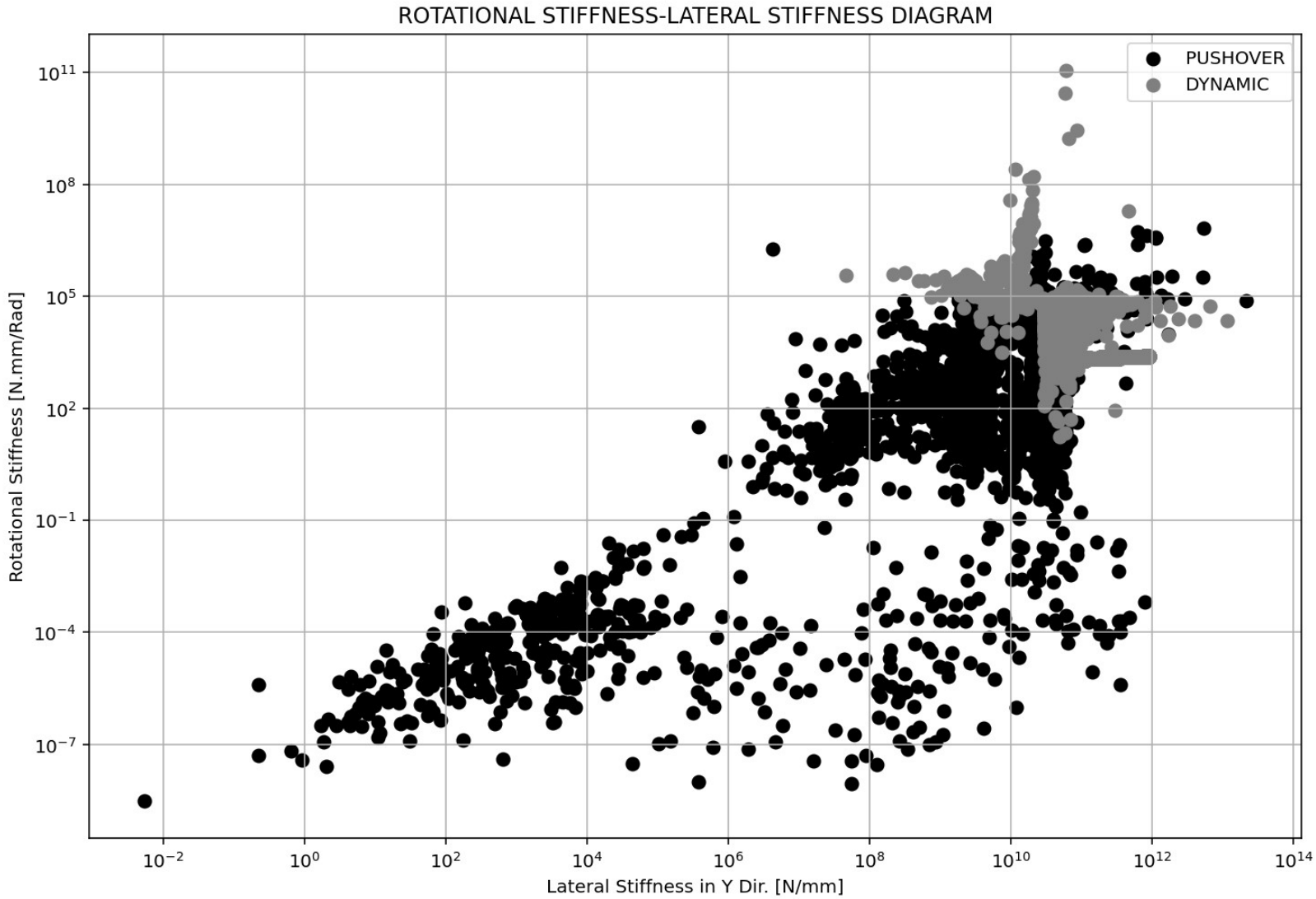

P-M Interaction
PUSHOVER
DYNAMIC
Axial Force [N]
Bending Moment [N.mm]
60
40
20
0
−20
−40
−60
−5000
−4000
−3000
−2000
−1000
0

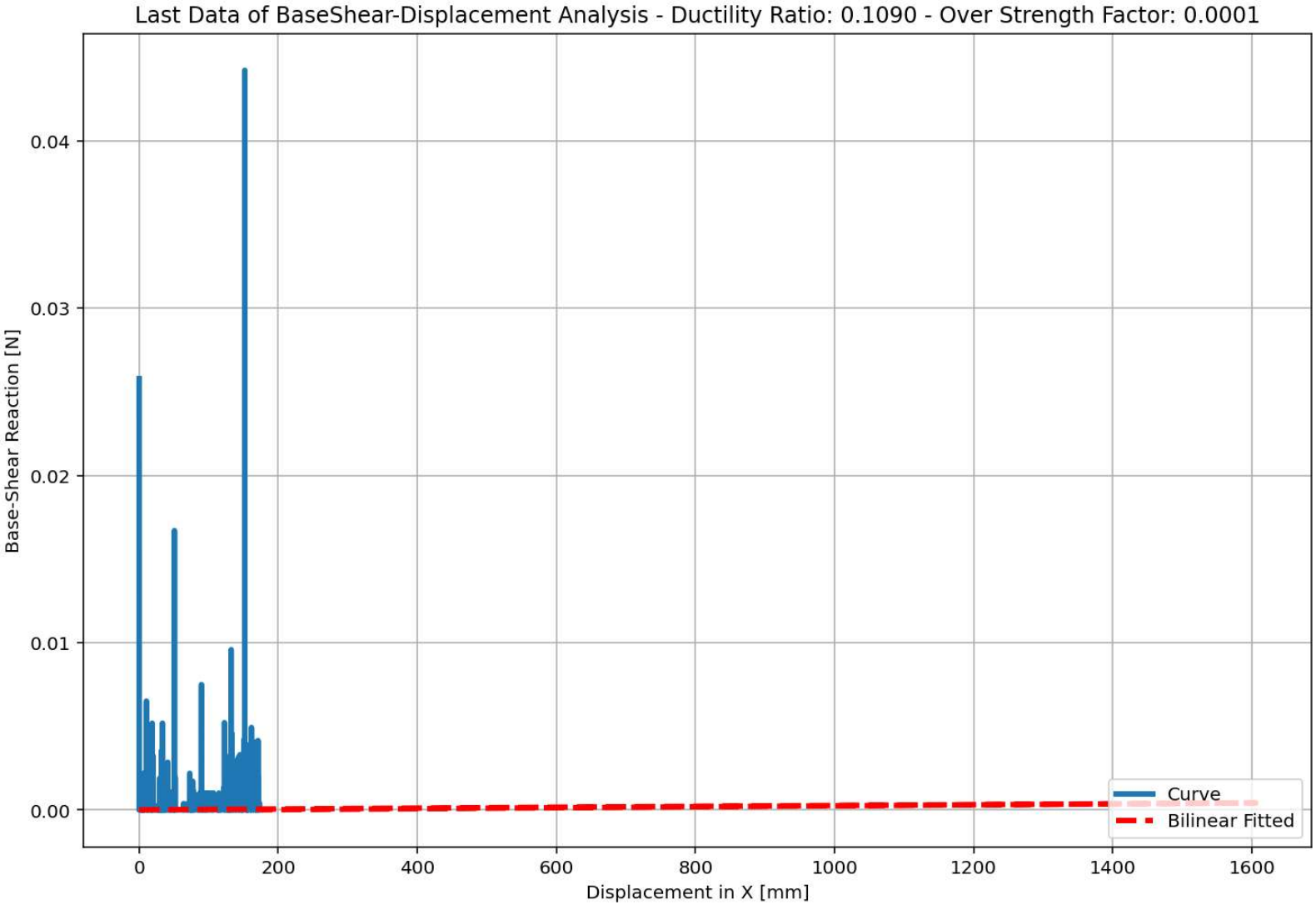

SHEAR FORCE-DISPLACEMENT DIAGRAM
PUSHOVER
DYNAMIC
Shear Force [N]
15
10
5
0
−5
−10
−15
−20
−25
0
25
50
75
100
125
150
175
Displacement in X [mm]


AXIAL FORCE-DISPLACEMENT DIAGRAM
PUSHOVER
DYNAMIC
Axial Force [N]
60
40
20
0
−20
−40
−60
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Displacement in Y [mm]

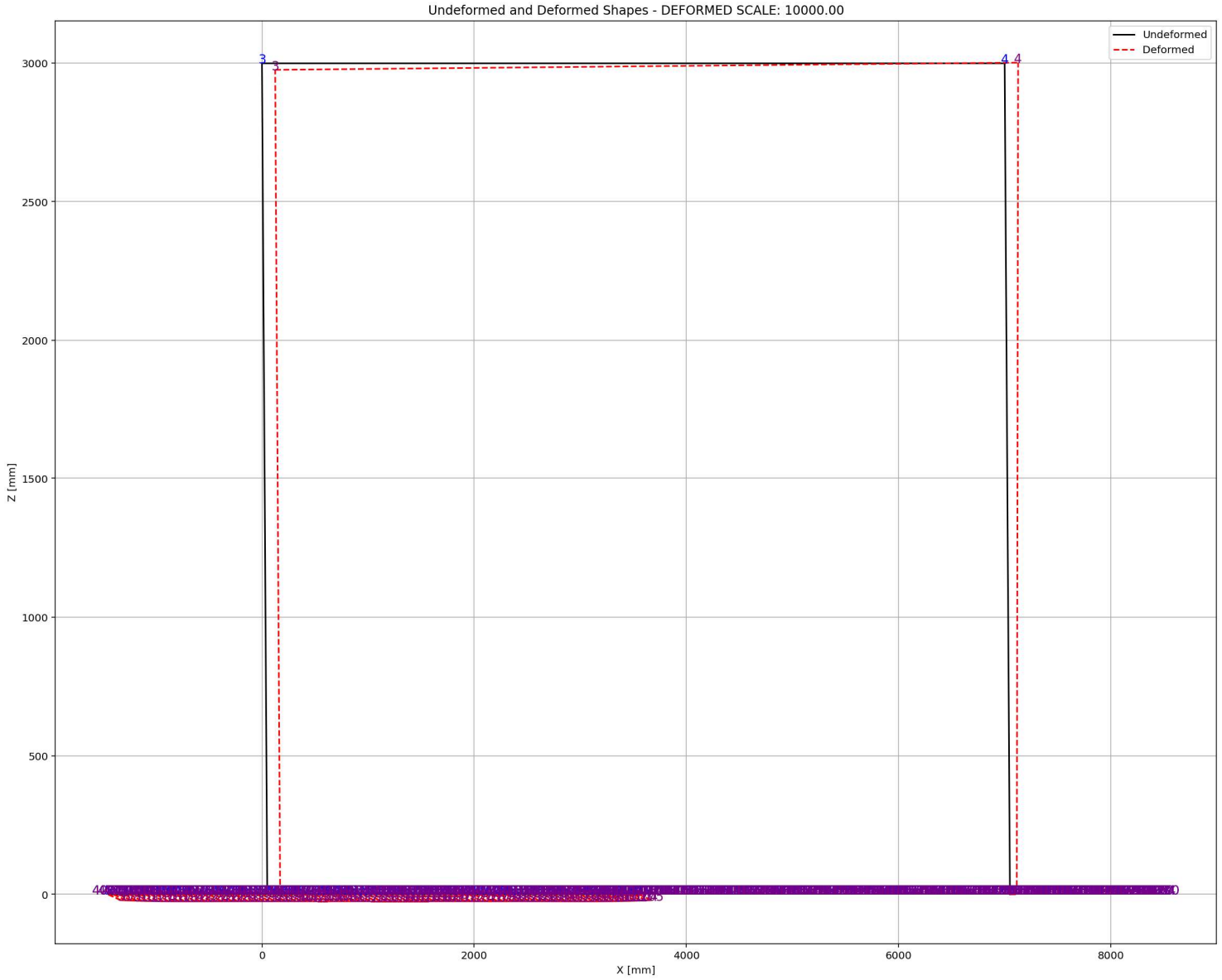

MOMENT-ROTATION DIAGRAM
0
−1000
−2000
−3000
−4000
−5000
Moment [kN.mm]
0.00000
0.00002
0.00004
0.00006
0.00008
0.00010
0.00012
Rotation [rad]
PUSHOVER
DYNAMIC

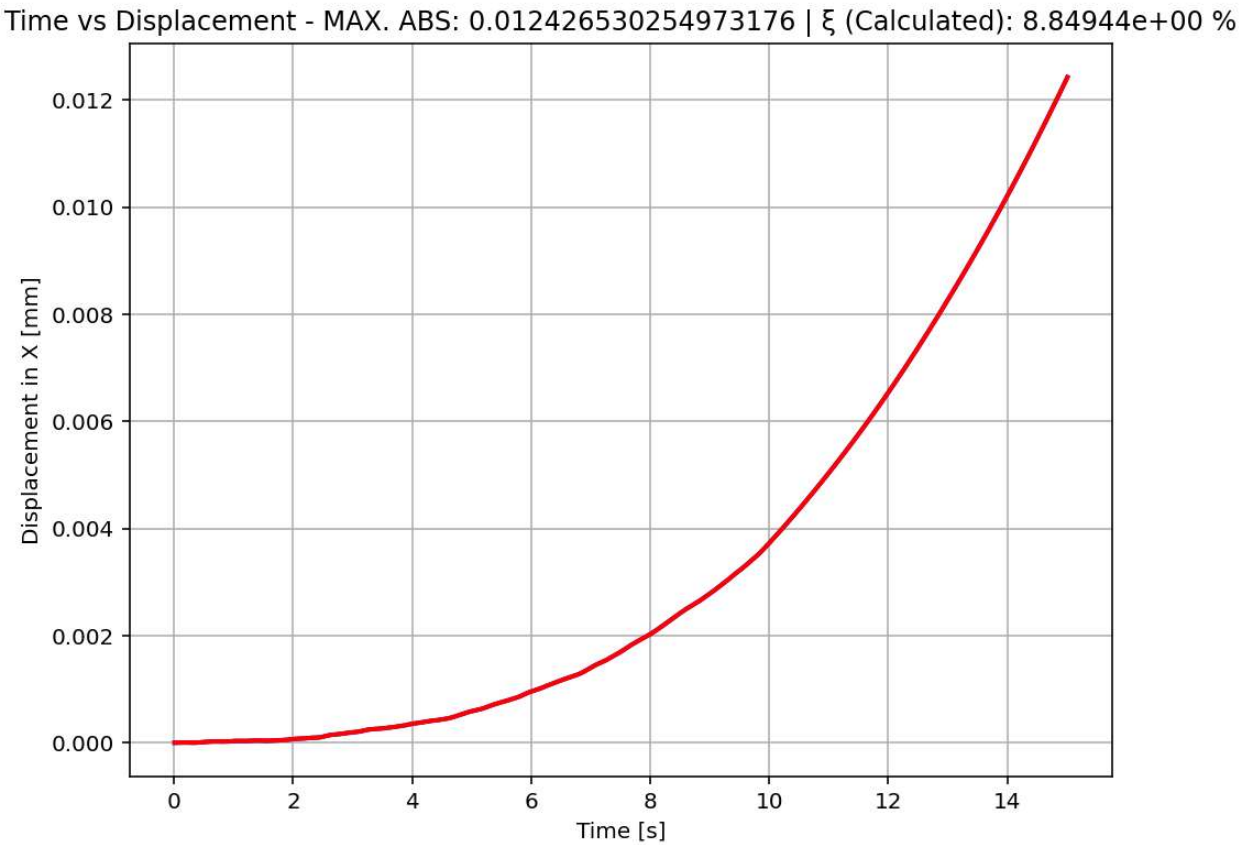

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
PUSHOVER
DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in X Dir. [N/mm]
10^{8}
10^{5}
10^{2}
10^{-1}
10^{-4}
10^{-7}
10^{-10}
10^{-2}
10^{0}
10^{2}
10^{4}
10^{6}
10^{8}
10^{10}
10^{12}
10^{14}

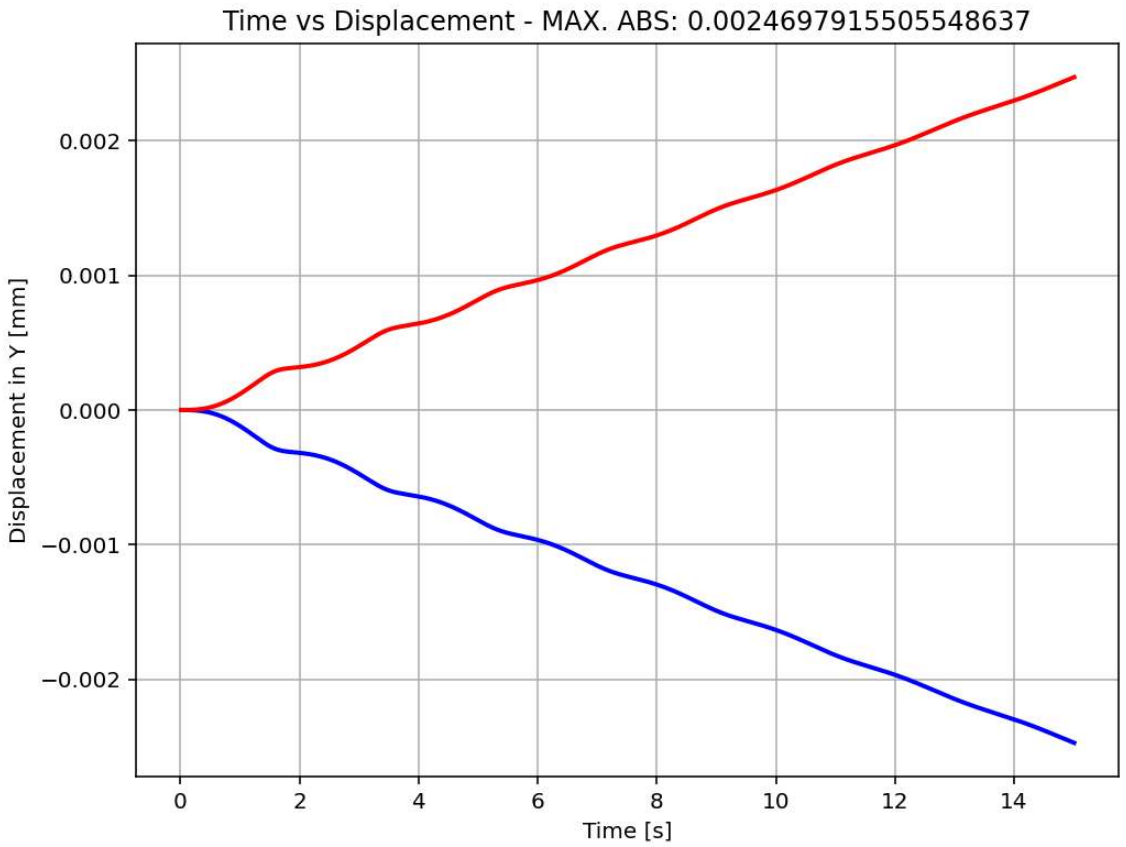

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
PUSHOVER
DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in Y Dir. [N/mm]
10^{11}
10^{8}
10^{5}
10^{2}
10^{-1}
10^{-4}
10^{-7}
10^{-2}
10^{0}
10^{2}
10^{4}
10^{6}
10^{8}
10^{10}
10^{12}
10^{14}

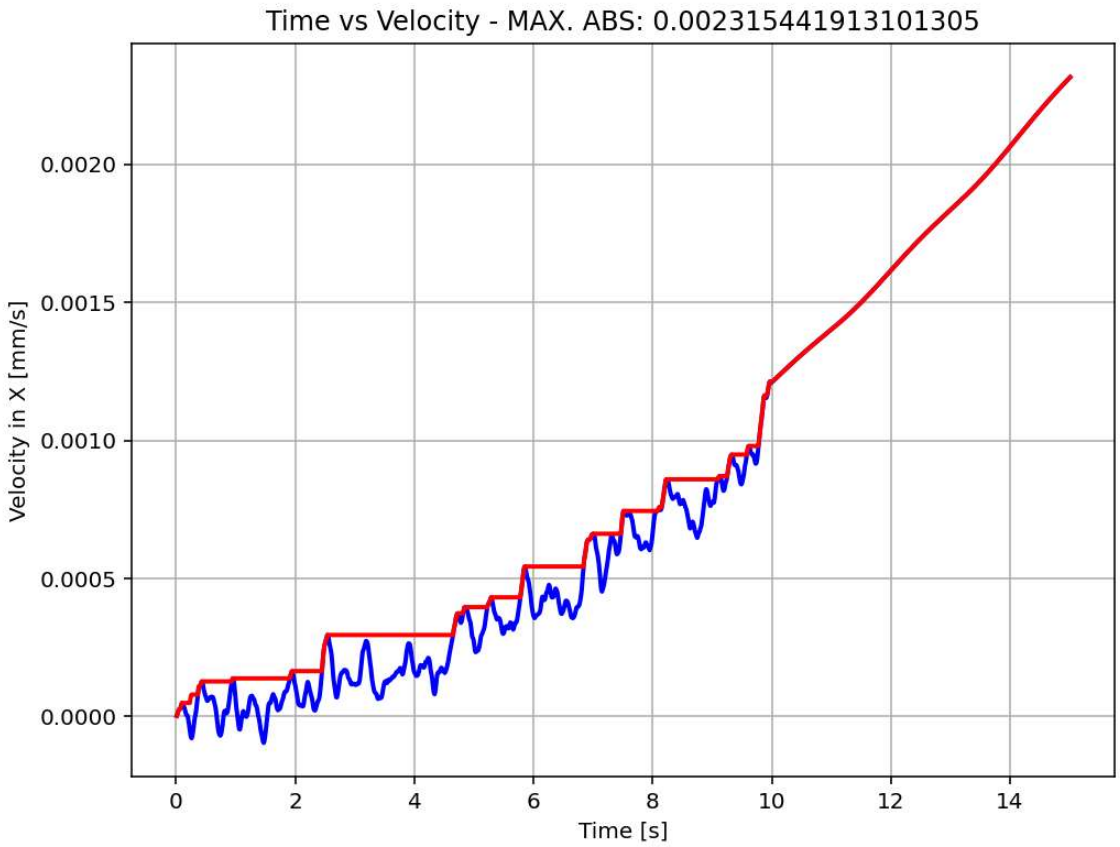

Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 0.1090 - Over Strength Factor: 0.0001
Base-Shear Reaction [N]
0.04
0.03
0.02
0.01
0.00
0
200
400
600
800
1000
1200
1400
1600
Displacement in X [mm]
Curve
Bilinear Fitted

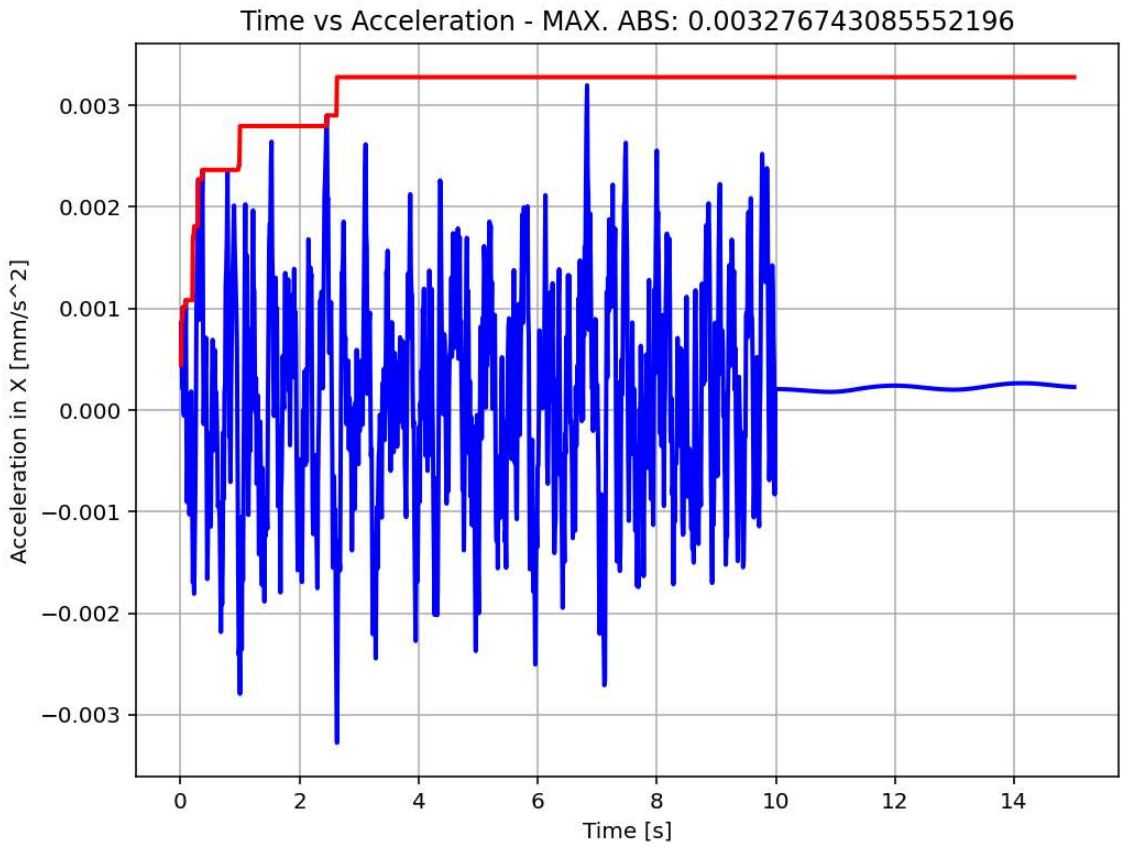
NONLINEAR DYNAMIC ANALYSIS

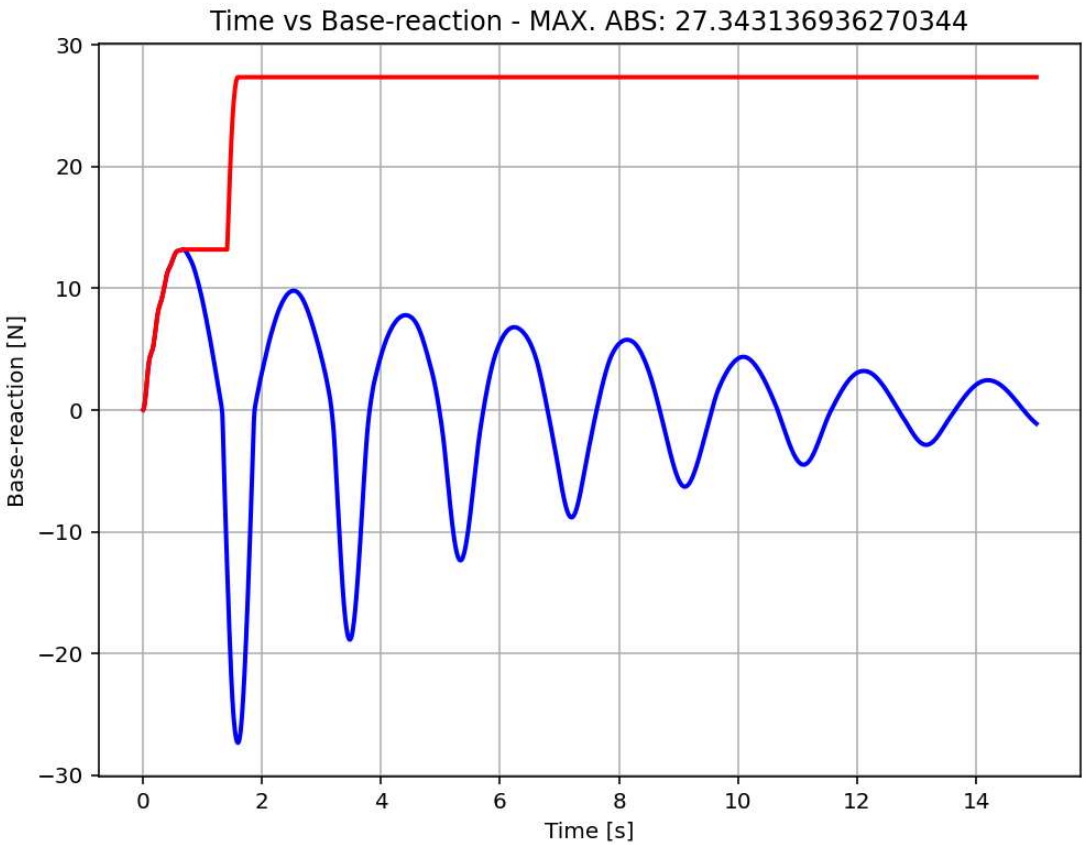

Undeformed and Deformed Shapes - DEFORMED SCALE: 10000.00
Undeformed
Deformed
Z [mm]
X [mm]
3000
2500
2000
1500
1000
500
0
0
2000
4000
6000
8000

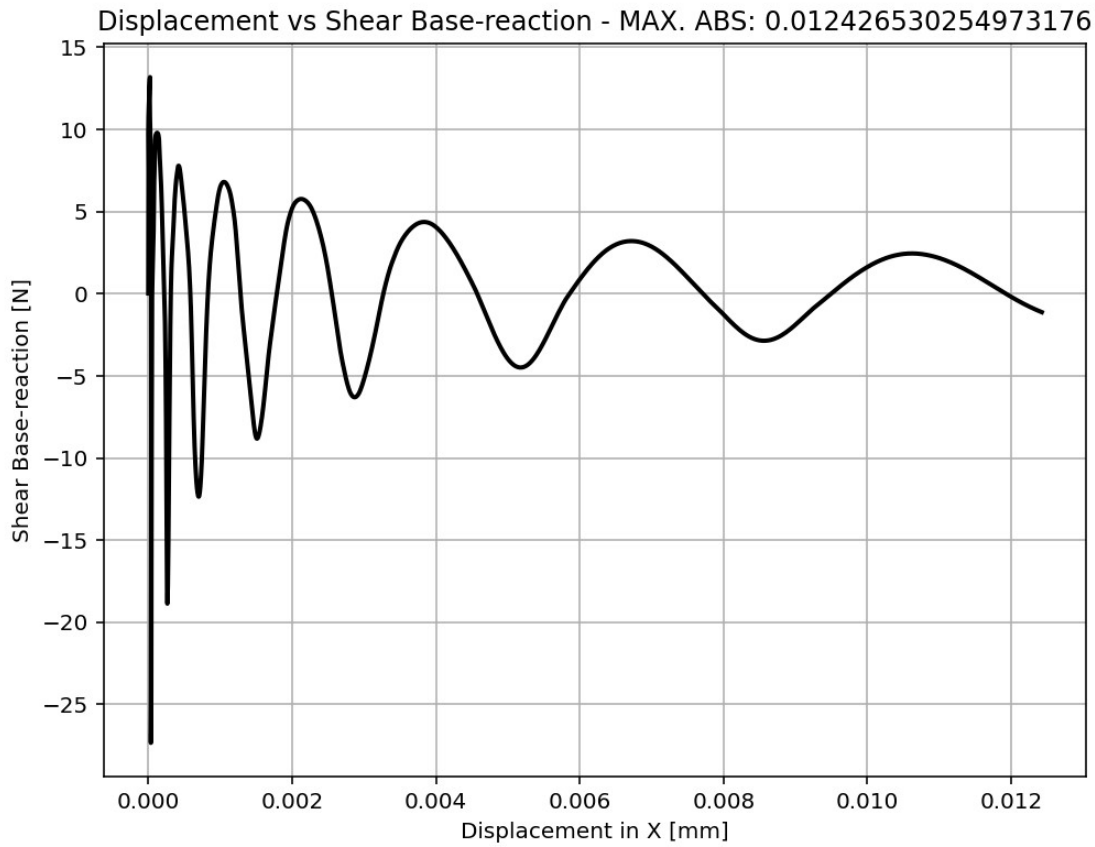

Time vs Displacement - MAX. ABS: 0.012426530254973176 | ξ (Calculated): 8.84944e+00 %
Displacement in X [mm]
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
2
4
6
8
10
12
14
Time [s]

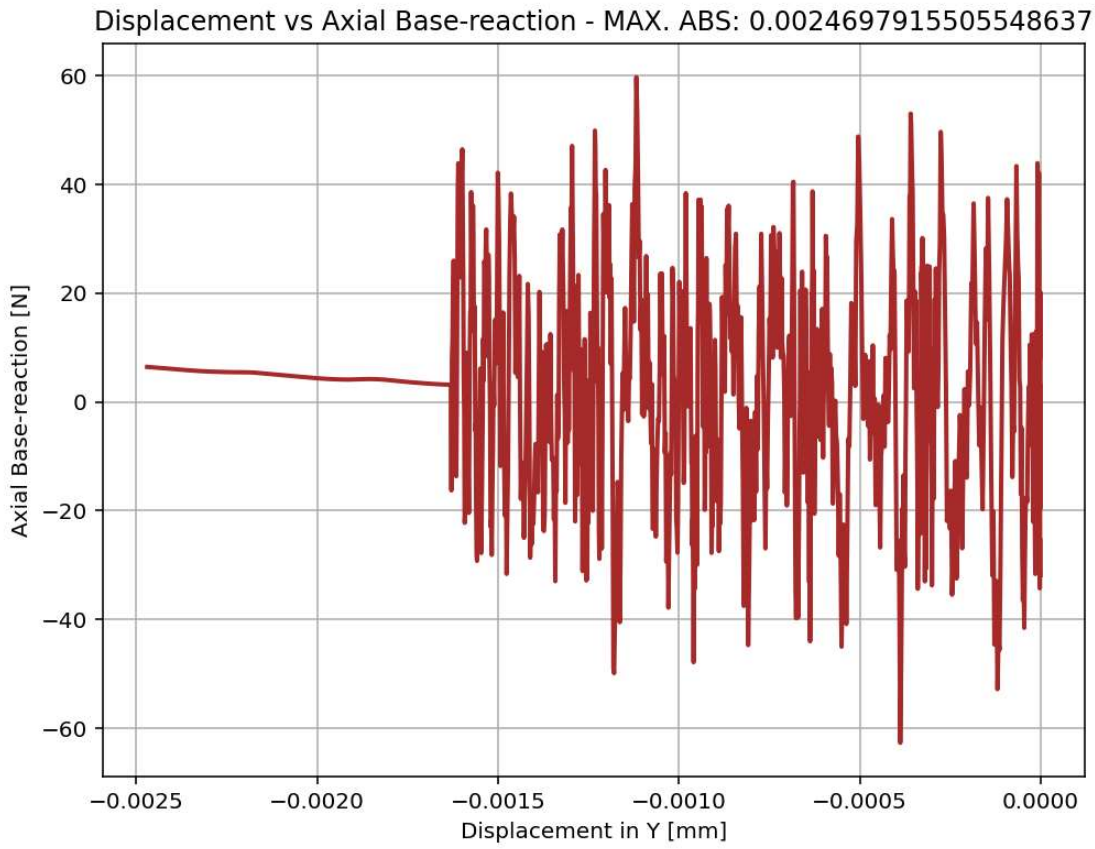

Time vs Displacement - MAX. ABS: 0.0024697915505548637
Displacement in Y [mm]
0.002
0.001
0.000
−0.001
−0.002
0
2
4
6
8
10
12
14
Time [s]


Time vs Velocity - MAX. ABS: 0.002315441913101305
Velocity in X [mm/s]
0.0020
0.0015
0.0010
0.0005
0.0000
0
2
4
6
8
10
12
14
Time [s]


Time vs Acceleration - MAX. ABS: 0.003276743085552196
Acceleration in X [mm/s^2]
Time [s]
0.003
0.002
0.001
0.000
−0.001
−0.002
−0.003
0
2
4
6
8
10
12
14


Time vs Base-reaction - MAX. ABS: 27.343136936270344
Base-reaction [N]
Time [s]
30
20
10
0
−10
−20
−30
0
2
4
6
8
10
12
14


Displacement vs Shear Base-reaction - MAX. ABS: 0.012426530254973176
Shear Base-reaction [N]
15
10
5
0
−5
−10
−15
−20
−25
0.000
0.002
0.004
0.006
0.008
0.010
0.012
Displacement in X [mm]


Displacement vs Axial Base-reaction - MAX. ABS: 0.0024697915505548637
Axial Base-reaction [N]
60
40
20
0
−20
−40
−60
−0.0025
−0.0020
−0.0015
−0.0010
−0.0005
0.0000
Displacement in Y [mm]