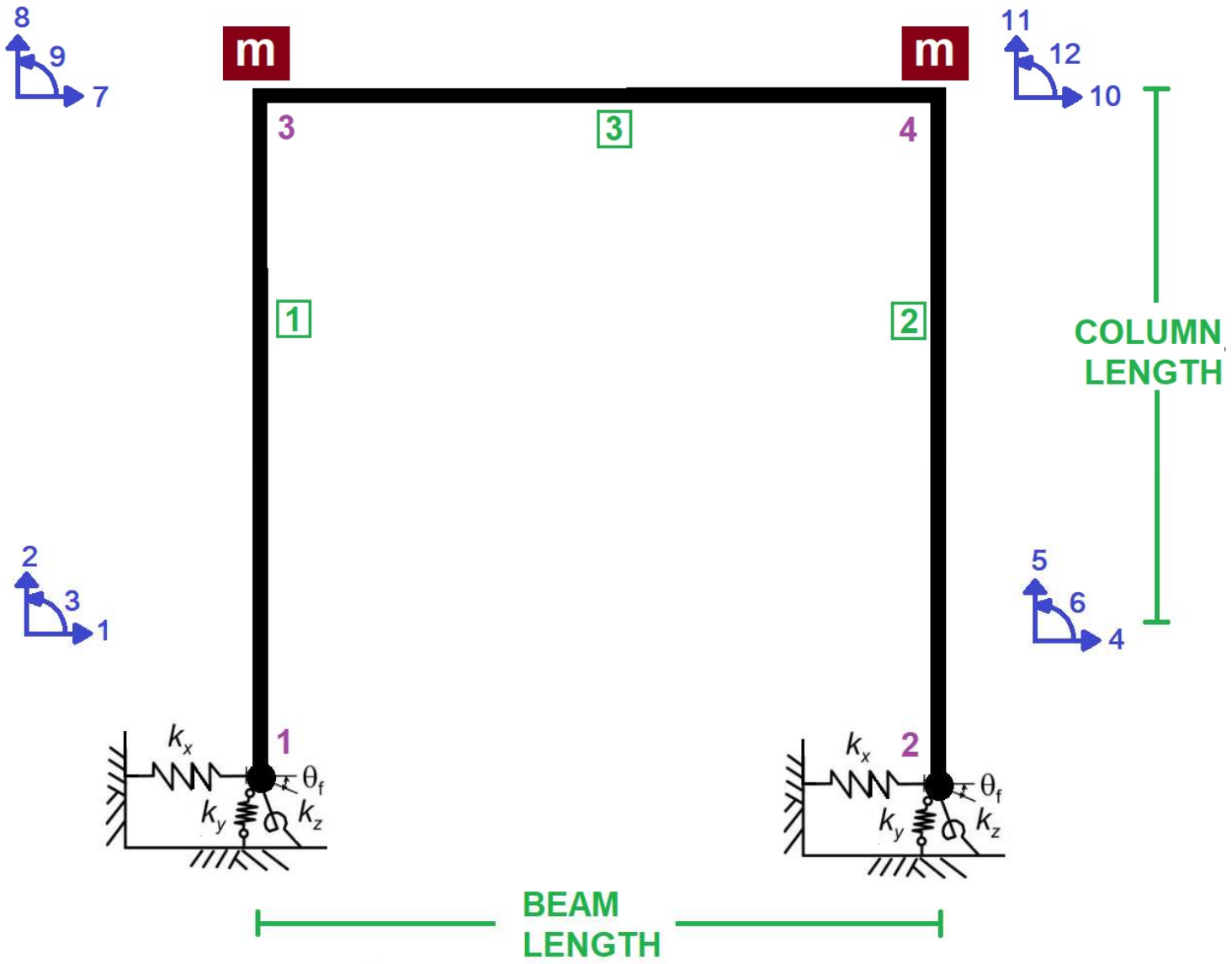
IN THE NAME OF ALLAH

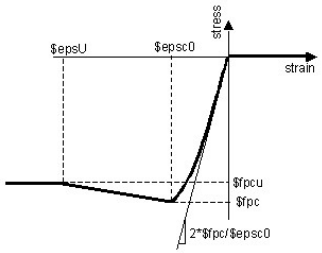
SOIL-FOUNDATION-STRUCTURE INTERACTION USING OPENSEES

SOIL-FOUNDATION INTERACTIONS SIMULATED WITH SIMPLE SPRINGS.

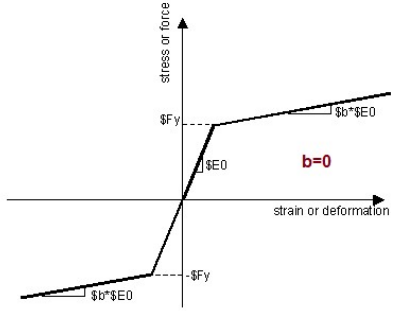
SOIL SPRINGS VALUES ARE NOT EXACT.

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

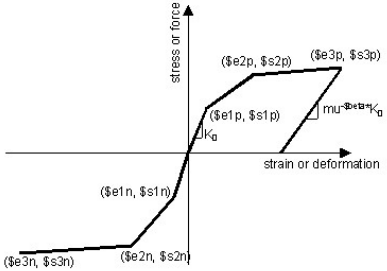

8
9
7
m
m
11
12
10
3
3
4
1
2
COLUMN
LENGTH
2
3
1
5
6
4
k_x
1
θ_f
k_y
k_z
k_x
2
θ_f
k_y
k_z
BEAM
LENGTH



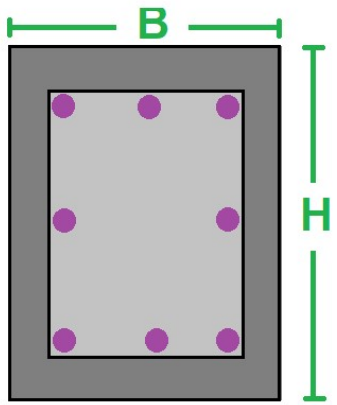
CORE AND COVER CONCRETE REALTION



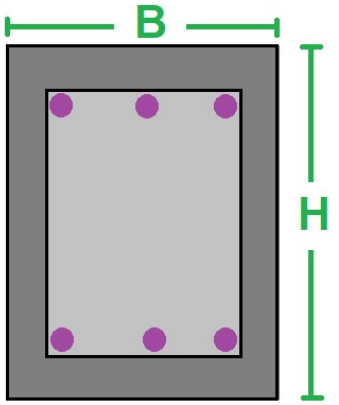
WITHOUT HARDENING AND ULTIMATE STRAIN



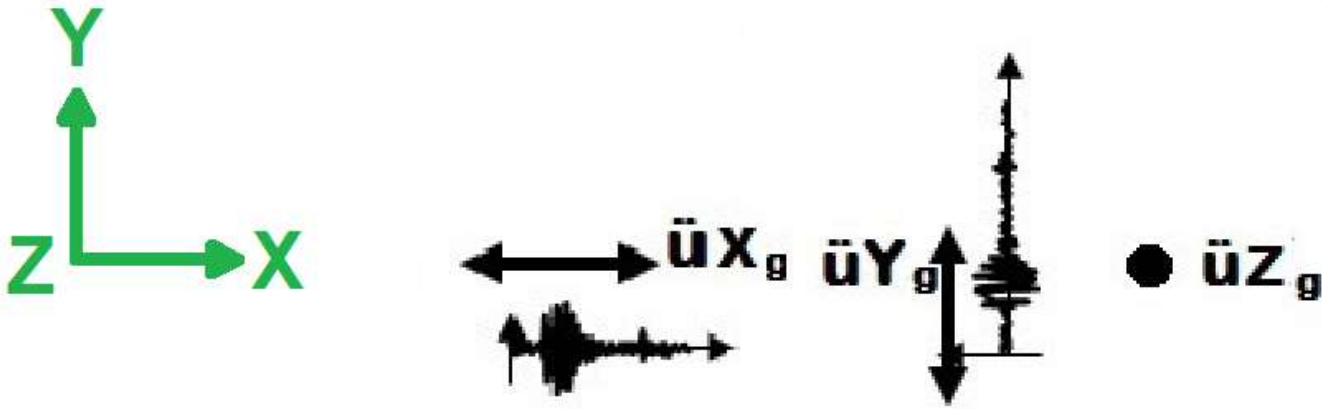
WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION



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

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

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

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

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

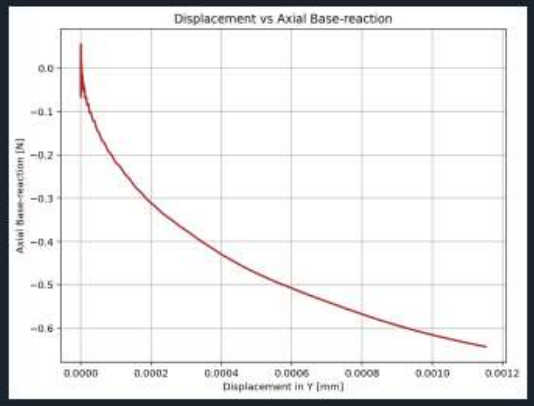
C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...01\CONCRETE_FRAME_SOIL-FOUNDATION-STRUCTURE_01.py

CONCRETE_FRAME_SOI...ON-STRUCTURE_01.py | CONCRETE_FRAME_SOI...ON-STRUCTURE_02.py

```
##########################################################################################
#                                        IN THE NAME OF ALLAH
#                            SOIL-FOUNDATION-STRUCTURE INTERACTION USING OPENSEES
#----------------------------------------------------------------------------------------
#                                        EXAMPLE 01:
#                       SOIL-FOUNDATION INTERACTIONS SIMULATED WITH SIMPLE SPRINGS.
#                                  SOIL SPRINGS VALUES ARE NOT EXACT.
#----------------------------------------------------------------------------------------
#                             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 `nonlinec
[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
```

...RAME_EXAMPLES\SOIL-FOUNDATION\SOIL-FOUNDATION-STRUCTURE_01

32 %



Help | Variable Explorer | Debugger | Plots | Files

Console 1/A

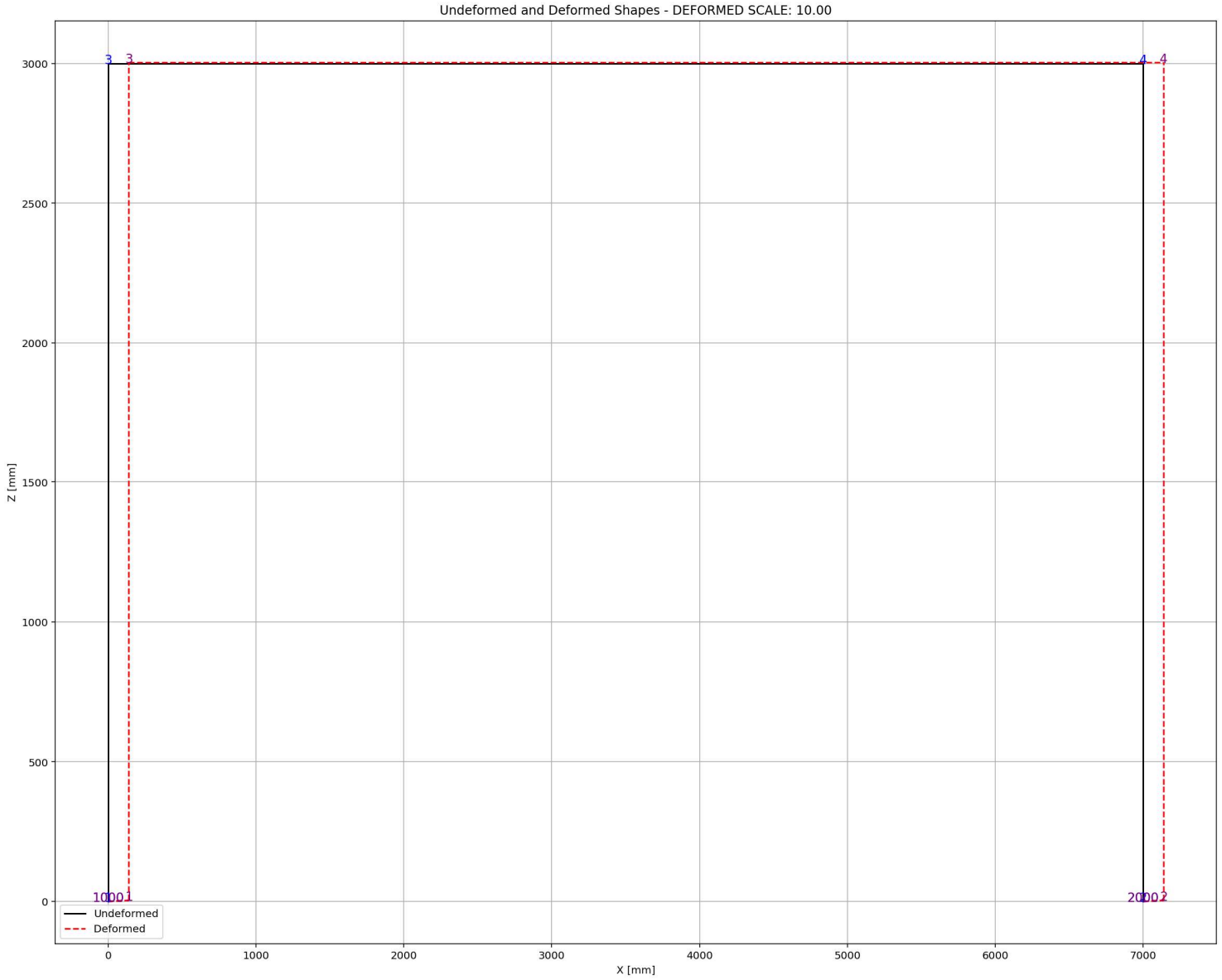
```
   ...: plt.show()
   ...:
   ...: plt.figure(7, figsize=(8, 6))
   ...: plt.plot(DISP_Yd, FORCE_Ad, color='brown', linewidth=2)
   ...: plt.xlabel('Displacement in Y [mm]')
   ...: plt.ylabel('Axial Base-reaction [N]')
   ...: plt.title(f'Displacement vs Axial Base-reaction')
   ...: plt.grid()
   ...: plt.show()

In [5]:
```

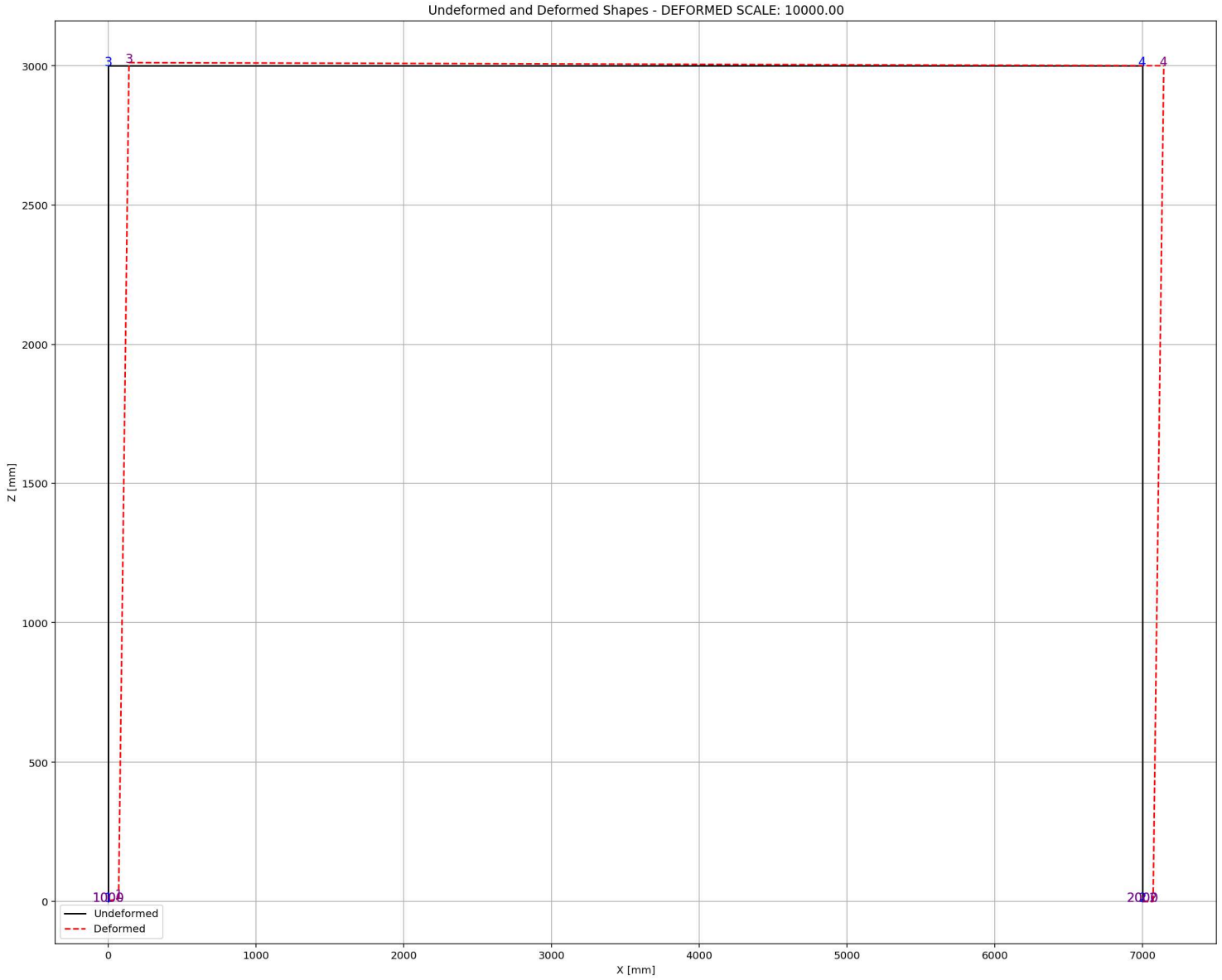
IPython Console | History

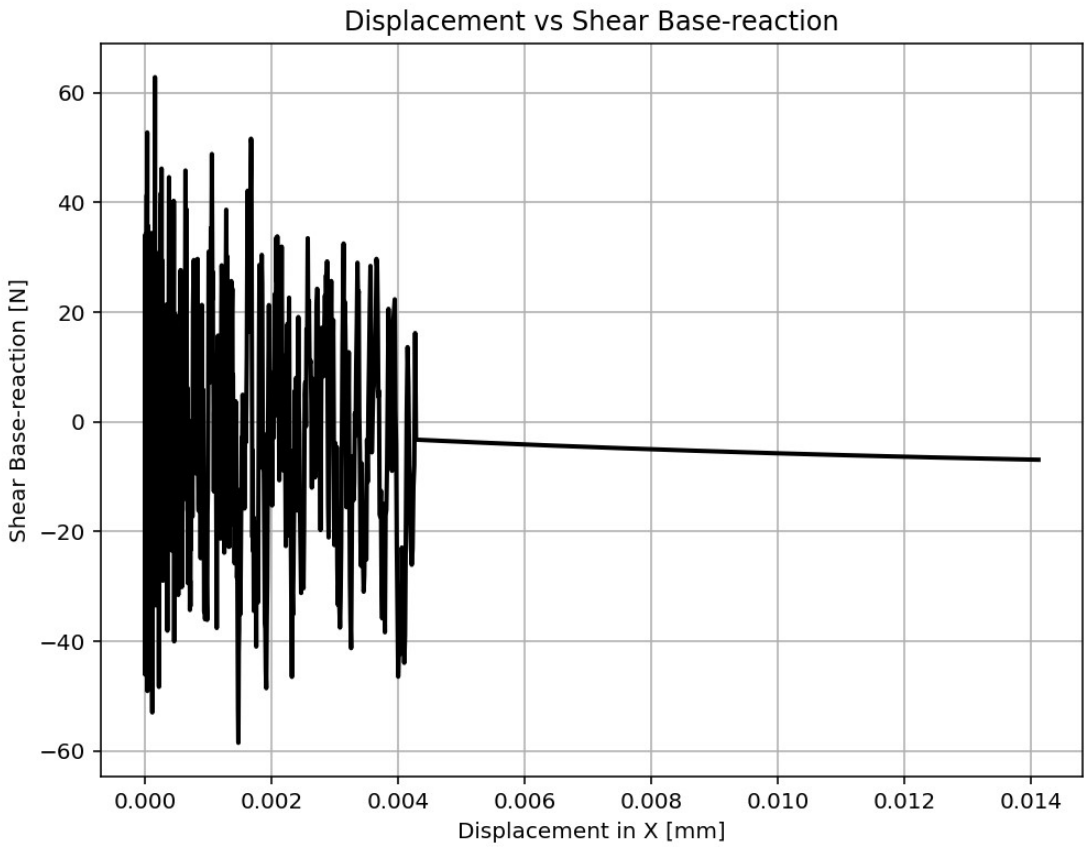
Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 7, Col 36 | UTF-8 | CRLF | RW | Mem 42%

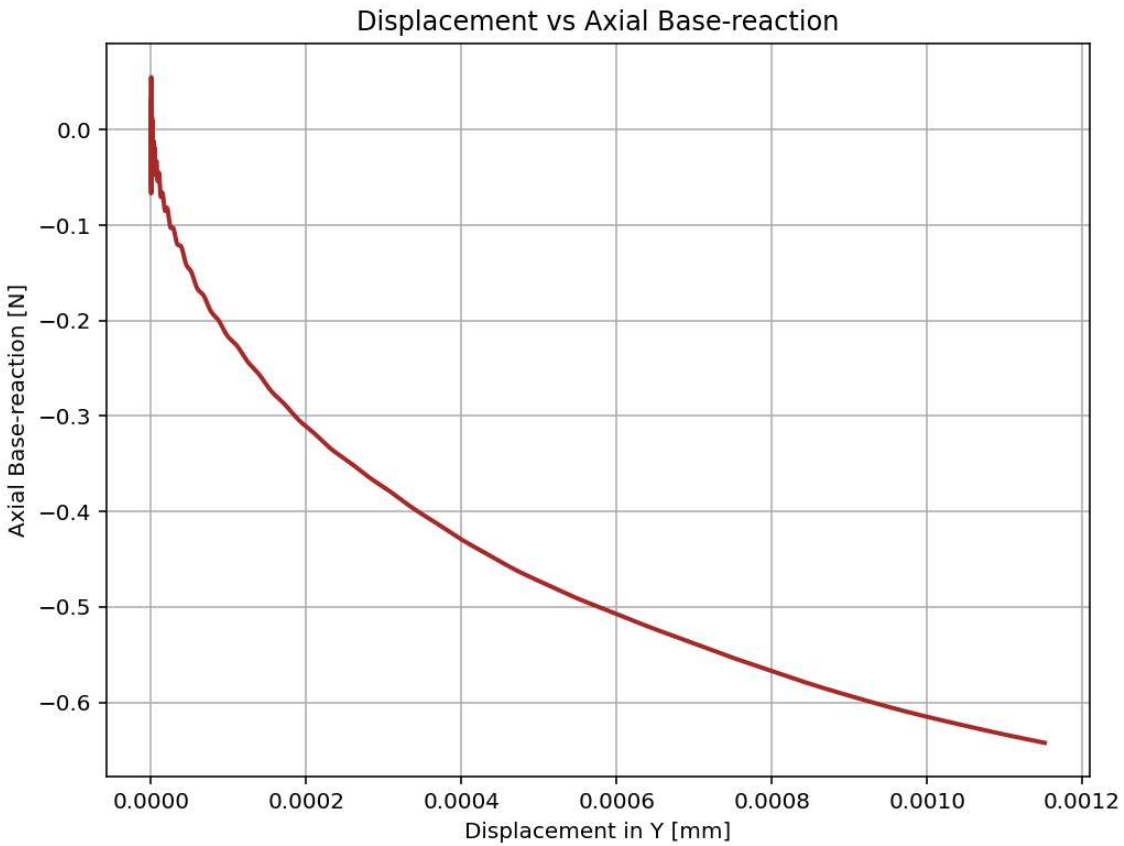
NONLINEAR STATIC ANALYSIS (PUSHOVER)

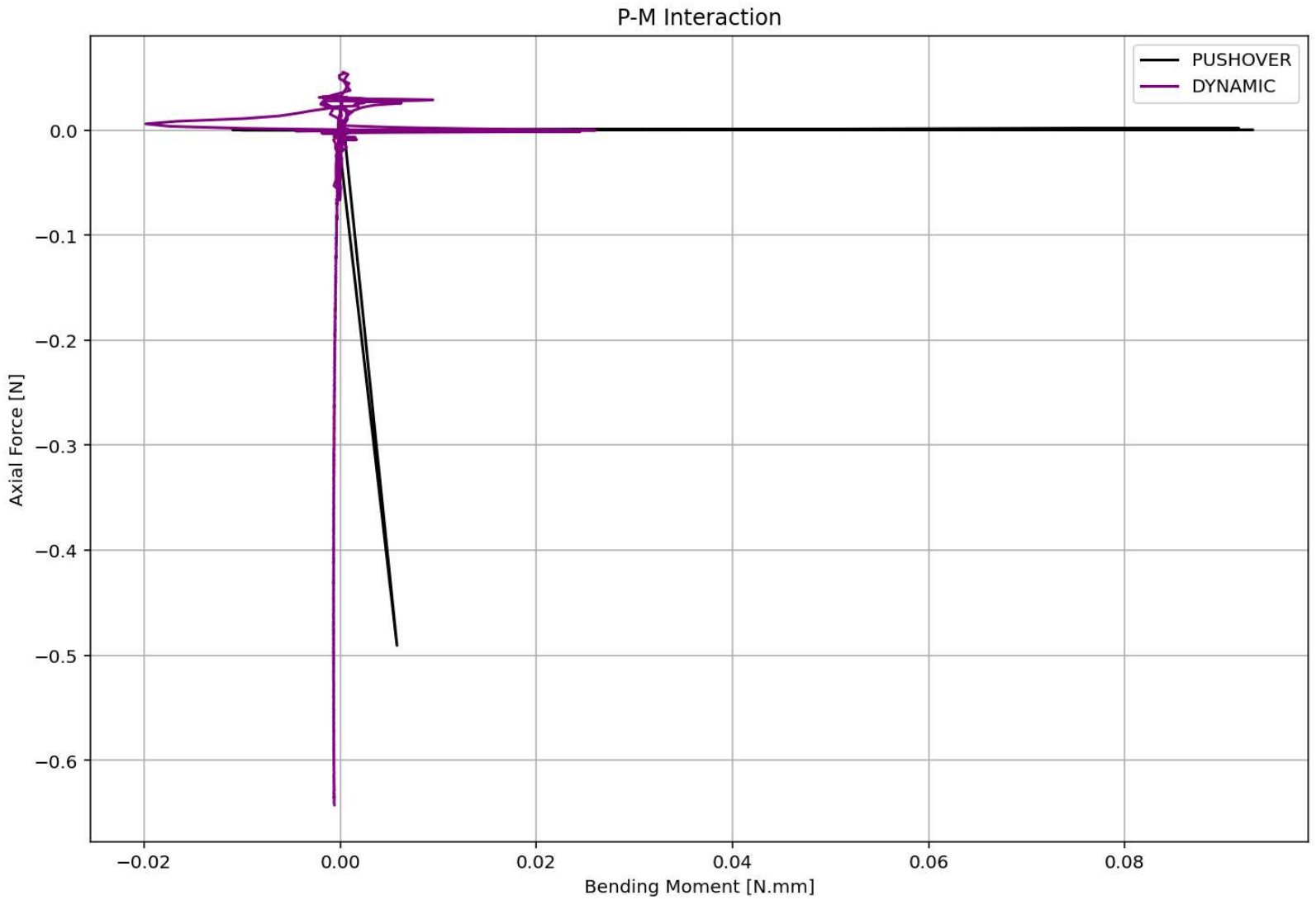

Undeformed and Deformed Shapes - DEFORMED SCALE: 10.00
Z [mm]
X [mm]
3000
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
5000
6000
7000
3
3
4
4
1000
1
2000
2
Undeformed
Deformed

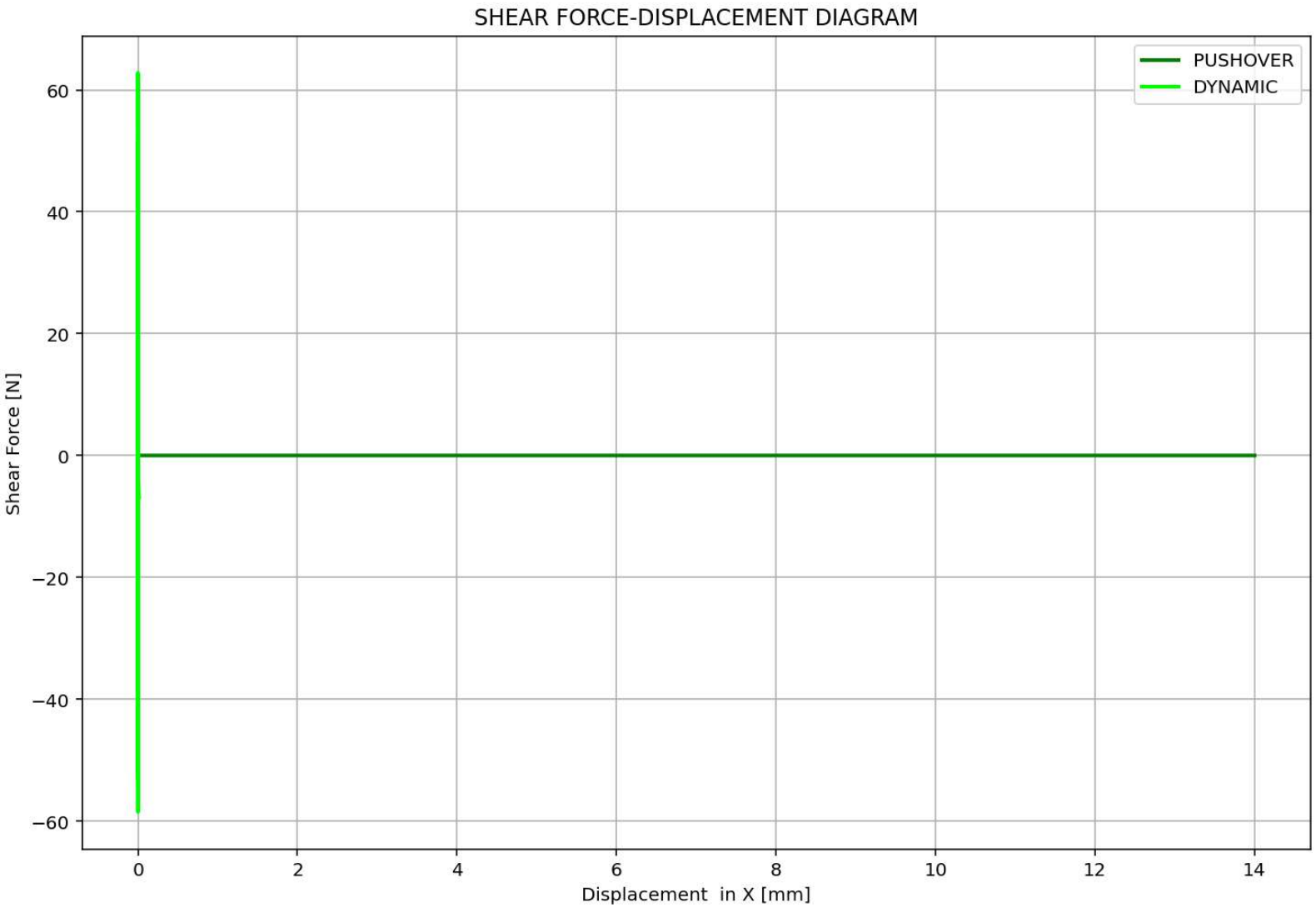
NONLINEAR DYNAMIC ANALYSIS

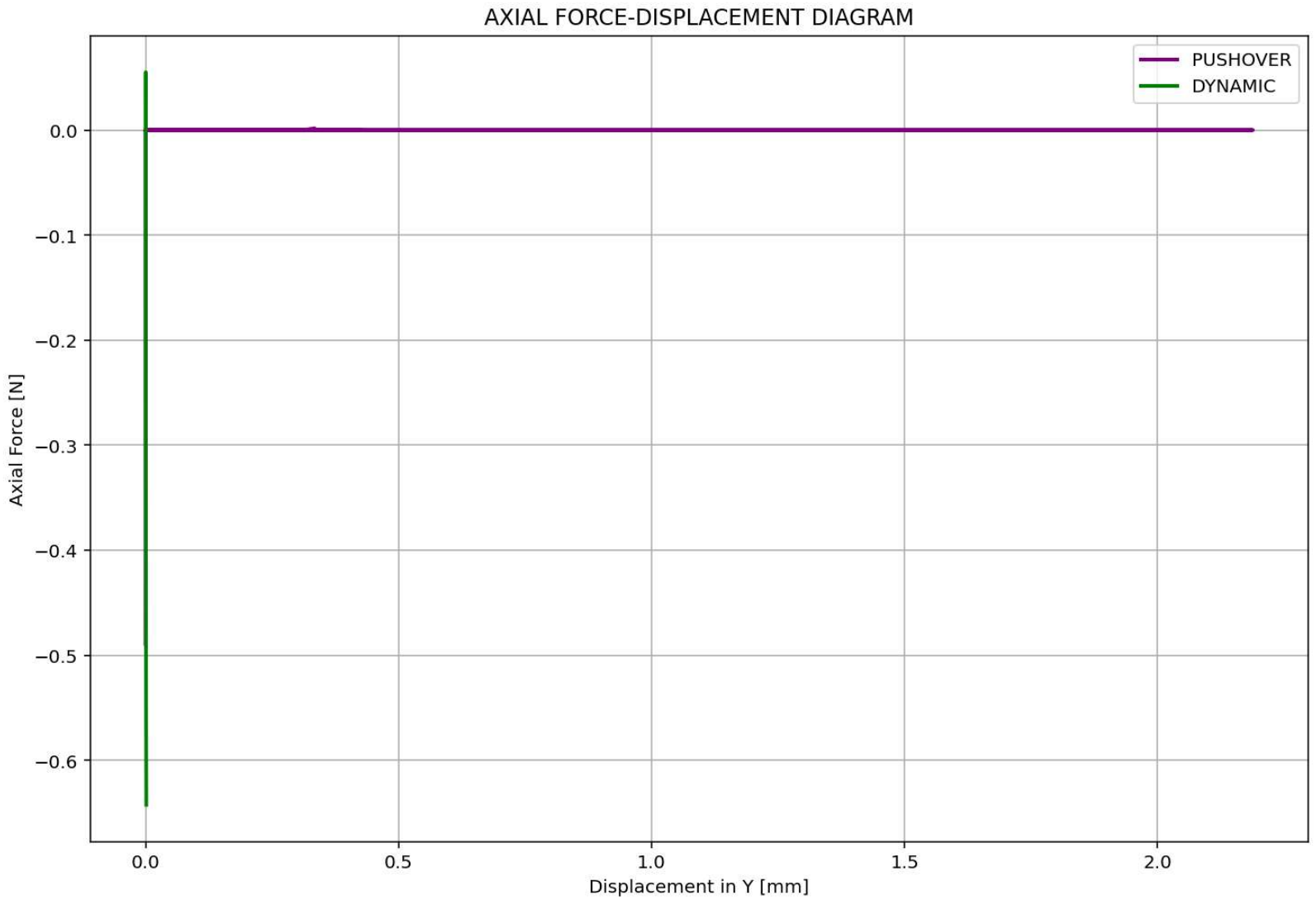

Undeformed and Deformed Shapes - DEFORMED SCALE: 10000.00
Z [mm]
X [mm]
Undeformed
Deformed
3
4
0
3000
2500
2000
1500
1000
500
0
1000
2000
3000
4000
5000
6000
7000

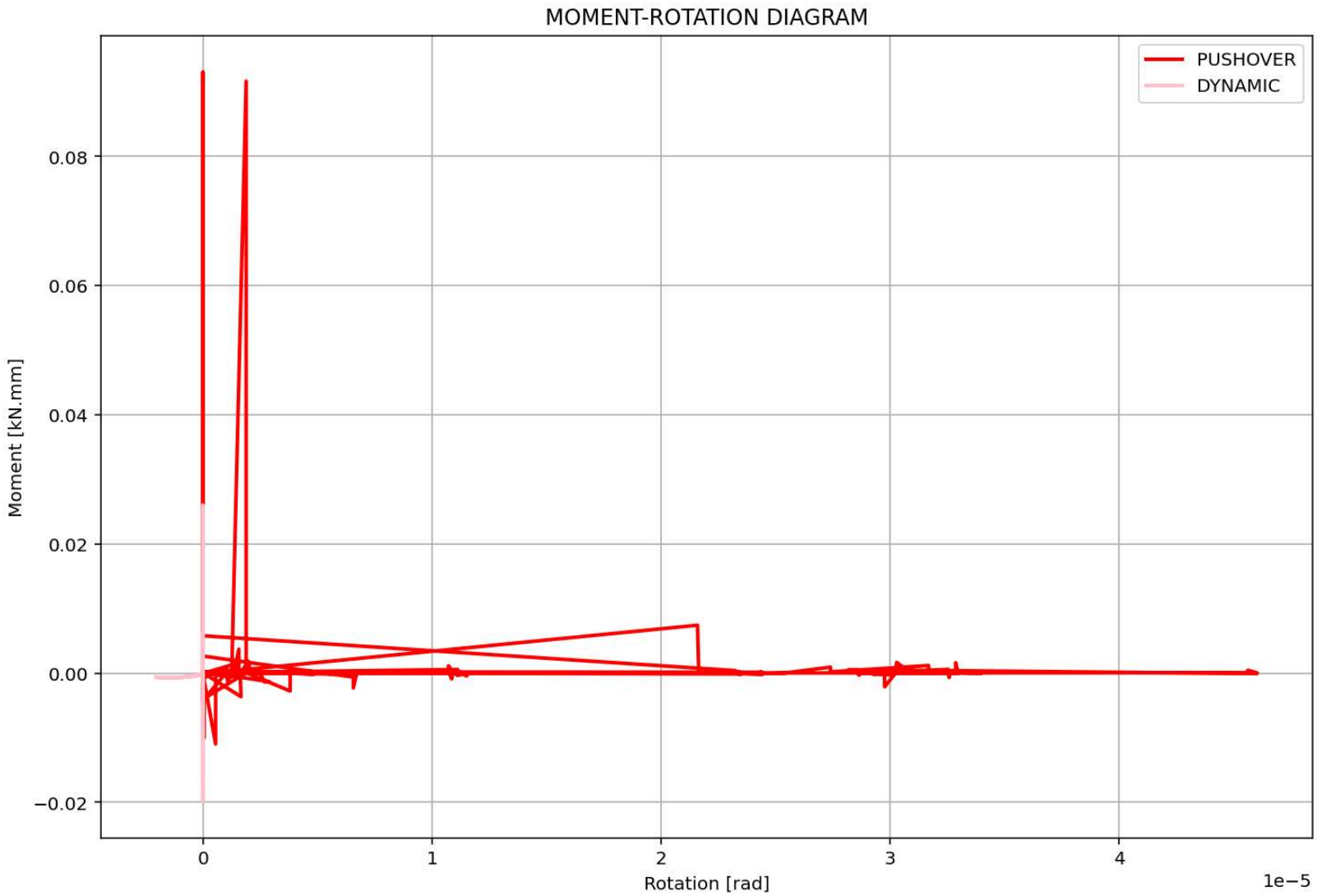

Displacement vs Shear Base-reaction
Shear Base-reaction [N]
60
40
20
0
−20
−40
−60
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
Displacement in X [mm]

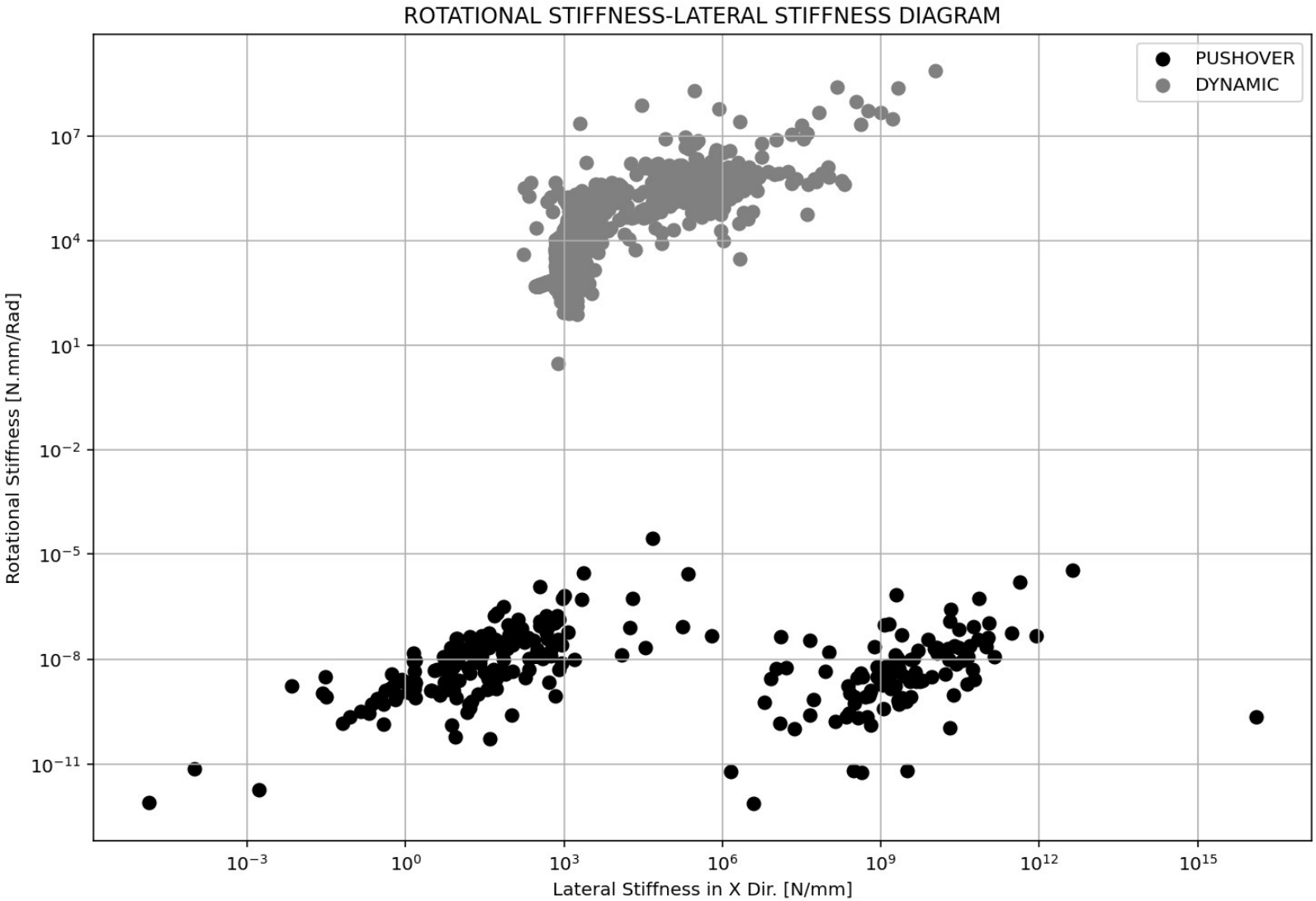

Displacement vs Axial Base-reaction
Axial Base-reaction [N]
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
0.0000
0.0002
0.0004
0.0006
0.0008
0.0010
0.0012
Displacement in Y [mm]

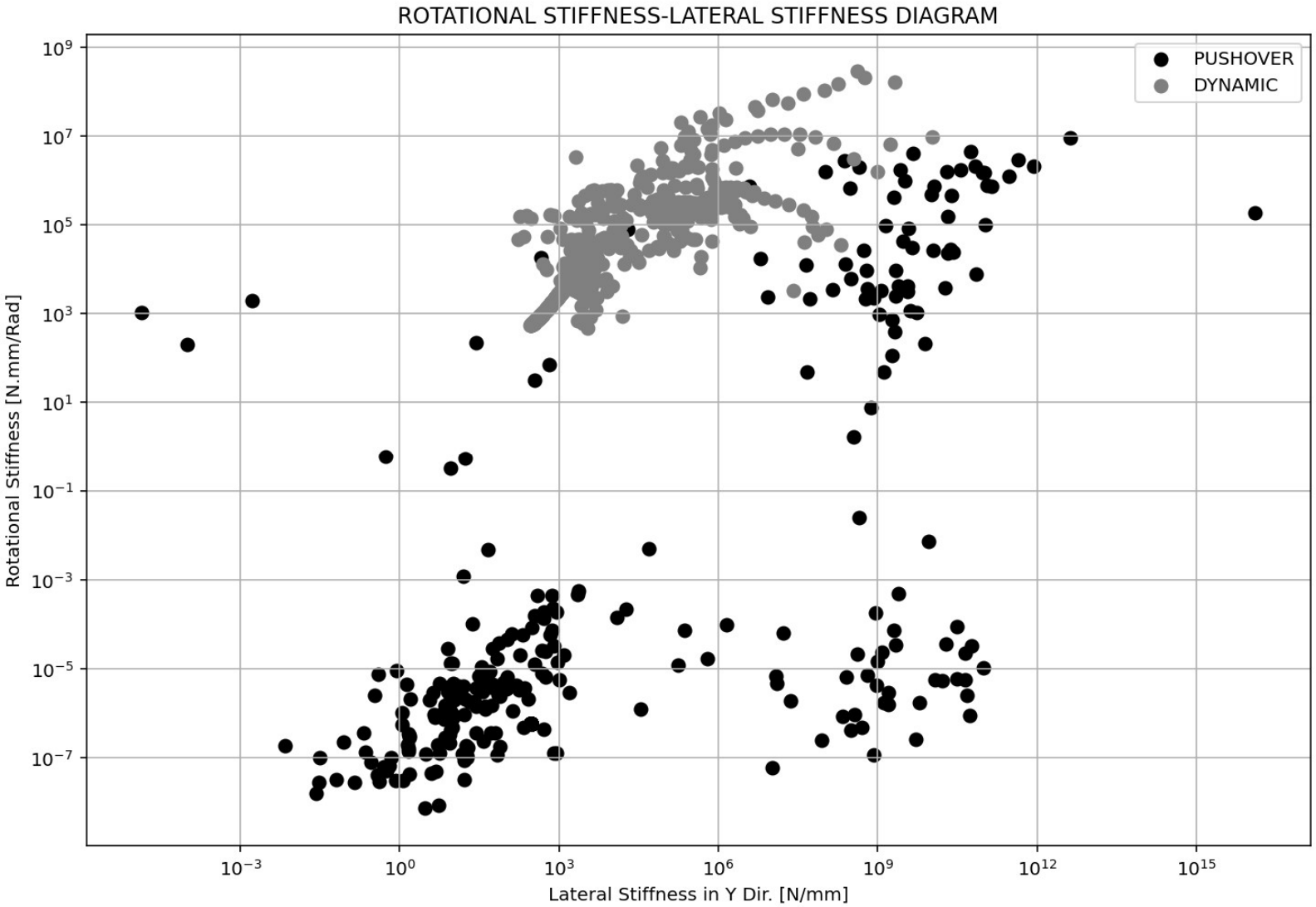

P-M Interaction
PUSHOVER
DYNAMIC
Axial Force [N]
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.02
0.00
0.02
0.04
0.06
0.08
Bending Moment [N.mm]

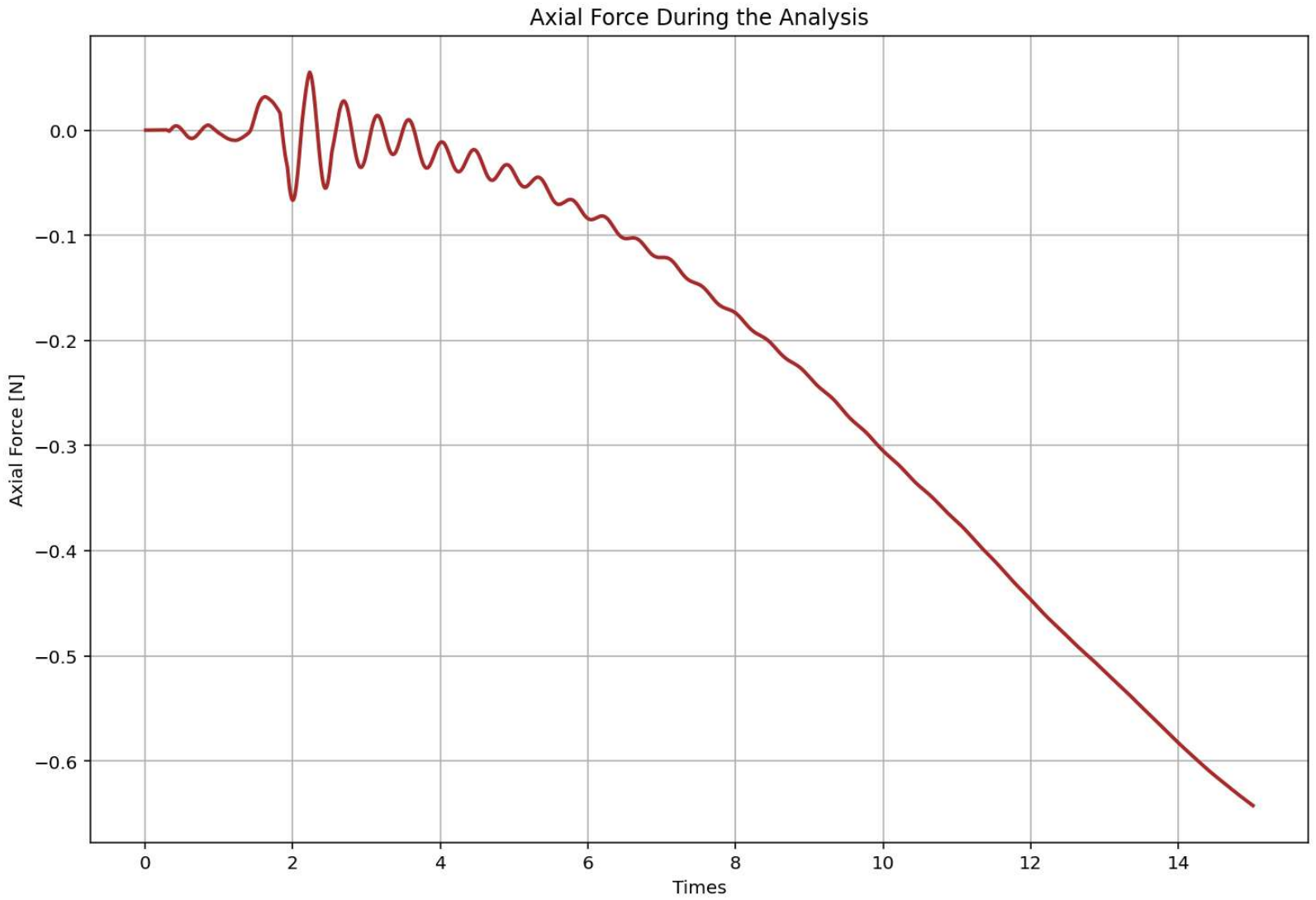

SHEAR FORCE-DISPLACEMENT DIAGRAM
PUSHOVER
DYNAMIC
Shear Force [N]
60
40
20
0
−20
−40
−60
0
2
4
6
8
10
12
14
Displacement in X [mm]

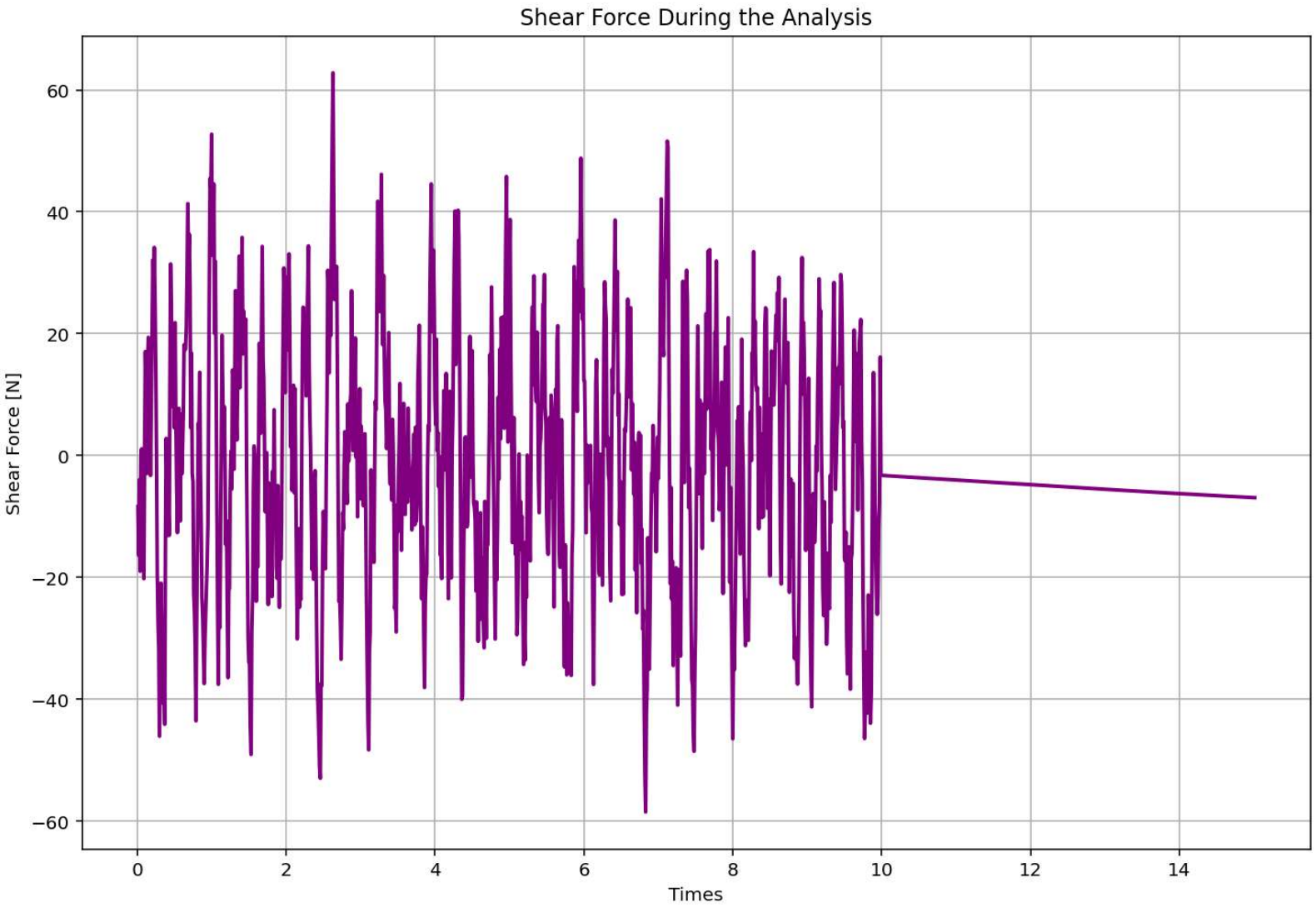

AXIAL FORCE-DISPLACEMENT DIAGRAM
PUSHOVER
DYNAMIC
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
Axial Force [N]
0.0
0.5
1.0
1.5
2.0
Displacement in Y [mm]

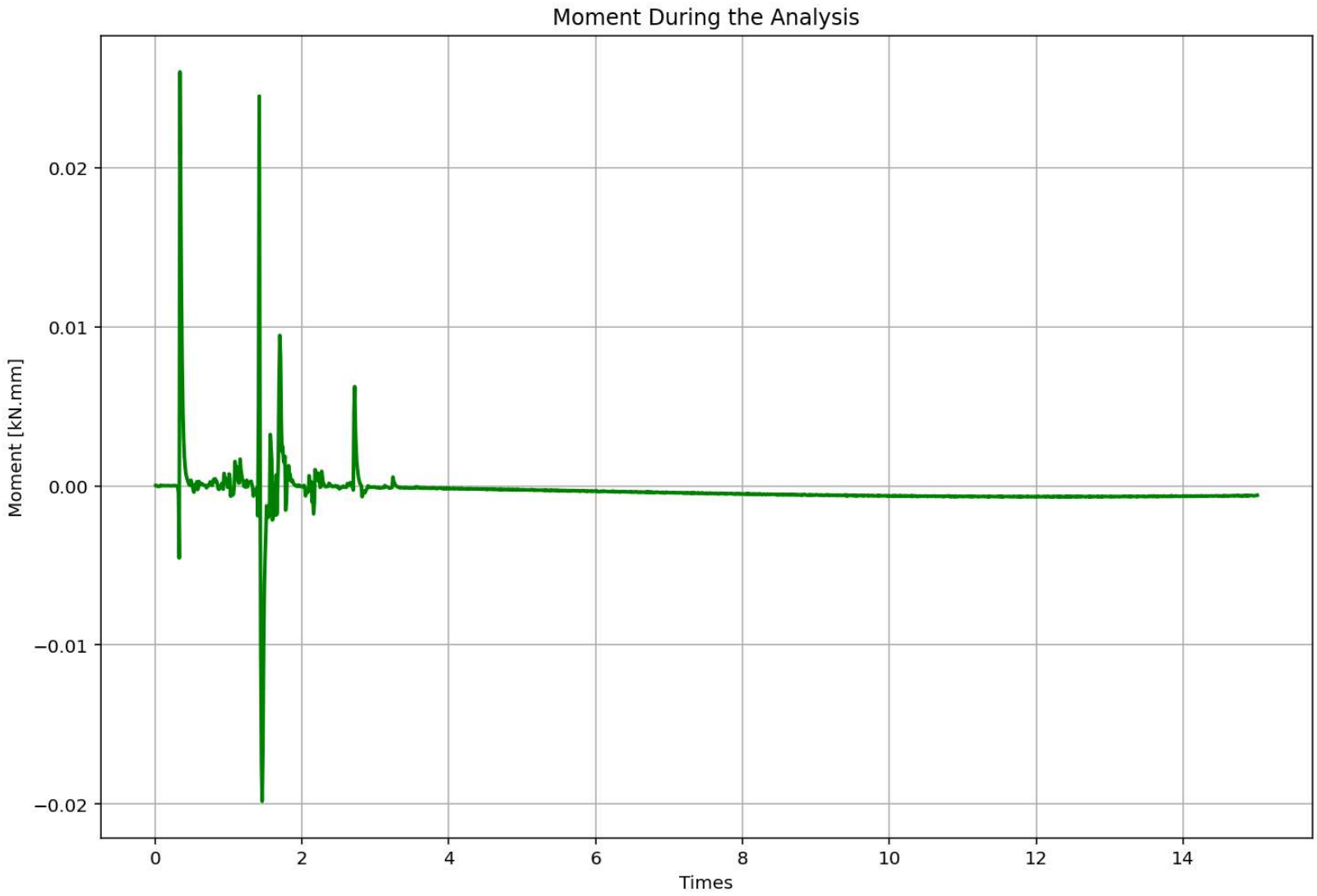

MOMENT-ROTATION DIAGRAM
PUSHOVER
DYNAMIC
Moment [kN.mm]
0.08
0.06
0.04
0.02
0.00
−0.02
0
1
2
3
4
Rotation [rad]
1e−5

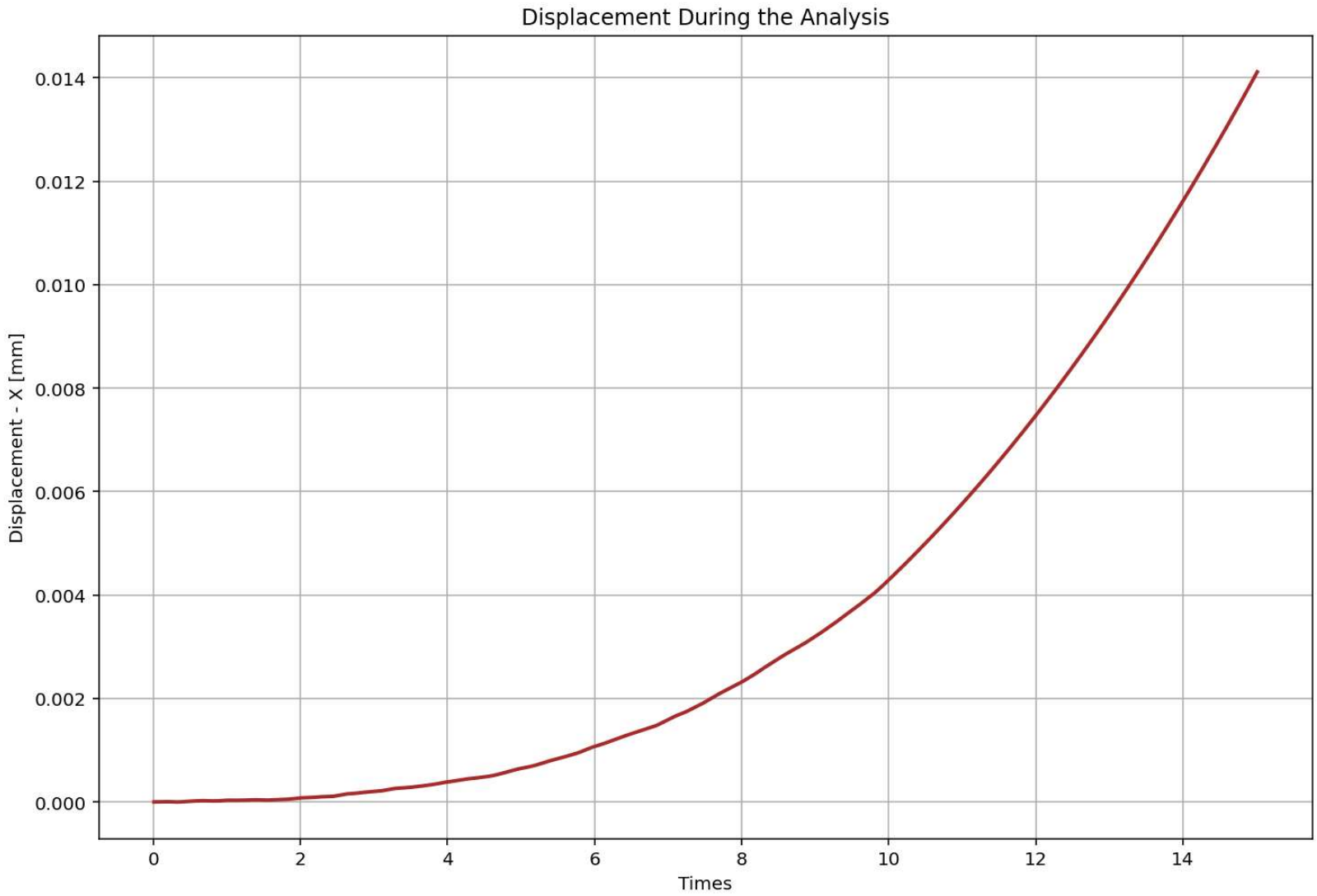

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
PUSHOVER
DYNAMIC
Rotational Stiffness [N.mm/Rad]
10^{7}
10^{4}
10^{1}
10^{-2}
10^{-5}
10^{-8}
10^{-11}
10^{-3}
10^{0}
10^{3}
10^{6}
10^{9}
10^{12}
10^{15}
Lateral Stiffness in X Dir. [N/mm]

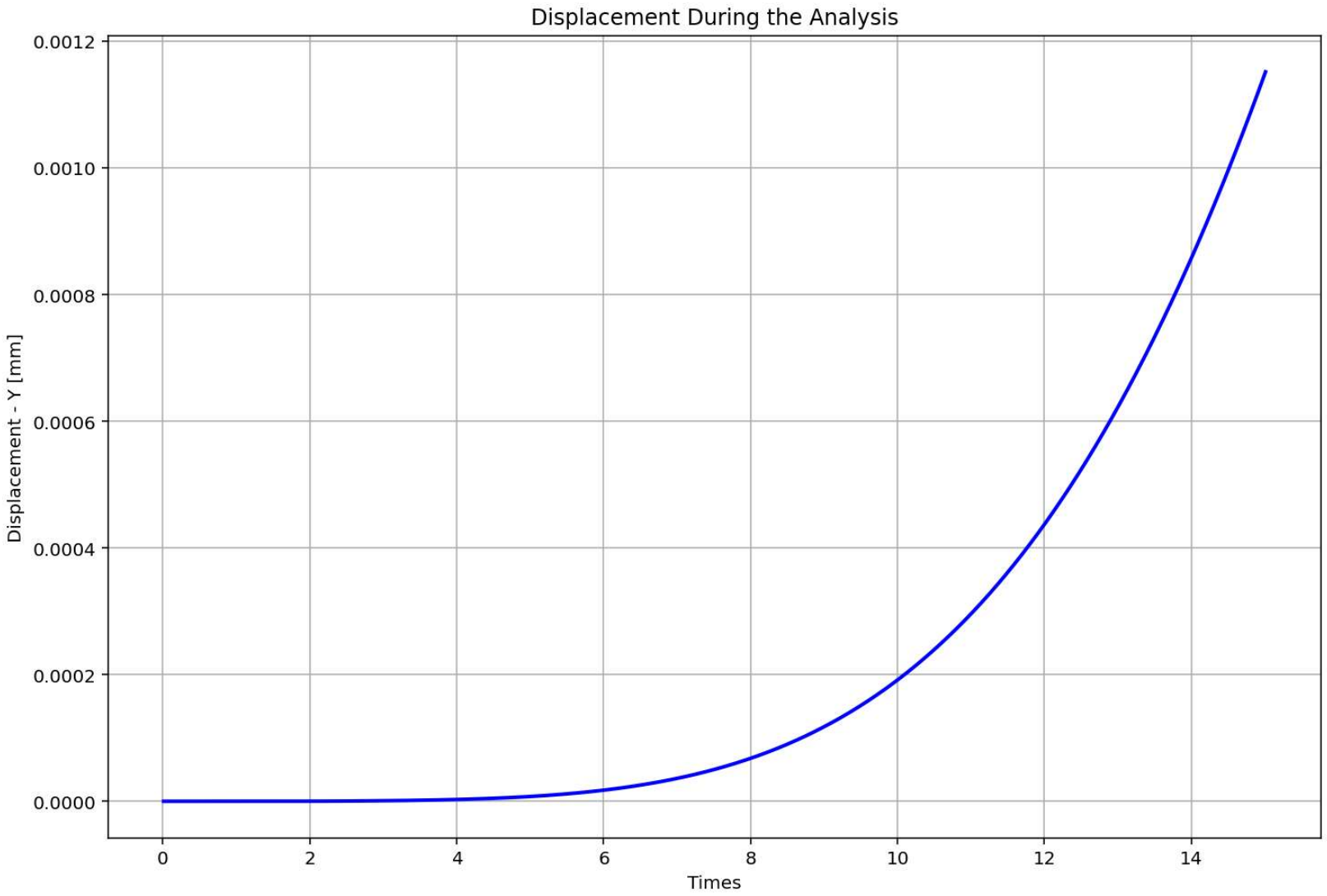

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
PUSHOVER
DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in Y Dir. [N/mm]
10^{9}
10^{7}
10^{5}
10^{3}
10^{1}
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^{-3}
10^{0}
10^{3}
10^{6}
10^{9}
10^{12}
10^{15}

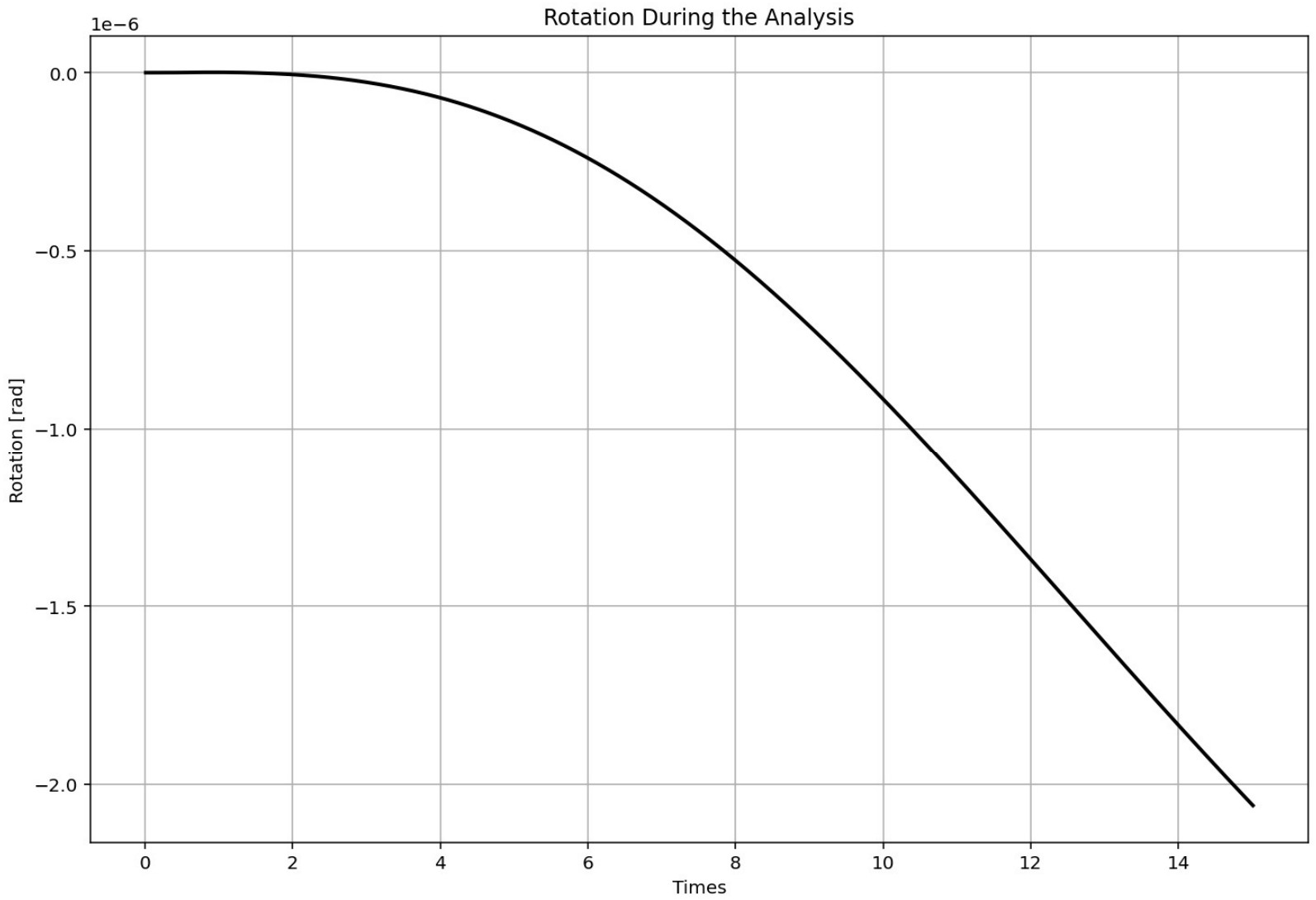

Axial Force During the Analysis
Axial Force [N]
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
0
2
4
6
8
10
12
14
Times

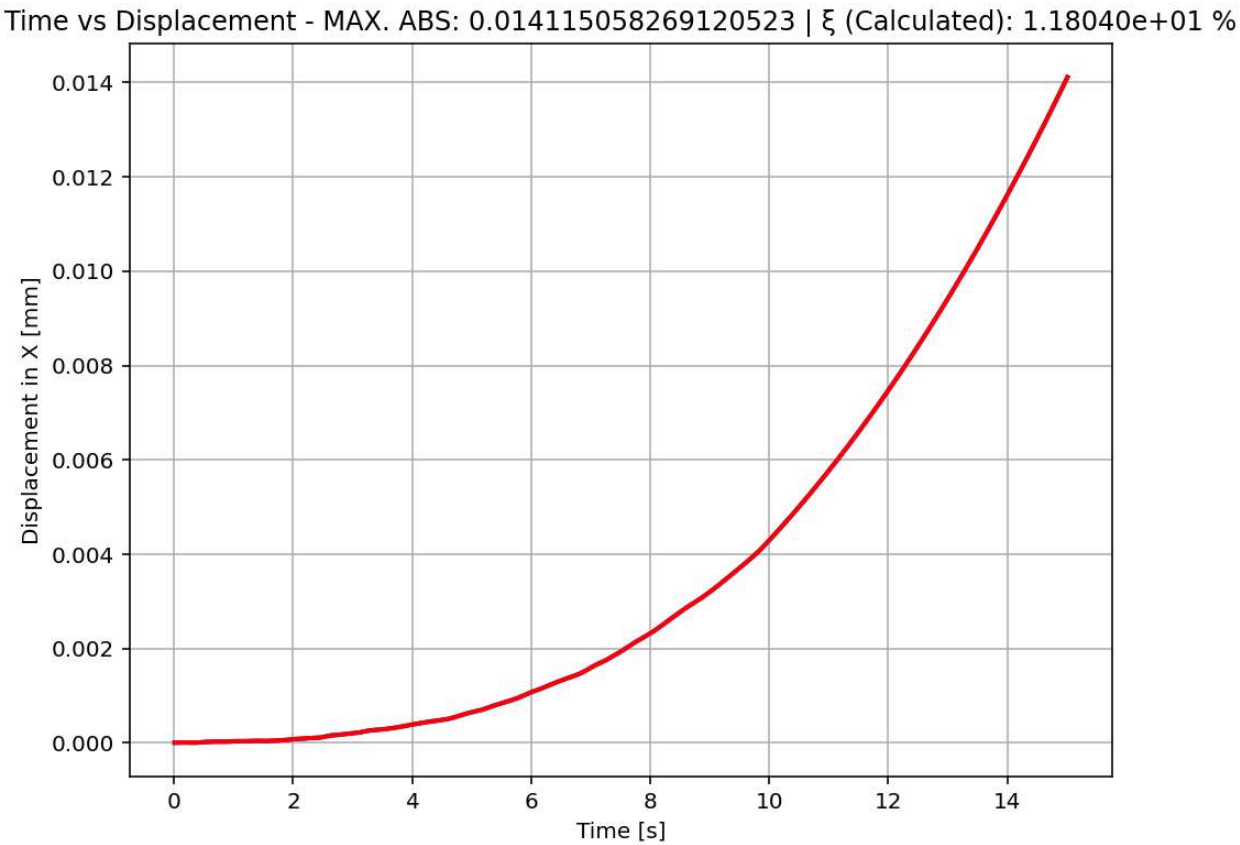

Shear Force During the Analysis
Shear Force [N]
60
40
20
0
−20
−40
−60
0
2
4
6
8
10
12
14
Times

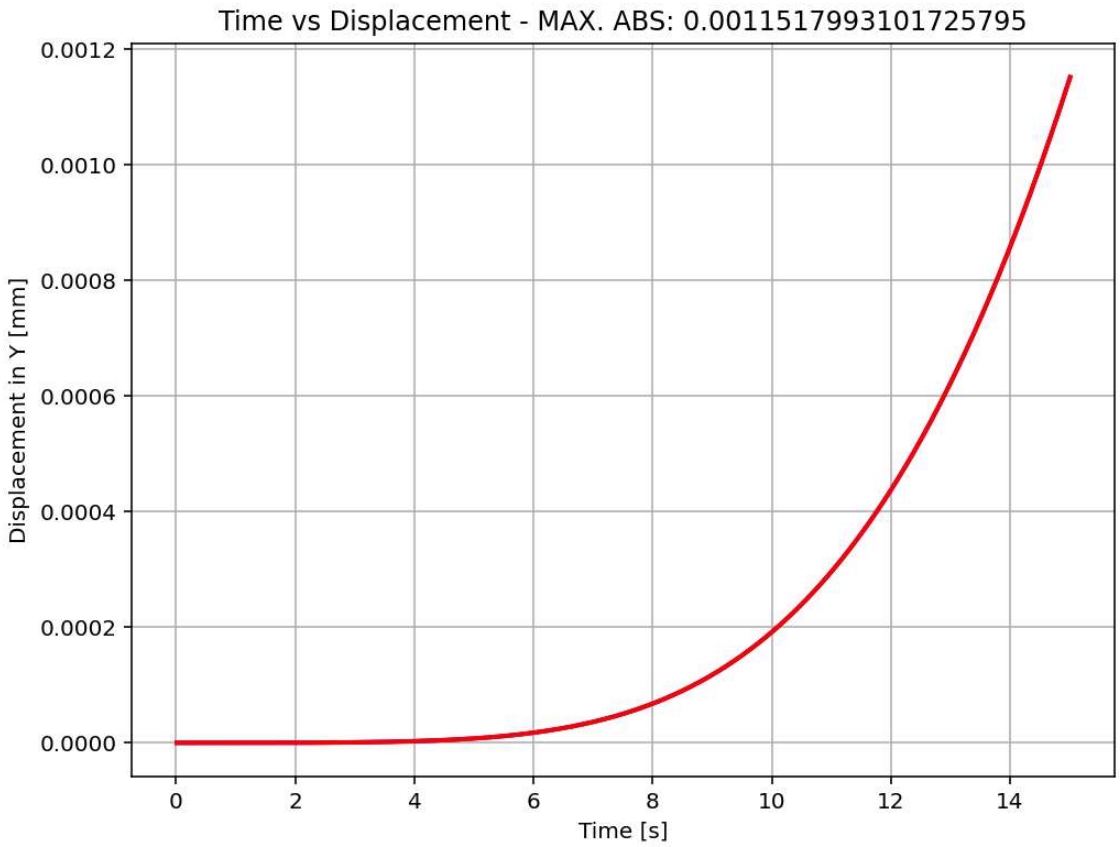

Moment During the Analysis
Moment [kN.mm]
0.02
0.01
0.00
−0.01
−0.02
0
2
4
6
8
10
12
14
Times

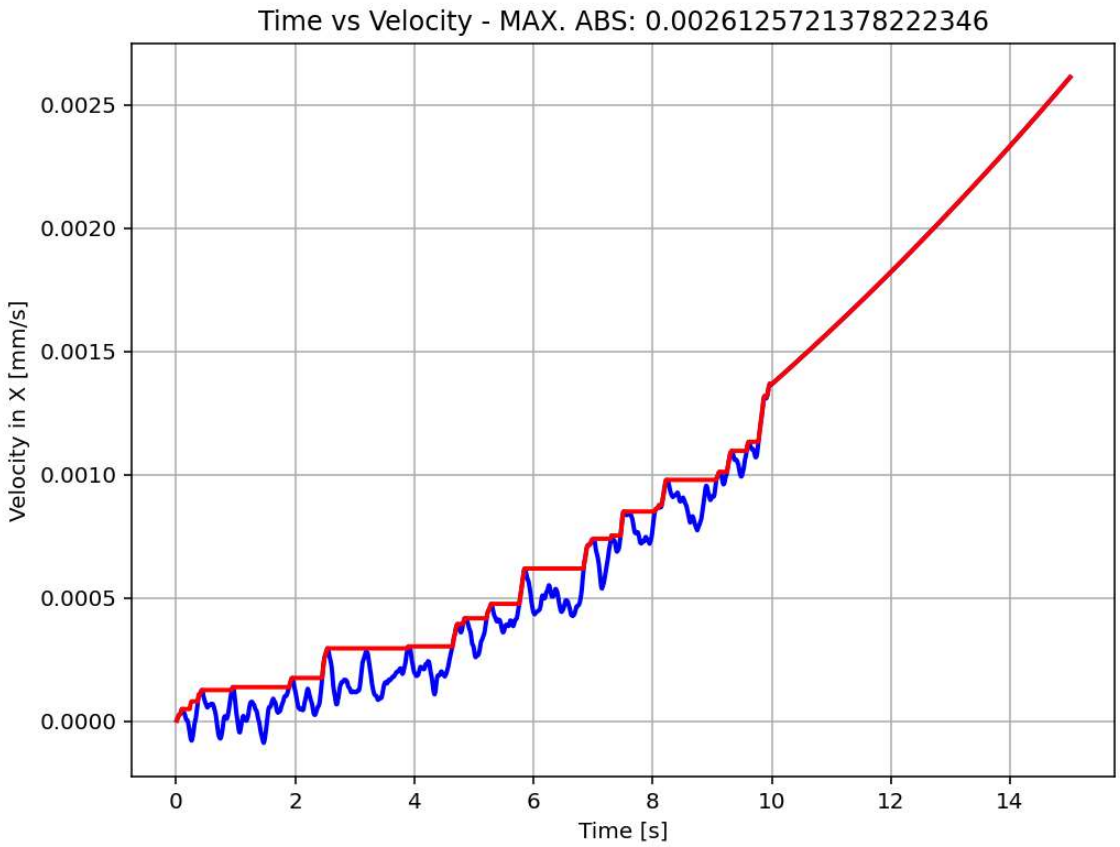

Displacement During the Analysis
Displacement - X [mm]
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
2
4
6
8
10
12
14
Times

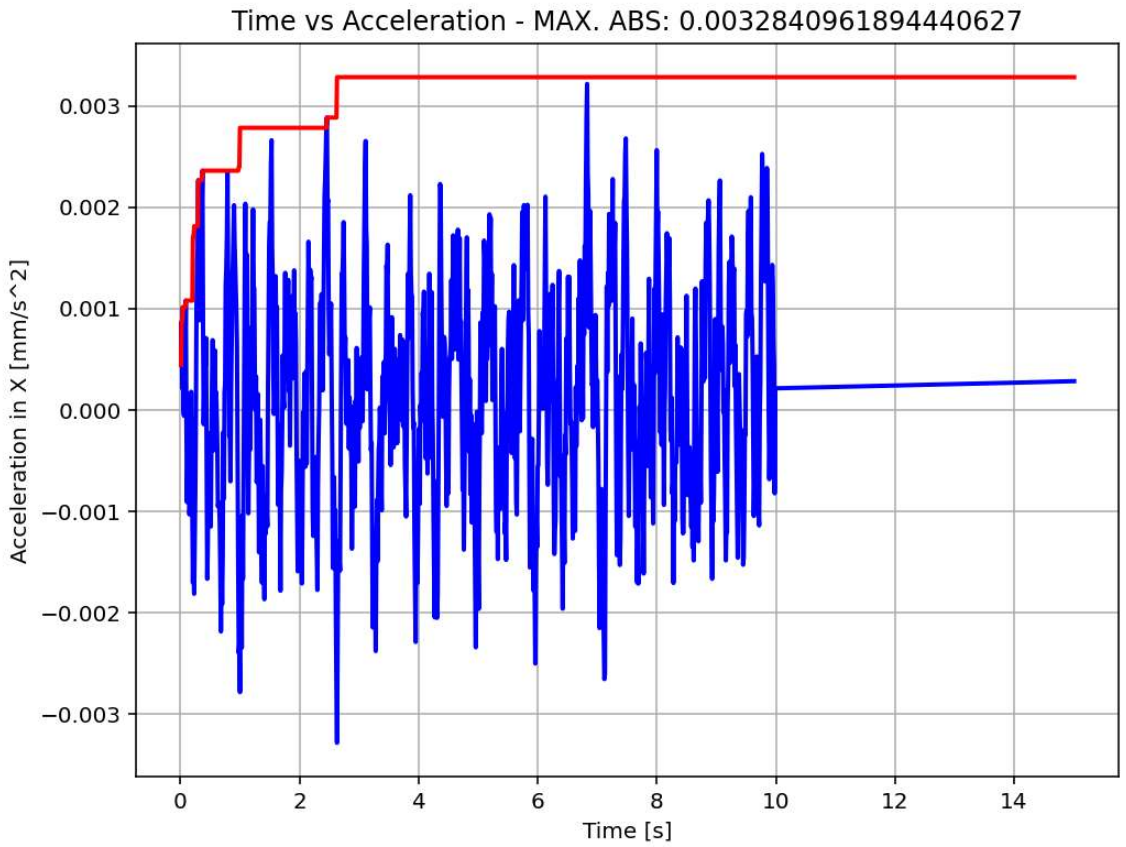

Displacement During the Analysis
Displacement - Y [mm]
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
0
2
4
6
8
10
12
14
Times

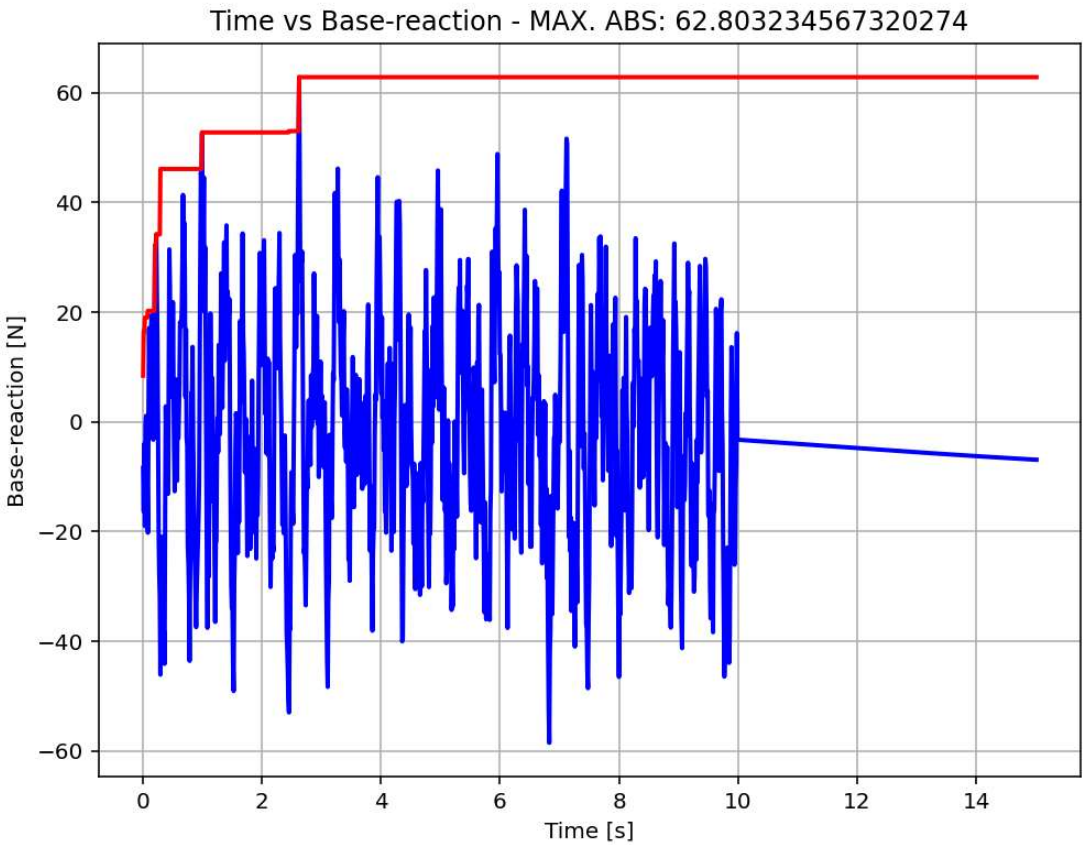

Rotation During the Analysis
1e−6
0.0
−0.5
−1.0
−1.5
−2.0
Rotation [rad]
0
2
4
6
8
10
12
14
Times

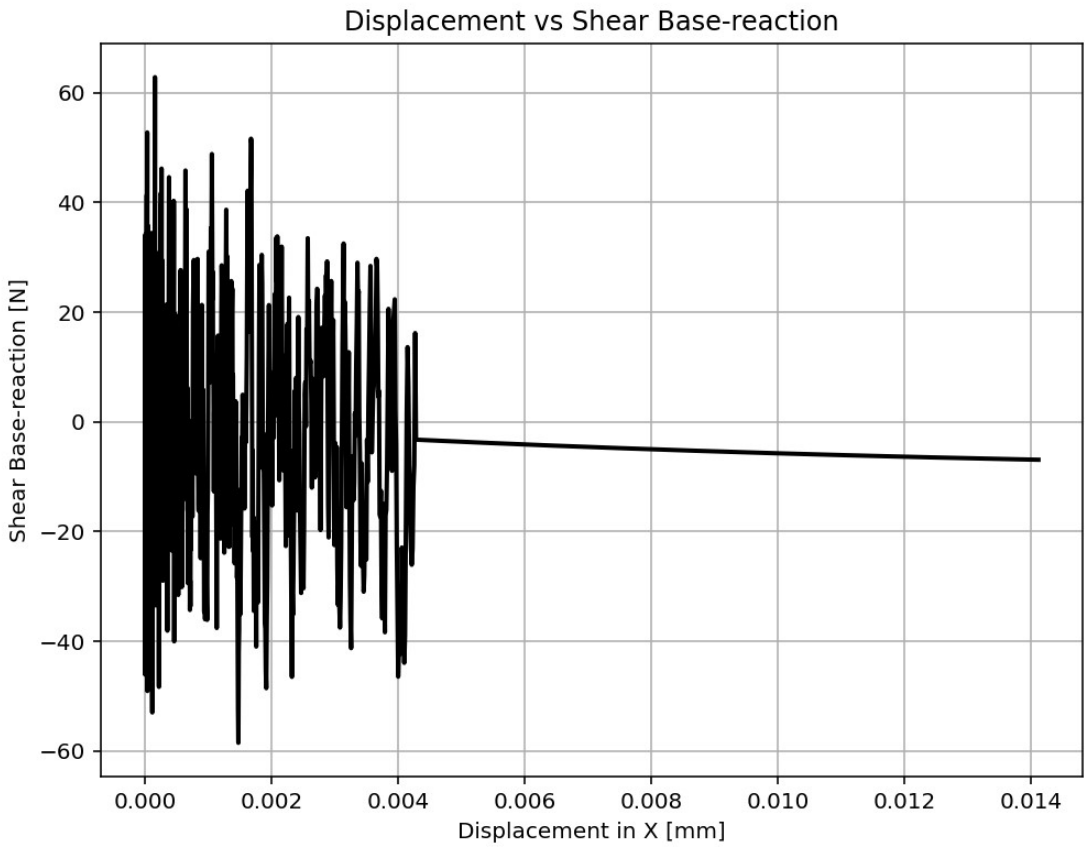

Time vs Displacement - MAX. ABS: 0.014115058269120523 | ξ (Calculated): 1.18040e+01 %
Displacement in X [mm]
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
2
4
6
8
10
12
14
Time [s]

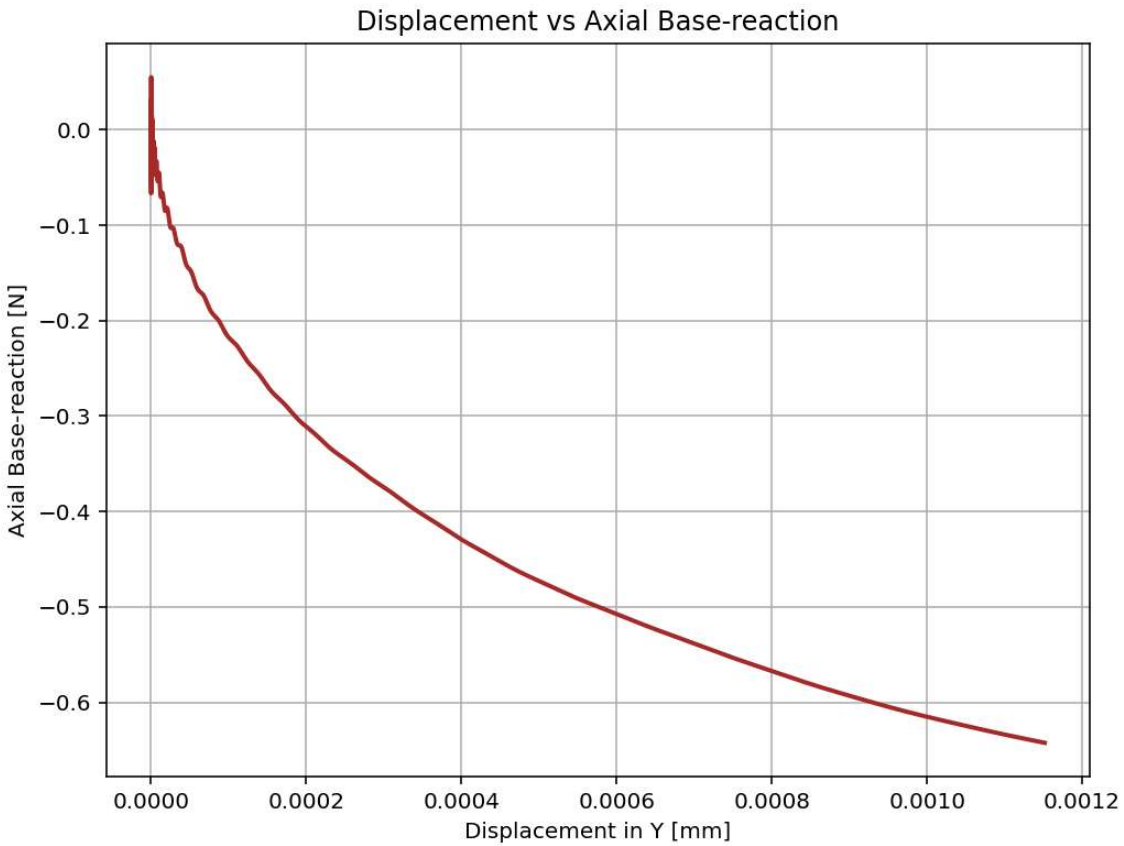

Time vs Displacement - MAX. ABS: 0.0011517993101725795
Displacement in Y [mm]
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
0
2
4
6
8
10
12
14
Time [s]


Time vs Velocity - MAX. ABS: 0.0026125721378222346
Velocity in X [mm/s]
0.0025
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: 0.0032840961894440627
Acceleration in X [mm/s^2]
0.003
0.002
0.001
0.000
−0.001
−0.002
−0.003
0
2
4
6
8
10
12
14
Time [s]


Time vs Base-reaction - MAX. ABS: 62.803234567320274
Base-reaction [N]
Time [s]
60
40
20
0
−20
−40
−60
0
2
4
6
8
10
12
14


Displacement vs Shear Base-reaction
Shear Base-reaction [N]
60
40
20
0
−20
−40
−60
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
Displacement in X [mm]


Displacement vs Axial Base-reaction
Axial Base-reaction [N]
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
0.0000
0.0002
0.0004
0.0006
0.0008
0.0010
0.0012
Displacement in Y [mm]