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

COMPREHENSIVE NONLINEAR SEISMIC ASSESSMENT OF STEEL A BEAM ELEMENT: AN OPENSEES FRAMEWORK FOR STATIC PUSHOVER, CYCLIC DEGRADATION, STATIC TIME-HISTORY AND DYNAMIC TIME-HISTORY ANALYSIS

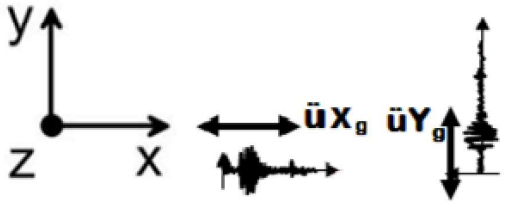
THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

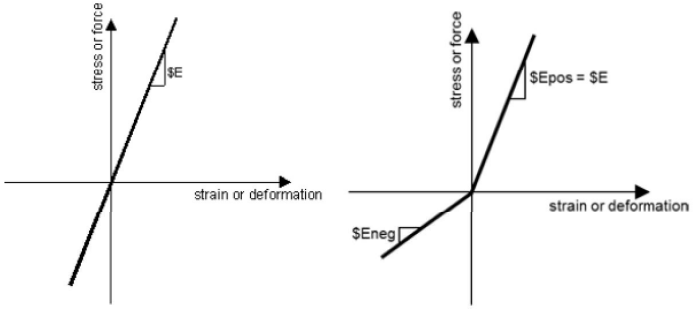
$$Axial\ Ductility\ Damage\ Index = \frac{\varepsilon_d - \varepsilon_y}{\varepsilon_u - \varepsilon_y}$$

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

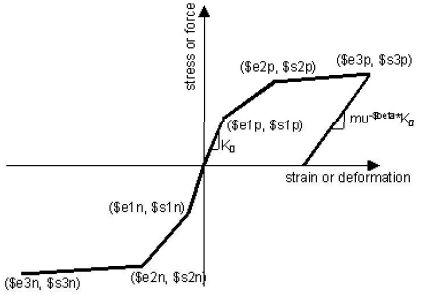
INCREMENTAL DISPLACEMENT

Length

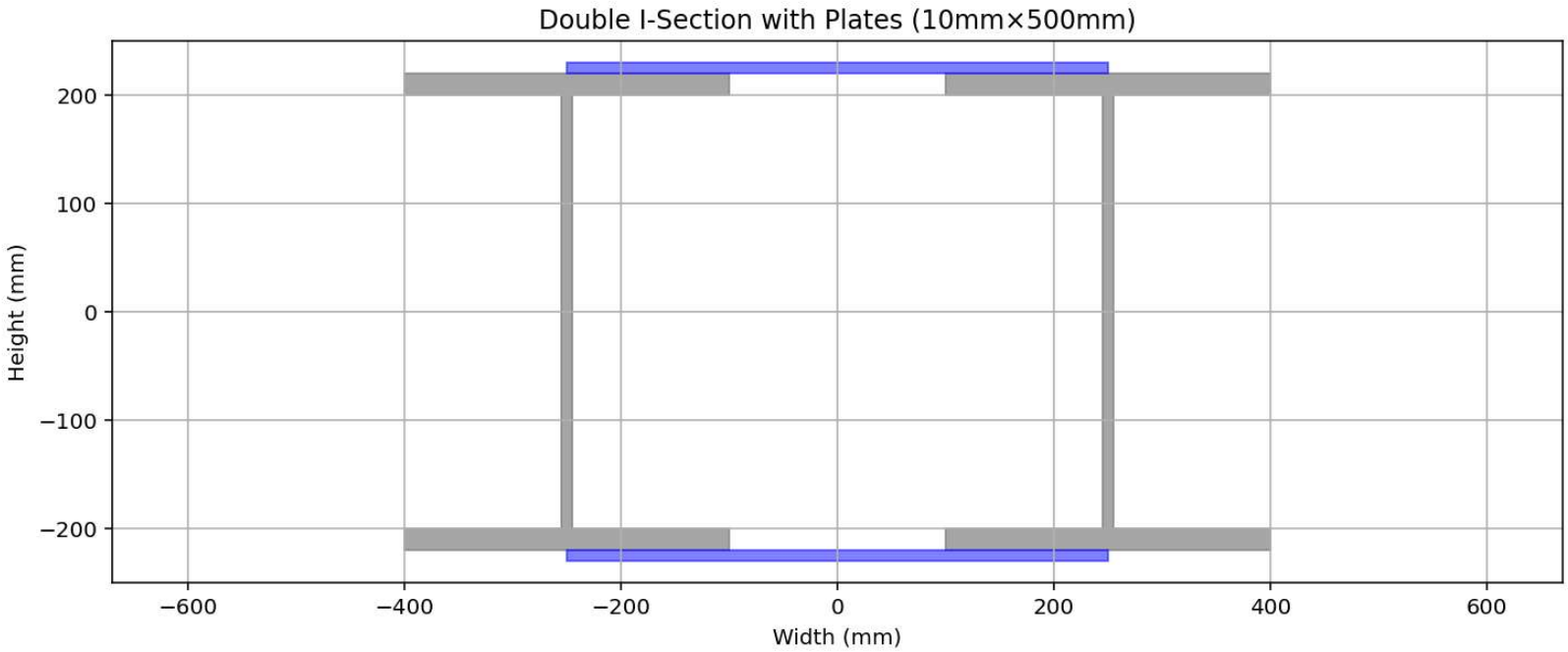




TRUSS ELEMENT ELASTIC MATERIAL



TRUSS ELEMENT INELASTIC MATERIAL


Double I-Section with Plates (10mm×500mm)
Height (mm)
200
100
0
−100
−200
−600
−400
−200
0
200
400
600
Width (mm)

Spyder (Python 3.12)

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C:\Users\Dell\Desktop\OPENSEES_FILES\+TRUSS_ONE_E...E_ELEMENT_REALSE_M3\BEAM_ONE_ELEMENT_REALSE_M3.py

BEAM_ONE_ELEMENT_REALSE_M3.py

```
##########################################################################################
#                    >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
#       COMPREHENSIVE NONLINEAR SEISMIC ASSESSMENT OF STEEL A BEAM ELEMENT : AN OPENSEES F
#       STATIC PUSHOVER, CYCLIC DEGRADATION, STATIC TIME-HISTORY AND DYNAMIC TIME-HISTORY
#----------------------------------------------------------------------------------------
#         ASSESSMENT OF DUCTILITY DAMAGE INDICES FOR STRUCTURAL ELEMENTS AND SYSTEMS AND E
#                                      OF ENERGY DISSIPATION CAPACITY INDEX
#----------------------------------------------------------------------------------------
#                            THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                    EMAIL: salar.d.ghashghaei@gmail.com
##########################################################################################
"""
Nonlinear Seismic Performance Assessment of a Beam Element:
An OpenSeesPy Framework for Material and Geometric Nonlinearity Under Static, Cyclic, and

This OpenSeesPy script performs rigorous nonlinear static and dynamic analysis of a Beam E
 for performance-based earthquake engineering. The 2D model incorporates both material non
 (elastic-perfectly plastic or hysteretic steel with strain hardening)
 and geometric nonlinearity to capture P-delta effects
 and large displacements—essential for collapse assessment.

The bridge spans 43m with 10-panel Warren configuration, assigning distinct cross-sectiona
 areas for chords and diagonals. Eigenvalue analysis tracks period elongation throughout
 loading, directly quantifying stiffness degradation and damage progression.

Eight analysis protocols are implemented:
(1) [PERIOD] : Structural Period
(2) [STATIC] : Gravity load analysis establishing dead load state
(3) [PUSHOVER] : Displacement-controlled pushover generating full capacity curves
 and plastic mechanism identification
(4) [CYCLIC_DISPLACEMENT] : Symmetric cyclic displacement protocol capturing hysteresis,
 pinching behavior, and energy dissipation degradation
(5) [STATIC_EXTERNAL_TIME-DEPENDENT_LOADING] : Static Analysis of External time-dependent
(6) [DYNAMIC EXTERNAL TIME-DEPENDENT LOADING] : Dynamic Analysis of External time-dependen
```

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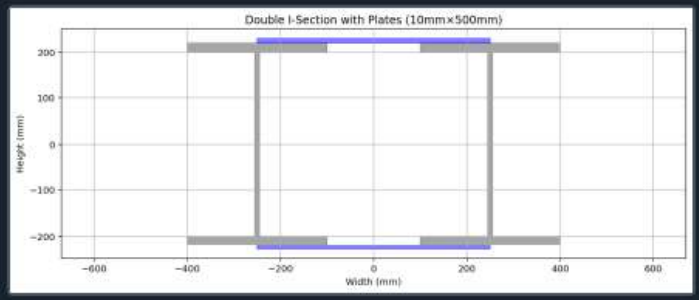
30 %



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STATIC ANALYSIS

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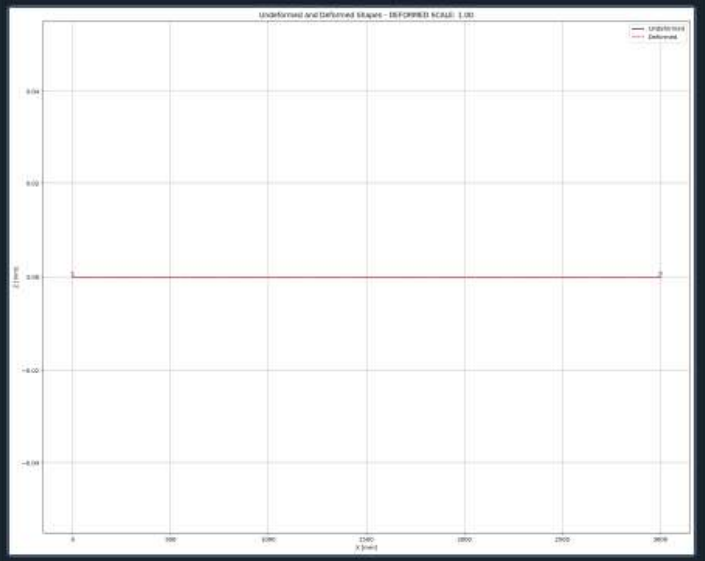
BEAM_ONE_ELEMENT_REALSE_M3.py

```
1009  AREA  = 2*2040.0      # [mm^2] Section Area for diagonal elements - 2 x UNP140
1010  TOTAL_MASS = 0.0      # [kg] Total Mass of Structure
1011  #%%------------------------------------------------------
1012  # PERIOD ANALYSIS
1013  #ELE_TYPE = 'elasticBeamColumn'      # MATERIAL LINEARITY
1014  ELE_TYPE = 'nonlinearBeamColumn'     # MATERIAL AND GEOMETRIC NONLINEARITIES
1015  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1016  ANAL_TYPE = 'PERIOD'
1017
1018  DATA = TRUSS_ONE_ELEMENT(LENGTH, AREA, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MASS)
1019  (PERIOD_MIN_X, PERIOD_MAX_X) = DATA
1020  print('Structure First Period:  ', PERIOD_MIN_X)
1021  print('Structure Second Period: ', PERIOD_MAX_X)
1022
1023  S01.PLOT_2D_FRAME(deformed_scale=1.0)
1024  #%%------------------------------------------------------
1025  # STATIC ANALYSIS
1026  #ELE_TYPE = 'elasticBeamColumn'      # MATERIAL LINEARITY
1027  ELE_TYPE = 'nonlinearBeamColumn'     # MATERIAL AND GEOMETRIC NONLINEARITIES
1028  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1029  ANAL_TYPE = 'STATIC'
1030
1031  DATA = TRUSS_ONE_ELEMENT(LENGTH, AREA, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MASS)
1032  (reaction, disp_mid,
1033   ele_force, ele_stress, ele_strain, ele_di,
1034   node_displacementsX, node_displacementsY,
1035   dispX, dispY) = DATA
1036
1037  S01.PLOT_2D_FRAME(deformed_scale=1.0)
1038  #%%------------------------------------------------------
1039  # PUSHOVER ANALYSIS (STATIC TIME-HISTORY ANALYSIS)
1040  #ELE_TYPE = 'elasticBeamColumn'      # MATERIAL LINEARITY
1041  ELE_TYPE = 'nonlinearBeamColumn'     # MATERIAL AND GEOMETRIC NONLINEARITIES
1042  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
```



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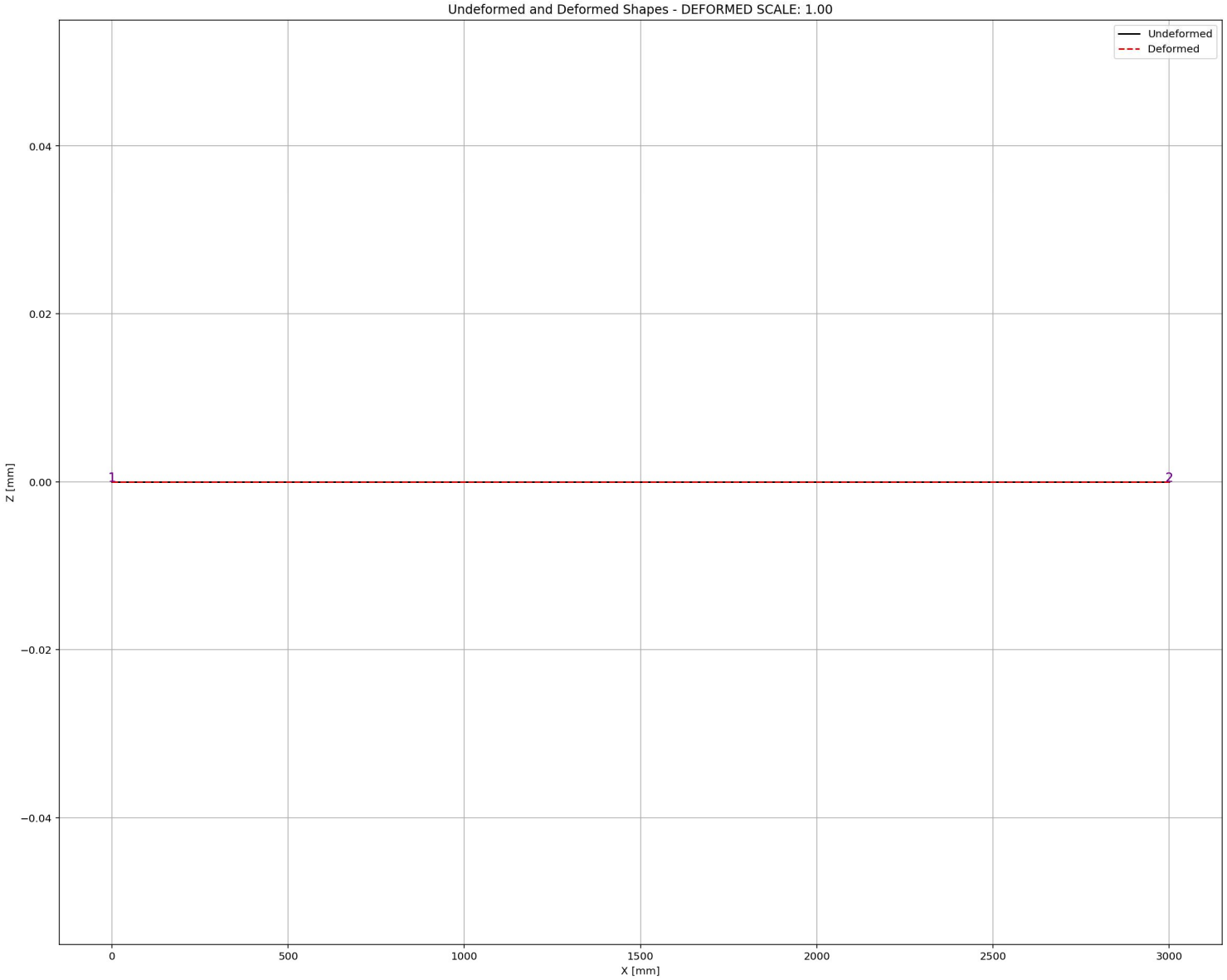
Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 48, Col 56 | UTF-8 | CRLF | RW | Mem 41%


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
0.04
0.02
0.00
−0.02
−0.04
Z [mm]
1
2
0
500
1000
1500
2000
2500
3000
X [mm]

PUSHOVER ANALYSIS

Spyder (Python 3.12)

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BEAM_ONE_ELEMENT_REALSE_M3.py

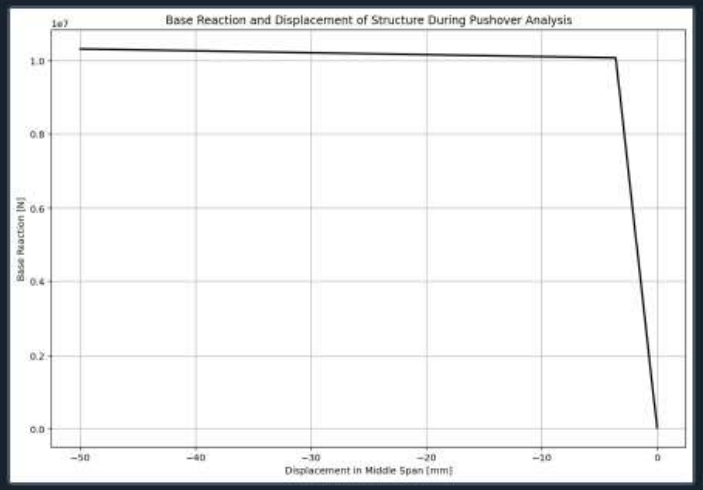
```
#%%-------------------------------------------------------
# PUSHOVER ANALYSIS (STATIC TIME-HISTORY ANALYSIS)
#ELE_TYPE = 'elasticBeamColumn'      # MATERIAL LINEARITY
ELE_TYPE = 'nonlinearBeamColumn'     # MATERIAL AND GEOMETRIC NONLINEARITIES
MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
ANAL_TYPE = 'PUSHOVER'

DATA = TRUSS_ONE_ELEMENT(LENGTH, AREA, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MASS)
(reaction_PUSH, disp_mid_PUSH,
 ele_force_PUSH, ele_stress_PUSH, ele_strain_PUSH, ele_di_PUSH,
 node_displacementsX_PUSH, node_displacementsY_PUSH,
  dispX_PUSH, dispY_PUSH,
 PERIOD_MIN_PUSH, PERIOD_MAX_PUSH,
 STRESSb_PUSH, STRAINb_PUSH, STRESSt_PUSH, STRAINt_PUSH, CURVATURE_PUSH) = DATA


XDATA = disp_mid_PUSH
YDATA = reaction_PUSH
XLABEL = 'Displacement in Middle Span [mm]'
YLABEL = 'Base Reaction [N]'
TITLE = 'Base Reaction and Displacement of Structure During Pushover Analysis'
COLOR = 'black'
SEMILOGY = False
PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)

DATA = S07.BILNEAR_CURVE(np.abs(disp_mid_PUSH), np.abs(reaction_PUSH), SLOPE_NODE=10)
(X_PUSH, Y_PUSH, Elastic_ST, Plastic_ST, Tangent_ST, Ductility_Rito, Over_Strength_Factor)

# PLOT STRUCTURAL PERIOD DURING THE ANALYSIS
plt.figure(0, figsize=(12, 8))
plt.plot(disp_mid_PUSH, PERIOD_MIN_PUSH, linewidth=3)
plt.plot(disp_mid_PUSH, PERIOD_MAX_PUSH, linewidth=3)
plt.title('Period of Structure During Pushover Analysis')
plt.ylabel('Structural Period [s]')
```



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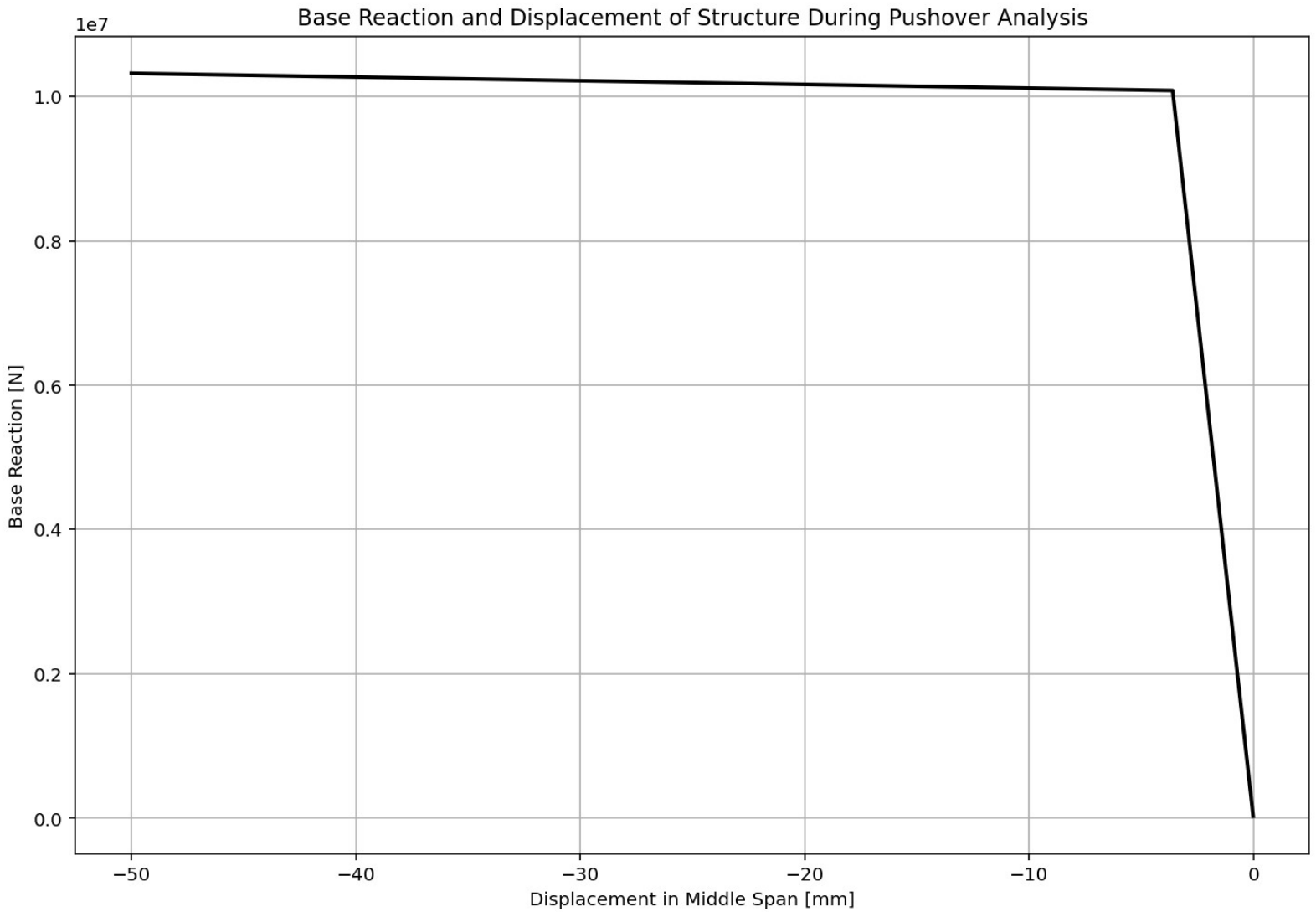
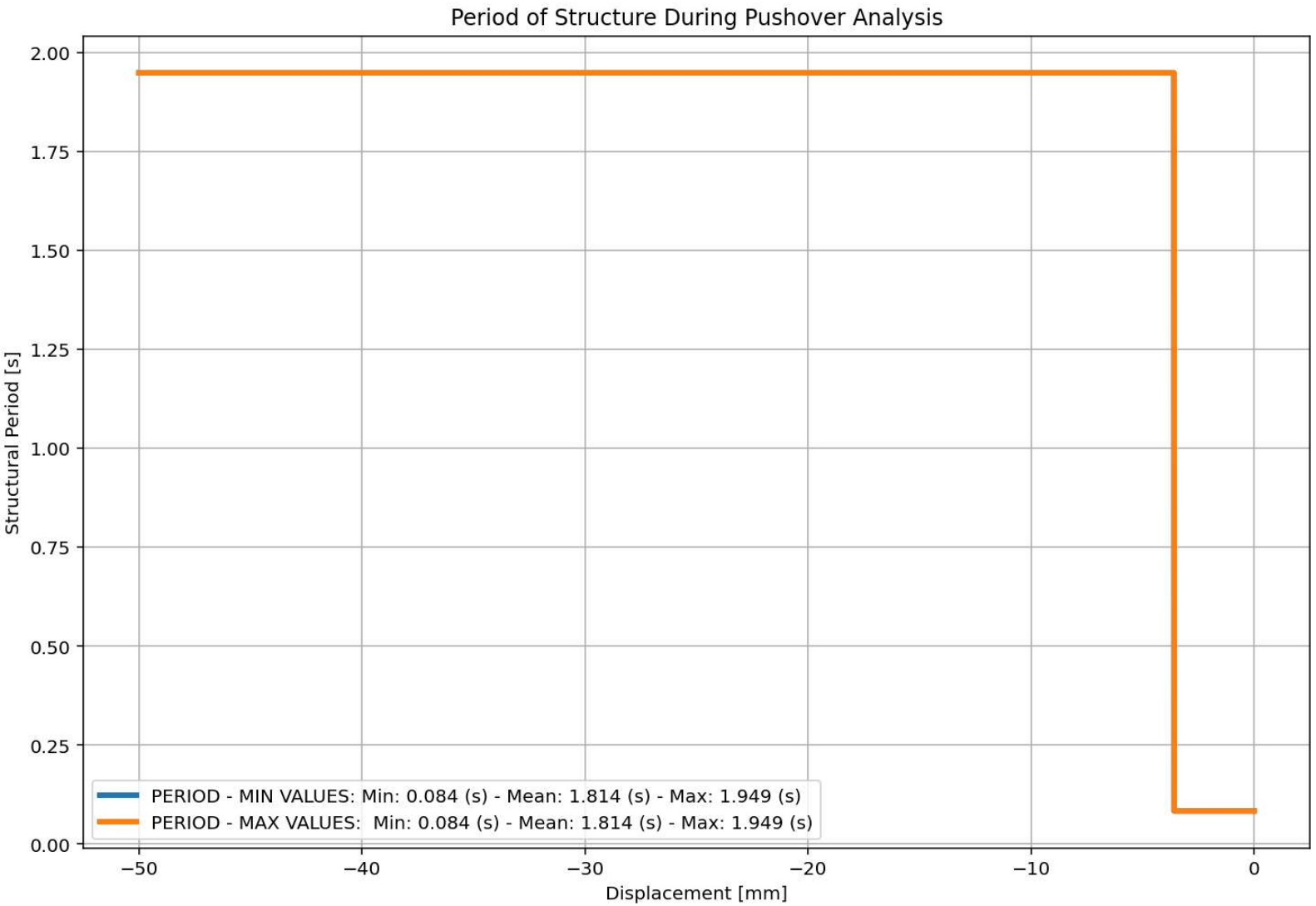
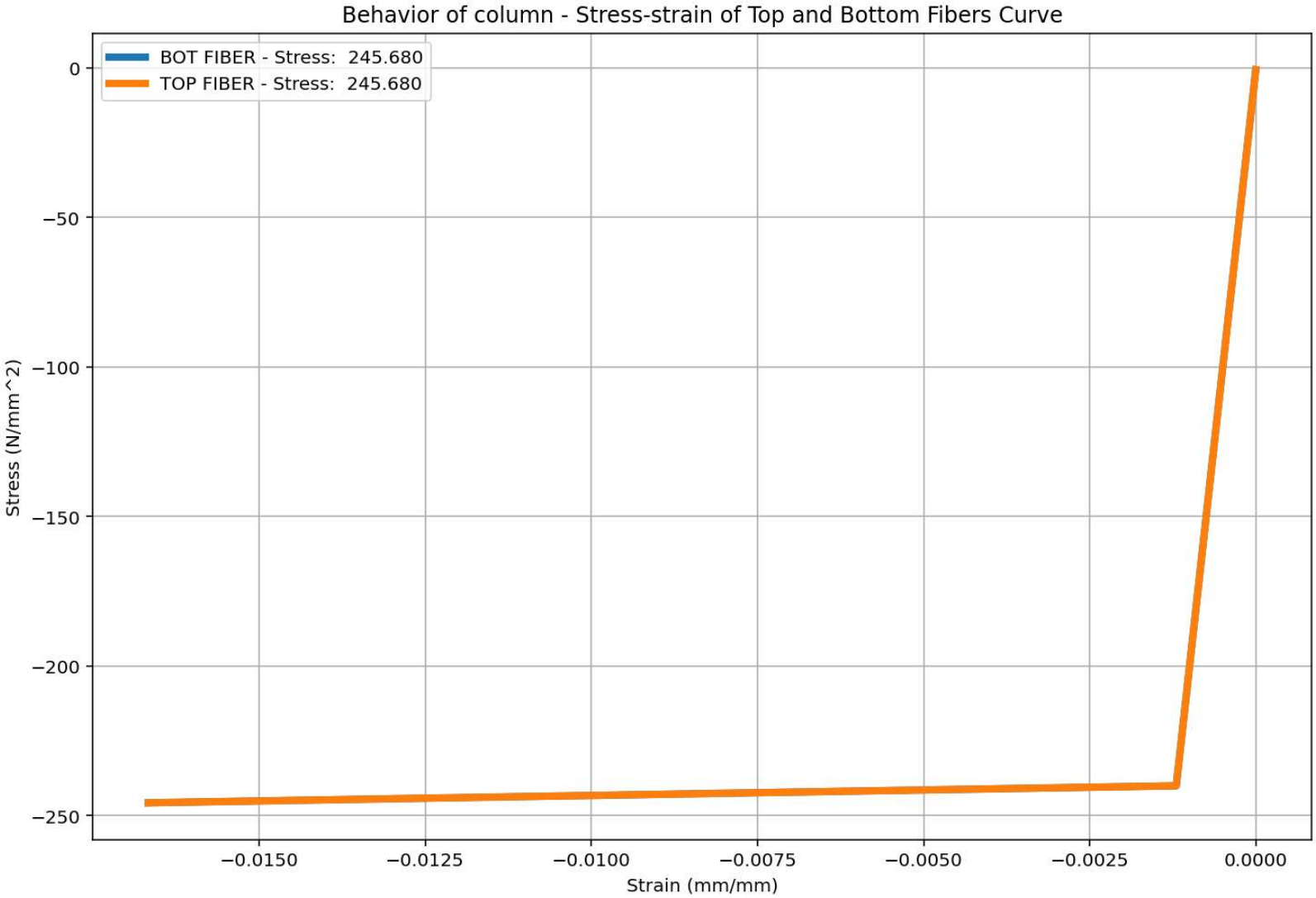
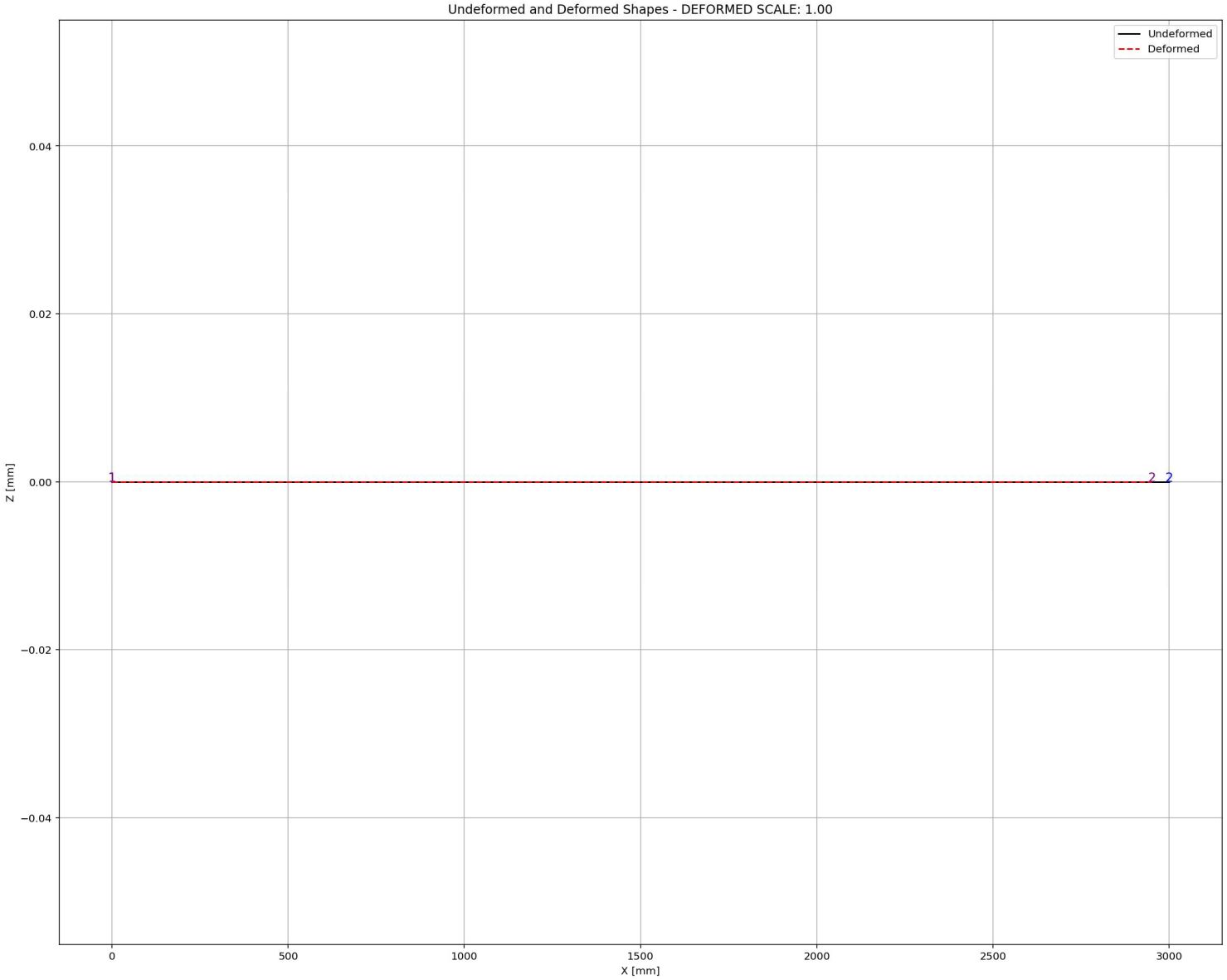
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 48, Col 56 UTF-8 CRLF RW Mem 40%


Base Reaction and Displacement of Structure During Pushover Analysis
1e7
1.0
0.8
0.6
0.4
0.2
0.0
Base Reaction [N]
−50
−40
−30
−20
−10
0
Displacement in Middle Span [mm]


Period of Structure During Pushover Analysis
Structural Period [s]
Displacement [mm]
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
−50
−40
−30
−20
−10
0
PERIOD - MIN VALUES: Min: 0.084 (s) - Mean: 1.814 (s) - Max: 1.949 (s)
PERIOD - MAX VALUES: Min: 0.084 (s) - Mean: 1.814 (s) - Max: 1.949 (s)


Behavior of column - Stress-strain of Top and Bottom Fibers Curve
BOT FIBER - Stress: 245.680
TOP FIBER - Stress: 245.680
0
−50
−100
−150
−200
−250
Stress (N/mm^2)
−0.0150
−0.0125
−0.0100
−0.0075
−0.0050
−0.0025
0.0000
Strain (mm/mm)


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
0.04
0.02
0.00
−0.02
−0.04
Z [mm]
0
500
1000
1500
2000
2500
3000
X [mm]
1
2
2

CYCLIC DISPLACEMENT ANALYSIS

Spyder (Python 3.12)

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BEAM_ONE_ELEMENT_REALSE_M3.py

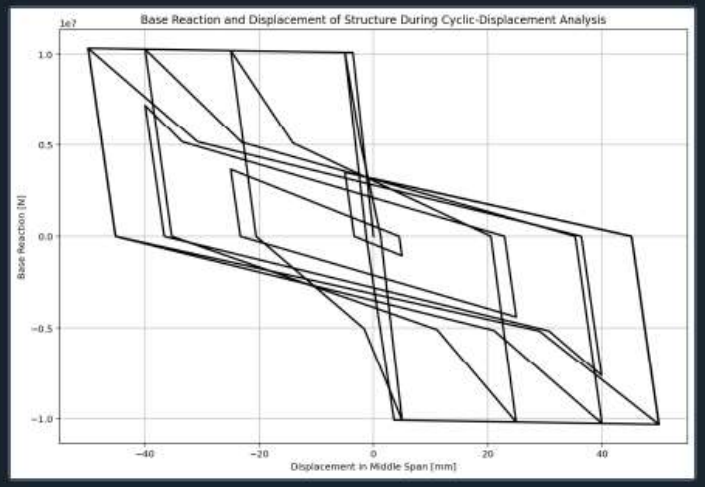
```
# CYCLIC DISPLACEMENT ANALYSIS (STATIC TIME-HISTORY ANALYSIS)
#ELE_TYPE = 'elasticBeamColumn'      # MATERIAL LINEARITY
ELE_TYPE = 'nonlinearBeamColumn'     # MATERIAL AND GEOMETRIC NONLINEARITIES
MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
ANAL_TYPE = 'CYCLIC_DISPLACEMENT'

DATA = TRUSS_ONE_ELEMENT(LENGTH, AREA, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MASS)
(reaction_CP, disp_mid_CP,
 ele_force_CP, ele_stress_CP, ele_strain_CP, ele_di_CP,
 node_displacementsX_CP, node_displacementsY_CP,
  dispX_CP, dispY_CP,
 PERIOD_MIN_CP, PERIOD_MAX_CP,
 STRESSb_CP, STRAINb_CP, STRESSt_CP, STRAINt_CP, CURVATURE_CP) = DATA


XDATA = disp_mid_CP
YDATA = reaction_CP
XLABEL = 'Displacement in Middle Span [mm]'
YLABEL = 'Base Reaction [N]'
TITLE = 'Base Reaction and Displacement of Structure During Cyclic-Displacement Analysis'
COLOR = 'black'
SEMILOGY = False
PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)

# PLOT STRUCTURAL PERIOD DURING THE ANALYSIS
plt.figure(0, figsize=(12, 8))
plt.plot(disp_mid_CP, PERIOD_MIN_CP, linewidth=3)
plt.plot(disp_mid_CP, PERIOD_MAX_CP, linewidth=3)
plt.title('Period of Structure During Cyclic Displacement Analysis')
plt.ylabel('Structural Period [s]')
plt.xlabel('Displacement [mm]')
#plt.semilogy()
plt.grid()
plt.legend([f'PERIOD - MIN VALUES: Min: {np.min(PERIOD_MIN_CP):.3f} (s) - Mean: {np.mean(P
```

31 %



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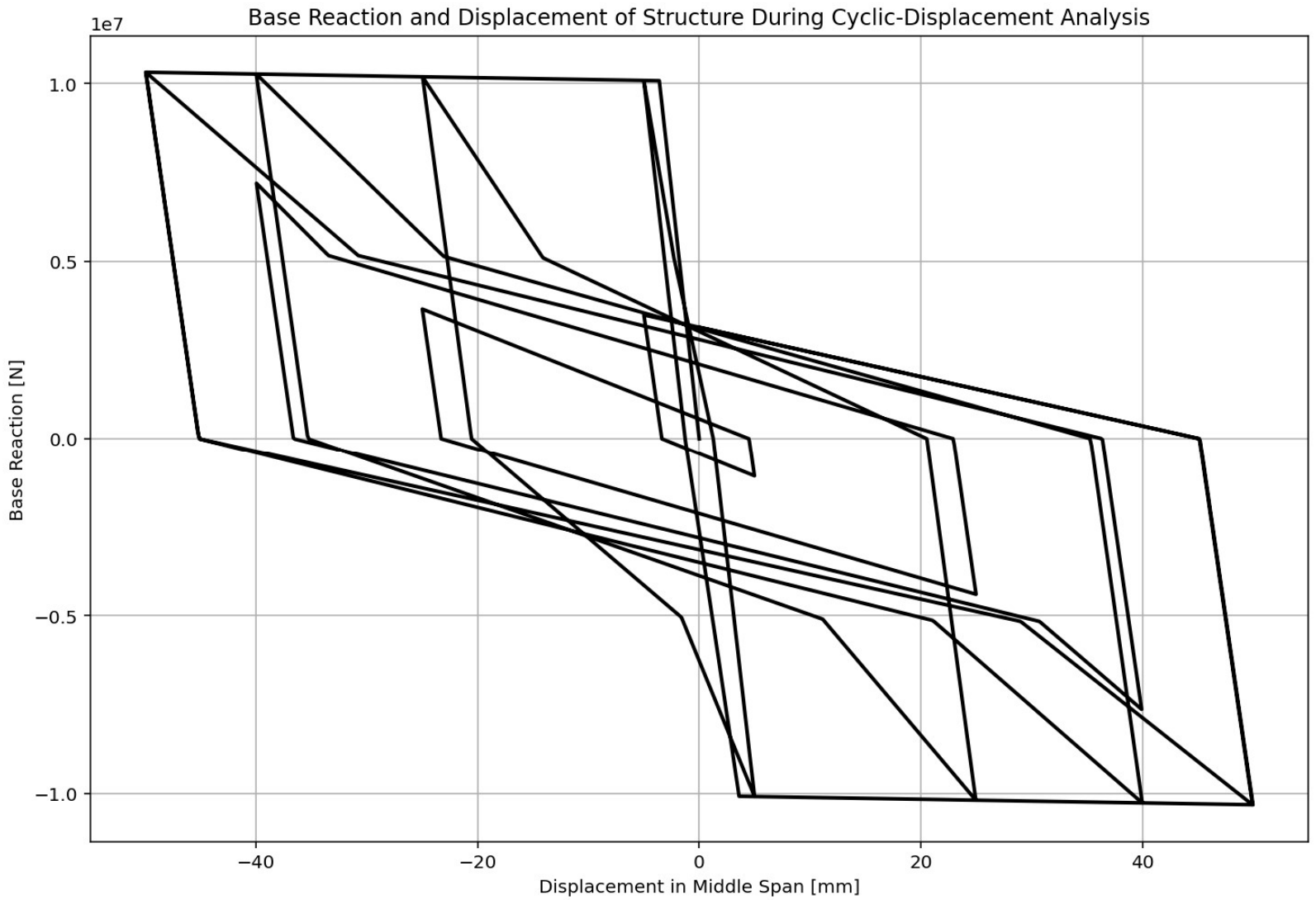
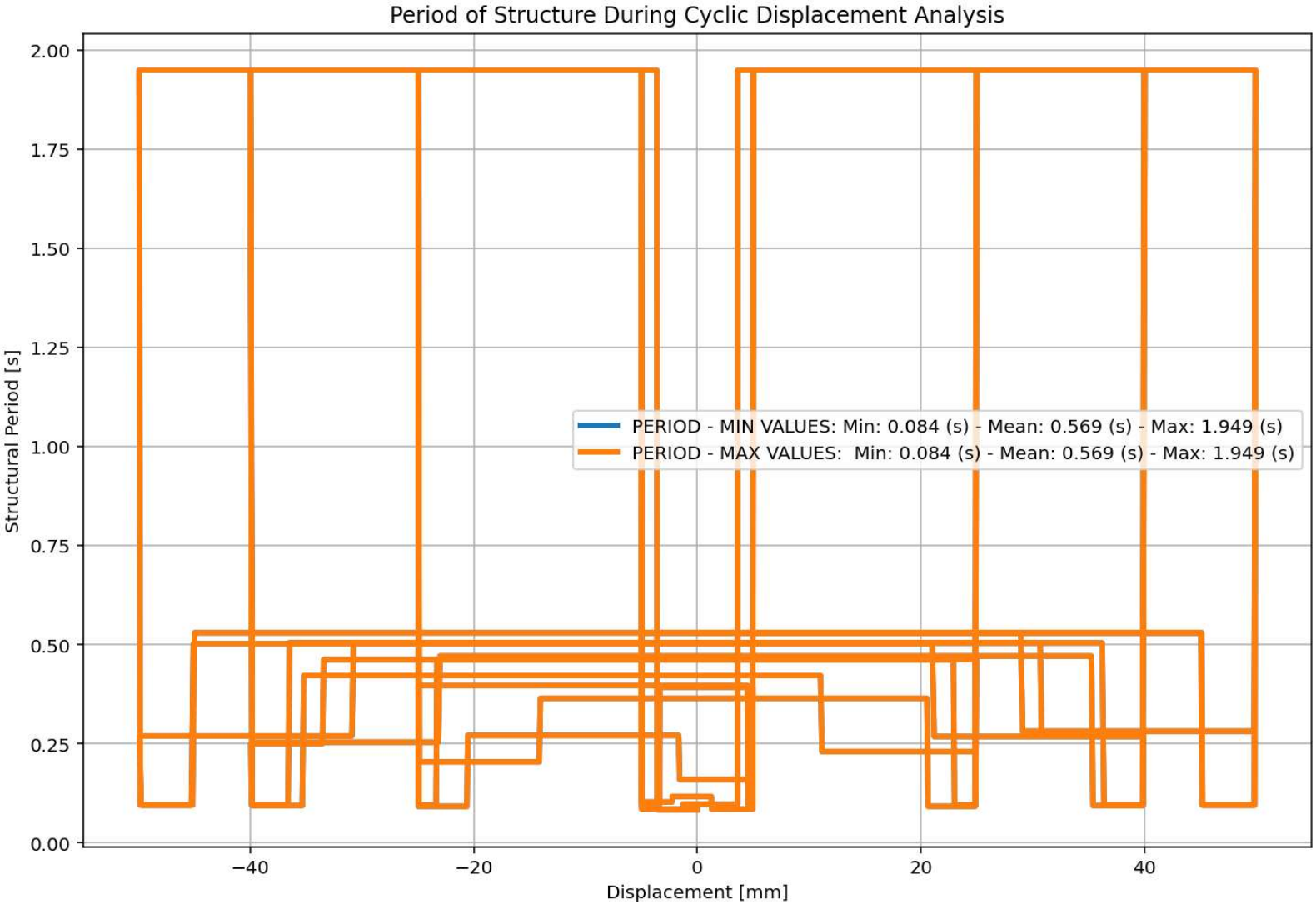
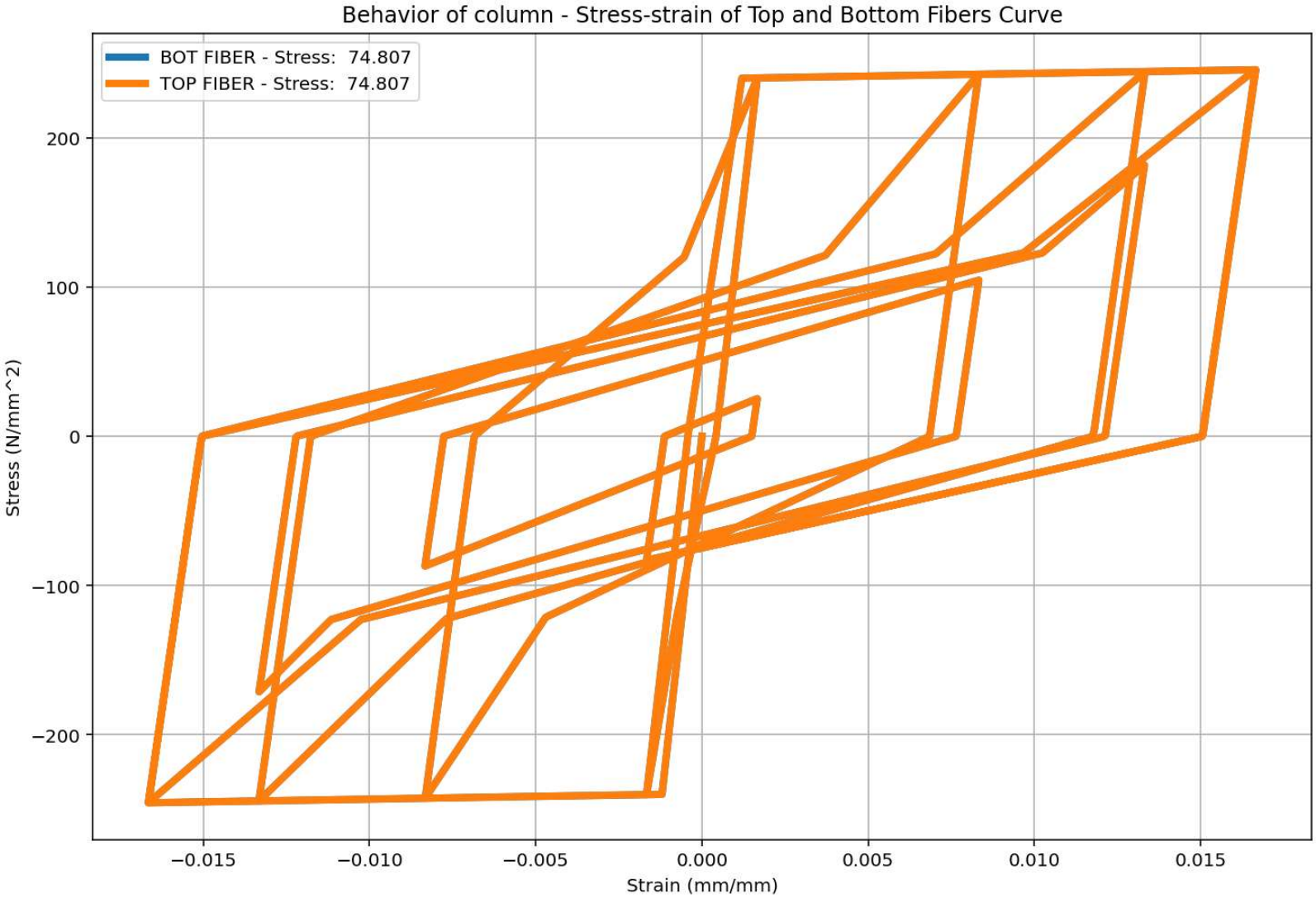
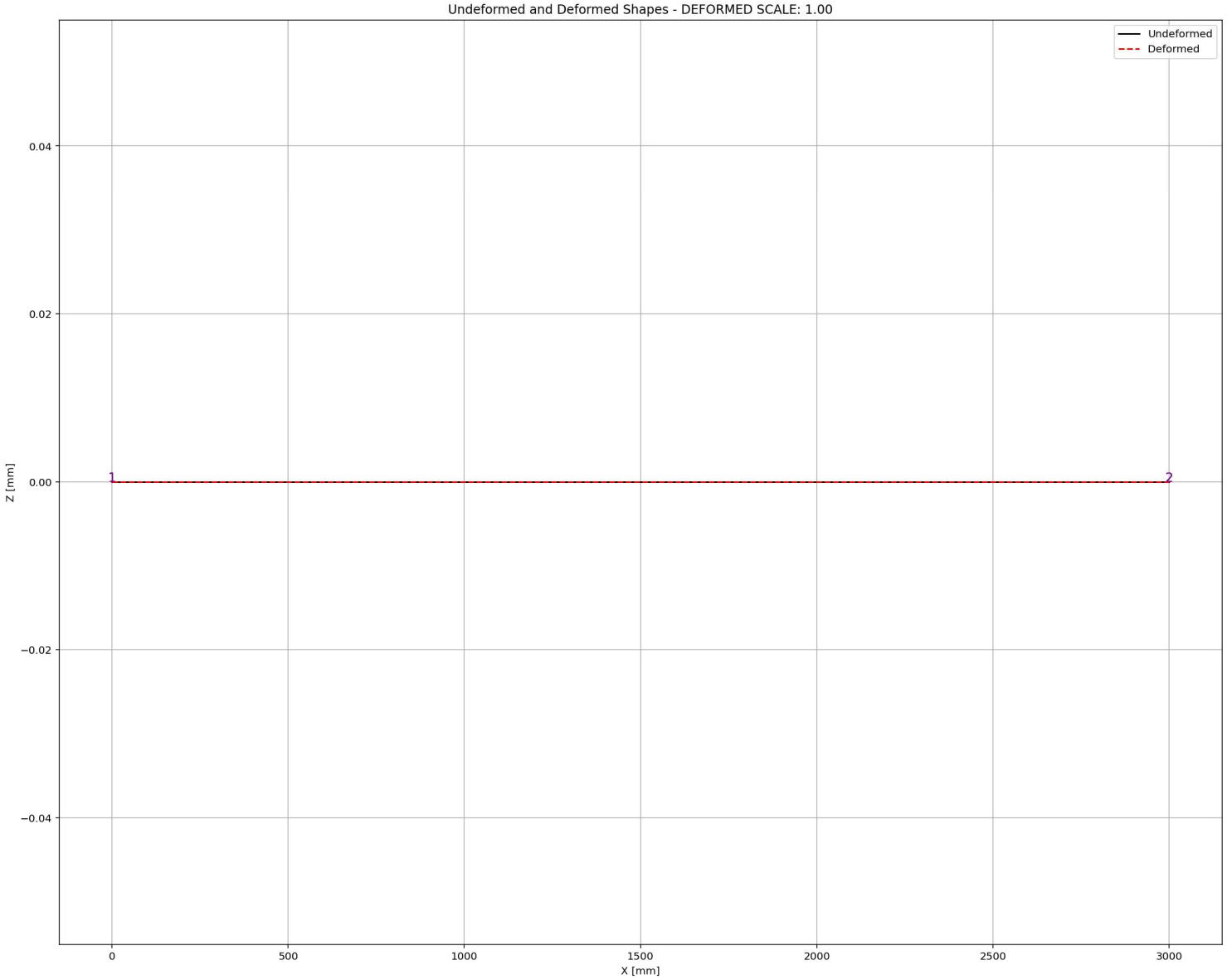

Base Reaction and Displacement of Structure During Cyclic-Displacement Analysis
1e7
1.0
0.5
0.0
−0.5
−1.0
Base Reaction [N]
−40
−20
0
20
40
Displacement in Middle Span [mm]


Period of Structure During Cyclic Displacement Analysis
Structural Period [s]
Displacement [mm]
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
−40
−20
0
20
40
PERIOD - MIN VALUES: Min: 0.084 (s) - Mean: 0.569 (s) - Max: 1.949 (s)
PERIOD - MAX VALUES: Min: 0.084 (s) - Mean: 0.569 (s) - Max: 1.949 (s)


Behavior of column - Stress-strain of Top and Bottom Fibers Curve
BOT FIBER - Stress: 74.807
TOP FIBER - Stress: 74.807
200
100
0
−100
−200
Stress (N/mm^2)
−0.015
−0.010
−0.005
0.000
0.005
0.010
0.015
Strain (mm/mm)


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
0.04
0.02
0.00
−0.02
−0.04
Z [mm]
1
2
0
500
1000
1500
2000
2500
3000
X [mm]

STATIC TIME-HISTORY WITH EXTERNALTIME-DEPENDENTLOADING ANALYSIS

Spyder (Python 3.12)

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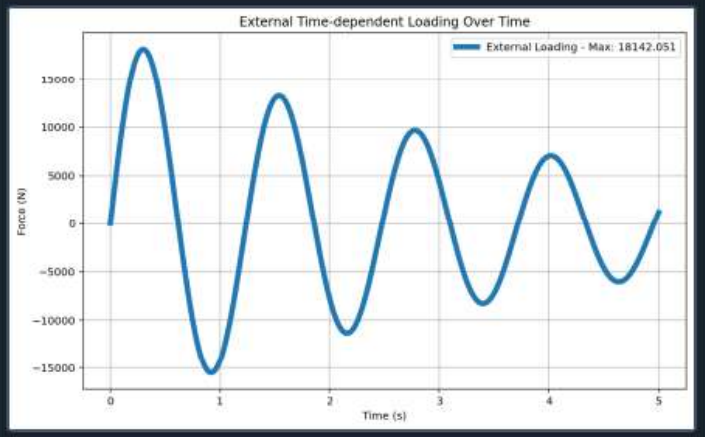
BEAM_ONE_ELEMENT_REALSE_M3.py

```
1144  # EXTERNAL TIME-DEPENDENT LOADING ANALYSIS (STATIC TIME-HISTORY ANALYSIS)
1145  #ELE_TYPE = 'elasticBeamColumn'      # MATERIAL LINEARITY
1146  ELE_TYPE = 'nonlinearBeamColumn'     # MATERIAL AND GEOMETRIC NONLINEARITIES
1147  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1148  ANAL_TYPE = 'STATIC_EXTERNAL_TIME-DEPENDENT_LOADING'
1149
1150  DATA = TRUSS_ONE_ELEMENT(LENGTH, AREA, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MASS)
1151
1152  (reaction_ETDLS, disp_mid_ETDLS,
1153   ele_force_ETDLS, ele_stress_ETDLS, ele_strain_ETDLS, ele_di_ETDLS,
1154   node_displacementsX_ETDLS, node_displacementsY_ETDLS,
1155    dispX_ETDLS, dispY_ETDLS,
1156   PERIOD_MIN_ETDLS, PERIOD_MAX_ETDLS,
1157   STRESSb_ETDLS, STRAINb_ETDLS, STRESSt_ETDLS, STRAINt_ETDLS, CURVATURE_ETDLS) = DATA
1158
1159
1160  XDATA = disp_mid_ETDLS
1161  YDATA = reaction_ETDLS
1162  XLABEL = 'Displacement in Middle Span [mm]'
1163  YLABEL = 'Base Reaction [N]'
1164  TITLE = 'Base Reaction and Displacement of Structure During Static External Time-dependent
1165  COLOR = 'black'
1166  SEMILOGY = False
1167  PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1168
1169  # PLOT STRUCTURAL PERIOD DURING THE ANALYSIS
1170  plt.figure(0, figsize=(12, 8))
1171  plt.plot(disp_mid_ETDLS, PERIOD_MIN_ETDLS, linewidth=3)
1172  plt.plot(disp_mid_ETDLS, PERIOD_MAX_ETDLS, linewidth=3)
1173  plt.title('Period of Structure During Static External Time-dependent Loading Analysis')
1174  plt.ylabel('Structural Period [s]')
1175  plt.xlabel('Displacement [mm]')
1176  #plt.semilogy()
1177  plt.grid()
```



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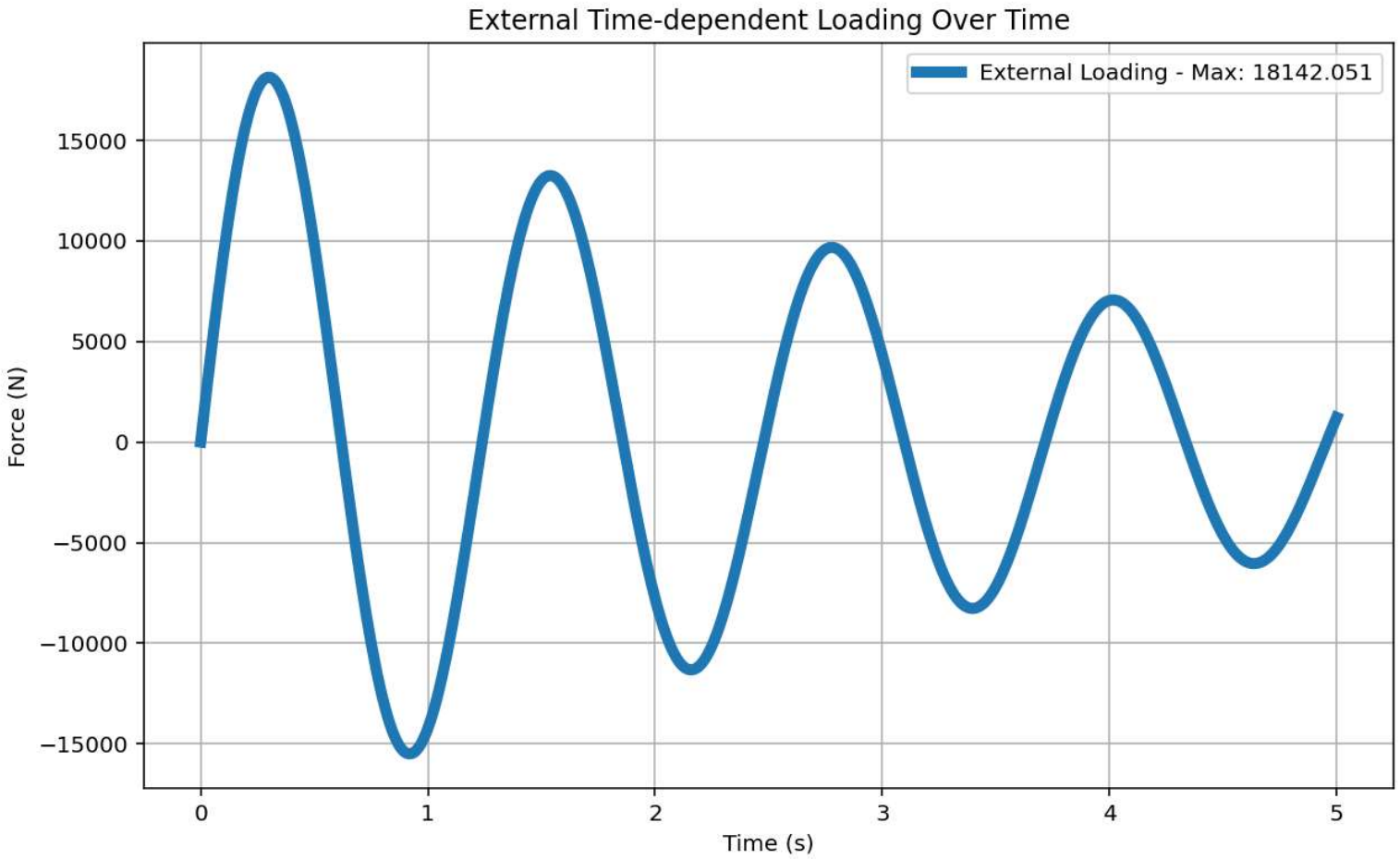
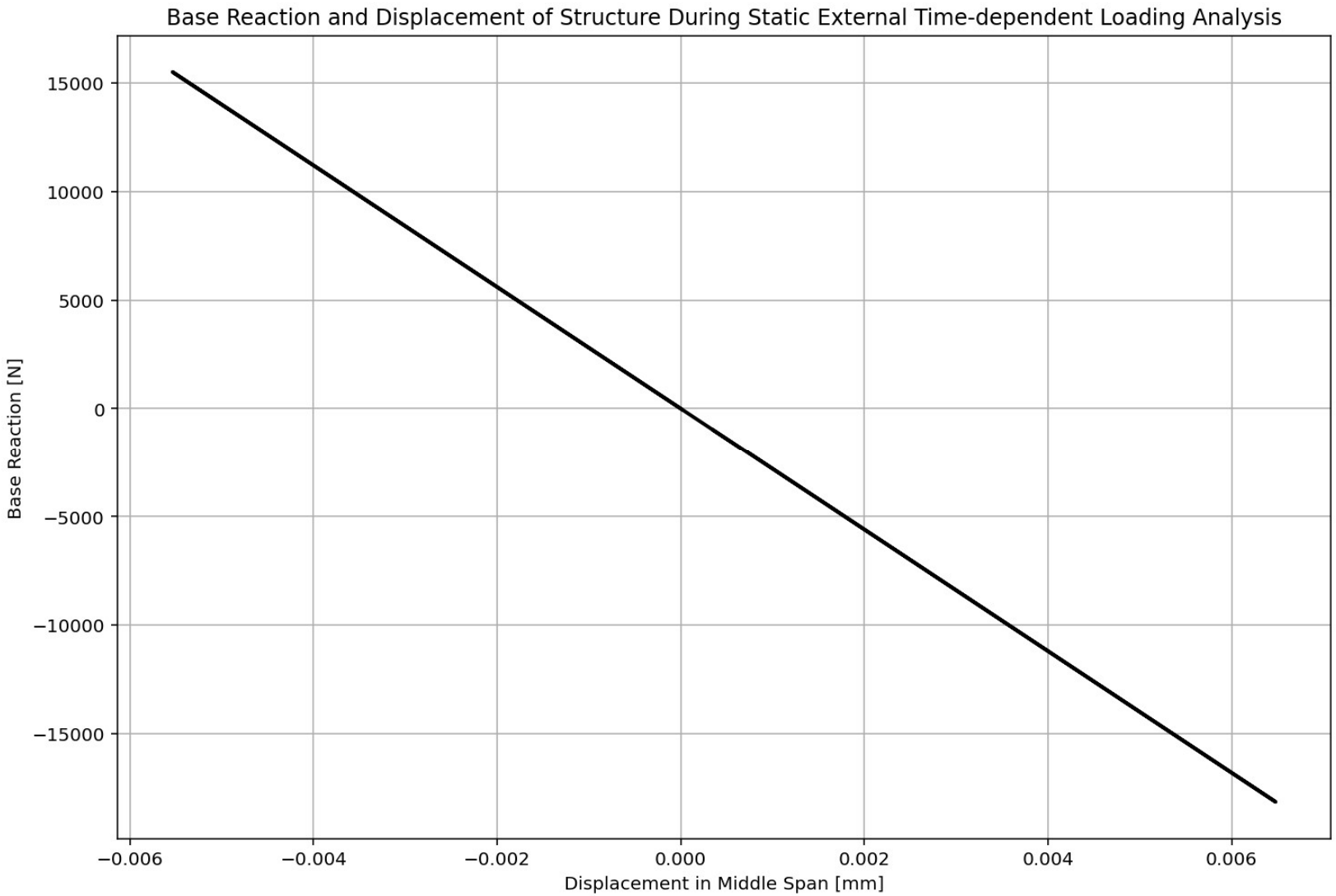
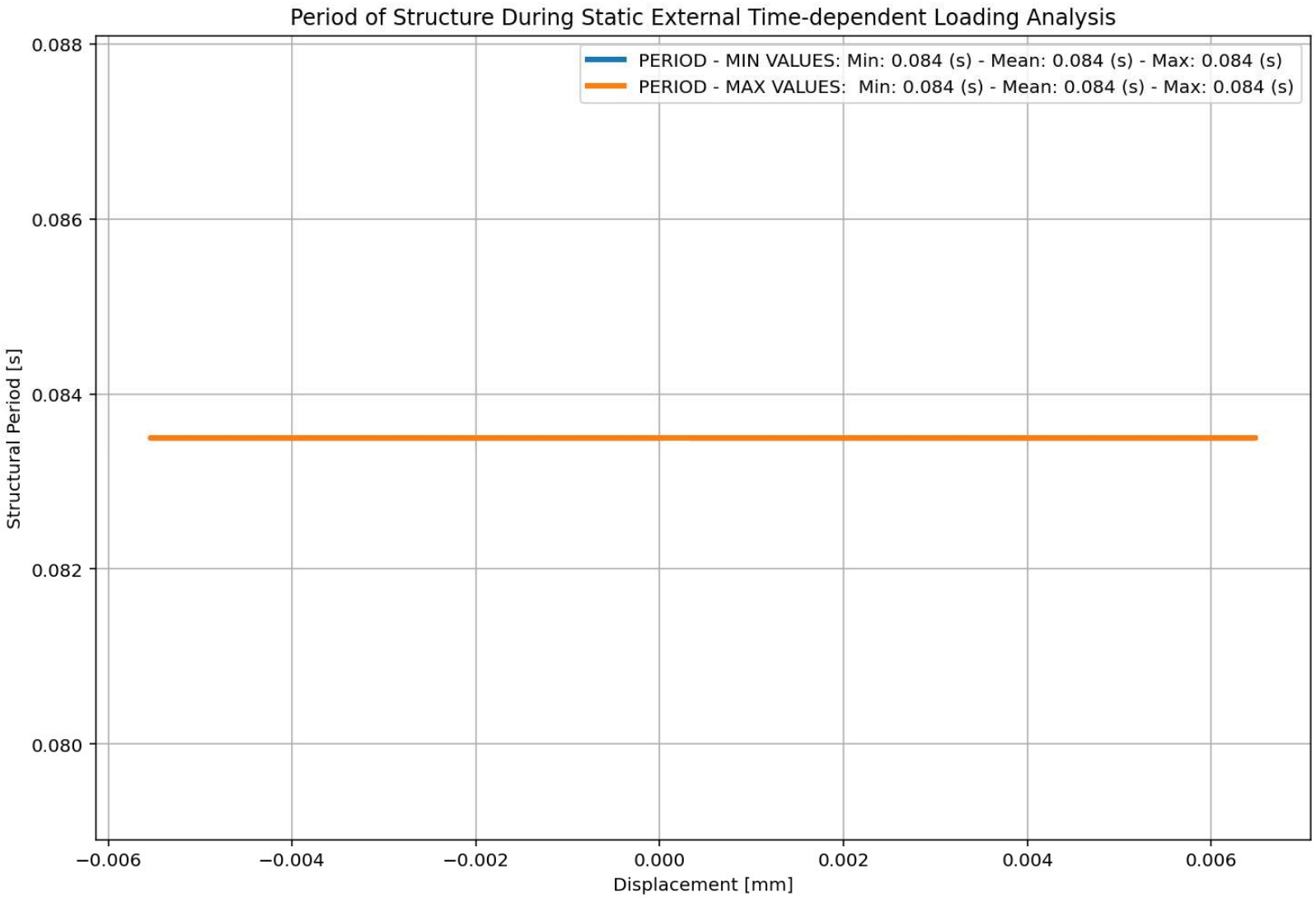
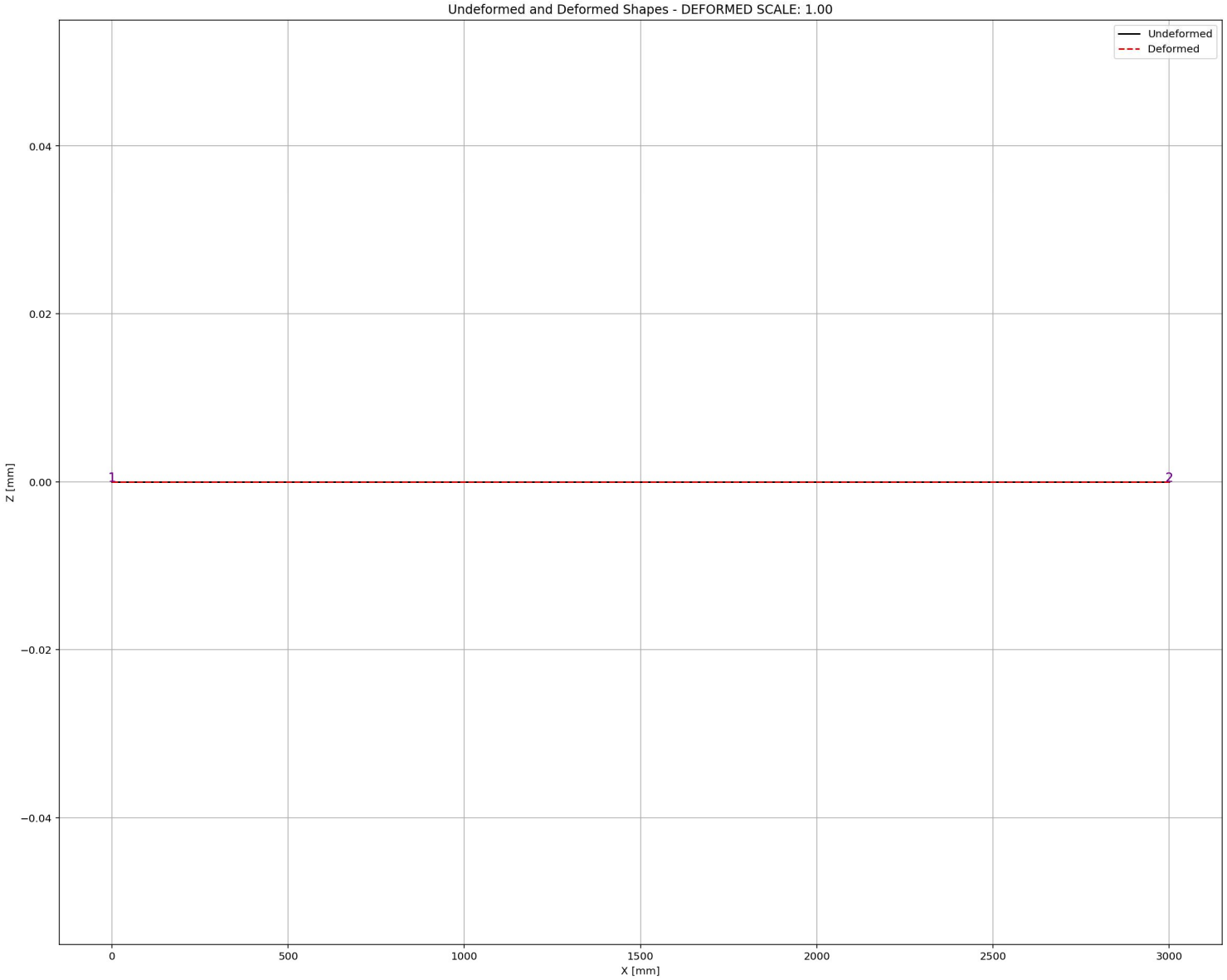
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 48, Col 56 UTF-8 CRLF RW Mem 42%


External Time-dependent Loading Over Time
External Loading - Max: 18142.051
15000
10000
5000
0
−5000
−10000
−15000
Force (N)
0
1
2
3
4
5
Time (s)


Base Reaction and Displacement of Structure During Static External Time-dependent Loading Analysis
Base Reaction [N]
15000
10000
5000
0
−5000
−10000
−15000
−0.006
−0.004
−0.002
0.000
0.002
0.004
0.006
Displacement in Middle Span [mm]


Period of Structure During Static External Time-dependent Loading Analysis
PERIOD - MIN VALUES: Min: 0.084 (s) - Mean: 0.084 (s) - Max: 0.084 (s)
PERIOD - MAX VALUES: Min: 0.084 (s) - Mean: 0.084 (s) - Max: 0.084 (s)
Structural Period [s]
0.088
0.086
0.084
0.082
0.080
−0.006
−0.004
−0.002
0.000
0.002
0.004
0.006
Displacement [mm]


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
0.04
0.02
0.00
−0.02
−0.04
Z [mm]
1
2
0
500
1000
1500
2000
2500
3000
X [mm]

DYNAMIC TIME-HISTORY WITH EXTERNALTIME-DEPENDENTLOADING ANALYSIS

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

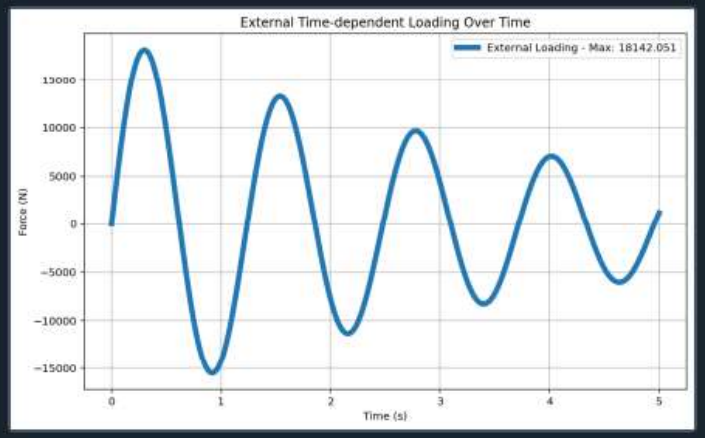
...ENSEES_FILES\+TRUSS_ONE_ELEMENT\BEAM_ONE_ELEMENT_REALSE_M3

C:\Users\Dell\Desktop\OPENSEES_FILES\+TRUSS_ONE_E...E_ELEMENT_REALSE_M3\BEAM_ONE_ELEMENT_REALSE_M3.py

BEAM_ONE_ELEMENT_REALSE_M3.py

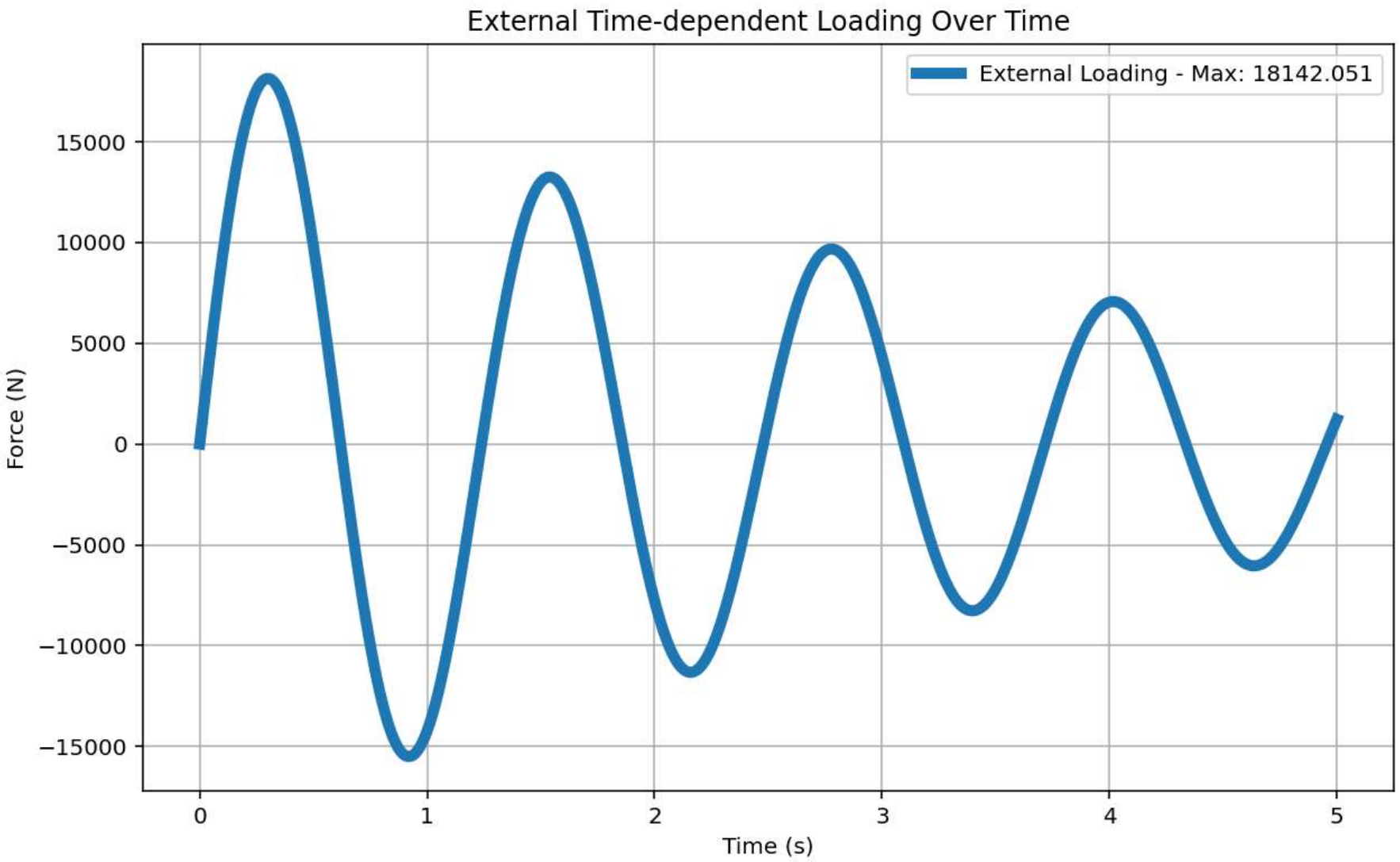
```
1196  # EXTERNAL TIME-DEPENDENT LOADING ANALYSIS (DYNAMIC TIME-HISTORY ANALYSIS)
1197  #ELE_TYPE = 'elasticBeamColumn'      # MATERIAL LINEARITY
1198  ELE_TYPE = 'nonlinearBeamColumn'     # MATERIAL AND GEOMETRIC NONLINEARITIES
1199  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1200  ANAL_TYPE = 'DYNAMIC_EXTERNAL_TIME-DEPENDENT_LOADING'
1201
1202  DATA = TRUSS_ONE_ELEMENT(LENGTH, AREA, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MASS)
1203
1204  (time_ETDLD, reaction_ETDLD, disp_mid_ETDLD,
1205  ele_force_ETDLD, ele_stress_ETDLD, ele_strain_ETDLD, ele_di_ETDLD,
1206  node_displacementsX_ETDLD, node_displacementsY_ETDLD,
1207  dispX_ETDLD, dispY_ETDLD,
1208  veloX_ETDLD, veloY_ETDLD,
1209  accX_ETDLD, accY_ETDLD,
1210  stiffness_ETDLD, PERIOD_ETDLD, damping_ratio_ETDLD,
1211  PERIOD_MIN_ETDLD, PERIOD_MAX_ETDLD,
1212  STRESSb_ETDLD, STRAINb_ETDLD, STRESSt_ETDLD, STRAINt_ETDLD, CURVATURE_ETDLD) = DATA
1213
1214
1215  XDATA = disp_mid_ETDLD
1216  YDATA = reaction_ETDLD
1217  XLABEL = 'Displacement in Middle Span [mm]'
1218  YLABEL = 'Base Reaction [N]'
1219  TITLE = 'Base Reaction and Displacement of Structure During Dynamic External Time-dependen
1220  COLOR = 'black'
1221  SEMILOGY = False
1222  PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1223
1224  PLOT_TIME_HISTORY(time_ETDLD, reaction_ETDLD, disp_mid_ETDLD,
1225                    dispX_ETDLD, dispY_ETDLD,
1226                    veloX_ETDLD, veloY_ETDLD,
1227                    accX_ETDLD, accY_ETDLD)
1228
1229  # PLOT ELEMENTS AXIAL FORCE
```

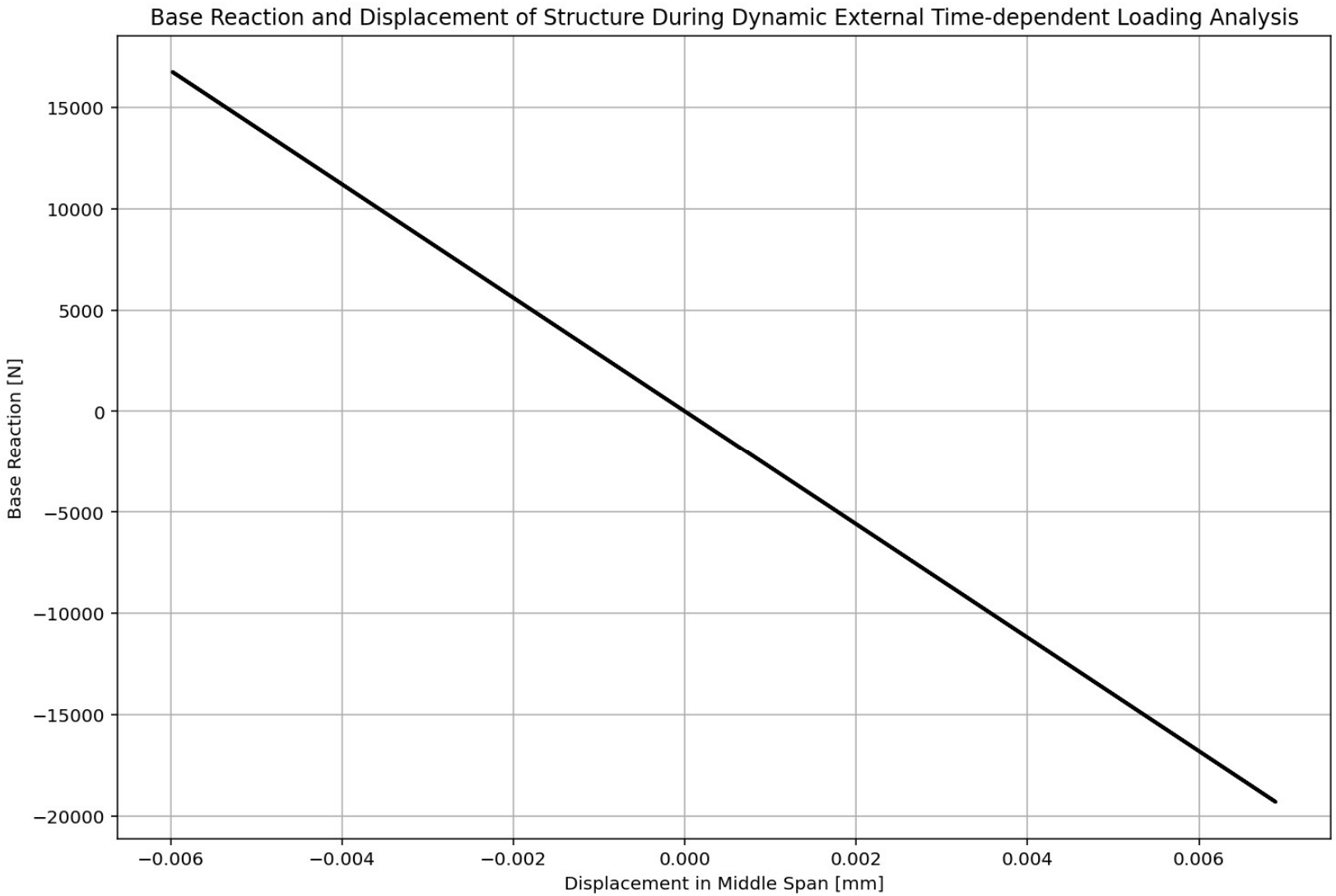
35 %

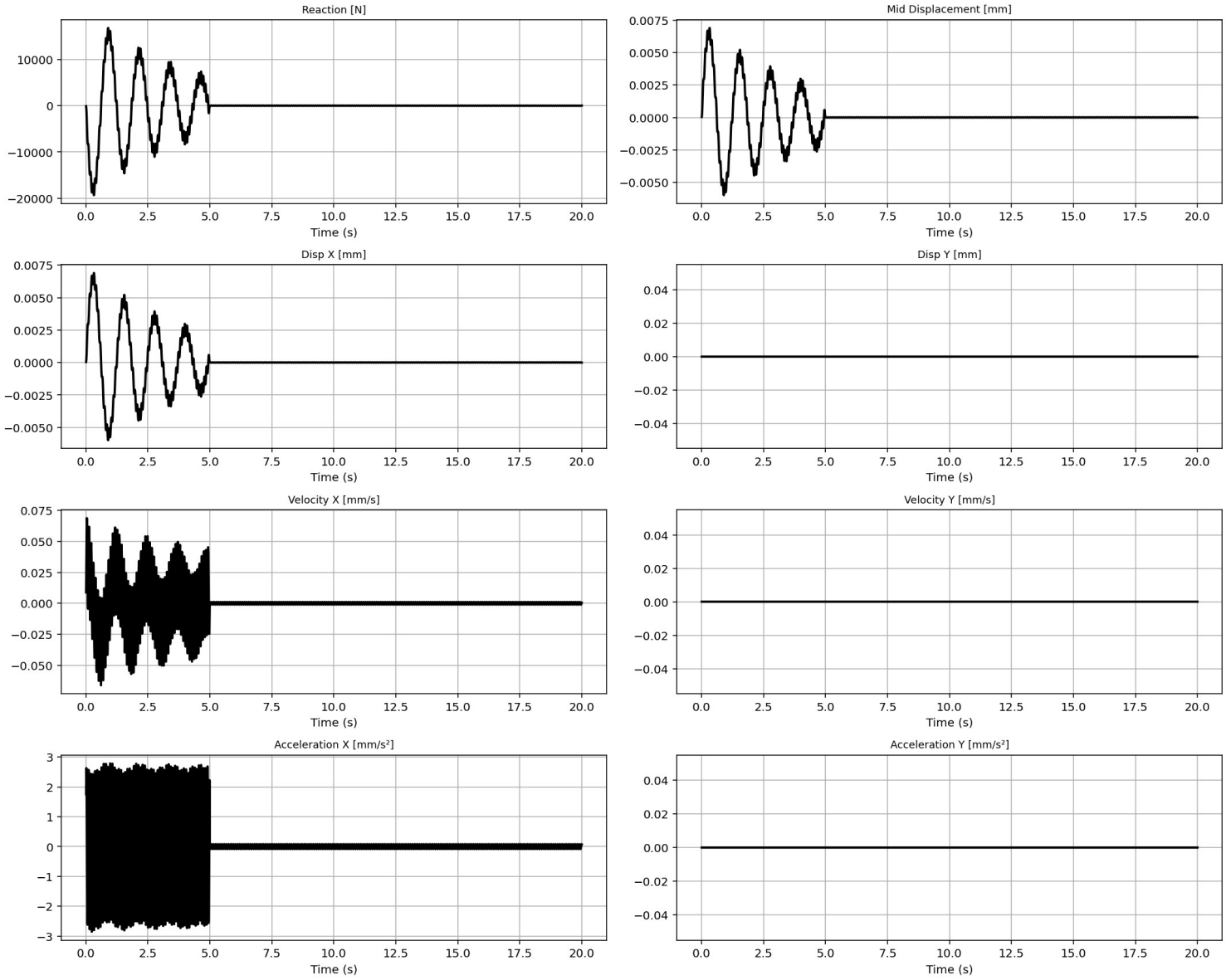


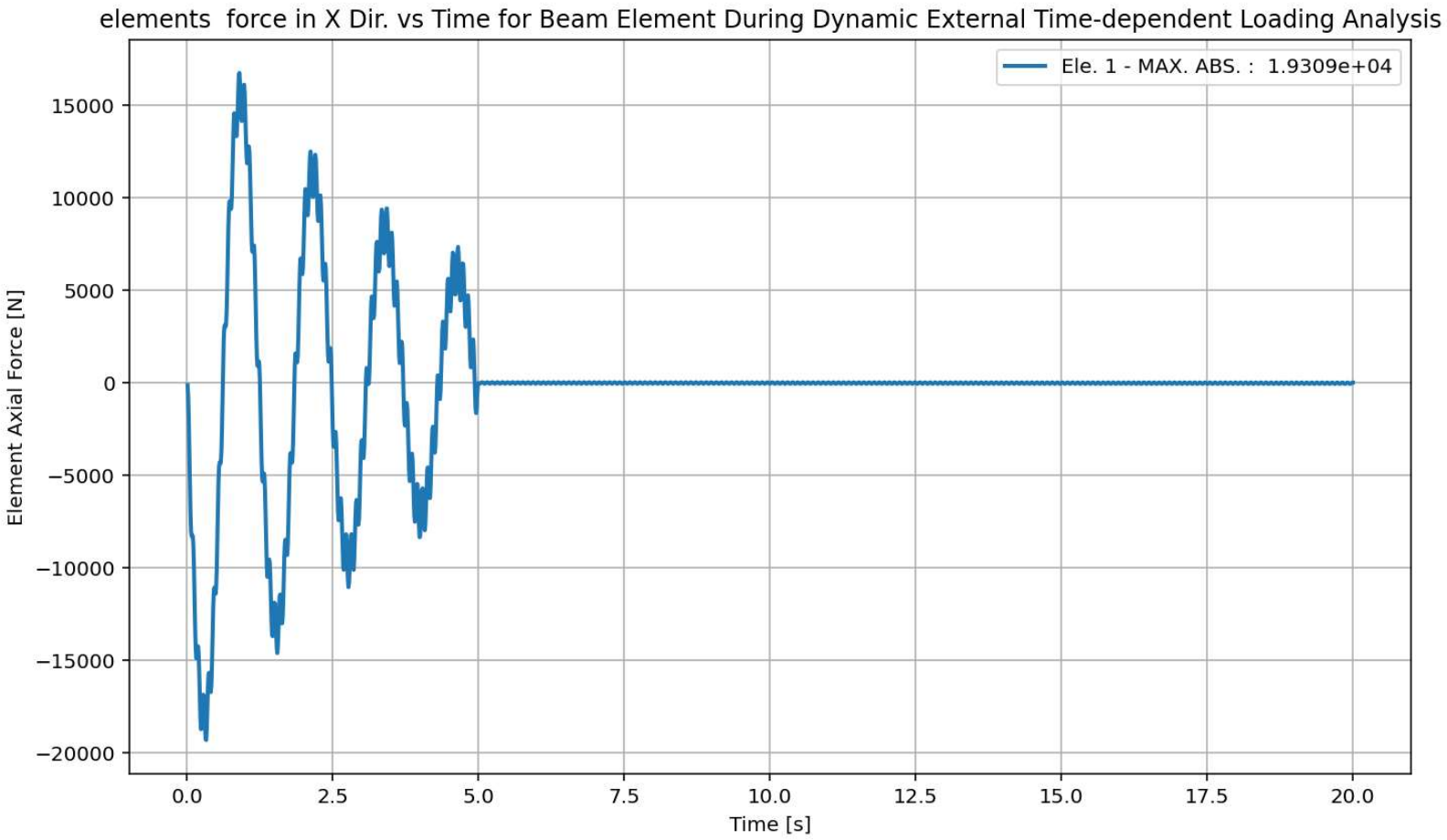
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

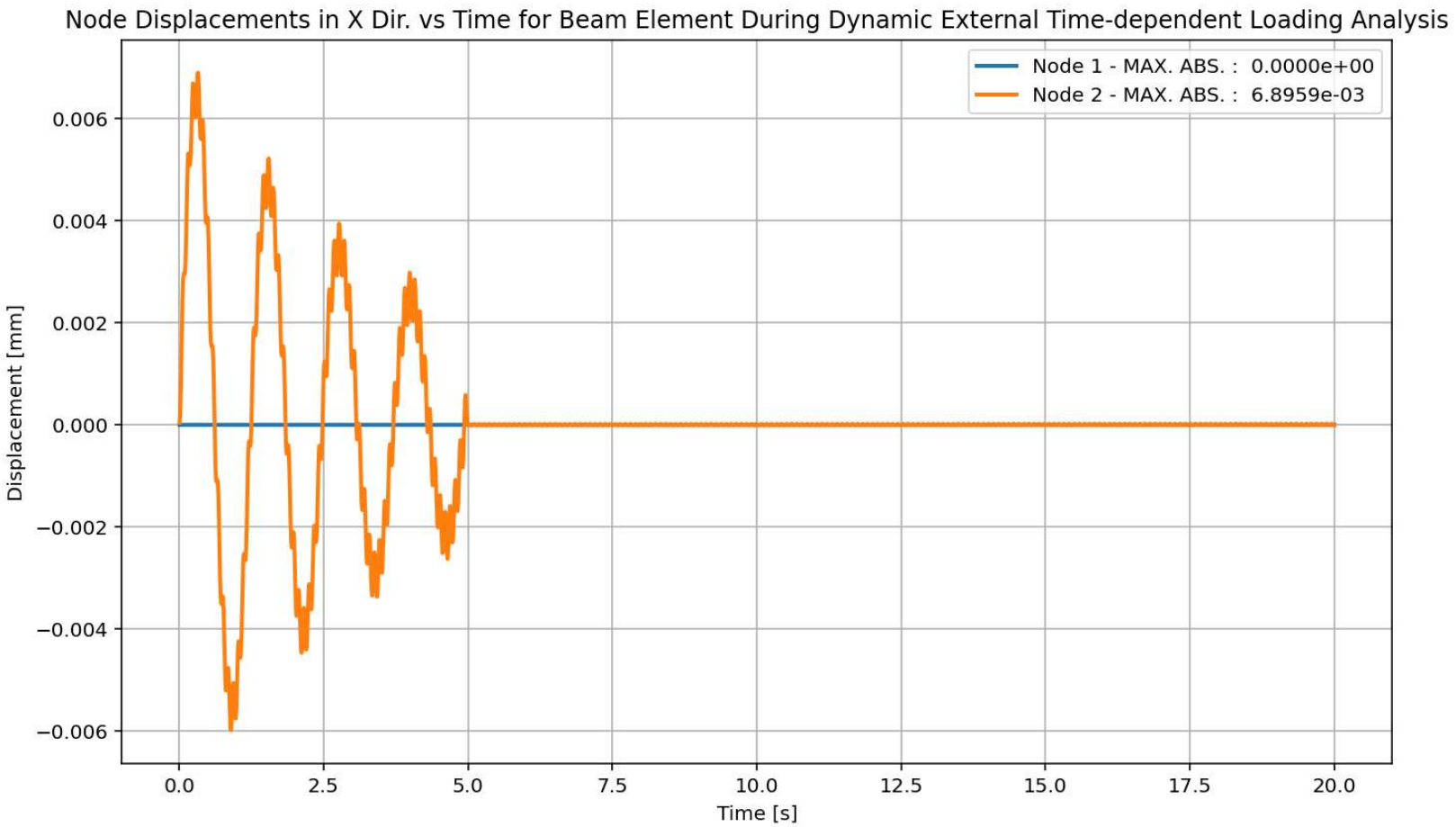
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 48, Col 56 UTF-8 CRLF RW Mem 42%

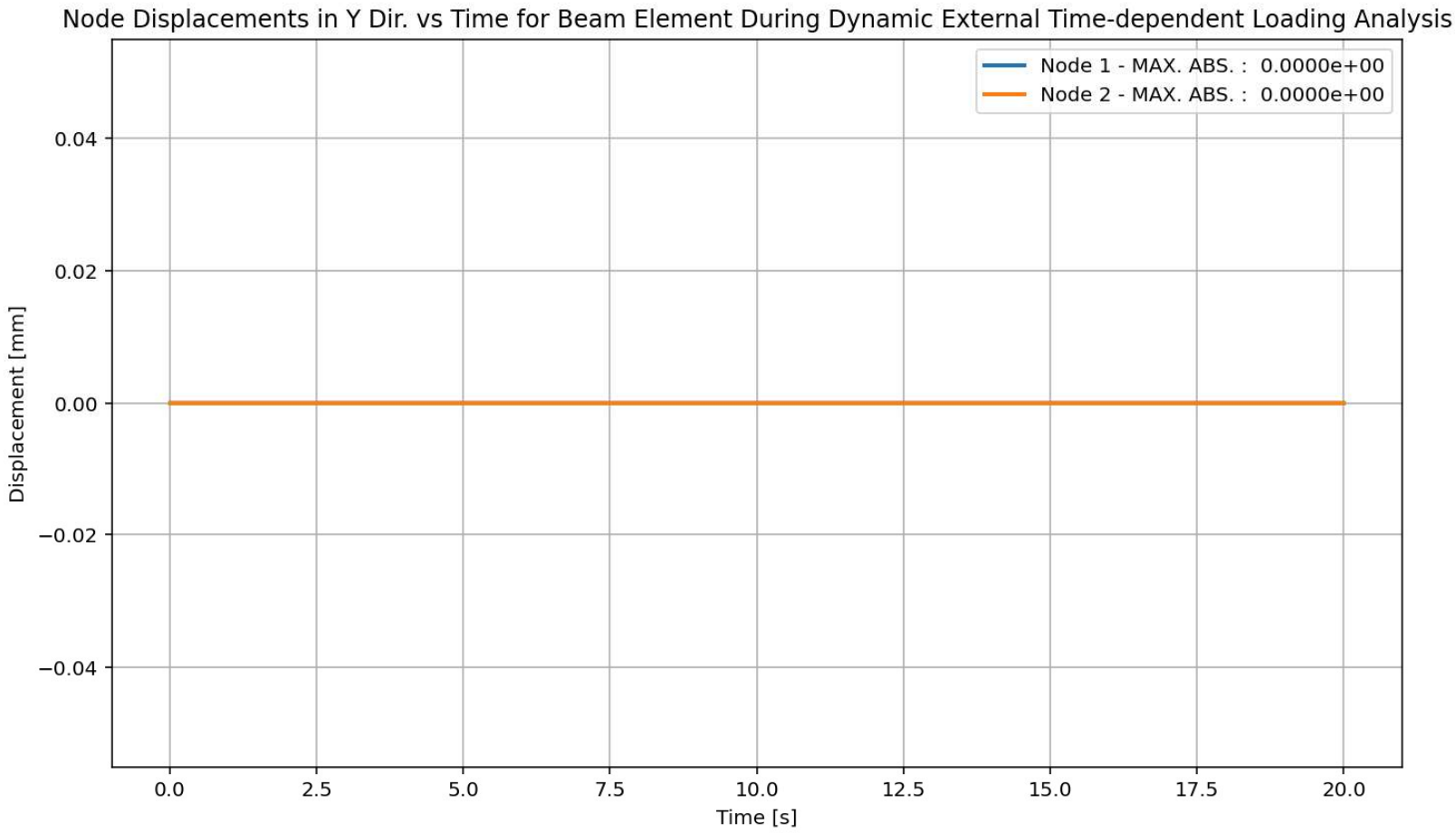

External Time-dependent Loading Over Time
External Loading - Max: 18142.051
15000
10000
5000
0
−5000
−10000
−15000
Force (N)
0
1
2
3
4
5
Time (s)

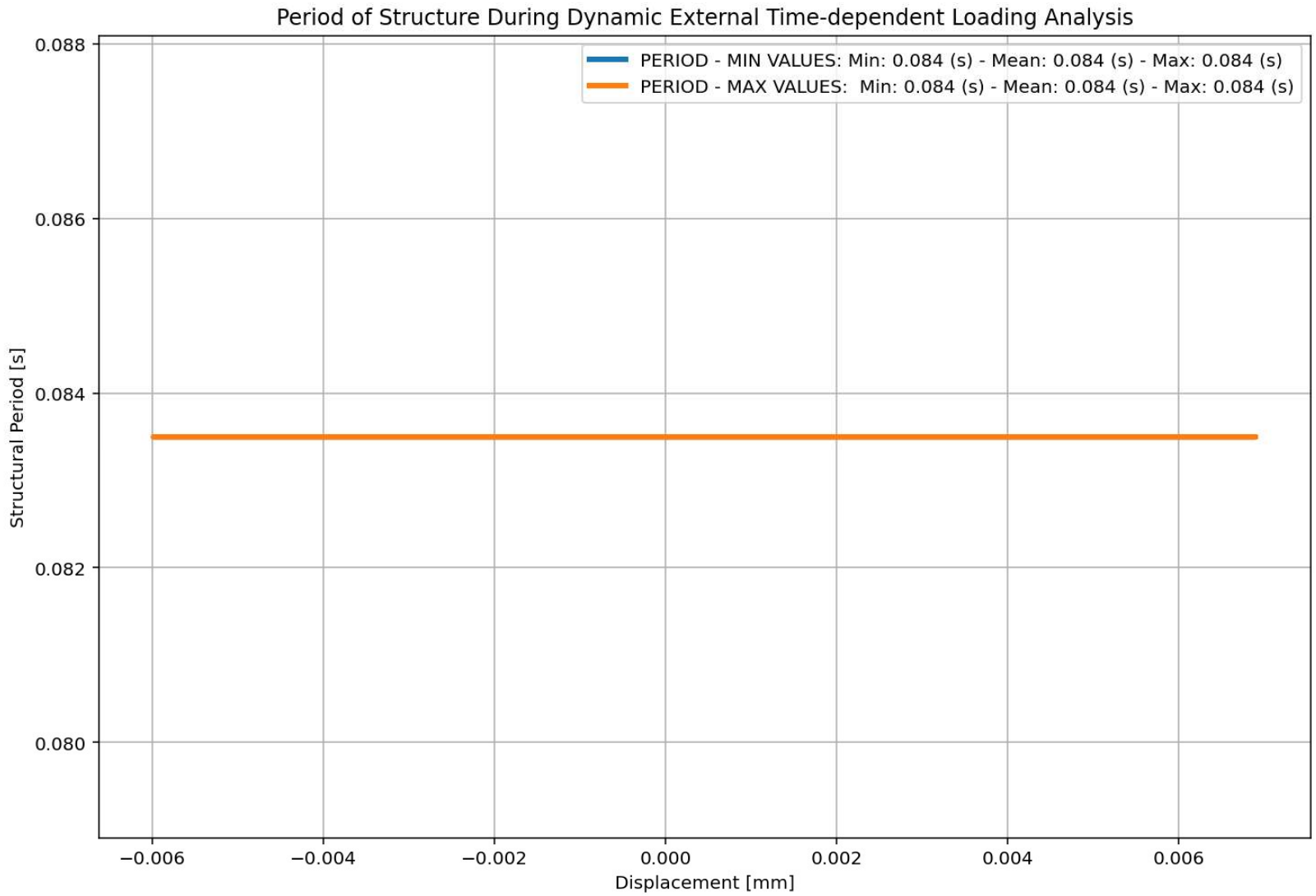

Base Reaction and Displacement of Structure During Dynamic External Time-dependent Loading Analysis
Base Reaction [N]
15000
10000
5000
0
−5000
−10000
−15000
−20000
−0.006
−0.004
−0.002
0.000
0.002
0.004
0.006
Displacement in Middle Span [mm]

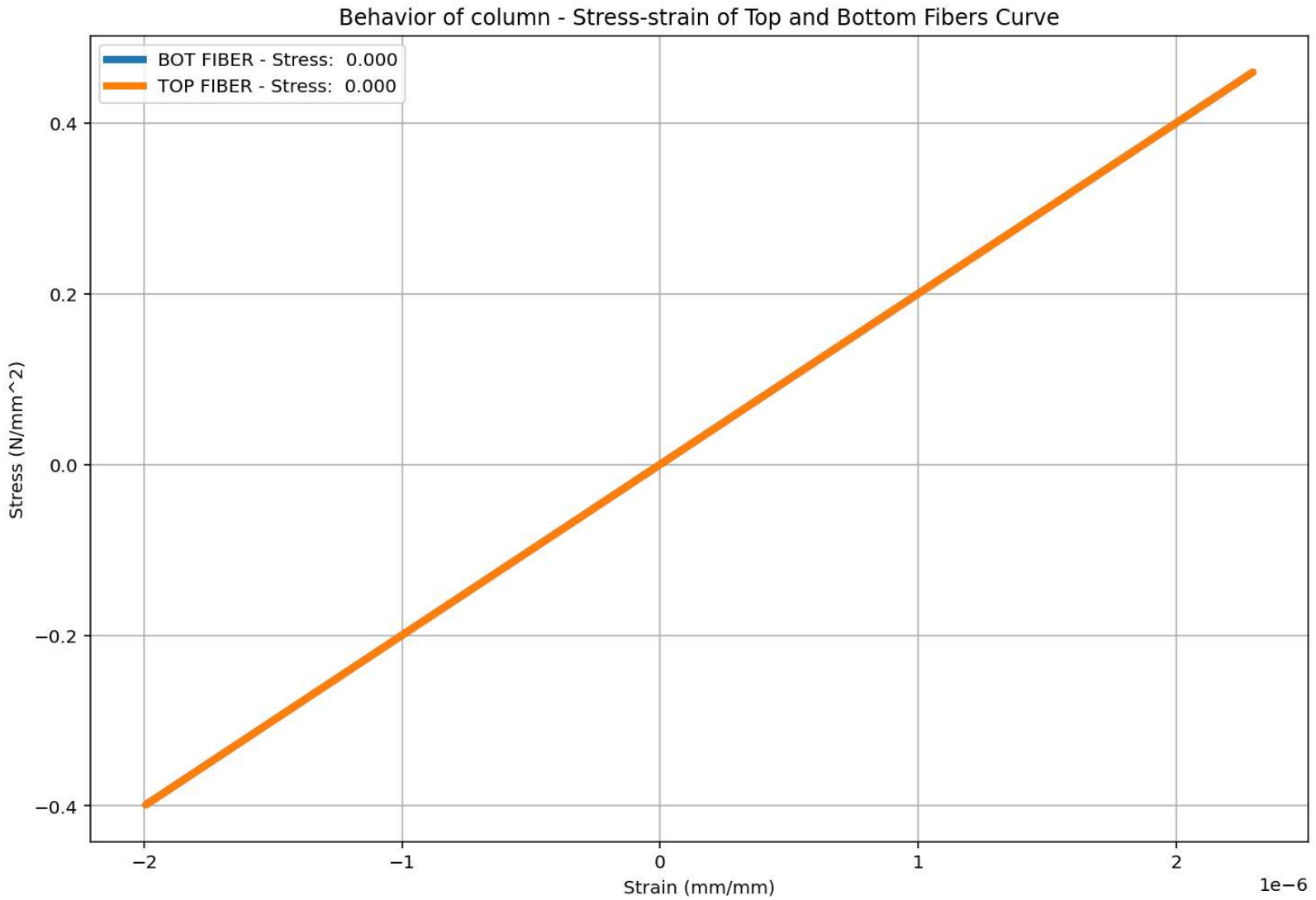

Reaction [N]
Time (s)
Mid Displacement [mm]
Time (s)
Disp X [mm]
Time (s)
Disp Y [mm]
Time (s)
Velocity X [mm/s]
Time (s)
Velocity Y [mm/s]
Time (s)
Acceleration X [mm/s²]
Time (s)
Acceleration Y [mm/s²]
Time (s)

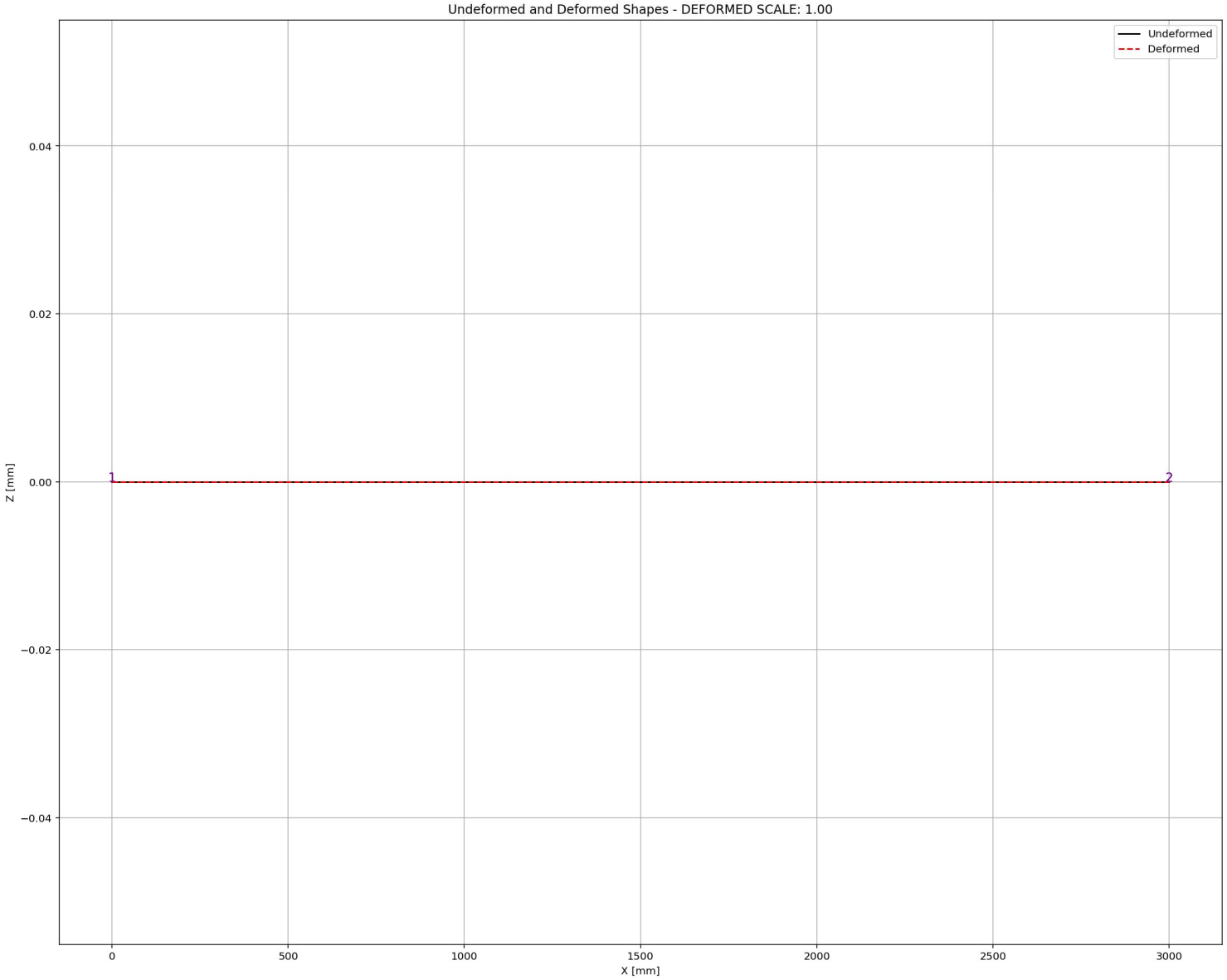

elements force in X Dir. vs Time for Beam Element During Dynamic External Time-dependent Loading Analysis
Ele. 1 - MAX. ABS. : 1.9309e+04
Element Axial Force [N]
15000
10000
5000
0
−5000
−10000
−15000
−20000
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Node Displacements in X Dir. vs Time for Beam Element During Dynamic External Time-dependent Loading Analysis
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 6.8959e-03
Displacement [mm]
0.006
0.004
0.002
0.000
−0.002
−0.004
−0.006
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Node Displacements in Y Dir. vs Time for Beam Element During Dynamic External Time-dependent Loading Analysis
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 0.0000e+00
0.04
0.02
0.00
−0.02
−0.04
Displacement [mm]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Period of Structure During Dynamic External Time-dependent Loading Analysis
PERIOD - MIN VALUES: Min: 0.084 (s) - Mean: 0.084 (s) - Max: 0.084 (s)
PERIOD - MAX VALUES: Min: 0.084 (s) - Mean: 0.084 (s) - Max: 0.084 (s)
Structural Period [s]
0.088
0.086
0.084
0.082
0.080
−0.006
−0.004
−0.002
0.000
0.002
0.004
0.006
Displacement [mm]


Behavior of column - Stress-strain of Top and Bottom Fibers Curve
BOT FIBER - Stress: 0.000
TOP FIBER - Stress: 0.000
0.4
0.2
0.0
−0.2
−0.4
Stress (N/mm^2)
−2
−1
0
1
2
Strain (mm/mm)
1e−6


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
0.04
0.02
0.00
−0.02
−0.04
Z [mm]
1
2
0
500
1000
1500
2000
2500
3000
X [mm]

FREE-VIBRATION ANALYSIS

Spyder (Python 3.12)

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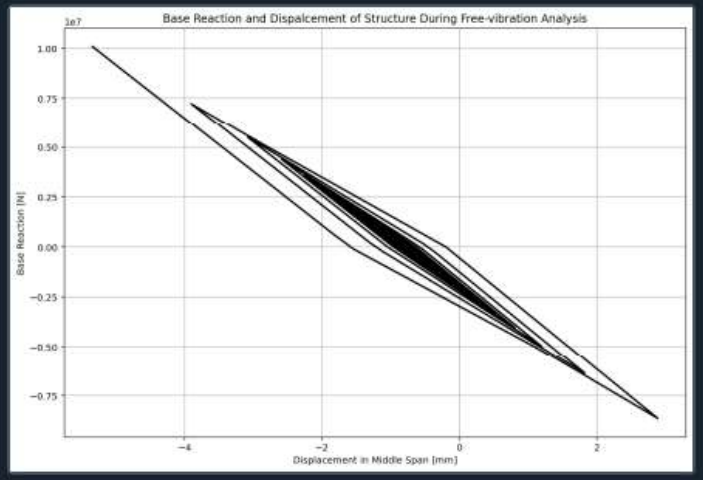
...ENSEES_FILES\+TRUSS_ONE_ELEMENT\BEAM_ONE_ELEMENT_REALSE_M3

C:\Users\Dell\Desktop\OPENSEES_FILES\+TRUSS_ONE_E...E_ELEMENT_REALSE_M3\BEAM_ONE_ELEMENT_REALSE_M3.py

BEAM_ONE_ELEMENT_REALSE_M3.py

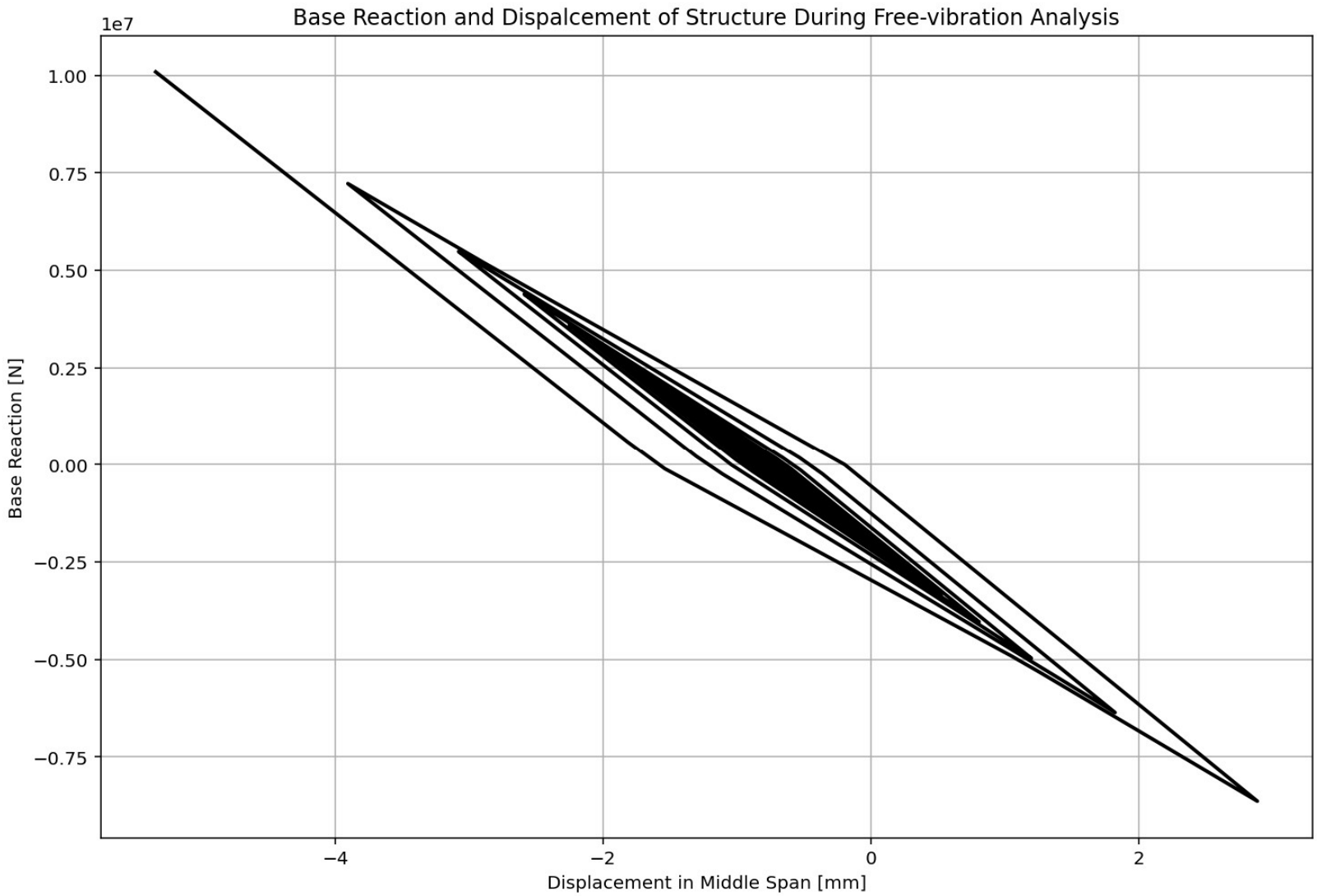
```
1278  # FREE-VIBRATION ANALYSIS (DYNAMIC TIME-HISTORY ANALYSIS)
1279  #ELE_TYPE = 'elasticBeamColumn'      # MATERIAL LINEARITY
1280  ELE_TYPE = 'nonlinearBeamColumn'     # MATERIAL AND GEOMETRIC NONLINEARITIES
1281  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1282  ANAL_TYPE = 'FREE-VIBRATION'
1283  DATA = TRUSS_ONE_ELEMENT(LENGTH, AREA, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MASS)
1284
1285  (time_FV, reaction_FV, disp_mid_FV,
1286  ele_force_FV, ele_stress_FV, ele_strain_FV, ele_di_FV,
1287  node_displacementsX_FV, node_displacementsY_FV,
1288  dispX_FV, dispY_FV,
1289  veloX_FV, veloY_FV,
1290  accX_FV, accY_FV,
1291  stiffness_FV, PERIOD_FV, damping_ratio_FV,
1292  PERIOD_MIN_FV, PERIOD_MAX_FV,
1293  STRESSb_FV, STRAINb_FV, STRESSt_FV, STRAINt_FV, CURVATURE_FV) = DATA
1294
1295  XDATA = disp_mid_FV
1296  YDATA = reaction_FV
1297  XLABEL = 'Displacement in Middle Span [mm]'
1298  YLABEL = 'Base Reaction [N]'
1299  TITLE = 'Base Reaction and Dispalcement of Structure During Free-vibration Analysis'
1300  COLOR = 'black'
1301  SEMILOGY = False
1302  PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1303
1304  PLOT_TIME_HISTORY(time_FV, reaction_FV, disp_mid_FV,
1305                          dispX_FV, dispY_FV,
1306                          veloX_FV, veloY_FV,
1307                          accX_FV, accY_FV)
1308
1309  # PLOT ELEMENTS AXIAL FORCE
1310  YLABEL = 'Element Axial Force [N]'
1311  TITLE = "elements  force in X Dir. vs Time for Beam Element During Free-vibration Analysis
```

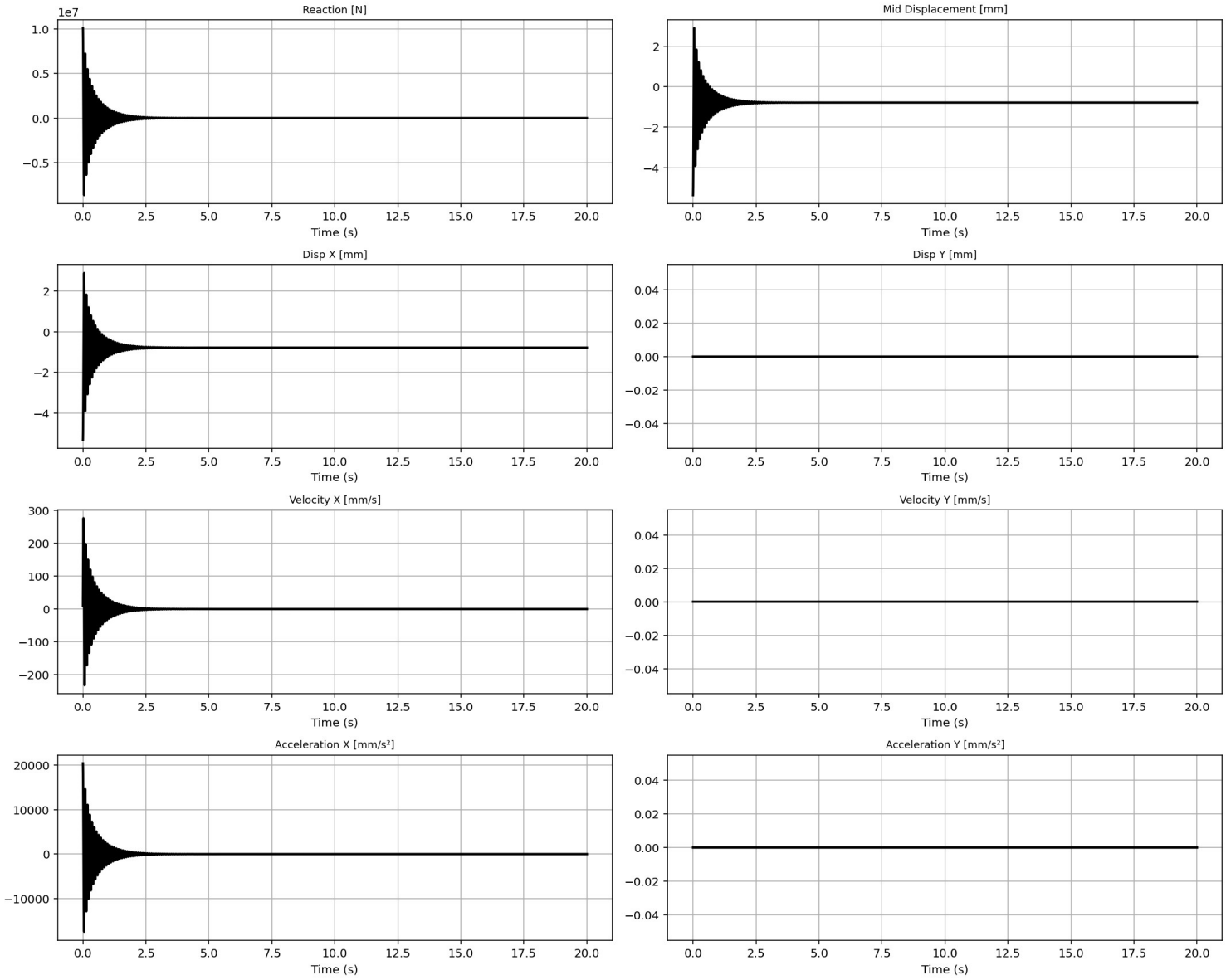
30 %

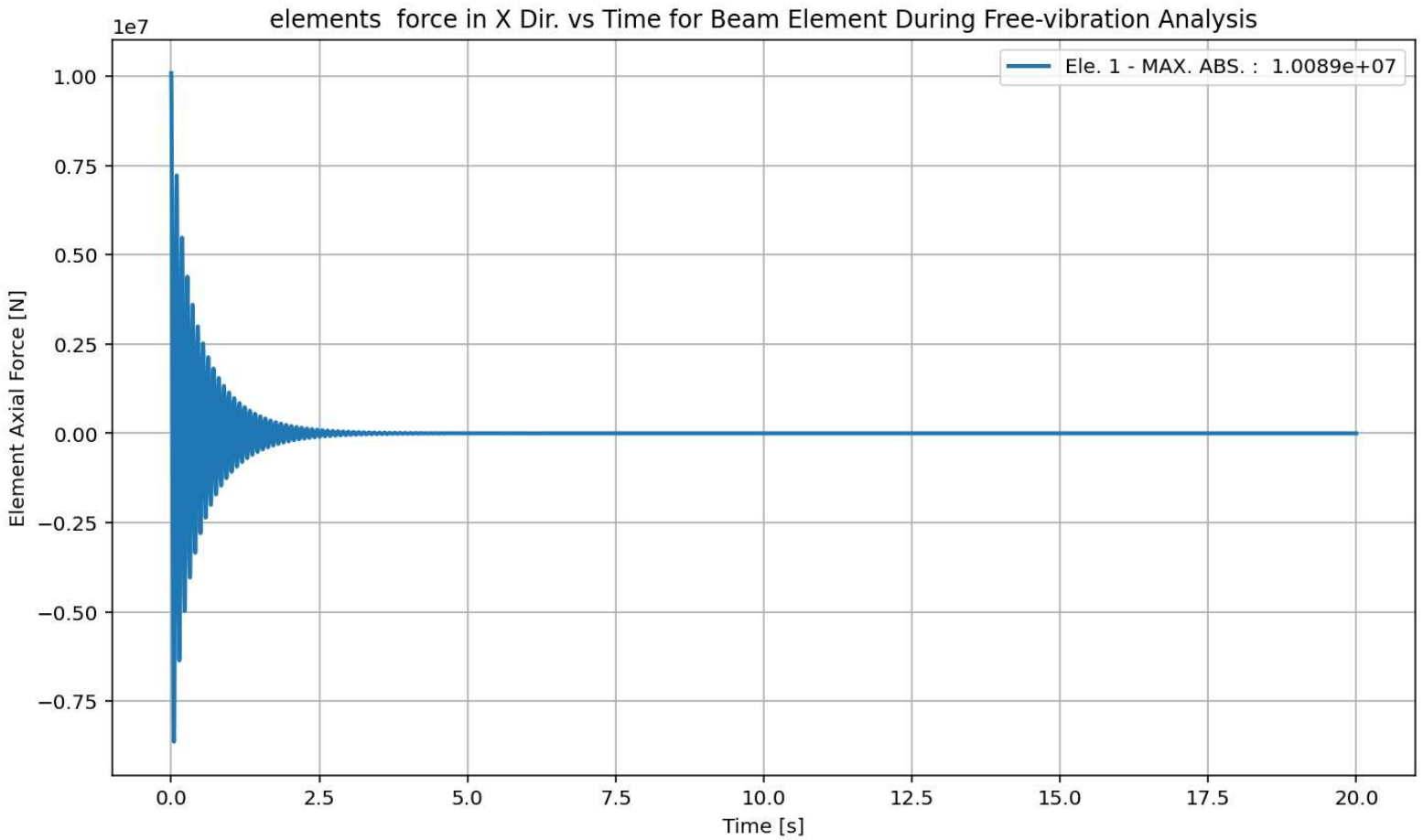


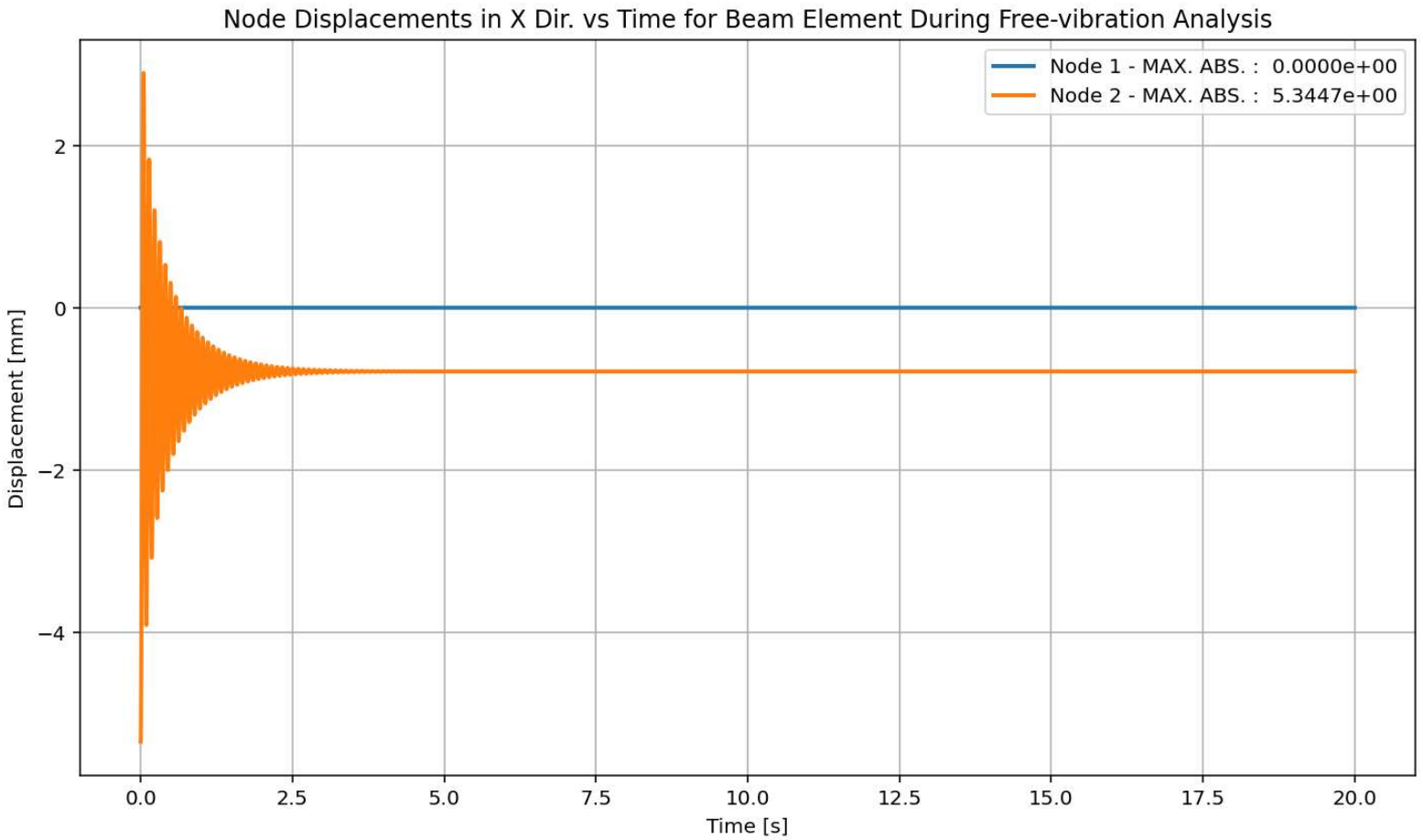
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

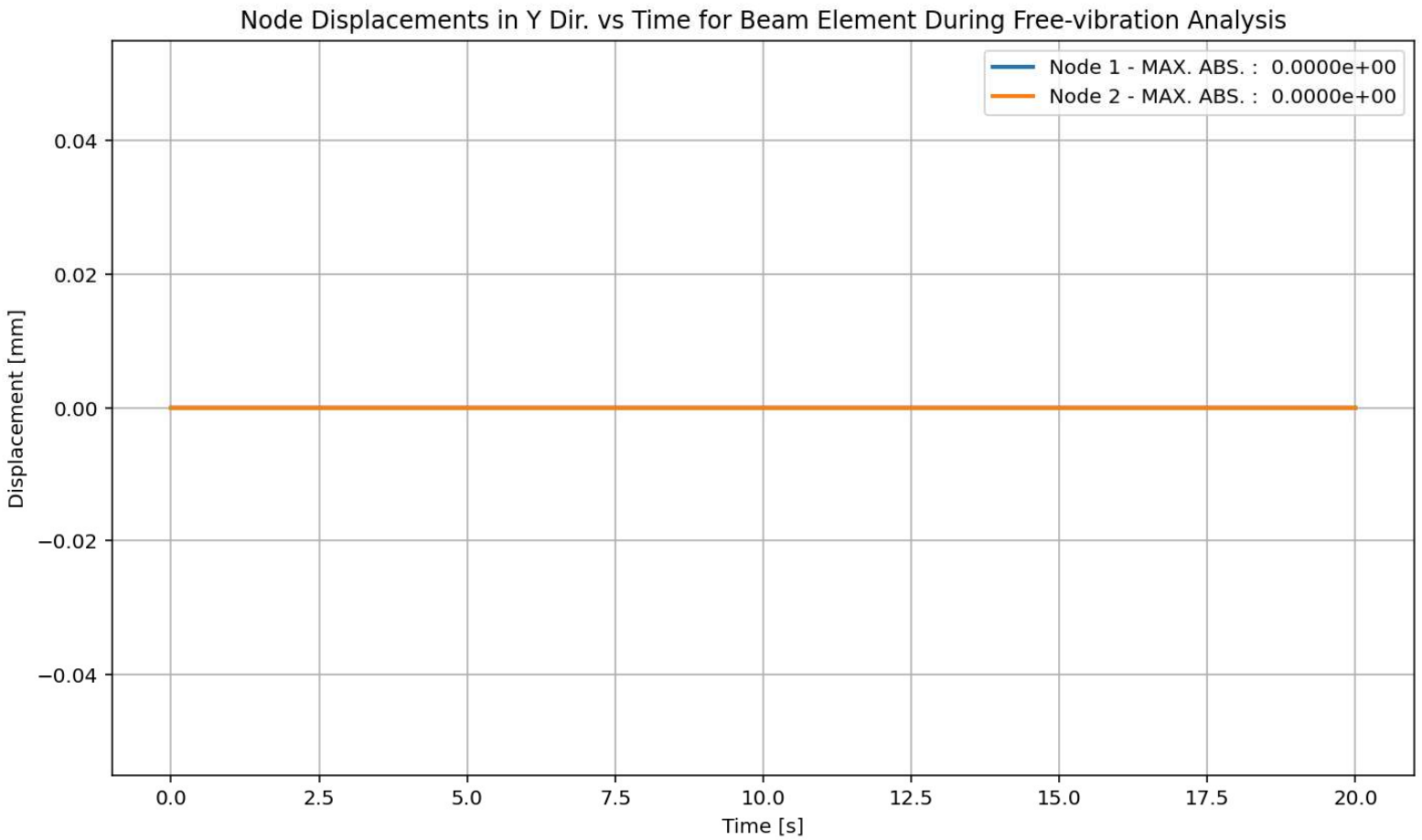
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 48, Col 56 UTF-8 CRLF RW Mem 43%

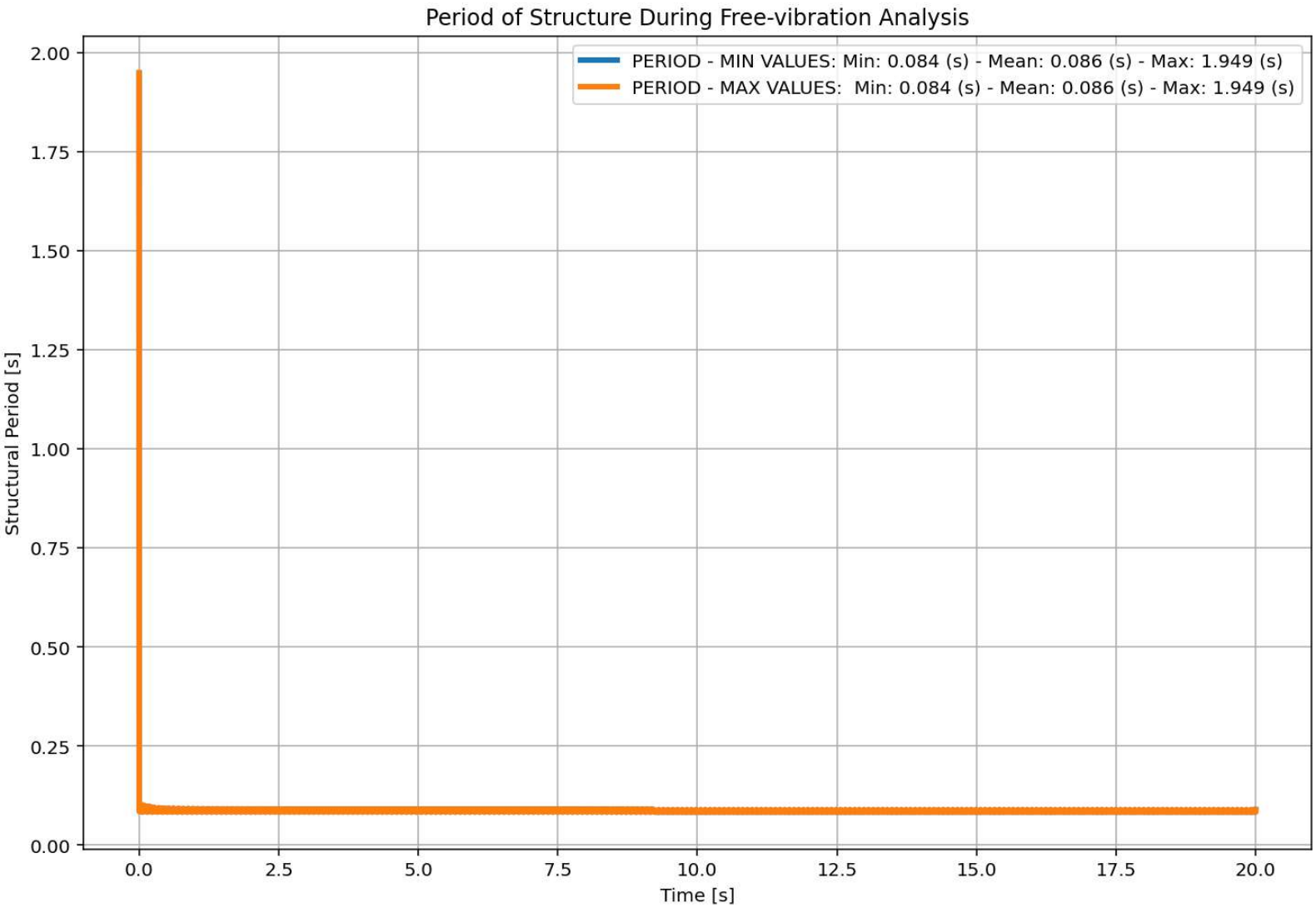

Base Reaction and Dispalcement of Structure During Free-vibration Analysis
1e7
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
Base Reaction [N]
−4
−2
0
2
Displacement in Middle Span [mm]

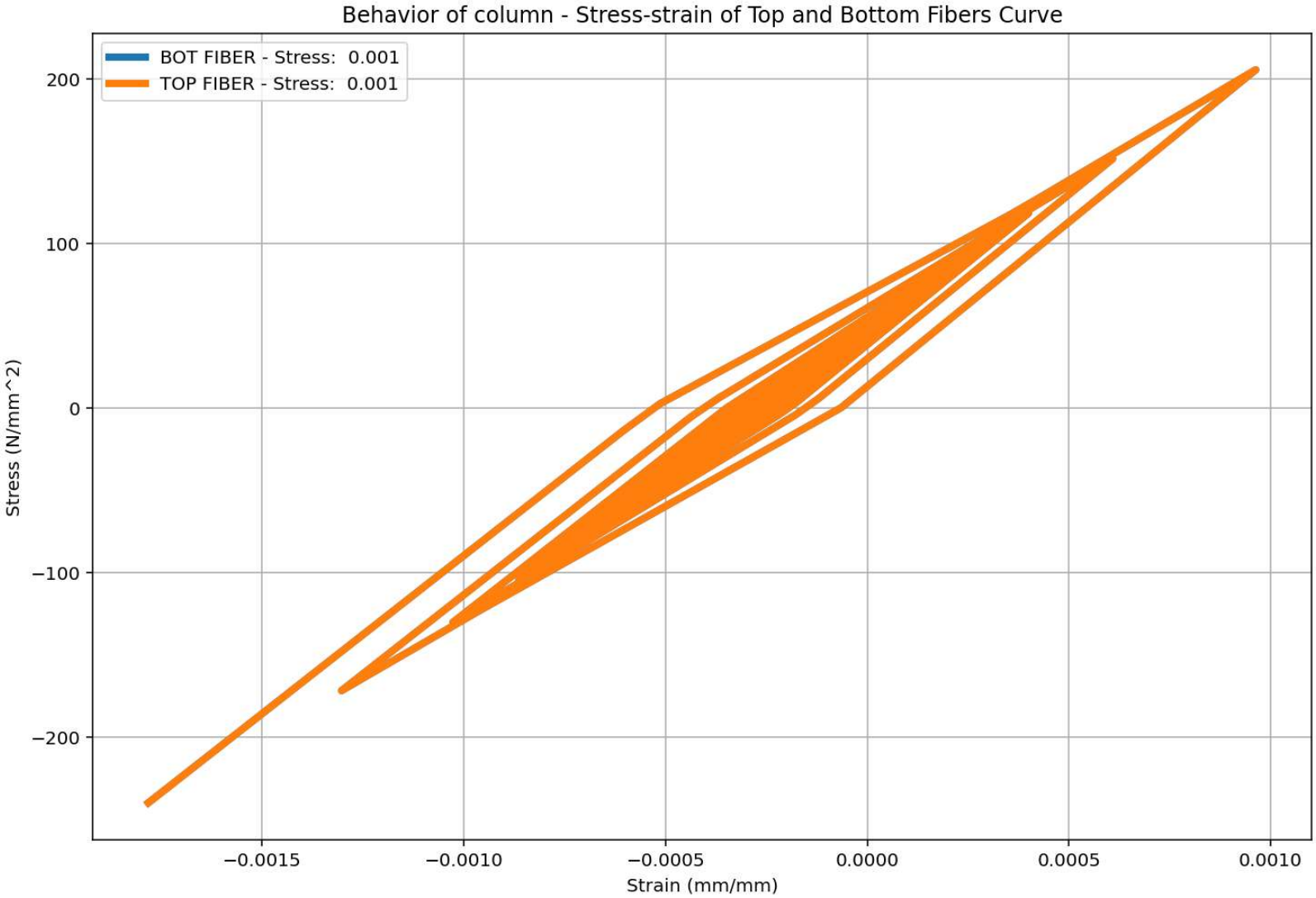

Reaction [N]
1e7
1.0
0.5
0.0
−0.5
Mid Displacement [mm]
2
0
−2
−4
Disp X [mm]
Disp Y [mm]
0.04
0.02
0.00
−0.02
−0.04
Velocity X [mm/s]
300
200
100
0
−100
−200
Velocity Y [mm/s]
Acceleration X [mm/s²]
20000
10000
−10000
Acceleration Y [mm/s²]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (s)

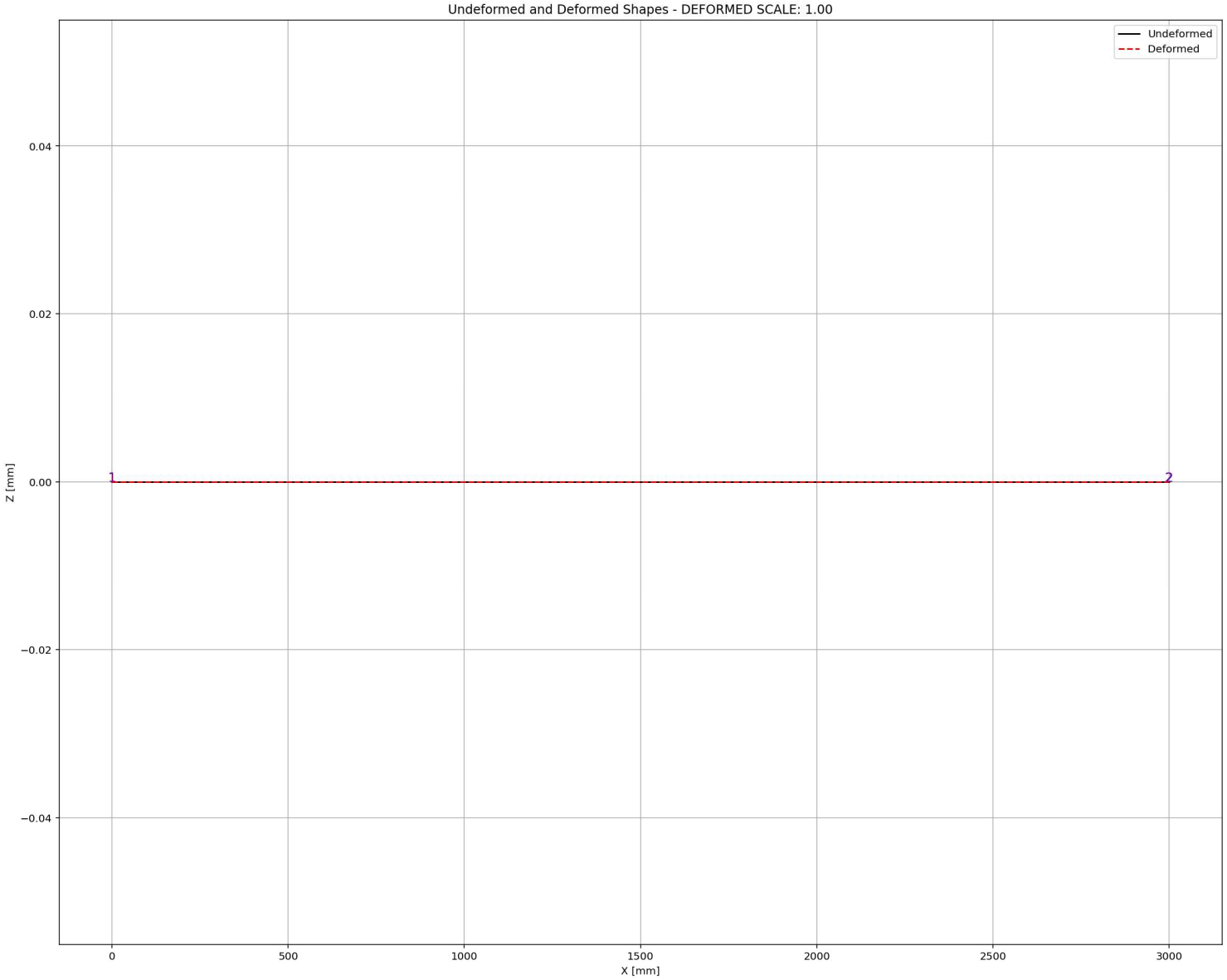

elements force in X Dir. vs Time for Beam Element During Free-vibration Analysis
1e7
Ele. 1 - MAX. ABS. : 1.0089e+07
Element Axial Force [N]
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Node Displacements in X Dir. vs Time for Beam Element During Free-vibration Analysis
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 5.3447e+00
Displacement [mm]
2
0
−2
−4
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Node Displacements in Y Dir. vs Time for Beam Element During Free-vibration Analysis
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 0.0000e+00
Displacement [mm]
0.04
0.02
0.00
−0.02
−0.04
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Period of Structure During Free-vibration Analysis
PERIOD - MIN VALUES: Min: 0.084 (s) - Mean: 0.086 (s) - Max: 1.949 (s)
PERIOD - MAX VALUES: Min: 0.084 (s) - Mean: 0.086 (s) - Max: 1.949 (s)
Structural Period [s]
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Behavior of column - Stress-strain of Top and Bottom Fibers Curve
BOT FIBER - Stress: 0.001
TOP FIBER - Stress: 0.001
200
100
0
−100
−200
Stress (N/mm^2)
−0.0015
−0.0010
−0.0005
0.0000
0.0005
0.0010
Strain (mm/mm)


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
0.04
0.02
0.00
−0.02
−0.04
Z [mm]
1
2
0
500
1000
1500
2000
2500
3000
X [mm]

SEISMIC ANALYSIS

Spyder (Python 3.12)

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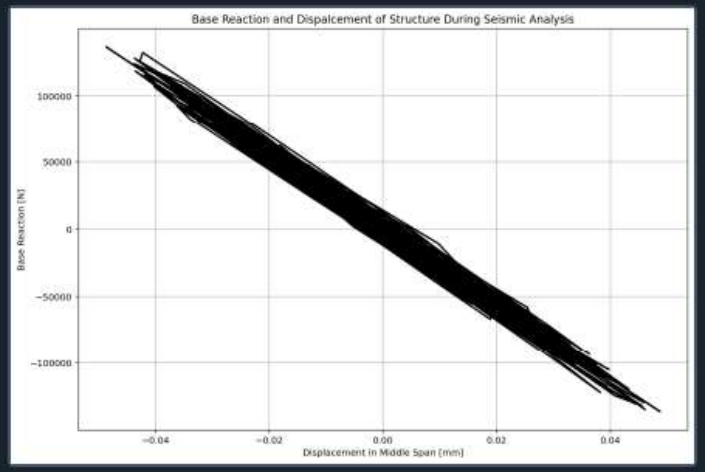
C:\Users\Dell\Desktop\OPENSEES_FILES\+TRUSS_ONE_E...E_ELEMENT_REALSE_M3\BEAM_ONE_ELEMENT_REALSE_M3.py

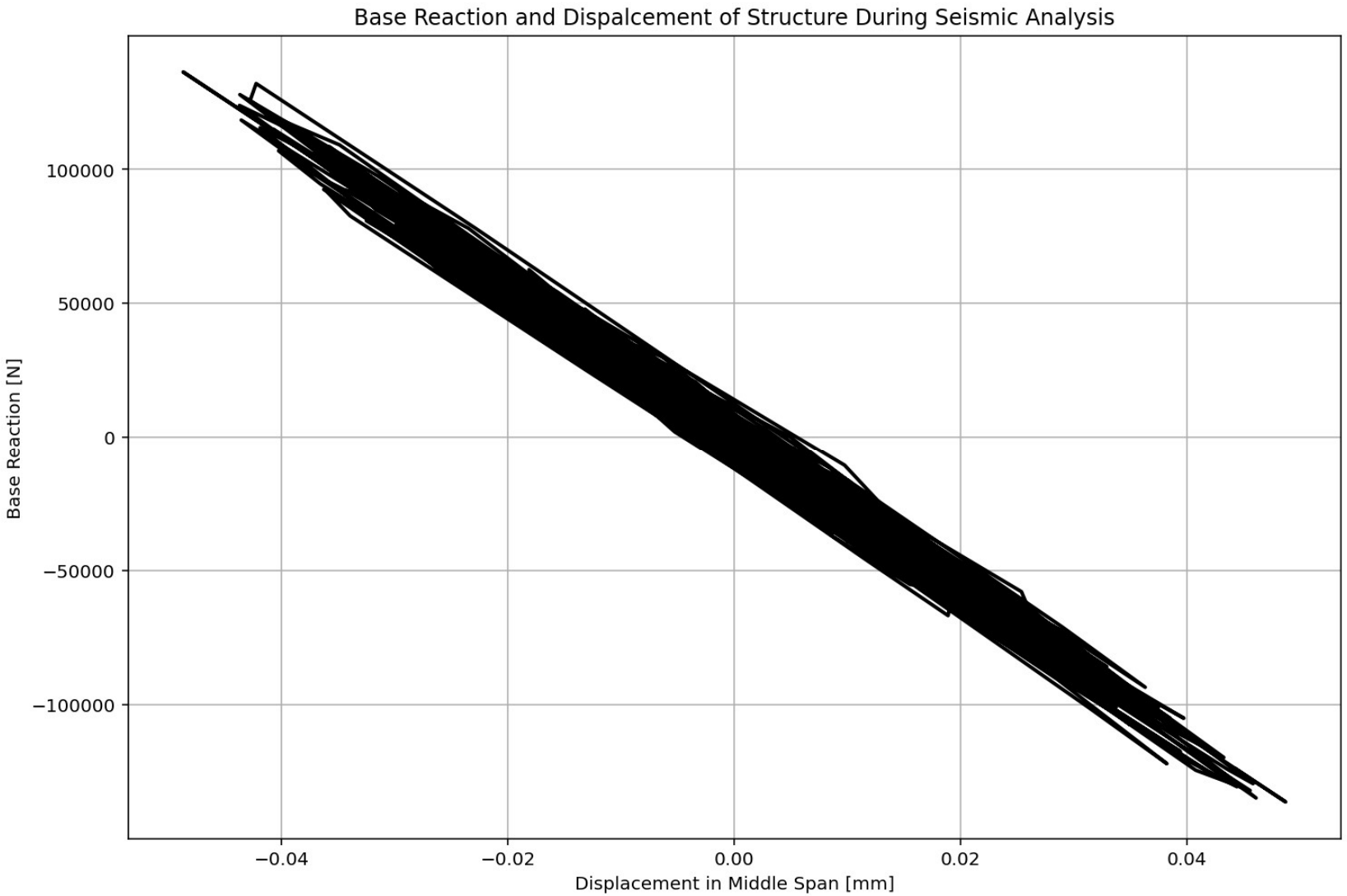
BEAM_ONE_ELEMENT_REALSE_M3.py

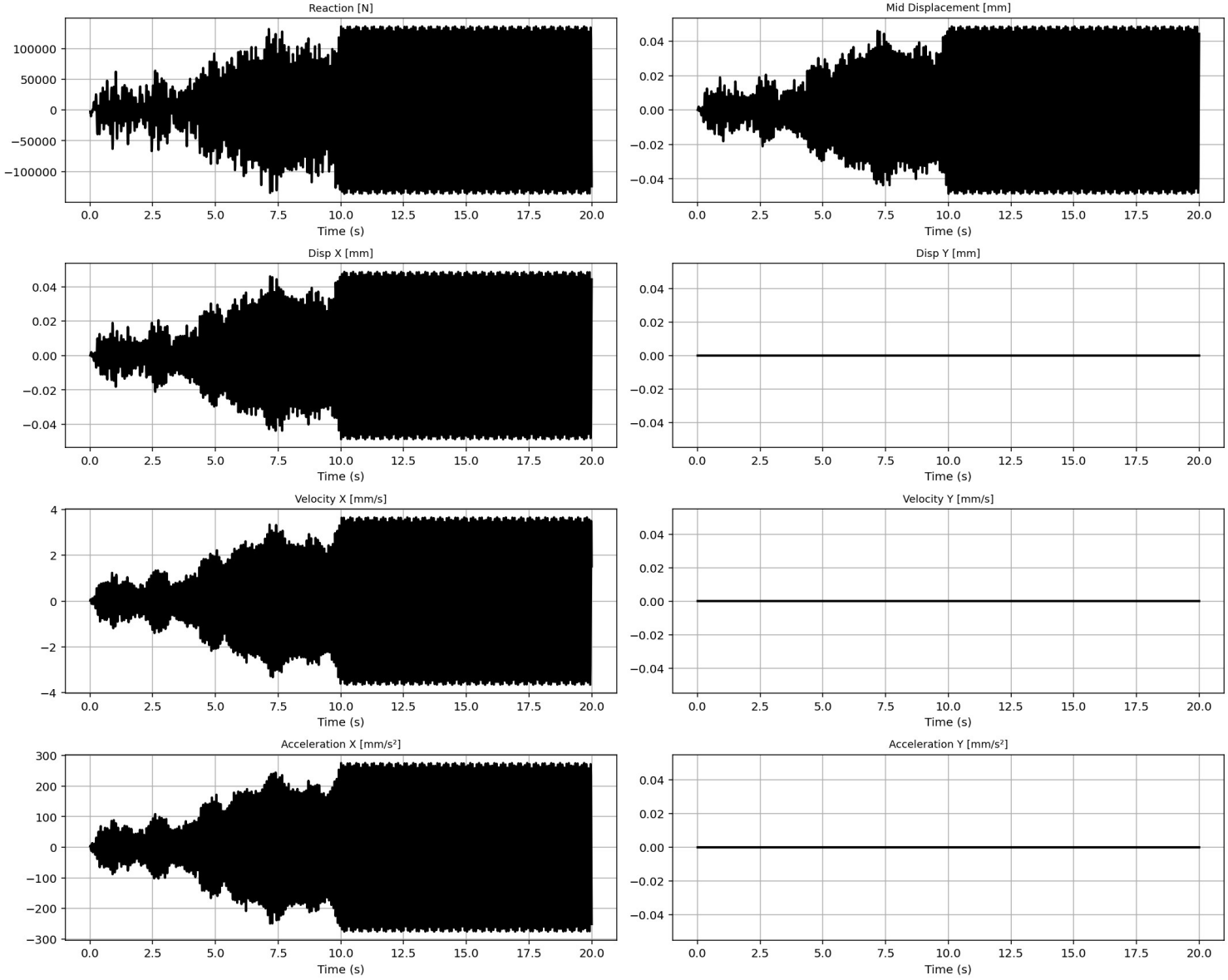
```
1357  # SEISMIC ANALYSIS (DYNAMIC TIME-HISTORY ANALYSIS)
1358  #ELE_TYPE = 'elasticBeamColumn'      # MATERIAL LINEARITY
1359  ELE_TYPE = 'nonlinearBeamColumn'     # MATERIAL AND GEOMETRIC NONLINEARITIES
1360  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1361  ANAL_TYPE = 'SEISMIC'
1362
1363  DATA = TRUSS_ONE_ELEMENT(LENGTH, AREA, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MASS)
1364
1365  (time_SEI, reaction_SEI, disp_mid_SEI,
1366   ele_axialforce_SEI, ele_stress_SEI, ele_strain_SEI, ele_di_SEI,
1367   node_displacementsX_SEI, node_displacementsY_SEI,
1368   dispX_SEI, dispY_SEI,
1369   veloX_SEI, veloY_SEI,
1370   accX_SEI, accY_SEI,
1371   stiffness_SEI, PERIOD_SEI, damping_ratio_SEI,
1372   PERIOD_MIN_SEI, PERIOD_MAX_SEI,
1373   STRESSb_SEI, STRAINb_SEI, STRESSt_SEI, STRAINt_SEI, CURVATURE_SEI) = DATA
1374
1375
1376  XDATA = disp_mid_SEI
1377  YDATA = reaction_SEI
1378  XLABEL = 'Displacement in Middle Span [mm]'
1379  YLABEL = 'Base Reaction [N]'
1380  TITLE = 'Base Reaction and Dispalcement of Structure During Seismic Analysis'
1381  COLOR = 'black'
1382  SEMILOGY = False
1383  PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1384
1385  PLOT_TIME_HISTORY(time_SEI, reaction_SEI, disp_mid_SEI,
1386                    dispX_SEI, dispY_SEI,
1387                    veloX_SEI, veloY_SEI,
1388                    accX_SEI, accY_SEI)
1389
1390  # PLOT ELEMENTS AXIAL FORCE
```

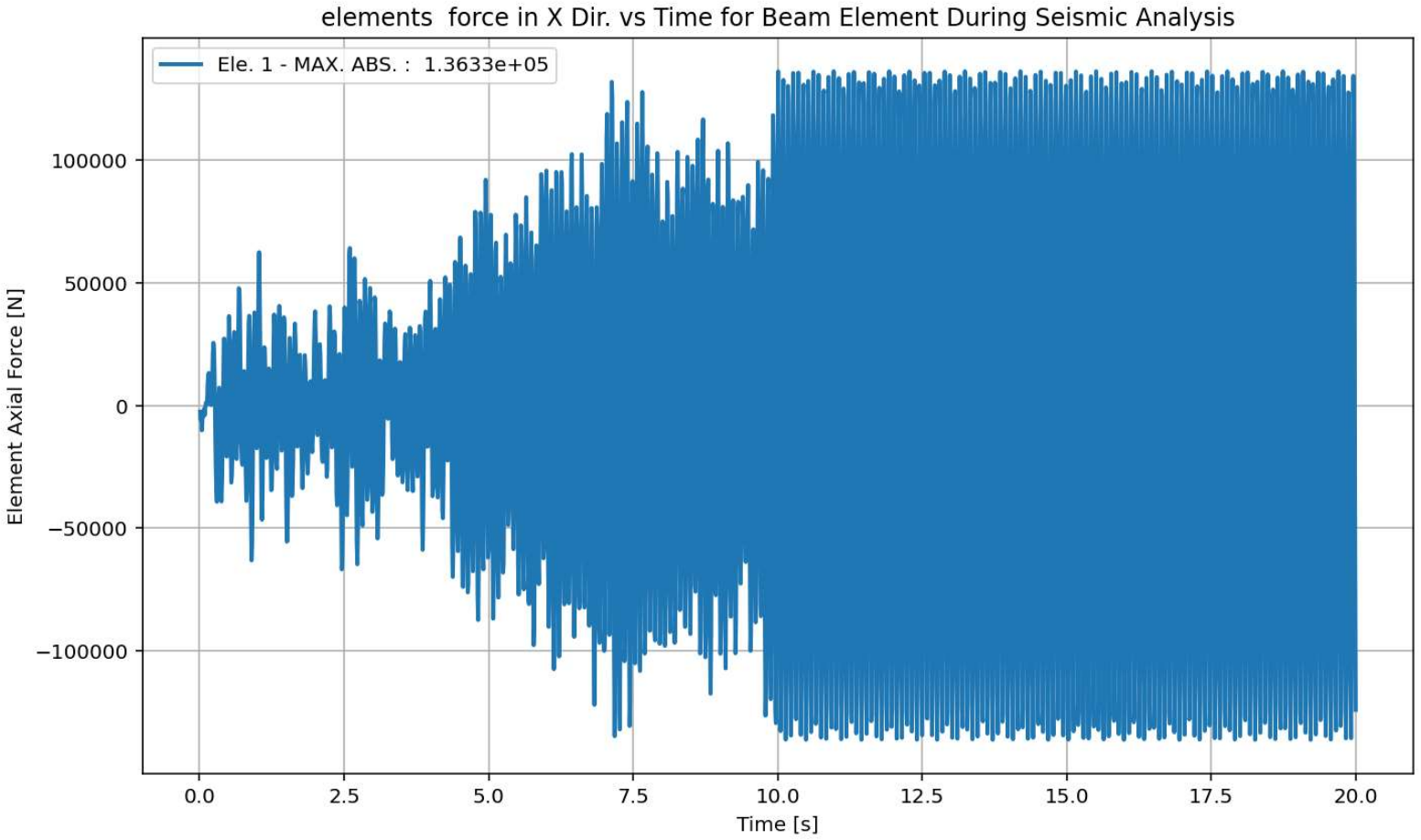


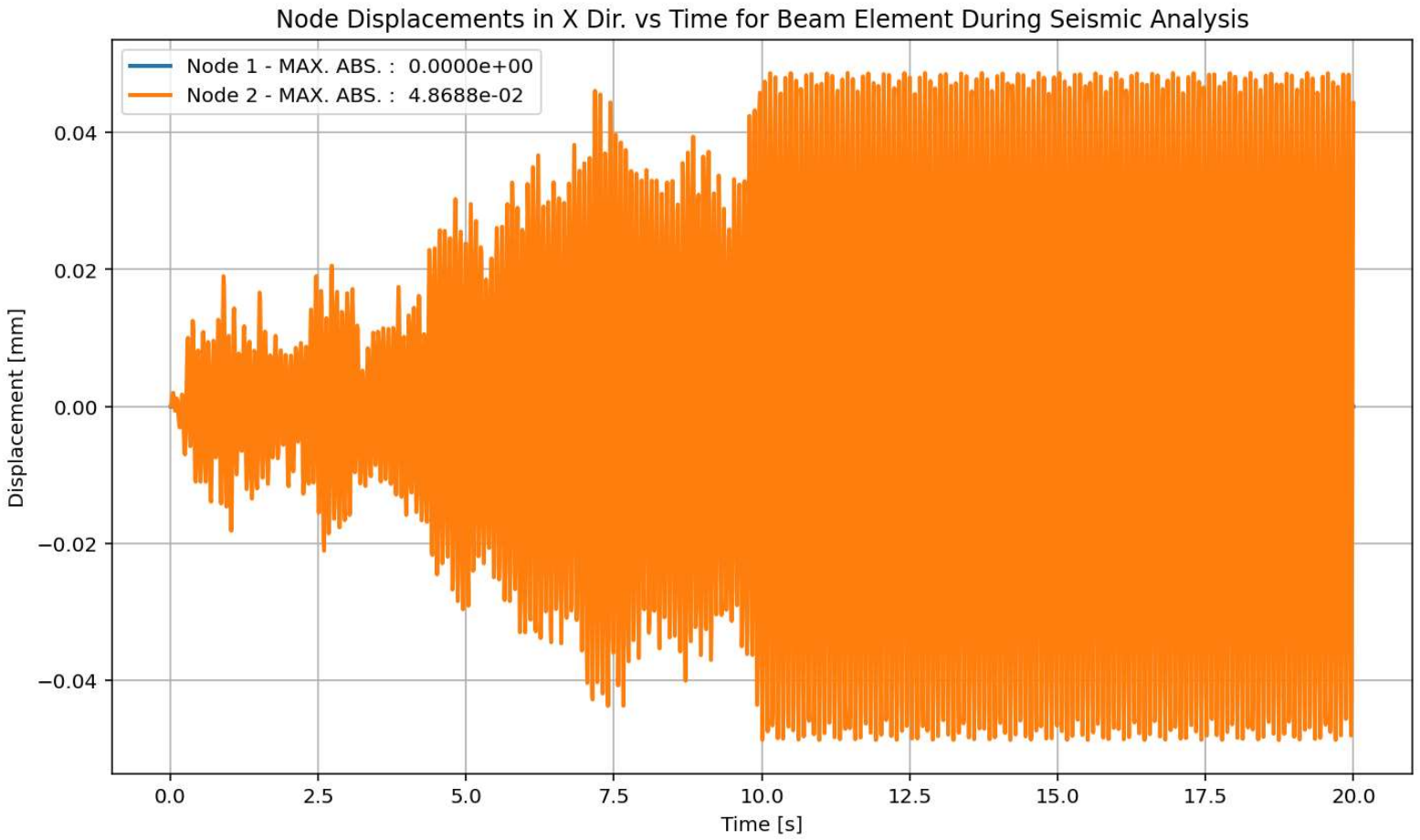
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

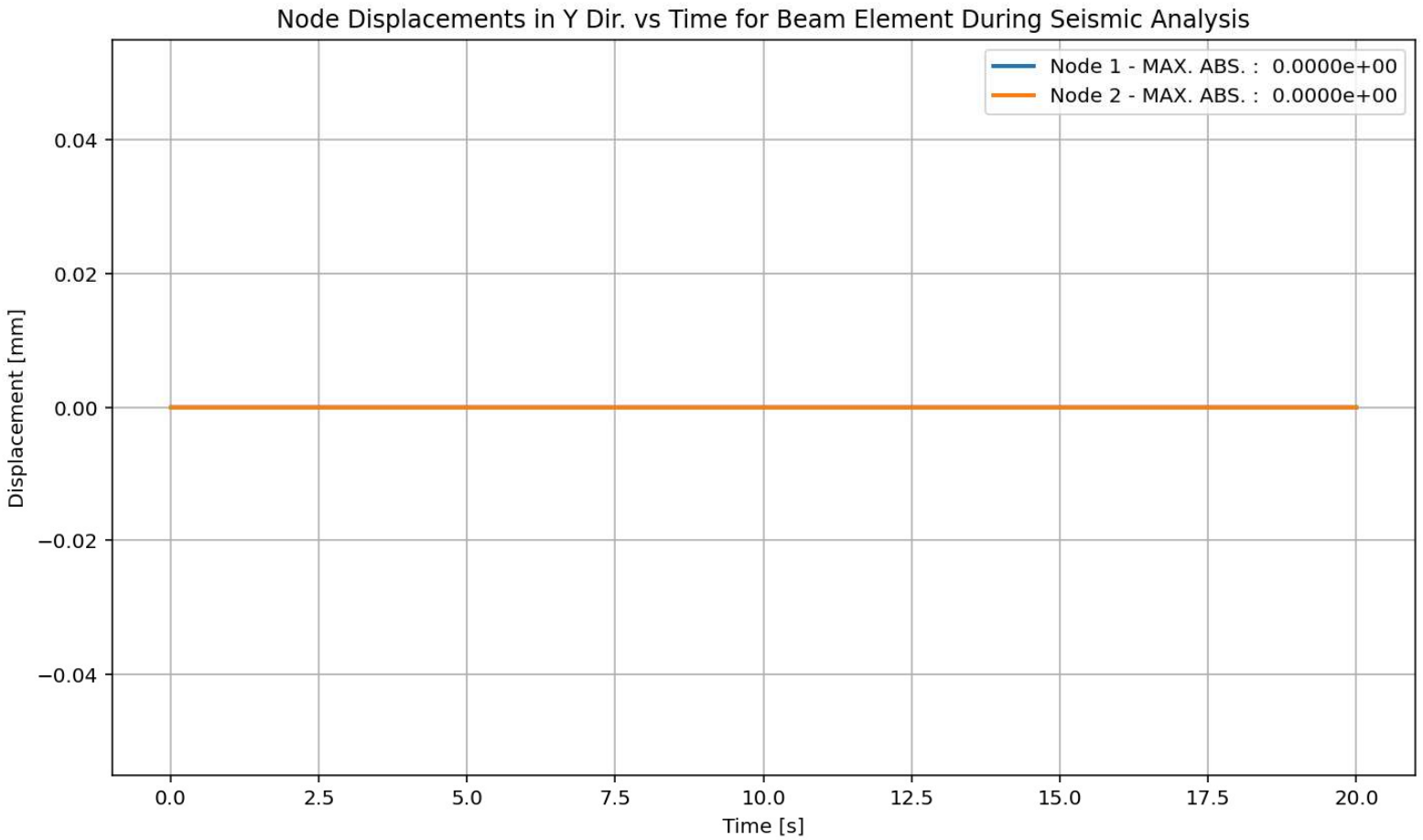
Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 48, Col 56 | UTF-8 | CRLF | RW | Mem 38%

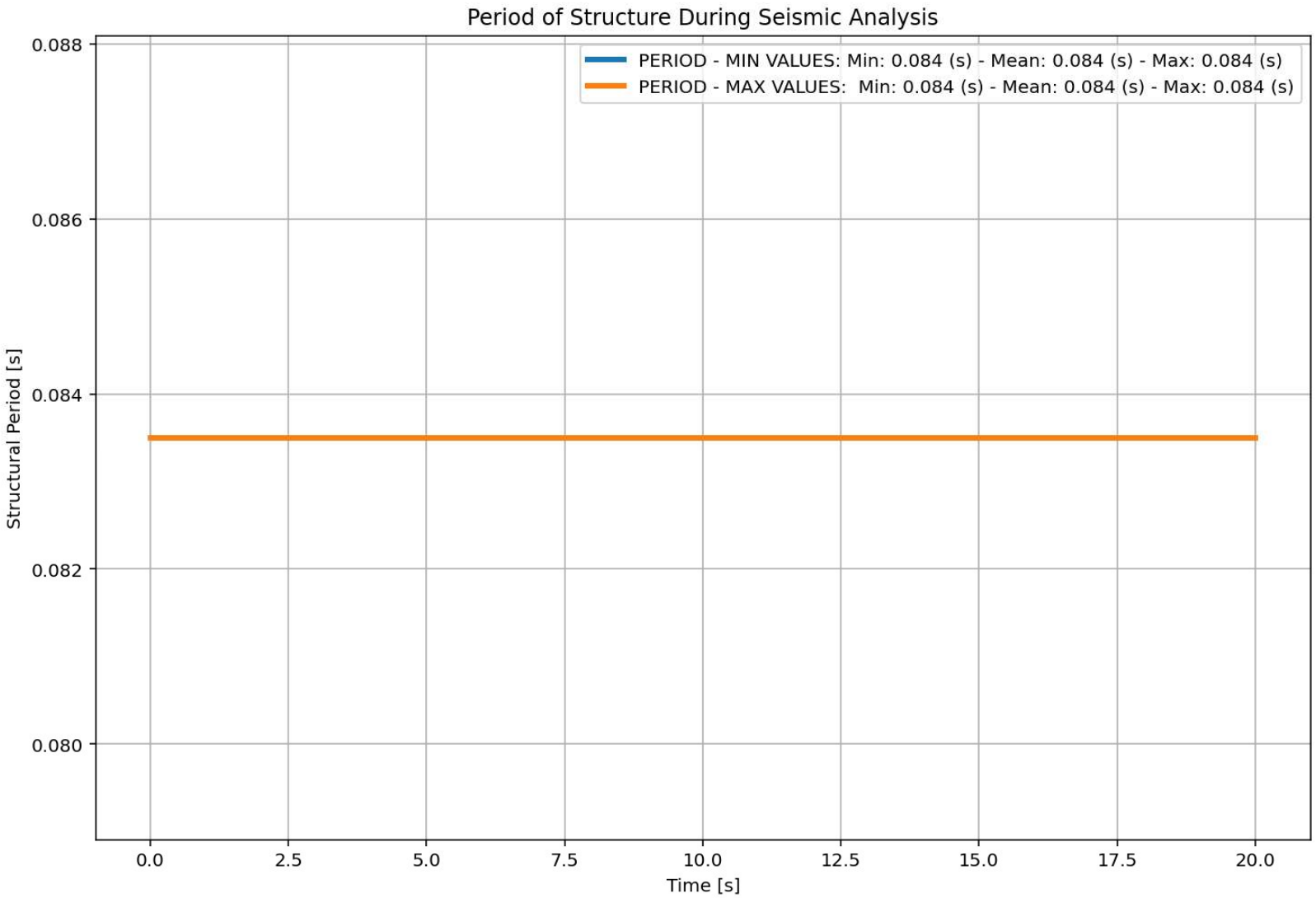

Base Reaction and Dispalcement of Structure During Seismic Analysis
Base Reaction [N]
100000
50000
0
−50000
−100000
−0.04
−0.02
0.00
0.02
0.04
Displacement in Middle Span [mm]

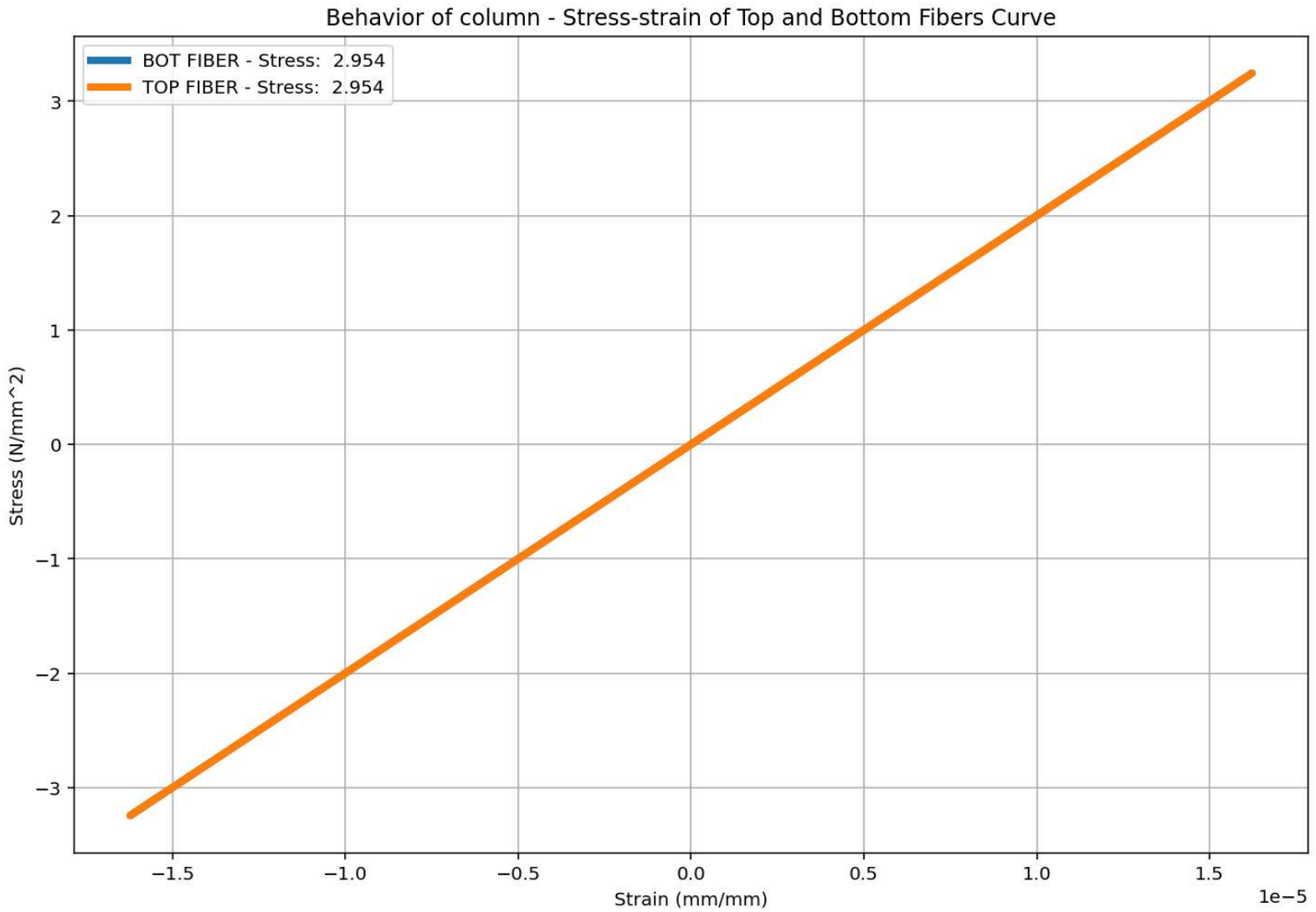

Reaction [N]
Time (s)
Mid Displacement [mm]
Time (s)
Disp X [mm]
Time (s)
Disp Y [mm]
Time (s)
Velocity X [mm/s]
Time (s)
Velocity Y [mm/s]
Time (s)
Acceleration X [mm/s²]
Time (s)
Acceleration Y [mm/s²]
Time (s)

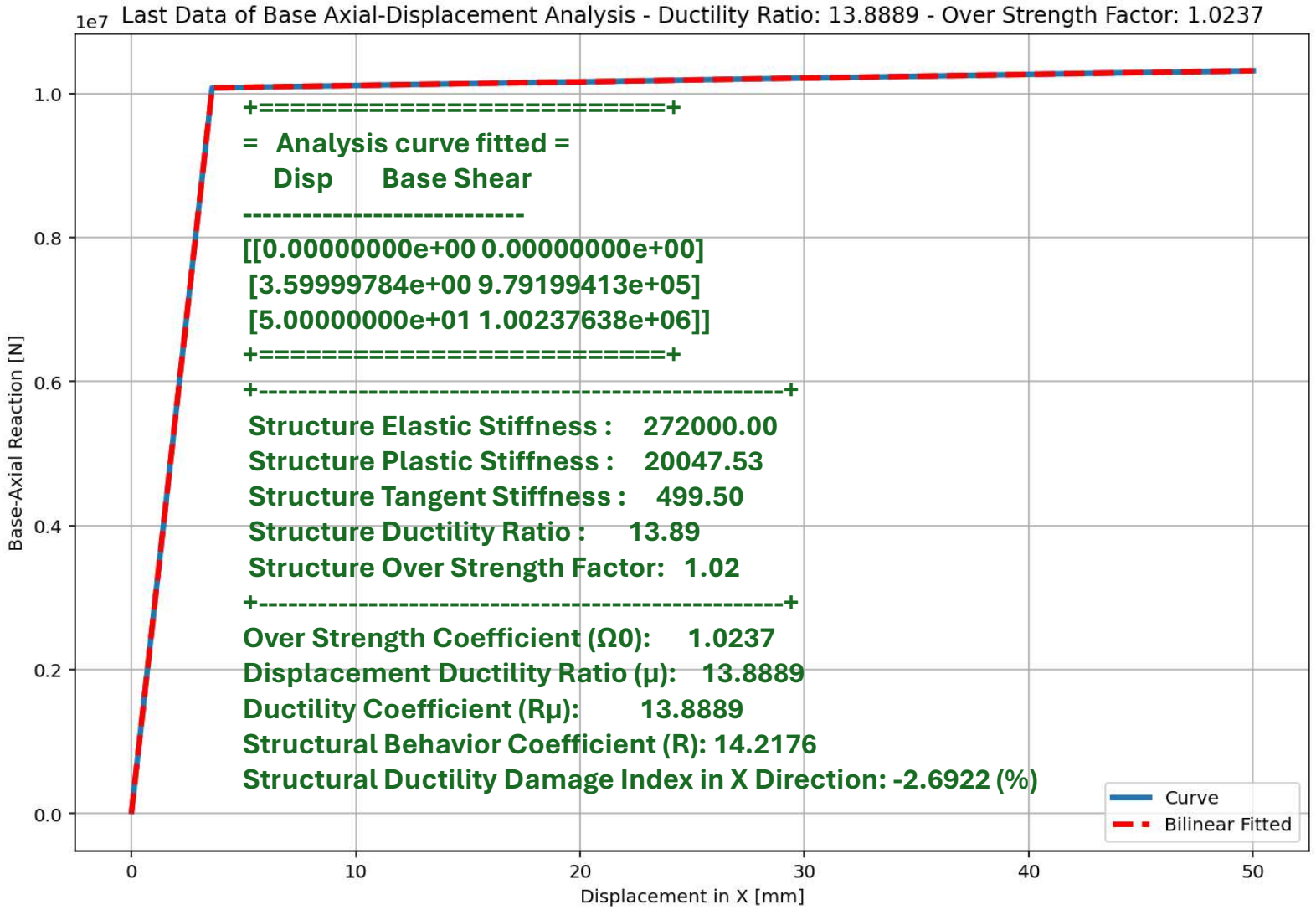

elements force in X Dir. vs Time for Beam Element During Seismic Analysis
Ele. 1 - MAX. ABS. : 1.3633e+05
Element Axial Force [N]
100000
50000
0
−50000
−100000
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Node Displacements in X Dir. vs Time for Beam Element During Seismic Analysis
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 4.8688e-02
Displacement [mm]
0.04
0.02
0.00
−0.02
−0.04
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]

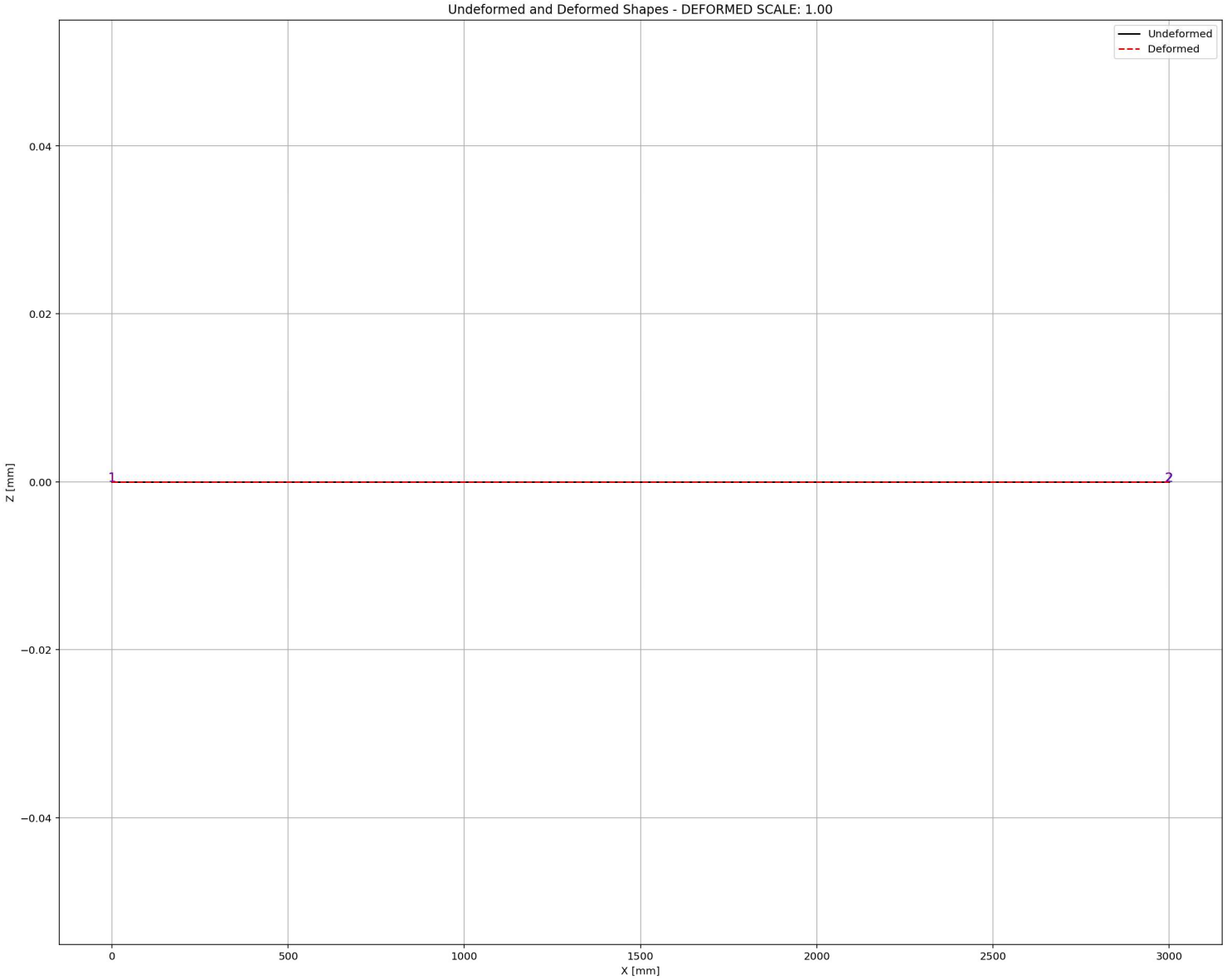

Node Displacements in Y Dir. vs Time for Beam Element During Seismic Analysis
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 0.0000e+00
Displacement [mm]
0.04
0.02
0.00
−0.02
−0.04
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Period of Structure During Seismic Analysis
PERIOD - MIN VALUES: Min: 0.084 (s) - Mean: 0.084 (s) - Max: 0.084 (s)
PERIOD - MAX VALUES: Min: 0.084 (s) - Mean: 0.084 (s) - Max: 0.084 (s)
Structural Period [s]
0.088
0.086
0.084
0.082
0.080
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]


Behavior of column - Stress-strain of Top and Bottom Fibers Curve
BOT FIBER - Stress: 2.954
TOP FIBER - Stress: 2.954
Stress (N/mm^2)
3
2
1
0
−1
−2
−3
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
Strain (mm/mm)
1e−5


Last Data of Base Axial-Displacement Analysis - Ductility Ratio: 13.8889 - Over Strength Factor: 1.0237
1e7
Base-Axial Reaction [N]
Displacement in X [mm]
+============================+
= Analysis curve fitted =
Disp Base Shear

[[0.00000000e+00 0.00000000e+00]
[3.59999784e+00 9.79199413e+05]
[5.00000000e+01 1.00237638e+06]]
+============================+
+--+
Structure Elastic Stiffness : 272000.00
Structure Plastic Stiffness : 20047.53
Structure Tangent Stiffness : 499.50
Structure Ductility Ratio : 13.89
Structure Over Strength Factor: 1.02
+--+
Over Strength Coefficient (Ω0): 1.0237
Displacement Ductility Ratio (μ): 13.8889
Ductility Coefficient (Rμ): 13.8889
Structural Behavior Coefficient (R): 14.2176
Structural Ductility Damage Index in X Direction: -2.6922 (%)
Curve
Bilinear Fitted


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
0.04
0.02
0.00
−0.02
−0.04
Z [mm]
1
2
0
500
1000
1500
2000
2500
3000
X [mm]