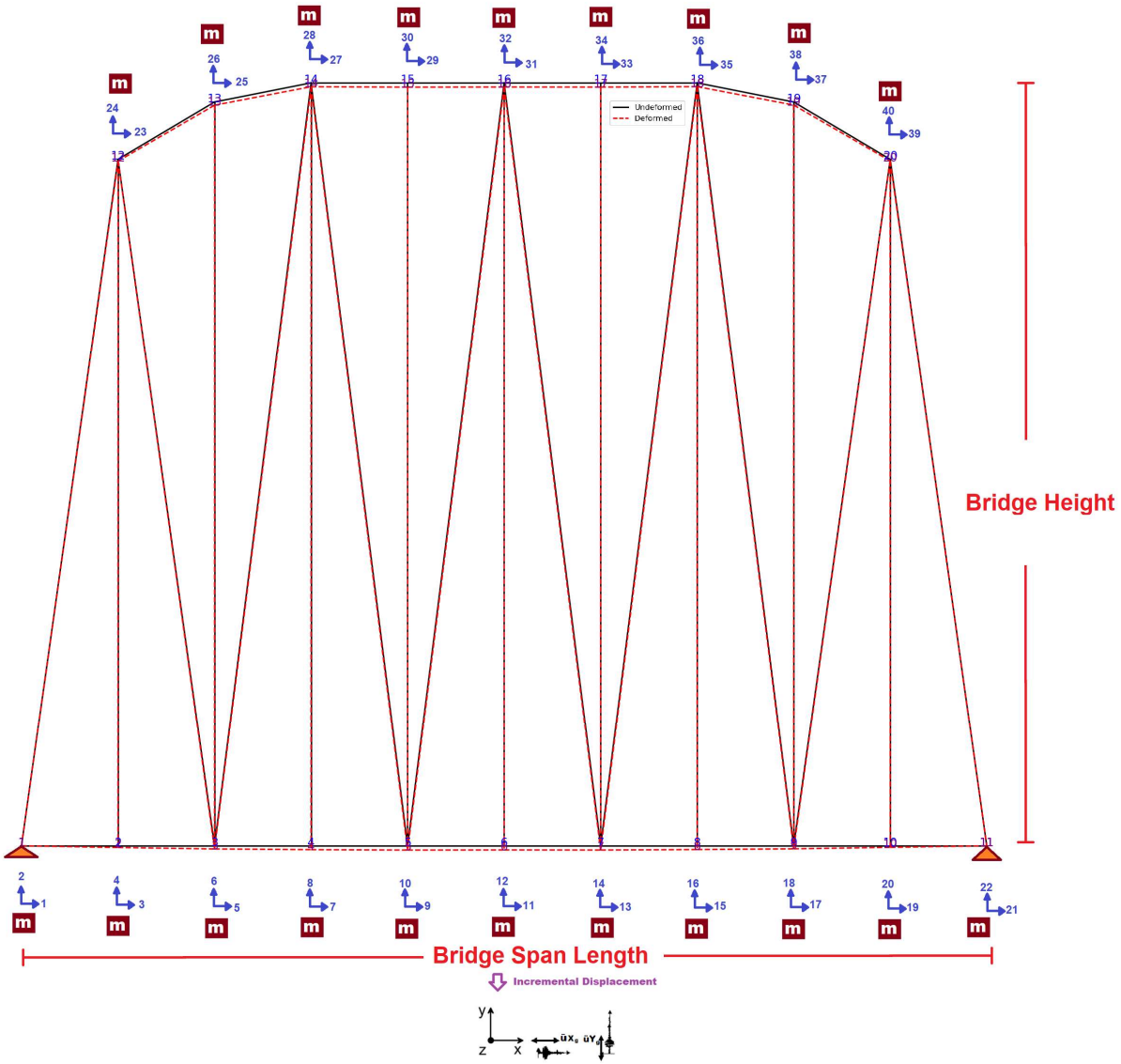
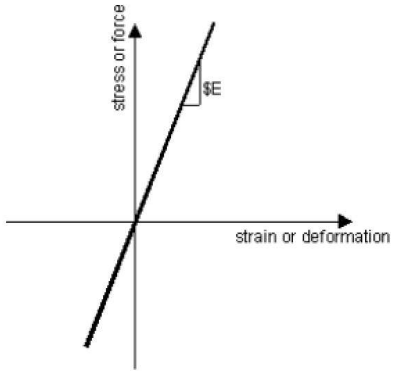
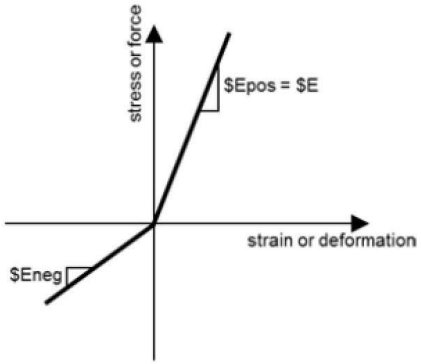
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

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

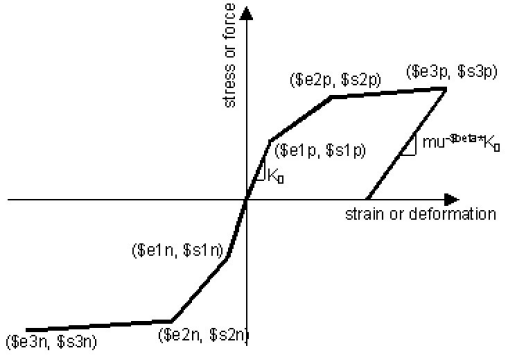
THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)







TRUSS ELEMENT ELASTIC MATERIAL



TRUSS ELEMENT INELASTIC MATERIAL

Spyder (Python 3.12)

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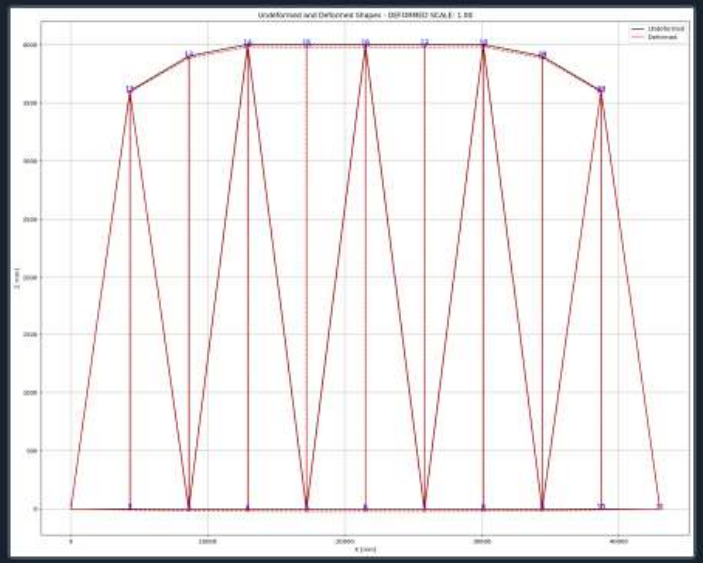
C:\Users\Dell\Desktop\OPENSEES_FILES\+BRIDGE_WARREN_TRUSS\BRIDGE_WARREN_TRUSS.py

BRIDGE_WARREN_TRUSS.py

```
1  ##########################################################################################
2  #                  >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
3  #      COMPREHENSIVE NONLINEAR SEISMIC ASSESSMENT OF STEEL TRUSS BRIDGES: AN OPENSEES FRAM
4  #       STATIC PUSHOVER, CYCLIC DEGRADATION, STATIC TIME-HISTORY AND DYNAMIC TIME-HISTORY
5  #------------------------------------------------------------------------------------------
6  #                          THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
7  #                                  EMAIL: salar.d.ghashghaei@gmail.com
8  ##########################################################################################
9  """
10 Nonlinear Seismic Performance Assessment of Warren Steel Truss Bridges:
11 An OpenSeesPy Framework for Material and Geometric Nonlinearity Under Static, Cyclic, and
12
13 This OpenSeesPy script performs rigorous nonlinear static and dynamic analysis of a Warren
14  for performance-based earthquake engineering. The 2D model incorporates both material non
15  (elastic-perfectly plastic or hysteretic steel with strain hardening)
16  and geometric nonlinearity (corotational truss formulation) to capture P-delta effects
17  and large displacements—essential for collapse assessment.
18
19 The bridge spans 43m with 10-panel Warren configuration, assigning distinct cross-sectiona
20  areas for chords and diagonals. Eigenvalue analysis tracks period elongation throughout
21  loading, directly quantifying stiffness degradation and damage progression.
22
23 Five analysis protocols are implemented:
24 (1) [STATIC] : Gravity load analysis establishing dead load state
25 (2) [PUSHOVER] : Displacement-controlled pushover generating full capacity curves
26  and plastic mechanism identification
27 (3) [CYCLIC_DISPLACEMENT] : Symmetric cyclic displacement protocol capturing hysteresis,
28  pinching behavior, and energy dissipation degradation
29 (4) [STATIC_EXTERNAL_TIME-DEPENDENT_LOADING] : Static Analysis of External time-dependent
30 (5) [DYNAMIC_EXTERNAL_TIME-DEPENDENT_LOADING] : Dynamic Analysis of External time-dependen
31 (6) [FREE-VIBRATION] : Free-vibration with initial conditions extracting damping ratios
32  via logarithmic decrement
33 (7) [SEISMIC] : Multi-directional seismic excitation with Rayleigh damping (3% ratio)
34  and uniform acceleration patterns.
```

19 %



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Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 13, Col 57 | UTF-8 | CRLF | RW | Mem 59%

STATIC ANALYSIS

Spyder (Python 3.12)

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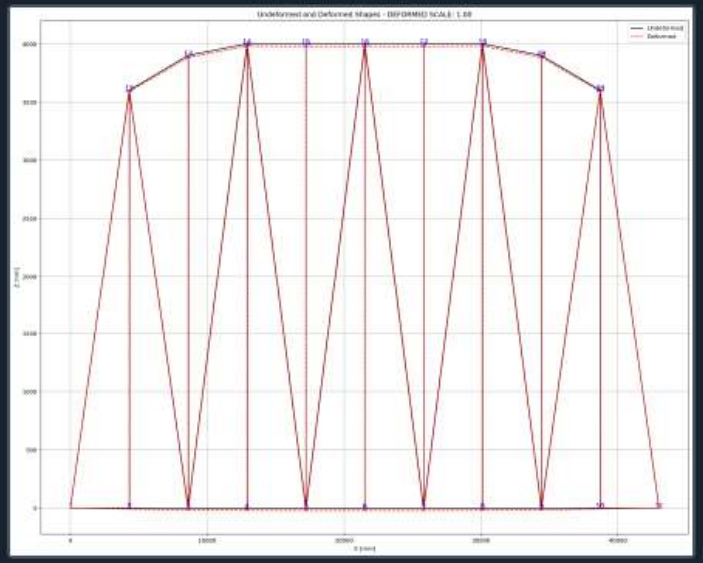
BRIDGE_WARREN_TRUSS.py

```
1070
1071        plt.xlabel('Time [s]')
1072        plt.ylabel(YLABEL)
1073        plt.title(TITLE)
1074        plt.legend()
1075        plt.grid(True)
1076        plt.tight_layout()
1077        plt.show()
1078
1079    #%%--------------------------------------------------
1080    L = 43000.0          # [mm] Bridge Length
1081    H = 4000.0           # [mm] Bridge Height
1082    A_chord = 5250.0     # [mm^2] Section Area for chord elements
1083    A_diag  = 5250.0     # [mm^2] Section Area for diagonal elements
1084    TOTAL_MASS = 5.0     # [kg] Total Mass of Structure
1085    #%%--------------------------------------------------
1086    # STATIC ANALYSIS
1087    #ELE_TYPE = 'Truss'      # MATERIAL NONLINEARITY
1088    ELE_TYPE = 'corotTruss'  # MATERIAL AND GEOMETRIC NONLINEARITIES
1089    MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1090    ANAL_TYPE = 'STATIC'
1091
1092    DATA = WARREN_TRUSS_BRIDGE(L, H, A_chord, A_diag, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MAS
1093    (reaction, disp_mid,
1094     ele_force, ele_stress, ele_strain,
1095     node_displacementsX, node_displacementsY,
1096     dispX, dispY) = DATA
1097
1098    S01.PLOT_2D_FRAME_TRUSS(deformed_scale=1.0)
1099    #%%--------------------------------------------------
1100    # PUSHOVER ANALYSIS (STATIC TIME-HISTORY ANALYSIS)
1101    #ELE_TYPE = 'Truss'      # MATERIAL NONLINEARITY
1102    ELE_TYPE = 'corotTruss'  # MATERIAL AND GEOMETRIC NONLINEARITIES
1103    MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
```

19 %



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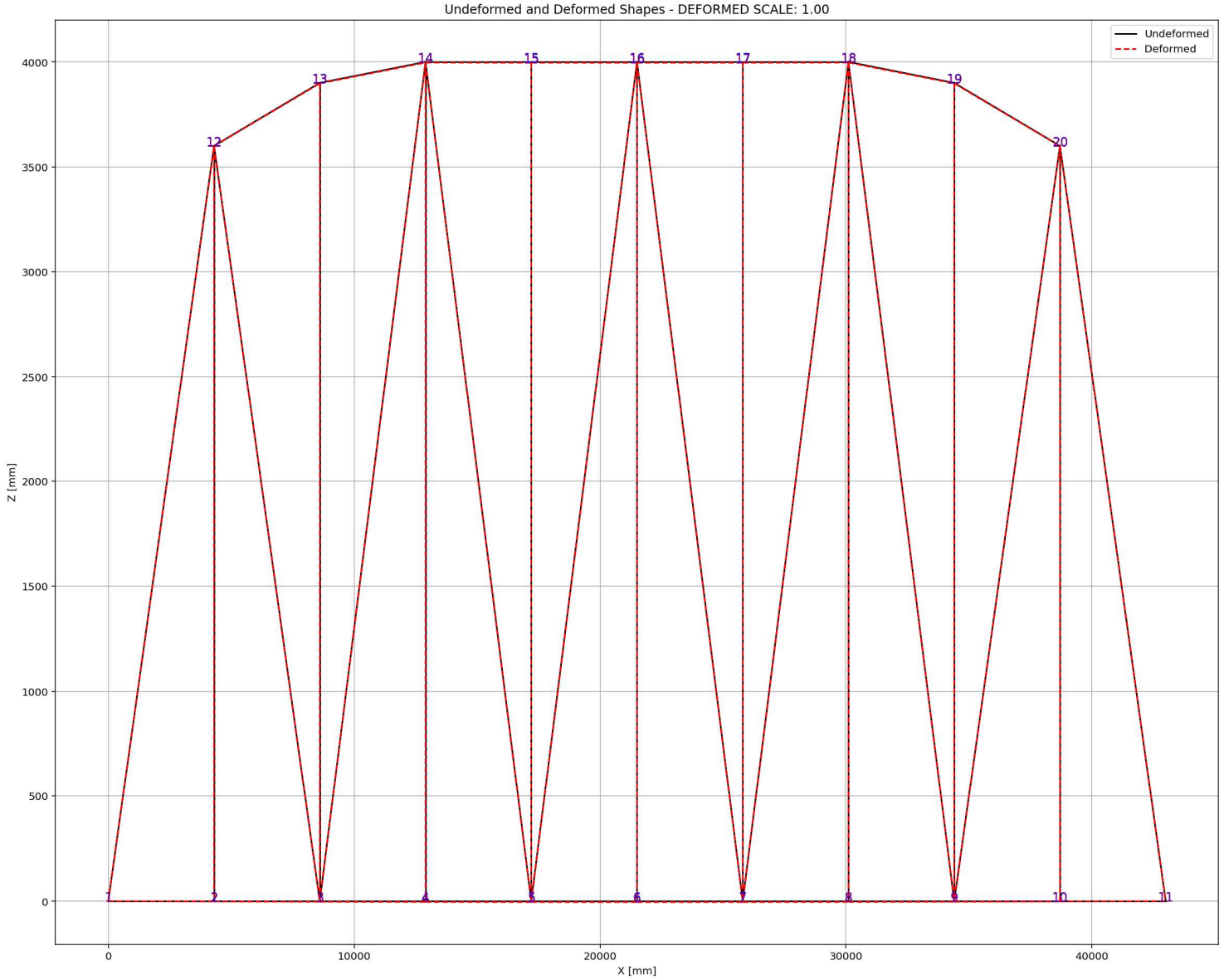
Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 13, Col 57 | UTF-8 | CRLF | RW | Mem 59%


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
3500
4000
0
10000
20000
30000
40000
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

PUSHOVER ANALYSIS

Spyder (Python 3.12)

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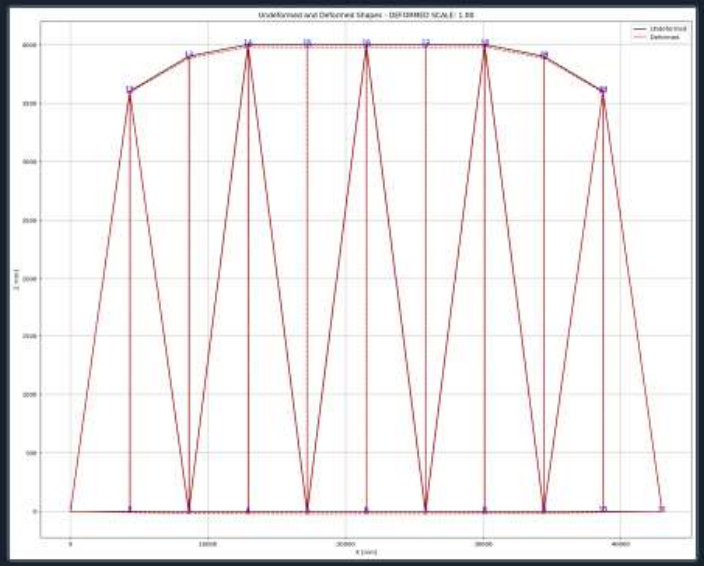
BRIDGE_WARREN_TRUSS.py

```
1099    #%%
1100    # PUSHOVER ANALYSIS (STATIC TIME-HISTORY ANALYSIS)
1101    #ELE_TYPE = 'Truss'      # MATERIAL NONLINEARITY
1102    ELE_TYPE = 'corotTruss'  # MATERIAL AND GEOMETRIC NONLINEARITIES
1103    MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1104    ANAL_TYPE = 'PUSHOVER'
1105
1106    DATA = WARREN_TRUSS_BRIDGE(L, H, A_chord, A_diag, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MAS
1107    (reaction_PUSH, disp_mid_PUSH,
1108     ele_force_PUSH, ele_stress_PUSH, ele_strain_PUSH,
1109     node_displacementsX_PUSH, node_displacementsY_PUSH,
1110      dispX_PUSH, dispY_PUSH,
1111     PERIOD_MIN_PUSH, PERIOD_MAX_PUSH) = DATA
1112
1113
1114    XDATA = disp_mid_PUSH
1115    YDATA = reaction_PUSH
1116    XLABEL = 'Displacement in Middle Span [mm]'
1117    YLABEL = 'Base Reaction [N]'
1118    TITLE = 'Base Reaction and Displacement of Structure During Pushover Analysis'
1119    COLOR = 'black'
1120    SEMILOGY = False
1121    PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1122
1123    # PLOT STRUCTURAL PERIOD DURING THE ANALYSIS
1124    plt.figure(0, figsize=(12, 8))
1125    plt.plot(disp_mid_PUSH, PERIOD_MIN_PUSH, linewidth=3)
1126    plt.plot(disp_mid_PUSH, PERIOD_MAX_PUSH, linewidth=3)
1127    plt.title('Period of Structure During Pushover Analysis')
1128    plt.ylabel('Structural Period [s]')
1129    plt.xlabel('Displacement [mm]')
1130    #plt.semilogy()
1131    plt.grid()
1132    plt.legend([f'PERIOD - MIN VALUES: Min: {np.min(PERIOD_MIN_PUSH):.3f} (s) - Mean: {np.mean
```

19 %



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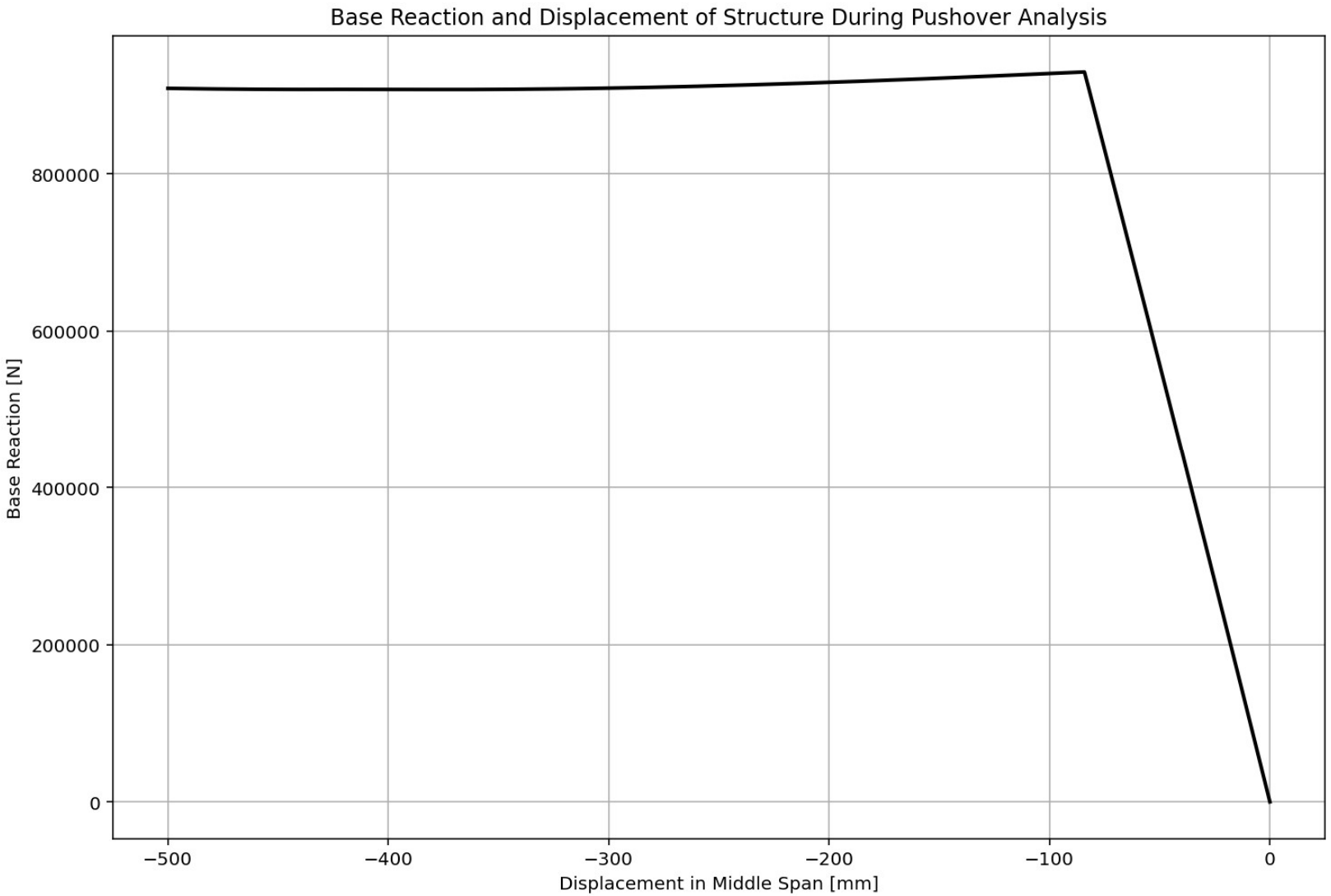
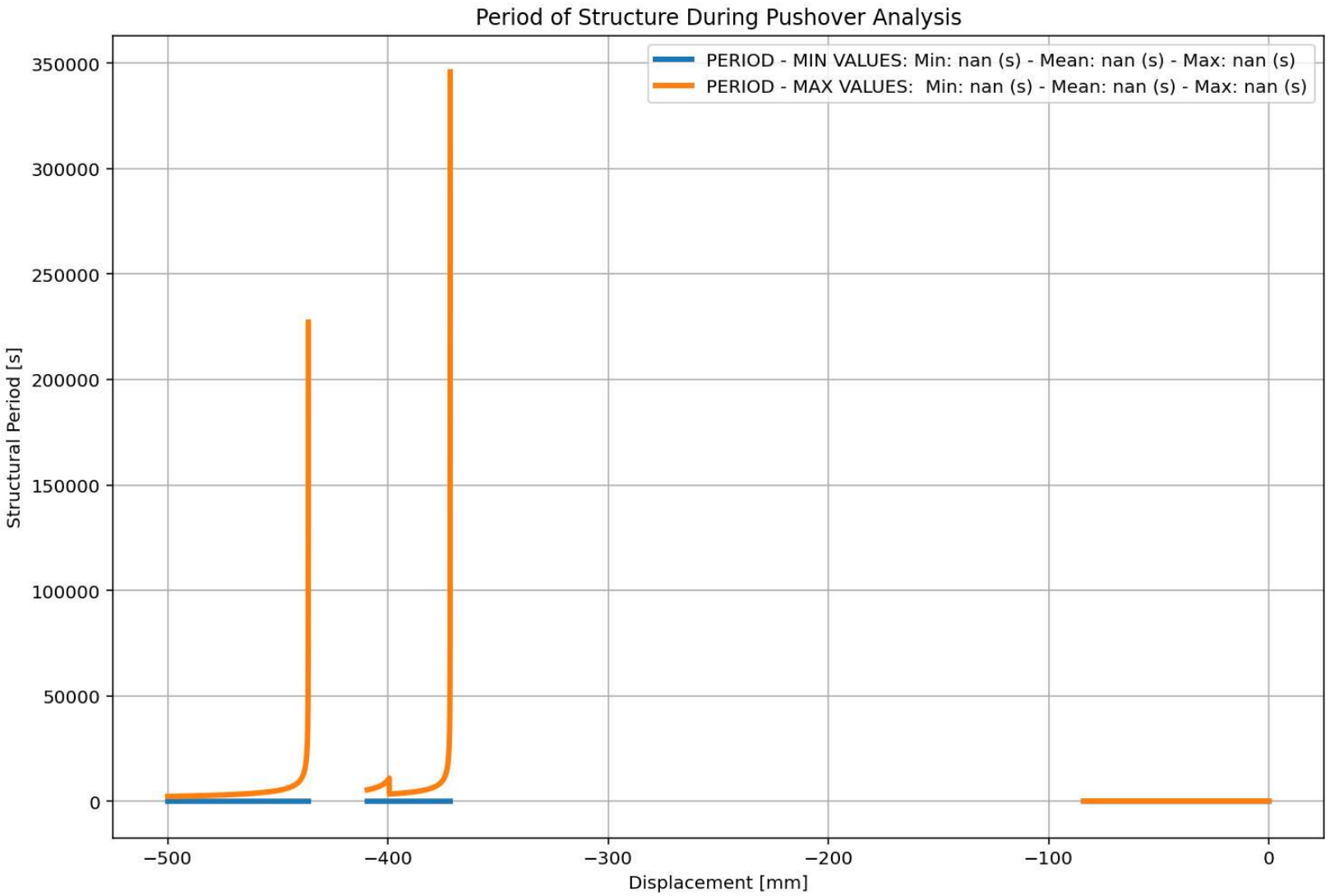
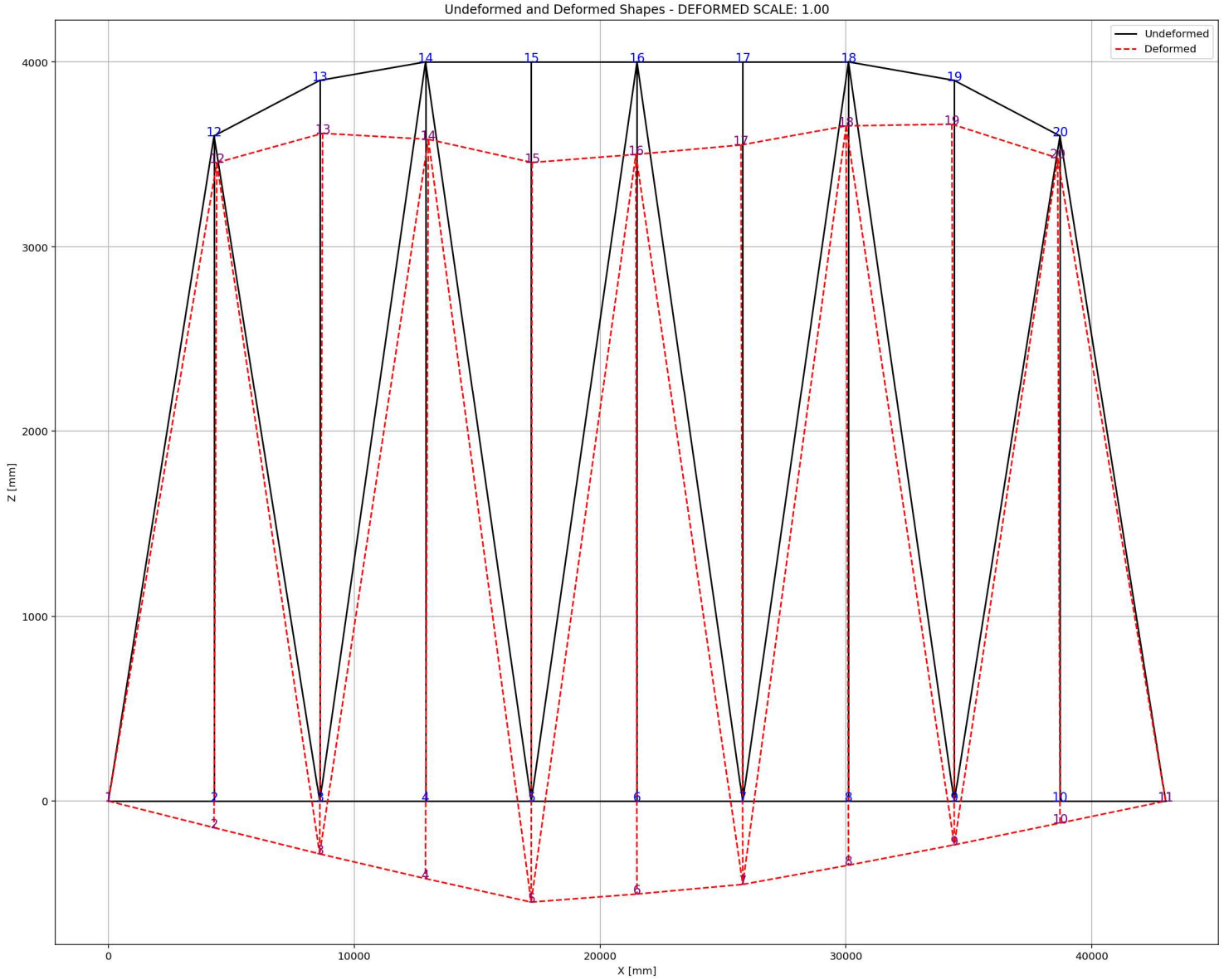

Base Reaction and Displacement of Structure During Pushover Analysis
Base Reaction [N]
800000
600000
400000
200000
0
−500
−400
−300
−200
−100
0
Displacement in Middle Span [mm]


Period of Structure During Pushover Analysis
PERIOD - MIN VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
PERIOD - MAX VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
Structural Period [s]
350000
300000
250000
200000
150000
100000
50000
0
−500
−400
−300
−200
−100
0
Displacement [mm]


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
1000
2000
3000
4000
0
10000
20000
30000
40000

CYCLIC DISPLACEMENT ANALYSIS

Spyder (Python 3.12)

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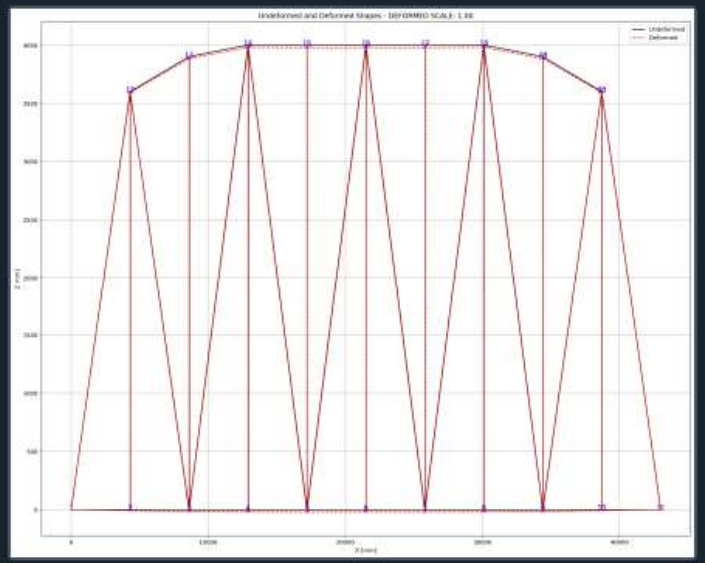
BRIDGE_WARREN_TRUSS.py

```
1139  # CYCLIC DISPLACEMENT ANALYSIS (STATIC TIME-HISTORY ANALYSIS)
1140  #ELE_TYPE = 'Truss'      # MATERIAL NONLINEARITY
1141  ELE_TYPE = 'corotTruss'  # MATERIAL AND GEOMETRIC NONLINEARITIES
1142  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1143  ANAL_TYPE = 'CYCLIC_DISPLACEMENT'
1144
1145  DATA = WARREN_TRUSS_BRIDGE(L, H, A_chord, A_diag, MAT_TYPE, ELE_TYPE, ANAL_TYPE  TOTAL_MAS
1146  (reaction_CP, disp_mid_CP,
1147   ele_force_CP, ele_stress_CP, ele_strain_CP,
1148   node_displacementsX_CP, node_displacementsY_CP,
1149    dispX_CP, dispY_CP,
1150   PERIOD_MIN_CP, PERIOD_MAX_CP) = DATA
1151
1152
1153  XDATA = disp_mid_CP
1154  YDATA = reaction_CP
1155  XLABEL = 'Displacement in Middle Span [mm]'
1156  YLABEL = 'Base Reaction [N]'
1157  TITLE = 'Base Reaction and Displacement of Structure During Cyclic-Displacement Analysis'
1158  COLOR = 'black'
1159  SEMILOGY = False
1160  PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1161
1162  # PLOT STRUCTURAL PERIOD DURING THE ANALYSIS
1163  plt.figure(0, figsize=(12, 8))
1164  plt.plot(disp_mid_CP, PERIOD_MIN_CP, linewidth=3)
1165  plt.plot(disp_mid_CP, PERIOD_MAX_CP, linewidth=3)
1166  plt.title('Period of Structure During Cyclic Displacement Analysis')
1167  plt.ylabel('Structural Period [s]')
1168  plt.xlabel('Displacement [mm]')
1169  #plt.semilogy()
1170  plt.grid()
1171  plt.legend([f'PERIOD - MIN VALUES: Min: {np.min(PERIOD_MIN_CP):.3f} (s) - Mean: {np.mean(P
1172              f'PERIOD - MAX VALUES:  Min: {np.min(PERIOD_MAX_CP):.3f} (s) - Mean  {np.mean(
```

19 %



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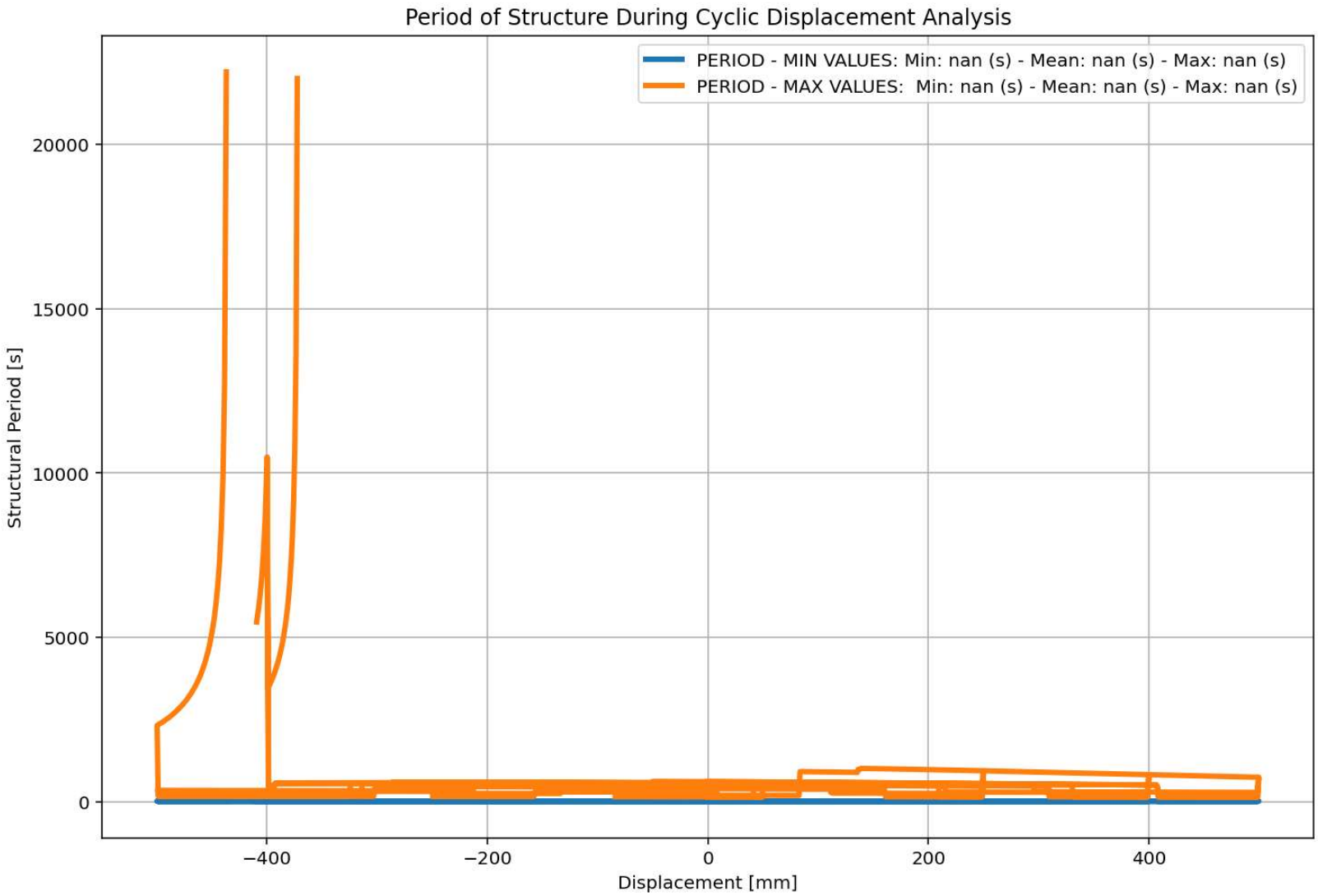
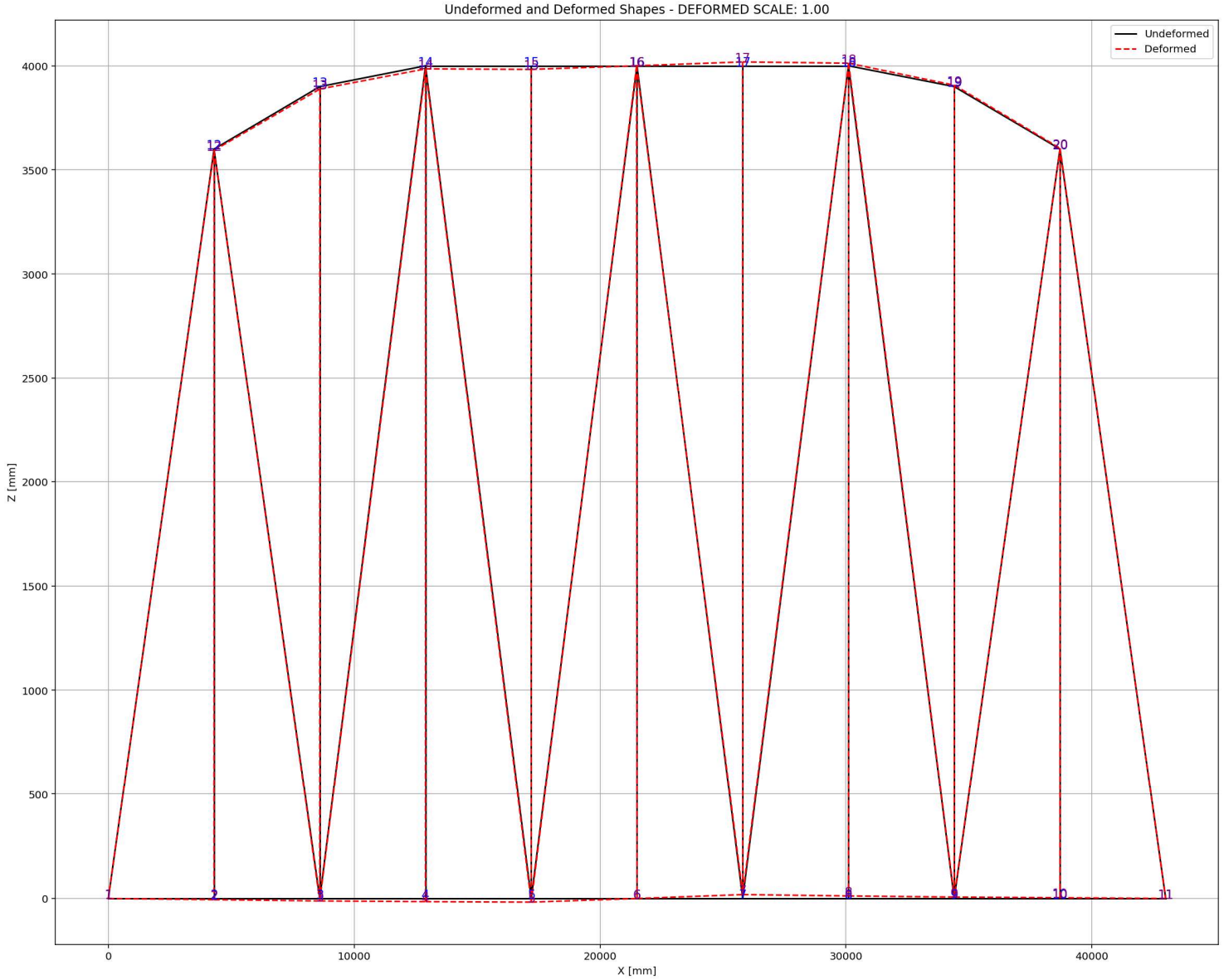
Base Reaction and Displacement of Structure During Cyclic-Displacement Analysis
1e6
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
Base Reaction [N]
−400
−200
0
200
400
Displacement in Middle Span [mm]


Period of Structure During Cyclic Displacement Analysis
PERIOD - MIN VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
PERIOD - MAX VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
Structural Period [s]
20000
15000
10000
5000
0
−400
−200
0
200
400
Displacement [mm]


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
3500
4000
0
10000
20000
30000
40000

STATIC TIME-HISTORY WITH EXTERNALTIME-DEPENDENTLOADING ANALYSIS

Spyder (Python 3.12)

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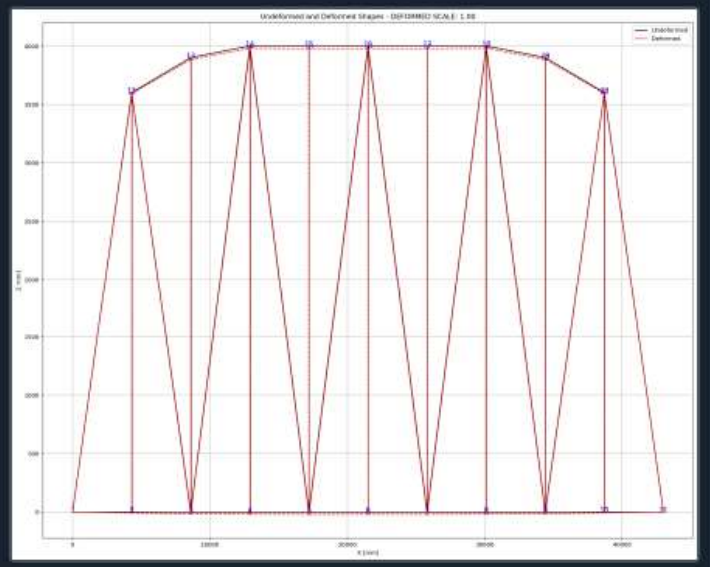
BRIDGE_WARREN_TRUSS.py

```
1178  # EXTERNAL TIME-DEPENDENT LOADING ANALYSIS (STATIC TIME-HISTORY ANALYSIS)
1179  #ELE_TYPE = 'Truss'      # MATERIAL NONLINEARITY
1180  ELE_TYPE = 'corotTruss'  # MATERIAL AND GEOMETRIC NONLINEARITIES
1181  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1182  ANAL_TYPE = 'STATIC_EXTERNAL_TIME-DEPENDENT_LOADING'
1183
1184  DATA = WARREN_TRUSS_BRIDGE(L, H, A_chord, A_diag, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MAS
1185
1186  (reaction_ETDLS, disp_mid_ETDLS,
1187   ele_force_ETDLS, ele_stress_ETDLS, ele_strain_ETDLS,
1188   node_displacementsX_ETDLS, node_displacementsY_ETDLS,
1189    dispX_ETDLS, dispY_ETDLS,
1190   PERIOD_MIN_ETDLS, PERIOD_MAX_ETDLS) = DATA
1191
1192
1193  XDATA = disp_mid_ETDLS
1194  YDATA = reaction_ETDLS
1195  XLABEL = 'Displacement in Middle Span [mm]'
1196  YLABEL = 'Base Reaction [N]'
1197  TITLE = 'Base Reaction and Displacement of Structure During Static External Time-dependent
1198  COLOR = 'black'
1199  SEMILOGY = False
1200  PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1201
1202  # PLOT STRUCTURAL PERIOD DURING THE ANALYSIS
1203  plt.figure(0, figsize=(12, 8))
1204  plt.plot(disp_mid_ETDLS, PERIOD_MIN_ETDLS, linewidth=3)
1205  plt.plot(disp_mid_ETDLS, PERIOD_MAX_ETDLS, linewidth=3)
1206  plt.title('Period of Structure During Static External Time-dependent Loading Analysis')
1207  plt.ylabel('Structural Period [s]')
1208  plt.xlabel('Displacement [mm]')
1209  #plt.semilogy()
1210  plt.grid()
1211  plt.legend([f'PERIOD - MIN VALUES: Min: {np.min(PERIOD_MIN_ETDLS):.3f} (s) - Mean: {np.mea
```

19 %



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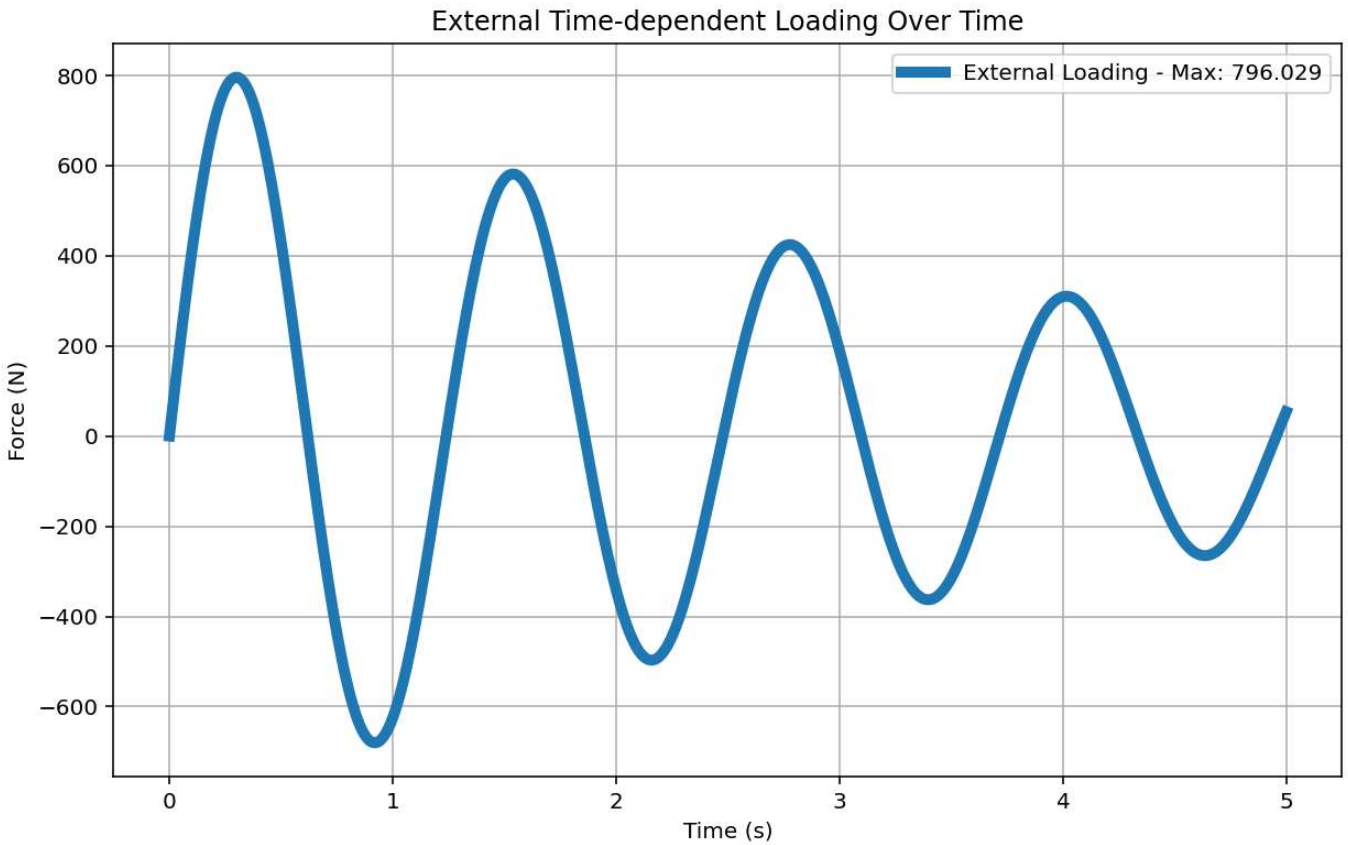
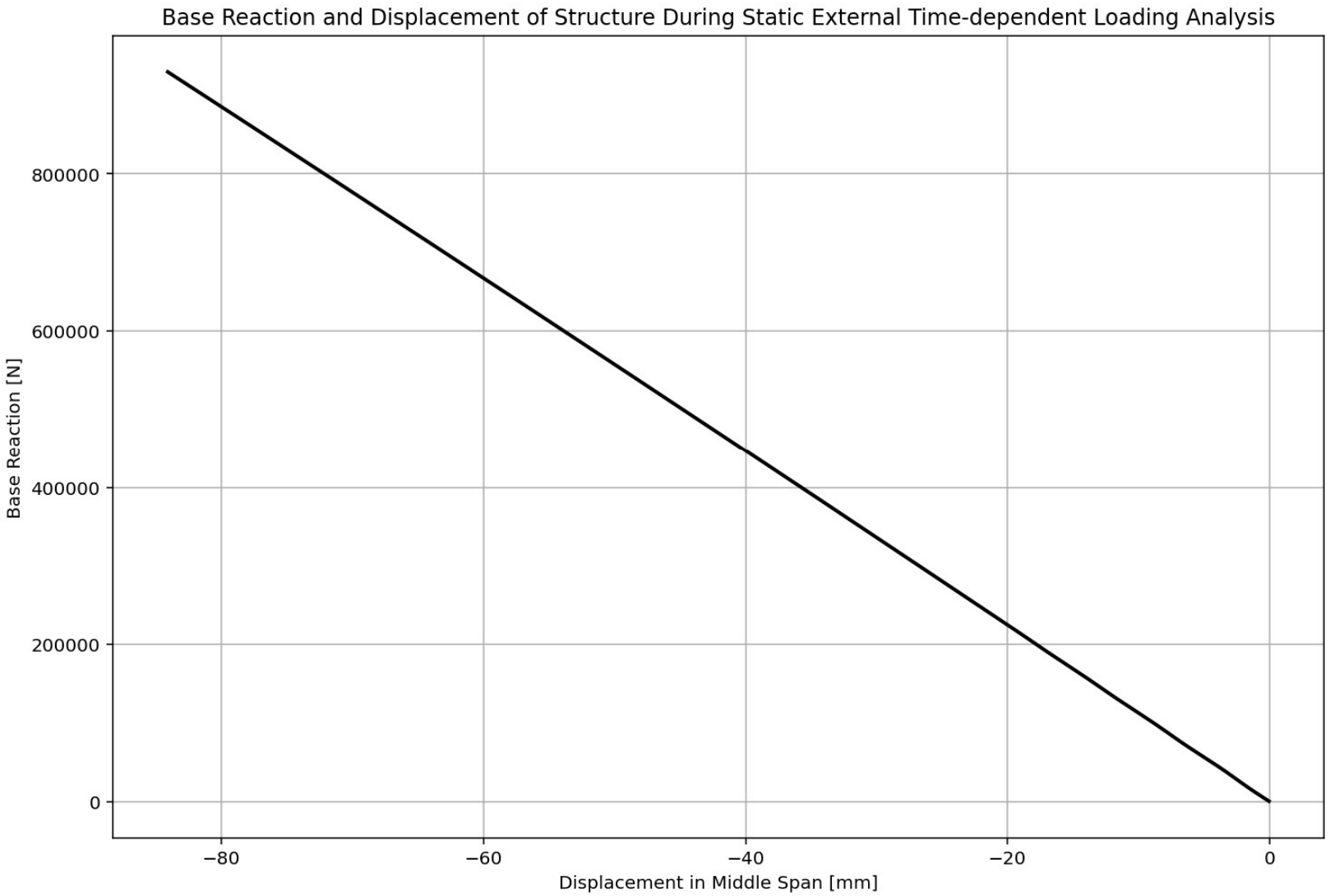
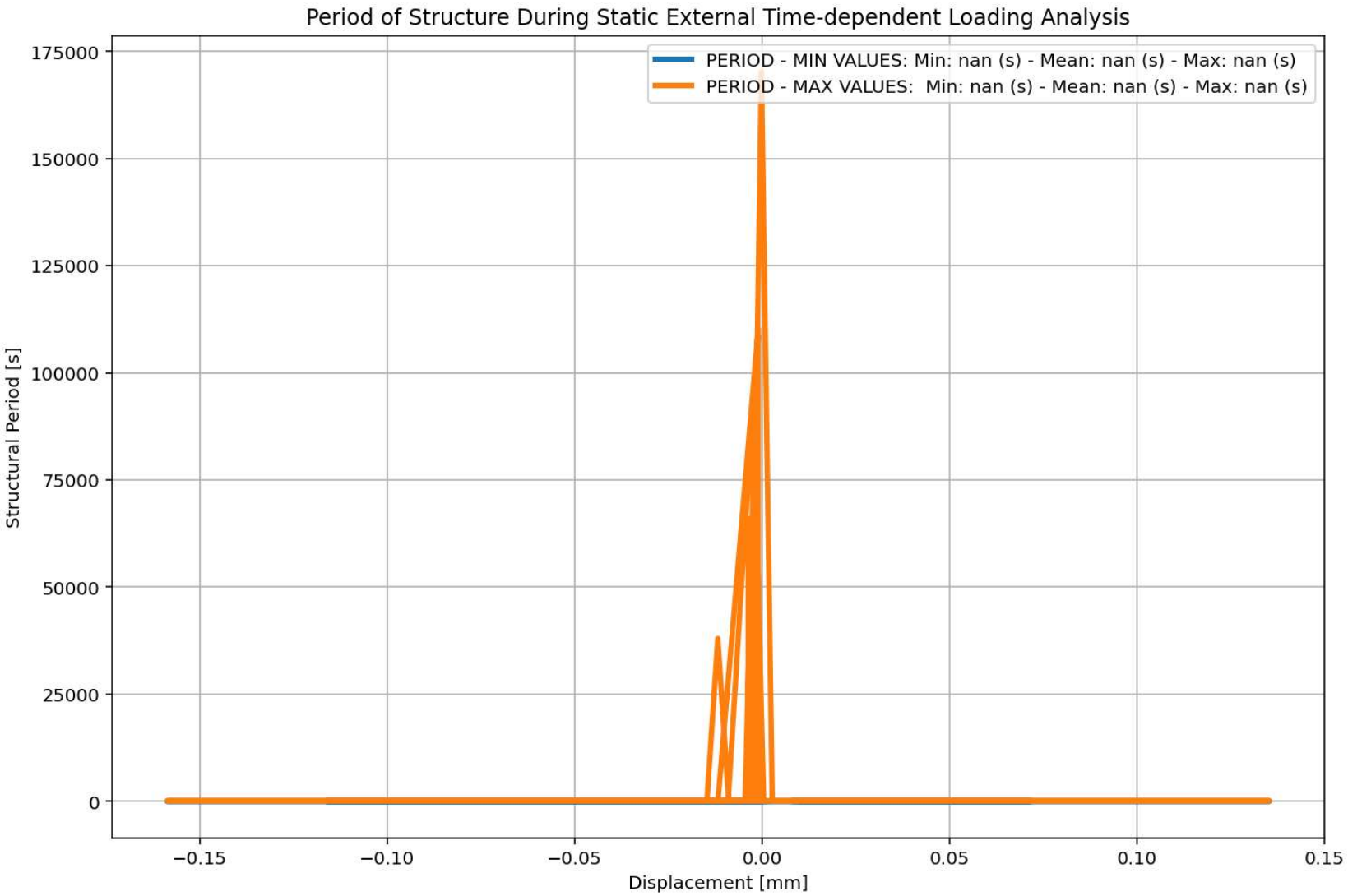
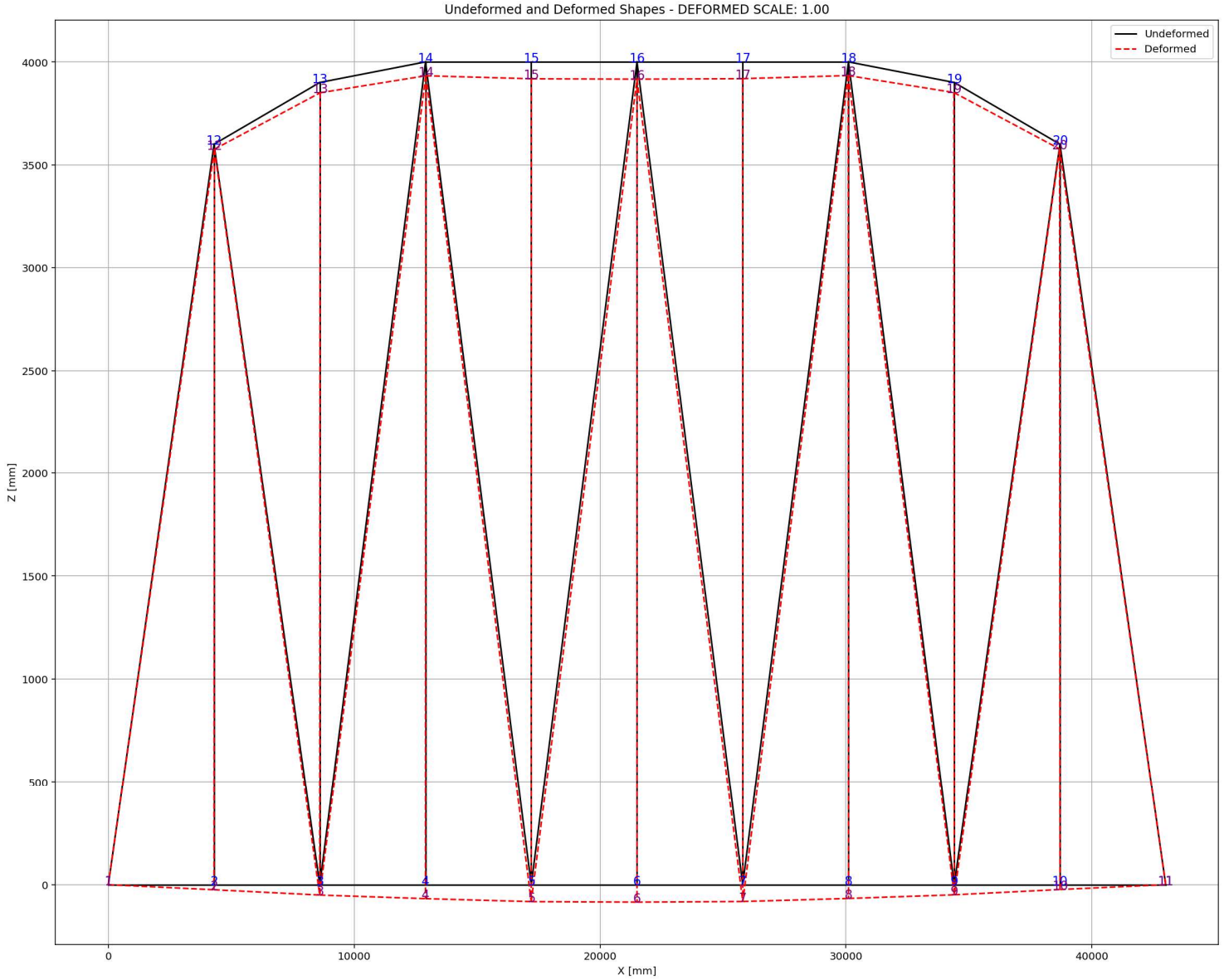

External Time-dependent Loading Over Time
External Loading - Max: 796.029
Force (N)
800
600
400
200
0
−200
−400
−600
0
1
2
3
4
5
Time (s)


Base Reaction and Displacement of Structure During Static External Time-dependent Loading Analysis
Base Reaction [N]
800000
600000
400000
200000
0
−80
−60
−40
−20
0
Displacement in Middle Span [mm]


Period of Structure During Static External Time-dependent Loading Analysis
PERIOD - MIN VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
PERIOD - MAX VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
Structural Period [s]
175000
150000
125000
100000
75000
50000
25000
0
−0.15
−0.10
−0.05
0.00
0.05
0.10
0.15
Displacement [mm]


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
10000
20000
30000
40000
500
1000
1500
2000
2500
3000
3500
4000

DYNAMIC TIME-HISTORY WITH EXTERNALTIME-DEPENDENTLOADING ANALYSIS

Spyder (Python 3.12)

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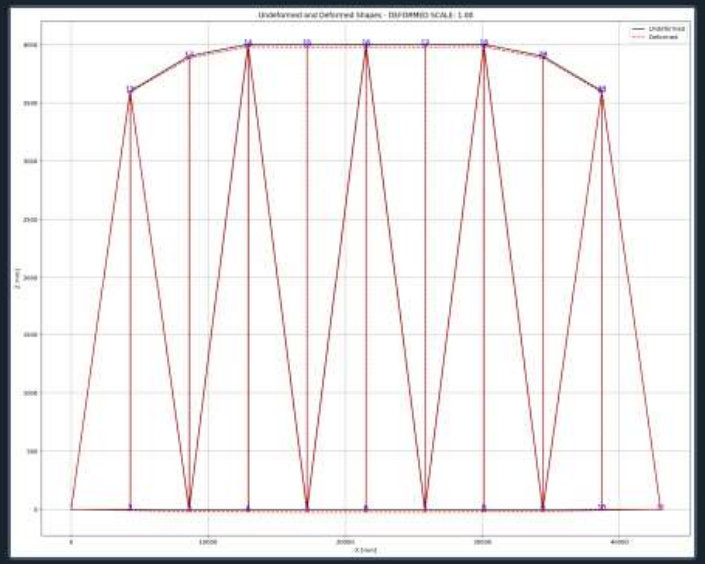
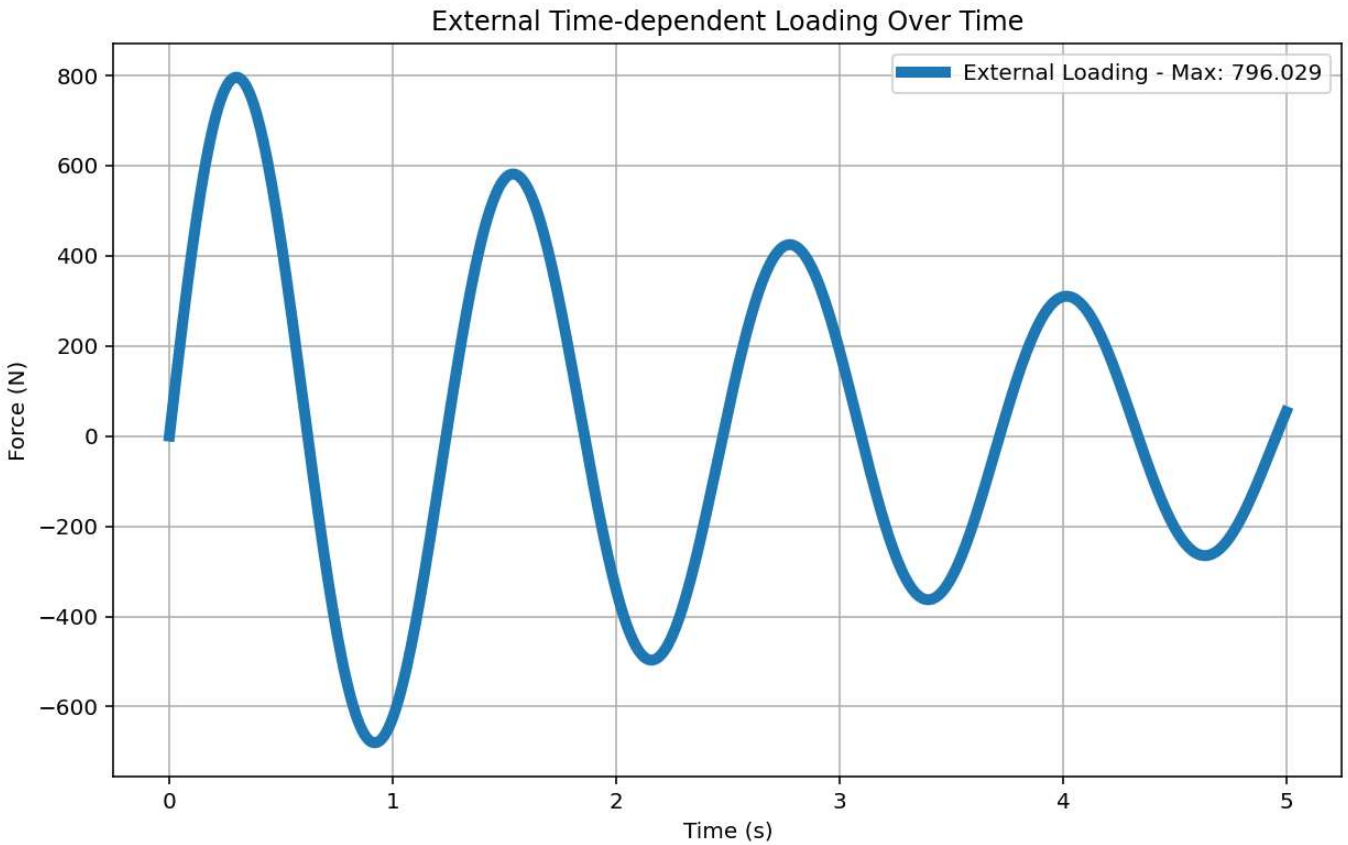
BRIDGE_WARREN_TRUSS.py

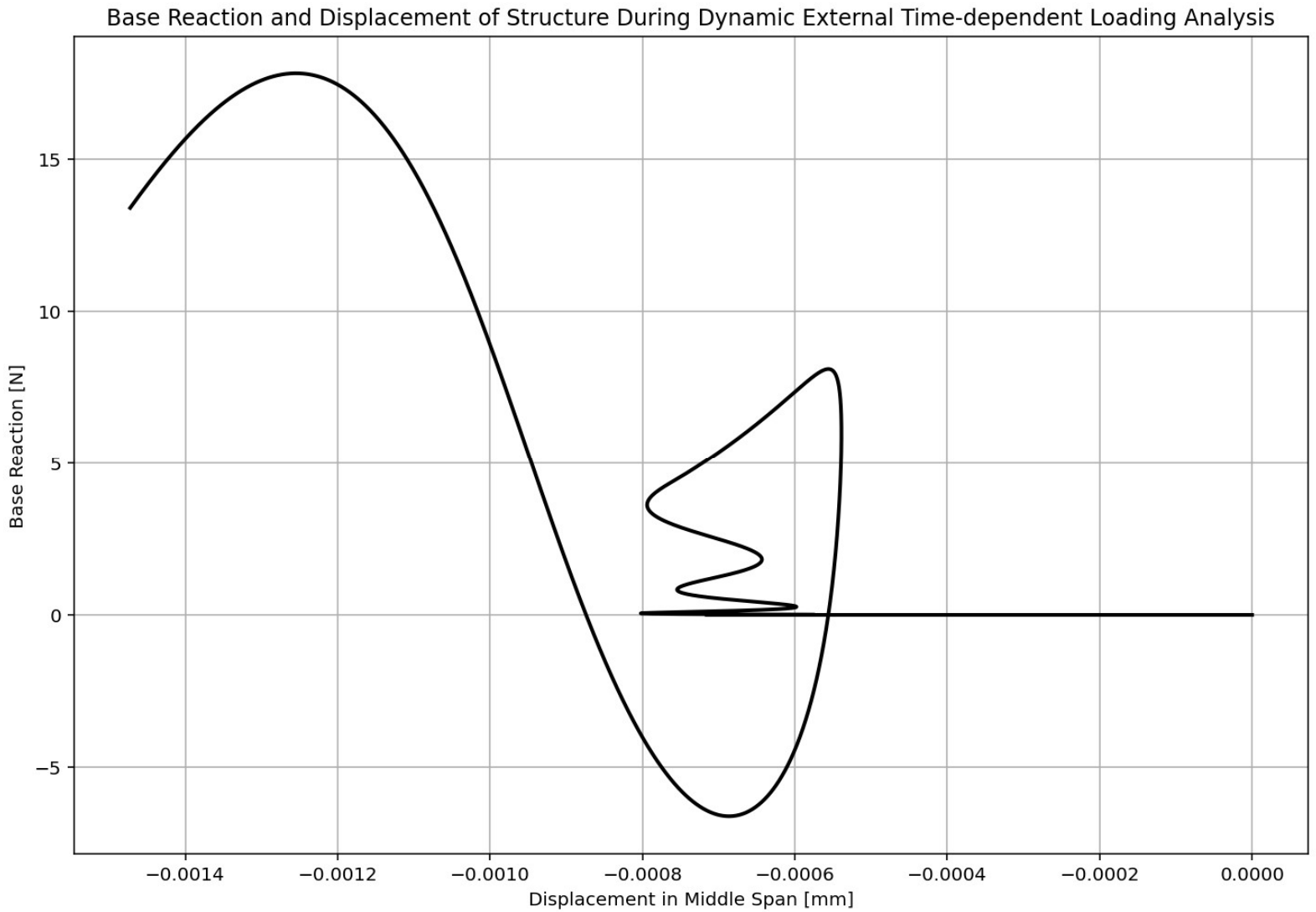
```
1218  # EXTERNAL TIME-DEPENDENT LOADING ANALYSIS (DYNAMIC TIME-HISTORY ANALYSIS)
1219  #ELE_TYPE = 'Truss'      # MATERIAL NONLINEARITY
1220  ELE_TYPE = 'corotTruss'  # MATERIAL AND GEOMETRIC NONLINEARITIES
1221  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1222  ANAL_TYPE = 'DYNAMIC_EXTERNAL_TIME-DEPENDENT_LOADING'
1223
1224  DATA = WARREN_TRUSS_BRIDGE(L, H, A_chord, A_diag, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MAS
1225
1226  (time_ETDLD, reaction_ETDLD, disp_mid_ETDLD,
1227  ele_force_ETDLD, ele_stress_ETDLD, ele_strain_ETDLD,
1228  node_displacementsX_ETDLD, node_displacementsY_ETDLD,
1229  dispX_ETDLD, dispY_ETDLD,
1230  veloX_ETDLD, veloY_ETDLD,
1231  accX_ETDLD, accY_ETDLD,
1232  stiffness_ETDLD, PERIOD_ETDLD, damping_ratio_ETDLD,
1233  PERIOD_MIN_ETDLD, PERIOD_MAX_ETDLD) = DATA
1234
1235
1236  XDATA = disp_mid_ETDLD
1237  YDATA = reaction_ETDLD
1238  XLABEL = 'Displacement in Middle Span [mm]'
1239  YLABEL = 'Base Reaction [N]'
1240  TITLE = 'Base Reaction and Displacement of Structure During Dynamic External Tim -dependen
1241  COLOR = 'black'
1242  SEMILOGY = False
1243  PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1244
1245  PLOT_TIME_HISTORY(time_ETDLD, reaction_ETDLD, disp_mid_ETDLD,
1246                    dispX_ETDLD, dispY_ETDLD,
1247                    veloX_ETDLD, veloY_ETDLD,
1248                    accX_ETDLD, accY_ETDLD)
1249
1250  # PLOT ELEMENTS AXIAL FORCE
1251  YLABEL = 'Element Axial Force [N]'
```

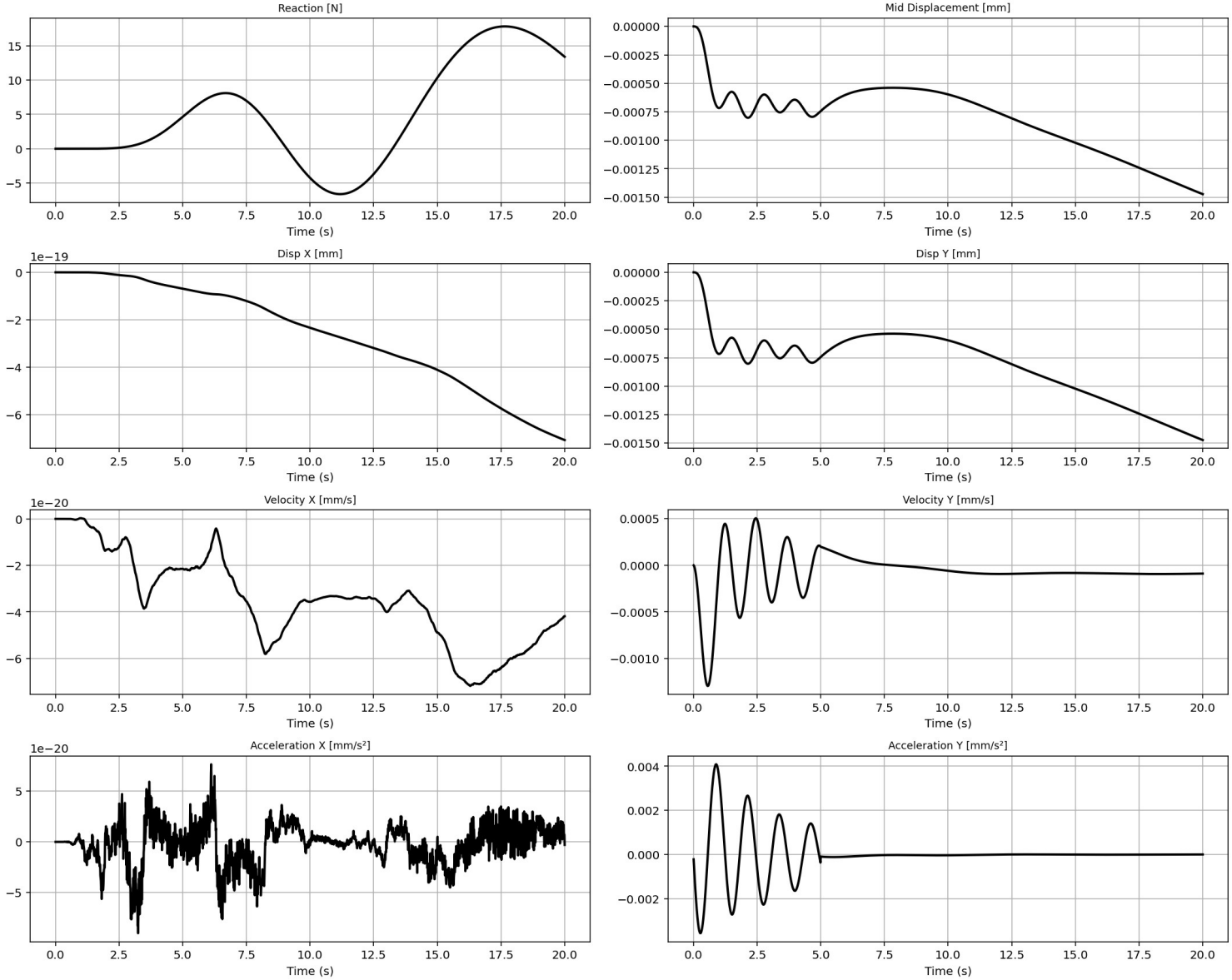


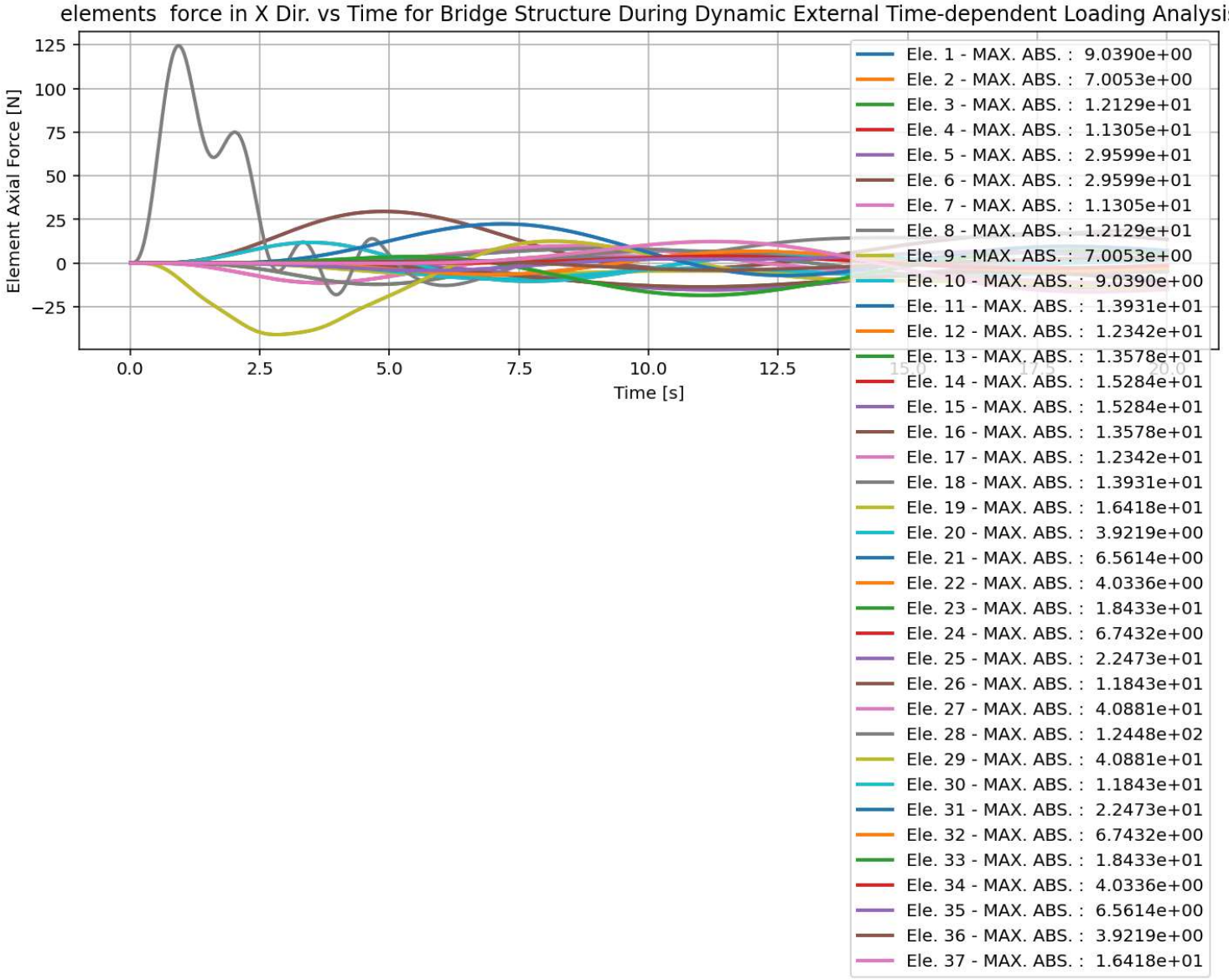
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

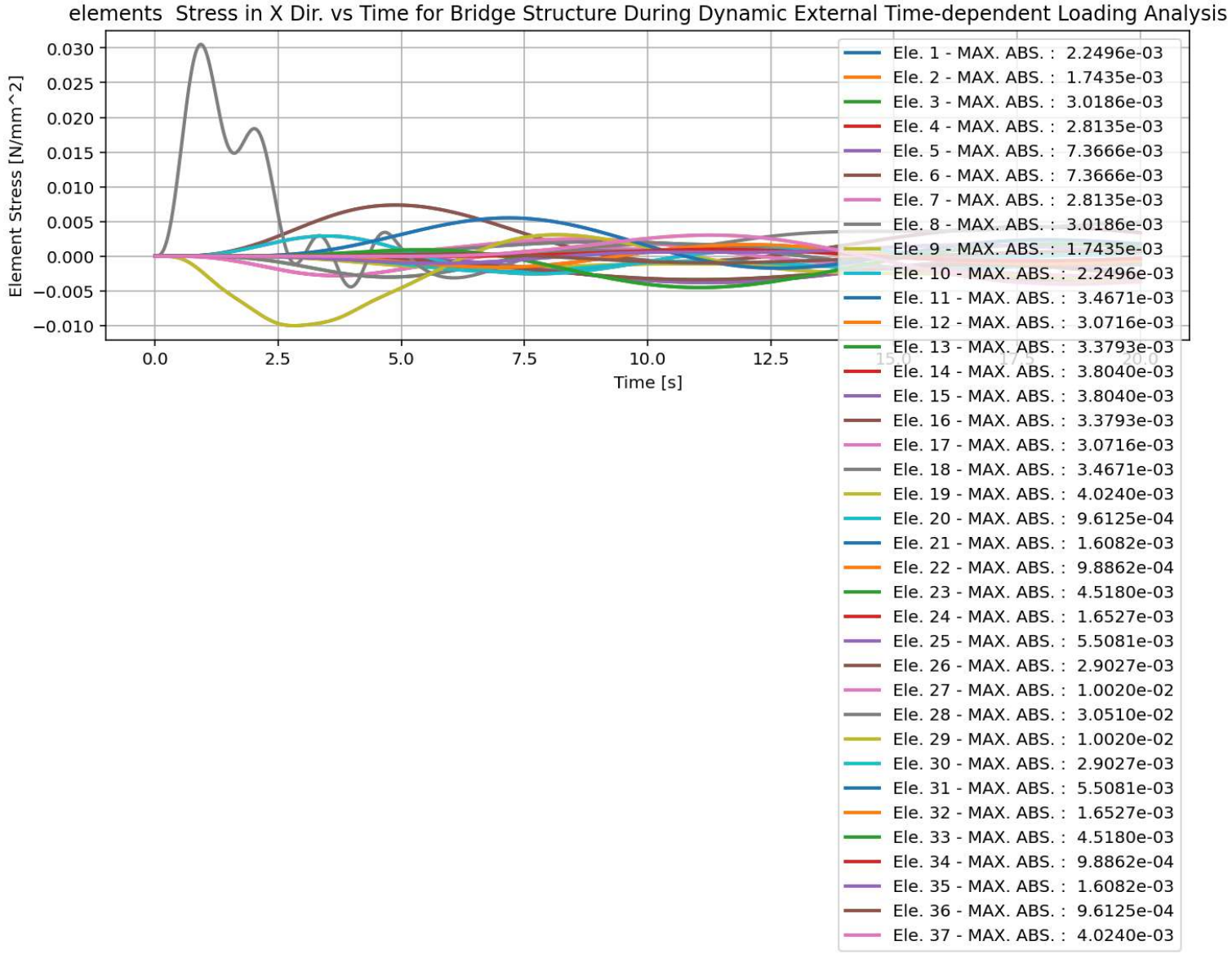
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 13, Col 57 UTF-8 CRLF RW Mem 60%

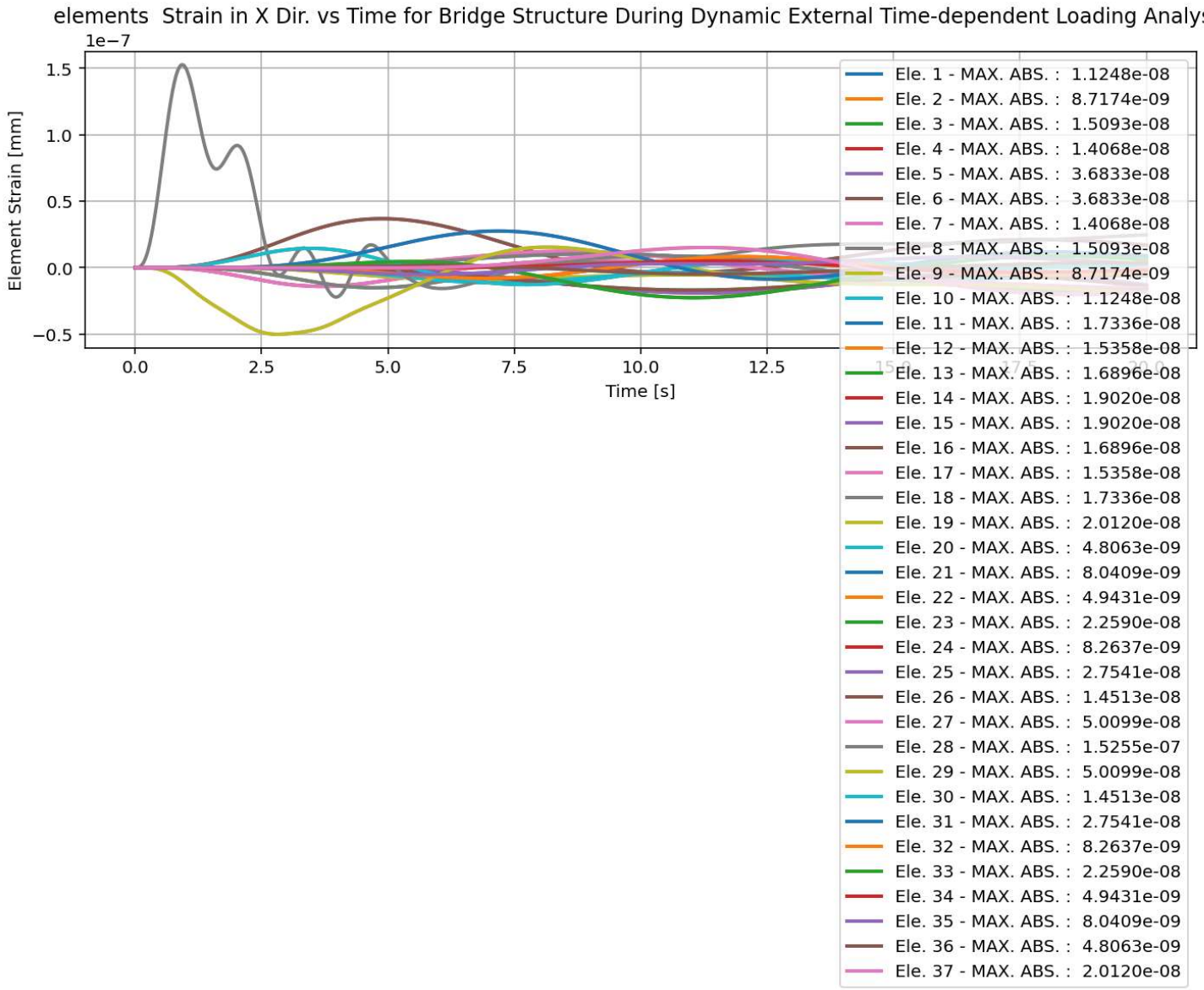

External Time-dependent Loading Over Time
External Loading - Max: 796.029
Force (N)
800
600
400
200
0
−200
−400
−600
0
1
2
3
4
5
Time (s)

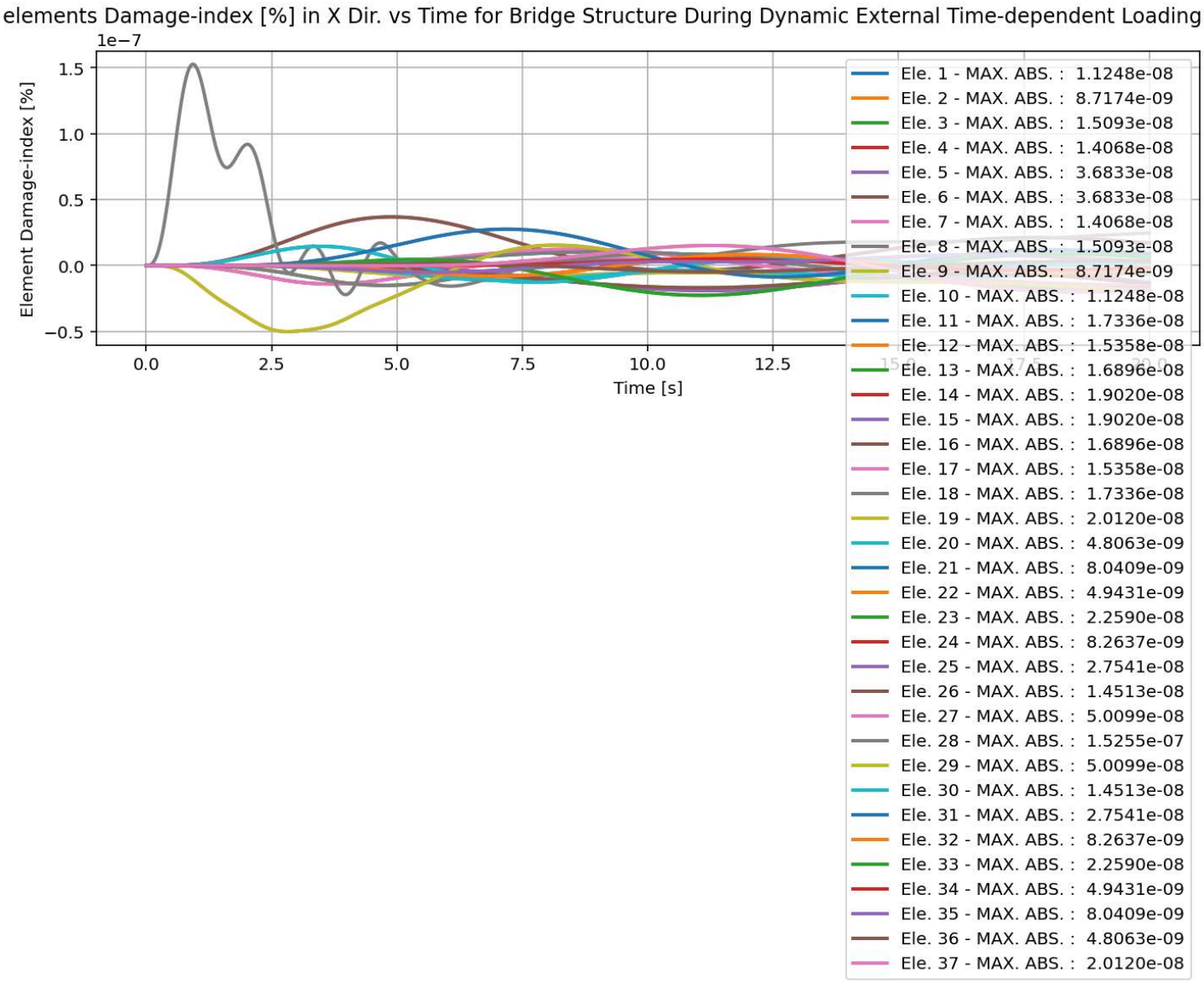

Base Reaction and Displacement of Structure During Dynamic External Time-dependent Loading Analysis
Base Reaction [N]
15
10
5
0
−5
−0.0014
−0.0012
−0.0010
−0.0008
−0.0006
−0.0004
−0.0002
0.0000
Displacement in Middle Span [mm]

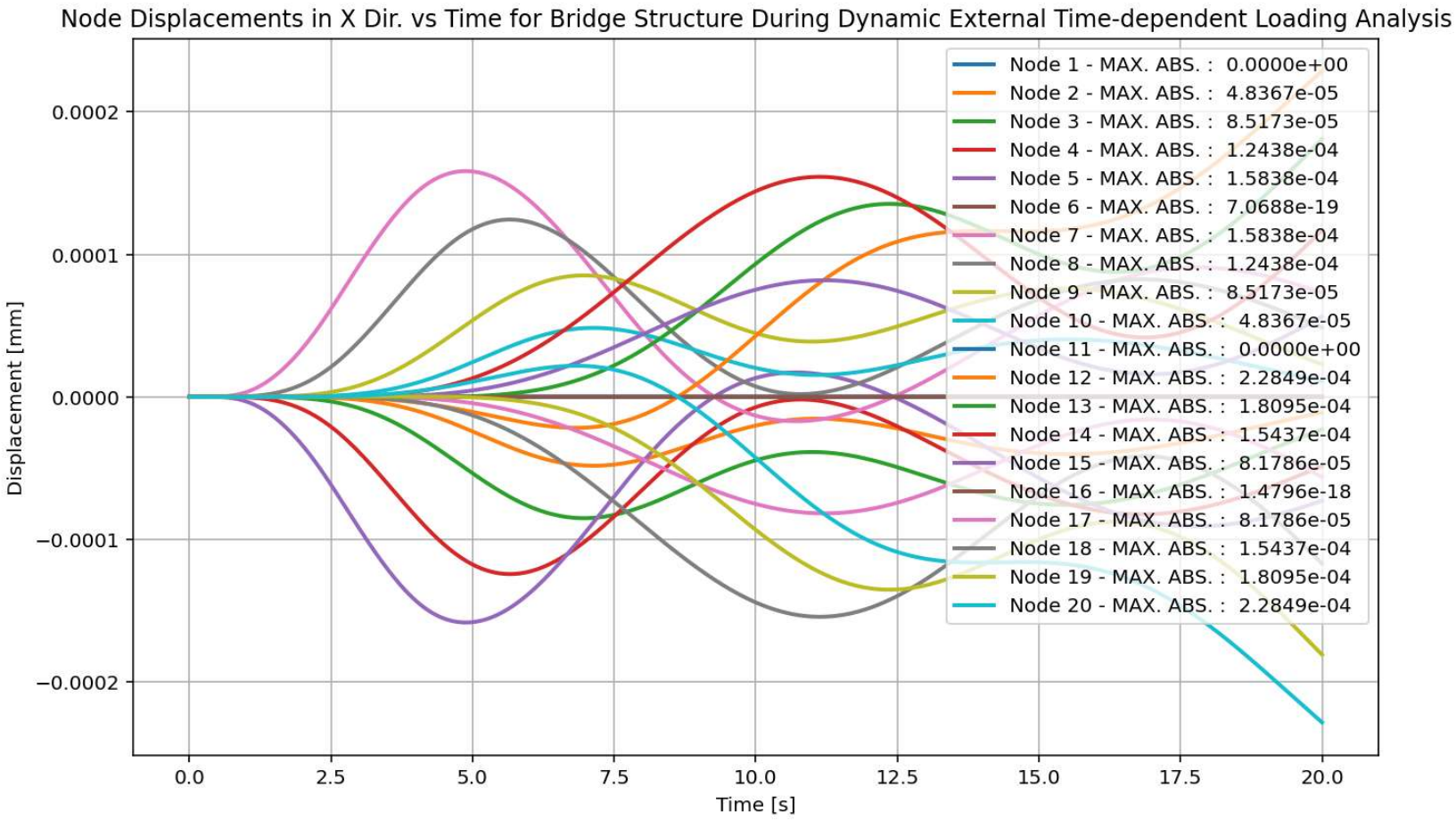

Reaction [N]
Time (s)
Mid Displacement [mm]
Time (s)
Disp X [mm]
1e−19
Time (s)
Disp Y [mm]
Time (s)
Velocity X [mm/s]
1e−20
Time (s)
Velocity Y [mm/s]
Time (s)
Acceleration X [mm/s²]
1e−20
Time (s)
Acceleration Y [mm/s²]
Time (s)

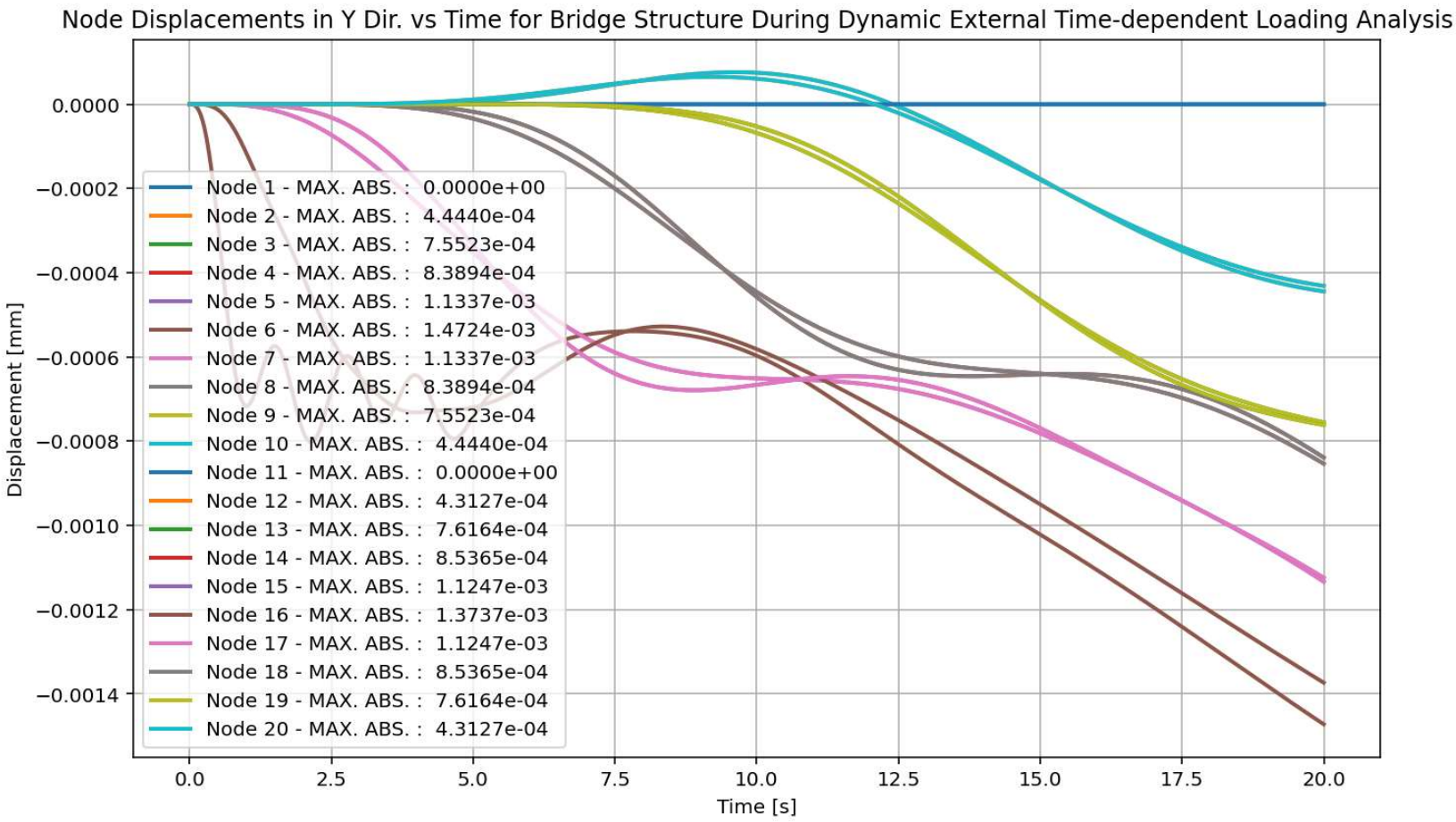

elements force in X Dir. vs Time for Bridge Structure During Dynamic External Time-dependent Loading Analysis
Element Axial Force [N]
125
100
75
50
25
0
−25
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 9.0390e+00
Ele. 2 - MAX. ABS. : 7.0053e+00
Ele. 3 - MAX. ABS. : 1.2129e+01
Ele. 4 - MAX. ABS. : 1.1305e+01
Ele. 5 - MAX. ABS. : 2.9599e+01
Ele. 6 - MAX. ABS. : 2.9599e+01
Ele. 7 - MAX. ABS. : 1.1305e+01
Ele. 8 - MAX. ABS. : 1.2129e+01
Ele. 9 - MAX. ABS. : 7.0053e+00
Ele. 10 - MAX. ABS. : 9.0390e+00
Ele. 11 - MAX. ABS. : 1.3931e+01
Ele. 12 - MAX. ABS. : 1.2342e+01
Ele. 13 - MAX. ABS. : 1.3578e+01
Ele. 14 - MAX. ABS. : 1.5284e+01
Ele. 15 - MAX. ABS. : 1.5284e+01
Ele. 16 - MAX. ABS. : 1.3578e+01
Ele. 17 - MAX. ABS. : 1.2342e+01
Ele. 18 - MAX. ABS. : 1.3931e+01
Ele. 19 - MAX. ABS. : 1.6418e+01
Ele. 20 - MAX. ABS. : 3.9219e+00
Ele. 21 - MAX. ABS. : 6.5614e+00
Ele. 22 - MAX. ABS. : 4.0336e+00
Ele. 23 - MAX. ABS. : 1.8433e+01
Ele. 24 - MAX. ABS. : 6.7432e+00
Ele. 25 - MAX. ABS. : 2.2473e+01
Ele. 26 - MAX. ABS. : 1.1843e+01
Ele. 27 - MAX. ABS. : 4.0881e+01
Ele. 28 - MAX. ABS. : 1.2448e+02
Ele. 29 - MAX. ABS. : 4.0881e+01
Ele. 30 - MAX. ABS. : 1.1843e+01
Ele. 31 - MAX. ABS. : 2.2473e+01
Ele. 32 - MAX. ABS. : 6.7432e+00
Ele. 33 - MAX. ABS. : 1.8433e+01
Ele. 34 - MAX. ABS. : 4.0336e+00
Ele. 35 - MAX. ABS. : 6.5614e+00
Ele. 36 - MAX. ABS. : 3.9219e+00
Ele. 37 - MAX. ABS. : 1.6418e+01

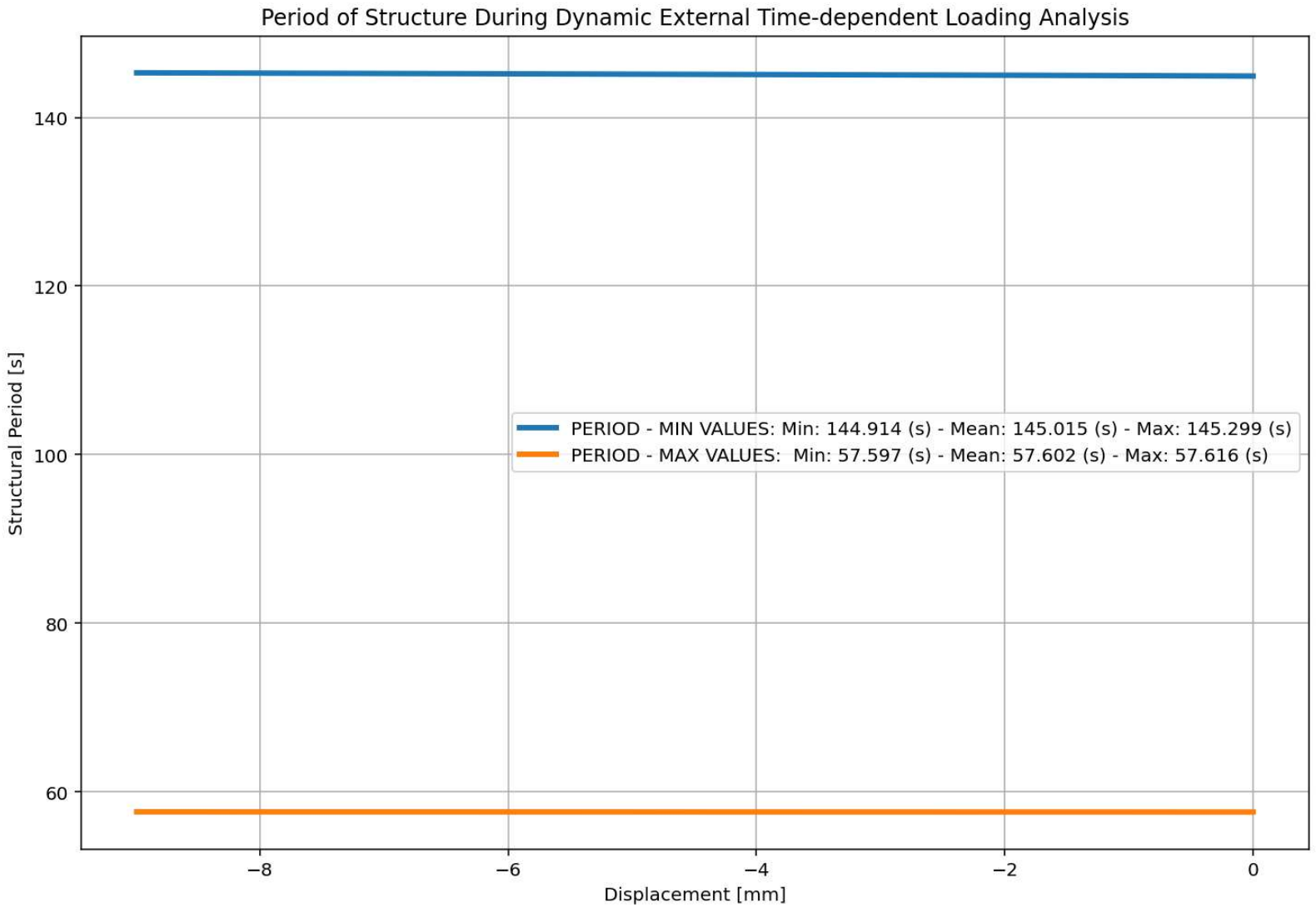

elements Stress in X Dir. vs Time for Bridge Structure During Dynamic External Time-dependent Loading Analysis
Element Stress [N/mm^2]
0.030
0.025
0.020
0.015
0.010
0.005
0.000
−0.005
−0.010
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 2.2496e-03
Ele. 2 - MAX. ABS. : 1.7435e-03
Ele. 3 - MAX. ABS. : 3.0186e-03
Ele. 4 - MAX. ABS. : 2.8135e-03
Ele. 5 - MAX. ABS. : 7.3666e-03
Ele. 6 - MAX. ABS. : 7.3666e-03
Ele. 7 - MAX. ABS. : 2.8135e-03
Ele. 8 - MAX. ABS. : 3.0186e-03
Ele. 9 - MAX. ABS. : 1.7435e-03
Ele. 10 - MAX. ABS. : 2.2496e-03
Ele. 11 - MAX. ABS. : 3.4671e-03
Ele. 12 - MAX. ABS. : 3.0716e-03
Ele. 13 - MAX. ABS. : 3.3793e-03
Ele. 14 - MAX. ABS. : 3.8040e-03
Ele. 15 - MAX. ABS. : 3.8040e-03
Ele. 16 - MAX. ABS. : 3.3793e-03
Ele. 17 - MAX. ABS. : 3.0716e-03
Ele. 18 - MAX. ABS. : 3.4671e-03
Ele. 19 - MAX. ABS. : 4.0240e-03
Ele. 20 - MAX. ABS. : 9.6125e-04
Ele. 21 - MAX. ABS. : 1.6082e-03
Ele. 22 - MAX. ABS. : 9.8862e-04
Ele. 23 - MAX. ABS. : 4.5180e-03
Ele. 24 - MAX. ABS. : 1.6527e-03
Ele. 25 - MAX. ABS. : 5.5081e-03
Ele. 26 - MAX. ABS. : 2.9027e-03
Ele. 27 - MAX. ABS. : 1.0020e-02
Ele. 28 - MAX. ABS. : 3.0510e-02
Ele. 29 - MAX. ABS. : 1.0020e-02
Ele. 30 - MAX. ABS. : 2.9027e-03
Ele. 31 - MAX. ABS. : 5.5081e-03
Ele. 32 - MAX. ABS. : 1.6527e-03
Ele. 33 - MAX. ABS. : 4.5180e-03
Ele. 34 - MAX. ABS. : 9.8862e-04
Ele. 35 - MAX. ABS. : 1.6082e-03
Ele. 36 - MAX. ABS. : 9.6125e-04
Ele. 37 - MAX. ABS. : 4.0240e-03

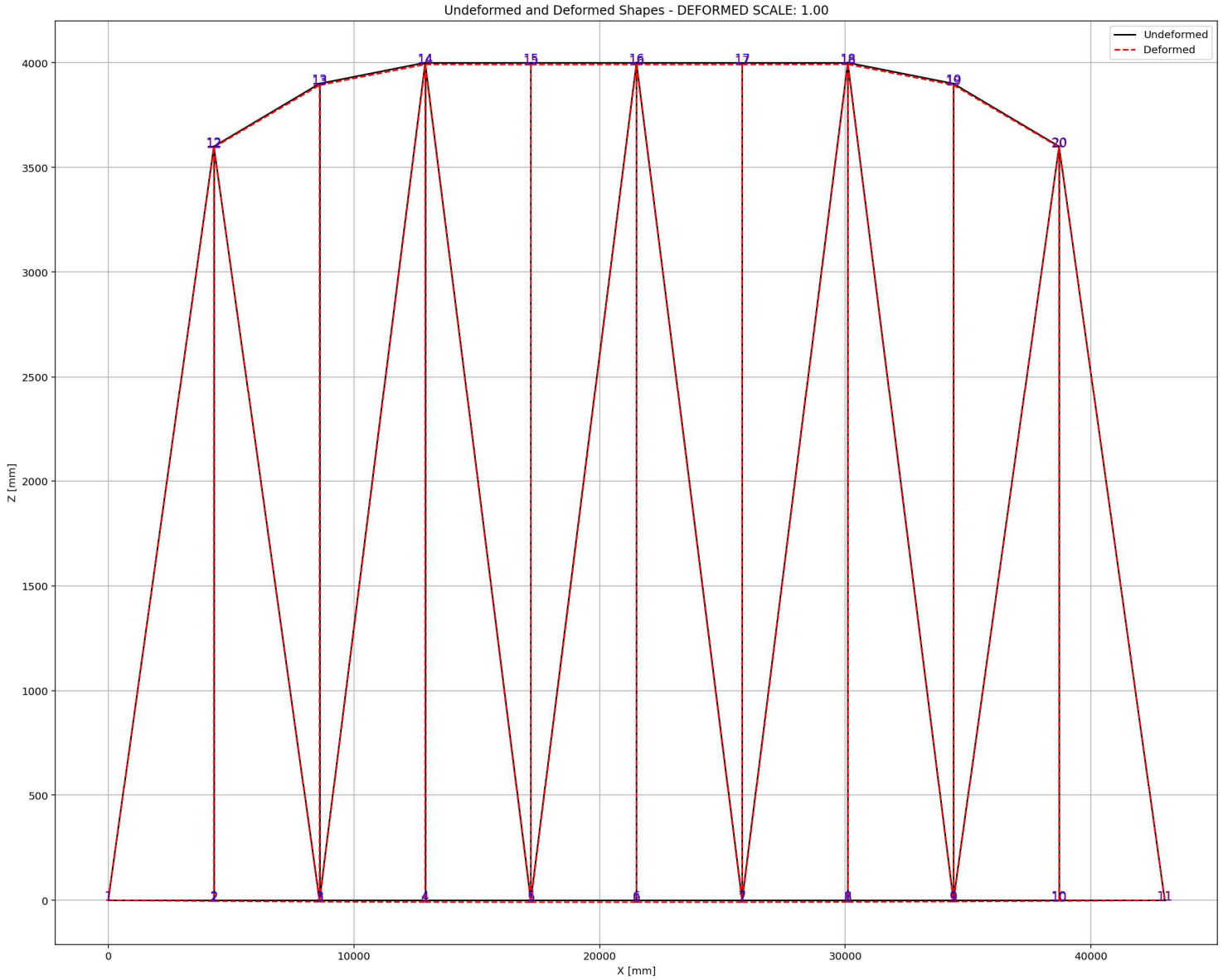

elements Strain in X Dir. vs Time for Bridge Structure During Dynamic External Time-dependent Loading Analysis
1e−7
1.5
1.0
0.5
0.0
−0.5
Element Strain [mm]
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 1.1248e-08
Ele. 2 - MAX. ABS. : 8.7174e-09
Ele. 3 - MAX. ABS. : 1.5093e-08
Ele. 4 - MAX. ABS. : 1.4068e-08
Ele. 5 - MAX. ABS. : 3.6833e-08
Ele. 6 - MAX. ABS. : 3.6833e-08
Ele. 7 - MAX. ABS. : 1.4068e-08
Ele. 8 - MAX. ABS. : 1.5093e-08
Ele. 9 - MAX. ABS. : 8.7174e-09
Ele. 10 - MAX. ABS. : 1.1248e-08
Ele. 11 - MAX. ABS. : 1.7336e-08
Ele. 12 - MAX. ABS. : 1.5358e-08
Ele. 13 - MAX. ABS. : 1.6896e-08
Ele. 14 - MAX. ABS. : 1.9020e-08
Ele. 15 - MAX. ABS. : 1.9020e-08
Ele. 16 - MAX. ABS. : 1.6896e-08
Ele. 17 - MAX. ABS. : 1.5358e-08
Ele. 18 - MAX. ABS. : 1.7336e-08
Ele. 19 - MAX. ABS. : 2.0120e-08
Ele. 20 - MAX. ABS. : 4.8063e-09
Ele. 21 - MAX. ABS. : 8.0409e-09
Ele. 22 - MAX. ABS. : 4.9431e-09
Ele. 23 - MAX. ABS. : 2.2590e-08
Ele. 24 - MAX. ABS. : 8.2637e-09
Ele. 25 - MAX. ABS. : 2.7541e-08
Ele. 26 - MAX. ABS. : 1.4513e-08
Ele. 27 - MAX. ABS. : 5.0099e-08
Ele. 28 - MAX. ABS. : 1.5255e-07
Ele. 29 - MAX. ABS. : 5.0099e-08
Ele. 30 - MAX. ABS. : 1.4513e-08
Ele. 31 - MAX. ABS. : 2.7541e-08
Ele. 32 - MAX. ABS. : 8.2637e-09
Ele. 33 - MAX. ABS. : 2.2590e-08
Ele. 34 - MAX. ABS. : 4.9431e-09
Ele. 35 - MAX. ABS. : 8.0409e-09
Ele. 36 - MAX. ABS. : 4.8063e-09
Ele. 37 - MAX. ABS. : 2.0120e-08


elements Damage-index [%] in X Dir. vs Time for Bridge Structure During Dynamic External Time-dependent Loading Analysis
1e−7
1.5
1.0
0.5
0.0
−0.5
Element Damage-index [%]
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 1.1248e-08
Ele. 2 - MAX. ABS. : 8.7174e-09
Ele. 3 - MAX. ABS. : 1.5093e-08
Ele. 4 - MAX. ABS. : 1.4068e-08
Ele. 5 - MAX. ABS. : 3.6833e-08
Ele. 6 - MAX. ABS. : 3.6833e-08
Ele. 7 - MAX. ABS. : 1.4068e-08
Ele. 8 - MAX. ABS. : 1.5093e-08
Ele. 9 - MAX. ABS. : 8.7174e-09
Ele. 10 - MAX. ABS. : 1.1248e-08
Ele. 11 - MAX. ABS. : 1.7336e-08
Ele. 12 - MAX. ABS. : 1.5358e-08
Ele. 13 - MAX. ABS. : 1.6896e-08
Ele. 14 - MAX. ABS. : 1.9020e-08
Ele. 15 - MAX. ABS. : 1.9020e-08
Ele. 16 - MAX. ABS. : 1.6896e-08
Ele. 17 - MAX. ABS. : 1.5358e-08
Ele. 18 - MAX. ABS. : 1.7336e-08
Ele. 19 - MAX. ABS. : 2.0120e-08
Ele. 20 - MAX. ABS. : 4.8063e-09
Ele. 21 - MAX. ABS. : 8.0409e-09
Ele. 22 - MAX. ABS. : 4.9431e-09
Ele. 23 - MAX. ABS. : 2.2590e-08
Ele. 24 - MAX. ABS. : 8.2637e-09
Ele. 25 - MAX. ABS. : 2.7541e-08
Ele. 26 - MAX. ABS. : 1.4513e-08
Ele. 27 - MAX. ABS. : 5.0099e-08
Ele. 28 - MAX. ABS. : 1.5255e-07
Ele. 29 - MAX. ABS. : 5.0099e-08
Ele. 30 - MAX. ABS. : 1.4513e-08
Ele. 31 - MAX. ABS. : 2.7541e-08
Ele. 32 - MAX. ABS. : 8.2637e-09
Ele. 33 - MAX. ABS. : 2.2590e-08
Ele. 34 - MAX. ABS. : 4.9431e-09
Ele. 35 - MAX. ABS. : 8.0409e-09
Ele. 36 - MAX. ABS. : 4.8063e-09
Ele. 37 - MAX. ABS. : 2.0120e-08


Node Displacements in X Dir. vs Time for Bridge Structure During Dynamic External Time-dependent Loading Analysis
Displacement [mm]
0.0002
0.0001
0.0000
−0.0001
−0.0002
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 4.8367e-05
Node 3 - MAX. ABS. : 8.5173e-05
Node 4 - MAX. ABS. : 1.2438e-04
Node 5 - MAX. ABS. : 1.5838e-04
Node 6 - MAX. ABS. : 7.0688e-19
Node 7 - MAX. ABS. : 1.5838e-04
Node 8 - MAX. ABS. : 1.2438e-04
Node 9 - MAX. ABS. : 8.5173e-05
Node 10 - MAX. ABS. : 4.8367e-05
Node 11 - MAX. ABS. : 0.0000e+00
Node 12 - MAX. ABS. : 2.2849e-04
Node 13 - MAX. ABS. : 1.8095e-04
Node 14 - MAX. ABS. : 1.5437e-04
Node 15 - MAX. ABS. : 8.1786e-05
Node 16 - MAX. ABS. : 1.4796e-18
Node 17 - MAX. ABS. : 8.1786e-05
Node 18 - MAX. ABS. : 1.5437e-04
Node 19 - MAX. ABS. : 1.8095e-04
Node 20 - MAX. ABS. : 2.2849e-04


Node Displacements in Y Dir. vs Time for Bridge Structure During Dynamic External Time-dependent Loading Analysis
Displacement [mm]
Time [s]
0.0000
−0.0002
−0.0004
−0.0006
−0.0008
−0.0010
−0.0012
−0.0014
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 4.4440e-04
Node 3 - MAX. ABS. : 7.5523e-04
Node 4 - MAX. ABS. : 8.3894e-04
Node 5 - MAX. ABS. : 1.1337e-03
Node 6 - MAX. ABS. : 1.4724e-03
Node 7 - MAX. ABS. : 1.1337e-03
Node 8 - MAX. ABS. : 8.3894e-04
Node 9 - MAX. ABS. : 7.5523e-04
Node 10 - MAX. ABS. : 4.4440e-04
Node 11 - MAX. ABS. : 0.0000e+00
Node 12 - MAX. ABS. : 4.3127e-04
Node 13 - MAX. ABS. : 7.6164e-04
Node 14 - MAX. ABS. : 8.5365e-04
Node 15 - MAX. ABS. : 1.1247e-03
Node 16 - MAX. ABS. : 1.3737e-03
Node 17 - MAX. ABS. : 1.1247e-03
Node 18 - MAX. ABS. : 8.5365e-04
Node 19 - MAX. ABS. : 7.6164e-04
Node 20 - MAX. ABS. : 4.3127e-04


Period of Structure During Dynamic External Time-dependent Loading Analysis
Structural Period [s]
140
120
100
80
60
−8
−6
−4
−2
0
Displacement [mm]
PERIOD - MIN VALUES: Min: 144.914 (s) - Mean: 145.015 (s) - Max: 145.299 (s)
PERIOD - MAX VALUES: Min: 57.597 (s) - Mean: 57.602 (s) - Max: 57.616 (s)


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
3500
4000
0
10000
20000
30000
40000
12
13
14
15
16
17
18
19
20
10
11

FREE-VIBRATION ANALYSIS

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

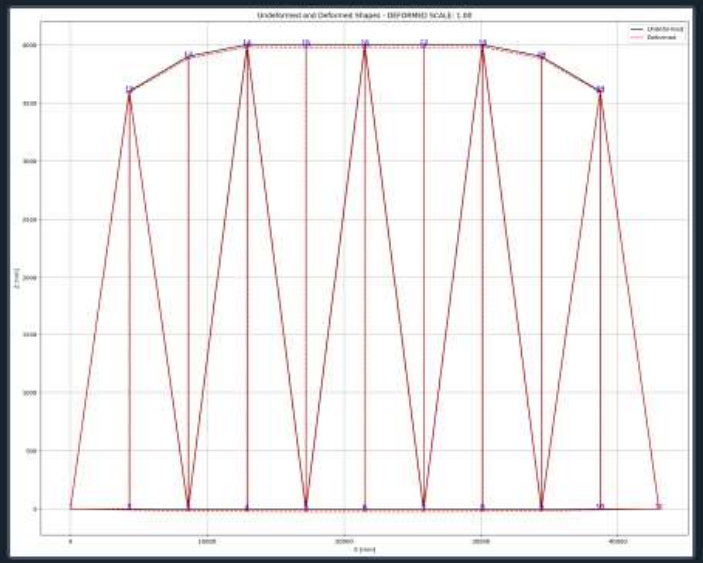
C:\Users\Dell\Desktop\OPENSEES_FILES\+BRIDGE_WARREN_TRUSS

C:\Users\Dell\Desktop\OPENSEES_FILES\+BRIDGE_WARREN_TRUSS\BRIDGE_WARREN_TRUSS.py

BRIDGE_WARREN_TRUSS.py

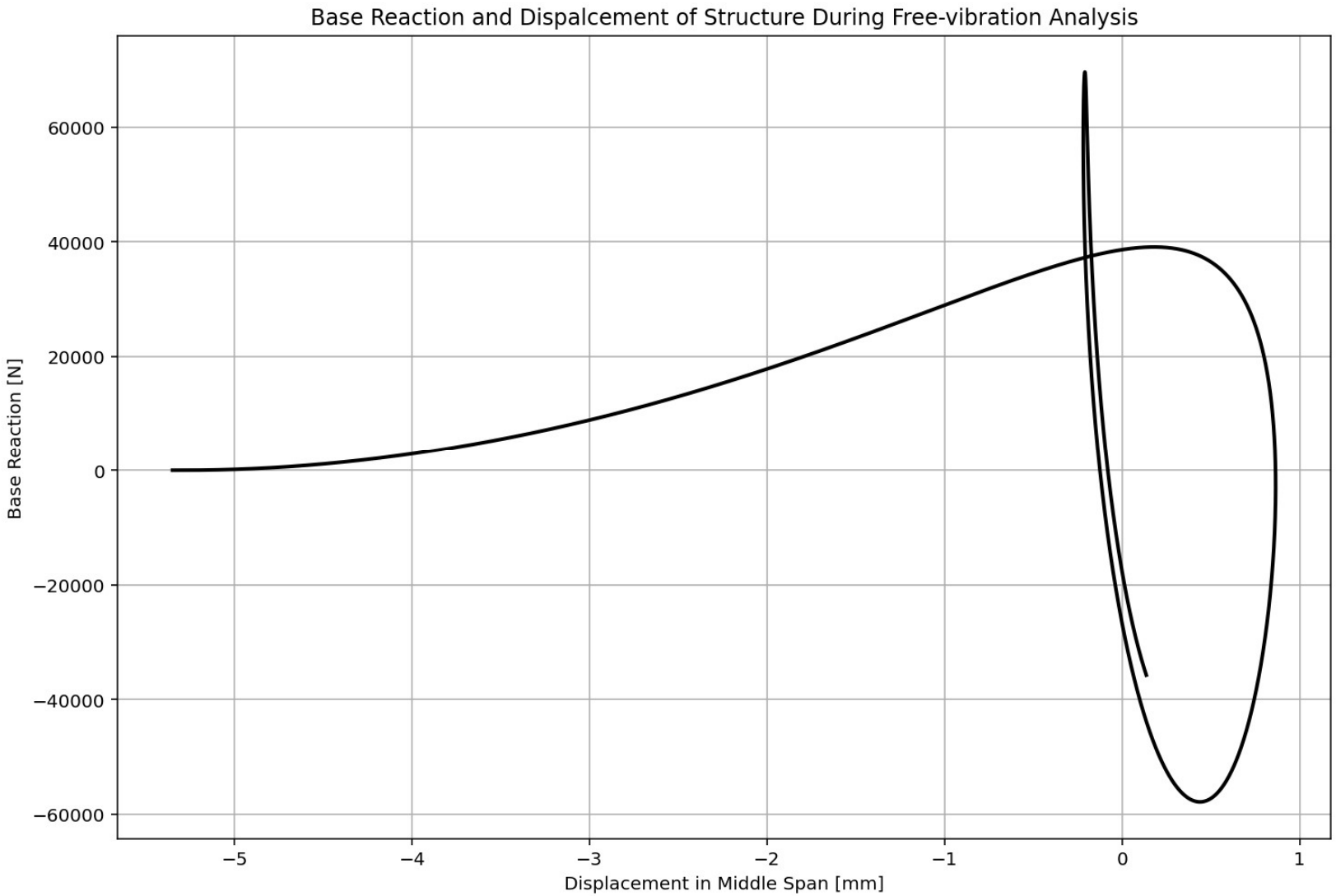
```
1276  # FREE-VIBRATION ANALYSIS (DYNAMIC TIME-HISTORY ANALYSIS)
1277  #ELE_TYPE = 'Truss'      # MATERIAL NONLINEARITY
1278  ELE_TYPE = 'corotTruss'  # MATERIAL AND GEOMETRIC NONLINEARITY
1279  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1280  ANAL_TYPE = 'FREE-VIBRATION'
1281  DATA = WARREN_TRUSS_BRIDGE(L, H, A_chord, A_diag, MAT_TYPE, ELE_TYPE, ANAL_TYPE, TOTAL_MAS
1282
1283  (time_FV, reaction_FV, disp_mid_FV,
1284  ele_force_FV, ele_stress_FV, ele_strain_FV,
1285  node_displacementsX_FV, node_displacementsY_FV,
1286  dispX_FV, dispY_FV,
1287  veloX_FV, veloY_FV,
1288  accX_FV, accY_FV,
1289  stiffness_FV, PERIOD_FV, damping_ratio_FV,
1290  PERIOD_MIN_FV, PERIOD_MAX_FV) = DATA
1291
1292  XDATA = disp_mid_FV
1293  YDATA = reaction_FV
1294  XLABEL = 'Displacement in Middle Span [mm]'
1295  YLABEL = 'Base Reaction [N]'
1296  TITLE = 'Base Reaction and Dispalcement of Structure During Free-vibration Analysis'
1297  COLOR = 'black'
1298  SEMILOGY = False
1299  PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1300
1301  PLOT_TIME_HISTORY(time_FV, reaction_FV, disp_mid_FV,
1302                    dispX_FV, dispY_FV,
1303                    veloX_FV, veloY_FV,
1304                    accX_FV, accY_FV)
1305
1306  # PLOT ELEMENTS AXIAL FORCE
1307  YLABEL = 'Element Axial Force [N]'
1308  TITLE = "elements  force in X Dir. vs Time for Bridge Structure During Free-vibration Anal
1309  PLOT_FORCES(time_FV, ele_force_FV, YLABEL, TITLE) # BRIDGE STRUCTURE - ELEMENTS AXIAL FORC
```

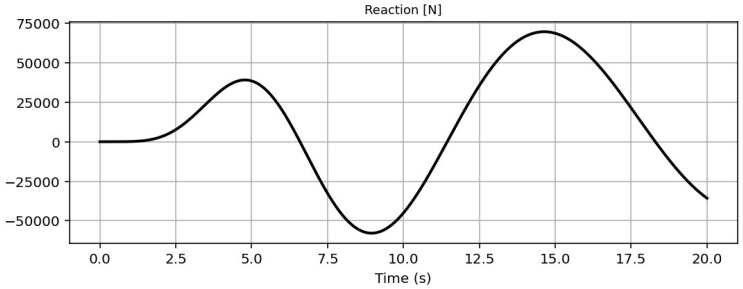
19 %

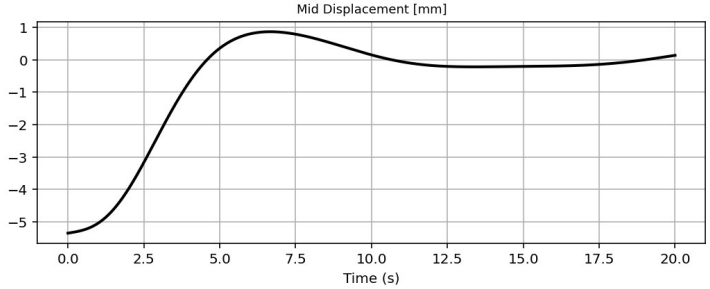


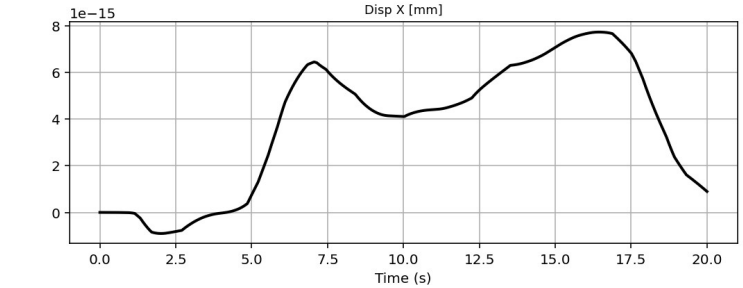
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

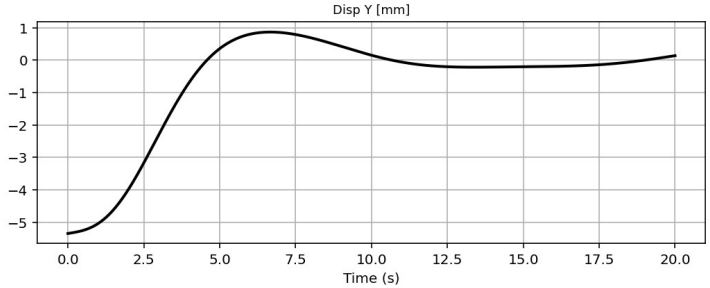
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 13, Col 57 UTF-8 CRLF RW Mem 60%

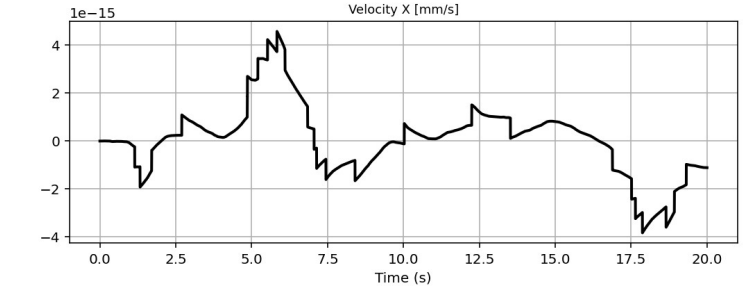

Base Reaction and Dispalcement of Structure During Free-vibration Analysis
Base Reaction [N]
60000
40000
20000
0
−20000
−40000
−60000
−5
−4
−3
−2
−1
0
1
Displacement in Middle Span [mm]

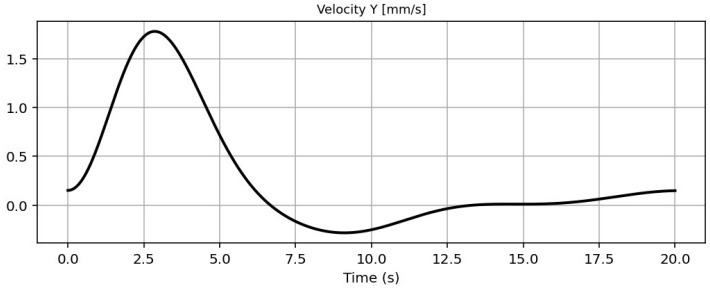

Reaction [N]
75000
50000
25000
0
−25000
−50000
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (s)

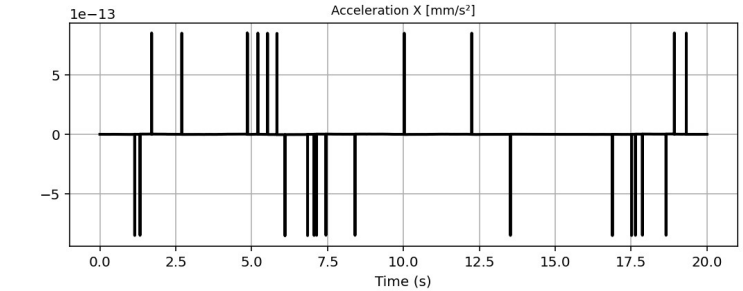

Mid Displacement [mm]
1
0
−1
−2
−3
−4
−5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (s)

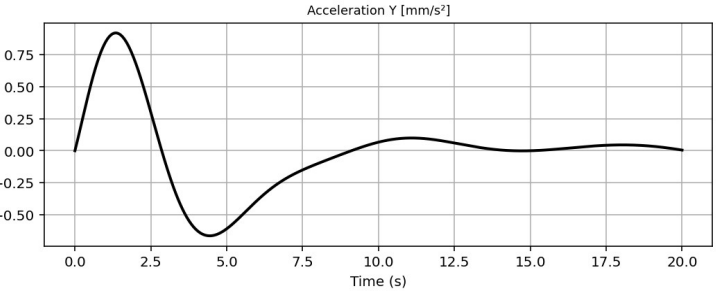

Disp X [mm]
1e−15
8
6
4
2
0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (s)

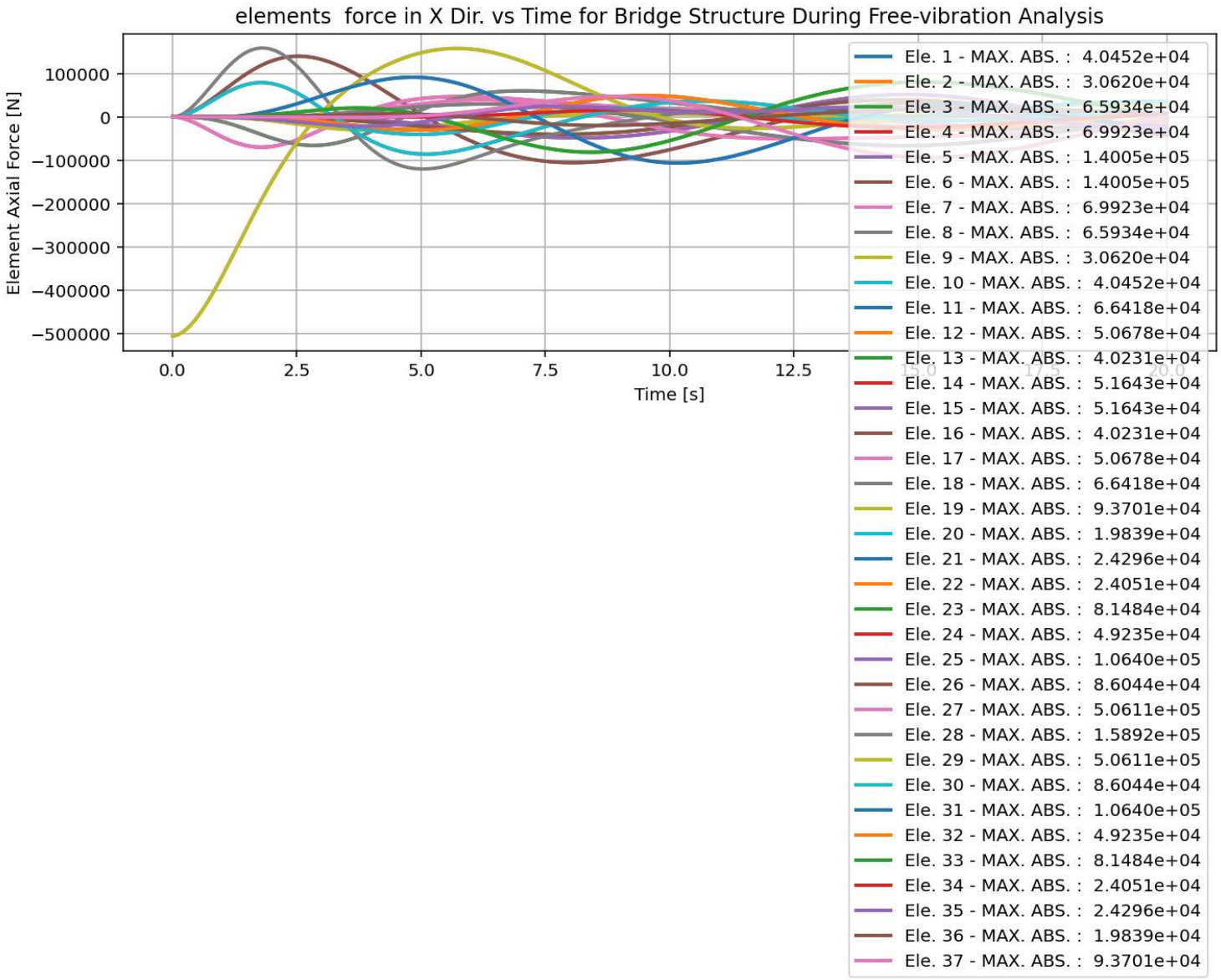

Disp Y [mm]
1
0
−1
−2
−3
−4
−5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (s)

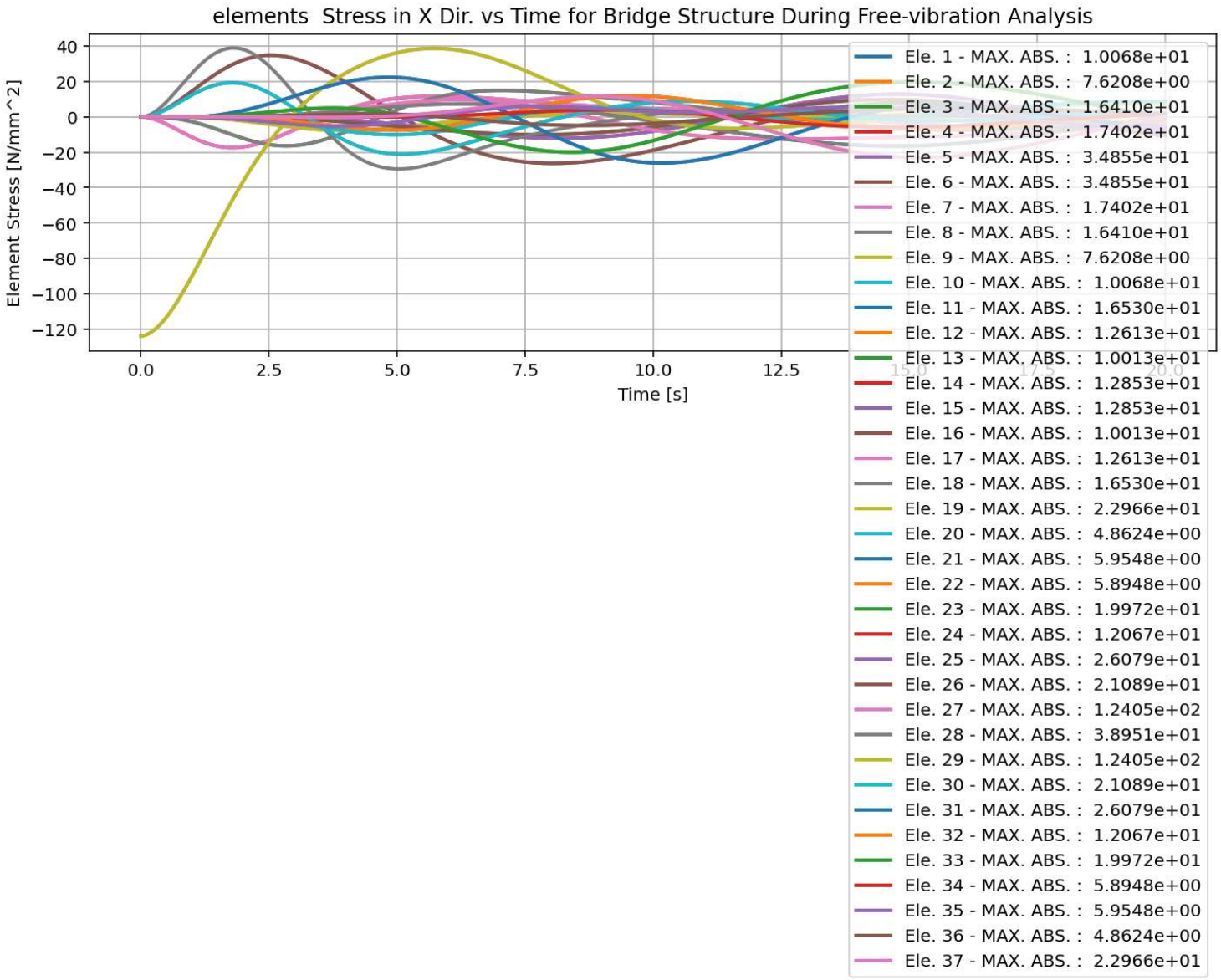

Velocity X [mm/s]
1e−15
4
2
0
−2
−4
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (s)

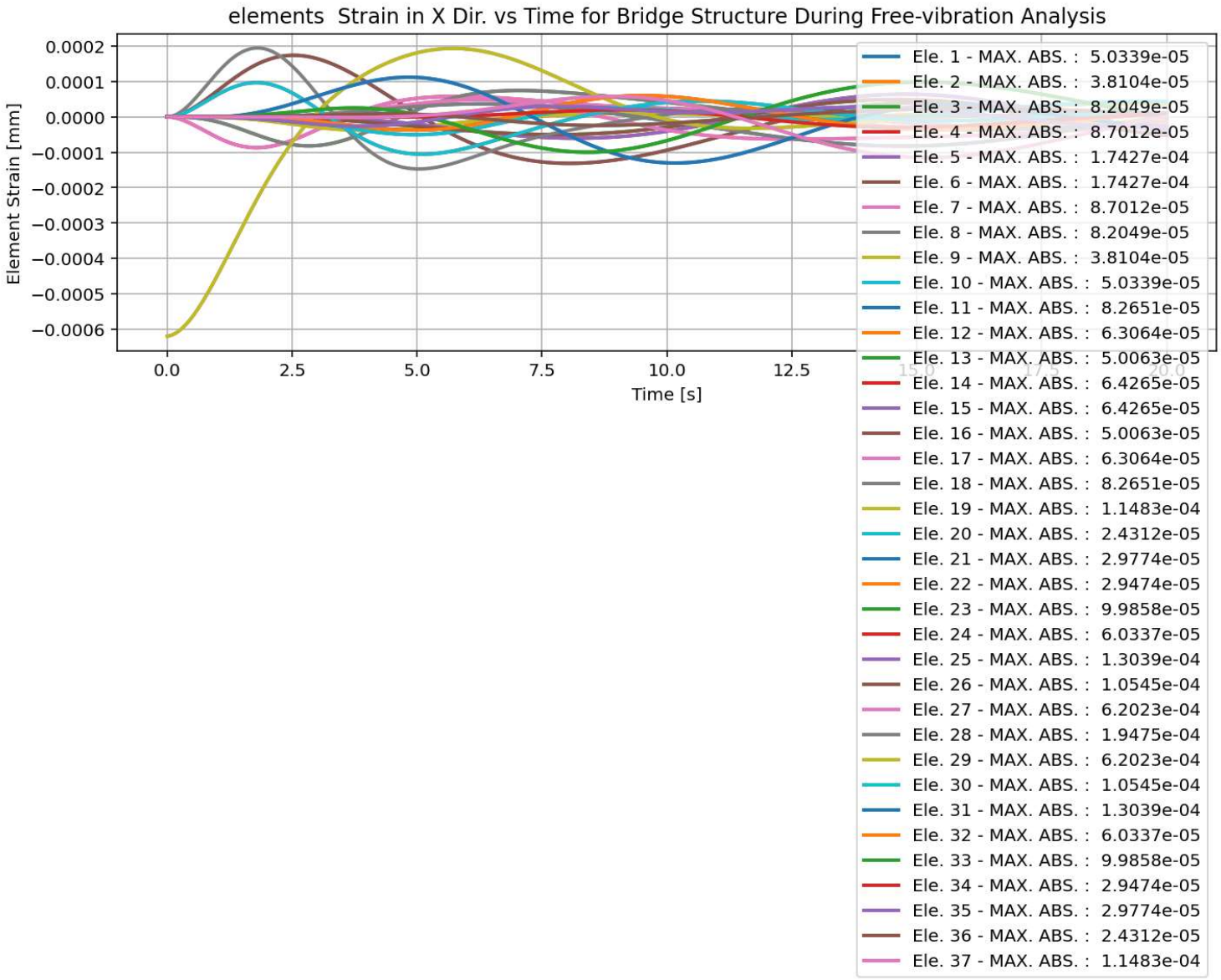

Velocity Y [mm/s]
1.5
1.0
0.5
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (s)

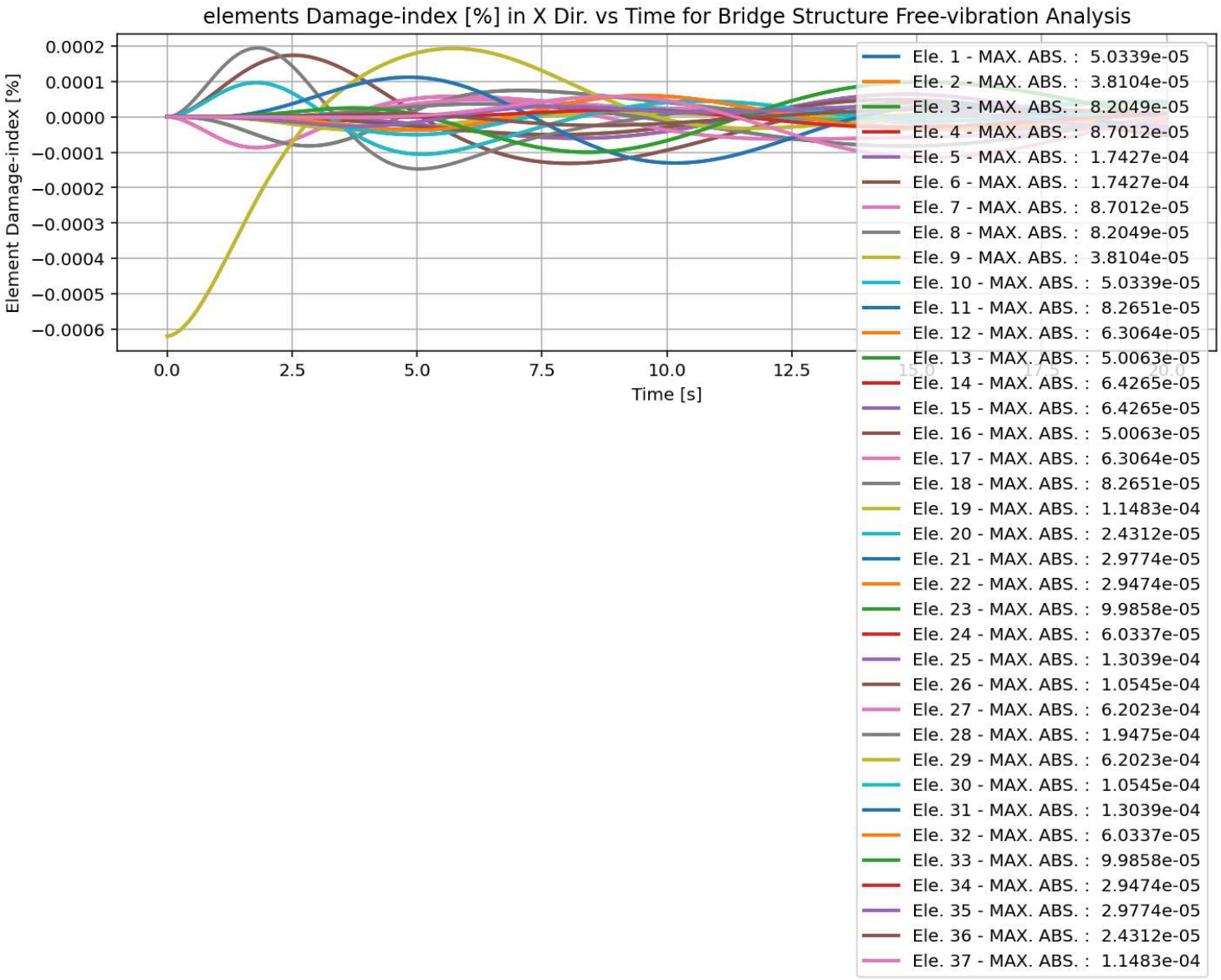

Acceleration X [mm/s²]
1e−13
5
0
−5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (s)

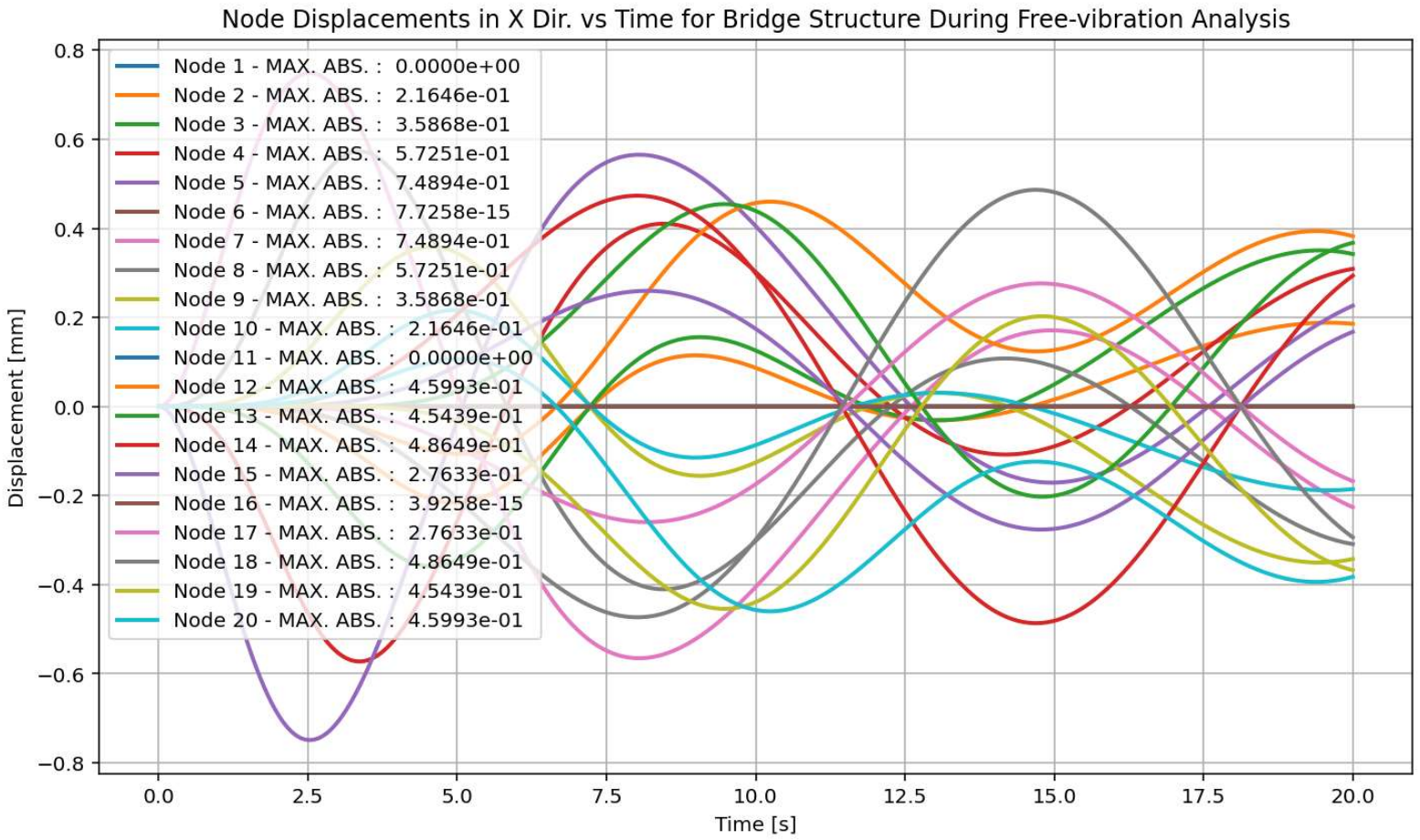

Acceleration Y [mm/s²]
0.75
0.50
0.25
0.00
−0.25
−0.50
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (s)

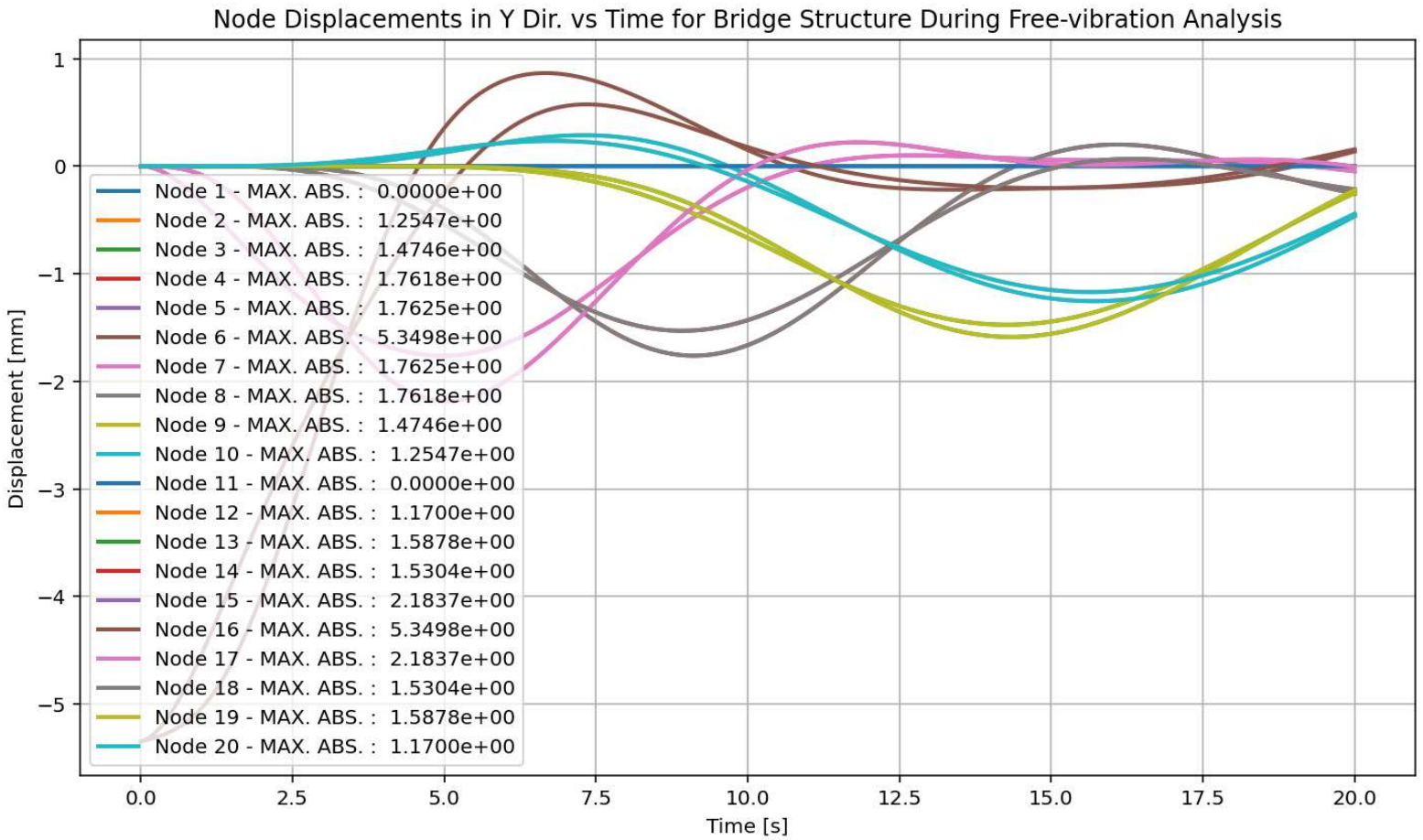

elements force in X Dir. vs Time for Bridge Structure During Free-vibration Analysis
Element Axial Force [N]
100000
0
−100000
−200000
−300000
−400000
−500000
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 4.0452e+04
Ele. 2 - MAX. ABS. : 3.0620e+04
Ele. 3 - MAX. ABS. : 6.5934e+04
Ele. 4 - MAX. ABS. : 6.9923e+04
Ele. 5 - MAX. ABS. : 1.4005e+05
Ele. 6 - MAX. ABS. : 1.4005e+05
Ele. 7 - MAX. ABS. : 6.9923e+04
Ele. 8 - MAX. ABS. : 6.5934e+04
Ele. 9 - MAX. ABS. : 3.0620e+04
Ele. 10 - MAX. ABS. : 4.0452e+04
Ele. 11 - MAX. ABS. : 6.6418e+04
Ele. 12 - MAX. ABS. : 5.0678e+04
Ele. 13 - MAX. ABS. : 4.0231e+04
Ele. 14 - MAX. ABS. : 5.1643e+04
Ele. 15 - MAX. ABS. : 5.1643e+04
Ele. 16 - MAX. ABS. : 4.0231e+04
Ele. 17 - MAX. ABS. : 5.0678e+04
Ele. 18 - MAX. ABS. : 6.6418e+04
Ele. 19 - MAX. ABS. : 9.3701e+04
Ele. 20 - MAX. ABS. : 1.9839e+04
Ele. 21 - MAX. ABS. : 2.4296e+04
Ele. 22 - MAX. ABS. : 2.4051e+04
Ele. 23 - MAX. ABS. : 8.1484e+04
Ele. 24 - MAX. ABS. : 4.9235e+04
Ele. 25 - MAX. ABS. : 1.0640e+05
Ele. 26 - MAX. ABS. : 8.6044e+04
Ele. 27 - MAX. ABS. : 5.0611e+05
Ele. 28 - MAX. ABS. : 1.5892e+05
Ele. 29 - MAX. ABS. : 5.0611e+05
Ele. 30 - MAX. ABS. : 8.6044e+04
Ele. 31 - MAX. ABS. : 1.0640e+05
Ele. 32 - MAX. ABS. : 4.9235e+04
Ele. 33 - MAX. ABS. : 8.1484e+04
Ele. 34 - MAX. ABS. : 2.4051e+04
Ele. 35 - MAX. ABS. : 2.4296e+04
Ele. 36 - MAX. ABS. : 1.9839e+04
Ele. 37 - MAX. ABS. : 9.3701e+04

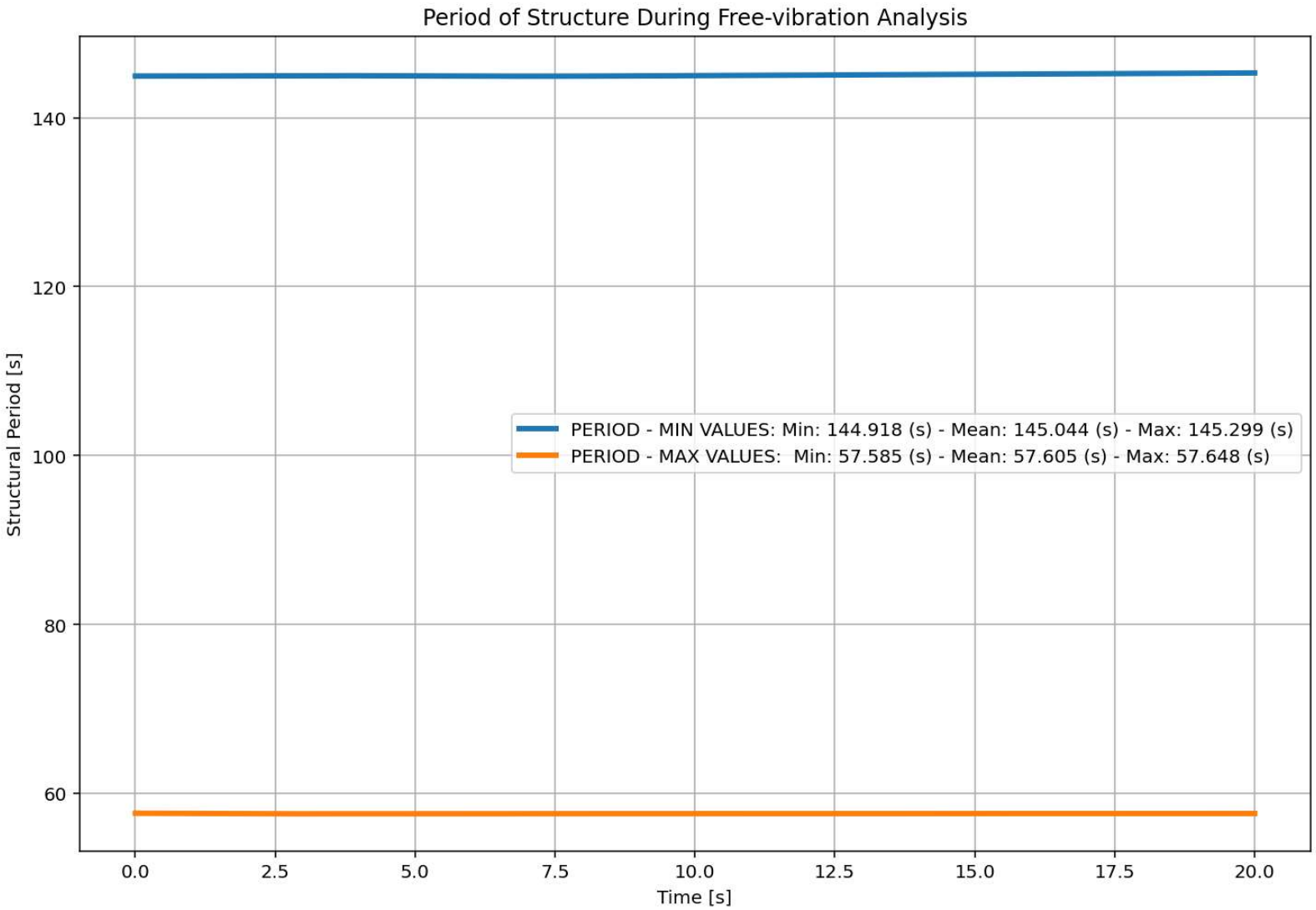

elements Stress in X Dir. vs Time for Bridge Structure During Free-vibration Analysis
Element Stress [N/mm^2]
Time [s]
40
20
0
−20
−40
−60
−80
−100
−120
0.0
2.5
5.0
7.5
10.0
12.5
Ele. 1 - MAX. ABS. : 1.0068e+01
Ele. 2 - MAX. ABS. : 7.6208e+00
Ele. 3 - MAX. ABS. : 1.6410e+01
Ele. 4 - MAX. ABS. : 1.7402e+01
Ele. 5 - MAX. ABS. : 3.4855e+01
Ele. 6 - MAX. ABS. : 3.4855e+01
Ele. 7 - MAX. ABS. : 1.7402e+01
Ele. 8 - MAX. ABS. : 1.6410e+01
Ele. 9 - MAX. ABS. : 7.6208e+00
Ele. 10 - MAX. ABS. : 1.0068e+01
Ele. 11 - MAX. ABS. : 1.6530e+01
Ele. 12 - MAX. ABS. : 1.2613e+01
Ele. 13 - MAX. ABS. : 1.0013e+01
Ele. 14 - MAX. ABS. : 1.2853e+01
Ele. 15 - MAX. ABS. : 1.2853e+01
Ele. 16 - MAX. ABS. : 1.0013e+01
Ele. 17 - MAX. ABS. : 1.2613e+01
Ele. 18 - MAX. ABS. : 1.6530e+01
Ele. 19 - MAX. ABS. : 2.2966e+01
Ele. 20 - MAX. ABS. : 4.8624e+00
Ele. 21 - MAX. ABS. : 5.9548e+00
Ele. 22 - MAX. ABS. : 5.8948e+00
Ele. 23 - MAX. ABS. : 1.9972e+01
Ele. 24 - MAX. ABS. : 1.2067e+01
Ele. 25 - MAX. ABS. : 2.6079e+01
Ele. 26 - MAX. ABS. : 2.1089e+01
Ele. 27 - MAX. ABS. : 1.2405e+02
Ele. 28 - MAX. ABS. : 3.8951e+01
Ele. 29 - MAX. ABS. : 1.2405e+02
Ele. 30 - MAX. ABS. : 2.1089e+01
Ele. 31 - MAX. ABS. : 2.6079e+01
Ele. 32 - MAX. ABS. : 1.2067e+01
Ele. 33 - MAX. ABS. : 1.9972e+01
Ele. 34 - MAX. ABS. : 5.8948e+00
Ele. 35 - MAX. ABS. : 5.9548e+00
Ele. 36 - MAX. ABS. : 4.8624e+00
Ele. 37 - MAX. ABS. : 2.2966e+01

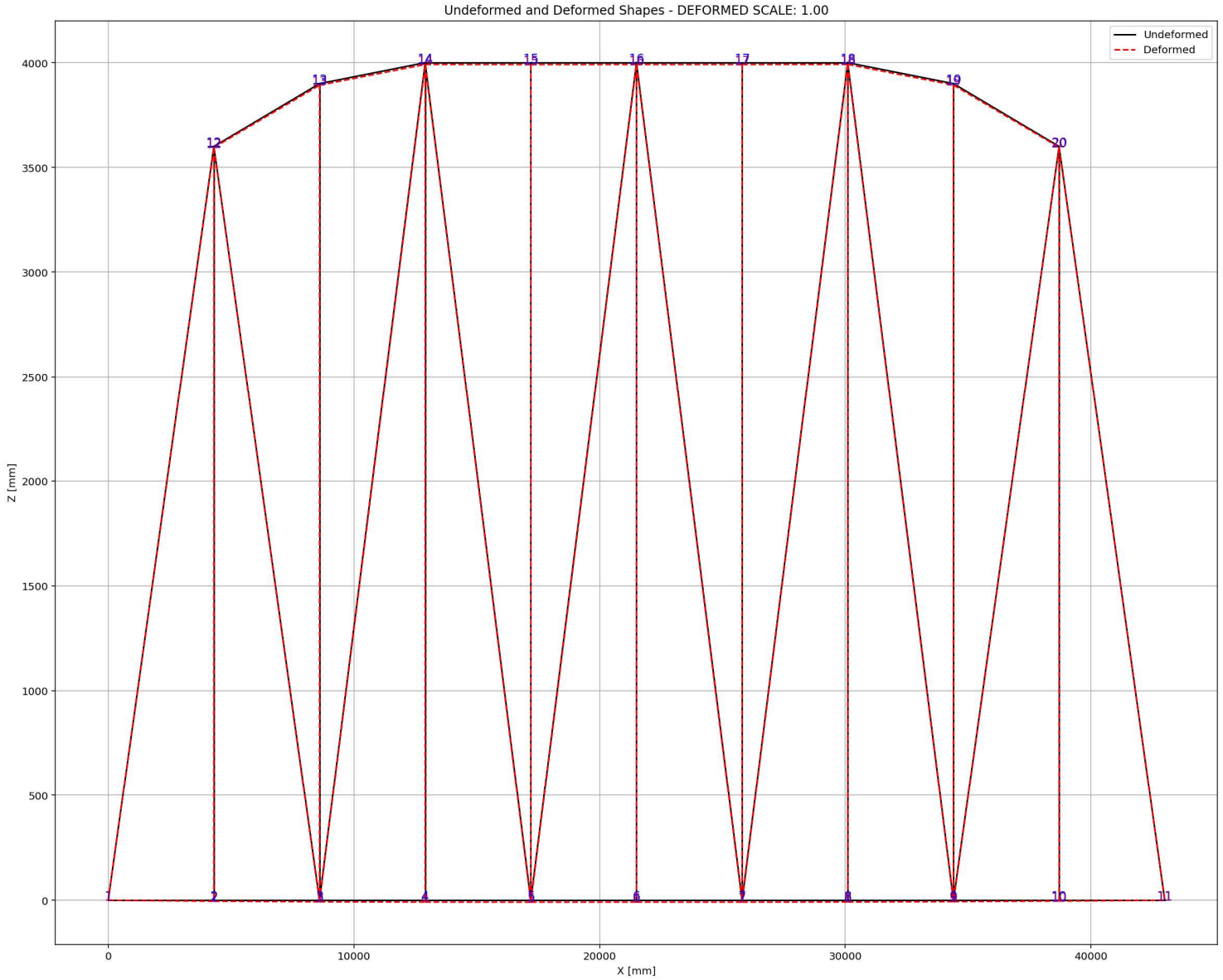

elements Strain in X Dir. vs Time for Bridge Structure During Free-vibration Analysis
Element Strain [mm]
0.0002
0.0001
0.0000
−0.0001
−0.0002
−0.0003
−0.0004
−0.0005
−0.0006
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 5.0339e-05
Ele. 2 - MAX. ABS. : 3.8104e-05
Ele. 3 - MAX. ABS. : 8.2049e-05
Ele. 4 - MAX. ABS. : 8.7012e-05
Ele. 5 - MAX. ABS. : 1.7427e-04
Ele. 6 - MAX. ABS. : 1.7427e-04
Ele. 7 - MAX. ABS. : 8.7012e-05
Ele. 8 - MAX. ABS. : 8.2049e-05
Ele. 9 - MAX. ABS. : 3.8104e-05
Ele. 10 - MAX. ABS. : 5.0339e-05
Ele. 11 - MAX. ABS. : 8.2651e-05
Ele. 12 - MAX. ABS. : 6.3064e-05
Ele. 13 - MAX. ABS. : 5.0063e-05
Ele. 14 - MAX. ABS. : 6.4265e-05
Ele. 15 - MAX. ABS. : 6.4265e-05
Ele. 16 - MAX. ABS. : 5.0063e-05
Ele. 17 - MAX. ABS. : 6.3064e-05
Ele. 18 - MAX. ABS. : 8.2651e-05
Ele. 19 - MAX. ABS. : 1.1483e-04
Ele. 20 - MAX. ABS. : 2.4312e-05
Ele. 21 - MAX. ABS. : 2.9774e-05
Ele. 22 - MAX. ABS. : 2.9474e-05
Ele. 23 - MAX. ABS. : 9.9858e-05
Ele. 24 - MAX. ABS. : 6.0337e-05
Ele. 25 - MAX. ABS. : 1.3039e-04
Ele. 26 - MAX. ABS. : 1.0545e-04
Ele. 27 - MAX. ABS. : 6.2023e-04
Ele. 28 - MAX. ABS. : 1.9475e-04
Ele. 29 - MAX. ABS. : 6.2023e-04
Ele. 30 - MAX. ABS. : 1.0545e-04
Ele. 31 - MAX. ABS. : 1.3039e-04
Ele. 32 - MAX. ABS. : 6.0337e-05
Ele. 33 - MAX. ABS. : 9.9858e-05
Ele. 34 - MAX. ABS. : 2.9474e-05
Ele. 35 - MAX. ABS. : 2.9774e-05
Ele. 36 - MAX. ABS. : 2.4312e-05
Ele. 37 - MAX. ABS. : 1.1483e-04


elements Damage-index [%] in X Dir. vs Time for Bridge Structure Free-vibration Analysis
Element Damage-index [%]
0.0002
0.0001
0.0000
−0.0001
−0.0002
−0.0003
−0.0004
−0.0005
−0.0006
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 5.0339e-05
Ele. 2 - MAX. ABS. : 3.8104e-05
Ele. 3 - MAX. ABS. : 8.2049e-05
Ele. 4 - MAX. ABS. : 8.7012e-05
Ele. 5 - MAX. ABS. : 1.7427e-04
Ele. 6 - MAX. ABS. : 1.7427e-04
Ele. 7 - MAX. ABS. : 8.7012e-05
Ele. 8 - MAX. ABS. : 8.2049e-05
Ele. 9 - MAX. ABS. : 3.8104e-05
Ele. 10 - MAX. ABS. : 5.0339e-05
Ele. 11 - MAX. ABS. : 8.2651e-05
Ele. 12 - MAX. ABS. : 6.3064e-05
Ele. 13 - MAX. ABS. : 5.0063e-05
Ele. 14 - MAX. ABS. : 6.4265e-05
Ele. 15 - MAX. ABS. : 6.4265e-05
Ele. 16 - MAX. ABS. : 5.0063e-05
Ele. 17 - MAX. ABS. : 6.3064e-05
Ele. 18 - MAX. ABS. : 8.2651e-05
Ele. 19 - MAX. ABS. : 1.1483e-04
Ele. 20 - MAX. ABS. : 2.4312e-05
Ele. 21 - MAX. ABS. : 2.9774e-05
Ele. 22 - MAX. ABS. : 2.9474e-05
Ele. 23 - MAX. ABS. : 9.9858e-05
Ele. 24 - MAX. ABS. : 6.0337e-05
Ele. 25 - MAX. ABS. : 1.3039e-04
Ele. 26 - MAX. ABS. : 1.0545e-04
Ele. 27 - MAX. ABS. : 6.2023e-04
Ele. 28 - MAX. ABS. : 1.9475e-04
Ele. 29 - MAX. ABS. : 6.2023e-04
Ele. 30 - MAX. ABS. : 1.0545e-04
Ele. 31 - MAX. ABS. : 1.3039e-04
Ele. 32 - MAX. ABS. : 6.0337e-05
Ele. 33 - MAX. ABS. : 9.9858e-05
Ele. 34 - MAX. ABS. : 2.9474e-05
Ele. 35 - MAX. ABS. : 2.9774e-05
Ele. 36 - MAX. ABS. : 2.4312e-05
Ele. 37 - MAX. ABS. : 1.1483e-04


Node Displacements in X Dir. vs Time for Bridge Structure During Free-vibration Analysis
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 2.1646e-01
Node 3 - MAX. ABS. : 3.5868e-01
Node 4 - MAX. ABS. : 5.7251e-01
Node 5 - MAX. ABS. : 7.4894e-01
Node 6 - MAX. ABS. : 7.7258e-15
Node 7 - MAX. ABS. : 7.4894e-01
Node 8 - MAX. ABS. : 5.7251e-01
Node 9 - MAX. ABS. : 3.5868e-01
Node 10 - MAX. ABS. : 2.1646e-01
Node 11 - MAX. ABS. : 0.0000e+00
Node 12 - MAX. ABS. : 4.5993e-01
Node 13 - MAX. ABS. : 4.5439e-01
Node 14 - MAX. ABS. : 4.8649e-01
Node 15 - MAX. ABS. : 2.7633e-01
Node 16 - MAX. ABS. : 3.9258e-15
Node 17 - MAX. ABS. : 2.7633e-01
Node 18 - MAX. ABS. : 4.8649e-01
Node 19 - MAX. ABS. : 4.5439e-01
Node 20 - MAX. ABS. : 4.5993e-01
Displacement [mm]
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
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 Bridge Structure During Free-vibration Analysis
Displacement [mm]
Time [s]
1
0
−1
−2
−3
−4
−5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 1.2547e+00
Node 3 - MAX. ABS. : 1.4746e+00
Node 4 - MAX. ABS. : 1.7618e+00
Node 5 - MAX. ABS. : 1.7625e+00
Node 6 - MAX. ABS. : 5.3498e+00
Node 7 - MAX. ABS. : 1.7625e+00
Node 8 - MAX. ABS. : 1.7618e+00
Node 9 - MAX. ABS. : 1.4746e+00
Node 10 - MAX. ABS. : 1.2547e+00
Node 11 - MAX. ABS. : 0.0000e+00
Node 12 - MAX. ABS. : 1.1700e+00
Node 13 - MAX. ABS. : 1.5878e+00
Node 14 - MAX. ABS. : 1.5304e+00
Node 15 - MAX. ABS. : 2.1837e+00
Node 16 - MAX. ABS. : 5.3498e+00
Node 17 - MAX. ABS. : 2.1837e+00
Node 18 - MAX. ABS. : 1.5304e+00
Node 19 - MAX. ABS. : 1.5878e+00
Node 20 - MAX. ABS. : 1.1700e+00


Period of Structure During Free-vibration Analysis
Structural Period [s]
140
120
100
80
60
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]
PERIOD - MIN VALUES: Min: 144.918 (s) - Mean: 145.044 (s) - Max: 145.299 (s)
PERIOD - MAX VALUES: Min: 57.585 (s) - Mean: 57.605 (s) - Max: 57.648 (s)


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
3500
4000
0
10000
20000
30000
40000
12
13
14
15
16
17
18
19
20
10
11

SEISMIC ANALYSIS

Spyder (Python 3.12)

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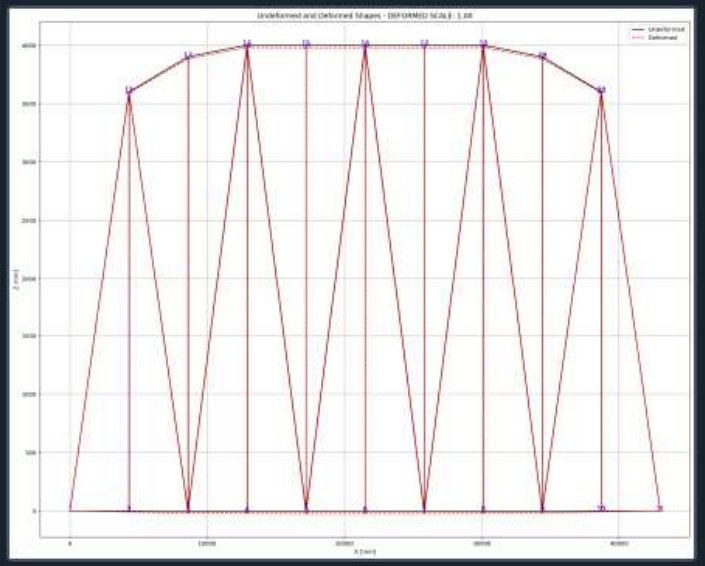
C:\Users\Dell\Desktop\OPENSEES_FILES\+BRIDGE_WARREN_TRUSS

C:\Users\Dell\Desktop\OPENSEES_FILES\+BRIDGE_WARREN_TRUSS\BRIDGE_WARREN_TRUSS.py

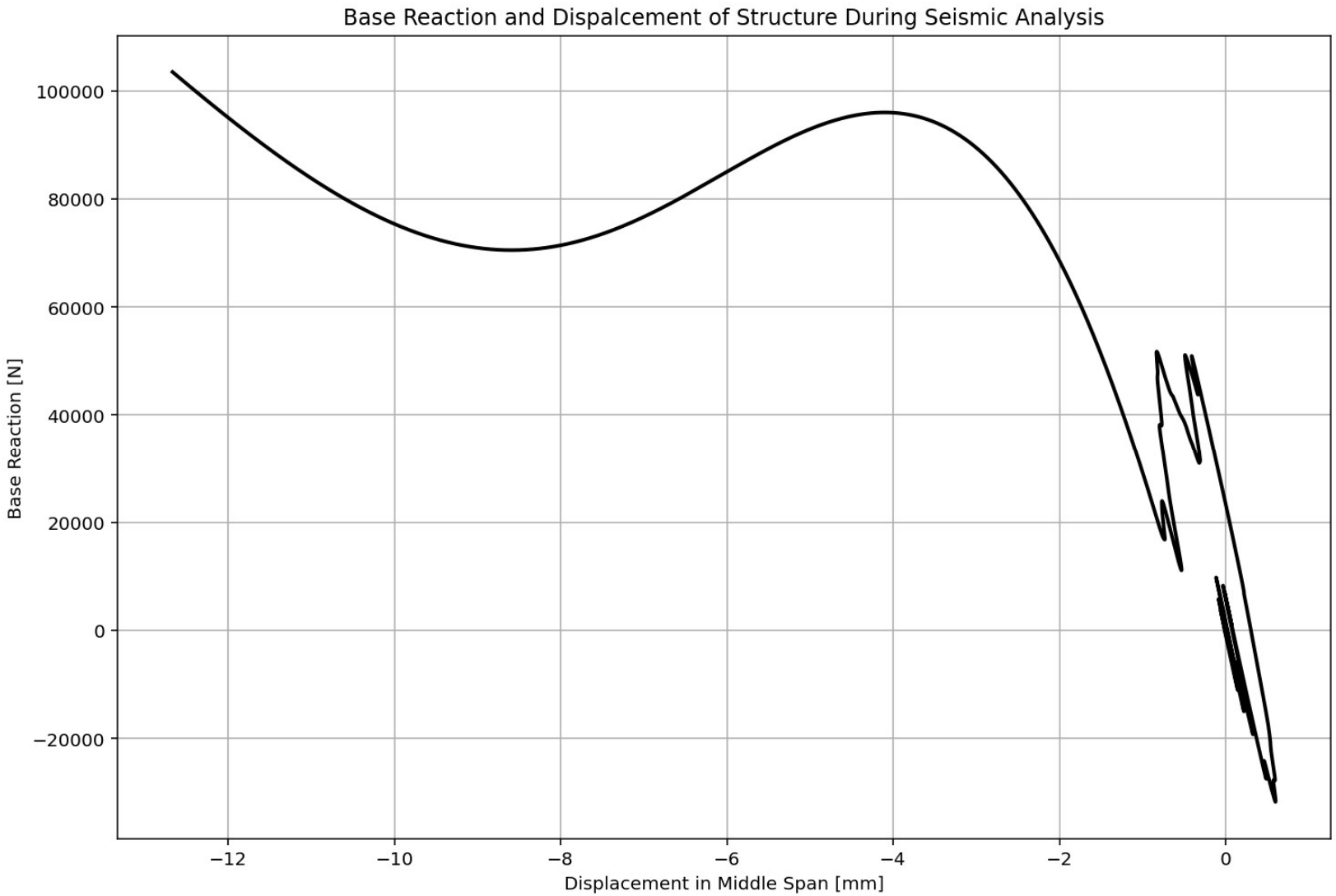
BRIDGE_WARREN_TRUSS.py

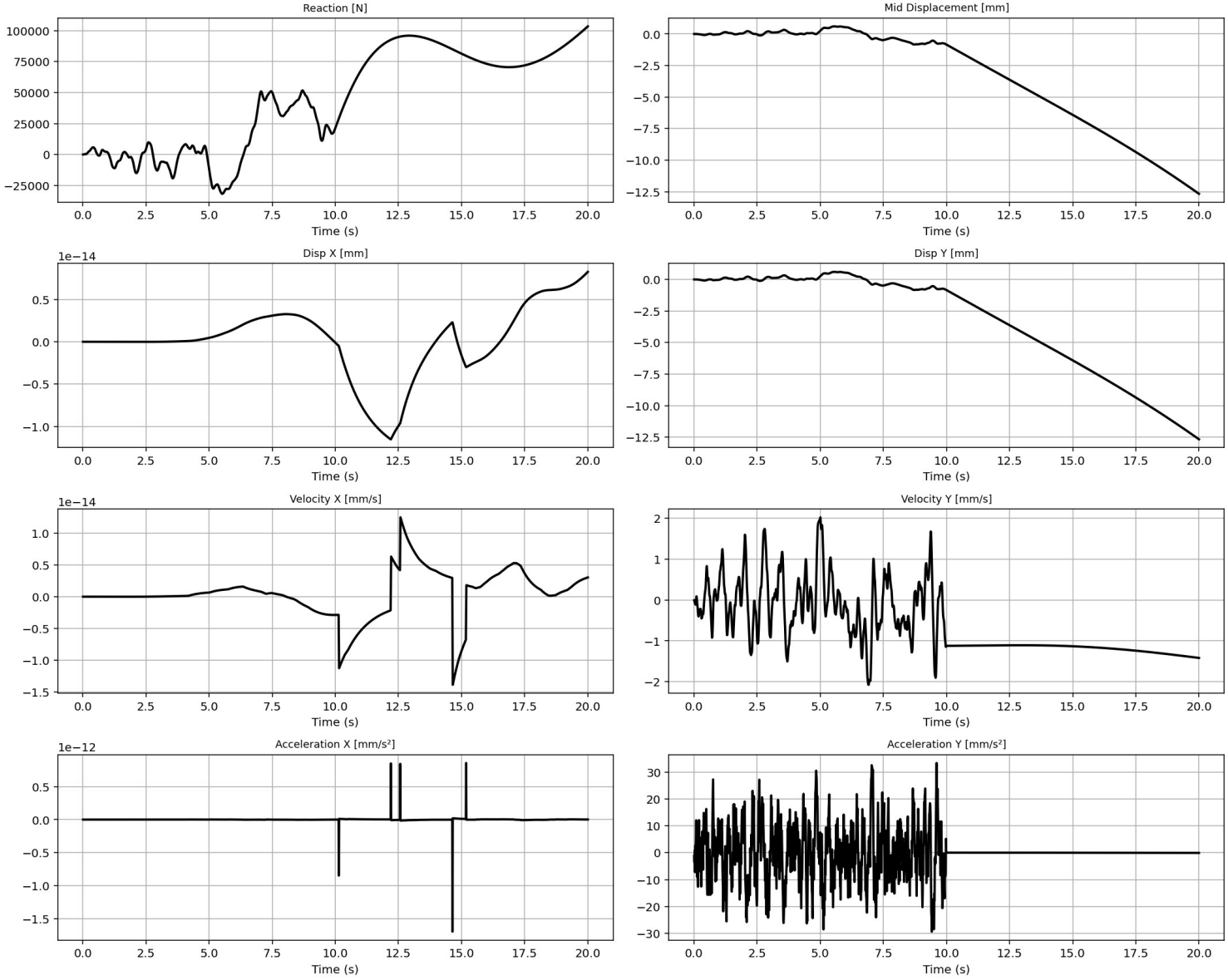
```
1331  # SEISMIC ANALYSIS (DYNAMIC TIME-HISTORY ANALYSIS)
1332  #ELE_TYPE = 'Truss'      # MATERIAL NONLINEARITY
1333  ELE_TYPE = 'corotTruss'  # MATERIAL AND GEOMETRIC NONLINEARITY
1334  MAT_TYPE = 'INELASTIC'   # 'ELASTIC' OR 'INELASTIC'
1335  ANAL_TYPE = 'SEISMIC'
1336
1337  DATA = WARREN_TRUSS_BRIDGE(L, H, A_chord, A_diag, MAT_TYPE, ELE_TYPE, ANAL_TYPE  TOTAL_MAS
1338
1339  (time_SEI, reaction_SEI, disp_mid_SEI,
1340   ele_axialforce_SEI, ele_stress_SEI, ele_strain_SEI,
1341   node_displacementsX_SEI, node_displacementsY_SEI,
1342   dispX_SEI, dispY_SEI,
1343   veloX_SEI, veloY_SEI,
1344   accX_SEI, accY_SEI,
1345   stiffness_SEI, PERIOD_SEI, damping_ratio_SEI,
1346   PERIOD_MIN_SEI, PERIOD_MAX_SEI) = DATA
1347
1348
1349  XDATA = disp_mid_SEI
1350  YDATA = reaction_SEI
1351  XLABEL = 'Displacement in Middle Span [mm]'
1352  YLABEL = 'Base Reaction [N]'
1353  TITLE = 'Base Reaction and Dispalcement of Structure During Seismic Analysis'
1354  COLOR = 'black'
1355  SEMILOGY = False
1356  PLOT(XDATA, YDATA, TITLE, XLABEL, YLABEL, COLOR, SEMILOGY)
1357
1358  PLOT_TIME_HISTORY(time_SEI, reaction_SEI, disp_mid_SEI,
1359                    dispX_SEI, dispY_SEI,
1360                    veloX_SEI, veloY_SEI,
1361                    accX_SEI, accY_SEI)
1362
1363  # PLOT ELEMENTS AXIAL FORCE
1364  YLABEL = 'Element Axial Force [N]'
```

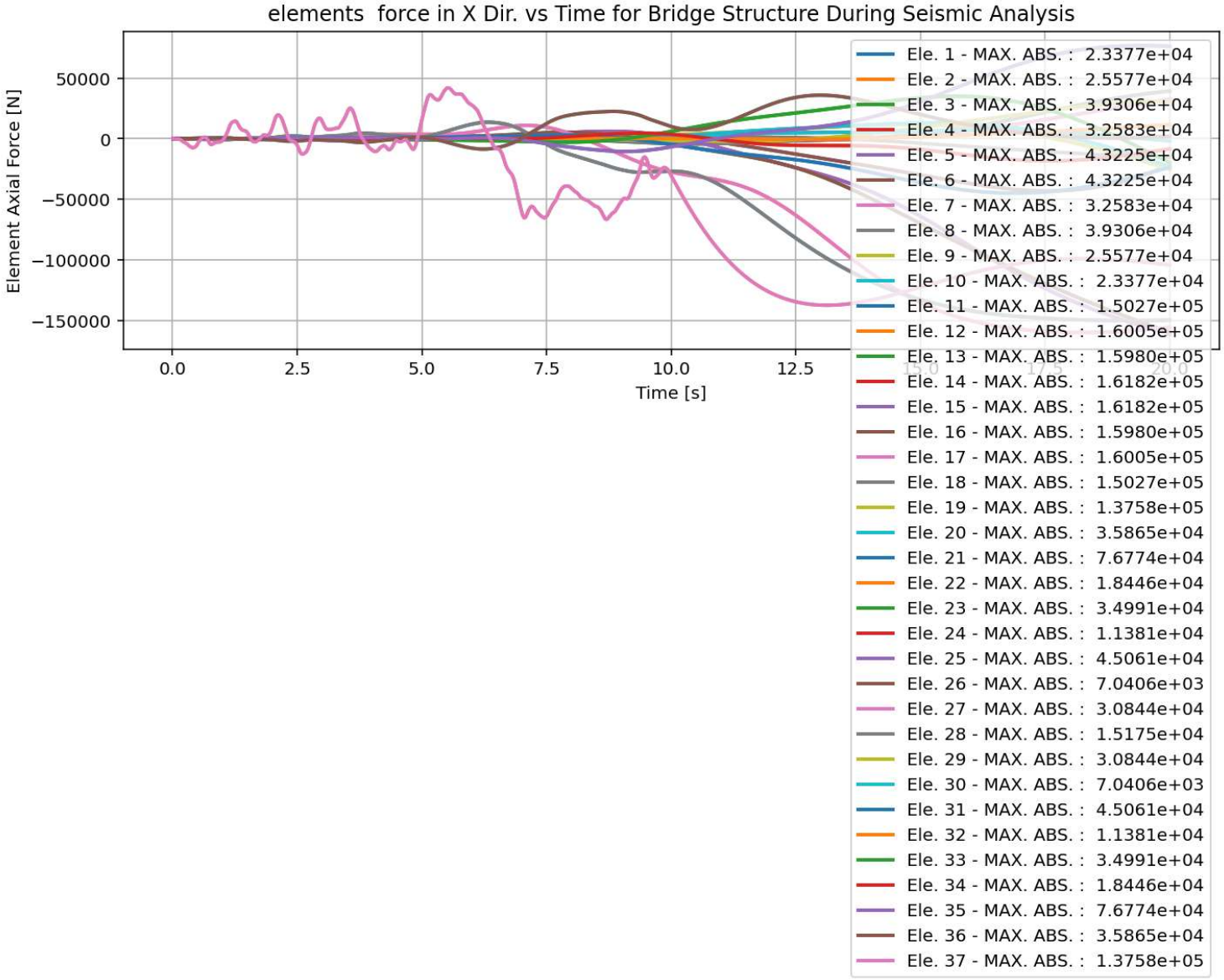


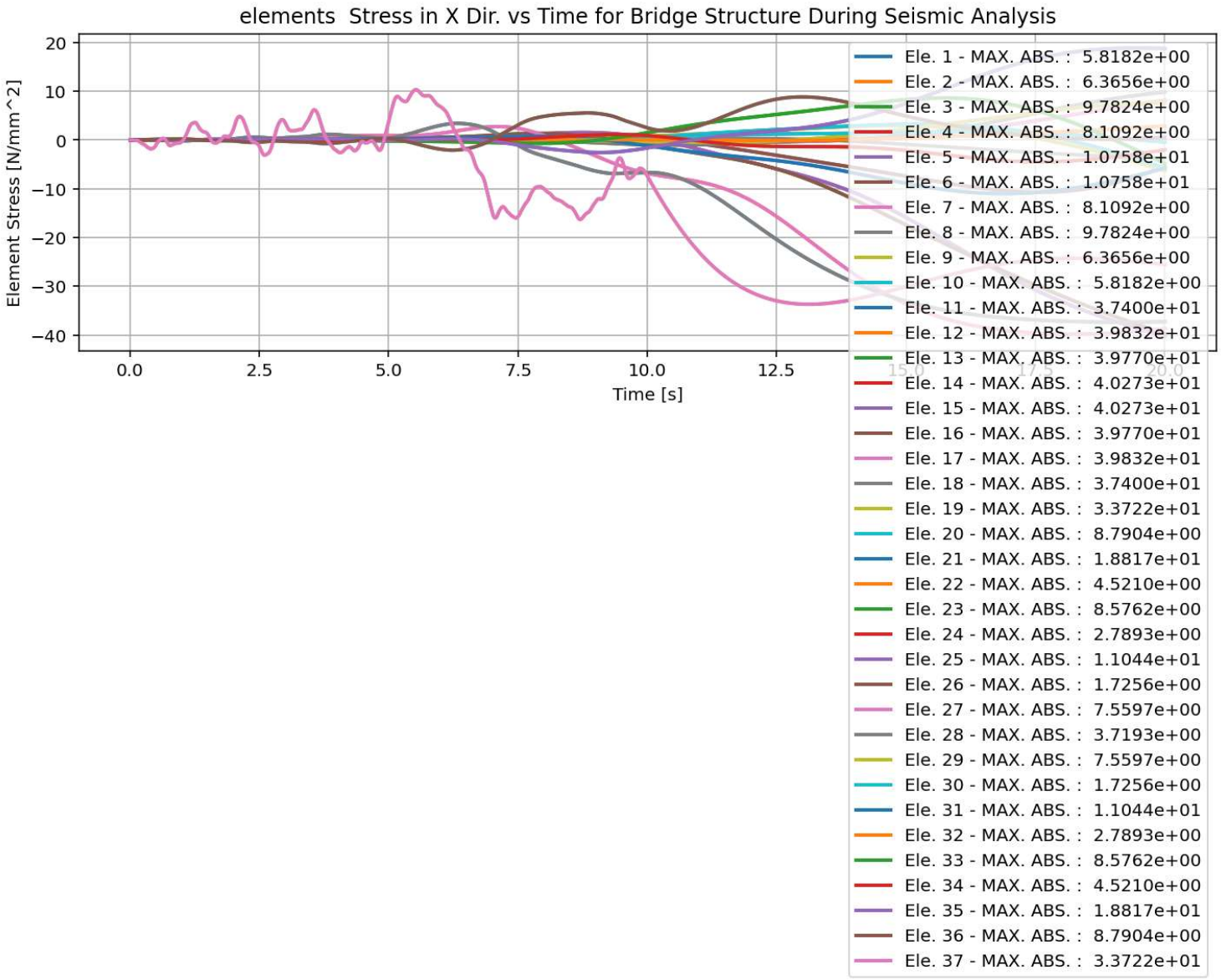
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

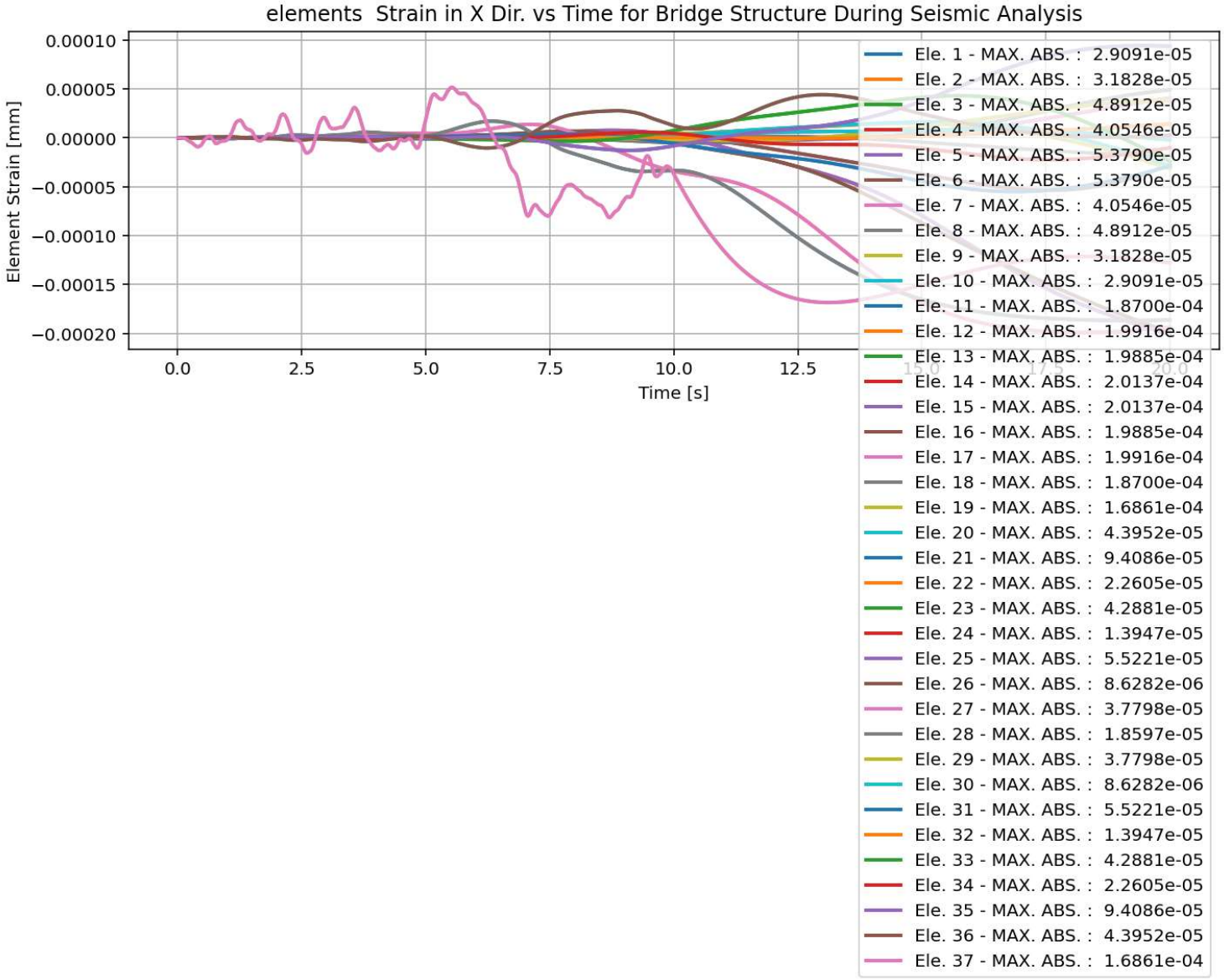
Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 13, Col 57 | UTF-8 | CRLF | RW | Mem 60%

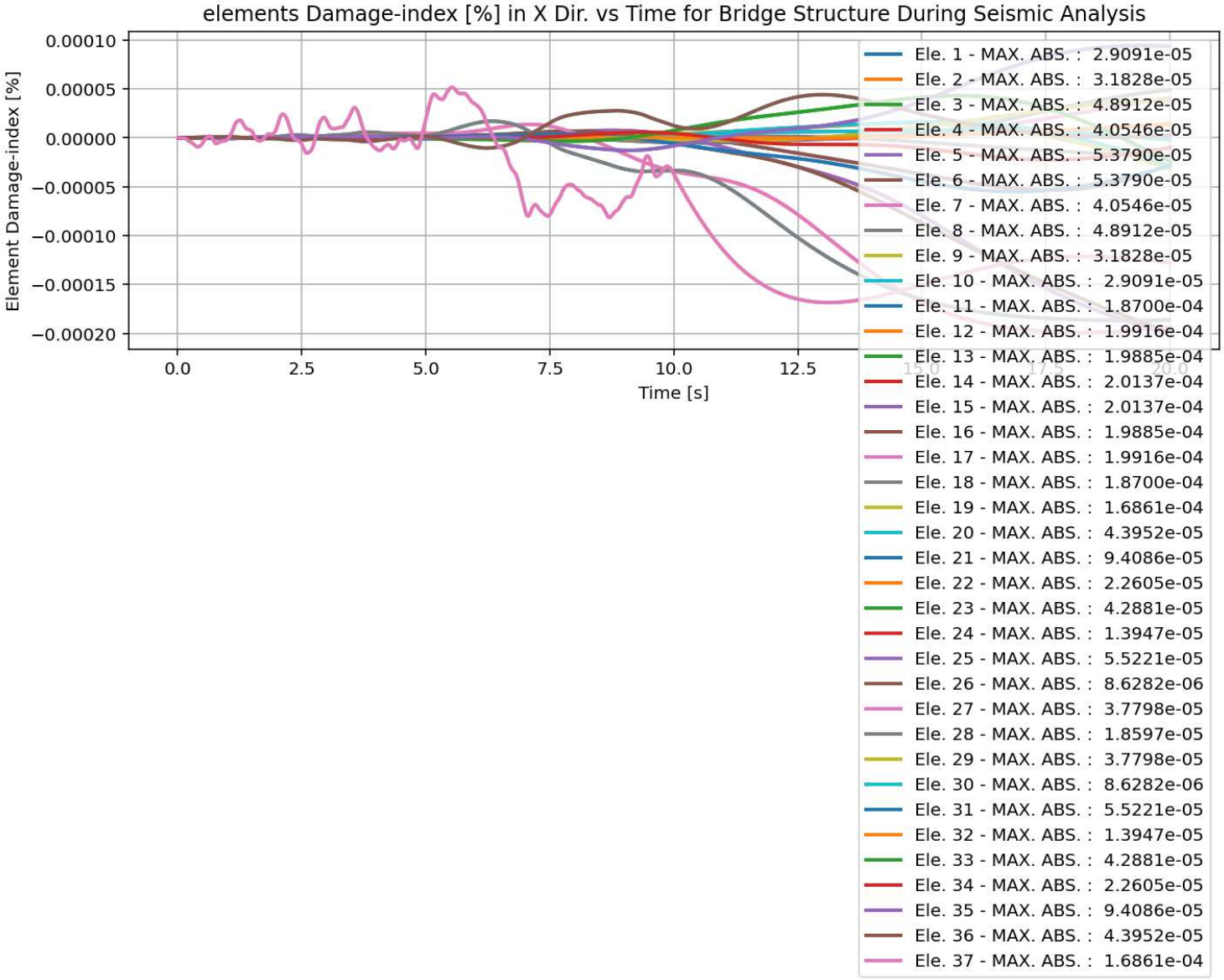

Base Reaction and Dispalcement of Structure During Seismic Analysis
Base Reaction [N]
100000
80000
60000
40000
20000
0
−20000
−12
−10
−8
−6
−4
−2
0
Displacement in Middle Span [mm]

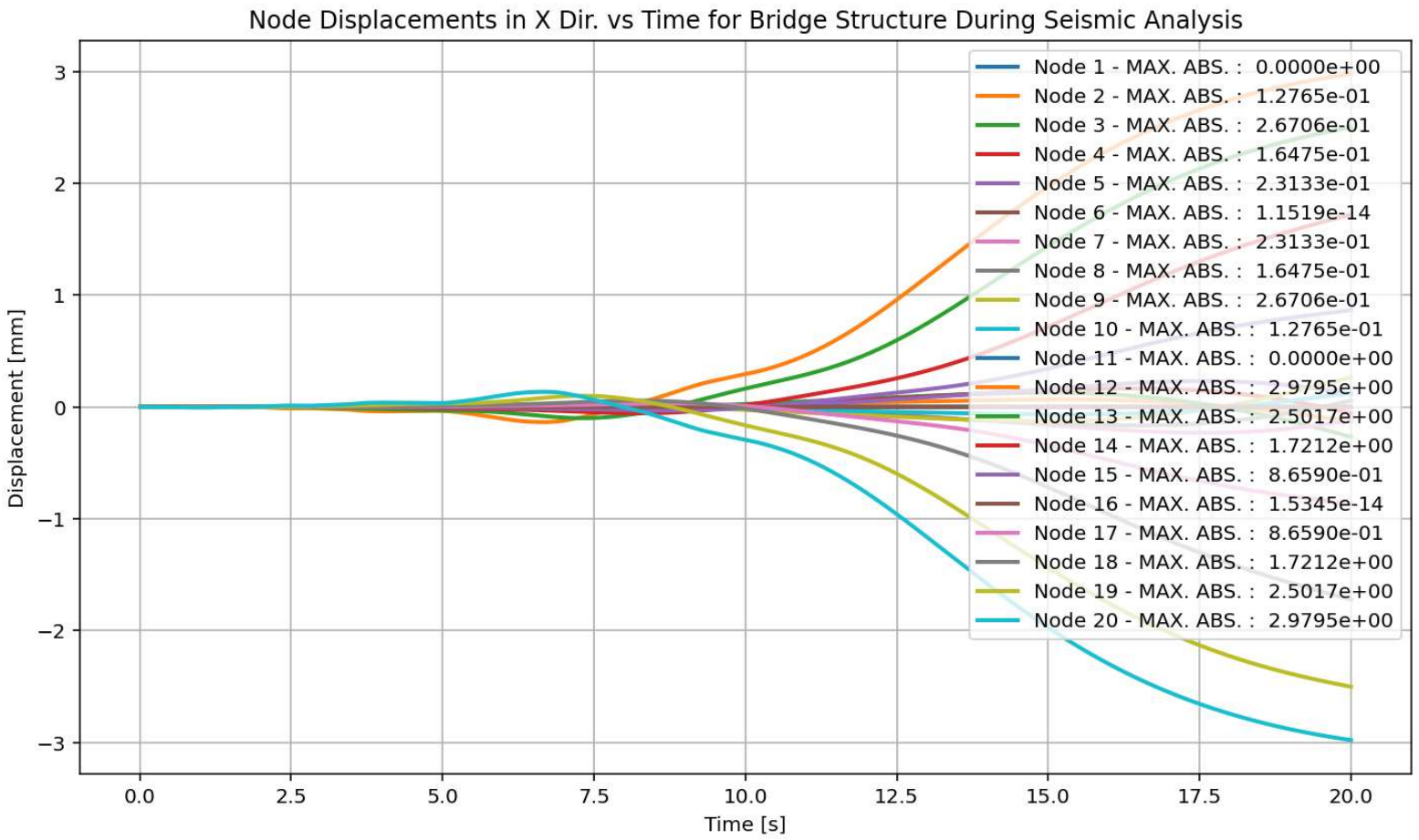

Reaction [N]
Time (s)
Mid Displacement [mm]
Time (s)
Disp X [mm]
1e−14
Time (s)
Disp Y [mm]
Time (s)
Velocity X [mm/s]
1e−14
Time (s)
Velocity Y [mm/s]
Time (s)
Acceleration X [mm/s²]
1e−12
Time (s)
Acceleration Y [mm/s²]
Time (s)

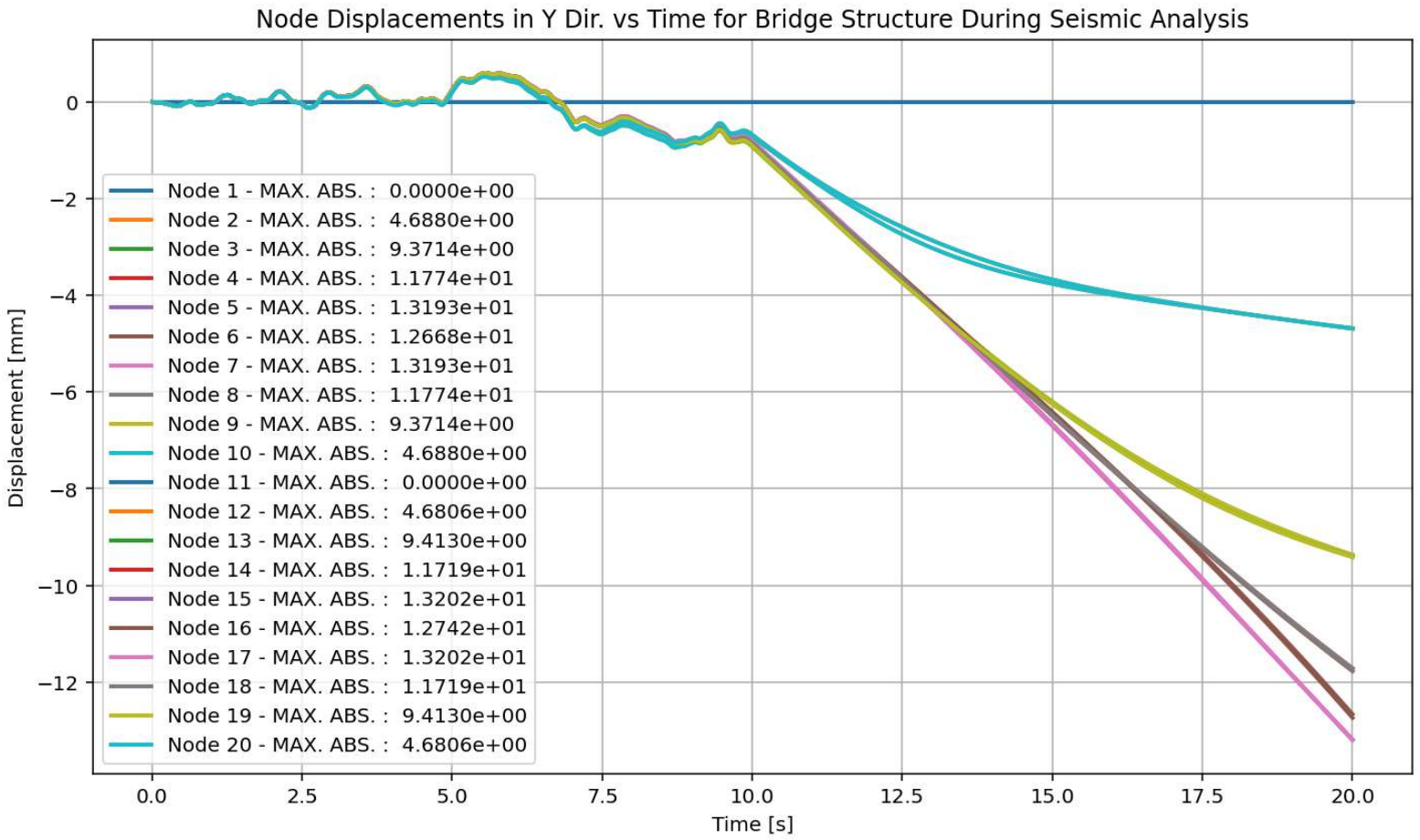

elements force in X Dir. vs Time for Bridge Structure During Seismic Analysis
Element Axial Force [N]
50000
0
−50000
−100000
−150000
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 2.3377e+04
Ele. 2 - MAX. ABS. : 2.5577e+04
Ele. 3 - MAX. ABS. : 3.9306e+04
Ele. 4 - MAX. ABS. : 3.2583e+04
Ele. 5 - MAX. ABS. : 4.3225e+04
Ele. 6 - MAX. ABS. : 4.3225e+04
Ele. 7 - MAX. ABS. : 3.2583e+04
Ele. 8 - MAX. ABS. : 3.9306e+04
Ele. 9 - MAX. ABS. : 2.5577e+04
Ele. 10 - MAX. ABS. : 2.3377e+04
Ele. 11 - MAX. ABS. : 1.5027e+05
Ele. 12 - MAX. ABS. : 1.6005e+05
Ele. 13 - MAX. ABS. : 1.5980e+05
Ele. 14 - MAX. ABS. : 1.6182e+05
Ele. 15 - MAX. ABS. : 1.6182e+05
Ele. 16 - MAX. ABS. : 1.5980e+05
Ele. 17 - MAX. ABS. : 1.6005e+05
Ele. 18 - MAX. ABS. : 1.5027e+05
Ele. 19 - MAX. ABS. : 1.3758e+05
Ele. 20 - MAX. ABS. : 3.5865e+04
Ele. 21 - MAX. ABS. : 7.6774e+04
Ele. 22 - MAX. ABS. : 1.8446e+04
Ele. 23 - MAX. ABS. : 3.4991e+04
Ele. 24 - MAX. ABS. : 1.1381e+04
Ele. 25 - MAX. ABS. : 4.5061e+04
Ele. 26 - MAX. ABS. : 7.0406e+03
Ele. 27 - MAX. ABS. : 3.0844e+04
Ele. 28 - MAX. ABS. : 1.5175e+04
Ele. 29 - MAX. ABS. : 3.0844e+04
Ele. 30 - MAX. ABS. : 7.0406e+03
Ele. 31 - MAX. ABS. : 4.5061e+04
Ele. 32 - MAX. ABS. : 1.1381e+04
Ele. 33 - MAX. ABS. : 3.4991e+04
Ele. 34 - MAX. ABS. : 1.8446e+04
Ele. 35 - MAX. ABS. : 7.6774e+04
Ele. 36 - MAX. ABS. : 3.5865e+04
Ele. 37 - MAX. ABS. : 1.3758e+05

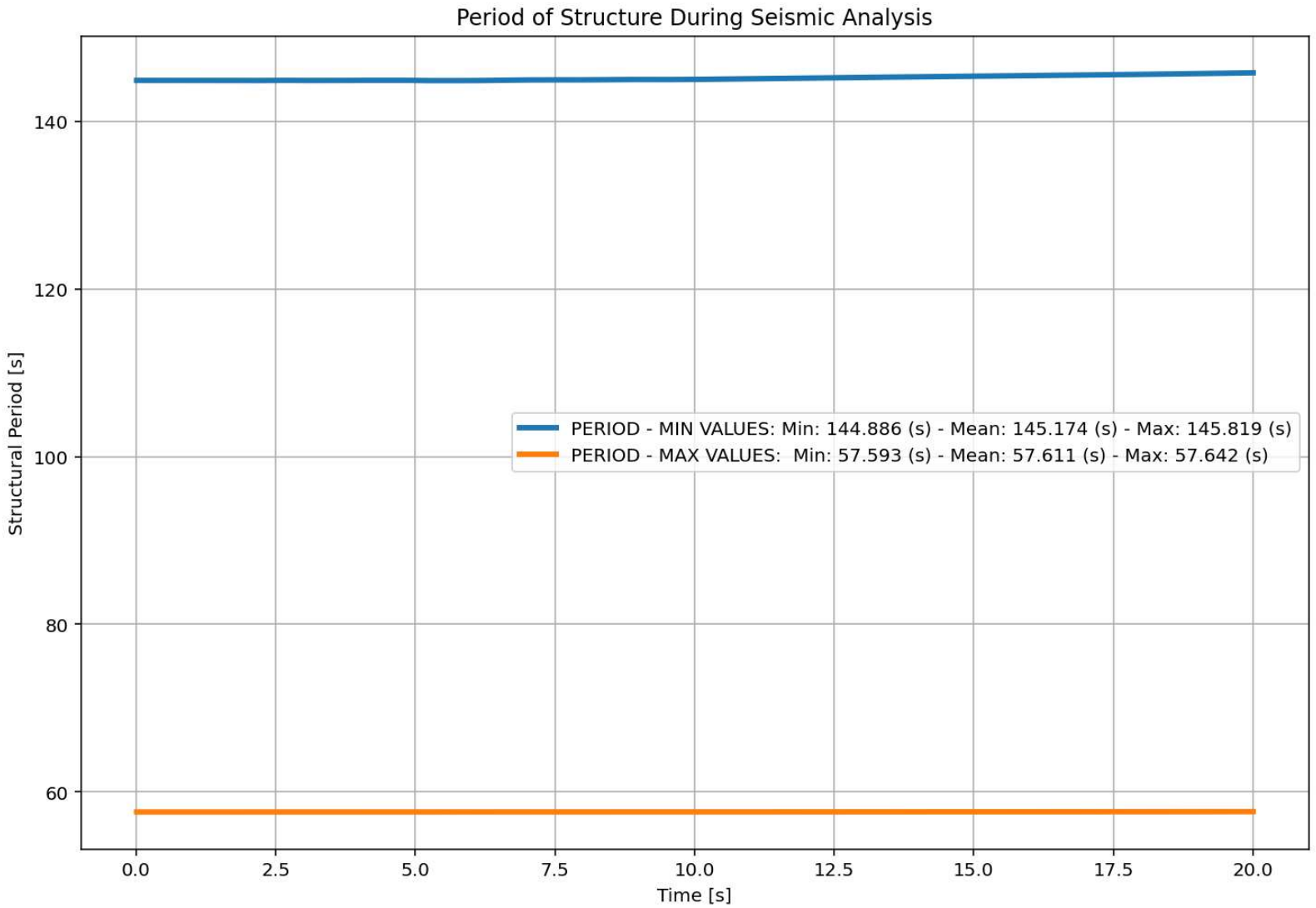

elements Stress in X Dir. vs Time for Bridge Structure During Seismic Analysis
Element Stress [N/mm^2]
Time [s]
20
10
0
−10
−20
−30
−40
0.0
2.5
5.0
7.5
10.0
12.5
Ele. 1 - MAX. ABS. : 5.8182e+00
Ele. 2 - MAX. ABS. : 6.3656e+00
Ele. 3 - MAX. ABS. : 9.7824e+00
Ele. 4 - MAX. ABS. : 8.1092e+00
Ele. 5 - MAX. ABS. : 1.0758e+01
Ele. 6 - MAX. ABS. : 1.0758e+01
Ele. 7 - MAX. ABS. : 8.1092e+00
Ele. 8 - MAX. ABS. : 9.7824e+00
Ele. 9 - MAX. ABS. : 6.3656e+00
Ele. 10 - MAX. ABS. : 5.8182e+00
Ele. 11 - MAX. ABS. : 3.7400e+01
Ele. 12 - MAX. ABS. : 3.9832e+01
Ele. 13 - MAX. ABS. : 3.9770e+01
Ele. 14 - MAX. ABS. : 4.0273e+01
Ele. 15 - MAX. ABS. : 4.0273e+01
Ele. 16 - MAX. ABS. : 3.9770e+01
Ele. 17 - MAX. ABS. : 3.9832e+01
Ele. 18 - MAX. ABS. : 3.7400e+01
Ele. 19 - MAX. ABS. : 3.3722e+01
Ele. 20 - MAX. ABS. : 8.7904e+00
Ele. 21 - MAX. ABS. : 1.8817e+01
Ele. 22 - MAX. ABS. : 4.5210e+00
Ele. 23 - MAX. ABS. : 8.5762e+00
Ele. 24 - MAX. ABS. : 2.7893e+00
Ele. 25 - MAX. ABS. : 1.1044e+01
Ele. 26 - MAX. ABS. : 1.7256e+00
Ele. 27 - MAX. ABS. : 7.5597e+00
Ele. 28 - MAX. ABS. : 3.7193e+00
Ele. 29 - MAX. ABS. : 7.5597e+00
Ele. 30 - MAX. ABS. : 1.7256e+00
Ele. 31 - MAX. ABS. : 1.1044e+01
Ele. 32 - MAX. ABS. : 2.7893e+00
Ele. 33 - MAX. ABS. : 8.5762e+00
Ele. 34 - MAX. ABS. : 4.5210e+00
Ele. 35 - MAX. ABS. : 1.8817e+01
Ele. 36 - MAX. ABS. : 8.7904e+00
Ele. 37 - MAX. ABS. : 3.3722e+01

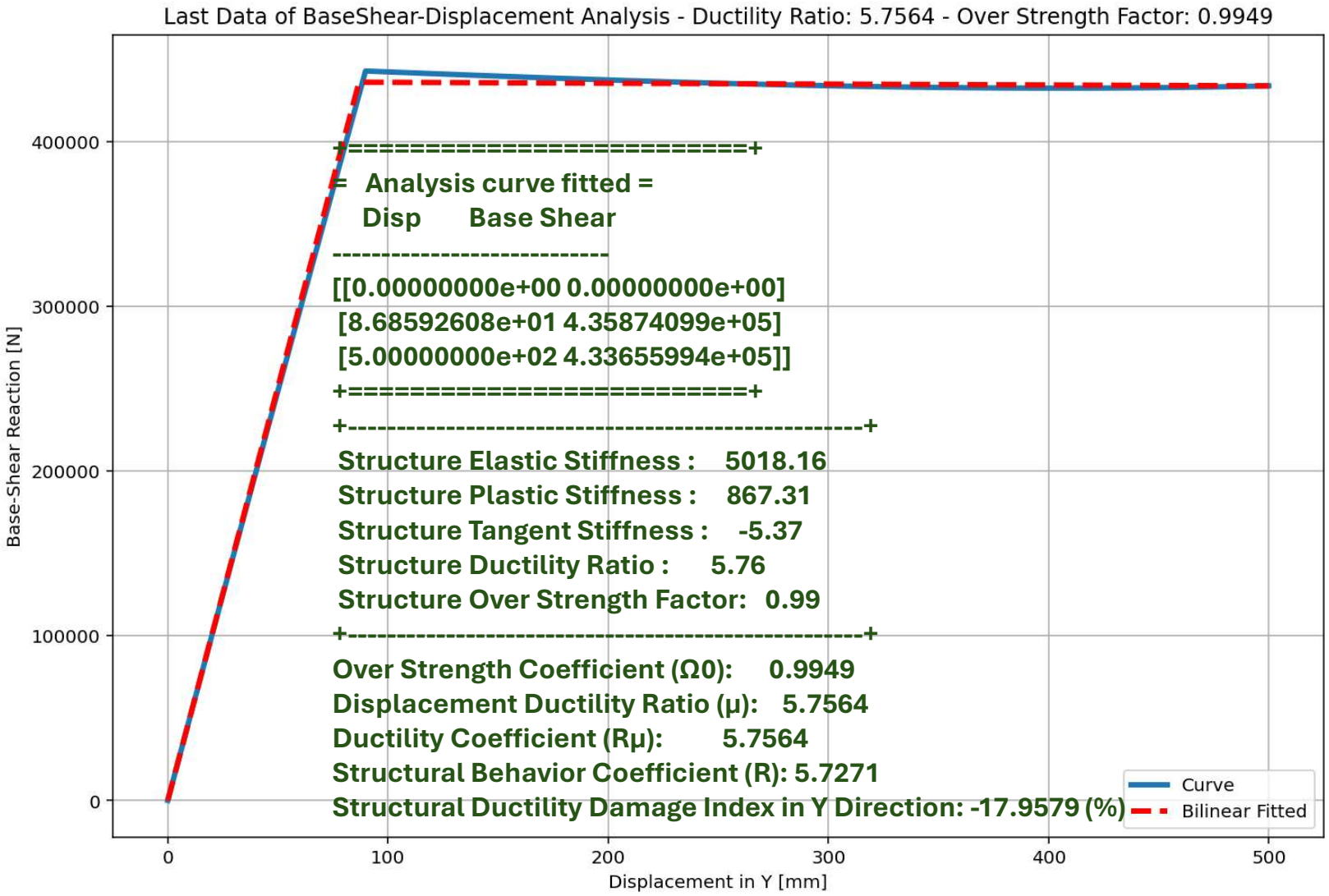

elements Strain in X Dir. vs Time for Bridge Structure During Seismic Analysis
Element Strain [mm]
0.00010
0.00005
0.00000
−0.00005
−0.00010
−0.00015
−0.00020
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 2.9091e-05
Ele. 2 - MAX. ABS. : 3.1828e-05
Ele. 3 - MAX. ABS. : 4.8912e-05
Ele. 4 - MAX. ABS. : 4.0546e-05
Ele. 5 - MAX. ABS. : 5.3790e-05
Ele. 6 - MAX. ABS. : 5.3790e-05
Ele. 7 - MAX. ABS. : 4.0546e-05
Ele. 8 - MAX. ABS. : 4.8912e-05
Ele. 9 - MAX. ABS. : 3.1828e-05
Ele. 10 - MAX. ABS. : 2.9091e-05
Ele. 11 - MAX. ABS. : 1.8700e-04
Ele. 12 - MAX. ABS. : 1.9916e-04
Ele. 13 - MAX. ABS. : 1.9885e-04
Ele. 14 - MAX. ABS. : 2.0137e-04
Ele. 15 - MAX. ABS. : 2.0137e-04
Ele. 16 - MAX. ABS. : 1.9885e-04
Ele. 17 - MAX. ABS. : 1.9916e-04
Ele. 18 - MAX. ABS. : 1.8700e-04
Ele. 19 - MAX. ABS. : 1.6861e-04
Ele. 20 - MAX. ABS. : 4.3952e-05
Ele. 21 - MAX. ABS. : 9.4086e-05
Ele. 22 - MAX. ABS. : 2.2605e-05
Ele. 23 - MAX. ABS. : 4.2881e-05
Ele. 24 - MAX. ABS. : 1.3947e-05
Ele. 25 - MAX. ABS. : 5.5221e-05
Ele. 26 - MAX. ABS. : 8.6282e-06
Ele. 27 - MAX. ABS. : 3.7798e-05
Ele. 28 - MAX. ABS. : 1.8597e-05
Ele. 29 - MAX. ABS. : 3.7798e-05
Ele. 30 - MAX. ABS. : 8.6282e-06
Ele. 31 - MAX. ABS. : 5.5221e-05
Ele. 32 - MAX. ABS. : 1.3947e-05
Ele. 33 - MAX. ABS. : 4.2881e-05
Ele. 34 - MAX. ABS. : 2.2605e-05
Ele. 35 - MAX. ABS. : 9.4086e-05
Ele. 36 - MAX. ABS. : 4.3952e-05
Ele. 37 - MAX. ABS. : 1.6861e-04


elements Damage-index [%] in X Dir. vs Time for Bridge Structure During Seismic Analysis
Element Damage-index [%]
0.00010
0.00005
0.00000
−0.00005
−0.00010
−0.00015
−0.00020
0.0
2.5
5.0
7.5
10.0
12.5
Time [s]
Ele. 1 - MAX. ABS. : 2.9091e-05
Ele. 2 - MAX. ABS. : 3.1828e-05
Ele. 3 - MAX. ABS. : 4.8912e-05
Ele. 4 - MAX. ABS. : 4.0546e-05
Ele. 5 - MAX. ABS. : 5.3790e-05
Ele. 6 - MAX. ABS. : 5.3790e-05
Ele. 7 - MAX. ABS. : 4.0546e-05
Ele. 8 - MAX. ABS. : 4.8912e-05
Ele. 9 - MAX. ABS. : 3.1828e-05
Ele. 10 - MAX. ABS. : 2.9091e-05
Ele. 11 - MAX. ABS. : 1.8700e-04
Ele. 12 - MAX. ABS. : 1.9916e-04
Ele. 13 - MAX. ABS. : 1.9885e-04
Ele. 14 - MAX. ABS. : 2.0137e-04
Ele. 15 - MAX. ABS. : 2.0137e-04
Ele. 16 - MAX. ABS. : 1.9885e-04
Ele. 17 - MAX. ABS. : 1.9916e-04
Ele. 18 - MAX. ABS. : 1.8700e-04
Ele. 19 - MAX. ABS. : 1.6861e-04
Ele. 20 - MAX. ABS. : 4.3952e-05
Ele. 21 - MAX. ABS. : 9.4086e-05
Ele. 22 - MAX. ABS. : 2.2605e-05
Ele. 23 - MAX. ABS. : 4.2881e-05
Ele. 24 - MAX. ABS. : 1.3947e-05
Ele. 25 - MAX. ABS. : 5.5221e-05
Ele. 26 - MAX. ABS. : 8.6282e-06
Ele. 27 - MAX. ABS. : 3.7798e-05
Ele. 28 - MAX. ABS. : 1.8597e-05
Ele. 29 - MAX. ABS. : 3.7798e-05
Ele. 30 - MAX. ABS. : 8.6282e-06
Ele. 31 - MAX. ABS. : 5.5221e-05
Ele. 32 - MAX. ABS. : 1.3947e-05
Ele. 33 - MAX. ABS. : 4.2881e-05
Ele. 34 - MAX. ABS. : 2.2605e-05
Ele. 35 - MAX. ABS. : 9.4086e-05
Ele. 36 - MAX. ABS. : 4.3952e-05
Ele. 37 - MAX. ABS. : 1.6861e-04

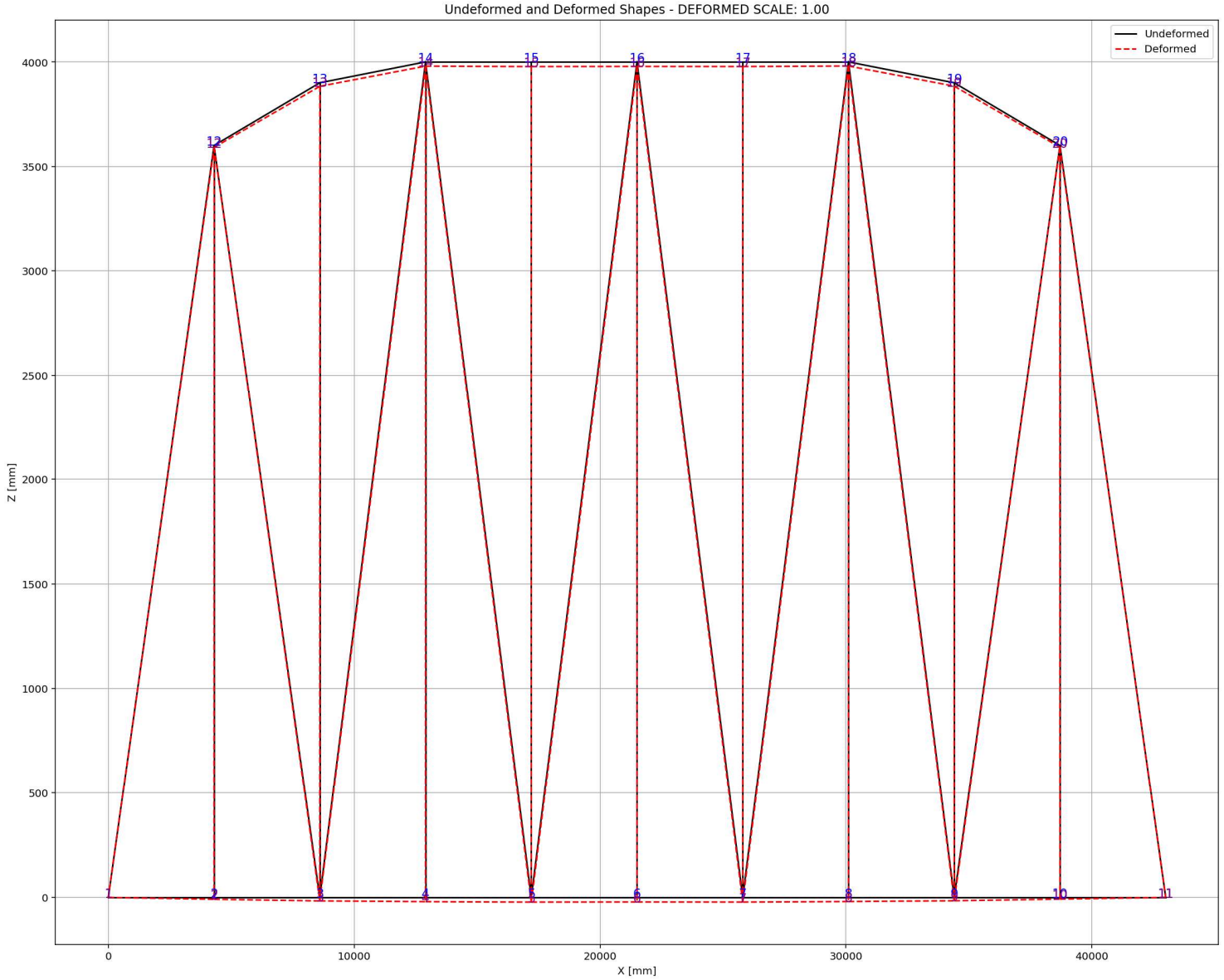

Node Displacements in X Dir. vs Time for Bridge Structure During Seismic Analysis
Displacement [mm]
Time [s]
3
2
1
0
−1
−2
−3
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 1.2765e-01
Node 3 - MAX. ABS. : 2.6706e-01
Node 4 - MAX. ABS. : 1.6475e-01
Node 5 - MAX. ABS. : 2.3133e-01
Node 6 - MAX. ABS. : 1.1519e-14
Node 7 - MAX. ABS. : 2.3133e-01
Node 8 - MAX. ABS. : 1.6475e-01
Node 9 - MAX. ABS. : 2.6706e-01
Node 10 - MAX. ABS. : 1.2765e-01
Node 11 - MAX. ABS. : 0.0000e+00
Node 12 - MAX. ABS. : 2.9795e+00
Node 13 - MAX. ABS. : 2.5017e+00
Node 14 - MAX. ABS. : 1.7212e+00
Node 15 - MAX. ABS. : 8.6590e-01
Node 16 - MAX. ABS. : 1.5345e-14
Node 17 - MAX. ABS. : 8.6590e-01
Node 18 - MAX. ABS. : 1.7212e+00
Node 19 - MAX. ABS. : 2.5017e+00
Node 20 - MAX. ABS. : 2.9795e+00


Node Displacements in Y Dir. vs Time for Bridge Structure During Seismic Analysis
Displacement [mm]
Time [s]
0
−2
−4
−6
−8
−10
−12
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Node 1 - MAX. ABS. : 0.0000e+00
Node 2 - MAX. ABS. : 4.6880e+00
Node 3 - MAX. ABS. : 9.3714e+00
Node 4 - MAX. ABS. : 1.1774e+01
Node 5 - MAX. ABS. : 1.3193e+01
Node 6 - MAX. ABS. : 1.2668e+01
Node 7 - MAX. ABS. : 1.3193e+01
Node 8 - MAX. ABS. : 1.1774e+01
Node 9 - MAX. ABS. : 9.3714e+00
Node 10 - MAX. ABS. : 4.6880e+00
Node 11 - MAX. ABS. : 0.0000e+00
Node 12 - MAX. ABS. : 4.6806e+00
Node 13 - MAX. ABS. : 9.4130e+00
Node 14 - MAX. ABS. : 1.1719e+01
Node 15 - MAX. ABS. : 1.3202e+01
Node 16 - MAX. ABS. : 1.2742e+01
Node 17 - MAX. ABS. : 1.3202e+01
Node 18 - MAX. ABS. : 1.1719e+01
Node 19 - MAX. ABS. : 9.4130e+00
Node 20 - MAX. ABS. : 4.6806e+00


Period of Structure During Seismic Analysis
Structural Period [s]
140
120
100
80
60
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time [s]
PERIOD - MIN VALUES: Min: 144.886 (s) - Mean: 145.174 (s) - Max: 145.819 (s)
PERIOD - MAX VALUES: Min: 57.593 (s) - Mean: 57.611 (s) - Max: 57.642 (s)


Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 5.7564 - Over Strength Factor: 0.9949
+============================+
= Analysis curve fitted =
Disp Base Shear

[[0.00000000e+00 0.00000000e+00]
[8.68592608e+01 4.35874099e+05]
[5.00000000e+02 4.33655994e+05]]
+============================+
+--+
Structure Elastic Stiffness : 5018.16
Structure Plastic Stiffness : 867.31
Structure Tangent Stiffness : -5.37
Structure Ductility Ratio : 5.76
Structure Over Strength Factor: 0.99
+--+
Over Strength Coefficient (Ω0): 0.9949
Displacement Ductility Ratio (μ): 5.7564
Ductility Coefficient (Rμ): 5.7564
Structural Behavior Coefficient (R): 5.7271
Structural Ductility Damage Index in Y Direction: -17.9579 (%)
Curve
Bilinear Fitted
Base-Shear Reaction [N]
Displacement in Y [mm]
0
100000
200000
300000
400000
0
100
200
300
400
500


Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
3500
4000
0
10000
20000
30000
40000