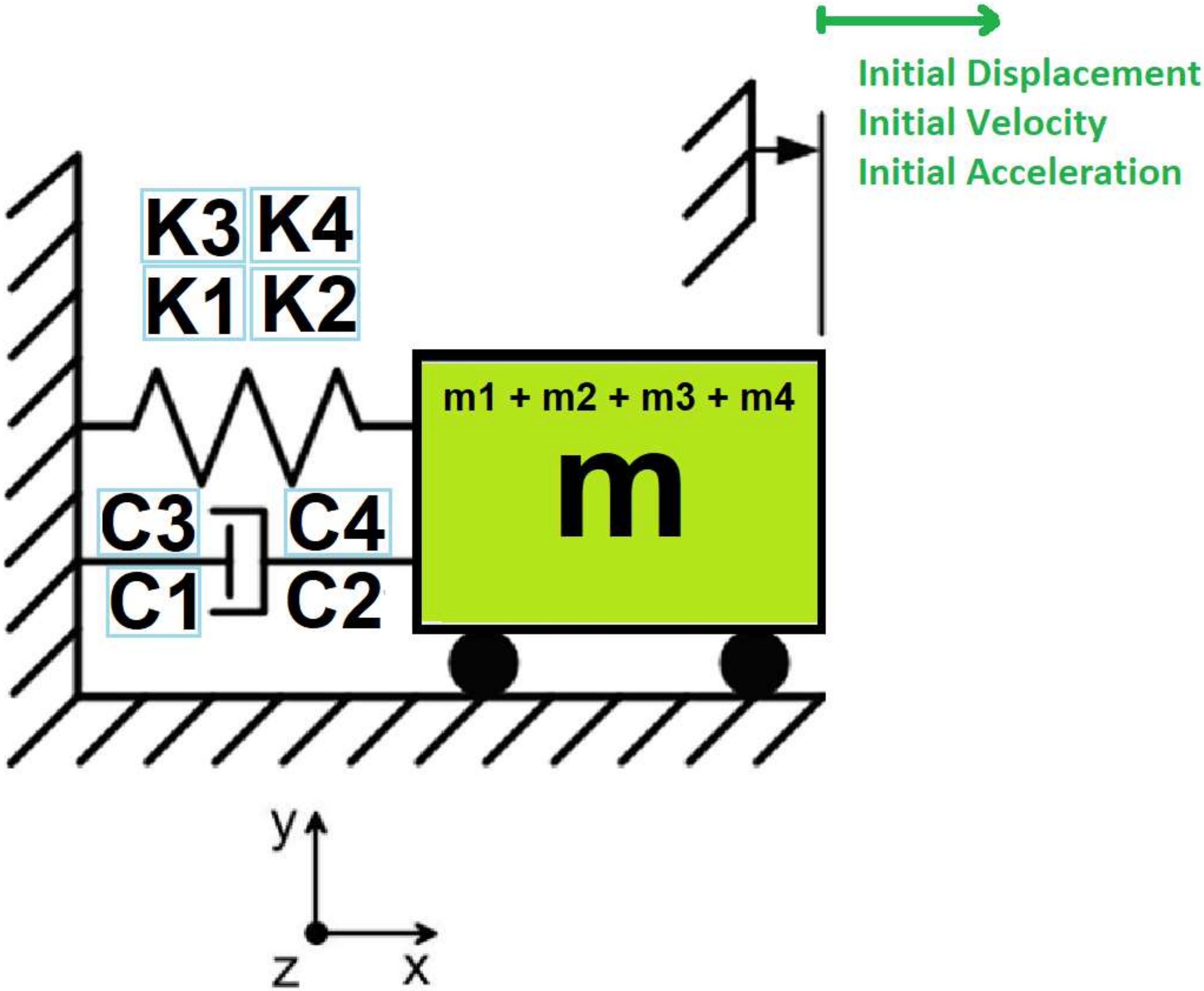
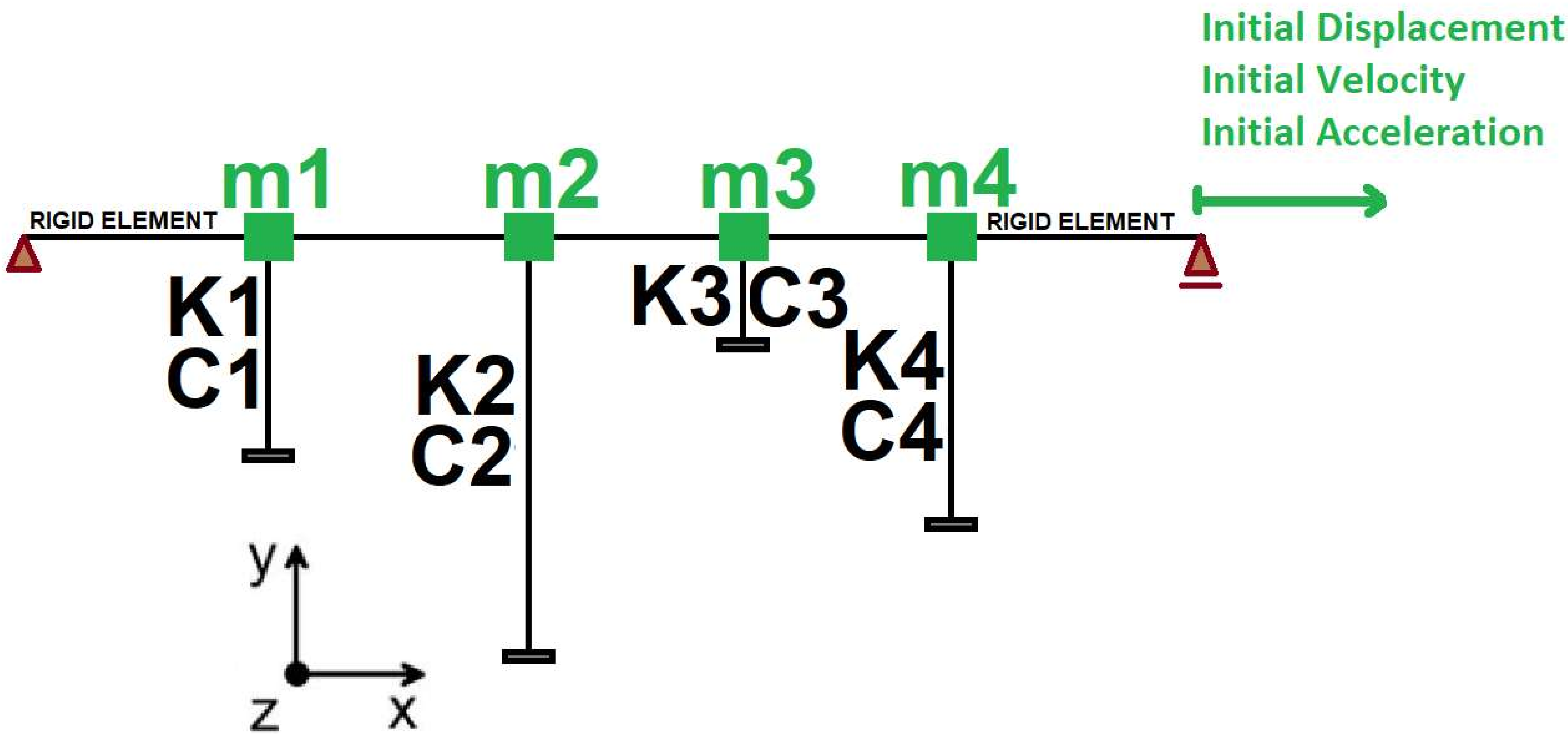
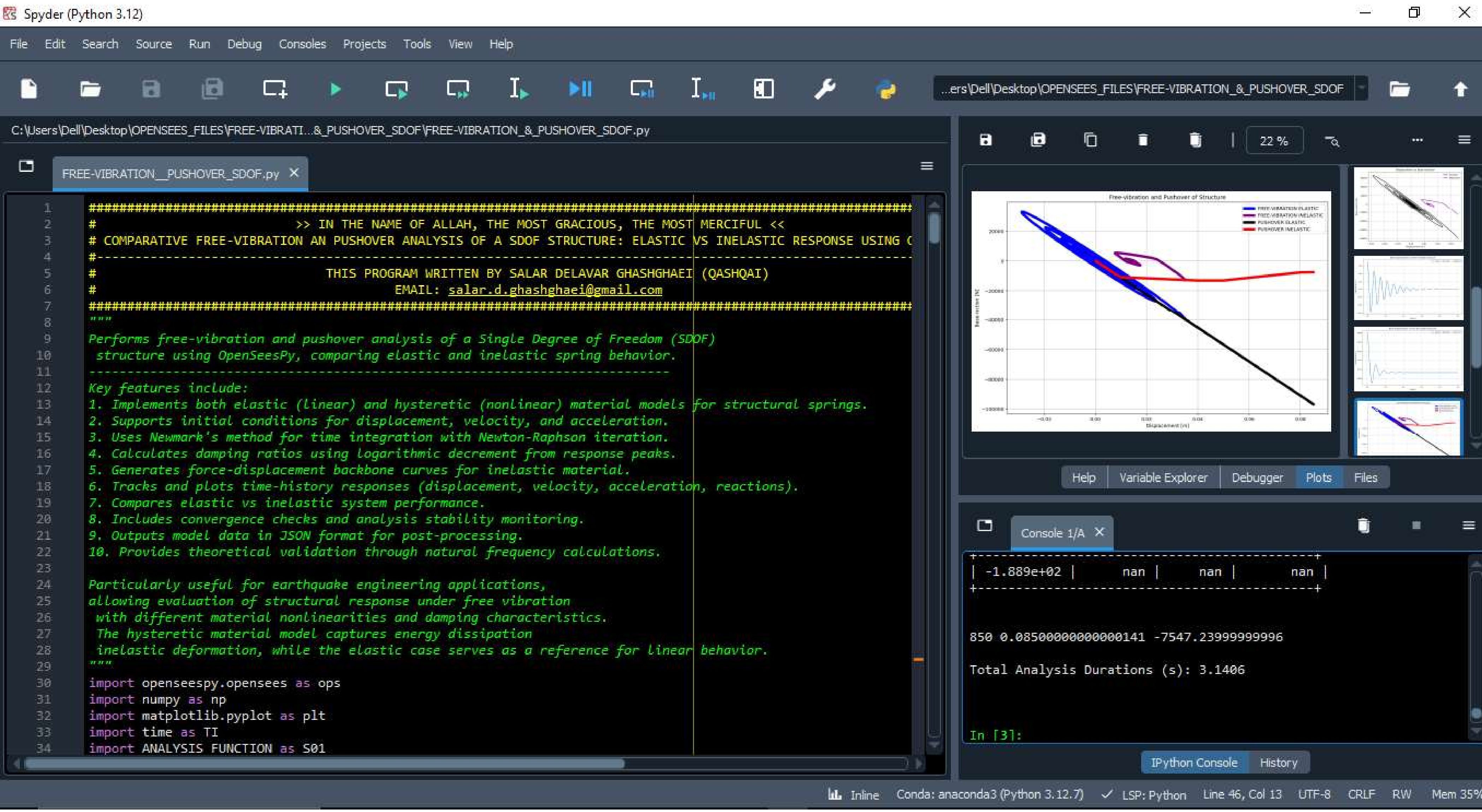
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

COMPARATIVE FREE-VIBRATION AND PUSHOVER ANALYSIS OF A SDOF STRUCTURE: ELASTIC VS INELASTIC RESPONSE USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


Initial Displacement
Initial Velocity
Initial Acceleration
K3
K4
K1
K2
m1 + m2 + m3 + m4
m
C3
C4
C1
C2
y
z
x


Initial Displacement
Initial Velocity
Initial Acceleration
m1
m2
m3
m4
RIGID ELEMENT
RIGID ELEMENT
K1
C1
K2
C2
K3
C3
K4
C4
y
z
x


Spyder (Python 3.12)
File Edit Search Source Run Debug Consoles Projects Tools View Help
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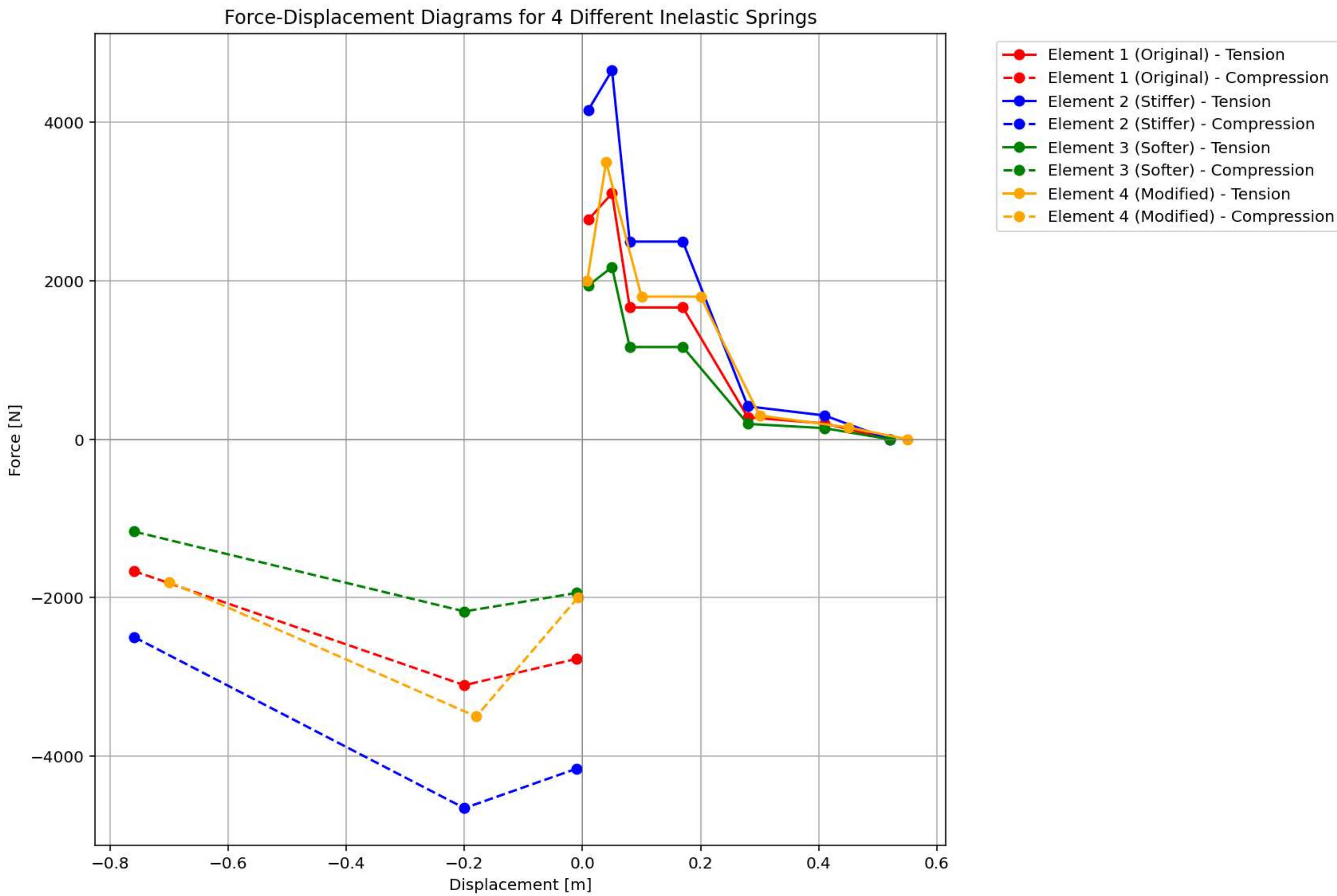
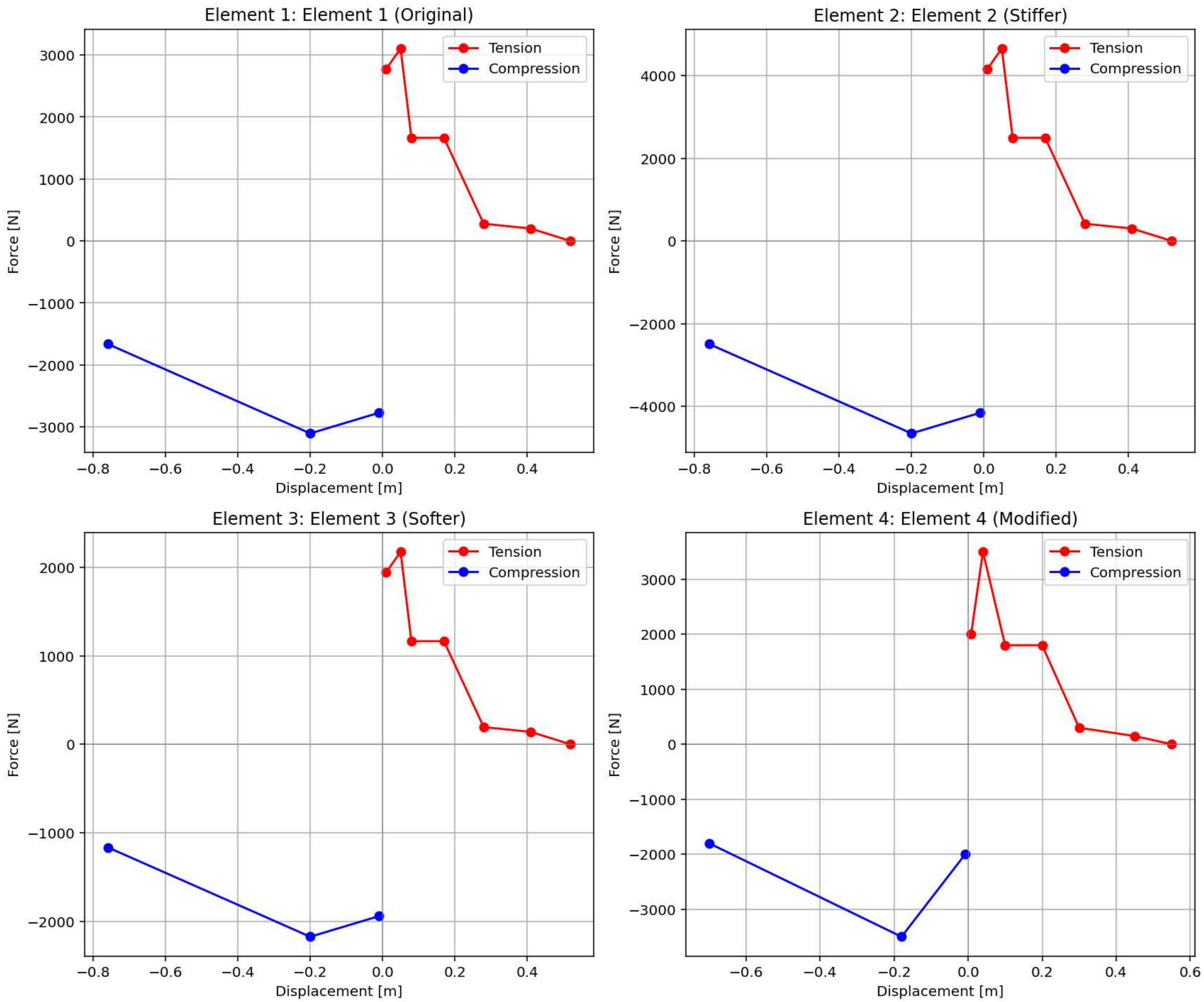
C:\Users\Dell\Desktop\OPENSEES_FILES\FREE-VIBRATI...&_PUSHOVER_SDOF\FREE-VIBRATION_&_PUSHOVER_SDOF.py
FREE-VIBRATION__PUSHOVER_SDOF.py
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
COMPARATIVE FREE-VIBRATION AN PUSHOVER ANALYSIS OF A SDOF STRUCTURE: ELASTIC VS INELASTIC RESPONSE USING
THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
EMAIL: salar.d.ghashghaei@gmail.com
"""
Performs free-vibration and pushover analysis of a Single Degree of Freedom (SDOF)
 structure using OpenSeesPy, comparing elastic and inelastic spring behavior.
Key features include:
1. Implements both elastic (linear) and hysteretic (nonlinear) material models for structural springs.
2. Supports initial conditions for displacement, velocity, and acceleration.
3. Uses Newmark's method for time integration with Newton-Raphson iteration.
4. Calculates damping ratios using logarithmic decrement from response peaks.
5. Generates force-displacement backbone curves for inelastic material.
6. Tracks and plots time-history responses (displacement, velocity, acceleration, reactions).
7. Compares elastic vs inelastic system performance.
8. Includes convergence checks and analysis stability monitoring.
9. Outputs model data in JSON format for post-processing.
10. Provides theoretical validation through natural frequency calculations.
Particularly useful for earthquake engineering applications,
allowing evaluation of structural response under free vibration
 with different material nonlinearities and damping characteristics.
 The hysteretic material model captures energy dissipation
 inelastic deformation, while the elastic case serves as a reference for linear behavior.
"""
import openseespy.opensees as ops
import numpy as np
import matplotlib.pyplot as plt
import time as TI
import ANALYSIS_FUNCTION as S01
22 %
Free-vibration and Pushover of Structure
Help Variable Explorer Debugger Plots Files
Console 1/A
| -1.889e+02 | nan | nan | nan |
850 0.08500000000000141 -7547.23999999996
Total Analysis Durations (s): 3.1406
In [3]:
IPython Console History
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 46, Col 13 UTF-8 CRLF RW Mem 35%


Force-Displacement Diagrams for 4 Different Inelastic Springs
Force [N]
Displacement [m]
4000
2000
0
−2000
−4000
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
Element 1 (Original) - Tension
Element 1 (Original) - Compression
Element 2 (Stiffer) - Tension
Element 2 (Stiffer) - Compression
Element 3 (Softer) - Tension
Element 3 (Softer) - Compression
Element 4 (Modified) - Tension
Element 4 (Modified) - Compression



Element 1: Element 1 (Original)
Element 2: Element 2 (Stiffer)
Element 3: Element 3 (Softer)
Element 4: Element 4 (Modified)
Tension
Compression
Force [N]
Displacement [m]

FREE-VIBRATION ANALYSIS

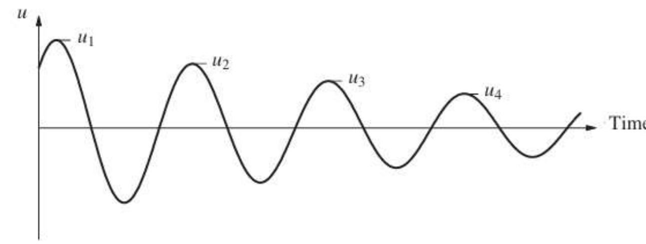
VISCOUSLY DAMPED FREE VIBRATION

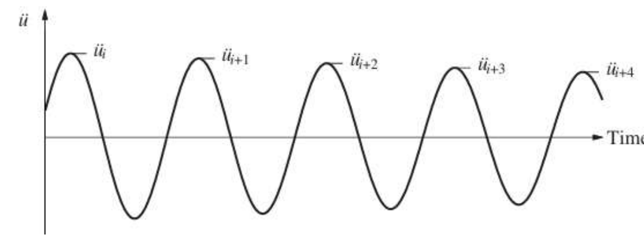
$$m\ddot{u} + c\dot{u} + ku = 0$$

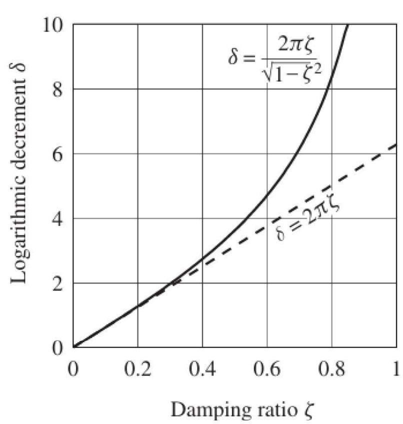
$$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u = 0$$

$$\omega_n = \sqrt{k/m} \quad \zeta = \frac{c}{2m\omega_n} = \frac{c}{c_{\text{cr}}} \quad \omega_D = \omega_n\sqrt{1-\zeta^2}$$

$$u(t) = e^{-\zeta\omega_n t}\left[u(0)\cos\omega_D t + \frac{\dot{u}(0) + \zeta\omega_n u(0)}{\omega_D}\sin\omega_D t\right]$$





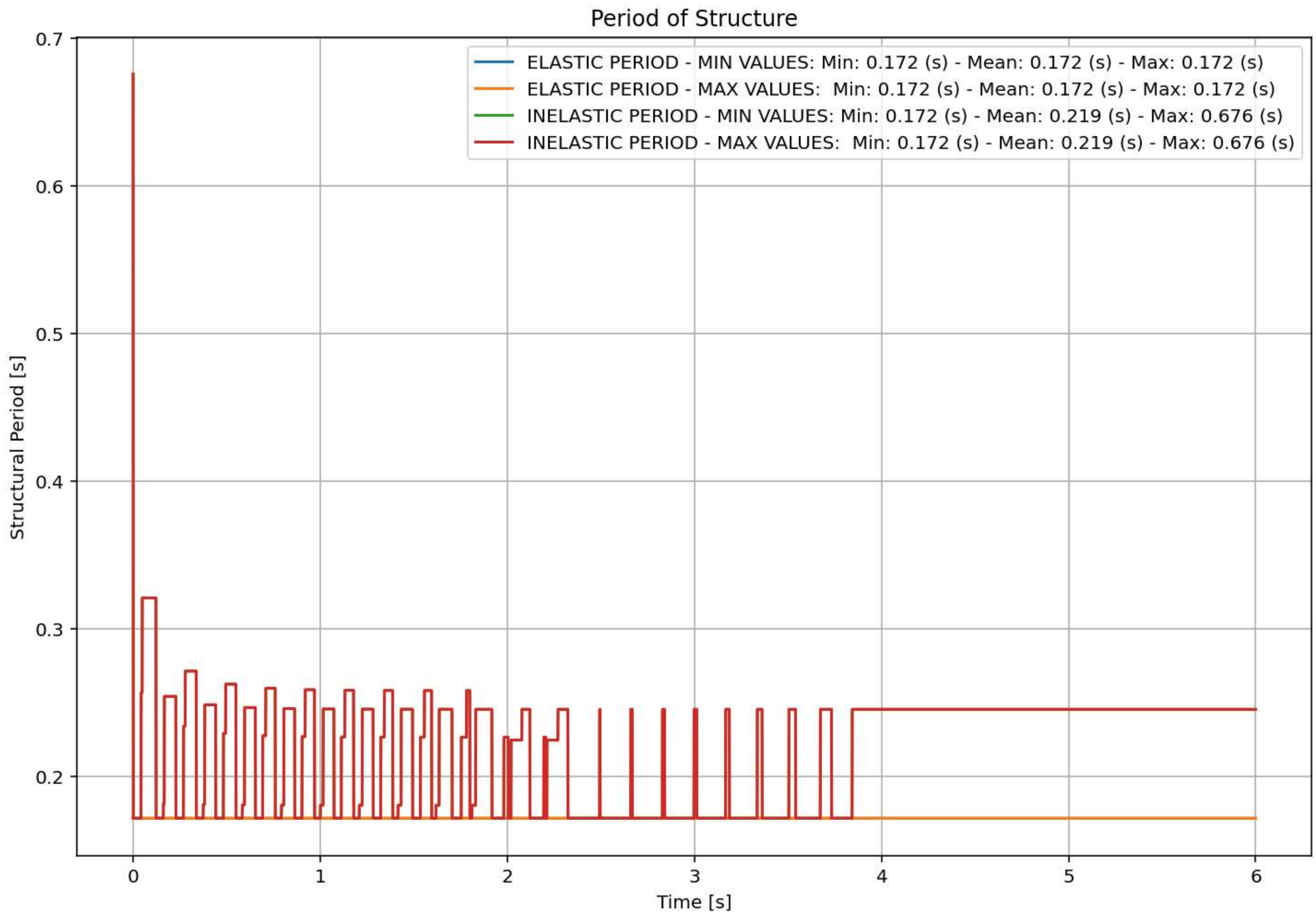


Decay of Motion

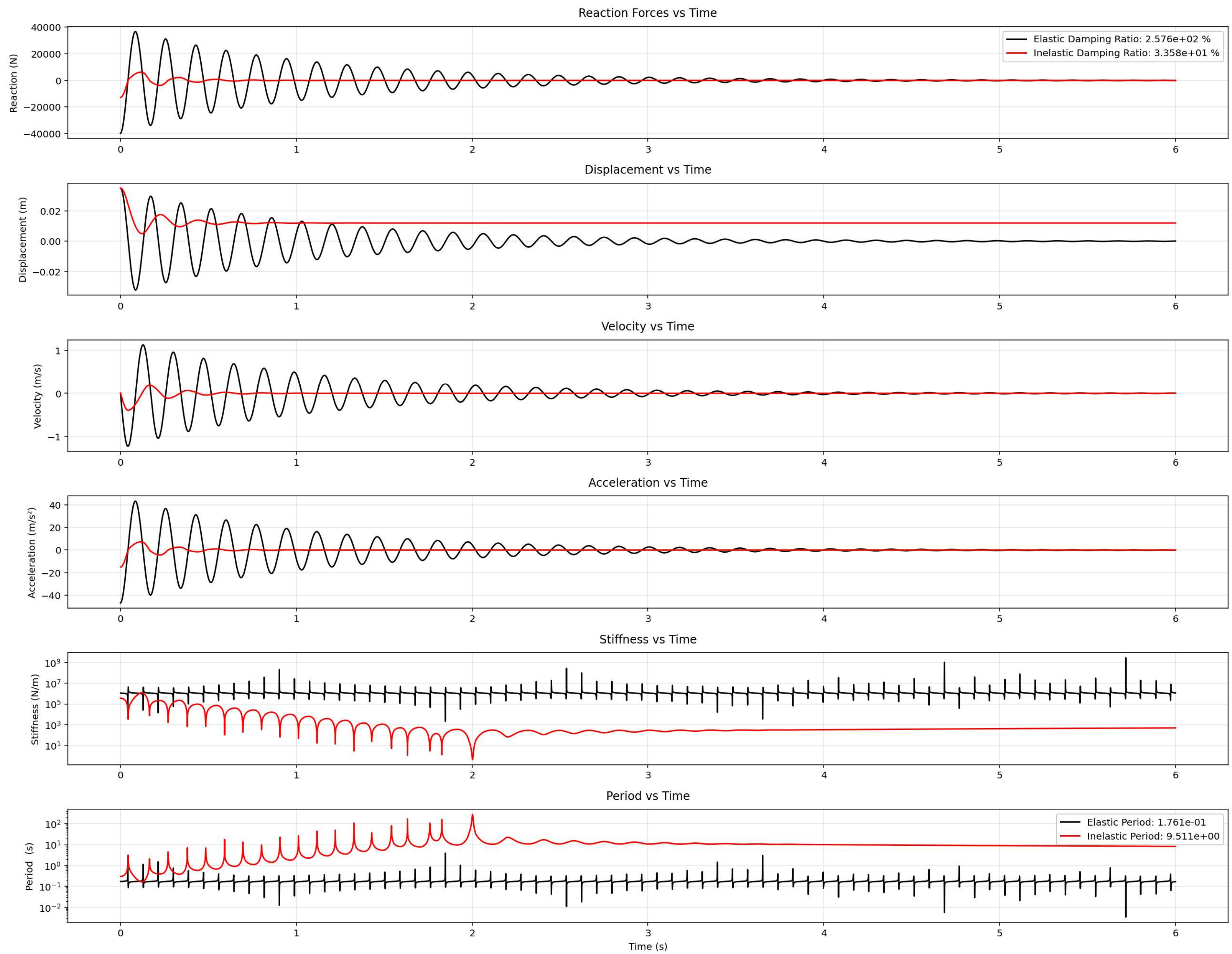
$$\delta = \ln\frac{u_i}{u_{i+1}} = 2\pi\zeta$$ **(APPROXIMATE RELATION)**

$$\delta = \ln\frac{u_i}{u_{i+1}} = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$ **(EXACT RELATION)**

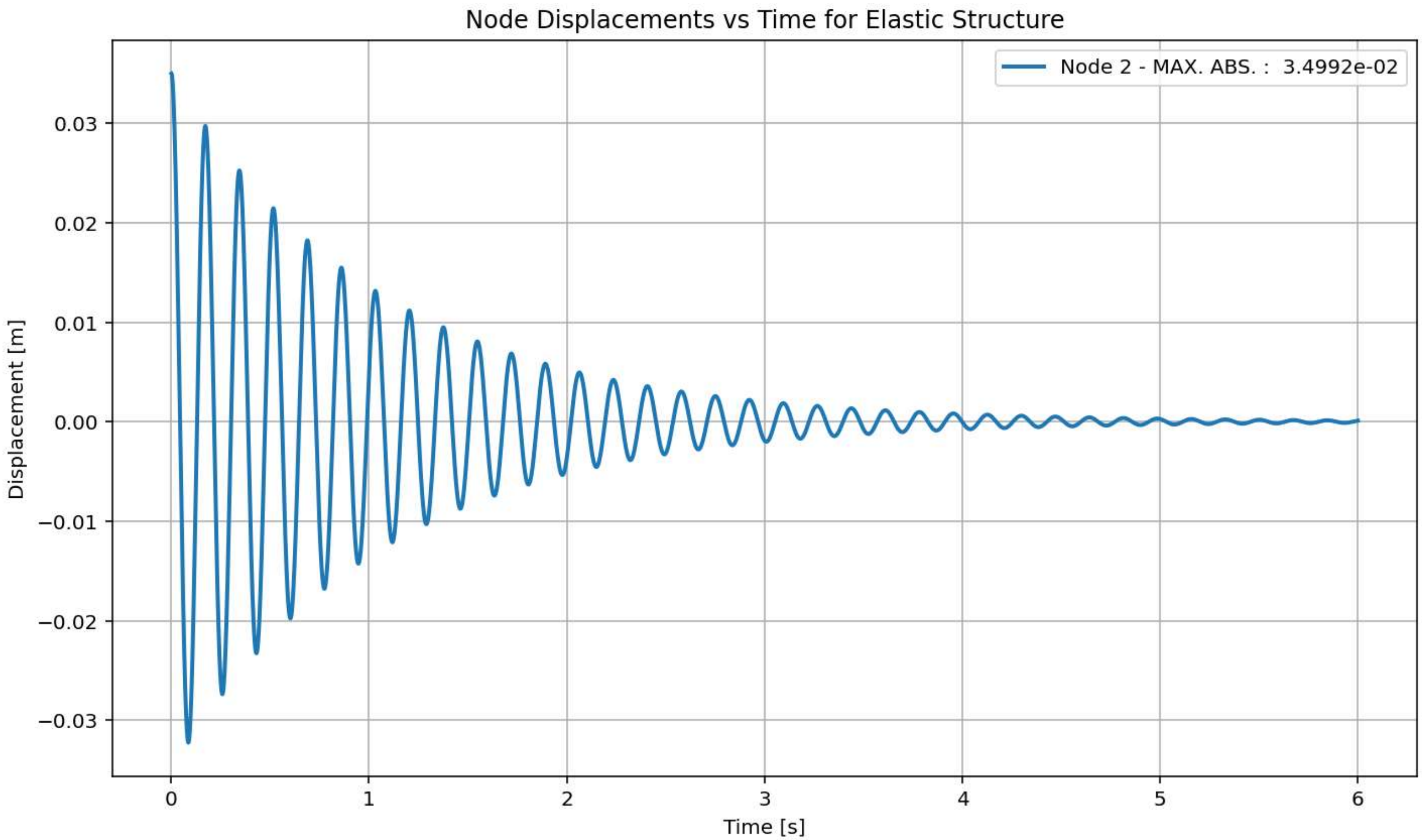
EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO



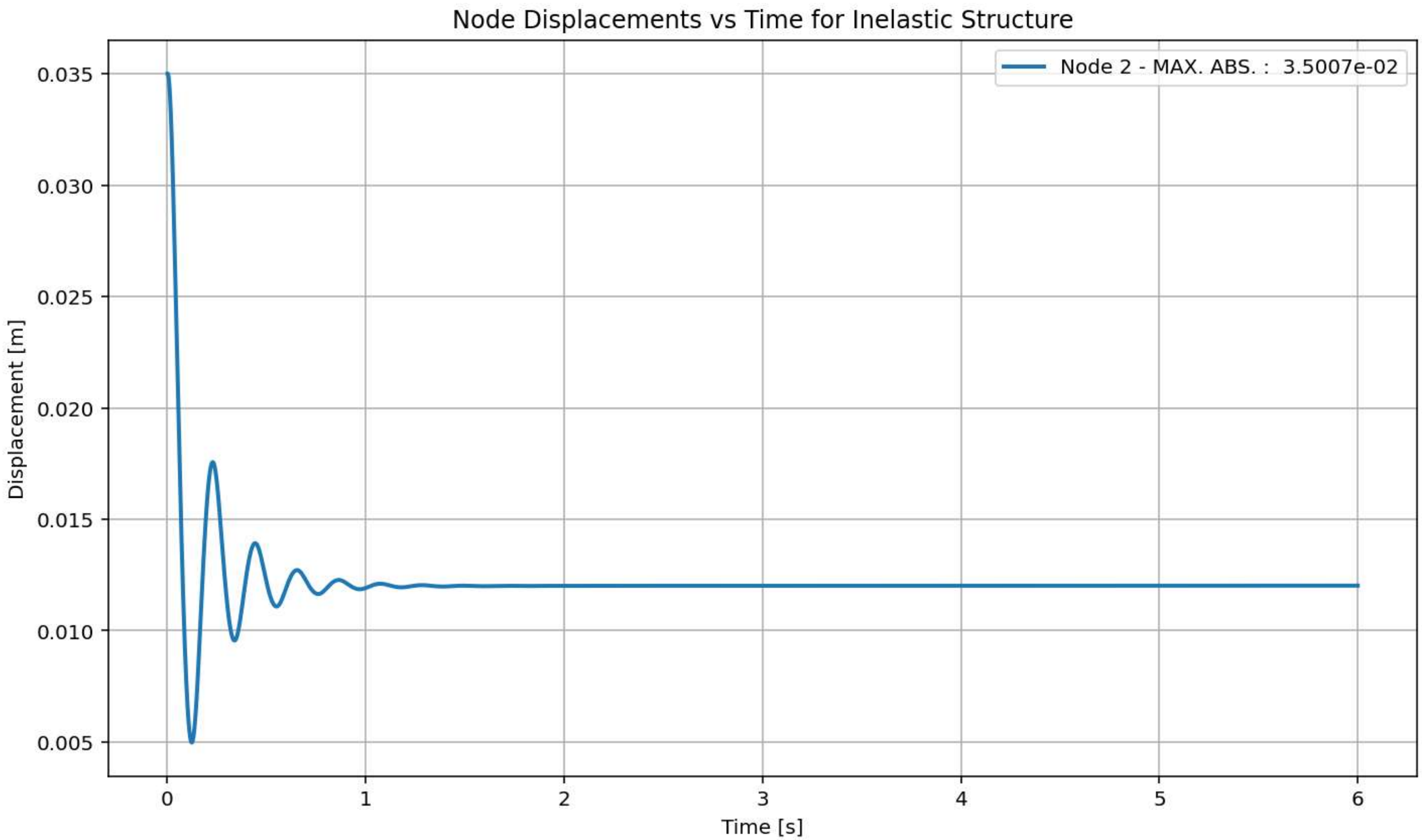
Period of Structure
ELASTIC PERIOD - MIN VALUES: Min: 0.172 (s) - Mean: 0.172 (s) - Max: 0.172 (s)
ELASTIC PERIOD - MAX VALUES: Min: 0.172 (s) - Mean: 0.172 (s) - Max: 0.172 (s)
INELASTIC PERIOD - MIN VALUES: Min: 0.172 (s) - Mean: 0.219 (s) - Max: 0.676 (s)
INELASTIC PERIOD - MAX VALUES: Min: 0.172 (s) - Mean: 0.219 (s) - Max: 0.676 (s)
Structural Period [s]
Time [s]
0.7
0.6
0.5
0.4
0.3
0.2
0
1
2
3
4
5
6

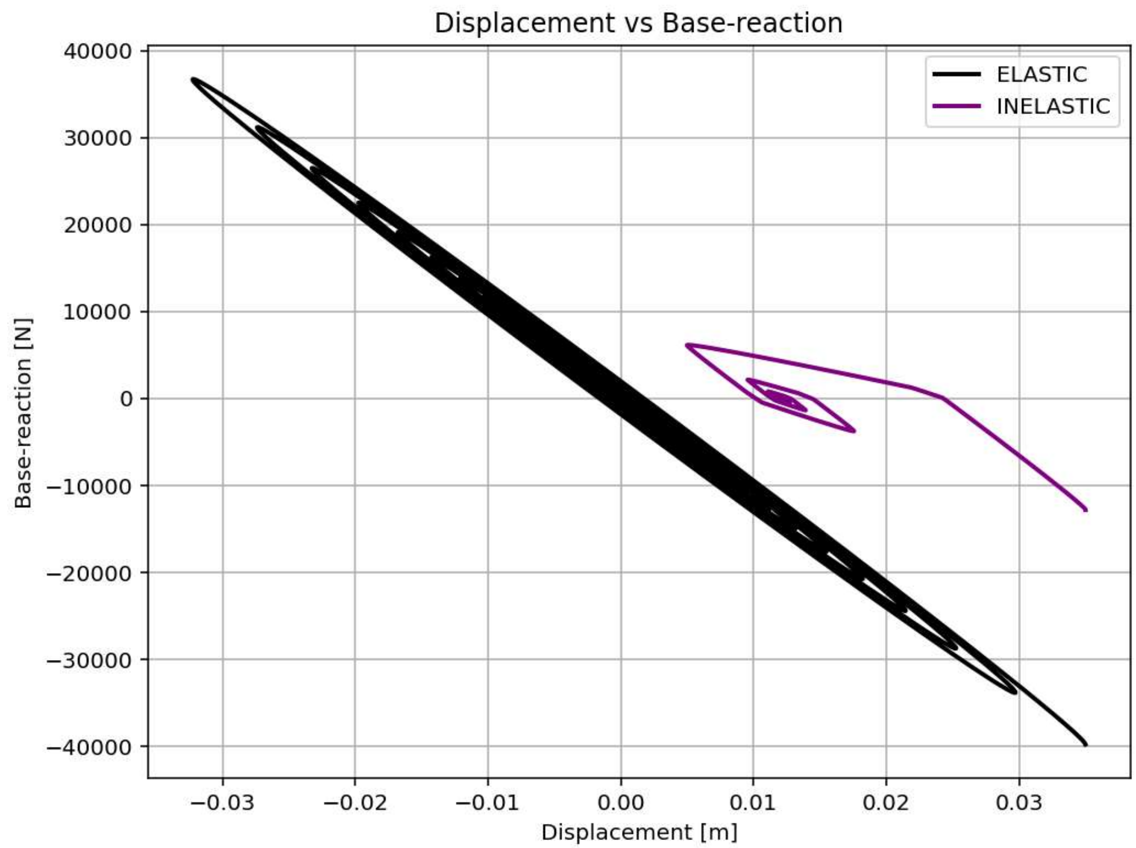


Reaction Forces vs Time
Reaction (N)
Elastic Damping Ratio: 2.576e+02 %
Inelastic Damping Ratio: 3.358e+01 %
Displacement vs Time
Displacement (m)
Velocity vs Time
Velocity (m/s)
Acceleration vs Time
Acceleration (m/s²)
Stiffness vs Time
Stiffness (N/m)
Period vs Time
Period (s)
Elastic Period: 1.761e-01
Inelastic Period: 9.511e+00
Time (s)

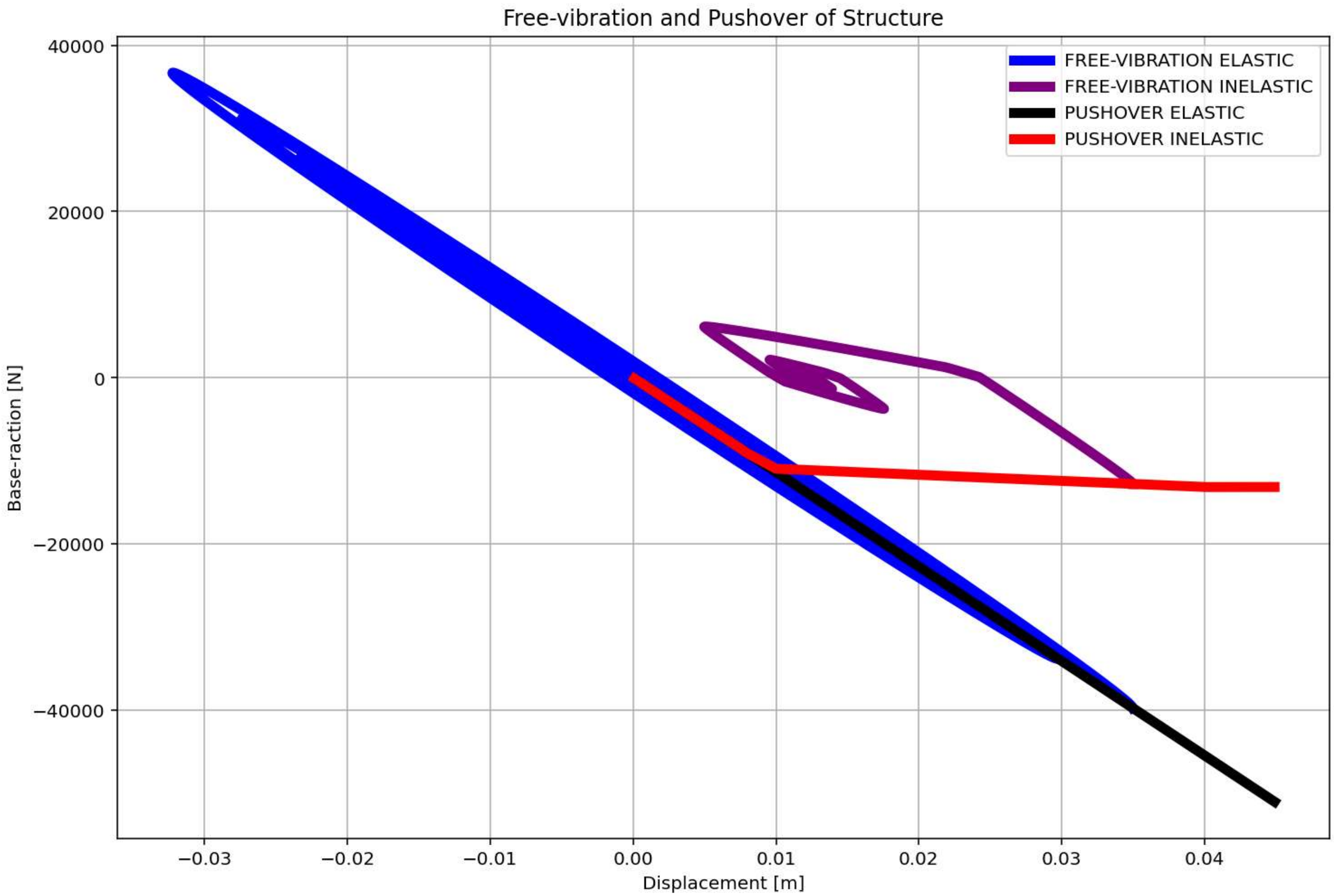


Node Displacements vs Time for Elastic Structure
Node 2 - MAX. ABS. : 3.4992e-02
Displacement [m]
Time [s]
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
0
1
2
3
4
5
6

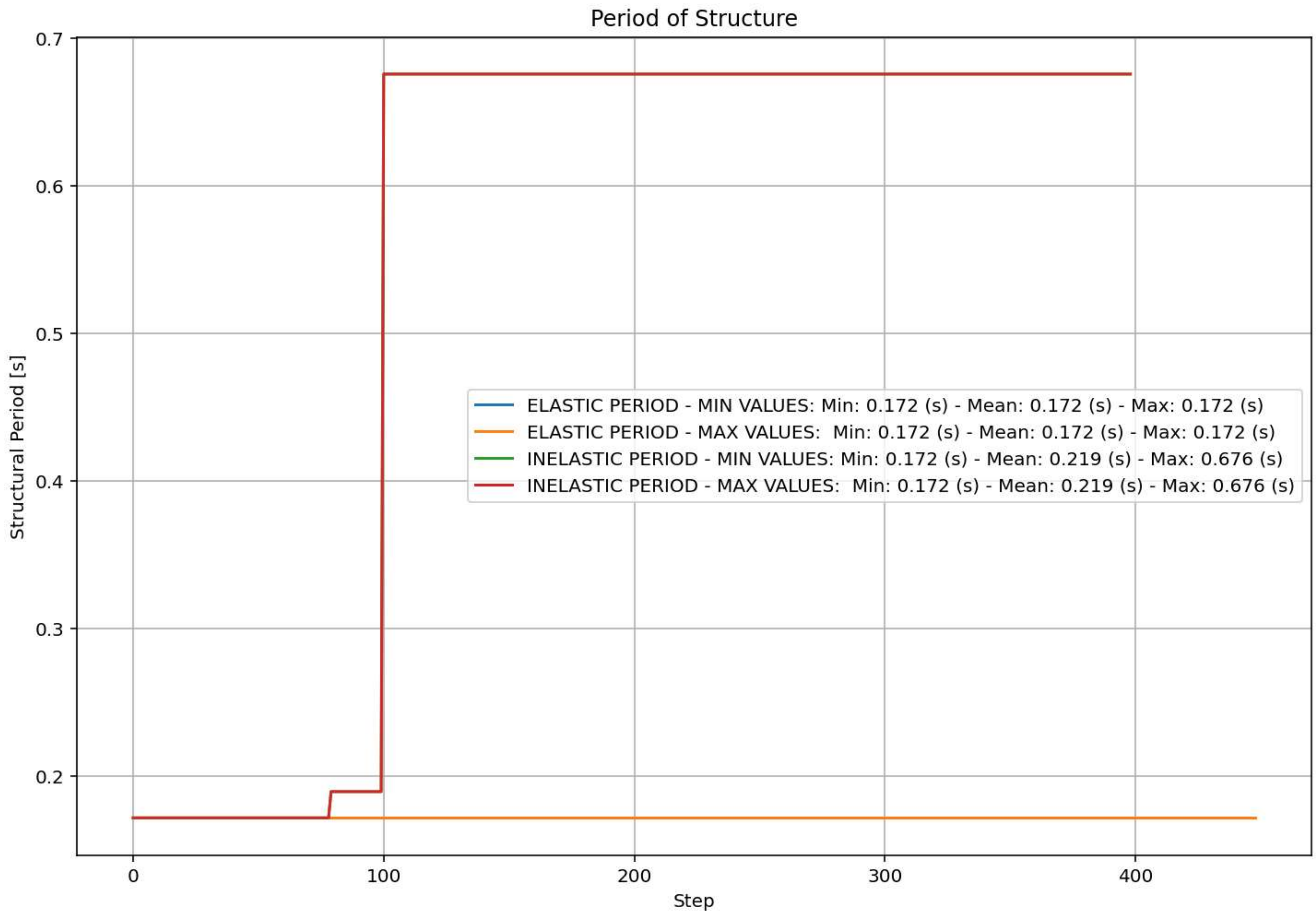

Node Displacements vs Time for Inelastic Structure
Node 2 - MAX. ABS. : 3.5007e-02
0.035
0.030
0.025
0.020
0.015
0.010
0.005
Displacement [m]
0
1
2
3
4
5
6
Time [s]

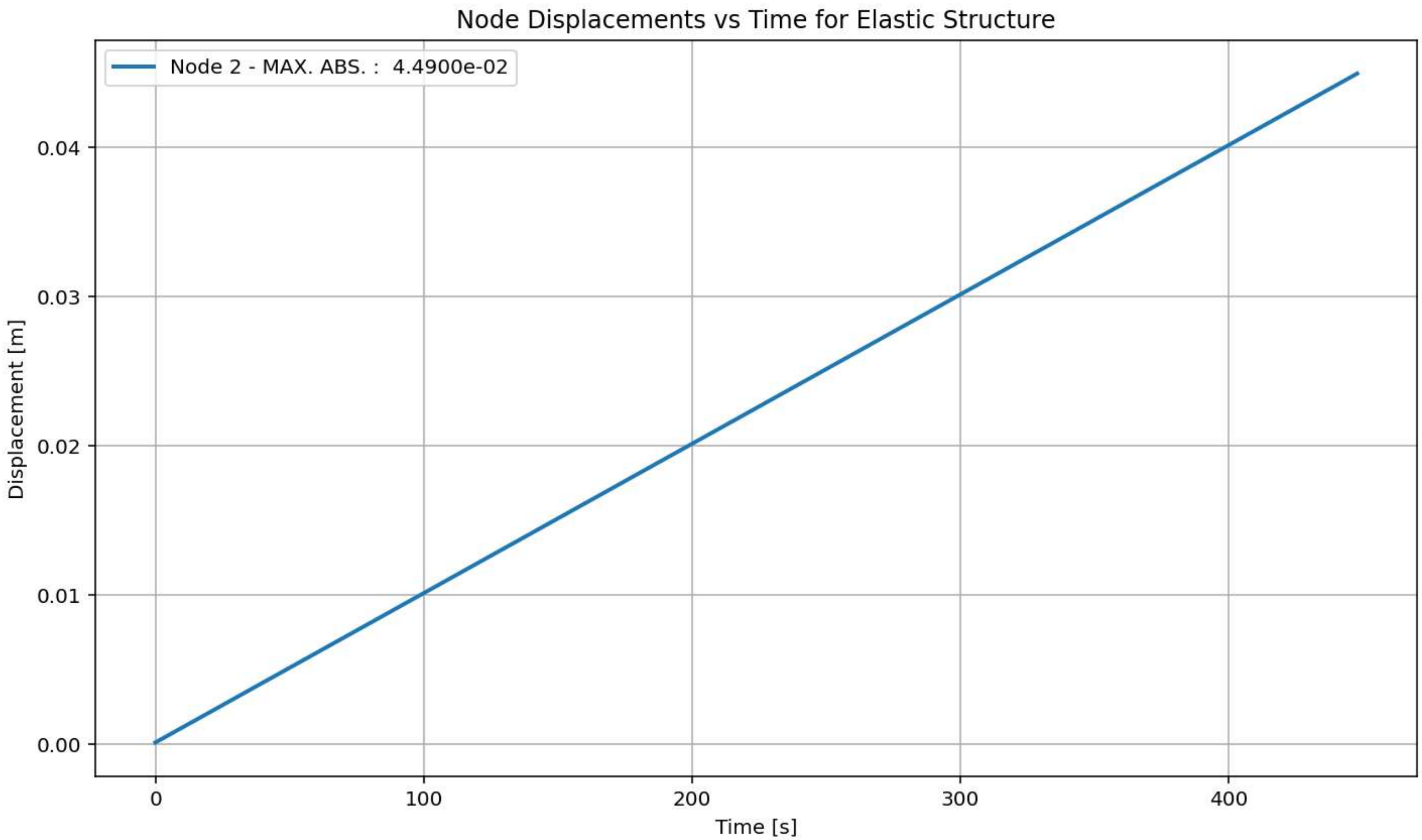

Displacement vs Base-reaction
ELASTIC
INELASTIC
Base-reaction [N]
Displacement [m]
40000
30000
20000
10000
0
−10000
−20000
−30000
−40000
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03

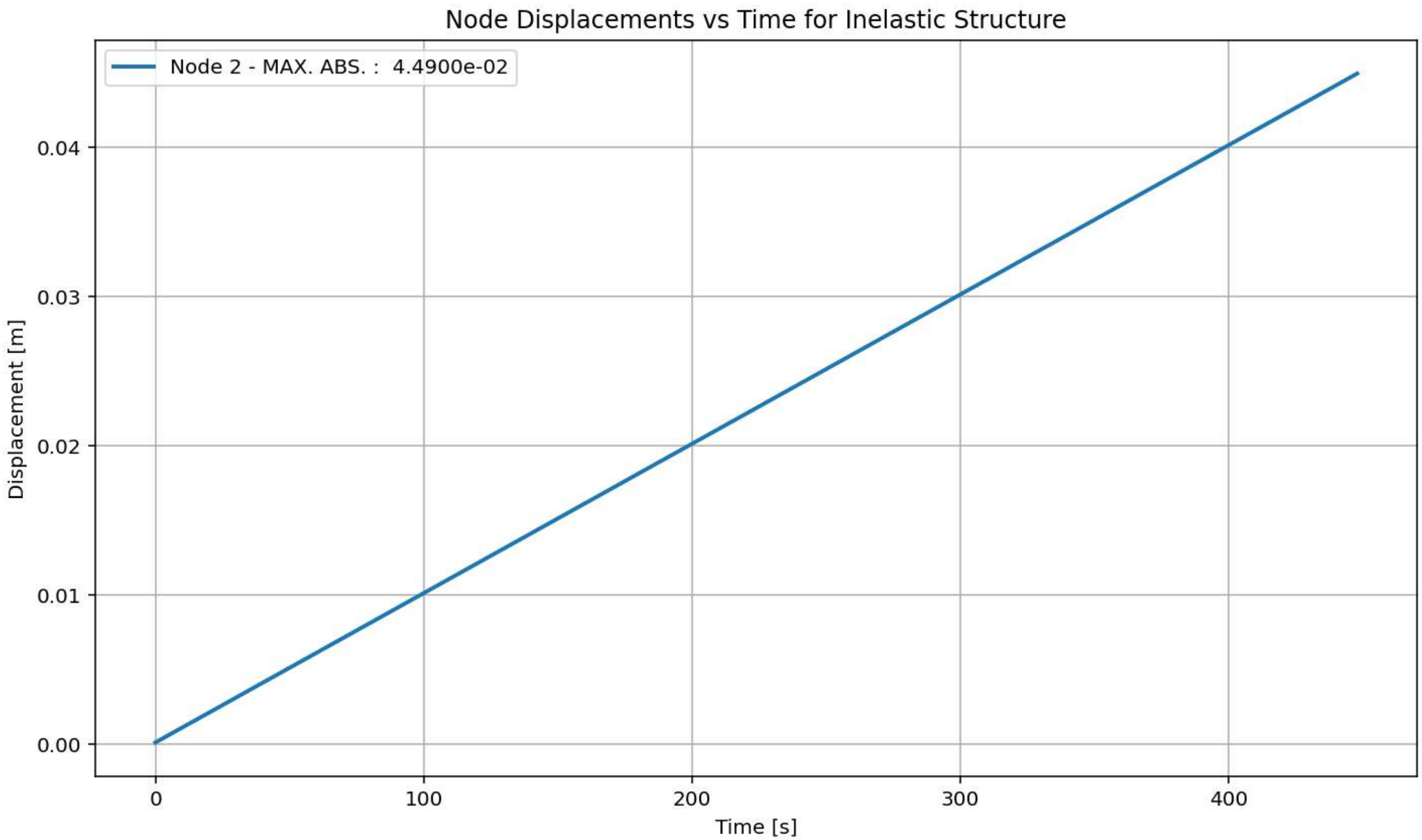
PUSHOVER ANALYSIS



Free-vibration and Pushover of Structure
FREE-VIBRATION ELASTIC
FREE-VIBRATION INELASTIC
PUSHOVER ELASTIC
PUSHOVER INELASTIC
40000
20000
0
−20000
−40000
Base-raction [N]
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
Displacement [m]


Period of Structure
Structural Period [s]
Step
0.7
0.6
0.5
0.4
0.3
0.2
0
100
200
300
400
ELASTIC PERIOD - MIN VALUES: Min: 0.172 (s) - Mean: 0.172 (s) - Max: 0.172 (s)
ELASTIC PERIOD - MAX VALUES: Min: 0.172 (s) - Mean: 0.172 (s) - Max: 0.172 (s)
INELASTIC PERIOD - MIN VALUES: Min: 0.172 (s) - Mean: 0.219 (s) - Max: 0.676 (s)
INELASTIC PERIOD - MAX VALUES: Min: 0.172 (s) - Mean: 0.219 (s) - Max: 0.676 (s)


Node Displacements vs Time for Elastic Structure
Node 2 - MAX. ABS. : 4.4900e-02
0.04
0.03
0.02
0.01
0.00
Displacement [m]
0
100
200
300
400
Time [s]



Node Displacements vs Time for Inelastic Structure
Node 2 - MAX. ABS. : 4.4900e-02
0.00
0.01
0.02
0.03
0.04
Displacement [m]
0
100
200
300
400
Time [s]