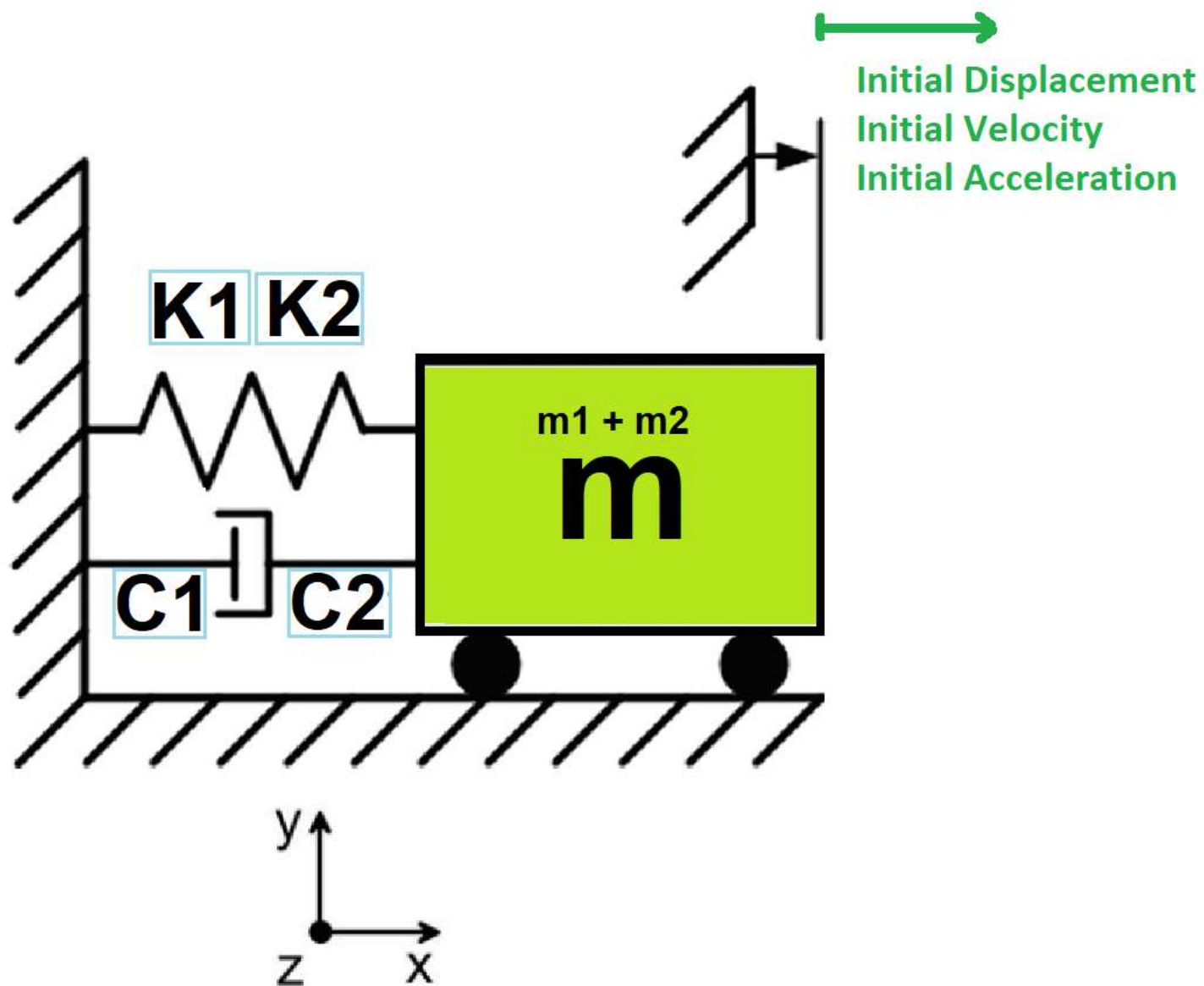
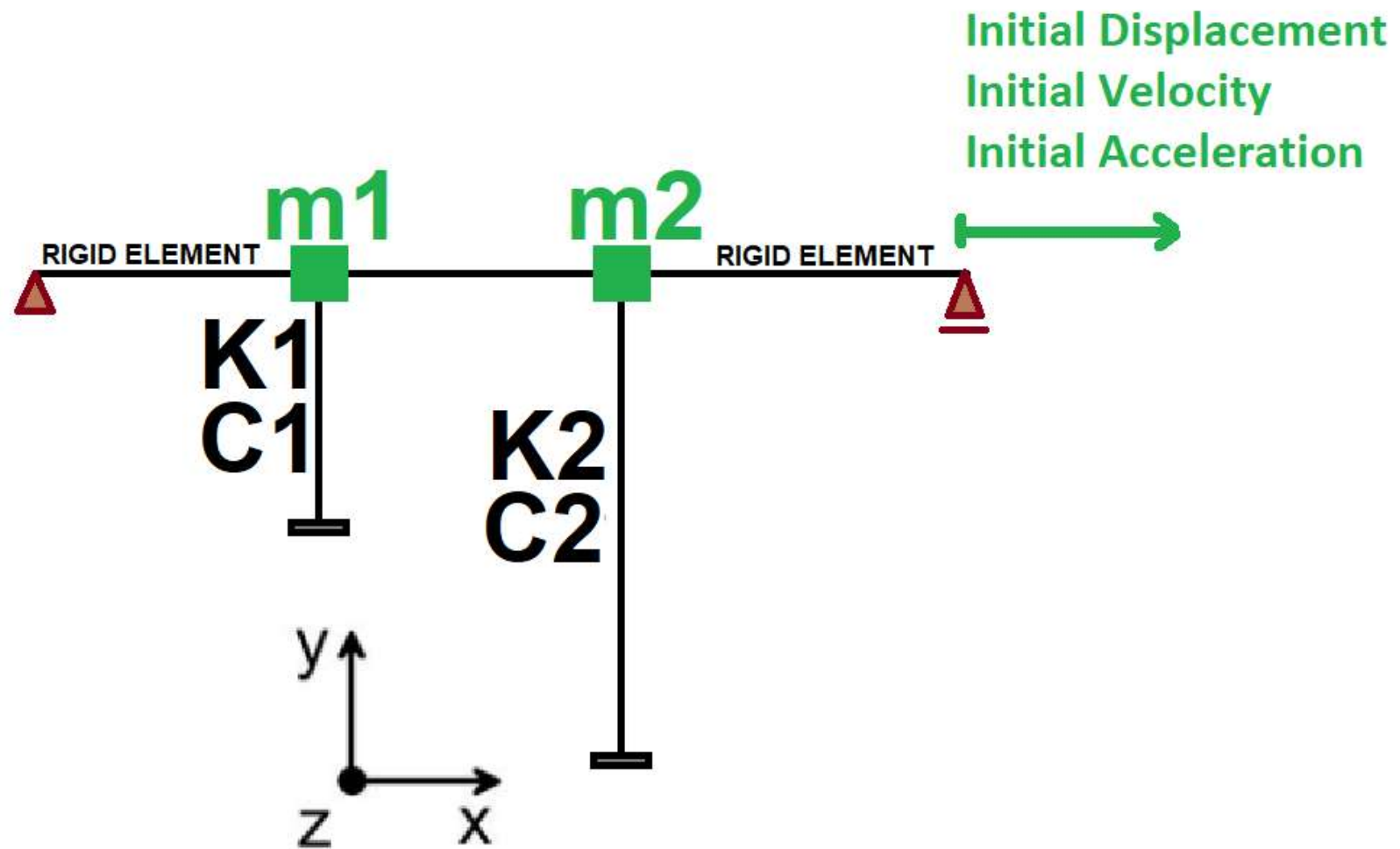


>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

# COMPARATIVE FREE-VIBRATION AND PUSHOVER ANALYSIS OF AN SDOF SYSTEM: ELASTIC VERSUS INELASTIC RESPONSE WITH PARALLEL SPRINGS FOR STRUCTURAL AND NON- STRUCTURAL ELEMENTS USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)





Spyder (Python 3.12)

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SDOF\_FREE-VIBRATIO...NON-STRUCTURAL.py

```
1 #####
2 # >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <
3 # COMPARATIVE FREE-VIBRATION AND PUSHOVER ANALYSIS OF AN SDOF SYSTEM: ELASTIC VERSUS INELA
4 # SPRINGS FOR STRUCTURAL AND NON-STRUCTURAL ELEMENTS USING OPENSEE
5 #
6 # THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
7 # EMAIL: salar.d.ghashghaei@gmail.com
8 #####
9 """
10 Performs free-vibration and pushover analysis of a Single Degree of Freedom (SDOF)
11 structure using OpenSeesPy, comparing elastic and inelastic spring behavior.
12
13 Key features include:
14 1. Implements both elastic (linear) and hysteretic (nonlinear) material models for structu
15 2. Supports initial conditions for displacement, velocity, and acceleration.
16 3. Uses Newmark's method for time integration with Newton-Raphson iteration.
17 4. Calculates damping ratios using logarithmic decrement from response peaks.
18 5. Generates force-displacement backbone curves for inelastic material.
19 6. Tracks and plots time-history responses (displacement, velocity, acceleration, reaction
20 7. Compares elastic vs inelastic system performance.
21 8. Includes convergence checks and analysis stability monitoring.
22 9. Outputs model data in JSON format for post-processing.
23 10. Provides theoretical validation through natural frequency calculations.
24
25 Particularly useful for earthquake engineering applications,
26 allowing evaluation of structural response under free vibration
27 with different material nonlinearities and damping characteristics.
28 The hysteretic material model captures energy dissipation
29 inelastic deformation, while the elastic case serves as a reference for linear behavior.
30 """
31 import openseespy.opensees as ops
32 import numpy as np
33 import matplotlib.pyplot as plt
34 import time as TI
```

Free-vibration and Pushover of Structure

Base reaction (N)

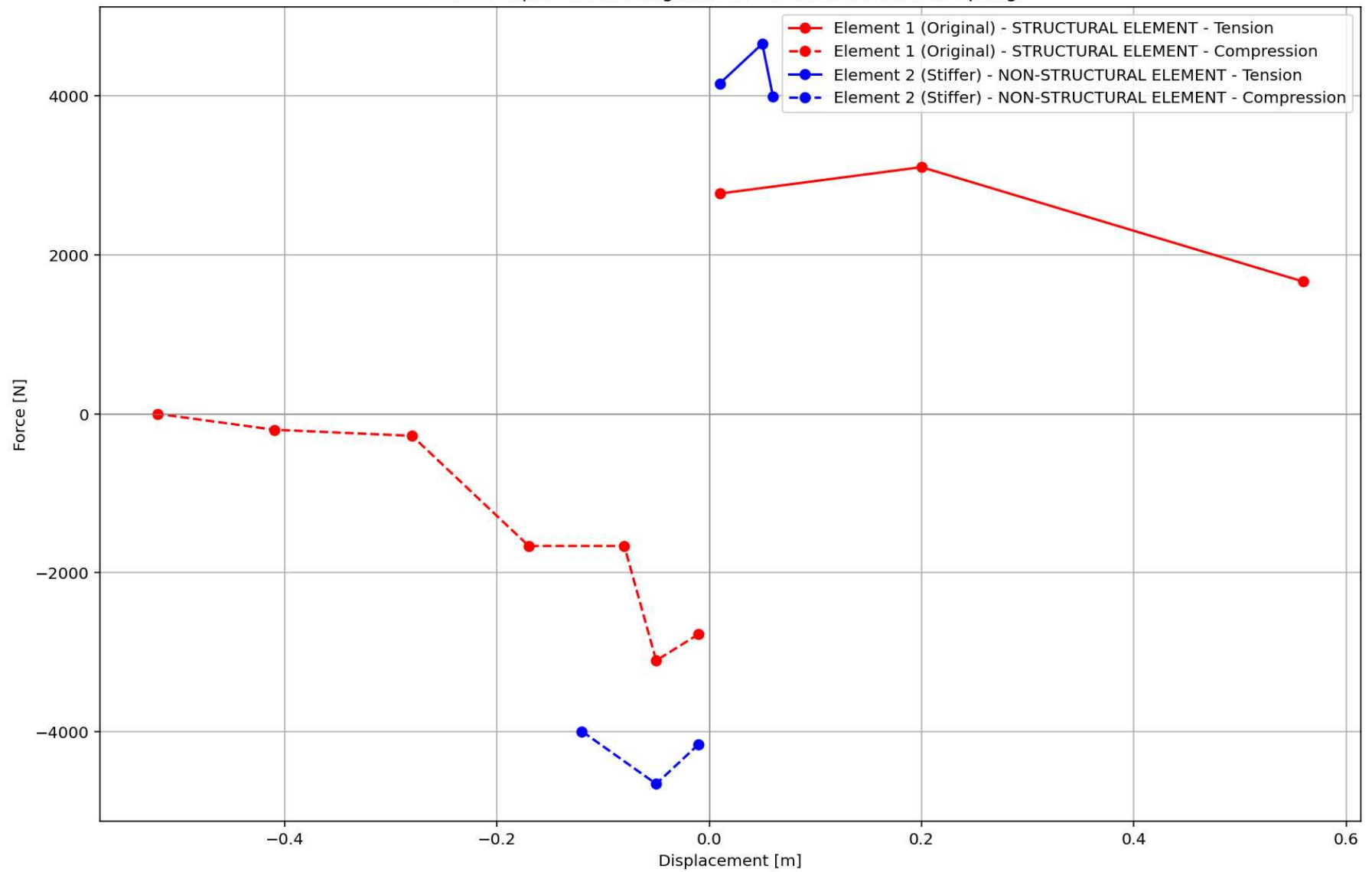
Displacement (m)

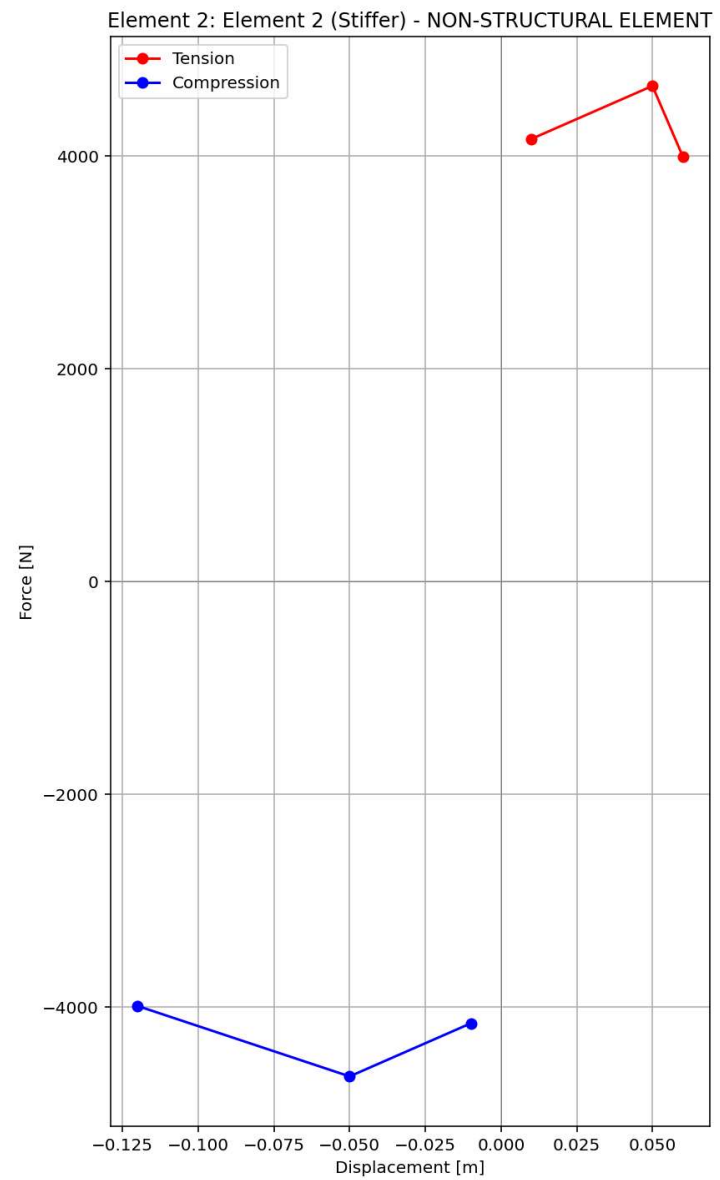
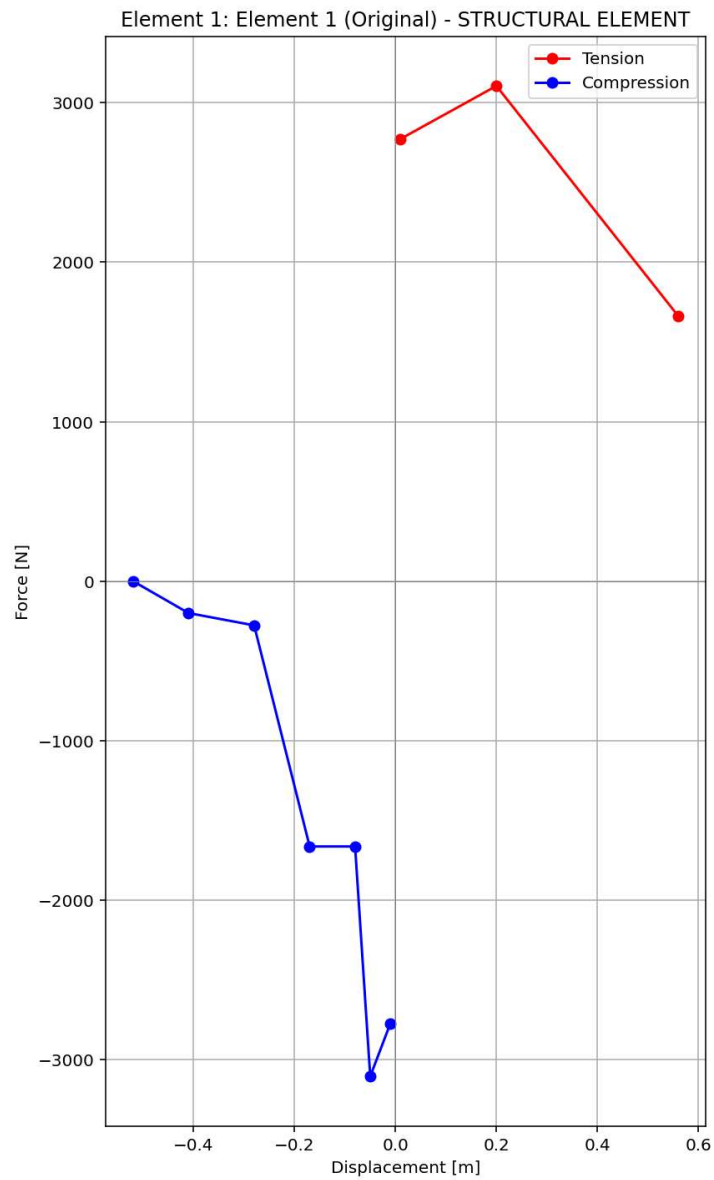
FREE-VIBRATION ELASTIC  
FREE-VIBRATION INELASTIC  
PUSHOVER ELASTIC  
PUSHOVER INELASTIC

IPython Console Files Help Variable Explorer Debugger Plots History

Inline Conda: anaconda3 (Python 3.12.7) ✓ LSP: Python Line 14, Col 49 UTF-8 CRLF RW Mem 35%

Force-Displacement Diagrams for 2 Different Inelastic Springs





# FREE-VIBRATION ANALYSIS

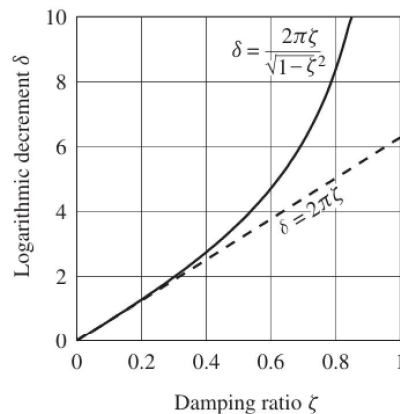
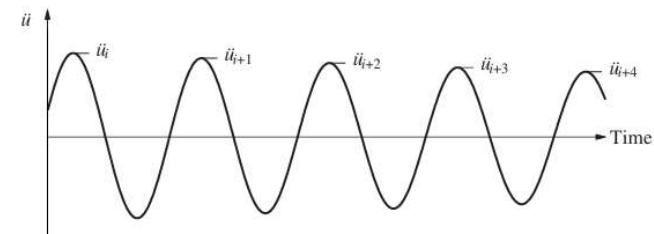
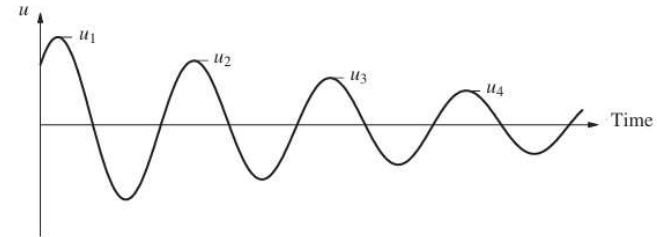
## VISCOUSLY DAMPED FREE VIBRATION

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

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

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

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

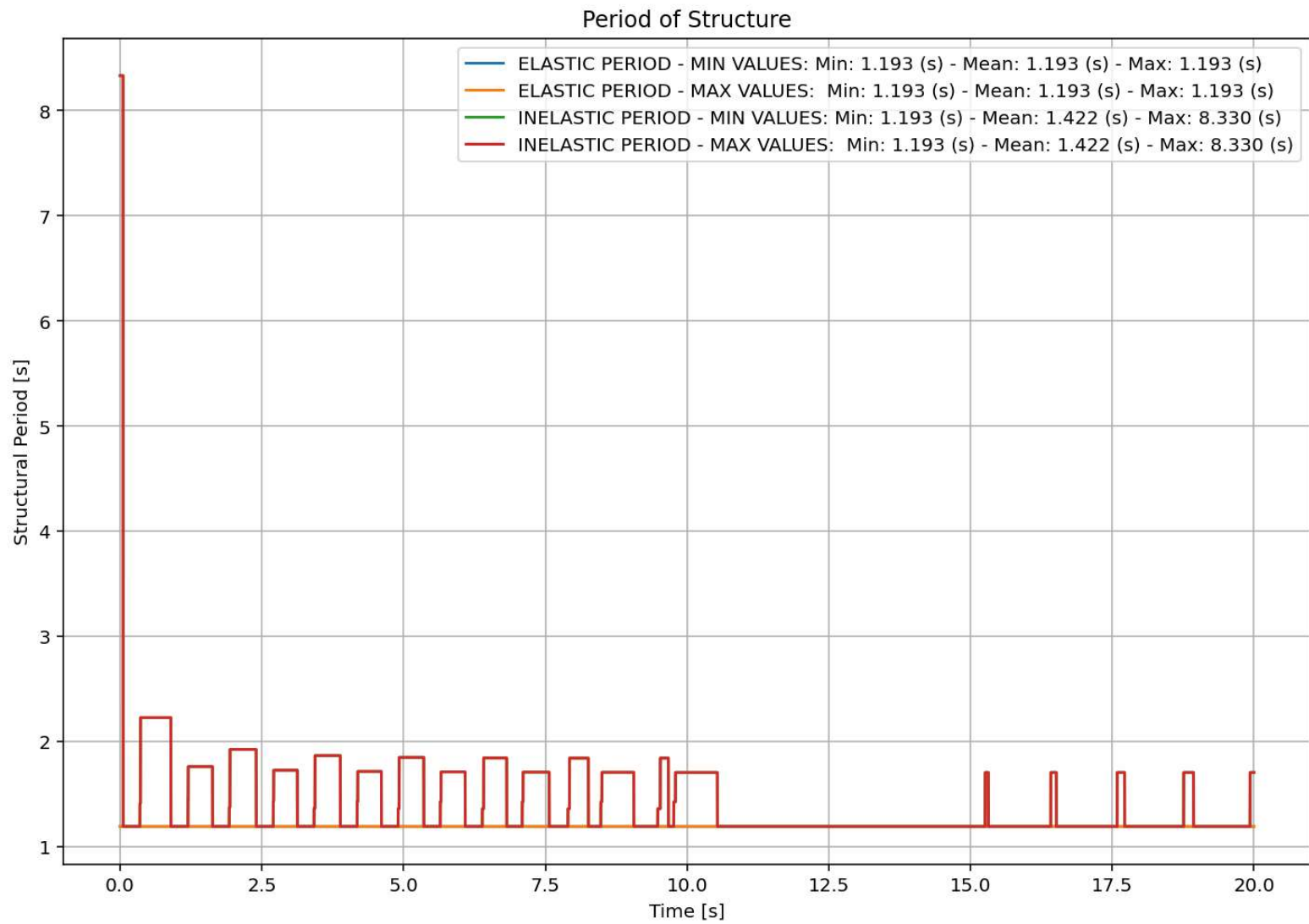


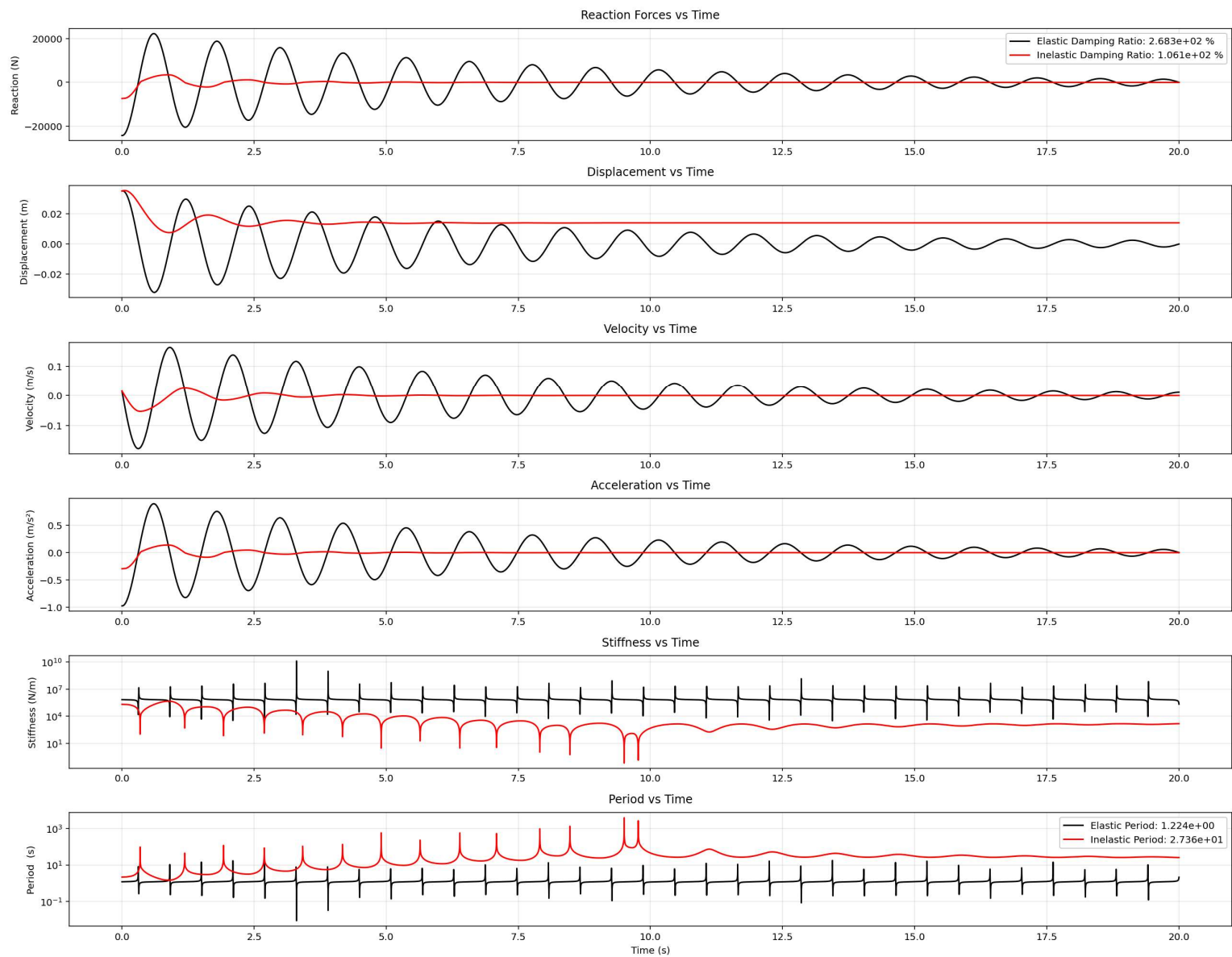
### Decay of Motion

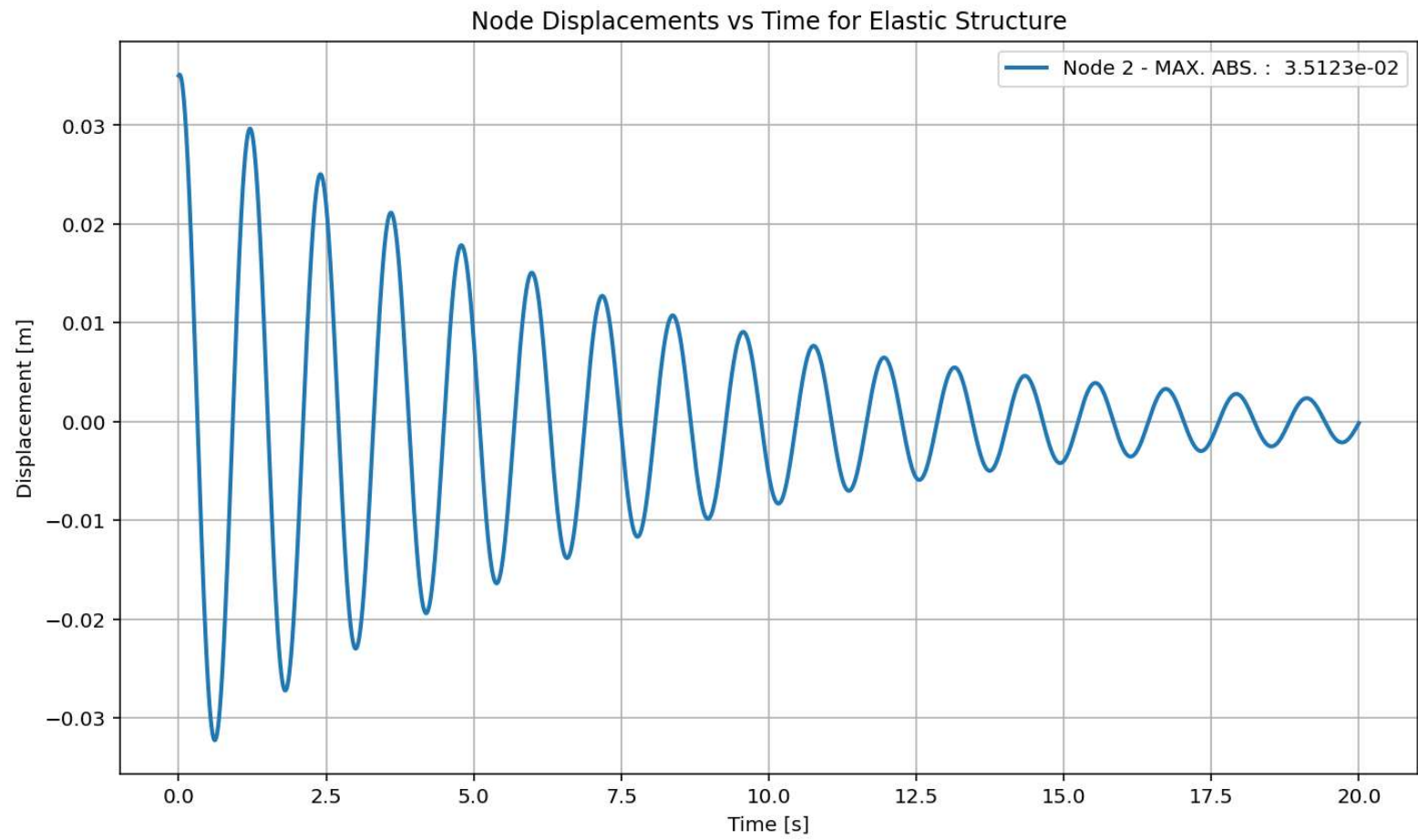
$$\delta = \ln \frac{u_i}{u_{i+1}} = 2\pi\zeta \quad (\text{APPROXIMATE RELATION})$$

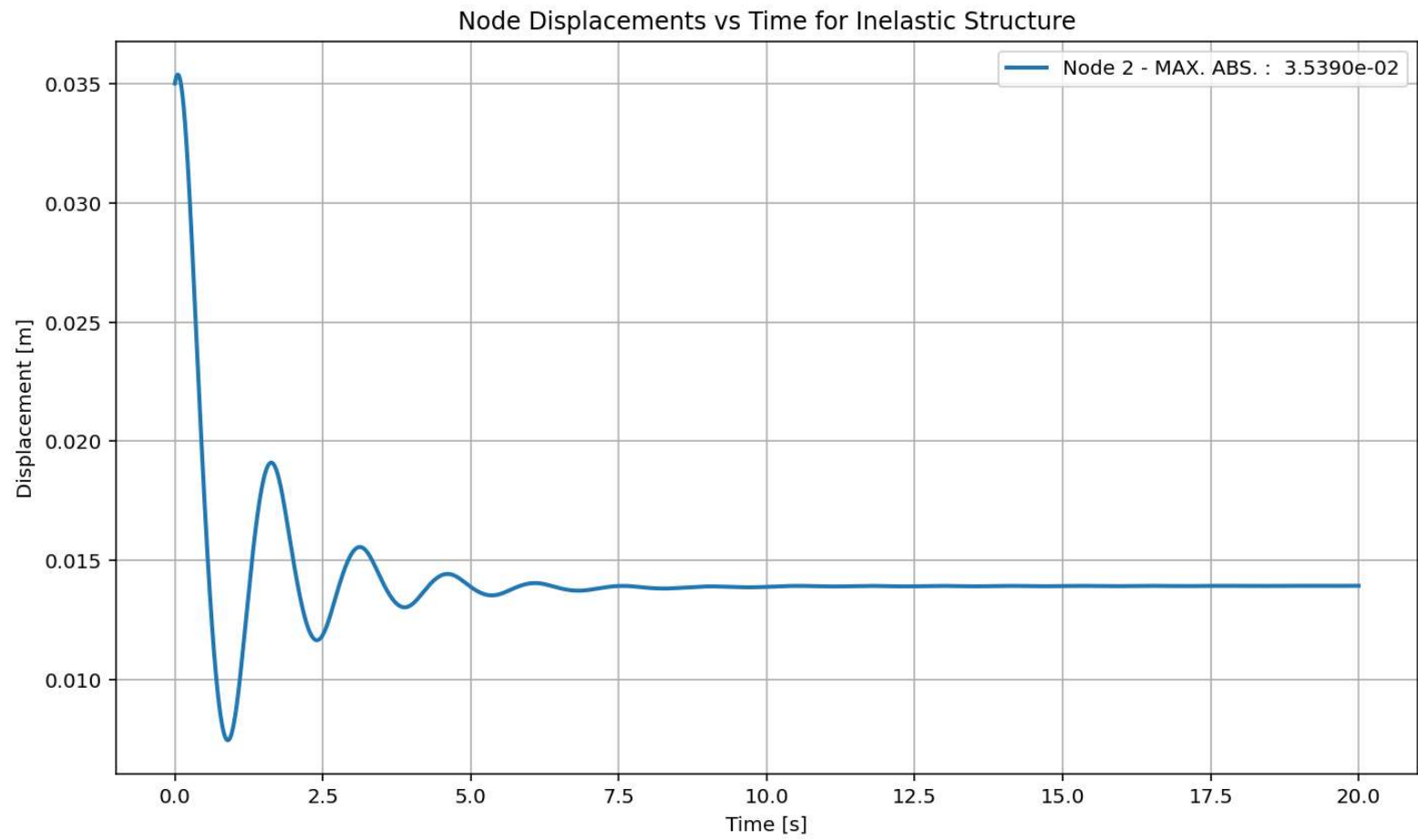
$$\delta = \ln \frac{u_i}{u_{i+1}} = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}} \quad (\text{EXACT RELATION})$$

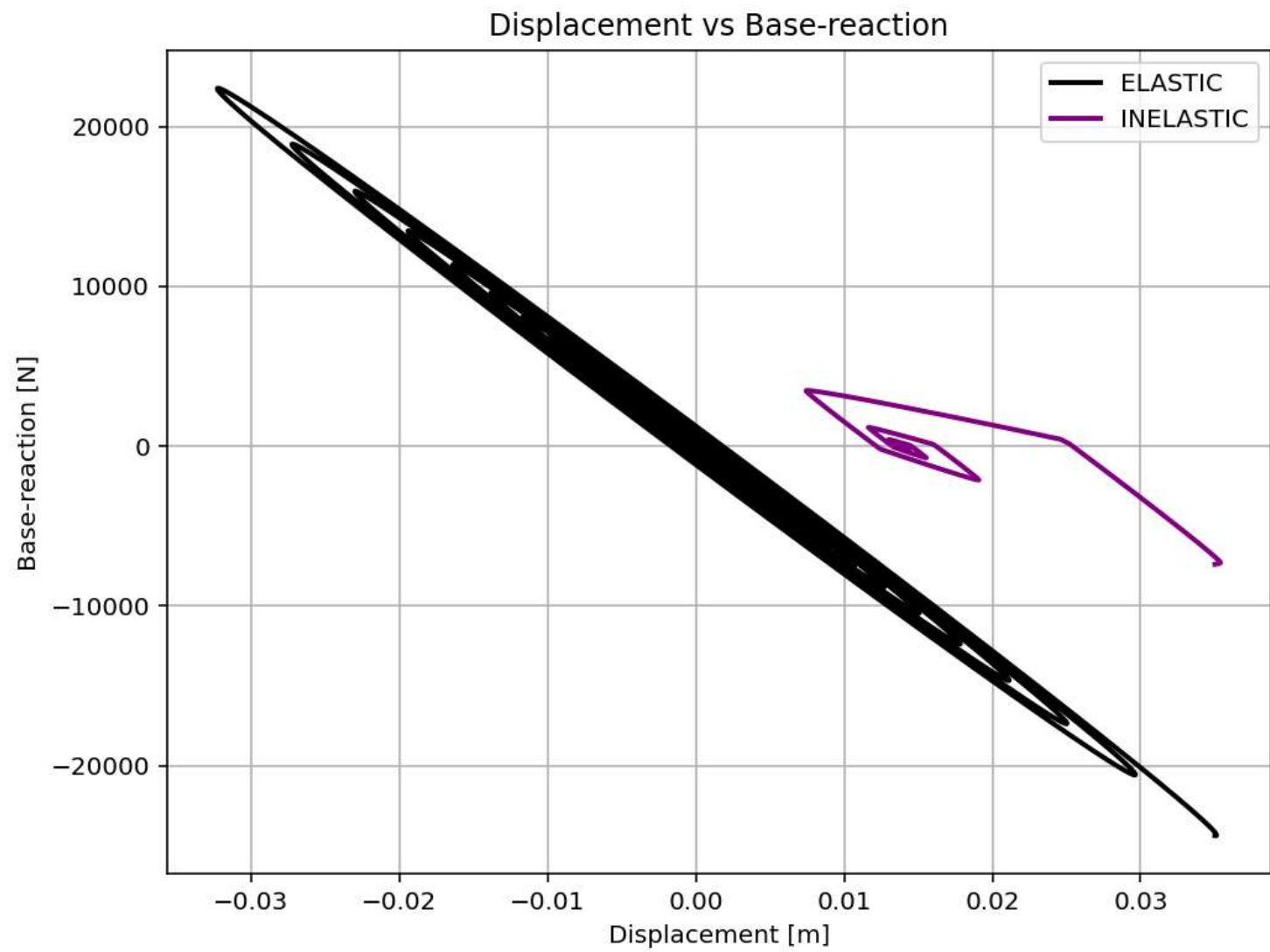
EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO











# PUSHOVER ANALYSIS

