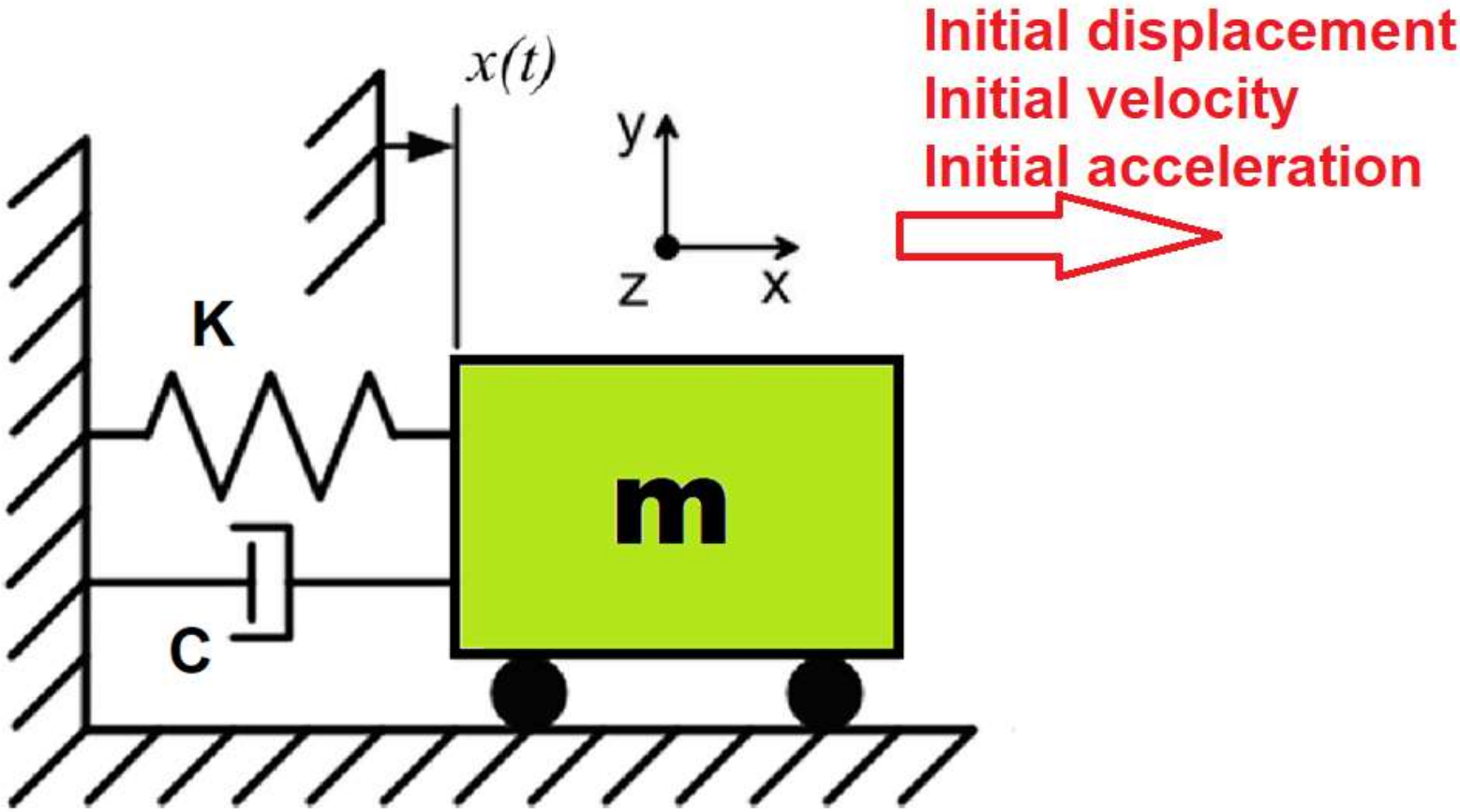
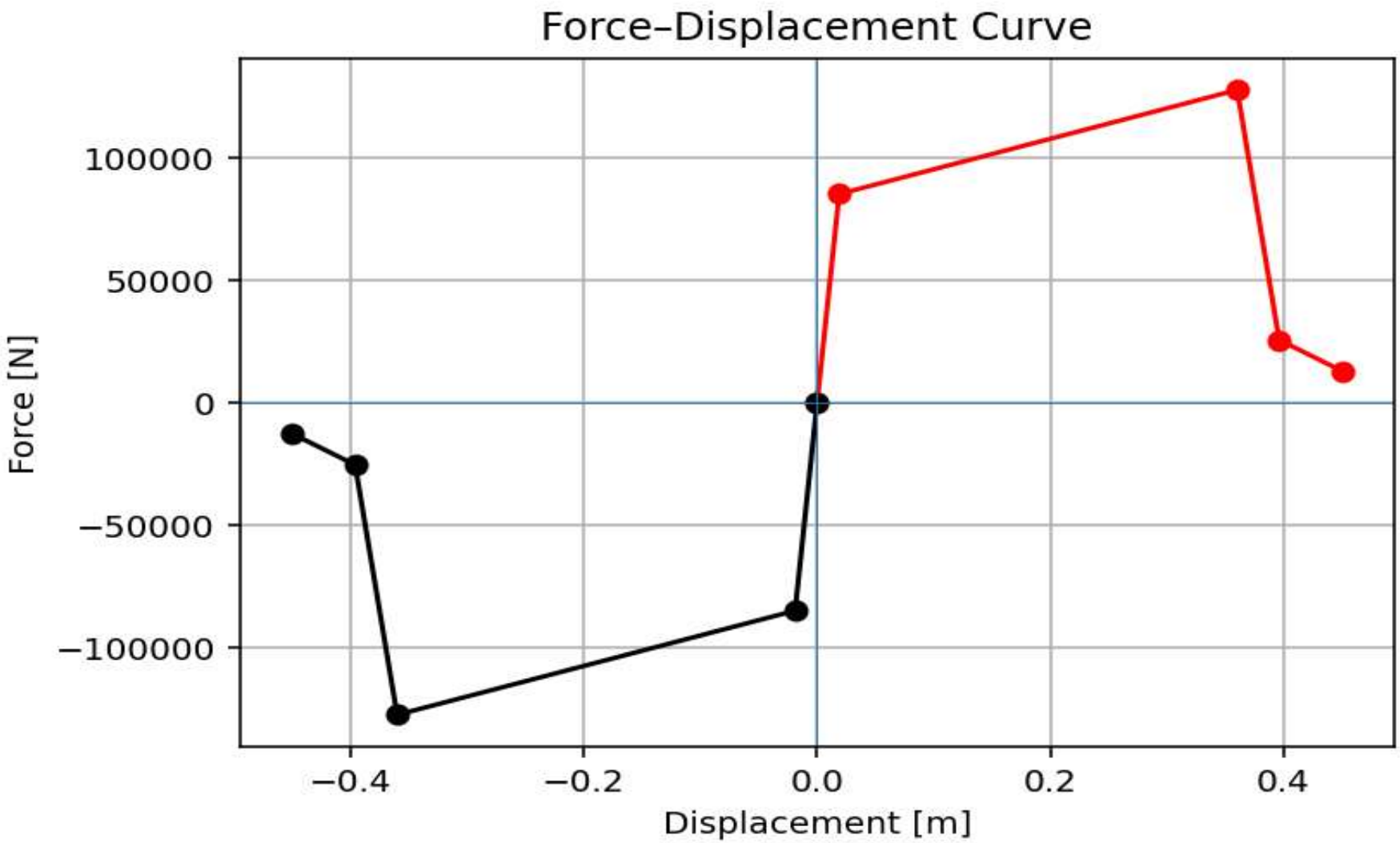
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

NONLINEAR DYNAMIC ANALYSIS UNDER FREE-VIBRAION COMPUTATION AND VISUALIZATION RESPONSE SPECTRA OF ACCELERAION, VELOCITY, DISPLACEMENT DUCTILITY DAMAGE INDEX USING OPENSEES

(CONSTANT STRUCTURAL DUCTILITY RATIO RESPONSE SPECTRUM)

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


x(t)
y
z
x
K
m
C
Initial displacement
Initial velocity
Initial acceleration


Force–Displacement Curve
100000
50000
0
−50000
−100000
Force [N]
−0.4
−0.2
0.0
0.2
0.4
Displacement [m]

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

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

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

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

Spyder (Python 3.12)

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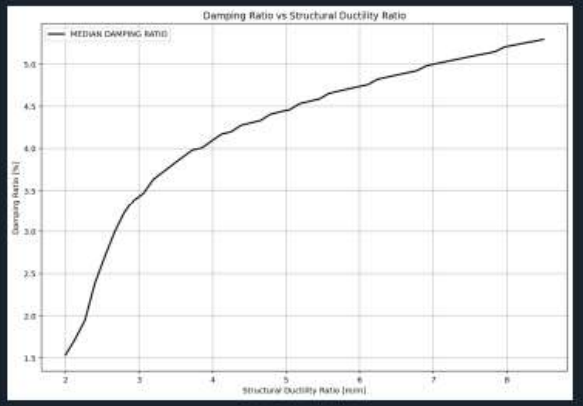
C:\Users\Dell\Desktop\OPENSEES_FILES\SDOF_RESPONS...SDOF_RESPONSE_SPECTRUM_FREE_VIBRATION_DUCT_OSF.py

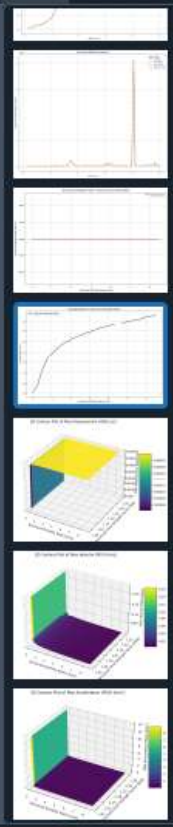
SDOF_RESPONSE_SPEC...,RATION_DUCT_OSF.py

```
##########################################################################################################
#                    >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
#             NONLINEAR DYNAMIC ANALYSIS UNDER FREE-VIBRAION COMPUTATION AND VISUALIZATION
#       RESPONSE SPECTRA OF ACCELERAION, VELOCITY, DISPLACEMENT DUCTILITY DAMAGE INDEX USING OPENSEES
#--------------------------------------------------------------------------------------------------------
#     INVESTIGATION OF THE EFFECTS OF SDOF STRUCTURAL DUCTILITY ON DAMAGE LEVEL AND STRUCTURAL DAMPING
#                                          USING FREE-VIBRATION
#--------------------------------------------------------------------------------------------------------
#                          CONSTANT STRUCTURAL DUCTILITY RATIO RESPONSE SPECTRUM
#--------------------------------------------------------------------------------------------------------
#                          THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                   EMAIL: salar.d.ghashghaei@gmail.com
##########################################################################################################

"""
Investigation of the Effects of Structural Ductility on Damage Level and Structural Damping:
This code implements a comprehensive nonlinear dynamic analysis framework for
performance-based earthquake engineering assessment of single-degree-of-freedom
(SDOF) systems. The methodology combines traditional nonlinear time-history
analysis with modern probabilistic and machine learning techniques for advanced
structural performance evaluation with changing structural ductility raio and over strength factor.

KEY ENGINEERING OBJECTIVES:
1. Comparative assessment of hysteretic models for free-vibration response prediction
2. Probabilistic free-vibration demand analysis using multiple ground motions
3. Development of fragility curves for performance-based earthquake engineering
4. Integration of data science methods for structural reliability assessment

ANALYTICAL FEATURES:
- Nonlinear material behavior with pinching and degradation
- Response spectrum analysis across period range
- Real-time structural health monitoring metrics
- Statistical characterization of free-vibration demands
- Machine learning-based damage prediction
-----------------------------------
Model setup:
```

...top\OPENSEES_FILES\SDOF_RESPONSE_SPECTRUM_SEISMIC_DUCT_OSF

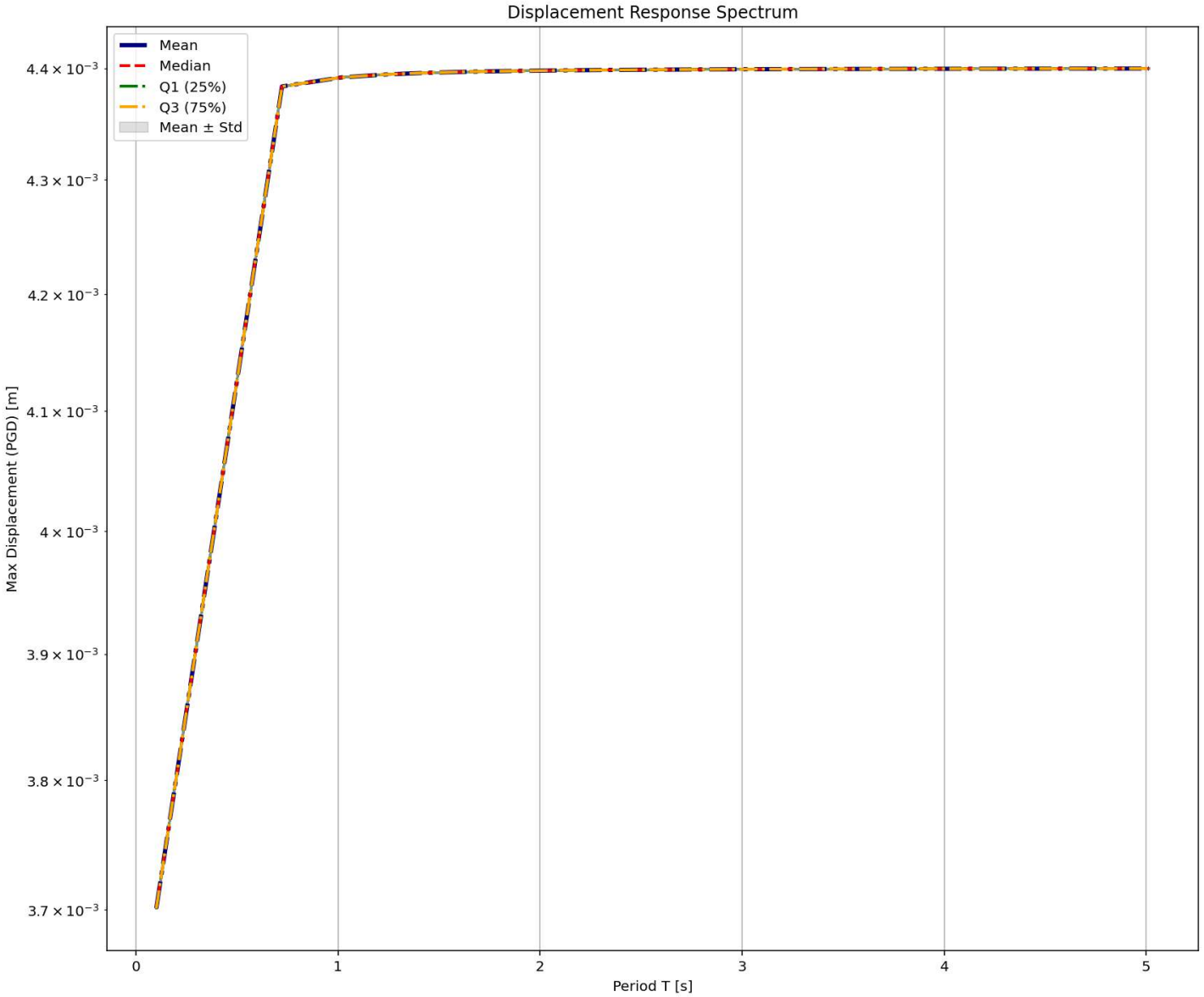
25 %

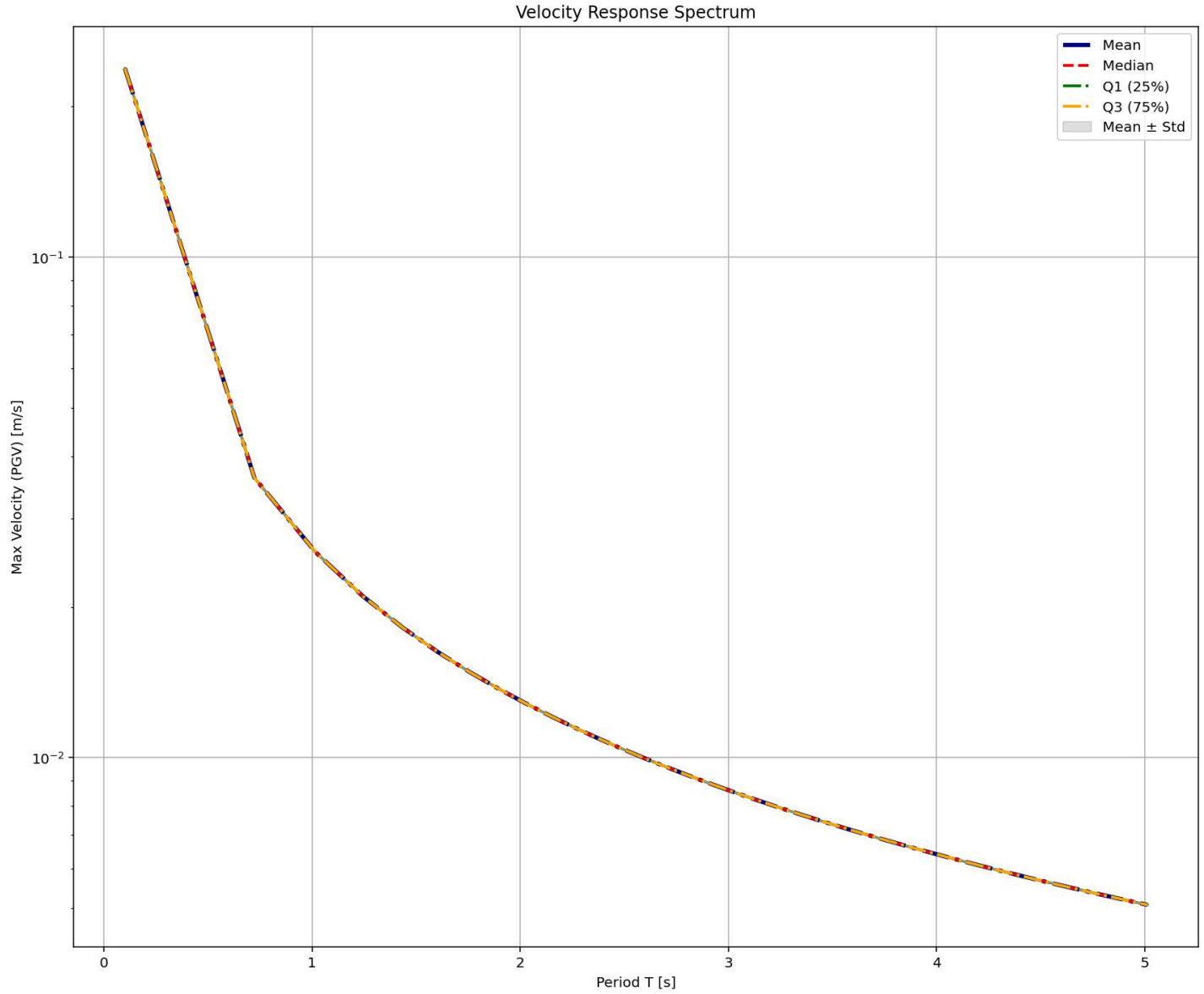


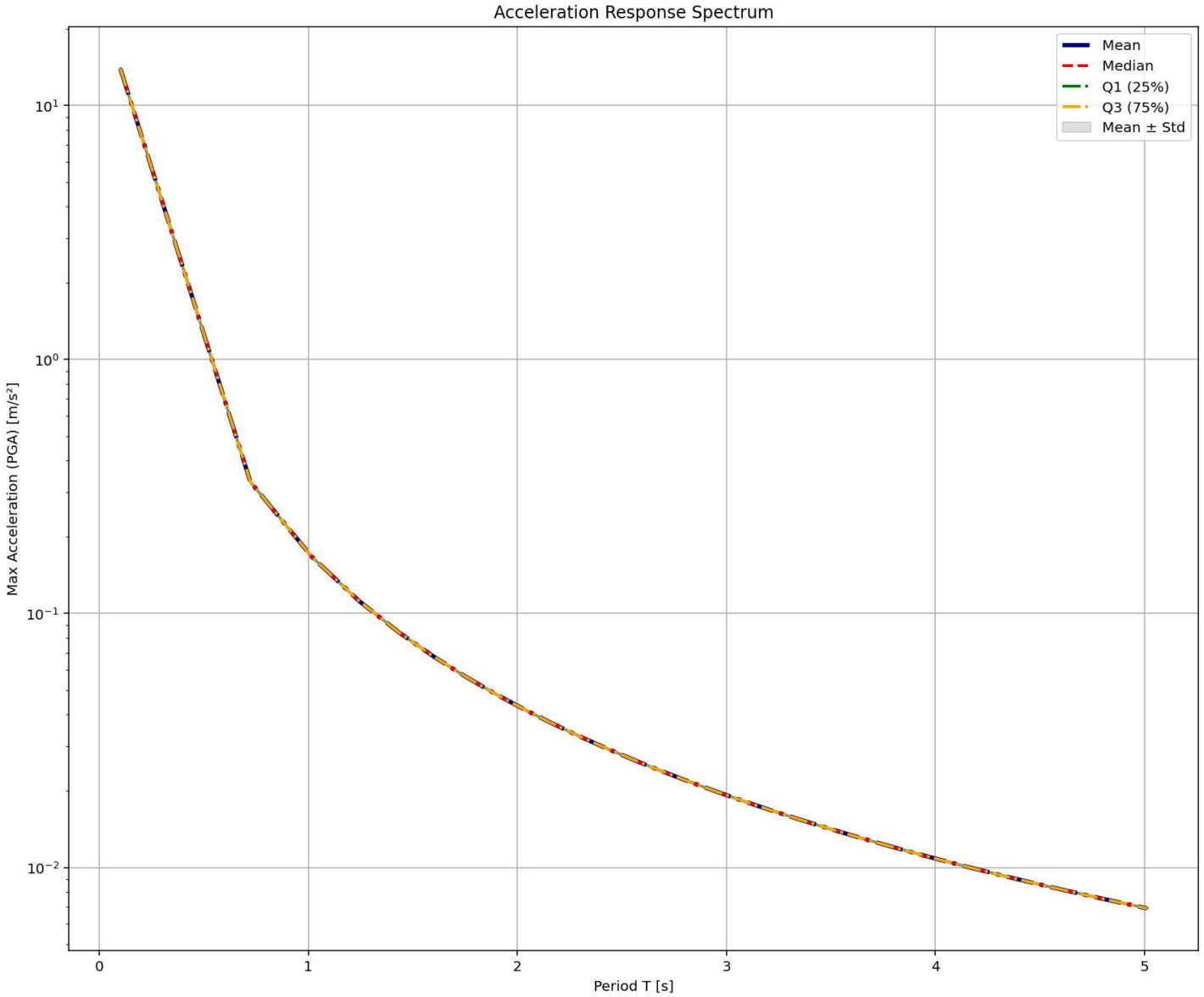


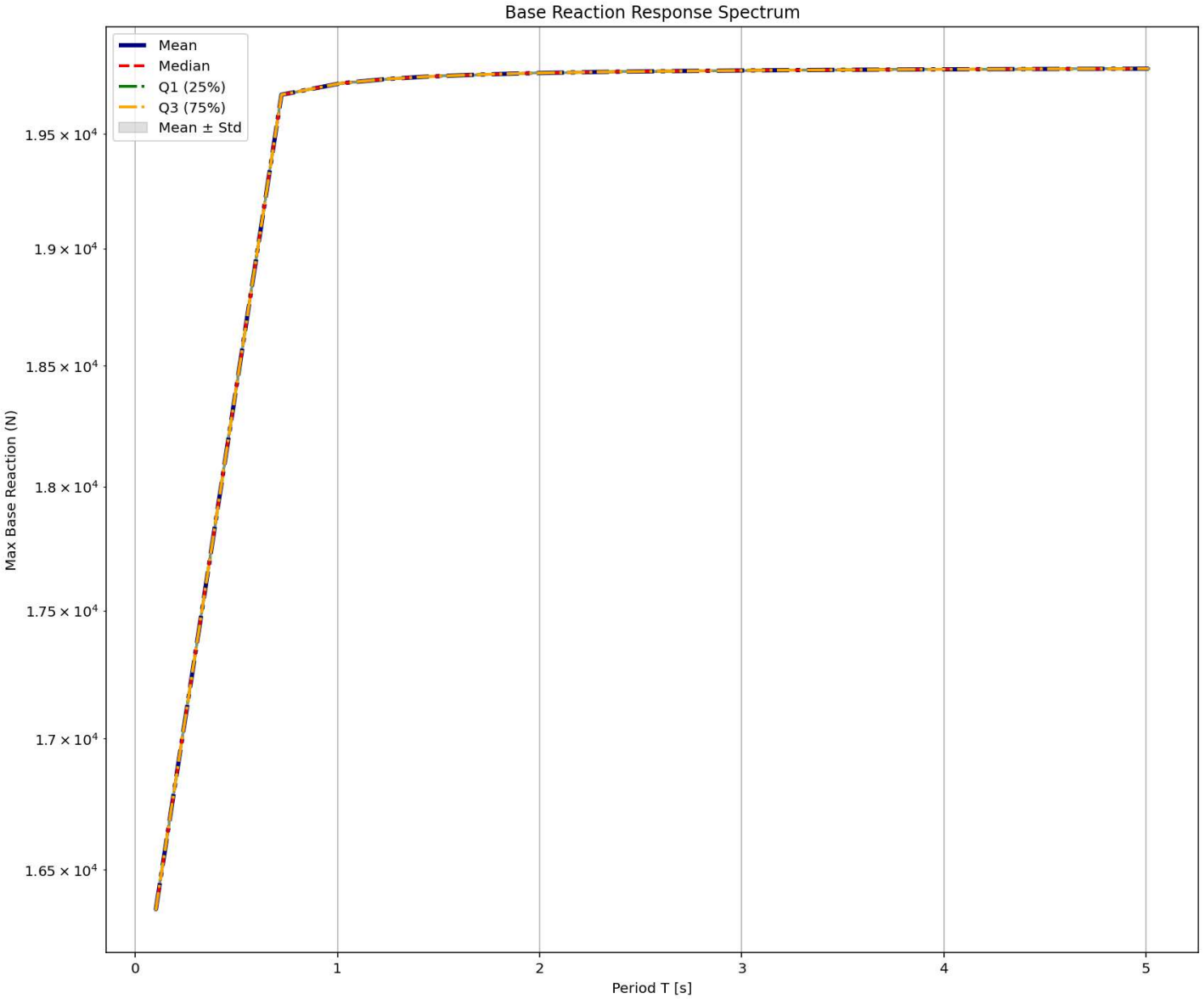
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

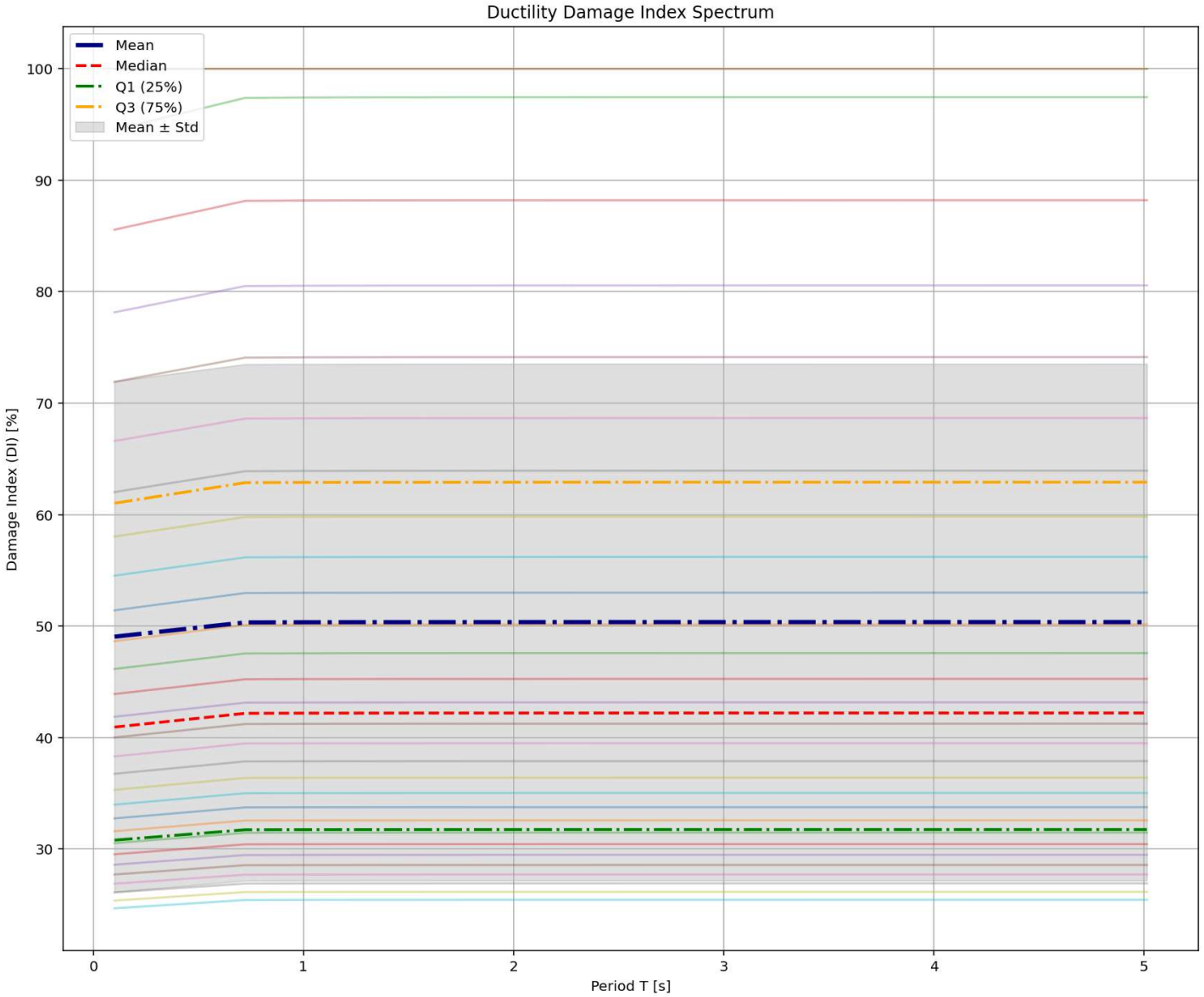
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 7, Col 108 UTF-8 CRLF RW Mem 39%

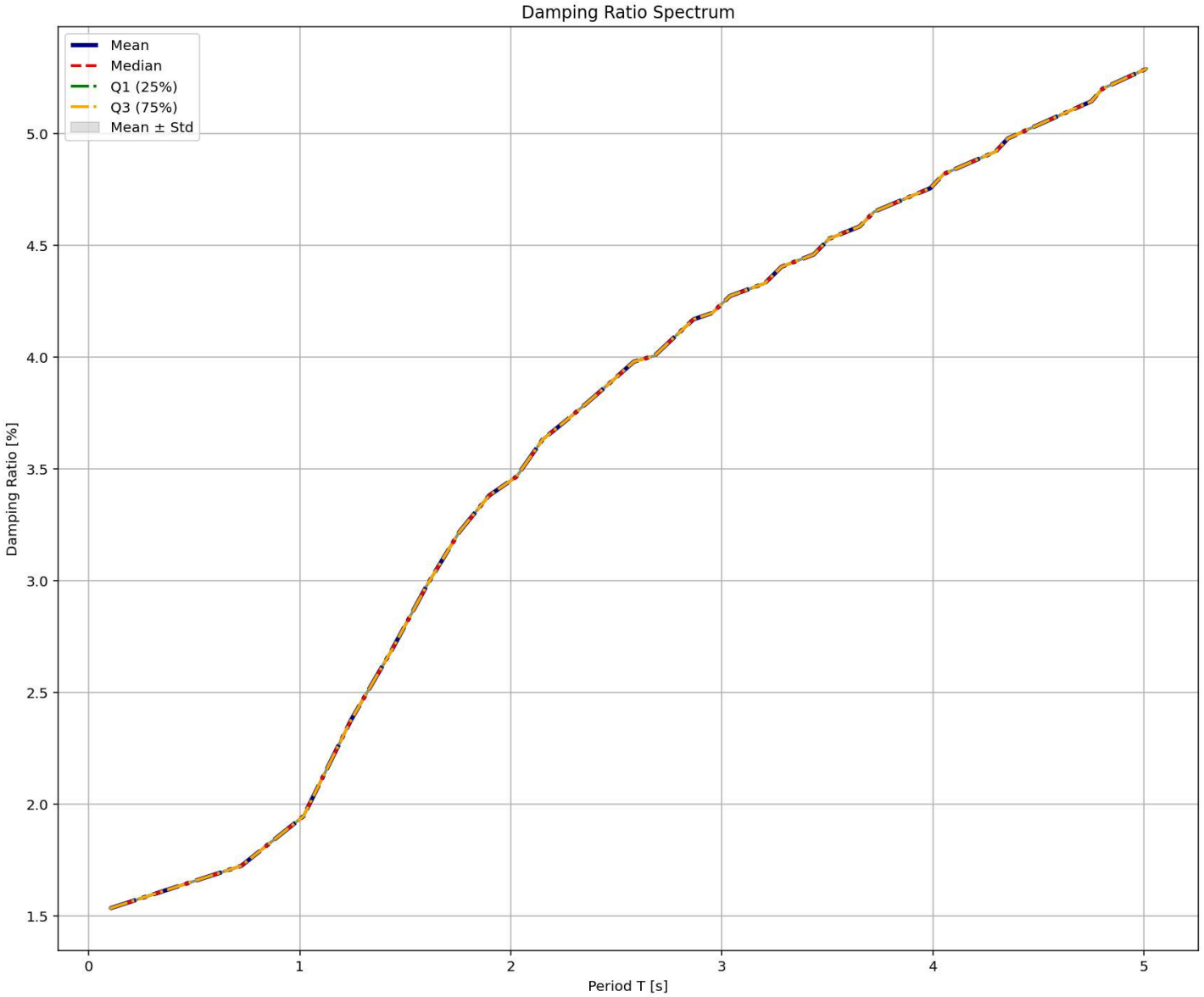

Displacement Response Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Max Displacement (PGD) [m]
4.4 × 10⁻³
4.3 × 10⁻³
4.2 × 10⁻³
4.1 × 10⁻³
4 × 10⁻³
3.9 × 10⁻³
3.8 × 10⁻³
3.7 × 10⁻³
0
1
2
3
4
5
Period T [s]

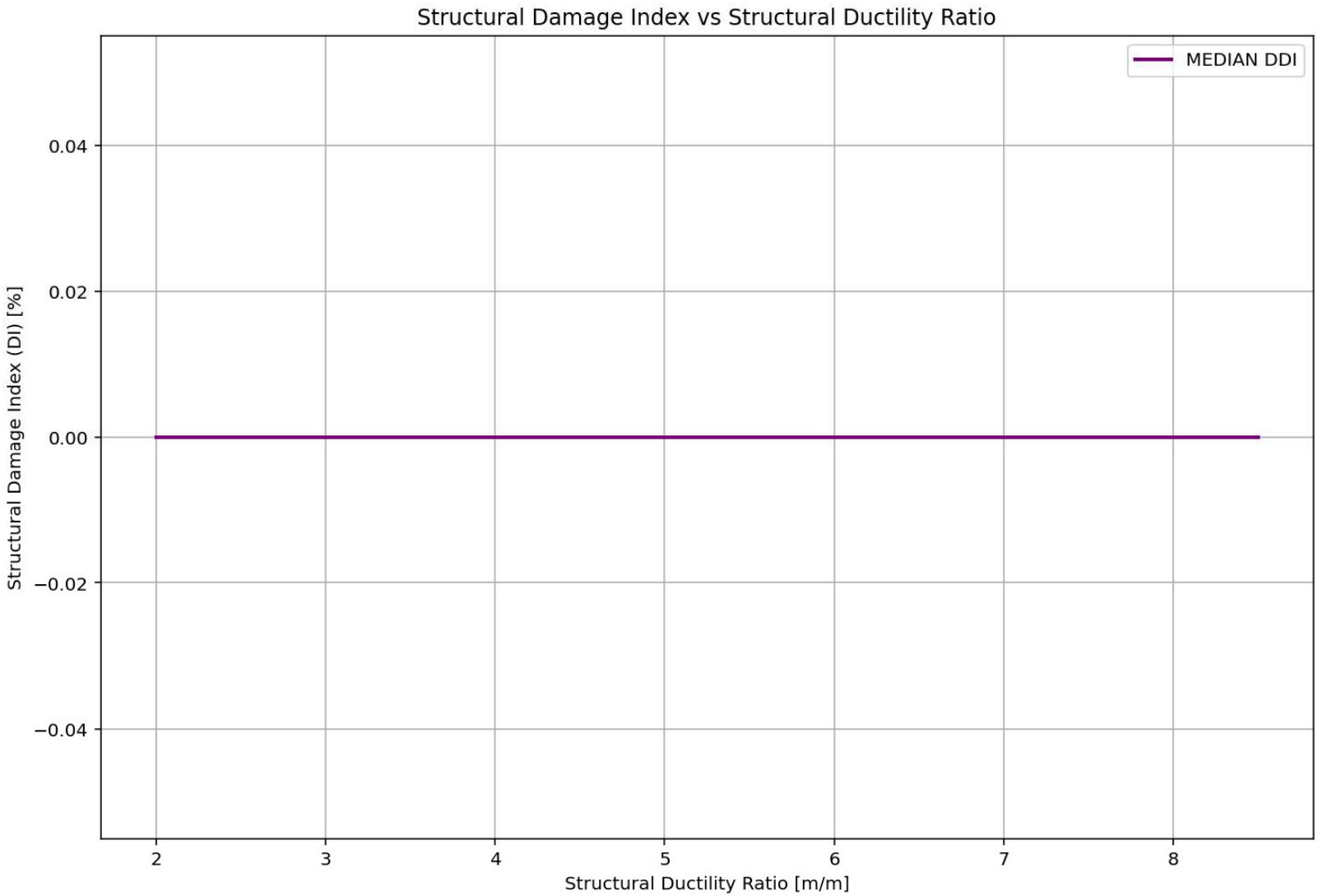

Velocity Response Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Max Velocity (PGV) [m/s]
10^{-1}
10^{-2}
0
1
2
3
4
5
Period T [s]

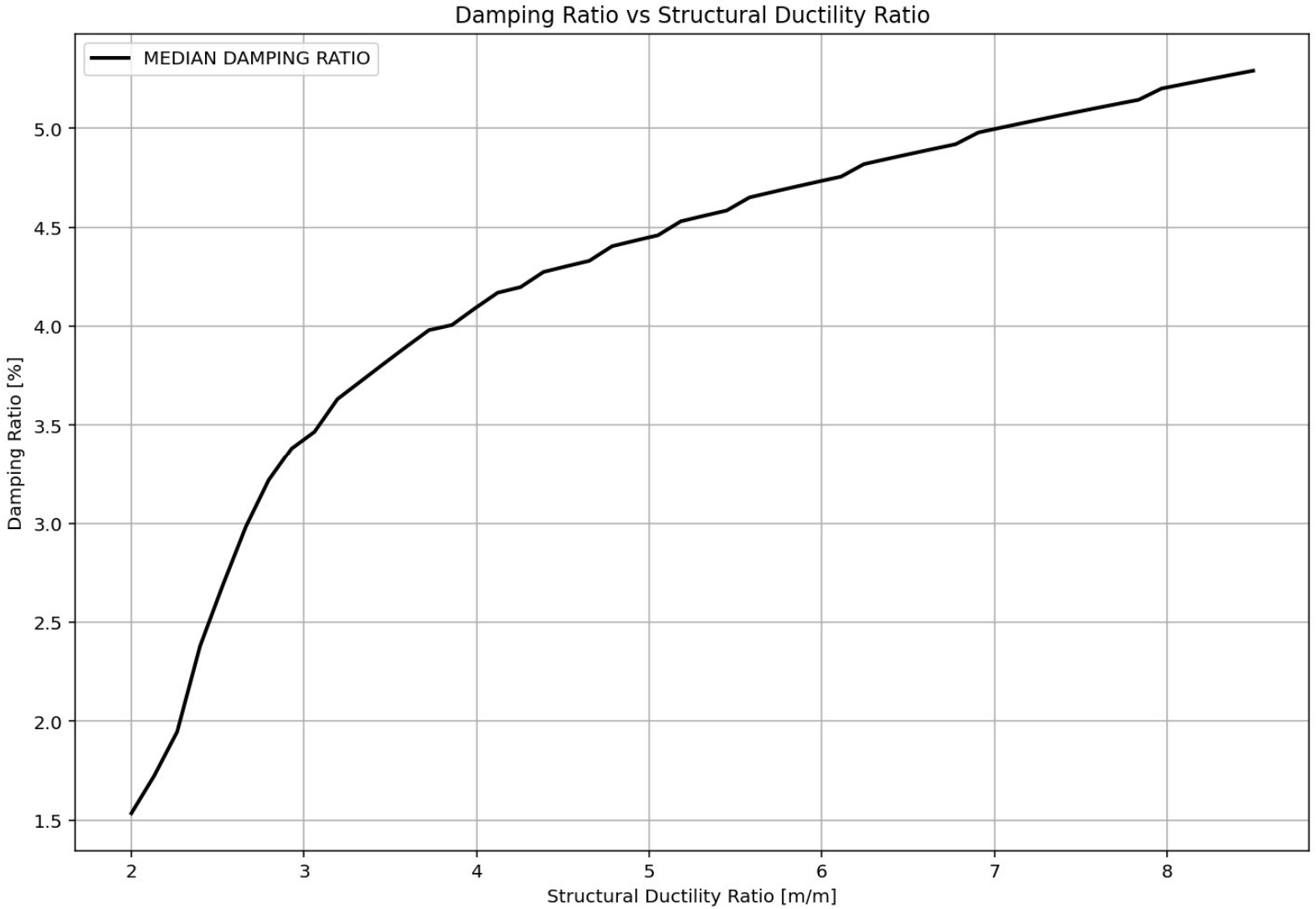

Acceleration Response Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Max Acceleration (PGA) [m/s²]
10^{1}
10^{0}
10^{-1}
10^{-2}
0
1
2
3
4
5
Period T [s]

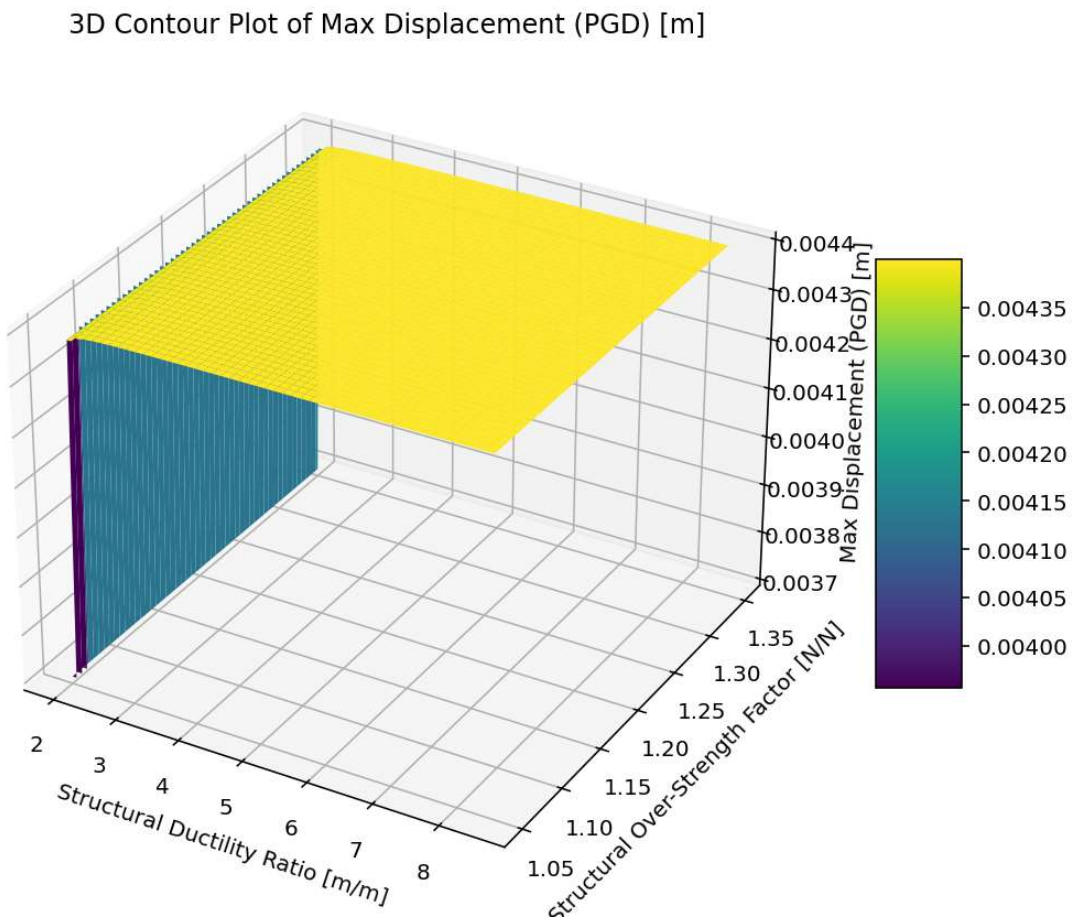

Base Reaction Response Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Max Base Reaction (N)
1.95 × 10⁴
1.9 × 10⁴
1.85 × 10⁴
1.8 × 10⁴
1.75 × 10⁴
1.7 × 10⁴
1.65 × 10⁴
0
1
2
3
4
5
Period T [s]

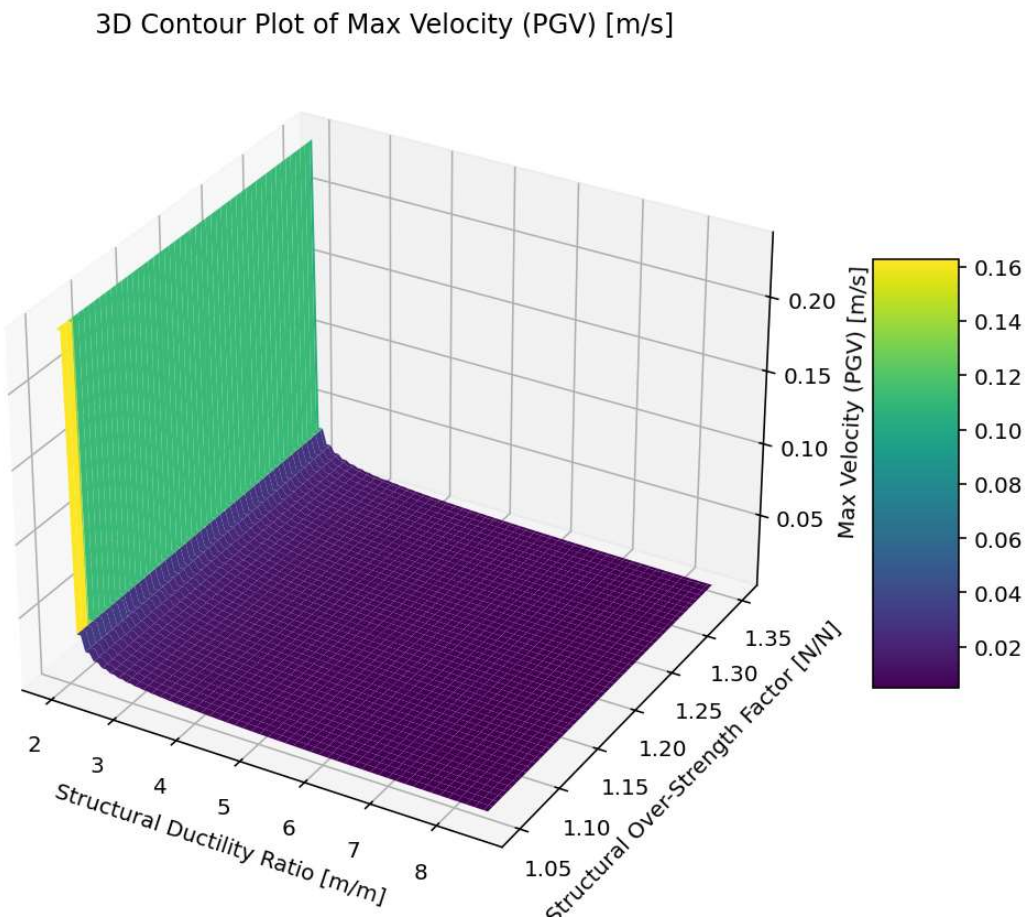

Ductility Damage Index Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Damage Index (DI) [%]
100
90
80
70
60
50
40
30
0
1
2
3
4
5
Period T [s]

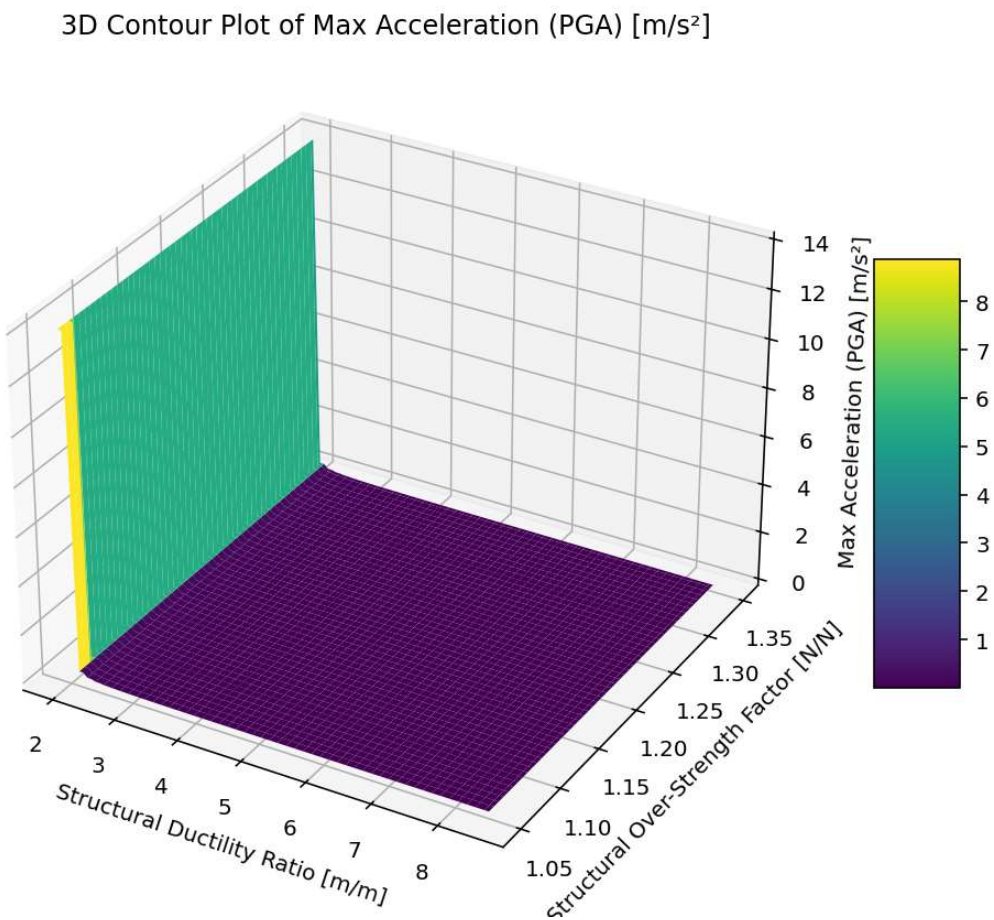

Damping Ratio Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Damping Ratio [%]
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
0
1
2
3
4
5
Period T [s]

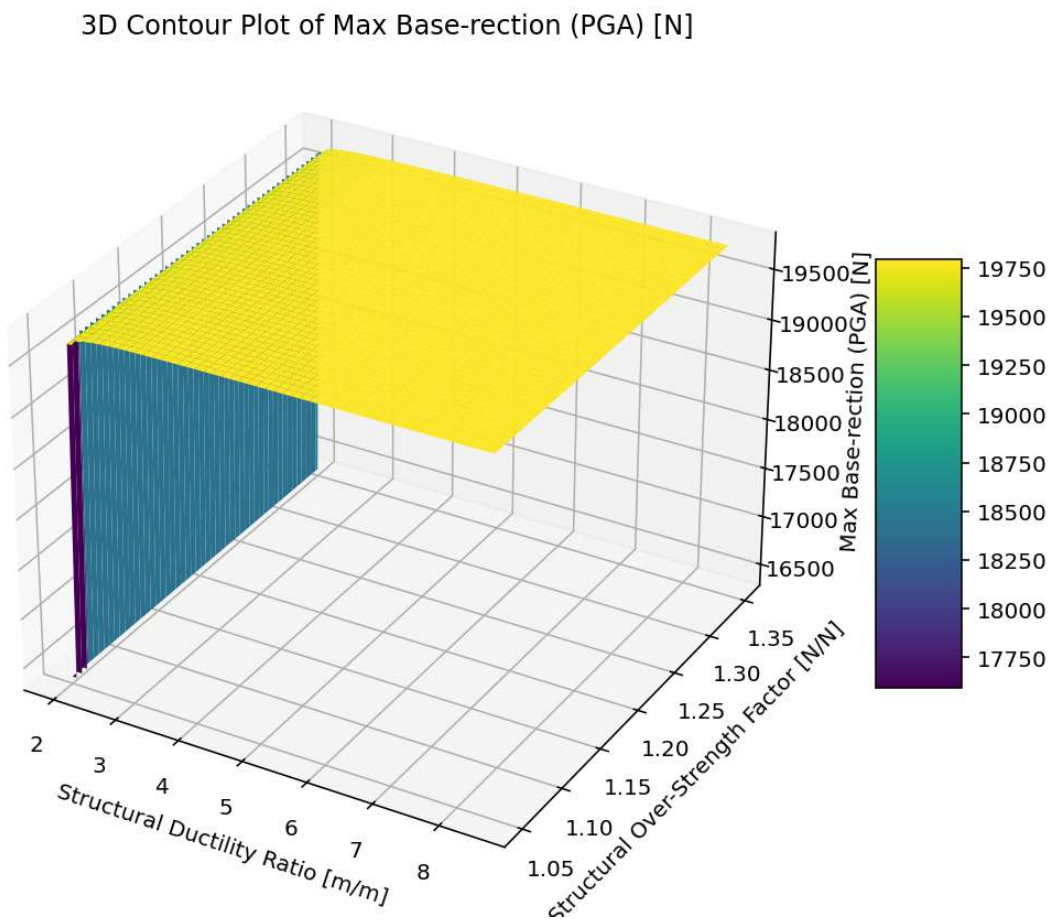

Structural Damage Index vs Structural Ductility Ratio
MEDIAN DDI
0.04
0.02
0.00
−0.02
−0.04
Structural Damage Index (DI) [%]
2
3
4
5
6
7
8
Structural Ductility Ratio [m/m]

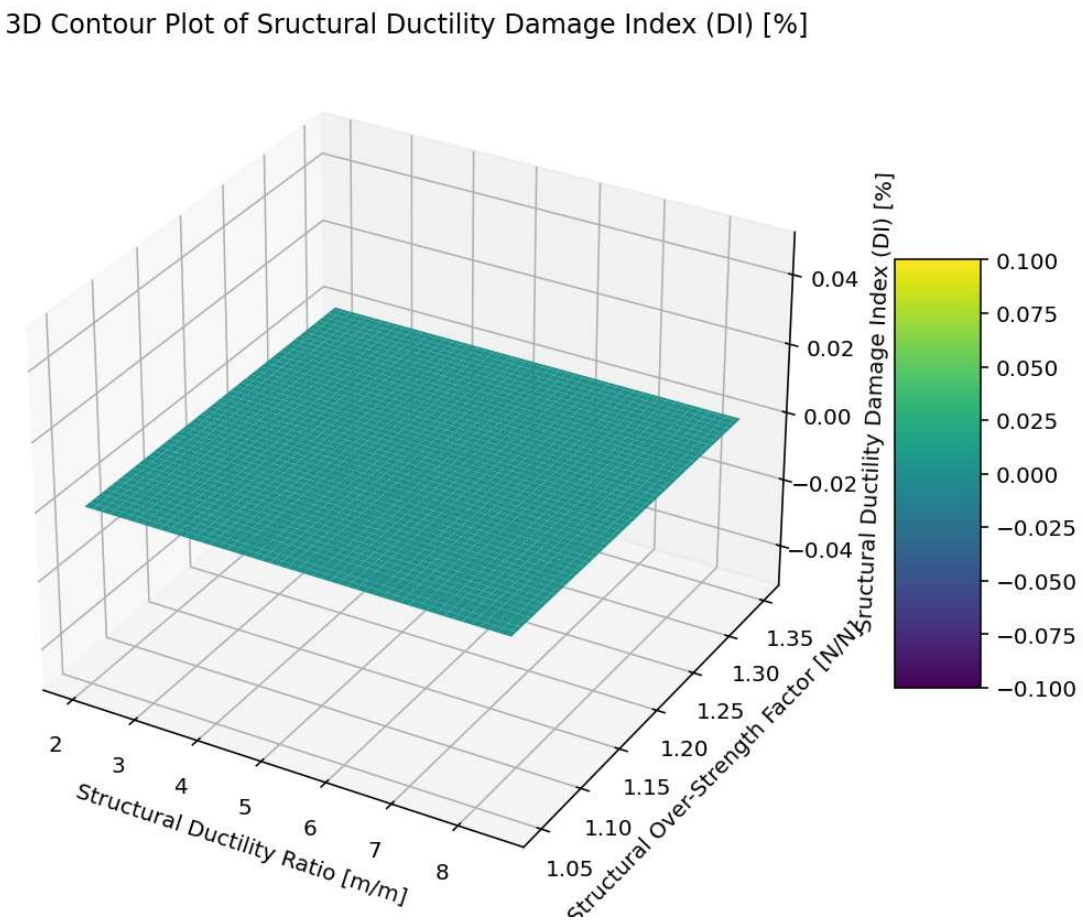

Damping Ratio vs Structural Ductility Ratio
MEDIAN DAMPING RATIO
Damping Ratio [%]
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
2
3
4
5
6
7
8
Structural Ductility Ratio [m/m]

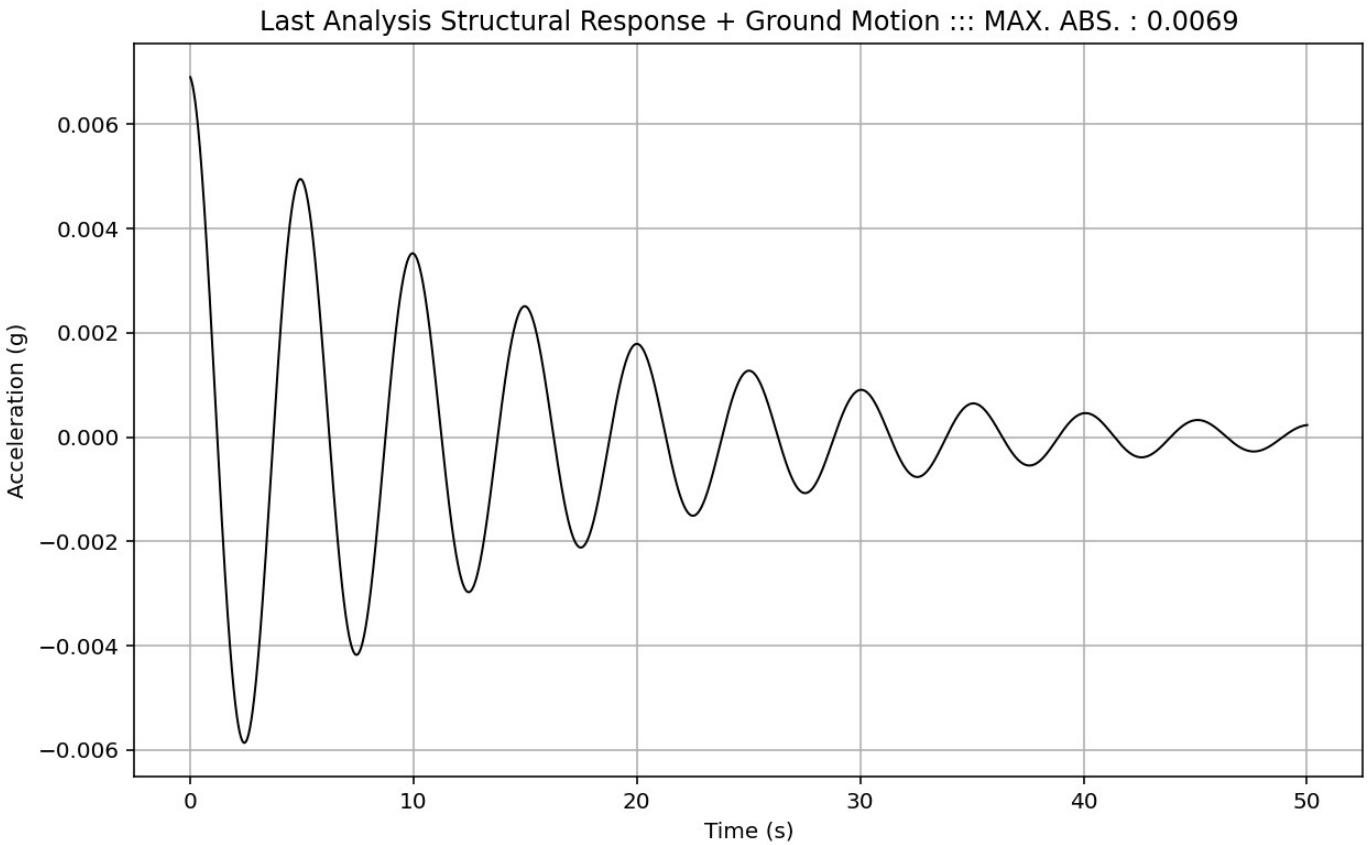

3D Contour Plot of Max Displacement (PGD) [m]
Max Displacement (PGD) [m]
0.0044
0.0043
0.0042
0.0041
0.0040
0.0039
0.0038
0.0037
0.00435
0.00430
0.00425
0.00420
0.00415
0.00410
0.00405
0.00400
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Structural Over-Strength Factor [N/N]
1.35
1.30
1.25
1.20
1.15
1.10
1.05

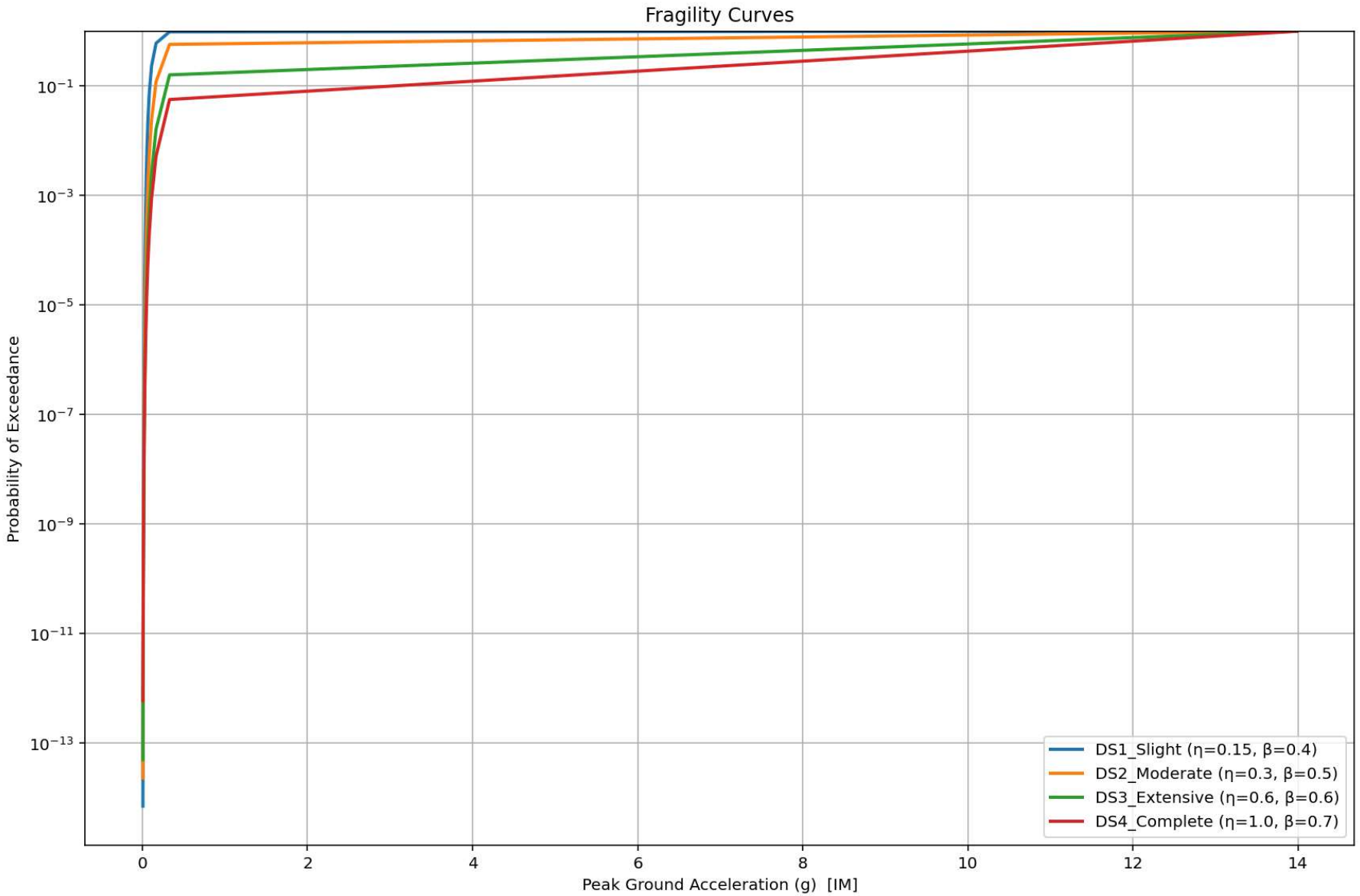

3D Contour Plot of Max Velocity (PGV) [m/s]
Max Velocity (PGV) [m/s]
0.20
0.15
0.10
0.05
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
2
3
4
5
6
7
8
Structural Ductility Ratio [m/m]
1.35
1.30
1.25
1.20
1.15
1.10
1.05
Structural Over-Strength Factor [N/N]

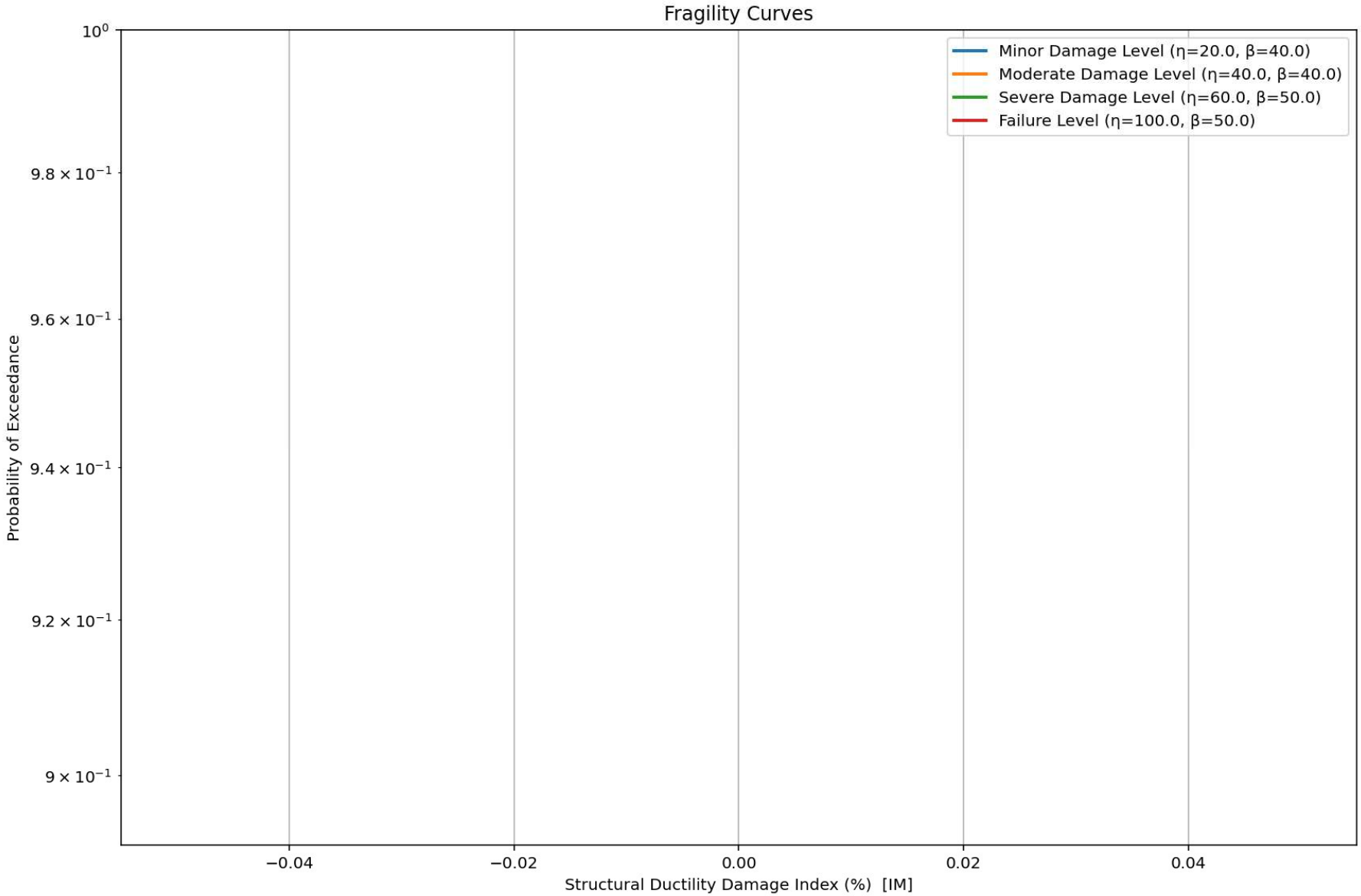

3D Contour Plot of Max Acceleration (PGA) [m/s²]
Structural Ductility Ratio [m/m]
Structural Over-Strength Factor [N/N]
Max Acceleration (PGA) [m/s²]
2
3
4
5
6
7
8
1.05
1.10
1.15
1.20
1.25
1.30
1.35
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
8

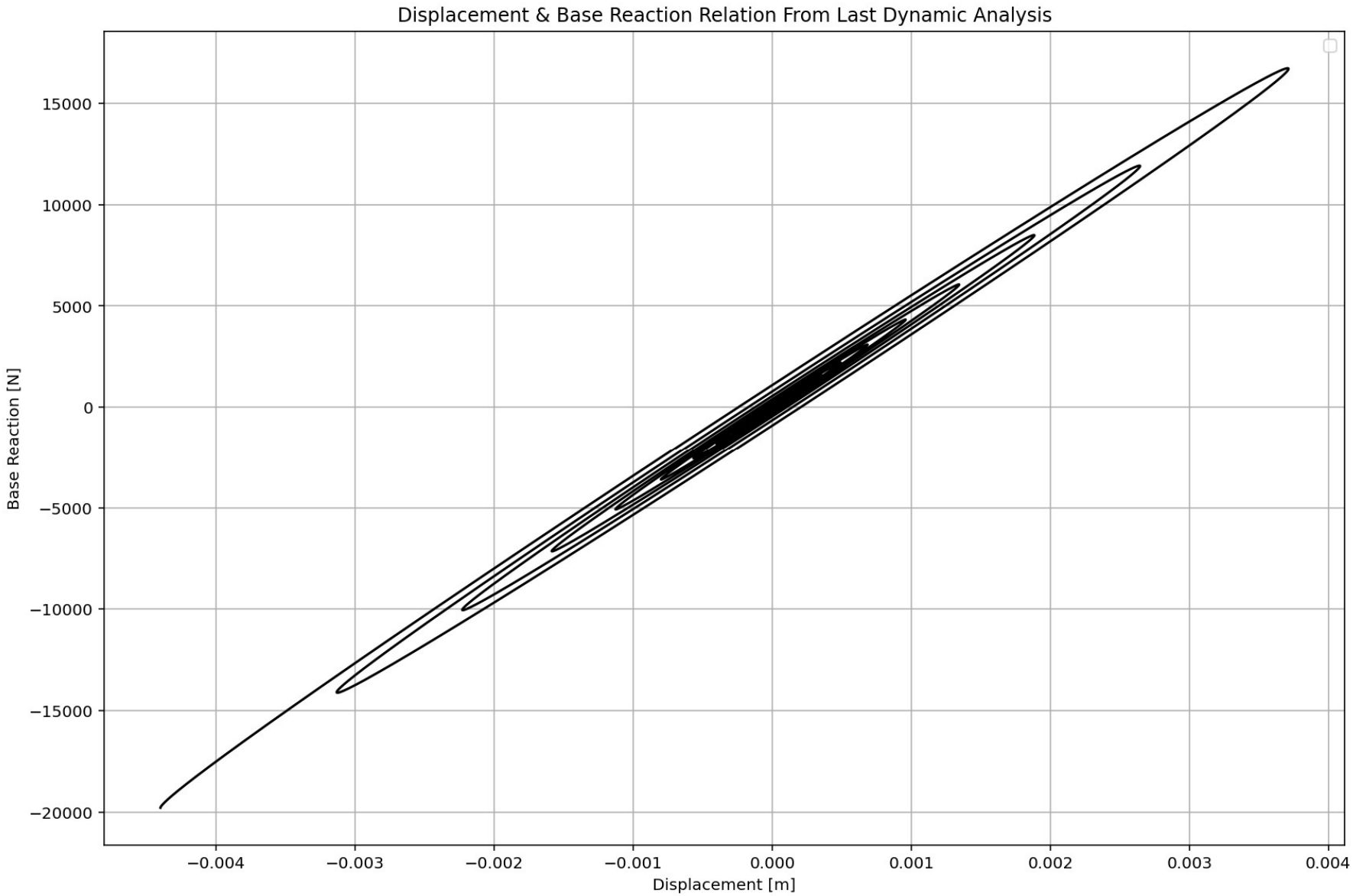

3D Contour Plot of Max Base-rection (PGA) [N]
Max Base-rection (PGA) [N]
19500
19000
18500
18000
17500
17000
16500
19750
19500
19250
19000
18750
18500
18250
18000
17750
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Structural Over-Strength Factor [N/N]
1.35
1.30
1.25
1.20
1.15
1.10
1.05

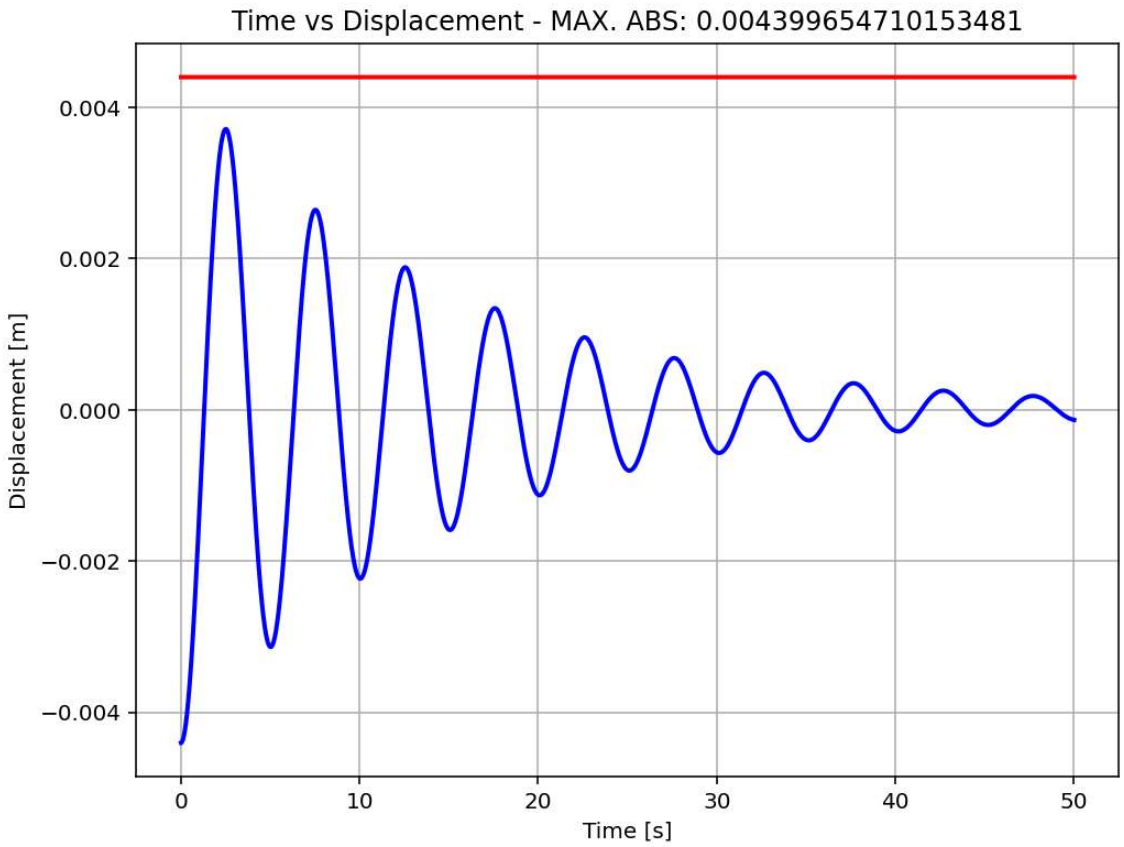

3D Contour Plot of Sructural Ductility Damage Index (DI) [%]
Structural Ductility Damage Index (DI) [%]
0.04
0.02
0.00
−0.02
−0.04
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100
Structural Over-Strength Factor [N/N]
1.35
1.30
1.25
1.20
1.15
1.10
1.05
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8

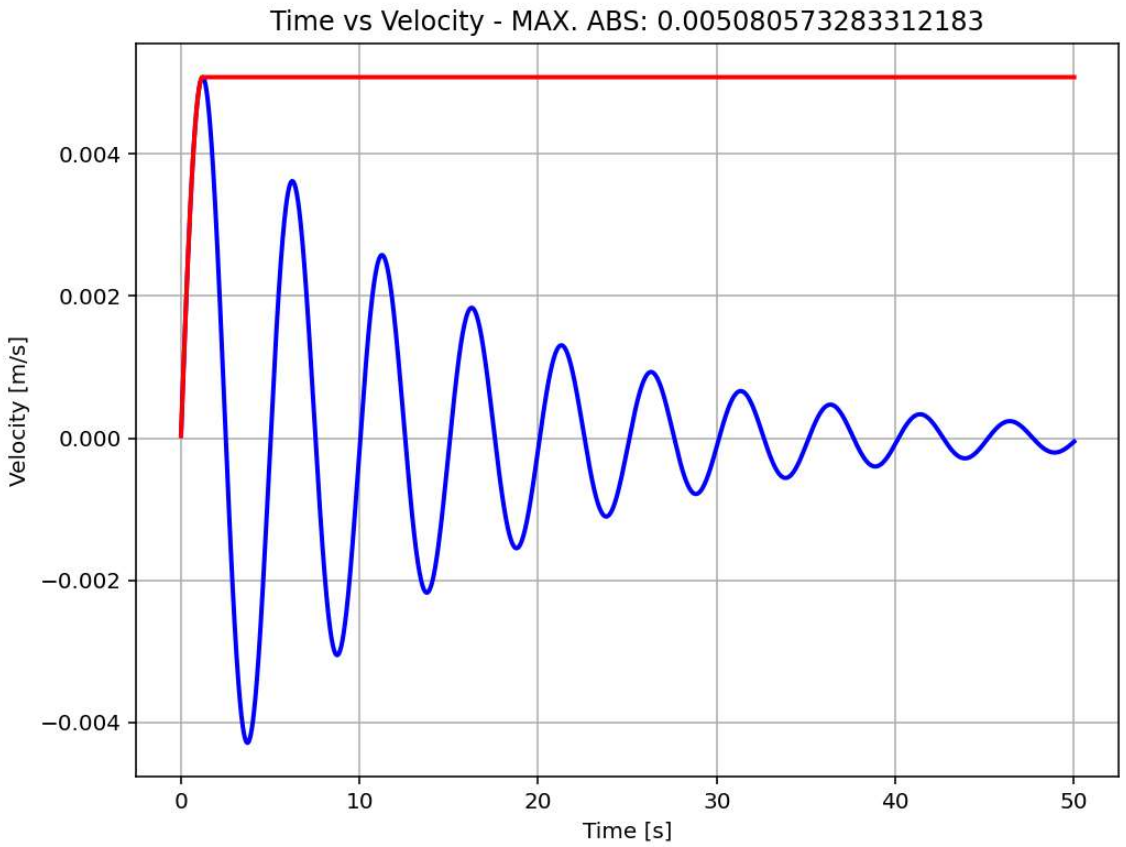

Last Analysis Structural Response + Ground Motion ::: MAX. ABS. : 0.0069
Acceleration (g)
0.006
0.004
0.002
0.000
−0.002
−0.004
−0.006
0
10
20
30
40
50
Time (s)

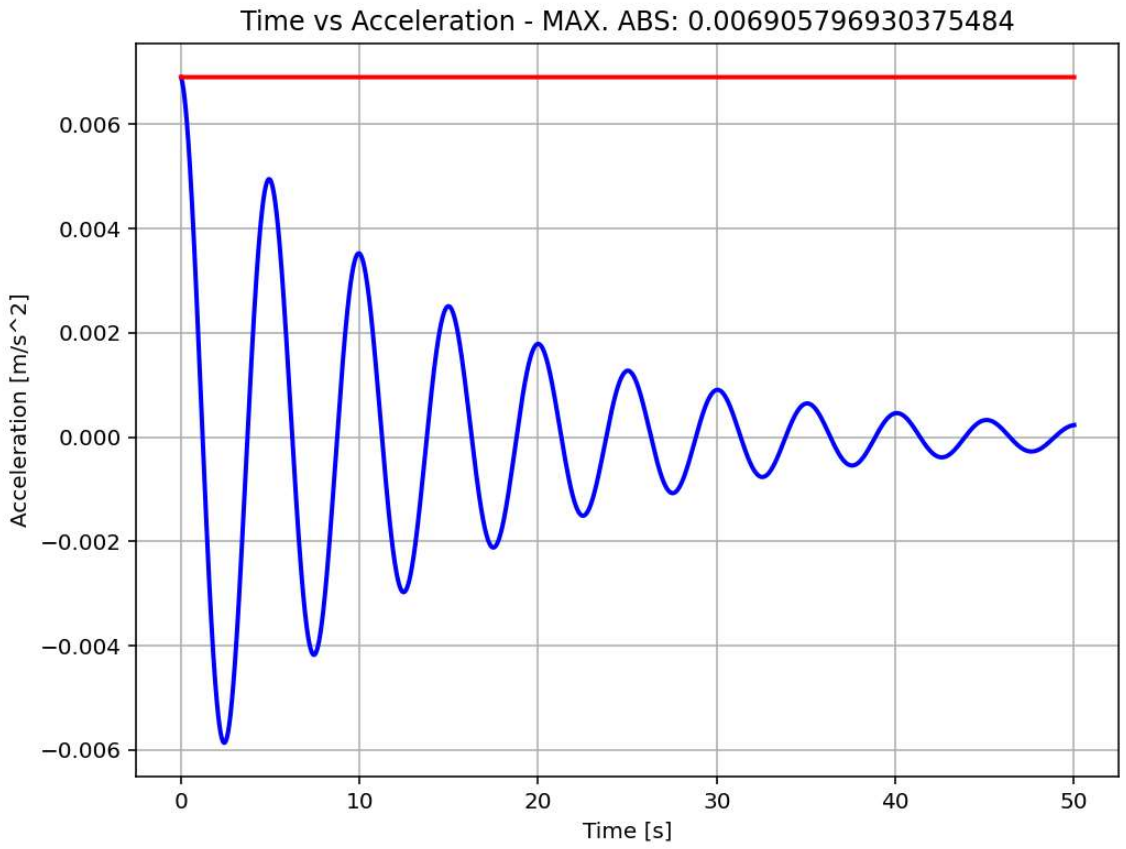

Fragility Curves
Probability of Exceedance
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^{-9}
10^{-11}
10^{-13}
0
2
4
6
8
10
12
14
Peak Ground Acceleration (g) [IM]
DS1_Slight (η=0.15, β=0.4)
DS2_Moderate (η=0.3, β=0.5)
DS3_Extensive (η=0.6, β=0.6)
DS4_Complete (η=1.0, β=0.7)

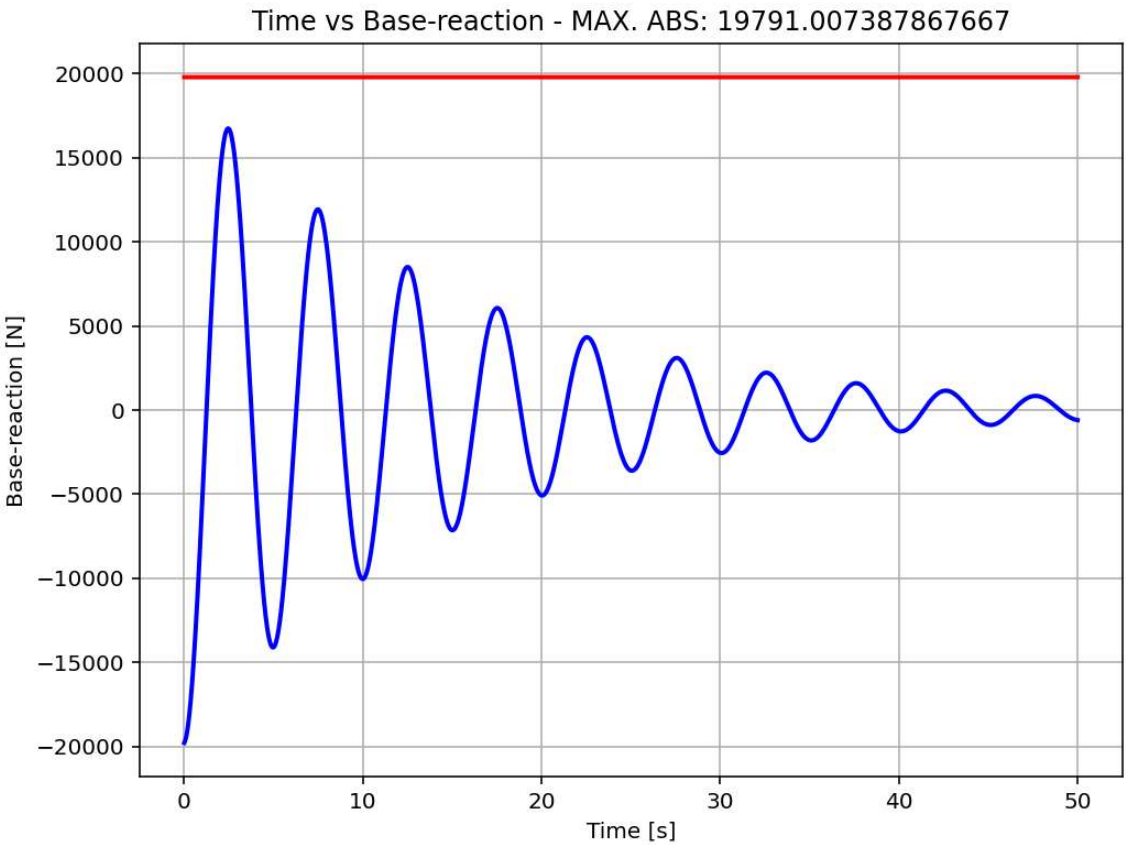

Fragility Curves
Minor Damage Level (η=20.0, β=40.0)
Moderate Damage Level (η=40.0, β=40.0)
Severe Damage Level (η=60.0, β=50.0)
Failure Level (η=100.0, β=50.0)
Probability of Exceedance
10^{0}
9.8×10^{-1}
9.6×10^{-1}
9.4×10^{-1}
9.2×10^{-1}
9×10^{-1}
−0.04
−0.02
0.00
0.02
0.04
Structural Ductility Damage Index (%) [IM]

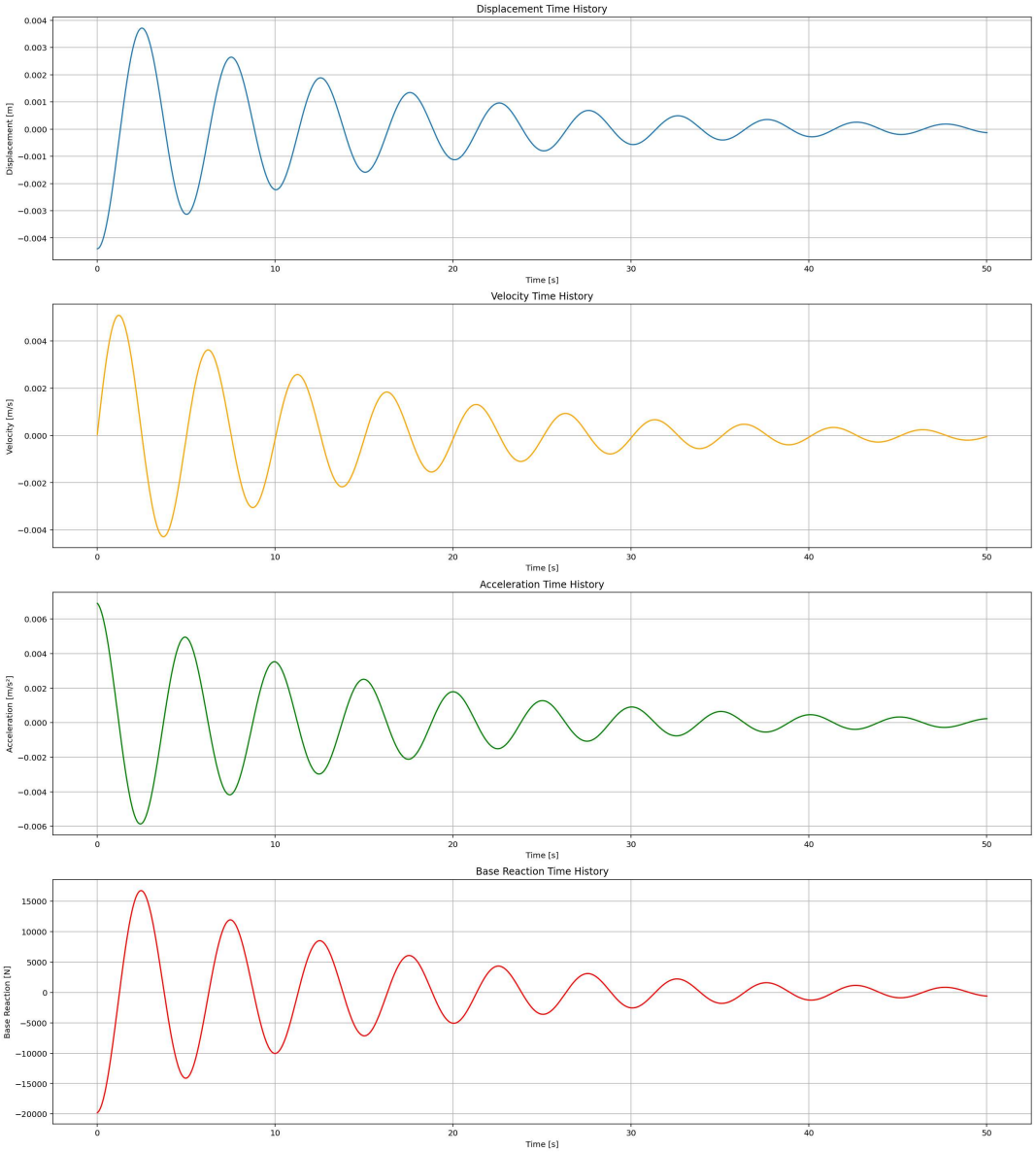

Displacement & Base Reaction Relation From Last Dynamic Analysis
Base Reaction [N]
15000
10000
5000
0
−5000
−10000
−15000
−20000
−0.004
−0.003
−0.002
−0.001
0.000
0.001
0.002
0.003
0.004
Displacement [m]

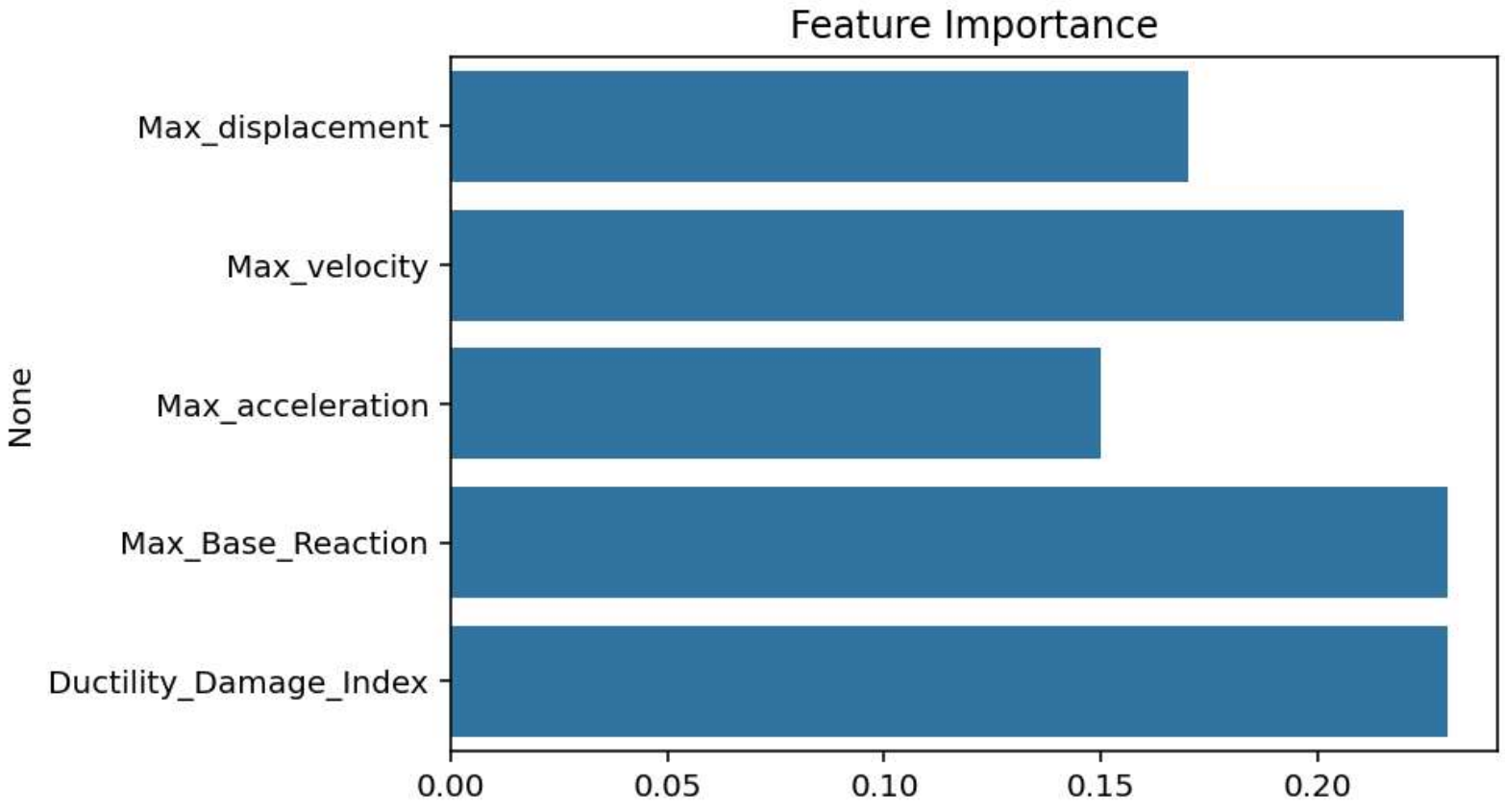

Time vs Displacement - MAX. ABS: 0.004399654710153481
0.004
0.002
0.000
−0.002
−0.004
Displacement [m]
0
10
20
30
40
50
Time [s]

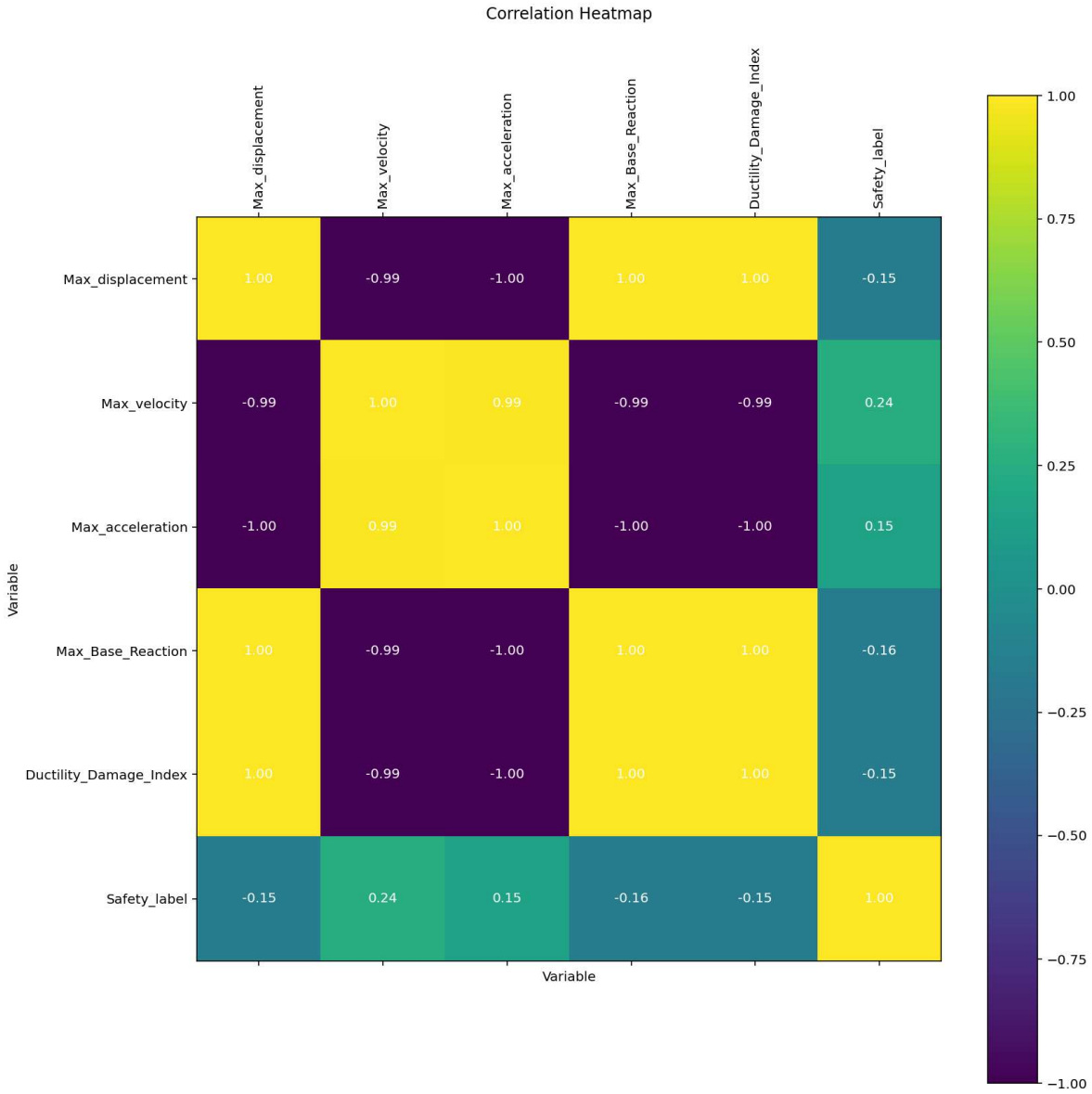

Time vs Velocity - MAX. ABS: 0.005080573283312183
Velocity [m/s]
0.004
0.002
0.000
−0.002
−0.004
0
10
20
30
40
50
Time [s]


Time vs Acceleration - MAX. ABS: 0.006905796930375484
Acceleration [m/s^2]
Time [s]
0.006
0.004
0.002
0.000
−0.002
−0.004
−0.006
0
10
20
30
40
50


Time vs Base-reaction - MAX. ABS: 19791.007387867667
Base-reaction [N]
Time [s]
20000
15000
10000
5000
0
−5000
−10000
−15000
−20000
0
10
20
30
40
50


Displacement Time History
Displacement [m]
Time [s]
Velocity Time History
Velocity [m/s]
Time [s]
Acceleration Time History
Acceleration [m/s²]
Time [s]
Base Reaction Time History
Base Reaction [N]
Time [s]


Feature Importance
Max_displacement
Max_velocity
Max_acceleration
Max_Base_Reaction
Ductility_Damage_Index
None
0.00
0.05
0.10
0.15
0.20


Correlation Heatmap
Max_displacement
Max_velocity
Max_acceleration
Max_Base_Reaction
Ductility_Damage_Index
Safety_label
Variable
Variable
1.00
-0.99
-1.00
1.00
1.00
-0.15
-0.99
1.00
0.99
-0.99
-0.99
0.24
-1.00
0.99
1.00
-1.00
-1.00
0.15
1.00
-0.99
-1.00
1.00
1.00
-0.16
1.00
-0.99
-1.00
1.00
1.00
-0.15
-0.15
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-0.16
-0.15
1.00
1.00
0.75
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0.25
0.00
−0.25
−0.50
−0.75
−1.00