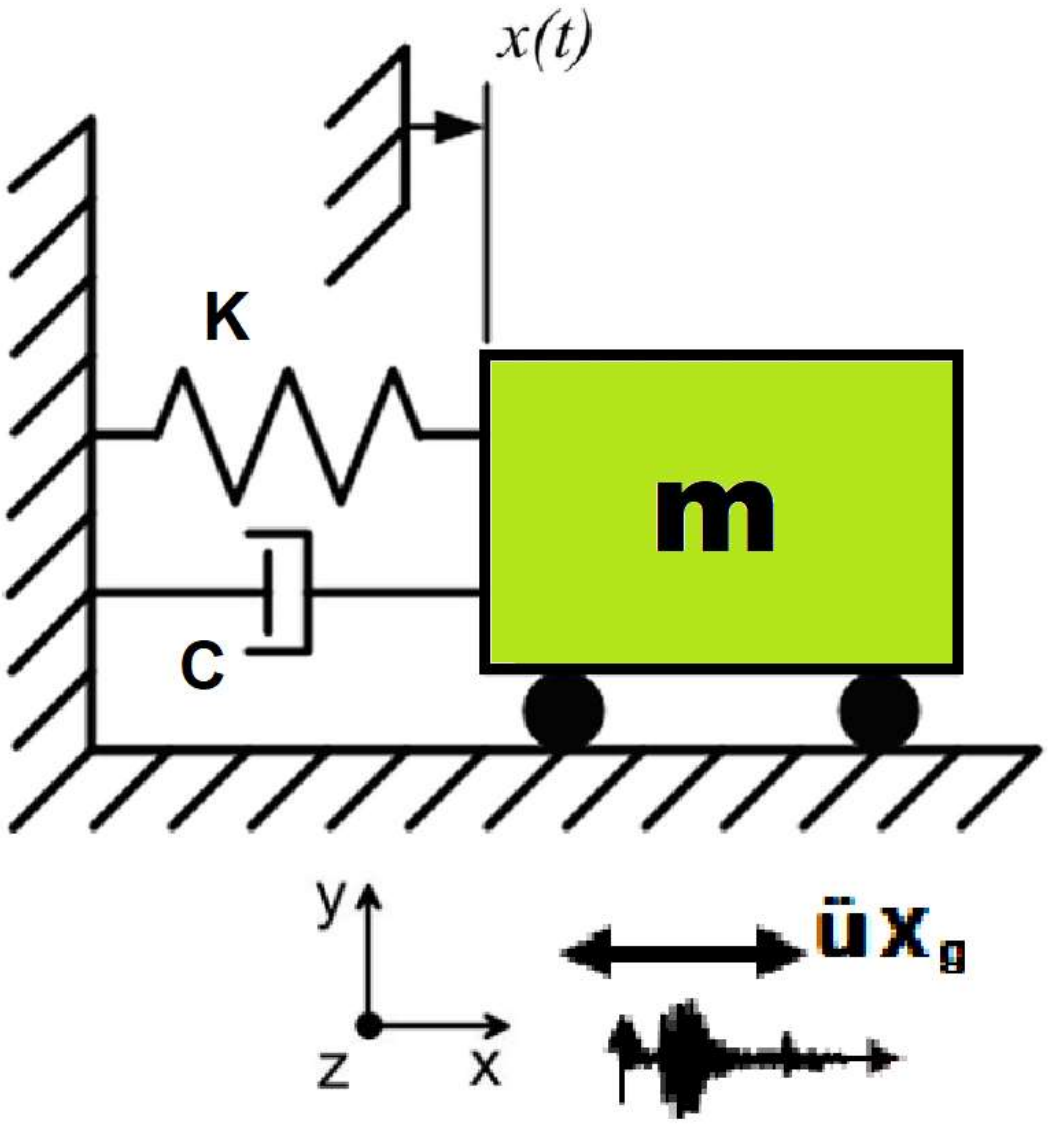
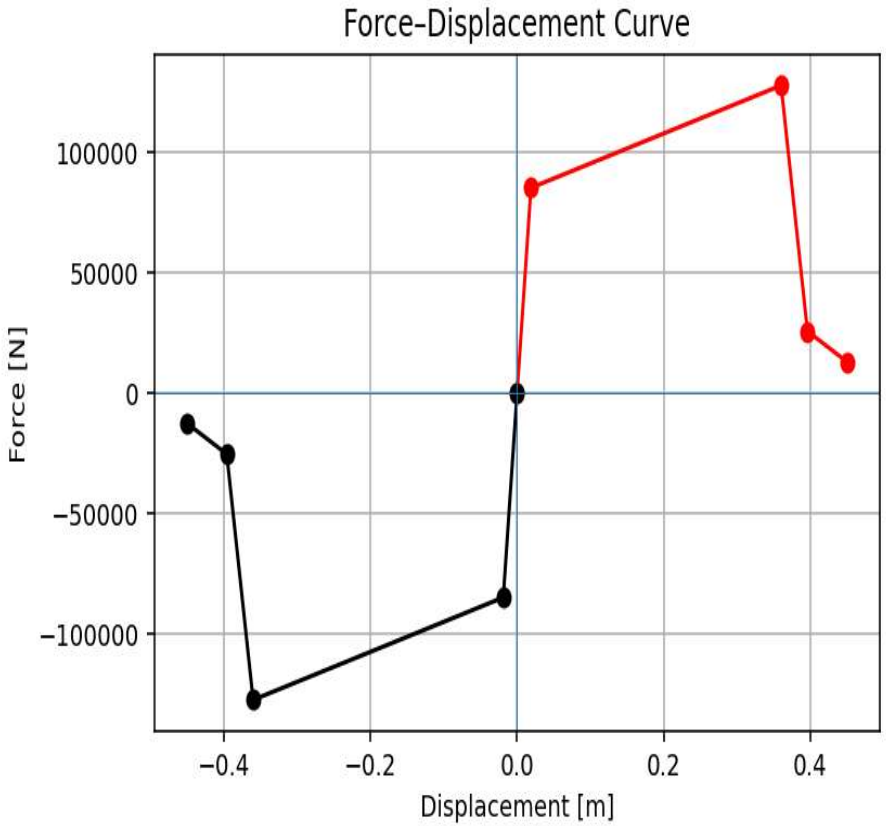
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

A NONLINEAR DYNAMIC ANALYSIS USING 20 GROUND MOTIONS: CALCULATION AND PLOTTING OF RESPONSE SPECTRA AND A DUCTILITY-BASED DAMAGE INDEX USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


x(t)
K
m
C
y
z
x
ü x g


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

Spyder (Python 3.12)

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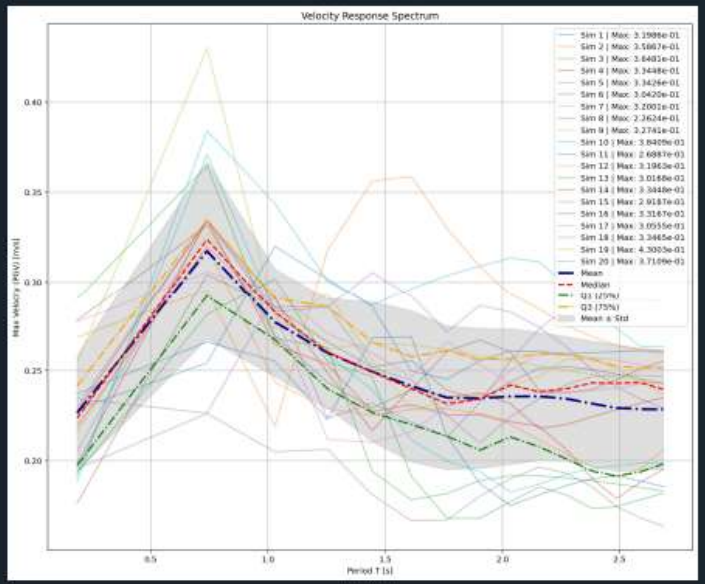
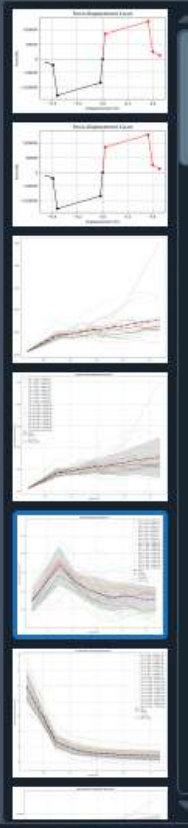
C:\Users\Dell\Desktop\OPENSEES_FILES\SDOF_RESPONS...ISMIC\INELASTIC_RESPONSE_SPECTRUM_SEISMIC_SDOF.py

INELASTIC_RESPONSE...UM_SEISMIC_SDOF.py

```
1  ##########################################################################################
2  #                    >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
3  #       DYNAMIC ANALYSIS AND PERFORMANCE ASSESSMENT OF INELASTIC SDOF SYSTEMS USING RESPONS
4  #                                        SPECTRUM METHODS IN OPENSEES
5  #------------------------------------------------------------------------------------------
6  #                           THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
7  #                                    EMAIL: salar.d.ghashghaei@gmail.com
8  ##########################################################################################
9
10 """
11 Objective:
12 The study evaluates the dynamic response of a single-degree-of-freedom (SDOF) inelastic sys
13 comparing two hysteretic models for the restoring force:
14  - HYSTERETICSM (multi-linear / pinching / stiffness degradation including ultimate strain)
15
16 Model setup:
17  - SDOF properties: mass (m), initial stiffness (k), yield displacement (Dy), ultimate disp
18  - Hysteresis models: HYSTERETICSM (pinching, stiffness degradation, strength decay).
19  - Damping: Rayleigh (or equivalent viscous) damping specified by target damping ratio xi f
20
21 Dynamic response:
22  - Natural period T = 2*pi*sqrt(m/k) computed from linearized stiffness.
23  - Time-history integration produces displacement, velocity, acceleration and base reaction
24  - HYSTERETIC model shows faster decay of amplitude and larger energy dissipation due to pi
25
26 Force-displacement behavior:
27  - BILINEAR: symmetric hysteresis loops with stable post-yield stiffness; residual displace
28  - HYSTERETIC: pinched loops, reduced unloading/reloading stiffness, strength decay and lar
29
30 Stiffness and strength evolution:
31  - Effective lateral stiffness reduces during the excitation for both models but degrades f
32  - Strength deterioration (reduced peak restoring force) in HYSTERETIC leads to reduced re-
33
34 Damping estimation:
```

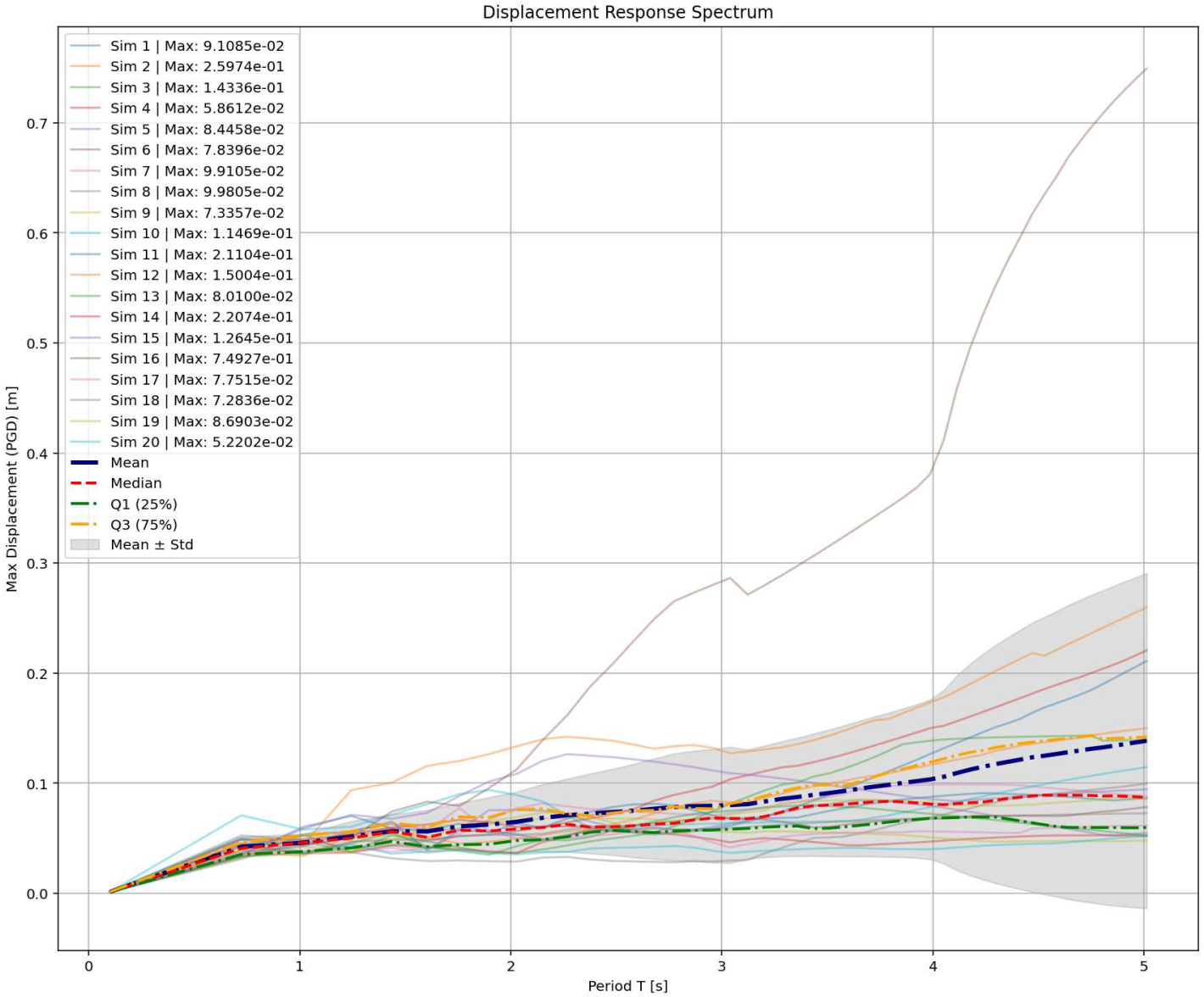
26 %

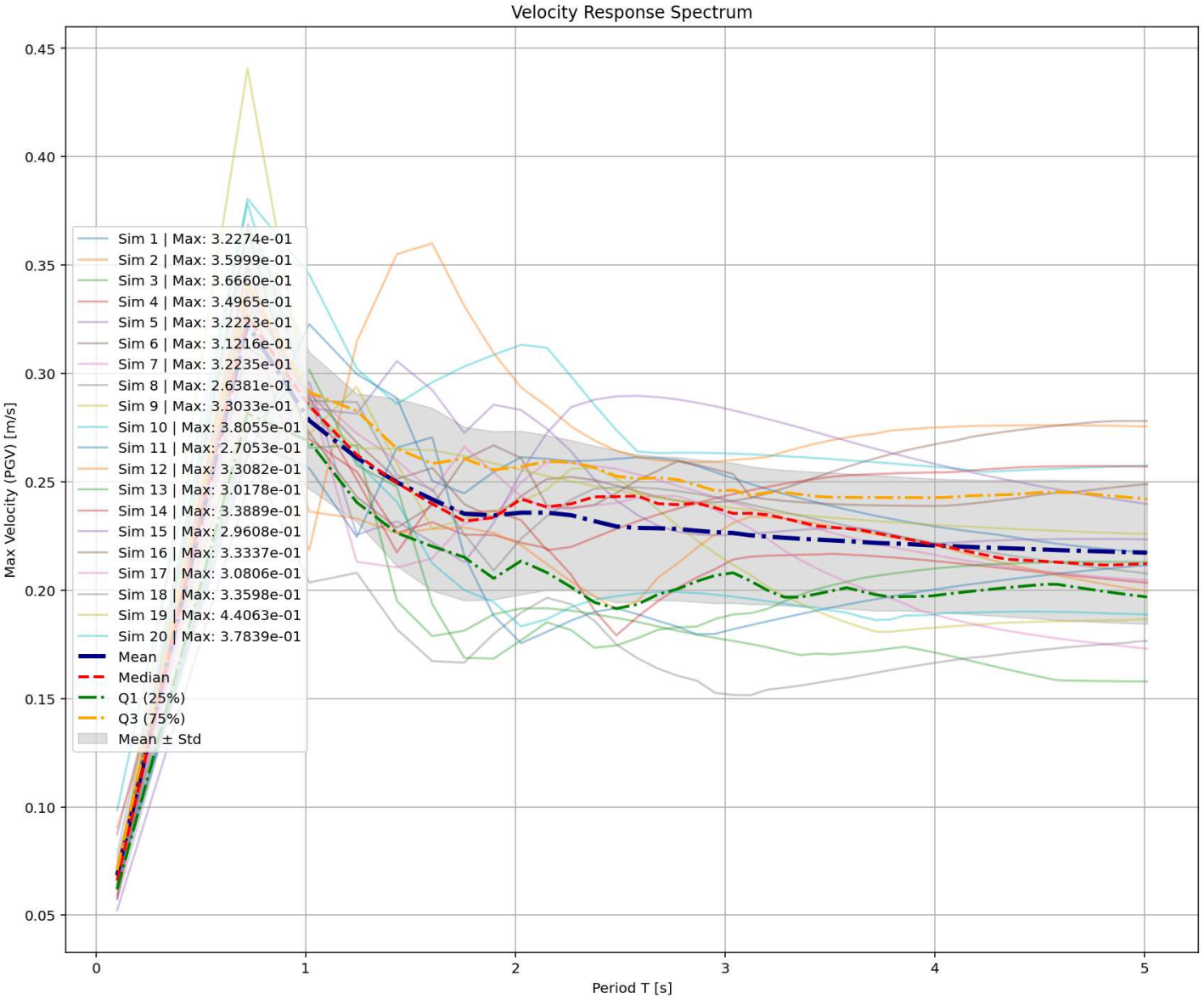


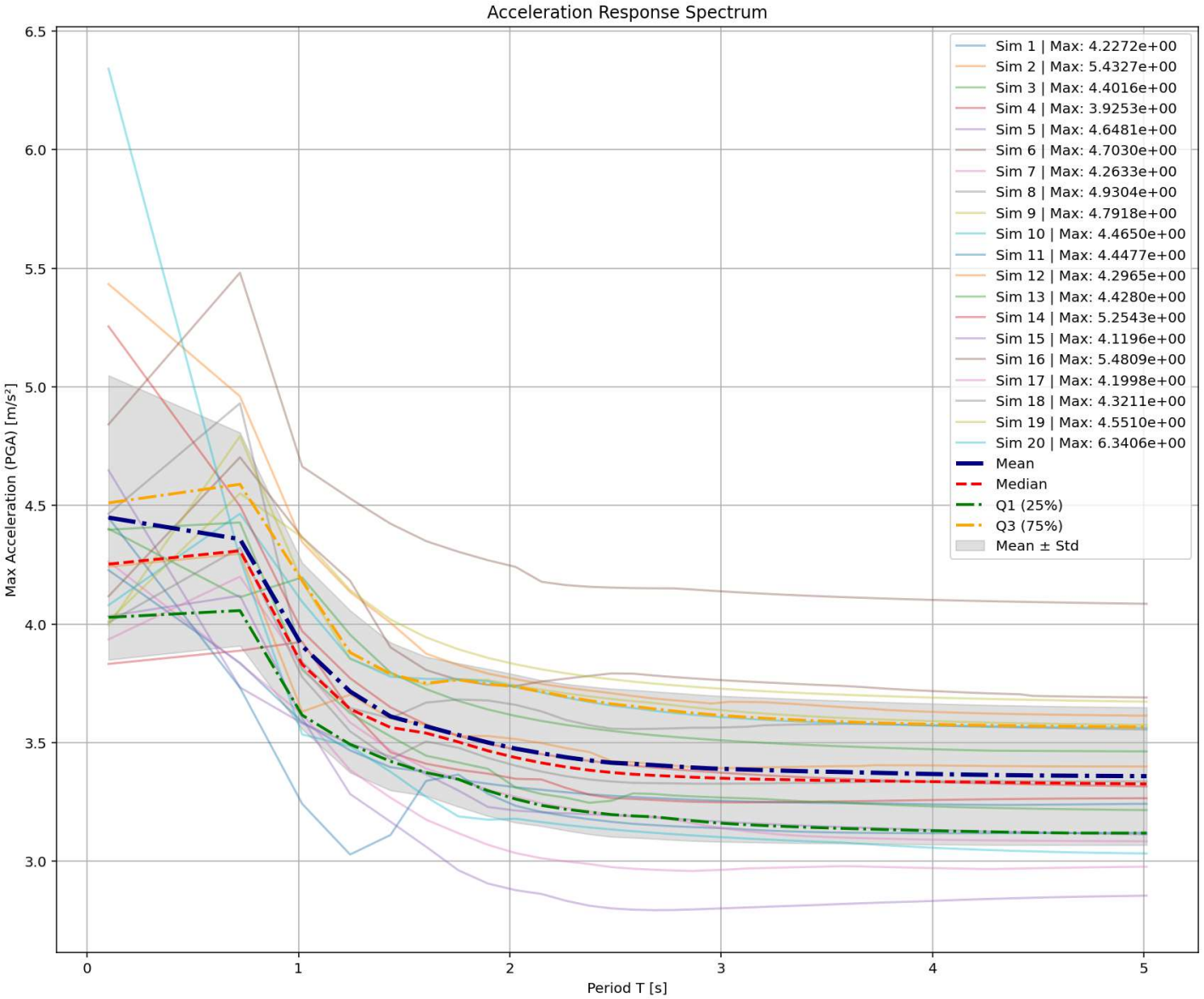


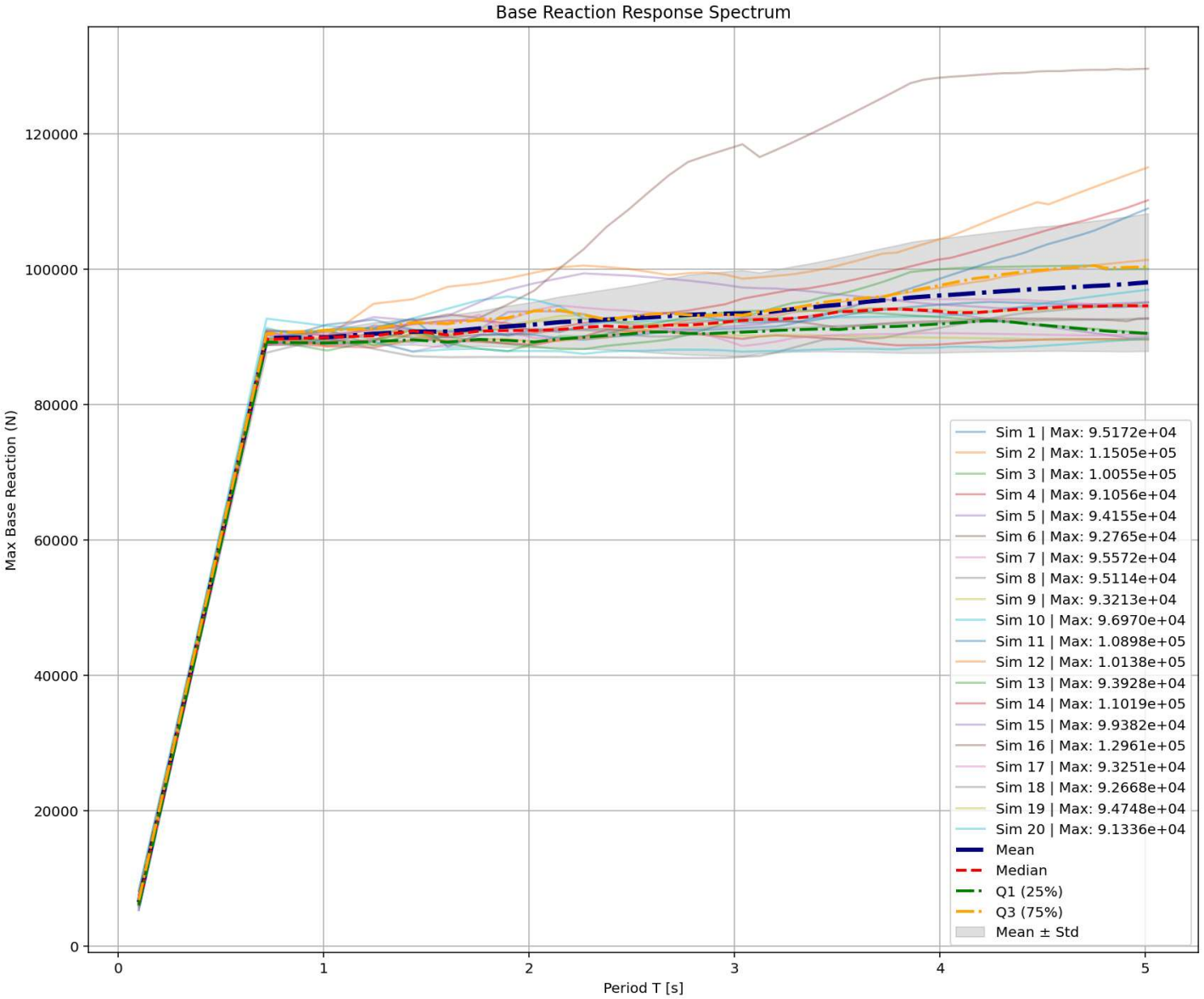
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

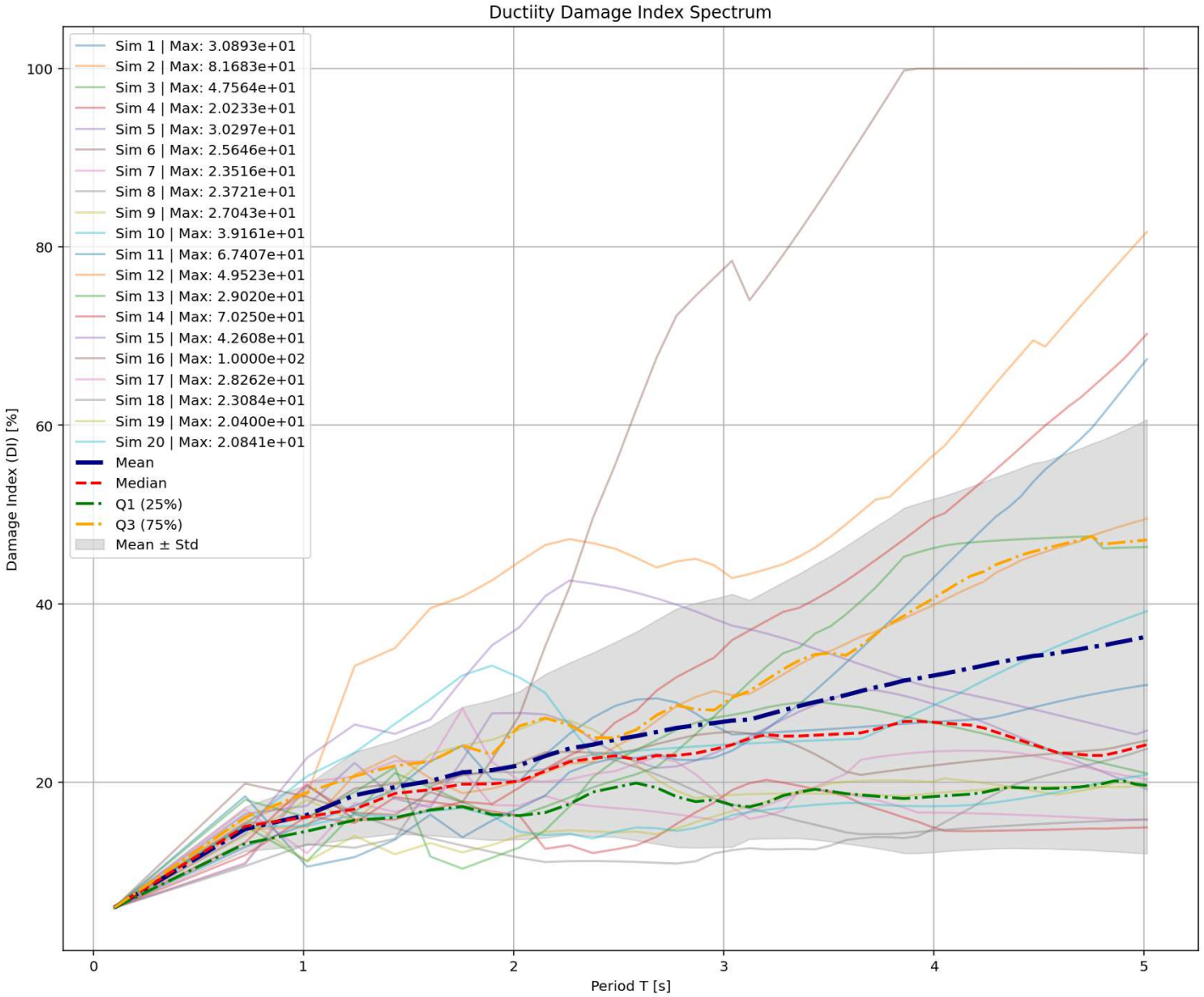
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 790, Col 63 UTF-8 CRLF RW Mem 39%

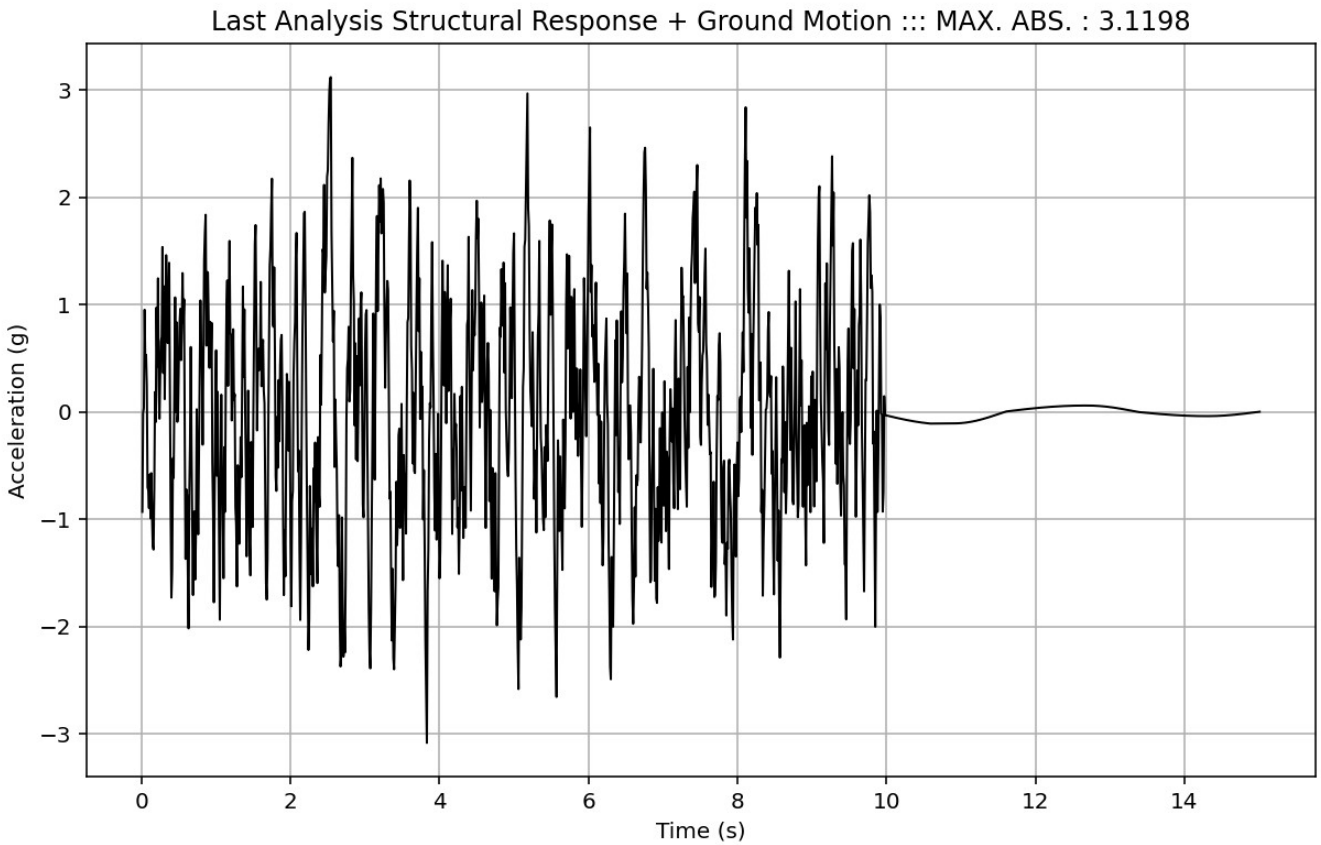

Displacement Response Spectrum
Sim 1 | Max: 9.1085e-02
Sim 2 | Max: 2.5974e-01
Sim 3 | Max: 1.4336e-01
Sim 4 | Max: 5.8612e-02
Sim 5 | Max: 8.4458e-02
Sim 6 | Max: 7.8396e-02
Sim 7 | Max: 9.9105e-02
Sim 8 | Max: 9.9805e-02
Sim 9 | Max: 7.3357e-02
Sim 10 | Max: 1.1469e-01
Sim 11 | Max: 2.1104e-01
Sim 12 | Max: 1.5004e-01
Sim 13 | Max: 8.0100e-02
Sim 14 | Max: 2.2074e-01
Sim 15 | Max: 1.2645e-01
Sim 16 | Max: 7.4927e-01
Sim 17 | Max: 7.7515e-02
Sim 18 | Max: 7.2836e-02
Sim 19 | Max: 8.6903e-02
Sim 20 | Max: 5.2202e-02
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Max Displacement (PGD) [m]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Period T [s]
0
1
2
3
4
5

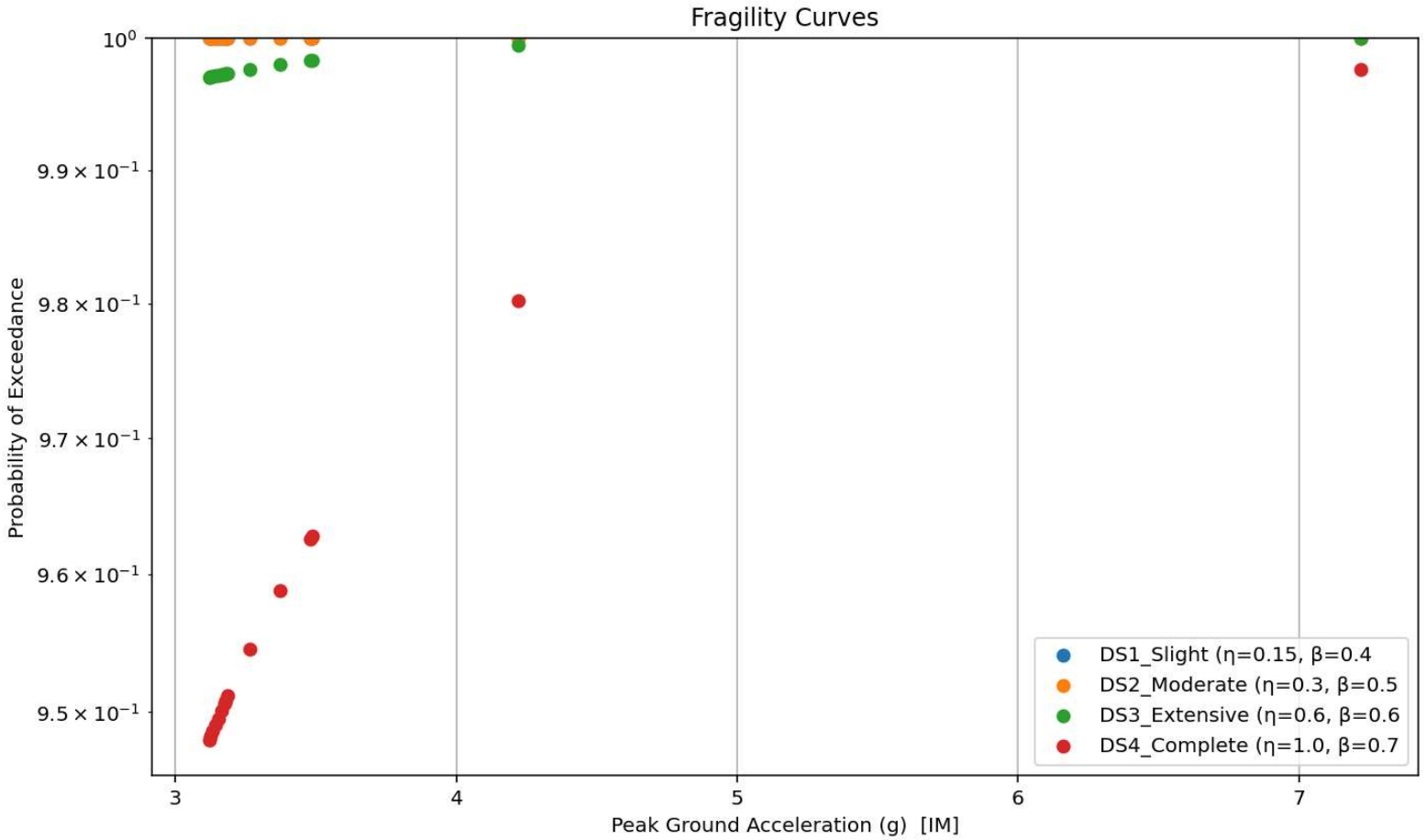

Velocity Response Spectrum
Max Velocity (PGV) [m/s]
Period T [s]
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
1
2
3
4
5
Sim 1 | Max: 3.2274e-01
Sim 2 | Max: 3.5999e-01
Sim 3 | Max: 3.6660e-01
Sim 4 | Max: 3.4965e-01
Sim 5 | Max: 3.2223e-01
Sim 6 | Max: 3.1216e-01
Sim 7 | Max: 3.2235e-01
Sim 8 | Max: 2.6381e-01
Sim 9 | Max: 3.3033e-01
Sim 10 | Max: 3.8055e-01
Sim 11 | Max: 2.7053e-01
Sim 12 | Max: 3.3082e-01
Sim 13 | Max: 3.0178e-01
Sim 14 | Max: 3.3889e-01
Sim 15 | Max: 2.9608e-01
Sim 16 | Max: 3.3337e-01
Sim 17 | Max: 3.0806e-01
Sim 18 | Max: 3.3598e-01
Sim 19 | Max: 4.4063e-01
Sim 20 | Max: 3.7839e-01
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std

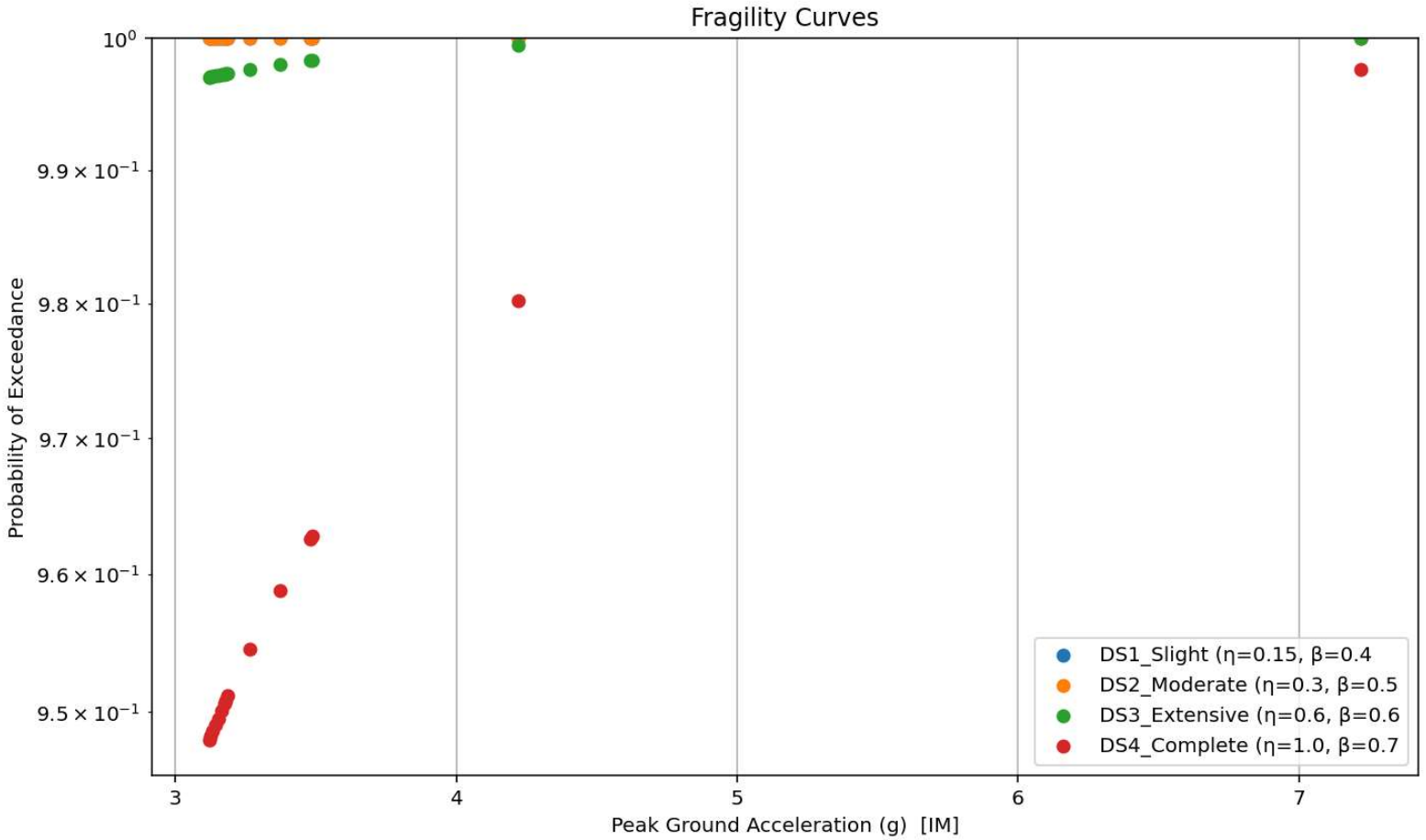

Acceleration Response Spectrum
Max Acceleration (PGA) [m/s²]
Period T [s]
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
0
1
2
3
4
5
Sim 1 | Max: 4.2272e+00
Sim 2 | Max: 5.4327e+00
Sim 3 | Max: 4.4016e+00
Sim 4 | Max: 3.9253e+00
Sim 5 | Max: 4.6481e+00
Sim 6 | Max: 4.7030e+00
Sim 7 | Max: 4.2633e+00
Sim 8 | Max: 4.9304e+00
Sim 9 | Max: 4.7918e+00
Sim 10 | Max: 4.4650e+00
Sim 11 | Max: 4.4477e+00
Sim 12 | Max: 4.2965e+00
Sim 13 | Max: 4.4280e+00
Sim 14 | Max: 5.2543e+00
Sim 15 | Max: 4.1196e+00
Sim 16 | Max: 5.4809e+00
Sim 17 | Max: 4.1998e+00
Sim 18 | Max: 4.3211e+00
Sim 19 | Max: 4.5510e+00
Sim 20 | Max: 6.3406e+00
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std

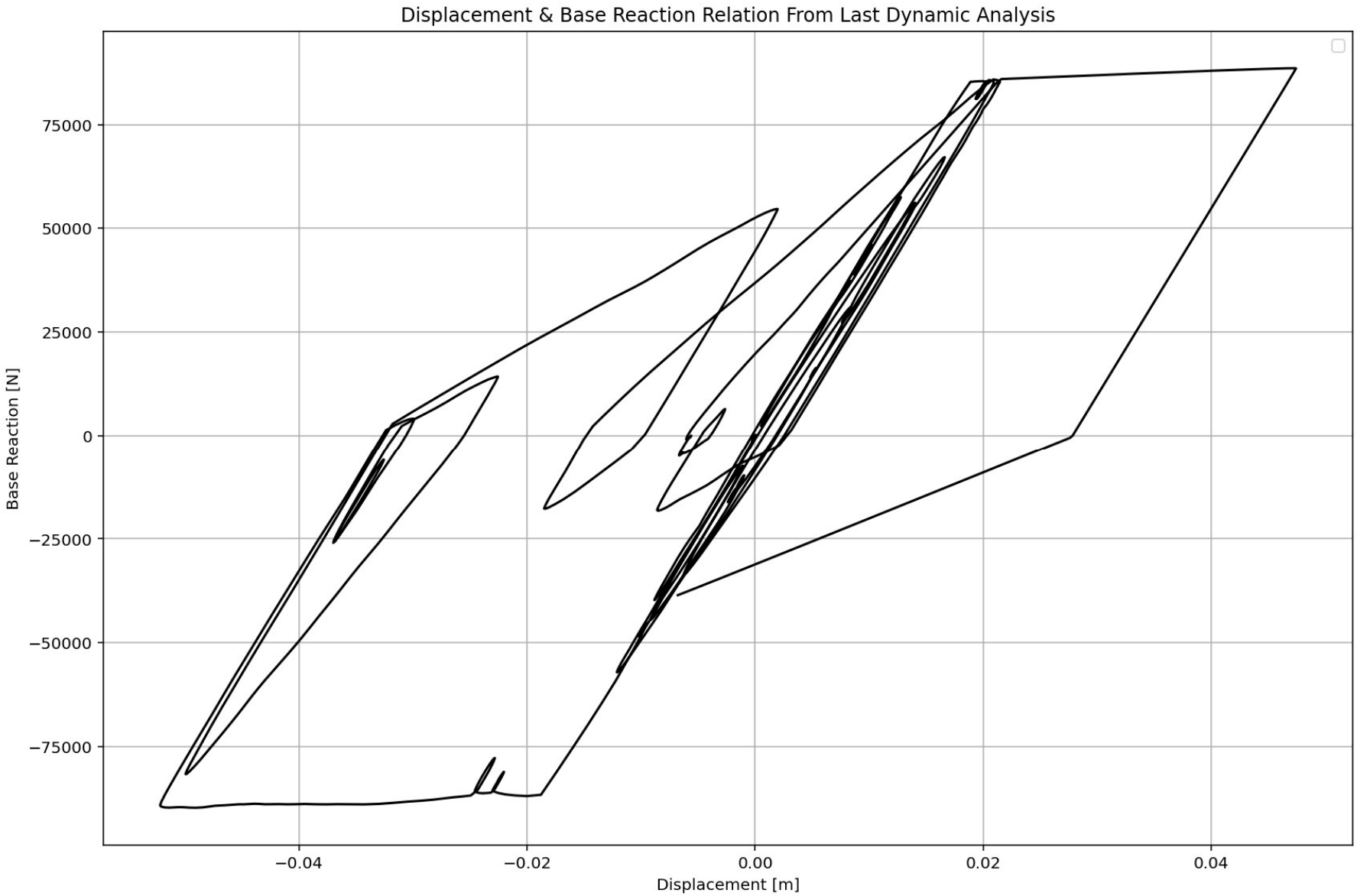

Base Reaction Response Spectrum
Max Base Reaction (N)
Period T [s]
0
20000
40000
60000
80000
100000
120000
0
1
2
3
4
5
Sim 1 | Max: 9.5172e+04
Sim 2 | Max: 1.1505e+05
Sim 3 | Max: 1.0055e+05
Sim 4 | Max: 9.1056e+04
Sim 5 | Max: 9.4155e+04
Sim 6 | Max: 9.2765e+04
Sim 7 | Max: 9.5572e+04
Sim 8 | Max: 9.5114e+04
Sim 9 | Max: 9.3213e+04
Sim 10 | Max: 9.6970e+04
Sim 11 | Max: 1.0898e+05
Sim 12 | Max: 1.0138e+05
Sim 13 | Max: 9.3928e+04
Sim 14 | Max: 1.1019e+05
Sim 15 | Max: 9.9382e+04
Sim 16 | Max: 1.2961e+05
Sim 17 | Max: 9.3251e+04
Sim 18 | Max: 9.2668e+04
Sim 19 | Max: 9.4748e+04
Sim 20 | Max: 9.1336e+04
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std

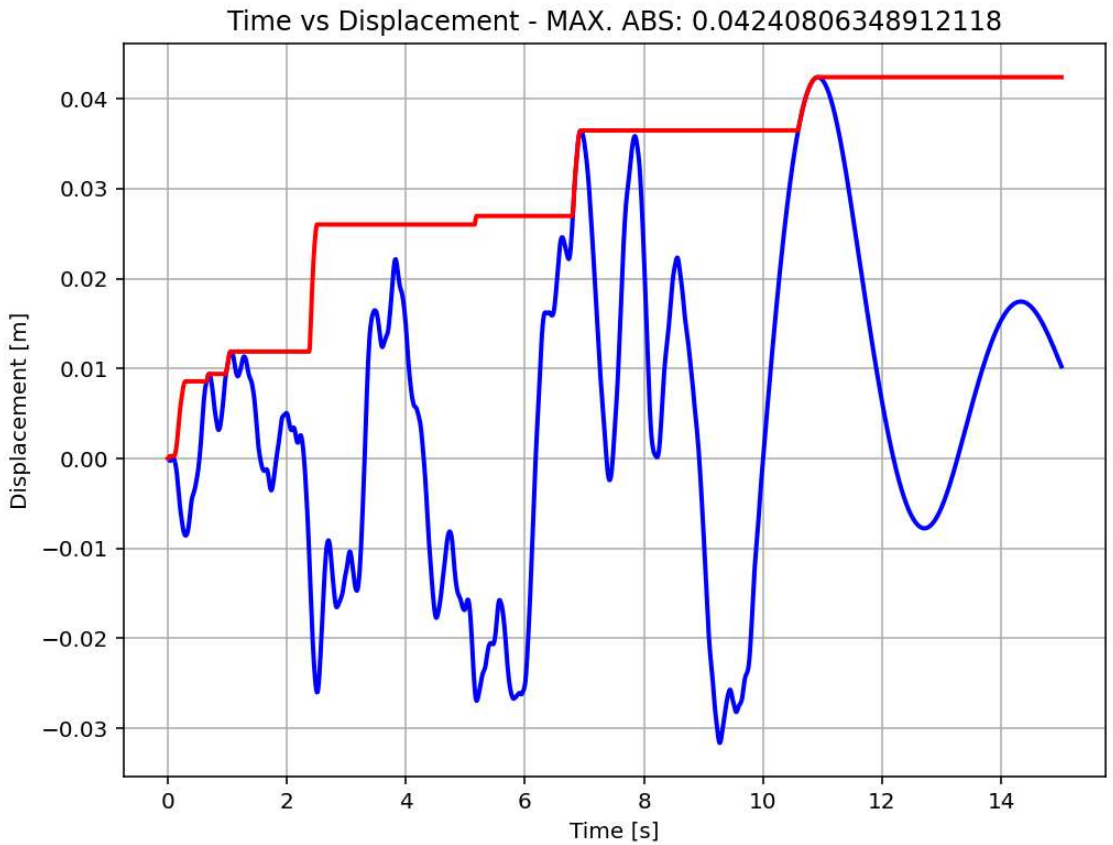

Ductiity Damage Index Spectrum
Sim 1 | Max: 3.0893e+01
Sim 2 | Max: 8.1683e+01
Sim 3 | Max: 4.7564e+01
Sim 4 | Max: 2.0233e+01
Sim 5 | Max: 3.0297e+01
Sim 6 | Max: 2.5646e+01
Sim 7 | Max: 2.3516e+01
Sim 8 | Max: 2.3721e+01
Sim 9 | Max: 2.7043e+01
Sim 10 | Max: 3.9161e+01
Sim 11 | Max: 6.7407e+01
Sim 12 | Max: 4.9523e+01
Sim 13 | Max: 2.9020e+01
Sim 14 | Max: 7.0250e+01
Sim 15 | Max: 4.2608e+01
Sim 16 | Max: 1.0000e+02
Sim 17 | Max: 2.8262e+01
Sim 18 | Max: 2.3084e+01
Sim 19 | Max: 2.0400e+01
Sim 20 | Max: 2.0841e+01
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Damage Index (DI) [%]
100
80
60
40
20
0
1
2
3
4
5
Period T [s]

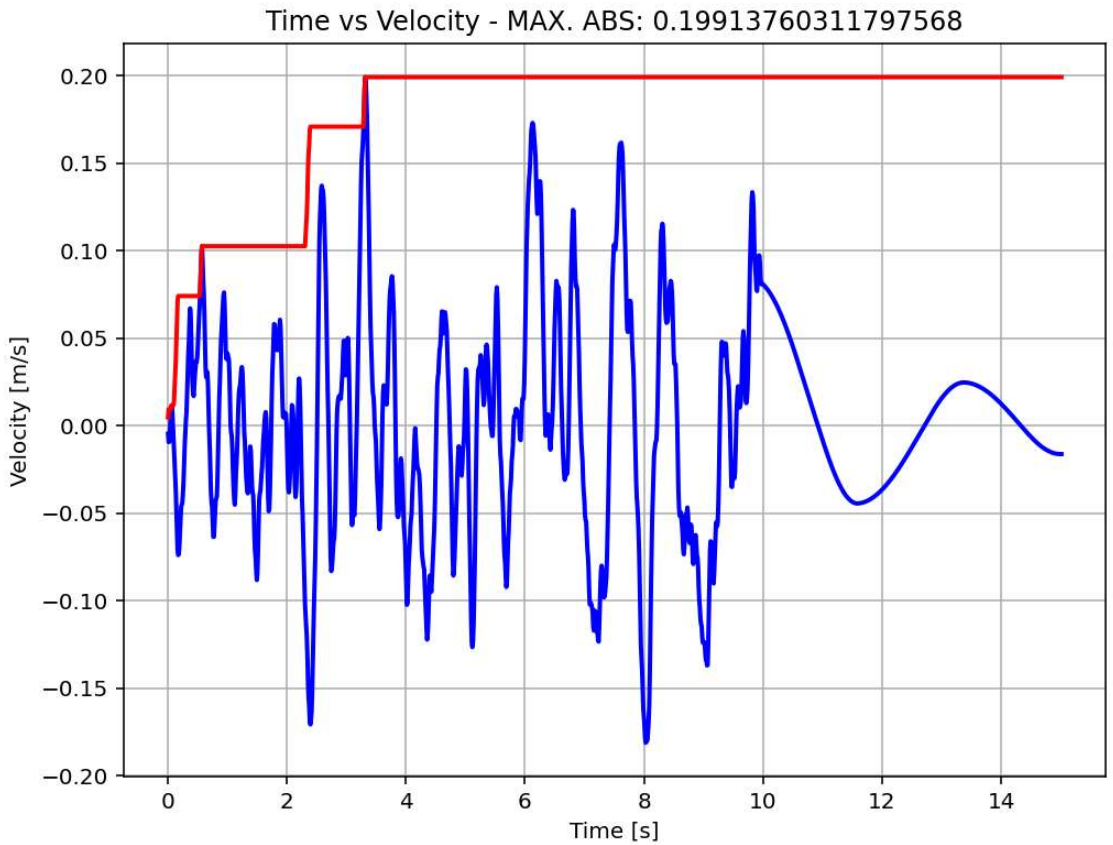

Last Analysis Structural Response + Ground Motion ::: MAX. ABS. : 3.1198
Acceleration (g)
Time (s)
3
2
1
0
−1
−2
−3
0
2
4
6
8
10
12
14

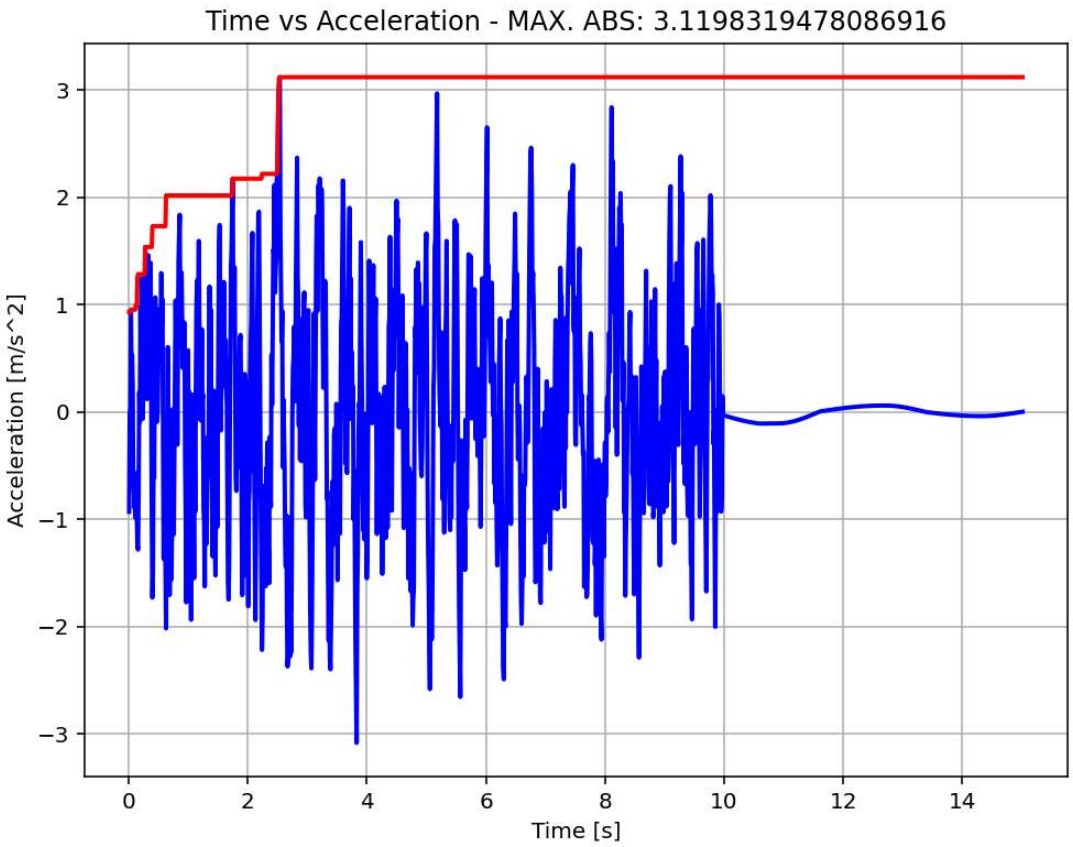

Fragility Curves
Probability of Exceedance
10^{0}
9.9×10^{-1}
9.8×10^{-1}
9.7×10^{-1}
9.6×10^{-1}
9.5×10^{-1}
3
4
5
6
7
Peak Ground Acceleration (g) [IM]
DS1_Slight (η=0.15, β=0.4
DS2_Moderate (η=0.3, β=0.5
DS3_Extensive (η=0.6, β=0.6
DS4_Complete (η=1.0, β=0.7

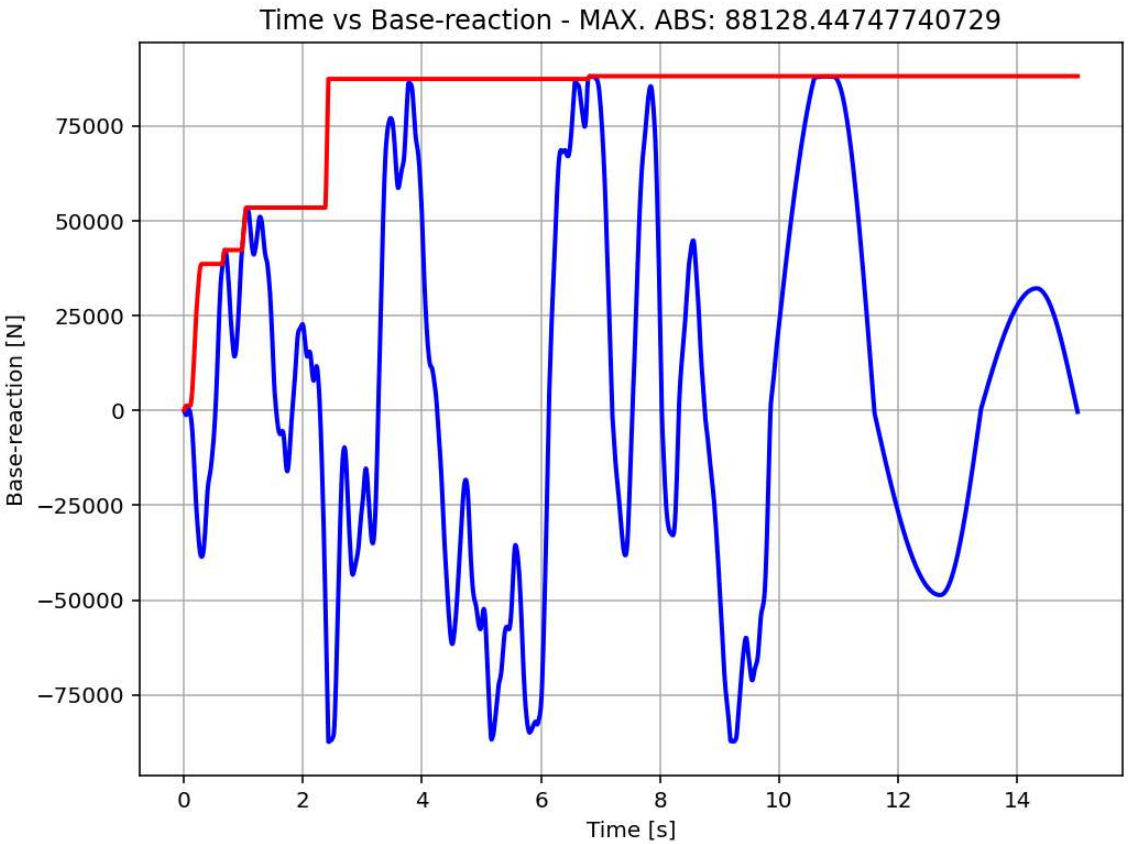

Fragility Curves
Probability of Exceedance
10^{0}
9.9×10^{-1}
9.8×10^{-1}
9.7×10^{-1}
9.6×10^{-1}
9.5×10^{-1}
3
4
5
6
7
Peak Ground Acceleration (g) [IM]
DS1_Slight (η=0.15, β=0.4
DS2_Moderate (η=0.3, β=0.5
DS3_Extensive (η=0.6, β=0.6
DS4_Complete (η=1.0, β=0.7

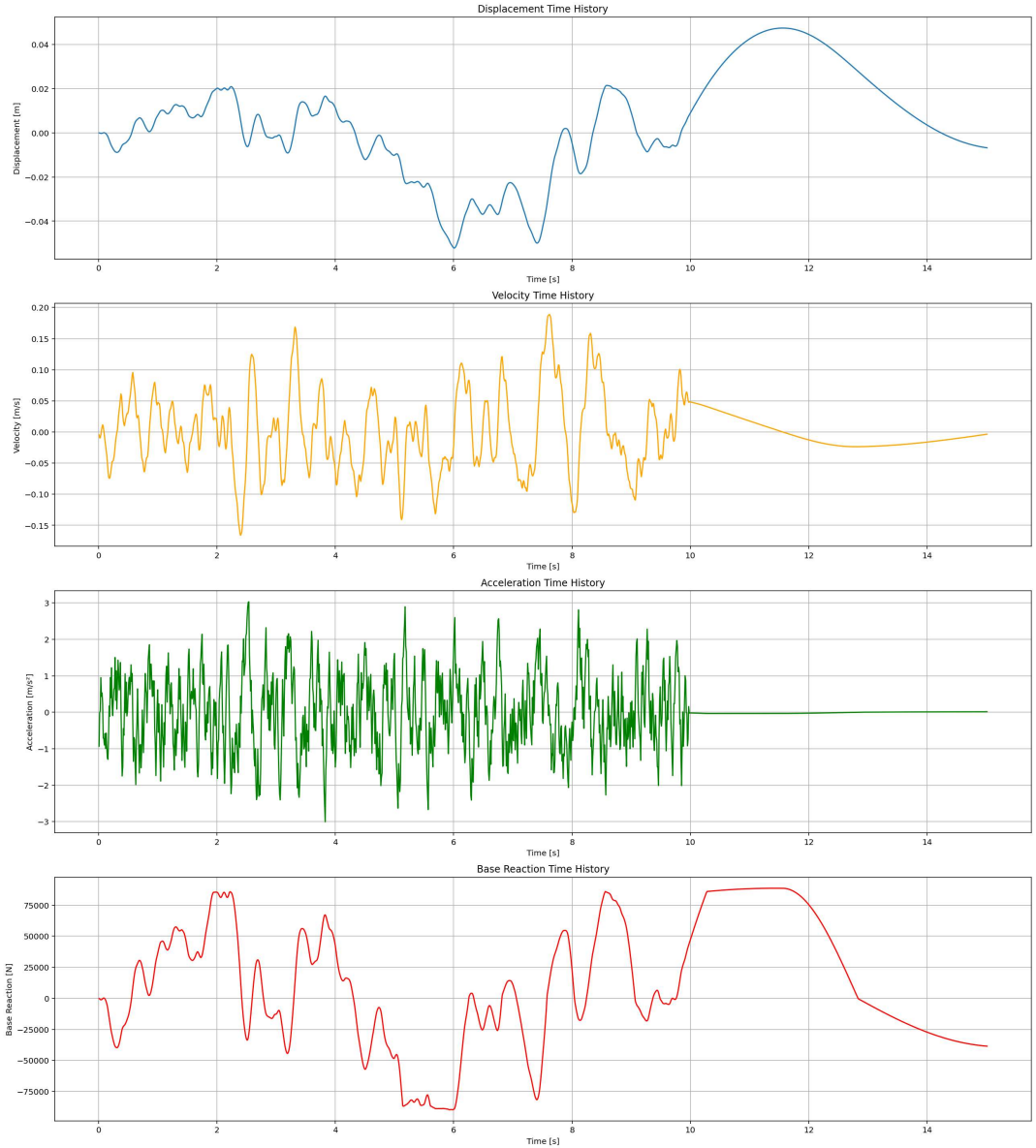

Displacement & Base Reaction Relation From Last Dynamic Analysis
Base Reaction [N]
75000
50000
25000
0
−25000
−50000
−75000
−0.04
−0.02
0.00
0.02
0.04
Displacement [m]

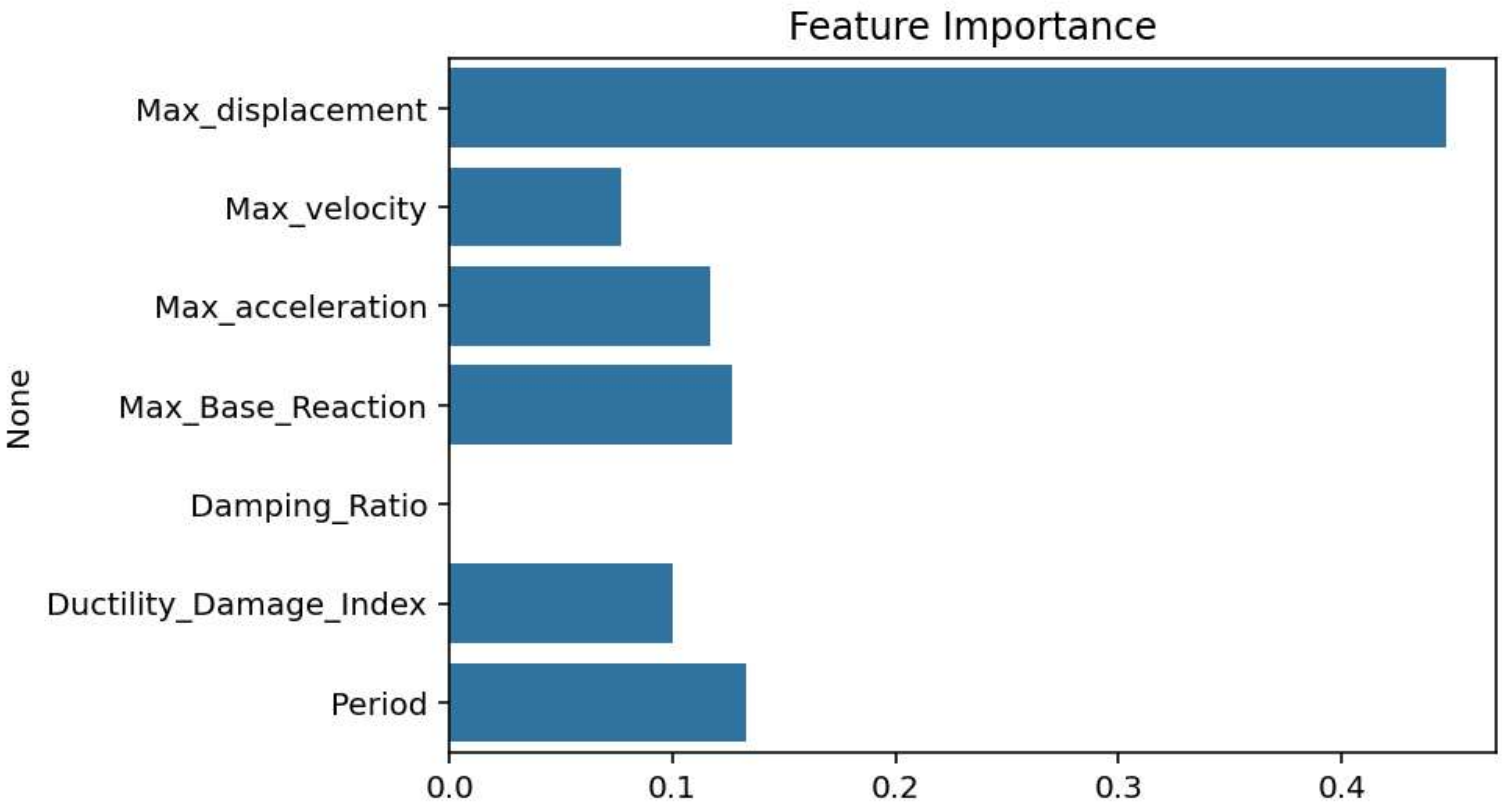

Time vs Displacement - MAX. ABS: 0.04240806348912118
Displacement [m]
Time [s]
0.04
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
0
2
4
6
8
10
12
14

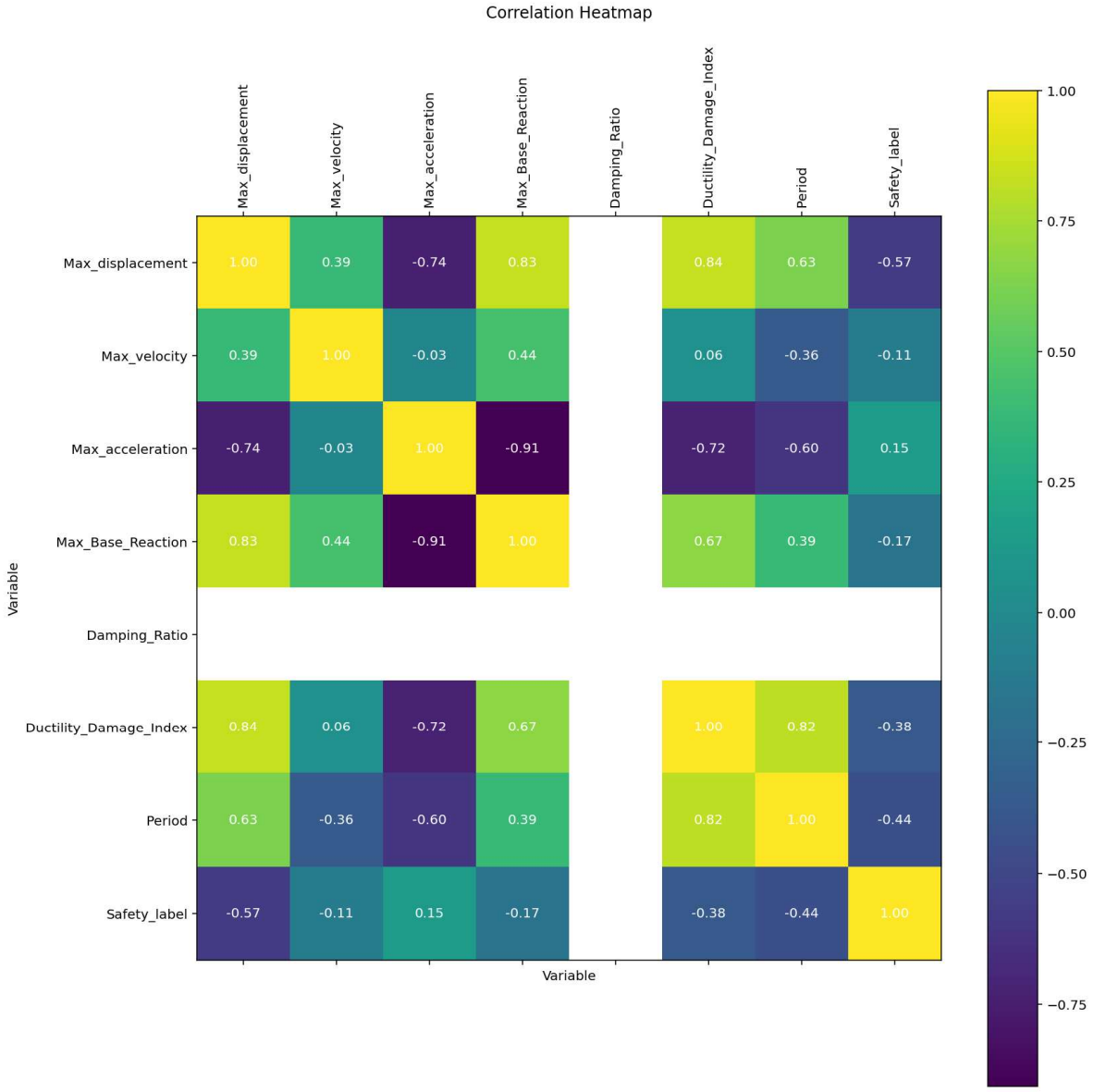

Time vs Velocity - MAX. ABS: 0.19913760311797568
Velocity [m/s]
Time [s]
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
0
2
4
6
8
10
12
14


Time vs Acceleration - MAX. ABS: 3.1198319478086916
Acceleration [m/s^2]
Time [s]
3
2
1
0
−1
−2
−3
0
2
4
6
8
10
12
14


Time vs Base-reaction - MAX. ABS: 88128.44747740729
Base-reaction [N]
75000
50000
25000
0
−25000
−50000
−75000
0
2
4
6
8
10
12
14
Time [s]


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
Damping_Ratio
Ductility_Damage_Index
Period
None
0.0
0.1
0.2
0.3
0.4


Correlation Heatmap
Max_displacement
Max_velocity
Max_acceleration
Max_Base_Reaction
Damping_Ratio
Ductility_Damage_Index
Period
Safety_label
Variable
Variable
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
1.00 0.39 -0.74 0.83 0.84 0.63 -0.57
0.39 1.00 -0.03 0.44 0.06 -0.36 -0.11
-0.74 -0.03 1.00 -0.91 -0.72 -0.60 0.15
0.83 0.44 -0.91 1.00 0.67 0.39 -0.17
0.84 0.06 -0.72 0.67 1.00 0.82 -0.38
0.63 -0.36 -0.60 0.39 0.82 1.00 -0.44
-0.57 -0.11 0.15 -0.17 -0.38 -0.44 1.00