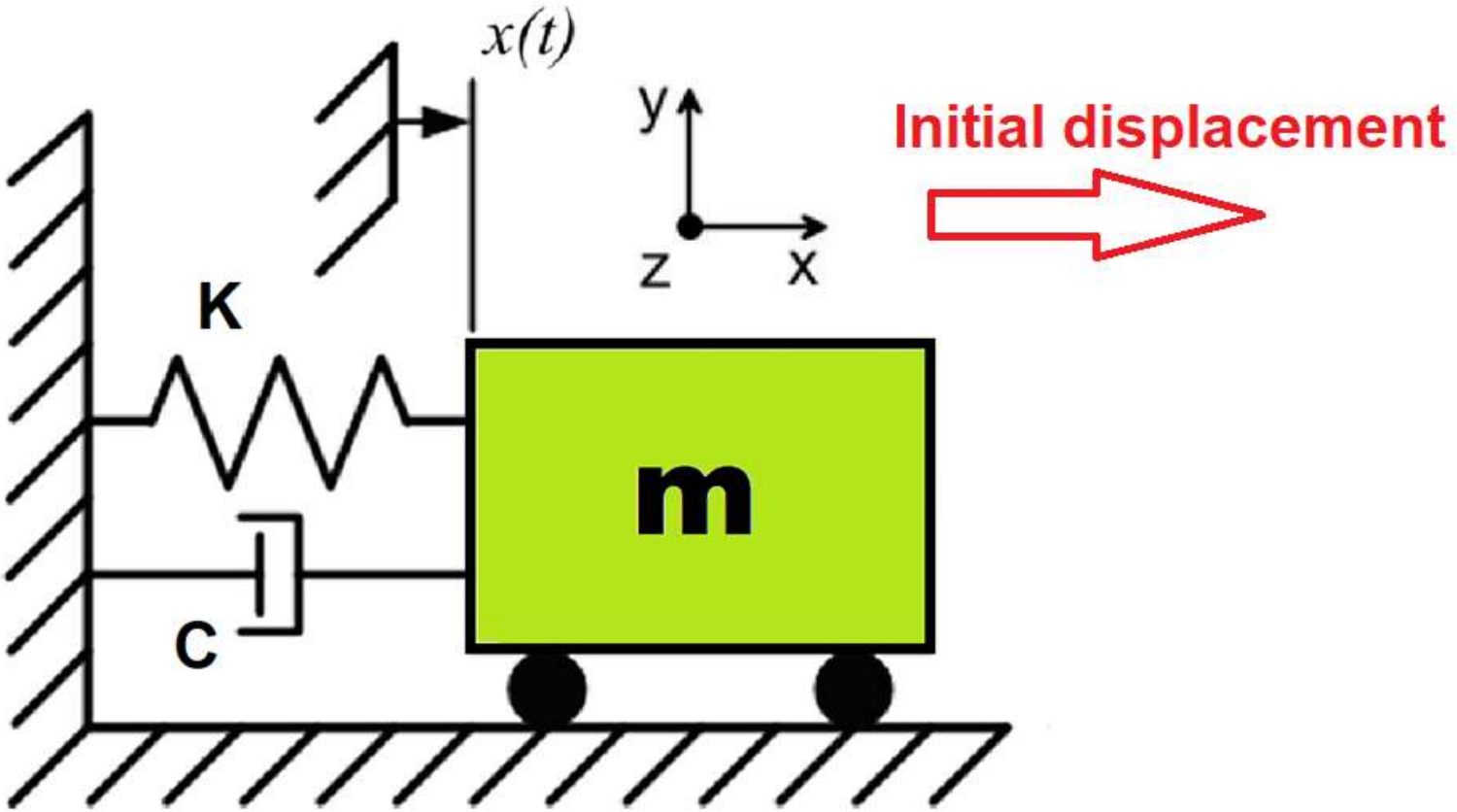
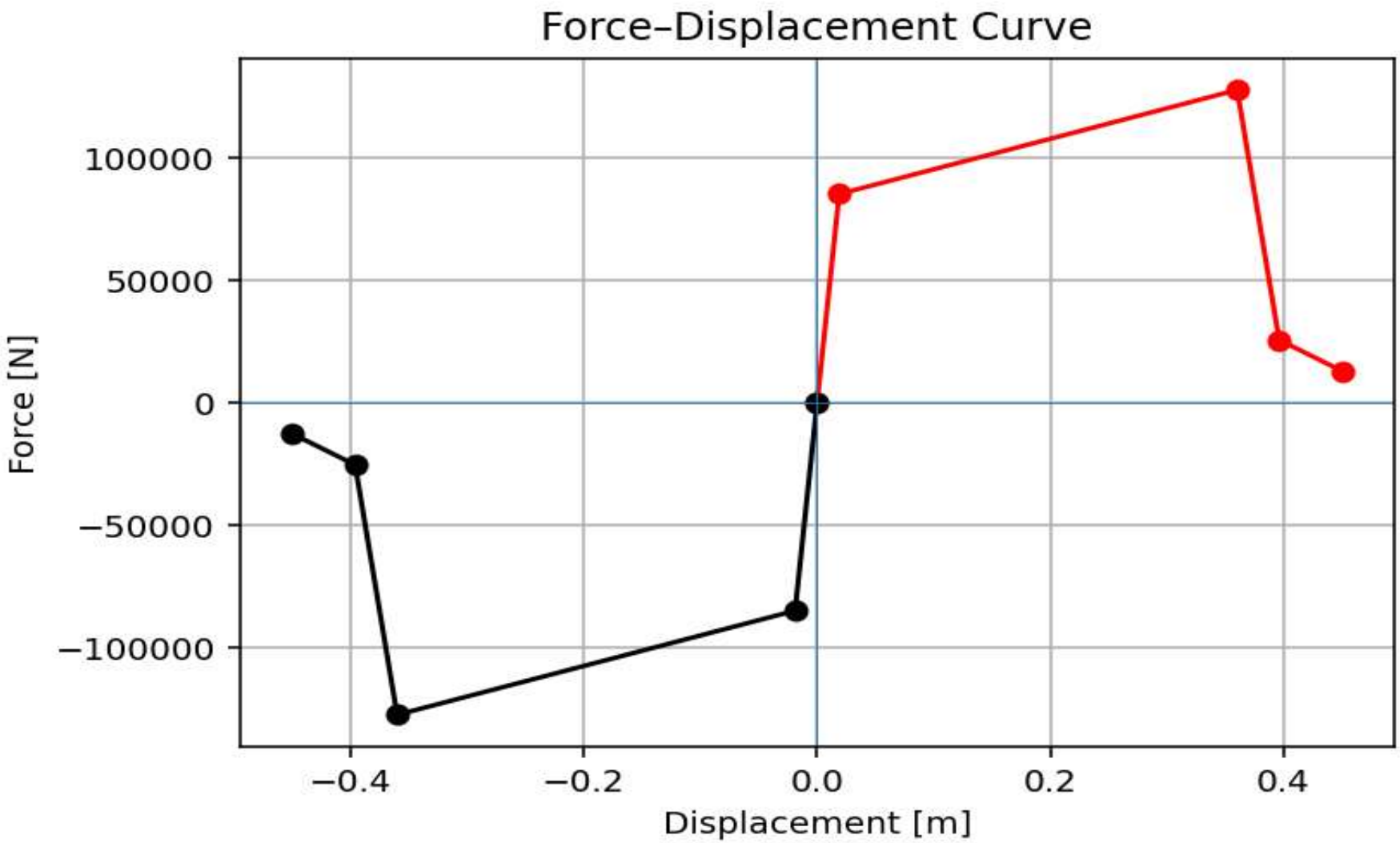
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

SENSITIVITY ANALYSIS OF SINGLE-DEGREE-FREEOM (SDOF) STRUCTURES USING FREE-VIBRATION:EFFECTS OF INTIAL DISPLACEMENT, MASS, STRCTURAL DUCTILITY RATIO AND OVER-STRENGTH FACTOR ON OUTPUT KEY PARAMETERS FROM NONLINEAR DYNAMIC ANALYSES USING PYTHON AND OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


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


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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...top\OPENSEES_FILES\SDOF_RESPONSE_SPECTRUM_SEISMIC_DUCT_OSF

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

SDOF_RESPONSE_SENS...RATION_DUCT_OSF.py

```
#############################################################################################################
#                          >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
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#              EFFECTS OF INTIAL DISPLACEMENT, MASS, STRCTURAL DUCTILITY RATIO AND OVER-STRENGTH FACTOR
#                  ON OUTPUT KEY PARAMETERS FROM NONLINEAR DYNAMIC ANALYSES USING PYTHON AND OPENSEES
#-----------------------------------------------------------------------------------------------------------
#                                  FREE VIBRATION ANALYSIS USING INITIAL DISPLACEMENT
#-----------------------------------------------------------------------------------------------------------
#                               THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                    EMAIL: salar.d.ghashghaei@gmail.com
#############################################################################################################
"""
1. This script performs a "sensitivity analysis of a single-degree-of-freedom (SDOF) structure" using
2. The objective is to study the effects of "initial displacement, mass, ductility ratio, and over-str
3. Structural properties such as "yield force, ultimate force, elastic stiffness, hardening ratio, mas
4. Elastic and plastic periods of the system are computed and reported.
5. Key seismic performance parameters are calculated, including "over-strength (Ω₀)", "ductility (μ)",
6. A nonlinear "hysteretic spring model" is used to represent structural behavior with strength degrad
7. A "viscous damper" is added to simulate energy dissipation.
8. The analysis considers "free vibration due to initial displacement" (no external ground motion).
9. The function `ANALYSIS_SDOF` builds the OpenSees model, applies initial conditions, and runs a tran
10. "Newmark time integration" and "Newton-Raphson iteration" are used for nonlinear solution.
11. "Rayleigh damping coefficients" are computed from the first eigenvalue.
12. Time histories of "displacement, velocity, acceleration, base reaction, stiffness, and damage inde
13. A "ductility-based damage index" is calculated at each time step.
14. The effective stiffness degradation is monitored during the response.
15. Multiple simulations are executed by looping over ranges of "mass, initial displacement, ductility
16. For each simulation, "maximum response values" are extracted.
17. Damage index values are limited between "0% and 100%".
18. All results are stored for post-processing and statistical analysis.
19. The script reports completion of each simulation and total runtime.
20. Overall, the code provides a "parametric nonlinear dynamic assessment" of SDOF systems under free
"""
```
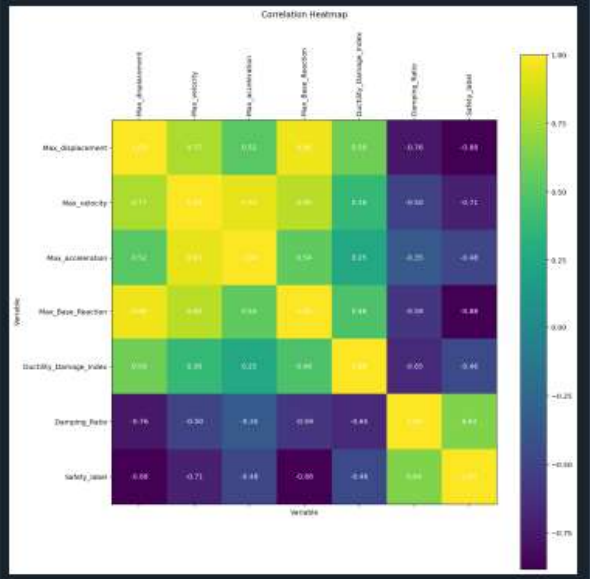
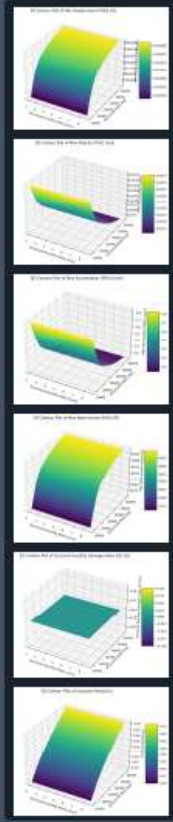
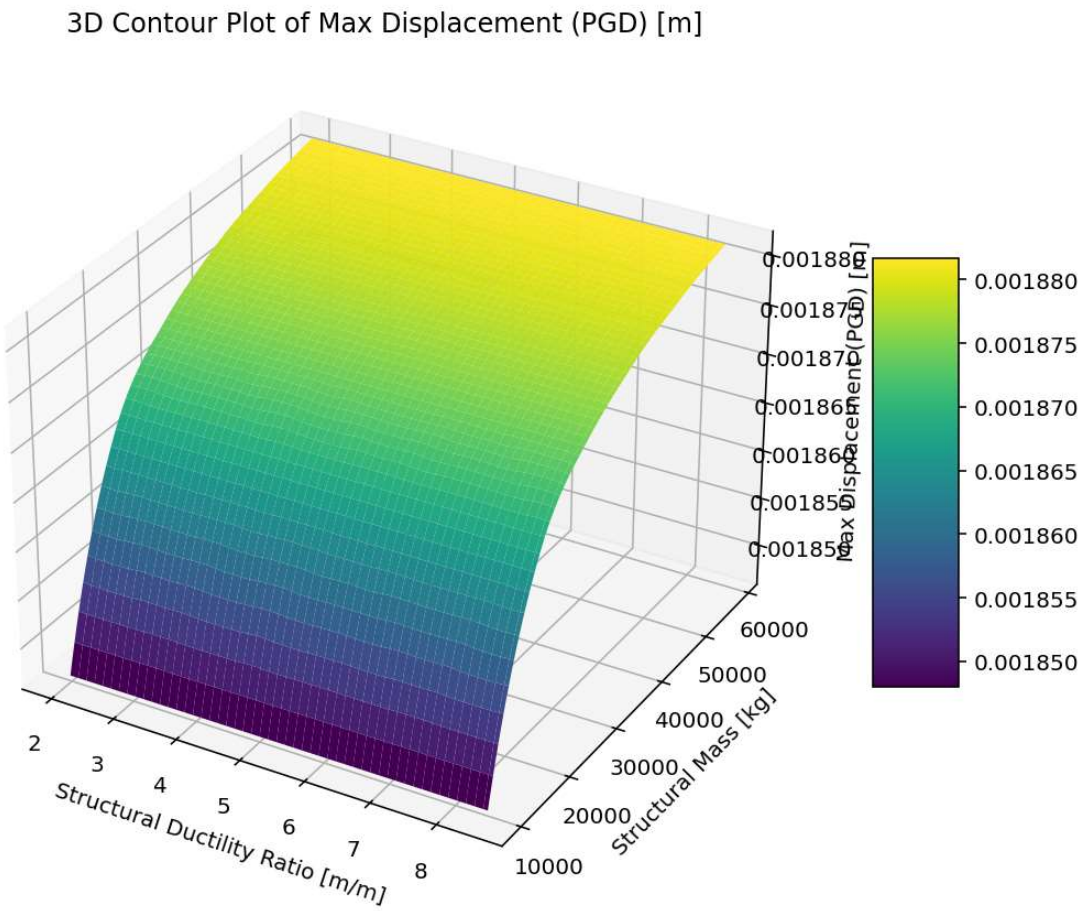

22 %

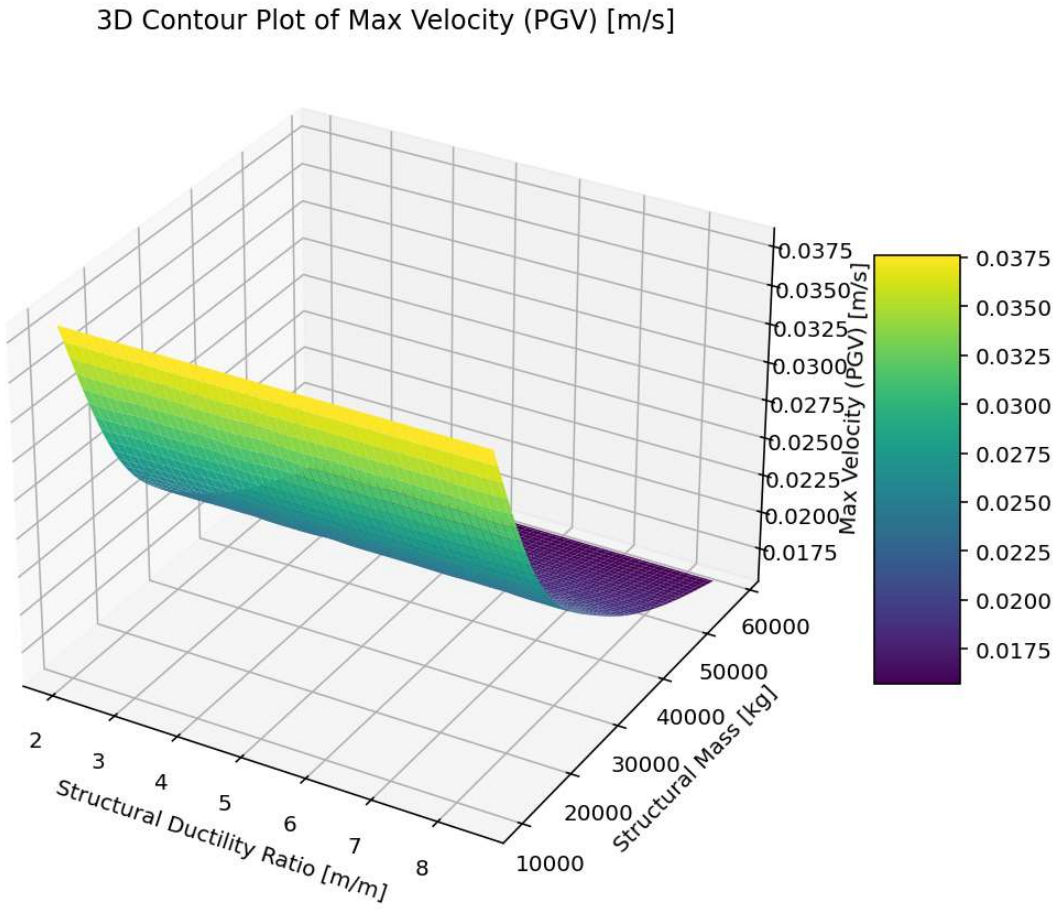


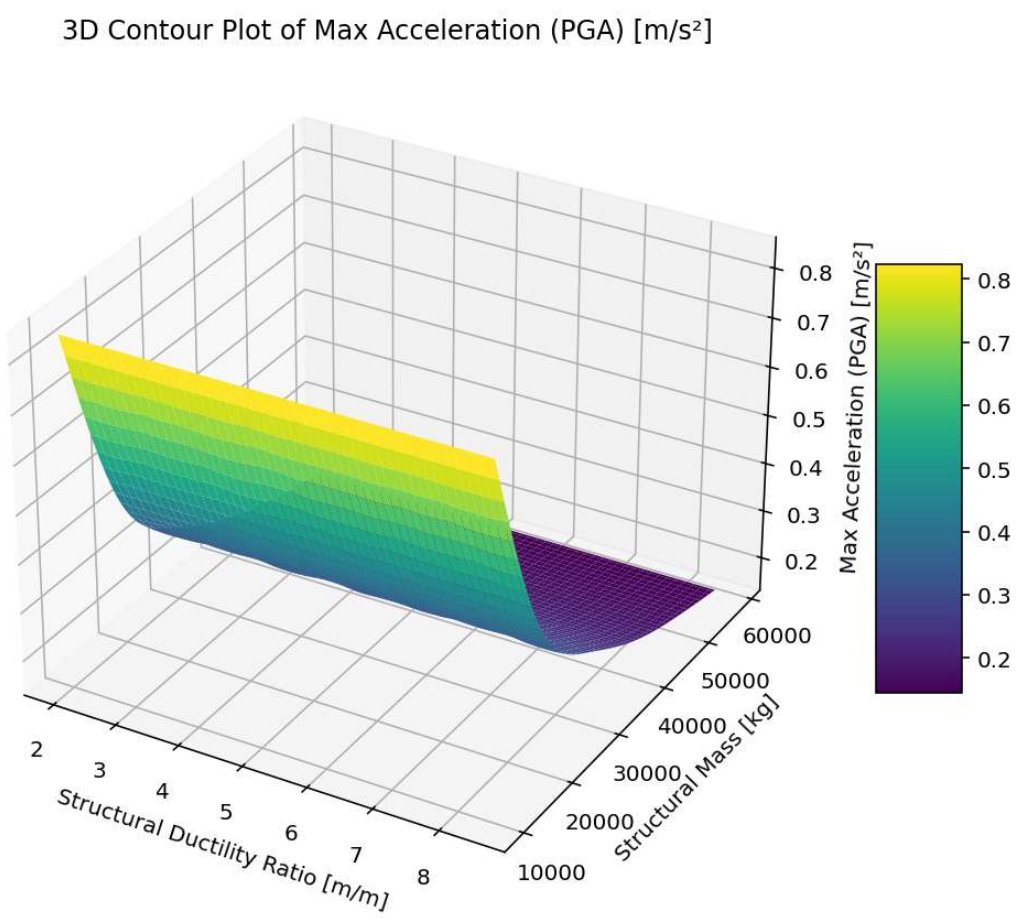


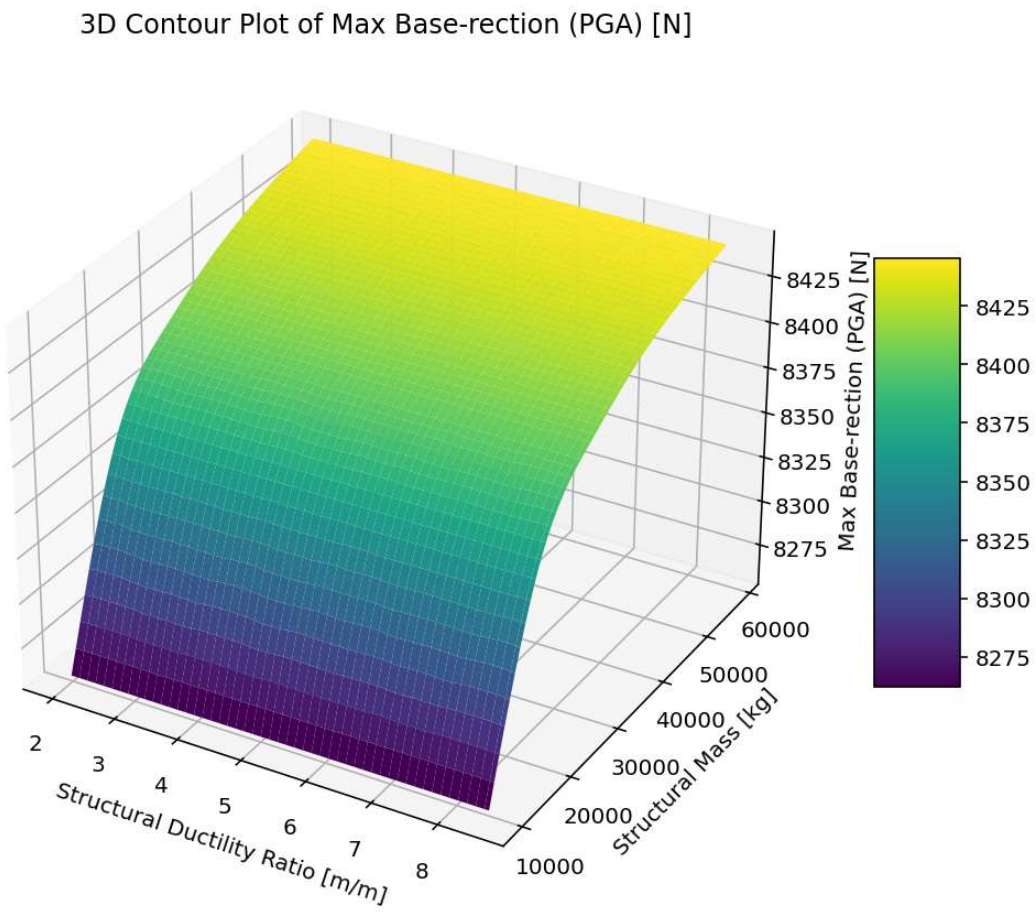
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

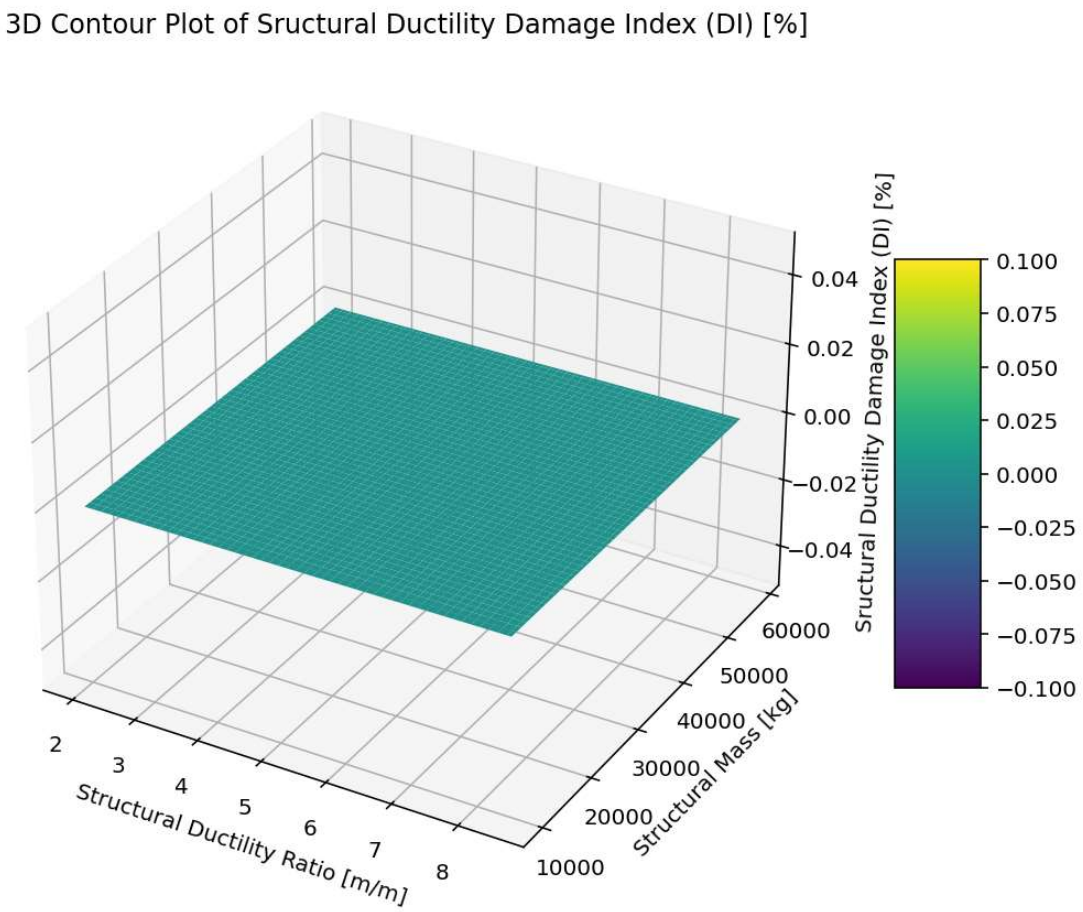
Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 32, Col 124 | UTF-8 | CRLF | RW | Mem 44%

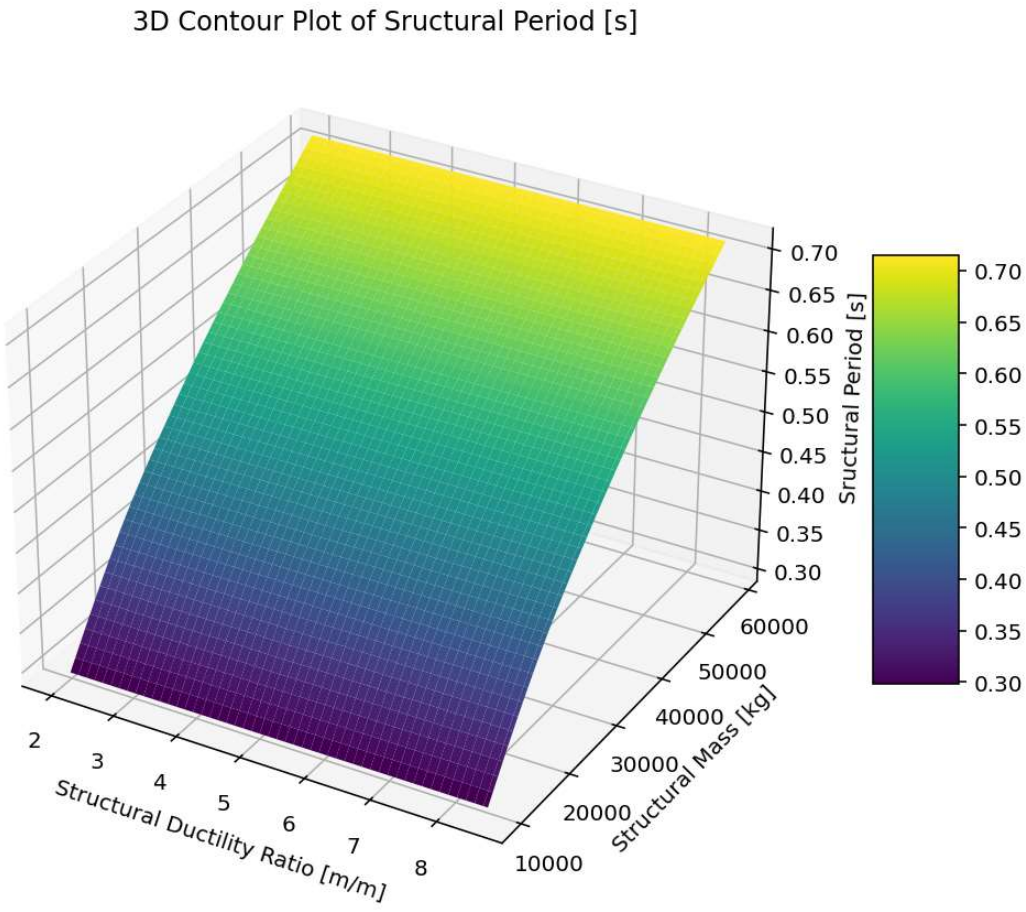

3D Contour Plot of Max Displacement (PGD) [m]
Structural Ductility Ratio [m/m]
Structural Mass [kg]
Max Displacement (PGD) [m]
2
3
4
5
6
7
8
10000
20000
30000
40000
50000
60000
0.001850
0.001855
0.001860
0.001865
0.001870
0.001875
0.001880

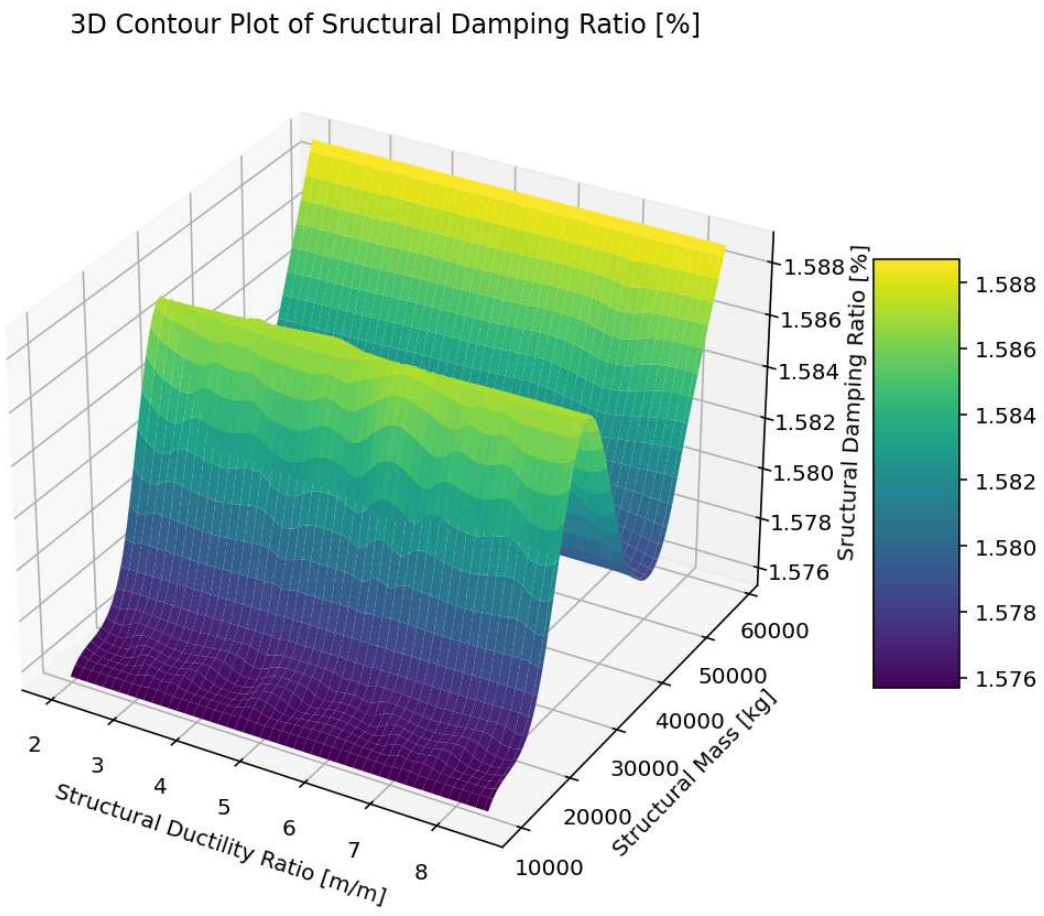

3D Contour Plot of Max Velocity (PGV) [m/s]
Max Velocity (PGV) [m/s]
0.0375
0.0350
0.0325
0.0300
0.0275
0.0250
0.0225
0.0200
0.0175
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Structural Mass [kg]
10000
20000
30000
40000
50000
60000

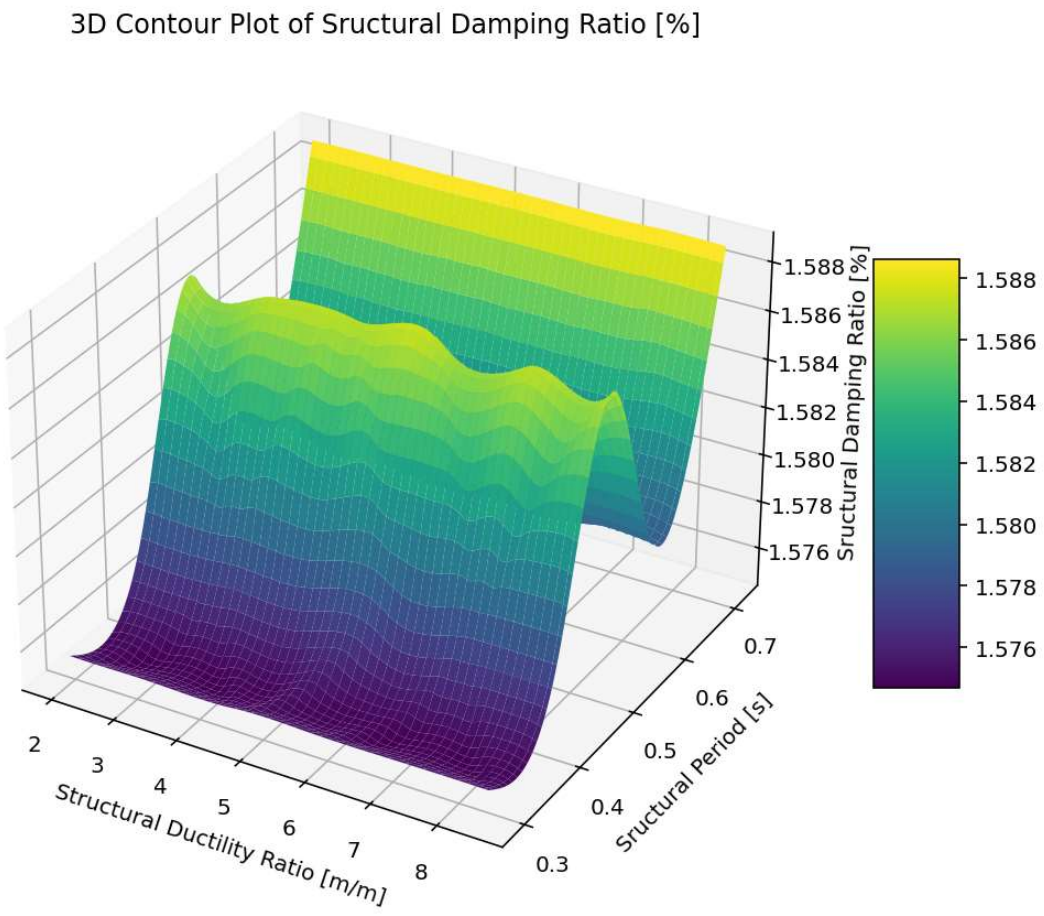

3D Contour Plot of Max Acceleration (PGA) [m/s²]
Structural Ductility Ratio [m/m]
Structural Mass [kg]
Max Acceleration (PGA) [m/s²]
2
3
4
5
6
7
8
10000
20000
30000
40000
50000
60000
0.2
0.3
0.4
0.5
0.6
0.7
0.8

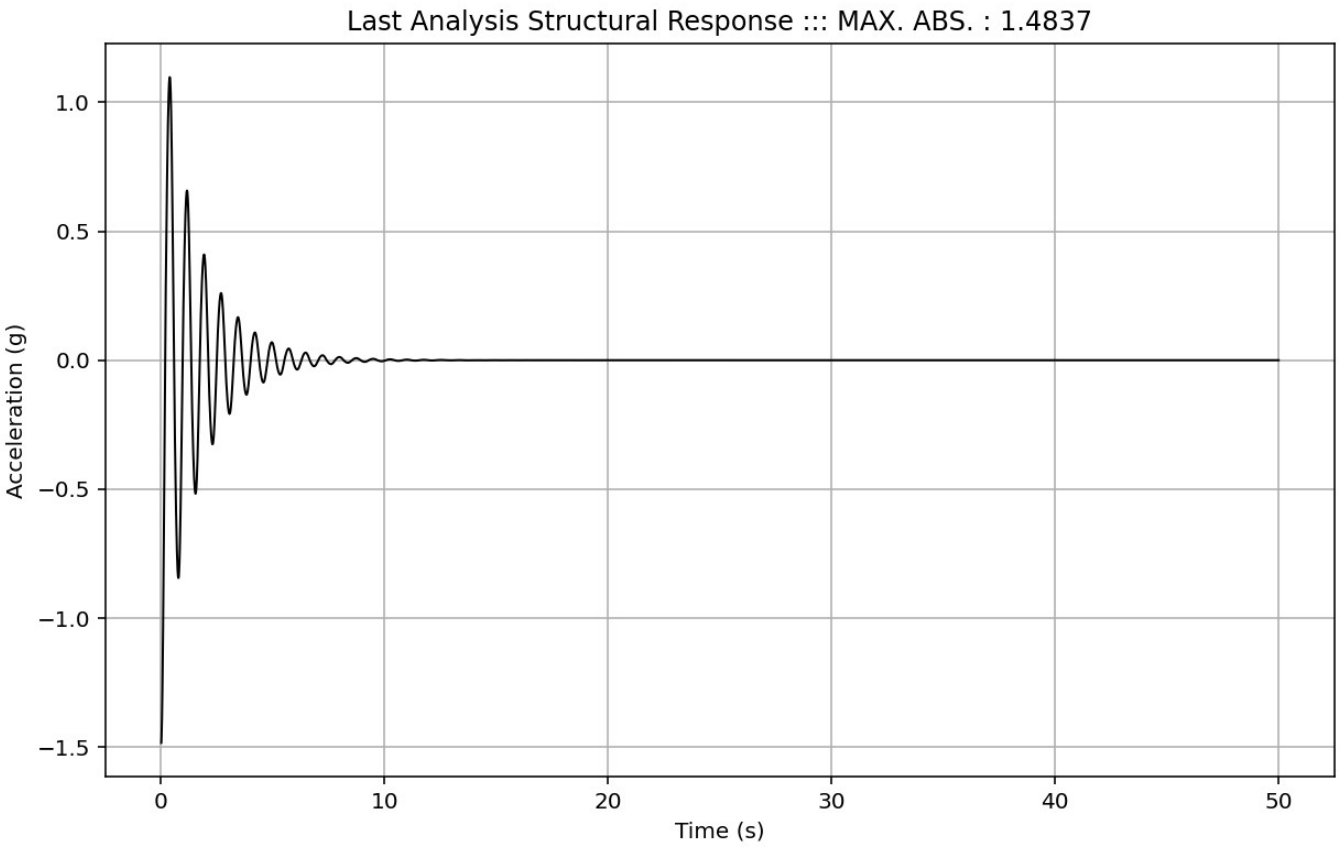

3D Contour Plot of Max Base-rection (PGA) [N]
Structural Ductility Ratio [m/m]
Structural Mass [kg]
Max Base-rection (PGA) [N]
2
3
4
5
6
7
8
10000
20000
30000
40000
50000
60000
8275
8300
8325
8350
8375
8400
8425

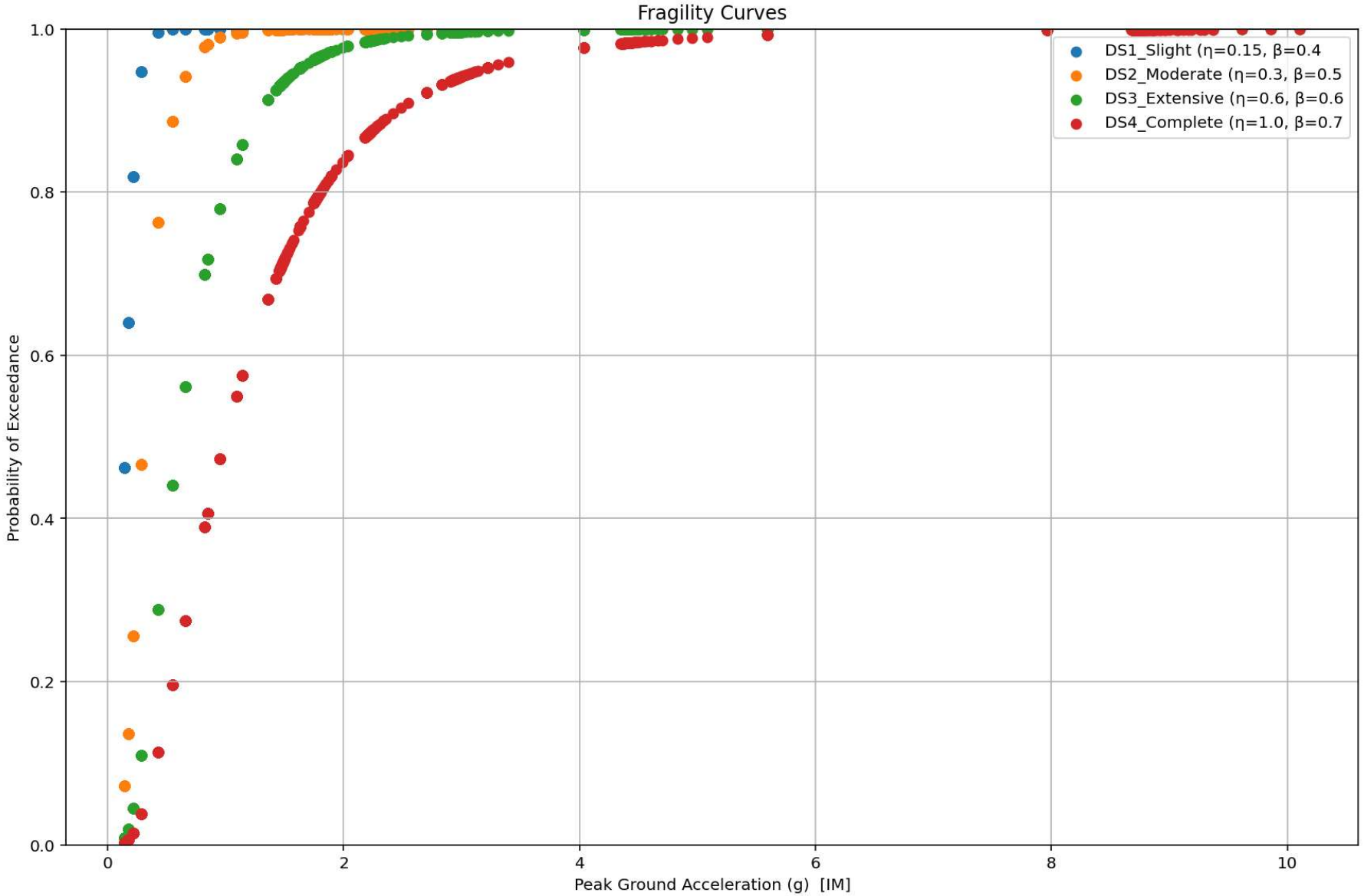

3D Contour Plot of Sructural Ductility Damage Index (DI) [%]
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Structural Mass [kg]
10000
20000
30000
40000
50000
60000
0.04
0.02
0.00
−0.02
−0.04
Sructural Ductility Damage Index (DI) [%]
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100

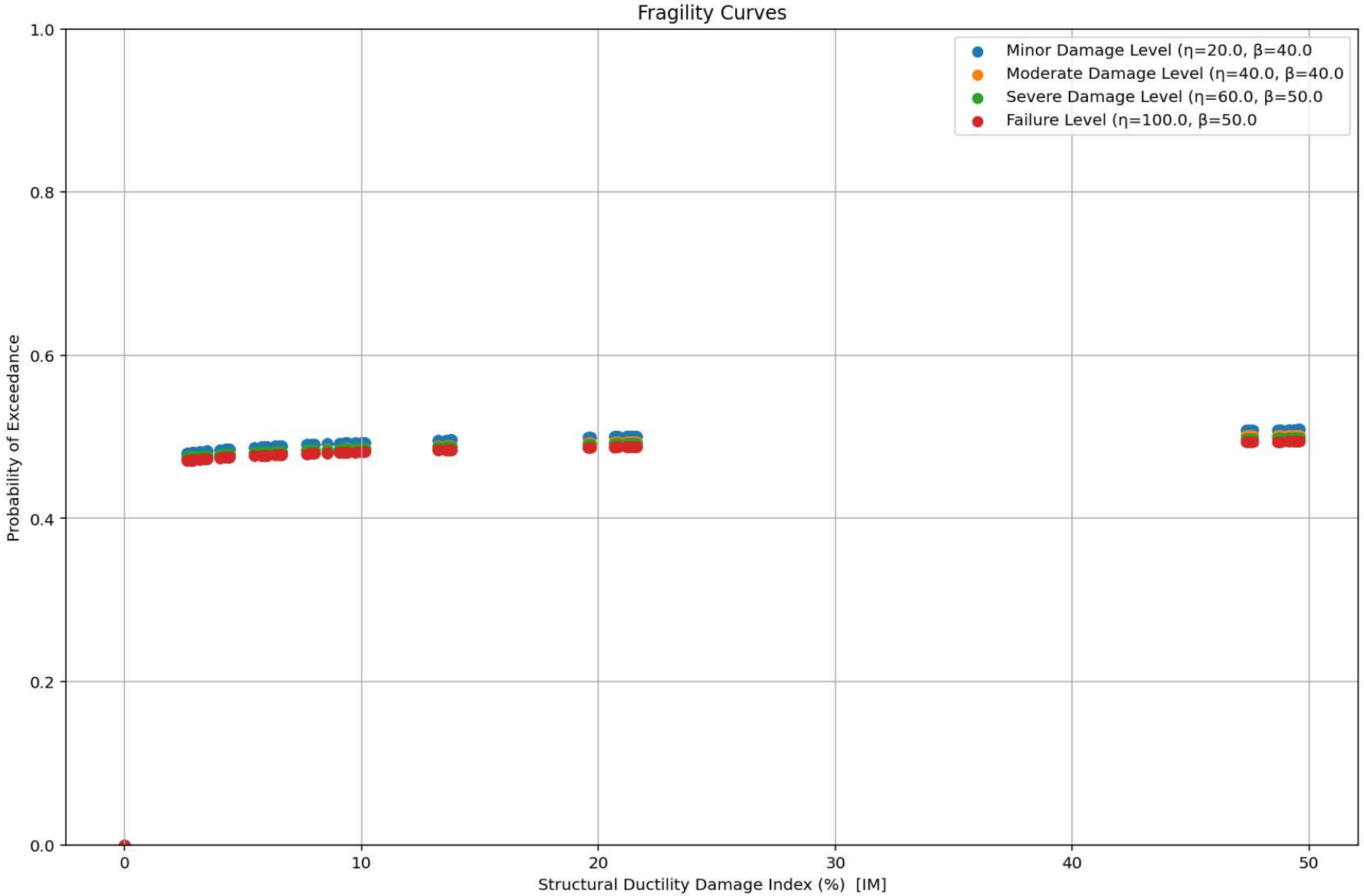

3D Contour Plot of Sructural Period [s]
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Structural Mass [kg]
10000
20000
30000
40000
50000
60000
Sructural Period [s]
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30

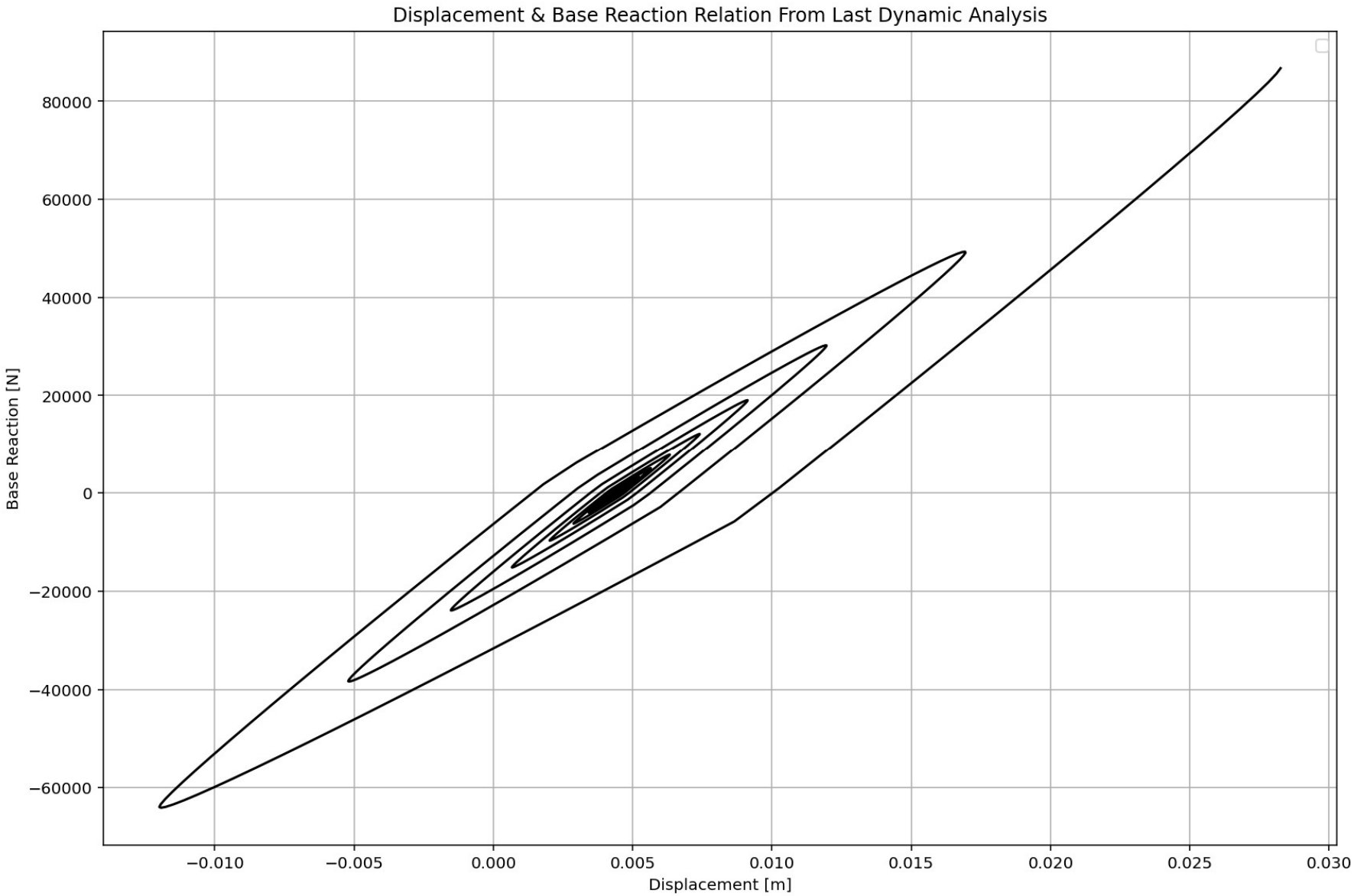

3D Contour Plot of Sructural Damping Ratio [%]
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Structural Mass [kg]
10000
20000
30000
40000
50000
60000
Sructural Damping Ratio [%]
1.576
1.578
1.580
1.582
1.584
1.586
1.588

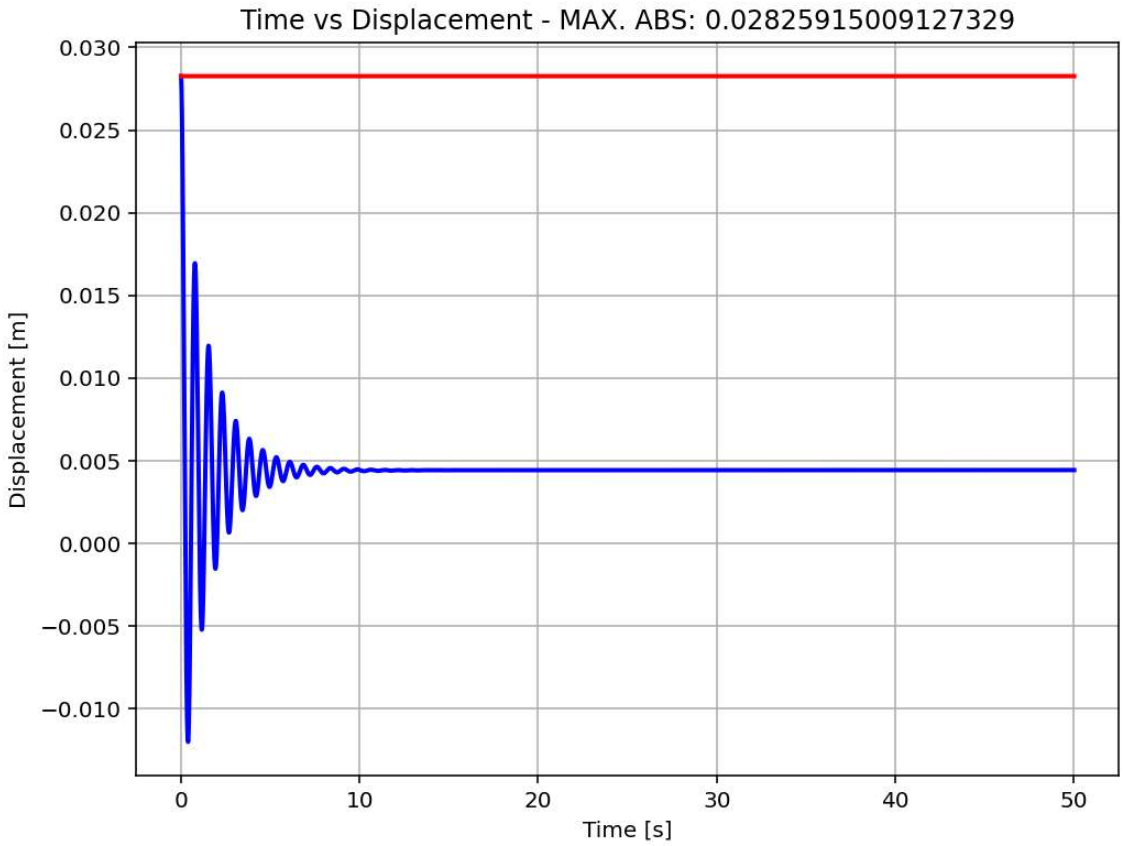

3D Contour Plot of Sructural Damping Ratio [%]
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Sructural Period [s]
0.3
0.4
0.5
0.6
0.7
Sructural Damping Ratio [%]
1.588
1.586
1.584
1.582
1.580
1.578
1.576

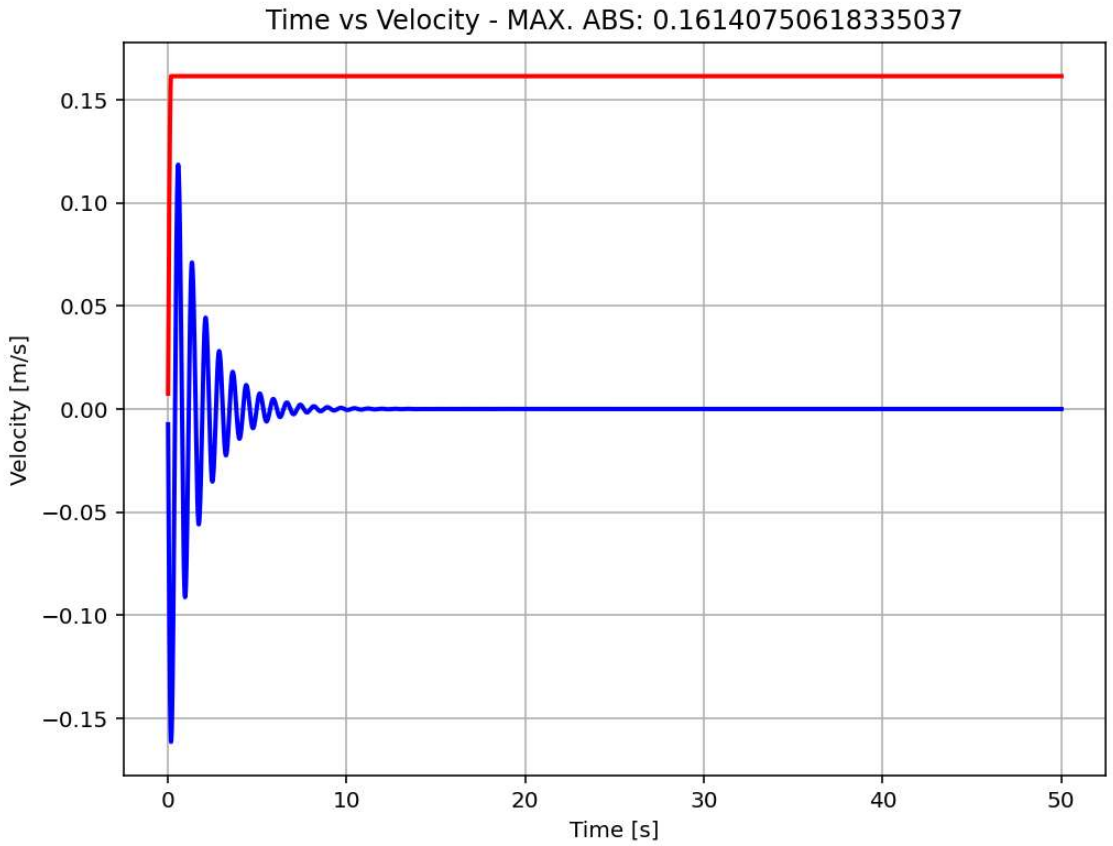

Last Analysis Structural Response ::: MAX. ABS. : 1.4837
Acceleration (g)
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
10
20
30
40
50
Time (s)

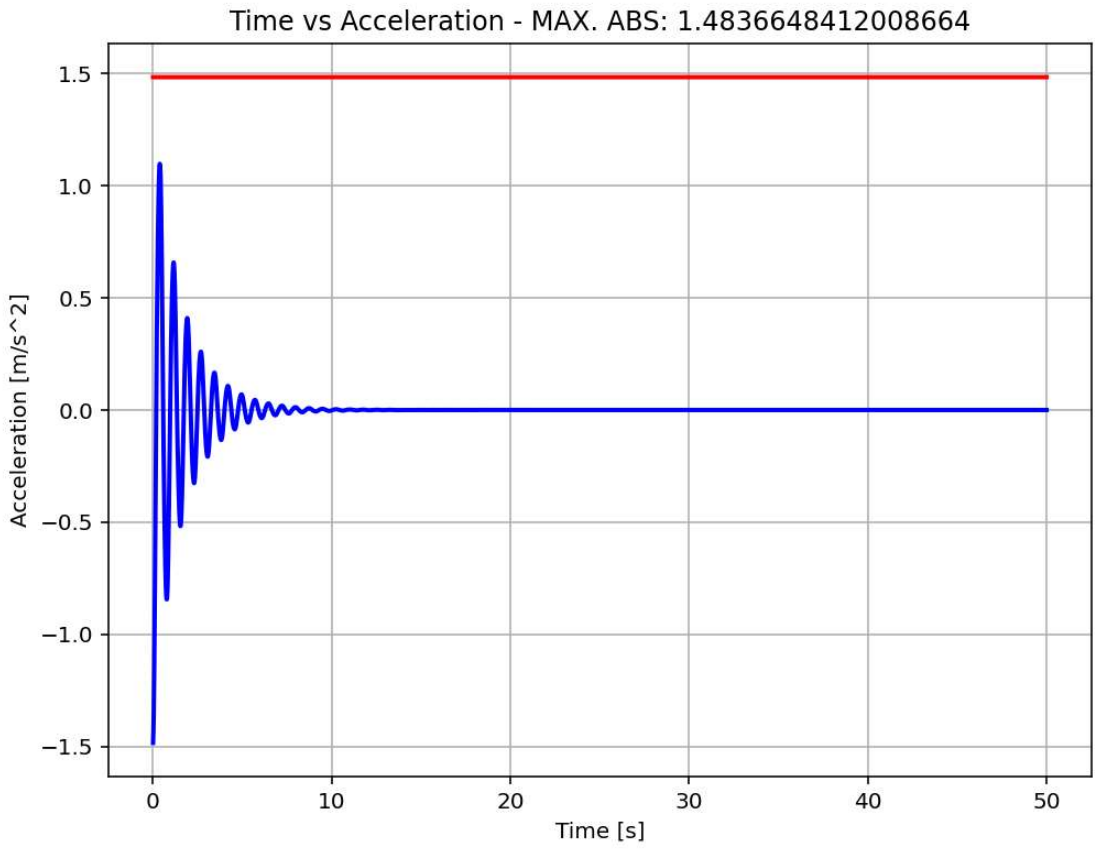

Fragility Curves
DS1_Slight (η=0.15, β=0.4
DS2_Moderate (η=0.3, β=0.5
DS3_Extensive (η=0.6, β=0.6
DS4_Complete (η=1.0, β=0.7
Probability of Exceedance
Peak Ground Acceleration (g) [IM]
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10

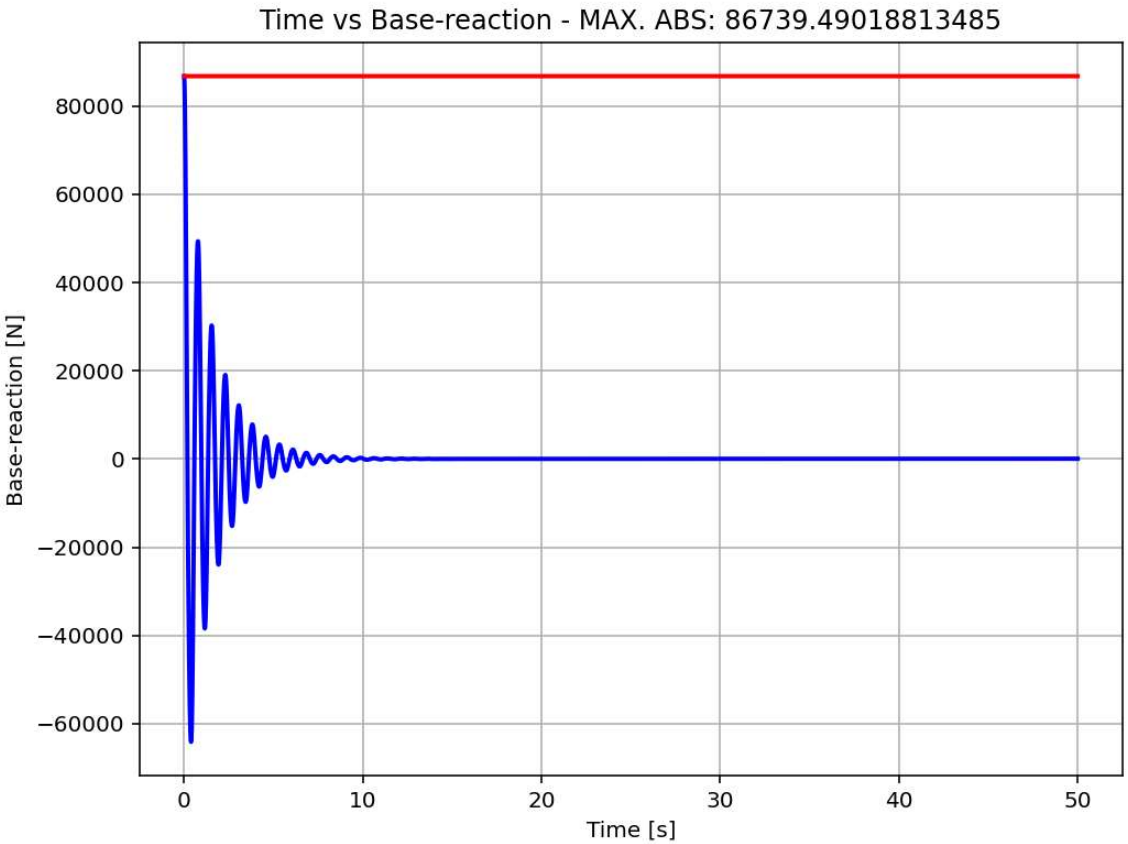

Fragility Curves
Minor Damage Level (η=20.0, β=40.0
Moderate Damage Level (η=40.0, β=40.0
Severe Damage Level (η=60.0, β=50.0
Failure Level (η=100.0, β=50.0
Probability of Exceedance
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Structural Ductility Damage Index (%) [IM]

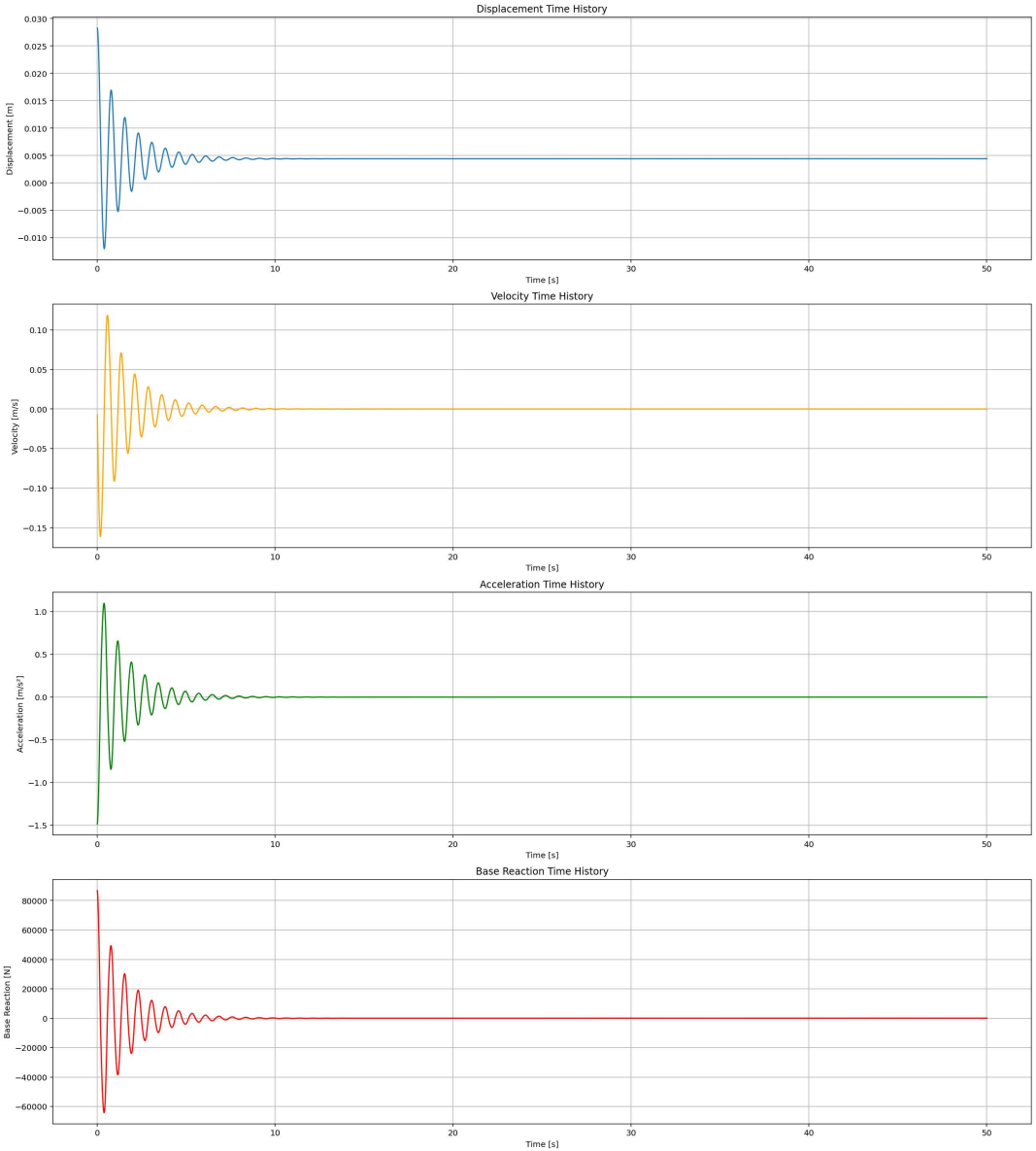

Displacement & Base Reaction Relation From Last Dynamic Analysis
Base Reaction [N]
80000
60000
40000
20000
0
−20000
−40000
−60000
−0.010
−0.005
0.000
0.005
0.010
0.015
0.020
0.025
0.030
Displacement [m]

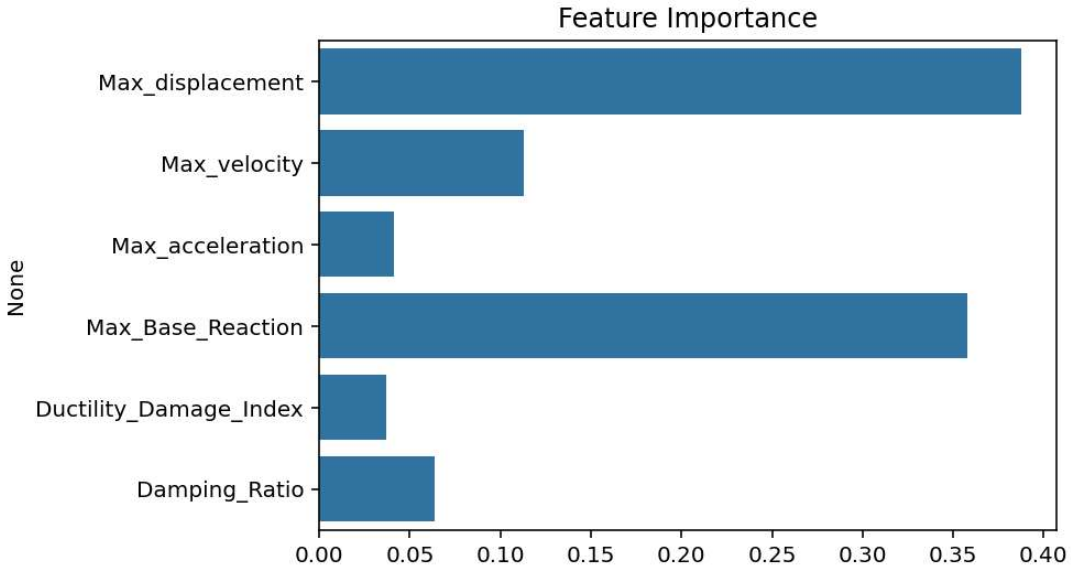

Time vs Displacement - MAX. ABS: 0.02825915009127329
Displacement [m]
0.030
0.025
0.020
0.015
0.010
0.005
0.000
−0.005
−0.010
0
10
20
30
40
50
Time [s]

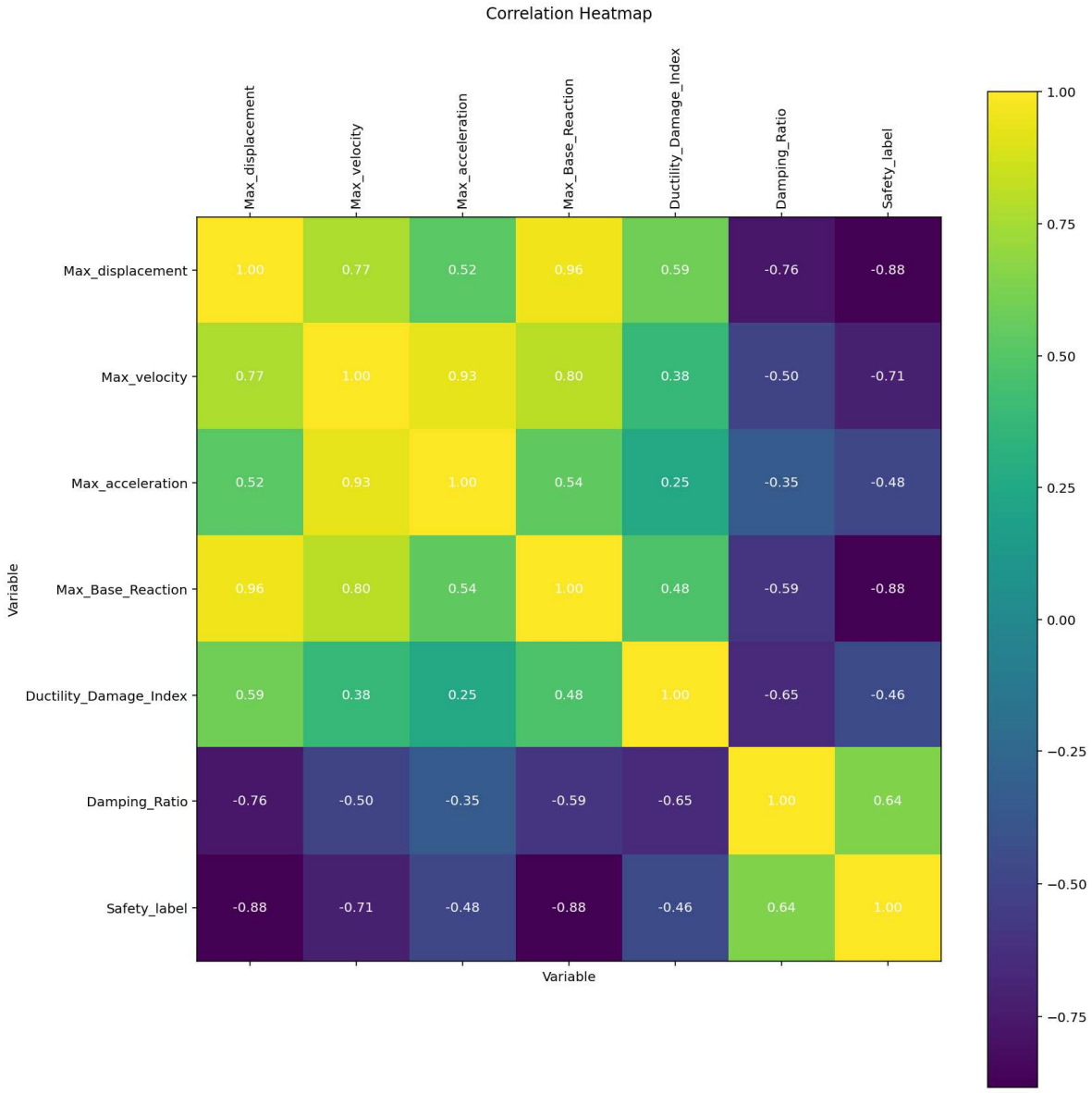

Time vs Velocity - MAX. ABS: 0.16140750618335037
Velocity [m/s]
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
0
10
20
30
40
50
Time [s]


Time vs Acceleration - MAX. ABS: 1.4836648412008664
Acceleration [m/s^2]
Time [s]
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
10
20
30
40
50


Time vs Base-reaction - MAX. ABS: 86739.49018813485
Base-reaction [N]
80000
60000
40000
20000
0
−20000
−40000
−60000
0
10
20
30
40
50
Time [s]


Displacement Time History
Displacement [m]
0.030
0.025
0.020
0.015
0.010
0.005
0.000
−0.005
−0.010
0
10
20
30
40
50
Time [s]
Velocity Time History
Velocity [m/s]
0.10
0.05
0.00
−0.05
−0.10
−0.15
0
10
20
30
40
50
Time [s]
Acceleration Time History
Acceleration [m/s²]
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
10
20
30
40
50
Time [s]
Base Reaction Time History
Base Reaction [N]
80000
60000
40000
20000
0
−20000
−40000
−60000
0
10
20
30
40
50
Time [s]


Feature Importance
Max_displacement
Max_velocity
Max_acceleration
Max_Base_Reaction
Ductility_Damage_Index
Damping_Ratio
None
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40


Correlation Heatmap
Max_displacement
Max_velocity
Max_acceleration
Max_Base_Reaction
Ductility_Damage_Index
Damping_Ratio
Safety_label
Variable
Max_displacement 1.00 0.77 0.52 0.96 0.59 -0.76 -0.88
Max_velocity 0.77 1.00 0.93 0.80 0.38 -0.50 -0.71
Max_acceleration 0.52 0.93 1.00 0.54 0.25 -0.35 -0.48
Max_Base_Reaction 0.96 0.80 0.54 1.00 0.48 -0.59 -0.88
Ductility_Damage_Index 0.59 0.38 0.25 0.48 1.00 -0.65 -0.46
Damping_Ratio -0.76 -0.50 -0.35 -0.59 -0.65 1.00 0.64
Safety_label -0.88 -0.71 -0.48 -0.88 -0.46 0.64 1.00
Variable
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75