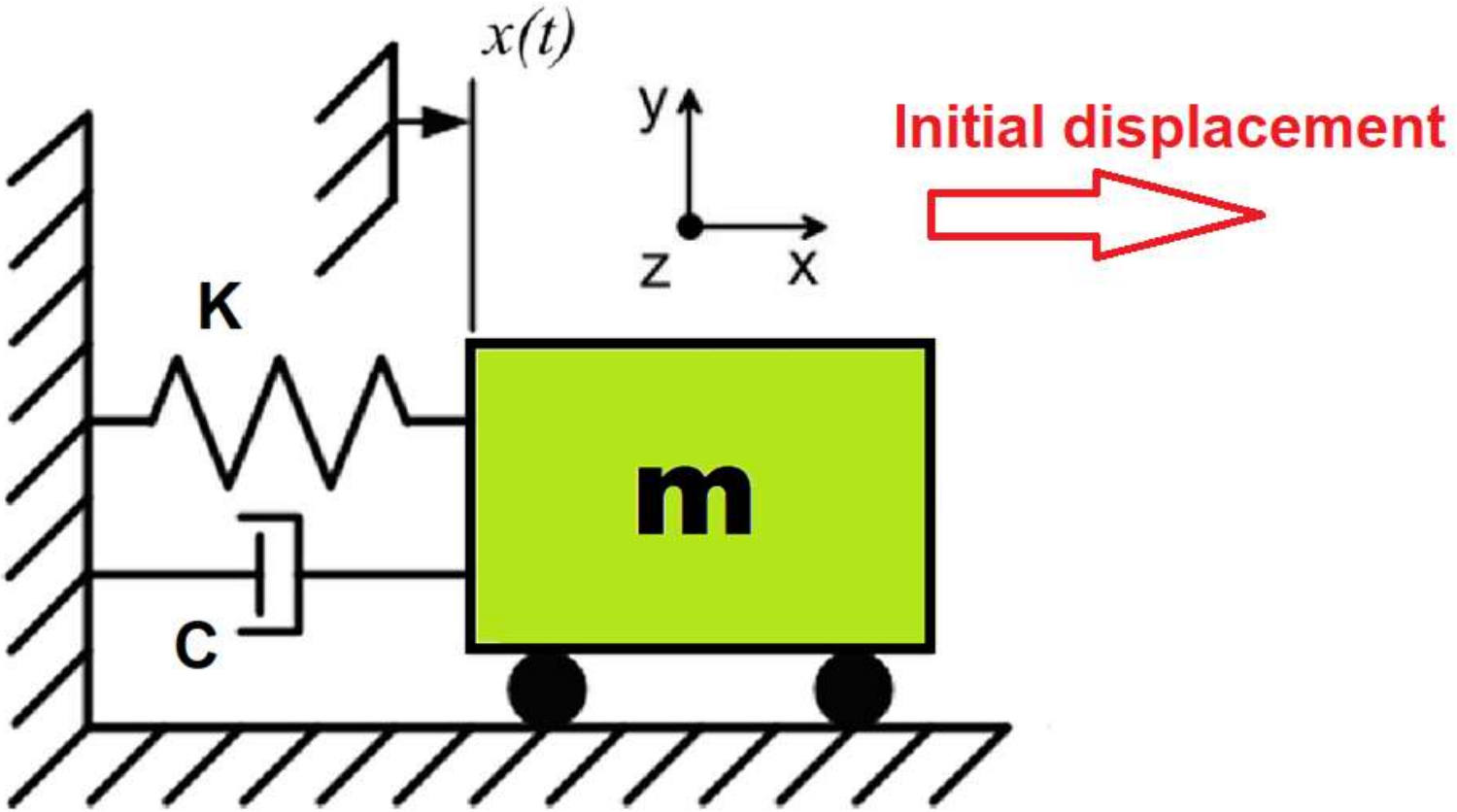
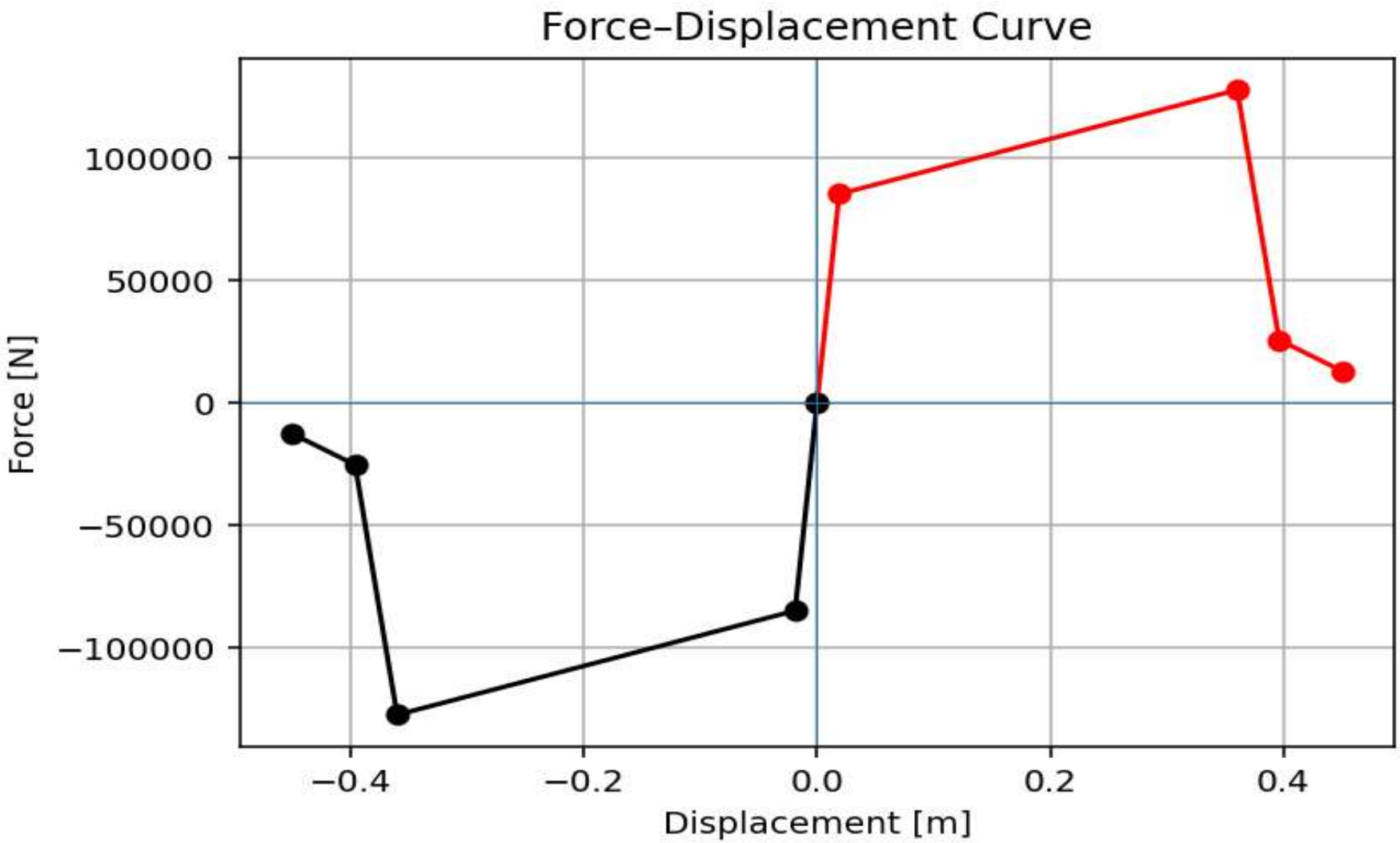
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

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

(PARALLEL COMPUTING METHOD)

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


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

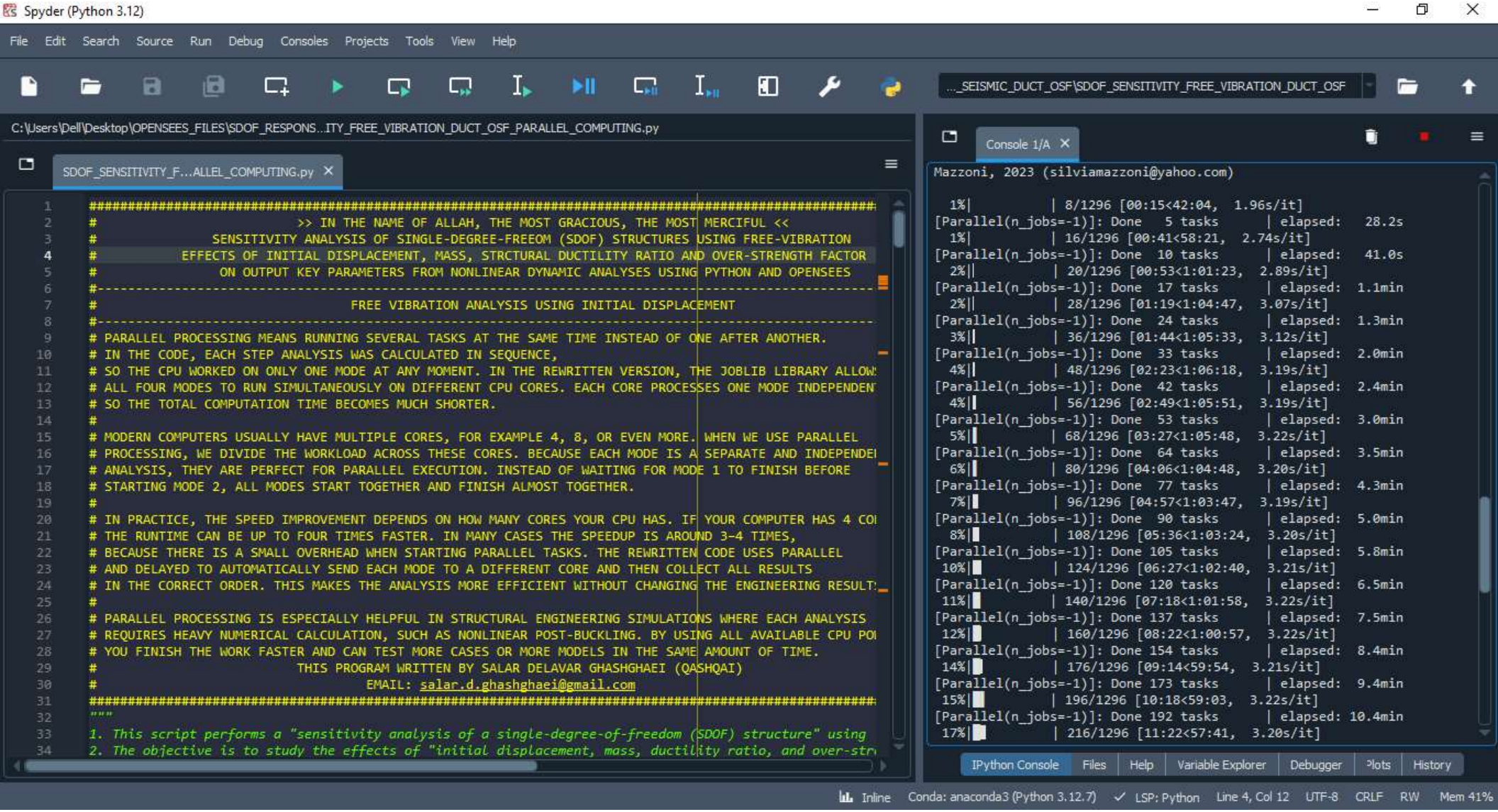

Force–Displacement Curve
100000
50000
0
−50000
−100000
Force [N]
−0.4
−0.2
0.0
0.2
0.4
Displacement [m]

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

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

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

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


Spyder (Python 3.12)
File Edit Search Source Run Debug Consoles Projects Tools View Help
C:\Users\Dell\Desktop\OPENSEES_FILES\SDOF_RESPONS...ITY_FREE_VIBRATION_DUCT_OSF_PARALLEL_COMPUTING.py
SDOF_SENSITIVITY_F...ALLEL_COMPUTING.py
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
SENSITIVITY ANALYSIS OF SINGLE-DEGREE-FREEOM (SDOF) STRUCTURES USING FREE-VIBRATION
EFFECTS OF INITIAL 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
PARALLEL PROCESSING MEANS RUNNING SEVERAL TASKS AT THE SAME TIME INSTEAD OF ONE AFTER ANOTHER.
IN THE CODE, EACH STEP ANALYSIS WAS CALCULATED IN SEQUENCE,
SO THE CPU WORKED ON ONLY ONE MODE AT ANY MOMENT. IN THE REWRITTEN VERSION, THE JOBLIB LIBRARY ALLOW
ALL FOUR MODES TO RUN SIMULTANEOUSLY ON DIFFERENT CPU CORES. EACH CORE PROCESSES ONE MODE INDEPENDEN
SO THE TOTAL COMPUTATION TIME BECOMES MUCH SHORTER.
MODERN COMPUTERS USUALLY HAVE MULTIPLE CORES, FOR EXAMPLE 4, 8, OR EVEN MORE. WHEN WE USE PARALLEL
PROCESSING, WE DIVIDE THE WORKLOAD ACROSS THESE CORES. BECAUSE EACH MODE IS A SEPARATE AND INDEPENDE
ANALYSIS, THEY ARE PERFECT FOR PARALLEL EXECUTION. INSTEAD OF WAITING FOR MODE 1 TO FINISH BEFORE
STARTING MODE 2, ALL MODES START TOGETHER AND FINISH ALMOST TOGETHER.
IN PRACTICE, THE SPEED IMPROVEMENT DEPENDS ON HOW MANY CORES YOUR CPU HAS. IF YOUR COMPUTER HAS 4 CO
THE RUNTIME CAN BE UP TO FOUR TIMES FASTER. IN MANY CASES THE SPEEDUP IS AROUND 3-4 TIMES,
BECAUSE THERE IS A SMALL OVERHEAD WHEN STARTING PARALLEL TASKS. THE REWRITTEN CODE USES PARALLEL
AND DELAYED TO AUTOMATICALLY SEND EACH MODE TO A DIFFERENT CORE AND THEN COLLECT ALL RESULTS
IN THE CORRECT ORDER. THIS MAKES THE ANALYSIS MORE EFFICIENT WITHOUT CHANGING THE ENGINEERING RESULT
PARALLEL PROCESSING IS ESPECIALLY HELPFUL IN STRUCTURAL ENGINEERING SIMULATIONS WHERE EACH ANALYSIS
REQUIRES HEAVY NUMERICAL CALCULATION, SUCH AS NONLINEAR POST-BUCKLING. BY USING ALL AVAILABLE CPU PO
YOU FINISH THE WORK FASTER AND CAN TEST MORE CASES OR MORE MODELS IN THE SAME AMOUNT OF TIME.
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
Console 1/A
Mazzoni, 2023 (silviamazzoni@yahoo.com)
1%| | 8/1296 [00:15<42:04, 1.96s/it]
[Parallel(n_jobs=-1)]: Done 5 tasks | elapsed: 28.2s
1%| | 16/1296 [00:41<58:21, 2.74s/it]
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 41.0s
2%| | 20/1296 [00:53<1:01:23, 2.89s/it]
[Parallel(n_jobs=-1)]: Done 17 tasks | elapsed: 1.1min
2%| | 28/1296 [01:19<1:04:47, 3.07s/it]
[Parallel(n_jobs=-1)]: Done 24 tasks | elapsed: 1.3min
3%| | 36/1296 [01:44<1:05:33, 3.12s/it]
[Parallel(n_jobs=-1)]: Done 33 tasks | elapsed: 2.0min
4%| | 48/1296 [02:23<1:06:18, 3.19s/it]
[Parallel(n_jobs=-1)]: Done 42 tasks | elapsed: 2.4min
4%| | 56/1296 [02:49<1:05:51, 3.19s/it]
[Parallel(n_jobs=-1)]: Done 53 tasks | elapsed: 3.0min
5%| | 68/1296 [03:27<1:05:48, 3.22s/it]
[Parallel(n_jobs=-1)]: Done 64 tasks | elapsed: 3.5min
6%| | 80/1296 [04:06<1:04:48, 3.20s/it]
[Parallel(n_jobs=-1)]: Done 77 tasks | elapsed: 4.3min
7%| | 96/1296 [04:57<1:03:47, 3.19s/it]
[Parallel(n_jobs=-1)]: Done 90 tasks | elapsed: 5.0min
8%| | 108/1296 [05:36<1:03:24, 3.20s/it]
[Parallel(n_jobs=-1)]: Done 105 tasks | elapsed: 5.8min
10%| | 124/1296 [06:27<1:02:40, 3.21s/it]
[Parallel(n_jobs=-1)]: Done 120 tasks | elapsed: 6.5min
11%| | 140/1296 [07:18<1:01:58, 3.22s/it]
[Parallel(n_jobs=-1)]: Done 137 tasks | elapsed: 7.5min
12%| | 160/1296 [08:22<1:00:57, 3.22s/it]
[Parallel(n_jobs=-1)]: Done 154 tasks | elapsed: 8.4min
14%| | 176/1296 [09:14<59:54, 3.21s/it]
[Parallel(n_jobs=-1)]: Done 173 tasks | elapsed: 9.4min
15%| | 196/1296 [10:18<59:03, 3.22s/it]
[Parallel(n_jobs=-1)]: Done 192 tasks | elapsed: 10.4min
17%| | 216/1296 [11:22<57:41, 3.20s/it]
IPython Console Files Help Variable Explorer Debugger Plots History
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 4, Col 12 UTF-8 CRLF RW Mem 41%

Spyder (Python 3.12)

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

SDOF_SENSITIVITY_F...ALLEL_COMPUTING.py

```
308         }
309
310     # ----------------------  PARALLEL PROCESSING  ----------------------
311     # Analysis Durations:
312     current_time = TI.strftime("%H:%M:%S", TI.localtime())
313     print("Start Time:", current_time)
314
315     # Parallel Execution + Checkpoint
316     if os.path.exists(CHECKPOINT_FILE):
317         print('Loading checkpoint...')
318         with open(CHECKPOINT_FILE, 'rb') as f:
319             results = pickle.load(f)
320     else:
321         print('Running parallel simulations...')
322         results = Parallel(
323             n_jobs=-1,
324             backend='loky',
325             verbose=10
326         )(
327             delayed(RUN_SIMULATION)(*case)
328             for case in tqdm(cases)
329         )
330
331         with open(CHECKPOINT_FILE, 'wb') as f:
332             pickle.dump(results, f)
333
334     df = pd.DataFrame(results)
335     print(df.head())
336
337     current_time = TI.strftime("%H:%M:%S", TI.localtime())
338     print("Finish Time:", current_time)
339     #%%-------------------------------------------------------------------------
340     def PLOT_3D_CONTOUR_XYZ(TAG, X, Y, Z, XLABEL, YLABEL, ZLABEL):
341         import numpy as np
```

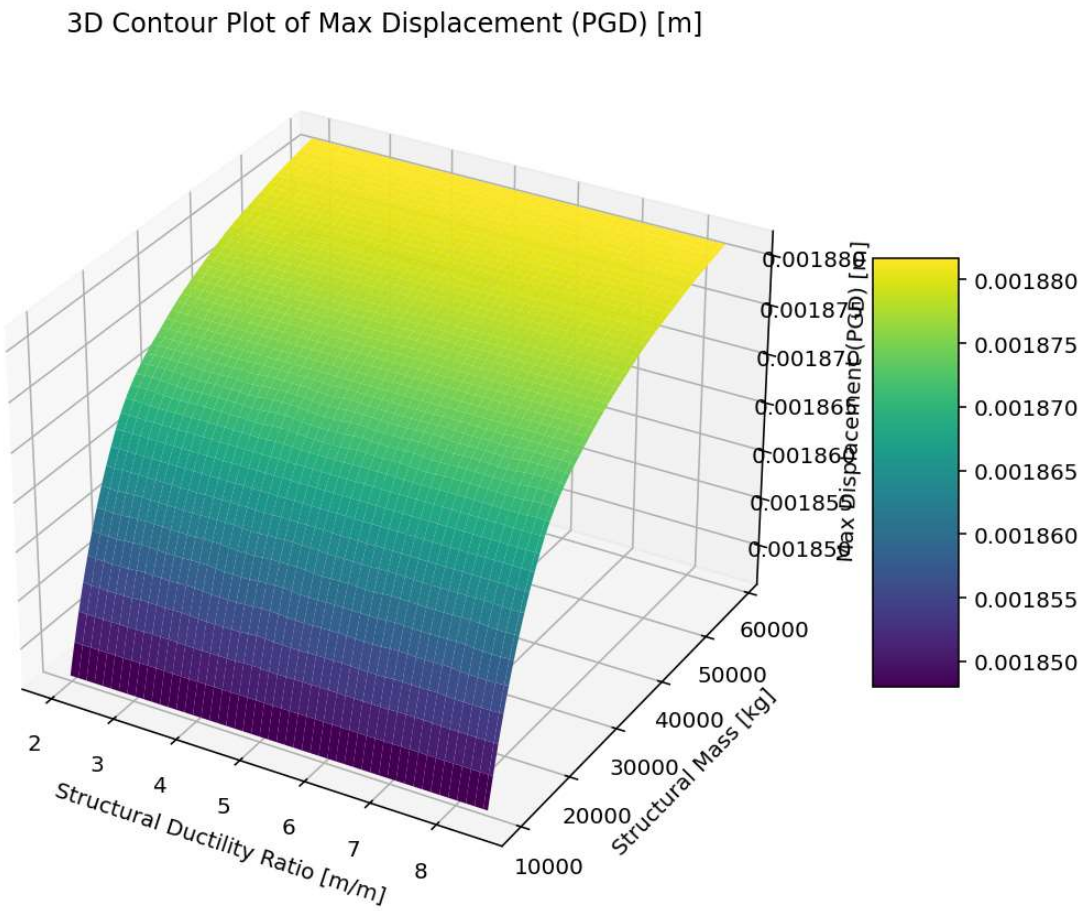
...SEISMIC_DUCT_OSF\SDOF_SENSITIVITY_FREE_VIBRATION_DUCT_OSF

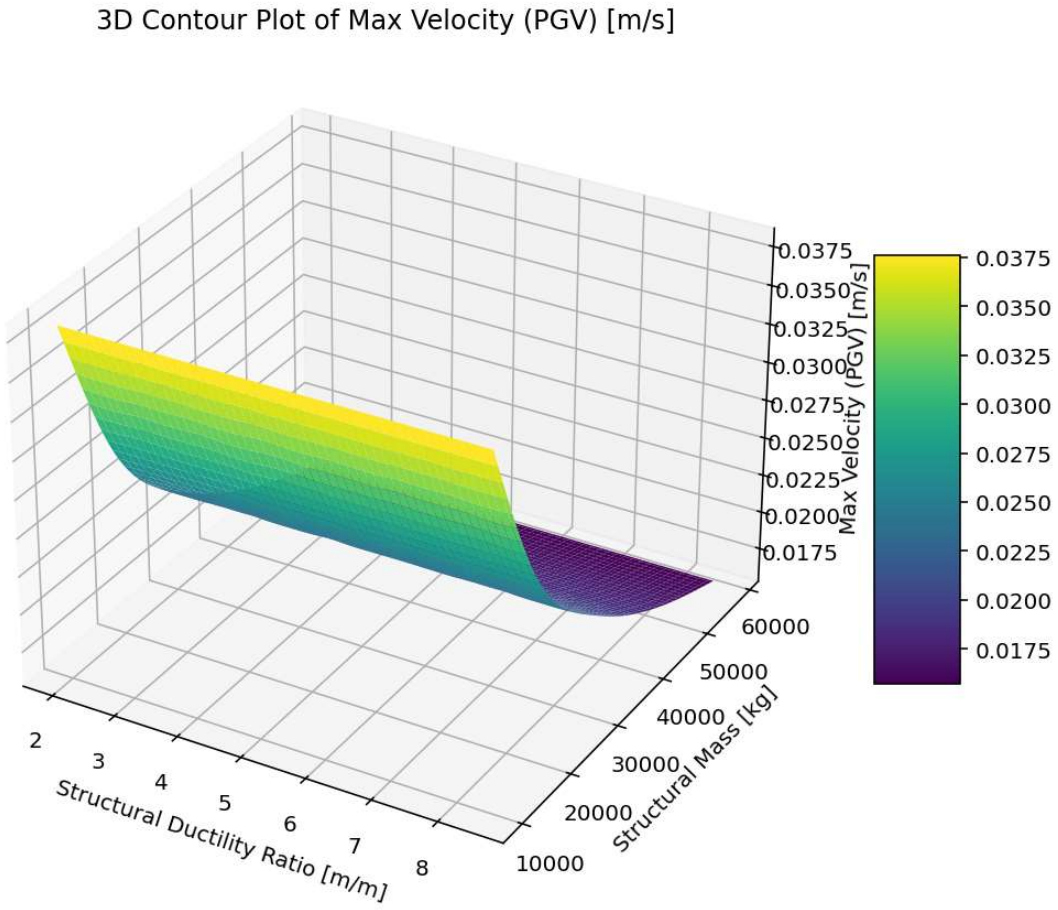
Console 1/A

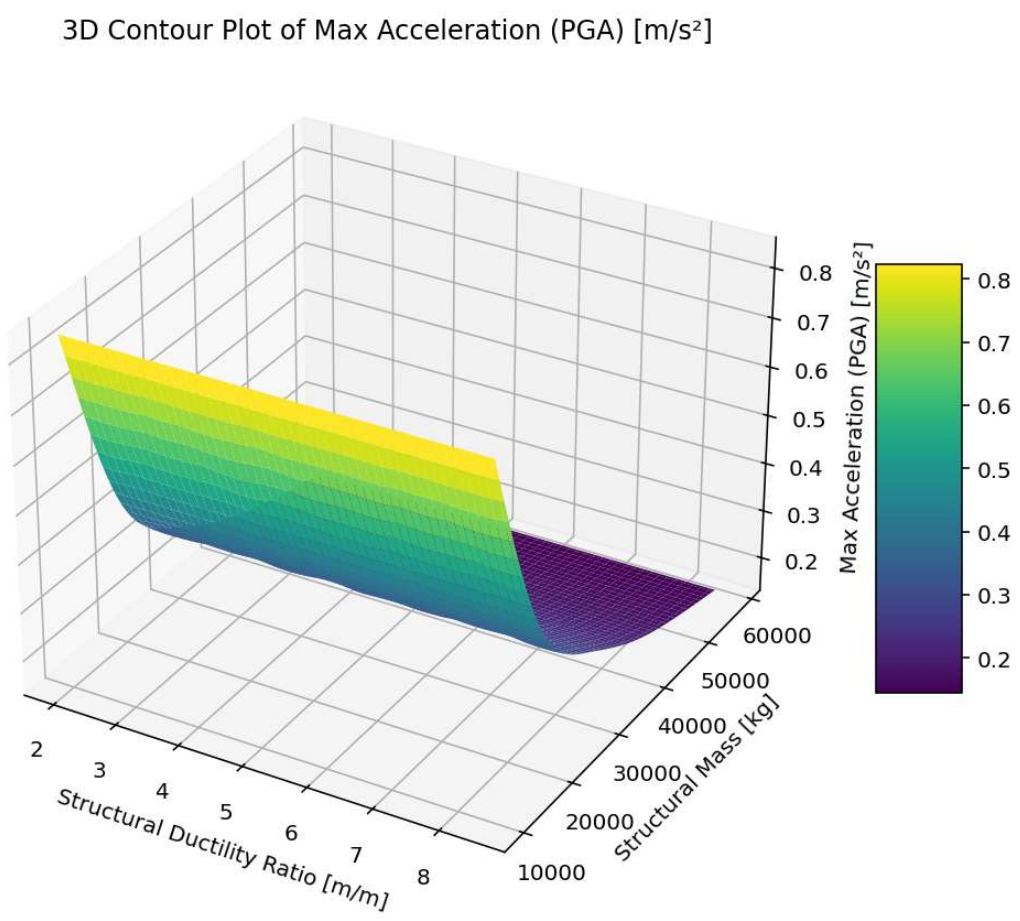
```
  6%|▌         | 80/1296 [04:06<1:04:48,  3.20s/it]
[Parallel(n_jobs=-1)]: Done  77 tasks      | elapsed:  4.3min
  7%|▋         | 96/1296 [04:57<1:03:47,  3.19s/it]
[Parallel(n_jobs=-1)]: Done  90 tasks      | elapsed:  5.0min
  8%|▊         | 108/1296 [05:36<1:03:24,  3.20s/it]
[Parallel(n_jobs=-1)]: Done 105 tasks      | elapsed:  5.8min
 10%|▉         | 124/1296 [06:27<1:02:40,  3.21s/it]
[Parallel(n_jobs=-1)]: Done 120 tasks      | elapsed:  6.5min
 11%|█         | 140/1296 [07:18<1:01:58,  3.22s/it]
[Parallel(n_jobs=-1)]: Done 137 tasks      | elapsed:  7.5min
 12%|█▏        | 160/1296 [08:22<1:00:57,  3.22s/it]
[Parallel(n_jobs=-1)]: Done 154 tasks      | elapsed:  8.4min
 14%|█▎        | 176/1296 [09:14<59:54,  3.21s/it]
[Parallel(n_jobs=-1)]: Done 173 tasks      | elapsed:  9.4min
 15%|█▍        | 196/1296 [10:18<59:03,  3.22s/it]
[Parallel(n_jobs=-1)]: Done 192 tasks      | elapsed: 10.4min
 17%|█▋        | 216/1296 [11:22<57:41,  3.20s/it]
[Parallel(n_jobs=-1)]: Done 213 tasks      | elapsed: 11.6min
 19%|█▊        | 240/1296 [12:38<55:48,  3.17s/it]
[Parallel(n_jobs=-1)]: Done 234 tasks      | elapsed: 12.7min
 20%|██        | 260/1296 [13:41<54:42,  3.17s/it]
[Parallel(n_jobs=-1)]: Done 257 tasks      | elapsed: 13.9min
 22%|██▏       | 284/1296 [15:01<56:02,  3.32s/it]
[Parallel(n_jobs=-1)]: Done 280 tasks      | elapsed: 15.1min
 24%|██▍       | 308/1296 [16:23<56:10,  3.41s/it]
[Parallel(n_jobs=-1)]: Done 305 tasks      | elapsed: 16.6min
 26%|██▌       | 336/1296 [17:59<55:02,  3.44s/it]
[Parallel(n_jobs=-1)]: Done 330 tasks      | elapsed: 18.0min
 28%|██▊       | 360/1296 [19:22<53:43,  3.44s/it]
[Parallel(n_jobs=-1)]: Done 357 tasks      | elapsed: 19.6min
 29%|██▉       | 376/1296 [20:17<53:22,  3.48s/it]
```

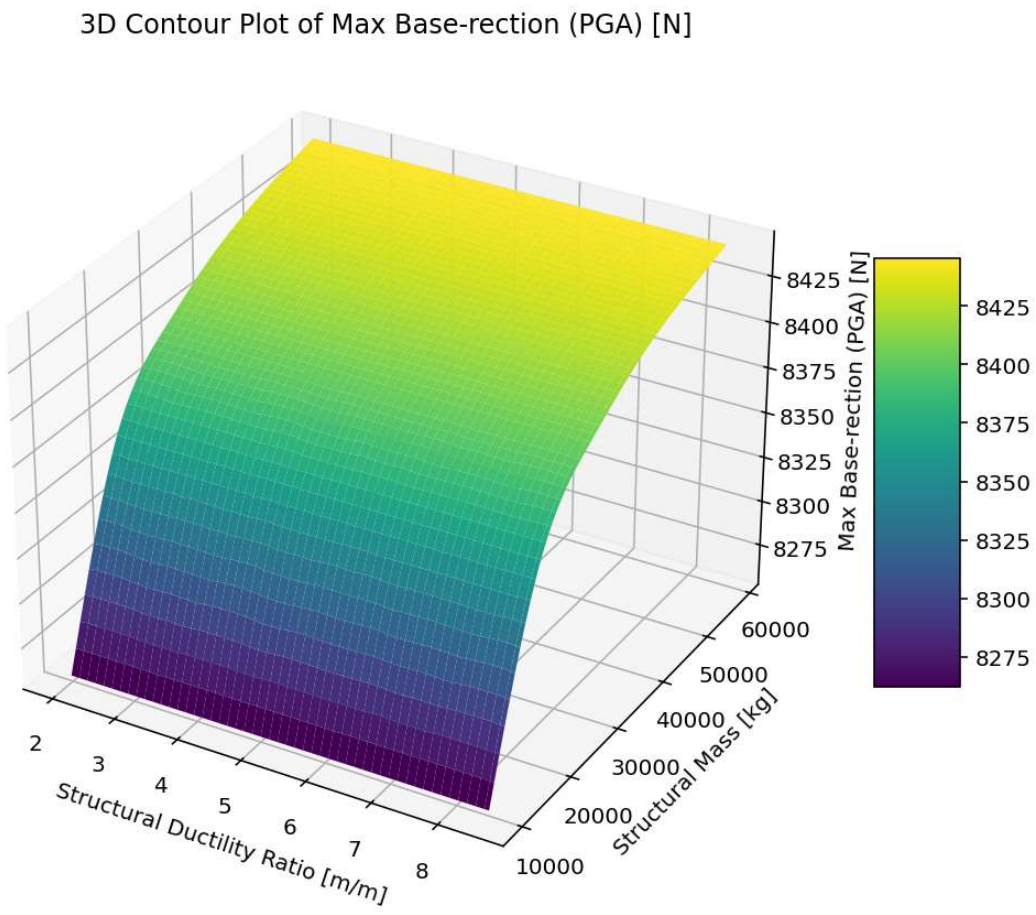
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

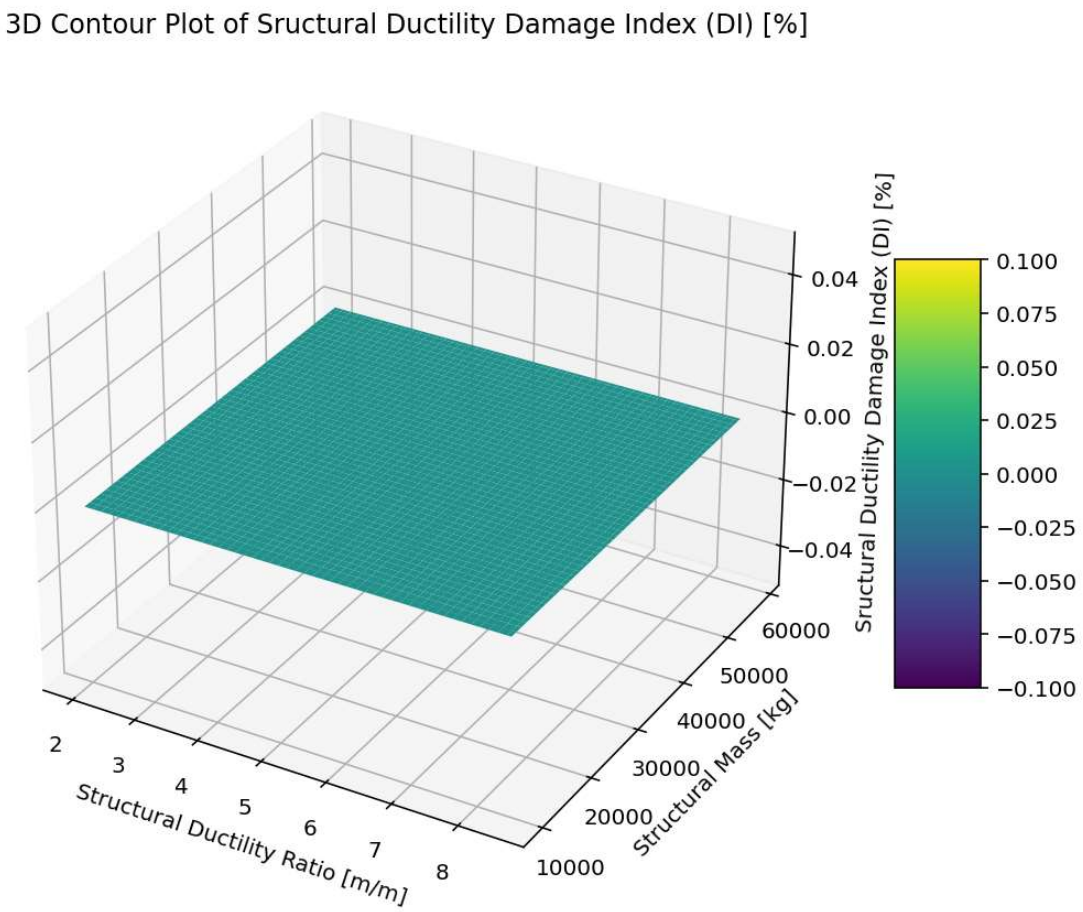
Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 4, Col 12 | UTF-8 | CRLF | RW | Mem 42%

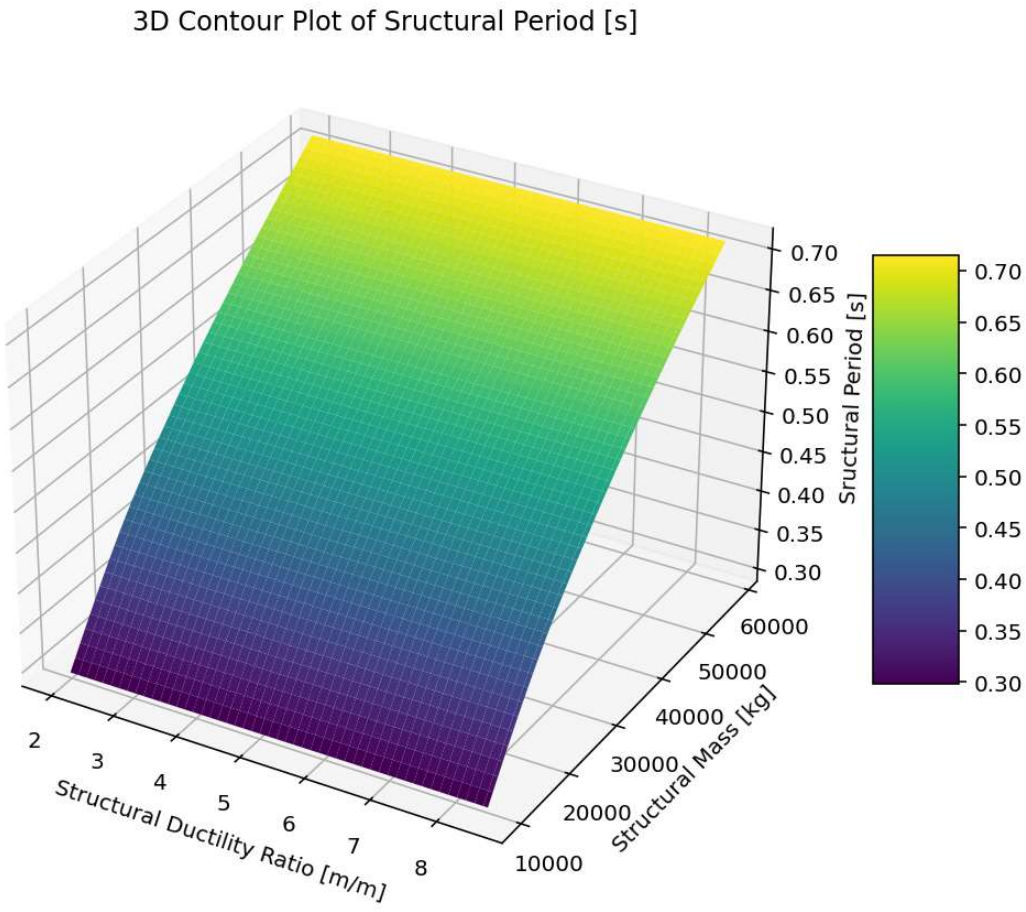

3D Contour Plot of Max Displacement (PGD) [m]
Structural Ductility Ratio [m/m]
Structural Mass [kg]
Max Displacement (PGD) [m]
2
3
4
5
6
7
8
10000
20000
30000
40000
50000
60000
0.001850
0.001855
0.001860
0.001865
0.001870
0.001875
0.001880

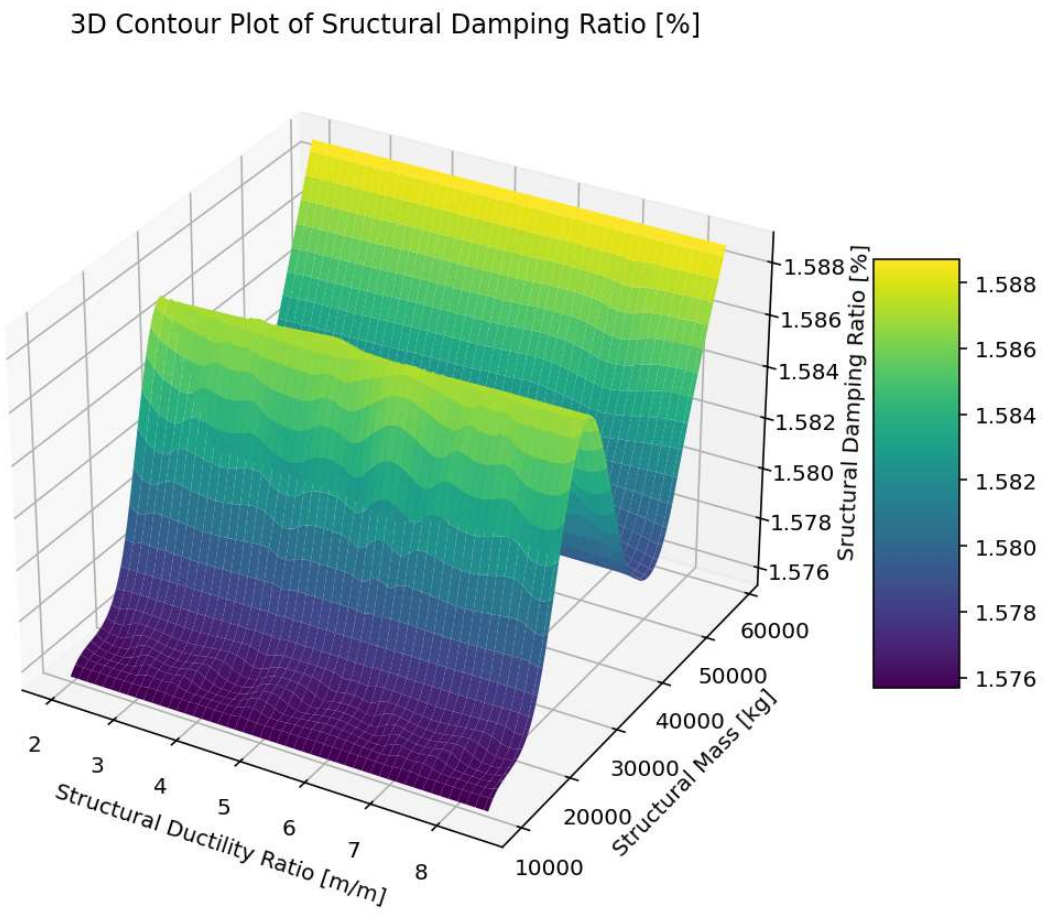

3D Contour Plot of Max Velocity (PGV) [m/s]
Max Velocity (PGV) [m/s]
0.0375
0.0350
0.0325
0.0300
0.0275
0.0250
0.0225
0.0200
0.0175
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Structural Mass [kg]
10000
20000
30000
40000
50000
60000

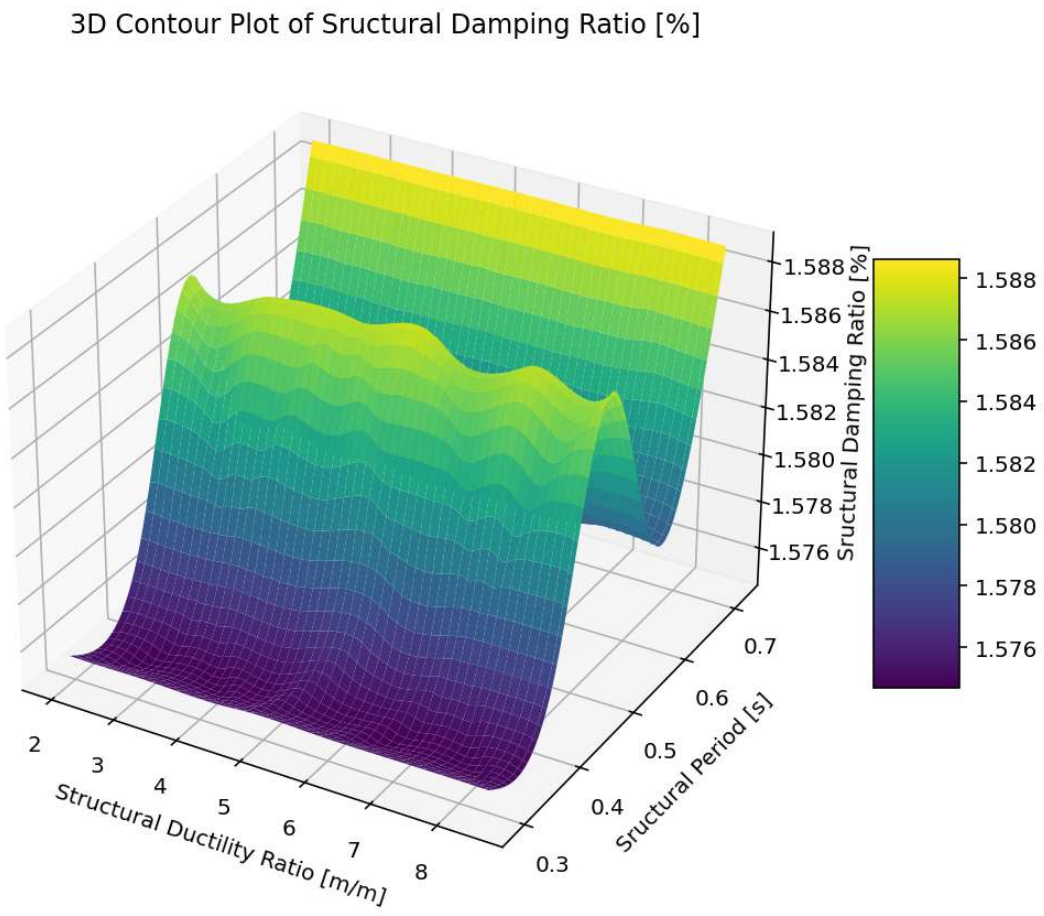

3D Contour Plot of Max Acceleration (PGA) [m/s²]
Structural Ductility Ratio [m/m]
Structural Mass [kg]
Max Acceleration (PGA) [m/s²]
2
3
4
5
6
7
8
10000
20000
30000
40000
50000
60000
0.2
0.3
0.4
0.5
0.6
0.7
0.8

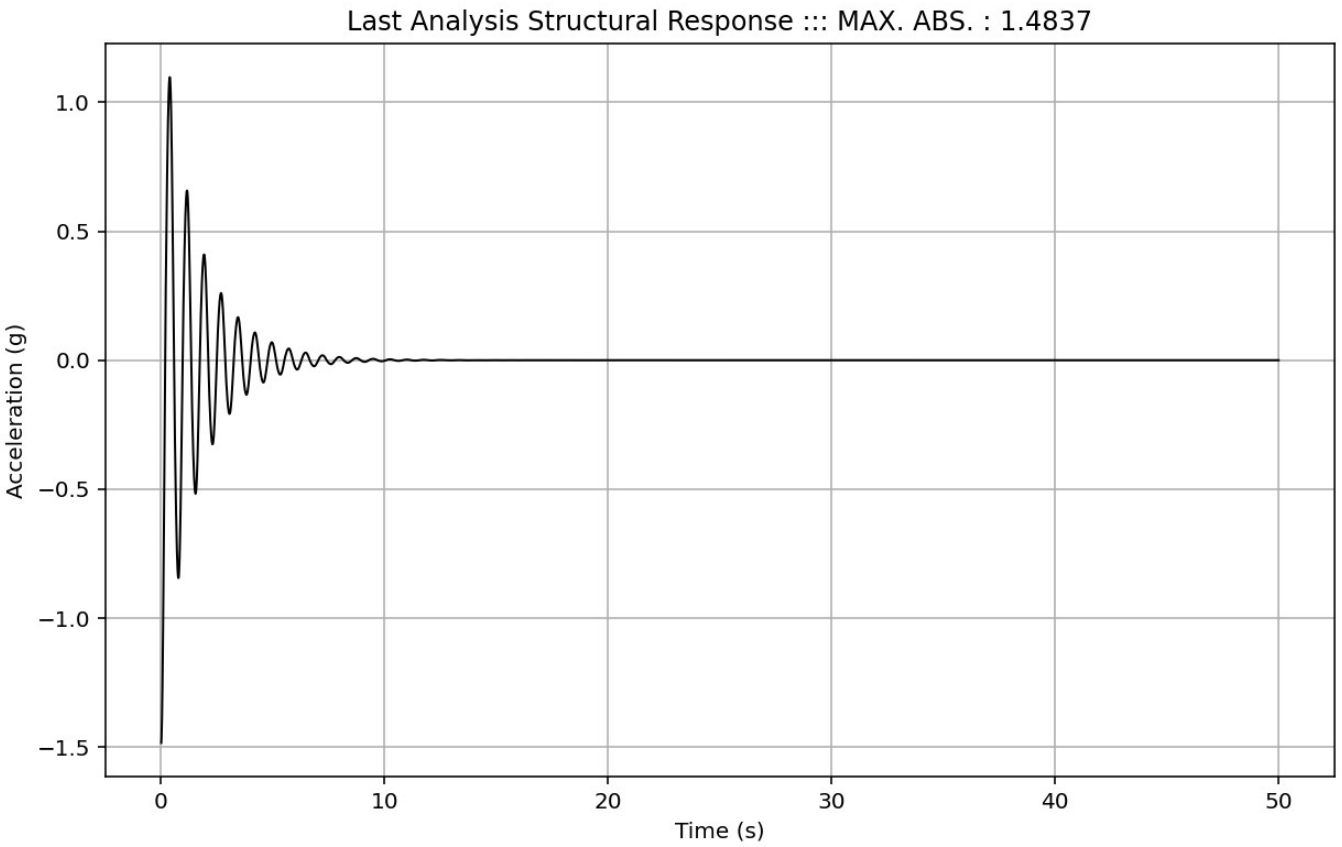

3D Contour Plot of Max Base-rection (PGA) [N]
Structural Ductility Ratio [m/m]
Structural Mass [kg]
Max Base-rection (PGA) [N]
2
3
4
5
6
7
8
10000
20000
30000
40000
50000
60000
8275
8300
8325
8350
8375
8400
8425

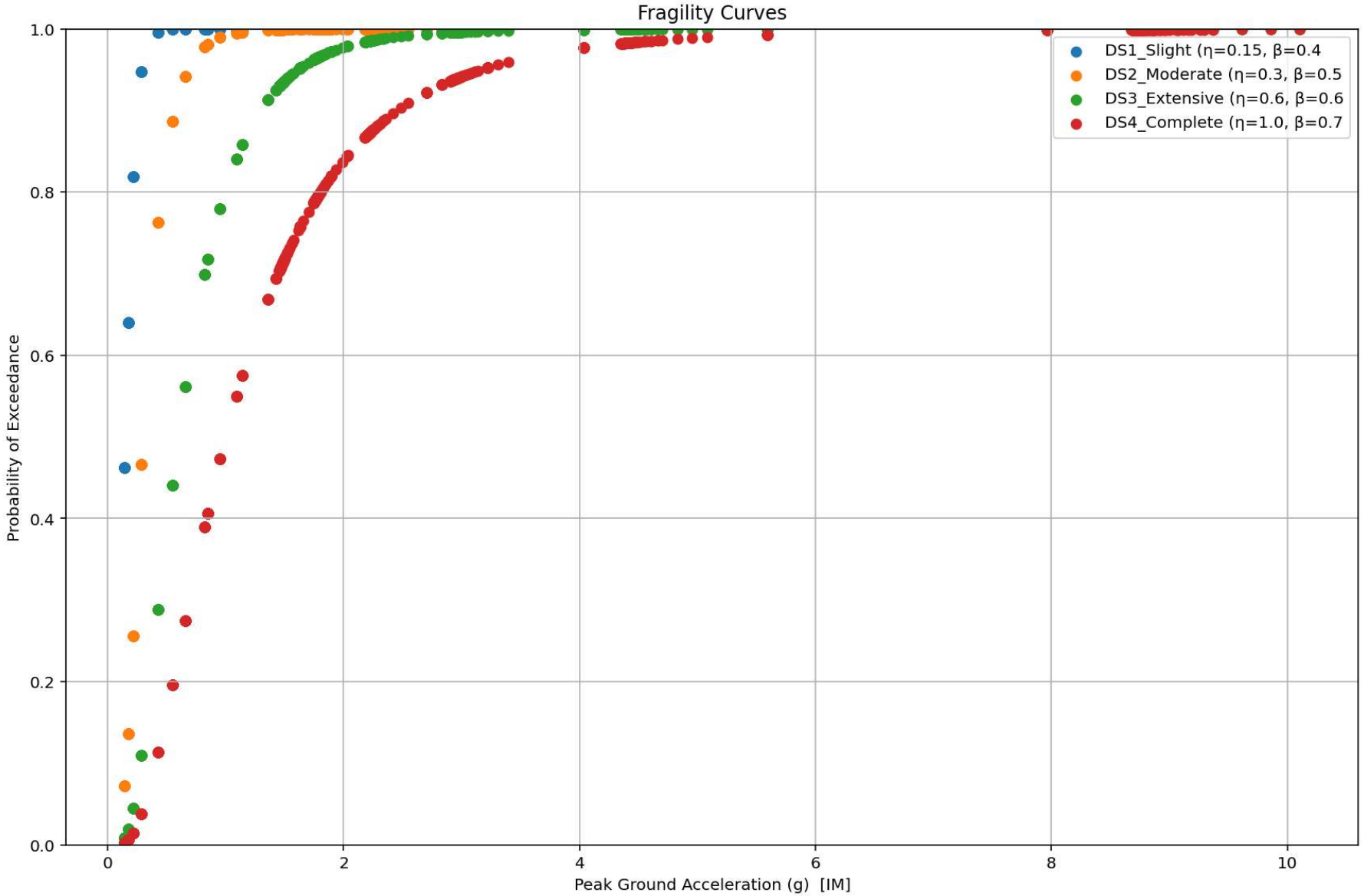

3D Contour Plot of Sructural Ductility Damage Index (DI) [%]
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Structural Mass [kg]
10000
20000
30000
40000
50000
60000
0.04
0.02
0.00
−0.02
−0.04
Sructural Ductility Damage Index (DI) [%]
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100

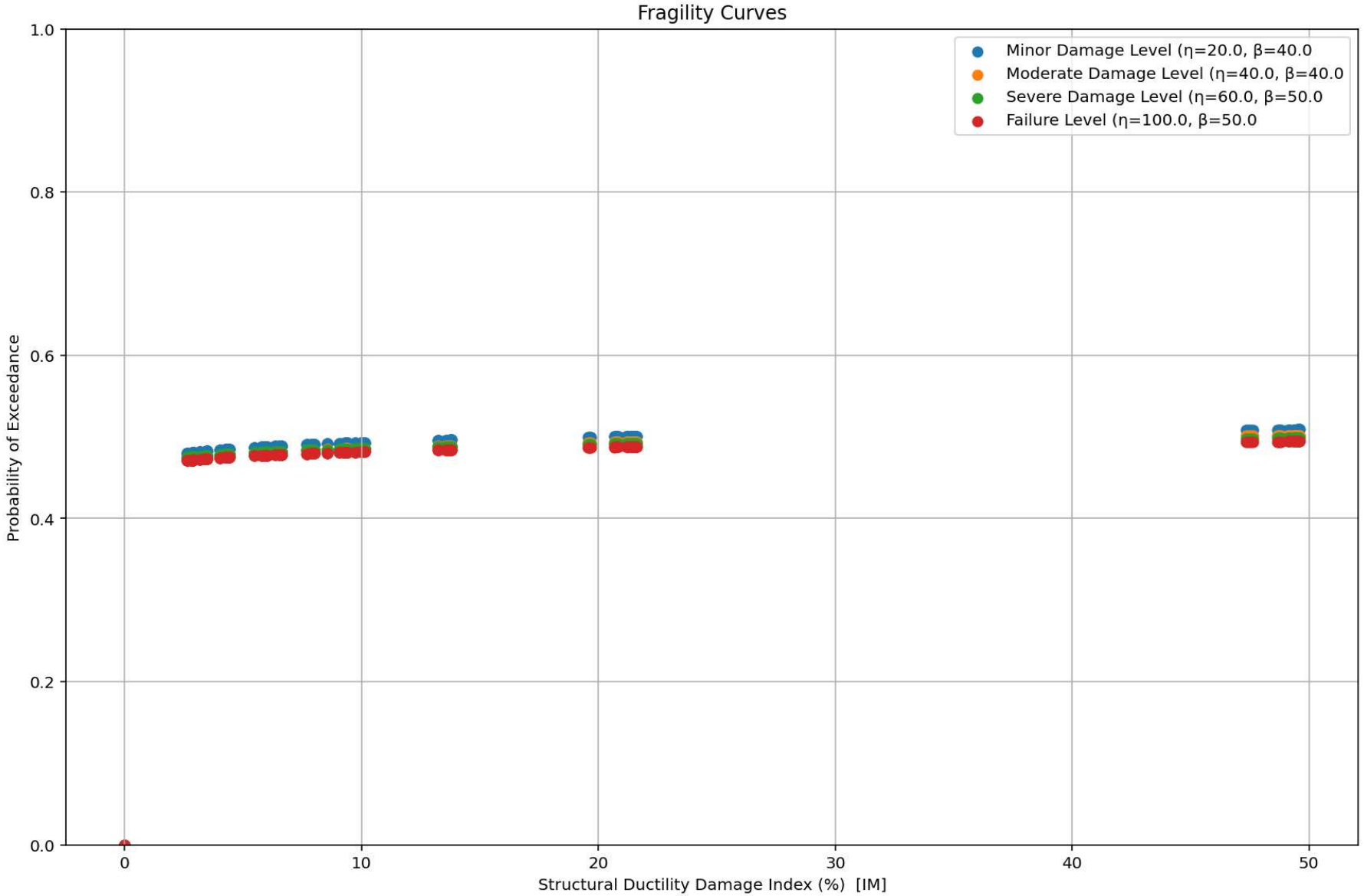

3D Contour Plot of Sructural Period [s]
Structural Ductility Ratio [m/m]
2
3
4
5
6
7
8
Structural Mass [kg]
10000
20000
30000
40000
50000
60000
Sructural Period [s]
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30


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]