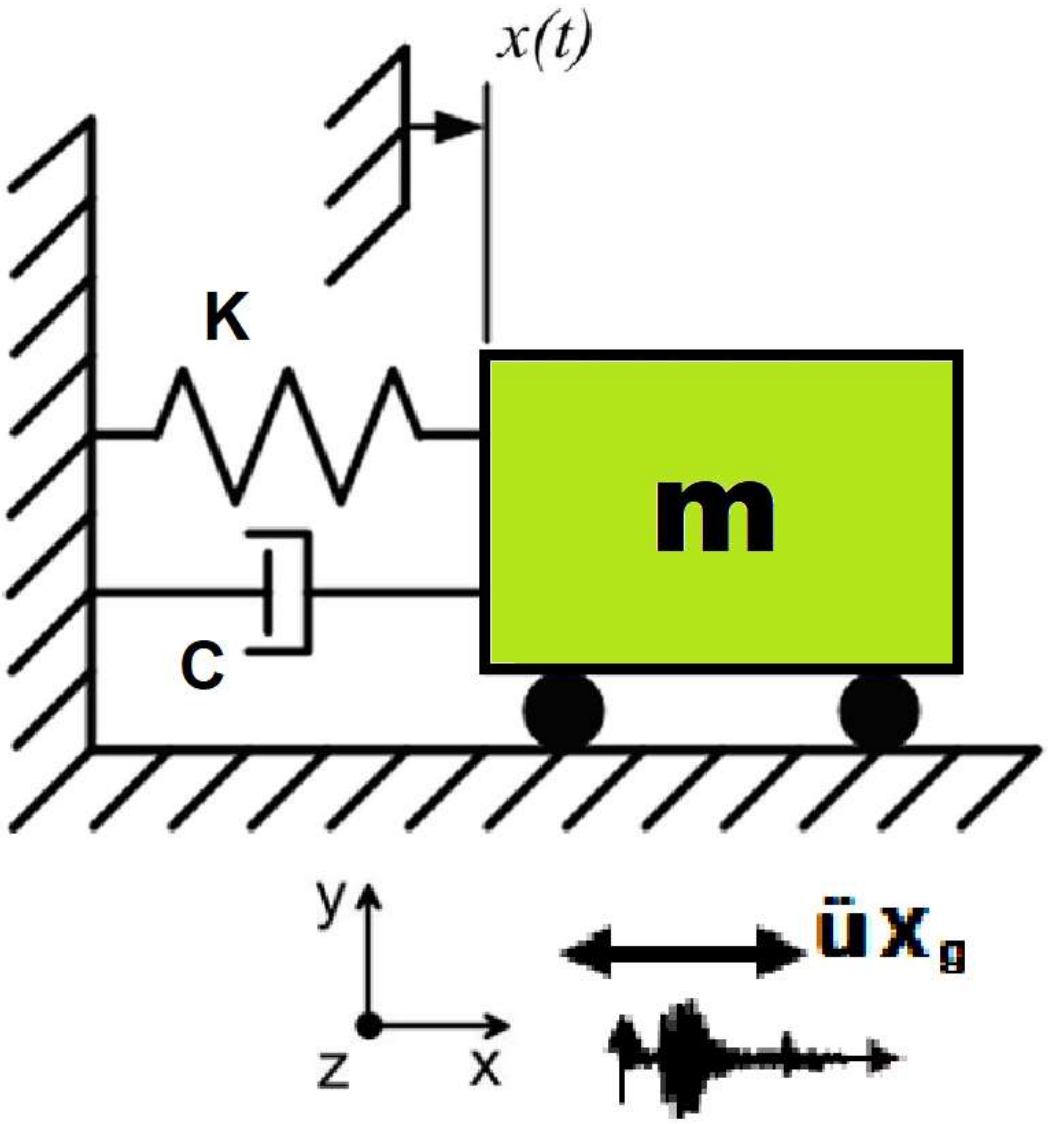
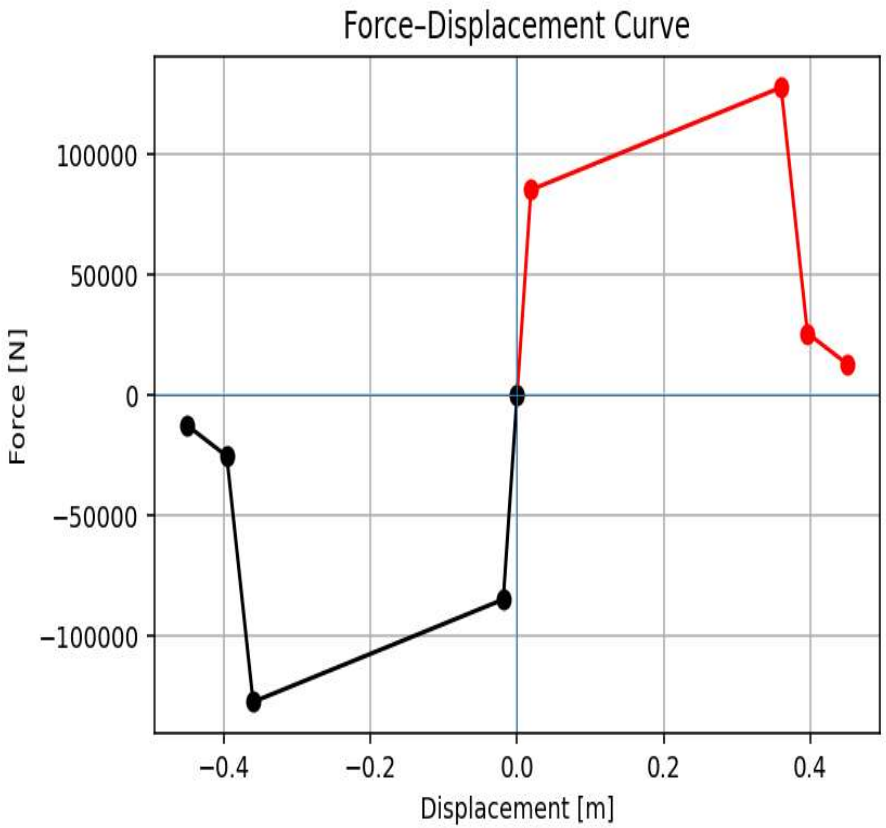
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

FRAGILITY ANALYSIS BASED ON ACCELERATION AND STRUCTURAL DUCTILITY DAMAGE INDEX WITH INCREMENTAL DYNAMIC ANALYSIS (IDA) OF A SINGLE-DEGREE-OF-FREEDOM (SDOF) SYSTEM UTILIZING 100 GROUND MOTIONS IN OPENSEES (PARALLEL COMPUTING VERSION)

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


x(t)
K
m
C
y
z
x
ü x g

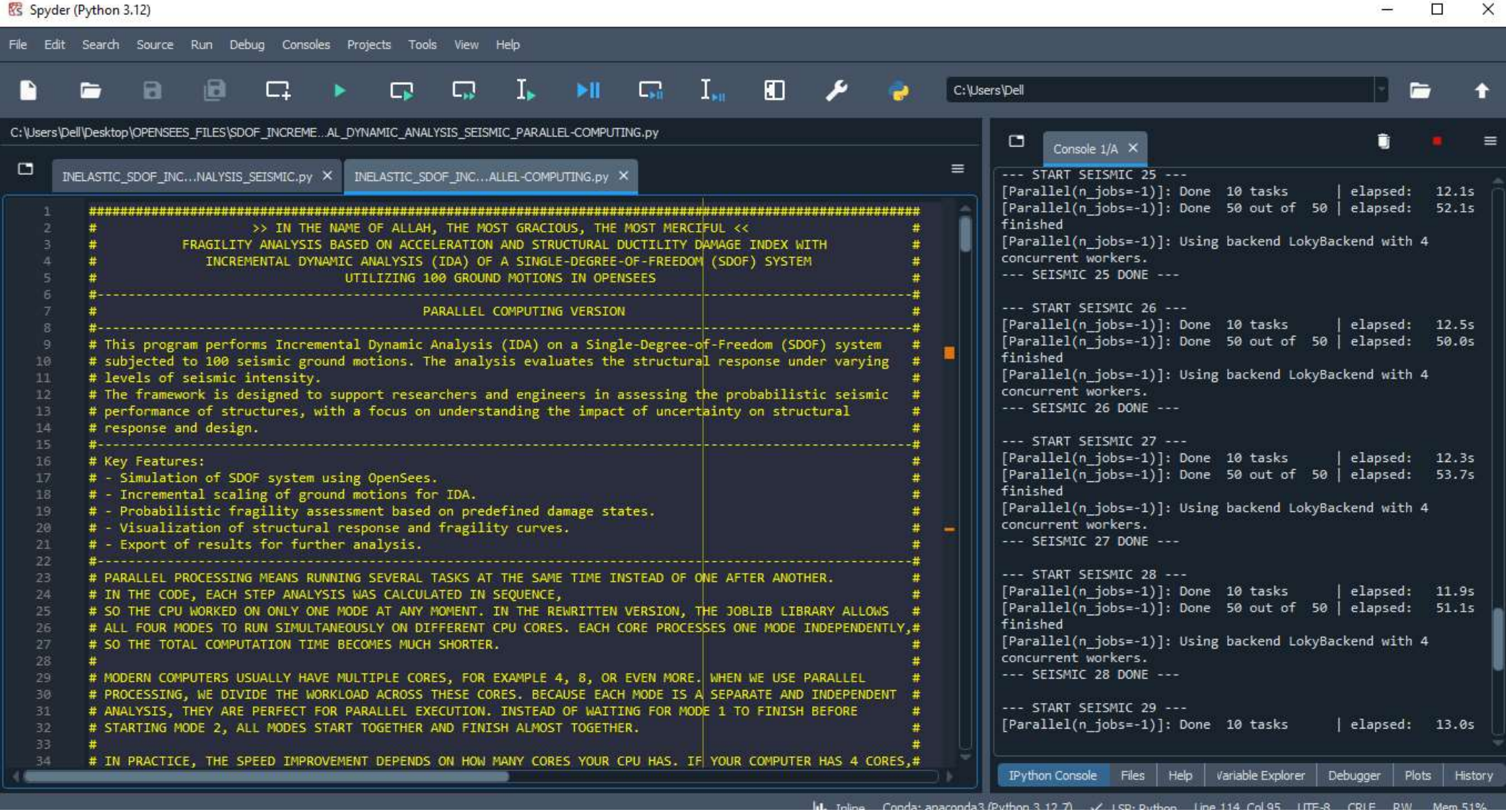

Force–Displacement Curve
Force [N]
Displacement [m]
100000
50000
0
−50000
−100000
−0.4
−0.2
0.0
0.2
0.4

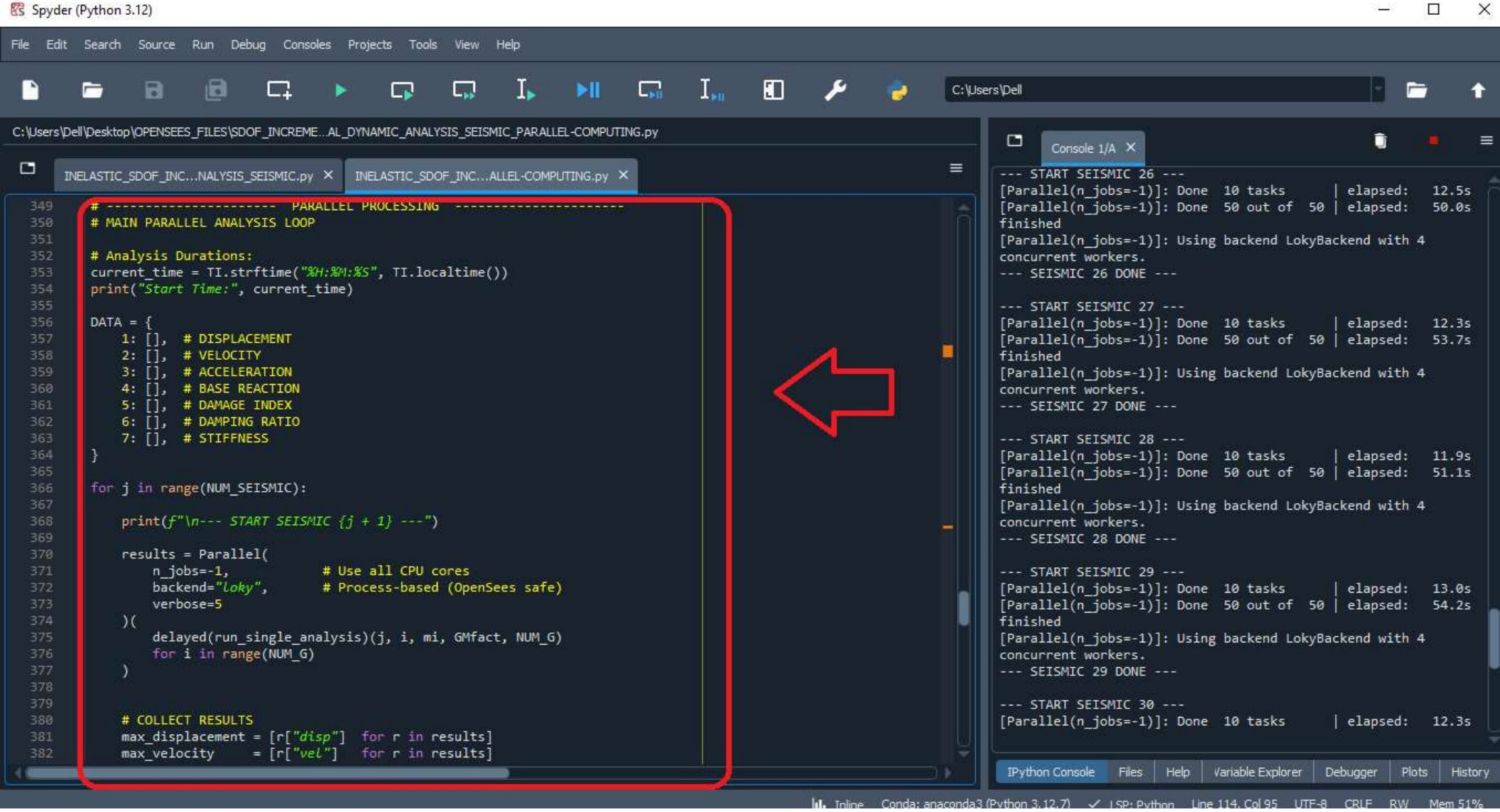
$$Structural\ Ductility\ Damage\ Index = \frac{\Delta_d - \Delta_y}{\Delta_u - \Delta_y}$$

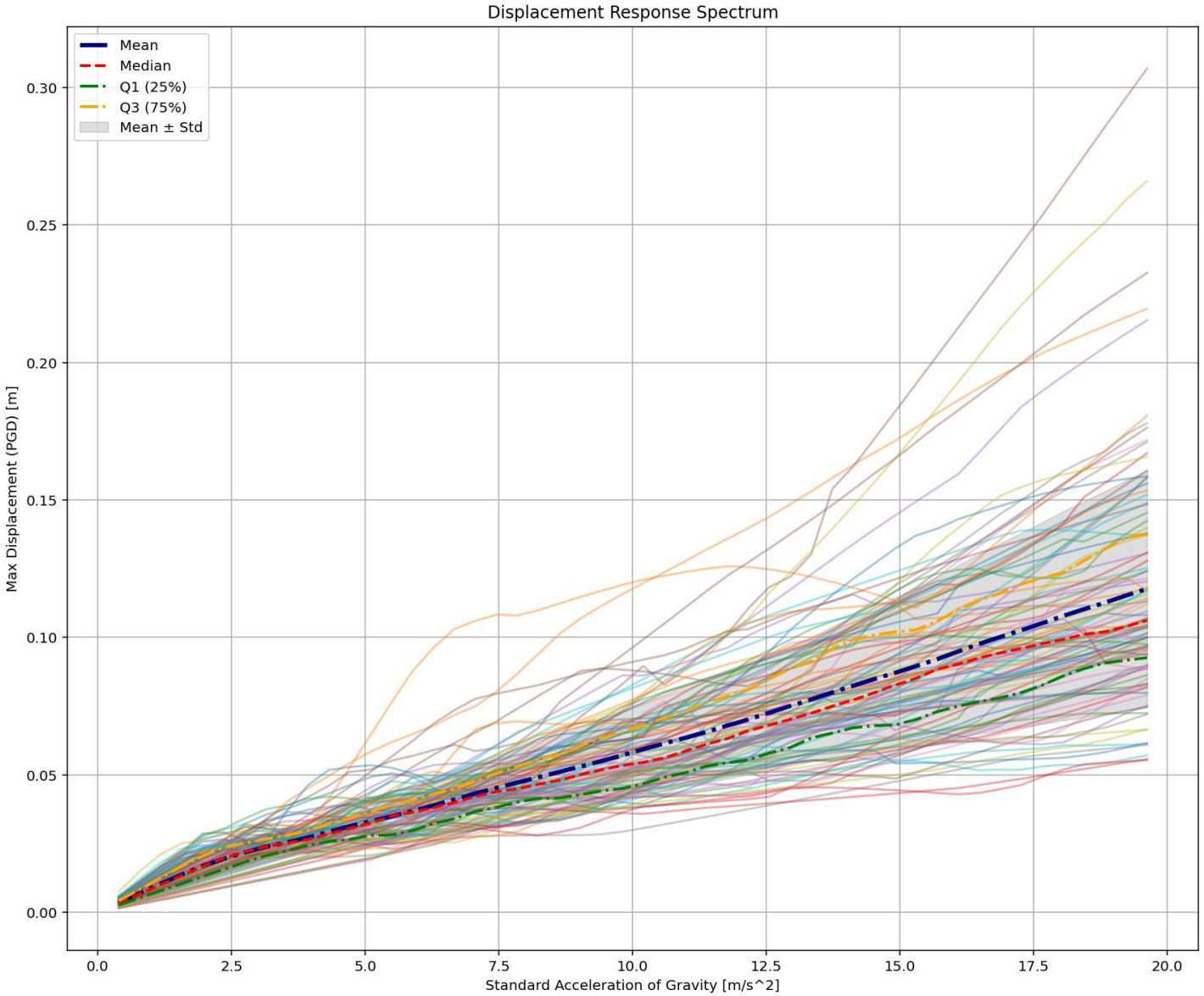
$$\Delta_d = Lateral\ Displaement\ from\ Dynamic\ Analysis$$

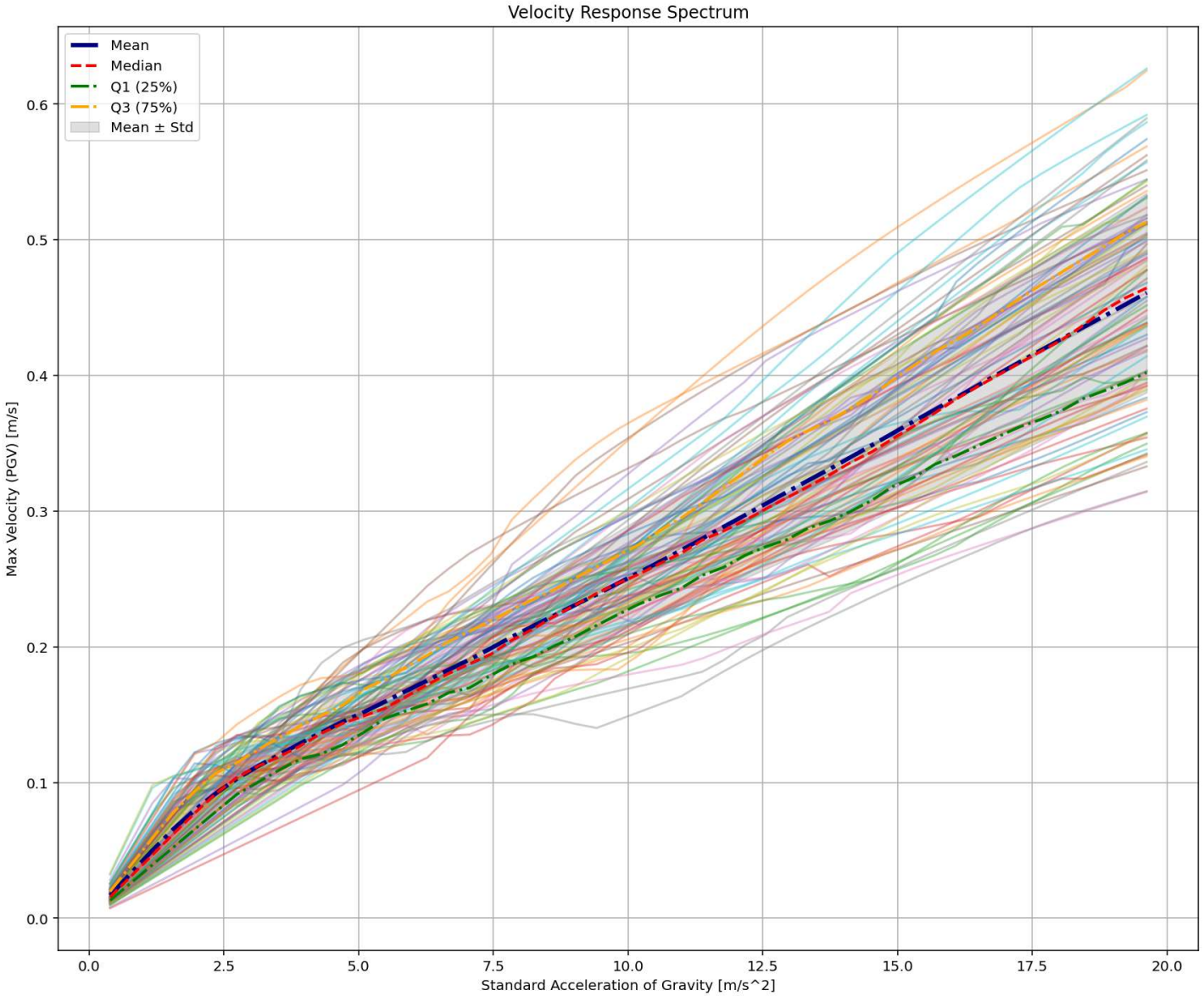
$$\Delta_y = Lateral\ Yield\ Displaement\ from\ Pushover\ Analysis$$

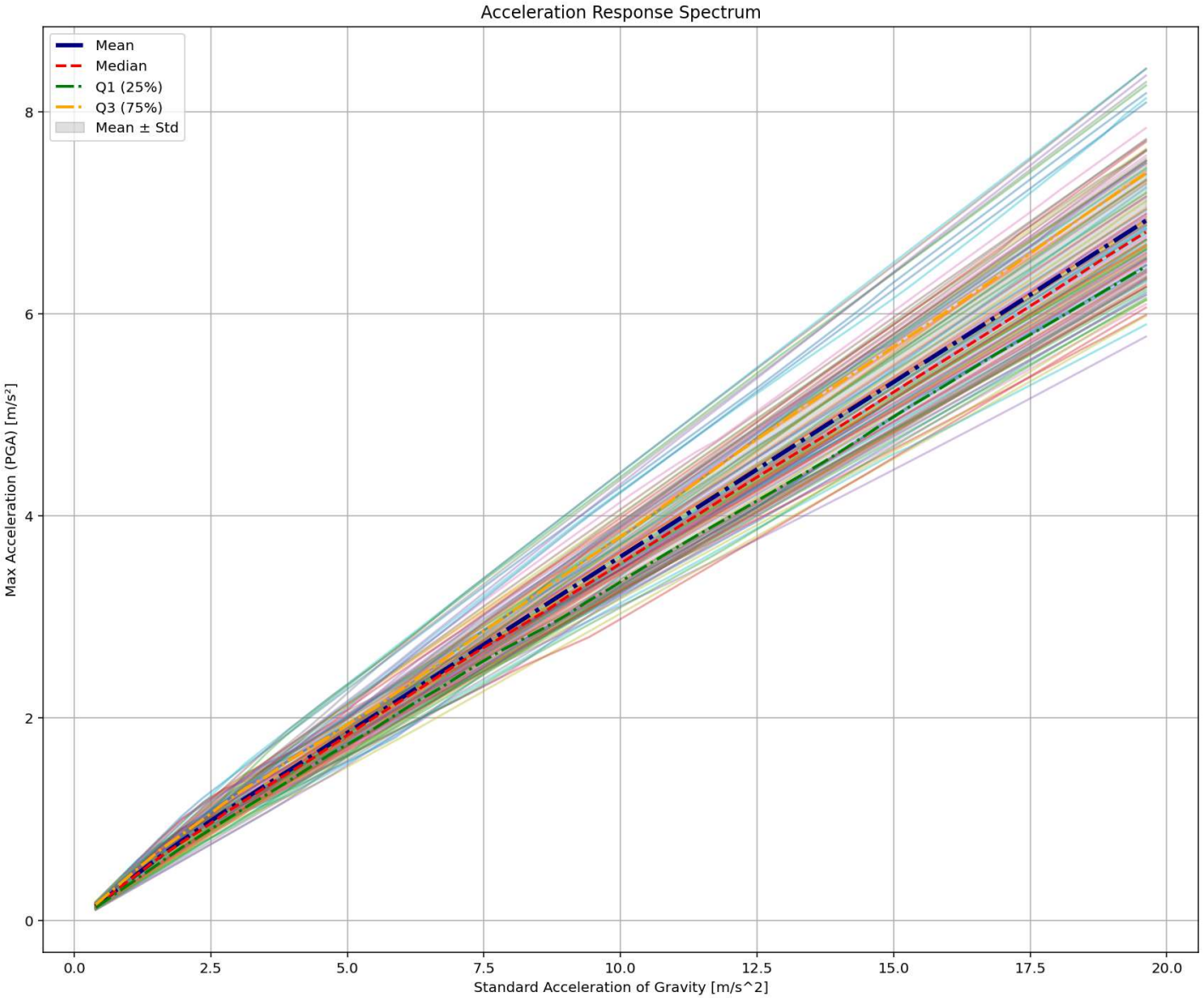
$$\Delta_u = Lateral\ Ultimate\ Displaement\ from\ Pushover\ Analysis$$

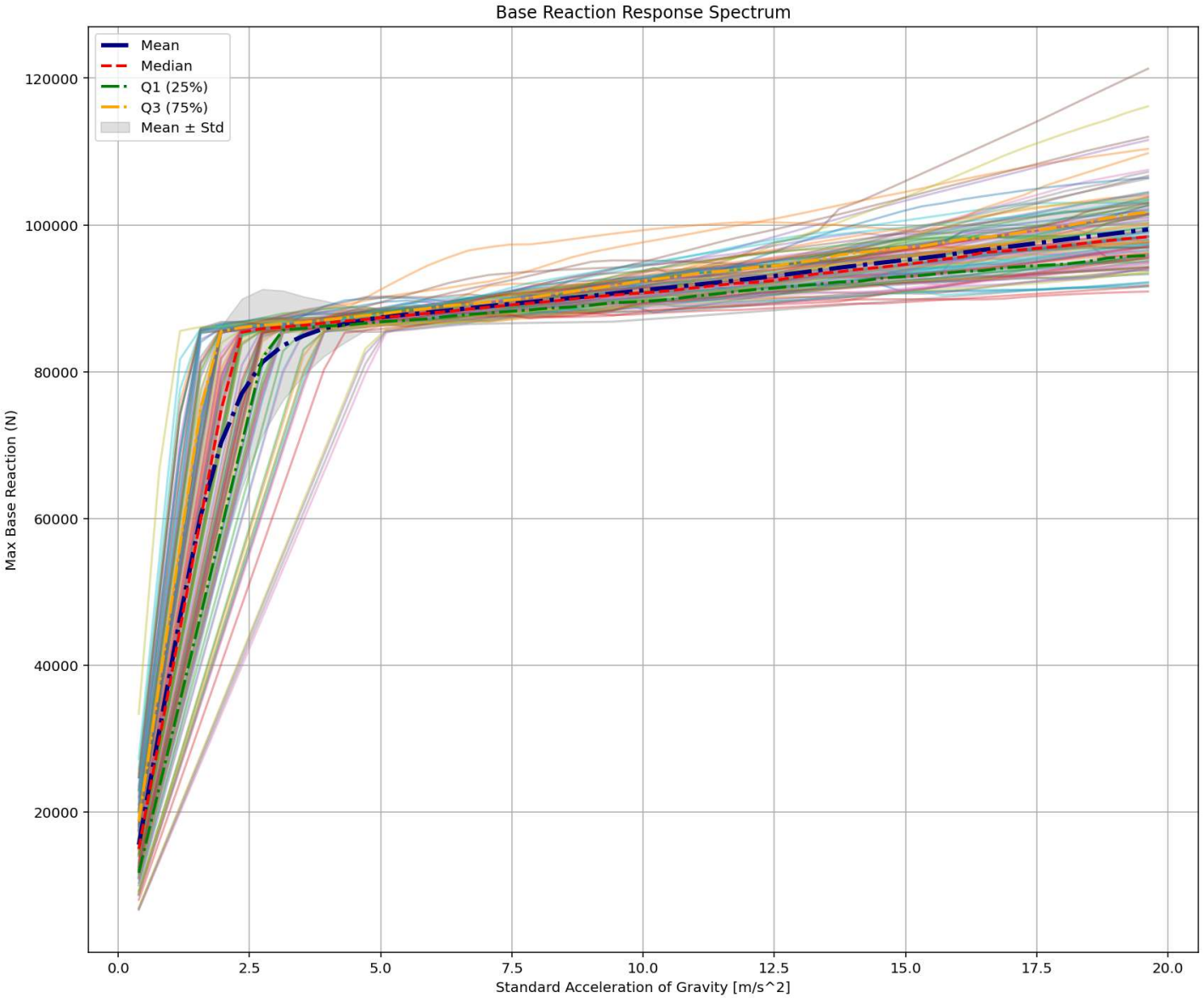

Spyder (Python 3.12)
File Edit Search Source Run Debug Consoles Projects Tools View Help
C:\Users\Dell
C:\Users\Dell\Desktop\OPENSEES_FILES\SDOF_INCREME...AL_DYNAMIC_ANALYSIS_SEISMIC_PARALLEL-COMPUTING.py
INELASTIC_SDOF_INC...NALYSIS_SEISMIC.py
INELASTIC_SDOF_INC...ALLEL-COMPUTING.py
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
FRAGILITY ANALYSIS BASED ON ACCELERATION AND STRUCTURAL DUCTILITY DAMAGE INDEX WITH
INCREMENTAL DYNAMIC ANALYSIS (IDA) OF A SINGLE-DEGREE-OF-FREEDOM (SDOF) SYSTEM
UTILIZING 100 GROUND MOTIONS IN OPENSEES
PARALLEL COMPUTING VERSION
This program performs Incremental Dynamic Analysis (IDA) on a Single-Degree-of-Freedom (SDOF) system
subjected to 100 seismic ground motions. The analysis evaluates the structural response under varying
levels of seismic intensity.
The framework is designed to support researchers and engineers in assessing the probabilistic seismic
performance of structures, with a focus on understanding the impact of uncertainty on structural
response and design.
Key Features:
- Simulation of SDOF system using OpenSees.
- Incremental scaling of ground motions for IDA.
- Probabilistic fragility assessment based on predefined damage states.
- Visualization of structural response and fragility curves.
- Export of results for further analysis.
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 ALLOWS
ALL FOUR MODES TO RUN SIMULTANEOUSLY ON DIFFERENT CPU CORES. EACH CORE PROCESSES ONE MODE INDEPENDENTLY,
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 INDEPENDENT
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 CORES,
Console 1/A
--- START SEISMIC 25 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 12.1s
[Parallel(n_jobs=-1)]: Done 50 out of 50 | elapsed: 52.1s
finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4
concurrent workers.
--- SEISMIC 25 DONE ---
--- START SEISMIC 26 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 12.5s
[Parallel(n_jobs=-1)]: Done 50 out of 50 | elapsed: 50.0s
finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4
concurrent workers.
--- SEISMIC 26 DONE ---
--- START SEISMIC 27 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 12.3s
[Parallel(n_jobs=-1)]: Done 50 out of 50 | elapsed: 53.7s
finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4
concurrent workers.
--- SEISMIC 27 DONE ---
--- START SEISMIC 28 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 11.9s
[Parallel(n_jobs=-1)]: Done 50 out of 50 | elapsed: 51.1s
finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4
concurrent workers.
--- SEISMIC 28 DONE ---
--- START SEISMIC 29 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 13.0s
IPython Console Files Help Variable Explorer Debugger Plots History

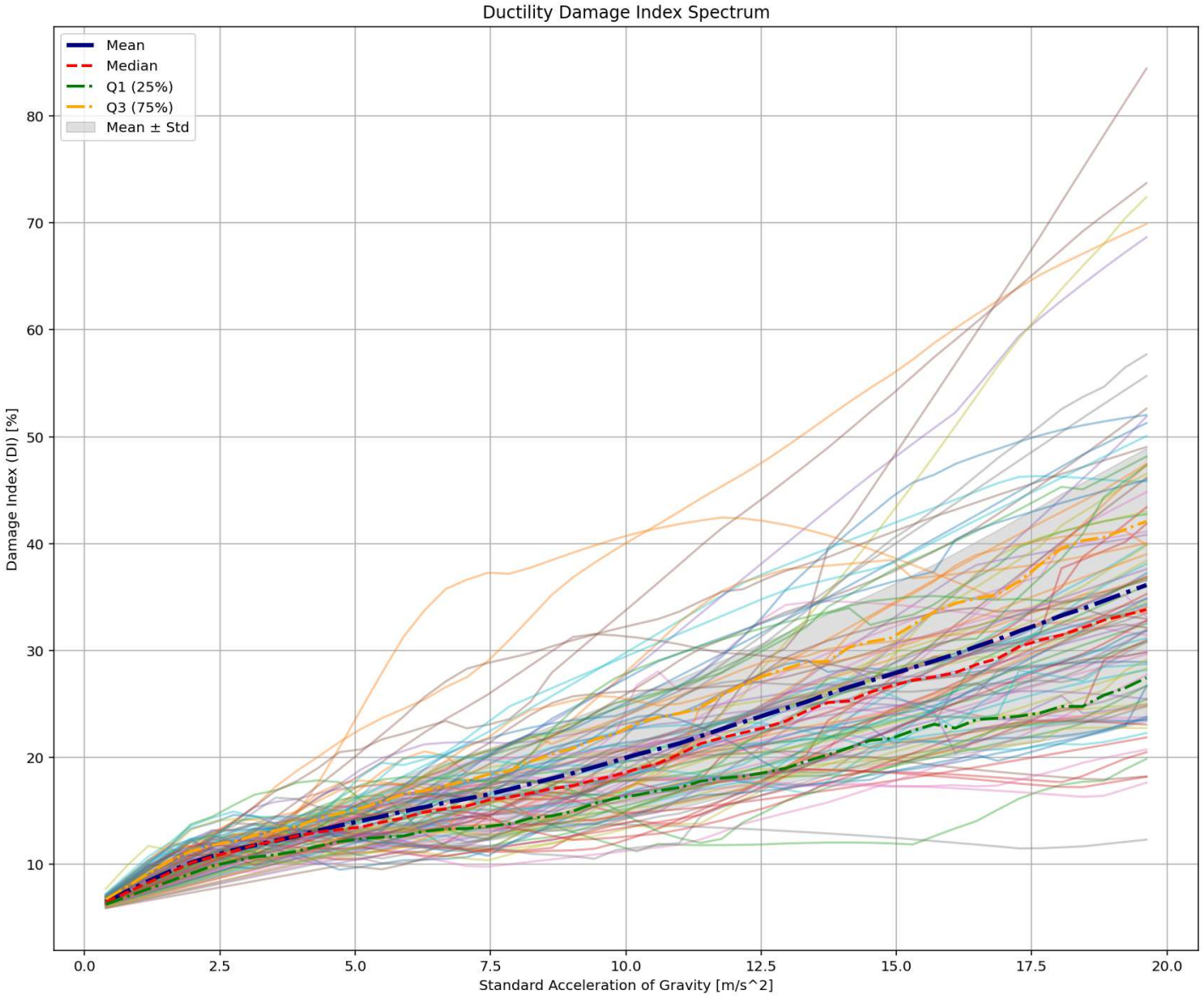

Spyder (Python 3.12)
File Edit Search Source Run Debug Consoles Projects Tools View Help
C:\Users\Dell
C:\Users\Dell\Desktop\OPENSEES_FILES\SDOF_INCREME...AL_DYNAMIC_ANALYSIS_SEISMIC_PARALLEL-COMPUTING.py
INELASTIC_SDOF_INC...NALYSIS_SEISMIC.py
INELASTIC_SDOF_INC...ALLEL-COMPUTING.py
# ---------------------- PARALLEL PROCESSING ----------------------
# MAIN PARALLEL ANALYSIS LOOP
# Analysis Durations:
current_time = TI.strftime("%H:%M:%S", TI.localtime())
print("Start Time:", current_time)
DATA = {
1: [], # DISPLACEMENT
2: [], # VELOCITY
3: [], # ACCELERATION
4: [], # BASE REACTION
5: [], # DAMAGE INDEX
6: [], # DAMPING RATIO
7: [], # STIFFNESS
}
for j in range(NUM_SEISMIC):
print(f"\n--- START SEISMIC {j + 1} ---")
results = Parallel(
n_jobs=-1, # Use all CPU cores
backend="loky", # Process-based (OpenSees safe)
verbose=5
)(
delayed(run_single_analysis)(j, i, mi, GMfact, NUM_G)
for i in range(NUM_G)
)
# COLLECT RESULTS
max_displacement = [r["disp"] for r in results]
max_velocity = [r["vel"] for r in results]
Console 1/A
--- START SEISMIC 26 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 12.5s
[Parallel(n_jobs=-1)]: Done 50 out of 50 | elapsed: 50.0s
finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4
concurrent workers.
--- SEISMIC 26 DONE ---
--- START SEISMIC 27 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 12.3s
[Parallel(n_jobs=-1)]: Done 50 out of 50 | elapsed: 53.7s
finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4
concurrent workers.
--- SEISMIC 27 DONE ---
--- START SEISMIC 28 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 11.9s
[Parallel(n_jobs=-1)]: Done 50 out of 50 | elapsed: 51.1s
finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4
concurrent workers.
--- SEISMIC 28 DONE ---
--- START SEISMIC 29 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 13.0s
[Parallel(n_jobs=-1)]: Done 50 out of 50 | elapsed: 54.2s
finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4
concurrent workers.
--- SEISMIC 29 DONE ---
--- START SEISMIC 30 ---
[Parallel(n_jobs=-1)]: Done 10 tasks | elapsed: 12.3s
IPython Console Files Help Variable Explorer Debugger Plots History
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 114, Col 95 UTF-8 CRLF RW Mem 51%

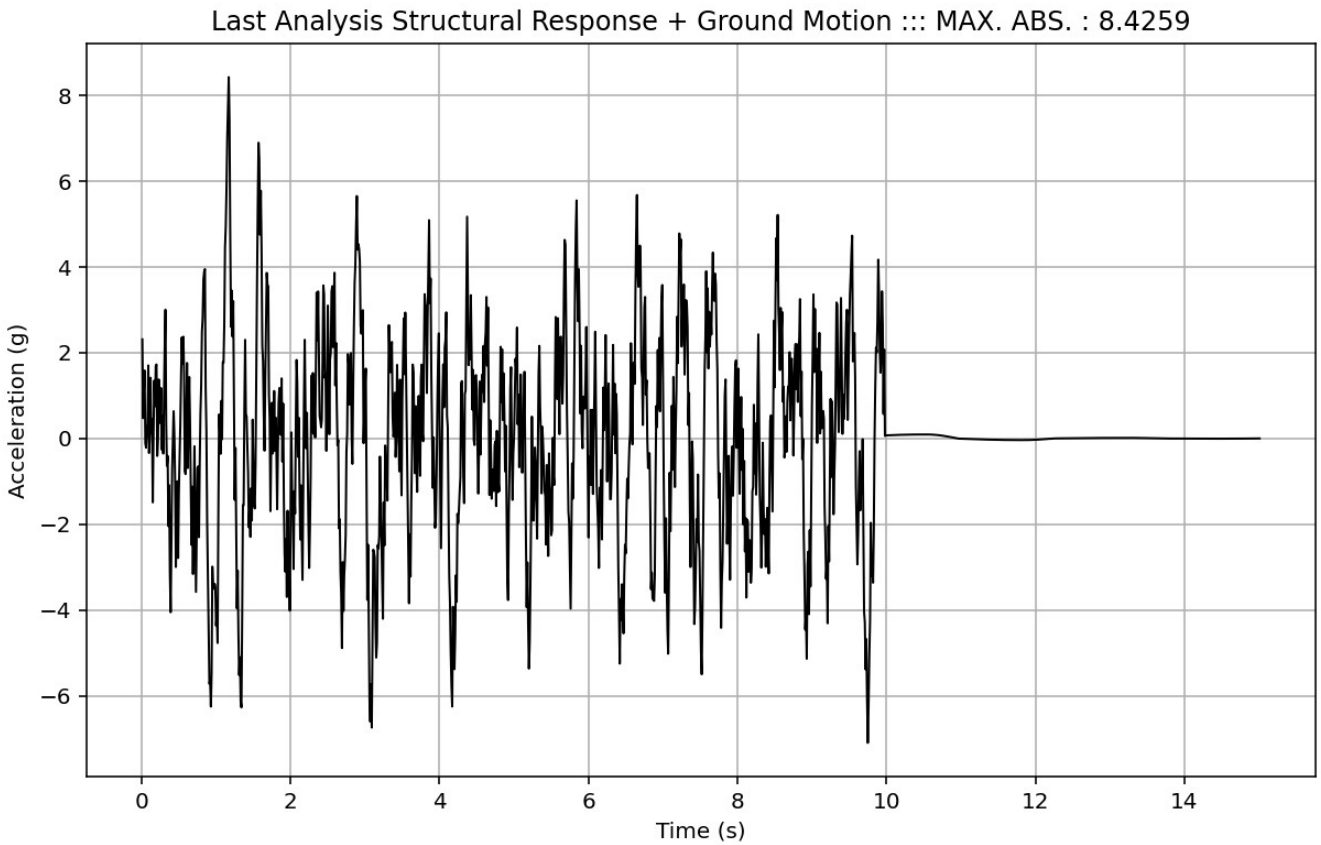

Displacement Response Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Max Displacement (PGD) [m]
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Standard Acceleration of Gravity [m/s^2]

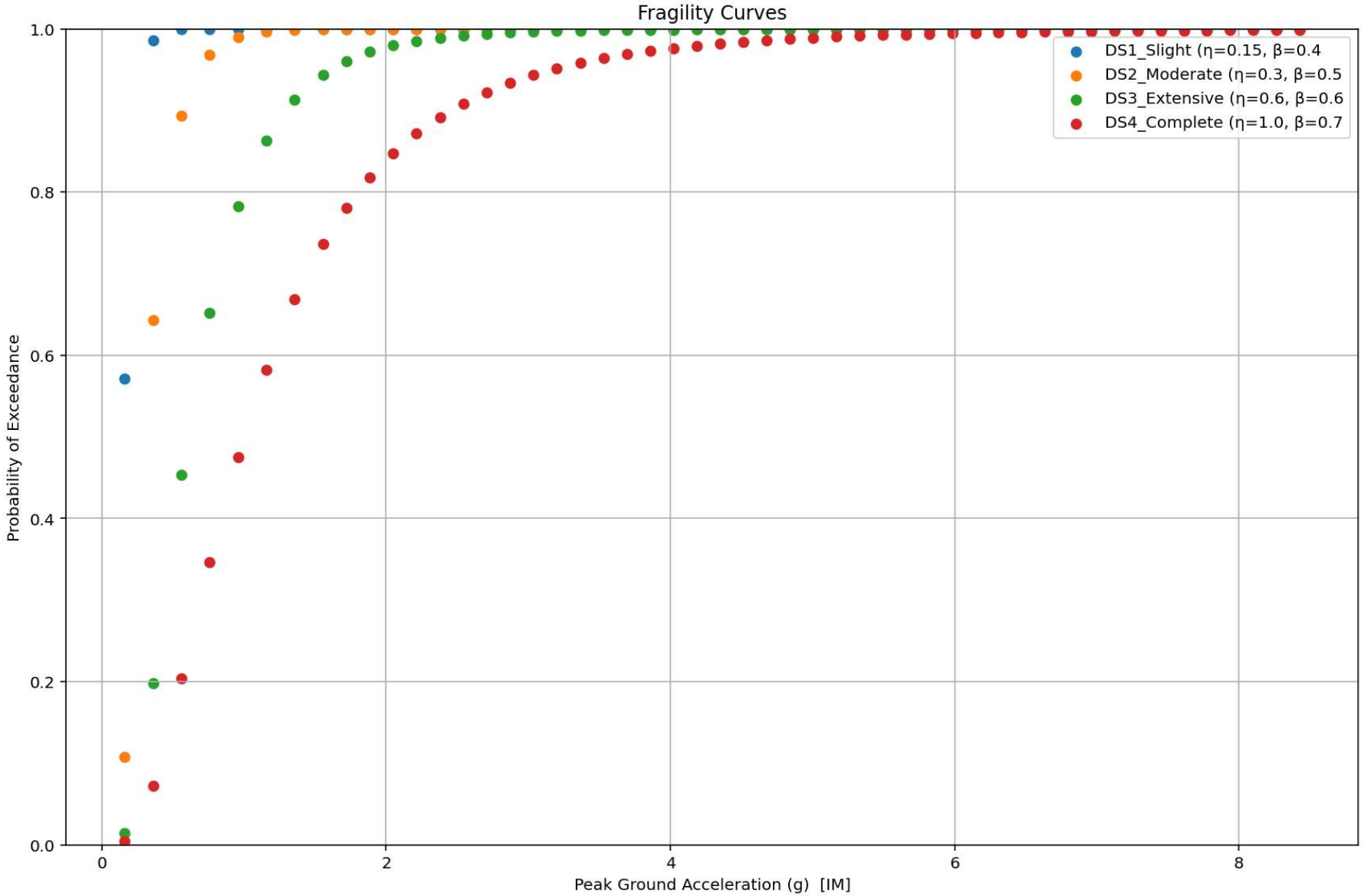

Velocity Response Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Max Velocity (PGV) [m/s]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Standard Acceleration of Gravity [m/s^2]

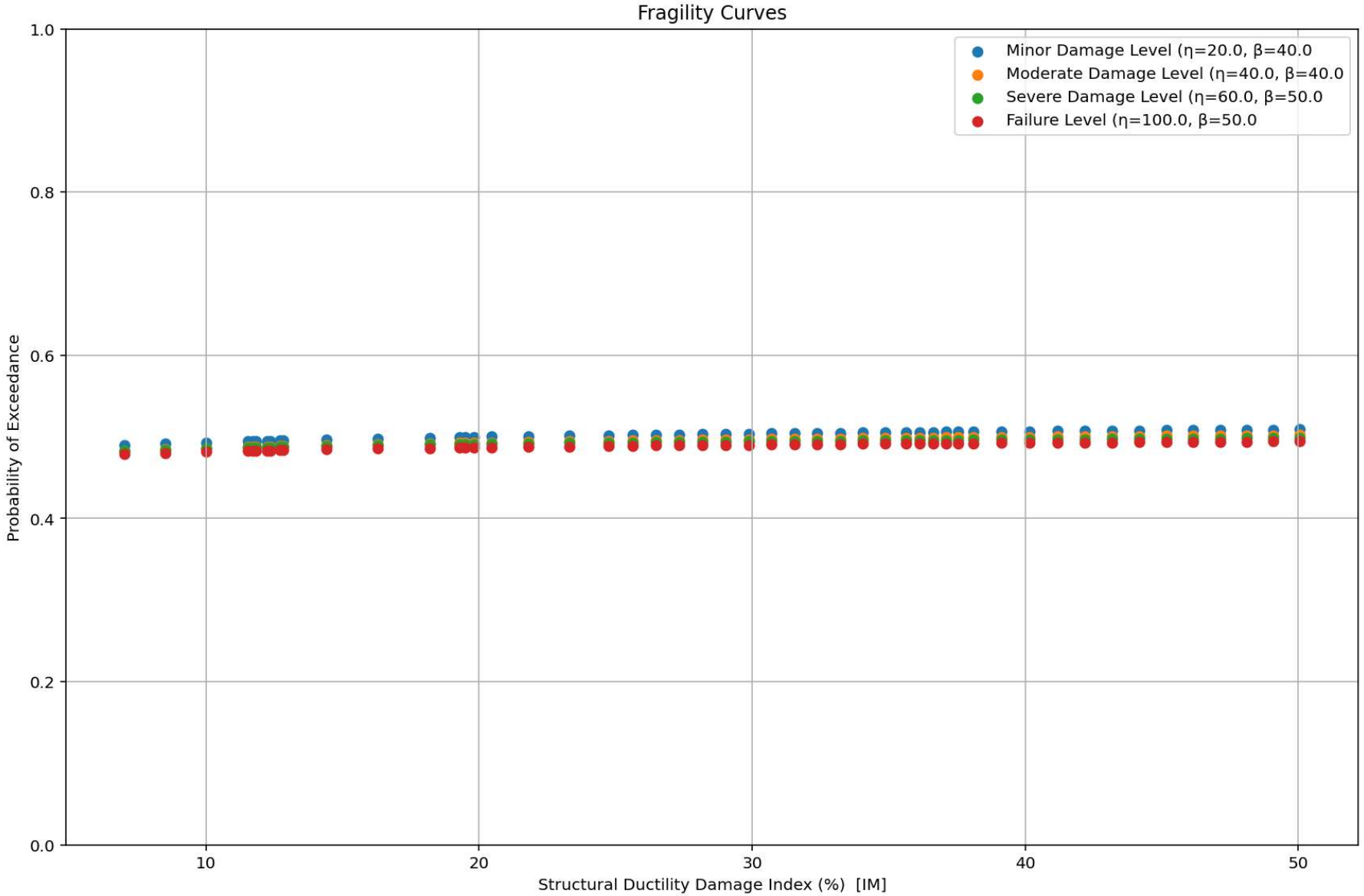

Acceleration Response Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Max Acceleration (PGA) [m/s²]
0
2
4
6
8
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Standard Acceleration of Gravity [m/s^2]


Base Reaction Response Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
120000
100000
80000
60000
40000
20000
Max Base Reaction (N)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Standard Acceleration of Gravity [m/s^2]


Ductility Damage Index Spectrum
Mean
Median
Q1 (25%)
Q3 (75%)
Mean ± Std
Damage Index (DI) [%]
Standard Acceleration of Gravity [m/s^2]
10
20
30
40
50
60
70
80
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0


Last Analysis Structural Response + Ground Motion ::: MAX. ABS. : 8.4259
Acceleration (g)
8
6
4
2
0
−2
−4
−6
0
2
4
6
8
10
12
14
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


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
10
20
30
40
50
Structural Ductility Damage Index (%) [IM]