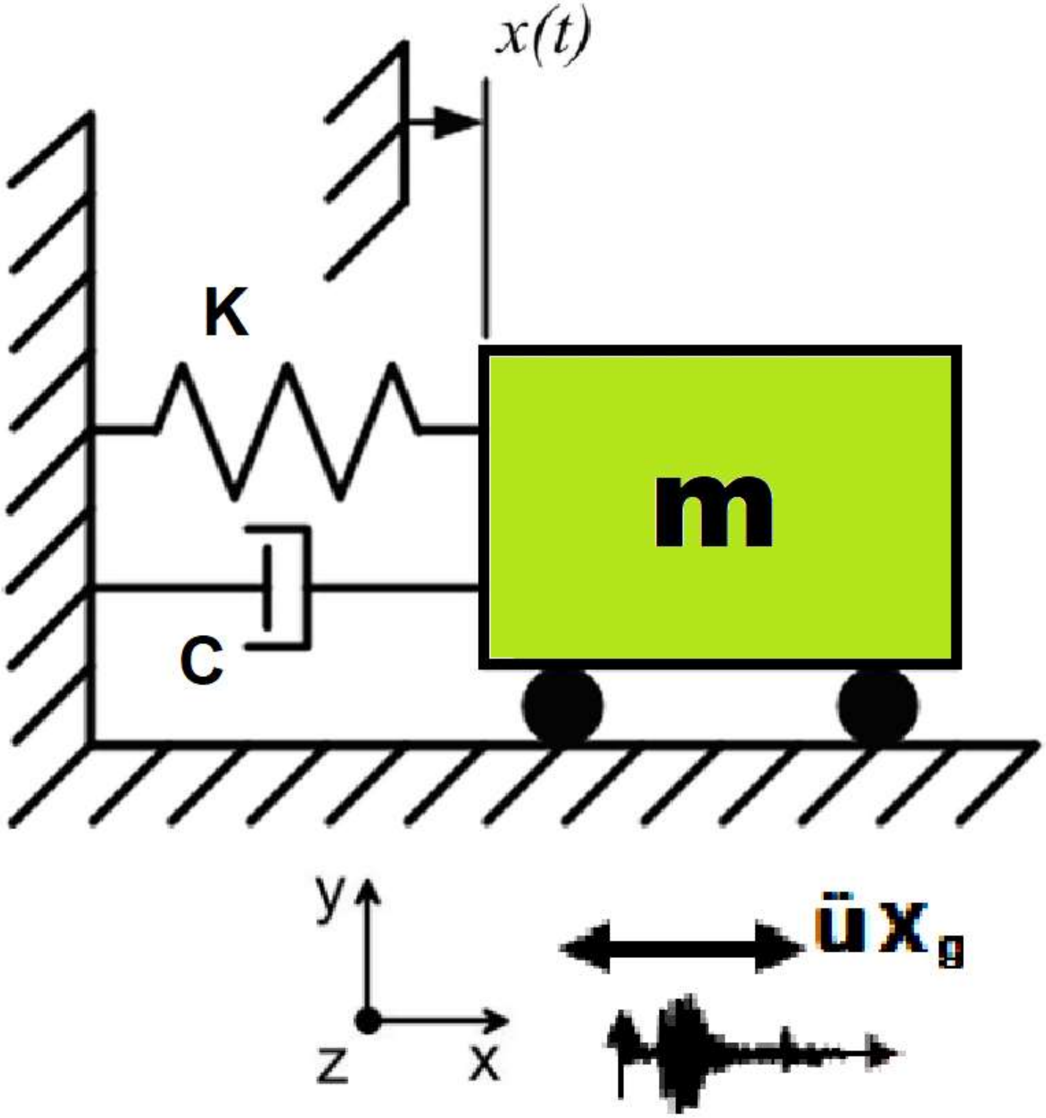
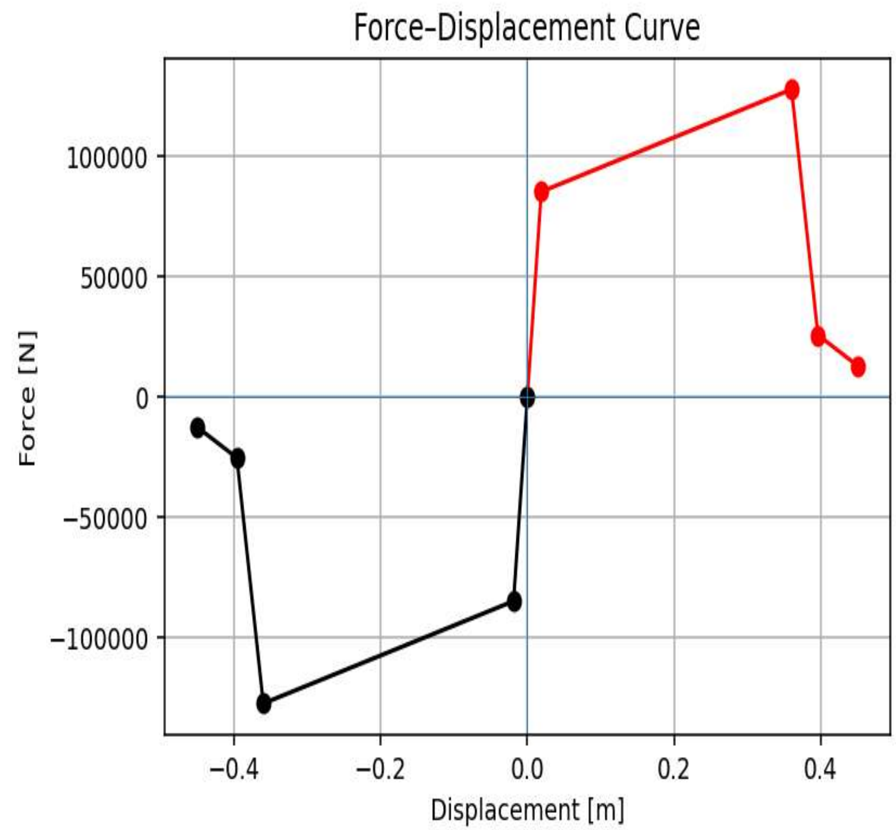
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

# PARALLEL COMPUTING IN OPENSES FOR SCALABLE NONLINEAR DYNAMIC ANALYSIS: RESPONSE SPECTRA AND DUCTILITY DAMAGE INDEX ASSESSMENT UNDER 20 GROUND MOTIONS

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


x(t)
K
m
C
y
z
x
üx g

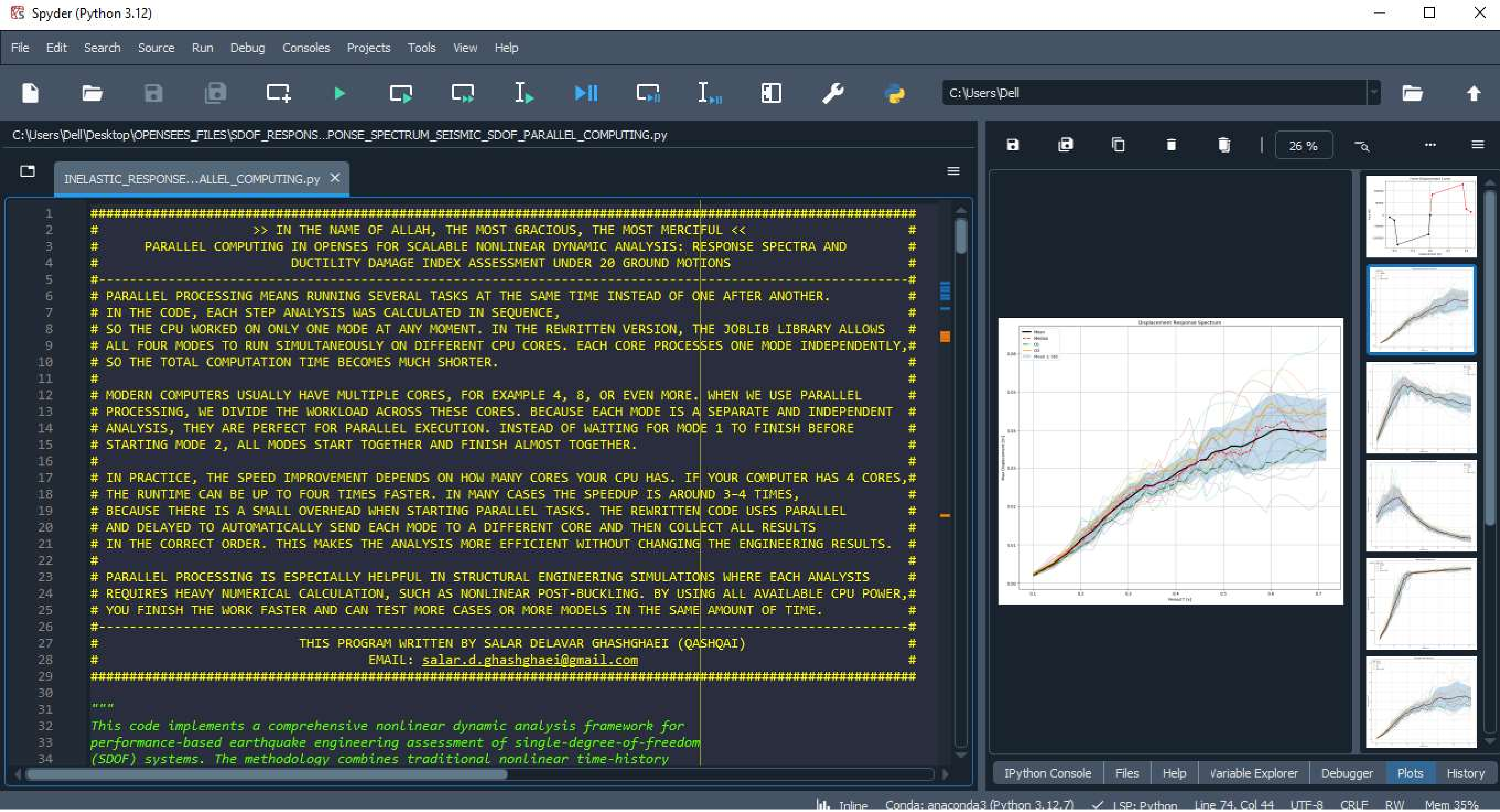

Force-Displacement Curve
100000
50000
0
−50000
−100000
Force [N]
−0.4
−0.2
0.0
0.2
0.4
Displacement [m]

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

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

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

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



Spyder (Python 3.12)
File Edit Search Source Run Debug Consoles Projects Tools View Help
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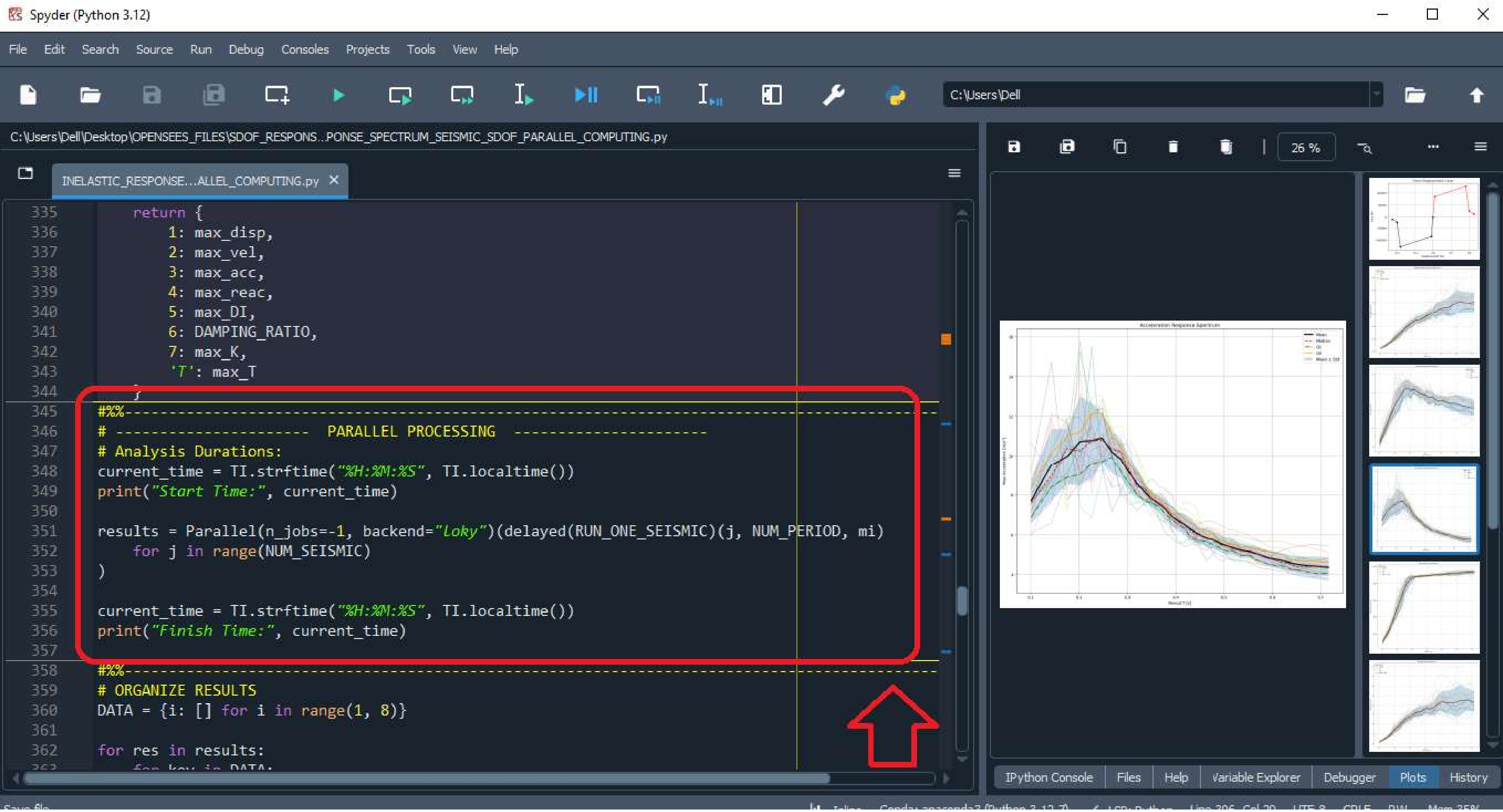
C:\Users\Dell\Desktop\OPENSEES_FILES\SDOF_RESPONS...PONSE_SPECTRUM_SEISMIC_SDOF_PARALLEL_COMPUTING.py
INELASTIC_RESPONSE...ALLEL_COMPUTING.py
##########################################################################################################
# >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL << #
# PARALLEL COMPUTING IN OPENSES FOR SCALABLE NONLINEAR DYNAMIC ANALYSIS: RESPONSE SPECTRA AND #
# DUCTILITY DAMAGE INDEX ASSESSMENT UNDER 20 GROUND MOTIONS #
#--------------------------------------------------------------------------------------------------------#
# 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,#
# 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 RESULTS. #
# #
# 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 POWER,#
# 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 #
##########################################################################################################
"""
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
26 %
Displacement Response Spectrum
IPython Console Files Help Variable Explorer Debugger Plots History
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 74, Col 44 UTF-8 CRLF RW Mem 35%


Spyder (Python 3.12)
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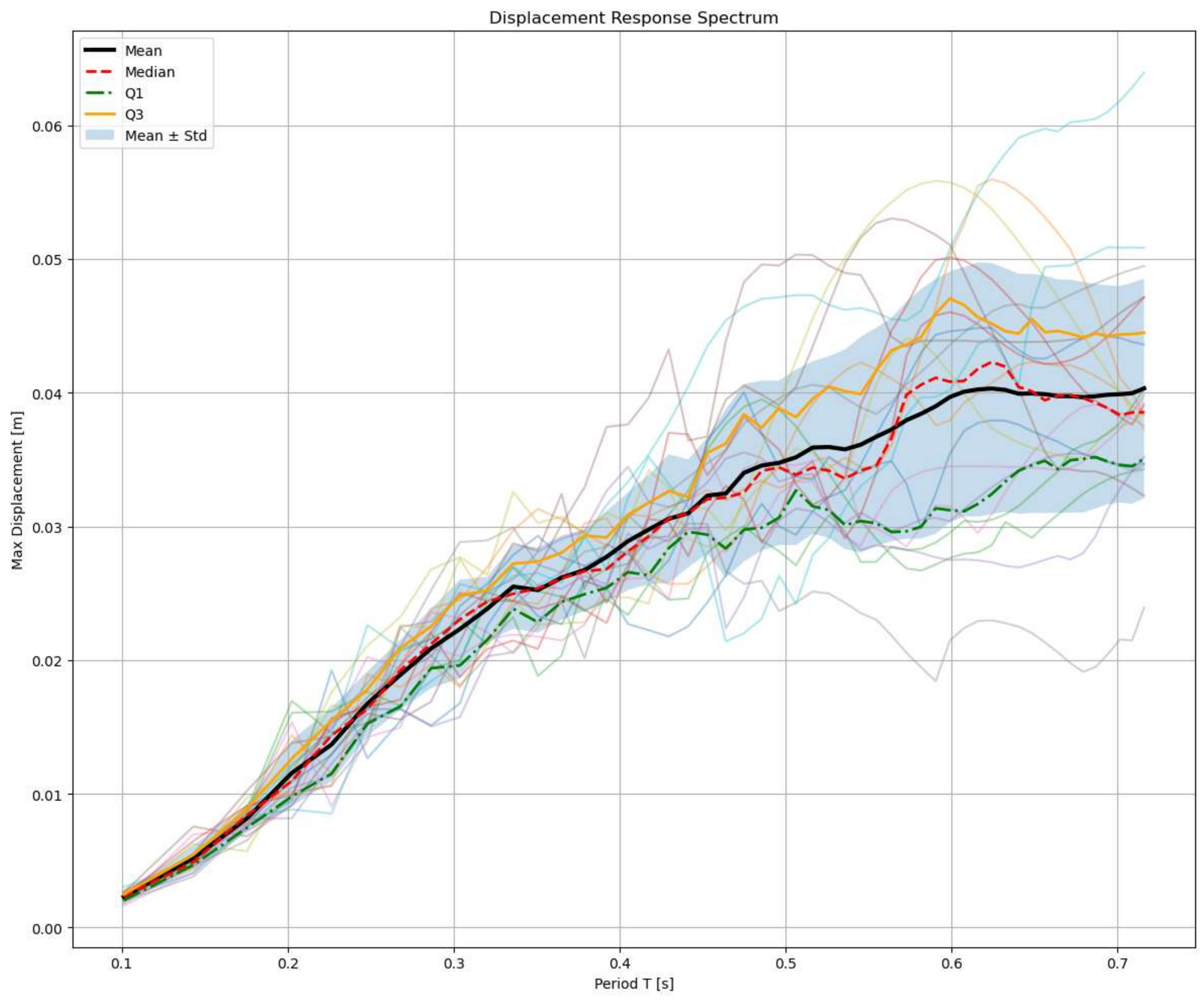
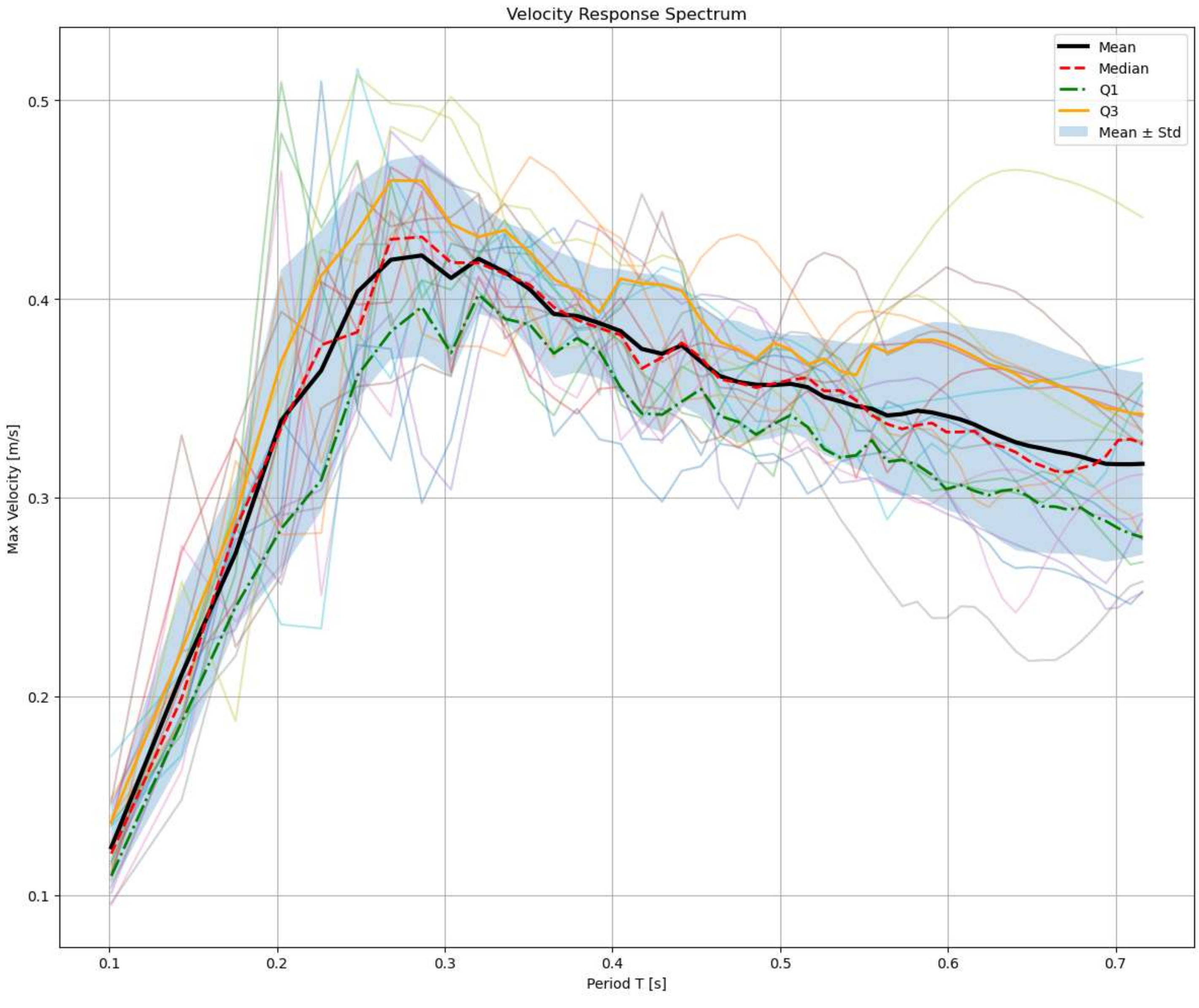
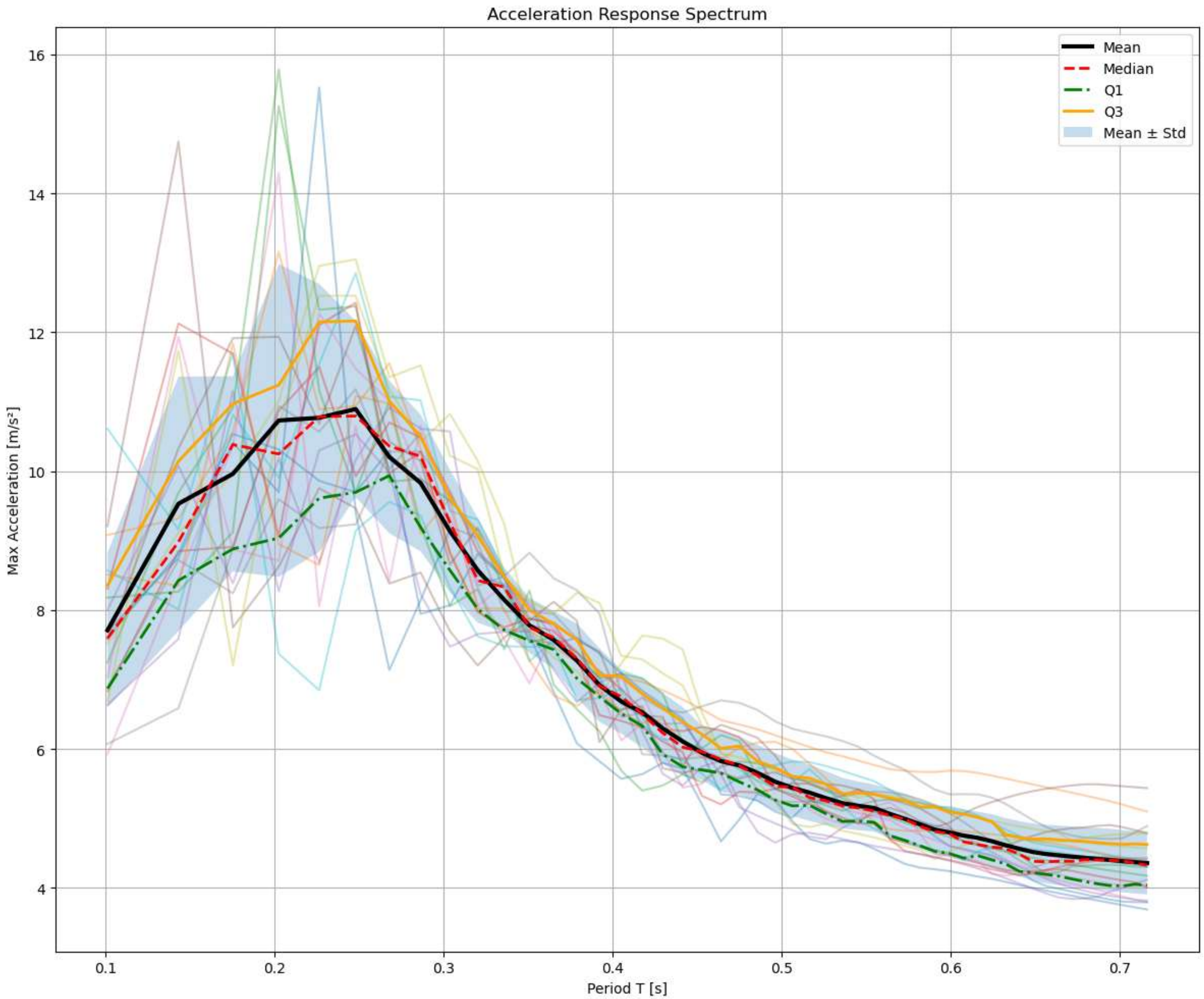
C:\Users\Dell\Desktop\OPENSEES_FILES\SDOF_RESPONS..PONSE_SPECTRUM_SEISMIC_SDOF_PARALLEL_COMPUTING.py
INELASTIC_RESPONSE...ALLEL_COMPUTING.py
    return {
        1: max_disp,
        2: max_vel,
        3: max_acc,
        4: max_reac,
        5: max_DI,
        6: DAMPING_RATIO,
        7: max_K,
        'T': max_T
    }
#%%------------------------------------------------------------------------------
# ---------------------  PARALLEL PROCESSING  ---------------------
# Analysis Durations:
current_time = TI.strftime("%H:%M:%S", TI.localtime())
print("Start Time:", current_time)
results = Parallel(n_jobs=-1, backend="loky")(delayed(RUN_ONE_SEISMIC)(j, NUM_PERIOD, mi)
    for j in range(NUM_SEISMIC)
)
current_time = TI.strftime("%H:%M:%S", TI.localtime())
print("Finish Time:", current_time)
#%%------------------------------------------------------------------------------
# ORGANIZE RESULTS
DATA = {i: [] for i in range(1, 8)}
for res in results:
26 %
Acceleration Response Spectrum
IPython Console
Files
Help
Variable Explorer
Debugger
Plots
History



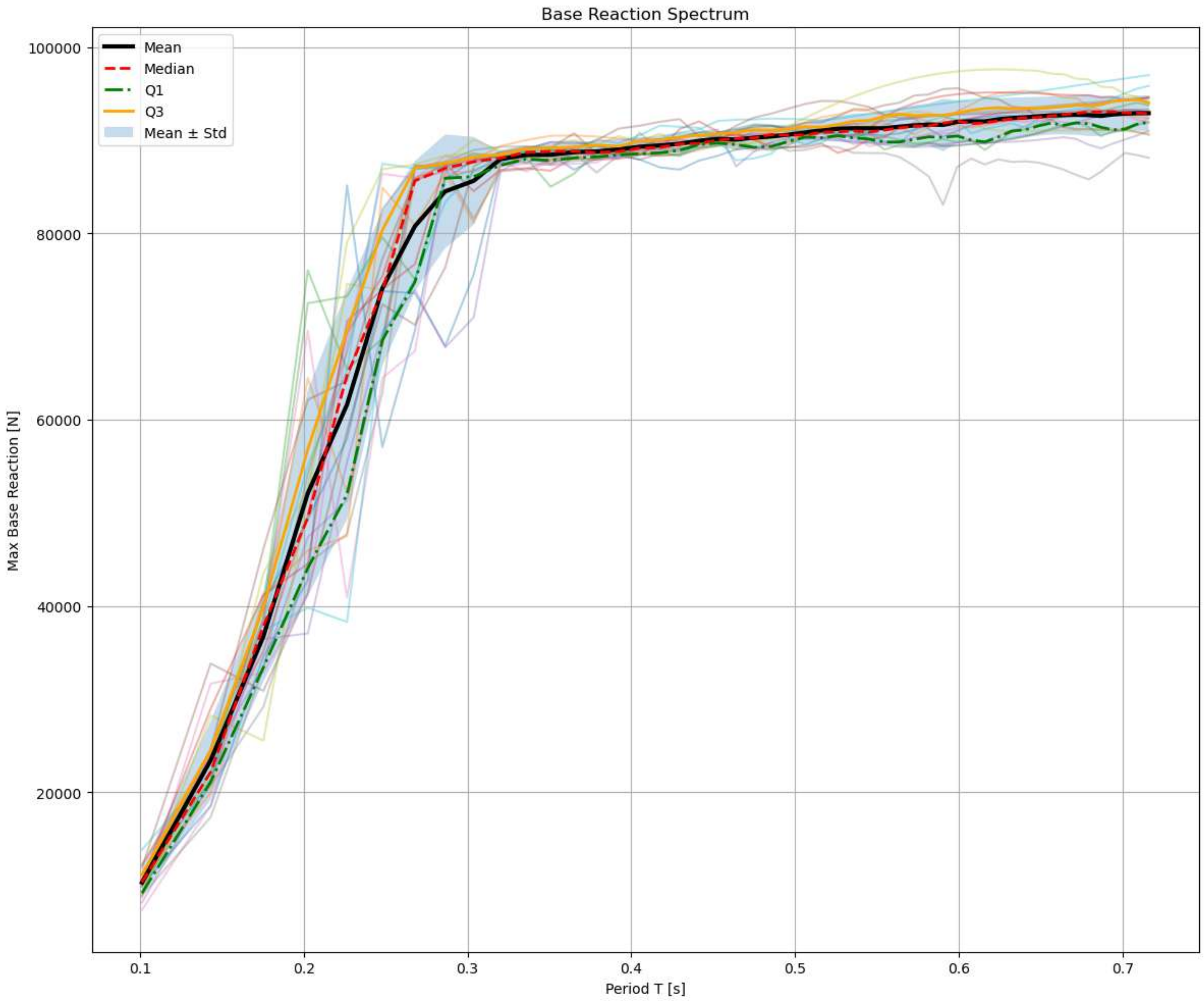
Displacement Response Spectrum
Mean
Median
Q1
Q3
Mean ± Std
Max Displacement [m]
Period T [s]
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.1
0.2
0.3
0.4
0.5
0.6
0.7



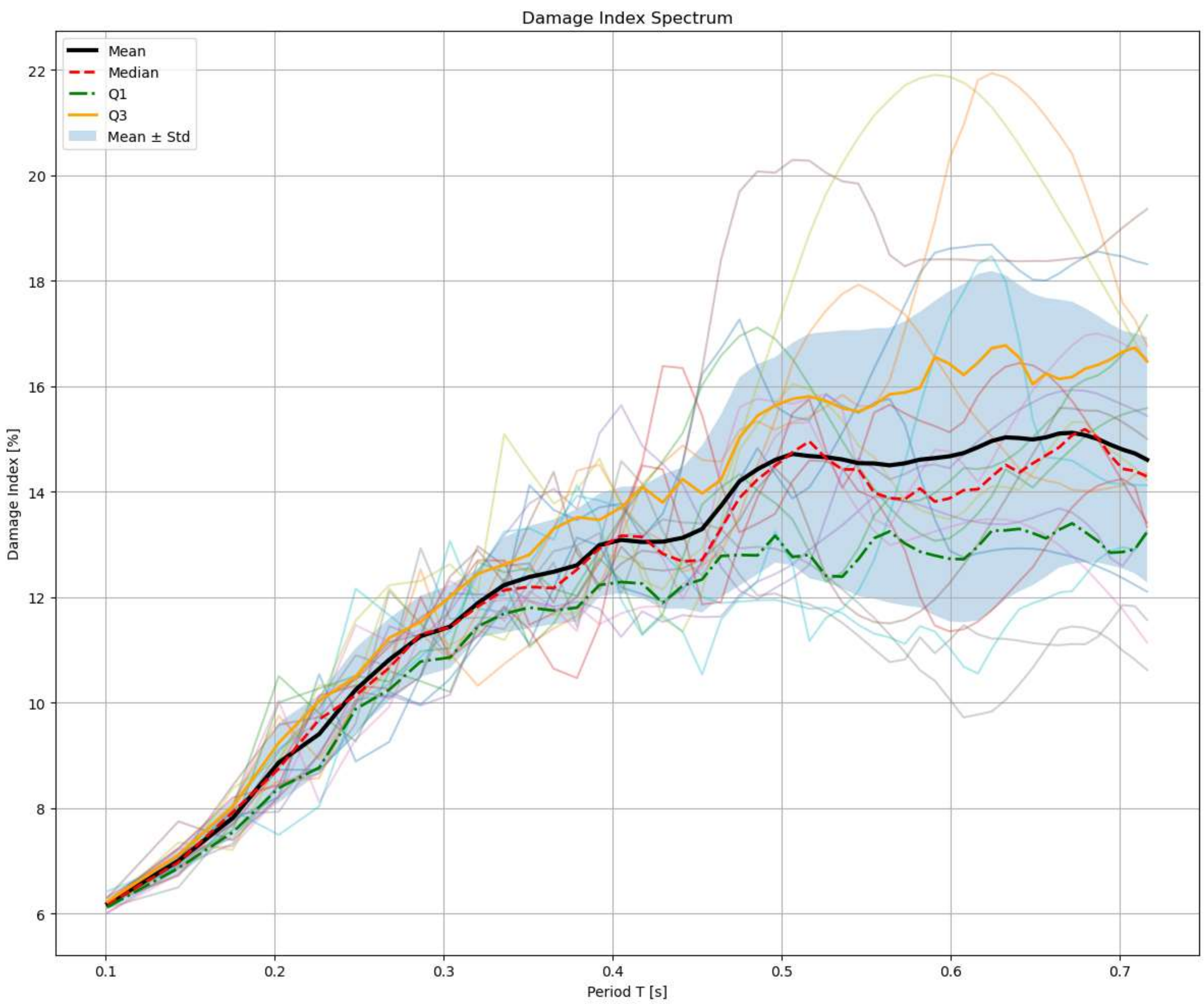
Velocity Response Spectrum
Mean
Median
Q1
Q3
Mean ± Std
Max Velocity [m/s]
Period T [s]
0.1
0.2
0.3
0.4
0.5
0.6
0.7

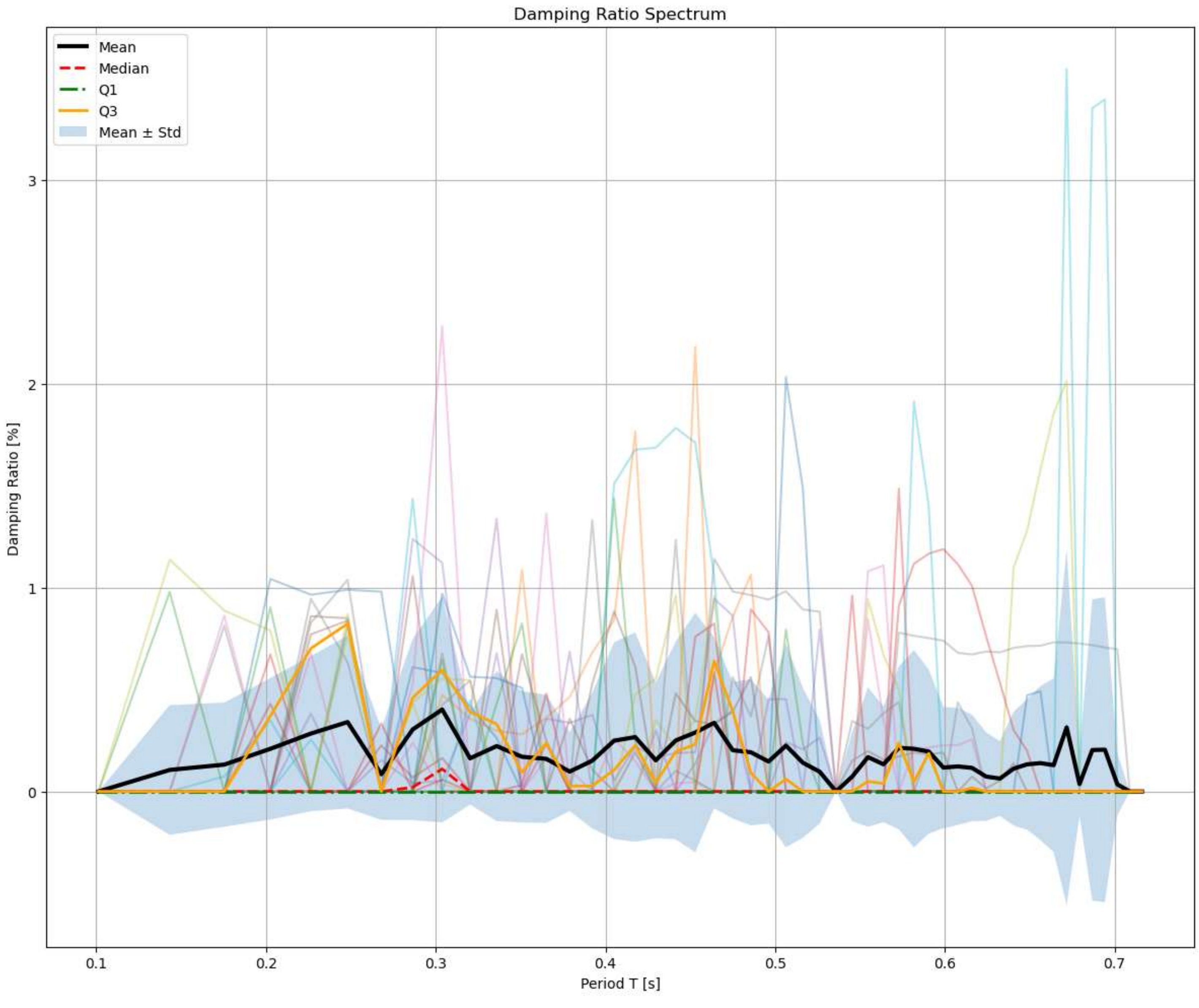


Acceleration Response Spectrum
Mean
Median
Q1
Q3
Mean ± Std
Max Acceleration [m/s²]
Period T [s]
16
14
12
10
8
6
4
0.1
0.2
0.3
0.4
0.5
0.6
0.7

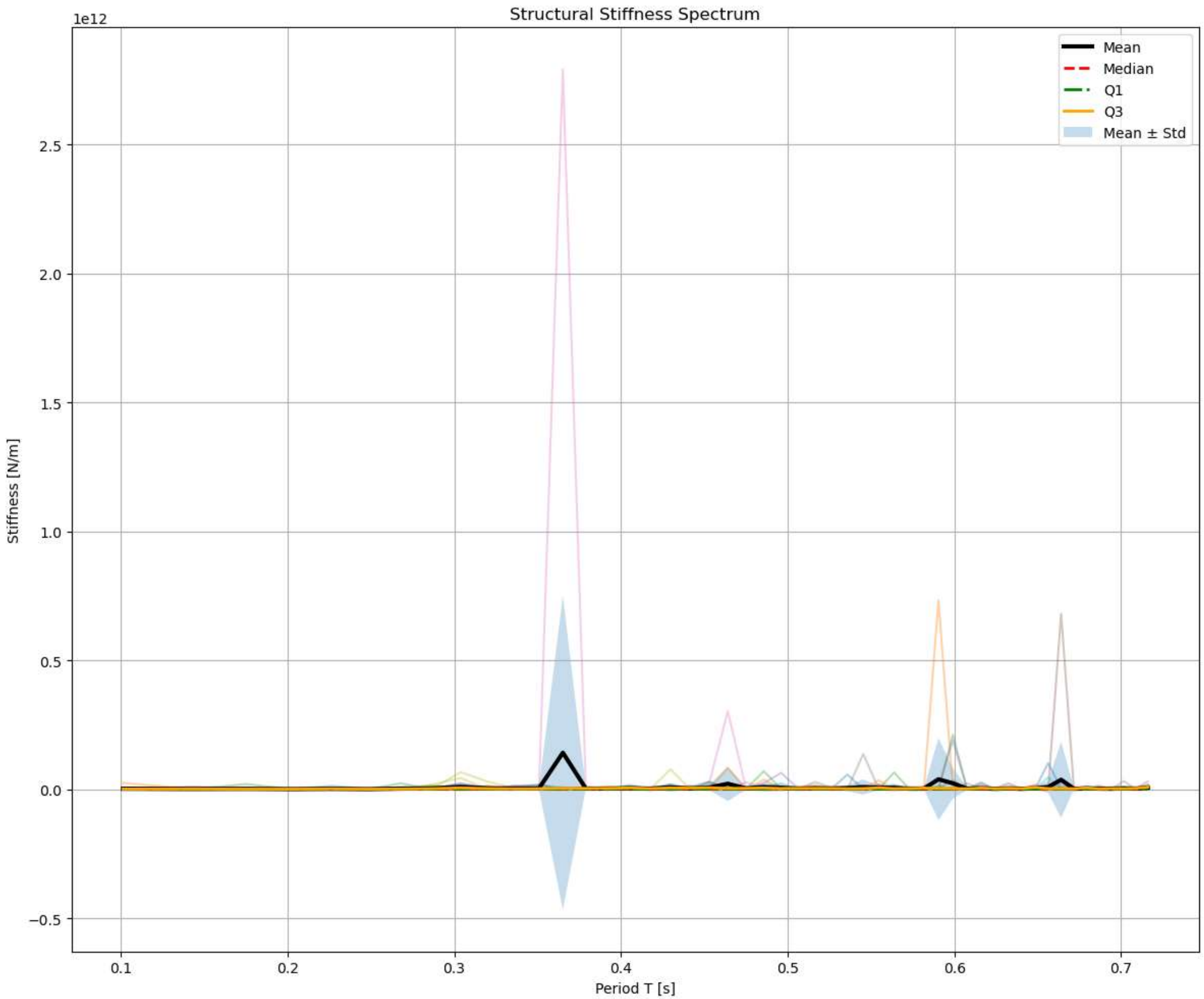


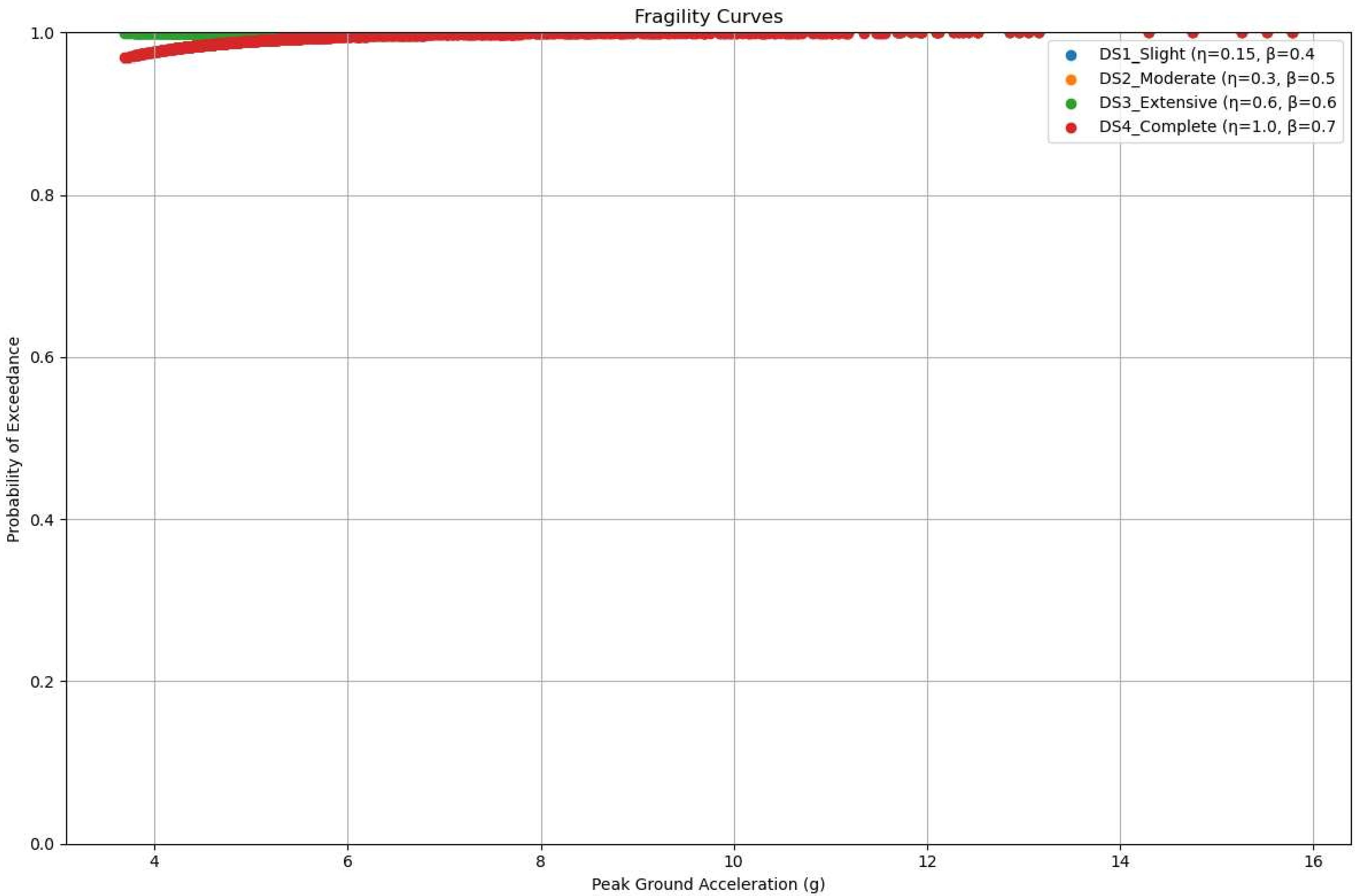
Base Reaction Spectrum
Mean
Median
Q1
Q3
Mean ± Std
Max Base Reaction [N]
Period T [s]
100000
80000
60000
40000
20000
0.1
0.2
0.3
0.4
0.5
0.6
0.7

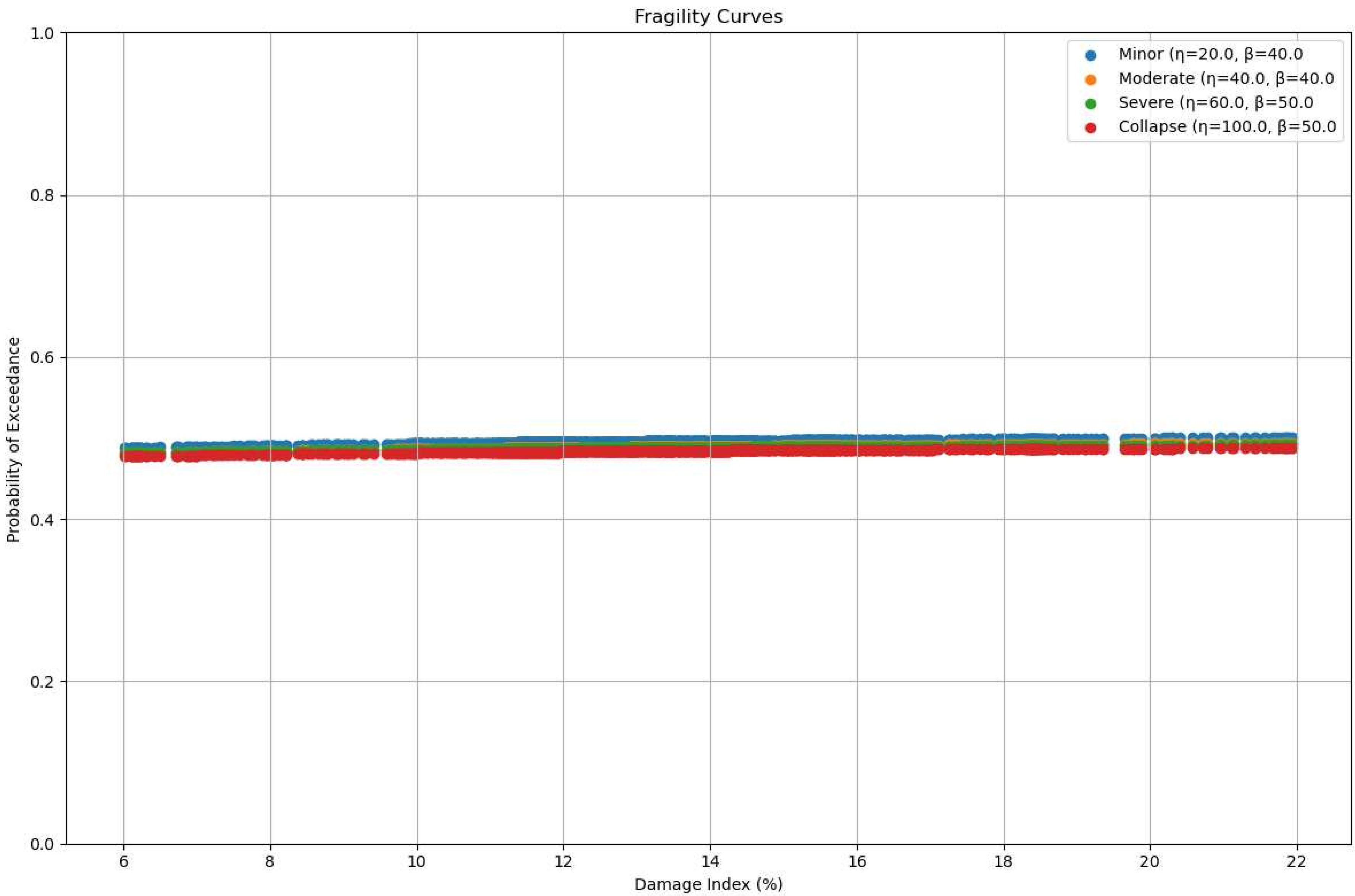

Damage Index Spectrum
Mean
Median
Q1
Q3
Mean ± Std
Damage Index [%]
Period T [s]
6
8
10
12
14
16
18
20
22
0.1
0.2
0.3
0.4
0.5
0.6
0.7



Damping Ratio Spectrum
Mean
Median
Q1
Q3
Mean ± Std
Damping Ratio [%]
Period T [s]
0
1
2
3
0.1
0.2
0.3
0.4
0.5
0.6
0.7


Structural Stiffness Spectrum
1e12
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
Stiffness [N/m]
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Period T [s]
Mean
Median
Q1
Q3
Mean ± Std


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)
1.0
0.8
0.6
0.4
0.2
0.0
4
6
8
10
12
14
16


Fragility Curves
Minor (η=20.0, β=40.0
Moderate (η=40.0, β=40.0
Severe (η=60.0, β=50.0
Collapse (η=100.0, β=50.0
Probability of Exceedance
Damage Index (%)
0.0
0.2
0.4
0.6
0.8
1.0
6
8
10
12
14
16
18
20
22