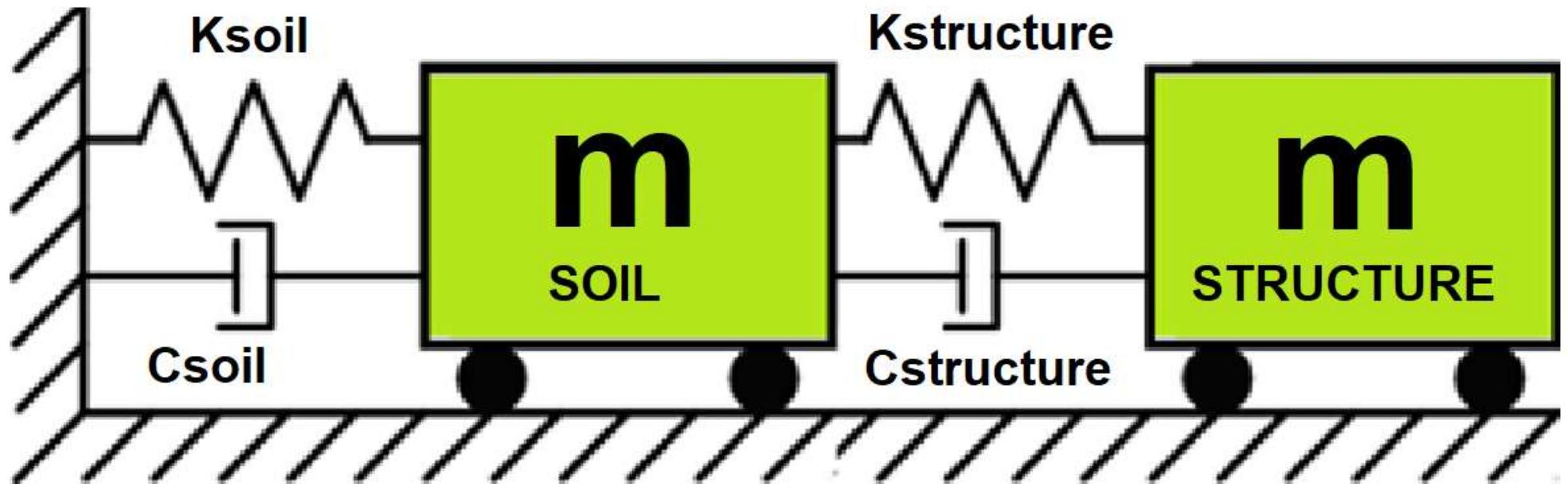
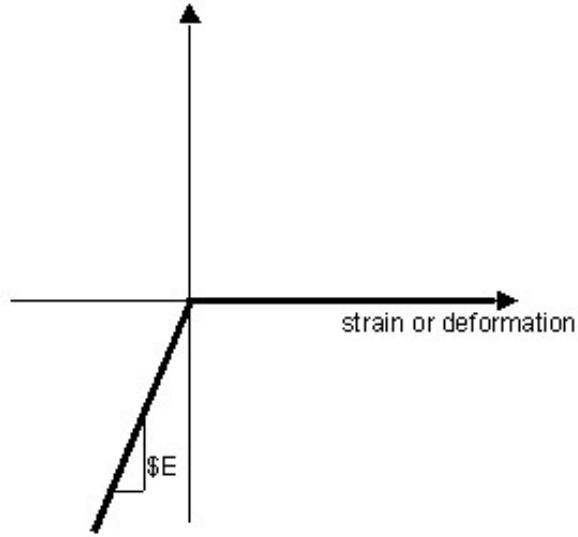


>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

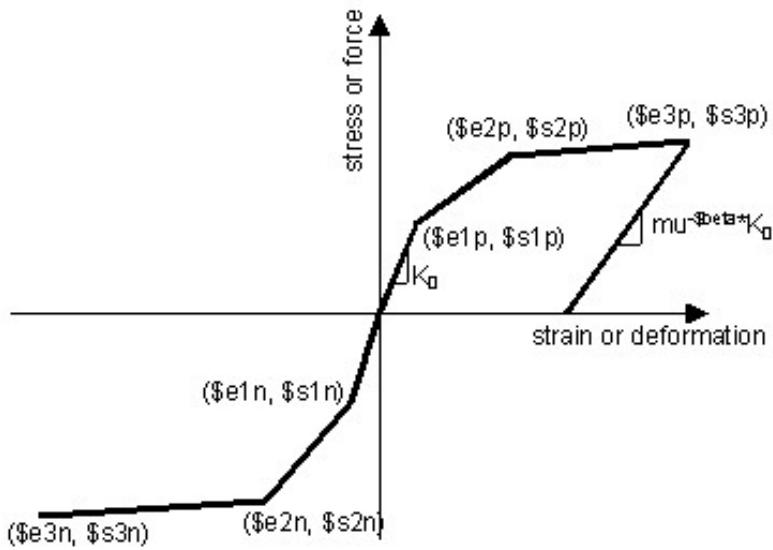
# **NONLINEAR DYNAMIC ANALYSIS OF A TWO-DOF SOIL-STRUCTURE SYSTEM UNDER 20 GROUND MOTIONS WITH RESPONSE SPECTRA AND DUCTILITY DAMAGE INDEX CALCULATION IN OPENSEES**

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)



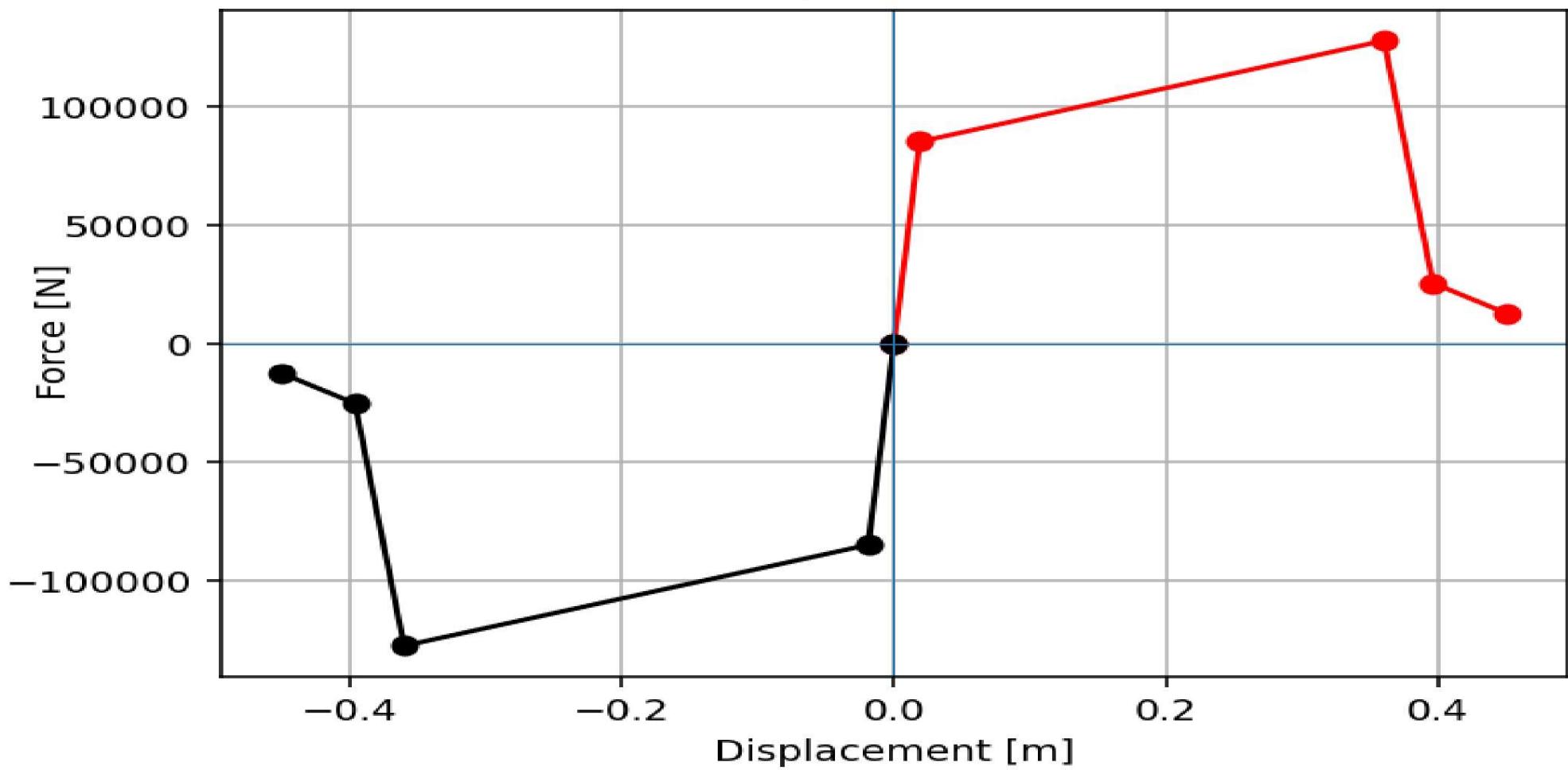


## SOIL STIFFNESS



## STRUCTURE STIFFNESS

### Force-Displacement Curve



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

$\Delta_d$  = Lateral Displacement from Dynamic Analysis

$\Delta_y$  = Lateral Yield Displacement from Pushover Analysis

$\Delta_u$  = Lateral Ultimate Displacement from Pushover Analysis

Spyder (Python 3.12)

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C:\Users\...Desktop\OPENSEES\_FILES\MDOF\_RESPONSE\_SPECTRUM\_SEISMIC\_SDOF.py

SOIL\_INELASTIC\_RESPONSE\_SEISMIC\_SDOF.py FRAGILITY\_CURVE\_FUN.py

```

1 ##### >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
2 # NONLINEAR DYNAMIC ANALYSIS OF A TWO-DOF SOIL-STRUCTURE SYSTEM UNDER 20 GROUND MOTIONS WITH #
3 # RESPONSE SPECTRA AND DUCTILITY DAMAGE INDEX CALCULATION IN OPENSEES #
4 #
5 # THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI) #
6 # EMAIL: salar.d.ghashghaei@gmail.com #
7 #####
8
9
10 """
11 This code implements a comprehensive nonlinear dynamic analysis framework for
12 performance-based earthquake engineering assessment of multi-degree-of-freedom
13 (MDOF) systems. The methodology combines traditional nonlinear time-history
14 analysis with modern probabilistic and machine learning techniques for advanced
15 structural performance evaluation.
16
17 KEY ENGINEERING OBJECTIVES:
18 1. Comparative assessment of hysteretic models for seismic response prediction
19 2. Probabilistic seismic demand analysis using multiple ground motions
20 3. Development of fragility curves for performance-based earthquake engineering
21 4. Integration of data science methods for structural reliability assessment
22
23 ANALYTICAL FEATURES:
24 - Nonlinear material behavior with pinching and degradation
25 - Response spectrum analysis across period range
26 - Real-time structural health monitoring metrics
27 - Statistical characterization of seismic demands
28 - Machine learning-based damage prediction
29
30 Model setup:
31 - SDOF properties: mass (m), initial stiffness (k), yield displacement (Dy), ultimate displacement (Du), visc
32 - Hysteresis models: HYSTERETICSM (pinching, stiffness degradation, strength decay).
33 - Damping: Rayleigh (or equivalent viscous) damping specified by target damping ratio xi for the fundamental
34

```

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Displacement & Base Reaction Relation From Last Dynamic Analysis

IPython Console Files Help Variable Explorer Debugger Plots History

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SOIL\_INELASTIC\_R...UM\_SEISMIC\_SDOF.py FRAGILITY\_CURVE\_FUN.py

```
1 def FRAGILITY_CURVE(im_values, damage_states, X_LABEL, SEMILOGY=True, PLOT_KIND=True):
2     # THIS FUNCTION WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
3     from scipy.stats import norm
4     import numpy as np
5     import matplotlib.pyplot as plt
6
7     # Fragility curves
8     plt.figure(1, figsize=(12, 8))
9     # Calculate and plot fragility curves for each damage state
10    for damage_state, (median, beta) in damage_states.items():
11        # Calculate log-normal probabilities
12        ln_im = np.log(im_values)
13        ln_median = np.log(median)
14        probabilities = norm.cdf((ln_im - ln_median) / beta)
15        if PLOT_KIND == False:
16            plt.scatter(im_values, probabilities, marker='o', label=f'{damage_state} (\u03b7={median}, \u03b8={beta})')
17        if PLOT_KIND == True:
18            plt.plot(im_values, probabilities, lw=2, label=f'{damage_state} (\u03b7={median}, \u03b8={beta})')
19    plt.xlabel(X_LABEL)
20    plt.ylabel('Probability of Exceedance')
21    plt.title('Fragility Curves')
22    plt.legend()
23    if PLOT_KIND == True:
24        plt.semilogy()
25        plt.ylim(0, 1.0)
26        plt.grid(True)
27        plt.tight_layout()
28        plt.show()
```

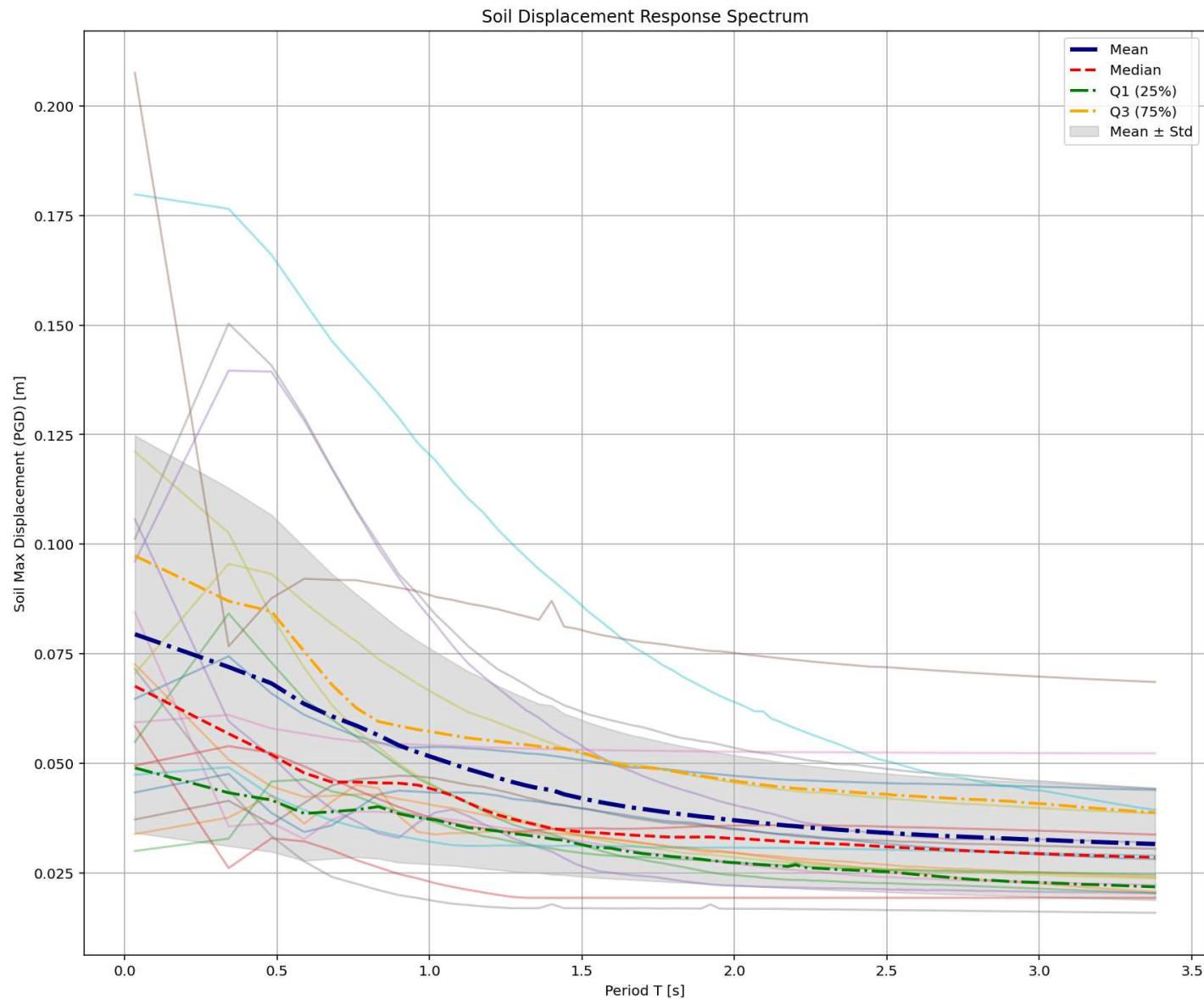
Ductility Damage Index Spectrum

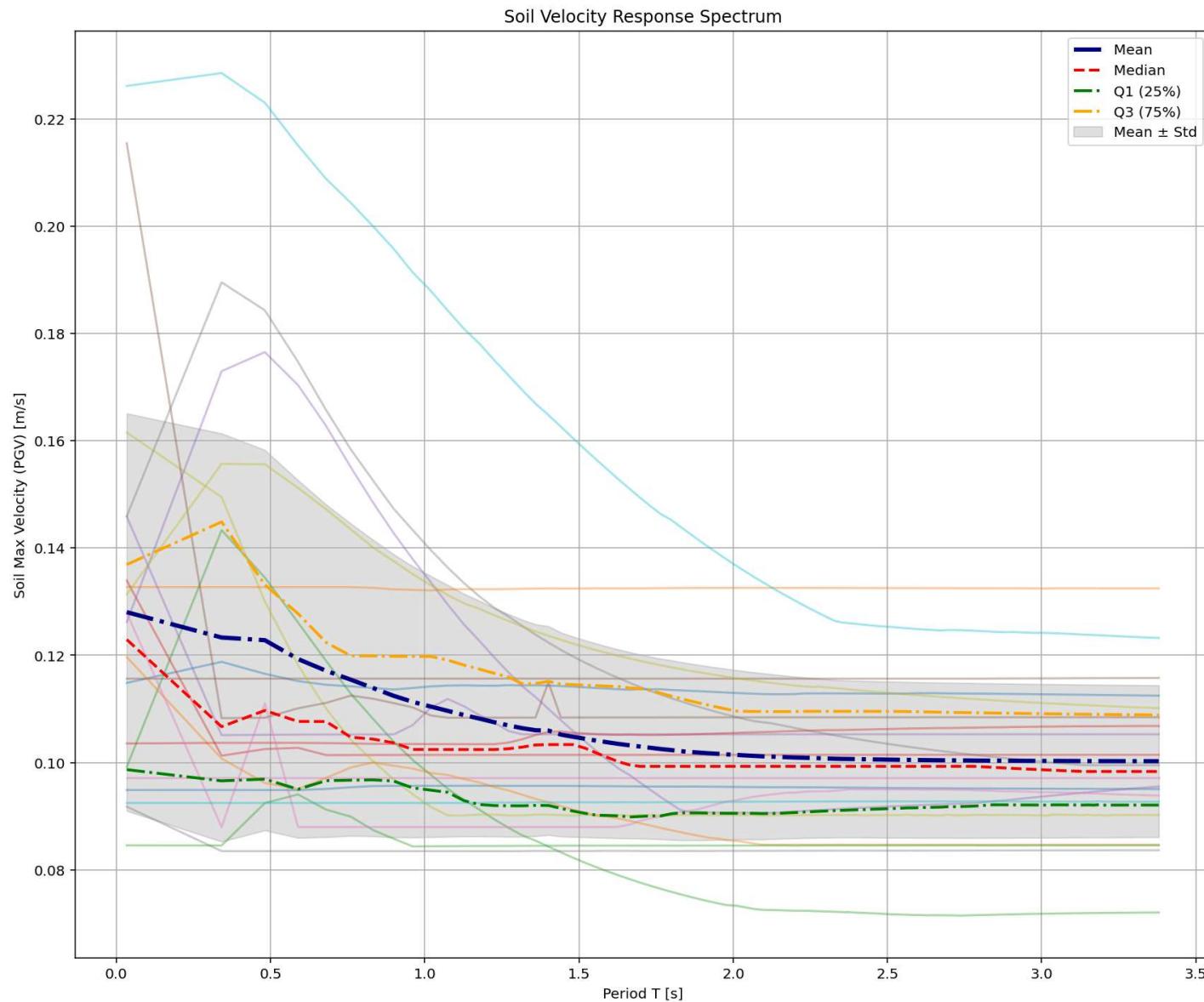
Probability of Exceedance (%)

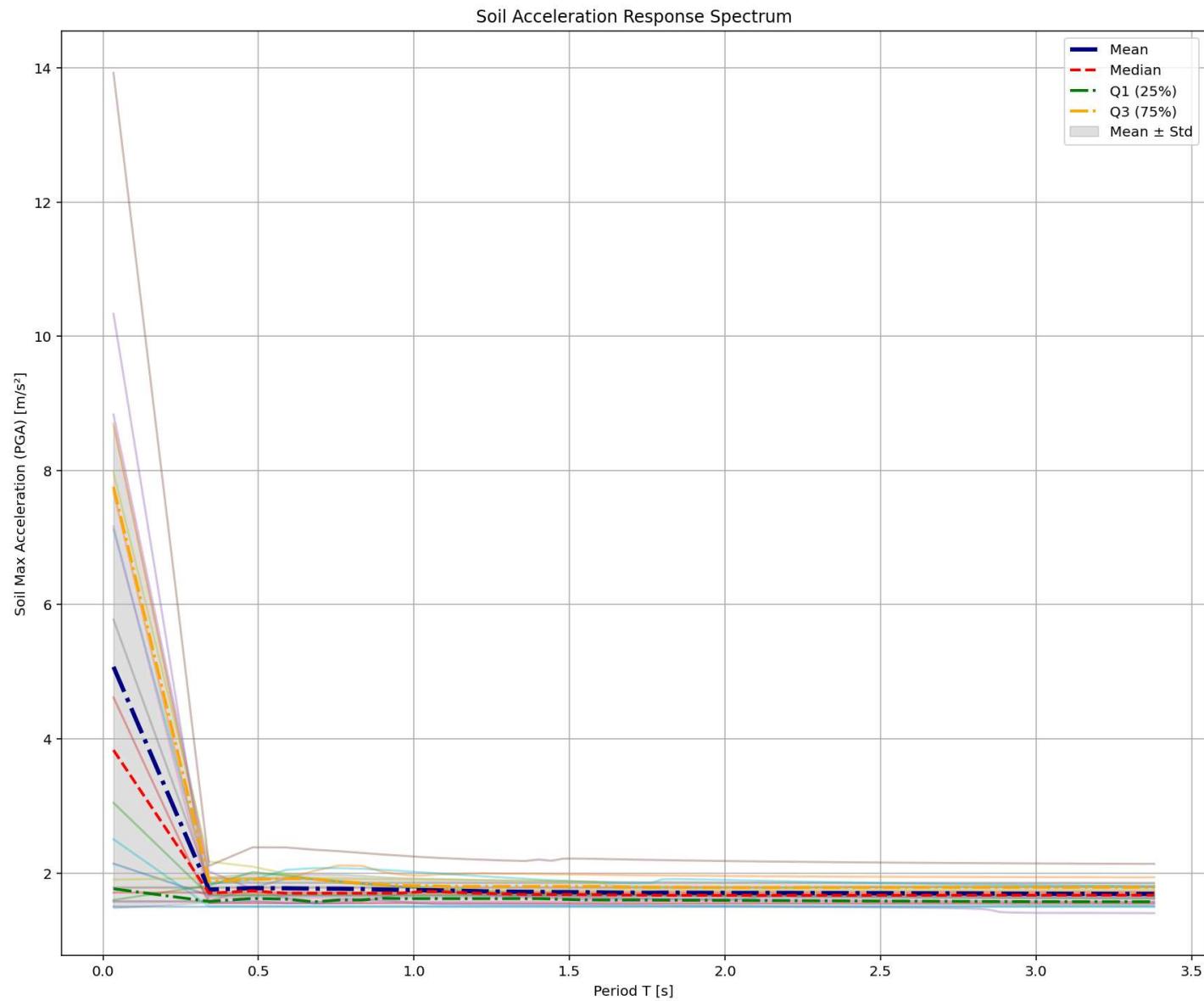
Ground Motion Intensity

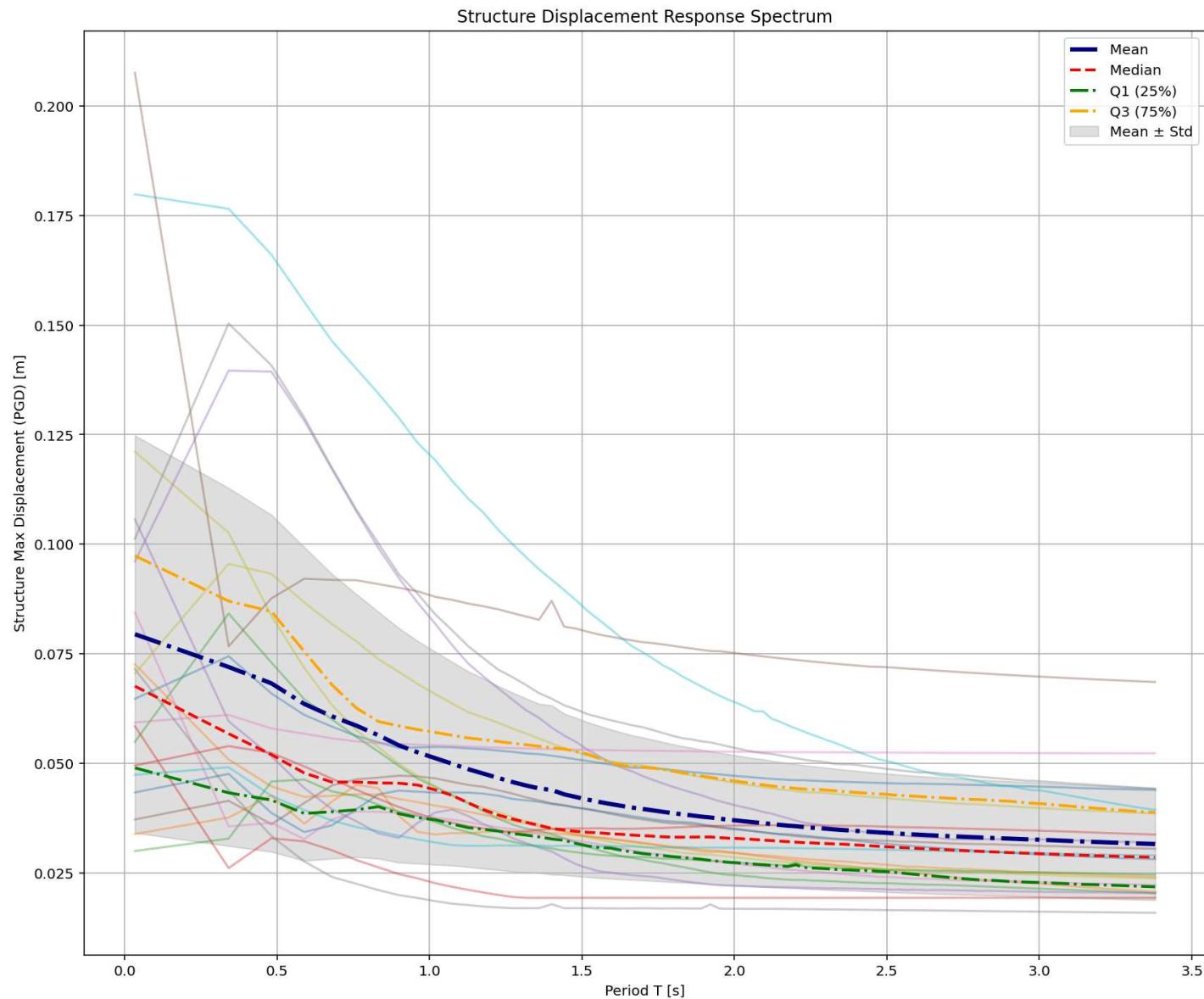
Mean Median 95% CDF 99% CDF

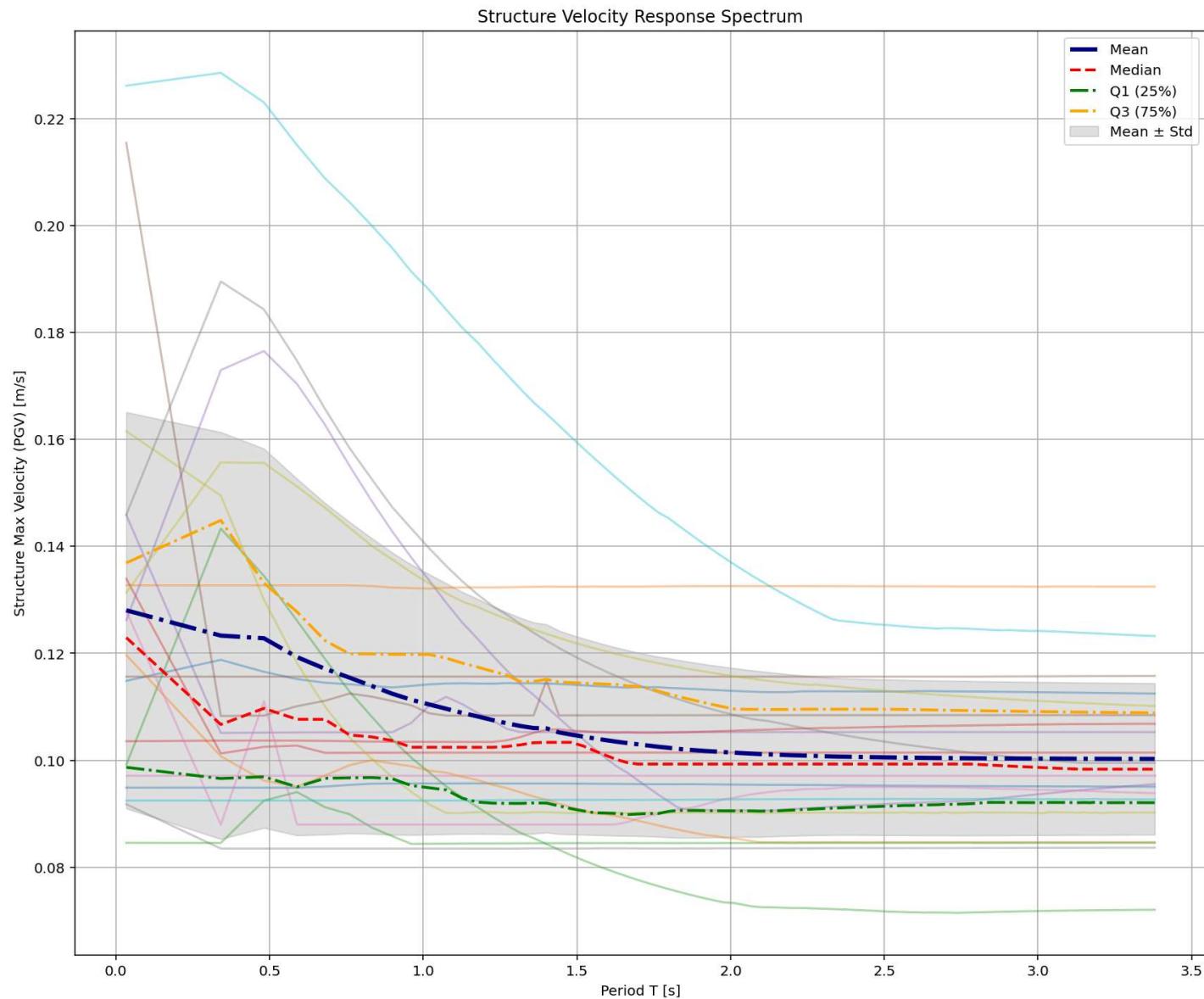
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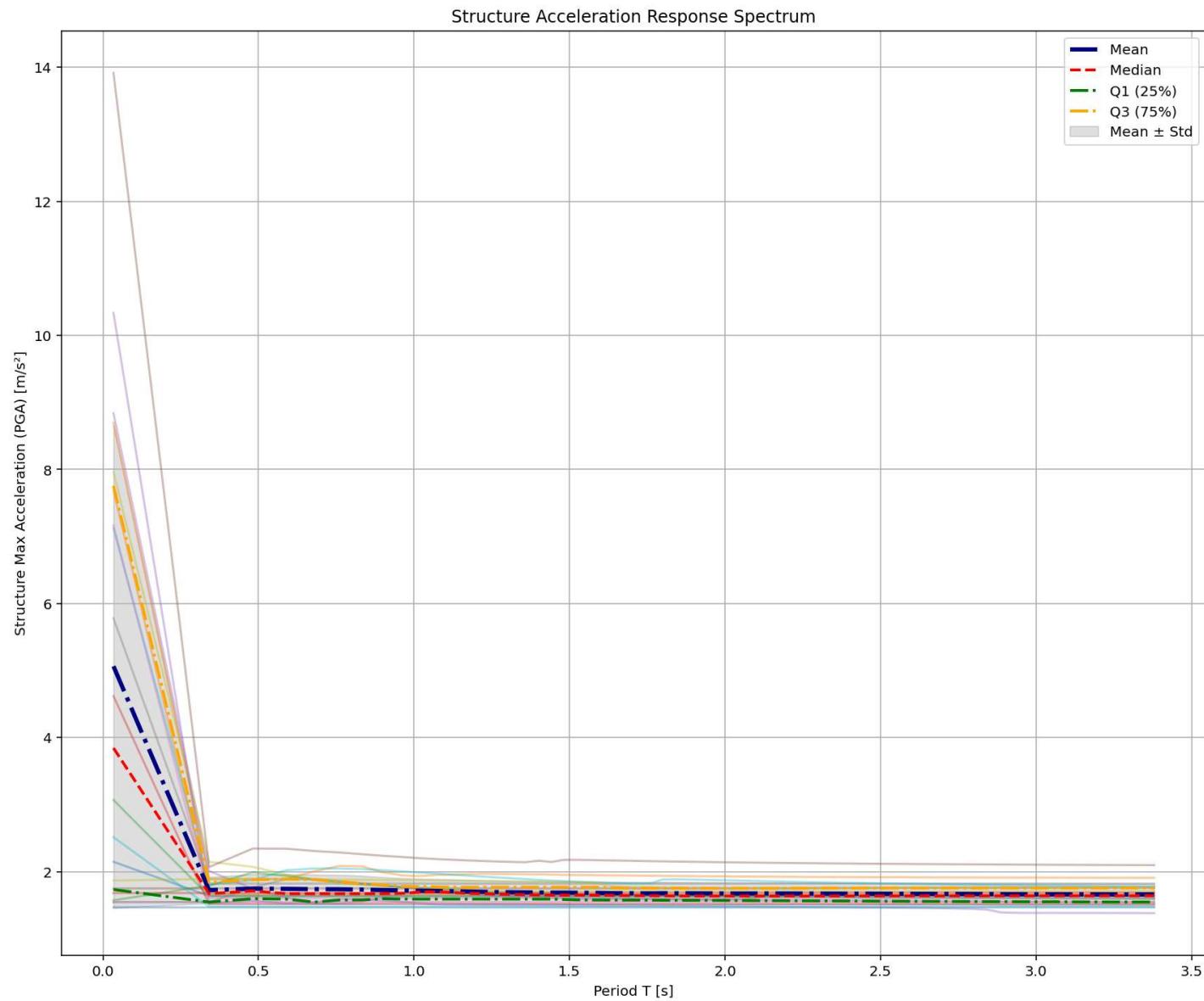


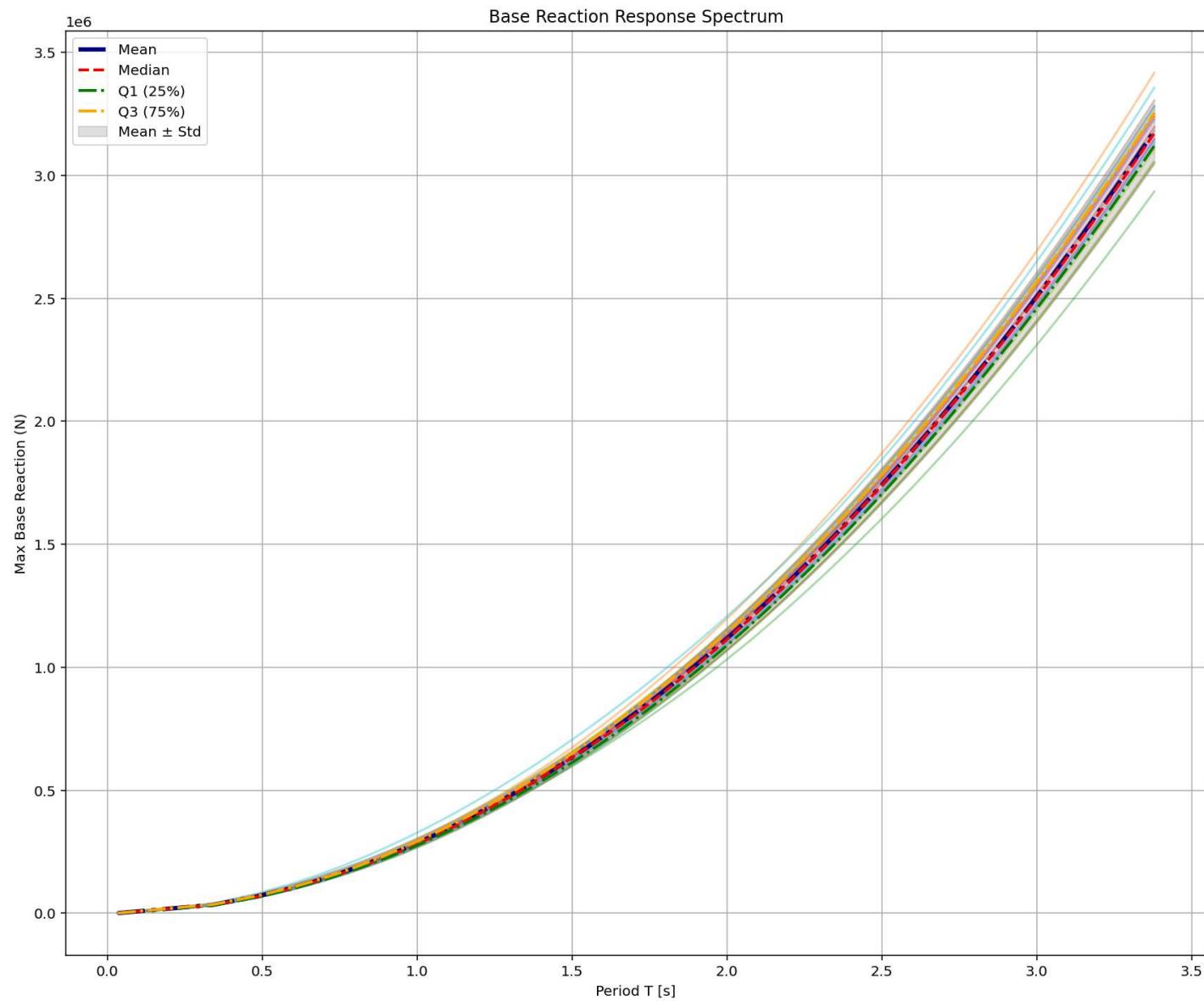


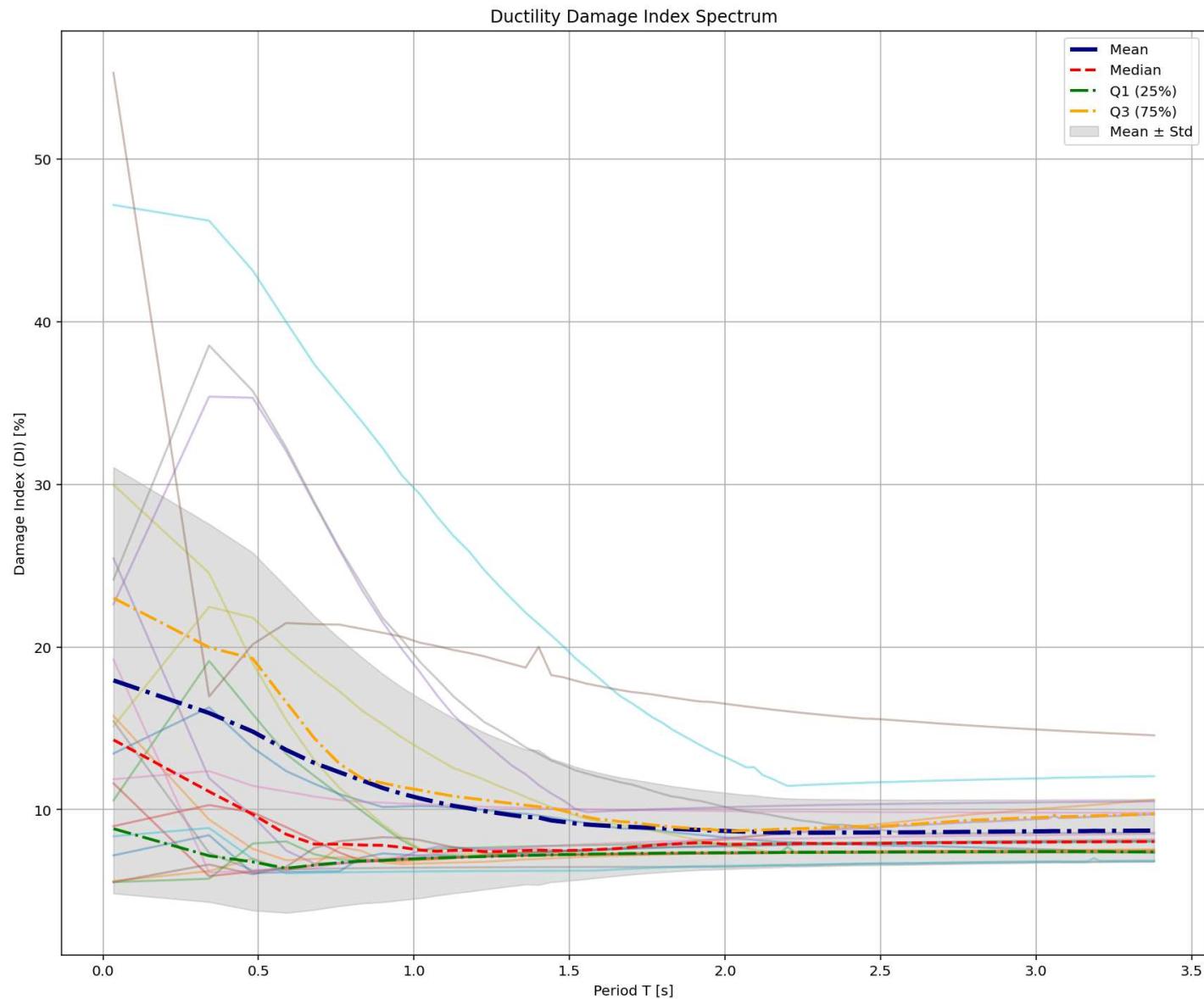


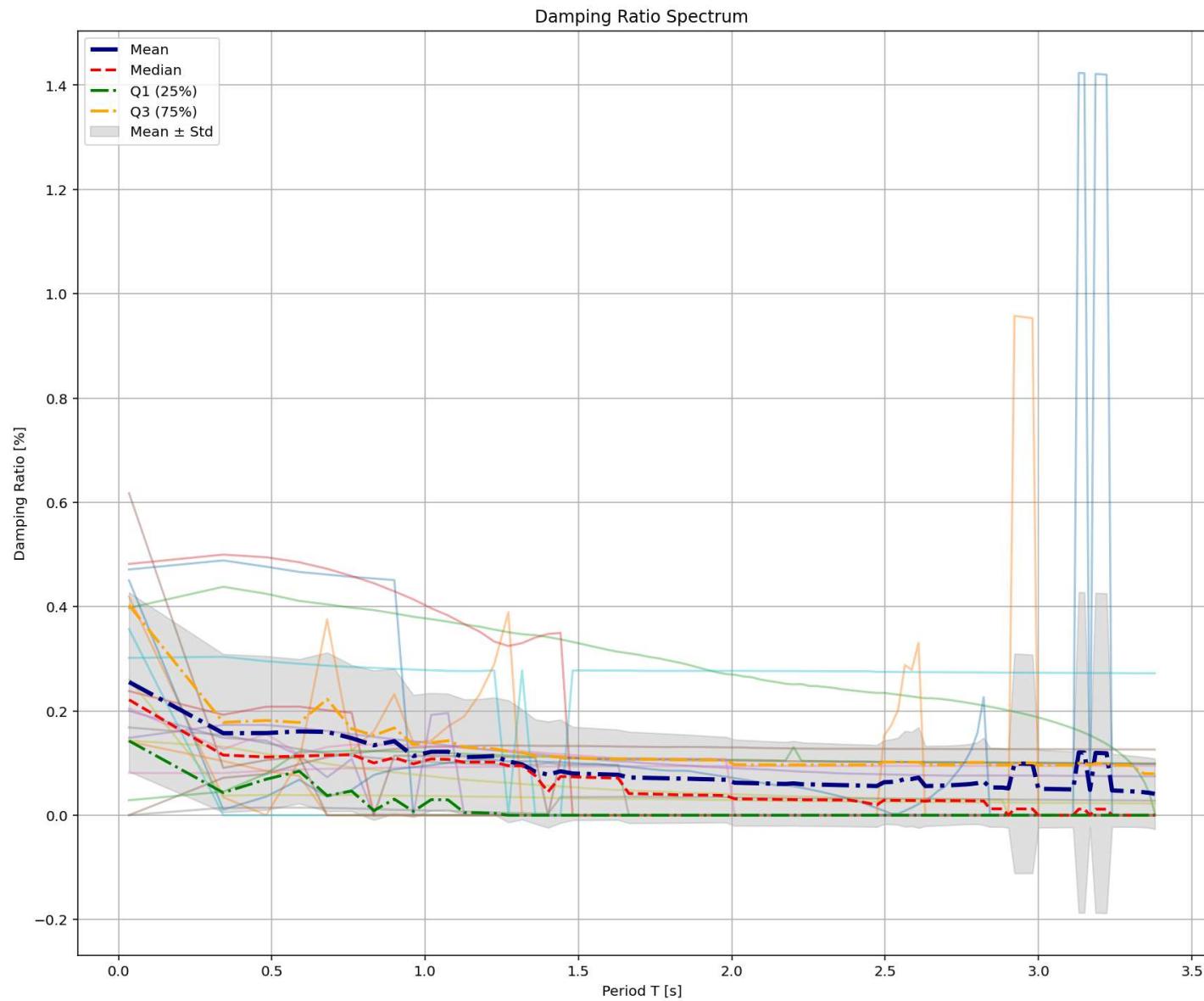


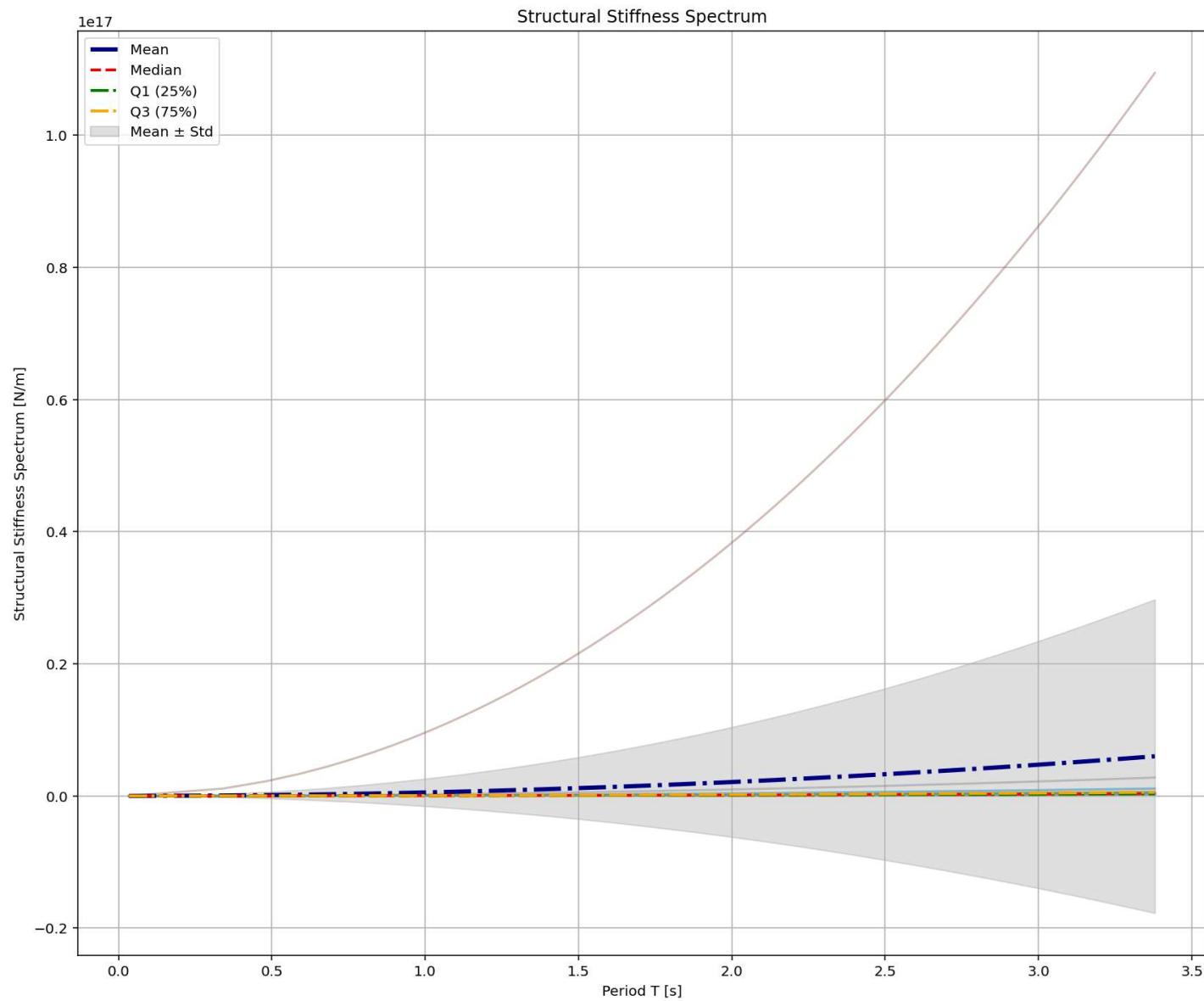












Last Analysis Structural Response + Ground Motion :: MAX. ABS. : 1.4792

