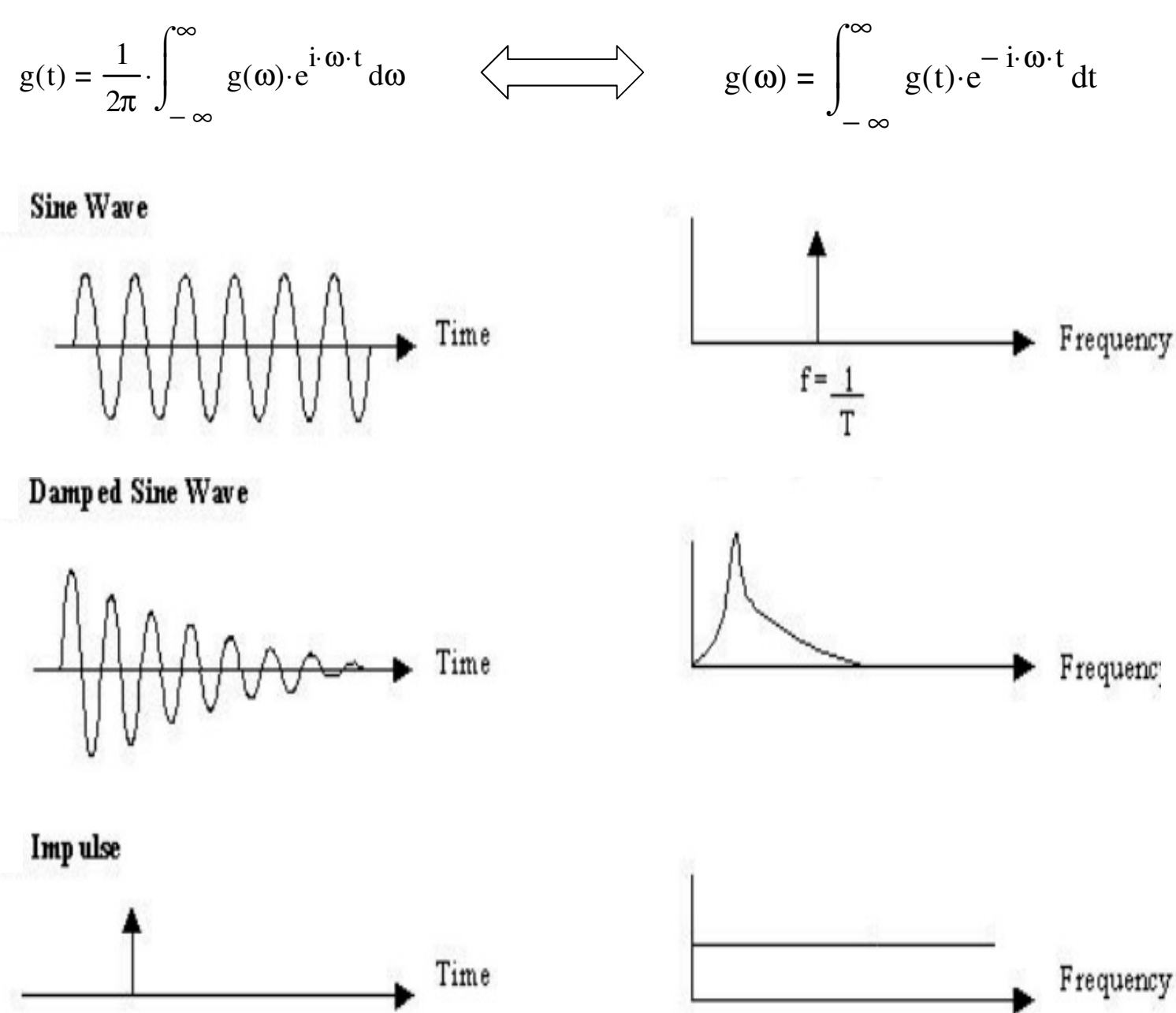


Experimental Frequency Analysis of Direct Shear in NSC and UHPC

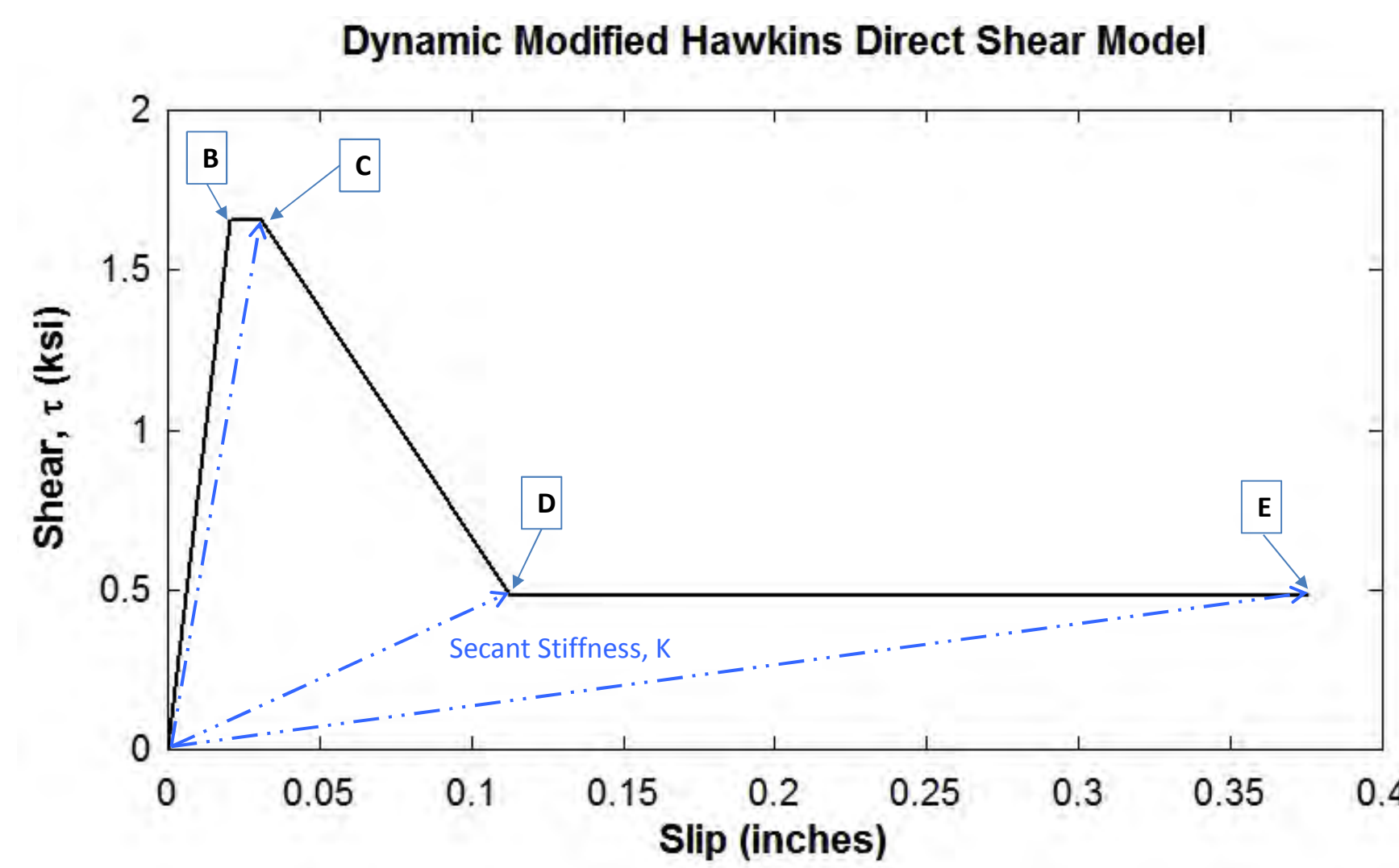
Objectives

The focus of this study was to characterize the direct shear behavior of NSC and UHPC by comparing impact test response data in the time and frequency domains in order to identify and validate shear model parameters.

Fourier Transform

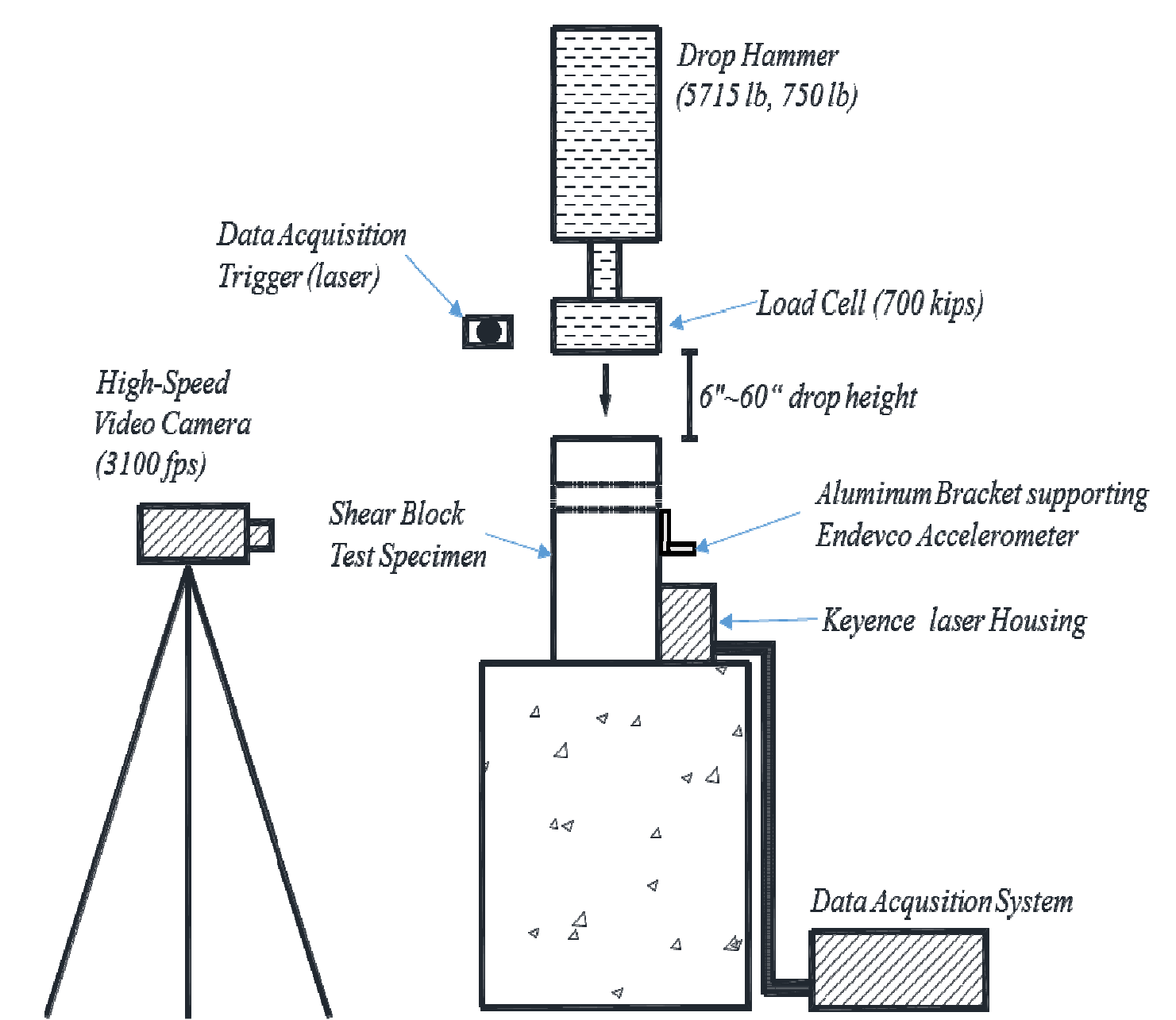


Research Methodology

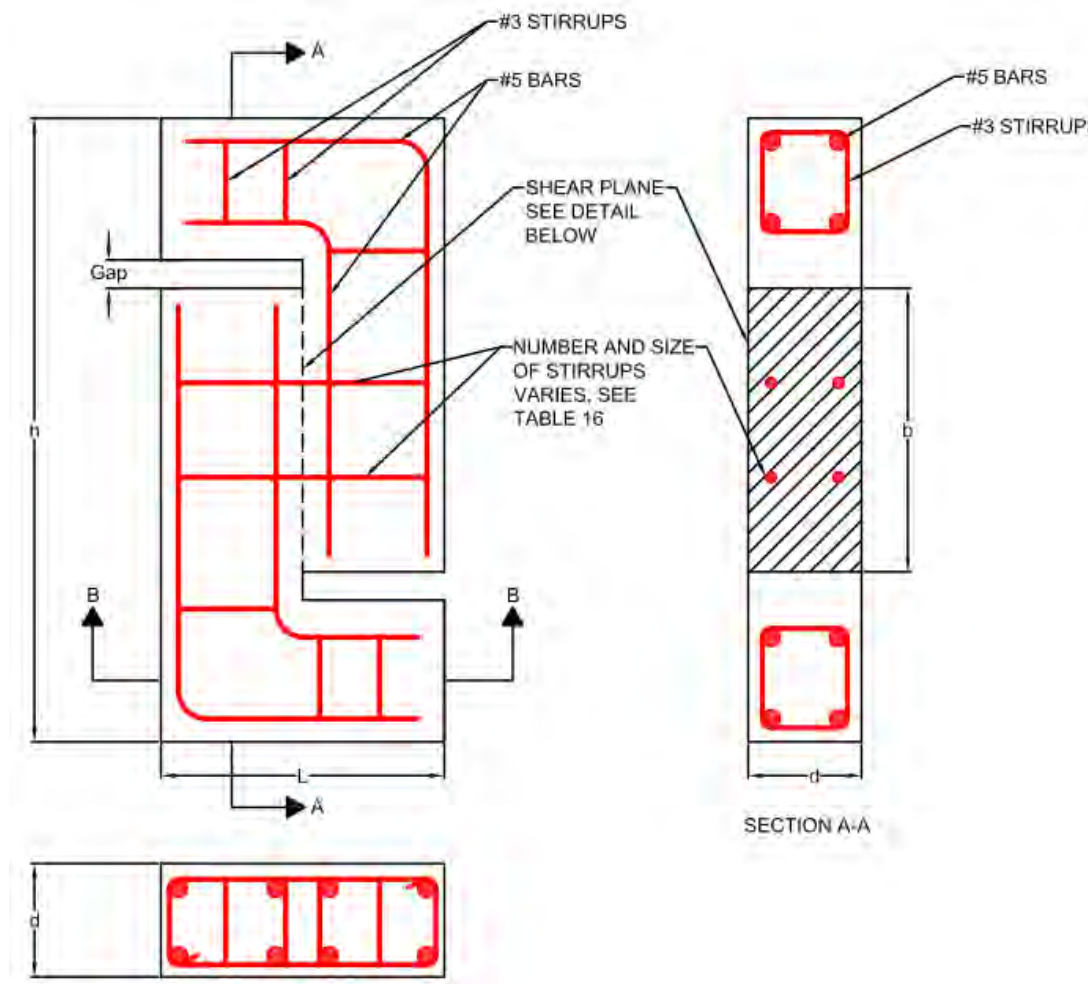


The secant frequencies were computed using the relations, $f = \frac{1}{2\pi} \sqrt{\frac{K}{m}}$ and $K = \frac{\tau \cdot A_c}{slip}$
 A_c is the area of the shear plane, m is the moving mass of the shear block, and K represents the slope of the secant line

Impact Test Setup



Test Specimens



Push-off specimen reinforcement and compressive strengths

| Specimen Type | f'_c (ksi) | Reinforcement Ratio, ρ | Number of Shear Bars | Stirrup Size |
|---------------|--------------|-----------------------------|----------------------|--------------|
| NC-1A-0-D-4 | 5 | 0.0% | 0 | NA |
| NCS-1-1-D-4-3 | 5 | 0.8% | 4 | #3 |
| NCS-1-1-D-5 | 5 | 0.8% | 4 | #3 |
| NCS-1-1-D-6 | 5 | 0.8% | 4 | #3 |
| NCS-1-1-D-7-6 | 5 | 0.8% | 4 | #3 |
| NCS-2-2-D-1 | 5 | 1.6% | 8 | #3 |
| CT1-1-1-D-3 | 29 | 0.8% | 4 | #3 |
| CT1-1-1-D-4 | 29 | 0.8% | 4 | #3 |

Push-off specimen geometry

| Specimen Size | L (in) | h (in) | d (in) | b (in) | Gap (in) | Shear Plane, bd (in^2) |
|---------------|--------|--------|--------|--------|----------|------------------------------|
| 1 | 11.5 | 25 | 5.5 | 10 | 1 | 55 |
| 1A | 11.5 | 27 | 5.5 | 11 | 1.5 | 60.5 |
| 2 | 14.5 | 31 | 5.5 | 13.5 | 2 | 74.25 |

Typical Test Results

NCS with 0.8% shear reinforcement



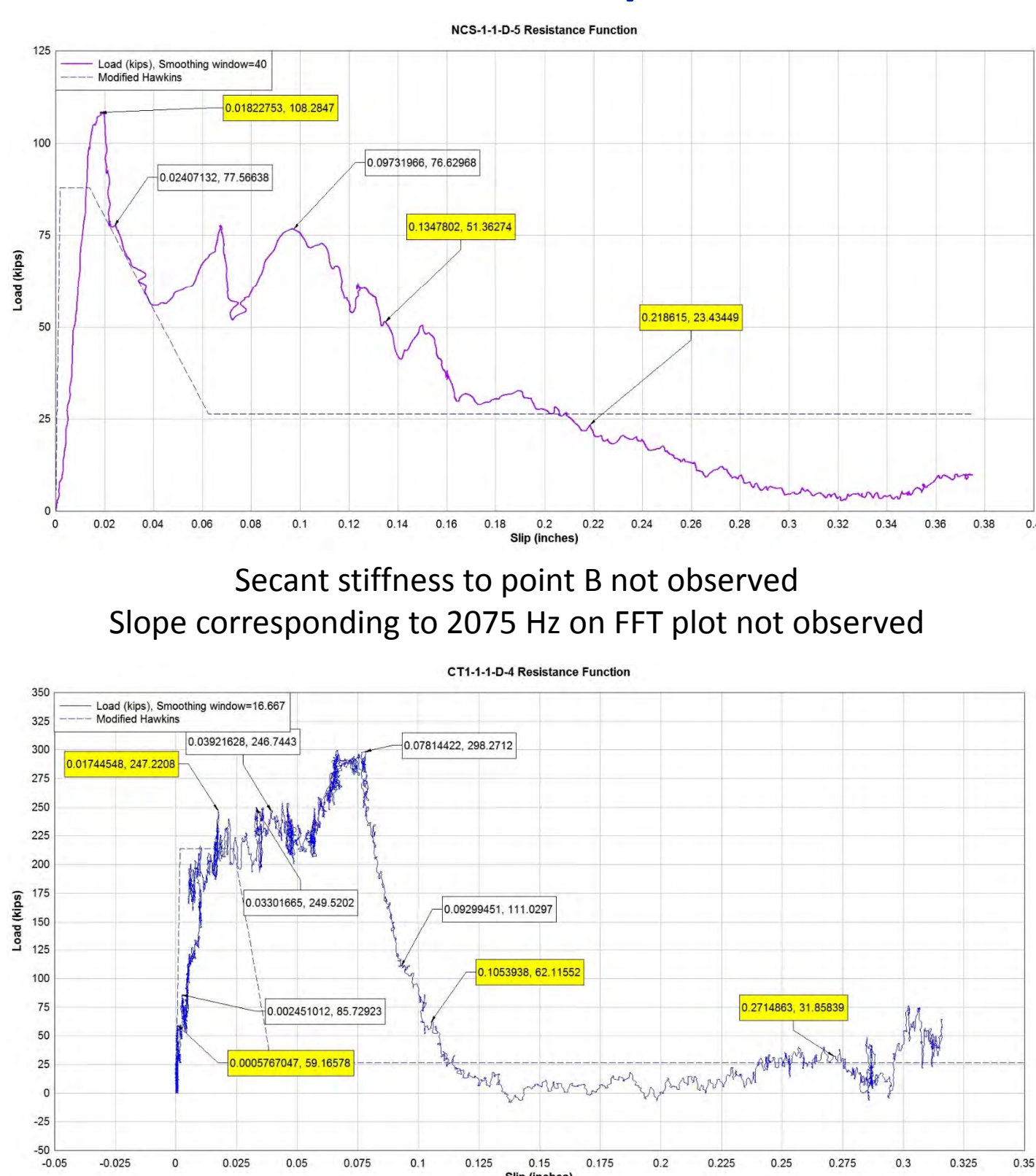
CORTUF-1 with 0.8% reinforcement



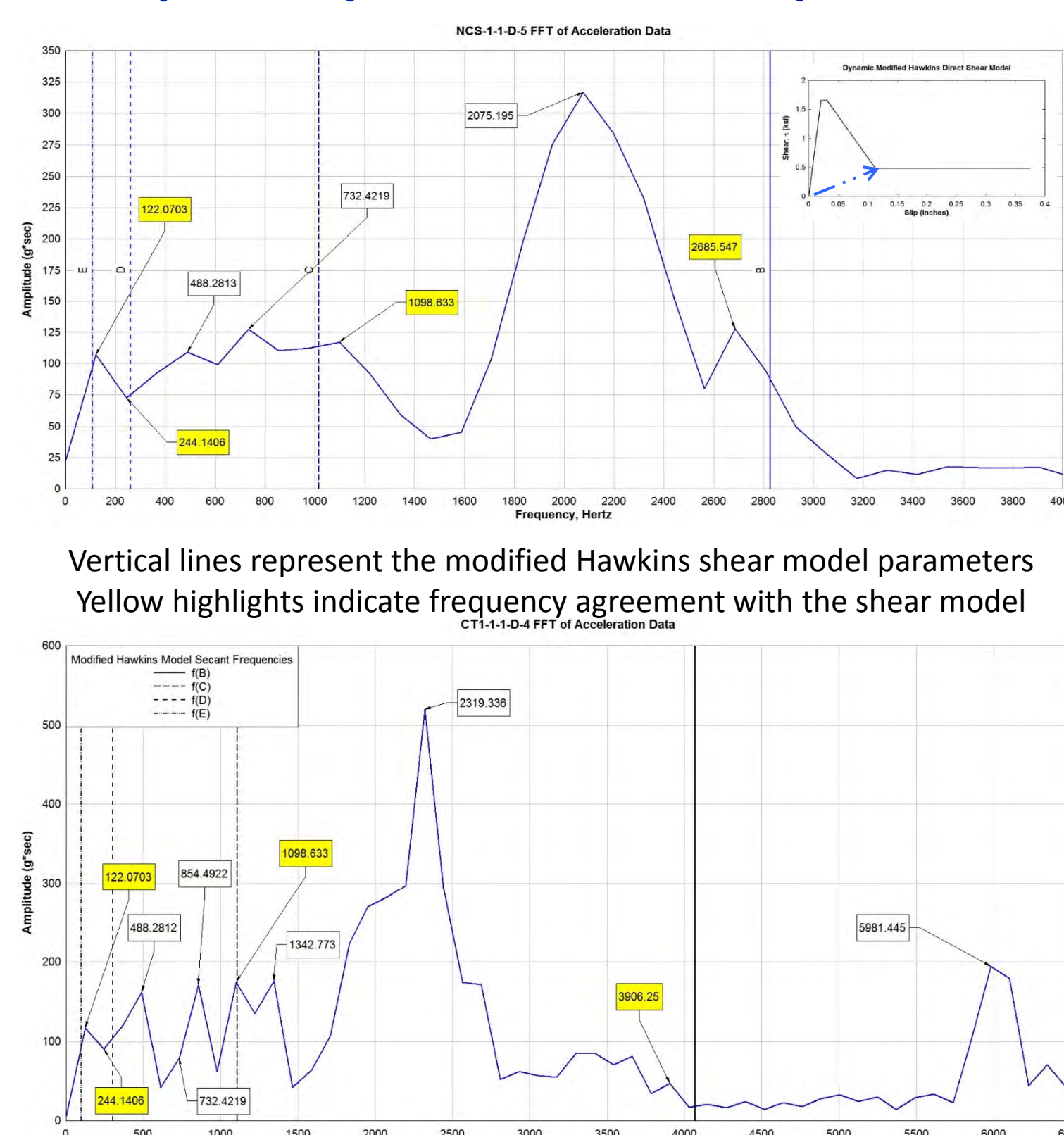
NCS with 1.6% reinforcement



Time Domain Response



Frequency Domain Response



Fourier Analysis Results

Frequency comparison between modified Hawkins, FFT and resistance function parameters

| Specimen | Modified Hawkins Parameters (Secant Slopes) | Modified Hawkins Secant Frequency (Hz) | FFT Frequency Spike (Hz) | Resistance Function Secant Frequency (Hz) |
|-------------|---|--|--------------------------|---|
| NCS-1-1-D-5 | B | 2828 | 2686 | slope undefined |
| | C | 1015 | 1099 | 979 |
| | D | 261 | 244 | 248 |
| | E | 107 | 122 | 131 |
| CT1-1-1-D-4 | B | 4070 | 3906 | 3672 |
| | C | 1109 | 1099 | 1017 |
| | D | 303 | 244 | 284 |
| | E | 98 | 122 | 127 |

Only one specimen each of NSC and UHPC shown
All specimens have similar agreement

Conclusions

- Frequencies for the entire response behavior for each specimen were captured by the accelerometers
- FFT frequencies showed close correlation to the frequencies determined from the modified Hawkins shear model and from resistance functions
- In several cases, early response modes could not be determined from the resistance function but could be identified in the corresponding FFT plot
- Recent and current shear models provide an overall response envelope for tests so far