

Is the Grouted Shear Stud Connection Durable in Cold Climates?

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What is the Grouted Shear Stud (GSS) Connection?

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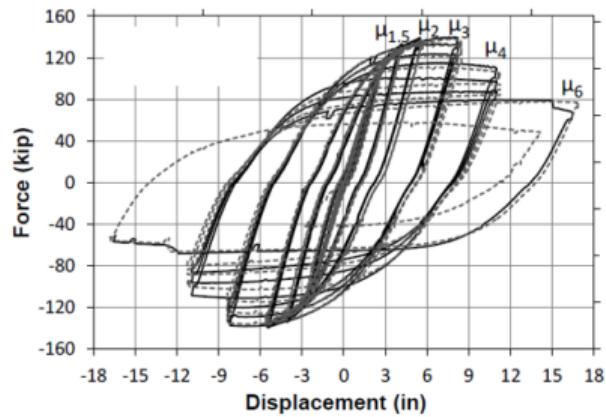
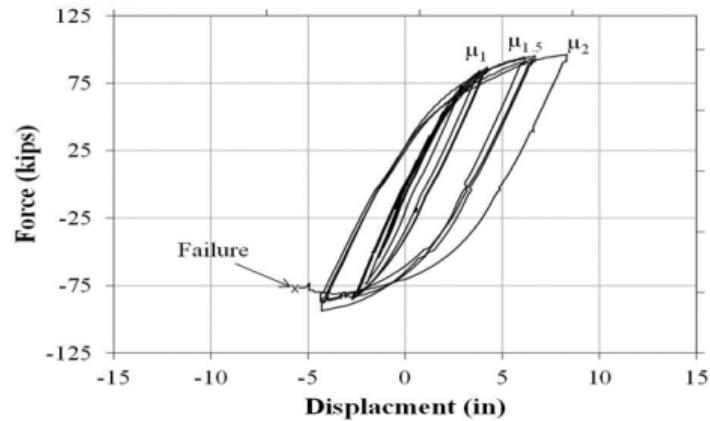
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What about its durability in cold climates?

Consequences of deteriorated GSS connection

We need to better understand the consequences of grout deterioration on structural performance.

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How to find out?

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Step 1

A control large scale test with new GSS connection.

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Step 2

Large scale tests with GSS connections simulating grout deterioration.

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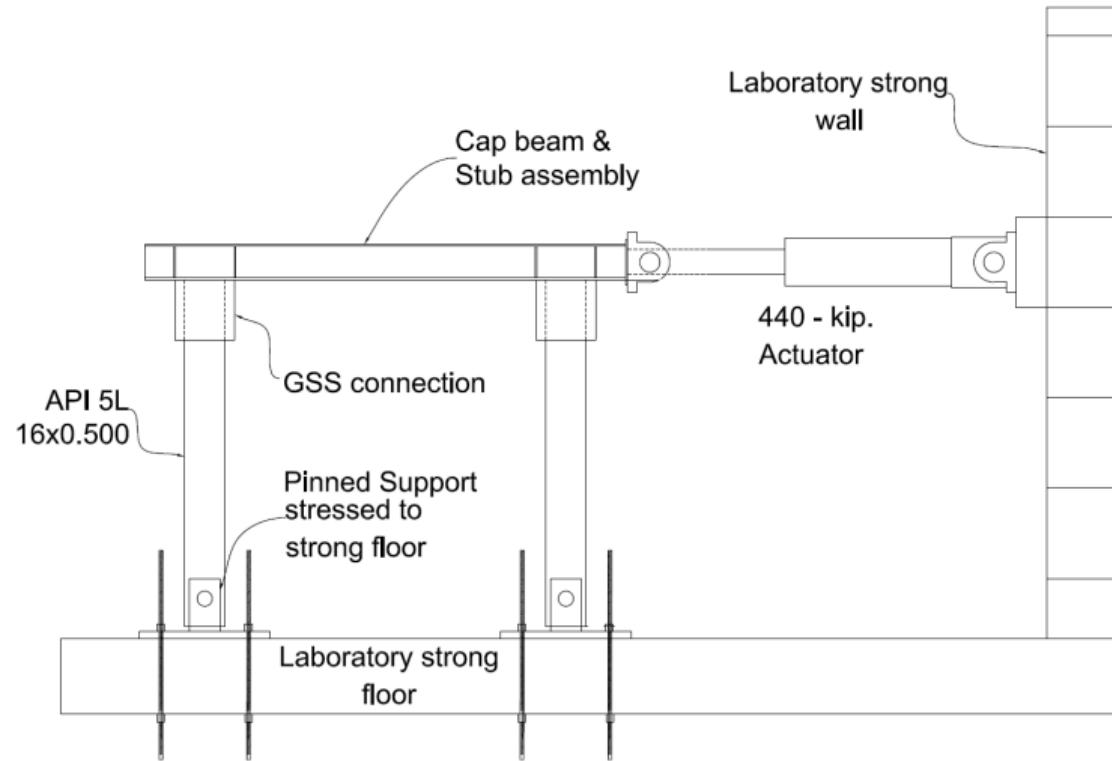
Step 2

Large scale tests with GSS connections simulating grout deterioration.

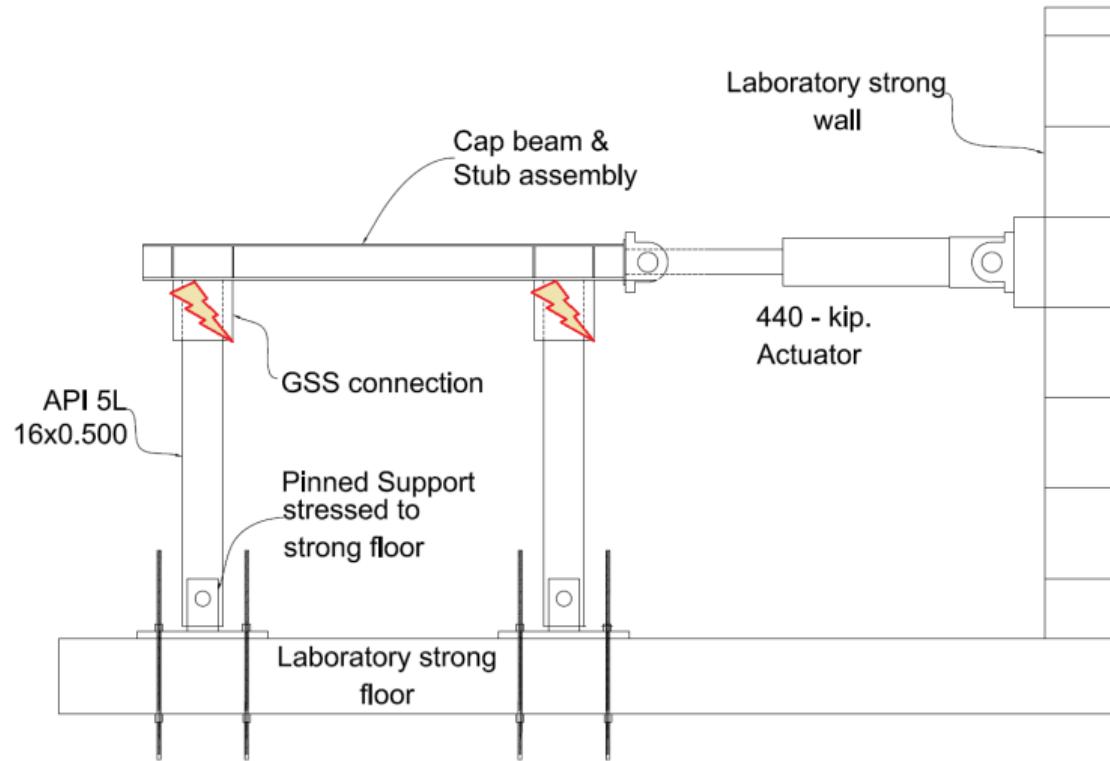
Step 3

Compare results to check for consequences of grout deterioration.

Research plan



Research plan

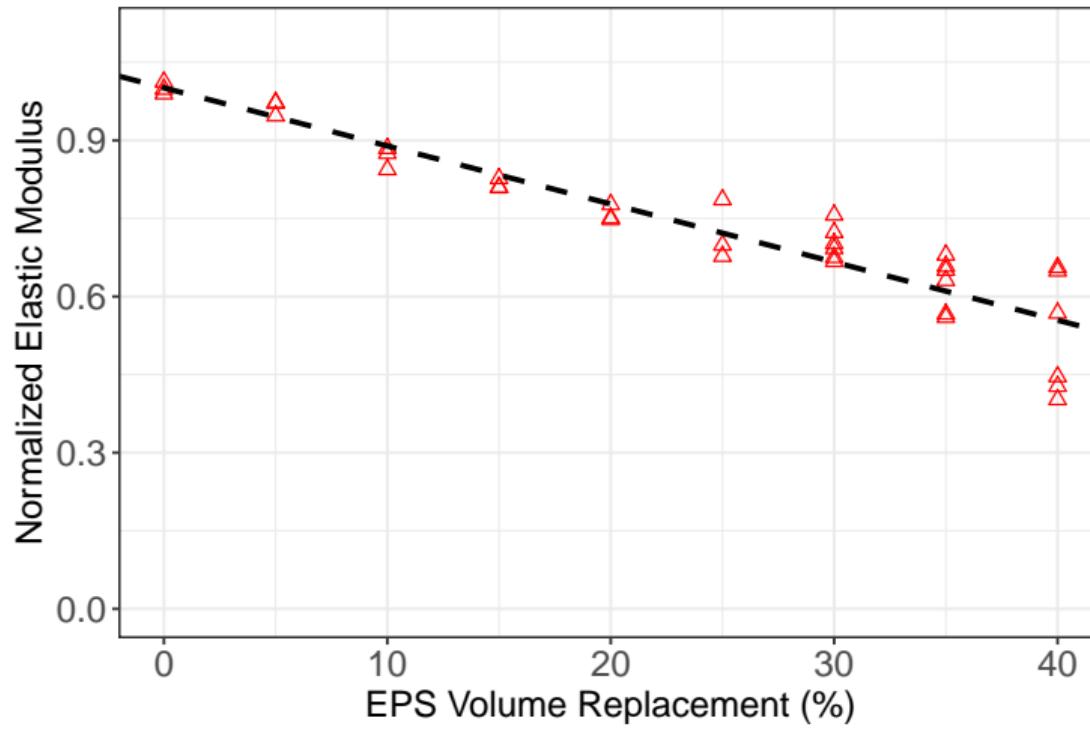


Simulating deterioration



Expanded Polystyrene (EPS) beads. (After Bucher 2009)

How much EPS?

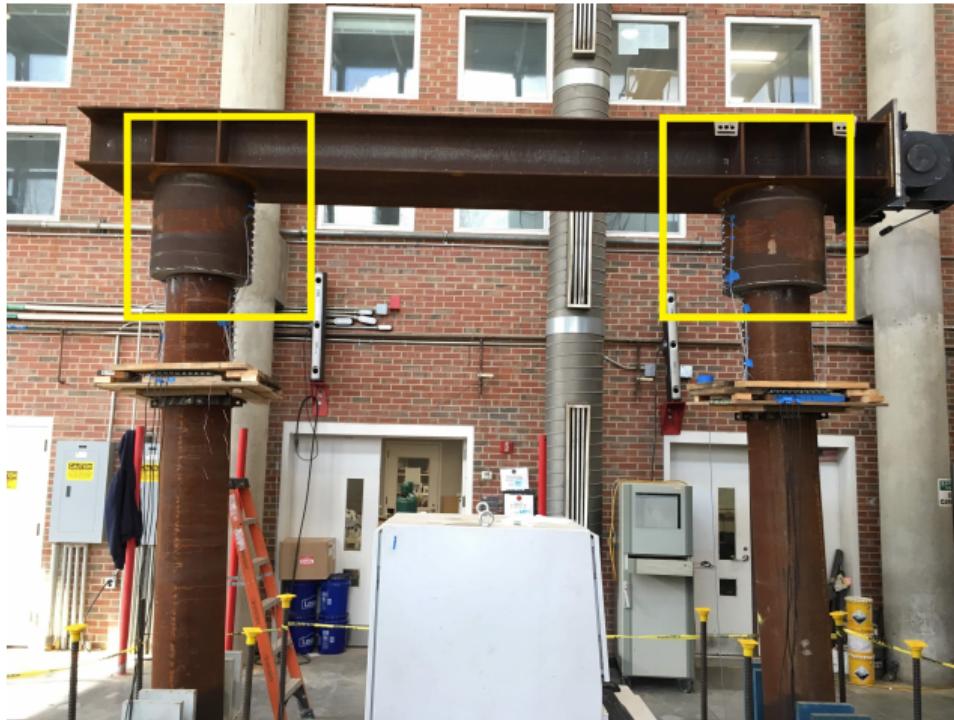


Elastic modulus versus volume of EPS

Test Implementation



Test Implementation



Test Implementation



Large Scale Test Matrix

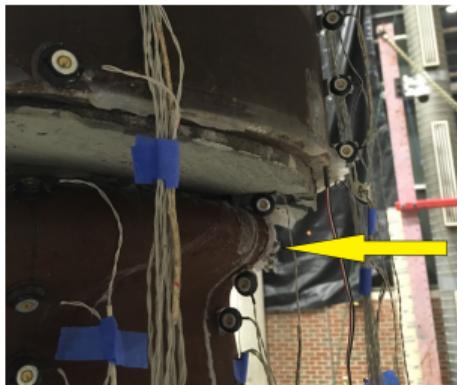
Control versus Deteriorated

Test No.	Test Code.	Characteristics
0	NG-96	New grout
1	NG-32	New grout
2	DG-32	Deteriorated grout ($0.7E$ & $0.35f'_c$)
3	DG-16	Deteriorated grout ($0.7E$ & $0.40f'_c$)

Experimental Comparisons - Failure mode

Pile wall buckling and plastic hinge formation

NG-32



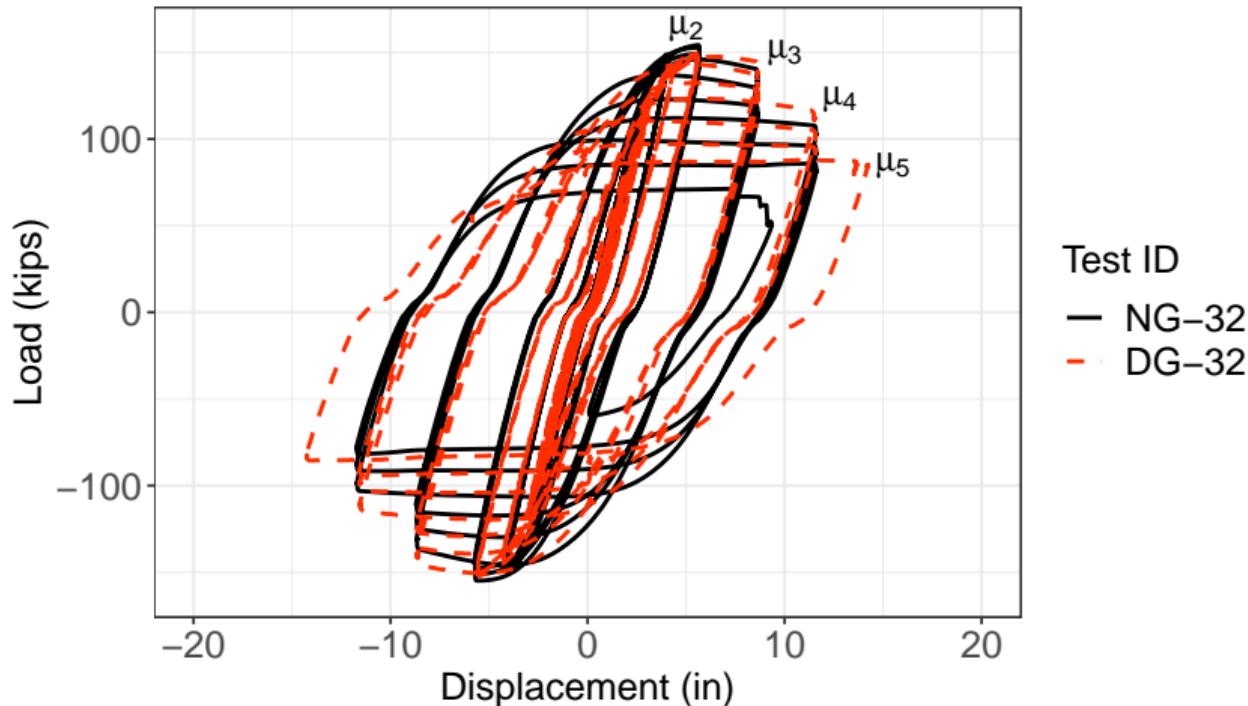
DG-32



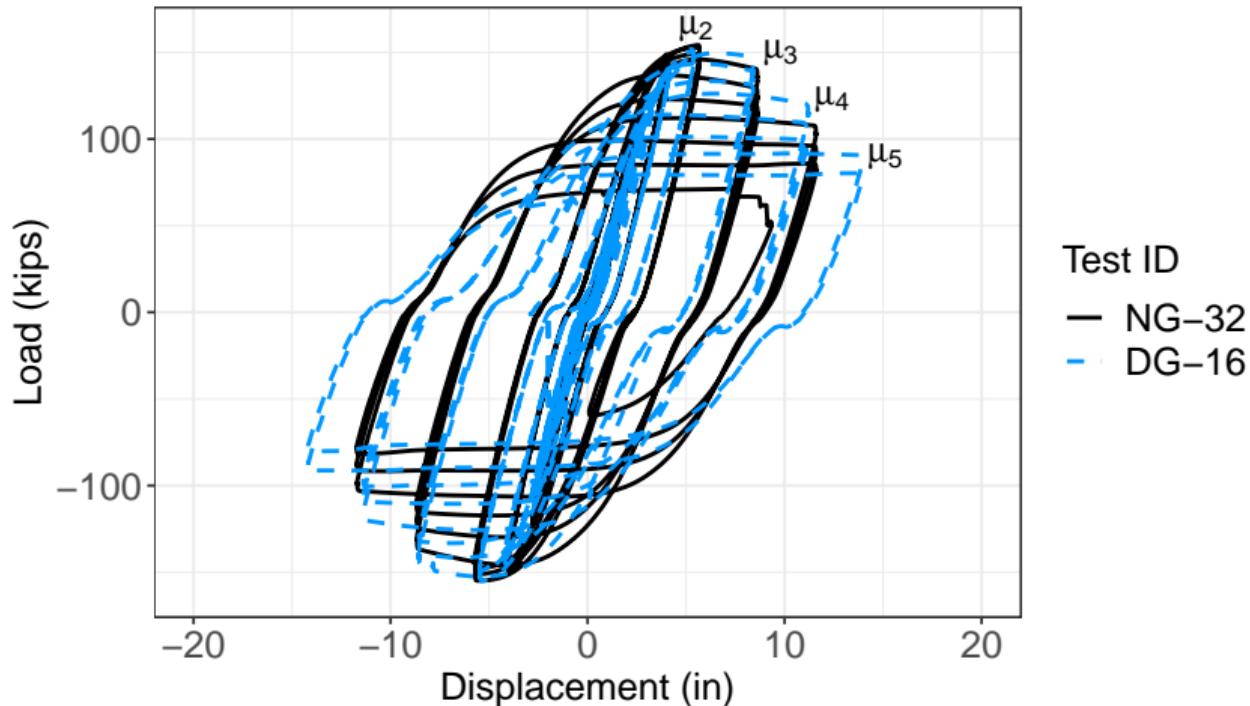
DG-16



Force Displacement Response

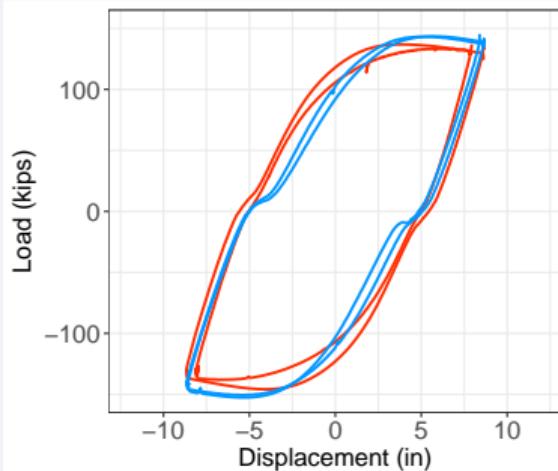


Force Displacement Response

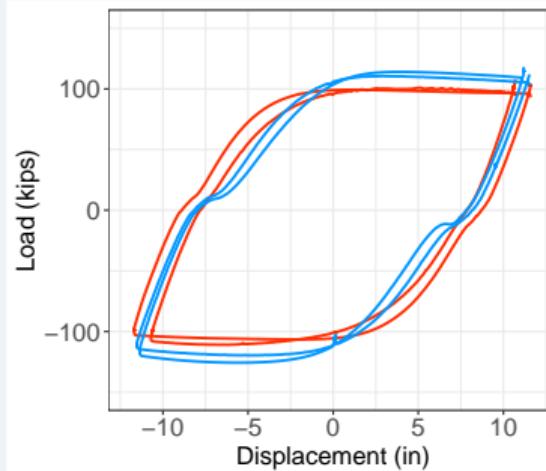


A closer look

Comparison of global hysteresis loops

 μ_3

Test_ID
— NG-96
— NG-32
— DG-32
— DG-16

 μ_4

Test_ID
— NG-96
— NG-32
— DG-32
— DG-16

Are there consequences of grout damage?

Conclusion

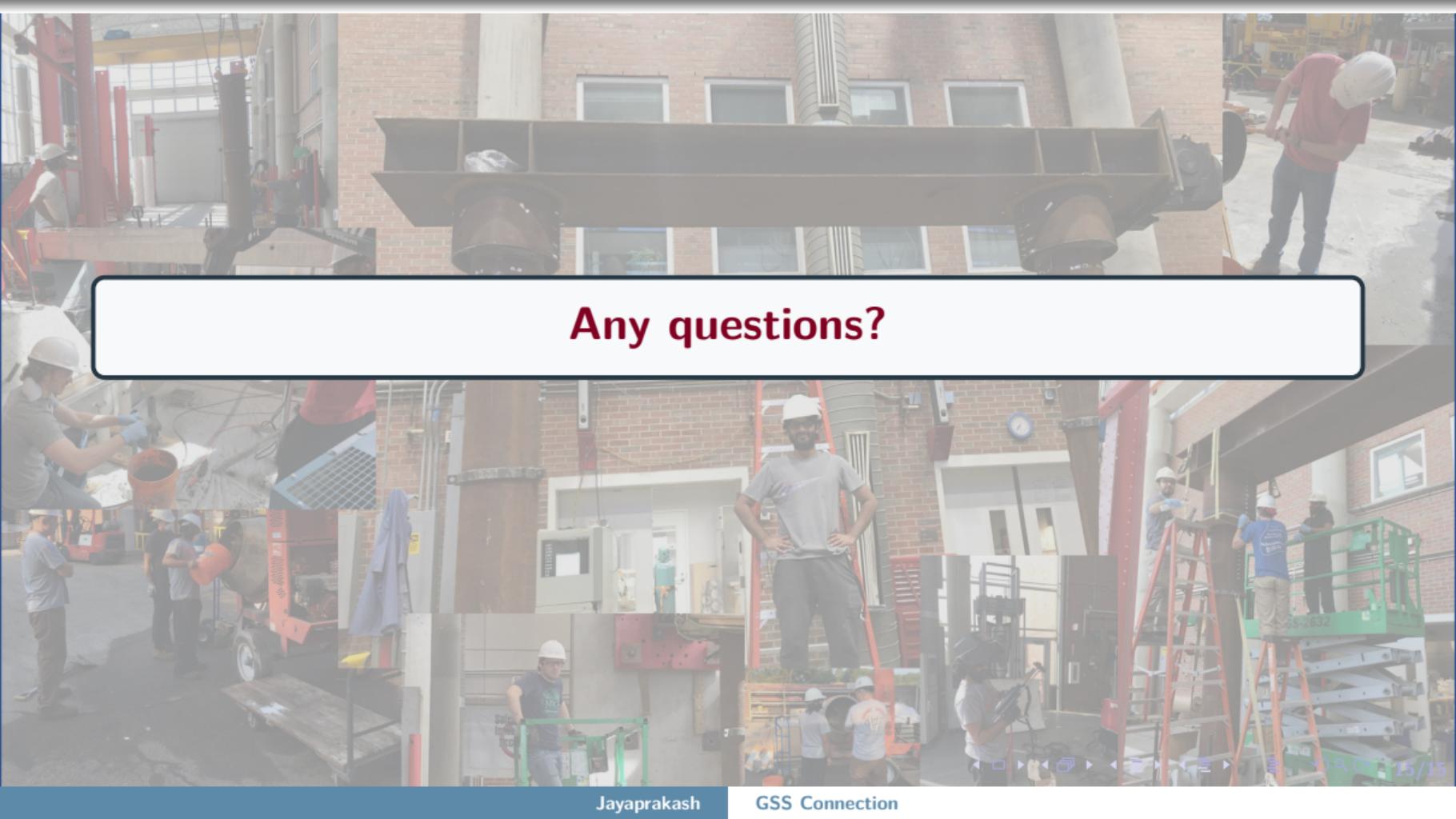
Large scale structural experiments indicate that **grout durability is not of significant concern** because the GSS connection performed satisfactorily even when grout properties (E and f'_c) were significantly reduced.

Acknowledgements

I want to thank...

- ① Alaska Dept. of Transportation
- ② Constructed Facilities Laboratory





Any questions?

Backup slides

Variables

Test 1

Test 2

Test 3

Test Features

Variables

Test 1

Standard grout

Test 2

“Damaged” grout

Test 3

“Damaged” grout

Variables

Test 1

Standard grout

$$E = E_0$$

$$f'_c = f'_{c0}$$

Test 2

“Damaged” grout

$$E = 0.7E_0$$

$$f'_c = 0.35f'_{c0}$$

Test 3

“Damaged” grout

$$E = 0.7E_0$$

$$f'_c = 0.4f'_{c0}$$

Variables

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Standard grout

$$E = E_0$$

$$f'_c = f'_{c0}$$

32 (1" dia.) shear studs

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"Damaged" grout

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16 (1" dia.) shear studs

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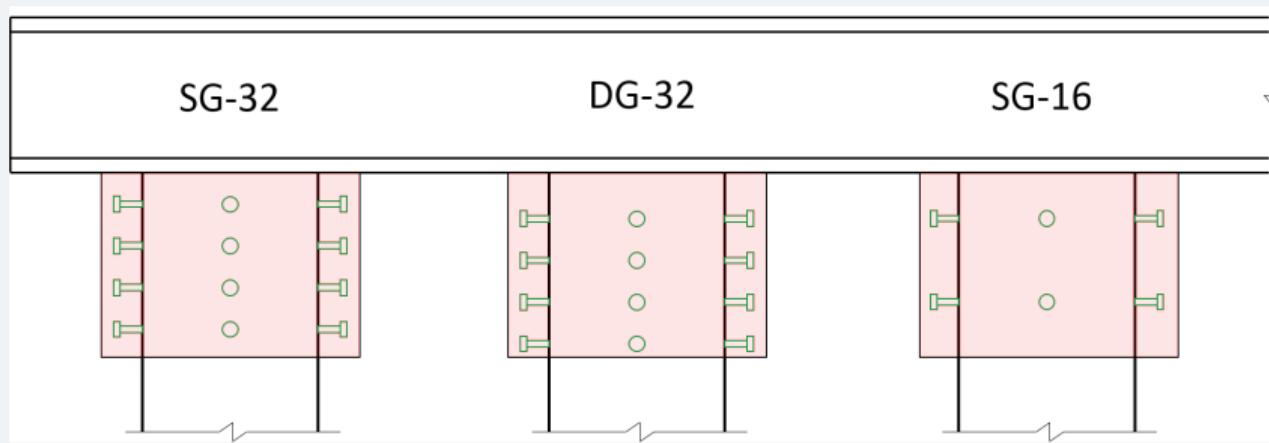
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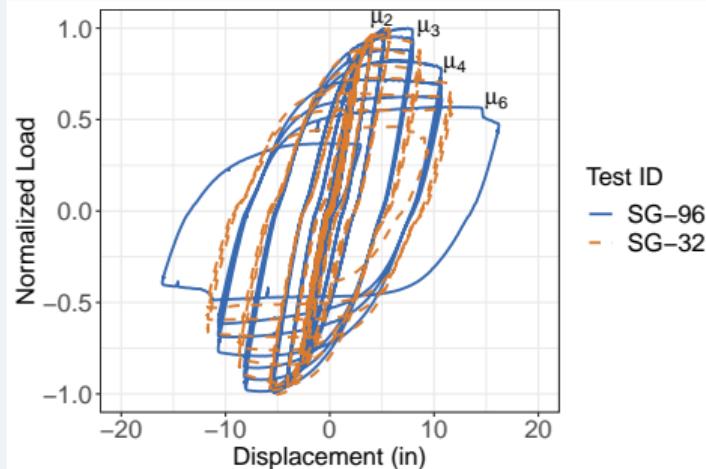
DG-16

Stud configuration

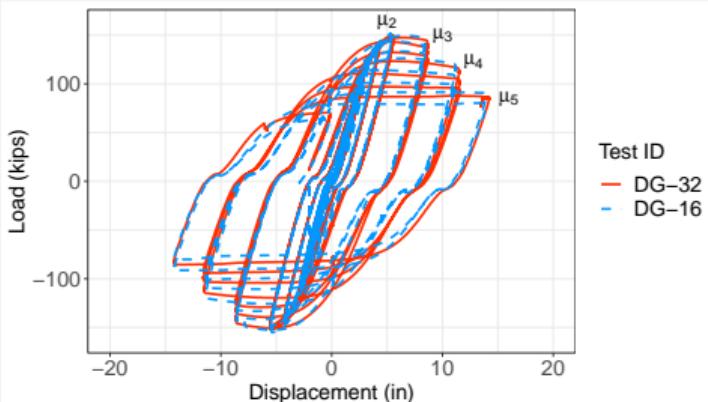


Effect of the number of shear studs

Comparison of global behavior



96-3/4" to 32-1"



32-1" to 16-1"

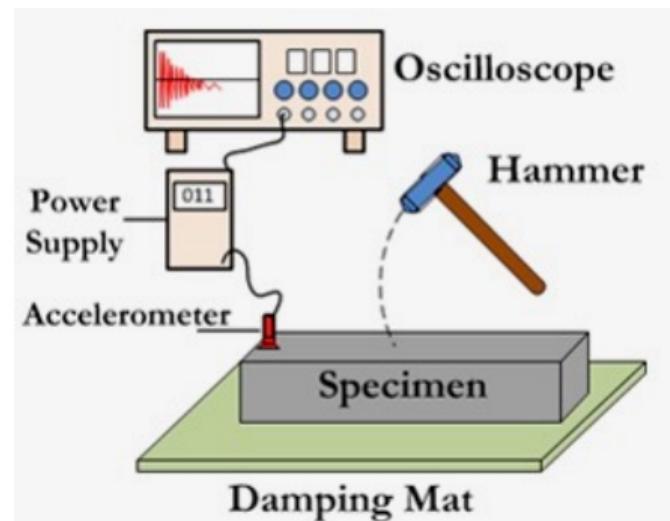
Testing FT resistance of grouts

Mechanism

Water expands inside grout upon freezing causing cracking.

- 4 different commercial grouts were tested.

- Testing Standard

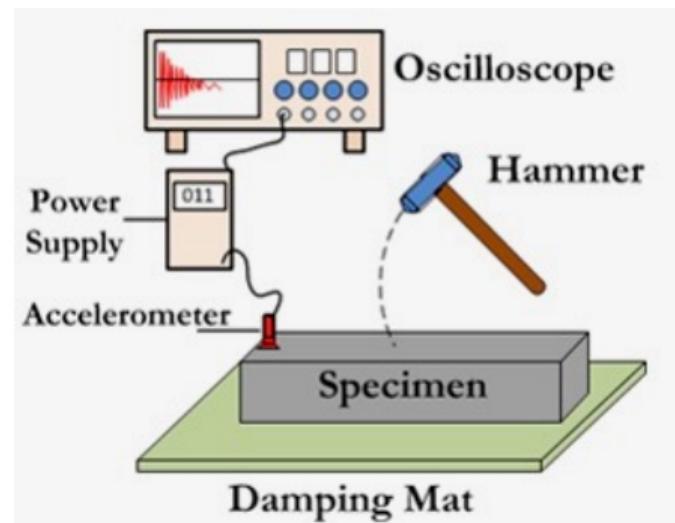


Testing FT resistance of grouts

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- ① 4 different commercial grouts were tested.
 - ① CG1, CG2, CG3, CG4
- ② Testing Standard
 - ① ASTM C666
 - ① 300 F-T Cycles
 - ① Relative Dynamic Elastic Modulus (RDME) to assess damage
 - ① Durability Factor (DF)

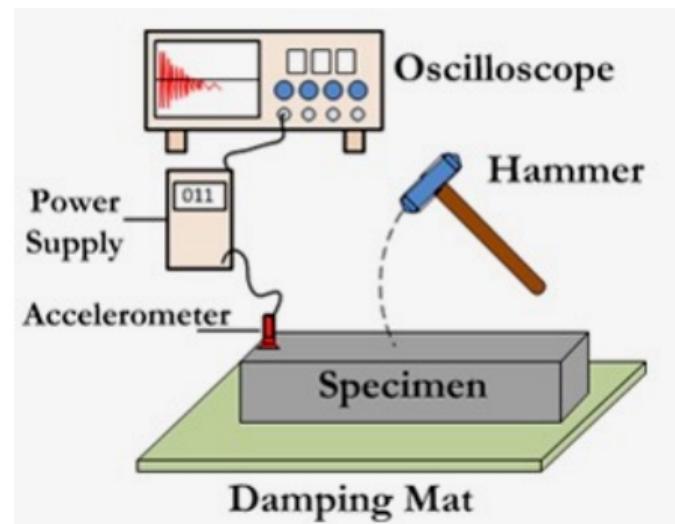


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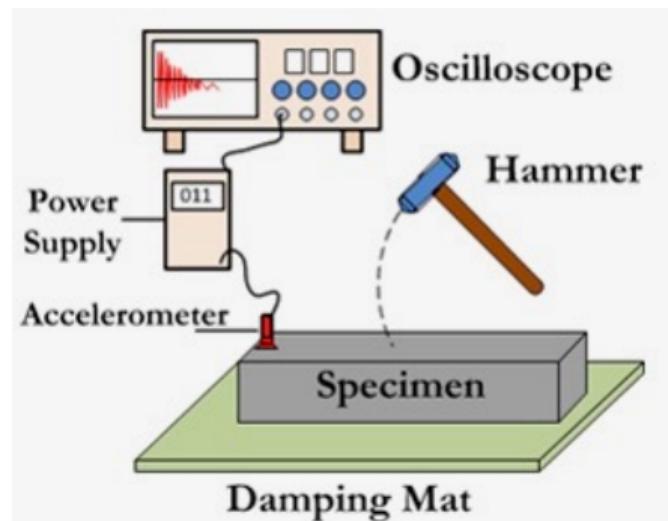
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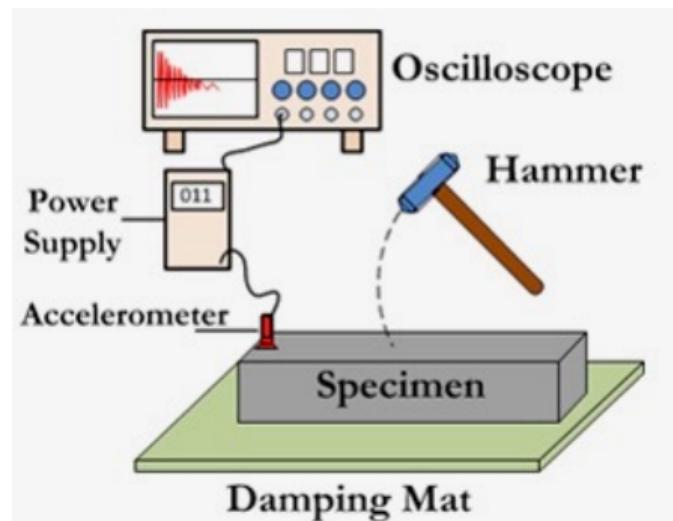


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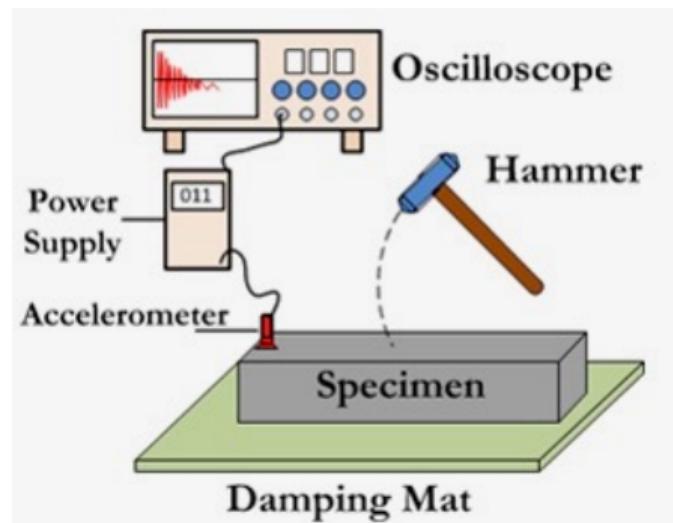


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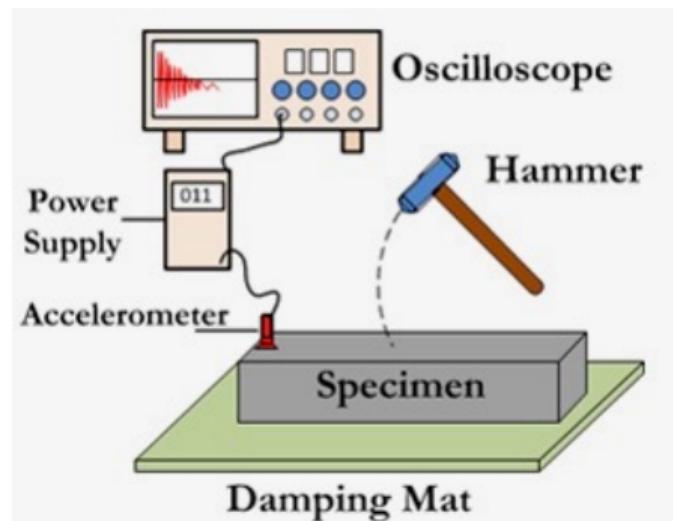


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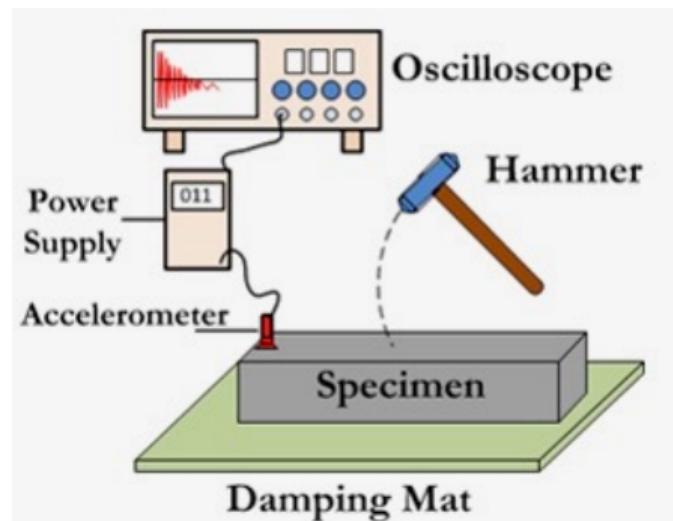


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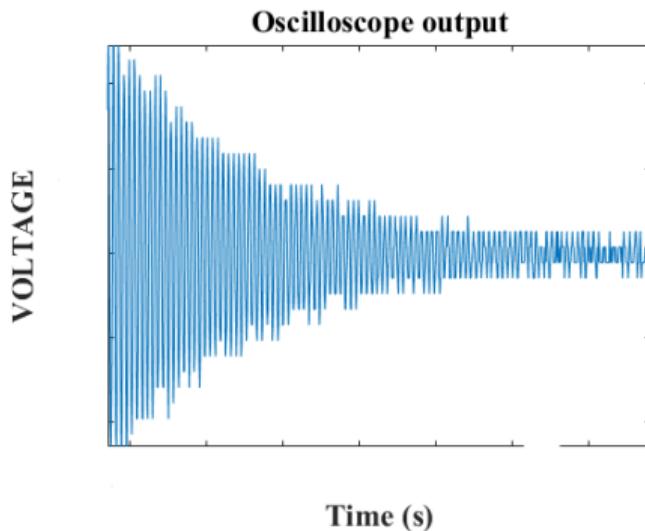
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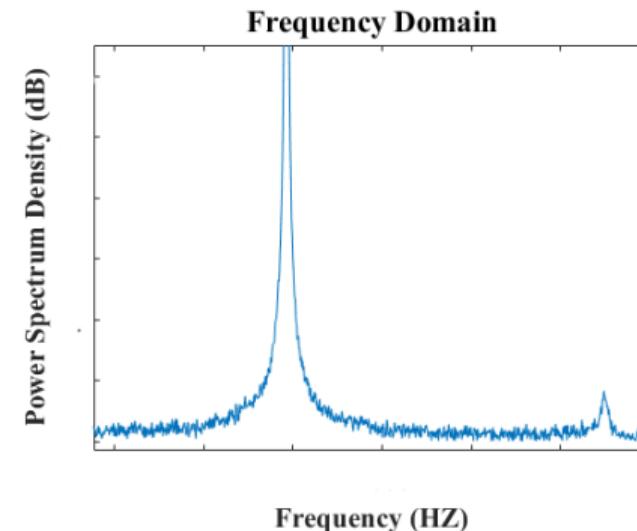


How to calculate RDME?

Impact gives time history response



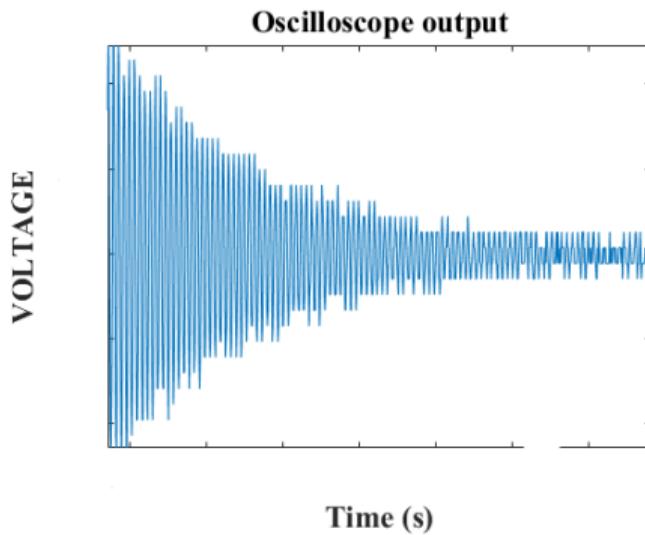
Convert to frequency domain



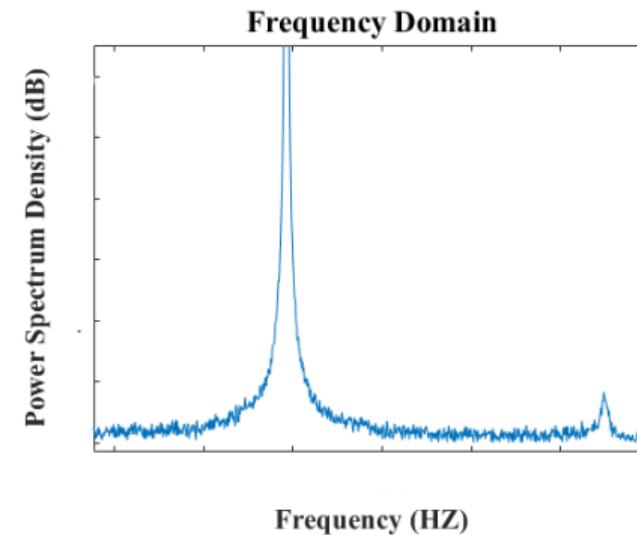
$$P = \frac{f^2}{f_0^2} = \frac{E}{E_0} (\text{RDME})$$

How to calculate RDME?

Impact gives time history response



Convert to frequency domain



$$DF = \frac{P \times N}{300}$$