MR damper location optimization for the mitigation of structural damage due to high-impact loads

Joanne Truong[1], Jake E. Hughes[2]

[1]Department of Civil Engineering, Northeastern University

[2]Department of Civil Engineering, Worcester Polytechnic Institute

Introduction

- Control systems used to mitigate caused by high-impact loads are necessary to prevent structural collapse, and death.
- A radar-based smart control system (RSCS) is proposed to help mitigate structural damage.
- The proposed RSCS would use a radar system to estimate the incoming vehicle's mass and velocity to plan for pre-impact structural control.
- After the initial impact, an adaptive controller will adjust the stiffness of magnetorheological (MR) dampers to mitigate damage on the bridge structure.
- In order to effectively mitigate damage, the location of the MR dampers must be optimized to reduce structural displacement and/or accelerations.

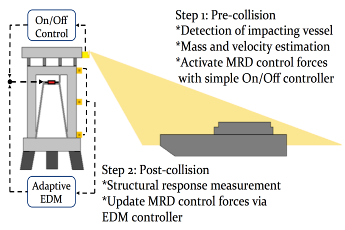


Figure 1. Proposed RSCS

Methodology

- Impact tests were conducted on a cantilever concrete beam designed as a scaled down bridge pier.
- Three MR dampers, an LVDT displacement transducer, and four accelerometers were attached to the beam.
- Drop tower impact tests were conducted from various drop heights, with different combinations of dampers.
- Passive damping voltages ranging from 0V to 5V in 0.5V increments were used.
- LabVIEW was used to send signals to the transducers, and to obtain data that was post-processed using MATLAB and Excel.

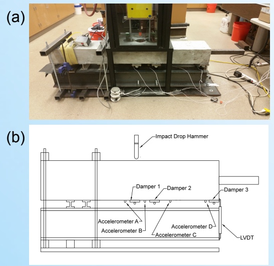


Figure 2. Bridge pier testing setup

Results

All Dampers:

- Using all three dampers shows the greatest response reduction for both displacement and acceleration.

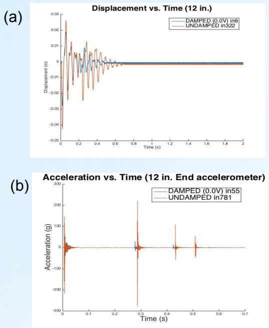
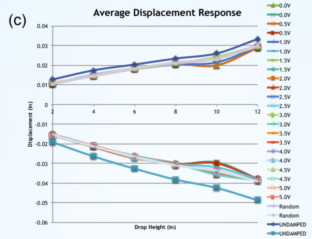


Figure 3. (a) Displacement response controlled with all dampers (b) Average displacement response controlled with all dampers (c) Acceleration response controlled with all dampers



All Dampers	Response Reduction Ratio
Max Displacement (C1)	0.835
Min Displacement (C2)	0.712
Max - Min Displacement (C3)	0.821
Displacement Energy (C4)	0.571
Max Acceleration (C1)	0.342
Min Acceleration (C2)	0.239
Max - Min Acceleration (C3)	0.297
Acceleration Energy (C4)	0.390

Table 1. Best average displacement and acceleration response reduction ratios across different drop heights with all dampers connected

- Table 1 shows a 16.5-28.8% reduction in displacement, and a 65.8-76% reduction in acceleration from the end accelerometer.

Dampers 1 & 2:

- Dampers 1 & 2 show excellent acceleration reduction

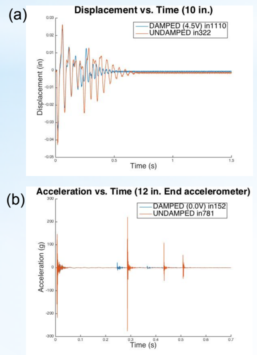
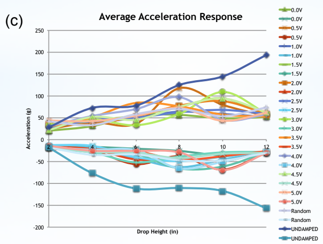


Figure 4. (a) Displacement response controlled with dampers 1 & 2 (b) Acceleration response controlled with dampers 1 & 2 (c) Average acceleration response controlled with dampers 1 & 2



- While the LVDT reduction is present, but not as significant as shown in other damper combinations.
- In figure 2c, a decline in acceleration is seen from the 10 inch drop height to the 12 inch drop height, which demonstrates the strong performance of dampers 1 & 2 in reducing acceleration response.

Dampers 2 & 3:

- Dampers 2 & 3 show excellent displacement reduction, and some acceleration reduction.

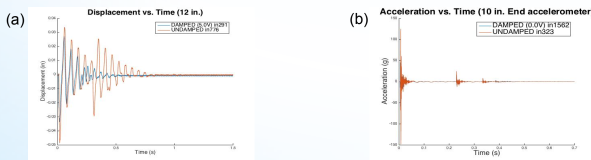


Figure 5. (a) Displacement response controlled with dampers 2 & 3 (b) Acceleration response controlled with dampers 2 & 3

Results cont.

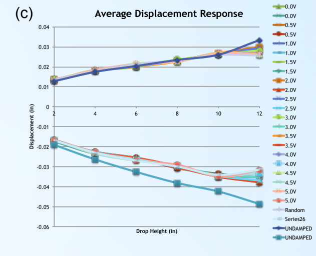


Figure 5 cont. (c) Average displacement response controlled with dampers 2 & 3

	Response Reduction Ratio For Dampers 1 & 2	Response Reduction Ratio For Damper 2 & 3
Max Displacement (C1)	0.930	0.640
Min Displacement (C2)	0.804	0.556
Max - Min Displacement (C3)	0.855	0.762
Displacement Energy (C4)	0.695	0.590
Max Acceleration (C1)	0.300	0.482
Min Acceleration (C2)	0.181	0.243
Max - Min Acceleration (C3)	0.247	0.377
Acceleration Energy (C4)	0.658	0.493

Table 2. Best average displacement and acceleration response reduction ratios across different drop heights with dampers 1 & 2 and dampers 2 & 3 connected

- Dampers 1 & 2 show a 70-82% reduction in acceleration response, and a 7-19.6% reduction in displacement.
- Dampers 2 & 3 show a 51.8-75.7% reduction in acceleration response, and a 36% – 44.4% reduction in displacement response.
- Both combinations are effective at reducing both displacement and acceleration response
- The combination of dampers 1 & 2 is more effective in reducing acceleration response, while the combination of dampers 2 & 3 is more effective in reducing displacement response.

Damper 3:

- Damper 3 on its own also does a good job of reducing structural response

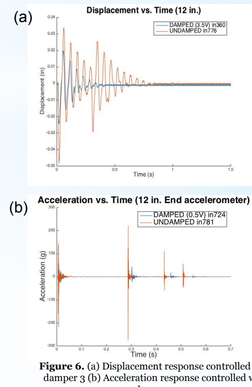


Figure 6. (a) Displacement response controlled with damper 3 (b) Acceleration response controlled with damper 3

Damper 3	Response Reduction Ratio
Max Displacement (C1)	0.914
Min Displacement (C2)	0.828
Max - Min Displacement (C3)	0.875
Displacement Energy (C4)	0.846
Max Acceleration (C1)	0.404
Min Acceleration (C2)	0.258
Max - Min Acceleration (C3)	0.688
Acceleration Energy (C4)	0.688

Table 3. Best average displacement and acceleration response reduction ratios across different drop heights with damper 3 connected

- Damper 3 shows an 8.6-17.2% reduction in displacement response, and a 60-74.2% reduction in acceleration response.
- Although the reduction is not as large as the reductions shown with multiple dampers, it still helps mitigate structural response.

Conclusion

- Dampers connected closer to the impact point were better at reducing acceleration response.
- Dampers connected closer to the end of the beam were better at reducing displacement response.
- The application of MR dampers on a bridge pier is very effective in reducing structural response

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For further information

Please contact truong.j@husky.neu.edu or jehughes@wpi.edu or yeesock@wpi.edu.