Multihazard-Resistant Highway Bridge Pier

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ABSTRACT

There are some similarities between seismic and blast effects on bridge structures: both major earthquakes and terrorist attacks/accidental explosions are rare events that can induce large inelastic deformations in the key structural components of bridges. Since many bridges are (or will be) located in areas of moderate or high seismic activity, and because many bridges are potential terrorist targets, there is a need to develop structural systems capable of performing equally well under both events.

This paper presents the findings of research to establish a multi-hazard bridge pier concept capable of providing an adequate level of protection against collapse under both seismic and blast loading, and whose members' dimensions are not very different from those currently found in typical highway bridges. A series of experiments on 1/4 scale multi-hazard bridge piers was performed. Piers were concrete-filled steel tube columns (CFST columns) with different diameters (D = 4", 5" and 6"), connected to a steel beams embedded in the cap-beam and a foundation beam. Fiber reinforced concrete was used for the cap-beam and the foundation beam to control cracking, which was deemed desirable against spalling of the concrete. The CFST column exhibited a ductile behavior under blast load, and no significant damage was suffered by the fiber reinforced concrete cap-beam as a result of the blast pressures.

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OBJECTIVE

The terrorist threat on bridges, and on the transportation system as a whole, has been recognized by the engineering community and public officials since recent terrorist attacks such as the one on the Alfred P. Murrah Federal Building in Oklahoma City and the World Trade Center in New York City. There are some similarities between seismic and blast effects on bridge structures: both major earthquakes and terrorist attacks/accidental explosions are rare events that can induce large inelastic deformations in the key structural components of bridges. Since many bridges are (or will be) located in areas of moderate or high seismic activity, and because many bridges are potential terrorist targets, there is a need to develop structural systems capable of performing equally well under both events.

The objective of this research project is to develop a multi-hazard bridge pier concept capable of providing an adequate level of protection against collapse under both seismic and blast loading, and whose members' dimensions are not very different from those currently found in typical highway bridges.

DESIGN OF MULTI-HAZARD BRIDGE PIERS

Preliminary work included the examination of several different structural configurations of bridge piers and potential bridge bent systems, to identify some systems deemed most appropriate in meeting the objectives of this research. In all cases, bents were assumed part of a typical 3-span continuous highway bridge located in an area of moderate seismic activity.

A pier-bent design concept consisting of concrete-filled steel tube columns (CFST columns) linked by a cap-beam proved to be more satisfactory, and was found possible using available tube sections (Bruneau and Marson, 2004a; Bruneau and Marson 2004b). It was found that material effectiveness was highest for piers having the highest diameter-to-thickness (D/t) ratio. CFST columns with cross-sections of 16" diameter were found to provide adequate blast and seismic resistance during the design process. These CFST columns are smaller than the typical 3'-diameter reinforced concrete pier column, but expected to perform significantly better under blast loads. This type of structural member was deemed likely to be accepted in practice (and incidentally is helpful in fulfilling the objective of accelerated construction). This structural configuration was therefore selected for experimental verification of its blast resistance.

EXPERIMENTS ON 1/4 SCALE MULTI-HAZARD BRIDGE PIERS

A series of tests was performed at U.S. Army Corps of Engineers Research Facility in Vicksburg, Mississippi. Due to constraints in the maximum possible blast charge weight that could be used at the test site, test specimen dimensions were set to be 1/4 scale of the prototype bridge piers.

Piers were CFST columns linked by a cap-beam and at the footing level. As indicated above, preliminary analyses showed this type of piers capable of providing high resistance and ductility against both blast and seismic loads. Experimental specimen is shown in Figure 1 and two identical specimens (Bent 1 and Bent 2) were constructed to be tested. Each specimen consists of three piers with different diameters (D = 4", 5" and 6"), connected to a steel beams embedded in the cap-beam and a foundation beam. Fiber reinforced concrete was used for the cap-beam and the foundation beam to control cracking, which was deemed desirable against spalling of the concrete due to either earthquake or blast loading. Summary of the pier tests are presented in TABLE I. Exact values of charge weights and stand off distances were omitted for security reason, instead these values were expressed by W and X respectively in TABLE I.

The experimental setup is shown in Figure 1. It consists of identical Bent 1 and Bent 2, and reaction frames between the two bents. Individual piers in each bent (Figure 2) were subjected to successive blast tests. Note that the cap-beams were not fixed to the reaction frames as it was intended to allow rotating to replicate actual conditions in bridges.

Maximum residual plastic deformations of each pier after testing is shown in TABLE I. Figure 3 shows Column 5 of Bent 1 after the test as an example. The CFST column exhibited a ductile behavior under blast load. Note that no significant damage was suffered by the fiber reinforced concrete cap-beam as a result of the blast pressures.

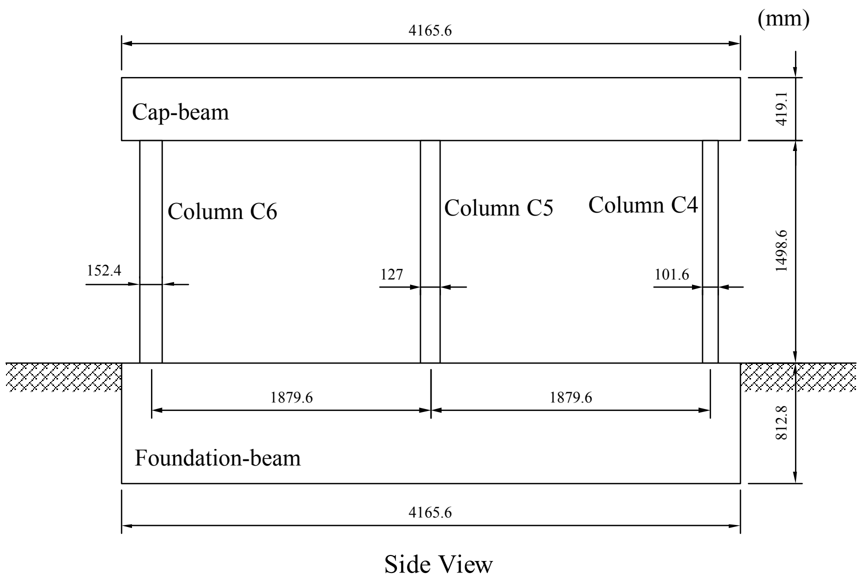

Figure 1. Experimental specimen

TABLE I. SUMMARY OF COLUMN TEST CASES AND RESULTS

#	Bent	Column	Charge Weight	X	Z (m)	Maximum Deformation (mm)
#1	B1	C4	0.1 W	3 X	0.250	0.0
#2	B1	C4	0.55 W	3 X	0.750	0.0
#3	B1	C4	W	2 X	0.750	30.2
#4	B1	C6	W	1.1 X	0.750	46.0
#5	B1	C5	W	1.3 X	0.750	76.2
#6	B2	C4	W	1.6 X	0.250	23.8
#7	B2	C4	W	0.6 X	0.250	139.7
#9	B2	C6	W	0.8 X	0.250	44.5
#10	B2	C5	W	0.8 X	0.250	100.0

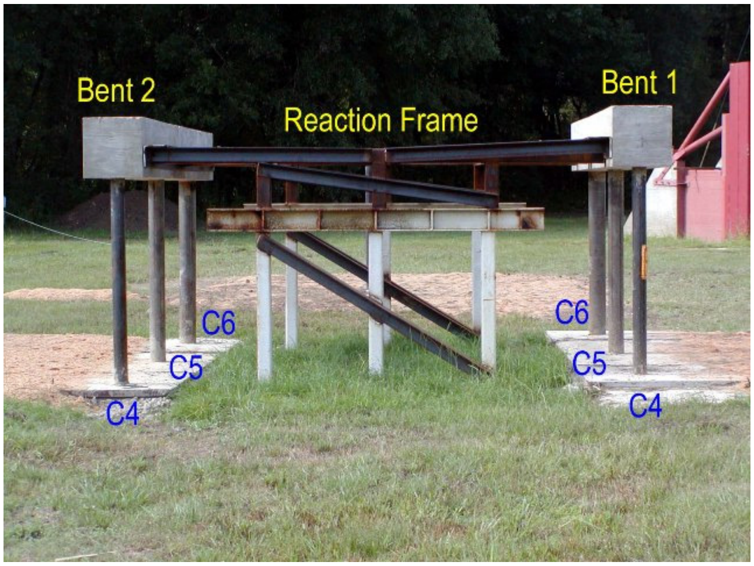

Figure 2. Test setup.

Figure 3. Bent 1-C5 (#5) after the test.

CONCLUSIONS

This paper has presented the findings of research to establish a multi-hazard bridge pier concept capable of providing an adequate level of protection against collapse under both seismic and blast loading. A series of experiments on 1/4 scale multi-hazard bridge piers was performed. The CFST column exhibited a ductile behavior under blast load, and no significant damage was suffered by the fiber reinforced concrete cap-beam as a result of the blast pressures.

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