Strengthening of Reinforced Concrete Bridge Piers by Carbon Fiber Sheet

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Summary

The 1995 Great Hanshin Earthquake destroyed many concrete bridge piers as well as the other structures. Lack of shear capacity is considered to be the main reason for the collapse. The piers with a proper capacity in bending ductility were escaped from collapse although they were severely damaged by bending. Strength improvement of the existing concrete bridge piers using carbon fiber sheet is proposed. This method is relatively easy to apply since it is only necessary to glue the sheet on the surface of a pier. The load bearing test of the model piers proved 20 to 40% improvement in the shear strength and 2 times improvement in the bending ductility.

1. Damage to RC piers

A lot of RC single piers suffered very severe damage by the Earthquake. Shear failure was the main reason for the collapse. Figure 1 shows the typical shear failure. On the other hand, relatively higher piers suffered bending failure but escaped from collapse although the damage was severe with a large plastic deformation. Figure 2 shows the example of bending failure.

2. Strength improvement by carbon sheet

According to the failure pattern of RC single piers, it is important to increase the shear strength and the bending ductility of the existing bridge piers to avoid their collapse by future earthquakes. Figure 3 shows the application of carbon sheet to RC piers. The thickness of the carbon sheet is 0.1mm. The tensile strength is about 2800MPa and the modulus of elasticity is about 2.5×10^5MPa. The specific gravity is 1.8, then the weight of the sheet is only 0.18kg/m^2. It is therefore very easy for handling. The application procedure is as follows;

1. Clean up the concrete surface and cut the corner edge of piers by more than 30mm in radius.
2. Paint epoxy primer on the concrete surface.
3. Adhere the sheet on the surface by epoxy resign.

The sheet is applied in the axial direction of the pier to improve the bending strength and in the circumferential direction to improve the shear strength and the bending ductility.

3. Experiment

3.1 Shear test

A pier model with the column of 119cm high and 60cm square was employed for the shear test. Horizontal force was applied at the top of the column in the back and forth direction under the constant axial force of 539kN. The shear span ratio is 2.5. Five specimens were tested, S-1 being without carbon sheet, S-2 with 1 layer, S-3 with 2 layers, S-4 with 5 layers of carbon sheet and S-5 with steel plate of 3.2mm thick. Figure 4 shows the test results.

According to these results, application of 2 layers of carbon sheet improved the shear strength of the test pier by 40%, while steel plate improved the shear strength by 64%.

3.2 Bending test

A pier model with the column of 254cm high and 60cm square was employed for the bending test. The shear span ratio is 5.0. Five specimens were tested. Table 1 shows the summary of the test specimens and test results. These results indicate that reinforcement by the carbon fiber sheet improved the ductility satisfactorily.

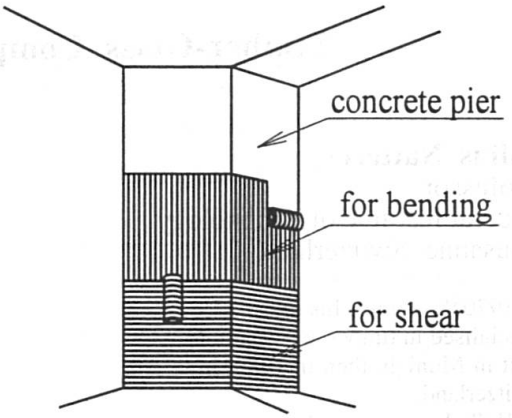

Fig. 3 Application of carbon fiber sheet

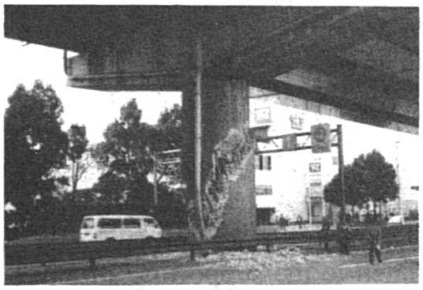

Fig. 1 Shear failure of a RC pier

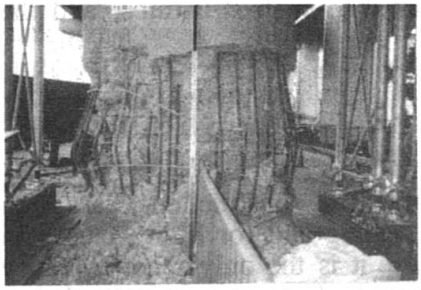

Fig. 2 Bending failure of a RC pier

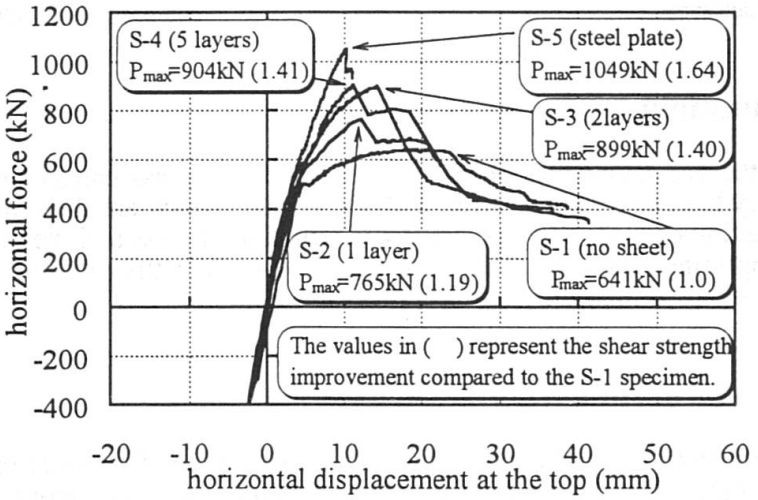

Fig. 4 Load-deflection curve of the shear test model

Table 1 Bending test results

Specimen	Reinforcement	Maximum horizontal force (kN)	Yield displacement δ y (mm)	Ultimate displacement* δ u(mm)	ductility δ u/ δ y
M-1	without carbon sheet	206.8	15.6	87.9	5.6
M-2	2 layers(circumferential direction)	203.8	13.6	98.8	7.3
M-3	4 layers(circumferential direction)	211.7	13.9	107.7	7.7
M-4	4 layers(circumferential direction) +1 layer(axial direction)	228.3	12.2	96.8	7.9
M-5	8 layers(circumferential direction)	225.4	13.1	144.8	11.1

* displacement when the horizontal force dropped to 80% of the maximum horizontal force

Conclusion

Application of carbon sheet to RC pier proved to improve the shear strength. Improvement of the ductility in bending was also achieved. About 40% increase of the shear strength was obtained by applying 2 layers of the carbon sheet. In the application of the carbon sheet to an actual pier, the size of the pier should be taken into consideration to determine the appropriate amount of the sheet to obtain the required strength improvement.

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