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DYNAMIC RESPONSE BEHAVIOR OF PARTIALLY PRESTRESSED CONCRETE PIERS UNDER SEVERE EARTHQUAKE

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1. INTRODUCTION

A common type of highway concrete bridges consists of PC or RC girders and reinforced concrete piers [1]. The benefits of using the reinforced concrete piers are to obtain high energy dissipation characteristics and high values of ductility factor during earthquake excitations. In spite of their energy absorption capacities, some RC bridge piers suffered great damage during the Hyogo-ken Nanbu 1995 earthquake. Additionally, high residual displacement values [2] were observed for the same piers after the earthquake. On the other hand, PC members have some merits such as small residual displacement and high cracking load while they have less energy absorption characteristics and ductility factor. As a consequence, The objective of this study is to examine the implementation of partially prestressed pier [3] in such a way to make a compromise between the merits and disadvantages of both RC and PC.

2. OUTLINES OF TESTS

Two specimens (S-1) and (S-2) were tested in this study. Specimen (S-1) was RC control specimen while Specimen (S-2) was PC specimen. Details of specimens are shown in Fig. 1 and in Table 1. The concrete compressive strength is about 36 N/mm^2, yielding stresses of reinforcements are 401 N/mm^2 for D13 and 411 N/mm^2 for D10 while the yielding stress of prestressing tendons SBPR12.7 is 1421 N/mm^2. The specimens were tested using the same setup shown in Fig. 2. The specimens were fixed to the testing floor. The yielding displacement was defined as the displacements corresponding to yielding loads of the reinforcing bars. The specimens were tested using a pseudo-dynamic testing technique [4] in which load was applied quasi-statically during the test and the restoring force was measured directly from the loading test system. The used ground acceleration was the modified Hyogo-Ken Nanbu 1995 (NS direction) earthquake. The time scale was the same as the original one while the maximum acceleration was considered as 563 gal and 474 gal for (S-1) and (S-2) respectively. The time interval was taken as 0.01 second. An axial stress value of 1 Mpa was applied at the top of specimens.

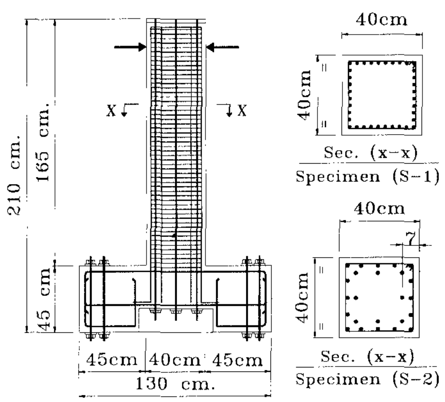

Fig. 1: Details of specimens

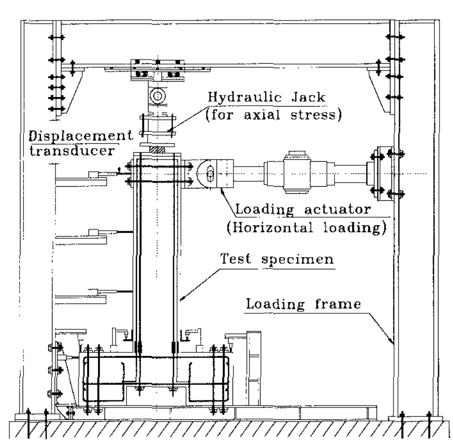

Fig. 2: Loading setup

3. TEST RESULTS

Fig. 3 shows the load-displacement curve for specimen (S-1) obtained experimentally. Both the bauschinger effect and stiffness degradation can be observed. The maximum displacement reached about 5.4 times the yielding displacement in the left side of the curve while it was about 2.1 times the one in the right side of the curve. It can be observed from the figure that high energy was dissipated during the test. Fig. 4 shows the displacement time history obtained during the test. Maximum attained displacement

Table 1: Details of specimens

Specimen No.	Cross Section	a/d Ratio	Reinforcing bars		Prestressing tendons		Shear reinforcement		Natural Period (sec.)
			Rein.	(As/bd) %	Tendons	(Aps/bd) %	Hoops	(Ash/bs) %	
S-1	40*40	4.00	32D13	2.65	x	x	D6@3 cm	0.47	0.30
S-2	40*40	4.00	16D10	0.79	8D12.7	0.63	D6@3 cm	0.47	0.30

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was about -0.11 m that occurred at the peak negative excursion after which there was a shift in the response towards the negative side. At the end of test a residual displacement of about -2.5 cm was observed.

Fig. 5 shows the load-displacement curve for specimen (S-2). Softening of the hystertic curve was clearly indicated showing that the bauschinger effect was dominant after unloading. Stiffness degradation during unloading was clear in both directions of loading. Also, marked changes in slope during reloading known as pinching [5] were clear. Pinching can be attributed to the fact that prestressed members usually show marked elastic recovery even after considerable inelastic deformations. Energy absorption was lesser than a comparable RC specimen (S-1) due to such inelastic recovery.

The residual tensile forces in the PC tendons were adequate to close previously opened cracks. Because of the existence of closely spaced transverse hoops, crushing was delayed inside the concrete core and buckling occurred only between two successive hoops in the plastic hinge locations. Fig. 6 shows the obtained displacement time history in which the maximum displacement was about -0.075 m. Although the difference between the maximum negative amplitude and the following positive amplitude is higher than of a comparable distance in Specimen (S-1), no shift of the response in the negative side was observed. Additionally, at the end of the test, the residual displacement of (S-2) was much smaller than that of (S-1), which can be considered as an advantage of using such PC piers.

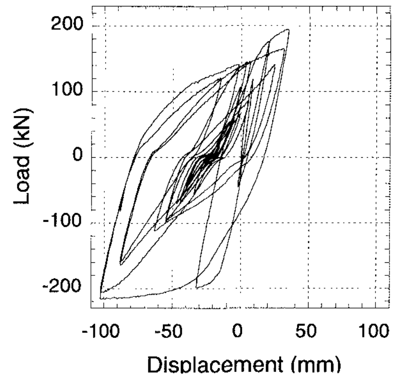

Fig.3: Load-displacement curve for specimen (S-1)

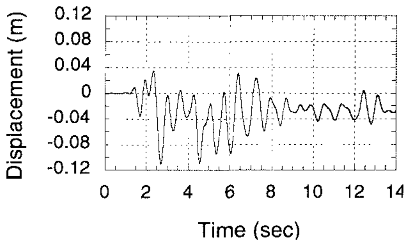

Fig. 4: Displacement time history for Specimen (S-1)

4. CONCLUSIONS

Pseudo dynamic tests were conducted in order to clarify the inelastic response behavior of partially prestressed concrete piers under severe earthquake. It can be concluded that the usage of such PC piers has the following merits and disadvantages:

1. There is a tendency to decrease the residual displacement and the response when a pier is excited by a ground acceleration of similar characteristics to the Hyogo-Ken Nanbu 1995 earthquake acceleration.
2. The cracking pattern after earthquake excitation can be improved as compared to ordinary reinforced concrete piers.
3. A disadvantage of having a lower energy dissipation capacity was observed for the PC specimens showing that a compromise between their benefits and disadvantages should always be done.

5. ACKNOWLEDGMENT

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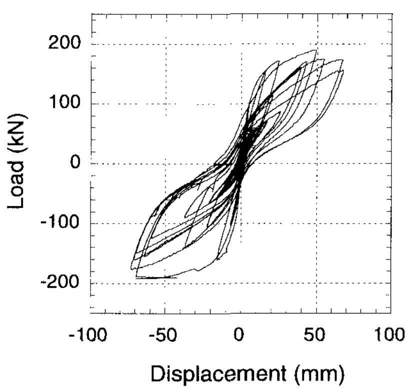

Fig.5: Load-displacement curve for specimen (S-2)

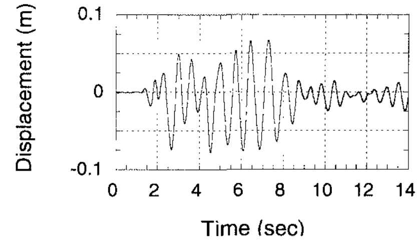

Fig. 6: Displacement time history for Specimen (S-2)

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