Shake Table Response of RC Bridge Piers to Near-Fault Earthquake

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Summary

Near fault ground motion (NFGM) is a single long period velocity pulse of large magnitude. These earthquakes have caused severe and impulsive damage on various infrastructures because the epicentre is close to the urban area. These characteristics are unique compared to the far-fault ground motion (FFGM), upon which nearly all seismic design criteria are based. The objective of this study is to explore the shake table response of reinforced concrete bridge piers and to investigate near-fault ground motion effects on reinforced concrete bridge piers compared to those by the far fault ground motion. The seismic performance of two RC bridge piers under near-fault and far fault ground motions was investigated on the shake table. In addition, comparative tests were made for RC bridge piers subjected to Pseudo-dynamic loadings and Quasi-Static loadings. Test results showed that NFGM generally induced worse seismic performance than FFGM.

Keywords: Near fault ground motion, Far fault ground motion, Shake table, Pseudo-dynamic, Quasi-Static

1. Introduction

The recent earthquakes have caused extensive damage to highway bridge structures with many loss of life. The damage of bridge piers in the plastic hinge regions that experience inelastic action depends on the characteristics of earthquakes as well as column details. Failure of these structures exposed a number of structural deficiencies in many bridges constructed before the new seismic design codes were in place. In particular, concrete columns with inadequate lateral reinforcement contributed to the catastrophic collapse of many bridges, and the poor detailing of the lapped starter bars in these columns compounded the problem of seismic deficiency. Plastic hinge regions with

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poor confinement and lap splice experienced rapid flexural strength degradation as a result of concrete cracking and splice slippage, but those with no splices and poor confinement exhibited moderate ductility with eventual degradation due to longitudinal bar buckling.

2. TEST

The shake table has dimension of 5m x 3m and payload of 300kN. Maximum moment capacity of the table is 500kN· m and maximum displacement is ±100mm. These dimensions of the shake table limited the size of test specimens and the magnitude of base excitations. Because of the payload limitation, scaled models were designed and the axial load was introduced by pre-stressing the force at the center of the column. All specimens have a diameter (D) of 400 mm and height (H) of 1400 mm which give an aspect ratio (H/D) as 3.5.

Fig. 1 Test setup

As shown in Fig. 1, the shake table at the research center of Hyundai E&C Co., Ltd was used with other test equipments for quasi-static test and pseudo-dynamic test. Multiple input motions with gradually increasing Peak Ground Acceleration (PGA) were applied to test specimens under NFGM and FFGM. This allowed the evaluation of the column performance under different earthquake levels.

Most of the specimens failed due to the bond failure and the buckling of longitudinal reinforcements. Most of the specimens developed flexural cracks in the plastic hinge area of the column during the excitation, and then the cover concrete spalled off.

To minimize major damage and to ensure the survival of structure with moderate resistance with respect to lateral force, structures must be capable of sustaining a high proportion of their initial strength when a major earthquake imposes large deformations. These deformations maybe well beyond the elastic limit. This ability of the structure of its components, or of the materials used to offer resistance in the inelastic domain of response, is described as the ductility by the general term. It includes the ability to sustain large deformations, and a capacity to absorb energy by hysteretic behavior. Natural frequencies and damping ratios of all specimens were computed using the Half-Power Bandwidth Method. Test results showed that NFGM generally induced worse seismic performance than FFGM as shown in Fig 2.

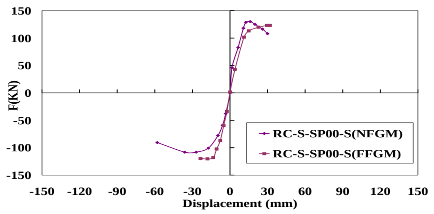

Fig. 2 Envelope Curves of Force-Displacement Hysteretic Loops

3. Conclusions

The shaking table test for RC bridge piers was performed to investigate their seismic behavior which was compared with the responses under the quasi-static test and the pseudo-dynamic test. It was concluded that:

a) The specimen on the shaking table showed lower displacement ductility and lower energy dissipation than the identical specimen under the quasi-static test and the pseudo-dynamic test.

b) Increase of transverse confinement in the plastic hinge region gave bigger energy absorption capacity and displacement ductility.

c) Input acceleration motion with larger PGA induced more damage, which resulted in the lower natural frequency and higher damping ratio at failure.

d) The specimen under NFGM induced less seismic performance than the specimen under NFGM as shown in Fig. 2.