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Networked pseudodynamic testing of bridge pier and precast pile foundation

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ABSTRACT

Using the internet-based network platform NetSLab, the seismic response of bridge pier and precast concrete pile foundation was investigated in this study. NetSLab was developed based on client/server concept along with a data model and communication protocols, and is capable of transferring control and feedback data and signals among geographically distributed laboratories or computers connected by the Internet. In this study, the bridge column was simulated numerically whereas the full-scale prestressed/precast pile model was tested physically with predetermined moment distribution along the pile model and neglecting pile group effects. The hybrid experimental results indicate that the sudden spalling of the thick concrete cover of the precast pile may cause unstable response of the bridge pier and pile foundation system under simulated earthquake loading, particularly when the bridge is subjected to near fault ground motions. The research also demonstrated the enhanced testing capabilities of the networked pseudo dynamic testing concept.

1. Introduction

The purpose of this study was two fold: to investigate the seismic response of bridge pier and prestressed/precast concrete (PC) pile foundation through pseudo dynamic testing, and to demonstrate the feasibility and usefulness of a networked platform, which connects geographically distributed testing and analysis facilities.

Following several disastrous earthquakes during the 1990s, various research programs on seismic behavior and design of bridge structures have been conducted. Most of the research has been primarily directed towards the design and retrofit of bridge piers and columns, however, studies of bridge footings and piles are relatively limited [1–6].

Under the support of the US Federal Highway Administration (FHWA), a joint research program was conducted at the State University of New York at Buffalo and the University of Southern California (USC) to study the seismic behavior of steel pile-to-pile-cap connections with typical details representing current design standards [6,7]. The tests conducted by Shama et al. [7] were on pile-to-pile-cap connections with deep embedment representative of typical bridge construction in the Eastern and Central United States, whereas the study at USC [6] was on testing the pile-to-pile-cap connections with very shallow embedment, typical in the western United States. At USC, five full-scale steel bearing pile (designated in the US as HP shaped steel pile)-to-pile cap connection subassemblies were tested and the test results revealed the following problems: (1) despite a pin connection design assumption, the actual connection can resist a substantial moment, however, the capacity is unreliable due to the lack of a proper flexural design; (2) the current design details used for the steel HP-pile connection anchor cannot develop the ultimate design tensile capacity [6].

Studies on seismic behavior of prestressed/precast (PC) concrete pile foundations are also quite limited. Previous studies conducted by Pam and Park [1], and Harries and Petrou [5] on PC pile-to-pile-cap connections were mainly concerned with the development of the pile moment capacity through proper embedment length and proper end confinement. Xiao [8] studied the pile to foundation connections with piles embedded into the pile cap with a shallow embedment length, which are common in the western United States, particularly in California. The study found that the PC pile connection had adequate tensile and compression capacity, however, similar to steel pile connection, the moment capacity was of concern due to the lack of flexural design. Xiao [8] also proposed methods for adequate estimation of the pile end moment capacity, which might be needed for rational design and analysis procedures.

The investigation described in this paper was concerned with the seismic behavior of PC pile foundation and bridge column pier as a system. The research program decided to adopt networked

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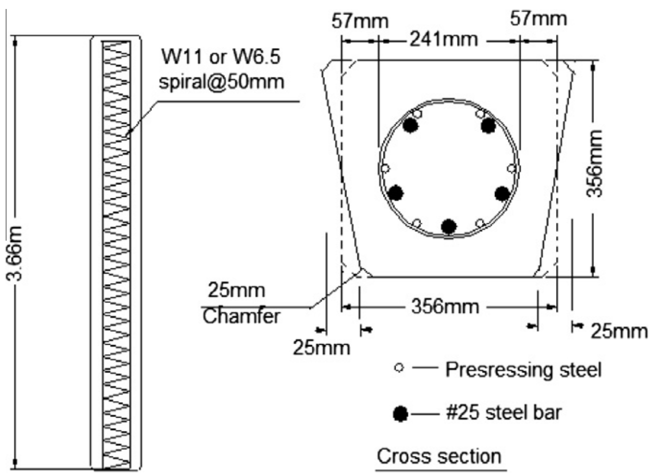

Fig. 1. Prestressed/precast concrete pile.

pseudo dynamic testing for the following reasons: (a) to simplify the testing model by physically testing a portion of the pile foundation only, since the response of the bridge column can be reasonably well modeled based on previous research experience and published information [9]; (b) to demonstrate the capability of the networked platform for structural laboratories NetSLab, which was developed by the authors [10,12].

Table 1
Cyclic loading testing matrix.

Specimen	Reinforcement details	Axial load (kN)	Loading method
PCP1	Six 12.5 mm grade 270	0	Cyclic loading
PCP3	strand	890	
PCP6	Five #25 steel bar W11 spiral wire @50 mm	890	Monotonic loading
PCP2	Six 12.5mm grade 270	0	Cyclic loading
PCP4	strand	890	
PCP5	Five #25 steel bar W6.5 spiral wire @50 mm	890	Monotonic loading

2. Experimental program

Two groups of tests were conducted on a total of eleven full-scale prestressed concrete pile models. In the first group, six piles were tested under quasi-static lateral loading, either cyclic or monotonic, with two different axial loading levels. Four pile models were subjected to cyclic lateral forces along with a constant axial compressive load, whereas the other two were tested without axial load. In the second group, five pile models were tested pseudo-dynamically, which were intended to examine the performance of a bridge bent system subjected to earthquake excitations.

The 356 mm square pile segments with a length of 3.66 m were constructed by a local precast concrete manufacturer in Los Angeles. The piles represented the California Transportation Department metric Class 900 full-scale piles [13]. The design compression capacity of the piles was 900 kN. The pile (Fig. 1) was actually built as an isosceles trapezoidal section with a difference of 25 mm between the bases for convenience of de-molding. The piles were prestressed using six 12.5 mm grade 270 (ultimate tensile strength of 270 ksi or 1862 MPa) seven-wire low-relaxation prestressing strands (nominal diameter = 12.5 mm). The pre-tensioning force in each strand was 171 kN, with prestress equivalent to 0.75 f_{pu}, where f_{pu} is the ultimate strength. The pile segments were designed to simulate the details of the portion near the pile-cap, so the longitudinal reinforcement also included five #25 steel bars (nominal diameter = 25 mm). The lateral confining steel used either W11 (nominal diameter = 11 mm) spiral or W6.5 (nominal diameter = 6.5 mm) spiral, both at a pitch of 50mm, corresponding to volumetric transverse reinforcement ratios based on the full column section of about 1.14% and 0.4%, respectively. The piles had a relatively thick concrete cover of 57 mm. Due to the use of the circular spirals for transverse reinforcement, the cover concrete was even thicker at the corners of the pile section, as shown in Fig. 1.

3. Cyclic and monotonic loading tests and observations

3.1. Testing method

Four piles were tested under cyclic lateral loading and two piles were tested under monotonic loading in order to establish the

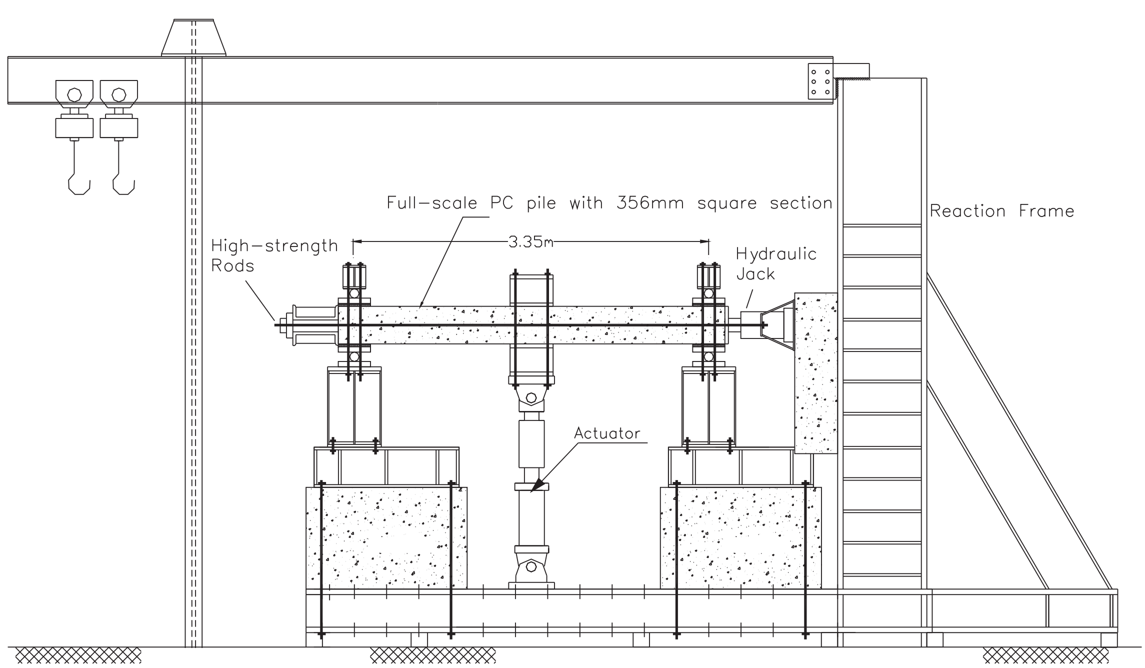

Fig. 2. Experimental test setup.