TESTS OF PRESTRESSED CONCRETE PILES SUPPORTING BRIDGE ABUTMENTS

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INTRODUCTION

The use of pile supported integral abutments has become accepted practice for bridges of short to medium length in a number of states. While not a pioneer in the use of integral abutments, Tennessee is currently recognized as the national leader in applying this concept to the design of highway bridges. Steel bridges up to 400 ft. (122 m) and concrete bridges up to 800 ft. (244 m) long are routinely designed with integral abutments. Pushing the envelope, the Tennessee Department of Transportation (TDOT) has designed a steel bridge 525 ft. (160 m) and a concrete bridge 1,175 ft. (358 m) long, both of which are currently in service.

The trend to longer jointless bridges led to a research project sponsored by TDOT and carried out by the Civil Engineering Department at The University of Tennessee, Knoxville. In the first phase of the research, steel H-piles were tested; in the second phase, currently nearing completion, tests were performed on prestressed concrete piles. The focus of this paper is on the second phase of research: testing of 14-in. (356 mm) square prestressed concrete piles.

The overall objectives of the research are (1) to observe, record, and quantify the behavior of the pile/abutments tested and (2) to evaluate the TDOT design criteria. The objectives of this extended abstract are threefold: (1) to describe briefly the testing program on prestressed concrete piles; (2) to present some typical test results; and (3) to discuss the practical implications of those test results.

TEST PROGRAM

Four prestressed concrete piles, 14-in. (356 mm) square, were driven approximately 36 ft. (11 m) into virgin red clay soil. Each pile had 6, ½ in. (12.7 mm) diameter, 270k, prestressed tendons. Bending in each pile was about the strong axis. The drawing in Figure 1 shows the test setup. The axial load on each pile at the beginning of a test was approximately 90 kips (400 kn). As a load was applied to the right in Figure 1, rotation of the top of the pile was resisted by hold-down arms attached to a reaction block of concrete. Load cells measured the horizontal pulling force and the hold-down force. The piles were tested at a slow rate simulating the rate of expansion and contraction due to temperature change in an actual bridge environment. The rate of testing in Phase I and the early tests in Phase II was 1 in. (25.4 mm) in 6 hours; for most of the tests in Phase II, the loading rate was 1 in. (25 mm) in 4 hours. The basic test regimen consisted of six tests in each direction: 3 tests to 0.5 in. and then 3 tests to 1 in. with a minimum rest period of overnight. When the tests in one direction were completed, tests in the other direction were performed. After completion of the basic test regimen on each of the first three piles, additional tests to larger deflections were performed. On the fourth pile only part of the basic regimen was completed, and other, more stringent, tests were performed.

TEST RESULTS

A typical plot of horizontal load versus deflection is given in Figure 2. Figure 3 presents five different load-deflection curves for the some pile tested on different dates, and Figure 4 shows a load-deflection curve for Pile No. 2 tested to extremely high displacements and finally to failure.

Each one of the piles cracked at horizontal displacements of approximately 0.5 in. (12.7 mm). However, this crack in the concrete did not affect the ability of the prestressed pile to function. The graphs in Figure 3 illustrate the ability of the piles to sustain large lateral loads repeatedly.

In Piles 1, 2 and 4, the six prestressed tendons were extended approximately 3 ft. (0.91 m) into the abutment and pull slab. The tendons in Pile 3 were cut flush with the top of the pile. While the embedment of the strands made essentially no measurable difference in the behavior of the pile/abutment under a lateral displacement of 0.5 in. (12.6 mm), there was somewhat more cracking at 1.0 in. (25.4 mm) displacement. At still larger displacements, the crack at the pile-abutment interface was significantly larger in Pile 3, and the magnitudes of moment and shear at the top of the pile were smaller.

CONCLUSIONS

While each pile cracked at the pile-abutment interface at a displacement of approximately 0.5 in. (12.6 mm), the prestressing force closed the crack when the displacement went back to zero. The initial stiffness of a pile was not appreciably affected by the application of successive load cycles.

The current TDOT practice of embedding the prestressing strands in the abutment is beneficial to the overall behavior of the pile-abutment system.

The test results indicate that the TDOT design criteria which allow 1 in. (25.4 mm) horizontal movement of the pile at the ground surface is reasonable. Each pile supported displacements larger than 1 in. (25.4 mm) and remained capable of performing as designed.

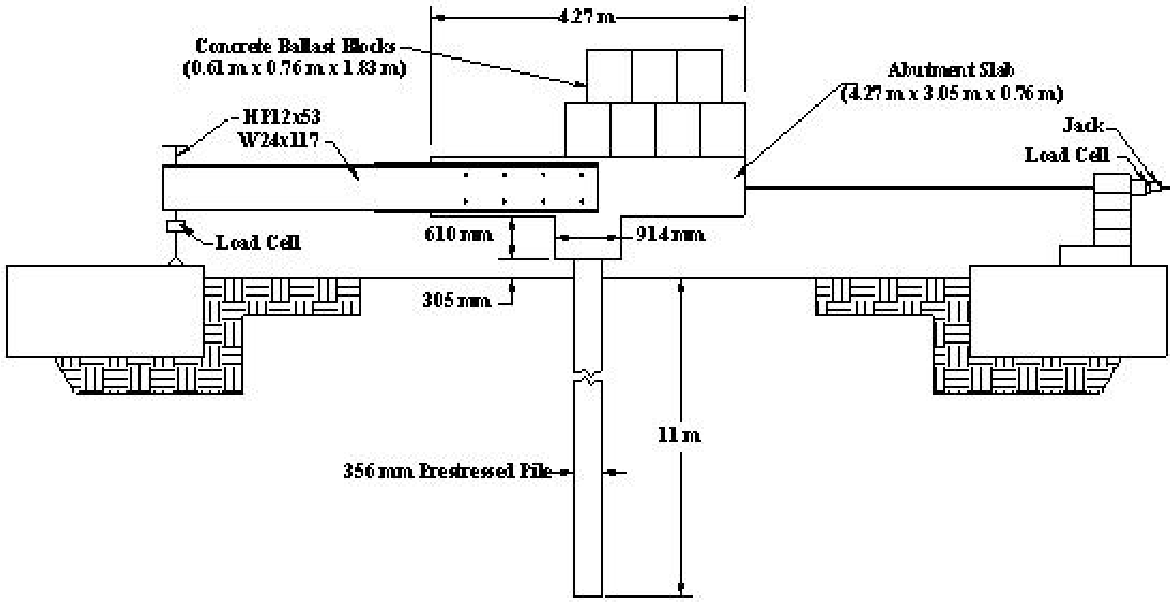

Figure 1. Field Test Setup

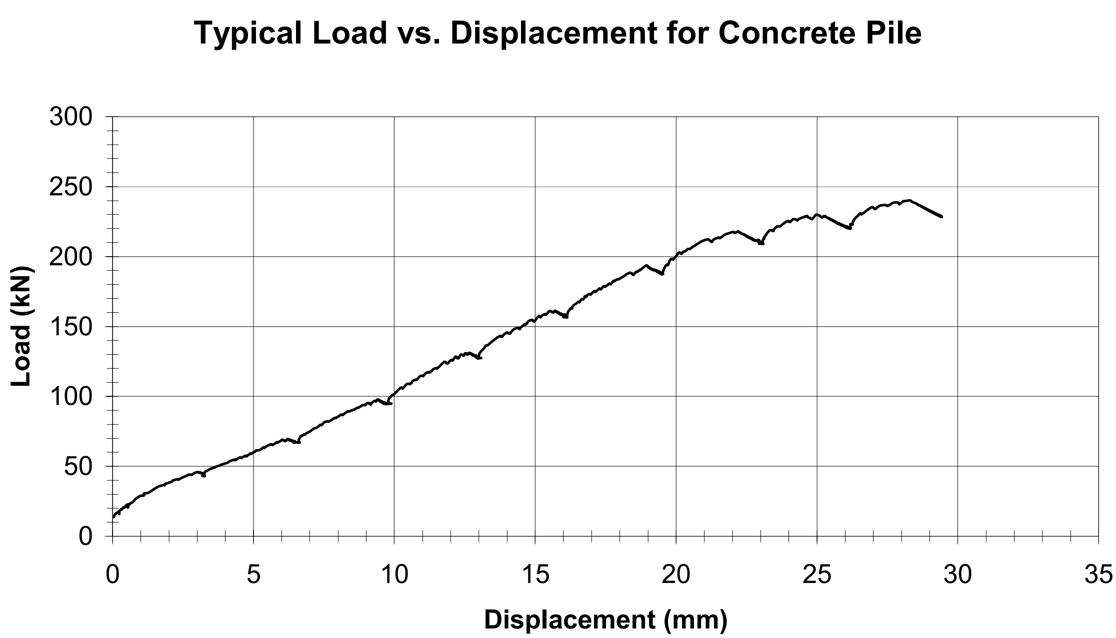

Figure 2. Typical Load vs. Displacement for Concrete Piles

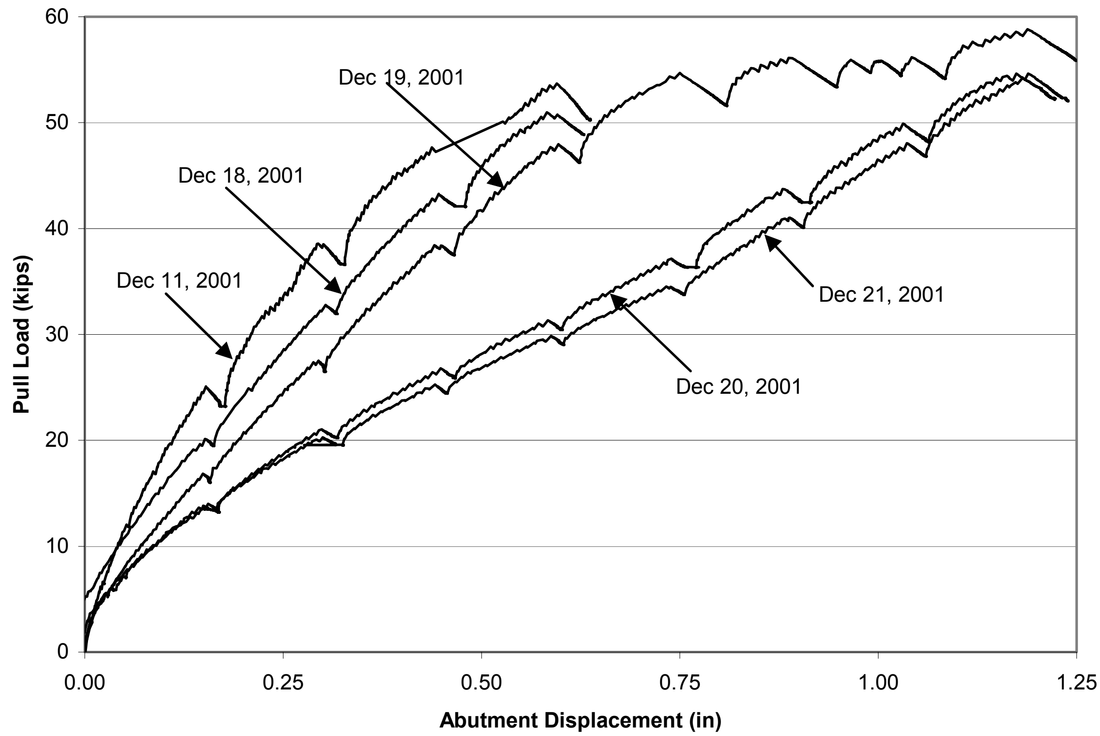

Figure 3. Pull Load vs Abutment Displacement - Pile 3 Pulling South

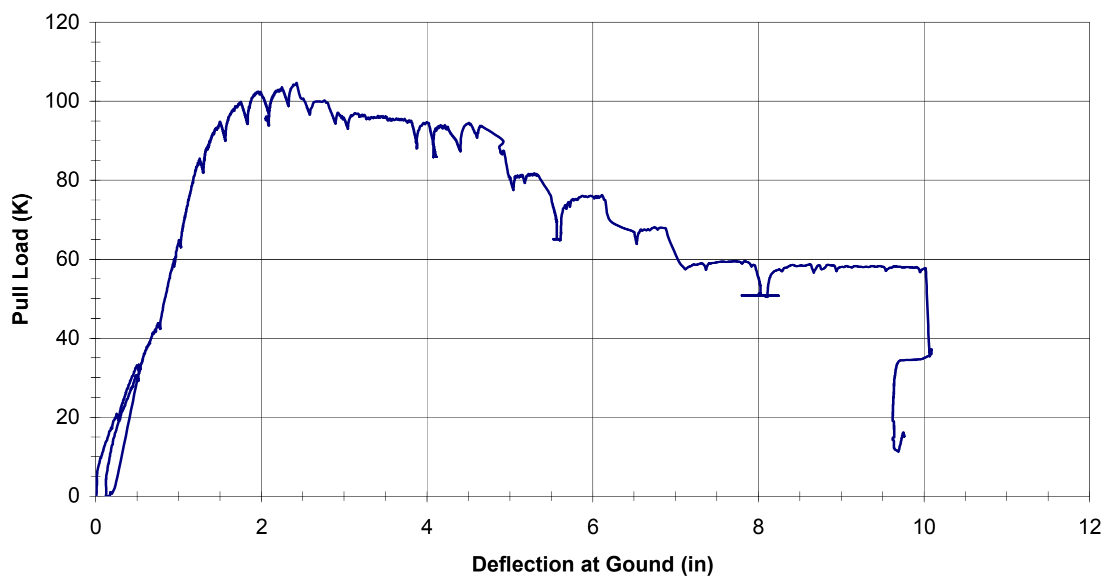

Figure 4. Pull Load vs Deflection – Pile 2 Test to Failure