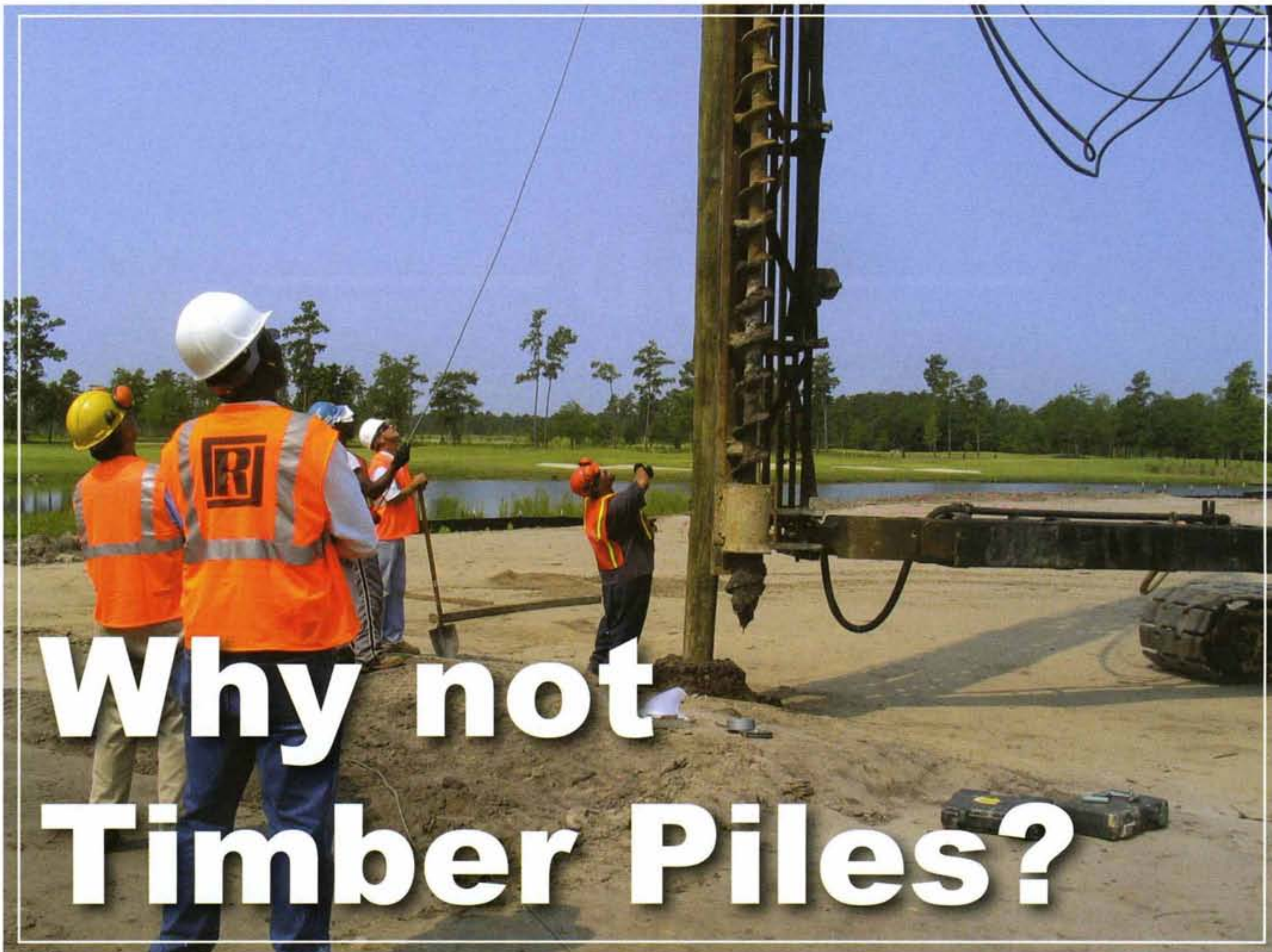

Why not Timber Piles?

Design loads and timber piles

By Scott Webster, GRL Engineers, Inc.

Timber piles have been the most widely used driven pile foundations in history with known structures being supported by timber piles dating back thousands of years. However, with the development of steel and concrete pile sections, the use of timber piles has steadily declined as they are generally considered to be less versatile. In fact, over the past several decades engineering codes have been written to limit the use of timber piles to lightly loaded structures by limiting the design loads for timber piles. This has primarily been done due to the belief that timber piles are not as consistent in strength as the steel or concrete pile alternatives.

I was recently asked to give a presentation for the Charleston, S. C., chapter of PDCA on the use of timber piles, with specific emphasis on how the design loads for these piles could be increased to expand their use. This topic seemed rather intimidating at first glance and like most engineers I also felt that use of timber piles should be limited to the more lightly loaded foundations. However, upon researching the available data, it has become apparent that the engineering community may not be giving timber piles appropriate consideration.

Based upon the current codes, the allowable design loads for timber piles are based on an allowable design stress ranging from approximately 0.8 to 1.2 ksi (AASHTO 2002 Standard Specification). This allowable design stress is conservatively applied only across the pile toe area to calculate the allowable design load; therefore, for the typical southern pine timber pile with an allowable design stress of 1.2 ksi and a minimum eight-inch diameter tip, the allowable design load would be 60 kips (30 tons). This result agrees with the Timber Pile Design and Construction manual that allows a 60-kip design load for an eight-inch tip diameter southern pine timber pile. However, both of these specifications appear to conservatively apply a design stress over the pile toe area only, neglecting the large pile area above the toe. To accept this approach, one would need to assume that the majority of the pile capacity for the timber piles would be achieved at the pile toe. Considering that timber piles are tapered and that most piles derive their pile capacity from a combination of skin friction and end bearing, this seems quite unreasonable.

For an eight-inch tip diameter timber pile the minimum pile butt diameter ranges from 11 to 14 inches (ASTM D25). For a timber pile having a length of 35 feet the minimum pile butt diameter would be 12 inches. If we apply the allowable design stress of 1.2 ksi to the 12-inch butt diameter, the resulting allowable design load would be 136 kips (68 tons). Based upon my experience with timber piles, such a high design load

with an adequate safety factor could be achieved, but only under ideal subsurface conditions. Therefore, it seems more logical to limit the design pile capacity based upon an average pile diameter rather than the pile diameter at either the pile tip or butt. Again, for eight-inch tip diameter piles with an average butt diameter of 12 inches, the average pile diameter would likely be very close to 10 inches. For a 10-inch average diameter timber pile the design pile load would then be 94 kips (47 tons). Depending upon the specific soil conditions, slightly higher or lower design loads may be more appropriate.

In order to justify the use of these increased design loads it is recommended that additional foundation testing at the start of the project be provided. Specifically, dynamic pile testing using the Pile Driving Analyzer (PDA) should be provided for a selected number of indicator piles across the project site. These PDA tests should be performed during both initial and restrike driving to fully evaluate ultimate pile capacities. Such testing is easily accomplished and will provide greater confidence in the installed foundations.

As an example, a recent project along the North Carolina seashore required timber piles to support a multistory condominium building. The eight-inch tip diameter piles were to be driven to a final penetration of approximately 25 feet below the existing grade for a design pile capacity of 50 kips (25 tons). Although the design loads were relatively low compared to the discussion above, dynamic pile testing was specified for the project in order to develop the driving criteria and to confirm that the design pile capacity with an appropriate safety factor would be achieved. As such, five indicator piles were planned to be driven and tested using the PDA during initial driving. Restrike testing if necessary, would be accomplished after waiting periods of only a few hours so that testing could be completed during a single day of testing. The general soil conditions at the time of testing consisted of between 1 to 12 feet of building pad fill, 13 to 24 feet of alluvial sands and silts underlain by clayey sand at a depth of 25 feet, which was the intended bearing layer.

PDA testing indicated that the ICE 32-S hammer being used transferred between 13 and 25 percent of the rated hammer energy. It should be noted that the hammer stroke was intentionally limited to about six feet to prevent pile damage. The pile top compression stress ranged from 1.4 to 1.6 ksi. The initial driving pile capacities ranged from 121 to 142 kips based upon the Case Method capacity estimates. A CAPWAP analysis of a selected test pile indicated an end of initial driving pile capacity of 132 kips, which would confirm the accuracy of the Case Method capacity estimates. Although sufficient pile capacity from the end of initial driving was confirmed for the 50-kip design load piles, restrike testing was performed to determine if additional pile capacity could be expected with time. Restrike testing performed after waiting between four to five hours indicated Case Method capacities ranging from 159 to 172 kips. A CAPWAP analysis performed for one of the test piles indicated a beginning of restrike pile capacity of 178 kips (see Figure 1). Based upon these results it was apparent that the piles would achieve safety factors well above two for the 50 kip design load. In fact, the average safety factor was approximately 3.3 based upon the restrike testing results. It should be noted that the restrike testing was performed after minimal waiting time and that additional pile capacity could likely have been identified with a longer waiting period after initial driving.

Obviously, based upon the results obtained at this project, a higher design load could have been achieved resulting in significant cost savings for the project. PDA results indicate that a design load on the order of 80 kips (40 tons) could have been used which could have resulted in up to 40 percent fewer piles being required for the foundations. Such cost savings should be taken advantage of when possible for any foundation design.

As discussed, the potential for expanded use of timber piles based on increased allowable design loads can be accomplished. Current design specifications do not appear to take advantage of the potential for timber piles, and in fact appear to handicap such piles by limiting their design loads based upon the pile toe area only. Such specifications are unrealistic in all but the most unusual circumstances for timber piles (end bearing only soil resistance). Finally, significant cost savings can and should be achieved by using PDA testing to determine the ultimate pile capacity of timber piles. Such testing is commonplace for steel and concrete piles and this has in part allowed for higher design loads for these piles. PDA testing for timber piles is much less prevalent but can and should be used to increase design loads of these piles. The primary reason that PDA testing on timber piles is not common is that local and international building codes do not require load testing of piles with design loads of less than 40 tons. As such, timber piles are often designed with loads below this limit to avoid such testing. However, by allowing these design loads to increase, significant cost savings can be achieved by reducing the number of piles to be driven. The cost for dynamic testing on projects of this nature is quite small compared to the potential cost savings for the foundation piles.

Scott Webster earned a BSCE from the Military College of S.C. and a MSCE from the Michigan Technological University. He has worked extensively since 1986 with the dynamic pile testing and analysis techniques on a variety of projects. Working with both STS Consultants and GRL Engineers has allowed him to develop a strong background in this field as well as geotechnical engineering. This experience is critical when performing dynamic pile testing and analysis for a wide range of projects within the United States and abroad. ▼

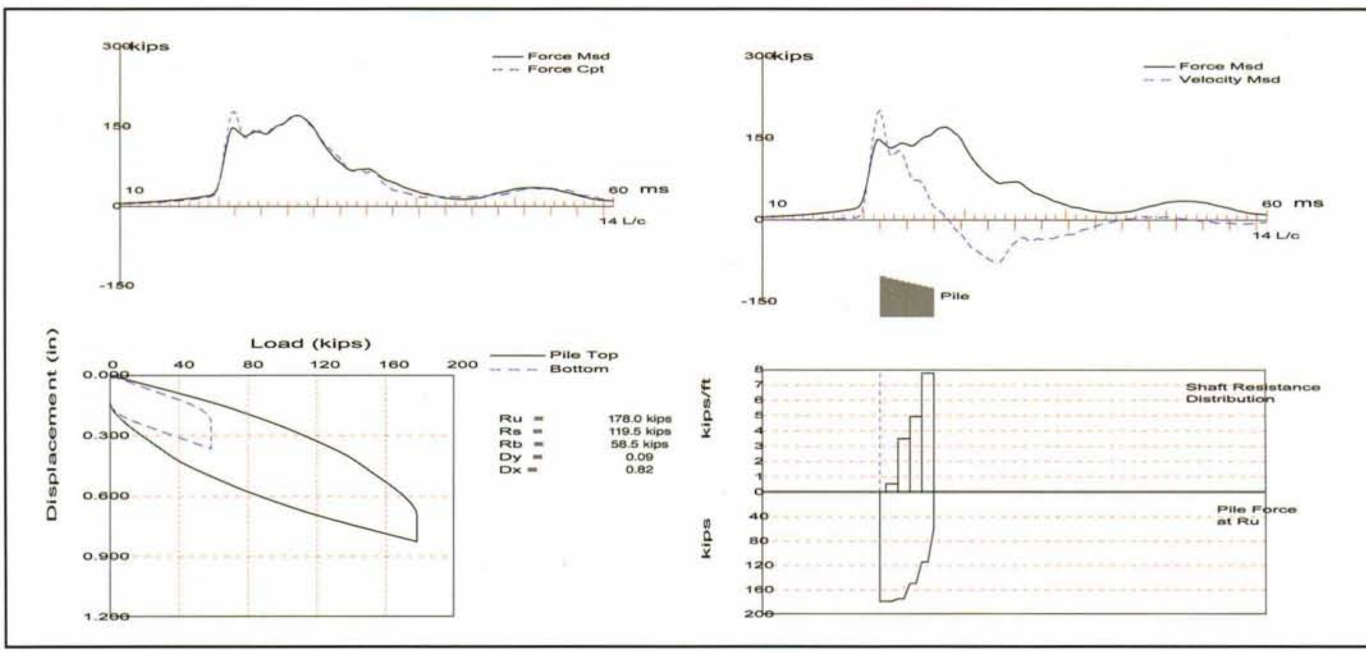

Figure 1 – CAPWAP results for restrike driving