Splicing precast, prestressed concrete piles has historically been difficult because the attachment detail either requires preplanned considerations and cast-in connection details or onsite coring and doweling when unplanned pile extensions are needed.

An alternative pile splicing approach incorporating post-tensioning was developed. The concept eliminates the limitations on tension stresses during driving.

This is the second of three papers that detail the development and implementation of this alternative approach, and it covers the full-scale field implementation and driving of a spliced pile and its comparison to a one-piece, unspliced pile.

Within the United States, 20 states provide specifications that address pile driving stresses (Fig. 1), while several others refer to American Association of State Highway and Transportation Officials (AASHTO) recommendations. In most cases, these specifications limit the magnitude of developed tensile stresses to the effective prestress plus a fraction of the tensile strength of the pile. The Florida Department of Transportation (FDOT) is the only state agency with a published limit on spliced piles. Prior to this study, FDOT limited tension stresses in spliced piles to either 250 or 500 psi (1.7 or 3.4 MPa) for epoxy dowel splices or mechanical splices, respectively. The newly developed post-tensioned pile splice system is not bound by these limits, which allows spliced piles to be handled and driven in the same manner as one-piece piles.

This is the second of three papers describing the development of a new post-tensioning system for splicing prestressed concrete piles. The first paper covered conceptual design of the proposed system and the development of its component parts. This paper describes the field application of the new splicing system. In this phase of the study, a 100 ft (30 m) long, 24 in. (610 mm) square pile spliced 70 ft (21 m) from the bottom was driven and its performance was compared with an adjacent one-piece pile driven with the same equipment. The final paper describes the concept’s implementation, scalability, and assessment through fabrication of laboratory and full-sized post-tensioning spliced prototypes and subsequent destructive testing in bending.

Within the United States, 20 states provide specifications that address pile driving stresses (Fig. 1), while several others refer to American Association of State Highway and Transportation Officials (AASHTO) recommendations. In most cases, these specifications limit the magnitude of developed tensile stresses to the effective prestress plus a fraction of the tensile strength of the pile. The Florida Department of Transportation (FDOT) is the only state agency with a published limit on spliced piles. Prior to this study, FDOT limited tension stresses in spliced piles to either 250 or 500 psi (1.7 or 3.4 MPa) for epoxy dowel splices or mechanical splices, respectively. The newly developed post-tensioned pile splice system is not bound by these limits, which allows spliced piles to be handled and driven in the same manner as one-piece piles.
Objectives and scope

This paper compares the driving performance of a two-piece pile spliced using the new post-tensioned system with a one-piece prestressed pile. A pile driving analyzer (PDA) was used to monitor driving stresses while the side-by-side piles were driven with the same diesel hammer.

In the studies that led up to this paper, pile segments were fabricated, spliced, and tested in a laboratory setting. In this phase, these operations were conducted at a commercial prestressing facility. For this reason, several changes were made to simplify construction. These changes are summarized and followed by a description of the fabrication of the pile segments, their assembly, and subsequent splicing using post-tensioning. The spliced pile was then transported to be driven adjacent to a production test pile that served as a control. The results from the driving are presented followed by an assessment of the new splicing system.

Fabrication of components

The field driving demonstration specimen was cast from two 24 in. (610 mm) square pile segments, a 70 ft (21 m) lower segment, and a 30 ft (9 m) upper segment. The splice location was set based on discussions with state engineers and practitioners who had observed that tensile stresses are often highest in the upper third of the pile length.

The core elements of the post-tensioned splicing system—chuck assemblies, confinement coils, deformed ducts, splice header, and grout manifolds—remained unchanged. However, several refinements were made to simplify and expedite construction based on lessons learned during the research program. Complete details of these changes are given in the final report; in general, changes were in response to unexpected complications. The modifications included the following:

- Threaded-back-cap chucks: The original design used the most common off-the-shelf prestressing chuck that incorporates a quick-release quarter-turn back cap with a spring that pushes the wedges against the strand. In practice, the back cap can be pushed in to overcome an internal locking tab and then unscrewed a quarter turn to remove the cap even when a strand is inserted. The shim washers used to reduce wedge setting losses removed all internal tolerances when a strand was inserted, but when the strand was not inserted (as in the casting bed), the

Figure 1. State-specified limits on driving stresses. Note: FDOT = Florida Department of Transportation. State numbers are assigned to each state alphabetically, with Alabama represented as 1 and Wyoming represented as 50. 1 ksi = 6.895 MPa.
quarter-turn back cap could still be pushed in. During fabrication of the full-scale specimen discussed in part three,有些 caps were inadvertently compressed by the extension ducts, thereby tightening the internal tolerances to a point where the strands could not be easily inserted during splicing. The use of threaded back caps eliminated this scenario.

- Reduced number of splicing strands: Practical considerations at the concept stage restricted the splicing strand sizes to those that can be reasonably stressed using commonly available handheld stressing jacks. This restriction removed 0.7 in. (18 mm) diameter strands from consideration; however, it was always possible to use splice strands larger than the pile prestressing strands to reduce the number of internal components and speed the splicing process. In this case, the pile was to use twenty ½ in. (13 mm) diameter special strands, which could be replicated or reduced to sixteen 0.6 in. (15 mm) diameter strands for the same effective prestress. As a point of reference, the full-scale 24 in. (610 mm) square bending specimen used the same number: twenty ½ in. diameter special strands. Sixteen 0.6 in. diameter splice strands were used for this part of the study.

- Bearing-plate conflicts: An oversight when scaling up from 14 in. (360 mm) square piles to 24 in. (610 mm) square piles revealed a spatial conflict where the 2.5 × 3 in. (63 × 75 mm) rectangular bearing plates nearest the corner of the strand configuration hit the duct on the adjacent side. This was due to a slight reduction in strand spacing from 3.75 in. (95.3 mm) to 3.5 in. (89 mm) in larger piles. The bearing plate shape was therefore reconfigured to fit around adjacent strands and ducts (Fig. 2). While the new shape was only needed in the corners, the plate shape and size were standardized for future piles to fit all strand sizes, pile sizes, and strand positions (Fig. 3).

- Splice-interface duct seals: For the full-scale 24 in. bending specimen, grouting had been performed before the epoxy had cured (14 in. [360 mm] prototypes were grouted several days after splicing). So despite the 1000 psi (7 MPa) precompression at the splice interface, the 80 psi (0.5 MPa) pressurized grout found pathways out of the uncured epoxy to the pile sides. The alignment dowels were redesigned to incorporate gaskets around each splicing duct to eliminate this occurrence (Fig. 4). A recess was cast in around each duct to accommodate the gaskets. The change was initiated to provide more scheduling flexibility for the contractor without compromising durability.

Figure 2 shows the new bearing-plate shape; the new process of pressing the duct into a red-hot back cap, which eliminated welding; and the finished fit to the bearing plate after heating and pressing. The off-the-shelf chucks were still welded to the bearing plate because those pieces were of similar thicknesses. Figure 3 shows all internal components ready for final assembly. Because four stagger locations were used per side, four different assembly types were needed.

The 24 in. (610 mm) square splice header plate fabricated earlier was used even though the center duct holes on each side were not needed because only sixteen 0.6 in. (15 mm) diameter strands were used instead of the 20 used previously.
Ducts were spot welded together in pairs instead of the five-duct panels used previously. Therefore, instead of four five-duct panels, eight pairs were used in each pile segment. Before each duct was assembled and welded into pairs, wedges or wedge spacers (only in the upper pile segment where wedge set losses would occur) were installed. All duct pairs were test fit in the fabrication shop with the ducts bolted to the header plate, the confining coils welded to the ducts, and the bearing plates welded to the chucks.

**Casting of pile segments**

The 24 in. (610 mm) square specimen was cast in segments, 70 and 30 ft (21 and 9 m) long, complete with internal splicing components that were delivered to the casting yard. Duct extensions were installed as separate pieces. The spiral spacing in the segments conformed to FDOT standard specifications where the five spirals closest to the ends of the pile segments (four ends total for two segments) were spaced at 1 in. (25 mm), followed by 16 at 3 in. (75 mm), and where the remainder of the pile length used a spacing of 6 in. (150 mm).

Anchorage locations were staggered into four load steps that corresponded to four ducts on each side of the pile. Because the wedge setting movement is a fixed distance, the use of larger 0.6 in. (15 mm) diameter strands would result in more losses. Therefore, the length of the splicing strands (between anchorages) was increased from 88 in. (2240 mm), as in part three, to 102 in. (2590 mm) to reduce these losses. This meant that some overlapping of post-tensioning and prestressing forces would exist behind the transfer-length region.

Casting followed standard procedures, where the splice header was inserted in the bed as a normal pile separation header and strands were progressively installed in order from bottom to top prior to installing ducts and pulling the spiral reinforcement (Fig. 5). The long lengths of duct extensions and duct pairs were placed in the bed after the strands were tensioned but before the spirals were pulled to the ends of the pile, which would have eliminated access. Two top strands were

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**Figure 4.** Revised alignment dowel incorporating grout seal. Note: 1 in. = 25.4 mm.

**Figure 5.** Strands threaded through header plates in casting bed, splice header (foreground) and chamfered jacking plate header (background).

**Figure 6.** Splicing system in place (center), four-duct adaptation increased concrete access/flow (right) compared with five-duct panels previously used (left).
left slack to ease installation and were tensioned only after all splicing fixtures were installed. The two-duct configuration eased installation over the previously used five-duct panel, which was difficult to handle inside the spirals. The anchorages and extension ducts were bundled inside and suspended by the upper stressed strands so that the spirals could be easily pulled over and spaced prior to final positioning of the ducts.

Figure 6 shows the finished assemblies tied into the bed. The black-and-red heat-shrink sealant denoted whether the duct assembly incorporated the wedge shim. (Black is shown on the top side of the splice header and the upper pile segment and contained the shim washer.)

Self-consolidating concrete was used, so vibrating wasn’t needed. Concrete test cylinders were made for compressive strength tests. Concrete strength at the time of detensioning (three days after casting) was 7900 psi (54 MPa), which increased to 8400 psi (58 MPa) at the time the pile segments were spliced (four days after casting).

Field splicing of demonstration pile

The cured pile specimens were removed from the bed and set aside in the yard, where they were made ready for splicing. During extraction, the bottom corners of the upper pile segment were chipped, leaving a 3 × 3 × 1 in. (75 × 75 × 25 mm) triangular gap in the cover region (Fig. 7). Some honeycombing was also noted on the lower pile in the same locations.

Preparation for splicing

During preparation work, all duct bolts were removed and each duct was inspected for debris with a borescope. The inspection showed no debris in the ducts or wedges. The mating surfaces of the piles were checked for flatness. The ends of 0.6 in. (15 mm) diameter strands were ground to remove burrs or sharp edges and then fed into the upper pile segment, where the exposed strands were clamped (Fig. 8) to ensure that no slippage into the upper pile segment would occur during splicing.

The pile segments were spliced horizontally using a mobile gantry crane. With the upper segment correctly positioned by the crane and strands in place and secured, each of the strands was fed into the lower-segment ducts. The pile segments were brought within 1 ft (0.3 m) of each other when the strand clamps were removed, and epoxy sealant was applied to both splicing surfaces. The remaining gap was closed to within approximately 1 in. (25 mm) of contact. As the weight was held by the crane in two positions, the vertical and horizontal alignment was easily controlled. Minor lateral adjustments could then be made as the alignment dowels fully engaged.

Post-tensioning

The post-tension stressing order was preset, and each pair of opposite strands was jacked to predetermined loads in three stages. This maintained balanced strain and reduced losses from elastic compression. For convenience, the stressing order of matched pairs was marked on the pile where all strands with the same anchorage locations were stressed in further sets of four. (That is, strands 1, 5, 9, and 13 all had anchorages 59 in. [1500 mm] into the lower pile and 43 in. [1100 mm] into the upper pile.) Three jacking cycles were used, starting at 8 kip (36 kN) and increasing in 20 kip (89 kN) increments up to 80% of 270 ksi (1860 MPa) in the 0.6 in. (15 mm) strands: first cycle, 8 kip; second cycle, 28 kip (120 kN); and third cycle, 48 kip (210 kN).

The strands extending beyond the jacking end (top of the spliced pile) were cut to permit access to the threaded duct ends for grouting. The jacking and header plate were removed to further facilitate access for grouting.

Grouting

Each duct was fitted with a ¾ in. (19 mm) diameter pipe nipple. One duct from each side was additionally fitted with a ball valve through which grout was pumped. An FDOT-ap-
proved post-tensioning tendon cable grout was pumped into each of the four side panels. As with the previous 24 in. (610 mm) square spliced pile specimen, all four ducts from each side of the pile were piped together to serve as one grout circuit (four circuits total). This meant that grout could be injected into any one of the ducts in the circuit and returned out the other three.

As each of the other three ducts confirmed return flow of grout, it was capped to direct flow to the remaining ducts. Figure 9 shows the fully grouted pile. The following week, the grout fittings were removed and the strands were all cut flush for pile driving.

**Pile driving demonstration**

The performance of the concept splice was demonstrated via a side-by-side comparison with a one-piece control pile of similar length. The control pile was driven as part of a routine test pile program at the Interstate 4 Deer Bridge wildlife crossing near DeLand, Fla., using a single acting diesel hammer. All piles on this bridge were placed into a 25 ft (7.6 m), pre-formed hole, which expedited the driving process while minimizing tensile stresses required to penetrate the upper soils.

The nominal bearing resistance for all piles in the two end bents was 494 kip (2200 kN), while the center pier pile resistance was 754 kip (3350 kN). Driving criteria for the unmonitored production piles were based on the number of hammer blows per foot with an associated energy per blow from hammer stroke (Table 1). FDOT further requires that once capacity is met, it must be sustained for 2 ft (0.6 m) of continued driving, with the blow count generally increasing over the same 2 ft.

Both the production test pile (test pile 1) and the spliced pile (test pile 1-1) were driven in end bent 3-3 of the two-span, three-pier bridge. A PDA was used to monitor concrete stress and pile movement using a combination of wired strain gauges and accelerometers. Among the significant features of the PDA algorithms (for example, maximum tension stress, maximum compression stress, blow count, estimated capacity) is the ability to compute the stress at a specific position along the length of the pile. For comparison, this location was selected to be 30 ft (9 m) from the top of the pile (corresponding to the splice location) for most of the driv-

**Table 1. Production driving criteria for end bent piles**

<table>
<thead>
<tr>
<th>Minimum stroke height, ft</th>
<th>Minimum number of blows per ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5</td>
<td>71</td>
</tr>
<tr>
<td>8.0</td>
<td>66</td>
</tr>
<tr>
<td>8.5</td>
<td>61</td>
</tr>
<tr>
<td>9.0</td>
<td>57</td>
</tr>
</tbody>
</table>

Note: 1 ft = 0.305 m.

**One-piece control pile installation**

The control test pile was 24 in. square × 115 ft long (610 mm square × 35.1 m long) and was driven through 85 ft (26 m) of fine sand and silt, terminating with refusal conditions in limestone at an embedment depth of 99.8 ft (30.4 m). Test piles and production piles for this bridge were driven with a 13.75 in. (349.3 mm) plywood pile cushion to control tensile stresses in the early stages of driving. At the end of driving, the pile had an estimated capacity of 1400 kip (6200 kN) at 150 blows per foot and had experienced 4035 blows. Figure 10 shows the recorded compressive and tensile stresses as a function of blow count. The 13.75 in. cushion was replaced at blow 2194, which temporarily reduced tension stresses.

Figure 10 shows the tension stresses from two PDA outputs. Tensile stress never exceeded 1 ksi (7 MPa) or the maximum FDOT allowable tensile stress of 1.25 ksi (8.62 MPa) (for 6 ksi [48 MPa] concrete), and the maximum tensile stress was the same as stresses 30 ft (9 m) from the top of the pile (corresponding to the splice location) for most of the driv-

**Figure 9.** Grouting fourth circuit as last duct showed grout return; all others capped.

**Figure 10.** Driving stresses in test pile used as comparative control. Note: 1 ft = 0.305 m; 1 ksi = 6.895 MPa.
ing. This confirmed that a splice in the upper third of the pile would experience the worst-case tensile stresses and provided the rationale for selecting that location for the splice in the demonstration spliced pile specimen.

**Spliced pile installation**

The demonstration spliced pile was driven adjacent to the one-piece test pile in line with the rest of end bent 3-3 but out of position. It was 100 ft (30 m) long, 15 ft (4.6 m) shorter than the control pile. While the chipped portion of the lower pile segment could have been patched, the corner was deliberately left unrepaired to simulate a possible worst-case field condition.

Figure 11 shows the pile in the preformed hole and close-up views of the splice interface prior to driving, including the corners damaged when pulled from the casting bed.

**Driving chronology**

The highest tensile stresses typically occur early, when no appreciable side shear has developed and the pile is free to resonate, or when the pile is being driven through a stiff soil layer into a weaker layer. To introduce tensile stresses that would approach or even exceed the maximum allowable stress, a thinner 11.75 in. (498.5 mm) plywood pile cushion was used at the onset. Recall that 13.75 in. (349.3 mm) was used on the test pile, which balanced driving efficiency and controlled excessive tension stress. The hammer used to drive the splice pile specimen was the same as that used for the test pile and had four fuel settings to control stroke height and the associated energy. A chronology of the driving progression is presented for the splice pile specimen:

- Starting with fuel setting one, the spliced pile was driven from 25 to 44 ft (7.6 to 13 m) of embedment (286 blows) with tensile stresses as high as 1.34 ksi (9.24 MPa), which occurred at the splice location. The average tensile stress for this portion of the drive was 1.25 ksi (8.62 MPa). The average compressive stress was 1.96 ksi (13.5 MPa).

- With an extended exposure to tensile stresses and to increase driving efficiency, an additional 7.5 in. (191 mm) of cushion was added (to lengthen load pulse and lower tension stress), which allowed the hammer to be run at higher energy levels. An additional 1195 blows were imparted, starting with fuel setting 1 from 44 to 52 ft (13 to 16 m), fuel setting 2 from 52 to 61 ft (18.6 m), fuel setting 3 from 61 to 62 ft (18.9 m), and fuel setting 4 from 62 to 76 ft (23 m). Average tensile stresses were 0.72, 0.80, 0.92, and 1.12 ksi (5.0, 5.5, 6.3, and 7.72 MPa) for fuel settings 1, 2, 3, and 4, respectively. Compressive stresses, however, were only 1.86, 2.12, 2.21, and 2.36 ksi (12.8, 14.6, 15.2, and 16.3 MPa), respectively.

- To further increase energy transfer into the pile, the pile cushion was removed and replaced with a thinner 9 in. (230 mm) cushion. The 19.25 in. (489 mm [298+ 191 mm]) original cushion thickness reduced to 14.5 in. (368 mm). An additional 2036 blows were applied to the pile immediately using fuel setting 4. The pile was driven from 76 to 95 ft (23 to 29 m) when driving was interrupted to remove the template, allowing it to be driven an additional 4 ft (1.2 m). Driving stresses for this portion of the drive started at 0.9 ksi (6 MPa) tension and 2.6 ksi (18 MPa) compression and concluded at 0.3 and 3.6 ksi (2 and 24 MPa), respectively. Pile driving records for both the test and splice piles can be found in the final report.22
At the end of drive, the PDA-estimated pile capacity was 1660 kip (7380 MPa) with 131 blows per foot. In comparison, the test pile was driven to 1400 kip (6200 MPa) with 150 blows per foot. In all, the pile withstood 3231 blows with no detrimental effects. Figure 12 shows the PDA-recorded tensile and compressive stresses for the splice pile specimen. The allowable tensile and compressive stresses were exceeded for the experimental pile. Under normal pile driving conditions these limits would not have been intentionally ignored.

During each pile cushion adjustment, the pile was visually inspected for obvious damage; no damage was found. Figure 13 shows the splice region at each cushion change (286 and 1481 blows). The integrity of the pile was continuously monitored via the integrity factor, which registered an average value of 97.4 out of 100 (minimum 90; maximum 100). In comparison, the one-piece control pile registered an average of 99.9 (minimum 89.4; maximum 100). The last visual inspection (prior to the splice going underground) showed a hairline crack in the epoxy. While the crack was completely closed, it appeared to have initiated from the chipped edge, which was expected given the notched shape and the associated stress concentrations.

The high energy applied to the pile resulted in cushion combustion and capacity being achieved with fewer blows than the control pile at the same tip elevation.

**Discussion**

Prototyping always involves trial and error from which improvements are made. In this case, each splice pile tested provided usable feedback to further advance the overall splice concept. Improvements and a splicing procedure and checklist ensued from this phase.

**Improvements**

- Fewer ducts reduced the number of components, casting yard installation time, splice preparation time, and number of strands stressed during the splice process.
- Self-consolidating concrete was used to cast the pile, so no direct comparison could be made with regard to the reduced congestion in the cage. However, the cage appeared to be open and any concrete vibrator would have been applicable.
- The use of threaded screw cap chucks removed all tolerance variations, and the strands were easily inserted in both the upper pile (with shim washers) and the lower pile segments.

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**Figure 12.** Driving stresses in spliced pile (end bent 3-3, pile 1-1). Note: 1 ksi = 6.895 MPa.

**Figure 13.** Visual inspection of splice at each cushion change (added 7.5 in. at 44 ft [left]; replaced with 9 in. at 76 ft [right]). Note: 1 in. = 25.4 mm; 1 ft = 0.305 m.
Grouting was still slow despite using larger 0.6 in. (15 mm) diameter chucks. No dedicated pathways around or through the wedges were provided, which should be considered.

The neoprene gaskets around the alignment dowels (in the preformed recesses) withstood the 500 psi (3400 kPa) grout pressure that was applied by the pump. No grout leaks were detected.

The additional stiffness of the 0.6 in. diameter strands more easily overcame the wedge spring resistance, making the splice process progress smoothly.

Simple vise-grip clamps were used on each strand instead of specialized clamps, which sped the upper pile preparation process (however, this is not recommended for shipping a pile prepared in advance for splicing).

Inadvertent damage at the splice face is inevitable. The type of damage experienced was perhaps the worst type of stress concentrator for the epoxy. Even then, the pile drove without notable concern from the PDA operators. A small chamfer should be considered to lessen the likelihood of chips, recognizing that the lower pile segment would normally be driven first. However, the standard chamfer is not recommended because it nearly replicates the chip in the tested pile. Suggested pile extraction techniques are outlined in the procedure described in the following section to minimize pile damage.

A two-piece, separable splicing header could be considered that can be disassembled prior to pile removal from the bed to minimize or prevent the damage experienced.

Driving the pile with wet epoxy would eliminate cracking and increase long-term durability by forming the seal after drive. For production applications, staying within FDOT allowable tension limits would also prevent cured epoxy from cracking.

Splicing checklist and procedure

While the research team was experienced in the steps to perform the splice, oversights and missed steps made it apparent that a comprehensive checklist should be used to streamline the overall process.

1. Detensioning (pile removal)
   - When extracting pile from bed, remove all duct fastening bolts from both sides of the splice header plate prior to detensioning.
   - After the strands have been cut roughly in the middle between pile segments, tap the strands with a hammer in all directions to loosen concrete bond between the strands and header.

2. Preparing splicing faces and jacking end (There are three faces to consider: the two splice faces and the upper jacking end face [top of upper pile]. The bottom end of the lower pile segment should be prepared using standard pile preparation techniques and is not considered part of this procedure.)
   - Grind off all prestressing strand stubs from the ends of each side of the splice faces.
   - Use a straight edge to ensure that no high points exist on either of the splice faces. Any high spot or bump will attract load and potentially cause a local failure or spall. Grind strands to be slightly below the splice surface plane.
   - Remove excess concrete from the edges of the splice faces. Ensure that the entire edge will not cause obstruction to the straight edge. Using a small ¾ × ¾ in. (19 × 19 mm) chamfer will minimize this effect.
   - The top face of the upper pile has a jacking plate that serves two functions: during casting, it aligns the ducts relative to the strands, and during splicing, it provides a bearing plate for the jack forces. Remove that plate prior to splicing while still on the ground to remove prestressing strand stubs completely, and reinstall the plate for jacking. Alternatively, the plate can be abandoned and a smaller bearing plate can be incorporated into the stressing jack. In either case, clean the pile face on the ground prior to stressing.

3. Prepare the upper pile half
   - Prepare prior to shipping to the project site or onsite.
   - Cut the splicing strands to length, and grind the sharp edges caused by cutting. This can be done either individually in advance or by directly pulling strand from the spool.
   - Before inserting strands in the upper pile segment, soften the leading edge of the strand with a grinder to minimize the potential for snagging in the wedges.
   - The length of the splicing strand should extend from the top and bottom of the upper pile segment with enough length to fully penetrate the lower pile ducts.
and provide for jacking. The length can be conservatively set as the upper pile segment length plus 15 ft (4.6 m).

- Install alignment dowel with 1/8 in. (3.2 mm) neoprene gasket into the duct openings and ensure no threads are exposed. The strand can be inserted through the alignment dowel after it is installed, or the alignment dowel can be slid onto the strand and installed after the strand is inserted.

- With the strand exposed the correct length out of the bottom of the pile, clamp the strand with an external fixture to prevent movement of the strand during shipping and splicing operations. For shipping, vise grips are not recommended because they may be inadvertently dislodged. A bolt-on clamp should be used for shipping, but the more easily removable vise grips (or similar) should be used during splicing.

- The strand will go one direction into the upper pile segment. Therefore, predetermine the length of strand that will be exposed out the bottom end. Staggering the strand lengths by an inch is a reasonable approach because no two strands will touch at the same time. However, a 10 ft (3 m) exposed length provides enough flexibility for bending and inserting. If the strand is inadvertently pushed too far into the upper pile segment, fully remove the strand out the top of the pile and reinstall with the correct exposed length and affix the clamp.

4. Splicing

- Apply epoxy to the splice faces prior to hoisting the upper pile half to prevent unnecessary workplace harm to the field technicians. For horizontally spliced piles, epoxy can be applied later.

- Lift the upper pile and suspend it over the lower pile segment oriented with the top of the bed faces aligned.

- Lower the upper pile while aligning each strand with the corresponding duct in the lower pile. Take care to prevent crossing the strands.

- As the pile comes within a couple inches of making contact, adjust the alignment to ensure that the dowels do not catch the lower pile face.

- Lower until contact is achieved but support the weight of the upper pile segment with the crane.

5. Post-tensioning

- The order of strand stressing should be balanced such that eccentricity is minimized and controlled. The order used for the specimens in this study stressed all strands with the same anchor locations. For example, the last pile had four staggers (positions) and four strands with each location (one per side). Therefore, opposite sides of the pile were stressed for each position and then the next set of four was systematically stressed at the same location.

- Stress strands in at least two stages (preferably three). The first stage should be one-third of the final jacking load but must exceed 10 kip (44 kN).

- After all strands have been stressed, cut strands flush for pile driving.

6. Grouting

- Depending on the specific grout duct configuration and circuit design, install 3/4 in. (19 mm) national pipe taper pipe nipples in each of the ducts.

- Pipe caps should be available to stop grout flow once return has been demonstrated.

- Connect the grout inflow hose to one of the circuit ducts, and pump grout until flow return is confirmed from the rest of the ducts in that circuit.

- Cap each duct as grout flow is observed.

- When all ducts are grouted, disconnect the grout hose and move to the next circuit.

- Remove caps and reuse them for the next circuit (vertical pile case).

- When all circuits have been grouted, remove all grout fixtures.

- While the design of the splice does not depend on the grout bond between the ducts and the strand for driving, there is benefit after the grout cures and strands become fully bonded. Therefore, grouting can be performed after driving when the pile top is nearer the ground surface and easier to access. Similarly, it is envisioned that pile driving can commence directly after splicing, while the grout is still fluid (or ungrouted) and epoxy is uncured. These conditions were not tested within the time frame of this study.

Summary

This study investigated the use of an alternative approach to splice prestressed concrete piles, which involved post-tensioning the two splice pile segments together. The overall effort included concept development, component fabrication, laboratory tests, and full-scale bending tests and culminated in a drivability demonstration with the splice located in the worst position to
maximize tension stresses. The pile was deliberately driven in excess of the normal driving stress limits but showed no detrimental effects. Compared with the one-piece control pile, the spliced test pile was driven harder and achieved a higher capacity with fewer blows at the same approximate tip elevation.

Future work is planned to perform the field splice in a more traditional fashion (vertically) after driving the first segment. Input from the contractor perspective will undoubtedly add value to this new system.

**Acknowledgments**

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Splicing precast, prestressed concrete piles has historically been difficult because the attachment detail either requires preplanned considerations and cast-in connection details or requires onsite coring and doweling when unplanned pile extensions are needed. When the pile must be driven after splicing, the splice connection is prone to tensile failures due to the inability to transfer driving stresses through the connection into the other pile segment. Focusing on preplanned splices, the Florida Department of Transportation limits tension stresses during driving to 250 and 500 psi (1700 and 3400 kPa) for epoxy dowel splices and mechanical splices, respectively. This can limit the ability to efficiently drive the pile to the point that it may even be impossible. In response, an alternative pile splicing approach incorporating post-tensioning was developed. The concept eliminates the limitations on tension stresses during driving. This is the second of three papers that detail the development and implementation of this alternative approach. Specifically, it covers the full-scale field implementation and driving of a spliced pile and its comparison to a one-piece, unspliced pile.
Keywords

Field, Florida, grout, pile, pile driving analyzer, post-tensioning, self-consolidating concrete, splice.

Review policy

This paper was reviewed in accordance with the Precast/Prestressed Concrete Institute’s peer-review process.

Reader comments

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