Post-Tensioned Slabs on Ground

Part 4: Existing Foundations

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This is the final of four articles on post-tensioned slab-on-ground design and construction. This article will focus on engineering and construction issues in regards to existing post-tensioned foundations. Please see the January, April and July 2010 issues of STRUCTURE® magazine for the previous articles.

As post-tensioned foundations have become more common place in residential construction, remodels and additions on these foundations have also become more frequent. Understanding a few simple steps should help engineers and contractors alike to produce buildable and economical designs that utilize the benefits of post-tensioning while also protecting the existing system. The first step is always to determine what type of foundation you are dealing with. Some of the larger tract home builders will imprint a stamp in the concrete or put a plaque on the garage identifying the foundation as being post-tensioned. The note is primarily to caution future contractors against drilling into the concrete without accounting for the existing tendons.

If a note or plaque isn't available, the governing building department may have the existing structural drawings which should contain the design or other indications of the foundation system. If a design/build contractor was used (which is fairly common in tract homes), the actual foundation drawings may not be available at the city, since they were most likely a deferred submittal. Building departments often view these documents as more of a shop drawing than part of the A&E package that they retain.

If no existing drawings are available, a simple investigation of the perimeter of the house may provide the answer. Typical residential construction will only require stressing of the tendons from one anchor. The stressing anchor is typically connected to the form boards by two 20d nails that are approximately 4 inches apart. After the concrete is placed and cured, the form boards are removed with the 20d nails sticking out of the slab. The nails are subsequently burned off with the tendons tails to the face of the concrete (*Figure 1*). Over time, the exposed nail will rust and leave two small reddish marks on the edge of the foundation. If these rust marks are noted approximately 3 to 4 feet on center, it is a strong possibility the existing foundation is post-tensioned. In addition, the marks will indicate the anchor location and the approximate cover to the strand as it extends across the foundation. Since tendons are placed at mid-depth of the slab, the cover to the strand should provide a reasonable estimate of the slab thickness.

Figure 1: Rust Marks of Burned off Anchor Nails.

Figure 2: Scanning Slab to Locate Existing Strands.

Locating Tendons

Once the foundation has been established as being post-tensioned, the tendons should be located in the areas adjacent to any future cores. This is especially critical for kitchen and bathroom remodels due to the size and number of penetrations. When remodels are performed that do not require structural engineering input, the contractor alone is left to determine if the foundation is post-tensioned. I have received numerous phone calls from exasperated home owners that have had a strand broken and who are now experiencing delays, additional costs to repair the foundation and in desperate search to find someone that understands what happened and can fix the tendon. Unfortunately, lack of proper due diligence can give post-tensioning a poor reputation.

There are several methods for locating strands that range from digital readouts of a concrete surface scan (*Figure 2*) to using a hand held metal detector and looking for spikes on the dial (*Figure 3*). The technician in *Figure 2* scanned a room with rough dimensions of 20 feet by 20 feet in about an hour and was able to mark the strand and anchor locations on the slab. With the tendons marked, the contractors could easily adjust their drill location to miss the existing reinforcing. Ground penetrating radar (GPR) can also be used for thicker foundations which will have a larger cover than their ribbed counterparts.

For cores in the interior of the foundation, the drill locations can be as close to the strands as required without damaging the sheathing. Since the foundations are constructed with unbounded strands, no bond is required for strain compatibility and any loss of concrete does not affect development or strength of the tendon. Instead of using expansion bolts or threaded rods for attaching new sill plates, shot pins have been successfully used and should be evaluated. Shot pins typically don't require drilling, and their relatively small embedment depth will usually stay within the cover to the top of the tendons. While shot pins may not work for shear walls, their use in bracing the sill plate of other non lateral walls may limit drilling and possible damage to the existing foundation.

If drilling is required on the perimeter where the anchors are typically located, the cores should be adjusted to miss the anchor and the concrete directly in front of the anchor. Even if the strand and anchor are not physically damaged by the core, removing concrete that is actively

Figure 3: Pacometer (Metal Detector) used to Locate Existing Strands.

resisting the loaded anchor can cause cracking or blowouts. The force from the anchor is typically assumed to radiate in a 45 degree cone away from the anchor surface. Locating the penetrations out of the zone of influence for roughly 24 to 36 inches from the anchor face is recommended.

Strand Repair

If a strand is broken, there are several repair methods available. The strand can be coupled using a mechanical splicer as shown in *Figure 4*. The couplers are significantly larger than the tendons, so the area around the broken tendon will need to be chipped out to create enough workable room. Care should be taken during this procedure so as not to damage additional strands. Depending on the size of the opening, overlapping epoxy dowels may be required to re-connect the concrete patch to the existing foundation. Prior to placing concrete, the vapor retarder should be repaired (if required) to maintain the effectiveness of the moisture intrusion system. With current technology, it is possible to re-thread a new, greased strand into the existing sheathing. The jack is used in reverse to push the new strand through the slab. This application does not require any additional drilling or verification by an engineer, since the full strength of the system has been replaced. Re-threading a strand is more realistic for newer construction where the grease between the strand and sheathing is still in reasonably good condition. For older foundations, re-threading is still possible, but a ⅜- or 7⁄16-inch diameter strand will most likely be required. With a smaller diameter strand, a reduced force will be applied to the foundation. An engineer may be required to determine what impact, if any, the reduced precompression level will have on the performance of the foundation.

Figure 4: Coupler Used to Re-Connect Broken Strands.

For larger slabs, it is possible to attach new anchors to each side of the broken strand and re-stress them to their full value. The opening in the slab will need to be large enough to allow access of the stressing equipment (typically around 36 inches) and to install epoxy dowels to reinforce the concrete between the anchors. In addition, each tendon will need to be at least 15 feet long to avoid accidentally overloading the strand. While the patched area will not have a strand(s) in one direction, the interior of the foundation is considered to be effectively in the dormant zone for expansive soil movement and the epoxied rebar should be designed to resist any superimposed loads. For the possible retrofits described, it is recommended to retain a contractor familiar and experienced in this type of work.

New Conditions

A frequent remodel condition is the addition of a heavily loaded post or column on the foundation. If the existing slab cannot support the load, a spread footing will be required. The typical construction procedure for conventionally reinforced slabs is to simply remove the concrete under the new column, prepare the soil as listed in the soils report, add the appropriate rebar and replace the concrete. The same general procedure can be used in a post-tensioned system; however ,the demolition process should not damage the tendons. Once the tendons have been located, the majority of the existing concrete can be removed with standard methods. The concrete adjacent to the strands should be chipped away in a method that does not damage the strands. This is often accomplished by a low velocity hammer or hand held chisel. If the strand is damaged, one of the previously mentioned repair procedures should be used. This detail is most effective in the interior of the foundation where the opening will have a negligible impact from the loaded anchors. *Figure 5* shows a pad footing being added to an existing foundation where one strand was damaged and is being repaired. Holes for future epoxy dowels have been drilled into the existing slab to reinforce and connect the new concrete to the existing foundation.

Creating a slab opening near live anchors will typically require engineering analysis to determine if the concrete is adequate for the temporary condition. After the concrete is removed, a pseudo beam will be created that would span across the opening while resisting the force of the strands. The depth of the section, compressive strength of the concrete and the slab thickness are typically the key factors in this calculation. If the concrete is inadequate, the tendons may need to be purposely de-tensioned and re-stressed after the footing has been constructed, to prevent cracking and possible blow outs.

When a remodel occurs, the foundation system needs to be re-analyzed with the revised loading. In general, a higher perimeter load will increase the stresses for the center lift condition while having minimal impact on edge lift. If the loading is large enough that the foundation does not satisfy the code requirements, a typical retrofit is to add a new perimeter footing that extends further into the soil than the existing foundation. Per section 3.7 of the Post-Tensioning Institute (PTI) manual, a deeper footing will act as a pseudo water barrier, reducing the amount of moisture migration in and out of the foundation. Essentially, if the barrier can prevent any substantial change in water content, the effects of expansive soils are reduced. The new footing is placed on the exterior of the perimeter footing and connected with epoxy dowels. To minimize any affect on usable space, the top of the new footing typically begins several inches below the grade level to allow for hardscaping or planting. In addition, the new footing can be used in resisting large post load or hold down forces.

Figure 5: New Pad Footing in an Existing Post-Tensioned Foundation.

If the remodel involves increasing the foundation footprint, the analysis is typically performed in two ways. The new foundation can be modeled and designed as a standalone element. The reinforcing in the expanded foundation will be self contained and the existing perimeter footing can be viewed as the edge for the new slab. This assumes the new slab will be connected to the existing concrete to create composite action. If the dimensions of the expansion are relatively small in comparison to a typical foundation, the calculated deflections may exceed the allowable limits even though the deflections are small numerically. The deflection criteria are a function of the plan dimensions and smaller plates will often generate unrealistic deflections limits. Engineering judgment should be used in evaluating this condition. In addition, the standalone design will not model the continuity affect of the existing foundation which will often reduce deflections.

The other option is to model the new and existing foundation as a complete system. Depending on how much information is available on the existing structure, interior footing depth, concrete compressive strength, spacing and tendon layout may have to be assumed or defaulted to code minimums. The new and existing foundation will need to be connected to provide the continuity to match the modeling assumptions. Larger foundations will require more strands to maintain the desired precompression level. Since the tendons in the expanded foundation will be shorter and have less subgrade friction than used in the design, engineering judgment should be used in specifying the number of tendons.▪

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