SLABS & FLOORS

POST-TENSIONED SLABS

Combining the advantages of prestressed and cast-in-place concrete.

By Jim Rogers

Post-tensioned concrete is a term heard more and more in the construction industry today. This method of reinforcing concrete enables a designer to take advantage of the considerable benefits provided by prestressed concrete while retaining the flexibility afforded by the cast-in-place method of building concrete structures.

Post-tensioning is simply a method of producing prestressed concrete, masonry, and other structural elements. The term prestressing is used to describe the process of introducing internal forces (or stress) into a concrete or masonry element during the construction process in order to counteract the external loads applied when the structure is put into use (known as service loads). These internal forces are applied by tensioning high-strength steel, which can be done either before or after the concrete is placed. When the steel is tensioned before concrete placement, the process is called pretensioning. When the steel is tensioned after concrete placement, the process is called post-tensioning. Because pretensioning requires specially designed casting beds, it is used generally in the precast manufacturing process to make simple shapes that can be trucked to a jobsite. Post-tensioning is done onsite by installing post-tensioning tendons within the concrete form-work in a manner similar to installing rebar.

What does post-tensioning do?

When a concrete slab is stressed by the post-tensioning method, it means the steel is being tensioned and the concrete is being compressed. Compression is a force that squeezes or crushes, and tension is a force that pulls something apart. As a building material, concrete is very strong in compression but relatively weak in tension. Steel is very strong in tension. Putting a concrete slab into compression and the steel into tension before any substantial service loads are applied puts both building materials into their strongest states. The result is a stiffer concrete slab that actively is compressed and has more capacity to resist tensile forces.

When a concrete floor slab is subjected to forces, it flexes and bends. These forces are a result of gravity pulling down on the slab while additional weight is applied to the top of the slab. The bending and flexing creates high tensile forces that can cause the concrete floor slab to crack (see Figure 1). This is where the use of reinforcing becomes important. Because steel has a high capacity to resist tensile forces, it can be

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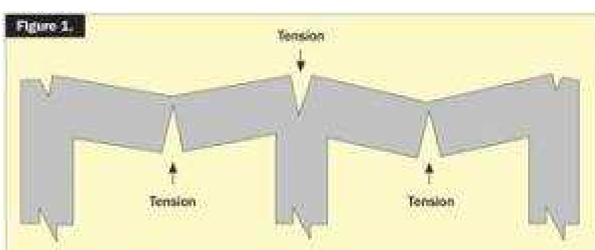
Post-tensioned floors increasingly are being used in high-rise construction.

embedded in the concrete at the tension zones—the areas that tensile failures could occur—allowing the tensile forces to be handled by the reinforcing steel.

Adding post-tensioned reinforcement instead of rebar alone combines the action of reinforcing the tension zones with the advantages of compressing the concrete slab. Additional benefits are obtained when the post-tensioned reinforcement is installed in a draped profile instead of running in a straight line. A typical draped profile in an elevated concrete slab would route the post-tensioned reinforcement through a high point over the slab's supports, and through a low point in between those supports (see Figure 2). Now optimum efficiency is obtained because the post-tensioned reinforcement is located in the tension zones, the concrete is compressed, and the post-tensioned reinforcement is creating an uplift force in the middle of the spans where it is needed the most.

Common uses and advantages

The first application of post-tensioning is believed to have been conceived by Eugene Freyssinet in 1933 for the foundation of a marine terminal in France and the technology was introduced to the United States in the 1950s. Post-tensioning now is used extensively in bridges, elevated slabs (parking structures and residential or commercial buildings), residential foundations, walls, and columns.



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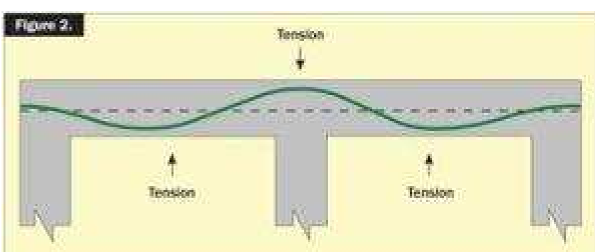
Bending and flexing creates high tensile forces that can cause the concrete floor slab to crack.

The use of post-tensioned reinforcement to construct floor slabs can result in thinner concrete sections and/or longer spans between supports. Designers commonly take advantage of this method to produce buildings and structures with clear open spaces allowing more architectural freedom. Reducing the thickness of each structural floor in a building can reduce the total weight of the structure and decrease the ceiling to floor height of each level. In belowgrade structures, this can mean less excavation, and in abovegrade structures, it can mean a reduced overall building height. In areas with building height restrictions, saving 8 to 12 inches (or more) of height on each level can add up by the time you reach 10 or 12 levels. The use of post-tensioning commonly is applied to "flat slab" or "flat plate" construction in multilevel structures. The longer spans cut down on the number of columns required and give the designer more freedom to layout the building. Even longer spans can be achieved by using beam and slab construction, such as in a parking structure where typical post-tensioned beams can span 60 to 65 feet.

There are not any special considerations or requirements for the formwork beyond what is used in non-post-tensioned construction, and the deck forms can be cycled as soon as the tendons are stressed, resulting in fast construction cycle times.

Construction process

The basic element of a post-tensioning system is called a tendon. A post-tensioning tendon is made up of one or more pieces of prestressing steel, coated with a protective coating, and housed inside a duct or sheathing. A tendon has anchors on each end to transmit the forces into the structure. Long tendons may have intermediate anchors along their length to allow for stressing at construction joints. The prestressing steel is manufactured to the requirements of ASTM A-416 and typical strand sizes are 0.50 and 0.60 inch diameters. The entire tendon assembly must meet the requirements of ACI 423, and should be manufactured and fabricated by a plant that is certified by a program such as the Post-Tensioning Institute's Plant Certification Program (see www.post-tensioning.org). To get an idea of the high strength of this type of steel, a typical steel strand used for post-tensioning will yield about 243,000 psi. In contrast, a typical piece of rebar will yield about 60,000 psi.



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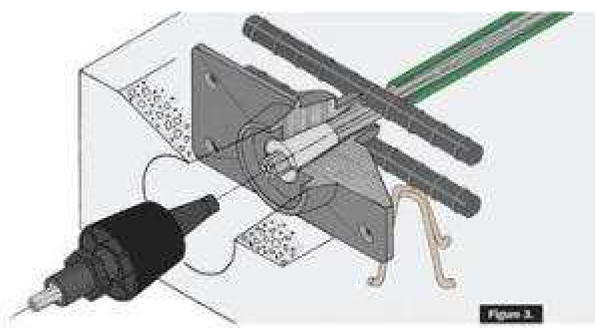
A typical draped profile in an elevated concrete slab would route the post-tensioned reinforcement through a high point over the slab's supports, and through a low point in between those supports.

The handling and installation of the post-tensioning tendons does require special skill and knowledge. Trained ironworkers will install the tendons in the precise locations dictated by the engineer of record, and shown on the post-tension field placement drawings. The high and low points of the draped profile (see Figure 2) are critical to maintain and the tolerance for the placement in these locations can be as tight as ± ¼ inch. Other trades working on the deck prior to concrete placement must be aware that they cannot disturb or move the tendons to accommodate their work. In elevated slab construction, the tendons typically are grouped in bundles in order to increase the spacing between tendons and improve the constructability of the slab.

After the concrete is placed, it must achieve proper strength before the tendons are tensioned. This is typically 75% of the concrete's 28-day design strength, and is specified in the project documents. The tensioning of the tendons, also known as the stressing operation, is achieved by using a hydraulic jack. At least one end of each tendon will have been installed with a length of prestressing steel protruding through the edge form and beyond the edge of the slab; this is known as the stressing tail. A plastic pocket former also will have been installed at this location to create a stressing pocket (see Figure 3). When the edge form and pocket former are removed, the strand tail and stressing pocket are exposed to allow the ironworker to use the stressing jack to apply the force in the tendon.

The forces generated when the tendons are stressed are high enough to damage the structure or even cause injury to people working on the job if the installation and stressing are not done properly. Individuals performing the installation and stressing of the post-tensioning system should be certified by an independent third-party certification program such as the Post Tensioning Ironworker Certification Program (www.ironworkercertification.com) to ensure the person has received the proper training and demonstrated the knowledge needed to properly perform the work.



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A plastic pocket former installed at this location creates a stressing pocket.

Safety during stressing includes making sure that no one is working in the area where the tendon is being stressed. The tensioning is done to a force equal to 80% of a strand's tensile strength. For a typical ½-inch grade 270 strand, the strand is tensioned to a force of 33,000 pounds. As the tensioning is occurring, the steel is being elongated, and the concrete is being compressed. When the proper tensioning force is reached, the prestressing steel is anchored in place. The anchors are designed to provide a permanent mechanical connection, keeping the steel in tension, and the concrete in compression.

The steel elongation is measured and recorded for each tendon. This measurement is reviewed to determine and verify that the proper force exists in each tendon. Once the elongation measurements have been approved, the stressing tails can be cut off just inside the edge of the concrete slab, and the stressing pocket is filled with nonshrink grout to provide cover and protection over the end of the prestressing steel.

The act of stressing the tendons transfers force off of the formwork and into the tendons, which carry the force over to the columns or other supports. This means that the deck forms can be removed and cycled up to the next placement as soon as it is determined that all of the tendons in the current slab have been properly stressed.

Jim Rogers is the managing director of Evaluation and Certification Services LLC, which administers the Post Tensioning Ironworker Certification Program in the United States and Canada, and publishes Post-Tension Magazine.