WHAT IS POST-TENSIONING?

OVERVIEW

Post-tensioning is a method of reinforcing (strengthening) concrete or other materials with high-strength steel strands or bars, typically referred to as tendons. Post-tensioning applications include office and apartment buildings, parking structures, slabs-on-ground, bridges, sports stadiums, rock and soil anchors, and water-tanks. In many cases, post-tensioning allows construction that would otherwise be impossible due to either site constraints or architectural requirements.

Although post-tensioning systems require specialized knowledge and expertise to fabricate, assemble and install, the concept is easy to explain. Imagine a series of wooden blocks with holes drilled through them, into which a rubber band is threaded. If one holds the ends of the rubber band, the blocks will sag. Post-tensioning can be demonstrated by placing wing nuts on either end of the rubber band and winding the rubber band so that the blocks are pushed tightly together. If one holds the wing nuts after winding, the blocks will remain straight. The tightened rubber band is comparable to a post-tensioning tendon that has been stretched by hydraulic jacks and is held in place by wedge-type anchoring devices.

BENEFITS

To fully appreciate the benefits of post-tensioning, it is helpful to know a little bit about concrete. Concrete is very strong in compression but weak in tension, i.e. it will crack when forces act to pull it apart. In conventional concrete construction, if a load such as the cars in a parking garage is applied to a slab or beam, the beam will tend to deflect or sag. This deflection will cause the bottom of the beam to elongate slightly. Even a slight elongation is usually enough to cause cracking. Steel reinforcing bars ("rebar") are typically embedded in the concrete as tensile reinforcement to limit the crack widths. Rebar is what is called "passive" reinforcement however; it does not carry any force until the concrete has already deflected enough to crack. Post-tensioning tendons, on the other hand, are considered "active" reinforcing. Because it is prestressed, the steel is effective as reinforcement even though the concrete may not be cracked. Post-tensioned structures can be designed to have minimal deflection and cracking, even under full load.

ADVANTAGES/APPLICATIONS

There are post-tensioning applications in almost all facets of construction. In building construction, post-tensioning allows longer clear spans, thinner slabs, fewer beams and more slender, dramatic elements. Thinner slabs mean less concrete is required. In addition, it means a lower overall building height for the same floor-to-floor height. Post-tensioning can thus allow a significant reduction in building weight versus a conventional concrete building with the same number of floors. This reduces the foundation load and can be a major advantage in seismic areas. A lower building height can also translate to considerable savings in mechanical systems and façade costs. Another advantage of post-tensioning is that beams and slabs can be continuous, i.e. a single beam can run continuously from one end of the building to the other. Structurally, this is much more efficient than having a beam that just goes from one column to the next.

Post-tensioning is the system of choice for parking structures since it allows a high degree of flexibility in the column lay-out, span lengths and ramp configurations. Post-tensioned parking garages can be either stand-alone structures or one or more floors in an office or residential building. In areas where there are expansive clays or soils with low bearing capacity, post-tensioned slabs-on-ground and mat foundations reduce problems with cracking and differential settlement. Post-tensioning allows bridges to be built to very demanding geometry requirements, including complex curves, variable superelevation and significant grade changes. Post-tensioning also allows extremely long span bridges to be constructed without the use of temporary intermediate supports. This minimizes the impact on the environment and avoids disruption to water or road traffic below. In stadiums, post-tensioning allows long clear spans and very creative architecture. Post-tensioned rock and soil anchors are used in tunneling and slope stabilization and as tie-backs for excavations. Post-tensioning can also be used to produce virtually crack-free concrete for water-tanks.

TERMINOLOGY

A post-tensioning "tendon" is defined as a complete assembly consisting of the anchorages, the prestressing strand or bar, the sheathing or duct and any grout or corrosion-inhibiting coating (grease) surrounding the prestressing steel. There are two main types of post-tensioning: unbonded and bonded (grouted).

An unbonded tendon is one in which the prestressing steel is not actually bonded to the concrete that surrounds it except at the anchorages. The most common unbonded systems are monostrand (single strand) tendons, which are used in slabs and beams for buildings, parking structures and slabs-on-ground. A monostrand tendon consists of a seven-wire strand that is coated with a corrosion-inhibiting grease and encased in an extruded plastic protective sheathing. The anchorage consists of an iron casting and a conical, two-piece wedge which grips the strand.

In bonded systems, two or more strands are inserted into a metal or plastic duct that is embedded in the concrete. The strands are stressed with a large, multi-strand jack and anchored in a common anchorage device. The duct is then filled with a cementitious grout that provides corrosion protection to the strand and bonds the tendon to the concrete surrounding the duct. Bonded systems are more commonly used in bridges, both in the superstructure (the roadway) and in cable-stayed bridges, the cable-stays. In buildings, they are typically only used in heavily loaded beams such as transfer girders and landscaped plaza decks where the large number of strands required makes them more economical.

Rock and soil anchors are also bonded systems but the construction sequence is somewhat different. Typically, a cased hole is drilled into the side of the excavation, the hillside or the tunnel wall. A tendon is inserted into the casing and then the casing is grouted. Once the grout has reached sufficient strength, the tendon is stressed. In slope and tunnel wall stabilization, the anchors hold loose soil and rock together; in excavations they hold the wood lagging and steel piles in place.

CRITICAL ELEMENTS

There are several critical elements in a post-tensioning system. In unbonded construction, the plastic sheathing acts as a bond breaker between the concrete and the prestressing strands. It also provides protection against damage by mechanical handling and serves as a barrier that prevents moisture and chemicals from reaching the strand. The strand coating material reduces friction between the strand and the sheathing and provides additional corrosion protection.

Anchorages are another critical element, particularly in unbonded systems. After the concrete has cured and obtained the necessary strength, the wedges are inserted inside the anchor casting and the strand is stressed. When the jack releases the strand, the strand retracts slightly and pulls the wedges into the anchor. This creates a tight lock on the strand. The wedges thus maintain the applied force in the tendon and transfer it to the surrounding concrete. In corrosive environments, the anchorages and exposed strand tails are usually covered with a housing and cap for added protection.

CONSTRUCTION

In building and slab-on-ground construction, unbonded tendons are typically prefabricated at a plant and delivered to the construction site, ready to install. The tendons are laid out in the forms in accordance with installation drawings that indicate how they are to be spaced, what their profile (height above the form) should be, and where they are to be stressed. After the concrete is placed and has reached its required strength, usually between 3000 and 3500 psi ("pounds per square inch"), the tendons are stressed and anchored. The tendons, like rubber bands, want to return to their original length but are prevented from doing so by the anchorages. The fact the tendons are kept in a permanently stressed (elongated) state causes a compressive force to act on the concrete. The compression that results from the post-tensioning counteracts the tensile forces created by subsequent applied loading (cars, people, the weight of the beam itself when the shoring is removed). This significantly increases the load-carrying capacity of the concrete.

Since post-tensioned concrete is cast in place at the job site, there is almost no limit to the shapes that can be formed. Curved facades, arches and complicated slab edge layouts are often a trademark of post-tensioned concrete structures. Post-tensioning has been used to advantage in a number of very aesthetically designed bridges.

ENSURING QUALITY CONSTRUCTION

The amount of post-tensioning strand sold has almost doubled in the last ten years and the post-tensioning industry is continuing to grow rapidly. To ensure quality construction, the Post-Tensioning Institute (PTI) has implemented both a Plant Certification Program and a Field Personnel Certification Training Course. By specifying that the plant and the installers be PTI certified, engineers can ensure the level of quality that the owner will expect. PTI also publishes technical documents and reference manuals covering various aspects of post-tensioned design and construction.

To find out more about post-tensioning, contact the Post-Tensioning Institute or visit our Web site at: www.post-tensioning.org.

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