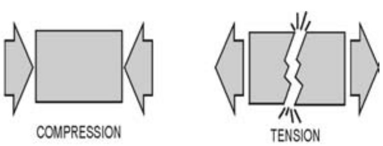
What is Post-Tensioning

Introduction

Post-tensioning is 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 that will be 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 actually placed. When the steel is tensioned before concrete placement the process is called *pre-tensioning*. When the steel is tensioned after concrete placement the process is called *post-tensioning*.

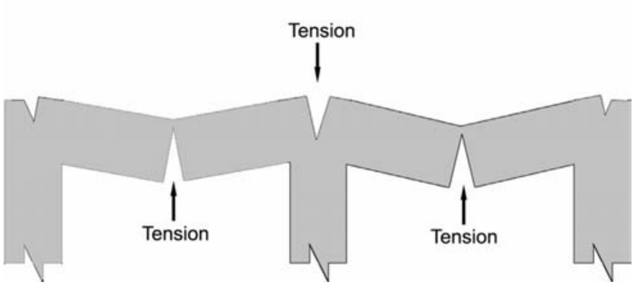
The advantages of utilizing prestressed concrete and masonry have long been recognized by engineers. When a designer wants to take advantage of those benefits, they must determine whether the structure is to be constructed using the pre-tension method or the post-tension method. Pre-tensioning is generally accomplished at a manufacturing facility where concrete members are constructed in special casting beds with steel bulkheads that hold the steel in place while tension is applied. Concrete is then placed around the pre-tensioned steel and allowed to harden. The steel is then cut loose from the bulkheads and the entire *precast concrete* member is transported to the project site for assembly. This process may be limited to the use of standard shapes, and sizes that can be easily transported.

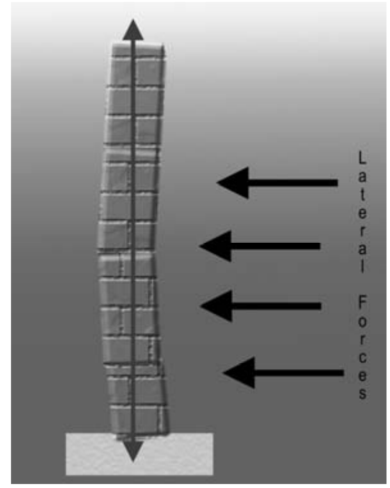
Post-tensioning is done at a project site and requires little to no modifications of the same forming system that would be used to construct non-prestressed concrete. The systems used to post-tension concrete and masonry consist of prestressing steel that is housed inside a duct or sheath, which allows the prestressing steel to be placed inside the typical job site formwork at the same time rebar and other reinforcing is placed. Concrete is placed in a typical manner and allowed to reach a predetermined strength before the steel is tensioned. Since the prestressing steel is housed in the sheathing or duct, it will be free to move inside the concrete during the tensioning operation, and since the steel is tensioned after concrete placement, the tensioning is done against the hardened concrete instead of relying on large steel bulkheads. Using the post-tensioning method of prestressing enables a builder to get all the advantages of prestressed concrete or masonry while still enabling the freedom to construct the member (slab, wall, column, etc,) on the job site in almost any shape or configuration imaginable.



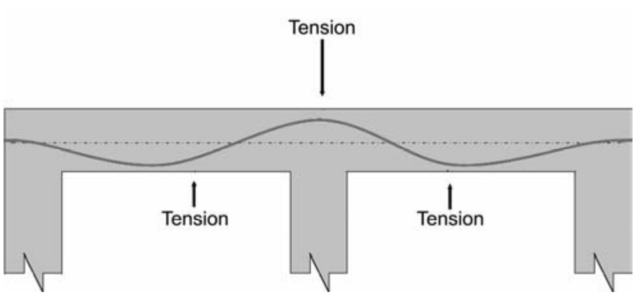
What Does Post-Tensioning do to Concrete and Masonry?

When a concrete or masonry element is prestressed, it means that the steel is being tensioned and the concrete or masonry is being compressed. *Compression* is a force that squeezes or crushes and *tension* is a force that pulls something apart. As building materials, concrete and masonry are very strong in compression, but they are relatively weak in tension. Steel, on the other hand, is very strong in tension. Putting the concrete or masonry into compression and the steel into tension before any substantial service loads are applied puts both of these building materials into their strongest states. The result is a stiffer concrete or masonry member that is being actively compressed and has more capacity to resist tensile forces.



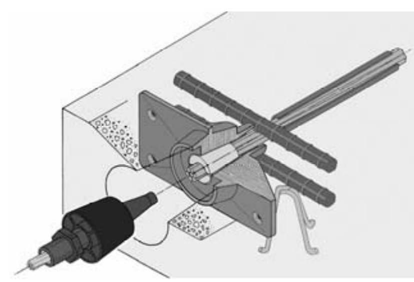


One of the things that happens to a concrete floor, or a masonry wall, is that they are subjected to forces that cause them to flex and bend. Examples of this include slabs on ground where the edges of the slab are forced upward by swelling soils, elevated concrete slabs where gravity and other applied loads pull down on the slab in between supports, and walls that might be subjected to lateral forces from wind or seismic activity. This bending creates high tensile forces that can cause the concrete and masonry to crack. This is where the use of reinforcing is applied. Since steel has a high capacity to resist tensile forces, it can be 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.

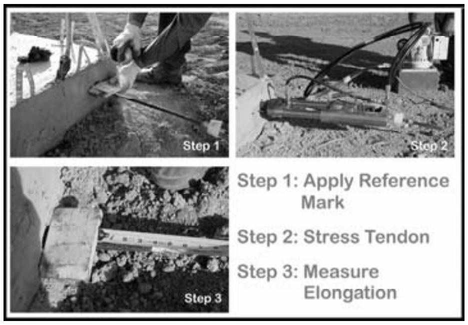


Adding post-tensioned reinforcing combines the action of reinforcing the tension zones with the advantages of compressing the concrete or masonry structure. Additional benefits are obtained when the post-tensioned reinforcing is installed in a *draped profile* instead of running in a straight line. A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

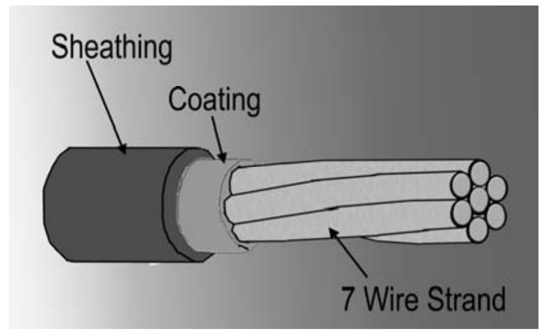
What Materials and Equipment are used in Post-Tensioning?



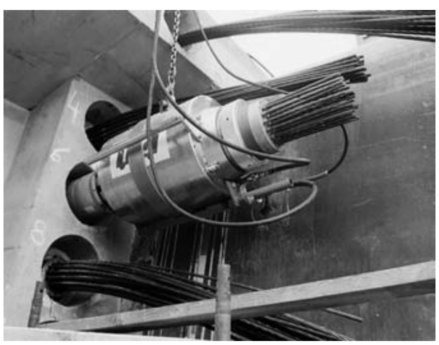
The basic element of a post-tensioning system is called a *tendon*. A post-tensioning tendon is made up of one or more pieces of prestressing steel, coated with a protective coating, and housed inside of a duct or sheathing. A tendon will have anchors on each end to transmit the forces into the structure. Long tendons may also have intermediate anchors along their length. The prestressing steel can be a high strength steel strand (typical in horizontal applications) or a high strength steel bar (typical in vertical applications). Prestressing steel is manufactured to applicable ASTM requirements. Typical strand sizes are 0.50 in. and 0.60 in. diameters, and bar sizes can typically range from 1 in. to 2.5 in. To get an idea of the high strength of this type of steel, a typical steel strand used for post-tensioning will yield at about 243,000 psi. In comparison, a typical piece of rebar will yield at about 60,000 psi.



Tension is applied to prestressing steel by using a *hydraulic stressing jack*. The jack bears against one of the anchors that is embedded in the concrete and pulls the steel to a predetermined force. As the tensioning is occurring, the steel is being elongated, and the concrete or masonry element 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, forever keeping the steel in tension, and the concrete in compression.



The duct or sheathing that houses the prestressing steel provides one layer of corrosion protection. A tendon with a duct that contains multiple pieces of prestressing steel strand is commonly called a *multistrand tendon*, and a tendon in which a single prestressing steel strand is covered in a plastic sheathing is commonly referred to as a *monostrand tendon*. Inside the duct or sheathing, the prestressing steel is covered in a protective coating that provides another level of corrosion protection. This coating can be a specially formulated type of grease, or it can be a specially designed type of grout. When grease is used, the prestressing steel is permanently free to move relative to the sheathing and the tendon is referred to as an *unbonded tendon*. When grout is used, the steel is permanently bonded to the sheathing and is referred to as a *bonded tendon*.



The hydraulic jacks used to tension the post-tensioning tendons range from compact 60 lb jacks used to stress monostrand tendons and small bar tendons, to very large jacks requiring special hoisting equipment, used to simultaneously tension all of the strands in large multistrand tendons.

What is the History and What are Some of the Current Uses?

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. The technology was introduced to the United States in 1950 in the Walnut Lane Bridge in Philadelphia, PA. Post-tensioning is now used extensively in bridges, elevated slabs (parking structures and residential or commercial buildings), residential foundations, walls, and columns.

Unbonded monostrand tendons have been used since the 1960's to reinforce the foundations of single and multi family homes, and are now used to reinforce hundreds of thousands of residential foundations throughout the United States each year. This use results in stiffer foundations that protect the house from structural damage due to soils that shrink and swell.

A slab will shrink as the concrete *cures* (hardens). In slabs on ground, the friction between the slab and the ground acts to resist this shrinkage and results in what are commonly referred to as shrinkage cracks. By using post-tensioned tendons to compress the concrete, the formation of visible shrinkage cracks can be greatly reduced or even eliminated. Post-tensioning is used in this manner in millions of square feet of warehouse floors, sport courts, housing and specialized paving applications.

Post-tensioning elevated concrete beams and slabs can result in thinner concrete sections and/or longer spans between supports. Designers commonly take advantage of this 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 decreases the ceiling to floor height of each level. In below grade structures this can mean less excavation, and in above grade 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.

Multistrand tendons are commonly used in bridges to produce long spans, and to facilitate segmental construction of long bridges. Bar tendons are used to stiffen tall columns and masonry walls. The use of post-tensioned reinforcing systems in North America has expanded rapidly in the last two decades, and many builders and designers are beginning to realize the benefits of applying external post-tensioned tendons to existing structures for strengthening and seismic upgrades. Major developments such as improvements in corrosion protection, certification programs for plants and personnel, educational programs, and new design aids have helped to propel this industry forward. Builders and designers around the World are increasingly recognizing the benefits of post-tensioned concrete and masonry on their construction projects. For additional information on post-tensioning, go to http://www.ptconcrete.com.

Post Tensioning Ironworker Certification™

References

1. Prestressing steel is manufactured to *ASTM Standard A414* (strand) and *ASTM Standard 721* (bar), ASTM International, http://www.astm.org
2. Unbonded monostrand tendons are manufactured to meet the requirements of *ACI Standard 421-06*, American Concrete Institute,http://www.concrete.org
3. Requirements for the components in bonded tendons can be found in PTI's *Acceptance Standards for Post-Tensioning Systems*, Post-Tensioning Institute, http://www.post-tensioning.org
4. Information on certification of field personnel that install bonded and unbonded tendons can be found at http://www.ironworkercertification.com

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