The author is Frank Haas, currently a freelance Estimator and owner of Haas Estimating Service, an estimating consulting service in Houston, Texas specializing in multi-family projects. In addition to his recent organization of Haas Estimating Service, Frank has been estimating in the multi-family industry for over twelve years serving as Senior Estimator, Estimator and Project Manager with companies such as Fairfield Development, Carbon Development, C.F. Jordan and Greystar Development and Construction. His duties included the development of estimating systems to assist in completing material take-offs of multi-family projects and the use of these systems to compile complete estimates for various multi-family projects. He has worked in the multi-family market in Dallas and Houston, Texas as well as working on multi-family projects all over the United States. He earned a BS in Construction Management from Texas A&M University in 1989.

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**Introduction**

Post-Tensioning is a method of reinforcing concrete by steel cables, housed in plastic sheathing placed in the slab. These cables or tendons, as they are referred to, are stressed to a specified force after the concrete reaches the specified strength. Prestressing concrete has internal stresses or forces induced into it during the construction phase for counteracting the anticipated external loads that it will encounter during the structure life. Some of the construction uses for post-tensioning are office and apartment buildings, parking garages, slab-on-grade, bridges, sport stadiums and water tanks. In most cases, post-tensioning is the only possible solution with site constraints or architectural requirements. Larger spacing between tendons, less reinforcement steel required and reduction of cracking (where there are expansive clays or soils with low bearing capacity) are among some of the advantages to using post-tension slab-on-grade construction.

**Main CSI Division – Division 3 - Concrete**

03050 Basic Concrete Material and Methods
03100 Concrete Forms and Accessories
03200 Concrete Reinforcement
  - 03210 Reinforcing Steel
  - 03230 Stressing Tendons
  - 03250 Post Tensioning
03300 Cast-in-Place Concrete
  - 03310 Structural Concrete
  - 03350 Concrete Finishing
  - 03380 Post-Tensioned Concrete

**Brief Description**

The post-tension slab-on-grade foundation is a foundation, placed directly on the ground using post-tension cables to overcome the compression force of the structure. The foundation includes components such as reinforcement steel, post tension tendons, vapor barrier, concrete accessories (anchor bolts) and concrete.

**Types and Methods of Measurements**

There are four major categories of a post-tension slab-on-grade estimate. Each of these categories requires a different type of method of measurement. These categories are:

- Grade beam excavation
- Formwork
- Post Tension Reinforcement
- Concrete

The standard measurement for grade beam excavation (trenching) is cubic yards (cyd). The formula for calculating cyds of concrete is:

\[
\text{CYDs} = \frac{L \times W \times D}{27}
\]

- \(L\) = Length of Beam
- \(W\) = Width of Beam
- \(D\) = Depth of Beam

The standard measurement of concrete formwork is square feet of contact area (SFCA). This is the way that labor is applied to
formwork. If formwork is to be built out of wood, then the quantity needs to be converted to board foot (BF) for pricing. The formula for calculating SFCA is:

\[ L \times W \]

\[ L = \text{Length of Forms} \]

\[ H = \text{Height of Forms} \]

To convert to BF take SFCA x 2.85

The standard measurement for post-tension tendons is linear footage (If), and then converted to pounds. The formula for calculating weight of cables required is

\[ \text{count} \times \text{length} \times .62 \]

\[ \text{count} = \text{count of tendons of a specified length} \]

.62 is the weight of tendon assembly, including the sheathing and anchors.

The standard measurement for concrete is cubic yard (cyd). The formula for calculating cyds is:

\[ \frac{(l \times w \times t)}{27} \]

\[ l = \text{length in feet} \]

\[ w = \text{nominal width feet} \]

\[ t = \text{nominal thickness in inches} \]

**FACTORS THAT MAY EFFECT TAKE-OFF AND PRICING**

**Effect of Small quantities vs. large quantities**

Larger projects allow for repeated use of form materials, thus significantly reducing the overall cost of the project. If the project has several similar buildings, then the learning curve of forming, placement of steel and placement of concrete will be greater, thus increasing your production, thus decreasing your labor cost of the foundation. The size of the project does not have a direct impact on the cost of the post-tension tendons.

**Effect on geographical location**

If the project is in a coastal region, then there is a code requirement to use encapsulated post-tension tendons to them from the calcium deposits from the overspray of the ocean. In some parts of the country, the grade beam must go past the frost line causing the depth of the beam to increase, thus adding additional labor and material cost. Clayed soils with the potential to shrink or swell are a major factor for the use of post-tensioned slabs. Texas, Louisiana and California are among the states with the highest concentration of clayed soils. The presence of rock can significantly increase the cost of the excavation of the grade beams. Heavier equipment such as rock trenchers may be required to excavate the beams. Under extreme conditions, the use of blasting done by specialized subcontractors is required, which will significantly increase the cost of the project.

**Seasonal effect on work**

In colder climates, the cost of concrete is higher due to the need by the ready mix companies to heat the aggregates and water prior to the batching of the concrete. The temperature of concrete as it is placed in the forms should be in the range of 50 to 70 degrees Fahrenheit. When the temperature of concrete is between 30 and 40 deg Fahrenheit, the water, sand and aggregates need to be heated up by the ready mix company. This procedure can be very expensive and the plant needs to be of close proximity to the project. Chemical admixtures known as accelerators may be used to shorten the setting time of the concrete. Calcium chloride, which is the most common accelerator used in concrete construction, should not be used in post-tension slab-on-grade due to its corrosive properties. Other precautions can be made at the job site such as covering the excavation with straw to keep the ground temperature above freezing prior to the placement of the concrete or the placement of insulation blankets or straw over the concrete after the placement and finishing process is complete to keep the concrete at a constant temperature while curing.

In warmer climates, the use of admixtures can be used to slow down the hydration process of the concrete. Water-reducing agents are helpful if they do not interfere with the strength of the concrete. Several factors influence the rate of affect the rate of evaporation and thus the strength of the concrete. These factors are concrete temperature, air temperature, relative humidity and wind velocity. These conditions should be monitored and recorded during the placement of concrete during hot weather. All of these factors should be considered in estimating post-tension slab-on-grade foundations in adverse climate conditions.

**OVERVIEW OF LABOR, MATERIAL, EQUIPMENT, INDIRECT COST**

There are four basic types of post-tensioned systems:

- **Type I** – Un-reinforced
- **Type II** – Lightly reinforced against shrinkage and temperature cracking
- **Type III** – Reinforced and stiffened.
- **Type IV** – Structural (elevated).

This report will cover Type II post-tension slab-on-grade systems with un-bonded tendons. The tendons discussed in the report will be seven wire ½-inch tendons with a capacity of 270 kip per square inch (kips). In order to get a clear understanding of the entire post-tension slab-on-grade system, this report will not only cover the basics for the post-tension system, but will cover the components around that system such as excavation, formwork, concrete placement and finishing. This report will not cover any grading of the site or layout of building corners, which are typically done by other contractors.

**Soil Investigation Report**

Prior to preparation of an estimate on post-tension slab-on-grade, it is important to get a clear understanding of the soil investigation report. Most sites will have a minimum of one boring done for each building. All boring will be a minimum of fifteen (15) feet unless un-wea thered rock or shale is encountered at a lesser depth. This report will give you the following information:
Types of soil in the area – If clay materials are found in the area, they will be of three types, Kaolinite, Illite or Montmorillonite in the order of their shrink-swell potential from most to least.

The presence and type of rock found in the area - If rock is encountered in the area, it will be one of three characteristics: soft, medium or hard.

Presence of high levels of water-soluble sulfate and chloride ion – If high levels of water-soluble sulfate or chloride ion is found in the soil, the post-tension system will require use of encapsulated tendons to reduce the risk of corrosion of the post-tension tendon assembly.

Laboratory test
Atterburg Limits – Gives the shrink-swell potential of soil
PI – The Plastic Index is a numerical value giving the shrink-swell potential in the soil. The smaller the value of the Plastic Index represents the less potential for vertical movement in the soil.
Compression test – gives the soil bearing capacity.
The Geo-technical Engineer will take the information from the soils report and make recommendations to the Structural Engineer as to what type of foundation should be designed for this site. The Structural Engineer will then take these design recommendations and prepare structural plans for the project. Only registered professional engineers should design the foundation; however, there is important information that should be taken from these borings by the estimator in pricing a post-tension slab-on-grade.

Formwork
The first item that is considered in estimating the cost of post-tension slabs is the type of formwork that needs to be used. If the elevation of the slab is less than 12 inches, then dimensional lumber may be used. However, if it is over 12 inches, it will be more cost-effective to used prefabricated steel or fiberglass forms. The use of plywood forms is not recommended in the construction of post-tension slabs due to the flex of the plywood material during the stressing operation of the tendon. To calculate the square foot of contact area (SFCA) of forms, the length of the perimeter of the foundation is multiplied by the height of the forms. If dimensional lumber is to be used for formwork, the square foot of contact area (SFCA) of the forms needs to be converted into board feet (BF). As a rule of thumb in the industry, there is 2.85 BF of lumber in every SFCA of forms.

Example – Forming of Slab-on-Grade.
Slab is 50 ft x 100 ft in size. Top of slab will need to be eight (8) inches above finish grade of building.

![Form Material Table]

<table>
<thead>
<tr>
<th>Condition Ct</th>
<th>Length</th>
<th>Ht</th>
<th>SFCA</th>
<th>Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>100 LF</td>
<td>0.67 Ft</td>
<td>134 SFCA</td>
<td>$350.00 MBF</td>
</tr>
<tr>
<td>2</td>
<td>50 LF</td>
<td>0.67 Ft</td>
<td>67 SFCA</td>
<td>$200.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total SFCA of Forms</th>
<th>BF / SFCA Factor</th>
<th>Form Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>201 SFCA</td>
<td>2.85 BF</td>
<td>572.85 BF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$350.00 MBF</td>
</tr>
</tbody>
</table>

| Note: BF factor includes all material to form and brace forms. |

![Crew Makeup Table]

<table>
<thead>
<tr>
<th>Crew</th>
<th>MHIRS</th>
<th>Quantity</th>
<th>Total MHIRS</th>
<th>Total Labor</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>F5</td>
<td>0.9 MLF</td>
<td>300 LF</td>
<td>2.7 MHIRS</td>
<td>$134.69 MHR</td>
<td>$363.42</td>
</tr>
</tbody>
</table>

| Note – All hourly wages includes fringe benefits. |

GRADE BEAM EXCAVATION
Grade beams are used to transfer the load of slab-on-grade foundations to stable soil. Most Post-Tension slabs will have grade beams similar to the two shown in figure 1.1 and 1.2.

The exterior grade beams are typically 10 to 12 inches wide and 18 to 24 inches deep. The interior grade beams are typically 12 inches wide and 18 to 24 inches deep. Some post-tension slab-on-grade foundations do not have interior beams. Interior beams, if required are usually located under load bearing walls. Post-tension slab-on-grade that do not have any interior beams are typically thicker than four inches and use a series of bounded cables grouped together to form internal beams in the thickness of the slab. It is more economical to pour a thicker slab than excavate and pour the interior beams.
To calculate the excavation of a grade beam, the length of each type of grade beam is multiplied by the width and depth of the grade beams. This will give the cubic feet (CFT) of material to be removed. To convert the cubic feet (CFT) quantity to cubic yard (CYDS) divide the quantity by 27.

**Example – Excavation of grade beams.**
Exterior grade beams – 10 inches wide x 18 inches deep.
Interior grade beams – 12 inches wide x 18 inches deep
Slab thickness will be 4 inches.

**VAPOR BARRIER**
The vapor barrier is placed between the gravel and the slab is usually included in the concrete takeoff. The vapor barrier has two uses in a post-tension slab-on-grade. First, it serves to keep the moisture in the concrete after placement to ensure proper curing; and second, it keeps moisture out of the building after it has been constructed. The vapor barrier material is typically polyethylene plastic, usually 4 to 6 millimeter (mm). It usually is purchased in widths of four to 20 feet and lengths of 100 feet.

**Example: - Estimating the vapor barrier**
In the previous example, use 20 ft wide x 100 feet long rolls.

**POST TENSION TENDONS**
In post-tension systems the “tendon” is defined as a complete assembly consisting of the anchorages, the prestressing strand, the sheathing and corrosion-inhibiting coating or grease that surround the prestressing steel. There are two types of Post-Tensioning:

- Bonded – Tendons that are bonded to concrete through use of grout, which is injected after the stressing operation of the cable takes place. This type of system is very uncommon in residential or multi-family construction due to the high cost of grouting the large amount of smaller tendons.
- Unbonded – Tendons are not grouted or bonded to the concrete.

Post Tension Tendons for slab-on-grade construction is typically seven wire, half-inch tendon, which means the tendon is constructed on seven (7) wires of steel cable for a total of a half (1/2) inch diameter. The amount of prestressing force applied per tendon is a function of the size of the tendon.

There are three typical sizes of strand tendons used in post-tension slab-on-grade construction. They are:
There are three types of post-tension anchors:

- **Stressing End Anchor (SE)** – This is the end by which the stressing operation will take place.
- **Dead End Anchor (DE)** – This is the anchor located at the opposite end of the stressing end.
- **Intermediate Anchorage (IE)** – The maximum length to stress a post-tension tendon from one direction is 100 ft. If the cable is over 100 feet, then an intermediate anchor shall be placed between the two stressing ends of the tendon.

Tendons are fabricated in a post-tension plant where they are cut to length, plastic coated, greased and have anchors mechanically fastened. The plastic sheathing is color coded to show which plant fabricated the tendon. Each tendon is coiled and numbered to show the location of the tendon to be placed on the job. These numbers will correlate with shop drawings that are shipped with the tendons to show the proper location and stressing order. To ensure quality construction, the Post-Tensioning Institute (PTI) has implemented both plant certification programs and certification training courses for field personnel. By ensuring that the plant and the installers be PTI-certified contractors, this ensures the level of quality that the owner will expect from a post-tension slab-on-grade. The following drawings are examples of post-tension systems.

Post-tension tendons are typically taken off by the linear foot of cable and then converted to pounds of cable by multiplying them by .62 which represents the weight of the entire assembly of the tendon. When measuring the stressing end of the tendon, two (2) feet must be added to the length to allow for excess cable for the stressing operation. At the completion of the stressing operation, the excess is cut off and grouted for the protection of post-tension tendons. This assembly includes all the anchor devices that are required to complete the system.
Example – Taking off Post-Tension Tendons.

### Post Tension Cable - In Beams

<table>
<thead>
<tr>
<th>Spacing of Uniform Tendons</th>
<th>36 inch o.c.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Tendons in Beams</td>
<td>2 Ea</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Tendon Mark</th>
<th>Tendon Type</th>
<th>Number of Tendons</th>
<th>Total Tendon Ct</th>
<th>Length</th>
<th>Total Length</th>
<th>Distance Between SE &amp; DE</th>
<th>SE</th>
<th>DE</th>
<th>IE</th>
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<tbody>
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<td>B1</td>
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<td>2</td>
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<td></td>
</tr>
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<td>2</td>
<td></td>
</tr>
<tr>
<td>B10</td>
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<td>204</td>
<td>100</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Subtotal Lf of Tendons: 2368

| Subtotal Ct | 34 | 34 |

### Tendon in Slab

<table>
<thead>
<tr>
<th>Tendon Type</th>
<th>Width</th>
<th>Spacing (inch)</th>
<th>Total Tendon Ct</th>
<th>Length</th>
<th>Total Length</th>
<th>Distance Between SE &amp; DE</th>
<th>SE</th>
<th>DE</th>
<th>IE</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>100</td>
<td>36</td>
<td>34</td>
<td>102</td>
<td>3468</td>
<td>100</td>
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<td></td>
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<tr>
<td>B</td>
<td>50</td>
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<td>17</td>
<td>52</td>
<td>884</td>
<td>50</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

Subtotal Lf of Tendons: 4352

| Subtotal Ct | 51 | 51 |

Total of Tendons: 6720

Wt Per Lf of Tendon Assembly: 0.62

Total Wt of Tendons: 4166.4
BACKUP STEEL
With any Post-Tension System, there is a requirement for a minimum amount of bonded steel to hold the anchor ends in place. Two #4 continuous rebar is required behind all post-tension anchors to hold them in place. There are also requirements of some tensile steel in the slab to strengthen the tensile strength of the concrete prior to the stressing of the tendons. Stakes are required in the beams to hold the tendons in place prior to the placement of the concrete. A post-tension supplier does not usually furnish backup steel. However, the required tonnage of backup steel for a post-tension slab can be calculated by multiplying the square footage (SF) of the slab by .20.

CONCRETE PLACEMENT, FINISHING AND CURRING
The minimum 28-day strength of concrete for post-tension slab-on-grade construction is typically 2,500 pounds per square inch (PSI) for single-family residence and 3,000 pounds per square inch (PSI) for multi-family construction. It is important to have the mix design approved by the Engineer on record prior to placement of the concrete to ensure it meets all the required specifications. Calcium chloride or admixtures that contain calcium chloride should never be used for Post-Tension Construction due to the corrosion it causes on the steel tendons. Concrete volume calculations are based on cubic yards. When figuring the depth of the beam, the thickness of the slab should be subtracted from the overall depth of the beam.

Example – Calculation for backup steel

<table>
<thead>
<tr>
<th>Slab Area</th>
<th>Factor</th>
<th>Backup Steel</th>
<th>Assembly Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000 SF</td>
<td>0.20</td>
<td>1000.00</td>
<td>$940.00 TN</td>
<td>$470</td>
</tr>
</tbody>
</table>

As a rule of thumb, .20 lb / sf are the factor that is used to calculate backup steel.
The volume of the grade beam should be divided by 27 to convert it to cubic yards. The volume of slabs is found by multiplying the area of the slab (sf) by the depth of the slab (inches). The volume of the concrete in the slab should be divided by 27, which converts the measurement to cubic yards (CYDS).

**Example – Calculating concrete quantity**

<table>
<thead>
<tr>
<th>Beam Size</th>
<th>Beam Count</th>
<th>Length of Beam</th>
<th>Base of Beam</th>
<th>Depth of Beam</th>
<th>Total CFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>10&quot; x 18&quot;</td>
<td>2</td>
<td>100.00</td>
<td>0.63</td>
<td>1.17</td>
<td>195.00 CFT</td>
</tr>
<tr>
<td>12&quot; x 18&quot;</td>
<td>2</td>
<td>49.17</td>
<td>1.00</td>
<td>1.17</td>
<td>95.50 CFT</td>
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<td>12&quot; x 18&quot;</td>
<td>4</td>
<td>50.00</td>
<td>1.00</td>
<td>1.17</td>
<td>526.50 CYD</td>
</tr>
<tr>
<td>12&quot; x 18&quot;</td>
<td>4</td>
<td>100.00</td>
<td>1.00</td>
<td>1.17</td>
<td>468.00 CYD</td>
</tr>
<tr>
<td>Total</td>
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<td></td>
<td></td>
<td></td>
<td>1,285.00 CFT</td>
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<tr>
<td>Convert CFT to CYD - Divide by 27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>47.59 CYD</td>
</tr>
<tr>
<td>Waste Factor</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
<td>2.38 CYD</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>49.97 CYD</td>
</tr>
</tbody>
</table>

There are many methods of concrete placement. Some of these methods consist of:
- Pump
- Direct Chute
- Crane and bucket
- Buggy or Wheelbarrow

Depending on the size of the project, access to the site and means available to the concrete subcontractor, one of these methods is used in pricing post-tension slab-on-grade foundations. After the placement of the concrete, there needs to be a decision made on what type of equipment will be used to consolidate, float, trowel and finish the concrete. During the placement process, concrete is vibrated for uniform consolidation. Consolidation is necessary to remove any entrapped air or pockets in the wet concrete.

Vibrating the concrete increases the tensile strength of the concrete, provides greater density of the concrete, improves the bond between the concrete and the reinforcement steel and reduces defects in the concrete such as voids or honeycombing. Screeding is the leveling process of striking off the excess concrete using guides to ensure the surface of the slab is level with the forms. On smaller jobs, a straight edge would be used; however, on large-scale jobs a vibratory truss screed is used. The vibratory truss screed is moved along forms by hydraulic or hand cranks. This type of screeding device is used for large warehouse slabs where great accuracy is required on the levelness of the slab.

Floating is a procedure that levels ridges left by the screeding process. Floating compacts the concrete, pushing down large aggregate and pull up paste to the surface. There are two types of floating devices used in concrete construction: hand floating and power floating. Hand floating is typically used in the residential and multi-family industry.

The final stage of finishing of a post-tension slab-on-grade is the troweling process. Finish troweling helps compact, compress and harden the concrete surface making it smooth and durable. Hand troweling is performed using either a steel or a Fresno trowel. After hand troweling is complete, power troweling is used to finalize the finish of the slab.

**Example – Calculating labor of Finishing of Slab-on-Grade.**

There are many methods of concrete placement. Some of these methods consist of:
- Pump
- Direct Chute
- Crane and bucket
- Buggy or Wheelbarrow
Concrete curing is the process of maintaining proper concrete moisture content and concrete temperature long enough to allow for hydration of the concrete. Concrete characteristics such as durability, strength and water tightness can be obtained through the proper curing methods of a post-tension slab-on-grade. Prior to estimating the cost of a post-tension slab-on-grade, the means used to cure the concrete will need to be decided. Most of the time, the specifications will address the desired means of curing the concrete. There are several methods for curing concrete. These methods are:

- **Curing with water**
  - Ponding – The use of water to cover the slab during the hydration process. The slab is actually flooded with water using dams at the perimeter to keep the water in. This is the most common curing process.
  - Spraying – The use of steady fine spraying of water during the hydration process.
  - Wet burlap – The use of wet burlap sheets to cover the slab during the hydration process.

- **Curing with barriers**
  - Liquid Membrane compounds – A membrane-forming compound that is sprayed onto the concrete to form a chemical barrier to prevent loss of moisture from the concrete.
  - Polyethylene film – The use of polyethylene film to cover the slab to keep the moisture in the concrete during the hydration process.
  - Water proofing paper – The use of flexible plastic material that covers the slab and keeps moisture in the concrete during the hydration process.

**STRESSING OF POST-TENSION TENDONS**

After the concrete reaches 85% of the maximum 28th day strength, the forms are removed and the cables stressed to the required strength. This operation usually occurs three to ten days after the placement of the concrete. Only a certified post-tension technician should do the stressing operation. After the desired elongation of the tendon is complete, the cable is cut off behind the stressing anchor leaving no more than one-inch clearance between the tendon and the edge of the form. All elongation values shall be written in a log and sent to the engineer for his approval. This log will then become a permanent part of the construction record.

The stressing void shall be grouted within seven days following the stressing operation to prevent any moisture from entering the stressing assembly.

**SPECIAL RISK CONSIDERATIONS**

When estimating the cost of a post-tension slab-on-grade, there are many risks which could affect the estimating versus the actual cost variations of the project. Some of these factors include:

- Availability of labor
- Availability of material
- Volatile material market
- Unknown soil conditions
- Underground obstructions
- Time of year work will be performed

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**Historical Data**

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<th>Project Type</th>
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<th>MHRS</th>
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<th>Lf of Post Tension Cables used</th>
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**RATIOS AND ANALYSIS**

Historical data is the best way to determine whether a post-tension slab-on-grade estimate is correct. Tracking the cost of similar projects and comparing them to the estimate is the most important part of the estimating process. The following is an example of historical data used for a concrete subcontractor.

In addition to using your company’s historical data, there are cost index books by companies such as R.S. Means and Craftsman, which have square foot tables for most any kind of foundation. These books are updated yearly and usually have an internet website that can update cost on a monthly basis. Construction costs will differ from area to area. To adjust the cost of different areas, most construction cost books will have an area modification factor that list most of the areas around the United States and percentage adjustments for those areas. The area modifier must be used to adjust costs by the geographical area in which the post-tension slab is being constructed.

The graph below shows the relationship of costs for a post-tension slab-on-grade.

### REFERENCES
- Post-Tensioning Manual Fifth Edition by Post-Tensioning Institute
- Concrete Principles by Thomas P. Fahl
- 2005 National Construction Estimator