PT BUILDINGS DESIGN AND CONSTRUCTION, BEST PRACTICES

ENGINEER, SUPPLIER, CONTRACTOR PERSPECTIVE

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This discussion has been adapted from a panel presentation made at the 2018 PTI Convention in Minneapolis, MN. This panel consisted of representatives of the three team members noted above. The structural engineer was represented by Carl Schneeman, P.E., the Director of Operations for the Minneapolis office of Walker Consultants. The post-tensioning supplier was represented by Neel Khosa, Vice President of Amsysco, Inc., Chicago, IL. And finally, the concrete construction subcontractor was represented by Victor Bretting, Executive Vice President/Partner of JVP Contracting and Consulting, LLC., Arvada, CO. The viewpoints expressed in this article and presentation are the opinions of the presenters noted, and they do not necessarily represent the consensus opinion of any PTI technical committee or of the Post-Tensioning Institute.

The process of delivering a post-tensioned concrete building to an owner/developer involves many different team members from start to finish. From initial conception through the final grand opening, significant involvement and contributions come from all members of the A/E/C team. The building's concrete superstructure is arguably the most critical portion of the entire project, and therefore, three of the most important members of the project team are the structural engineer, the post-tensioning supplier, and the concrete construction subcontractor. This discussion takes a closer look at the best practices recommended by each of these team members from their own perspectives and experiences.

STRUCTURAL ENGINEER

The primary goal of the structural engineer of record for the post-tensioned concrete design is to clearly communicate their design intent to the general contractor, subcontractors, suppliers, and testing agency. The drawings communicate the shape of the building, sizes of elements, and various specific details regarding reinforcement and connectivity of those elements. The specifications communicate requirements for building materials and processes. This essentially forms a handshake agreement during construction between the engineer's intent and the contractor's implementation.

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The structural drawings need to thoroughly show geometry, reinforcement, post-tensioning, tendon drapes, and material properties in the effort to express the design intent. Drawings must be very specific and clear, describing how the building is going to come together. PT drapes and forces need to be shown, and in unique situations, extra care should be taken to clearly express what is required. Additional detailing is important where unusual framing situations and circumstances are occurring. PT anchorage reinforcement should be clearly shown, with backup bars and bursting steel that is required. The engineer should have the best handle on what else is going on at beam/column intersections and at the edge of slab, so he/she should be responsible for all reinforcement details in these areas.

Always remember that it is less expensive to figure out a design on paper than it is in the field on the fly. One should not solely rely on standard details. It is very common for sleeves, floor openings, and voids to move around on a project, so good information is needed to clearly explain what to do with reinforcement around those openings. Anticipate certain reinforcing situation contingencies that are likely to arise during construction and prepare the information on how to handle them in advance. Resolve congestion issues, stressing access, and unique conditions in advance.

As a best practice, the engineer should carefully think about restraint to shortening during design. Plan out expansion joints and pour strips for delayed concrete placement and stressing block outs. A recommended concrete pour sequence can be used to alleviate issues caused by restraint while at the same time aiming for construction, economy, and work flow. Terms like "may", "should", and "suggested" are used in recommended pour sequences because the engineer is not dictating means and methods to the contractor. Keep the efficient cycling of formwork in mind always. It is extremely helpful to get early agreement with the contractor regarding the location of construction joints and pour strips because changes can later affect the design. The engineer needs to avoid details that are too costly or add too much time to the contractor's schedule. Holding formwork hostage for extended periods of time can have a significant negative impact on construction efficiency. Industry guides such as PTI DC20.9, "Guide for Design of Post-Tensioned Buildings," and ACI 423.3R, "Recommendations for Concrete Members Prestressed with Unbonded Tendons," are useful references.

The project specifications are very important. Carefully follow industry standards for unbonded, encapsulated PT systems, such as PTI M10.2-17, "Specification for Unbonded Single Strand Tendons," as well as ACI 423.7, "Specification for Unbonded Single-Strand Tendon Materials," and ASTM A416, "Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete." Make sure the concrete specification allows the concrete mix design to gain strength fast enough to allow for cost-effective cycling of formwork. The required concrete strength at transfer of the PT stressing forces is 3000 psi; there is no need to specify any higher strength in the project specifications. Also, make sure the concrete mix works well with and is compatible with all reinforcement materials.

PTI and ACI specifications are a very good guidance, and engineers should read these documents and understand them. All parts of the system including the strand, sheathing, corrosion-inhibiting PT coating, anchorage, assembly, and grout for stressing pockets are very important. Durability should always be a focus. Key PTI documents such as PTI Technical Note 18 discuss this issue further, and documents from

ACI 362 and 423 stress the importance of durability as well. The project specifications should require all key items, such as proper handling and protection of tendons, installation by PTI-certified installers, and repair of any tendon damage before concrete placement. Follow the PTI Field Procedures Manual for proper procedures, including use of the proper non-reactive, self-adhesive, elastic repair tape.

The PT supplier and installer expects the engineer to have an understandable and buildable PT design that complies with PTI and ACI. Clear communication is needed for special requirements such as stage stressing of transfer girders and other unique conditions. The supplier expects the engineer to provide timely shop drawing reviews, both before all MEP impacts are known as well as later when adjustments for MEP and other architectural elements may be needed. It is important that the engineer's shop drawing review comments are not aimed at showing extensive changes in the design in lieu of issuing an Architect's Supplemental Instructions (ASI) or bulletin to the contract documents.

The engineer's role in the PT stressing process is critical for the project. The engineer should make sure he/she has a current copy of the field use drawings. Reviewing stressing records is a high priority, and it must be done quickly and correctly. When observing and reviewing a deck pour prior to concrete placement, clearly communicate to the contractor and testing agency what you expect now and going forward. This includes tolerances per project specifications, quantity and drape of all PT plus reinforcing bar layout, and so on. Communicate any needed tendon repair expectations as well.

PT SUPPLIER

The PT supplier first typically gets involved with a project during the estimating process. They become familiar with the structure by carefully reviewing the engineer's design documents, drawings, and specifications. During this phase it is important for the supplier to submit any pre-bid requests for information (RFIs) needed to clarify the design intent of the engineer. The earlier information can be clarified and coordinated, the better.

The PT supplier's bid to the contractor will include the overall price as well as quantities of PT strand, anchors, accessories, and so on. These are all gleaned from the engineer's contract documents, but in some cases where certain items and conditions aren't completely defined, the supplier should list qualifications and exclusions to account for those undefined items. This is where the supplier's experience and expertise with similar conditions provides important clarity and completion for the contractor in their overall bid to the owner. It is a best practice for the PT supplier to include a concrete pour sequence (or use and review one provided by the engineer) as a basis for their bid quantities and project approach.

Complete submittals are key to achieving a successful PT project. The supplier should include the tendon plan, support plan, beam anchor patterns, details, and all notes that are required to document his/her clear interpretation of the engineer's contract documents. Friction calculations with PT forces and elongations should also be included to justify the number of tendons shown in the PT installation drawings. Physical samples of the PT system elements may also be a required submittal, as these help the engineer verify the supplier's complete compliance and understanding of the system specifications. Lastly, accurate submission of stressing jack calibration information for all ram/gauge combinations that will be used can help alleviate issue with elongations during the stressing procedure.

PTI plant certification is critical to establish quality control and traceability of all materials used in the fabrication process. If any issues arise, the supplier can then go back and check where materials came from and troubleshoot accordingly. Mill certifications help confirm accurate material properties for a specific material supply. The supplier should include a bill of lading and cutting lists for all PT delivered to the jobsite, so the installer can easily align tendons with the PT installation drawings. The supplier's professional staff should stand ready to provide field assistance as needed to resolve any issues that might arise—for instance, help with resolving conflicts with floor openings needed by other trades such as MEP.

The supplier should make sure that all stressing equipment is maintained in good working order, and they should be readily available to troubleshoot equipment issues with the PT installer if they occur. Maintaining stressing equipment that consistently works well, in addition to the sufficient number of jacks needed to keep the construction cycle flowing, is very important. The supplier should also be closely engaged in the process of working with the engineer, installer, and testing agency to reconcile tendon elongations on the stressing record. Assisting with this process and providing remediation solutions where needed is key to staying on top of these time-sensitive efforts.

The PT installer must make sure there are both enough field personnel, as well as enough qualified field personnel to handle the work associated with each deck placement. It is also important for an experienced installer to lend another set of eyes to the review of the design drawings against the PT shop drawings to confirm that everything makes sense. The PT Field Procedures Manual should be readily consulted by the installer, and PTI Level 1 certified personnel should be working on the installation. It is a best practice for the installer to resolve any issues early on instead of remaining quiet and letting them become a problem. An accurate and ongoing inventory of PT materials should be kept in the field.

PTI Level 2 certified personnel should be involved in the stressing operations. It is critical that stressing equipment is well maintained throughout the project and that good coordination occurs with the PT inspector. After stressing approval, it is very important that tendon tails are cut, anchors are capped, and stressing pockets are grouted quickly and efficiently as specified by the engineer to maintain durability of the installed PT system.

Though typically under contract to the owner, it is important to confirm that the PT inspector holds PTI Level 2 certification and that they have a very good understanding of the PT Field Procedures Manual. The inspector must be accurate with their counts and measurements, and with the elongations on stressing records.

CONCRETE CONTRACTOR

Fast-track construction can create situations where projects are still being designed after construction has already started. There is an ongoing push towards delivering projects faster and at a lower cost. The concrete contractor's primary focus to meet these goals is the forming cycle and speed of casting and reshoring each level of the building.

The contractor should carefully review the PT design documents during bidding. Special attention should be given to backup bars and support bars so there isn't a "hole" in the estimate when it comes to figuring out the labor required to install this type of PT-specific reinforcing bar. During pre-bid RFIs, a best practice for the contractor is to focus on what's "different" about the PT design rather than looking for what to do. Requirements such as 3750 psi concrete strength at stressing rather than 3000 psi have a significant impact on costs and the desire for a 3-day forming cycle. If there is stage stressing, that will hold up formwork and equipment flow. For the contractor to be competitive on cost, they need to be able to provide the least amount of formwork on site that will keep schedule.

As previously mentioned, the initial concrete strength specified by the engineer before PT stressing can occur is critical. A specification that calls for 75% of f_c', where $f_c' = 5000$ psi would require the concrete to reach 3750 psi before stressing. This additional 750 psi beyond the customary requirement for 3000 psi impacts cost and schedule. The high-early-strength mixture design required to hit this higher mark in 1 day rather than having to wait 2 days can be as much as an additional $30 per cubic yard. You wind up with the equivalent of a 6500 to 7000 psi, 28-day mixture instead of 5000 psi.

The other concern is that a higher cement content adds to the heat of hydration, which can increase the potential for flash set and surface cracking, especially during hot weather construction. If the extra day is added to every pour to reach the required strength, this creates a significant impact on the overall schedule and efficient formwork flow. It is critical for the contractor to work with the engineer early in the project to aim for 3000 psi instead because a change to this during construction can require extra time and money for the engineer to change the structural design.

The PT supplier needs to have a thorough scope review with the contractor during the bid phase. Both should fully understand total weights of materials during the bid proposal. It is important to have a good construction schedule for planning deliveries, pour dates, equipment, and so on. Good communication with the supplier is required for delivery coordination, especially at a tight downtown jobsite where "just-in-time" deliveries are needed due to lack of laydown and staging area. Having a pour sequence set with the PT supplier that doesn't change is important, as this affects elongations, tendon quantity, and so on. Often a pour will need to be stressed in two locations at the same time to make cycle time, so as many as four stressing jacks can be needed as well as two testing agency inspectors to record elongations.

The contractor must always provide the most current design documents to the PT supplier. The contractor needs to unload and store PT materials correctly per PTI specifications to avoid damage and loss and take good care of the stressing equipment. The contractor needs to provide coordination with other trades to avoid conflicts. Good concrete construction is essential to making the PT installation work.

The easier to understand the engineer's design drawings, the better for the contractor. True craftsmen are more a thing of the past and hard to find. Part of the reason forming systems are becoming easier to assemble and "click together" is that we no longer have the carpenters and craftsmen we used to have to build them.

A pre-construction meeting is critical for project success. The engineer, concrete supplier, PT supplier, PT installer, testing lab, and contractor should all attend. There should be a minimum 4-week look-ahead delivery schedule. The QC, inspection, and approval process need to be established, and the engineer need to be able to gain trust that he is being given the right information. Stressing procedures, time frames, when to break concrete cylinders, and so on all need to be established. Stressing records must be complete and legible. The contractor must understand the complete inspection requirements of the engineer, city, and county, before pour placement. The time needed must be accounted for in the schedule. It might take a few hours, or it might take all day. It is not just the testing agency's responsibility to monitor the inspection process; it is on the contractor to stay on top of things to maintain control over their own schedule and cycles.

The contractor should always provide a safe jobsite environment for the PT installer. The stressing area should be taped off to protect people from the operation. Verify that each stressed tendon's elongation falls within the specified tolerance. Advance coordination with the engineer and PT supplier regarding liftoff or restressing requirements, for out-of-tolerance tendons can save several hours of resolution after the fact. The contractor needs to make sure the engineer and PT supplier simultaneously get the inspector's stressing records to maintain an expedient review schedule.

After engineer approval, the tendon finishing steps should be completed right away. This helps protect the PT system from exposure. It is a PT installer and contractor best practice to carefully comply with the requirements set forth in ACI 301-16, Section 9.3.8.2, for cutting, capping, and grouting. It costs a contractor more money to go back and work on tendon ends up in the air after he is already three or four floors ahead with the form deck. It's also a safety issue trying to prevent tails from falling to the ground below.

Care should be taken when torching off tails because this can blacken the edge of the PT floor structure. If architectural aesthetic requirements come into play, shears should be used instead. It's also important for the contractor to fully understand architectural requirements in this same condition when it comes to grouting PT tendon pockets. It can be quite challenging to get grouting to consistently match the color of the surrounding concrete structure.