Procedures for Prestressed Concrete Construction (SOP 5-4)

Purpose- The purpose of this document is to establish the minimum qualifications for the manufacture and acceptance of prestressed concrete structural members. This document will provide the requirements for the approval of producers, testing guidelines, re-testing procedures, product identification, acceptance, and verification.

Background- The Division of Materials and Tests Prestressed Standard Operating Procedure (SOP) supersedes all previously issued circular letters regarding prestress issues. It is to be followed for the manufacturing of prestressed concrete members intended to be utilized on Tennessee Department of Transportation (TDOT) or TDOT affiliated projects. It shall be used in conjunction with the following when applicable in order of priority:

1. TDOT Project Specific Proposal Contracts
2. TDOT Project Plans
3. TDOT Approved Shop Drawings
4. TDOT Standard Drawings
5. TDOT Supplemental Specifications
6. TDOT Standard Operating Procedures
7. Prestressed Concrete Institute Manual

Approval Procedures for all Prestressed Concrete Structural Members

1. Safety

Working in prestressed plants is inherently very hazardous because of the large tensioning forces, debris, heavy equipment, etc., necessary to the operation. The inspector shall comply with all safety requirements at his/her assigned plant and shall take any other steps he/she deems necessary for safety.

Work areas that are dangerous shall be brought to the attention of the producer’s management and safety personnel, and the situation shall be corrected prior to proceeding with work and/or inspection.
2. **Producer Requirements**

2.1 All producers of prestressed concrete structural members to be supplied on TDOT projects shall be CERTIFIED by the Precast/Prestressed Concrete Institute (PCI). Certified producers must submit a copy of their current certification with the initial application and annually to Headquarters Materials and Tests. Also, the producer shall provide the corresponding PCI field review results and any correction of deficiencies. The Department will review the results to ensure that all deficiencies have been addressed within a reasonable timeframe agreed upon between the Department and the Producer.

2.2 The producer shall develop, for approval by Headquarters Materials and Tests, an extensive Quality Control Plan (QCP) similar to that described in Section 604.03(b) of the Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction January 1, 2015 (Standard Specifications). The QCP shall be submitted to Headquarters Materials and Tests with the initial application. The QCP shall include, but is not limited to, an organization chart, a “Buy America” statement for all reinforcement materials, a complete list of material suppliers and their location, a detailed pre pour process, a detailed post pour process, producer testing procedures, detailed marking for TDOT products, batching tolerances, etc. It shall also identify the proposed testing and frequency needed to properly assure that a quality product meeting all requirements has been properly produced. Active facilities listed on the TDOT Producers List must review their QCP annually ensuring that all information is up-to-date. In the event any changes are made to the production process, key personnel, change in ownership, etc. an updated QCP must be resubmitted immediately to Headquarters Materials and Tests and the appropriate Regional Materials and Tests reflecting all changes or corrections.

2.3 The manufacturing process and all materials used in the construction of prestressed concrete structural members must meet TDOT requirements. Daily reporting shall be documented on TDOT Form DT-0283, Daily Report of Prestressed Concrete Plant Inspection. Final reporting for acceptance shall be completed on TDOT Form DT-0289, Report on Precast/Prestressed Concrete. Testing for acceptance and verification shall be performed in accordance with SOP 1-1, Standard Operating Procedure for the Sampling, Testing, and Acceptance of Materials and Products.

3. **Materials**

3.1 Aggregates- All aggregates used for prestressed concrete structural members shall be in accordance with Sections 903.01, 903.03 and 903.22 of the Standard Specifications.
3.2 Cement- All cements shall meet the requirements of Section 901.01 of the Standard Specifications and be on the TDOT Qualified Product List (QPL). The producer shall retain copies of material certifications with chemical and physical properties.

3.3 Fly Ash, Ground Granulated Blast Furnace Slag, Silica Fume- Other cementitious and pozzolanic materials must meet the requirements of Sections 921.15 or 921.16 of the Standard Specifications and be on the TDOT QPL.

3.4 Reinforcing steel and wire strands- Steel used for reinforcement shall be in accordance with the applicable AASHTO or ASTM Standard for the structure or as required by TDOT Standard Drawings. All certifications shall contain a signed “Buy America” statement. The producer shall retain copies of all mill test reports and material certifications.

3.5 Admixtures- All admixtures must comply with Sections 604.03 and 921.06 of the Standard Specifications and be listed on the QPL.

4. Mixture Design

4.1 The producer shall submit to TDOT for approval a concrete mix design for each mixture that will be used. The concrete mix design submittal shall contain the minimum information required in Subsection 604.03 A.2. of the Standard Specifications and SOP 4-4 with the following exception. The concrete mix design will be valid for a one-year period (January 1st – December 31st) and must be resubmitted annually with break data within the past ninety (90) days. Producers shall then associate approved mix designs to contracts using the Concrete Design Contract Association Request Form. Concrete mix designs for the upcoming year shall be submitted no later than November 1st. Review of the concrete mix designs shall be completed by December 31st. Proportioning and mixing of the concrete shall comply with Section 615.09 of the Standard Specifications. The maximum allowable substitution rates of cementitious materials will be as specified in Table 604.03-3 of the Standard Specifications. All other concrete mix design criteria (i.e. strength, etc...) shall be in accordance with the applicable AASHTO/ASTM Standard Specifications, Approved Shop Drawings, Contract Plans, or TDOT Standard Drawings and Specifications. An approved mix design will designate the maximum strength requirement that the design is approved for use. The producer may choose to use a concrete mix design approved for a higher strength requirement than that specified on the Approved Shop Drawings, Contract Plans, or TDOT Standard Drawings and Specifications.

4.2 Producers requesting to use self-consolidating concrete (SCC) mixtures must submit a design in accordance with the chemical admixture
manufacturer’s recommendations and further demonstrate through trial batches that the mixture can be produced homogeneously without segregation. The TDOT Regional Materials and Tests must witness and approve the trial batch demonstrations for acceptance prior to the mix design approval.

5. Quality Control Program

5.1 Quality Control of Materials

5.1.1 Form Release Agents

Since the integrity of pre-tensioned members is based on development of uniformly high bond on all strands, the necessity of clean strands cannot be over emphasized. Form release agents manufactured from resin, paraffin, or vegetable oil bases will be permitted, provided the release agent be a type that dries to a degree that it cannot contaminate any strand that comes in contact with it. Special care shall be taken when pulling strands across prestressed beds to make certain that the release agent shall be of the approved type and that it has dried sufficiently.

5.1.2 Cylinders

Concrete testing cylinders for prestressed concrete shall be a set of two (2) cylinders 4 inches in diameter by 8 inches in length. See SOP 1-1 Part Two: Acceptance Samples and Tests for testing frequencies.

5.1.3 Concrete Temperature

The temperature of concrete used in prestressed applications shall not drop below 50°F or rise above 90°F during pouring operations.

5.1.4 Ambient Temperature

The ambient temperature surrounding the concrete shall be in accordance with 615.10 of the Standard Specifications.

5.1.5 Aggregate Stockpiles

Aggregate stockpiles shall be properly labeled and maintained in an uncontaminated and unsegregated manner. Concrete batching shall not be permitted if the aggregate stockpiles exhibit frozen material.
5.2 Testing Equipment and Laboratory

5.2.1 Each production facility shall have, or have immediate access to a “Type A” laboratory as defined in Section 106.06 of the Standard Specifications to conduct quality control testing. Laboratory qualifications shall meet requirements stated in SOP 1-4 (Laboratory Qualification Requirements).

5.2.2 The testing equipment shall be certified a minimum of every twelve (12) months. The producer shall maintain documentation and records of all certifications.

5.2.3 Gradations shall be performed at the prestressed facility on each aggregate used at least once per week.

5.2.4 Hydraulic jacks and pressure gauges shall be calibrated every six (6) months.

5.3 Quality Control Personnel

5.3.1 Each production facility shall have an individual responsible for the quality production of prestressed concrete products. This individual shall have authority to make necessary adjustments, reject concrete, cease production, or reject products when the quality of the product is in question.

5.3.2 Technicians and other individuals who conduct sampling and testing for quality control must be at least TDOT – Concrete Plant Quality Control Technician certified. Any individual designing a concrete mix design must be TDOT – Concrete Mix Design Technician certified or a licensed Professional Engineer in the State of Tennessee. A Concrete Plant Quality Control Technician (QC Personnel) shall be on site anytime that a TDOT product is being produced.

5.4 Concrete Batching/Central Mixing Plant

5.4.1 The concrete batch/central mixing plant shall have all scales, weighing devices, and/or metering devices calibrated and correlated a minimum of every six (6) months. Documentation shall be available to show the calibration results.

5.4.2 Concrete may be supplied by a ready mix producer provided the plant and hauling equipment are in compliance with sections 501.04 and 604.03 of the Standard Specifications. The plant must be
further approved by TDOT and meet requirements stated in SOP 4-3, Ready Mix Concrete Plant Certification Procedures.

6. **Acceptance** - Acceptance testing of all materials shall be performed at the frequency stated in the Procedures for the Sampling, Testing, and Acceptance of Materials and Products (SOP 1-1).

6.1 **Reporting Prestressed Items for Payment** -

When a contractor or producer requests payment on prestressed or precast items produced for a specific project, the inspector will accomplish the following:

6.1.1 All units will meet the requirements of the specifications and shop drawings. Dimensional tolerances shall be in accordance with Table 615.17-1 of the Standard Specification.

6.1.2 All units must be ready for shipment (steel bent, 28-day strength met, unit marked correctly, holes filled, drains opened, all honeycombed areas, etc. repaired).

6.1.3 When stockpile payment is required, the Regional Materials and Tests Inspector will mark each unit with plant letter and report number at one end of each unit accepted. The inspector is to make out a test report for the units on which stockpile payment is to be made. The inspector must state on the report the material listed above is stockpiled at the producer’s plant and may be paid for on a partial payment basis.

6.1.4 No material is to be stamped or stenciled before it is loaded for shipment. After loading and prior to shipping, the Regional Materials and Tests inspector shall perform a final inspection of the units, and if found acceptable, shall stamp showing final acceptability.

7. **Stamping** - Each prestressed item, (beam, panel, piling), shall be identified by stamping the top surface. As small an area as possible is to be stamped. The lettering shall be a minimum of two (2) inches in height. Information included in the marking shall be the project number, county, station number or bridge number, unit mark number, and date made.

It is understood that some items, such as piling, are poured for stock (poured for no specific project) and stored on the producer’s yard. When these items are assigned to a project, or before shipment to a project, the above identification will be put on each piece with waterproof ink or paint.
8. **Documentation and Reporting** - The manufacturer shall keep daily reports documenting each product made that day and the number made. The report shall identify all the applicable information as stated in Section 2.3 and results of all acceptance tests made for that product. The manufacturer shall maintain this information for a minimum of five (5) years. All documents are subject to review by the Department.

9. **TDOT Verification Testing and Inspection**

   9.1 Verification of all materials shall be performed at the frequency stated in the Procedures for the Sampling, Testing, and Acceptance of Materials and Products (SOP 1-1). TDOT retains the right to test and/or request the producer to retest any prestressed concrete product for verification purposes. The frequency of testing may vary at the discretion of the Regional Materials and Tests Supervisor.

   9.2 Any corrective action shall be performed in accordance with standard industry practices approved by Regional Materials and Tests and Structures Division. Any products used for corrective action shall be listed and approved on the Department’s Qualified Products List.

10. **Removal of Prestress Plant from Producer List (Quality Control Plan, Product Failure, Verification Requirements, etc.)**

    10.1 If a producer fails to maintain their certification as stated in Section 2., Producer Requirements, of this SOP, they will not be allowed to produce products for use on TDOT projects and will be removed from the Producer List.

    10.2 TDOT shall remove a producer from the Producer List if they fail to manufacture, test, accept, or certify in accordance with the procedure set forth herein.

    10.3 TDOT shall remove a producer from the Producer List if they falsify test results or certify/stamp products that do not meet acceptance criteria.

    10.4 If a facility is removed from the Producer List, TDOT Regional Materials and Tests shall notify the Producer in writing within seven (7) days. This notification shall direct the manufacturer not to supply any products of the specific type containing the error to TDOT projects. Upon such notice, the Producer shall immediately cease production, shipment, and placement of such product(s) supplied to TDOT projects. After such notice is issued, the Producer reserves the right to enter into the appeals process requesting an informal meeting to discuss the cease of product(s) for TDOT projects.
10.4.1 Producers shall provide TDOT Regional Materials and Tests with a list of products supplied to TDOT projects from the date of the last passing inspection that will include certifications and contract numbers.

10.4.2 Installed items shall be left in place; however, a review of installed items will determine corrective action or replacement as necessary.

10.4.3 Uninstalled items on projects are subject to being recalled from the date of the last passing test until the date of the failing test based on further evaluation by an agreed upon 3rd party. All cost incurred will be the responsibility of the producer.

10.5 Time of facility removal from the Producer List shall be as designated below:

10.5.1 First finding will result in the facility being removed for a minimum of three (3) months.

10.5.2 Any offense in a two (2) year period which will begin from the date the producer was placed back on the Producer List from the first offense will result in the facility being removed for a minimum of six (6) months.

10.5.3 Any offense in a two (2) year period which will begin from the date the producer was placed back on the Producer List from the second offense will result in the facility being removed for a minimum of twelve (12) months.

10.5.4 Any more than three (3) findings and TDOT will make a determination of any additional appropriate actions.

10.6 After the minimum time has passed, a letter must be submitted to Headquarters Materials and Tests requesting to be reinstated to the Producer List. No product shall be accepted until a formal response has been given by the Department. Also, before any producer may resume shipping products to TDOT projects, they must provide an Action Plan for their Quality Control Plan addressing actions taken resolving any issues of non-compliance. If the producer is placed back on the Producer List after the calendar year in which they were removed, they must follow the guidelines for new producers as stated in Sections 1 - 6 of this SOP.

10.7 Appeals Process - If a producer disagrees with the removal of a prestressed concrete plant from the Producer List, the producer shall provide such disagreement in writing within seven (7) days.
10.7.1 The producer must request a meeting with the Materials & Tests Division Coordinator/Director to discuss the disagreement in detail.

10.7.2 TDOT will meet with the producer within fourteen (14) days of receiving this request. Upon the completion of this meeting, TDOT shall provide the producer the written intent to proceed with the removal for the remainder of the time or reverse the direction and reinstate the producer.

10.7.3 If the removal is not reversed the producer may choose to continue the appeals process. The producer shall provide such written notice to the TDOT Chief Engineer (who has the authority to resolve disagreement) within thirty (30) days of the initial notification of removal from the Producer List.

10.7.4 TDOT Chief Engineer or delegated designee will meet with the producer within fourteen (14) days of receiving this request to provide final resolution within forty five (45) days of the initial removal.

11. **Shipment** - No products shall be shipped from the fabrication plant/stockyard until they have met all acceptance criteria as stated in SOP 5-2: Policy for Precast/Prestressed Concrete Acceptance.
Appendix A: Production Guidelines

A.1 Placement of Voids in Box Beams- Forms for internal voids shall be held in place during the operations of placing and consolidating concrete. Their correct positions with respect to the horizontal and vertical axes of the beam shall be maintained within the limits of dimensional tolerances in accordance with Section 615.17 of the Standard Specification or as indicated on approved shop drawings.

Hold-down devices shall be properly spaced to prevent the void from rising in the beam. Other templates shall be used to keep the void from being displaced laterally. Restraints to position the void above the bottom slab shall be capable of supporting the void and concrete during placement without puncturing or damaging the void material. If pieces of the void become dislodged, they shall be removed so as not to be incorporated in the concrete portion of the beam. Hold-down devices and/or other templates shall remain in place a sufficient distance behind the placing of concrete so that the void shall not move when these restraints are removed. The concrete shall be sufficiently plastic so that non-consolidated material resulting from the removal left by the hold down devices and/or other templates shall be filled into the surrounding concrete mass.

Dimension Verification for Box Beams:

A.1.1 Prior to Fabrication

A.1.1.1 Bottom Slab- Restraint heights and void placement shall be verified to meet the dimensions of the bottom slab as shown on the approved shop drawings. Any discrepancies shall be addressed and corrected prior to concrete placement.

A.1.1.2 Webs- Web thickness shall be checked by the inspector at each void corner. Any discrepancies shall be addressed and corrected prior to concrete placement.

A.1.2 During Fabrication

A.1.2.1 Top Slab- After the beam has been screeded and finished to the required depth and grade, the inspector shall probe through the fresh concrete to the top of the void to determine the amount of cover above the void. A minimum of two (2) measurements per void section at opposite ends of the void is required.

A.1.2.2 Webs- Web thickness at each void section on each side of the beam shall be checked during the pour as the concrete is being placed in the web areas at two (2) randomly selected locations directly below the top slab. Any discrepancies shall be addressed and corrected prior to the continuance of the concrete placement.
A.1.3 After Fabrication- Random thickness measurements shall be performed by providing approved inserts or by drilling holes in the web of the girder after the forms have been removed. Two (2) measurements per side shall be required per void section. (The thickness can be verified while the concrete is in the plastic state OR after fabrication on hardened concrete.)

A.1.4 Documentation- All measurements as indicated in the Production Sections (Prior to Fabrication, During Fabrication, and After Fabrication) shall be documented in the checklist listed in Appendix B. Two measurements per beam for the Production Sections shall be recorded on the daily report and an attached drawing showing the maximum and the minimum measurements as recorded in the checklist listed in Appendix B.

A.2 Pressure Gauges- Pressure gauges shall have a full pressure capacity of approximately twice their normal working pressure. The loads to be gauged shall not be less than one-fourth or more than three-fourths of the total graduated capacity unless calibration data clearly establishes consistent accuracy over a wider range. A separate low-pressure gauge shall be provided for initial tensioning (preload) when the main pressure gauge does not meet the above requirements for the initial tensioning force.

Each pressure gauge shall be capable of indicating loads directly in pounds, or be accompanied by a chart from which the dial reading shall be converted into pounds. Pressure gauges shall have dials at least eight (8) inches in diameter and be clearly readable. The smallest dial graduation shall not be more than 200 pounds. Pressure gauges shall have appropriate bypass pipes, valves, and fittings so that the gauge dial indicator shall not fluctuate but shall remain steady until the jacking load is released. Calibration of hydraulic jacks and pressure gauges shall be repeated at intervals of not more than six (6) months per Section 615.07 of the Standard Specification. Documentation of calibration is mandatory.

A.3 Preload and Prestressing Procedure- The amount of stress given to each strand shall be as shown on the Plans and/or approved shop drawings. For all methods of tensioning, force in the tendons shall be determined by monitoring either applied force or elongation and independently checked by measuring the other. The control measurements and computed theoretical values of force and elongation shall agree with each other within ±5%. If more than seven (7) days has elapsed from the time final tension has been applied, or if the anticipated concrete temperature has changed, verify final tension with a jack on a minimum of two (2) strands in the presence of a TDOT Representative.
A.3.1 Initial Tensioning (Preloading)- After the strand has been positioned, an initial force of no more than 5000 pounds or as approved by the Engineer shall be applied to each strand, whether straight or draped.

In a single strand tensioning, the initial and final loads may be applied in immediate succession on each strand. The initial load on the strand shall be applied and held momentarily while reference marks are made and measured for elongation and live end slippage. The strand shall then be loaded to its final stress value and anchored as detailed in the following sections.

A.3.2 Final Stressing of Straight Strands

A.3.2.1 Single Strand Stressing- After application of the preload and establishment of reference marks for measuring elongation and slippage, the full load shall be applied to each strand.

A.3.2.2 Multiple Strand Stressing- Following application of initial stress and seating of each strand on the anchorage header, reference marks shall be established for measuring elongation and slippage. Since elongation is measured by travel of the anchorage, a reference mark shall be made at the face of the anchorage on each side of the bed. Reference marks to determine slippage shall be made by marking a straight line across the strands in each row along the face of the anchorage. For uniform application of load to the strands, the face of anchorage at final load must be in a plane parallel to its position under initial load. Parallel movements shall be verified by equal measurements of movement on opposite sides of the anchorage and a check of its plumb position before and after the application of the final load.

A.3.3 Stressing of Draped Strands- Strands are tensioned in a straight position or on a partially draped trajectory to a predetermined intermediate stress value between initial and final stress. The final stress is induced by strains (elongation) resulting from uplifting or depressing strands at all other points of change in strand alignment. This method requires a carefully predetermined layout of members on the bed and definite positions of lifting and hold-down devices in order that the changes in length of strand resulting from its being forced into the draped position can be computed. This method can be used with either single strand or multiple strand tensioning.

If this method is to be used, the fabricator must submit plans to the Structures Division, detailing the layout of the beams in the line and showing calculations for the preload and final load induced by deflecting the strands. Final elongation shall be measured by making two (2) marks 30
feet apart on two tendons on the live and dead ends of the bed after initial tensioning. The distance between these marks shall be measured after all tendons are placed in their final position. The acceptable elongation shall be calculated using the following equation with a tolerance of ±5%. The inspector has the option to use a load cell, provided by the fabricator, on draped or partially draped strands on the dead end anchorage of the bed to verify consistent tension is achieved at both dead and live anchorage.

\[
\Delta_{\text{Drape}} = \frac{\Delta_{\text{Straight}} \times 360}{L_{\text{Bed}}} 
\]

Where:
- \(\Delta_{\text{Drape}}\) = Draped Strand Elongation (inches)
- \(\Delta_{\text{Straight}}\) = Calculated Straight Strand Elongation (inches)
- \(L_{\text{Bed}}\) = Bed Length (inches)
- 360 = conversion factor, \((30 \text{ ft} \times 12 \text{ in/ft}) = 360 \text{ inches}\)

Strands are stressed to final value in their draped position for the full length of the bed. The strands shall pass over pin and roller fixtures, effectively minimizing friction at all deflection points. Support and hold-down devices shall be of sufficient rigidity and have adequate support so that the position of the strands shall remain substantially unchanged under the induced loads.

When using draped strands, if the required elongation has not been attained at one end of the bed when the load value, as indicated by the pressure gauge, is exceeded by 5%, the strand shall be jacked from the other end of the bed to the required elongation. If this requires an overstress as indicated by the gauge in excess of 5%, the number of deflection points and consequently the number of members on the bed shall be reduced until the elongation shall be attained with not more than 5% overload. When final stressing is accomplished by jacking only from one end of the bed, stress shall be measured on at least two strands at the other end. This stress shall not be below the specified value by more than 5%.

A.4 Elongation Corrections- Losses that are incidental to the operations of tensioning vary between casting beds and shall be evaluated and compensated for computing elongation. TDOT uses the Precast/Prestressed Concrete Institute (PCI) method for determining prestressed elongation corrections. The current PCI Quality Control Manual contains detailed procedures for a complete overview of prestressed elongation calculations. TDOT provides an Excel worksheet to aid in elongation corrections, located in Form DT-0283.

Factors that must be taken into consideration during prestressed elongation corrections are:
A.4.1 Abutment Rotation- Strands being stressed by a hydraulic jack place considerable force on the opposing anchoring abutment. Despite the high design strengths of abutments, slight abutment rotation will occur during stressing operations. If elongation is being measured relative to the abutment, rotation of the abutment will falsely register as strand tensioning movement. The rotation of the abutment must be considered during tensioning computations.

It is important to note that abutment rotation shall be measured at the strand height level. The top of the abutment will experience more displacement than the lower end of the abutment. Thus, strands toward the top of the abutment will experience more deflection than strands located on lower regions.

A.4.2 Dead End Slippage- The “dead end” of the prestressing bed refers to the end opposite from which the hydraulic jacking is taking place. “Dead end slippage” refers to the slipping of the strand through chuck holding devices at the “dead end” area due to tensioning by the hydraulic jacks.

Dead end seating occurs between the time that initial tension has been applied to the strand and the achievement of final load. Dead end slippage will falsely register as strand elongation if disregarded in elongation calculations. The effects of dead end slippage shall be included during elongation calculations.

A.4.3 Live End Seating- Live end seating occurs when the final load is released from the stressing jack and the strand is wedged into the live end chuck. The strand slips through the chuck before the chuck fully holds the strand, resulting in live end seating. Cleaning, lubrication, and inspection of chucks shall minimize live end seating, but it is not possible to completely eliminate chuck slippage. The effect of live end seating shall be compensated by over pulling the strand(s) during tensioning to compensate for chuck slippage.

A.4.4 Temperature Adjustments- Self stressing beds are not affected by thermal differences because the strands, form bed, and strand anchors move together with temperature changes. Therefore, losses for temperature adjustments should not be considered when using self stressing beds.

When using abutment stressing beds, the effect of temperature is significant and compensation shall be made if the net force differential is greater than 2.5%. Abutment stressing beds are utilized at the majority of prestressing plants that produce for TDOT. Thermal losses are caused by the strands and abutments
acting independent of the form bed and thereby not moving with the form bed during thermal expansion and contraction. This most commonly occurs on a cold morning when strands are tensioned. Then, later in the day, warm concrete is placed onto the strands causing the strands to expand and tension in the strands will decrease.

The opposite temperature situation will also cause tension problems in strands. For instance, if strands were tensioned at elevated temperatures and then cooler concrete was later placed on the strands, the strands would contract and tension in the strand would increase.

To compensate for thermal variations, a general rule shall be followed: for every 10°F rise in temperature expected in the strand, a 1% decrease in stress will occur. For instance, if the strand temperature rises 30°F from the time of stressing to the time it is surrounded by concrete, the strand stress will decrease by 3%. The opposite is true when the temperature of the concrete is colder than the stressing temperature. The strand would contract and increase in stress by 1% for every 10°F temperature change. It requires a 25°F change in temperature to affect the force 2.5%. Thus, this adjustment is made only if the temperature of the strand at the time of tensioning differs by more than 25°F from the anticipated temperature of the concrete that will surround the strand(s) at the time the concrete is placed. Consideration shall be given to partial bed length usage and adjustments made when the net effect on the length of bed used exceeds the allowable 2.5% force differential. If sequential pours are to be performed, the anticipated temperature difference at the time of concrete placement of each sequential pour shall not vary by more than 20°F of the anticipated temperature difference used at the time of stressing. If the time elapsed between final tensioning and the time concrete is placed in any sequential pour is greater than 1 week, the stress in at least 2 strands from the far abutment shall be verified. For example, if a 35°F rise is expected between a 50°F ambient temperature at the time the strands are stressed and a 85°F concrete temperature at the time of casting when only 75% of the bed is utilized, then the strands should be overstressed by \((1\%) \times \frac{35}{10} \times 0.75 = 2.63\%\) to offset the expected loss of stress. The table below shows the percent of strand stress change due to temperature differentials. Compensation for the amount of bed usage greater than 75% is normally ignored. If the amount of bed usage in the example above was 70%, the stress change would be 2.45% and no correction is necessary because it is not greater than the allowable 2.5%.
A.5 Breaking Bond Strands- When using bond breaking, it is essential that no grout find its way inside the bond breaking material. If using solid plastic tubing, the ends shall be taped. If using split plastic tubing, both the ends and the entire length of the split joint shall be taped. The use of tape alone shall not be allowed.

A.6 Bridge Deck Panels

A.6.1 General- Prestressed bridge deck panels are to be constructed according to TDOT Standard Drawings STD-4-1 and STD-4-2, the producer’s approved shop drawings, Standard Specifications, and the applicable special provisions.

A.6.2 Dimensional Tolerances- These are set forth on TDOT Standard Drawings STD-4-1 and STD-4-2.

A.6.3 Cracking- A minor amount of shrinkage cracking is to be expected and shall not be cause for rejection of the panels. Care in pouring and curing shall eliminate most of the causes for these. Structural cracks as listed in Section 921.13 of the Standard Specification shall be the cause for rejection.

Refer to the PCI manual: “A Manual for the Repair of Precast/Prestressed Bridge Beams and Deck Panels” for detailed information on structural diagnosis.

A.6.4 Finishing- Finishing shall be in accordance with TDOT Standard Drawing STD-4-1.
A.6.5 Handling and Storage of Panels - Panels shall be removed from the forms in such a manner that no damage is done to the concrete or the protruding shear ties. When stacking panels, wood spacers thick enough to protect the shear ties shall be used.

Refer to the PCI manual: “A Manual for the Repair of Precast/Prestressed Bridge Beams and Deck Panels” for detailed information on handling structures.

A.6.6 Placing of Concrete - Since the concrete in these members is relatively thin, proper care must be taken to keep the concrete within the allowable temperature ranges given in Section 501.11 of the Standard Specification. It could conceivably be necessary to heat or cool the steel forms prior to pouring. Freshly placed concrete must be protected from sun and wind to prevent evaporation, therefore, concrete is to be covered as soon as possible. A support for the cover shall be used that will allow for free circulation of steam.

A.6.7 Removal of Grout from Shear Ties - All exposed steel shall be cleaned of concrete, other than light deposits of cement paste, immediately after placing and consolidation is complete.
Appendix B: Prestress Inspection Checklist

Prestress Inspection Checklist

Preliminary

☐ Assure that jacks and/or load cells have been calibrated within the last 6 months

☐ Assure that the lab equipment, mixer trucks, and the concrete plant have been inspected annually.

☐ Assure that concrete mix designs and shop drawings have been approved and are available.

Sampling:

☐ Assure that certifications for incidental/misc. materials intended for TDOT use are obtained as they are being delivered to the plant.

☐ Sample aggregates (coarse and fine) monthly.

☐ Sample cement/fly ash monthly

☐ Sample strand reel packs a minimum of 10% of the heat numbers per size and type included in each shipment or daily delivery (Two - 42±2 inch pieces are a sample). Verify that reel packs are properly tagged for identification and values.

☐ Sample re-bar per bar size a minimum of 10% of the heat numbers included on each shipment or daily delivery (Two - 34 inch samples per bar size per heat number)

☐ Sample bearing pads and obtain certifications for each lot number. (Two - 4”x4” cut pads)

Pre-Pour Inspection:

☐ Request profile of beam, panel or piling bed to be completed prior to beginning production operations. Profiles may be performed less frequently if the beds are sufficiently secured to a permanent foundation.

☐ Monitor and verify that the strand placement pattern on beds matches the strand placement pattern on approved shop drawings.

☐ Monitor and verify that strand reel packs being used are the correct size and type and have been sampled for verification testing in accordance with SOP 1-1.

☐ Check headers prior to use for damage.
During stressing operations monitor and verify strand tension forces and verify at least 10% of the elongation measurements are within calculated tolerances. Make any necessary adjustments to calculated tension force due to temperature differences of strand at the time of stressing and anticipated concrete temperatures at time of placement (see SOP 5-4).

If drape strands are used, have a load cell placed on the dead end of bed to check that the calculated tension force is achieved for the drape strands after pull or verify by stressing a minimum of 2 strands on the opposite end to assure the combined elongation measurements are within 5% of the calculated values.

After stressing operations have been completed, verify that strand heights and spacings are within tolerances shown either on the approved shop drawing, in the TDOT Standard Specifications, or applicable TDOT Standard Drawings in accordance with SOP 5-4.

Prior to setting forms, monitor and verify steel placement, bar sizes, inserts, and voids match approved shop drawings and are located within tolerances shown on approved shop drawings or in the TDOT Standard Specification section 615.17.

Prior to setting forms, inspect them for any damage or irregularities that could cause voids or deformations of the beam.

Prior to setting forms, make sure they have been sprayed or coated with an approved release agent along with the bed. Assure that strands, spiral ties, and rebar are not contaminated with release agent oils.

After forms have been set, verify they have been string lined to insure straightness of the product.

Verify and document Box Beam voids and restraint measurements as identified in SOP 5-4.

During Pour Inspections:

During pouring operations monitor concrete testing and reject any loads that do not meet the required tolerances in TDOT Standard Specifications section 615.09 or as identified on the approved mix design.

Assure that concrete testing and cylinders are made randomly from concrete being placed in each bed or beam. For beams, a set of 28 day and back-up cylinders shall be required for the beginning, middle, and end of the bed. For panels and piling, a set of 28 day and back-up cylinders are required to represent the beginning and end of pours. Release cylinders for stress transfer shall be cast from each end of the
bed for all products. 28 day cylinders shall be sent to TDOT Nashville Lab for testing. A back-up set of companion cylinders for each set of 28 day cylinders shall be stored at the Regional Lab or at a TDOT approved facility. Release cylinders are to be tested at the yard in the presence of TDOT. Cylinders from each end shall meet the minimum strength identified before stress transfer is allowed.

- Monitor concrete placement to ensure concrete is being poured in proper lifts and is being vibrated properly.
- Verify that cylinders for release strength are being cured in the same manner as the beams.

**Post-pour Inspections:**
- After the pour is completed ensure that the bed is covered and temperature monitors are installed on the live and dead end portions of the bed and at intervals no greater than 200 feet. Temperature time recordings are to be attached to the daily report.
- Assure curing temperatures of recording devices comply with TDOT specifications and SOPs.
- Monitor transfer of stress cylinder breaks and verify the minimum strengths have been achieved before de-tensioning operations begin. (Note: release cylinders may be tested 12 hours after the end of concreting operations if steam cured and 24 hours after the end of concreting operations if water cured).
- Monitor and verify that the stress release pattern as shown on the approved shop drawings is being used during transfer of stress operations.
- Inspect products for damage, cracking, deformations, or honey-combing prior to removing them from the bed. If any strands are exposed due to improper consolidation of concrete for a length greater than 5 feet, do not allow detensioning.
- Notify the appropriate TDOT authority of any damage, cracking, or deformations found during initial post pour inspection.
- If any damage is found, do not allow stacking or storage of beam until a repair procedure can be discussed and approved by TDOT. Proposed repair procedures shall reference the PCI Repair Manual as identified on SOP 5-4.
- Complete form DT-0283, Daily Report for each pour.
Final Inspections:

☐ Prior to stamping and shipment of prestress units, complete a final inspection to ensure they are not damaged, cracked, or spalled, and meet the dimensional tolerances as shown on the plans and/or TDOT Standard Specifications.

☐ Stamp beams after they have been loaded and secured for shipment.

☐ Complete form DT-0289 for shipped products or products the contractor has requested stockpile or partial payment. Fax or email the form to the project supervisor or representative consultant.
Appendix C: Guidelines for Prestress Yard Epoxy Injection of Cracks in Concrete Structures

C.1 Equipment

For the equipment used to inject the epoxy, meet the recommendations of the epoxy injection material manufacturer and the following requirements:

C.1.1 Use equipment that has the capacity to automatically proportion the material components within the mix ratio tolerances set by the epoxy materials manufacturer.

C.1.2 Use equipment that has the capacity to automatically mix the epoxy component materials within the pump and injection apparatus. The Engineer will not allow batch mixing.

C.1.3 Use equipment that has the capacity to inject the epoxy resin under controlled variable pressures up to 200 psi, with a pressure gauge mounted at or near the nozzle to indicate the actual working pressure.

C.2 Injection Personnel Qualifications

Employ personnel trained in injection work similar to that required for the products to properly perform the epoxy injection of cracks in concrete. Provide an on-site supervisor for the epoxy injection work who is qualified by one of the following methods:

C.2.1 Certified by the manufacturer of the epoxy injection material as having the necessary competence to accomplish the epoxy injection work in a satisfactory and safe manner in compliance with these guidelines.

C.2.2 Furnish documented evidence that he/she has a minimum of three years’ experience of on-site supervision of similar epoxy injection work.

C.3 Crack Surface Preparation and Cleaning Requirements

Clean the area surrounding the cracks of all deteriorated concrete, laitance, oil, debris, moisture, and other contaminants detrimental to the adhesion of the surface sealing epoxy paste. Clean the interiors of the cracks with filtered air under sufficient pressure to remove loose materials entrapped within the crack.

C.4 Preparation and Sealing Cracks for Epoxy Injection

After cleaning, drill injection port holes using a swivel drill chuck and hollow drill bits, including a vacuum attachment which will remove dust and debris generated during drilling. Determine the spacing of the injection port holes by the size and
depth of the crack in the concrete substrate as identified in the manufacturer’s literature. Generally, space the injection ports beginning 4 inches from the termini of the crack and at 4 to 8 inches apart depending on the width, length, and location of the repair. Determine the actual spacing of injection ports by field trials to ensure the crack is filled. Insert ports on both faces of through cracks when accessible. Space ports a maximum of the member’s thickness if only accessible from one side.

Drill the port holes to a minimum depth of 5/8 inch, or as recommended by the port nozzle manufacture, exercising care in aligning the hole along the plane of the crack so that the hole follows the crack for its full depth. Insert the injection ports, approximately 1/4 inch before seating completely in the member allowing for a small reservoir of resin between the injection port tip and the bottom of the drilled hole. After cleaning the cracks and drilling the injection port holes, seal the crack surface and the injection ports with a suitable epoxy paste as recommended by the resin manufacture and capable of withstanding injection pressures.

C.5 Epoxy Resin Additives for Injection into Concrete

The epoxy resin adhesive shall be of low enough viscosity such that it flows to the next open port in the surface seal material. The adhesive shall be capable of penetrating crack widths down to 0.005 in., pumped under pressure, and able to achieve strengths of the concrete being repaired. The material shall be capable of bonding to dry or damp surfaces and shall be on the Departmental QPL.

C.6 Epoxy Injection

Mix and inject the epoxy in accordance with the epoxy manufacturer’s instructions. Determine the actual injection procedures and pressures in field trials based on crack widths and depth into the substrate. Epoxy injection shall begin at the lower entry port and continue until there is an appearance of epoxy at the adjacent entry port. Injection shall continue until all cracks are completely filled. If port to port travel is not apparent, the work shall be stopped immediately. The Engineer shall be notified. The work shall be performed with 2-component automatic metering and mixing equipment calibrated within 6 months.

C.7 Cleaning After Epoxy Injection

Clean concrete surface areas of excess epoxy materials and injection ports after completing the epoxy injection work. Clean in a manner which will not damage the concrete by scraping, light sand blasting, grinding, use of solvents, or any other appropriate method approved by the Department. Clean excess materials so that no epoxy material or injection ports extend beyond the plane surface of the concrete.
C.8 Qualification

Select, with a Departmental representative, a product not intended for TDOT use with similar cracking as compared to the member(s) to be repaired. Perform the crack injection work following industry practices or as otherwise approved. Drill three 4-inch diameter cores centered over the repaired cracks as directed by the Engineer. TDOT will review and accept the on-site supervisor and key personnel for the epoxy injection work represented by the core samples when;

C.8.1 The core samples indicate that 95% of the crack void greater than 0.005 inch wide is filled with epoxy resin, and the concrete of the core sample is bonded through the crack into a unit.

C.8.2 The rupture of a core after compression testing is not in the crack area, or the compressive strength achieved exceeds that specified for the concrete or that which is observed from the strength of control specimens.