Rev Date 9/6/2023

Tennessee Department of Transportation
Division of Materials and Tests

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 Materials and Tests (M&T) Division Prestressed Standard Operating Procedure (SOP) 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.

1. Initial Producer Qualification Requirements

For initial approval, the Producer shall submit, at a minimum, to the M&T Division in a letter or to TDOT.PrecastMTR@tn.gov:

- Proof of national certification – Precast/Prestressed Concrete Institute (PCI)
- Most recent plant inspection report completed by the certifying agency
- Formal response to each deficiency noted by the certifying agency
- Product request with detailed list of products to be produced
- Standard/Alternate Drawings, Plans, or Specifications to be used
- TDOT specific Quality System Manual (QSM)
- Proof of Quality Control personnel certifications
- Concrete mix design(s) per products produced

1.1 All producers of prestressed concrete products to be supplied on TDOT projects shall be certified by the approved National Quality Control Program: (PCI)

1.2 All producers shall provide written consent to the certifying agency allowing all plant inspection documentation to be forwarded to TDOT immediately after the inspection is complete.

1.3 Producers shall request, from M&T, approval for products to be supplied to TDOT projects. This request should contain a detailed list of the products that will be produced from the following list of prestressed concrete products. Correspondences should be sent to tdot.precastmtr@tn.gov.

- Prestressed Beams
- Prestressed Deck Panels

- Prestressed Pilings

1.4 All prestressed concrete products shall be manufactured in accordance with the dimensions and details shown in the following:

- TDOT Project Specific Proposal Contract
- TDOT Standard/Supplemental Specifications (Specifications)
- TDOT Standard Operating Procedures (SOP)
- TDOT Standard Drawing(s) (Standard Drawing(s)
- TDOT Approved Shop Drawing(s)
- Producer's approved alternate drawing to the Standard Drawing(s)
  - Once approval is given for alternate drawings stamped by a Professional Engineer licensed in the State of Tennessee will be valid until a change is made to the Standard Drawing(s). All alternate drawings are to be submitted to Structures Division and will then be sent to the Design Division for review prior to producing a product.
- Contract Plans
- American Association of State Highway and Transportation Officials
  American Society for Testing and Materials
  (AASHTO/ASTM) Standards
- PCI Manual

1.5 Materials

The Producer shall retain copies of all material certifications.

1.5.1 Aggregates - All aggregate sources shall be on the Producer List and in accordance with Sections 903.01, 903.03, and 903.22 of the Specifications.

1.5.2 Cement - All cements shall be on the Producer List and in accordance with Section 901.01 of the Specifications.

1.5.3 Fly Ash, Ground Granulated Blast Furnace Slag, Silica Fume - Other cementitious and pozzolanic materials shall be on the Producer List and in accordance with Sections 921.15 or 921.16 of the Specifications.

1.5.4 Reinforcing Steel and Wire Strands

1.5.4.1 Steel used for reinforcement shall be submitted in accordance with procedures per SOP 1-1 *Quality Assurance for the Sampling of Materials and Products* and listed on the Producer List. The steel used shall follow the applicable AASHTO/ASTM Standard for the structure or Standard Drawings. All certifications shall contain a signed "Buy

America" statement. The Producer shall retain copies of all mill test reports and material certifications.

1.5.5 Admixtures - All admixtures shall be listed on the TDOT Qualified Products List (QPL) 4 *Air-Entraining and Chemical Admixtures for Concrete* and in accordance with Sections 604.03 and 921.06 of the Specifications.

1.5.6 Water - All water shall be in accordance with Section 921.01 of the Specifications.

1.5.7 Patching Material – All patching material shall be listed on QPL 13 *Patching Materials*.

1.6 Quality Control Program

1.6.1 Quality Control Manual (QCM)

1.6.1.1 Each production facility shall have a TDOT specific QCM.

1.6.1.2 The QCM shall include, at a minimum but not limited to, an organizational chart including a back-up quality control technician, 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.

1.6.2 Quality Control (QC) Personnel

1.6.2.1 Each production facility shall have a designated individual and a back-up responsible for the quality production of prestressed products. This individual shall have authority to make necessary adjustments, reject concrete, cease production, and/or reject products when the quality of the product is in question. QC Personnel shall be on site anytime that a TDOT product is being produced.

1.6.2.2 QC Personnel must be in good standing with a TDOT Concrete Plant QC Technician Certification. QC Personnel shall also hold current certificates of completion for PCI Level I Quality Control Technician/Inspector Certification. Any individual designing a concrete mix design must also be TDOT Concrete Mix Design Technician certified.

1.7 Quality Assurance Inspection

1.7.1 A plant and laboratory inspection will be performed by representatives of M&T and documented on the Precast/Prestressed Inspection Checklist. Any deficiencies found during the inspection shall be addressed within forty-five (45) days. Representatives of M&T shall retain a copy of the Precast Inspection Checklist and send a copy to the Producer. A copy shall be kept at the plant and be readily available for review.

1.7.2 After all verification testing has been completed and all requirements have been met, M&T will then add the producer to the Producer List.

2. Producer Facility and Equipment Requirements

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

2.2 The testing equipment shall be certified and/or calibrated a minimum of every twelve (12) months.

2.3 Gradations shall be performed at the prestressed facility on each aggregate used at least once per week. Design changes will require additional gradation testing.

2.4 Hydraulic jacks and pressure gauges shall be certified and/or calibrated a minimum of every six (6) months.

3. Producer Concrete Batching/Central Mixing Plant

3.1 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.

3.2 Concrete may be supplied by a ready-mix producer provided the plant and hauling equipment are in compliance with section 604.03 of the Specifications and listed on Producer List.

3.3 Temperature of the concrete and the area surrounding the concrete shall be in accordance with sections 615.09 and 615.10 of the Standard Specifications.

3.4 All documentation regarding certifications, calibrations, etc. must be retained for a minimum of five (5) years.

4. Producer's Acceptance Testing

4.1 Verification testing of all materials shall be performed at the frequency stated in SOP 1-1.

4.2 Reporting Prestressed Items for Payment: When a contractor requests payment on prestressed or precast items produced for a specific project, the producer will accomplish the following:

4.2.1 All members will meet the requirements of the specifications and approved shop drawings, etc. Dimensional tolerances shall be in accordance with Table 615.17-1 of the Specifications.

4.2.2 Documentation along with concrete cylinders for prestressed concrete shall be provided for a set of 4"x8" twenty-eight (28)-day cylinders per sample location. Cylinders will be considered TDOT verification cylinders and labeled in accordance with: 28-Day Cylinders Procedure for Regional M&T Staff. TDOT Verification cylinders are to be broken in Nashville by M&T.

The Producer must provide break data showing that their quality control cylinders for that product(s) have achieved the design strength, detention strength, etc. to request the department to approve for shipment.

4.2.3 Alternative Verification: The producer shall provide documentation of Estimating Compressive Strength using the Maturity Method (AASHTO T 325) in accordance section 604.15.D of the Specifications.

4.2.4 The Producer will ensure that all products and records are ready for shipment and marked correctly in accordance with PCI and TDOT certification requirements. Other items to be reviewed are: holes filled, drains opened, all honeycombed areas, etc. repaired. Verify that repairs have been completed and documented accurately if applicable. Any corrective action shall be performed in accordance with standard industry practices and approved by the Structures Division. Any products used for corrective action shall be listed and approved on the QPL.

4.2.5 When stockpile payment is requested, the Producer shall notify M&T representatives and provide the department with all acceptance testing documentation for each member in accordance with PCI standards and TDOT Certification Requirements. The producer will mark each member with plant letter and report number at one end of each member. The producer is to make out a test report

for the members 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.

4.2.6 Each prestressed product (beam, panel, piling, etc.) shall be marked legibly, on the face visible after installation, by stamping or labelling with the following information:

- TDOT Contract Number
- County/PIN Number (Local Program, Bridge Grant, State Aid)
- Station Number / Bridge Number / Product Number
- Mark Number
- Date of Pour

It is understood that some members, such as piling, are poured for stock, and stored on the Producer's yard. The product shall be marked with the applicable above information allowing the additional information to be added by the Producer once identified as an item assigned to a project prior to shipping to the project site.

4.2.7 Complete the appropriate checklist of items.

4.2.8 Final acceptance by verification shall be completed by utilizing Forms DT-0283 and DT-0289 filled out by the producer. Those documents are found at: https://www.tn.gov/tdot/materials-and-tests/field-operations/forms.html

No material is to receive a TDOT acceptance stamp or stencil marking before it is loaded for shipment. After loading and prior to shipping, the Materials and Tests Inspector shall perform a final inspection of the prestressed member(s), and if found acceptable, shall stamp showing approval for shipment.

5. Verification Program

5.1 Verification of all materials shall be performed at the frequency stated in SOP 1-1 Part 3 *Verification/Check Samples and Tests.* TDOT retains the right to test and/or request the Producer to retest any product for verification purposes.

5.2 The Producer shall keep daily reports documenting each product made that day and the number made. The report shall contain the results of all verification tests for each product tested as well as pre-pour, pour, and post pour inspections. The Producer shall maintain this information for a minimum of five (5) years or until completion of the project in which the product was placed. All documents are subject to review by M&T.

5.3 The Producer must submit along with other required documentation a completed certification form to be signed by QC Personnel as designated in the QCM for each shipment to a TDOT project. This form shall contain a statement certifying the products were manufactured, tested, and accepted in accordance with Specifications.

5.4 When members must be shipped or delivered to a project site before twenty-eight (28) days, the Producer may email a letter request (*Prestressed Early Shipping Request Letter*) along with documentation of all QC tests to the M&T Division. M&T personnel will respond and schedule a visual inspection within five (5) business days following the submission. If QC cylinders obtain the specified strengths, and with the approval of the Engineer, the members may ship to the project site after they have cured for a minimum of seven (7) days unless otherwise noted in the plans. Loading of the beams will be as noted in the plans. Products that have been cured for twenty-eight (28) days may be shipped once acceptance criteria has been met in accordance with SOP 1-1 *Quality Assurance for the Sampling, Testing of Materials and Products.*

6. Verification Failures

6.1 All verification cylinder sets will be broken at twenty-eight (28) days. Verification break data will be monitored as a check on each individual concrete mix design. If a design continuously fails to achieve the design strength, these breaks can be used as a basis to expire the mix design.

6.2 One week of break data per Producer per month will be randomly selected for break data analysis. If all breaks achieve the concrete mix design strength, then verification will resume the following month. If a failure happens during the randomly selected week, then the following week will also be reviewed for the Producer.

6.3 If the second consecutive week of checks achieves the concrete mix design strength, then the verification check will resume the following month. If the second week also yields failing results, then M&T and the Producer must meet to discuss a resolution to move forward with certifications.

6.4 TDOT Structure reserves the right to request that any prestressed product be cored for a structural analysis as a basis for acceptance.

Rev Date 9/6/2023

Prestress Inspection Checklist for TDOT Audits

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.

During Pour Inspections Verification:

- ☐ Assure that concrete testing and verification cylinders are made randomly from concrete being placed in each bed or beam. For beams, a set of twenty-eight (28)-day quality control and verification cylinders shall be required for each bed poured. For panels and piling, a set of twenty-eight (28)-day quality control and verification cylinders are required to represent the beginning and end of pours. Tension release cylinders for stress transfer shall be cast from each end of the bed for all products. Twenty-eight (28)-day verification cylinders shall be sent to the M&T Laboratory for testing. Tension release cylinders are to be tested at the yard. Cylinders from each end shall meet the minimum strength identified before stress transfer is allowed.
- ☐ Verify that cylinders for release strength are being cured in the same manner as the beams.

Final Inspections:

- ☐ Prior to stamping and shipment of prestress members, 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 Specifications.
- ☐ Stamp beams after they have been loaded and secured for shipment.
- ☐ Verify all acceptance test has been documented for each member.
- ☐ Verify all pre, during, and post pour documentation from the prestressed quality control inspection.

Rev Date 9/6/2023

Prestress Inspection Checklist for Producer Quality Control

Pre-Pour Inspection:

- ☐ 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 Specifications, or applicable 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 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 Specifications section 615.09 or as identified on the approved mix design.

- Verify that concrete testing and cylinders are made randomly from concrete being placed in each bed or beam. For beams, a set of twenty-eight (28)-day quality control and verification cylinders shall be required for each beam poured. For panels and piling, a set of twenty-eight (28)-day quality control and verification 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. Twenty-eight (28)-day cylinders shall be sent to the M&T Laboratory for testing. 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.

- Verify 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 honeycombing 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 de-tensioning.

- 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.

Rev Date 9/6/2023

General Guidelines for Quality Control (QC)

Quality System Manual (QSM)

The Producer shall develop, for review and record keeping by M&T, an extensive QSM like that described in Section 604.03.B of the Specifications. The QSM shall be submitted annually to M&T with the initial application accompanied by the concrete mix designs. Alternatively, a letter stating that there are no changes to the previous QSM will suffice. The QSM shall include, but is not limited to:

- Active PCI Certification
- An Organization Chart
  - Including Quality Control personnel contact information
- All course documentation
  - Certificate(s), certification number(s), and expiration date(s)
- Buy America Statement
  - All applicable materials in accordance with SOP 1-8: Build America, Buy America (BABA) Requirements
- List of all material suppliers and their location
- A detailed pre pour process
- A detailed post pour process
- Quality Control testing procedures and records
- Detailed marking for TDOT products
- Batching tolerances
  - Tickets/Records of batches

It shall 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 QSM 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 QSM must be submitted immediately to M&T reflecting all changes or corrections.

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. Testing for acceptance and verification shall be performed in accordance with SOP 1-1: Quality Assurance Program for the Sampling and Testing of Materials and Products.

All producers of prestressed concrete structural members to be supplied on TDOT projects shall be certified by the PCI. Certified producers must submit a copy of their current certification with the initial application annually to M&T with their QSM submission. 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.

Quality Control Personnel

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.

Technicians and other individuals who conduct sampling and testing for quality control must be TDOT or ACI Concrete Field Testing certified and TDOT Concrete Plant Quality Control Technician certified. Any individual designing a concrete mix design must be TDOT Concrete Mix Design Technician certified. A TDOT Concrete Plant Quality Control Technician shall be batching concrete anytime that a TDOT product is being produced.

Quality Control of Materials

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 encounters 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.

Aggregate stockpiles shall be from an approved source on the TDOT Producer List, properly labeled, and maintained in an uncontaminated and unsegregated manner. Concrete batching shall not be permitted if the aggregate stockpiles exhibit frozen material.

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 Specifications and SOP 4-4: Submittal and Approval of Concrete Mixture Designs. Proportioning and mixing of the concrete shall comply with Section 615.09 of the 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, Standard Drawings, or 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 Standard Drawings and Specifications. Approved mix designs shall not be modified.

Quality Control Cylinders

Quality control cylinders shall be tested and recorded by the Producer in accordance with the Producer's approved QSM procedures. The basis of sample selection and the frequency of sampling shall be denoted in the QSM. Compression strength data must be shown on the product certification. Quality control cylinders must achieve design strength prior to submitting an early break cylinder request.

Quality Control Documentation

The Producer 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 5.3 and results of all quality control 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.

Reporting

Producer's Certification – Each shipment to the project site must be accompanied with a report certifying the work completed in the production of the prestressed member. Successive reports shall include the percentage of prestressed work that has been completed and shipped to the project site. Reports used for certification/acceptance purposes must include the following items:

- Letter certifying that all PCI and TDOT requirements have been met prior to shipping to the project site
- Form DT-0283: Daily Report of Prestressed Concrete Plant Inspection
- Form DT-0289: Report on Precast or Prestressed Concrete

Rev Date 9/6/2023

General Guidelines for Quality Control (QC) - Box Beams

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 Specifications 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**:**

- Prior to Fabrication

  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 by the QC Inspector.

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

- During Fabrication

  Top Slab- After the beam has been screeded and finished to the required depth and grade, the QC 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.

  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 by the QC Inspector. (*The thickness can be verified while the concrete is in the plastic state OR after fabrication on hardened concrete.)*

- 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.)*

  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. This information shall be available to TDOT for review.

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 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 the Inspector.

A.3.1 Initial Tensioning (Preloading)- After the strand has been positioned, an initial force of no more than 5,000 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 thirty (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.

$$\delta_{Drape} = \delta_{Straight} \times 360 / L_{Bed}$$

Where:

δ_{Drape}= Draped Strand Elongation (inches)
$\delta_{Straight}$= Calculated Straight Strand Elongation (inches)
L_{Bed}= Bed Length (inches)
360=conversion factor, (30 ft x 12 in/ft) = 360 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 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 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 35ºF rise is expected between a 50ºF ambient temperature at the time the strands are stressed and a 85ºF concrete temperature at the time of casting when only 75% of the bed is utilized, then the strands should be overstressed by (1%) (35/10) (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 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%.

% of Bed Used	Temperature Variation (degrees Fahrenheit)					
	25	30	35	40	45	50
5	0.13	0.15	0.18	0.20	0.23	0.25
10	0.25	0.30	0.35	0.40	0.45	0.50
15	0.38	0.45	0.53	0.60	0.68	0.75
20	0.50	0.60	0.70	0.80	0.90	1.00
25	0.63	0.75	0.88	1.00	1.13	1.25
30	0.75	0.90	1.05	1.20	1.35	1.50
35	0.88	1.05	1.23	1.40	1.58	1.75
40	1.00	1.20	1.40	1.60	1.80	2.00
45	1.13	1.35	1.58	1.80	2.03	2.25
50	1.25	1.50	1.75	2.00	2.25	2.50
55	1.38	1.65	1.93	2.20	2.48	2.75
60	1.50	1.80	2.10	2.40	2.70	3.00
65	1.63	1.95	2.28	2.60	2.93	3.25
70	1.75	2.10	2.45	2.80	3.15	3.50
75	1.88	2.25	2.63	3.00	3.38	3.75
80	2.00	2.40	2.80	3.20	3.60	4.00
85	2.13	2.55	2.98	3.40	3.83	4.25
90	2.25	2.70	3.15	3.60	4.05	4.50
95	2.38	2.85	3.33	3.80	4.28	4.75
100	2.50	3.00	3.50	4.00	4.50	5.00

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.

General Guidelines for Quality Control (QC) - Bridge Deck Panels

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

A.6.2 Dimensional Tolerances- These are set forth on the 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 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 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.

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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 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 member.

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.