PRECAST/PRESTRESSED CONCRETE MANUAL

ISSUED BY

COMMONWEALTH OF KENTUCKY
TRANSPORTATION CABINET
DEPARTMENT OF HIGHWAYS

DIVISION OF MATERIALS
FRANKFORT, KENTUCKY

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TRANSPORTATION CABINET
Frankfort, Kentucky 40622
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OFFICE OF THE SECRETARY 103077
OFFICIAL ORDER _____

SUBJECT: *PRECAST/PRESTRESSED CONCRETE GUIDANCE MANUAL*

This manual has been prepared to provide information and guidance to personnel of the Kentucky Transportation Cabinet. Its purpose is to establish uniformity in the interpretation and administration of laws, policies, regulations, and procedures applicable to the operation of the Division of Materials and its relationship with other units of the Cabinet.

The policies and procedures set forth herein are hereby approved and declared effective unless officially changed.

All previous instructions, written and oral, relative to or in conflict with this manual are hereby superseded.

Signed and approved this 19th day of July 2005.

Bill Nighbert
Acting Secretary

Approved as to Form And Legality

Office of Legal Services

PURPOSE AND SCOPE

The Division of Materials has prepared this manual for the purpose of setting guidelines for inspectors. It is intended for use in the fabrication and inspection of standard precast or prestressed concrete products in Kentucky Transportation Cabinet (KYTC) projects. It will aid in training inexperienced inspectors and also help experienced inspectors perform more efficiently. It is also a source of essential producer information. Section 605 of the *Kentucky Standard Specifications for Road and Bridge Construction* (*Kentucky Standard Specifications*) states that fabrications must conform to the Department of Highways' *Precast/Prestressed Concrete Manual.*

This manual is intended as a supplement. It is in no way a replacement for KYTC contract specifications. If there is a conflict between directions in the *Kentucky Standard Specifications* and governing contract specifications, the *Kentucky Standard Specifications* must be followed (see Section 605–Prestressed or Precast Concrete Members–of the current edition of the *Kentucky Standard Specifications).*

The procedures specified in this manual are normal requirements to determine the acceptability of materials under normal conditions. The responsible engineer or inspector is expected to perform additional inspection and/or testing when required to meet specific project needs. He or she may also reduce inspection and/or testing when it can be justified according to specific project situations.

This manual is maintained on the KYTC's Web site at http://transportation.ky.gov/materials and is available to the public from this location. If you have comments or suggestions, please contact the Director of the Division of Materials by telephone at 502-564-3160 or by fax 502-564-7034. The mailing address is as follows:

Transportation Cabinet
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1227 Wilkinson Boulevard
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The Director's Internet e-mail address is enclosed here in parentheses (Wesley.Glass@ky.gov).

Wesley Glass, P.E., P.G., Director, Division of Materials — Date: 7/27/06

NOTE: This edition of the *Precast/Prestressed Concrete Manual* is a modification of Official Order 103077, signed by the Secretary of Transportation on July 19, 2005, and supersedes all parts in conflict with Official Order 103077.

Should you not have Internet access and wish to obtain a hard copy of this manual, contact the KYTC's Policy Support Branch at 502-564-3670.

DISCLAIMER: This manual assumes no liability on the part of the Kentucky Transportation Cabinet.

Table of Contents

I. DRAWING APPROVAL

A. THE DIVISION OF BRIDGE DESIGN

The Division of Bridge Design, or authorized representative, approves shop drawings, which must show:

1. Type of Prestressing
2. Bed layouts (only when draped strands are used)
3. Total number of stirrups for each mark
4. Position of any tack welding to be done on the steel reinforcement
5. Diagram of the detensioning procedure and elongation calculations for draped strands when the "lift up" method is used
6. Any splices

B. NO CASTING

No casting can start unless the inspector has an approved set of prints or has verification from the Division of Bridge Design that the contractor's prints are accurate and additional prints are being distributed.

II. RESPONSIBILITIES OF INSPECTORS AND PRODUCERS

A. INSPECTOR RESPONSIBILITIES

1. **Before Construction Begins:** The inspector should be thoroughly familiar with the plans, Section 605 of the *Kentucky Standard Specifications*, and special provisions that pertain to the construction to be inspected. The inspector and producer should review and discuss these items, along with the provisions of this manual, so no misunderstanding concerning interpretations will occur during production.

2. **Construction Phases:** The inspection of construction for prestressed concrete members is highly technical and demands that the inspector be informed of all phases of the operation. The inspector should observe all significant phases of construction to assure conformity with the plans and specifications and also to ensure that proper materials and construction methods are used.

3. **Observed Infractions:** The inspector must notify the fabricator immediately of any observed infractions or departures from shop drawings and/or specifications. They must also make sure that corrective actions are taken to ensure that the finished product meets specifications.

4. **Daily Inspection Diary:** This diary is maintained by the inspector and includes record of air content, slump tests, any observed departures from the plans or specifications, and any corrective measures applied. The inspector keeps this diary on file at his or her workstation.

B. PRODUCER RESPONSIBILITIES

1. **Certification:** Providers of prestressed concrete products for use in KYTC projects must be certified. Certification is awarded by the Division of Materials and is based on:

   a. Conformance of the production facility and necessary equipment to specification requirements

   b. Quality assurance program meeting the requirements of this manual

   c. Record of acceptable quality products production

2. **Notarized Agreement:** A notarized agreement signed by an authorized company representative must be submitted to the Division of Materials on an annual basis. These requirements must be followed in order to provide prestressed concrete products for KYTC projects.

3. **Additional Prestressed Concrete Certification:** Certification ensures that all prestressed concrete members supplied to the KYTC are manufactured in a plant that is certified under the appropriate Prestessed Concrete Institute (PCI) quality control program and is designated as a PCI Certified Plant.

4. **Specifications:** The producer must have the necessary equipment that meets specification requirements. They must have a national accredited lab or a lab accredited by the Division of Materials. They must also have the necessary supervisors, quality control personnel, testing equipment, technicians, and production workers to fabricate quality products in conformance with specifications. The producer must ensure that the superintendent, bed foreman, and quality control personnel are fully informed of the requirements pertaining to fabrication, curing, and care and handling of the beams.

5. **Required Testing:** The producer must provide and maintain the required testing equipment in accurate working condition to perform the following tests (*KM* stands for *Kentucky Method*):

   a. Slump of the Plastic Mix (KM 64-302)

   b. Air content of the Plastic Mix (KM 64-303 and/or KM 64-304)

   c. Moisture content of Coarse and Fine Aggregate, if applicable, (KM 64-306)

   d. Making Concrete Strength Specimens (KM 64-305)

   e. Testing Concrete Strength Specimens (See the **Prestress Concrete** portion of this manual.)

   f. Concrete Cover over Steel in the Finished Product (See the **Evaluating the Finished Prestress Product** portion of this manual.)

   g. Temperature of Freshly Mixed Concrete (KM 64-320)

   Note: State Inspector must be present when the producer's quality control personnel perform these tests.

6. **Safety Program:** The producer must have a safety program that complies with prescribed law. This program must recognize potential hazards involved with prestressed concrete manufacturing. Producers must sound a warning buzzer or horn prior to stressing strand or closing forms when a hydraulically closed system is used. This is to remind production personnel of the potential hazards involved. Each plant must practice good housekeeping.

III. QUALITY CONTROL

A. GENERAL REQUIREMENTS

1. **Certified Concrete Technicians:** The producer must have a currently certified concrete technician that is responsible for the design and control of concrete mixtures and for performing necessary quality control and process control testing. The concrete technician's certification must be an ACI Level I and KRMCA Level II awarded by the Kentucky Ready Mix Concrete Association.

2. **Tack Welding:** All tack welding procedures and tack welders must be qualified biennially by the Division of Materials through tests in accordance with KM 64-109. Any proposed tack welding must be indicated on the shop drawings and is only permitted at the intersection of bars. No tack welding is permitted in the web portion of the hairpin stirrup or in any steel reinforcement in the top 5.5 inches of box beams.

B. PRINCIPAL FACTORS OF QUALITY CONTROL

Many factors enter into the quality control of prestressed concrete products. Some of the most important are:

1. Management commitment to a quality control program
2. Qualified personnel for all stages of design and construction
3. Testing and inspection of the various materials selected for use
4. Clear and complete shop drawings (Good production drawings translate contract documents into usable information for manufacture, handling, and erection of precast/prestressed units.)
5. Accurate stressing procedures
6. Control of dimensions and tolerances
7. Correct positioning of all embedded items
8. Proportioning and adequate mixing of concrete
9. Handling, placing, and consolidation of concrete
10. Adequate curing
11. Handling, storing, transporting, and erection of members
12. Thorough documentation

C. UNIFORMITY IN PRACTICE

The following requirements must be met in order to achieve a satisfactory level of quality control:

1. Quality control should be the responsibility of the general manager or chief engineer for functional structure.
2. Inspection must be performed by personnel other than those responsible for production.

3. Quality standards in policy and practice should be set.

4. Whenever possible, highly varied practices that are subject to human error in judgment should be eliminated.

5. Uniform methods for reporting, reviewing, and record keeping should be established.

D. INSPECTION AND RECORDS

1. **Scope of Inspection:** In general, prestressed concrete plant inspections should include the following:

   a. Identification, examination, testing, and acceptance of materials

   b. Inspection and recording of tensioning

   c. Inspection of beds and forms prior to concreting

   d. Checking of the dimensions of members, number, size, and positions of tendons, reinforcing steel, other incorporated materials, openings, blockouts, etc.

   e. Regular inspection of batching, mixing, conveying, placing, compacting, finishing, and curing of concrete

   f. Observation of test performances for slump and air content and the preparation of concrete specimens for strength testing

   g. Inspection of operations of detensioning, product removal from beds, and handling and storing

   h. Final inspection of finished product prior to shipment (that is, monitoring dimensions, camber, blockouts, and adequate concrete cover and finishes)

   i. General observation of plant equipment, working conditions, weather, and other items that may potentially affect the products

2. **Records System:** Records must be kept by each plant to show complete information regarding materials testing, tensioning, concrete proportioning, placing and curing, and final conditions of members before shipment. These records will establish evidence of proper manufacture and quality of prestressed concrete members.

E. IN-DEPTH INSPECTIONS

1. **By Division of Materials:** The Concrete Section of the Division of Materials will perform a minimum of two in-depth quality control inspections each year, provided the prestress producer regularly produces for KYTC projects during the year. A minimum of one in-depth inspection will be conducted when a producer has at least one major project in a year for the KYTC.

2. **Ratings:** Prestressed producers are evaluated by the following guidelines:

RATING	QUALITY CONTROL
90+	Excellent
80-89	Good
70-79	Poor
69 or less	Unacceptable

A rating of 69 or less requires that the prestress producer be removed from the *List of Approved Materials* (*LAM*) for a period of time to be determined by the KYTC. Two consecutive ratings of 70-79 will require that the producer be placed on probation for a period of time to be determined by the KYTC. A rating of 79 or less during a probationary period will require that the producer be removed from the *LAM* for a period of time to be determined by the KYTC.

IV. APPROVAL OF CONCRETE BATCHING EQUIPMENT AND CONCRETE BATCHING PROCEDURES

A. CONCRETE BATCHING PLANT INSPECTION AND EQUIPMENT

The concrete batching plant and concrete batching equipment must be inspected for conformance to Section 601 of the *Kentucky Standard Specifications* prior to any fabrication for KYTC projects. Follow-up inspections will be conducted at no greater than one-year intervals for the plant and six-month intervals for the scale check. These approval inspections are documented on the Concrete Plant Checklist and Scale Report for Concrete Plants (TC 64-316). Copies are kept on file by the District Materials Engineer (DME) and prestress plant inspectors. The concrete truck mixer inspection, if applicable, must be conducted in accordance with KM 64-311.

B. CONCRETE BATCHING PROCEDURES

Concrete batching procedures, including the storage and handling of materials, must conform with requirements contained in Section 601 of the *Kentucky Standard Specifications*.

V. INGREDIENT MATERIALS

A. CONCRETE MATERIALS

1. **Cement:** The cement must be Type I or Type III portland cement, conforming to the requirements of Section 801 of the *Kentucky Standard Specifications*. Shipments of cement can be used immediately if the accompanying bill of lading indicates a company and the plant location that is on the *LAM* and the shipment has a statement signed by a company official indicating compliance with the applicable ASTM (American Society for Testing and Materials) standard and certifying the cement type. Samples must be taken by the inspector in accordance with KM 64-316 at a minimum of one per month when the plant is producing for the KYTC. Samples can be taken from the weigh hopper or cement truck. Preferably, the inspector will alternate sample sites. The sample size should be approximately one gallon. Appropriate documentation, a completed KMIMS form, and the cement sample are then sent to the Division of Materials for physical and chemical testing. Sample containers may be obtained from the DME or the Division.

2. **Aggregate:**

   a. The aggregate must be from sources on the *LAM* and must meet the applicable requirements of the *Kentucky Standard Specifications* (fine aggregate, Section 804; coarse aggregate, Section 805).

   b. Aggregates must be transferred from stockpiles or other sources to the plant in such a manner as to secure uniform grading. Separate stockpiles of each size must be maintained. If they become segregated, intermixed with other materials, or contaminated with any foreign materials, they cannot be used.

   c. **Samples:** Monthly quality assurance (-200 wash test and sand equivalent) and gradation samples must be taken by the inspector and tested by the materials lab of the responsible district, when the plant is manufacturing for Kentucky.

   d. For box beams used for the riding surface, aggregate must conform to Section 805.04.01 of the *Kentucky Standard Specifications*.

3. **Mixing Water:** Water supplied by public distribution systems is normally accepted without testing. Water from other sources must meet the requirements of Section 803 of the *Kentucky Standard Specifications*.

4. **Fly Ash:**

   a. Shipments of fly ash must have a bill of lading indicating the company and plant location, a signed certification that the fly ash complies with ASTM C 618 and the *Kentucky Standard Specifications*, and the latest actual test results for fineness and loss on ignition. The company and plant location must be on the *LAM.*

   b. **Samples:** A one-gallon sample must be taken monthly. This sample, along with a complete KMIMS form and a copy of the bill of lading, should be sent to the Division of Materials for physical and chemical testing.

5. **Admixtures:** The inspector must determine that all concrete admixtures are on the LAM. The inspector must obtain a one-quart sample of each admixture on a yearly basis and forward it to the Division of Materials for chemical analysis along with a completed KMIMS form.

B. REINFORCING STEEL

1. **Prestressing Steel Strand:**

   a. A certification from the strand supplier for each heat number is required, stating that the strand meets ACI 318 requirements for transfer and development strength. Unless specified otherwise, prestressing strands must have ½-inch nominal diameter and be 270 grade low-relaxation uncoated seven-wire strand as in accordance with AASHTO (American Association of State Highway Transportation Officials) M203. Each reel must be identified by heat number and reel number. All strands must be free of dirt, oil, paint, corrosion, or any material that may prevent bond between the strand and the concrete. Strands with kinks, beads, nicks, or other defects cannot be used. A light coat of rust is not cause for rejection if the loose rust is removed and the surface of the strand is not visibly damaged. Strands must be stored in a dry enclosure and/or kept covered by a waterproof material.

   b. **Samples:** Strands are sampled by the inspector at a rate of two 54-inch pieces per heat number per shipment. Submit them to the DME, with two copies of a completed KMIMS LAB-PHYSICAL form. As part of the sampling procedure, the ends of each piece are braised or fused together (all seven wires) by the producer.

2. **Reinforcing Bars:**

   a. Reinforcing bars must be on the *LAM* and comply with the applicable standards of Sections 602 and 811 of the *Kentucky Standard Specifications*. The inspector must visually inspect each shipment for defects, rust, proper grade marking, and (if epoxy-coated) any damage to the coating. Each shipment from the manufacturer must be accompanied by a Fabricator's Heat Number Identification of Reinforcing Bars (TC 64-122), listing the heat numbers and amount (in pounds) shipped for each heat. Shipments of epoxy-coated steel should also have a certificate of compliance from the epoxy coater. Any reinforcing bars that are not heat identifiable cannot be accepted.

   b. Completed copies of the KMIMS LAB-PHYSICAL form and Fabricator's Heat Number Identification of Reinforcing Bars must be submitted to the DME. (For epoxy-coated shipments, epoxy coaters' certificates of compliance must also be submitted.) All shipments require submission of one 54-inch check sample. All steel must be stored on pallets or racks in areas free of mud and debris.

C. MISCELLANEOUS ACCESSORIES

1. **General:** Lifting devices, inserts, tie rod tubes, dowel bar tubes, and void drains must be fabricated and anchored or tied in place as shown on the plans and visually approved by the plant inspector.

2. **Cork:** Each shipment must contain a copy of the manufacturer's certification stating conformance to AASHTO M153. A completed copy of the certification must be submitted with the beam shipment to the DME.

3. **Guardrail:** The inspector must check all items in shipment for conformity to dimensional requirements and condition of galvanizing. For projects requiring 1,000 feet or less, the guardrail may be accepted by certification. Any item can be tested if either the dimensions or the quality of the galvanizing is questionable. Samples and two copies of a completed KMIMS LAB-PHYSICAL form must be submitted to the DME.

4. **Tie Rods:** A copy of the manufacturer's certification stating that the steel meets the requirements of ASTM A36 must be obtained. A completed copy of the KMIMS LAB-PHYSICAL form and the manufacturer's certification must be submitted to the DME.

5. **Voids:** Fabricate voids of styrofoam or from cardboard that has been treated with a waterproofing agent. Glue and band all voids made by stacking more than one piece of material to prevent separation during concreting operations. The engineer will regard any evidence of separation as cause for rejection. Inspectors must determine that voids are stored so that no damage due to inclement weather or improper handling occurs. If the voids are damaged, the inspector will require proper repair before they can be used. The void position must be checked during beam fabrication to determine that the dimensional tolerances of Section 605.03.08 of the *Kentucky Standard Specifications* are met.

6. **Strand Chucks:** Chucks must be capable of anchoring the strand without slippage after seating. Any vise that becomes visibly worn or distorted or shows evidence of post-seating slippage of the strand must be discarded.

VI. STRESSING REQUIREMENTS

A. METHODS OF STRESS MEASUREMENT

Stressing force measurement methods consist of: (1) pressure gauges to measure force from the pressure applied to hydraulic jacks, (2) dynamometers connected in tension into the stressing system, (3) load cells connected into the stressing system so the stressing operation imparts a compressive force to the sensing element, and (4) elongation computed from the force applied to the strand based on its physical properties and compensation adjustment. This fourth method is used as a check on Methods 1-3.

B. GAUGING SYSTEMS

1. **Calibration Requirements:** Hydraulic pressure gauges, dynamometers, load cells, or other devices for measuring the stressing load must be calibrated to an accuracy of ± 2%. Gauges, jacks, and pumps must be calibrated as a system in the same manner as they are used in tensioning operations. Calibrations must be performed prior to the start of production and then annually. Calibrations must be performed by an approved testing laboratory with standard weights and measures meeting the requirements of the United States Bureau of Standards. A certified calibration curve must accompany each tensioning system. Calibrations must be performed anytime when a tensioning system indicates erratic results.

2. **Hydraulic Gauge Requirements:** Hydraulic gauges must have dial size of 6 inches or more and indicate the load on the jacking ram directly in pounds, with a minimum graduation interval of 500 pounds. The gauges must have a full pressure capacity of approximately twice the working pressure; and unless calibration data clearly establishes an accuracy over a greater range, the loads to be gauged must not be less than ¼ or more than ¾ of the total graduated dial capacity.

3. **Additional Requirements:** A tensioning system using hydraulic gauges must have appropriate by-pass pipes, valves, and leak-proof fittings so gauge pointers remain steady until the jacking load is released. Gauges must be mounted at or near working eye level and within 6 feet of the operator. They must also be positioned so readings can be made without parallax. The tensioning operation must be halted if the system is not operating satisfactorily.

VII. PRETENSIONING

A. CASTING BEDS AND FORMS

1. **Casting Beds Preparation:**

   a. **Inspection for Deviations:** Inspectors must periodically check the casting beds for deviations from a plane surface. If deviations exist that cause irregularities in the bearing area of the beams, the producer will be informed and the situation corrected before production begins. Also, if any other observed irregularities approach or exceed the established tolerances, they must be corrected before production begins.

   b. **Release Agent:** The casting bed must be treated with a non-petroleum based release agent (see Section 605.02.05 of the Kentucky Standard Specifications) before stringing of strands. Release agents that remain as an oil and do not dry must be evenly applied. This coating will ensure release, and should be applied without excess or puddles that would contaminate strands placed in the form. The inspector should examine the strands before the side forms are placed. Any contaminated strand will be replaced or satisfactorily cleaned.

2. **Forms:**

   a. **Specifications:** Forms must comply with the provision of Section 605.03.02 of the *Kentucky Standard Specifications.* The inspector must ensure that the forms meet all specifications. Forms, bulk heads, spacers, spreader bars, templates, and other equipment that has a bearing upon the accuracy of dimensions and trueness of lines of the completed beams must be periodically checked.

   b. **Maintenance:** Forms must be clean and free from the encrustations of hardened concrete. To ensure this, forms must be cleaned after each pour. Producers will be informed of any observed discrepancies and the necessary corrections must be made. Extreme care must also be exercised to prevent the debonding agent from coming into contact with the strands and reinforcement.

B. STRINGING AND TENSIONING STRANDS SEQUENCE

To avoid possible entanglement of strands during tensioning, a definite sequence of stringing and tensioning should be followed. The stringing of the strands should start with the bottom row and progress to the top row. For each row, the stringing should progress from one side of the bed to the other. An orderly procedure of stringing and tensioning the strands also facilitates record keeping. This is essential when the data from a load- recording device is to be identified with the individual strands tensioned.

C. PRELOAD

After strands are positioned, an initial force (given on approved drawings) in the range between 2,000 and 5,000 pounds should be applied to each strand. This force will straighten the strands and eliminate undue sag. It will also provide a reference point for measuring elongation under the subsequent loading. In the case of multiple strand tensioning, preloading produces essentially the same stress in all strands before the simultaneous pulling is started. The length of the casting bed and strand size will affect the amount of preload required.

D. DESIGN LOAD

1. **Reference Points:** Before the design load is applied to the tendons, reference points for measuring elongation due to the additional tensioning forces must be established. With hydraulic gauge systems, reference points or marks are placed on each strand adjacent to the strand vice (chuck) after preloading. Location of reference points will vary with different methods of tensioning and with the physical characteristics of the equipment used.

2. **Tensioning:**

   a. **Measurements:** In all methods of tensioning, stress induced in the tendons is determined by monitoring the applied force and measuring elongation. These two checks must agree within ± 5%.

   b. **Retensioning:** If the two measurements do not agree within the required tolerance, the strand must be retensioned. During this operation the inspector will look for possible misalignment of the jacking ram, entanglement of strands, or any other conditions that may have a bearing on the accuracy of applying the load. If the discrepancy still persists, three or more additional strands should be tensioned and the agreement between the gauge and strands observed. The gauge is considered operative if agreement well within the tolerance limit is observed. Some variation in the modulus of elasticity of the strands sometimes exists. Because of this variation, the tensioning of the strand in question may be accepted if the difference between the elongation measurement of the load and the dial measurement does not exceed ¼ inch. Also, only 10% of the total number of strands tensioned on any casting bed can be accepted on that basis.

3. **Discontinuation of Tensioning:** The tensioning will be discontinued if the difference between the two measurements persistently falls near or encroaches upon either of the tolerance limits. Before tensioning continues, the equipment and operation must be carefully checked and the source of the error determined and corrected.

E. DRAPED STRANDS

1. **Tensioning:**

a. **Strand Positioning:** Draped or deflected strands must be tensioned in the deflected position. The strands are held in the deflected position, with respect to the casting bed, at all points of change in slope by positioning devices. These devices must have a pin and roller feature that minimizes friction during tensioning. They must also be sufficiently rigid and adequately support the strand position so it will not move under the induced loads. To accommodate casting beds, a deviation in longitudinal direction (see Section 605.03.08 of the *Kentucky Standard Specifications*) not exceeding 6 inches from the position shown on the plans is permitted. This deviation is with respect to the hold-down device on either side of the center of the beams, provided that the symmetry of their locations about the center is maintained.

b. **Loads:** Each strand must be tensioned to the preload and design load. The loads determined by elongation measurements are based on the true length of the deflected strand, not the length of the casting bed.

2. **Multiple Beam Tensioning:**

a. **Tension Strand at Both Ends:** If more than one beam is in the casting bed, the draped strand must be tensioned successively from both ends. At each end, the strand is pulled to the desired load and elongation measured. The load determined from the sum of the two elongation measurements must agree within 5% of the gauge reading. If the casting bed is set up for one beam and the 5% tolerance in elongation is achieved by the cable at one end, tensioning at the subsequent end can be waived.

b. **Positioning Devices:** Friction at each of the positioning devices resists some of the force exerted in pulling the strand. The load actually applied to the strand, therefore, is decreased at each successive point of deflection away from the source of pull. When several beams are cast in the same bed involving a large number of positioning devices, the loss of stress away from the source or sources of pull may be excessive. This occurs even though tensioning is performed from both ends and is evident by the disagreement between elongation measurements and gauge readings. When this situation occurs, the number of beams to be cast on the bed must be reduced sufficiently so friction losses do not influence the tensioning beyond the permissible degree.