PRECAST/PRESTRESSED CONCRETE MANUAL

ISSUED BY

COMMONWEALTH OF KENTUCKY
TRANSPORTATION CABINET
DEPARTMENT OF HIGHWAYS

KENTUCKY
TRANSPORTATION
CABINET

DIVISION OF MATERIALS
FRANKFORT, KENTUCKY

June 2006

Kentucky
UNBRIDLED SPIRIT™

TRANSPORTATION CABINET
Frankfort, Kentucky 40622
www.kentucky.gov

Ernie Fletcher
Governor

Bill Nighbert
Acting Secretary

Jim Adams
Deputy Secretary

Marc Williams
Commissioner of Highways

Dan Druen
Commissioner of
Administrative Services

Paul Steely
Commissioner of Aviation

Roy Mundy
Commissioner of
Vehicle Regulation

OFFICE OF THE SECRETARY
OFFICIAL ORDER 103077

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All previous instructions, written and oral, relative to or in conflict with this manual are hereby superseded.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
Department of Highways
Division of Materials
1227 Wilkinson Boulevard
Frankfort, KY 40601

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 — 7/27/06 Date

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

PRESTRESS PRODUCTS

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.

F. ELONGATION MEASUREMENTS

1. **General Information:**

a. **Gauge Readings:** In single-strand tensioning, gauge readings are preferred over elongation measurements. Loads determined from elongation measurements, assuming that slippage and other losses are properly taken into account, are subject to errors introduced by variations of the modulus of elasticity of individual strands from that used in calculating the loads. These errors are normally within tolerance limits. Since gauges become inoperative, a check between the two methods of determining the load must be made. Elongation measurements, when properly made, establish dependability of the loads applied.

b. **Accuracy:** The degree of accuracy needed in reading the elongation depends on its size, which in turn depends on the length of the strand tensioned. The load corresponding to the error of measurement should not exceed 1/2% of the final load. On this basis, measurements to the nearest 1/8 inch, which should correspond to maximum errors of approximately 1/16 inch, are satisfactory for casting beds 150 feet in length or longer. If shorter beds are used, the inspector should try to make measurements to the nearest 1/16 inch.

c. **Reference Marks:** To improve accuracy, reference marks are used in elongation measurements. They can be made with a suitable pencil and show adequate contrast against the strand. These marks will also form a boundary to ensure accurate readings. When marks are made after preloading, they should be placed so they can be seen by a person standing upright.

2. **Strand Slippage:**

a. **Compensation:** Release of strands from a single-strand jack results in a seating loss as the strand anchors into the live end chuck. To compensate, strands should be stressed and elongated additionally to offset the seating. Slippage or "slip back" of 1/4 inch to 1/2 inch is common. The inspector must observe the slip back during tensioning to make corrections specifically for each plant. When slippage from strand to strand becomes excessively inconsistent, the grips in the chuck should be replaced. Slip back is a loss and must be compensated for with a load correction.

b. **Slippage:** Slippage at the far end anchorage should be indicated by the difference in the gauge reading and the measured elongation. Therefore, to compensate for this slippage, the inspector should add the typical value to the theoretical elongation calculated. The typical value is determined by making reference marks on the strands 1 inch from the chucks after preloading. After the design load is applied, the amount of slippage can be measured. These determinations should be made on a few strands during each tensioning operation. Slippage at the far end anchorage is a gain and must be added to the computed elongation.

3. **Anchorage Movements:**

a. **Corrections:** The loads on the tensioned strands unavoidably produce some movement of the anchorages. Depending upon the construction of the anchorages, various conditions may contribute to this movement, such as the deflection of cantilevers, shortening of casting beds, transverse deflection of strand grillages, and perhaps others. Some think that anchorage movements are generally so small that they do not need to be considered. However, the inspector must make measurements to see whether corrections are necessary. Once accurate measurements have been made for any pair of anchorages, they do not have to be repeated for similar strand patterns and comparable loads.

b. **Measuring Movements:** Anchorage movements are measured at the level of the uppermost row of strands in the bottom slab of deck beams and the center of I-beams. Unless a better method is available, the movements are determined by measuring, before and after tensioning, the horizontal distance from each anchorage to a fixed point. The fixed point can be a rod driven solidly in the ground behind each anchorage at a location that will not be influenced by forces exerted during tensioning. Anchorage movements should be checked annually and corrections made accordingly. Anchorage movements are gains and should be added to the elongation computations.

c. **Strand Stresses:** Since tensioned strands are held at a fixed length, temperature variations produce changes in the strand stresses. A differential in temperature between the time of tensioning and the time when the strands reach the temperature of the concrete placed around them results in either a reduction or an increase of the strand stresses. This result depends on whether the temperature differential causes elongation or contraction of the strands. In cold weather the thermal correction is an addition to the elongation calculation; in hot weather the correction is subtracted.

d. **Corrections:** If the temperature differential of the strands results at the time of tensioning and the concrete exceeds 20°F, a correction must be made for the amount the strands may contract or expand. Strands should never be tensioned if the ambient temperature is below 20°F and no artificial heat source is available to warm the bed and strand. Theoretically, the temperature of the concrete at the time the bond with the strand becomes effective should be considered rather than the temperature of the concrete mixture. However, when this occurs is indeterminate, and the error is believed to be insignificant. Therefore, the temperature of the mixture at the time of placement is considered the temperature the strands reach. When correction is to be made, the temperature of the mixture used in determining the differential must be maintained as near as possible when placing the concrete.

e. **Determining Correction:** Only the length of the strand to be embedded in the concrete should be considered when determining the correction to be applied to the load on each strand. The thermal coefficient of expansion for the steel is taken as 0.0000065 inch per inch of strand per degree (F) of temperature differential.

f. **Continuous Pour:** Concreting operations must be arranged so that when the temperature at the time of tensioning is such that corrections must be made to compensate for change in strand stresses. All beams on the bed should be cast in a continuous pour.

4. **Strand Splices:**

a. **Permitted:** Only one splice is allowed on any one strand between abutments. The location of the splice cannot fall within a beam. In the case of single-strand tensioning, there is no limit to the number of strands that can be spliced because the slippage of individual splices can be checked and corrections made for excessive slippage. Even though only one manufacturer can be used in any one tensioning operation, there is a possibility that variation in manufacturer may exist. Making sure the direction of the wire twists is the same as that of the strands spliced will verify that no variation exists.

b. **Slippage Compensation:** Slippage of strand splices must be compensated for in elongation measurements. Appropriate reference marks should be made at each splice chuck so that measurements can be taken. If unusual slippage occurs that will not be compensated, the inspector should contact his or her supervisor.

c. **Reference Marks:** Since some time may elapse between tensioning and fabrication of the beams, reference marks for checking slippage after tensioning should be made with indelible ink or a band of suitable adhesive tape around each strand.

d. **Inspection:** All spliced strands must be checked for slippage prior to concreting. If slippage of any strand is found that affects the design load by more than 1%, the strand or strands must be retensioned. Slippage of strand splices is a gain and must be added to the computed elongation.

5. **Wire Breaks:** Occasionally during tensioning, wires in the strand will break. The inspector must check the bed after tensioning. The number of wire breaks permitted to remain on prestressed concrete beds having the following quantities of strands are:

STRANDS	WIRE BREAKS
Less than 10	None
10-29	One
30-49	Two
50+	Three

a. **Beyond Limitations:** If any strand pattern has more than the permissible number of wire breaks, the strand or strands must be removed and replaced. Also, if any individual strand has more than one broken wire, it must be replaced.

b. **Within Limitations:** If any permissible wire breaks occur, the ends should be tied to the strand with wire. When tensioning a strand with a broken wire, the strand should be pulled to the same elongation as strands with no broken wires but not on the same load. Theoretically, the elongation should be obtained with approximately 86% of the load required for whole strands because the effective cross-sectional area is reduced by about 14%.

6. **Strand Rotation (Observation of Jacking Ram Rotation):** In single-strand tensioning, there is a tendency for the jacking ram to rotate and, to some degree, unwind the strand. This rotation will affect a change in the modulus of elasticity of the strand so that the elongation measured does not correspond to the modulus used in calculating load applied. Rotation of more than one revolution of the jacking ram during tensioning, therefore, must be prevented. With current hydraulic ram systems, strand rotation is very unlikely and need not be compensated for in elongation computations.

7. **Remnant Strands:** Strands that have previously been tensioned one time can be used three additional times providing they are properly identified, clean, free of vice nicks, or other damaged areas and have attained the computed elongation when retensioned. For economic reasons, fabricators should consider using the remnant strands in beams prior to tensioning them four times. Using strands from different manufacturers in the same bed is not allowed.

8. **Debonding of Strands:** The debonding of strands must be accomplished using methods or materials approved by the Division of Materials. When split sheathing is used, it must be taped at the ends, and the sheathing must prevent leakage of paste into the sheathing by wrapping 1½ times or by taping entire length. Solid sheathing must be taped at each end.

G. ELONGATION NOMENCLATURE AND FORMULAS

1. **General Information:** Both inspector and producer should be thoroughly familiar with the nomenclature and formulas used in computing strand elongations. It is the inspector's responsibility to calculate strand elongations according to the nomenclature and formulas in this manual. The producer should check all calculations before stressing.

2. **Nomenclature:**

The following nomenclature applies specifically in the use of the formulas to follow:

A_S = Cross-sectional area of steel in one prestressing strand (square inches)

e_d = Draped strand elongation from preload to design load (inches)

e_{je} = Jacking end "slip back" or seating loss (inches)

e_{st} = Straight strand elongation from preload to design load (inches)

e_o = Correction due to operational loses (inches)

e_t = Elongation correction due to thermal effects (inches)

e_c = Corrected elongation ($e_{st} + e_o + e_t$) (inches)

E_s = Modulus of elasticity of prestressing strand (pounds per square inch)

L = Length of straight strands being gauged, usually the length from the far end anchorage to elongation reference mark placed at preload (inches)

L_b = Length of beams in casting bed (feet or inches)

L_d = Length of draped strands being gauged (inches)

P = Load per (inch) of elongation (pound/inch)

P_c = Load correction for thermal effects and jacking end slip back (pounds)

P_D = Specified design load on strand (pounds)

P_i = Initial load or preload on strands (pounds)

R_L = Ratio of draped cable length to straight cable length

3. **Formulas:**

Total Elongation: The following expression represents total elongation, from preload to design load:

$$e = \frac{(P_D - P_i)L}{A_S \times E_s}$$

The specified design load (P_D) on a strand is read directly from the shop drawings. The actual cross-sectional area of the strand (A_S) and the modulus of elasticity (E_s) are provided by the manufacturer. The ratio of the load on the strand (from preload to final load) to the corresponding elongation, that is the load per (inch) of elongation, is conveniently used in determining load equivalents of corrections that must be made due to loss or gain in strand elongation. This ratio is expressed as follows:

$$P = \frac{(P_D - P_i)}{e}$$

Please note that the value of P depends upon the values of L, A_S, and E_s and remains constant only when all these values remain constant.

4. **Example:** To illustrate the use of formulas and the computations involved, suppose you are required to determine the necessary data for tensioning ½-inch strand. Assume the following:

- The modulus of elasticity of the strand (E_s) is 29,500,000 pounds per square inch.
- The specified design load (P_D) is 29,100 pounds.
- The length of the strand between anchorages is 3,413 inches.
- The preload (P_i) is 3,000 pounds.
- There are 20 straight and 8 draped strands.
- The draped strands are a total of 4 inches longer than the straight strands.
- The cross-sectional area of the strand is 0.153 inches square.
- The temperature of the strand at the time of tensioning is 32° F, while the concrete temperature is 62° F.
- Operational losses are:
  - Slip Back = 1/4 inch
  - Far End Slippage = 1/8 inch
  - Anchorage Movement = 1/16 inch
  - There are no splice cables.

Note: See **Exhibit 1** for a table of decimal equivalents that will help in converting decimals into fractions to the nearest 1/16 inch.

5. **Tensioning Data:**

a. **Single vs. Draped Strand:** The elongation for Prestressed Concrete Members (TC 64-310) is provided for calculating and recording single- strand tensioning data. When the ratio of draped-strand length to straight- strand length is not greater than 1.002, the tensioning data calculated for the straight strand can be used for both. In this case the ratio of draped-strand length to straight-strand length must be shown on the form. If the ratio is greater than 1.002, the calculations for the draped strand must be shown on the form.

b. **Thermal Effects:** When required, correction for thermal effects as calculated on the example worksheet, *Correction for Thermal Effects on Strand Load* **(Exhibit 2),** must be properly included in the tensioning-data calculation. In the example, tensioning in cold weather was assumed. When the temperature of the strand is increased to that of the concrete mixture, it relieves some of the strand tension. Such loss must be compensated for beforehand by the proper increase of the load when tensioning. If the tensioning is done in hot weather and the temperature of the strand is decreased to the concrete-mixture temperature, the situation is reversed.

c. **Operational Losses:** In correcting operational losses, the term "loss" is a reference to any condition that requires an algebraic addition to the elongation computed on the basis of the theoretically required load and an equivalent addition to that load. Losses that affect only certain individual strands, such as slippage due to splices, are noted separately. The inspector will make the necessary corrections for these instances as they are tensioned. Tensioning-data calculations must be kept on file at the district office as part of the project's records.

6. **Calculation Examples:**

1. $e_{st} = \frac{(P_D - P_i)^L}{A_s \times E_s} = \frac{(29{,}100 - 3{,}000) \times 3413}{0.153 \times 29{,}500{,}000} = 19.74\ (19\ 3/4)$

2. Ratio of Draped-Cable Length to Straight-Cable Length:

   $R_L = \frac{3{,}417 \text{ in.}}{3{,}413 \text{ in.}} = 1.001$ (Elongation for draped cable is approximately equal to straight cable.)

3. Thermal Correction:

   a = 0.0000065 inch per inch strand per °F.

   $T = T_2 - T_1 = 62°F - 32°F = 30°F$

   L_b = (3 beams at 72 feet each) = 216 feet x 12 inches/foot = 2,592 inches

   et = a x L_b x T = 0.0000065 x 2,592 x 30 = 0.51 inches (1/2 inch)

4. Corrections for Operational Losses and Gains:

   Far End Slip + 1/8 = 0.125

   Anchorage Movement + 1/16 = 0.0625

   # Spliced Strands = 0 Spliced Strands

   e_o = 0.125 + 0.0625 + 0 = + 0.1875 = + 3/16

   Corrected Elongation:

   $e_{cst} = e_{st} + e_t + 0.1875 = 19\ 3/4 + 1/2 + 3/16 = 20\ 7/16$

5. Load Correction for Thermal Effects (P_c) and Slip Back (e_{je}):

   $P = \frac{P_D - P_L}{e} = \frac{29{,}100 - 3{,}000}{19.74} = 1{,}320$ pounds/inch

   $P_c = P \times (e_t + e_{je}) = 1{,}320 \times (1/2 + 1/4) = 990$ pounds

6. Corrected Load:

   $P_D + P_c = 29{,}100 + 990 = 30{,}090$ pounds

   Elongation:

   $e_{cst} = 20\ 7/16$
   e_{cst} (min) = 0.95 x e_c = 19 1/12
   e_{cst} (max) = 1.05 x e_c = 21 1/12

VIII. STRAND RELEASE

A. GENERAL INFORMATION

1. **When to Transfer Stress:** Stress cannot be transferred to pretensioned members until the last batch in the casting bed or until the batch that contains the weakest concrete due to higher slump or air content has attained specific release strength. (Refer to Section 605.03.05 D) of the *Kentucky Standard Specifications*.)

2. **Heat-Cured Members:** If members have been heat cured, then forms must be removed and members detensioned within 30 minutes after curing is discontinued. Section 605.03.05 D) states that members must be detensioned immediately after curing. The 30-minute allowance is a reasonable amount of time to uncover the casting bed, loosen side forms, and begin the detensioning process without allowing excessive cooling of the members after the heat or steam source has been turned off. Curing should never be discontinued before detensioning strengths are obtained. (Refer to Section 605.03.05 E) of the *Kentucky Standard Specifications.*)

3. **Prestressing Forces:** In all detensioning procedures, the prestressing forces must be kept nearly symmetrical about the vertical axis of the member and must be applied in a way that will minimize sudden shock or loading. In all cases shop drawings must show the proposed detensioning pattern that will be followed.

4. **Trimming Prestressed Strands:** The ends of prestressed strands (except those to be encased in concrete) must be trimmed within 1/8 inch of the concrete. The ends should then be thoroughly coated with asphalt paint prior to storage of the beam or within 48 hours of form removal. Coating will help prevent the strands from rusting during storage.

B. DETENSIONING

1. **Draped Strands:** Draped pretensioned strands should be detensioned in the following manner:

    a. The following sequence should be followed for detensioning, unless the precast concrete member is twice the weight of the total forces required to hold the strands in the low position within the member or unless the members are weighted or restrained in an approved manner to resist the uplifting forces on the member at the hold-down points:

        1. Release the tension in the draped strands at the ends of the members by heating each strand until it fails. The draped strands should be heated to failure at each uplift point in accordance with an approved sequence as shown in the working drawings.

        2. All hold-down devices for the draped strands should be released and the hold-down bolts within the members removed.

        3. Straight pretensioned strands should be detensioned after the draped strands and hold-downs have been detensioned. Straight strands may be detensioned by either the single-strand or the multiple-strand release method.

    b. When the weight of the precast concrete member is more than twice as great as the total of the forces required to hold the deflected strand in the low position within the member, the following sequence for detensioning the prestressed strands can be used at the fabricator's option:

1. Hold-down devices for the deflected strands can be released and the hold-down bolts within the member removed.

2. Deflected strands and straight strands can be detensioned by either the single-strand or the multiple-strand release method.

c. When the weight of the member is less than twice as great as the total of the hold-down forces, weights or an approved vertical restraint can be applied to the member in order to counteract the uplifting forces at the hold-down points when hold-down devices are released. The weights or vertical restraint added to the member should be placed directly over the hold-down points for the deflected strands. When the total weight of the member plus the added weights or restraint is more than twice as great as the hold-down forces, the strand-detensioning method of releasing hold-down devices before releasing strand tension can be followed.

2. **Multiple Strands:** Strands are released simultaneously by hydraulic dejacking. The total force is taken from the header by the jack and then released gradually.

   Note: The overstress required to loosen lock nuts or other anchoring devices at the header cannot exceed the force in the strand by more than 5%.

3. **Single Strands:** The strands are released by heating the strands in accordance with an approved pattern and schedule. Heating is performed simultaneously at both ends and at one place near the center of the prestressing bed and preferably at all spaces between ends of members. Where spaces between ends of individual members are short, simultaneous heating at all spaces between members may not be required; however, any variance must be in accordance with an approved sequence.

4. **Heating Requirements:** In order for release of the strands to occur gradually, they should be heated until the metal gradually loses strength. Heating should be done with a low-oxygen flame (fairly large) played along the strand for a minimum of five seconds. Heating tips are required on the torches. The sequence for heating the strands should be according to an approved schedule indicated on the shop drawings. This sequence must keep the stresses nearly symmetrical about the axis of the members.

IX. POST TENSIONING

A. GENERAL INFORMATION

1. **Post-Tensioned Member Stressing:** Many of the considerations applicable to pretensioned concrete also apply to post-tensioned member stressing. The concrete must have developed the specific compressive strength as indicated by test cylinders. Tendons must be tensioned in accordance with a required sequence, as determined by the design, to keep stresses within predetermined limits of symmetry about the axis of the member.

2. **Measuring Stress:**

   a. **Hydraulic Jacks and Gauges:** Hydraulic jacks must be equipped with calibrated hydraulic pressure gauges that will allow calculation of the tendon stress at any time. A calibration chart, current within six months, must be furnished for each jack-pump-gauge unit. If inconsistencies between the measured elongation and the jack gauge reading occur, the jack and gauge must be recalibrated.

   b. **Elongation and Gauge Readings:** These must also be used to measure stress in tendons. Due to frictional losses associated with post-tensioned members, and generally due to their relatively short length (as compared to most pretensioning beds), the predetermination of jacking loads, elongations, accuracy in measurement, and reconciliation are particularly important. The elastic shortening of the concrete members during tensioning must be considered when computing apparent elongations.

   c. **Records:** Records must be maintained for plant post-tensioning operations in the same manner as other plant operations. General records will include tensioning and grout testing.

   d. **Many Varied Systems:** Some systems are patented and use varied tensioning techniques and types of tendons. Post-tensioning systems must be installed in accordance with manufacturers' directions and proven procedures. Manufacturers' recommendations must be observed regarding end block details and specific reinforcement in anchorage zones applicable to their particular systems.

B. DUCTS

1. **Details and Positions for Ducts:**

   a. **Usual Formation:** Ducts are usually formed by flexible or semi-rigid metal tubing installed within the member. Tendons which will not be bonded by grouting may be installed in ducts of plastic, fiber, or other material. Metal ducts must be of ferrous metal and may be galvanized. Aluminum or PVC cannot be used for ducts.

   b. **Alignment and Position Are Critical:** Ducts must be properly aligned and positioned within the member. Short kinks or wobbles in alignment will result in appreciable increases in friction during tensioning. The trajectory of ducts must not depart from the curved or straight lines shown on the design drawings by more than 1/2 inch per 10 feet. For curved members, the tendons, and consequently the ducts, must be placed on or symmetrically about the axis of the member that is parallel to the direction of the curvature. The vertical position of the ducts at critical locations must be maintained within a dimensional tolerance consistent with the size and usage of the members. The maximum variation from the specified position can be ± 1/4 inch or 1/8 inch per foot of depth, whichever is smaller. The area of alignment of ducts must allow the tendons to move free within them. If grouting is used, the area must be large enough to permit the grouts free passage. Ducts installed in members prior to concrete casting must be constructed so they will not admit concrete or mortar during casting. Ducts or duct forms must be supported and fastened so they won't move during casting and compaction of concrete.

2. **Friction in Ducts:** Coefficients and constants used for computing frictional effect have been established by common usage. The jacking force necessary to provide the required stress and overcome frictional force must be indicated. Production documents must also show the techniques used in jacking. These may consist of over-jacking and over-elongation followed by a reduction of load for seating the anchorage or of jacking from both ends.

3. **Applying the Load:**

   a. **Initial Load:** A minimum initial load of 10% of the full load must be applied to the tendons to take up slack and provide a starting point for elongation measurements.

   b. **Final Load:** The final load is then applied, including any overload and release that may be called for in the procedure. The rate of the load application must be in accordance with the post-tensioning manufacturer's recommended procedure. Final force applied to tendons and actual elongation measurements must check with the theoretical values within 5%. If stressing is not achieved within these limits, stressing procedures must be altered until tolerances are met.

C. ANCHORAGES AND GROUTING

1. **Anchorages:** Anchorage devices for all post-tensioning systems must be aligned with the direction of the axis of the tendon at the point of attachment. Concrete surfaces against which the anchorage devices bear must be normal to this line of direction. Anchorage losses, due to slippage or other causes, must be measured accurately and compared with the assumed losses shown in the post-tensioning schedule and must be adjusted or corrected in the operation when necessary.

2. **Grouting:**

   a. **Purpose:** Grouting is an important operation serving to protect the tendons, relieve the anchorage of stress fluctuation, and increase the efficiency of the tendon in resisting ultimate movements.

   b. **Preparation:** Prior to grouting, ducts must be blown free of water after curing and provision made to keep water out of the ducts. To provide maximum protection to the tendons, grouting must be performed within 10 days after completion of the tensioning operation unless otherwise specified. If a delay is expected in grouting, a rust inhibitor can be applied to the tendon before placement in the duct.

c. **Requirements:** Grouting must be done with an approved grout. The cementatious component of the grout must be composed of 20% to 25% Class F fly ash by weight. Other admixtures such as microsilica, "anti-bleed" additives, and/or high-range water reducers may be used in the grout when approved by the engineer. No expansive agents or admixtures containing chlorides or nitrates can be used. The consistency must allow it to be pumped to completely fill the ducts.

d. **Application:** Grout must always be applied by pumping toward open vents. Grout must be applied continuously under moderate pressure at one point in the duct until all entrapped air is forced out the open vents. Vents must not be closed until they discharge a steady stream of grout. Once all vents are closed, pumping should continue until a steady pressure of 100 psi is maintained for 10 seconds.

e. **Temperature Requirements:** Grouting cannot be performed if the surface temperature of the concrete is less than 40°F or if the temperature of the grout is greater than 90°F. Grout and concrete temperature must be maintained at 40°F or above until the grout has attained a compressive strength of 3,000 psi.

3. **Sealing Anchorages:** Tendon anchorages must receive a concrete or grout seal to provide the minimum cover required for the tendon material elsewhere in the structure. This seal must be adequately covered for curing, since shrinkage or contraction cracks will permit moisture penetration. If a concrete or grout seal cannot be provided, the anchorage and tendon end must be completely coated with a corrosion-resistant paint or sealer. The anchorage and tendon end must then receive a cover that will provide fire resistance at least equal to that required for the structure.

X. CONCRETE MIX DESIGN

A. ACCEPTABLE CONCRETE

1. **Requirements:** Section 601.03.04 of the *Kentucky Standard Specifications* allows Class D or Class D Modified concrete for use in all prestressed members except noncomposite concrete box beams. Noncomposite concrete box beams must be made of Class D Modified concrete only. The producer is allowed to use either Type I or Type III cement.

2. **Certified Concrete Technicians:** The producer is required to have a current certified concrete technician who is responsible for the design of the concrete mixtures and for performing quality-control and process-control testing as necessary (see Section 605.02.09 of the *Kentucky Standard Specifications*). The concrete technicians certification must be an ACI Level I and a KRMCA Level II awarded by the KRMCA or the Division of Materials.

B. CONCRETE MIX

1. **Producers Design:** Concrete mix design must be done by the KRMCA Level II and be within the following KYTC limits:

   a. The cement content cannot be less than that specified but cannot exceed 800 pounds per cubic yard.

   b. To ensure that the cement factor is maintained and the allowable water cement ratio is not exceeded, the producer must agree to either increase the cement factor over the minimum allowable by 0.2 bag per cubic yard or perform at least daily (more often if needed for process control) moisture-content tests on the coarse and fine aggregate to be used in calculating the maximum allowable water that can be added at the mixer.

   c. Free moisture tests must be performed in accordance with KM 64-306.

   d. Other requirements as outlined in Section 601.03.03 of the *Kentucky Standard Specifications*.

2. **Seasonal Mix Design:** The *Precast and Prestressed Concrete Mix Design Data* form (TC 64-313) must be submitted to the Division of Materials annually for approval. Also, the *Prestressed Concrete Daily Mix Design Report* (TC 64-315) must be completed by the producer and submitted to the KYTC's inspector. All members represented by the report must be noted on the form.

C. KYTC INSPECTOR

1. **Samples:** Before work begins, the producer must notify the inspector so samples of coarse aggregate, fine aggregate, and cement can be taken. The inspector will resubmit samples whenever there is a source change or at one-month intervals or sooner for the same source.

2. **Producer Compliance:** The KYTC's inspector must have free entry to the producer's facilities to ensure the above criteria are being followed. Inspectors will continue to sample the individual components of the concrete mix at the usual frequency even though the producer is responsible for the final mix design.

XI. BATCH PLANTS, MIXERS, AND ADMIXTURES

A. BATCH PLANTS AND MIXERS

The concrete-batching plant and concrete-mixing requirements must conform to the applicable requirements of this manual and the *Kentucky Standard Specifications*.

B. ADMIXTURES

The use of admixtures must be in conformance with Section 802 of the *Kentucky Standard Specifications*. Admixtures must be added to the concrete mixture separately and through separate dispensers. They are not permitted to intermingle except as they separately intermingle with the concrete in each batch. This is very important because direct contact between the two types of admixtures may impair or nullify the intended effect of one or both.

XII. CONCRETE TESTING

A. PLANT REQUIREMENTS

1. **Concrete-Specimen Testing:** It is important that plants be properly equipped and have an adequate program for testing concrete specimens so that concrete strengths can be readily and accurately determined during transfer of stress and at design age. Each plant must be equipped with approved testing equipment and staffed with certified personnel trained in its use to ensure proper control of concrete and specimen testing.

2. **Test-Equipment Instructions:** Manufacturers' operating instructions must be obtained for all testing equipment and applicable industry standards, KYTC requirements, etc., for materials and testing. These instructions must be kept on file and generally understood by all testing personnel.

B. CONCRETE TEST CYLINDERS

1. **Critical to Quality Control:** Testing concrete strengths by means of test cylinders is an important part of the quality control program at all prestressed plants. For cylinder testing to provide valid results, specimens must closely represent the concrete used in the members.

2. **Quality-Control Personnel:** The producer must have quality-control personnel who make, handle, and test the cylinders. Until test time all cylinders are cured in the same manner as the beam they represent.

3. **Kentucky Test Methods:** Concrete must be sampled and cylinders made in accordance with the following Kentucky test methods:

   a. KM 64-301—Sampling Fresh Concrete

   b. KM 64-305—Making and Curing Concrete Strength Test Specimens in the Field

4. **Requirements:** A minimum of three sets of cylinders must be made from concrete used in each box beam or I-beam. An exception to this is if one batch or truckload of concrete will complete more than one beam. Then, three sets of cylinders must be made from that batch or truckload to represent the number of beams completed. This applies only to box beams without voids, "Type I" I-beams and "Type II" I-beams less than 50 feet long. A minimum of three sets of test cylinders must be from concrete used in each bed of prestressed piling or prestressed deck panels. In all cases, the producer can make more than the required three sets of cylinders if they wish. The producer is required to provide sufficient cylinder molds conforming to ASTM C-470, as well as other necessary equipment needed in molding cylinders.

C. CYLINDER TESTING

1. **Cylinder Testing:**

   a. **Producer Responsibility:** The producer is responsible for cylinder testing. Tests must be made in the presence of the inspector who will observe and record results on the *Inspection for Prestressed Concrete Members* (TC 64-309) form.

   b. **Testing Equipment Calibration:** The testing machine must be calibrated before production begins and annually thereafter. The inspector may require more frequent testing if needed. The machine must be calibrated to ± 1.0% precision. Calibrations must be performed by an approved calibration agency that has equipment traceable to the National Bureau of Standards.

   c. **Temperature Considerations:** Because testing at elevated temperatures may adversely affect strength, cylinders removed directly from steam curing should be permitted to cool to temperatures of 70°F to 90°F before testing.

   d. **Average Cylinder Strength:** All quality decisions for strand release and for beam acceptance must be based on the average strength of one set of cylinders. Therefore, at least one set of cylinders representative of each beam (or beams, see Concrete Test Cylinders of the **Concrete** portion of this manual) on a casting bed must show an average strength of more than that specified before the strands can be released. Also, at least one set of cylinders representative of each beam must show an average strength not less than that specified for acceptance. If the cylinders tested for strand release meet the minimum strength specified for acceptance, one test is sufficient for both release and acceptance.

2. **Test Conditions and Procedures:**

   a. **Condition 1:** The average of one set of cylinders meets or exceeds the specified strength with neither cylinder being less than 90% of the specified strength.
   Procedure: Member is detensioned and/or accepted.

   c. **Condition 2:** The average of one set of cylinders falls within 300 psi of the specified strength.
   Procedure: The producer may elect to test an additional set of cylinders, and the member may be released or accepted if the average strength of both sets of cylinders meets or exceeds the specified strength. If an individual cylinder is 80% or less of the specified strength, the low value is disregarded.

   d. **Condition 3:** The average of one set of cylinders falls below the specified strength by 300 psi or more.
   Procedure: The member must be allowed additional curing before subsequent testing. Cylinders tested prior to additional curing cannot be averaged with those tested after additional curing is allowed. Therefore, at least one additional set of cylinders must be tested to determine release or acceptance strengths (use Condition 1 or 2). An average of two sets in sequence cannot be accepted if one or more of the individual cylinders is 90% or less of the minimum specified strength.

   e. **Condition 4:** The cylinder supply is exhausted before reaching the specified strength.
   Procedure: The producer is responsible for obtaining two cores from each member falling in this category and submitting them through the DME to the Division of Materials for testing.

   Note: The use of impact hammers to determine strand release or acceptance strength is not allowed.

D. PLASTIC MIX TESTING

1. **Minimum Requirements:** The producer is responsible for a minimum of one slump and one air test each time cylinders are made.

2. **Kentucky Test Methods:** Tests must be performed in the presence of the inspector and in accordance with the following Kentucky Methods:

   a. KM 64-301—Sampling Fresh Concrete

   b. KM 64-303—Air Content of Freshly Mixed Concrete by the Pressure Method