PCI Gulf South
A Chapter of the Precast/Prestressed Concrete Institute

Discussion Items with LADOTD and ALDOT

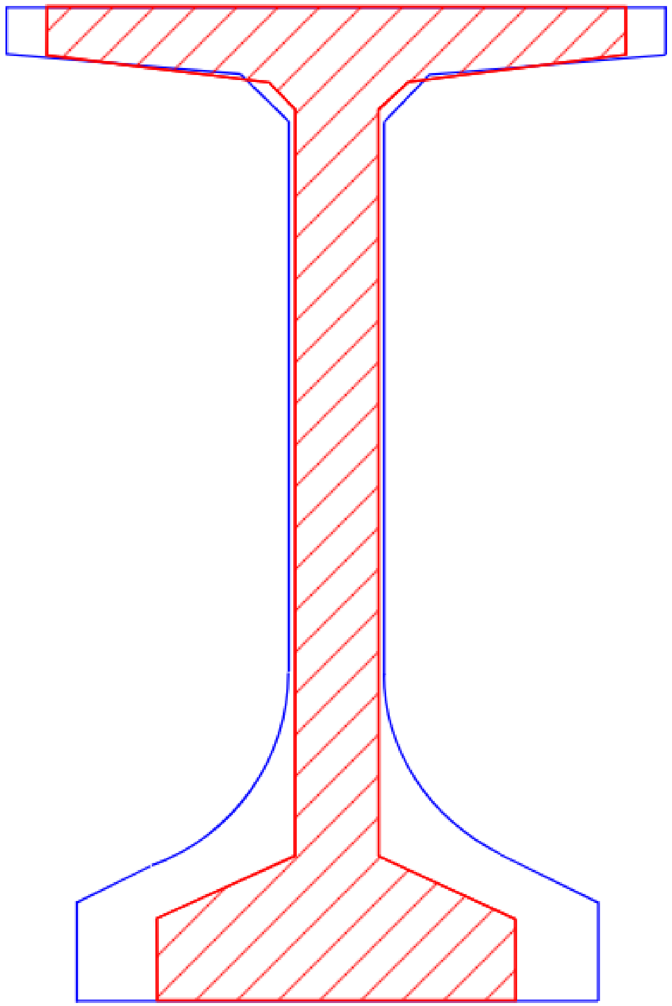
Meeting with ALDOT May 17, 2023

Meeting with LADOTD July 10, 2023

David Tomley, P.E. (GCP/TCP-Chief Engineer)

Section Properties

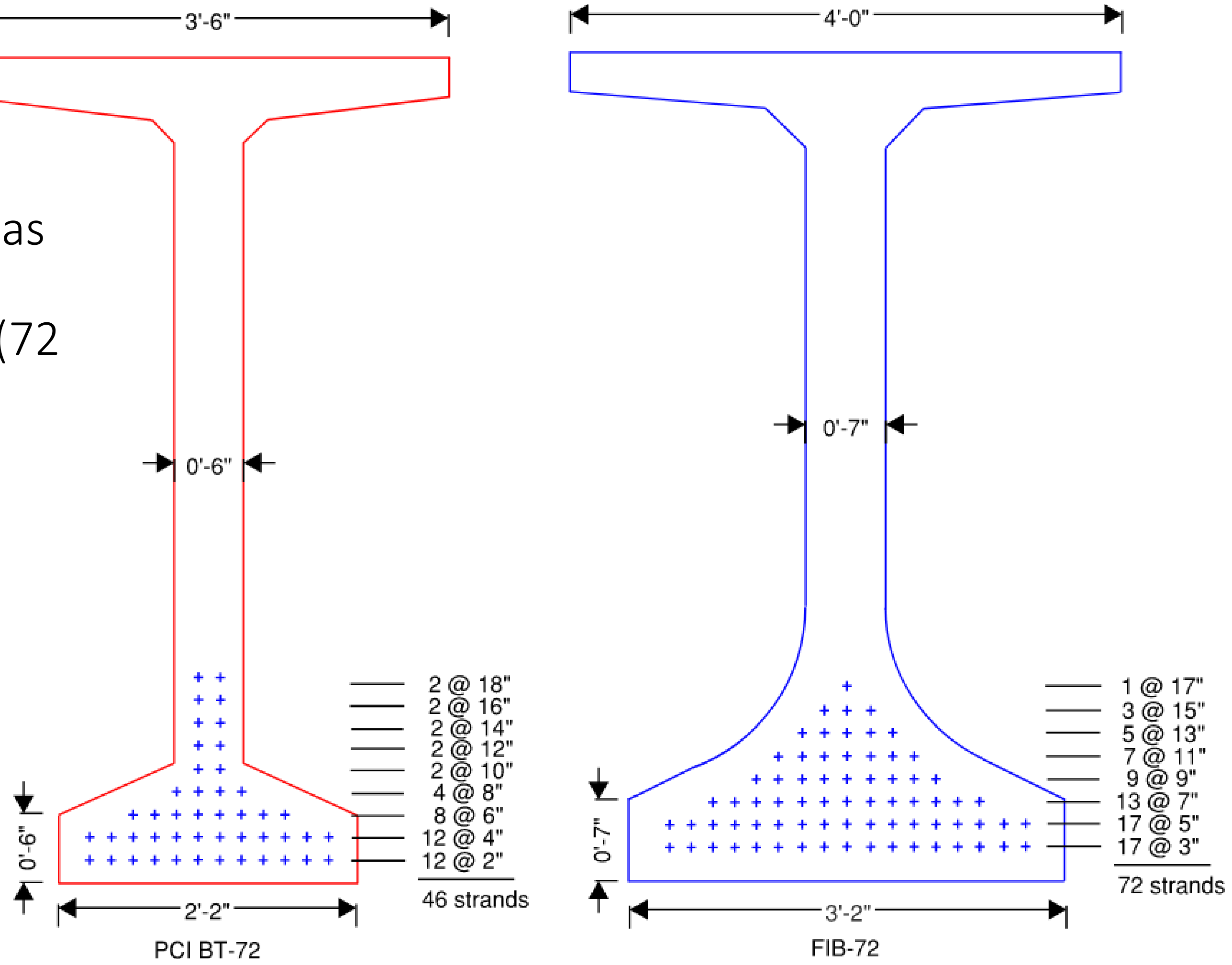
The FIB-72 girder has 36% greater moment of inertia and 38% greater area



	I (in^4)	A (in^2)
PCI BT-72	545,113	766.4
FIB-72	740,416	1058.6
	1.36	1.38

Strand pattern

The FIB-72 girder has 26 more strands in the bottom flange (72 vs. 46)



Girder Efficiency Factor

New Deep WSDOT Standard Sections Extend Spans of Prestressed Concrete Girders

Stephen J. Seguirant, P.E.
Director of Engineering
Concrete Technology Corporation
Tacoma, Washington

PCI JOURNAL

July-August 1998

Guyon[6] proposed an equation based on maximizing section moduli for the top and bottom fibers for a given cross-sectional area. This efficiency factor, ρ, is defined as:

$$\rho = \frac{r^2}{y_t y_b}$$

where

r = radius of gyration of section $= \sqrt{I/A_c}$

y_t, y_b = distance from center of gravity to top and bottom fibers, respectively

I = moment of inertia

A_c = cross-sectional area

6. Guyon, Y., *Prestressed Concrete*, V. 1, Jointly published by Contractors Record Ltd., London, United Kingdom, and John Wiley & Sons, Inc., New York, NY, 1953, p. 239.

Aswad[7] proposed an efficiency ratio based on the stress in the bottom fibers. This efficiency ratio, α, is defined as:

$$\alpha = \frac{3.46 S_b}{A_c h}$$

where

S_b = section modulus for bottom fibers

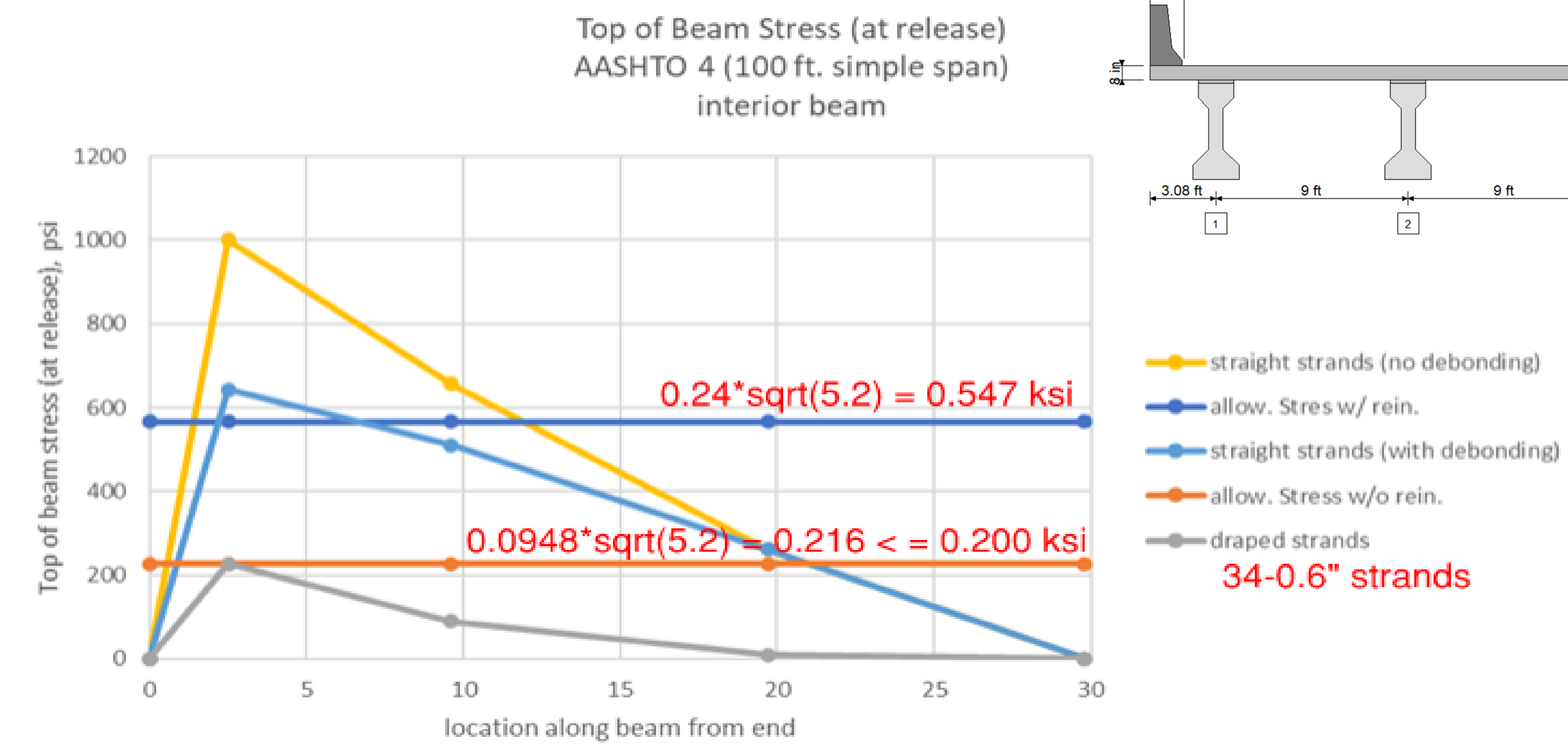
A_c = cross-sectional area

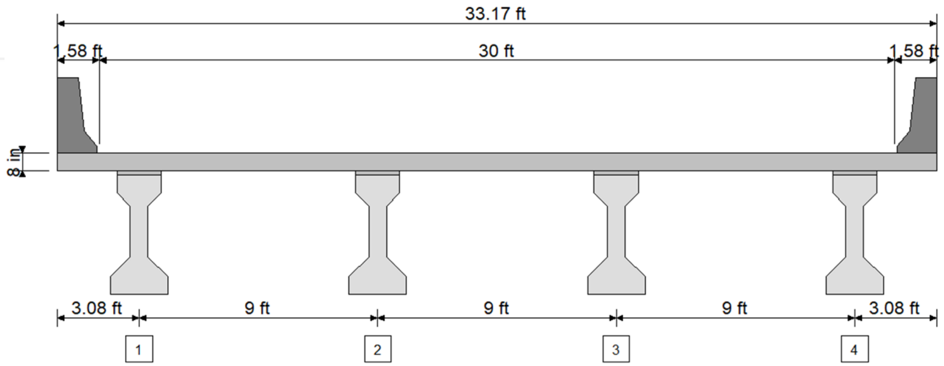
h = depth of section

7. Aswad, A., "An Efficiency Criterion for Pretensioned I-Girders" (unpublished).

	I	A	r=sqrt(I/A)	H	yb	yt	Sb	Guyon	Aswad
FIB72	740416	1058.6	26.44673	72	31.94	40.06	23181.47	0.55	1.05
LG72	728715	1044	26.41974	72	32.33	39.67	22539.9	0.54	1.04
TX70	628747	966	25.51229	70	31.91	38.09	19703.76	0.54	1.01
PCI BT72	545113	766.4	26.66954	72	36.63	35.37	14881.6	0.55	0.93

Release stresses (top flange) draped & straight strand with debonding





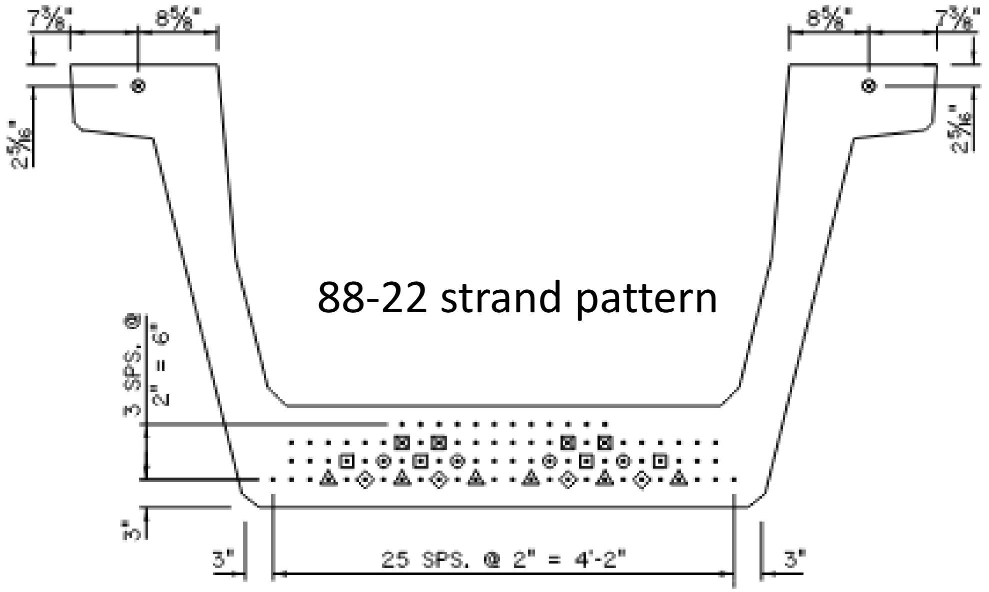
LU Girders

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
PLANS OF PROPOSED STATE HIGHWAY

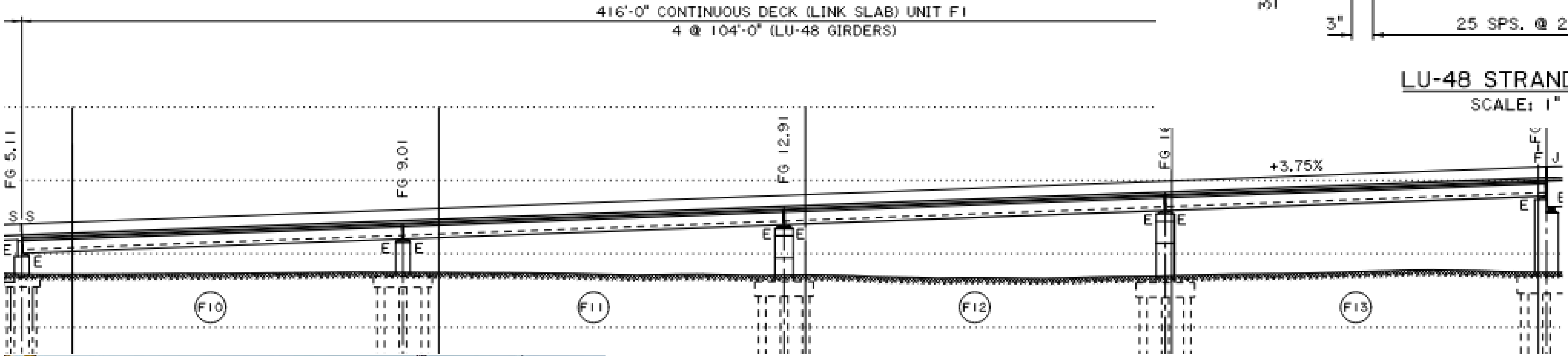
FEDERAL AID PROJECT NO. H011670
STATE PROJECT NO. H.011670

I-10 / LOYOLA INTERCHANGE IMPROVEMENT

JEFFERSON PARISH
RAMPS F & G - SUPERSTRUCTURE PH II (DU B7)



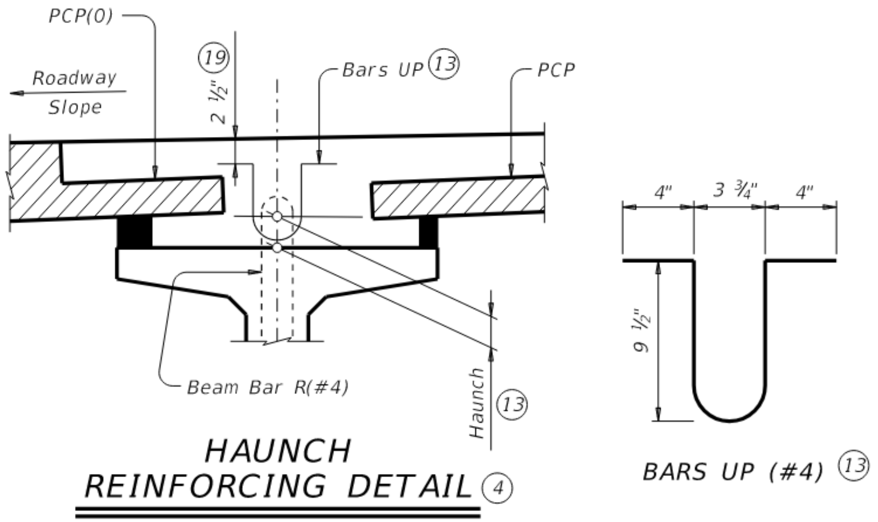
LU-48 STRAND PATTERN
SCALE: 1" = 1'-0"

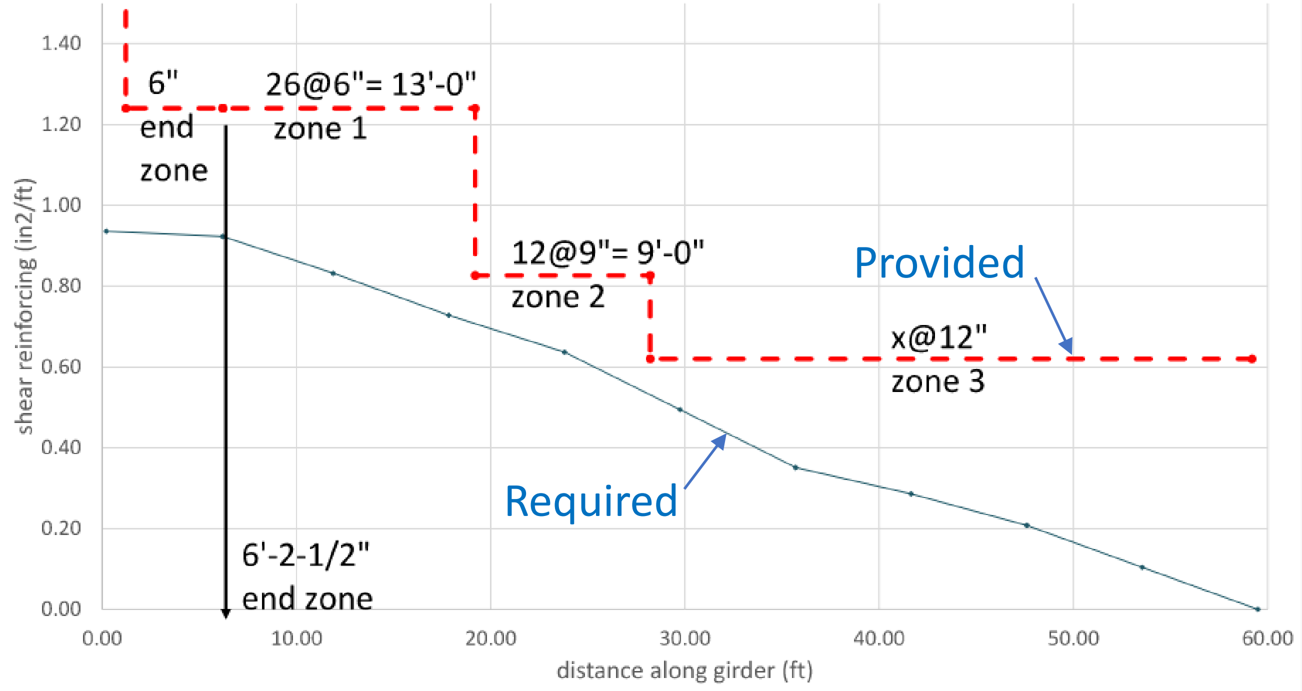


Girder Design, Fabrication Standardization, & WWR

Standardization

- Same stirrup lengths and projection height
  - TxDOT haunch reinforcing detail for haunch thickness T > 3.5”
  - space #4 bar with stirrups
- Same stirrup spacing for each girder section
- Benefits
  - Facilitate fabrication
  - Improve QA/QC
  - Streamline girder design and review process
  - Reduce costs





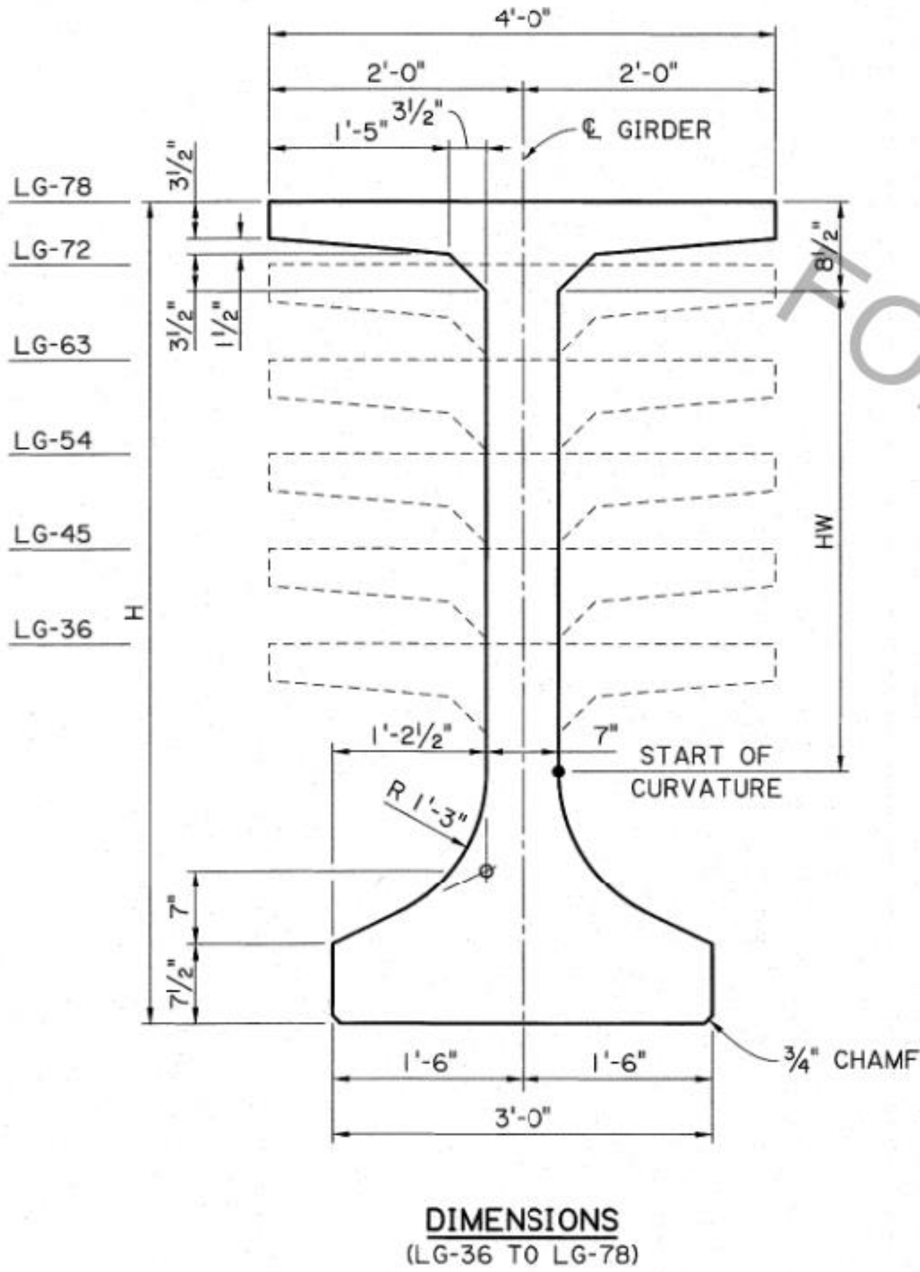
LG girders standard stirrup spacing

Using LADOTD’s shear design charts with grade 60 ksi

Proposed stirrup spacing and reinforcing area based on largest girder spacing = 12.0 ft. and maximum girder lengths

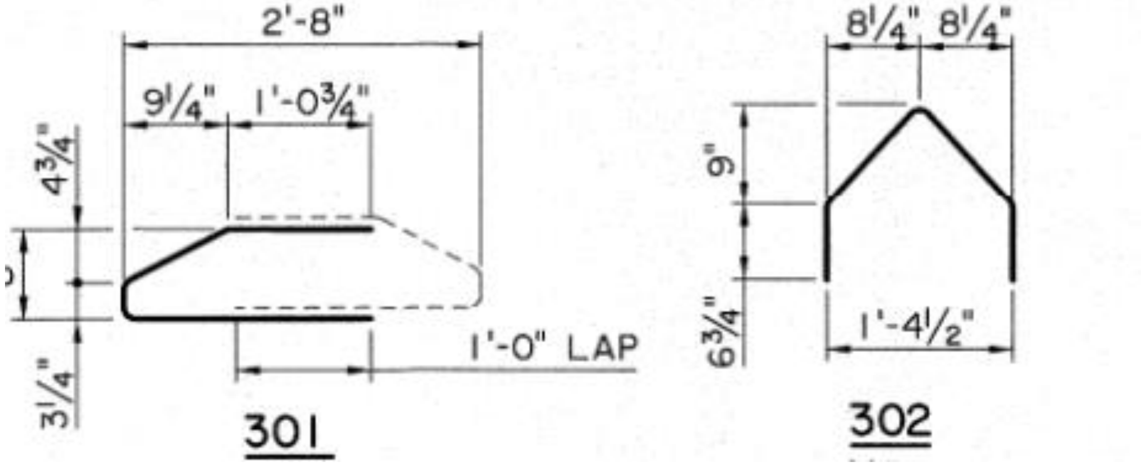
Standardizing the shear reinforcing, top mats, and bottom reinforcing provides the following benefits:

- Improve overall production efficiencies and streamline girder fabrication
- Improve product quality
- Facilitate quality control (QC) & quality assurance (QA) activities
- Facilitate girder design & reviews



301 & 302 bottom flange confinement reinforcing

- Confinement reinforcing required in all anchorage zones according to AASHTO LRFD 5.10.10.2
  - Provide reinforcement to confine the concrete that surrounds the prestressing strands in the bottom flange
  - Be provided for a distance of 1.5d from the girder end
  - Minimum #3 bar with max. spacing 6 inches
  - Be shaped to confine (enclose) the prestressing strands
- Beyond the anchorage zone, for vertical clearances < = 20.0 ft., bundle 301 & 302 bars with 501 bars throughout beam
- Beyond the anchorage zone, for vertical clearances > 20.0 ft., 301 & 302 bars not required unless specified on the plans on certain overpass spans



Welded Wire Reinforcement

- Refer to article "Welded Wire Reinforcement: A Primer for the Bridge Designer, Part 1 and Part 2", ASPIRE Magazine, Winter and Spring 2022 by Paul Aubee, Artisan Structural PLLC.
- Part 1 addresses WWR manufacture, material characteristics, benefits, design compatibility, and use in bridge elements.
- The Benefits – For the design professional, there is ease in having design interchangeability between WWR and individual reinforcing bars in the provisions of the AASHTO LRFD specifications and AREMA manual. This opens the door to the most tangible benefits of WWR: the contractor's ability to greatly reduce installation time and streamline the allocation of labor for reinforcement placing activities, all while installing a structural reinforcement with unparalleled control of fabrication and placement tolerances. These on-site advantages over loose reinforcement have never been more valuable given today's climate of increasing labor shortages and accelerated construction timelines.
- Part 2 shifts the focus to the implementation of WWR in contract drawings and the critical role played by the manufacturer's WWR detailing staff in preparing shop and placement submittals for engineer and contractor reviews.

Concrete Strength and Modulus of Elasticity Data

Concrete Strength and Modulus of Elasticity Data

- Prestressed Concrete Girder Camber Overview
- Modulus of Elasticity Data Collection
- Historic Concrete Strengths (girder mix-design)
- Historic Camber Data
  - LADOTD Project Nos. H.009481, H.001166, H.004791, and H.001234 (LG girders)
  - LADOTD Project No. H.001120 (BT-72)
  - LADOTD Project No. H.011670 (LU-48)
  - LADOTD Project No. H.013866 (AASHTO 3)

F’c and Measured E values

- Measurements collected by GCP at 1, 3, 7, 14, 28, 56, 90, and 180 days

- Using previous E equation

$$E_c = 33000 \cdot K_1 \cdot {w_c}^{1.5} \cdot \sqrt{f_c}$$

- Current AASHTO LRFD BDS, Ninth Edition, 2020 E equation

$$E_c = 120{,}000 K_1 w_c^{2.0} f_c'^{\,0.33}$$

What effects camber & DL deflections and items included in camber & DL deflection calculations

- Material properties (concrete strength, unit weight, modulus of elasticity, type of aggregate, mix-design) & material behavior (elastic shortening, creep & shrinkage)
- Curing process (wet vs. steam)
- Weather (temperature, humidity)
- Prestressing force & layout (draped vs. straight pattern w/ debonding), losses, & transfer length
- Time/Age
- Support location (storage & in-service) and bearing pad size & stiffness
- End of beam support conditions and related construction sequence for end diaphragm construction and deck pour sequence
- Girder length & section properties (area, moment of inertia, center of gravity)
- Weight of added dead load (deck, haunch thickness, SIP forms, barriers)

$$\Delta_g = \frac{5WL^4}{384EI}$$

$$\Delta_{ip} = \frac{P_i L^2}{8EI}\left[e_c + \left(e_e - e_c\right)\frac{4b^2}{3L^2}\right]$$

Camber estimating

- ALDOT

ALDOT Structural Design Manual

- Concrete strengths: Use ***expected*** concrete strengths computed as follows:
    - At prestress transfer, f^*_{ci} :
      For 4 ksi $\leq f'_{ci} \leq$ 5 ksi, $f^*_{ci} = f'_{ci} + 1.95$ ksi
      For 5 ksi $< f'_{ci} \leq$ 9 ksi, $f^*_{ci} = 0.9f'_{ci} + 2.45$ ksi
    - At 28 days, f^*_{c} :
      For $f'_{ci} \leq$ 9 ksi, $f^*_{c} = 1.3f'_{ci} + 3.5$ ksi

Camber estimating

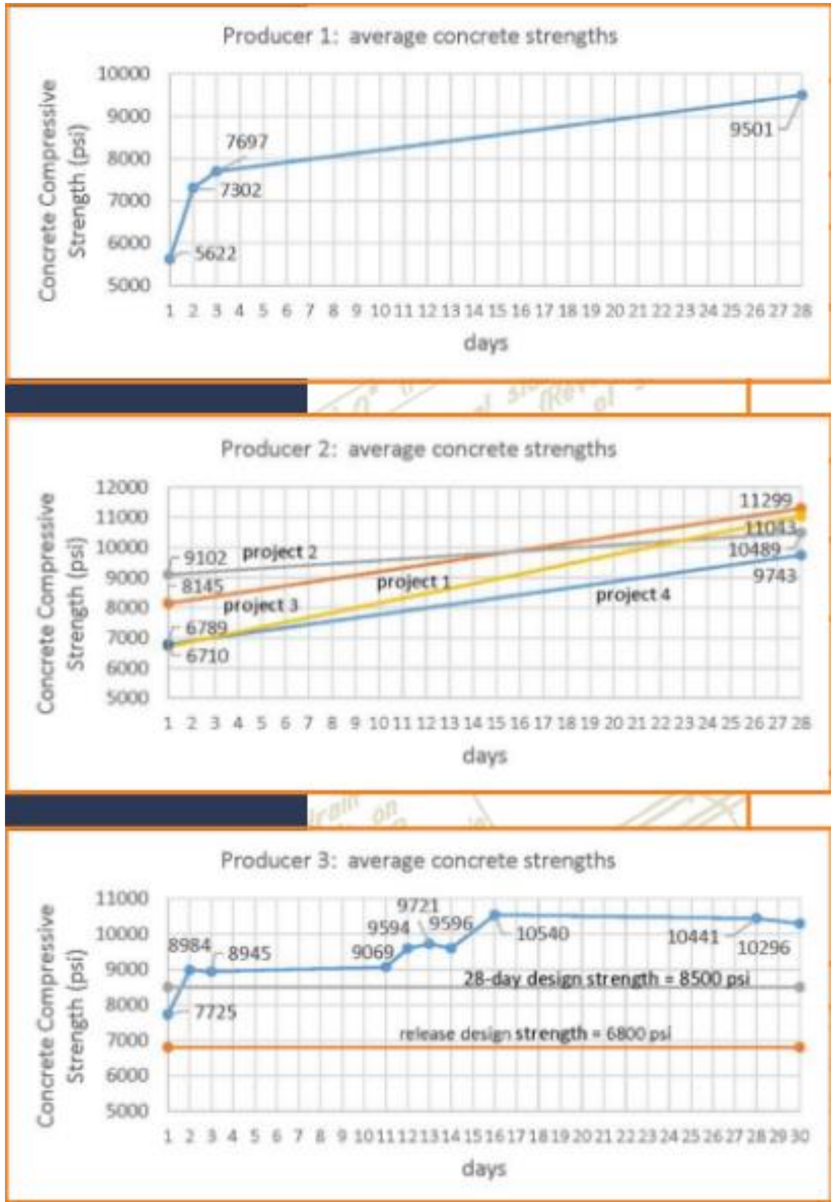
Historic Material Data provided by 3 MS Producer members

- MDOT

Best Practices for Estimating Camber of Bulb T and Florida Girders research completed April 2019

Objective: Improve accuracy for estimating camber

Benefits: improved expectation of material property versus strength, enhance understanding of items that influence camber, and reduce construction delays and/or added costs when differences between actual and estimated occur



Camber estimating

- MDOT

Recommendations:

1. Continue using PCI multiplier method with adjusted concrete strengths of 1.25*f'ci at release and 1.50*f'c at 28-days with a unit weight of 155 pcf
2. Use PCI multiplier method with a modified multiplier of 1.65 for both the downward deflection component due to dead load and upward deflection component deflection due to prestressing
3. Monitor recommended camber estimating procedures using both approaches with actual/measured field camber data to determine which camber estimating approach provides more accurate estimates

Camber-Industry Best Practices & Trends

- Additional data collection (for all girder types and span lengths)
  - Camber measurements over time
  - Concrete strengths over time
  - Modulus of elasticity
    - Type of aggregates & stiffness factors (K1)
  - Prestress forces
  - Unit weights
  - Dead load deflections during deck pours
- Research leading to State specific camber guidelines
- Address design & construction implications for under-camber and over-camber girders
- Maturity curve & concrete strength gain
- Closer evaluation into equations to estimate modulus of elasticity compared to measured E
  - Previous AASHTO LRFD eq.

$$E_c = 33000 \cdot K_1 \cdot w_c{}^{1.5} \cdot \sqrt{f_c}$$

  - Current AASHTO LRFD Ninth Ed., 2020 eq.

$$E_c = 120,000 K_1 w_c{}^{2.0} f_c'^{\,0.33}$$

- Camber tolerances should be compared with estimated camber using as-built material properties and NOT design material properties

Deflection and camber (PCI multiplier method)

According to LADOTD BDEM 1.1.1 – Design Assumptions, use gross section and include elastic gains for prestress losses and use PCI Multiplier method for camber & deflections

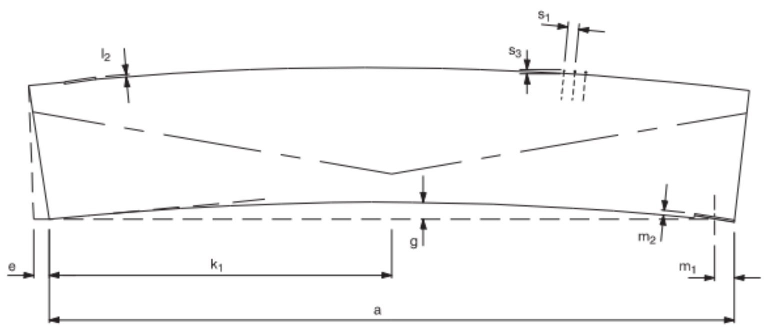
Camber

Camber definition

- MNL-116 Quality Control
- (1) The deflection that occurs in prestressed concrete members due to the net bending resulting from stresses associated with the effects of the prestress forced (not including dimensional inaccuracies); and (2) a built-in curvature to improve appearance

Camber Tolerances

- MNL-135-00 Tolerance, Figure 10.10.1-I Beams (Girders) or Bulb Tee Girders



Elevation

g = camber variation from design camber

- 1/8 inch per 10 ft. length

- ½ inch maximum up to 80 ft length

- 1 inch maximum for length greater than 80 ft.

Current ballot out to revise camber tolerances to:

For predicted camber ≤ 1 in., tolerance is ± ½ in.
For predicted camber ≥ 1 in., tolerance is ± 50% of the predicted camber.

Out of tolerance products should be further investigated by qualified personnel to identify the presence of possible deficiencies. Camber alone should not be the sole cause of rejection.

Constructability

Hauling & Handling responsibility

- According to AASHTO LRFD Bridge Design Specifications article 5.14.1.2.1 and commentary C5.14.1.2.1 referring to the AASHTO LRFD Bridge Construction Specifications, the contractor is responsible for safe storage, handling, shipping/hauling, and erection. C5.14.1.2.3 addresses similar responsibilities by the Contractor for lifting devices.

5.14.1.2.1—Preservice Conditions

The preservice conditions of prestressed girders for shipping and erection shall be the responsibility of the contractor.

C5.14.1.2.1

AASHTO LRFD Bridge Construction Specifications places the responsibility on the Contractor to provide adequate devices and methods for the safe storage, handling, erection, and temporary bracing of precast members.

C5.14.1.2.3

AASHTO LRFD Bridge Construction Specifications allows the Contractor to select the type of lifting device for precast members provided that the Contractor accepts responsibility for their performance. Anchorages for lifting devices generally consist of loops of prestressing strand or mild steel bars, with their tails embedded in the concrete or threaded anchorage devices that are cast into the concrete.

Quality Control/Quality Assurance

ALDOT PCI Plant Certification Requirements

SECTION 513
PRESTRESSED CONCRETE BRIDGE MEMBERS

513.03 Construction Requirements.

(a) Manufacturer's Plant, Laboratory and Personnel Requirements.

The concrete bridge member manufacturing plant shall be certified by the Precast/Prestressed Concrete Institute (PCI) Plant Certification Program. Certification of the production plants shall be Category B4 (Prestressed Deflected Strand Bridge Members). The manufacturer shall submit proof of the plant certification to the Materials and Tests Engineer prior to the start of production.

The manufacturing plant shall have on site, at the time of manufacturing bridge components for ALDOT, at least one technician that is certified as an ALDOT Concrete Technician. This technician shall also be certified as PCI Level I/II. The manufacturer shall submit proof of this certification to the Materials and Tests Engineer prior to the start of production and during production when required by the Engineer.

The manufacturer's laboratory and laboratory personnel shall be qualified in accordance with the requirements given in ALDOT-405, "Certification and Qualification Program for Concrete Technicians and Concrete Laboratories".

QC/QA

- This is a new agenda topic as a result of input from the summer meeting towards expanding the Transportation Committee agenda to include topics related to quality control and quality assurance.
- PCI's Manual for Quality Control for Plants and Production of Structural Precast Concrete Products (MNL 116-21) has a few quality definitions.

Quality – (1) The appearance, strength, and durability that are appropriate for the specific product, particular application, and expected performance requirements. (2) The totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs.

Quality assurance (QA) – The planned activity and systematic actions necessary to provide adequate confidence to the owner and other parties that the products or services will perform their intended functions. Quality assurance is a management tool.

Quality control (QC) – Actions related to the physical characteristics of the materials, as well as to processes and services, that provide a means to measure and control the characteristics to predetermined quantitative criteria. Quality control is a production tool.

QC/QA

- PCI Audits & Plant Certifications
- PCI Quality Control Schools (Level I, II, and III)

https://www.pci.org/PCI/News-Events/Event-Category?type=qc

> PCI offers training courses (QC Schools) to prepare individuals for PCI personnel certification examinations. It is important to note that passing an examination satisfies only one of the requirements of personnel certification and that the final decision on certification is made independently by the PCI Quality Assurance department.

- Other QA/QC topics include:
  - Processes
  - Documentation
  - Repairs
  - Communication

QC/QA

PCI MNL 116-21

1.2 PLANT QUALITY ASSURANCE PROGRAM

1.2.1 General

The plant shall implement and maintain a documented quality assurance program in addition to this manual. Each plant shall have a unique plant Quality System Manual (QSM) based on operations at that facility.

The QSM shall, as a minimum, cover the following:

a. Management commitment to quality.

b. Organizational structure and relationships, responsibilities, and qualifications of key personnel.

c. Management review of the quality assurance program at regular intervals, not to exceed one year, to ensure its continuing suitability and effectiveness. This review will include handling of nonconformances, corrective actions, and responses to customer complaints.

d. General layout of the plant facilities that describes allocation of areas, services, machinery, and equipment.

e. Purchasing procedures for quality control compliance, including project specification review for specific requirements.

f. Identification of training needs and provisions for training personnel in quality assurance procedures and requirements.

g. Control, calibration, and maintenance of necessary inspection, measuring, and test apparatus.

h. Uniform methods for reporting (including sample forms), reviewing, and maintaining records. Each precast concrete unit shall be uniquely identified to a specific set of applicable quality control records.

i. Standards for shop (production and erection) drawings to ensure accuracy and uniform interpretation of instructions for manufacturing and handling.

j. Procedures for review and dissemination of project-specific requirements to production and quality control personnel.

PCI Manual for Quality Control for Plants and Production of Structural Precast Concrete Products, MNL 116-21

6.1 INSPECTION

6.1.1 Necessity for Inspection

To ensure that proper methods for all phases of production are followed and the finished product complies with specified requirements, inspection personnel and a regular program of inspecting all aspects of production shall be provided in all plants. Inspectors shall be responsible only for monitoring quality and shall not be responsible for or primarily concerned with production.

Every effort toward cooperation shall be observed between production and quality control personnel. Production personnel are responsible for quantity and quality. Inspection personnel are responsible for observing, monitoring, and measuring quality.

ALDOT-367

- https://www.dot.state.al.us/publications/Materials/TestingManual/pdf/Pro/ALDOT367.pdf

ALDOT-367
PRODUCTION AND INSPECTION OF PRECAST NON-PRESTRESSED AND PRESTRESSED CONCRETE

Alabama NEXT beam bridges