Best Practices

for Estimating Camber of Bulb T and Florida Girders

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Objective

The objective of this research study is to improve the accuracy for estimating the camber for longer Bulb T and Florida girders with high design compressive strength by implementing some "Best Practices". The research study will also increase MDOT's knowledge base related to beam camber, and includes a review of other State DOT practices related to beam camber.

Methods

The study was based on a comprehensive literature search, survey of other State DOT current practices related to beam camber, review of MDOT and Mississippi Concrete Girder Manufacturers' ("Producers") documentation to compare design concrete strength versus actual concrete strength, and a review of historical measured camber data.

Camber data sets were investigated, and included varying girder lengths for AASHTO Type 4, BT-54, BT-72, and FIB-72 girders. Various parameters that influence camber were included to capture the variations in estimating camber.

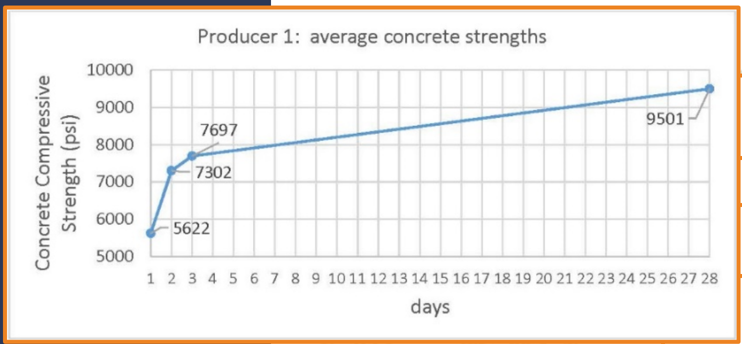
Benefits

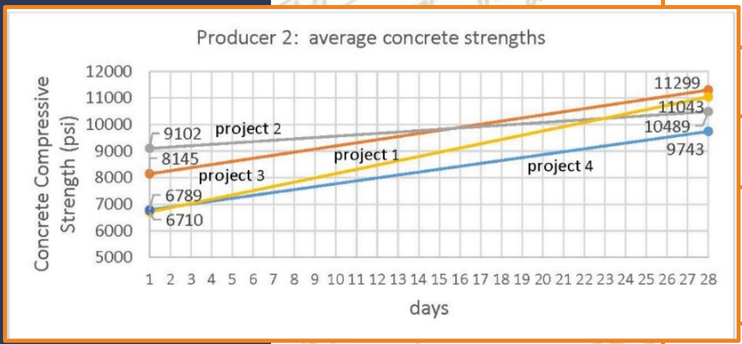
- **Improved ride due to better camber prediction**
- **Improved vertical clearance prediction**
- **Improved expectation of material property versus strength**
- **Increased knowledge-base surrounding beam camber and items that influence beam camber estimation**
- **Reduced construction delays and / or added costs due to differences between estimated and actual cambers**

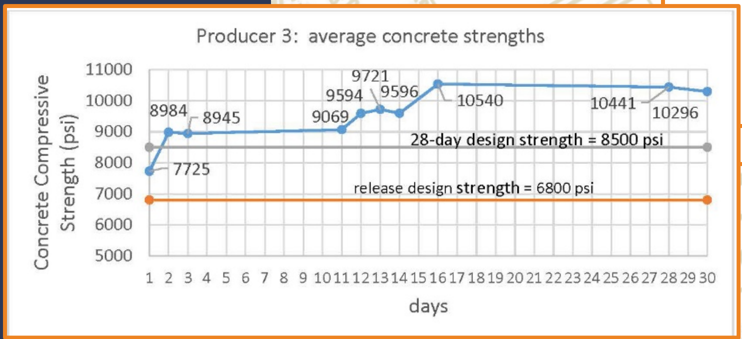
Historic Material Data

Mississippi currently has three concrete girder manufacturers: F-S Prestress, Gulf Coast Pre-Stress, and J.J. Ferguson Prestress-Precast. The Mississippi Concrete Girder Manufacturers (referred to as Producers in the following graphs) provided the historic material data which included concrete compressive strengths at release and at 28-days.

Producers' Average Concrete Strengths







	Producer 1	Producer 2	Producer 3
Design f'ci	5600 psi	4480 psi	6800 psi
Average actual f'ci	5622 psi	7503 psi	7725 psi
Ratio of average actual f'ci / design f'ci	1.004	1.67	1.14
Design f'c	6500 psi	5625 psi	8500 psi
Average actual f'c	9501 psi	10644 psi	10441 psi
Ratio of average actual f'c / design f'c	1.46	1.89	1.23
Ratio of Average actual f'ci / average actual f'c	0.59	0.71	0.74

Producer 1 provided three concrete test reports from the same project, with a required design release concrete strength of 5.6 ksi and required design 28-day concrete strength of 6.5 ksi.

The Producers' data provided insight into manufacturing capabilities, steered the research for the study, and led to the recommendations for improvement.

Producer 2 provided concrete pour reports from several separate projects. The required design concrete strength at release varied from 4.2 to 5.0 ksi, and the required design concrete strength at 28-days varied from 5.0 to 6.0 ksi.

Producer 3 provided fourteen concrete test reports from the same project, with a required design release concrete strength of 6.8 ksi and required design 28-day concrete strength of 8.5 ksi. The table above summarizes the historic material data and includes ratios comparing the design concrete strength to the average actual concrete strength, and also ratios of the average release and 28-day concrete strengths.

Recommendations

Increase Concrete Strengths for Design of Precast, Prestressed Concrete Bridge Girders

The historic material data for the actual average concrete strengths manufactured by the Mississippi Concrete Girder Manufacturers were approximately 25% and 50% greater than the design concrete strengths at release and 28-days respectively, and contained an average 28-day actual concrete strength of 10,195 psi. As a result, increased concrete strengths on select MDOT projects can be considered, to optimize superstructure designs and/or eliminate a girder line, which can reduce construction costs.

According to the MDOT Bridge Division Design Manual (Version 6.1) current design parameters, the 28-day compressive strength for beam concrete shall be 5,000 psi. Strengths of 5,500 psi and 6,000 psi can be used as required by design. MDOT's Bridge Design Manual can be updated to include MDOT's current practice of designing Florida I-Beams (FIBs) using 8,500 psi for the 28-day compressive strength.

Since the average actual 28-day concrete strengths were 10,195 psi; an upper-bound of 10,000 psi for the 28-day design concrete compressive strength is recommended on select MDOT projects.

Concrete Strength Design Table

concrete release strength f'ci (psi)	concrete 28-day strength f'c (psi)	15% lower bound	10% lower bound	10% upper bound	15% upper bound
4000	5900	5000	5300	6500	6800
4500	6600	5600	6000	7300	7600
5000	7400	6300	6600	8100	8500
5500	8100	6900	7300	8900	9300
6000	8800	7500	7900	9700	10100
6500	9600	8100	8600	10500	11000
7000	10300	8800	9300	11300	11800
7500	11000	9400	9900	12100	12700
8000	11800	10000	10600	12900	13500
8500	12500	10600	11300	13800	14400
9000	13200	11300	11900	14600	15200
9500	14000	11900	12600	15400	16100
10000	14700	12500	13200	16200	16900

Based on the historic material data and ratio of f'ci/f'c, a design table is recommended for various values of f'c and f'ci accounting for 10-15% upper and lower bounds for the 28-day concrete strength. The design table uses an average ratio of the average actual release concrete strength to average 28-day concrete strength provided by the Mississippi Concrete Girder Manufactures of 0.68. The design table provides for a range of the f'ci/f'c ratio between 0.59 to 0.80. To use the design table:

1. For a given required 28-day design concrete strength (e.g., 7500 psi) find the row or rows that include 7500 psi in the lower and upper bounds column(s) and select the respective concrete design strength at release (e.g., 4500, 5000, 5500, and 6000 psi). This would indicate that the available manufactured release strength could range between 4500 to 6000 psi for a desired 28-day concrete strength of 7500 psi.

2. For a given required release design concrete strength (e.g., 5500 psi), move across the same row to find the lower and upper bound available for the manufactured 28-day strength (e.g., 6900 to 9300 psi).

Supplement Camber Estimating Practices

Both approaches are recommended to supplement MDOT's current practices for estimating camber of Bulb-T and Florida girders.

1. Continue using the PCI Multiplier Method, and (based on the historic material data provided by the Mississippi Concrete Girder Manufacturers), use adjusted concrete strengths and adjusted modulus of elasticity values based on the average actual strengths, and a unit weight of 155 pcf when calculating camber estimates. The research data sets used an increased value of 1.27 times the design release concrete compressive strength and an increased value of 1.53 times the design 28-day concrete compressive strength for the various analyses designated as average f'ci and f'c. For implementation, round the adjusted values to 1.25 for the release and 1.50 for the 28-day concrete compressive strengths. MDOT can continue to collect historic material and beam camber data from the Mississippi Concrete Girder Manufacturers to compare with the historic average values for f'ci and f'c, and update the adjusted f'ci and f'c average values accordingly when estimating camber.

2. Modify the PCI Multipliers to match the camber estimates using the average actual strengths provided by the Mississippi Concrete Girder Manufacturers and a unit weight of 155.pcf. An adjusted multiplier of 1.65 applied to both the deflection and camber components at release provided comparable erection camber estimates (after added dead load deflections) for the BT-54 (Marshall County) and BT-72 (Leake County) girders.

It is recommended that both approaches be used initially to compare with actual / measured field data on future MDOT projects before deciding which approach correlates best with the actual / measured cambers.

Implementation Plan

Since the results of the research study include several recommendations and conclusions, MDOT can decide how to move forward with implementing the research results. The flowchart below presents an overview to the information exchange within MDOT and to the Transportation Industry, and highlights a few of the action items.

Modifications to MDOT's current practices for estimating camber of Bulb T and Florida Girders will require internal and external communication. Updates to MDOT's camber estimating practices will require some level of training or knowledge-base dissemination to both internal MDOT employees, and external Transportation Industry personnel (e.g., Contractors, Mississippi Concrete Girder Manufacturers, and Consultants). Any changes to the information that is documented or collected in the field to advance MDOT's best practices will require collaboration between the Mississippi Concrete Girder Manufacturers, Contractors, and MDOT Division & District Staff.

MDOT can continue to collect historic concrete strength material and beam camber information provided by the Mississippi Concrete Girder Manufacturers to advance MDOT's knowledge-base / database. Maintaining and updating MDOT's database of historic material information provides MDOT with the latest information concerning concrete girder production, broadens MDOT's knowledge-base of information, and provides for access to project records. A transparent database can assist with future project life-cycle decisions that address bridge management activities including: bridge design and load rating, bridge construction, concrete girder manufacturing, bridge inspection, and bridge maintenance.