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Project Summary Report 0-4086-S
Project 0-4086: Allowable Design Release Stress for Pretensioned Concrete Beams
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PROJECT SUMMARY REPORT

An Investigation of Early Release of Pretensioned Beams: A Summary

Premature deterioration of precast bridge girders has been detected at numerous locations throughout the State of Texas. Two chemical mechanisms known as alkali-silica reaction (ASR) and delayed ettringite formation (DEF) have been identified as the main causes. These mechanisms lead to expansion and cracking of concrete and, consequently, to loss of strength and durability. Controlling them involves reducing the overall alkali load in concrete and the heat of hydration.

Precast producers must meet one of several requirements listed in ACI Special Provision 201 to limit ASR. Many have chosen to use low-alkali cement. However, this type of cement is more expensive and results in a lower rate of strength gain for concrete containing this cement than for concrete containing ASTM C150 Type III cement.

Another option for reducing ASR, as well as reducing heat of hydration, involves reducing the amount of Type III cement. Although it is more economical, this option would lead to even lower rates of compressive strength

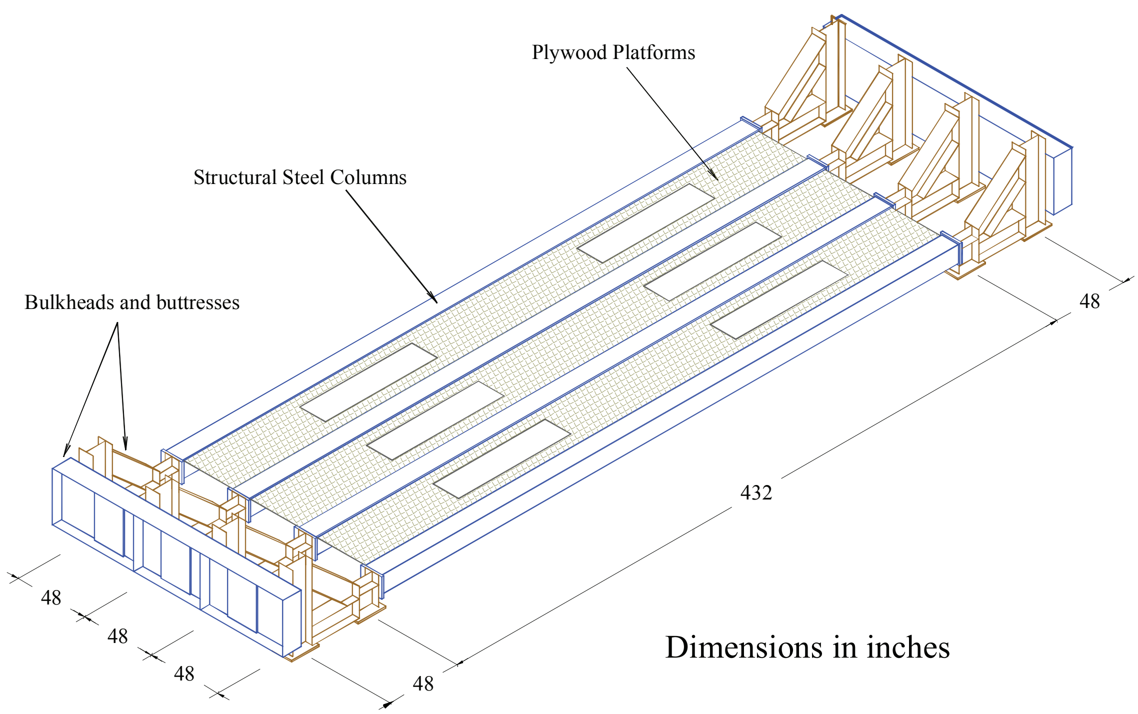

Figure 1: Prestressing Facility at Ferguson Laboratory

Figure 2: Fabrication of Pretensioned Beams

gain, delaying the release of pretensioned members unless the allowable stress limits at prestress transfer specified by AASHTO and ACI are increased. The required concrete compressive strength at prestress force release is determined by these limits. Therefore, increasing them would not only compensate for delays in prestress release resulting from lower rates of concrete strength gain, but could positively impact the economic advantages of pretensioned concrete by enhancing the productivity in precast manufacturing plants.

What We Did...

A research program was conducted in Ferguson Structural Engineering Laboratory at The University of Texas at Austin to determine whether elevated concrete stresses at extreme flexural fibers, relative to current allowable stresses, can be applied to pretensioned concrete beams at transfer. A thorough review of documents related to allowable stresses in prestressed concrete was followed by the construction of a prestressing bed (Figure 1) capable of accommodating six 15-foot-long beam specimens.

Five sets of six pretensioned beams were cast and monitored between June 2002 and May 2003 (Figure 2). These sets included specimens that were representative of standard U beams, I girders, and double-tee beams. Instrumentation for these beams consisted of strain gauges on prestressing strands and linear potentiometers supported on steel frames to measure changes in camber. At prestress force transfer, extreme fiber compressive stresses in these specimens ranged from $0.46f'_{ci}$ to $0.91f'_{ci}$. Tensile stresses ranged from $1.5\sqrt{f'_{ci}}$ to $9.3\sqrt{f'_{ci}}$.

What We Found...

Based on the five sets of pretensioned beams fabricated and monitored (Figure 3) in this study, camber increased with increases in maximum compressive stress at release, expressed as a function of f'_{ci}, regardless of the cross-section geometry and type of concrete used to fabricate the specimens.

Fifteen beam specimens were subjected to extreme compressive fiber stresses greater than or equal to $0.75f'_{ci}$. Higher release stresses appear to result in high rates of camber growth.

The use of match-curing systems can significantly enhance productivity at precast plants. Even though temperatures measured in some of the test specimens were not as high as those commonly experienced in precast plants, compressive strengths at prestress transfer determined using standard cylinders were at least 10 percent lower than strengths determined using match-cured 4 by 8-inch cylinders.

The Researchers Recommend...

The allowable stress design method typically overestimates extreme fiber compressive stresses at transfer. However, this approach may not be conservative for calculating extreme fiber tensile stresses. For example, the extreme fiber tensile stress in a test specimen, calculated based on linear-elastic assumptions, was lower than the assumed modulus of rupture ($7.5\sqrt{f'_{ci}}$). In reality, this beam exhibited flexural cracks, as predicted by the nonlinear analysis approach. This observed behavior might have been further exacerbated by differences between assumed and actual concrete tensile strength at the very early age at which the prestressing force was released.

The research results of TxDOT Project 0-4086 provide a preliminary basis for suggesting that raising the allowable stress factors for release may be an alternative. Increasing allowable stress factors could positively impact the economic advantages of pretensioned concrete by enhancing the productivity in precast manufacturing plants. However, further testing of the specimens is necessary to determine the effects of having exposed the relatively "green" concrete to elevated compressive stresses. This may have an impact on the live load and fatigue behavior of this concrete.

Figure 3: Monitoring of Camber

For More Details...

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The research is documented in the following report:

0-4086-2 Allowable Design Release Stress for Pretensioned Concrete Beams

To obtain copies of a report: CTR Library, Center for Transportation Research,
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