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Performance Analysis of High Early-Strength Concrete for Accelerated Bridge Construction Closure Pour Connections

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***Keywords*— Accelerated Bridge Construction, Closure joints, durability and high-early strength.**

Abstract*— *Accelerated bridge construction (ABC) are becoming a popular alternative for new bridge construction as well as in existing bridge deck replacement because of its reduced time spent in situ activities. A main function of these bridges is the use of prefabricated components. Prefabricated structural components are joined in the field with closure pours using high performance materials such as steel and concrete to ensure proper transfer of forces between components. The purpose of this research was to create a method to develop concrete mixtures that are designed using some general constituents and that satisfy performance requirements of accelerated bridge construction closure pours primarily high early strength and long-term durability. Two concrete mixtures were developed with a primary goal of reaching high-early strength while maintaining constructability. The secondary goal of the concrete mixtures was to be durable; therefore, measures were taken during the development of the concrete mixture to generate a mixture that also had durable properties.

I. INTRODUCTION

Accelerated bridge construction (ABC) is a construction technique that has become popular with existing bridge deck replacement and even with some new bridge construction projects because of the reduction in on-site activities. By reducing the on-site activities, ABC techniques reduce the overall construction time, which results in economic savings. ABC techniques also create safer roadway conditions and reduce traffic delays when compared to traditional construction techniques.

One common technology used with ABC is prefabricated bridge elements and systems.

The prefabricated structural members are the components of ABC technology which allows for a reduction in construction time and cost (Beerman 2016). Prefabricated components are joined on site with small volume closure pours using high performance materials, commonly comprised of steel and concrete. Concrete closure pours must ensure adequate load transfer between structural components before the bridge is in use by developing high strengths in a short period of time.

Generally, most materials used for closure pours contain proprietary components, such as ultra-high performance concrete (UHPC) that contains steel fibers, or rapid setting concrete that contains proprietary cements. These materials currently used for ABC closure pours utilize properties of proprietary components, making it expensive for extensive use and hindering the widespread application of these materials. It is also difficult to sole-source proprietary materials in state bridge projects, which often makes it impractical to specify these materials for ABC.

Consequently, a need for the development of concrete mixtures comprised of generic components has emerged. These concrete mixtures must still satisfy some of the performance requirements of ABC closure pours, including a high strength gain rate and long-term durability.

The main objective of this research project was to develop and validate concrete mixtures that develop high-early strength without detrimentally affecting their long-term performance.

Closure joints for accelerated bridge construction

Closure joints, normally, refer to joints for connecting the bridge deck elements to each other and to the substructure. Application of the ABC using prefabricated elements and assemblies necessitates the use of joints for connecting and integrating the bridge structure. Different types of ABC connections and evaluation of the available connections have been experimentally and analytically studied.

Fig. 1: Closure joints for accelerated bridge construction

II. LITERATURE REVIEWS

A bridge database stored with several parameters extracted from bridges part of the National Highway Inventory was studied to identify the key parameters. Using mean values from the database, a hypothetical bridge was created for each bridge type. Finite-element or grillage analysis was carried out to assist in the development of the LLDF formulas. Important parameters considered in the analyses included different bridge types, span lengths, edge-to-edge widths, skew angles, number of girders, girder depths, slab thickness, overhangs, curb to curb widths, year of construction, girder eccentricity, girder moment of inertia, and girder area. A sensitivity study was performed to identify the key parameters for live-load distribution (Zokaie 2000).

Barr et al. (2001) evaluated the accuracy of finite-element modeling techniques and code equations for determining flexural live load distribution factors for prestressed concrete girder bridges. The study also investigated the effects of lifts, IDs, EDs, continuity, skew angle, and load type. The evaluation was based on the response of a live-load test on a bridge as per earlier studies. The experiment was used to ensure that moment obtained from finite element model corresponded to the observe behaviour of the prototype bridge.

Cai et al. (2002) examined the effect of diaphragms on live load distribution factors and maximum strain through numerical predictions and comparisons with load testing for six prestressed concrete bridges. The bridges included different AASHTO girder types, skew angles, span lengths, diaphragm layouts, and number of lanes. These bridges were analyzed using slab-on-grid finite element technique with four different cases. In each case, the bridges were analyzed differently to consider effects of end and intermediate diaphragms. In all the cases, EDs were modeled integral with the beam ends and assuming stiffness based on uncracked sections. For IDs, full composite action with the beam was not assumed since reinforcing bars are discontinuous at the interface of the two members. Different stiffness levels were used in modeling the IDs as a result of cracking assumed to develop in the concrete. Composite behavior between IDs and the slab was also assumed in some of the models.

Sengupta and Breen (1973) investigated the influence of IDs in prestressed concrete bridges using four 1/5.5 scale microconcrete simply supported models. Physical models of the bridges were tested under static and dynamic loads. Variables included in the tests were span lengths, skew angles, stiffness, number and location of diaphragms. Experimental results were used to validate a computer program for analysis of the bridge which was then used to study, the general effect of diaphragms in load distribution of a variety of bridge models.

Air pollution has reduced by 20% to 30% during the covid period because of lockdown in several countries and in India air pollution has reduced by 30%.This will improve the health of people who got health issues from air pollution there by reducing mortality (Ravi Manne et. al. 2020).

Wong and Gamble (1973) carried out an investigation to study the effects of diaphragms on load distribution characteristics of continuous, straight slab and girder highway bridges. The study focused on the influence of change in diaphragm stiffness and location on the variation of maximum positive and negative moments. The results of load distribution from continuous bridges were compared to those from simply supported bridges. It was found that when diaphragm stiffness exceeded the optimum stiffness, exterior beams experienced a higher maximum moment than the absolute maximum moments in the beams of the bridge without IDs. Increasing diaphragm stiffness reduced the moments in the interior girders and increased the moments in the edge girders.

III. EXPERIMENTAL SETUP

An experimental program consisting of ponding and strength tests was designed and implemented. For comparison purposes, three specimens with and three specimens without the UHPC longitudinal connection (named jointed and joint less specimens, respectively) were fabricated, instrumented, and tested.

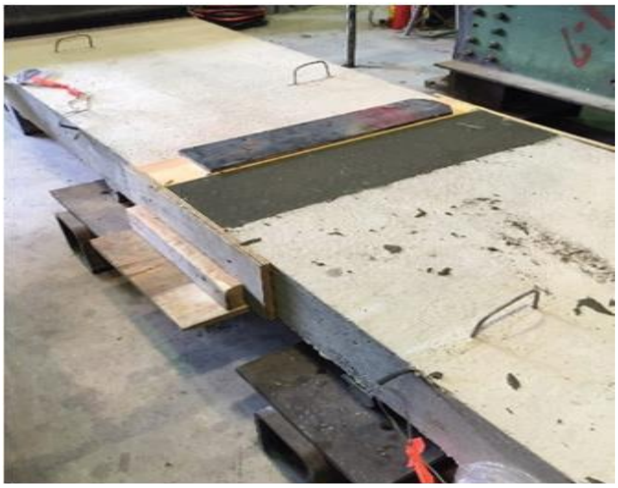

Fig. 2: Experimental setup for connection testing

Strength tests were conducted to check whether the jointed specimens had the same strength as did the joint less specimens. All specimens were tested under the loading and boundary conditions. Two-line loads were applied to the jointed specimen 10 cm. away from the outermost interface surface. The loads were continuously applied on the specimens by two hydraulic actuators each fitted with load cells to record the applied loading. The loading continued until it was seen that each specimen has failed. Each specimen was visually observed multiple times throughout the experiment.

IV. RESULTS

Before failure of each specimen, cracks occurred above the two center supports, between the two loading lines, and in the first and third spans, as shown in Figure. For the jointed specimens, cracks also formed at the connection interface because of the separation of the normal concrete and UHPC,

A flexural-shear failure occurred at the center span of the joint less and jointed specimens. The concrete crushed near a loading line, and large diagonal cracks formed and were extended from a center support to the loading line. No concrete crushing or cracks were found in the UHPC.

V. CONCLUSION

Strength tests were conducted to evaluate the behavior of the longitudinal closure pour connection planned to be used in the precast constructed Bridge. For comparison purposes, specimens with and without a UHPC longitudinal connection were fabricated, instrumented, and tested. The following conclusions were drawn:

- The UHPC connections show no cracks or leakage in the joint due to early-age drying shrinkage and temperature changes.
- Under strength loading conditions, the jointed specimens had slightly lower cracking loads than the joint less specimens.
- Cracks formed at the connection interface, and no concrete crushing or cracks were found in the UHPC pour.

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