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A REVIEW PAPER ON EARLY-STRENGTH CONCRETE FOR ACCELERATED BRIDGE CONSTRUCTION

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ABSTRACT

Accelerated bridge construction (ABC) has become a popular alternative to using traditional construction techniques in new bridge construction and existing bridge deck replacement because of the reduction of time spent in field activities. A key feature of bridges built using ABC techniques is the extensive use of prefabricated components. Prefabricated components are joined in the field using small volume closure pours involving high performance materials (steel and concrete) to ensure adequate transfer of forces between components. To date, the materials developed for closure pours have been based on proprietary components, so a need has arisen for development of mixes that use generic components. The goal of this research was to create a method to develop concrete mixtures that are designed using generic constituents and that satisfy performance requirements of accelerated bridge construction closure pours in New England, 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.

Keywords: Prefabricated components, proprietary components, constructability, durability

1. INTRODUCTION

The concrete mixtures developed in this research project have a primary goal of achieving high-early strength while maintaining constructability. The concrete mixtures were designed to achieve a compressive strength of 4000 psi in 12 hours. This strength development was defined in consultation with the project technical committee and the PCI-NE Bridge Technical Committee. The constructability of the concrete was evaluated qualitatively by the ability to cast the concrete into common molds used for various material tests, and by measuring slump or spread tests depending on mix flowability, and through set time tests. Trial batches were modified through an iterative process until desired strength and constructability goals are met. The secondary goal of the concrete developed in this research project was for it to be durable. Measures were taken during the development of the concrete mixture design to generate a mixture that also had durable properties. Once concrete mixtures achieved the primary strength and constructability goals, two mixtures were selected for further testing. The two selected mixtures were tested for air content, shrinkage, bond strength of reinforcement with concrete, and alkali-silica reactivity. The test results were analyzed and reported in Chapter 0. Freeze-thaw and chloride permeability tests are recommended to be performed to further analyze the durability of the selected concrete mixtures. Because of the long-term nature of these tests and/or the need for specialized equipment, they will not be performed as part of this project.

2. MOTIVATION OF THE STUDY

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. When this technology is utilized for ABC, structural components of the bridge are built offsite or adjacent to the alignment. When the structural components of the bridge are prefabricated, they can be fabricated concurrently with other construction activities and shipped to the site. This is unlike traditional construction methods, where structural members are constructed on site sequentially (i.e. the pier columns and caps must be built before the beams and decks are placed, etc.). 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 shortperiod of time.

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3. LITERATURE REVIEW

Sowmya.et.al. (2000), some tests were conducted using the recycled aggregates to study and compare the results with the naturally available aggregates. The tests were conducted on the aggregates which weren't subjected to any prior treatment. The impact value for recycled aggregate was obtained as 35% and that for natural aggregate as 29.9%. The abrasion value for recycled aggregate was obtained as 47.4% and that for natural aggregate as 29.6%. Water absorption of recycled aggregate (4.2%) was found to be higher when compared to the natural aggregate (0.4%). It was found that compressive strength of concrete made from the recycled aggregate is about 76% of the strength of concrete made from natural aggregate for normal strength concrete (M20). Flexural strength of the recycled aggregate concrete is almost 85% and 80% of natural aggregate concrete. Amnon.et.al (2002), concrete having a 28-day compressive strength of 28 MPa was crushed at ages 1, 3 and 28 days to serve as a source of aggregate for new concrete, simulating the situation prevailing in precast concrete plants. The properties of the recycled aggregate and of the new concrete made from it, with nearly 100% of aggregate replacement, were tested. The properties of the concrete made with recycled aggregates were inferior to those of concrete made with virgin aggregates. Effects of crushing age were moderate: concrete made with aggregates crushed at age 3 days exhibited better properties than those made with aggregates of the other crushing ages. Shailendrakumar.et.al. (2004), in this paper, the author found the relationship between split tensile strength and compressive strength for RCA concrete as well as controlled concrete. The recycled concrete aggregate used was that passing through IS sieve 40mm and retained on IS sieve 4.75mm. For controlled concrete the natural stone chips of same nominal size was used in making concrete. If required a dose of superplasticizer [Conplast SP 430 (M)] was also added to ordinary tap water to obtain desired degree of workability. In this study, 3 mixes were prepared i.e. replacement of natural aggregates by 0%, 50% and 100% RCA. The strength was tested at 28 days maturity of casted concrete. It was observed that recycled concrete aggregate has lower value of specific gravity and moderately high values of water absorption, crushing value, impact value and abrasion value. Furthermore, similar to concrete containing natural aggregate, tensile strength of recycled aggregate concrete containing recycled concrete aggregate, mainly depends on compressive strength.

4. EXPERIMENTAL INVESTIGATION

Several studies have investigated the effect of cement type on of high-early strength development in concrete. Many cements that are used to produce a high-early strength concrete mixture are proprietary, such as Ultimax Cement and CTS Cement. The compressive strength of concrete containing Ultimax Cement was determined to be 20 to 40% higher than concrete containing ASTM Type I/II Cement, without chemical or mineral admixtures being added to any mix (Al-manaseer et al. 2000). Other proprietary cement types have shown similar effects on strength gain of concrete (Balaguru and Bhatt 2001). The objective of this research is to develop a mix using non-proprietary materials; therefore, the use of these proprietary cements was not considered an option.

Non-proprietary cement considered for this project were ASTM Type I, I/II, II and III. While ASTM Type I/II cement is the most widely used and available, ASTM Type III cement is high early strength so it seemed the most appropriate for the requirements of high early strength development in this project. ASTM Type III cement has shown to have the most significant strength gain increase at 1 day and earlier, compared to other non-proprietary cements (Freyne et al. 2004). During this study Freyne et al. also found that ASTM Type III cement reached the highest splitting tensile strength of the non-proprietary cements tested in their research. The early strength development of ASTM Type III cement has been attributed to a greater fineness of particles, which often exceeds 500 m^2surface area per kg of cement (500 m2/kg). The increased fineness of cement means results in a higher surface area of cement particles that interact with mixing water in the concrete mixture compared with normal strength cement (ASTM Type I/II). The larger surface area has a direct effect on the rate at which cement hydrates, predominantly during the early period of hydration, and therefore, the rate at which strength is gained (ACI Committe E-701 2013). Accordingly, ASTM Type

was the hydraulic cement type selected forthis research project.

Aggregates

Aggregate properties significantly affect the workability of fresh concrete, as well as the strength, durability, density and thermal properties of hardened concrete. The following sectionsdiscuss these effects.

Aggregate Texture and Aggregate Shape

The texture of aggregates is a property that alters the workability of and strength of concrete mixtures. Surface texture of aggregates refers to the degree of irregularity or roughness of the aggregate particle surface. Terms such as rough or granular are used to define aggregate particles that have a large amount of irregularity in their surface. Alternatively, smooth or glassy are used to describe aggregate particles with very little surface irregularity. Studies have shown that

there are benefits of both types of surface textures, depending of the desired properties of a concrete mixture. Smooth particles require less mixing water, and therefore require less cementitious material at a fixed w/cm ratio and workability of concrete The surfaces have a strength benefit over using aggregates with smooth surfaces. This is due to the larger bonding area rough aggregate surfaces have with cement paste in comparison with smooth aggregate surfaces (ACI Committee E-701 1999).

The shape of aggregates is another property that contributes to the workability of fresh concrete as well as the strength of hardened concrete. Rounded aggregates, such as a natural river stone, are best in terms of the workability of concrete. The higher the sphericity of a particle, the lower the surface area and, therefore, the lower the demand for mixing water in concrete to yield the same workability. Aggregates with angular shape, such as crushed stone, are best to develop higher strength concrete compared with spherical aggregates. (ACI Committee E-701 1999; Taylor et al. 2015

Aggregate Size

The maximum aggregate size has a strong impact on the strength of concrete. The main reason for this is attributed to the change in bond strength between coarse aggregates and cement paste with different aggregate sizes (Xie et al. 2012). There is contradictory information that can be found regarding the optimal maximum coarse aggregate size. There have been studies showing that concrete containing larger coarse aggregate sizes are stronger, and that coarse aggregates should be graded up to the maximum size that is practical based on constructability considerations (Transportation Research Board 2013; Xie et al. 2012). Other resources indicate that smaller maximum coarse aggregate sizes increase the strength of concrete (ACI Committee 211 2008; ACI Committee E-701 1999; Koehler and Fowler 2007). Although there is discrepancy about the optimal maximum aggregate size, there is agreement on the strong correlation between maximum aggregate size and bond strength between coarse aggregate.

5. CONCLUSION

Currently, most concrete mixture designs used for accelerated bridge construction closure pours are proprietary, making it difficult to specify these mixtures in federally funded projects.

Therefore, the use of these materials in accelerated bridge construction projects is hindered. The goal of this research was to create a method to develop concrete mixtures that are designed using generic constituents and that satisfy performance requirements of accelerated bridge construction closure pours in New England, 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. More specifically, a compressive strength equal to 4000 psi in 12 hours and a slump greater than or equal to 3 inches without segregation occurring. 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.

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