EFFECT OF INTERFACE MOISTURE CONTENT ON THE BOND PERFORMANCE BETWEEN A CONCRETE SUBSTRATE AND A NON-SHRINK CEMENT-BASED GROUT

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ABSTRACT

An increasing amount of bridge construction in the U.S. is completed through the use of prefabricated bridge elements (PBE), commonly relying on field-cast grout-type materials to complete the connections between precast concrete elements. The interface bond between the grout and the substrate concrete can be a key factor in the long-term durability of the structural system. This paper evaluates bond performance of a non-shrink cementitious grout, and examines how the supply of extra moisture at the grout-concrete interface affects the bond strength. The results show increased bond strength when supplemental moisture is provided to the substrate interface.

INTRODUCTION

The connection of prefabricated concrete elements using field-cast “non-shrink” cementitious grouts is a common practice in accelerated bridge construction (ABC) projects (1). The grout material should have sufficient strength and should offer good bond to the concrete element in order to insure adequate stress transfer not only during loading of the structure, but also during expansion and/or contraction of the newly placed grout material. However, recent studies have reported dimensional stability concerns (primarily shrinkage) in these grout materials (2), which could lead not only to durability problems of the grout material but also to the reduction of the bond between the grout and the prefabricated concrete element.

Many are the variables that affect the bond performance of a cementitious material (e.g., grout) when it is placed in contact with another cementitious material (e.g., concrete substrate) (3). One of them is the provision of extra moisture at the concrete surface before the pour of the new material. This is done with the goal of achieving a saturated-surface dry (SSD) condition on the substrate surface. It is hypothesized that the presence of this extra moisture to achieve an SSD condition will reduce the moisture transfer that might occur from the fresh material into the concrete substrate, thus allowing the fresh material to use of all its available mixing water for a better hydration, as well as reducing shrinkage derived from the water migration. Shrinkage in the freshly poured material will not only increase the “gap” between the two materials, but it will also induce shrinkage stresses at the interface, typically causing microcracking. Since this practice of achieving an SSD condition by adding extra moisture has become common in the construction industry (especially in repair applications), this paper focuses on evaluating the effect that the supply of that extra moisture at the grout-concrete interface has on the bond performance.

EXPERIMENTAL

The bond assessment was performed using the ASTM C1583 test method (“pull-off” test method) on a grout-concrete slab (Figure 1). The slab dimensions were 36 in x 36 in x 4 in (914 mm x 914 mm x 102 mm) with a 2-inch (50-mm) thick overlay of a non-shrink cementitious grout. Prior to the grout pour, the top surface of the concrete slab was pressure washed at 24 h after casting in order to create an exposed aggregate interface, achieved by using a commercially available in-form paint-like retarder agent. The grout was cured for 2 d or 14 d prior to execution of the bond tests. The results are then presented as “2-d” or “14-d” bond strength which refers to the age of the grout when the bond test was performed.

In this study, the moisture is provided by either saturating the concrete surface during the 24 h that precede the casting of the grout, so that an SSD condition is achieved, or by means of internal curing (IC) through the use of pre-wetted light-weight aggregates (LWA) being included in the grout material. The LWA used had a specific gravity value of 1.57, and a water absorption value of 16.6 %. The amount of LWA added was 23 % of the solid content, by mass. Water from the LWA will be released at the appropriate time (typically after set), and will theoretically migrate to the regions where water is demanded (e.g., grout-concrete interface). The provision of IC using LWA, besides providing extra moisture at the interface, will also reduce shrinkage of the grout and improve grout curing conditions (4). Finally, images taken from an environmental scanning electron microscope (SEM) will be utilized in order to observe if the extra moisture provided has an influence on the microstructural features (e.g., main hydration products formed) of the grout-concrete interface.

RESULTS

Figure 1 shows the 2-d and 14-d pull-off results. All the specimens failed at the grout-concrete interface (except for the tensile results in which the specimens failed within the grout material). Results labelled as "control" correspond to the specimens where no moisture was added (i.e., drying conditions at a temperature of 23 °C ± 1 °C and a relative humidity of 50 % ± 5 %). "SSD" and "IC" correspond to the specimens where additional moisture was provided via 24-h water saturation or IC, respectively. The pull-off tensile strength of the grout material for all the specimens was added for reference purposes. As can be observed, the bond strength increases over time, since the 14-d strength is (in all cases) larger than at 2 d. The bond strength of the SSD specimens is about 45 % and 17 % higher than that of the control at 2 d and 14 d, respectively. As for the IC specimens, while the 2-d bond strength is about 18 % higher than the control, the bond strength obtained at 14 d was not significantly different. One aspect to point out about the IC samples is that they showed a larger number of air pockets (e.g., large porosity) at the interface. This might be attributed to the fact that the LWA needed to provide IC is added to the grout material, reducing its paste content per unit volume and slightly changing the rheology by making the material less fluid. It is conjectured that this could have an impact on the bond strength by reducing the contact area. The same effect was also observed at 2 d, although the bond strength obtained was slightly larger (perhaps, other variables such as the increased degree of hydration due to the extra moisture have more effect on the bond strength at this age). The tensile strength is always larger than that of the interface failure, confirming that the weakest region is located at the grout-concrete interface, at least up to 14 d of hydration (noting that the 2-d IC tensile strength could not be measured).

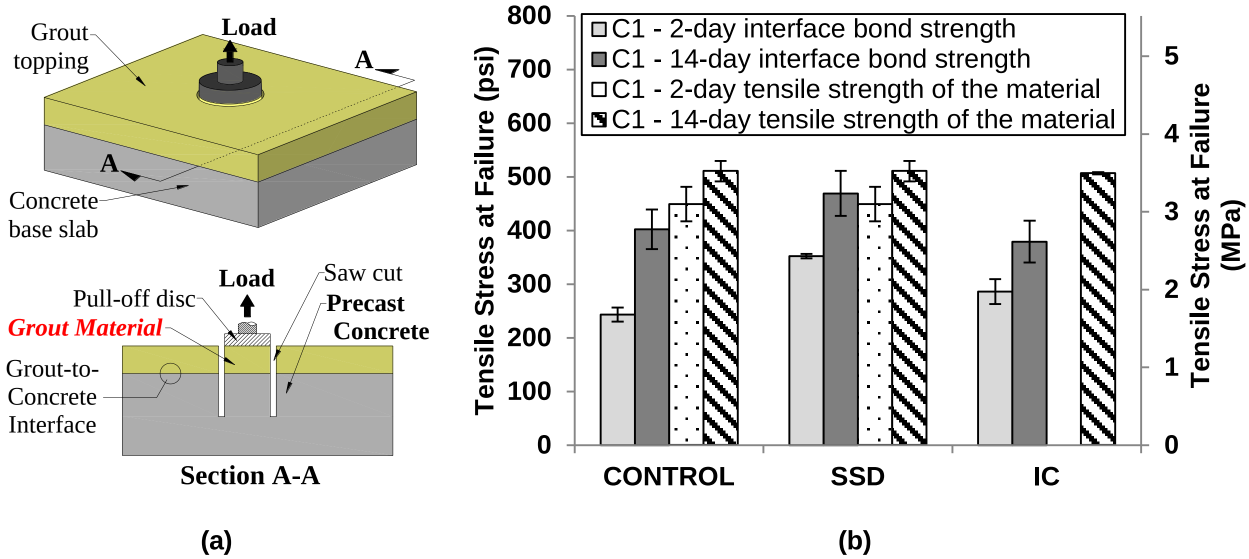
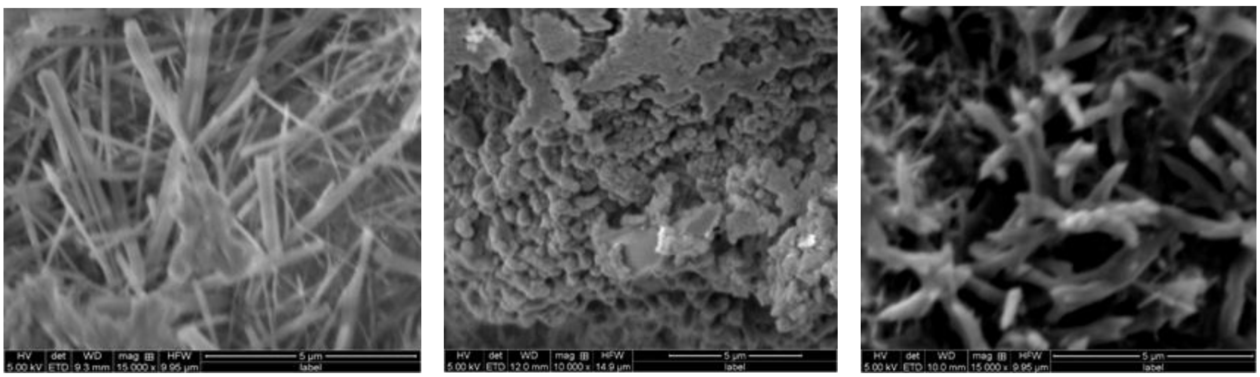


Figure 1. (a) Illustration of the pull-off test on the grout-concrete slab via ASTM C1583, (b) 2-d and 14-d pull-off bond strength for the different interface moisture conditions. (Error bars represent ± one standard deviation from the average of four samples)

DISCUSSION AND CONCLUSIONS

In an attempt to explain the bond strength results, SEM images were collected from the grout side of the interface in each of the specimens studied: control, SSD, and IC. A clear difference on the type of crystals formed was observed between the control and the specimens with extra moisture (SSD and IC). While the microstructure on the control specimen was dominated by the presence of large blade-shaped crystals randomly oriented, both SSD and IC specimens showed a microstructure dominated by the presence of denser 'equant' crystals, with a morphology closer to cubical and thick needle shapes (Figure 2b, 2c). The earlier formation of this type of crystal was promoted by the presence of extra moisture at the interface. Eventually, the bladed-shaped crystals of the control specimen will also transform into the denser equant crystals (as observed in the 14-d SEM micrographs, although not shown in this paper). The presence of extra moisture accelerates this transformation. It is then conjectured that the equant shape of those crystals increases the contact area between the grout and the concrete, compared to that of the blade-shaped crystals (that is, a more interpenetrating contact type).



(a) (b) (c)

Figure 2. 2-d SEM micrographs of the control fractured sample at the grout side of the interface: (a) control, (b) SSD, (c) IC.

In conclusion, the presence of extra moisture (i.e., SSD condition) at the concrete surface changes the type of microstructure present at the interface, increasing the bond strength at the grout-concrete interface.

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