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Grout-concrete interface bond performance: Effect of interface moisture on the tensile bond strength and grout microstructure

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HIGHLIGHTS

- Tensile bond between a cementitious grout and a concrete substrate is evaluated.
- Presence of interface moisture increases tensile bond strength.
- Correlation between bond strength results and microstructural features is provided.

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ABSTRACT

Bond between two cementitious materials is crucial in applications such as repairs, overlays, and connections of prefabricated bridge elements (PBEs), to name just a few. It is the latter that has special interest to the authors of this paper. After performing a dimensional stability study on grout-like materials commonly used as connections between PBEs, it was observed that the so-called 'non-shrink' cementitious grouts showed a considerable amount of early-age shrinkage. This might have negative effects on the integrity of the structure, due not only to the grout material's early degradation, but also to a possible loss of bond between the grout and the prefabricated concrete element. Many factors affect the bond strength between two cementitious materials (e.g., grout-concrete), the presence of moisture at the existing concrete substrate surface being one of them. In this regard, pre-moistening the concrete substrate surface prior to the application of the grout material is sometimes recommended for bond enhancement. This topic has been the focus of numerous research studies in the past; however, there is still controversy among practitioners on the real benefits that this practice might provide. This paper evaluates the tensile bond performance of two non-shrink cementitious grouts applied to the exposed aggregate surface of a concrete substrate, and how the supply of moisture at the grout-concrete interface affects the bond strength. "Pull-off" bond results show increased tensile bond strength when the concrete surface is pre-moistened. Reasons to explain the observed increased bond strength are given after a careful microstructural analysis of the grout-concrete interface. Interfaces where the substrate surface is pre-wetted, such that moisture movement from the grout is minimized, show reduced porosity and increased hydration on the grout side of the interface, which is thought to directly contribute to the increased tensile bond strength.

1. Background

The bond between cementitious materials is a topic that has been extensively researched in the past decades [1–8]. The literature has identified a number of key factors that influences the measured bond strength, including the substrate surface preparation, the use of bonding agents, the mechanical properties of the two materials, and even the test method used to assess the bond strength [1,5,9].

One parameter that is recognized to affect the bond performance between two cementitious materials is the availability of moisture at the concrete substrate surface prior to the casting of the new material [10–12]. It has been reported that when pouring a fresh material over a dry concrete substrate, the substrate may absorb part of the mixing water from the former, thus forcing the water to migrate from the new material to the substrate [13]. This effect might be more pronounced in highly fluid materials

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(e.g., cementitious grouts). The water migration would lead to internal stresses at the interface, thus making it a weak location. It is therefore believed that by providing extra moisture at the interface prior to the application of the fresh material, it is possible to reduce the water migration. This has been observed using neutron images [14] in repair mortar overlays cast over concrete substrates in "saturated surface dried" (SSD) conditions, compared to dry substrates.

While there is a certain degree of consensus regarding the beneficial effects of pre-moistening the substrate, there is some controversy among researchers and practitioners as to if this is really the case [11,12]. Courard, et al., have reported that there is an optimum substrate moisture range between 55% and 90% degrees of saturation [8]. Outside of this range of degree of saturation, the bond strength decreases. The practice of pre-moistening the concrete substrate surface in order to achieve SSD conditions has become common in the construction industry [15].

In a review of the literature of the topic, the authors have identified that recommendations to pre-moisten the substrate are dependent on the test method being used, the surface preparation techniques used, and the types of materials being bonded. This study focuses on evaluating the effect that the supply of extra moisture at a grout-concrete interface has on the bond performance, specifically targeting the potential application in connections of pre-fabricated bridge elements (PBE). For that purpose, the surface of the concrete substrate has been prepared according to current field practices (more details will be given in the next sections) [16]. This study assesses the tensile bond strength between cementitious grouts and a concrete substrate using "pull-off" bond tests. Additionally, the paper presents scanning electron microscope (SEM) images along with measured porosity and hydration profiles in the grout material along the interface with the concrete material to correlate the pull-off bond results to the grout microstructure features.

2. Materials

2.1. Concrete substrate

An ordinary Portland cement, ASTM C150-16 Type I/II, with a Blaine fineness of 382 m^2/kg, and a density of 3070 kg/m^3, was used to prepare the concrete substrate. The fine aggregate (FA) used was ordinary river sand with a SSD apparent specific gravity of 2.59. The coarse aggregate (CA) consisted of dolomitic limestone with a SSD apparent specific gravity of 2.85. The concrete mixture was developed to perform similarly to a prefabricated concrete element in terms of strength. Therefore, the concrete was designed with a water-to-cement ratio (*w/c*) of 0.35 by mass, cement:FA:CA ratio of 1:1.7:2.5 (by mass), a minimum slump of 76 mm (3 in.) (achieved by using a high-range water reducer) per ASTM C143, and a targeted 28-d compressive strength of 55 MPa (8000 psi).

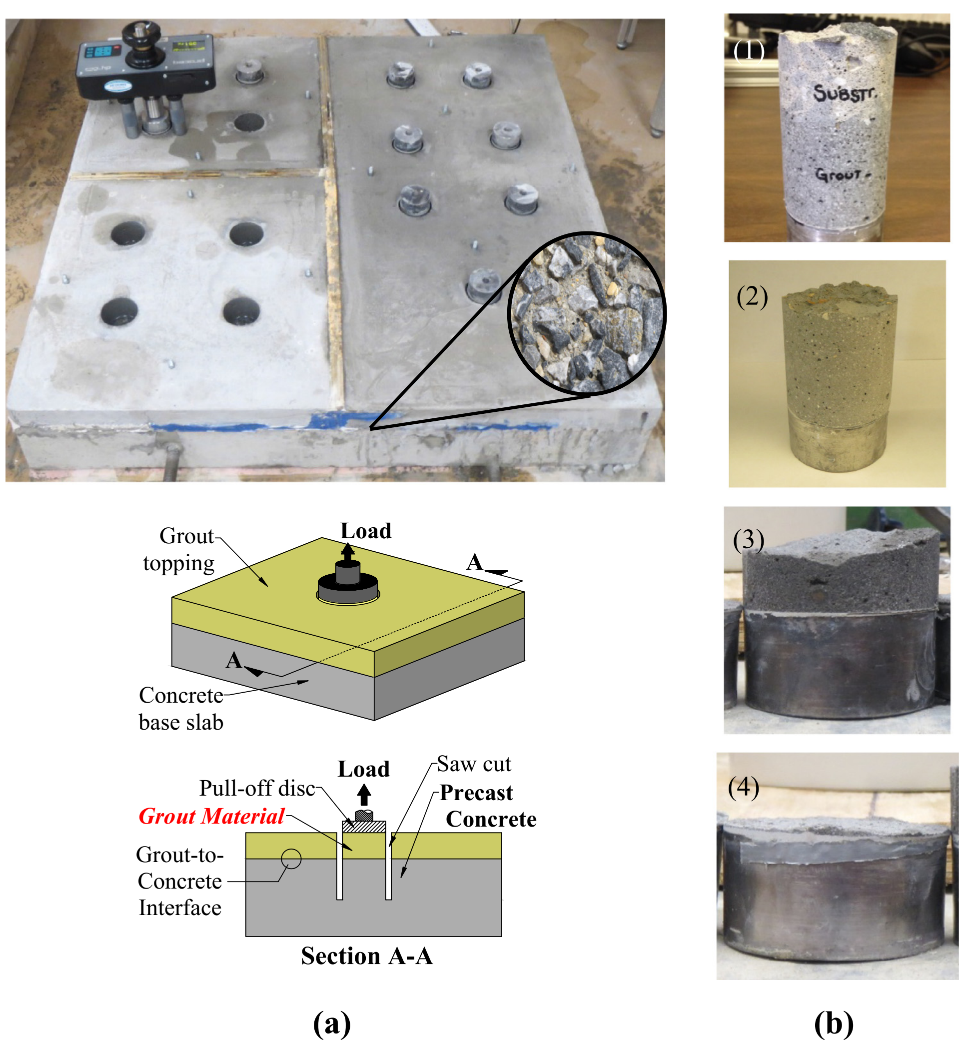

Fig. 1. (a) Grout-concrete slab for pull-off tests (concrete substrate surface was prepared with an in-form retarder agent to expose the coarse aggregates, as shown in the figure) with illustration of pull-off bond test method via ASTM C1583, and (b) four possible failure modes obtained after executing pull-off tests: (1) substrate failure, (2), interface failure, (3) grout failure, (4) glue failure.