FIELD-CAST CONNECTION PERFORMANCE: SOLUTIONS TO SHRINKAGE AND INTERFACE BOND ISSUES

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ABSTRACT

Field-cast connections between prefabricated bridge elements have traditionally been a weak link in accelerated bridge construction (ABC) systems. Although high quality prefabricated steel and concrete elements can be delivered to the project, the field construction activities related to connecting the elements have been less controlled and have used materials with lesser durability. These connections, including their design, materials, interfaces, constructability, and durability, must be robust else the advantages gained through the use of ABC can be lost through poor system performance. Grout-like materials are often used for these connections, with cementitious grouts being the most common due to its low cost. However, serviceability problems in the form of shrinkage and loss of interface bond have been observed in these connections. This paper presents a summary of suite of research studies focused on improving the shrinkage and interface bond properties of field-cast connections. Strategies to improve both properties are suggested, creating the opportunity for better performing ABC solutions.

INTRODUCTION

Accelerated bridge construction (ABC) has become popular in the bridge construction industry. More than 120 projects have been completed solely in the United States as of 2019 (1). The use of prefabricated bridge elements (PBE) is one strategy that can meet the objectives of ABC. These structural components are built offsite, and include features that reduce the onsite construction time and mobility impact time that occur from conventional construction methods (2). Once transported to the construction site, these elements need to be connected. Cementitious grouts are most often used to easily and efficiently complete these connections due to their low material cost. However, serviceability problems often in the form of shrinkage and loss of interface bond have been observed in these connections.

SHRINKAGE

Shrinkage is an inherent mechanism of any cement-based material. When cement reacts with water, the hydration reaction products occupy less volume than the reactants (3). Once the hydrating material reaches its set point, this volume reduction causes internal stresses that may ultimately crack the material. This effect is harsher in drier environmental conditions, where the evaporation of the material's water contributes to increased shrinkage. Cementitious grouts are then expected to exhibit some degree of shrinkage, despite their popular commercial nomenclature of 'non-shrinking' materials. Figure 1(a) shows high shrinkage deformations of several commercially-available cementitious grouts that could be used in PBE connection applications (adapted from (4)).

INTERFACE BOND

Large amounts of shrinkage in PBE connections are expected to affect the bond between the grout connection and the prefabricated concrete element. Bond in cement-based materials is a complex mechanism affected by many simultaneous parameters including as shrinkage of the materials being bonded. Other parameters include substrate surface moisture/roughness levels, and curing and rheological properties of the materials, to name just a few (5). To visually understand the shrinkage and potential bond issues of a grouted connection, Figure 1(b) shows the cracking pattern of a cementitious grout that connected two concrete elements tested under mechanical fatigue loading (6). Cracks before loading (blue lines) correspond to shrinkage cracking, which propagated through the material as well as to the grout-concrete interface after the specimen was loaded (yellow lines).

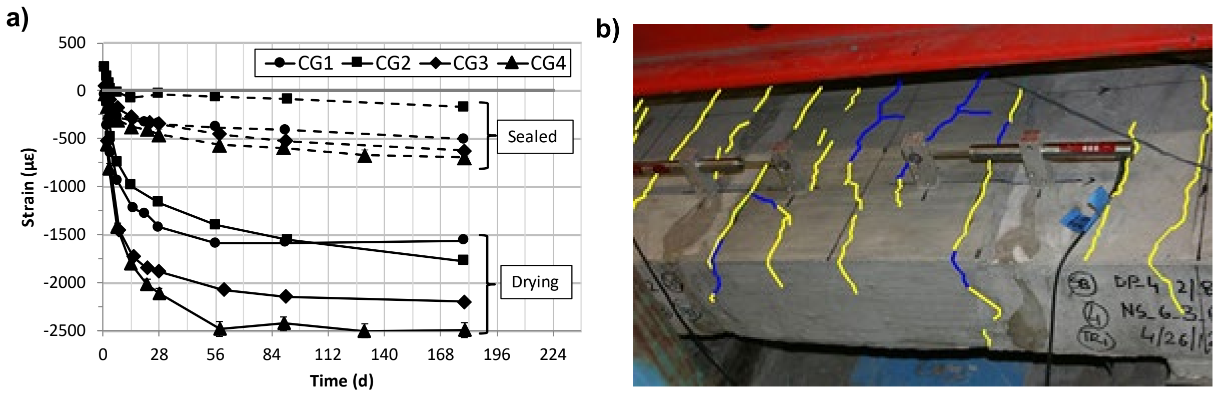

Figure 1. (a) Measured autogenous (sealed) and drying shrinkage of four commercially-available cementitious grouts (adapted from (4)), (b), Grout-concrete connection showing shrinkage cracks (blue lines) and mechanical loading cracks (yellow lines) (6).

SOME PROPOSED SOLUTIONS TO SHRINKAGE AND INTERFACE BOND ISSUES

Some of the results obtained in investigations carried out by the authors of this paper to overcome shrinkage issues in cementitious grouts are presented here; namely, the inclusion of internal curing (IC) in cementitious grouts, and the use of advanced materials such as ultra-high-performance concrete (UHPC). While the former technology has been proven in conventional concretes with successful outcomes (7), the latter has gained much popularity given the outstanding performance that the material provides. Figure 2(a) shows the measured shrinkage of a commercially-available cementitious grout with and without IC, compared to a UHPC material. As observed, both internally-cured grout and UHPC significantly exhibited less shrinkage than the control grout in both drying and sealed (autogenous) humidity conditions. Reasons to explain these results can be found elsewhere (8).

Similarly, one of the investigated solutions to overcome the potential loss of bond due to high shrinkage at the grouted connection is presented in Figure 2(b). The figure shows 'pull-off' tensile bond strength results of both a cementitious grout and a UHPC. In this case, the effect that different substrate surface roughness levels have on the bond strength was studied. The different roughness profiles were achieved through the use of commercially-available in-form retarders (6). As expected, the rougher the surface, the higher the bond strength. However, the UHPC material only needed a minimum roughness level to achieve much higher bond strengths, explained by the ideal consolidation properties and high mechanical properties of this type of material (9).

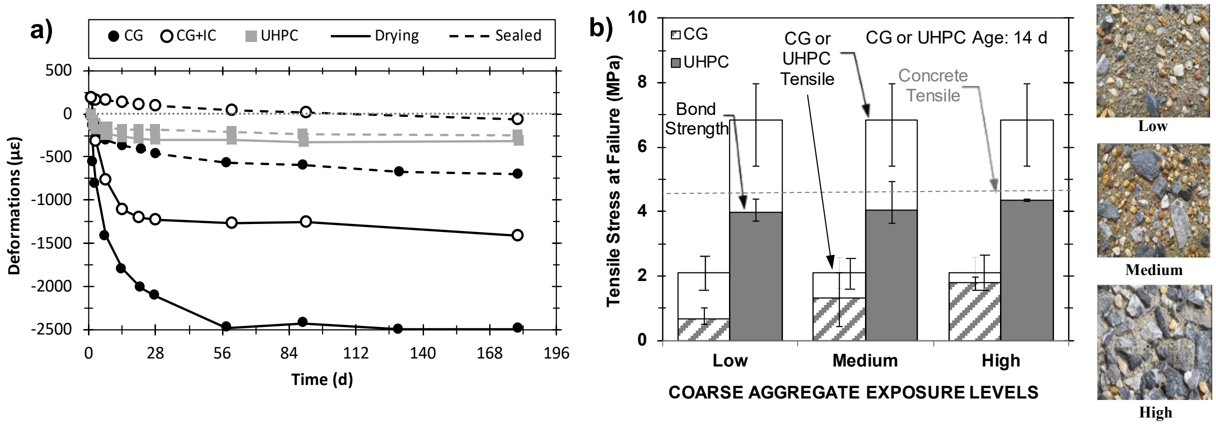

Figure 2. (a) Measured autogenous (sealed) and drying shrinkage of a cementitious grout with and without IC, and an UHPC (adapted from (8)), (b) Tensile bond strength of a cementitious grout and an UHPC cast over a concrete substrate surface roughened at different levels (8).

CONCLUDING REMARKS

Design and detailing of connections between prefabricated bridge elements is critical to achieving a functional, durable, and robust structural system. Cold joints between the prefabricated concrete elements and field cast closure grouts are unavoidable and can result in premature shrinkage cracking and loss of bond at the grout-concrete interface. Therefore, the paper presented easy-to-implement solutions to address some of these issues. A broader set of solutions and recommended practices are provided in the conference presentation.

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