Acceptance Criteria of Ultra-High Performance Concrete for Field Cast Connections, Link Slabs, Beam End Repairs, and Joint Headers on California Department of Transportation Projects

Hesamaddin Nabizadeh, P.E., M.ASCE – Materials Engineer, California Department of Transportation, Sacramento, CA, USA, Email: hesam.nabizadeh@dot.ca.gov

Abstract

There has been a desire in California Department of Transportation (Caltrans) to implement Ultra-High Performance Concrete (UHPC) in its structures. UHPC supports the implementation of Accelerated Bridge Construction by providing a material for field-cast connections of prefabricated structural elements that can provide more robust long-term performance.

Utilizing UHPC could be a step forward for Caltrans towards building a sustainable future. Structures utilizing UHPC will result in a more efficient design. Implementing UHPC will effectively lessen Caltrans' environmental footprint. UHPC has additional benefits including increasing strength and service life of structures and reducing construction time.

Caltrans currently allows the use of proprietary UHPC as a sole source item on its projects. To allow contractors to use UHPC products from multiple vendors on Caltrans projects, a list of prescriptive and performance requirements was developed to create an approved list of prequalified proprietary UHPC. This work provides Caltrans prescriptive and performance requirements of UHPC and examples of using UHPC on Caltrans projects with lessons learned.

Keywords: UHPC, Acceptance Criteria, Applications, Field-Cast Connections, Lessons Learned.

1. Introduction

Caltrans defines UHPC as "a low permeability cementitious composite material that consists of an optimized gradation of granular constituents with a discontinuous pore structure, a low water to cementitious materials ratio and a high percentage of discontinuous internal steel fibers."

Caltrans originally developed acceptance criteria for UHPC in the last decade, and since then started using UHPC in its structures. As Caltrans started using UHPC on more projects and gain more experience with UHPC, it was recommended to revise and update the acceptance requirements due to lessons learned on projects and advances in materials characterizations such as a newly developed test method to determine tensile strength, AASHTO T397.

2. UHPC Acceptance Criteria

Caltrans has been allowing the use of UHPC on its projects through Non-Standard Special Provision (NSSP) and the acceptance criteria are defined in NSSP. In 2022, Caltrans developed a list of prescriptive and performance requirements and created an Authorized Materials List (AML) for UHPC. UHPC AML criteria are provided in Table 1 and Table 2.

Table 1: Material Characteristic Criteria for UHPC.

Material Characteristic	Requirement
Minimum Steel Fiber Strength	190 ksi
Steel Fiber Dimensions	Length 0.5±0.03 inch Diameter 0.008±0.0003 inch
Minimum Steel Fiber (% by Volume)	2%
Maximum Water to Cementitious Material Ratio	0.25

Table 2: Performance Acceptance Criteria for UHPC.

Performance Characteristic	Test Method	Requirement
Density	ASTM C138	Report only, lb/ft^3
Static Flow	ASTM C1437*	8-10 inches, uniform fiber distribution and no matrix segregation
Compressive Strength at 2, 4, 7 and 14 days	ASTM C39*	Report only, ksi
Minimum Compressive Strength at 28 days	ASTM C39*	18 ksi
Tensile Strength for Direct Tension at 28 days	AASHTO T397	Effective Cracking Strength $f_{t,cr}$ > or = 0.8 ksi Crack Localization Stress, $f_{t,loc}$ > or = $f_{t,cr}$ Crack Localization Strain, $\varepsilon_{t,loc}$ > or = 0.0025
Bond Strength	ASTM C1583	Minimum of 400 psi and Complete failure in substrate concrete**
Modulus of Elasticity at 28 days	ASTM C469*	6,500 – 9,400 ksi
Maximum Long-Term Shrinkage at 28 days	ASTM C157*	800 microstrains
Maximum Chloride Ion Penetrability	ASTM C1202*	250 coulombs at 28 days (without fibers)
Scaling Resistance	ASTM C672	Y < 3
Maximum Abrasion Resistance	ASTM C944*	Total loss of 0.1 oz.
Freeze Thaw, Minimum Relative Dynamic Modulus (RDM)	ASTM C666A*	95% after 300 cycles
Alkali-Silica Reaction***	ASTM C1260	Innocuous

*Modified per ASTM C1856.
**Substrate concrete must be a minimum strength of 4 ksi at 28 days.
***Material must be mixed from a pre-bag mix without fibers with manufacturers recommended water.

3. Projects Lessons Learned

Caltrans has used UHPC on several projects on highways with heavy traffic volumes as the connection between prefabricated elements including Laurel St. on I-780 in 2017, Echo Summit on US-50 in 2020, and 21st Avenue undercrossing on SR-99 in 2021. Caltrans faced new issues on each project and UHPC NSSP was revised based on lessons learned. Some of the lessons learned include contractors experience with UHPC, importance of mockups, having contingency plans, time interval between pre-wetting of surfaces and UHPC placement, UHPC pouring methods, heat curing methods, number and location of temperature sensors, water leakage prevention, and number and location of quality control and quality assurance cylinders. The following sections provide three examples of lessons learned.

3.1. Contractors Experience with UHPC

Different contractors were awarded the projects with UHPC phase, and the contractors did not have prior experience with UHPC. Contractors think of UHPC as a normal/conventional concrete. This issue emphasizes the importance of mockups and having experienced representatives from the owner agencies and manufacturers present during mockups and field placement.

3.2. Contingency Plan

Unpredicted circumstances happen on most of the construction projects. On 21st Avenue undercrossing project, UHPC placement was delayed about 12 hours and instead of midnight was started around noon day after. The ambient temperature was about 100°F during the pour and the high temperature caused the fresh mix to lose workability faster than predicted and UHPC waste was about twenty percent. The high percentage of waste caused shortage of UHPC on the jobsite.

3.3. Placement Method

On Kelsey Creek Bridge replacement project, UHPC was used as the connection between prefabricated elements. The contractor poured UHPC into head pressure buckets instead of directly pouring the mix into joints during the mockup, and the manufacturer representative approved the method. However, the mockup was rejected after saw cutting and coring the prefabricated elements due to existence of voids and cold joints.

Figure 1. Voids and Cold Joints Observed After Saw Cutting and Coring Mockups.