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Effect of Fine Aggregate Particle Size on Ultra High Performance Concrete Properties

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Material and Characterization

Mixture design

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Extended Abstract

UHPC mixture proportions are developed by eliminating coarse aggregates to enhance the homogeneity and improve the mechanical strength of UHPC. UHPC mixtures are typically developed using fine aggregate with a top size of 600 µm. From a sustainability point of view, use of larger size sand particles in UHPC mixtures should be investigated with the objective of utilizing more of the raw sand and reducing labor cost associated with sieving. Scalping sand at the 600 µm (ASTM No. 30) sieve is a labor-intensive practice that can waste material if the scalped material is not utilized. However, optimal ranges for aggregate top size are needed because they have a direct effect on maximum paste thickness (MPT) and consequently decreasing mechanical strength. More specifically, increasing the aggregate top size in UHPC mixtures can reduce the flexural strength of UHPC mixtures.

A comprehensive laboratory-based program consists of testing a range of UHPC mixtures developed with fine aggregate top sizes up to 4.75 mm (ASTM No. 4) and study the effect of particle size on mechanical and durability properties of UHPC. Both plain and fiber reinforced UHPC mixtures were developed. Four different curing regimens were investigated that includes standard water curing at room temperature (23±2ºC), moist curing at 100% relative humidity, warm water bath curing at 90ºC, and heat curing (warm water bath curing at 90ºC until two days prior to the testing and oven dry curing for the remaining two days at 90ºC). A range of initial UHPC mixtures were developed by varying water to cementitious materials ratio (w/cm) from 0.30 down to 0.17. In these mixtures, sand passing through ASTM No. 30 (600 µm) sieve was used. Tests to evaluate

compressive strength, split tensile strength, chloride penetration, and potential alkali reactivity of aggregate were performed. All these mixtures exhibited targeted compressive strength of 17,000 psi (as per ASTM 1856) was obtained.

Fiber reinforced UHPC cured according to heat curing regimen exhibited greater strengths for any w/cm ratio. The greatest 2-inch cube compressive strength of 20,620 psi was achieved with a w/cm of 0.17 while its greatest split tensile strength was 2055 psi from 4-inch diameter and 8-inch long cylinders. Rapid Chloride Permeability Test (RCPT) was conducted on all these initial mixtures according to ASTM C1202 to assess chloride ion permeability of UHPC. RCPT values obtained for the specimens produced from these UHPC mixtures were below 200 coulombs that shows negligible to very low chloride ion penetrability. Reduction of RCPT values have been observed with reduction of w/cm.

Among these mixtures, the mixture with 0.17 w/cm was selected for further research to investigate the effect of particle size on UHPC properties. Initially, several plain UHPC mixtures were developed by replacing 600 µm (ASTM No. 30 sieve) sand with 1.18 mm (ASTM No. 16 sieve size) sand at 10%, 25%, 50%, 75% and 100% replacement levels to determine the optimum replacement level. 2-inch cube specimens were produced from these mixtures, cured according to heat curing regimen and tested for 7-day compressive strengths. Compressive strengths greater than 17,000 psi were achieved even for 100% replacement level. Average RCPT value has been observed below 100 coulombs for the specimens produced with 100% replacement level, which shows negligible ion penetrability. Therefore, 100% replacement of ASTM No. 30 sand with larger fine aggregate top size can be utilized to develop UHPC mixtures. Three different aggregate top sizes have been selected for further study. These are 1.18 mm (ASTM No. 16 sieve size), 2.36 mm (ASTM No. 8 sieve size) and 4.75 mm (ASTM No. 4 sieve size) and will be used to replace the 600 µm sand. The 28-day cube compressive strengths of UHPC mixtures produced using the sand passing through ASTM No. 8 and ASTM No. 4 sieves were 22,000 psi and 23,500 psi, respectively while their split tensile strengths were 1,940 psi and 2,170 psi, respectively. The RCPT values for these mixtures were ranged from 53 coulombs to 400 coulombs that indicates negligible to very low chloride ion penetrability. Alkali silica expansions were found to be innocuous. Test results from this study shows that the UHPC mixtures can be produced using sand with particle sizes larger than 600µm (up to 4.75 mm) without any negative affect on mechanical strength and durability.