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STRENGTH ANALYSIS OF ULTRA HIGH PERFORMANCE CONCRETE

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ABSTRACT

Now a days, several construction materials are in use to construct several structures ,well engineered to perform to their ultimate levels in terms of straength ,reliability and long life.In traditional civil engineering practices,materials for construction like cement,concrete,aggregates and steel are used for all purposes including general purpose like constructions of apartment buildings, and special purpose like bridges,spill ways and bunds[1].Sometimes there are some situations which tend the structures to face extreme conditions like abrupt temperature and climatic changes,natural calamities and alteration of superstructural designs etc., which may lead to failure situations of the structure built using traditional construction materials.So, in order to overcome these situations,we need to implement materials with special properties ; the past decade significant advances have been made in the field of high performance concretes (HPC). The next generation of concrete, ultra-high performance concrete (UHPC), exhibits exceptional strength and durability characteristics that make it well suited for use in highway bridge structures. This material can exhibit compressive strengths, significant tensile toughness, and minimal long-term creep or shrinkage. It can also resist freeze and thaw and scaling conditions with virtually no damage and is nearly impermeable to chloride ions. This report presents the results from a large suite of material characterization tests that were completed in order to quantify the load behaviors of a commercially available UHPC. The characteristics of this UHPC under four different curing regimes[2] were captured. This study focused on strength-based behaviors (e.g., compressive and tensile strength), long-term stability behaviors (e.g., creep and shrinkage), and durability behaviors (e.g., chloride ion penetration and freeze and thaw).

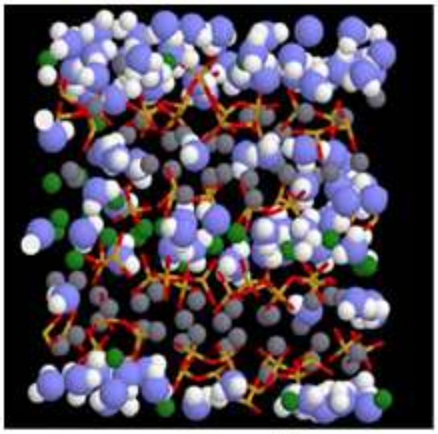
KEYWORDS: tensile toughness;freeze and thaw; High Performance Concretes ; Calcium aluminate cement; Wear resistance

INTRODUCTION

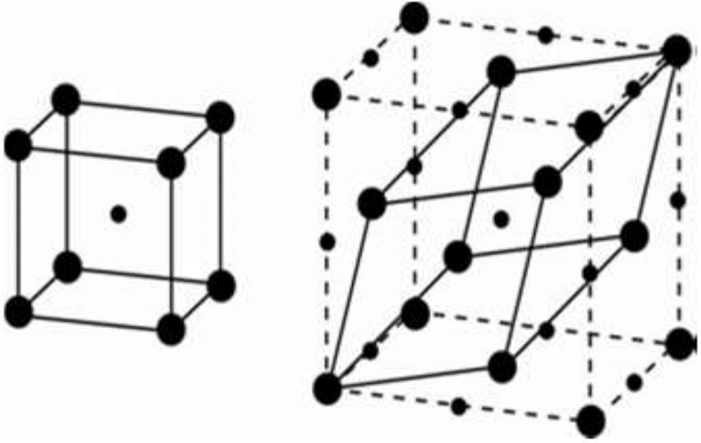
Around the world, a wide scope of research is currently being concerned about the use of High Performance Concrete materials in the field of civil engineering and architecture. Although several researches are being conducted on the strengthening of traditional structures constructed using traditional construction materials with the help of external plates or wraps[3],sometimes also with different combinations of aggrecates and steel of different strengths and also sometimes reinforced with special materials and alloys ; which are impractical for mass production of such materials in the industrial level. there is very less success results regarding this work on the behavior of strengthened traditional structures; However, most of the design techniques were introduced for strengthening of the traditional construction material[5]. A critical reviews regarding this concept shows that there is a need for the focus of researchers and engineers regarding the development of the High Performance Concretes .

MATERIALS AND METHODS

Calcium aluminate cements have a different chemical structure of molecule arrangement compared to traditional Portland cements. With regard to their higher cost, they cannot be a direct substitute with Portland cements. Even though, concretes based on these cements have very high performance in specific construction applications. Two of these materials with regard to be termed as HPC are introduced in this article with tests on them which includes: resistance to acid attack and particularly biogenic corrosion(due to algal formation and water trapping in the structure) and abrasion resistance in hydraulic structures. Such applications extend the range of applications for cement-oriented materials[6].



C-S-H model



molecular structure

REVIEW OF LITERATURE

i. Ultra High Performance Concrete (UHPC) Workshop, 2011

The Ultra High Performance Concrete (UHPC) Workshop was held on January 11 – 12, 2011 at Columbia University in New York City. The workshop was sponsored by the U.S. Department of Homeland Security (DHS), Science and Technology (S&T) Directorate, and the National Transportation Security Center of Excellence (NTSCOE) at the University of Connecticut. The purpose of the workshop was to identify impediments to UHPC acceptance and usage in the U.S., and to identify actions needed to promote UHPC acceptance and use in U.S. construction. The workshop was attended by over 80 participants from 8 countries representing federal and state agencies, laboratories, universities, industry associations and organizations, and the private sector.

ii. Mega Architectural Projects,2011 and 2012

Mega" Architectural UHPC projects have been utilized in Paris, France. In 2011 and 2012, two large projects – the Stade Jean Bouin, and the Museum of Civilizations in Europe and the Mediterranean ("MuCEM") – were constructed using architectural UHPC precast elements. These projects take advantage of the superior properties of UHPC with architectural and structural properties such as ease of curvature and texture, as well as high compressive and flexural strengths.

This open lattice facade comprised of UHPC at the Stade Jean-Bouin in Paris

ARCHITECTURAL UHPC

Architectural precast UHPC products reach a minimum compressive strength of 17,000 psi (117 MPa) after 28 days. They are blended with PVA fibers[7] in order to achieve ductile behavior under tension, which may eliminate the need for passive (non-prestressed) reinforcement. Appropriate batching, casting, finishing and curing procedures are of the utmost importance in order to ensure the highest level of quality, appearance and performance.

The main principle of this technology is based on systematic elimination of inherent weaknesses associated with conventional concrete. The ductile behavior of this material is a first for concrete, with the capacity to deform and support flexural and tensile loads, even after initial cracking. These superior performance characteristics are the result of improved microstructural properties of the mineral matrix and control of the bond between the matrix and the fiber.

The optimization of granulars, fibers and admixtures provide a very low porosity in a cement-based mineral granulometric matrix. The premix components consist of granular material with a diameter less than 1 mm, and a highly reduced water- cement ratio (less than 0.25, depending on the type of UHPC formulation). Elimination of coarse aggregates, along with the granular gradation and fiber aspect ratio, facilitates a high fiber content and isotropic dispersion[8].

Due to UHPC's plastic and hardened properties, plus the elimination of rebar, precasters can achieve complex shapes that are extremely durable and cost effective, and require little maintenance. The material replicates textures, form and shape with high precision and can be produced in a range of long-lasting colors. It works well for new, innovative concrete applications and supports new trends in architecture: purity of line, delicacy, enhancement of texture and mineral bias.

With UHPC, precasters can offer new, innovative building envelope solutions for creative architects; for example: structural, decorative perforated facades in mesh or lattice-style designs; ultra thin, lightweight panels with large surface areas and perforation rates that exceed 50%; and full facades with complex shapes, curvatures and textures.

UHPC has also been used in a variety of urban furnishings. Because of its strength, impact resistance, durability and low maintenance requirements, it is an excellent alternative to traditional materials. A range of elements, such as sculptures, benches, bollards and street furnishings, have been added to the product offerings of traditional precast manufacturers. Also, interior designers and precasters may create new, contemporary, lightweight, colored and textured products such as chairs, stairs and tiles for floors and walls[8][9].

MANUFACTURING OF UHPC AT INDUSTRIAL LEVEL

The manufacturing process of UHPC Materials require less human effort as it include highly sophisticated and advanced automation processes implemented in the industry which provides high yielding rates requiring less raw material quantity as well as less by product and wastage.

RAW MATERIALS :

i. **Dry Materials**

The dry materials in UHPC are cement, silica fume, ground quartz and silica sand. These materials conform to the Mill Certificate specifications; a copy of each is kept on file.

ii. **Fiber Reinforcement**

Architectural UHPC precast products are fiber reinforced with PVA fibers having a minimum tensile strength of 140 ksi and a diameter of up to 300 microns. The PVA fibers conform to the Mill Certificate specifications. A copy of each Mill Certificate is kept on file.

iii. **Water**

Water should be potable (drinkable), but if not potable it must be free of contaminations such as oils, acids, salts, chlorides or other compounds that may be harmful to concrete.

iv. **Chemicals**

Admixtures for concrete are used to enhance and/or obtain certain properties of fresh and hardened UHPC. High-range water reducers are essential to UHPC for providing the plasticizing effects, allowing the concrete to flow to self consolidation. Air-entraining admixtures are not used in UHPC.

v. **Accelerators**

There are two types of accelerators that alter the early strength characteristics of concrete in distinct ways. Set accelerators shorten the set time, whereas strength accelerators speed up early strength gain but do little to alter the initial set characteristics. The dosage rate varies by supplier. Consult the supplier for product details and mix time prior to incorporating an accelerator. Calcium chloride accelerators are not recommended, as the additional chlorides promote degradation of reinforcement and may promote drying shrinkage. The 28-day strength of concrete with the incorporation of accelerating admixtures may be slightly lower than mixes without them.

vi. Color Pigments

Solid or liquid pigments can be utilized for architectural UHPC.

Solid Pigment: When using a solid pigment, the flow properties start to change once the volume surpasses 1% of total dry materials. In order to maintain similar flow, water will have to be added to compensate for the additional dry material. The only way to know the exact impact of this change on the UHPC properties is through testing.

Liquid Pigment: When using liquid pigment, one must be aware of the water being added to the concrete mix. If the liquid pigment dose surpasses the maximum of 3% mass of dry materials, the user could cause negative effects on the UHPC matrix, which must be validated using appropriate laboratory testing methods.

vii. Storage of Raw Materials

A dry, separate storage area for UHPC raw materials must be provided, as raw materials should not be exposed to moisture. Chemical admixtures must not be exposed to freezing temperatures.

Figure 1 *(top left)* ***– High shear mixer; Figure 2*** *(left)* ***– Small (14-50 bags mixer); Figure 3*** *(above)* ***– UHPC batching facility.*** (Photos courtesy of Lafarge)

MANUFACTURING ARCHITECTURAL UHPC PRECAST ELEMENTS

The manufacture of precast UHPC elements presents the industry with new challenges and opportunities. Recognizing that production methods must be reassessed for UHPC production, it is a fundamental change to conventional manufacturing processes. For instance, precasters are required to review their current batching methods, casting techniques, molding expertise and handling techniques.

Batching

To date, many different UHPC product formulations have been successfully batched in various mixers, ranging from a small two-bag mixer to a fully automated batching plant. The mixing efficiency and mixing performance depends on: the type and speed of the mixer; requested mixing time by the precaster; and the required UHPC volume for precast production. When setting up the batch plant for UHPC at a precast facility, the introduction of raw materials into the mixer must be considered. The key to producing high-quality UHPC products is very precise proportion control of raw materials, temperature control and optimization of the mixer's performance requirements.[10]

For the most efficient and consistent mixing of UHPC, high shear mixers (Figure 1) have been used successfully, especially counter-current pan mixers, which can provide accelerated mixing times. These high shear mixers disperse water and admixtures onto the cement particles without heating the mix through kinetic energy generated by the mixing process. Others, such as mortar, horizontal shaft or pan mixers (Figure 2) have also been used, but they are generally slower. The precaster should therefore consider the tradeoffs of mixing time, batch volume and material placement. Prior to dedicating a mixer for UHPC production, it is recommended to calibrate the mixer by measuring mixing time and flow characteristics of UHPC and comparing the compressive strength to reference strength. For projects requiring larger volumes, mixing procedures have been perfected to allow batching of UHPC in ready mix concrete trucks.

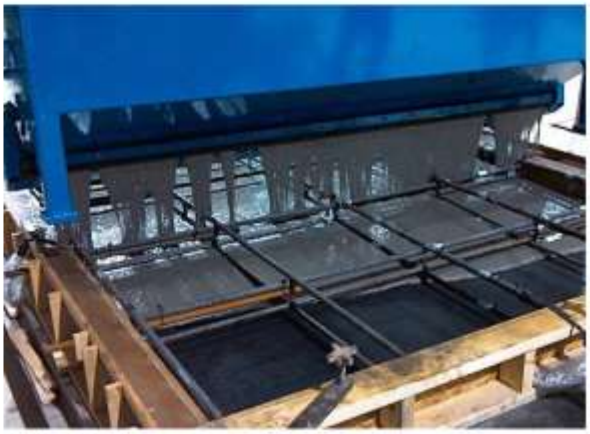


Figure 4 – Placing UHPC behind the leading edge.

Figure 5 – Injection casting.

Forming

Successful execution of a precast UHPC project depends on the design of the molds and the procedures developed to use them. Traditional hand screeding and finishing of UHPC is not normally used due to its high flow and fiber content of the plastic matrix. Self-leveling UHPC formulations have no internal shear in the plastic state and behave similar to self-consolidating concrete. This creates challenges when developing formworks that are completely enclosed with tight tolerances, as well as opportunities for the precaster to offer a new range of products with almost any surface texture on all sides of the element.

Placing

The casting sequence of architectural UHPC precast elements should be planned in order to achieve an appropriate preferential fiber orientation. Molds are filled slowly to prevent entrapped air. No internal vibration is permitted. Limited external vibration can be used to aid in air removal. Do not allow excessive external vibration, as PVA fibers may float to the surface. Filling of the molds should be completed in a continuous casting process by following behind the leading edge of the UHPC.

Figure 6 – Displacement casting.

Curing

Architectural precast UHPC elements are typically removed from the mold after final set has been reached (11,000 psi). If the elements have structural requirements, they can be thermally treated after setting and demolding. This process requires the UHPC precast element to be exposed to 140 F at 95% relative humidity for 72 hours. This allows the hardened architectural UHPC element to reach its ultimate strength and durability characteristics by hydrating all of the free water within the matrix. Thermal treatment also provides improved dimensional stability of the product.

Surface Treatment

Different sealers can be used with architectural UHPC products. The type of sealer depends on the application. For instance, vertical elements do not typically require much abrasion resistance but could be exposed to substantial heat, UV light and staining. Horizontal precast applications could be exposed to the same conditions as vertical applications as well as abrasion. Topical sealers generally repel staining but perform poorly with respect to abrasion. Penetrating sealers tend to bond well into the micro surface of UHPC and perform well in abrasive conditions but do not perform well with staining. It is therefore recommended that the precaster

Figure 7 – The plastic flow of each batch is determined

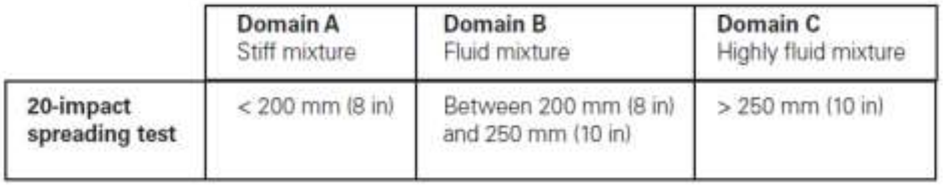
Mock-ups

UHPC architectural projects typically require production of precast samples and/or mock-ups for evaluation. The samples must represent the desired color, texture and special shapes (if applicable) of the finished product. To achieve successful completion of any UHPC project, it is recommended that this is a Best Practice procedure.

TEST EVALUATION

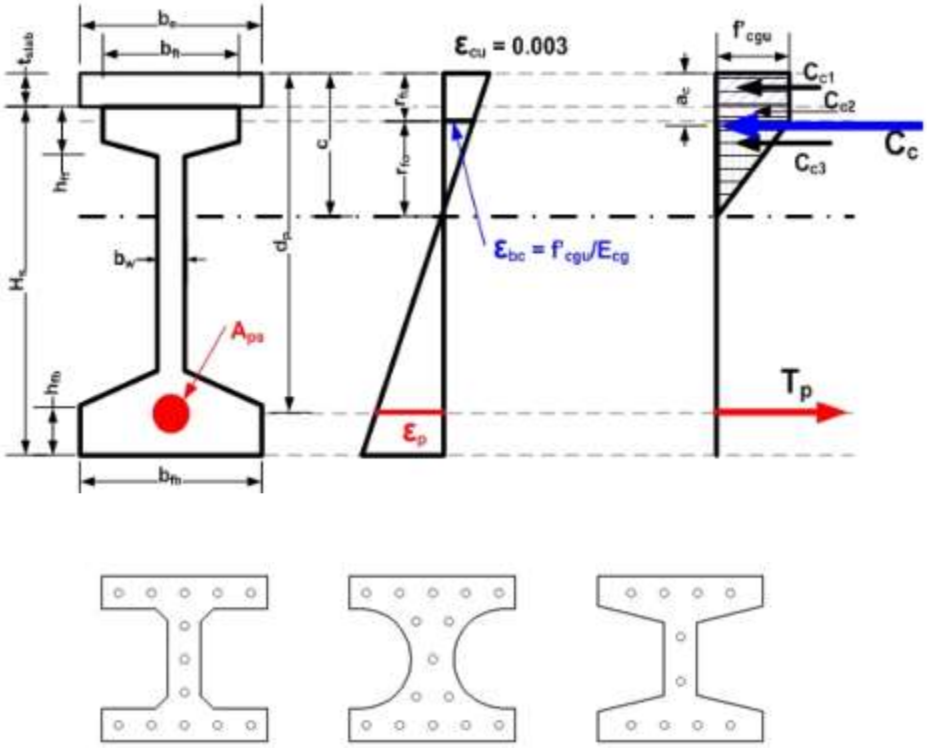
Testing for Compressive Strength:

Compressive strength specimens are tested at 145 psi/second. For each daily production run, six compressive cylinders can be made: three specimens to confirm the minimum stripping strength and three specimens for 28-day testing. If thermal treatment is used, extra cylinders should be tested after completion of the thermal treatment cycle.

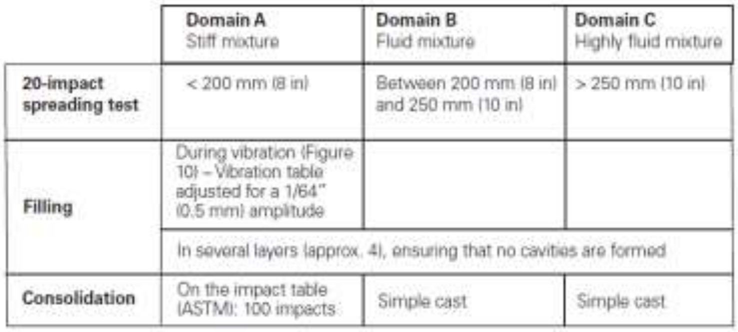


	Domain A Stiff mixture	**Domain B** Fluid mixture	**Domain C** Highly fluid mixture
20-impact spreading test	< 200 mm (8 in)	Between 200 mm (8 in) and 250 mm (10 in)	> 250 mm (10 in)

Table: different combinational mixtures of test specimens



Design Approach forPrestressed UHPC Girder Design



	Domain A Stiff mixture	Domain B Fluid mixture	Domain C Highly fluid mixture
20-impact spreading test	< 200 mm (8 in)	Between 200 mm (8 in) and 250 mm (10 in)	> 250 mm (10 in)
Filling	During vibration (Figure 10) – Vibration table adjusted for a 1/64" (0.5 mm) amplitude		
	In several layers (approx. 4), ensuring that no cavities are formed		
Consolidation	On the impact table (ASTM): 100 impacts	Simple cast	Simple cast

Table: test results of different combinational mixtures of test specimens

Advantages of UHPC:

- Existing capabilities that could produce or be modified to produce UHPC
- Required equipment modifications and acquisitions and their costs

CONCLUSION

The research work presented in this paper develops a new structural construction material substite able to simulate the mechanical behavior of high strength factors in terms of interfacial shear and normal stresses in the are presented using analytical model based on nonlinear fracture mechanics. The following are advantages of using the proposed concept: (i) Provides a reliable low cost alternative to traditional construction materials, (ii) provides a sound mechanical description and interpretation for failure modes as compared to portland cement with different combinations of aggregates of RCC structures, (iii) allows reducing the complexity and cost ofdevloping stable and sustainable alternative, and (iv) simulates the structural response of the considered structural systems with accuracy satisfactory for practical applications.

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