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Effects of Rice Husk Ash on Mechanical Properties of Ultra-High-Performance Concrete.

Michael Haambozi[1], Qiannan Wang[1]
[1] *School of Civil Engineering and Architecture, Zhejiang University of Science and Technology, Hangzhou, Zhejiang, 310023, China*

ABSTRACT:
This article is aimed to research and know the effects of Rice husk Ash (RHA) on the mechanical properties of Ultra-High Performance Concrete (UHPC). It also presents precise overview of work carried out on Rice Husk Ash (RHA) by various scientists and researchers both in cement concrete and ultra-high performance concrete.
Keywords: Rice husk Ash (RHA); Ultra-High Performance Concrete (UHPC); compressive strength; flexural strength;

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I. INTRODUCTION

In every man-made structure, from roads to skyscrapers and bridges to dams, concrete is used as the major constituent of all. Concrete is second only to water in terms of its use by mankind. Cement is the most essential ingredient of the concrete which binds all the coarse and fine aggregate together in the matrix but cement is both energy & resource intensive material. The production of one metric ton of the ordinary Portland cement (OPC) requires 4GJ of energy, and also emits about one metric ton of carbon dioxide into the atmosphere [1]. The cement industries nearly contribute 7% of total CO_2 emitted annually. As early as a few decades ago, some scientists have realized the potential value of rice husk, a more common thing, as a building material, but because of the incineration of rice husks, the early rice ash is too high in carbon. Therefore, it is difficult to use as a substitute for ordinary cement. Therefore now-a-days extensive research work is going on both supplementary cementitious materials such as: (RHA), fly ashes (FA), silica fume (SF) and ground granulated blast furnace slag (GGBS) etc. RHA is the by-product of rice milling industries which is left after the production of bio-mass energy. Generally the RHA is burnt in the boiler at a controlled temperature by means of direct combustion or gasification which produces heat energy. When the Rice husk is burnt at a controlled temperature it has SiO_2 content and most of it is in amorphous form [2]. Asian countries produce the most rice worldwide, while countries in Africa, Latin America, and the Middle East have shown considerable increase in rice consumption and demand. With the development of concrete technology, studies on highly active mineral admixtures have been gradually brought into the schedule, and SF has the best activity because of its mass amorphous component SiO_2. However, the product amount generated by SF is less, collecting SF is more difficult and its price is higher, so that the extensive application of SF is limited [1, 2]. Accordingly, studies on seeking for a concrete additive with similar activity and physical-chemical properties as SF, as well as high output compared to SF, will be of great value [3, 4].

II. LITERATURE REVIEW

Advances in the knowledge and understanding of the behaviors of concrete on the micro-structural level have led to the development of the next generation of concrete, namely (UHPC)[4,,5]. UHPC is a new class concrete that has been developed in recent decades for its exceptional properties of strength and durability [6]. This high performance can be utilized in structural rehabilitation and accelerated construction of bridges and several other applications. Advances in the knowledge and understanding of the behaviors of concrete on the matter. The high durability property of UHPC directly correlates to a longer service life, which makes it an ideal material for a number of structural applications [7]. In my research UHPC was made from mixing sand, cement, super plasticizer, water and RHA, etc. RHA is a by-product of the agricultural industry which contains high amount of silicon dioxide (SiO2). We used coarse sand instead of fine sand in the making of UHPC to see if it would still show a great strength with RHA was added. The advantage of this is its economical.

III. SIGNIFICANCE OF ULTRA HIGH-PERFORMANCE CONCRETE WITH RHA

UHPC is generally made with low w/c mixtures and by adding silica fume. Low w/c mixtures, however, exhibit high autogenous shrinkage, while a high amount of silica fume increases the price of these mixtures. For designing ultra-high strength mixtures with low autogenous shrinkage and lower costs the possibility of using RHA as alternative for silica fume has been studied. The use of RHA as replacement of cement is well known, but the application of this material for UHPC mixtures has hardly been considered yet. China is a large agricultural country. How to improve the utilization rate of rice husks is worth thinking about. The research and application of RHA concrete can play two roles: improving the performance of concrete; handling a large number of rice husks, achieving the purpose of effective use of resources and environmental protection. However, due to the source of RHA in RHA concrete, the incineration of rice husk requires special equipment and specific temperature, so the production cost of RHA cement concrete has become a major bottleneck for its promotion. However, due to its unique properties and the proven RHA, RHA can replace silica fume in construction, indicating that the full utilization of RHA can not only ease the requirements of the construction industry for silica fume, but also meet the construction industry in the need to prepare a variety of concrete. In addition, RHA is a low-energy, sustainable green building material that facilitates the development of concrete in green and high performance. The high cement content (900-1000 kg/m^3) used to produce UHPC causes some disadvantages from the sustainability development point of view. Pozzolans are powders used in concrete in relatively large amounts and mainly used as cement replacements in order to enhance early and long term performance. The use of these materials reduces the cost of concrete production and environmental benefits. Regarding to the sustainable development in relationship with concrete technology, the American Concrete Institute Board of Direction formed a Task Group with a mission “to encourage development and application of environmentally friendly, sustainable concrete materials, design, and construction” (Malhotra 2002).

IV. EFFECTS OF RHA ON THE WORKABILITY OF CONCRETE.

High activity RHA enhances the mechanical properties of concrete and remarkably improves the durability. However, RHA decreases the workability of concrete. Many studies have showed that RHA increases the water usage of concrete and the water reducing agent for designed slumps because of its abundant pores and ultra-high specific surface area, which significantly affects the workability of concrete. RHA raises the dosage of water reducer and will influence the extensive application of RHA because of economic efficiency. It’s reported that concrete incorporating RHA needed a mass of water reducer. For the 50-100 mm slumps, when RHA replaced cement by 20% or 30%, the amount of water reducing agent needed was 1.7 kg/m3, which increased to 3.3 kg/m3 when it was 50%C.C Guillermo et al. reported that with the 10%, 15% and 20% content of RHA, the 130 mm slumps of concrete decreased to 100 mm, 60 mm and 20 mm, respectively. Thus, increasing the dosage of water reducer is a necessary measure to improve the workability of concrete. D. Ouyang reported that RHA has a water-increasing function. The water reducer hardly affects the water demand of the RHA concrete, because the vast majority of RHA surface area is the internal surface of the pore, whereas water reducing agent can only efficiently work on the water adsorbed in the outside surface.

V. PERFORMANCE OF ULTRA HIGH-PERFORMANCE CONCRETE WITH.

UHPC has a compressive strength 10 times that of traditional concrete. Compressive strength is the ability of a material to resist bending under a load (or in compression). Normal concrete used in bridges has a compressive strength of 3,000 to 5,000 psi. UHPC has a compressive strength of 18,000 to tensile strength or tension. This is how strong a material is when you pull it.

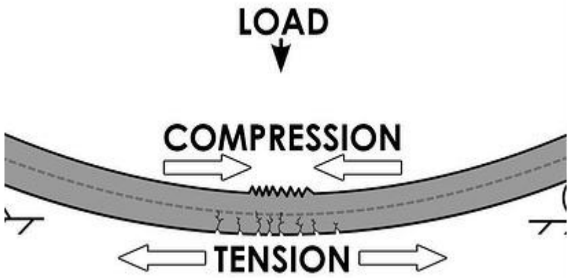

Figure 2.1 tension and compression

VI. CHARACTERISTICS OF RICE HUSK ASH IN ULTRA HIGH-PERFORMANCE CONCRETE.

As a part of ultra-high-performance concrete, the Characteristics of RHA in concrete include workability, strength, setting times and effects of concrete admixtures on its properties are discussed. Characteristics of RHA concrete at the early stages mainly depend on following factors:

a) Water cement ratio
b) Amount of RHA added
c) Amount of paste used in the mix
d) Type and amount of admixture
e) Mix proportion designed

A small addition of RHA (lesser than two to three by weight of the cement), to a given water cement ratio, is sufficient and helpful to improve the stability as well as the workability. This would not lead to any bleeding or segregation problems. This property is gained by the RHA due to its large surface area- in the range of 50 to 60m2/g.

The addition of RHA in larger amount will result in the dry mixture, due to higher water demanded by the larger surface area. This can be compromised by the incorporation of Super plasticizers or any adequate admixtures.

VII. COMPOSITION OF ULTRA HIGH-PERFORMANCE CONCRETE

To produce ultra-high performance concrete, the following materials are used; The materials used in this study were silica sand with a mean particle size of 225 µm, Portland cement (CEM I 52.5N) with a Blaine specific surface area of 4500 cm2/g, condensed SF(silica fume), RHA, and polycarboxylate based superplasticizer with 30% solid content by weight. The SF has an amorphous SiO2 content of 97.2% and its mean particle size is about 0.1 - 0.15 µm.water and water binder.

Rice husk is an agricultural residue which accounts for 20% of the 649.7 million tons of rice produced annually worldwide. RHA produced by using a ferro-cement furnace[11]. Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor. When silica fume is added to concrete, initially it remains inert. Once Portland cement and water in the mix start reacting with each other (hydrating), primary chemical reactions produce two chemical compounds: Calcium Silicate Hydrate (CSH), which is the strength producing crystallization, and Calcium Hydroxide (CH), a by-product also called free lime which is responsible for nothing much other than lining available pores within concrete as a filler or leaching out of inferior concrete. Pozzolanic reaction occurs between silica fume and the CH, producing additional CSH in many of the voids around hydrated cement particles. This additional CSH provides the concrete with not only improved compressive, flexural and bond- strength but also a much denser matrix, mostly in areas that would have remained.

Compressive Strength

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension (being pulled apart). Compressive strength is an effective way of measuring how much load a surface or material can bear. The test for this sort of strength is performed by exerting force downward on top of the object, paired with an equal and opposite force exerted upward on the bottom. In other words, you squash it and then use a simple mathematical formula to determine the compressive load it took before the material failed. For designers, compressive strength is one of the most important engineering properties of concrete. It is a standard industrial practice that the concrete is classified based on grades. From the raw data, the load over the area of the specimen, were used to obtain the value of compression in MPa. The rectangular specimen is placed on the compressive strength testing machine and the load is applied vertically as shown in Figure below.

Figure 2.2 silica fume

1. Advantages

1. One of the primary advantages of UHPC to owners is its long-term durability and Construction of Ultra High Strength Fiber Reinforced Concrete Structures.

2. It has a high strength and the extremely high strength of UHPC results in very short rebar lap and development lengths.
3. Resistance to leaching and corrosion
4. It is also cheaper to produce.
5. Low porosity of UHPC.
6. Improved micro-structure and homogeneity, high flexibility with the addition of fibers.

2. Disadvantages

1. Material procurement. Finding the right material for production can be hard and expensive. High quality materials must be used. These materials may cost more than materials of lower quality.
2. Pollution of the environment. In our case we implement the use of RHA which has bad effects on the environment as it causes pollution during combustion.
3. Cost of materials and cost of project
4. Mix proportion: UHPC is very much sensitive to materials used. A slight change in the material and you won't get the desired result.

Effects of RHA on Flexural Strength of UHPC And Age.

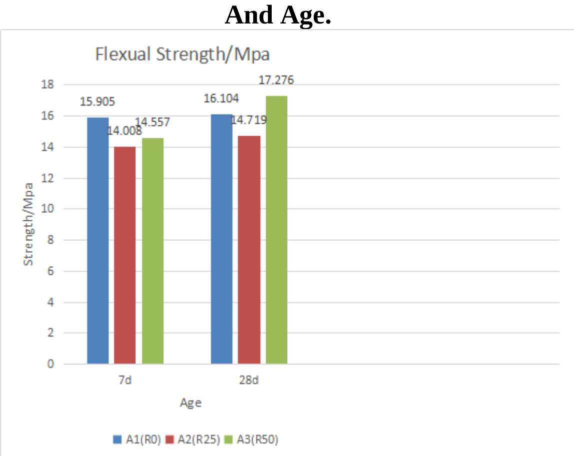

Figure 2.3 Flexural strength of different specimens containing 0%, 0.25% & 0.5% RHA at different ages.

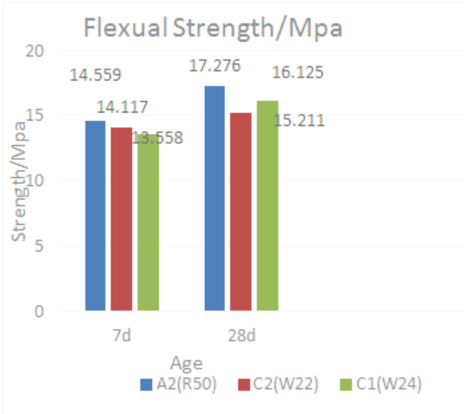

Figure 2.4 shows the flexural strength of different specimens containing 0.2%, 0.22% & 0.24% W/B agent at different age

VIII. MICRO-STRUCTURAL ANALYSIS

Improvements in the mechanical and durability properties of concrete containing RHA can be explained by the chemical and physical effects of RHA. Chemical effects are mainly due to the Pozzolanic reaction between the amorphous silica of RHA and calcium hydrate produced by the cement hydration to form the calcium silicate hydrates. The physical effects which can be also considered as filler effects is that RHA particles increase the packing density of the solid material by filling the spaces between the cement grains in which the same way as cement fills the spaces between aggregates and fine aggregate fill the spaces between coarse aggregates in concrete. Small additions generate a large number of nucleation sites for the precipitation of the hydration products. This will accelerate the reaction and form smaller C-H crystals. RHA reduces the number of large pores and increases the probability of transforming the continuous pores into discontinuous ones. Therefore all the mechanisms make the micro-structure of the paste more homogeneous and denser.

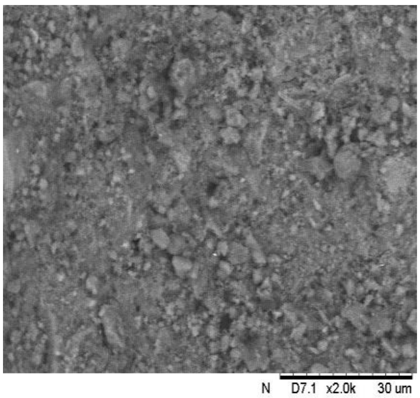

Figure 2.5 shows UHPC

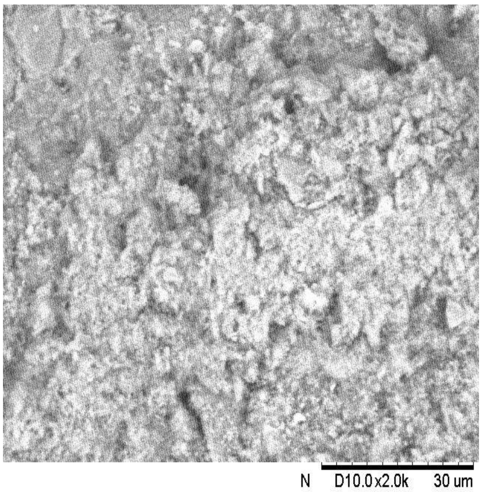

Figure 2.6 shows normal concrete

IX. TEST RESULTS AND ANALYSIS

Compilation of Test Data

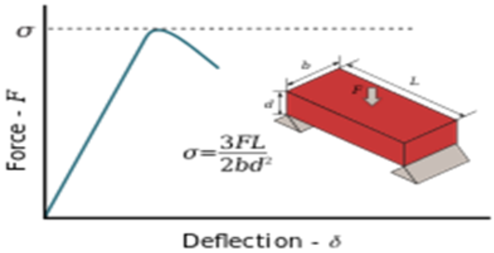

Figure 2.7 Flexural Strength Formula

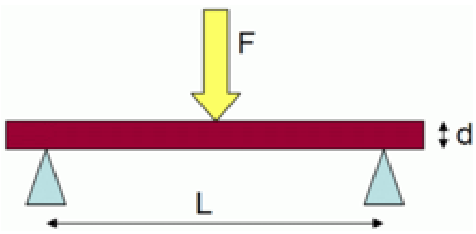

Figure 2.8 load under 3-point bending

Calculation of the flexural strength is given by the equation 5.1 below:

$$\sigma_f = \frac{3FL}{2bd^2}$$

Where:
F is the load (force) at the fracture point in Newton's (N)
L is the length of the support span
b is the width in mm
d is the thickness in mm

This equation is the most frequently employed as it measures the flexural strength when the member is bent until fracture or yielding. It represents the highest stress experienced within the material at its moment of yield. It represents the tensile strength when the material is homogeneous, initiating pure bending, where there is no simultaneous presence of axial, shear or torsion forces.

Flexural Strength

Flexural strength, also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexural test. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of yield. It is measured in terms of stress, and given by the symbol sigma. The flexural stress σ_f was calculated by means of the three-point bending flexural test. If the strength value exceeds 10% of the average value then the average value should be removed and then taken as flexural strength test. The main advantage of a three point flexural test is the ease of the specimen preparation and testing. However, this method has also some disadvantages: the results of the testing method are sensitive to specimen, loading geometry and strain rate. The sample is placed on two supporting pins a set distance apart as shown in figure above.

X. CONCLUSIONS

This study shows the effect of RHA on mechanical property of ultra-high-performance concrete. The conclusions drawn from this study are as follows:

i. Under the same mix ratio, the flexural and compressive strength of UHPC increases with curing age. In the earlier curing days strength increases faster.

ii. On the mechanical properties, an increase in dosage of RHA increases both the flexural and compressive strength of ultra-high-performance concrete. But too much dosage would lead to sample been dry hence creating huge voids leading to lower strength.

iii. Ultra-high-performance concrete shows a rise in flexural strength the smaller the finess modulus of sand is, and shows the opposite result for compressive strength as its reduced the smaller the finess of modulus is. This also follows the bigger the finess of modulus of sand is the bigger the compressive strength. Till date there has not been research on which particle size is most suitable to be used for UHPC manufacture.

iv. According to micro-structure analysis, UHPC is denser than normal concrete which makes it have higher strength.

v. UHPC has a high shrinkage because of its coarse aggregate hence the implementation of RHA. The RHA has a porous structure to absorb water hence offering a higher shrinkage and prevention of cracking.
vi. The more water content in concrete mix the lower the strength of the sample
vii. The performance of concrete with cement replacement by RHA is outstanding considering the resistance to water and chloride ion penetration which is in many cases the most important characteristics concerning durability and corrosion prevention.

Till today there are some roadblocks which are faced in the UHPC productions, such as there is no U.S testing/design standard, with this UHPC remains undefined in concrete industry specifications and standards. Moreover, there is further research needed to improve and learn more about it and specifying UHPC would require aggressive QA.

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