Experimental study on the compressive strength of ultrahigh performance prefabricated concrete walling materials

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Abstract. Ultra High Performance Concrete (UHPC) is a new type of cement-based material composed of cement, fine aggregates, fibers and a high performance water reducing agent. In the present study, experiments were performed to assess the influence of the different components on the performances of this material. It is shown that the compressive strength increases with an increase in the silica fume content. With an increase in the steel fiber content, the compressive strength value of the sample first increases and then attains a plateau. When the volume content of steel fiber exceeds 1.5%, the compressive strength displays a downward trend. The coarse aggregate content has a great influence on the compressive strength. When it is 24%, the UHPC test block under four water-binder ratios attains the maximum compressive strength value.

Keywords: Ultra-High Performance Concrete; Steel fiber; Coarse aggregate; Compressive strength.

1. Introduction

Traditional concrete is made of cement, sand, stone, admixture and water according to a certain proportion, after mixing, pouring curing molding cement-based composite material. Due to its advantages of low cost and simple process, it is widely used in construction, bridge, industrial production and other fields, and is now an important building material [1]. With the development of society and the progress of science and technology, people have higher and higher requirements for buildings, and higher requirements for the performance and strength of concrete. Apparently, traditional concrete has been unable to meet such needs [2]. Ultra High Performance Con-Crete (UHPC) is a new type of cement-based material. Its raw materials are mainly composed of cement, ultrafine particles, fine aggregate, fiber and high performance water reducing agent. By adding ultra-fine active particles and high-efficiency water-reducing agent, the purpose of increasing the material compactness and low water-binder ratio is achieved, so as to improve the performance of concrete materials [3]. In view of this research problem, Zheng, H., et al proposed that the water vapor density and temperature gradient were taken as driving potential, and the results of water vapor distribution and temperature distribution on the wall under periodic boundary conditions were given [4]. Considering the freezing of water inside the wall, Hamiruddin, N. A. et al. modified the driving potential of Luikov equation to be the partial pressure and temperature of water vapor, and gave the heat and moisture transfer equation considering the freezing condition respectively [5]. Junya, TSURUMI et al. proposed a model in which the driving potential was temperature and relative humidity. They studied the underground cave wall, bamboo board wall, aerated concrete wall and red brick wall respectively, and gave the distribution law of temperature and humidity on the wall [6]. The heat consumption of external walls is not only related to the thickness of wall materials and inherent thermal and physical parameters, but also related to the moisture content of materials and the wet flow through the wall [7].The moisture transfer in the wall can affect the indoor thermal environment and the energy consumption of heating and cooling. Moreover, the thermal and moisture performance parameters of the wall are also the basis for solving the relevant transfer model. However, at present, the research of prefabricated building wall is more focused on the formulation, and the performance test is basically focused on dry density, compressive strength, frost resistance, durability, thermal conductivity and pore structure. Among them, the test of thermal performance of prefabricated building walls only involves thermal conductivity, and the test of wet property parameters is not perfect [8].Based on current research in this paper, As a new type cement-based composite material, UHPC is still in the initial stage of development, lack of relevant specifications and guidance. The high performance concrete mix proportion design and experimental study on compressive strength method, this method is silica fume concrete and steel fiber content of UHPC compressive strength, the influence of coarse aggregate content of UHPC compressive strength, the influence of curing conditions on the UHPC compressive strength, the influence of the experimental results show that with the increase of dosage of silica fume. The compressive strength value of (Reactive Powder Concrete,RPC) increases [9].

2. Fabrication and compressive strength test of UHPC

2.1 Raw materials for UHPC test

Cement: hubei Wuhan Yangfang brand P.I52.5 ordinary Portland cement. Silica fume: gray powder, average particle size 0.15 ~ 0.2μm, silica content 85% ~ 97%. Fly ash: Class ii, fineness not greater than 20%, apparent density of 2.20g/cm^3. Quartz sand: refined quartz sand, particle size of 600μm, apparent density of 2.62g/cm^3. Coarse aggregate: the coarse aggregate is basalt, which is cleaned and dried until the saturated surface is dry. The particle size is 5 ~ 10mm. Water reduction rate is greater than 30%. Steel fiber: wire cut type copper plated steel fiber, diameter 0.2mm, length 12mm. Water: laboratory tap water.

2.2 Specimen making and curing

UHPC was prepared by using a vertical concrete mixer with rotation speed of 120r/min. Step 1: Dry mix coarse aggregate (RPC preparation process does not contain coarse aggregate), cement, fly ash, silica fume and quartz sand for 3min; Step 2: the volume of about 70% of the water reducing agent and all water for mixing, and then added to the blender mixing for about 3min; Step 3: When the mixture becomes thick and uniform, evenly disperse the steel fibers into the mixture by hand and mix for 3min; Step 4: Slowly add the remaining superplasticizer until the mixture has a good fluidity.

In this test, 100mm×100mm×100mm triple compression test mold was used. All samples were removed after being preserved for 24h at the test site. The test blocks with natural curing were removed and placed in the curing box with water for natural curing. The test blocks with hot water curing (water temperature :80±5°C) were removed and placed in the curing box with hot water for hot curing.

2.3 Test Methods

The 3000kN microcomputer controlled electro-hydraulic servo pressure tester was used. Compressive strength value method: Three test blocks were taken from each UHPC mix ratio and placed under the electro-hydraulic servo pressure testing machine for compressive strength test.

3. Results and analysis

3.1 Experimental phenomenon

3.1.1 Specimen of steel fiber reinforced concrete

At the early stage of loading, the test block has no obvious change; In the middle of loading, the side of the test block began to bulge outward and vertical cracks appeared along the loading direction, and the concrete on the surface of the test block spalling [10]. At the later stage of loading, the test block began to flake off locally, and the vertical cracks continued to expand and extend along the inside of the test block. When the load reaches the ultimate load, the test block emits a crisp cracking sound, and the fragments collapse and splash.

3.1.2RPC test block doped with steel fiber

As the loading process continues, the side of the test block slightly bulges outwardly, and vertical microcracks appear along the loading direction, accompanied by sharp tearing sound. The steel fibers are pulled out, the cracks continue to expand, and the surface concrete spalling. When the ultimate load is reached, the press reading rapidly decreases after reaching a maximum value. Due to the presence of steel fibers, the test block is damaged but does not splash around [11].

3.1.3 Ca-UHPC test block doped with coarse aggregate

The failure phenomenon of test block is similar to that of RPC test block mixed with steel fiber. However,the increase in coarse aggregate content,when the ultimate load is reached, the sound of test block failure gradually becomes louder, and the press reading rapidly decreases after reaching a maximum value. Due to the restraint effect of steel fiber, there is no significant difference in the scattered degree of stones when the test block with different coarse aggregate content is destroyed [12].

3.1.4 Effect of water adhesive on UHPC

UHPC reduces the proportion and size of aggregate, disperses the aggregate in the concrete body and improves the uniformity of the concrete body. Therefore, the quality of slurry determines the performance of concrete. Because the slurry contains cement and a variety of fine particle components, the amount of water consumption directly determines the hydration reaction of these components, and also determines the density of the structure after hydration reaction, which determines the performance of concrete after hardening.

3.2 Effects of silica fume and steel fiber content on UHPC

The influence of silica fume on strength is mainly reflected in: silica fume particle size is small and has a high degree of dispersion, can be fully filled in the cement particles, improve the density of the slurry hardening; The amorphous S_iO_2 reacts with cement hydration products to form colloids, which can improve the strength of concrete and make the microstructure denser. It reacts with various alkaline substances to reduce the alkalinity of the hydration system, thus determining the properties of hardened concrete [13].

Strength of steel fiber on mainly reflected in: the influence of elastic modulus of steel fiber is five times higher than that of concrete, when cracks UHPC specimen under pressure load,the bonding strength between steel fiber and matrix has a certain crack resistance,at the same time, with the increase of the steel fiber can gelled material matrix of internal friction, so as to improve the uniformity and compactness of the internal. Thus determines the hardening properties of concrete. Figure 1,2 shows the influence of silica fume content and steel fiber content changes on the compressive of UHPC [14].

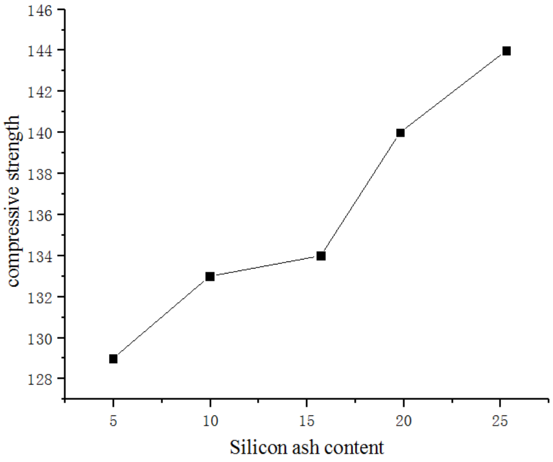

Figure 1. The influence of silica fume content on the compressive of UHPC

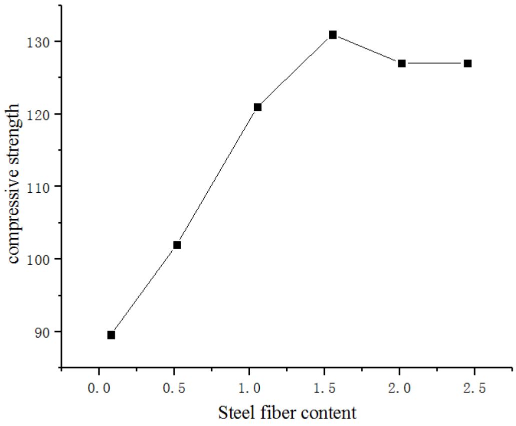

Figure 2. Influence of steel fiber content on the compressiveof UHPC

As can be seen from Figure 1, with the proportion of silica fume in the cementitious material gradually increased, the compressive strength of the specimen gradually increased. The main reason is that the micro-filling effect of silica fume helps to fill the gap between cement particles, so that the cementitious material has a good gradation and improves the compactness of UHPC. In addition, the silica fume has A strong reactivity, the main component S_iO_2 can make the cement particles hydration more fully, which is conducive to the improvement of the strength of UHPC.

As can be seen from Figure 2, with the increase of steel fiber content, the compressive strength value of the specimen increases first and then becomes stableIt levelled off after rising from 90 to 132. Mainly because of adding steel fiber have played an important role energy barrier, when UHPC specimen load crack under pressure, have to gather a lot of energy to destroy steel fiber, at the same time, the steel fiber requires a lot of slurry packages and filling, make UHPC internal friction increases.

3.3 Effect of curing conditions on UHPC compressive

The influence of coarse aggregate on the compressive strength of UHPC is mainly reflected in two aspects: the selected coarse aggregate itself is basalt, which has high compressive strength and rough gravel surface, which can improve the bonding ability of the transition zone between UHPC matrix and aggregate interface; The coarse aggregate forms a rigid skeleton in the system, and the occlusal effect of the aggregate is enhanced, which inhibits the shrinkage and cracking of the test block, and improves the compression performance of UHPC as a whole. Figure 3 shows the influence of coarse aggregate content change on the compressive strength of UHPC.

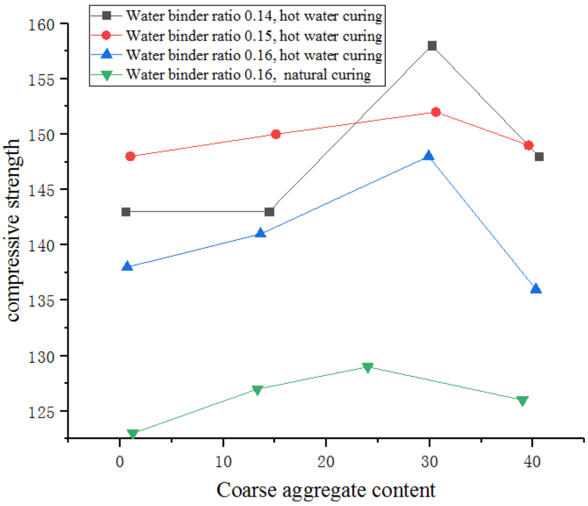

Figure 3. Effect of coarse aggregate content on compressive strength of UHPC

As can be seen from Figure 3, under different water-binder ratios and different curing conditions, the compressive strength of specimens first increased and then decreased with the increase of coarse aggregate content, and the maximum compressive strength appeared when the coarse aggregate content was 24%. The reason: the bond capacity between the aggregate particles and matrix and coarse aggregate in the matrix form of rigid frame are improved to some extent the compressive performance of UHPC, but UHPC compressive strength value with the increase of coarse aggregate content decreases because: coarse aggregate added to block the internal causes weak area, with the increase of coarse aggregate content, The area of weak area will increase, which weakens the framework and leads to the decrease of compressive strength. Excessive coarse aggregate content will reduce the fluidity of UHPC, and with the increase of coarse aggregate content, the phenomenon of steel fiber agglomeration is more and more serious, resulting in the increase of internal defects of UHPC, resulting in a decrease in the compressive strength value.

3.4 Influence of curing conditions on the compressive strength of UHPC

Whether UHPC can achieve its super high performance is closely related to its late humid heat curing. The influence of moisture-heat curing on the strength of UHPC can be divided into three stages. The heating stage is the first stage of UHPC curing after release, and it is also the finalize stage of UHPC structure. The thermal curing can accelerate the reaction rate inside the UHPC matrix, reduce the generation of internal pores in the matrix, and improve the strength faster in the initial setting process. The constant temperature stage is the main growth stage of UHPC strength, but also the consolidation stage of UHPC structure. With the continuous extension of the moisture-heat curing time, hydration is generated continuously, and micro-cracks in the matrix are healed, the density of the structure is improved, and the strength of UHPC is increased. Cooling stages, namely, after reaching a certain period of time need to test the strength of UHPC maintenance, this stage under natural cooling in the air can have significantly reduced the strength of the specimens, and the block to slow cooling in hot water, avoid cracking temperature stress caused by the moisture evaporation inside the UHPC and formation of the channel, the strength loss compensation effect. Figure 4 shows the effect of conservation conditions on UHPC compressive pressure.

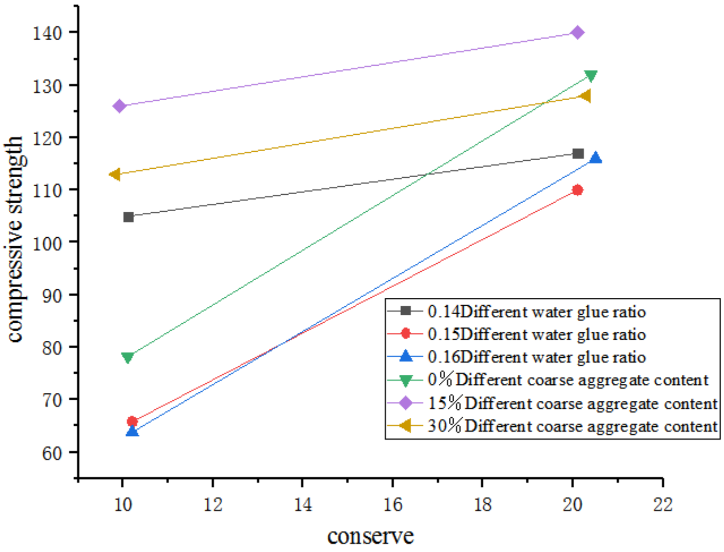

Figure 4. Effect of conservation conditions on UHPC compressive pressure

As can be seen from Figure 4, the compressive strength of specimens under hot water curing is significantly higher than that under natural curing under different water-binder ratios and different coarse aggregate content. The reason: hot water curing reaction speeds up the ash, improving the microstructure of natural gas hydrates, generate low alkaline hydrated calcium silicate, the formation of the hydration products is amorphous, can fill the matrix of internal cracks, with the increase of age, hydration products generated continuously, keep filling capillary porosity, improve cement microstructure, strength increasing, the late maintenance and testing phase, The test block is placed in hot water to cool down slowly, so that the structural damage caused by cracks caused by temperature stress is avoided and the strength loss is minimized. In conclusion, compared with natural curing, hot water curing can significantly improve the compressive strength of UHPC.

4. Conclusions

As a new cement-based composite material, UHPC is still in the initial stage of development, lack of relevant specifications and guidance. Ultra-high performance concrete prefabricated building wall materials, testing compressive strength, by silica fume and dosage of UHPC compressive strength of steel fiber, the influence of the various test results show that with the increase of dosage of silica fume, compressive strength of RPC values increase, When the proportion of silica fume in the cementitious material reaches 25%, the effect of silica fume on the fluidity of the matrix and the decrease of the compressive strength have not been shown. With the increase of steel fiber content, the compressive strength value of the sample first increases and then becomes stable. When the volume of steel changes exceeds 1.5%, the compressive strength value of the sample has a downward trend. The coarse aggregate content has a great influence on the compressive strength value of UHPC, and it shows a consistent rule under different water-binder ratios. When the coarse aggregate content is 24%, the UHPC test block under four water-binder ratios obtains the maximum compressive strength value, and 24% can be used as the optimal coarse aggregate content value. As a testing unit, we refer to the current concrete testing standards, combine the CHARACTERISTICS of UHPC, and strive to improve the UHPC testing system, so as to reduce the differences between the UHPC specimens and the actual mechanical properties. It is believed that the specification and standard for UHPC will accelerate the promotion of UHPC in the future.

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