7th International Conference on the Durability of Concrete Structures
20-22 May **2022**
University of Jinan, Jinan, Shandong, China

Effect of ultrafine supplementary cemetitious materials (U-SCM) on the early cracking of concrete

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ABSTRACT

Concrete structures are now the most widely used structures, and mass concrete is the most common application of concrete in engineering. Due to the weakness of its own constituent materials, cracks are inevitable due to the inadequacy of the materials themselves, especially in mass concrete. The causes that make concrete crack are mainly divided into two types - load cracks and non-load cracks, and since non-load cracks account for 80% of the total cracks in concrete, the main discussion in this paper is on non-load cracks. After the experiment, it is concluded that in C30, when the proportion of U-SCM is 31.25%, the compressive strength increases by 6.32% and the tensile strength increases by 8.84%, and when U-SCM is mixed in concrete, C30 its crack area gradually decreases from 3434mm^2/m^2 to 1386mm^2/m^2.

1. INTRODUCTION

Ultrafine supplementary cemetitious materials, as a cementitious material, is often added to cement as an admixture. Studying the effect of U-SCM on the properties of cementitious materials helps to understand the effect of fineness conditions on the properties of concrete. Due to the hydration of cementitious materials, concrete exhibits high strength and stiffness [1,2,3]. Various admixtures are added to cement, fly ash, silica fume, and mineral powder, and the addition of various types of admixtures not only improves the disadvantages of cement but also further optimizes its strength, while the addition of U-SCM reduces part of the cement dosage, which can effectively reduce the heat of hydration of concrete and improve its performance.

The main difficulty of mass construction comes from the fact that the thermal conductivity of mass concrete is very low and produces a very large heat of hydration, which leads to its early expansion and easy cracking. This cracking then seriously affects the durability of the mass concrete. This cracking is actually an inherent property of concrete. Microcracks are present inside the concrete after it is cast and formed, even if it is not subjected to load [4,5]. Macro cracks are relative to micro cracks and refer to cracks visible to the naked eye with a width of 0.05 mm or more, and if not specifically stated, the cracks mentioned below are macro cracks.

It is well known that the addition of mineral U-SCM to concrete helps to improve the compatibility between cement and high efficiency water reducing agent. Replacing part of the cement clinker with U-SCM improves both the fluidity and the strength and durability of the concrete, making it an indispensable component of bulk concrete [6]. The role of U-SCMs, in addition to having a microscopic filling effect. It can also have morphological plasticization effect or volcanic ash effect, etc.At the same time. In the study of U-SCM can not be separated from the use of water reducing agent, the performance of water reducing agent directly determines the use of U-SCM effect some composite U-SCM mixed with a certain amount of water reducing agent. Practice has proved that the practical application of mineral U-SCM and water reducing agent "double blending" technology in concrete engineering is better, and is the most fundamental means to achieve green concrete [7,8,9].

2. MATERIALS AND METHODS

2.1 Materials

Its cementitious material composition is cement(C), River sand(RS) and Tailings sand(TS), Granulated blast furnace slag(GBFS), Ultrafine supplementary cementitious materials(U-SCM), fly ash(FA). The cement is P.042.5 grade reference cement; The ore powder is the granular blast furnace slag used in Pingdu Weili Mixing Station in Qingdao City, Shandong Province. Fly ash is used in Pingdu Weili Commercial mixing station in Qingdao city, Shandong Province. The main composition of U-SCM is a mixture of higher fineness mineral powder and fly ash.

Fine aggregate: fine aggregate is a mixture of natural river sand and tailing sand, whose fineness

modulus is 2.5. The water content of river sand is estimated to be 5.8%, while that of natural tailing sand is 3.8%, and there is no mud content.

Coarse aggregate: benign gravel with grade of 10-20m is selected for coarse aggregate. The mud content of coarse aggregate is controlled below 0.2%, and there is no mud lump content.

Admixture: in this test environment, the admixture selected is pingdu Weili mixing station polycarboxylic acid water-reducer(P).

2.2 Testing procedure

Test the strength test of U-SCM on concrete specimens, a blank group and U-SCM group are set up, and U-SCM is used to replace mineral powder and a small amount of fly ash for testing the improvement of U-SCM on compressive strength. The experiments will start with C30 concrete. C30S0, C40S0, C30S80, C40S130 are mainly used for the observation of cracks, while C30-X is used for the statistics of 7d and 28d compressive strength. All groups were tested for collapse.

Table 1. Mix design (unit: kg/m3).

Group	C	GBFS	FA	U-SCM	Gravel	RS	TS	P	Water
C30-1	220	80	60	-	1060	540	220	12	170
C30-2	200	-	40	80	1070	560	230	12	170
C30-3	190	-	30	100	1070	560	230	12	170
C30S0	210	60	40	-	1080	795		6.9	195
C30S80	190	-	40	80	1080	795		6.9	195
C40S0	310	80	50	-	960	780		8.1	170
C40S130	240	-	50	130	960	780		8.1	162

The above setup for grouping will explore the main effect of U-SCM on its strength. The experimental method uses an electro-hydraulic pressure tester to determine its compressive strength, and the concrete compressive strength is determined by referring to JGJ 81-85 for operation, and its 7d and 28d compressive strength and collapse degree are measured respectively.

Start to test whether the U-SCM has any effect on the early cracking of concrete. For C30S0, C40S0, C30S80 and C40S130 concrete, the 1d rebound strength was tested using rebound meter.

The effect of the admixture of U-SCM on cracks was also tested to see if the cracking of concrete improved after admixture of U-SCM without any maintenance.

Experimental scheme:

The observation of cracks is observed by special concrete crack observation instrument, every 1h into the observation, and the distribution of cracks statistics, and the average cracking area of concrete calculation formula is as follows:

$$a = \frac{1}{2N}\sum_{i=1}^{N}(W_i \times L_i)$$

W: The maximum width of crack i(mm), accurate to 0.01m,

L: Length of crack I (mm), accurate to 1mm,

N: Total number of cracks (strips),

A: The area of the plate (m2), to two decimal places,

a: Average crack area per crack (mm'/strip), accurate to 1mm/ strip

3. RESULTS

3.1 C30 test result

Through experiments can be concluded that the first set of contrast intensity distribution, is divided into 7 days of strength and 28 days strength, as well as various slump, is clear from the figure, after mixing in U-SCM, in addition to the slump of C30-2 fell slightly, other groups of concrete collapsing are improved, but the dosage of slag U-SCM 31.4%, Replacement of fly ash cement content of 14%, it shows that the U-SCM on the fluidity of concrete has a lot to improve, to reduce the cracks appear at the same time can reduce the mixed water reducing agent, water reducing agent in the concrete early have exacerbated the shrinkage of concrete, caused the cracks of the early, the mixed U-SCM in different aspects, reduce the cracks of the early [10].

In Fig 1, the 28d compressive strength of concrete without the addition of U-SCM is 35.6MPa. The 28d compressive strength of concrete changes obviously with the increase of the content of U-SCM. When the content of U-SCM is 31.4%, the 28d compressive strength of concrete reaches 37MPa.The main reasons for the increase of concrete strength are as follows: slag U-SCM has potential hydraulic properties. Under the activation of cement alkalinity, the activity of slag U-SCM is increased, the density of internal filling is improved, and the strength of concrete is increased. The main reason for the smaller slump loss and good plasticity of concrete with U-SCM is that the addition of U-SCM of slag can slow down the setting speed of concrete.

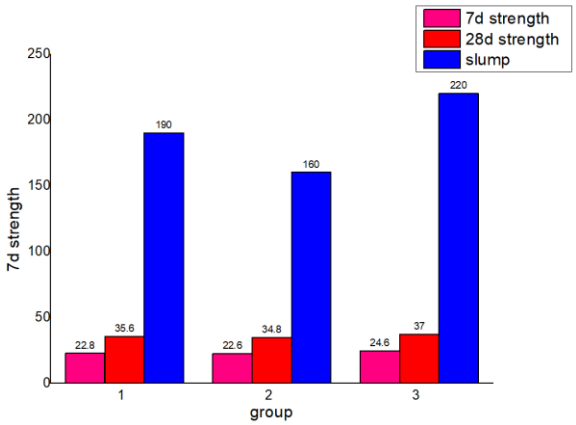

Fig 1. Compressive strength and slump of C30-X at 7d and 28d.

The effect of U-SCM on early cracking was observed by for the cracking of its blank group and U-SCM group. The improvement of early cracking by U-SCM was huge, and the total area of concrete cracking was reduced by 59.64%. In the experiment, the cracking of U-SCM was superior in the absence of any maintenance method. The possible reason for this is that the early water evaporation is small and the initial shrinkage is low in the U-SCM group.

3.2 C40 Test Result

For the application in C40 concrete, we also concluded by experiment. The rebound test for C40S0, C40S130, the 1d compressive strength of C40S130 was reduced by 10.07%, which is because in concrete, the U-SCM hydrates more slowly in the early stage.

Number of cracks per unit area decreased for C40S130, while Average cracking area and Total cracking area increased, resulting in an overall improvement. The cracking situation did not improve substantially, probably because of the increase of water reducing agent in C40, in therefore did not improve the early cracking. After further application of maintenance measures, all the effective cracks tended to disappear.

The main experimental data are presented in Table 2, where ac represents average area of cracks, Nunit represents number of cracks per unit area, AC represent total area of cracks per unit area, Rs represents rebound strength

Table2. The crack resistance grades of face slab concretes to plastic shrinkage determined by slab test.

Group	*Rs*(**N**)	a_c(**mm2/Bar**)	N_{unit} (**Bar / m2**)	A_C(**mm2/ m2**)
C30S0	12.6	97	35.4	3434
C30S80	12.4	83	16.7	1386
C40S0	13.9	40	8.3	332
C40S130	12.5	58	6.3	365

Fig 2. Blank group concrete A and U-SCM group concrete B under no curing condition

4. CONCLUSIONS

After a series of experiments, the main influence of U-SCM in the application of concrete can be concluded that the application of U-SCM instead of mineral powder in concrete is beneficial to improve the performance of concrete. The main experimental conclusions are as follows:

(1) The U-SCM used in concrete, can improve the C30 concrete compressive strength, this is mainly because if there is the potential hydraulic U-SCM and its [12] bigger specific surface area, under alkaline cement inspire, motivate the U-SCM have higher activity, more rapid hydration, early 7 d improves the internal filling compactness, Thus increasing the strength of concrete.

(2) The slump loss of concrete mixed with U-SCM is small and the plasticity is good. The main reason for this result is that the addition of slag U-SCM can slow down the setting speed of concrete. Although the addition of water-reducing agent will aggravate the cracking of concrete, mainly increasing the voids of concrete, it can also effectively reduce the generation of cracks by adjusting the amount of admixture and selecting the appropriate mix ratio [13].

(3) U-SCM C30 concrete without any maintenance also significantly reduces the early cracking, and has a good improvement for its early shrinkage. And C40 concrete in the early cracking no greater improvement.

With the continuous development of the construction industry, the solution of concrete defects has become an inevitable trend of the development of modern architecture. In this paper, the application of U-SCM in concrete is analyzed through experiments, and it is proved that adding slag U-SCM into concrete can effectively improve the fluidity, plasticity, compressive strength and early cracking resistance of concrete. In the construction project, according to the design requirements, the

reasonable addition of U-SCM instead of cement can effectively improve the construction quality and get better benefits.

ACKNOWLEDGMENTS

This study is financially supported by and Natural Science Foundation of Shandong Province (ZR2019BEM034)

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