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Application of sintered lytag concrete in bridge reinforcement and reconstruction project in cold areas

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ABSTRACT

On the issue of low salt scaling resistance of ordinary concrete, a sintered lytag concrete is developed to replace the ordinary concrete in the application of reinforcing and reconstructing a bridge in cold areas. This paper presents the test methods and the evaluation parameters of the salt scaling resistance for the concrete, and the test standard for the salt scaling resistance of the concrete (CDF) recommended by RILEM was chosen to study the salt scaling resistance of the sintered lytag concrete and ordinary concrete. The results show that the frost resistance of one side of the sintered lytag concrete with the mineral admixtures is greatly higher than that of the ordinary concrete at the same strength grade; the single-side frost resistance order of the mineral admixtures in 56 times tests is (from higher to lower): silicon ash + slags> silicon ash +fly ash> slags+ fly ash> silicon ash>fly ash > slags. As the sintered lytag concrete has a good salt scaling resistance, the bridge in the severe cold area reinforced through the sintered lytag concrete not only can effectively improve the salt scaling resistance of the bridge, but also can greatly reduce the weight of the bridge.

KEYWORDS

Lytag, concrete; Cold areas; Bridge reinforcement and reconstruction.

INTRODUCTION

The lightweight aggregate concrete has the following excellent properties, such as the lightweight, high strength, seismic resistance and good durability [1]. Therefore, the lightweight aggregate concrete is more and more widely used in the construction engineering. Due to the large weight and higher foundation construction costs, the large-scale bridges built on the soft soil foundation in cold areas are one of fields which can best embody the benefit advantage of the lightweight aggregate concrete. Due to the characteristic of the small density, the application of the lightweight aggregate can effectively reduce the dead weight of the upper structure of the bridge and significantly reduce the expenses of the foundation, the lower structure and the prestressed steel. As one of the important components of the concrete, the mineral admixtures are more commonly applied into concrete to improve the workability and long-term durability of the concrete [2-3].

With the continuous improvement of the highway grade, the increasing old bridges need to be widened, because the pavement layer should be applied to the bridge deck of the whole widened old bridges, the pavement with the ordinary concrete will inevitably increase the dead load of the bridge desk slabs of the old bridges, which is adverse to the structural safety of the bridge. In this case, it is particularly important to look for a material which has the performance similar to the ordinary concrete and the light volume-weight instead of the ordinary concrete. As a new type of lightweight high-strength concrete, the sintered concrete is just filling in the gaps in the pavement materials for widening the bridge decks of old bridges.

In combination with examples for the reinforcement and reconstruction project of the long-span bridge structure in a cold area, this paper presents the study on the application of the sintered lytag concrete in the reinforcement and reconstruction project in the cold areas. The practice shows that the utilization of the sintered lytag concrete in the reinforcement of the bridges in the cold areas can bring the very obvious social benefits.

PROJECT PROFILE

A bridge in a cold area falls in to the disrepair. The girder span of the bridge is 28 m and the girder is composed of 4 simply supported hollow plate girders for each lane. Some components of the original bridge are identified by the related testing company to fail to meet the requirements of the strength and rigidity, so these components must be reinforced. However, the ordinary concrete has a poor frost-resistance. After comprehensive consideration, therefore, the sintered fly-ash concrete is decided to be used for the reinforcement of the bridge. In order to study the feasibility that the sintered fly-ash concrete is used to reinforce and reconstruct the bridges in the cold areas, the laboratory research is conducted and focuses on the salt scaling resistance of the sintered lytag concrete before the reinforcement and reconstruction of the actual structure.

TEST METHODS

Frost-resistance test methods

For the China’s frost-resistance test methods and the rapid freezing and thawing test method of the ASTM [4-5], six surfaces of each test piece are immersed in the water during the thawing process in order to let more water enter into the concrete. In practice, however, this case is rare, because when the front end of the ice moves to the concrete on site, one or more surfaces are not frozen, in this way, the water will retreat from the concrete pore structure system before the front end of the ice arrives, which shall ease up the freezing destroy. The single-side freezing and thawing test is closer to the case that the concrete is exposed to the freezing and thawing cycle environment. The CDF method, the standard for EU salt freezing test, is a single-side freezing and thawing method and it can also detect the internal destroy of the concrete [6]. The Freezing and Thawing Test Method with Deicing Salt Immersion (DIN EN 13687-1:002) [7] is similar to the slab test recommended by RELIM.

Test Equipment

The NM-4A nonmetal ultrasonic testing analyzer from Beijing Koncrete Engineering Testing Technology Co., Ltd is used.

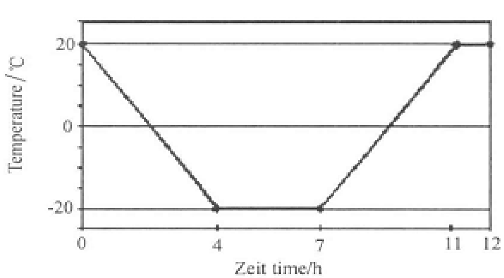

Figure 1 Freezing-thawing cycle of CDF test

Figure 2 Experimental device for one-side freez-thaw

The self-developed concrete freezing-thawing cycle testing machine and its intelligent control device can implement the single-side salt freezing test, with the freezing and thawing system in accordance with the CDF test method, as shown in Figure 1.The test equipment for this test is shown in Figure 2.

Test procedure

The test is conducted by reference to the CDF method, the standard for EU salt freezing test. The concrete test pieces are mixed at the mix proportion specified in Table 2. The sizes of the test pieces are 150mm*150mm*55 mm, of which the 150 mm*150mm face refers to the test face and each group has 5 test pieces. The test pieces should be placed in the standard curing room for 28d, and then dry up at 80 for 24 h. Later, take them out to cool them down to the room temperature. After that, seal the test pieces around with the aluminum foil containing the butyl rubber. Keep one side of each test piece soaked in the icing salt solution for 6d, with the immersion depth of 5 mm. Take them out and use the ultrasonic tester to measure the initial time-of-flight that the ultrasonic wave passes through the test pieces. Then immerse the test pieces in the deicing salt solution and then place them in the freezing-thawing cycle testing machine for the test. Separately measure the denudation quantities of the test pieces and the time-of-flight that the ultrasonic wave passes through the test pieces during the 14th, 28th, 42th and 56th freezing-thawing cycles, and observe the denudation on the surface of the test pieces. The mix proportion of the concrete is as shown in Table 1.

TABLE 1 The mix proportion and compressive strength of LYTAG concrete

	cement	slag	Fly ash	Silica fume	water	sand	LYTAG	Slumps	compressive strength
O	530.0	0	0	0	244.0	565	568	175	39.0
A	487.6	0	0	42.4	271.0	565	568	175	42.2
B	424	106	0	0	244.0	565	568	165	38.1
C	424	0	106	0	244.0	565	568	170	37.8
D	424	53.0	53.0	0	244.0	565	568	165	39.1
E	424	0	63.6	42.4	244.0	565	568	170	39.8
F	424	63.6	0	42.4	244.0	565	568	165	41.2

RESULTS AND DISCUSSION

Denudation quantity

Three test pieces fixed and formed at each mix proportion are subject to the test. After placing the test pieces in the standard curing room for 28d, immerse them in the 3% NaCl solution for 6d before the anti-freezing test, with two freezing-thawing cycles every day. Weigh the spalls before the test and after the different freezing-thawing cycles to measure the mass loss of the test pieces caused by the freezing and thawing cycles. After the 14^{th}, 28^{th}, 42^{th} and 56^{th} freezing-thawing cycles, the denudation quantities of the concrete are shown in Figure 3. Seen from the Figure 3, the single-side frost resistance of the sintered lytag concrete mixed with the mineral admixtures is significantly superior to that of the ordinary concrete, and the single-side frost resistance of the concrete with the compound mineral admixtures is vastly superior to that of the concrete with the single mineral admixture. During the 56^{th} freezing-thawing cycle, the denudation quantities of the test pieces A, B, C, D, E and F are separately 30.3%, 34.6%, 31.7%, 18.5%, 9.7% and 7.1% of the denudation quantities of the ordinary concrete. Besides, the Table 3 shows that the salt scaling resistance of the concrete mixed with the 20% fly ash is similar to that of the concrete mixed with the slag mineral admixtures during the 56^{th} freezing-thawing cycles. The salt scaling resistance order of the compound mineral admixtures at the 56^{th} freezing-thawing cycle is (from higher to lower): silicon ash + slags > silicon ash +fly ash> slags+ fly ash.

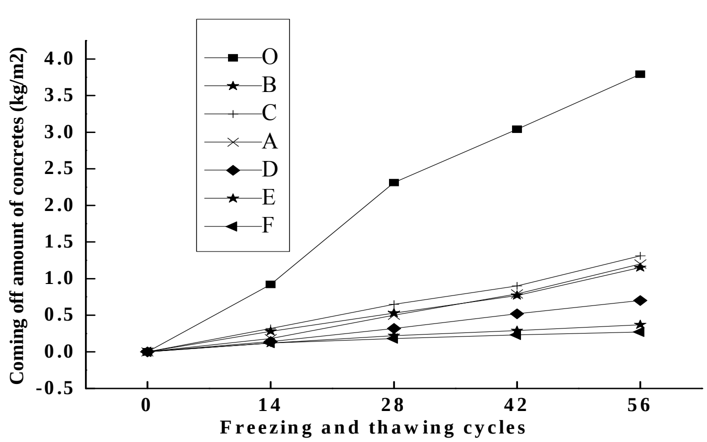

Figure 3 Coming off amount of concretes

Dynamic modulus of elasticity

In order to reveal the inside destroy of the concrete caused by the freezing-thawing cycles, the concrete ultrasonic detector is used to conduct the ultrasonic detection for the concrete test pieces before freezing and after the 14th, 28th, 42th and 56th freezing-thawing cycles to get the relation between the loss ratio of the dynamic modulus of elasticity and the freezing and thawing cycles, as shown in Figure 4.

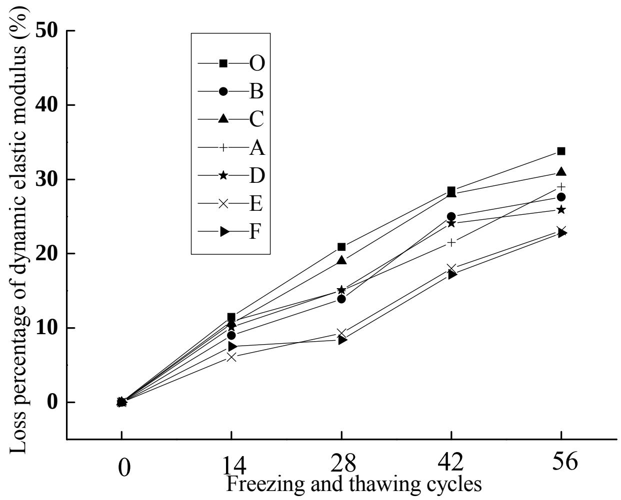

Figure 4 Loss percentage of dynamic elastic madulus

Seen from the Figure 4, the loss of the concrete dynamic modulus of elasticity tends to be equal to the denudation quantity. The dynamic modulus loss of elasticity of the sintered fly-ash concrete mixed with the mineral admixture is lower than that of the ordinary concrete. During the 56^{th} freezing-thawing cycle, the dynamic modulus loss of elasticity of the ordinary concrete is 42%, while the dynamic modulus losses of elasticity of the sintered fly-ash concrete test pieces A, B, C, D, E and F are 27.6%, 30.9%, 29%, 30.9%, 23.1% and 22.8%, respectively. The dynamic modulus loss of elasticity of the compound mineral admixtures is significantly lower than that of the ordinary concrete.

Surface flaking

The internal destroy caused by the freezing and thawing cycles and the surface flaking caused by the freezing of the external water and salts are two basic problems the frost resistance durability faces. In order to reveal the external destroy of the concrete as the results of the freezing and thawing cycle, the Figure 5 shows the surface flaking phenomena of the ordinary concrete and the sintered lytag concrete after the 56^{th} freezing-thawing cycle. In the paper, as the water content of the ordinary concrete is quite high, the surface denudation of the concrete is very serious and some aggregates are exposed after freezing and thawing. Although there are the surface flaking phenomena for the sintered lytag concrete, the part of the screed is peeled off and the lytag is not exposed, which shows that the salt scaling resistance of the sintered lytag concrete mixed with various mineral admixtures is obviously superior to that of the ordinary concrete in the same strength grade in this test.

a) C30 ordinary concrete b) CL30 lytag concrete

Figure 5 Surface scaling of concretes

Mechanism analysis

Because of the Ca^{2+} ions shift in the interface region between the set cement and the lytag, with the abrupt change of Si element along the direction from the lightweight aggregate to the set cement as the judging criterion for the starting point of the interface, the author analyzes the interval length of the Si element change in the content from high to low and then keeping stable, and measures the width of the interface between the set cement and lightweight aggregate of six groups of samples. Adjust the magnification to 5000 and choose 5μm as the scanning step size to conduct the line scanning from the lightweight aggregate surface along the direction of the cement primary structure, with the results shown in Figure 6.

Seen from Figure 6, there is the higher S/C mass ratio in the interface region relative to the primary structure, on the one hand, this is because the Ca^{2+} ions in the interface region shift to the lightweight aggregate, while the Ca^{2+} ions in the primary structure shift to the interface region at the slower speed, in this way, the S/C mass ratio in the interface region is higher than that in the primary structure; on the other hand, this shows that the content of calcium hydroxide in the interface region is low. As shown in the Figure 6, the S/C mass ratios of test pieces in the interface region are gradually reduced along the direction from the lightweight aggregate to the set cement and then keep stable. Within the scope of 5 ~ 20μm for the interface width, the S/C mass ratios of test pieces in Group F are the lowest, which shows that the content of calcium hydroxide of the test pieces in Group F is highest.

The width of the interface between the lightweight aggregate and the set cement is about 5 ~ 20μm, of which the interface widths of the test pieces in Group A, B, C, D, E and F are separately 10μm, 20μm, 15μm, 10μm, 10μm and 5μm, that is, the interface width order of the test pieces in each group is : B > C > A = D = E> F; the smaller the width of the interface is, the superior frost resistance the test pieces have, therefore, the conclusion is consistent with the conclusions from the measurement of the mass loss, ultrasonic measurement and surface flaking phenomena.

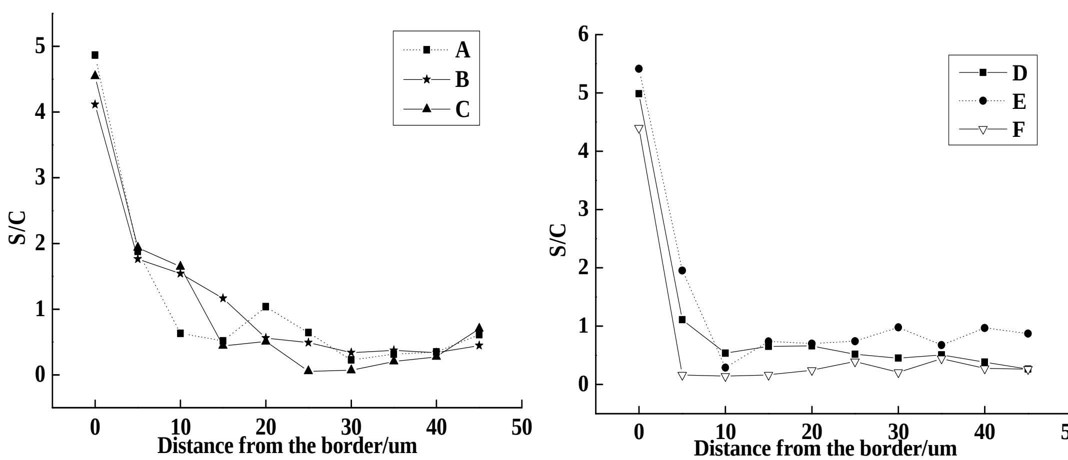

Figure 6 Silica/calcium oxide (S/C) mass ratio in interfacial transition zone

REINFORCEMENT AND RECONSTRUCTION SCHEME

To increase span of bridge

The utilization of the sintered lytag concrete in the reinforcement and reconstruction works of the bridges can reduce the weight of the upper structure of the bridge by 25%, under the condition of considering the construction lifting weight, to increase the bridge span can obviously cut the construction cost, especially for the bridges built on the soft soil foundation. Therefore, the span of the bridge girder is increased from 28 m to 36 m in the reinforcement and reconstruction works.

To change structure of main girder

The main girders of the original bridge was composed of 4 simply supported hollow plate girders for each lane, and after the reinforcement and reconstruction, the main girders are composed of 2 pieces of precast box girders in each lane which are connected through the continuous cast-in-place concrete slabs, which can save the prestressed steel, increase the integrity of the structure and enhance the seismic performance of the structure.

Bridge deck pavement

The original bridge deck was paved with the common concrete and in the reinforcement and reconstruction project, the sintered lytag concrete instead of common concrete are used for the bridge deck pavement, thus greatly reducing the structure weight and basically not affecting its strength. At the same time, it can also improve the abrasion resistance and durability of the bridge deck and obtain the good social and economic benefits, therefore the sintered lytag concrete can further be spread and applied.

CONCLUSIONS

The conclusions are as follows from the case that the sintered lytag concrete is applied in the reinforcement and reconstruction of a bridge in a cold region:

● The frost resistance of one side of the sintered lytag concrete with the mineral admixtures is greatly higher than that of the ordinary concrete at the same strength grade

● The single-side frost resistance order of the mineral admixtures in 56 times tests is (from higher to lower): silicon ash + slags> silicon ash +fly ash> slags+ fly ash> silicon ash>fly ash > slags.

● The width of the interface between the lightweight aggregate and the set cement is about 5 ~ 20μm, of which the interface width order of the test pieces in each group is: B > C > A = D = E> F; the smaller the width of the interface is, the superior frost resistance the test pieces have.

● For the sintered lytag concrete applied in the reinforcement and reconstruction of bridges, its most prominent advantages are the lightweight, high strength and good frost resistance. The utilization of the sintered lytag concrete in the reinforcement of the bridges in the cold areas can bring the very obvious social benefits. At the same time, the research on the new materials will provides a better idea that the lightweight concrete is widely used in the highway bridge construction.

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