An Experimental Study on the Properties of High Strength Concrete

Yanjie LIU [*,1,2], Lin DING [1,2], Kun HU [1]

[1]*School of Civil Engineering, Heilongjiang University, Harbin 150086, P.R. China*

[2] *Northeast Frost Civil Engineering Key Laboratory of Heilongjiang University, Harbin 150086, P.R. China*

***Abstract* — Research on high-strength concrete is not systematic in China, based on the suitable materials and methods, the technical and mechanics properties of the high strength concrete are studied in this paper. A study of the durability of concrete in a mixture of silica fume is carried out on the compressive strength of high-strength concrete as influenced by the water binder ratio, silica fume and other parameters. Through suitable test methods, the optimal mixture ratio design of high strength concrete was determined in different circumstances. The results show that the concrete produced by using silica fume has good durability. The performance of high strength concrete with mixture of silica fume is higher than the standard high strength concrete.**

Keywords - Silica fume, high strength concrete, compressive, anti-freeze-thaw strength.

I. INTRODUCTION

Concrete long term exposure to various environments, it often can cause varying degrees of damage, or even completely destroyed. Concrete engineering mostly is permanent, so the durability of concrete is one of the most important indexes to measure the performance of concrete[1,2]. A lot of research shows that the durability of high strength concrete is good. The frost resistance of concrete is especially important in the northern area. Ordinary concrete is difficult to achieve high frost resistance requirements[3,4]. Application of silicon powder concrete is undoubtedly improve the frost resistance in concrete engineering. The incorporation of silica powers, greatly improve the concrete freezing and thawing properties[5,6].

In this paper, the early strength and frost resistance of high strength concrete mixed with silica fume was studied.

II. THE INITIAL STRENGTH OF THE HIGH STRENGTH CONCRETE

For ordinary concrete, antifreeze incorporation can prevent freeze thaw damage. For the ordinary concrete with high water ash, the air lead gas is still the best method for producing frost resistant concrete[7,8].

Early stage high strength concrete (strength of 80-120MPa) [9], Due to super plasticizer greatly reduce the water cement ratio, so that the porosity of cement paste is very low, the aperture is small and not connected to each other. So there is only a small amount of or no frozen water in high strength concrete, and the influence of wet dry cycle on the saturation of high strength concrete is also less than that of ordinary concrete[10].

So, in theory, even without air agent, high strength concrete should be frost resistant. In the paper, the early compressive strength, frost resistance and frost resistance mechanism of high strength concrete was studied., which water cement ratio are 0.32 and 0.37， and the effect of silica fume on the freezing resistance of concrete

TABLE 1. SILICA FUME CONCRETE MIX DESIGN /KG

Group	Breakstone	Sand	Cement	Silica powder	Water
1	84	45	50	0	16
2	84	45	47. 75	2. 25	16
3	84	45	44. 5	5. 5	16
4	84	45	44	6	16
5	84	45	50	0	18. 5
6	84	45	50	0	18. 5
7	84	45	47. 75	2. 25	18. 5
8	84	45	44. 5	5. 5	18. 5
9	84	45	44	6	18. 5

In this paper, the initial strength of 9 groups of high strength concrete was studied. The early strength were tested with different age, different water cement ratio and different silica fume admixture, the result was show tables 1 and 2.

TABLE 2. INITIAL STRENGTH OF HIGH STRENGTH CONCRETE /MPA

	W/C= 0. 37				**W/C= 0. 32**			
	Silica powder							
Day	0%	5%	10%	15%	0%	5%	10%	15%
1	83	89	90	103	103	104	109	128
2	85	85	93	97	92	100	100	129
3	80	93	86	103	99	100	111	131
4	80	88	91	106	104	112	118	130
5	75	87	89	89	97	110	129	128
6	89	82	82	91	101	99	105	124
7	86	92	81	94	97	105	112	133
28	78	87	89	100	96	104	114	130

III.THE FROST RESISTANCE OF THE HIGH STRENGTH CONCRETE

A. The Damage Reason of Concrete Freezing Thawing

The frost damage to concrete is related to the organization structure and the content of water in concrete. When water freezes, the volume increased 9%. The destructive function mainly include ice expansion pressure, water pressure and microscopic analysis of water [11].

B. Effects of Ice Expansion Pressure

When water freezes, its destructive effect mainly occurs is relatively coarse pores in the full of water. When the pores are filled with water and fast ice, it will produce very big ice expansion pressure. The capillary wall is subjected to tensile stress, resulting in concrete material were destructed. The size of the ice expansion pressure and damage degree, they depending on the material pore water saturation degree and the material deformation ability [12].

C. Effects of Water Pressure

Most of the concrete material, various types pores and the water filling degree are not the same in the internal .When water freeze in the different aperture gradually, and accompanied by the ice volume increased, resulting in excess water has not frozen move to the specimen edges[13]. In the process, water pressure generated, so that the pore wall is subjected to tensile stress, resulting in material volume expansion. When ice melts, material volume will shrinkage, but will leave some residual stress and deformation. After many times of freezing and thawing, material will be destroyed.

D. Effects of Microscopic Analysis of Water

Water in pores, usually is dilute solution of salts. Once frozen, pure ice was precipitation, and the concentration of the solution to improve. At this time, if adjacent pores in freeze and there are still the original concentration of the solution, which produce the concentration difference, water has migration to frozen regional and quickly frozen [14].

To the pure water, when the temperature decreases, its surface tension increases, transfer to larger pore, and make the ice increases, causing the ice expansion pressure and water pressure are more serious. Because the phenomenon of microscopic analysis of water, so that freeze-thaw damage intensifies [14].

IV. MECHANISM OF SILICA POWDER

Silica powder is a kind of blend materials. The particles is fine (particle size is 0. 1~ 1.0 μm), and the activity is very high (specific surface area is 20~ 25 m2/ g) . The main composition of silica powder is amorphous silica. when the silica powder and efficient water reducer introducted into concrete, silica powder and Ca (OH) 2 reaction of hydrated calcium silicate gel, filling the gap between the cement particles, improving the interface structure and bonding force, so as to improve the concrete strength.

In addition, judging from its structure, silica powder mixed in concrete, although the crevice rate of cement stone is basically the same with no the content, but the coarse pores and capillary pores large reduction, and ultrafine pore increase. Ultrafine pore have larger adsorption to the water, make the water's freezing point decreased, thus, delaying the process of freezing and thawing, and reduces the failure stress. It is because of the increase of strength and structure improvement, so as to improve the frost resistance of concrete.

V. CONTRAST TEST

A. Raw Materials

The raw materials of experiment is shown in Table 3.

B. Determination of Concrete Proportioning

Through the comparative test of different silica powder

dosage concrete and not mixed with silica powder concrete, to determine the effect of the frost resistance concrete on silica powder. The experimental conditions is water cement ratio is constant, control collapse depth 3 ~4 cm, and change the amount of silicon powder. The test block is cuboid, 10 cm× 10 cm× 40 cm. Maintenance is 28 d, water cement ratio is 0.5, sand rate is 44%, High efficiency water reducingagent (UNF) is 9%, the packet is shown in table 4.

TABLE 3. THE RAW MATERIALS OF EXPERIMENTAL

Materials	Standards
cement	42.5 ordinary portland cement
sand	medium sand FM= 2.7
Break stone	D max= 20 mm
admixtures	High efficiency water reducing agent
silica powder dosage	10%和 15%

TABLE 4. MIXTURE RATIO WITH THE GROUPING TEST

Group	1 m3 concrete amount of materials / kg			
	Cement	Break stone	Silica powder	Sand
1	400	1000	40	550
2	400	1000	60	550
3	400	1000	---	550

TABLE 5. THE TEST RESULTS OF THE CONCRETE IN THE PROCESS OF FREEZING AND THAWING

	Weight loss ratio / %			The relative dynamic elastic modulus/ MPa		
The times of freezing and thawing	**1 (with silica powder 40 kg)**	**2 (with silica powder 60 kg)**	**3 (with silica powder 0 kg)**	**1**	**2**	**3**
0	0	0	0	100	100	100
50	0.1	0.1	0.7	95.2	95.4	91.0
100	0.2	0.2	1.6	93	94.9	85.7
150	0.3	0.3	2.1	89.3	92.6	72.2
200	0.4	0.4	2.8	85.9	92.6	61.0
250	0.5	0.5	3.2	83	88.8	45.2
300	0.6	0.5	3.5	81.5	88.8	24.8

The experimental equipment adopt freeze-thaw test machine. The specimen in the freezing and thawing process are in a saturated state. The specimen in the frozen thaw process, the center temperature respectively control in between 17~ 18℃. One freeze-thaw cycle about 3 h. The test results are shown in Table5.

VI. TEST ANALYSIS

The relative dynamic elastic modulus decreased, showed that concrete micro crack deformation stored energy release. The crack tip stress concentration started to spread in the vicinity of cement gel block.

From the experimental results, the effects of silica fume, after 300 cycles, the dynamic elastic modulus decreased to 88.8, but not with silica fume concrete, the elastic modulus decreased to 24.8.

In addition, weight loss rate were 0.6%, 0.5%, 3.5%,

and this reflects that the surface of silica powder concrete almost no cracking condition after freezing and thawing, while the ordinary concrete cracking is generated actual state of cracking from peeling .

VII. CONCLUSIONS

The silica powder concrete compared with conventional concrete, not only the excellent mechanical properties, the freeze-thaw cycle number > 500, but also the durability of the material with good freezing and thawing.

The silica powder improve the internal structure of concrete, which leads to 300 freeze-thaw cycles, the decrease of relative dynamic modulus of elasticity is small. The silica powder improved the properties of concrete itself, increase the adhesive force between materials, limiting the concrete crack propagation, maintains the integrity of concrete.

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