Influence of Silicon Powder on Concrete Freezing Resistance

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***Abstract* — With the rapid development of construction industry, improve the strength of concrete is the most common concern problem in today's civil construction circles of all countries in the world. The studies on the durability of the concrete with the mixture of silica powder are carried out. The results show that the concrete produced by using silica powder has very nice durability. All results show that the performance of the concrete with mixture of silica powder is higher than the standard concrete, and is increased significantly. This paper expounds origin and mechanism of concrete of freezing and thawing destroy. The test result validates that silicon powder have great impact on concrete frost resistance.**

Keywords - Silicon powder; freezing and thawing; movement modulus elastic; structure

I. INTRODUCTION

Silica powders have great effective activity due to its extreme fineness and silica content. Silica fume can improve concrete properties [1-2]. Silica powder could improve compressive strength, bond strength, frost-resistance and abrasion-resistance; Silica powder reduces permeability and therefore helps in protecting reinforcing steel from corrosion. Silica fume concrete has been widely used in civil and hydropower engineering, highway engineering and bridge engineering [3]. Silica powder is used in concrete to improve permanent stability and frost resistance [4-5]. Silica powder powders concrete is suitable to use in freezing regions. Research on mix proportions of silica powders concrete has important theoretical meaning and can provide a basis for applications [6-7]. 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 [8-9]. The frost resistance of concrete is especially important in the northern area. Ordinary concrete is difficult to achieve high frost resistance requirements [10-11]. 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 [12-13].

II. 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 [14-15].

A. Effects of Ice Expansion Pressure

When water freezes, its destructive effect mainly occurs is relatively coarse pores in the full of water [16]. 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 [17]. The size of the ice expansion pressure and damage degree, they depending on the material pore water saturation degree and the material deformation ability [18].

B. Effects of WaterPressure

Most of the concrete material, various types pores and the water filling degree are not the same in the internal [19] .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 [20]. 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 [21]. After many times of freezing and thawing, material will be destroyed.

C. Effects of Microscopic Analysis of Water.

Water in pores, usually is dilute solution of salts. Once water frozen, pure ice was precipitation, and the concentration of 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 [22]

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.

III. MECHANISM OF SILICA POWDER

Silica powder is a kind of blend materials. The particles is fine (particle size is 0. 1~ 1.0 μ m), and the activity is very high (specific surface area is 20~ 25 m^2/ g) . The main composition of silica powder is amorphous silica. when the silica powder and efficient water reducer introduced 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 [18-19].

IV. CONTRAST TEST

D. Raw Materials

The raw materials of experiment is shown in Table 1.

TABLE I. THE RAW MATERIALS OF EXPERIMENTAL

Materials	Standards
Cement	42.5 ordinary cement
Sand	medium sand FM= 2.7
Breakstone	D max= 20 mm
Admixtures	High efficiency water reducing agent
Silica Powder Dosage	10%和 15%

E. Determination of Concrete Proportioning

First with the orthogonal experiment design method, the analysis of water/cement ratio（W/C）, dosage of silicon powder and sand ratio of silicon powder concrete compressive strength, the results show that the W/C ratio on compressive strength of silicon powder concrete effect most, silicon powder content. Sand ratio of silicon powder concrete compressive strength of the minimal impact, but looked from the mixing process, sand ratio for 32% of the workability of concrete mixing content is better than that of 30% and 34%. Therefore, in the back of the experiment, sand ratio 32%.

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 cube，10 cm× 10 cm× 40 cm. Maintenance is 28 d, water cement ratio is 0.5, sand rate is 44%, High efficiency water reducing agent (UNF) is 9%, the packet is shown in table 2.

TABLE II. MIXTURE RATIO WITH THE GROUPING TEST

Group	1 M^3 Concrete quantity of Materials / Kg			
	Cement	Breakstone	Silica Powder	Sand
1	400	1000	40	550
2	400	1000	60	550
3	400	1000	---	550

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 Table 3

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

The times of freezing and thawing	Weight loss ratio/ %			The relative dynamic elastic modulus/ MPa		
	1 (with silica powder 40 kg)	2 (with silica powder60 kg)	3 (with silica powder0 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

V. 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.

Freezing test method using specimens size are $100mm \times 100mm \times 400mm$ prism, each specimen 300 freeze-thaw cycles in a row, if before a 300 - cycle the relative dynamic elastic modulus of concrete to the initial value of 60% decreased or 5% weight are loss, test is terminated. The test method using DF characterization of the frost-resistance of concrete durability index, DF computation formula is as follows:

$$DF = \frac{PN}{300_s} = \frac{NE_N}{300E_0}$$

Here P---N times after freezing and thawing cycle of relative dynamic elastic modulus;

E_N ---- N times freeze-thaw circulation after the dynamic modulus of elasticity;

E_0- ---the initial dynamic modulus of elasticity.

If *DF* values is less than 0.4, it means that frost-resistance of concrete is bad; if *DF* value is 0.4 ~ 0.6 , the freezing- resistance are acceptable; When the *DF* is greater than 0.6,the frost-resistance are suitable.

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 .

Based on the test, studied the W/C ratio and the dosage of silicon powder on the properties of silicon powder concrete impermeability. Study shows that silicon powder can effectively improve the permeability-resistance of concrete, concrete permeability resistance increased with the increase of silicon powder, when near 12% of silicon powder, silicon powder, the permeability-resistance of concrete performance-resistance is the best, more of silicon powder, permeability performance declines.

Through experiment， the W/C ratio and the dosage of silicon powder on the properties of silicon powder concrete shrinkage effect are discussed ，silicon powder concrete early shrinkage strain with silicon powder increases with increasing dosage, when 10% of silicon powder, reach maximum shrinkage strain, if silicon powder content increase, shrinkage strain decreases rapidly. The dry shrinkage deformation of concrete mainly occurs within the 7d, 28d specimen near dry shrinkage deformation basically stable.

VI. 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.

Antifreeze and superplastic incorporation can increase frost resistance of concrete. Compare to silica fume and water-binder-ratio, the effect of antifreeze and super plastic on frost resistance of concrete is very little. Silica fume incorporation increases highly frost resistance of concrete. The optimum silica fume replacement percentage for s frost resistance is 10%. If silica fume is 10%, index of frost resistance DF is larger than 0.4. If water-binder-ratio is from 0.3 to 0.35, index of frost resistance DF is larger than 0.6. At the beginning, frost resistance of concrete increases with the increase of silica fume. Frost resistance of concrete reduces with the increase of silica fume.

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