Effect of Silica Powder to Frost Resistance of Concrete

Yanjie Liu1,2, Lin Ding1,2*, Tianyu Yang1, and Xunan Wang1
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
*Corresponding author’s e-mail: 18646387888@163.com

Abstract: The improving strength of concrete is the hot issue. The concrete with silica powder was studied. This experimental study comprises 3 groups concrete specimens with a fixed water/cement ratio. The concrete using various silica powder had improved the concrete relative dynamic elastic modulus and weight loss rate. The experiments showed that the concretes with mixture of silica powder showed good performance, and the concrete frost resistance increased significantly. The silica powder improved its structure of concrete. The tests proposed that silicon powder has great impact.

1. Introduction
The concrete often can be damaged by the environments, sometimes even made structure completely destroyed. Concrete engineering projects are used in many area, so the durability of indexes for concrete is one of the most important factor. The frost resistance of concrete is especially important in the cold area buildings. To improve the frost resistance of concrete that using silica powder was studied in the paper. The result showed that the silica powder greatly improves the concrete freezing and silica powder properties.

2. The concrete damage by freezing and thawing in cold area
The damage of concretes are related to the volume change of water turn into ice which the volume increased 9%, it cause the structure of concrete deformed. When water in the concrete rate have great effects by the freezing and silica powder. The destructive function mainly includes ice expansion pressure, water pressure and microscopic analysis of water [1-2].

2.1. Effects of ice expansion pressure in the concrete
When water is freezing because the temperature is below zero, its ice occurs in pores which the full of water in concretes. When the water that filled with pores in concrete changed into ice, ice will occur very big ice expansion pressure. The capillary wall changed into tensile stress, resulting in concrete of buildings 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 [3].

2.2. Water pressure in the concrete
The concretes have various types pores that cause by the materials and curing conditions etc. The water filling degree which are based on the internal structure and its environments. When water in concretes freezes in various gradually, and the ice volume of concretes increased, resulting in that excess water which has not frozen will move to the ice specimen edges [4]. In the process, water pressure
generated, also the pore wall is subjected to tensile stress, material volume expansion were happened. When ice melt into water, material volume will be shrinkage, residual stress and deformation were released. With many times of freezing and thawing cycles, concretes were destroyed.

2.3. Microscopic Analysis of Water in the concretes
Pore water in the concretes usually is dilute solution of salts. When water was frozen, pure ice was precipitation, and the concentration of solution was changed. During this period, if adjacent pores of concretes in freeze and there are still the original concentration of the solution, made the concentration difference, water in the concretes have migration to frozen regional and quickly frozen [5].

To the pure water in concrete, when the temperature decreases, water surface tension will be increased, cause water transfer to larger pore, and the ice in the concrete will be increased, causing the ice expansion pressure and water pressure are increased quickly. The phenomenon of microscopic analysis of water in the concrete, so that freeze-thaw damage intensifies [6].

3. Mechanism of silica powder worked in the concretes
Silica powder is one kind of fine blend materials. The particles size is 0.1~1.0 μm, and the activity is very high because its specific surface area is very high. The main composition is amorphous silica. While the silica powder and water reducer were used in concrete, silica powder and Ca (OH)₂ have the reaction each other and hydrated calcium silicate gel, it filling the gap between the cement particles, so it improved the interface structure and increased bonding force, so as to improve the concrete strength.

Judging from its structure, silica powder were mixed in concrete, although the crevice rate of cement stones were basically the same with no the content, but the coarse pores and capillary pores in the concretes reduced, and ultrafine pore increase. Ultrafine pore have larger adsorption to the water, it cause the water's freezing point decreased. Delaying the process of freezing and thawing, and it will reduce the failure stress. The increase of strength and structure were improved, en-strength the frost resistance of concrete [7].

4. Contrast test

4.1. Experimental Raw Materials of the concretes
The raw materials of experimental are shown in Table 1.

4.2. Design of the Concrete Proportioning
The comparative tests of different silica powder volumes concretes, for determine the effect of silica powder in concretes to the frost resistance. The experimental conditions were water cement ratio was constant, control collapse depth were 3~4 cm, and change the amount of silicon powder in the concretes. The test samples were cuboid, its size was 10 cm × 10 cm × 40 cm. Curing time is 28 d, water cement ratio was 0.5, sand rate was 44%, high efficiency water reducing agent (UNF) used 9%, the packet is shown in table 2.

| Materials       | Standards               |
|-----------------|-------------------------|
| Cement          | 42.5 Portland cement    |
| Sand            | Medium sand FM= 2.7     |
| Breakstone      | D max= 20 mm            |
| Admixtures      | water reducing agent    |
| Silica powder   | 10%和 15%               |

Table 1. The experimental materials
Table 2. Mixture ratio of 3 groups.

| Group | $1 \text{ m}^3$ / kg |
|-------|---------------------|
|       | 42.5 Cement | Break stone | Silica powder | Sand |
| 1     | 400         | 1000        | 40            | 550  |
| 2     | 400         | 1000        | 60            | 550  |
| 3     | 400         | 1000        | ---           | 550  |

The experimental study used freeze-thaw test machine. The specimen in the freezing and thawing process were in a saturated state. The specimen in the frozen thaw process, the center temperature respectively control in between -17~18°C. Once freeze-thaw cycle took about 6 h. The test results are shown in Table 3.

Table 3. The test results of the concretes with different freezing and thawing cycles.

| The times of freezing and thawing | Weight loss ratio/ % | The relative dynamic elastic modulus/ MPa |
|----------------------------------|----------------------|----------------------------------------|
|                                  | 1                    | 2                                      | 3                                      |
| 1 (with silica powder 40 kg)     | 0                    | 0                                      | 0                                      |
| 2 (with silica powder 60 kg)     | 0.1                  | 0.1                                    | 0.7                                    |
| 3 (with silica powder 0 kg)      | 0.2                  | 0.2                                    | 1.6                                    |
| 1                                | 0.3                  | 0.3                                    | 2.1                                    |
| 2                                | 0.4                  | 0.4                                    | 2.8                                    |
| 3                                | 0.5                  | 0.5                                    | 3.2                                    |
| 1                                | 0.6                  | 0.5                                    | 3.5                                    |

5. Analysis and discussion

Based on the experiments of the concrete with freezing and thawing cycles tests results, the relative dynamic elastic modulus were decreased, the concrete micro crack propagation path and toughening was put forward, the structure deformation stored energy release. The crack tip stress concentration started to spread in the vicinity of cement gel block. The study is developed by the effects of composition silica fume replacement ratio, Results indicate that dynamic elastic modulus decreased to 88 after 300 freezing and thawing cycles, compare to no silica fume concrete, the elastic modulus decreased 24.

The concrete weight rate were 0.6%, 0.5%, 3.5%, and indicate that the surface of silica powder concrete control cracking occur after freezing and thawing, while the ordinary concrete cracking is generated actual state of cracking from peeling.

6. Conclusions

The effect of silica powder in concrete was not only have the excellent mechanical properties, it was also the freezing-thawing cycle number is bigger than 500, but also have nice durability.

The result showed that silica powder improves the internal structure, density and strength which leads to 300 freezing-thawing cycles, and the decrease of relative dynamic modulus of elasticity is
small. The silica powder mix design by optimizing resistance of freezing-thawing improved the properties of concretes.

Acknowledgments
The research work was supported by the Heilongjiang Science and Technology Bureau Project (2017RA003, HDJCCX-201627), and by State Key Laboratory of Frost Soil Engineering (SKLFSE 201802), the Key Laboratory of China (No. SKLHSE-2017-B-01), and by the Heilongjiang University Student Entrepreneurship Project(201810212080, 201810212079).

References
[1] Hilal A A, Thom N H, Dawson A R. On entrained pore size distribution of foamed concrete[J]. Construction & Building Materials, 2014, 75:227 – 233.
[2] LI Y, SUN D S, WU X S, WANG A G. (2012) Dry Shrinkage and Compressive Strength of Blended Cement Pastes with Fly Ash and Silica Fume. Advanced Materials Research, 535-537:1735-1738.
[3] Md Azree Othuman, Y. C. Wang. Elevated-temperature thermal properties of lightweight foamed concrete [J]. Construction and Building Materials, 2011, (25): 705-716.
[4] A. Remadnia, R. M. Dheilly, B. Laidoudi, M. Queneudec. Use of animal proteins as foaming agent in cementitious concrete composites manufactured with recycled PET aggregates[J]. Construction and Building Materials, 2009, (23): 3118-3123.
[5] KAKOOEI S, AKIL H M, DOLATI A, et al.(2012) The corrosion investigation of rebar embedded in the fibers reinforced concrete. Constr Build Mater, 35: 564-570.
[6] BEUSHAUSEN H, ALEXANDER M G.(2006) Failure mechanisms and tensile relaxation of bonded concrete overlays subjected to differential shrinkage. Cement and Concrete Research, 36:1908-1914.
[7] HALIT YAZICI L.(2007) Utilization of coal combustion byproducts in building blocks . Construction and Building Materials, 86:929–937.