Influence of stone powder content on performance of sand stone concrete in freeze-hawing environment

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Abstract. In this paper, the sand stone concrete was studied on 0%, 2%, 4%, and 6% of stone powder content through experiment. It reports a study on the factors affecting the properties of sand stone concrete include the microstructure, mass loss and compressive strength after freeze-thaw cycles of 0, 5, 10, 15, 20, 25, 30, 35, 40. The results show that it can improve frost resistance of sand stone concrete with proper amount of stone powder. It can provide experimental basis for good performance of sand stone concrete.

1. Introduction
Concrete can resist the environmental media, and long-term maintain its good performance and appearance integrity, and keep the safety and normal use of concrete structures. It is called concrete durability. In cold regions, durability damage is mainly caused by the lack of freeze-thaw resistance, especially in contact with the water and cold environment concrete need high resistance to freezing and thawing. So in cold regions, concrete frost resistance is an important index to measure the durability of concrete[1]. The study on frost resistance of concrete is an important aspect to solve the problem of concrete durability. Sand stone concrete, also called fine stone concrete[2], is composed of water, cement and gravel. Without natural sand, aggregate gradation of stone concrete is worse than that of ordinary sand aggregate. Due to particles of manufactured aggregate are rough and angular with unsatisfactory grading, it needs more water to prepare concrete. The mixes are of low workability and ease of segregation. But the amount of powder can improve the sand stone concrete workability, increase the density of concrete, and improve the compressive strength. The performance of stone concrete with stone powder content in 4% ~ 8% can be got even better than that of the ordinary concrete. When the powder content is 6%, the comprehensive performance of sand stone concrete is best[3-4]. In this paper, content of dust effect on frost resistance of sand stone concrete is researched. Limestone was disposable crushed by jaw crusher. Powder and gravel were sieved directly. Stone powder accounted of 0%, 2%, 4%, 6% of the concrete was directly prepared without adding natural sand. 0, 10, 15, 20, 25, 30, and 40 times of complete freeze-thaw cycle test of concrete specimens were carried out for 28d ages.

2. Test materials
Cement: P.C32.5R, which produced by China United Cement Corporation Lunan Co., Ltd. The performance index of the technology meets national standards and construction requirements (see Table 1).
Aggregates: Both coarse and fine aggregate are produced by siliceous limestone, which have high strength, high hardness and good durability (see Table 2).

Jaw crusher is used in this test, which model is PE60 × 100. By adjusting the size of the crusher outlet, different sand rate are got. The maximum particle size of 15mm have continuous grading gravel, without watering and screening. The content of stone powder (particle size is <0.15mm, which accounted for about 65% of the total dust <0.075mm) accounted for 2.3%~8.1% of the weight of gravel. Gravel particle size less than 4.75mm fineness modulus is 3.0~3.4, particle size distribution accords with the ordinary concrete sand quality standard and test method of sand (JGJ52-2006 ).The particle size range is 1, coarse sand, sand gradation is qualified. Concrete can be formulated separately.

Water reducing admixture: FDN-C naphthalene series water super reducer, which produced by Yunzhe Concrete Admixture Ltd. It is technical index see Table 3.

Water: tap water.

| Chemical Constituents (%) | Setting Time (min) | Stability | Specific Surface Area (m²/kg) | Flexural Strength (MPa) | Compressive Strength (MPa) |
|--------------------------|--------------------|-----------|-------------------------------|------------------------|--------------------------|
| MgO | SO₃ | Initial | Final | 3d | 28d | 3d | 28d |
| 2.1 | 2.73 | 150 | 240 | qualified | 330 | 5.9 | 9.1 | 20.8 | 39.5 |

| Apparent Density (kg.m⁻³) | Water Absorption (%) | Compressive Strength (MPa) | Mineral Composition (%) |
|---------------------------|----------------------|---------------------------|-------------------------|
| 2600 | 0.7 | 83 | Quartz | Mica | Calcite | Others |
| | | | 7 | 9 | 82 | 2 |

| Table 3. Parameter of naphthalene series water reducer |
|---------------------------------------------|
| Solid-Containing Content | PH | Surface Tension 1% Solution | NaSO₄ | Fluidity of Cement Paste (mm) |
| powder 90% | 7.9 | 70% | 15-20% | 240mm |

3. Experimental process and results analysis
The test pieces were divided into 9 groups. Each group have 27 pieces, and the total pieces are 243. Each was respectively marked with number. The 9 groups of specimens were carried out for 0, 5, 10, 15, 20, 25, 30, 35, and 40 freeze-thaw cycles. Before the test, the dry specimens were removed to soak in water for a period of time, and put into the low temperature test box. Set temperature is -15 °C. The specimens were frozen after one day and night, taken out and placed at room temperature to melt a day, then one freeze-thaw cycle was end. After each freeze-thaw cycle, it was necessary to observe the appearance of the specimens, and measure the change of the mass with the increase of freeze-thaw cycles. After completing the corresponding freeze-thaw cycles, the compressive strength of the specimens was measured, and the compressive strength of the specimens was installed between the loading plates of the test machine. The displacement and strain of specimens under pressure, were done by computer dynamic acquisition, record data, and taken the average value. Then specimens were remained into the low temperature test box to next freeze-thaw cycle. This cycle was operated repeatedly. The data was analyzed of and line chart was drawn.

3.1. Effects of Stone Power Content on Sand Stone Concrete Microstructure after Freeze-thaw Cycles of 40
Sand stone concrete specimens with 0%, 2%, 4%, and 6% powder content were performed after 40 freeze-thaw cycles. The sand specimen surface will become rough, not smooth, a tiny hole appears, there will be cement particles dislodged from the specimen. Microstructure performance results are shown in Figure 1.
Figure 1. Influences of Stone Power Content on the Microstructure of Concrete.

The following conclusions can be obtained by observing the microstructure of concrete after 40 freeze-thaw cycles:

1) The freeze-thaw cycle has a great effect on the microstructure of the sandstone concrete.
2) The amount of stone powder has a certain effect on the damage of the microstructure of the sand concrete.

3.2. Effects of Stone Power Content on Sand Stone Concrete Mass Loss after Freeze-thaw Cycles

Sand stone concrete specimen is dipped in water after a period of time and dried with a damp cloth. Mass of specimen is known as $G_{0i}$. Also dried with a damp cloth after n times of freeze-thaw cycle test, it is called the mass of specimen is $G_{ni}$. The rate of mass loss of the sand stone concrete after freeze-thaw cycle is $\Delta W_n$. The calculation formula is as follows:

$$\Delta W_{ni} = \frac{G_{0i} - G_{ni}}{G_{0i}} \times 100\%$$  \hspace{1cm} (1)

Form in: $\Delta W_{ni}$—the mass loss rate of the first i sand concrete specimens after n times freezing and thawing cycles (%).
$G_{0i}$—the mass of the i series sand concrete specimens with 0 times of freeze-thaw cycles (kg).
$G_{ni}$—the mass of the i series sand concrete specimens with n times of freeze-thaw cycles (kg).

$$\Delta W_n = \frac{\sum_{i=1}^{3} \Delta W_{ni}}{3} \times 100\%$$  \hspace{1cm} (2)

Form in: $\Delta W_n$—Average mass loss rate of a group of gravel concrete specimens after n times of freeze-thaw cycles.

The variation of mass loss of sandstone concrete specimens with 40 cycles of freeze-thaw cycles under different powder content are shown in Table 4 and Figure 2.

Table 4. The mass loss of sandstone concrete with freeze-thaw cycles under different powder content.

| The Number of Freezing-thawing Cycles | Mass Loss of Concrete Specimens under Different Powder Content (°) |
|--------------------------------------|---------------------------------------------------------------|
|                                      | 0%   | 2%   | 4%   | 6%   |
|--------------------------------------|------|------|------|------|
| 0                                    | 0    | 0    | 0    | 0    |
| 10                                   | 1.11 | 0.95 | 1.13 | 1.2  |
| 15                                   | 1.4  | 1.3  | 1.25 | 1.35 |
| 20                                   | 2.55 | 2.56 | 2.35 | 2.54 |
| 25                                   | 2.64 | 2.68 | 2.46 | 2.56 |
| 30                                   | 3.73 | 3.7  | 3.36 | 3.71 |
| 35                                   | 3.87 | 3.88 | 3.52 | 4.2  |
| 40                                   | 4.52 | 4.84 | 4.09 | 4.96 |
Figure 2. Influences of stone powder content on the mass loss of concrete.

The data analysis shows that with the increase of the number of freeze-thaw cycles, the mass of water absorption increased is far less than mass loss of concrete specimens by freeze-thaw cycle erosion. And eventually leading to loss of mass is more and more serious. When the number of freeze-thaw cycle increases to 40 times, sand stone concrete test piece rate of mass loss due to dust incorporation is different. The mass loss of is minimum with 4% dust content. It indicates that proper powder can improve the frost resistance of sand stone concrete.

There are two reasons for the relationship between stone power content and sand stone concrete mass loss after freeze-thaw cycle:

On the one hand, after freeze-thaw cycles the surface of the sand stone concrete specimens will be damaged. The surface mortar layer peeling phenomenon will began to appear, and small particles will fall off. The mass loss of the specimen will be caused. But in the early stage of freeze-thaw cycles, the specimen surface mortar peeling is not very serious, so the mass change little. With the increase of the number of freeze-thaw cycles, peeling test of coarse aggregate and mortar surface is more obvious. Part of the coarse aggregate will fall off, and the specimen surface will form many rugged small pits. So the mass of concrete is obviously reduced, and the mass loss rate increases.

On the other hand, in the freeze-thaw process, both stress of sand stone concrete inside and outside surface with temperature difference and frost heaving pressure surface pore water freezes are beyond bearing of concrete. Sand stone concrete will crack. With the increase of powder content, concrete pores will be filled. It can absorb less water, and improve frost resistance of concrete. Thereby the sand stone concrete specimen mass loss is reduced.

3.3. Effects of Stone Power Content on Sand Stone Concrete Compressive Strength after Freeze-thaw Cycles

After 0, 10, 15, 20, 25, 30, 35, 40 times of freeze-thaw cycle, each group of sand stone concrete specimens with 0%, 2%, 4%, 6% powder content were put on the pressure test machine to get compressive strength test. It obtained the relationship between the content of stone power and compressive strength (see Table 5 and Figure 3) in 0, 10, 15, 20, 25, 30, 35, 40 times of freeze-thaw cycle test.

The frost resistance of concrete is closely related to the degree of compaction. So as to improve the freeze-thaw resistance of concrete, it is necessary to make the inner part of the concrete to form discontinuous pores [5]. The test data shows that stone powder will have an impact on the strength of concrete. With different powder content of concrete subjected to freeze-thaw cycles, the concrete strength decreases continuously. But 4% powder volume of sand stone concrete’s compressive strength decrease slowly. The final compressive strength is higher than that of sand stone concrete without mixing powder. Thus it can be seen that the powder with water reducer can improve the compactness of concrete. And the effect of micro aggregate filling can make the inner pores more refined and reduce
the porosity of concrete. So it can improve the pore structure of concrete and improve the frost resistance of concrete.

At the same time, the dust particles are dispersed in the pores between the aggregate and the cement particles. And the excess pore water is absorbed to further improve the frost resistance of the concrete. The experimental data also show that with the addition of excessive dust, the hydration products of cement decrease correspondingly, and the compactness of concrete structure reduce. Therefore, under the condition of adding water reducing agent, adding appropriate amount of stone powder into the concrete will improve the frost resistance of concrete.

**Table 5.** The compressive strength of concrete under different powder content.

| The Number of Freezing-thawing Cycles | The Compressive Strength of Concrete under Different Powder Content (%) |
|--------------------------------------|--------------------------------------------------|
| 0%                                   | 2%                                   | 4%                                   | 6%                                   |
| 0                                     | 38.9                                 | 38.4                                 | 38.4                                 | 38.5                                 |
| 10                                    | 35.1                                 | 34.7                                 | 35.5                                 | 34.5                                 |
| 15                                    | 34.8                                 | 33.5                                 | 34.9                                 | 33.6                                 |
| 20                                    | 32.9                                 | 31.6                                 | 33.1                                 | 31.2                                 |
| 25                                    | 29.2                                 | 28.3                                 | 29.4                                 | 28.5                                 |
| 30                                    | 28.7                                 | 27.5                                 | 28.9                                 | 27                                   |
| 35                                    | 27.7                                 | 27.3                                 | 28.4                                 | 27.2                                 |
| 40                                    | 25.1                                 | 24                                   | 25.4                                 | 24.3                                 |

**Figure 3.** Influences of stone powder content on the compressive strength of concrete.

4. **Conclusions**

In this paper, sand stone concrete was studied on 0%, 2%, 4%, and 6% of stone powder content through experiment. It reports a study on the factors affecting the properties of sand stone concrete including the microstructure, mass loss and compressive strength after freeze-thaw cycles of 0, 5, 10, 15, 20, 25, 30, 35, 40.

1. The microstructure of sand stone concrete is greatly influenced by freeze-thaw cycle. But proper stone powder content have improving effect of microstructure of concrete.

2. With the stone powder content mixing into sand stone concrete, the micro aggregate filling effect of the inner pore is refined, the compactness of concrete is improved, and the porosity of concrete is reduced. It can improve the concrete pore structure, reduce powder absorption to pore water, and reduce the presence of pore water. Without affecting the strength of concrete, the frost resistance of concrete is improved.

3. The results show that it can get best frost resistance of sand stone concrete with 4% amount of stone powder.
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