Experimental Study on High Performance Cement in Aeolian Sand Concrete

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Abstract. In order to alleviate the current shortage of river sand resources in China, the experimentation of producing C30 concrete utilizing the aeolian sand as fine aggregate was carried out, in this experimentation, high-performance cement was used instead of ordinary cement, the basic mechanical properties of aeolian sand concrete was tested after maintenance. The results show that the flexural strength of concrete with aeolian sand content of 30% is nearly 4 MPa, the compressive strength fits the standard requirement. The high-performance cement exhibits its superior cementation ability, and the application of aeolian sand in concrete is preliminarily realized.

Keywords. High performance cement, concrete, aeolian sand, natural graded gravel.

1. Introduction

The demand for sand and gravel materials is huge in Chinese construction market, which results in the deficient river sand resource and its price soared. According to the investigation statistics [1], in July 2019, the purchase price of river sand in Guangdong Province was 213 RMB per cubic meter, and the price of desalinated treatment sea sand was 254 RMB/m³. The sand price rose to 200-300 RMB per cubic meter in Pearl River Delta region. The sand price in Zhuzhou area, Nanjing and Beijing-Tianjin-Hebei region were 210-220 RMB, 150 RMB and 70-100 RMB per ton respectively. The Hebei Water Resources Department has issued a river sand mining ban notice. In the middle and lower reaches of the Yangtze River, it is convenient to get the sand and gravel resource for a long time. In the coastal areas of South China, the treated sea sand is widely used. People mainly relies on the tributaries of the Yangtze River and mines to extract river sand and manufactured sand in the southwestern region. However, environmental protection has play an important role in economic development and the country has paid more and more attentions on ecological environment recovery recently. So the searching for alternative resources is imminent. The reserves of river sand in the North and Northwest of China are extremely small, the sand price ranged 100-150 RMB per ton in some areas, which will be higher in the future, because China’s sandstone resources are facing a severe test. On the other hand, China’s desert area accounts for about 16% of the country’s land area, the problem of desertification needs to be solved urgently. If the aeolian sand could replace the natural sand in concrete, it will reduce the exploitation of river sand and protect the riverbeds. The aeolian sand is wealthy and cheap, the waste will be turned into treasure for the application in engineering construction, and it can effectively reduce the engineering
cost and indirectly control the desert extension. The research [2] on the preparation method of aeolian sand concrete can realize the effective utilization of aeolian sand resource, which brings great benefit to all aspects of development in China.

2. Raw Material

High-performance cement [3] is a new type of cementitious material that can bond mud particles better compared with ordinary cement. The main components of high-performance cement are alumina, silica, active substances and additives, such as water reducing agent. When preparing concrete samples, the mud can be firmly bonded with other aggregates together, the internal structure of the concrete is integrative and the strength is improved. Aeolian sand has smaller particle size and larger specific surface area than riversand, so it requires larger water-to-binder ratio for concrete fabrication [4]. The using of high-performance cement effectively reduces the water-to-binder ratio and porosity of aeolian sand concrete, increases the degree of bonding between cementitious materials and aggregates, improve the internal compactness of concrete, so the strength and durability can be greatly improved.

The following indicators of high performance cement and ordinary Portland cement were measured according to the specifications. The results are shown in table 1.

| Projects                      | High performance cement | Ordinary 42.5# | Standard |
|-------------------------------|-------------------------|----------------|----------|
| Standard consistency (%)      | 135                     | 147            | /        |
| Initial setting time (min)    | 190                     | 151            | ≥45      |
| Final setting time (min)      | 251                     | 179            | ≤600     |
| Fineness (%)                  | 6.23                    | 9.88           | <10      |
| Stability                     | Qualified               | Qualified      | Qualified|
| Flexural strength (MPa)       | 4.3                     | 3.5            | ≥2.5     |
| 3d                             | 7.9                     | 6.7            | ≥6.5     |
| 28d                            | 30.5                    | 25.3           | ≥10      |
| Compressive strength (MPa)    | 51.9                    | 45.8           | ≥42.5    |
| 3d                             |                         |                |          |
| 28d                            |                         |                |          |

Three kinds of aggregates, Luopu material, Yulong Kashi River material, and Hetian airport material were used to prepare concrete respectively. The grading was obtained as shown in table 2. The oversized particles were removed. The grading of the aeolian sand is shown in table 3.

| Material                  | Sieve pore (mm) | 37.5 | 31.5 | 26.5 | 19 | 16 | 13.2 | 9.5 | 4.75 | 2.36 | 1.18 | 0.6 | 0.3 | 0.15 | 0.075 | Bottom |
|---------------------------|-----------------|------|------|------|----|----|------|------|------|------|------|----|----|------|-------|--------|
| Luopu Passin              | g rate (%)      | 100  | 97.2 | 92.2 | 76.7 | 71.2 | 63.9 | 54.7 | 39.1 | 29.8 | 25.6 | 21.3 | 15.7 | 13   | 10.6  | 0      |
| Yulong Kashi River       |                 | 100  | 86.4 | 73.8 | 63.9 | 58.3 | 55.5 | 50.4 | 46.9 | 45.5 | 45.1 | 44.4 | 27.4 | 11.2 | 3.7  | 0     |
| Hetian airport           |                 | 100  | 93.8 | 87.1 | 73.4 | 68.8 | 63.5 | 56.3 | 44.9 | 36.7 | 31.9 | 26.4 | 20   | 18   | 16   | 0     |
Table 3. Aeolian sand grading table.

| Sieve pore (mm) | 0.6 | 0.3 | 0.15 | 0.075 | Sieve bottom |
|-----------------|-----|-----|------|-------|--------------|
| Passing rate (%)| 100 | 94.5| 55.4 | 13.8  | 0            |

3. Experimental Procedure

The C30 concrete with aeolian sand addition was designed and prepared, mechanical property test was carried out in accordance with the “Testing Regulations for Highway Engineering Cement and Cement Concrete” (JTG E30-2005). There were two sets of pure natural aggregate tests (1# and 2#) and three groups with aeolian sand content of 30%. The test configurations are shown in table 4. Making concrete with the Yulong Kashi River material and the Hetian Aircraft Plant material respectively as comparative tests (3-5#). The concrete without aeolian sand was first prepared, then the particles below 4.75 mm were sieved, and aeolian sand was added eventually. An extra test was added with size of 9.5mm above when using Hetian Airport material. After cured for 24 hours in room temperature, the mold was released, then cured under standard environment (temperature 20±2℃, relative humidity 95%), the strength was tested for 7 days and 28 days.

Table 4. Concrete mixture ratio.

| Aggregate                     | Water cement ratio | Aeolian sand content (%) | Cement: aggregate | Concrete strength |
|-------------------------------|-------------------|--------------------------|-------------------|-------------------|
| Luopu material (1#)           | 0.42              | 0                        | 1:5.5             | C30               |
| Yulong Natural aggregate (2#) | 0.63              | 0                        | 1:5.5             | C30               |
| Kashi River 4.75 mm above (3#)| 0.54              | 30                       | 1:5.5             | C30               |
| Hetian 4.75 mm above (4#)     | 0.55              | 30                       | 1:5.5             | C30               |
| Airport material 9.5 mm above (5#) | 0.53          | 30                       | 1:5.5             | C30               |

4. Results and Discussions

By observing the data in figures 1 and 2, it can be seen that the strength of the cement concrete of Luopu meets the standard requirements, and the strength is the highest compared with others. It can be seen from table 2 that the grading of Luopu material is relatively good with a 10.6% mud content, and the water-cement ratio is 0.42. The high-performance cement has strong cementation ability and the activator within formed substance with fine particles which is conducive to the formation of concrete strength. It can also activate some soil minerals’ surface and change the unfavorable factors. A compact structure could be observed by SEM shown as figure 3b). This set of tests proved the high-performance cement has the ability for adapting adverse conditions for concrete fabrication, which laid the foundation for subsequent experiments.

According to figure 1 and figure 2, the 28-day strength of Yulong Kashi River concrete did not meet the requirements, because the proportion of particles with size of 0.6 mm below accounts for 44.4%, which was much larger than the ratio of the same particle size of Luopu, resulting in slightly larger water-cement ratio and sand ratio, meanwhile, the lack of aggregate particles of 1.18mm to 4.75mm lead to insufficient inner adhesion, which caused a loose structure as shown in figure 3a). When the particle size component was changed, the aeolian sand particles made the whole sample more closely conform to the tight packing theory, and the high-performance cement with water reducing agent reduced the water-cement ratio by 14%, so the compressive strength is about 35% higher than that of the pure Kashgar concrete. 7-day flexural strength increased less, indicating that when the aeolian sand was excessively added, it will impair the flexural property of concrete.

The compressive strength of the two sets of concrete (4# and 5#) meets the requirements of C30 concrete. The compressive strength of concrete prepared by using 9.5 mm above is higher, since quantity of coarse aggregate, large particles can effectively resist external pressure, thus the compressive strength
is higher. Concrete prepared by using 4.75 mm above and aeolian sand, the flexural strength is higher, because the aggregate particles of this group are relatively uniform, and the particles of different sizes can be interlocked with each other, the aeolian sand can act as fine aggregate to improve the density of internal structure. High-performance cement is finer than traditional cement and has a larger specific surface area, which can improve the fluidity of concrete. Therefore, the water-cement ratio is decreased, the porosity is lowered, and the interface between the aggregates is much tightly bonded, so the flexural strength is improved.

![Figure 1. Concrete compressive strength diagram.](image1)

![Figure 2. Concrete flexural strength diagram.](image2)

![Figure 3. The matrix microstructure comparison of (a) Yulong Kashi River concrete and (b) Luopu concrete.](image3)

5. Conclusions
(1) High-performance cement can effectively bind the fine powder in aggregate to make it combinative with other particles, so the internal compactness of the concrete is high.

(2) Initially solving the problem of large water demand for aeolian sand, reducing the water-to-binder ratio and the number of pores in aeolian sand concrete, meeting the requirements of the concrete compressive strength.

(3) When the mass ratio of aeolian sand is 30%, it is possible to improve the internal particle arrangement of concrete and make the concrete structure much denser, thereby improving the concrete performance.

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