Wind Erosion of Recycled Concrete on Sulfate Attack

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Abstract. The wind erosion on recycled concrete on sulfate attack was investigated by the sandblasting machine which can provide a gas-solid two phase flow. The wind erosion was performed on different replacement ratio of recycled concrete on sulfate attack. The results show that the erosion ratio of recycled concrete under sulfate attack is higher and the the erosion ratio is increasing as the replacement ratio increase.

1. Introduction

According to the statistics of the National Bureau of Statistics, China’s commercial concrete consumption in 2016 is as high as 1,792 m³. At present, there are about 60 million tons of waste concrete produced each year in the United States, and about 170 million tons of waste concrete is produced each year in Europe. The huge consumption of concrete will lead to the mass production of waste concrete. Nowadays, the disposal of waste concrete in China is mostly landfill treatment and pollutes the environment. Recycling the coarse aggregate in the waste concrete, partially or completely replacing the coarse aggregate in concrete, can not only save raw materials, but also protect the environment and meet the requirements of sustainable development.

The durability of recycled concrete is a hot trend in current research. Many scholars at home and abroad have studied the durability of recycled concrete.

Jingwei Ying studied the effect of recycled aggregate replacement ratio on the durability of recycled concrete.

Hongsheng YAN studied the effect of recycled concrete under sulfate attack.

Xinzheng An studied the properties of recycled concrete under sulfate attack.

Evangelist studied the durability performance of concrete made with fine recycled concrete aggregates.

Based on the previous research results, the experimental program is studying the wind erosion of different replacement ratio of recycled concrete on sulfate attack.
2. Test raw materials and test methods

2.1. Test raw materials
This design is based on Table 1. The ordinary portland cement is from Hongshi Holding Group Co., Ltd with a strength grade of P·O42.5; The fine aggregate is washing sand; The coarse aggregate is gravel and the coarse aggregate in the waste concrete; Water is edible water; C30 recycled concrete samples with two different replacement ratio; Yahui Liu studied the investigations on effect of solution concentration and temperature on rate of concrete on sulfate attack, depend on his study, the sulfate concentration in the experimental research here is saturated concentration. The sample size is 100mm×100mm×100mm and was maintained to 28d under normal curing condition quantity and then immersion in saturated sulfate concentration and water for 100 days respectively. The 28d and 100d compressive strength of the concrete samples with two different replacement ratio is shown in Table 1.

Table 1. Mix proportion and 28d/100d compressive strength of the concrete samples

| Replacement ratio | 50% RC | 100% RC | 50% RCSA | 100% RCSA |
|-------------------|--------|---------|----------|-----------|
| Solution          | water  | water   | sulfate concentration | sulfate concentration |
| Cement/ (kg/m³)   | 394    | 394     | 394      | 394       |
| Sand/ (kg/m³)     | 571    | 571     | 571      | 571       |
| Gravel/ (kg/m³)   | 1250   | 1250    | 1250     | 1250      |
| Water/ (kg/m³)    | 185    | 185     | 185      | 185       |
| 28d Compressive Strength/MPa | 34.48 | 33.27 | 34.48 | 33.27 |
| 100d Compressive Strength/MPa  | 45.1  | 44.7  | 42.17 | 40.37 |

2.2. Testing instrument
The instrument used in this experiment are air compressor that provides pressure, sandblasting machine for sand supply, and test spaces (placement samples). The air compressor provide a certain pressure, and the yellow sand in the sandblasting machine is taken out. The nozzle forms a gas-solid two phase flow, and the surface of the concrete sample is eroded at a certain speed, and the erosion speed can be changed by adjusting the output pressure of sandblasting machine. In this experiment, yellow sand was used as the abrasives. The physical diagram of the test instrument is shown in Figure 1.

![Figure 1. Test instrument](image)

2.3. Test methods
In this experiment, the control variable method was used to test, the abrasive was yellow sand. Test 1 studied different time on the erosion rate of two different replacement ratio of recycled concrete on
sulfate attack. The wind speed was 22 m/s and the impact angle on erosion was 90° and the erosion time was adjusted to 1, 2, 3, 4, 5, 6 and 7 min. Test 2 studied different wind speeds on the erosion rate of two different replacement ratio of recycled concrete on sulfate attack. The erosion time was 3 min and the impact angle on erosion was 90°. By adjusting the output pressure of the sandblasting machine to 0.1 MPa, 0.16 MPa, and 0.22 MPa respectively, the corresponding gas-solid two phase flow speeds are 17 m/s, 22 m/s, and 25 m/s. Test 3 studied different impact angle on erosion on the erosion rate of two different replacement ratio of recycled concrete on sulfate attack. The erosion time was 3 min and the wind speed was 22 m/s and the impact angle on erosion was adjusted to 30°, 60° and 90°.

2.4. Test result processing
The concrete samples were eroded in the sandblasting machine in a group of three. The weighing tool use an electronic balance with a range of 3 kg and a precision of 0.01 g. The mass before and after the erosion was measured.

The formula for calculating the erosion rate is as follows:

$$E = \frac{\Delta m}{m}$$

Where: $\Delta m$ is the mass reduction of concrete sample before and after erosion, g; $m$ is the mass of concrete sample before erosion, g.

3. Test results and analysis

3.1. Effect of erosion time on erosion ratio of concrete sample

Figure 2 shows that the curve of erosion ratio changes when two different replacement ratio of recycled concrete on sulfate attack have the impact angle on erosion of 90° and the wind speed of 22 m/s, and the erosion times are 1, 2, 3, 4, 5, 6 and 7 min respectively. As can be seen from the figure: 1. The erosion rate of concrete samples increase with time and is linear. 2. The erosion ratio is increasing as the replacement ratio increase. Due to the high water absorption, high porosity and low apparent density of recycled aggregates, recycled concrete has higher inhomogeneity and more complex microstructure. When the replacement ratio is higher, more cracks and other weak layers appear on the surface and inside of the recycled concrete, which causes the concrete surface to be more susceptible to damage, and in the same case, the erosion rate is greater. 3. The erosion rate of recycled concrete on sulfate attack is higher than normal recycled concrete. Because $SO_4^{2-}$ enters the interior of the concrete through the inherent pores of the concrete, and some components in the cement hydration product biochemical reaction and products ettringite and gypsum. The volume of ettringite is larger than that of the original cement hydrate, so when the corrosion progresses to a certain extent, it will fill the space of the concrete and cause cracks in the surface of concrete. When the cracks appear, the concrete is more likely to be destroyed, resulting in greater erosion ratio.
3.2. Effect of Wind Speed on Erosion Ratio of Concrete sample

Figure 3 shows that the curve of erosion ratio changes when two different replacement ratio of recycled concrete on sulfate attack have the impact angle on erosion of 90° and the erosion time is 3min, and the wind speeds are 17, 22, 25 m/s respectively. As can be seen from the figure: 1. The erosion rate of concrete samples increase with wind speed. When the wind speed is from 17m/s to 22m/s, the erosion rate increases more slowly than the wind speed from 22m/s to 25m/s. The kinetic energy of the sand is proportional to the square of the wind speed. Therefore, the greater the wind speed, the greater the kinetic energy variation of the sand, and the greater the impact energy is when sand reach to the concrete samples, which will increase the loss caused of concrete samples. 2. The erosion ratio is increasing as the replacement ratio increase. 3. The erosion rate of recycled concrete on sulfate attack is higher than normal recycled concrete.

3.3. Effect of impact angle on erosion on Erosion Ratio of Concrete sample

Figure 4 shows that the curve of erosion ratio changes when two different replacement ratio of recycled concrete on sulfate attack have the erosion time is 3min, the wind speed is 22m/s, and the impact angles on erosion are 30°, 60°, and 90° respectively. As can be seen from the figure: 1. the erosion rate of concrete samples increase with the impact angle on erosion, this is consistent with the erosion law of brittle materials. The performance characteristics of brittle materials are high strength and hardness, but
low plasticity and toughness. For brittle materials, the normal velocity component of the erosion abrasives is the main factor causing the loss of materials, and the normal component of the velocity at low impact angle on erosion is small. The impact energy is low and requires multiple impacts to cause materials loss. Therefore, the erosion rate is low when the impact angle on erosion is low, and the normal component of the velocity at high impact angle on erosion is big, results in the erosion rate is high \(^8\). The erosion ratio is increasing as the replacement ratio increase. \(^3\) The erosion rate of recycled concrete on sulfate attack is higher than normal recycled concrete.

![Graph showing erosion ratio vs impact angle on erosion](image)

**Figure 4.** Erosion ratio under impact angle on erosion

4. Conclusion
1. The erosion rate of concrete samples increase with time, wind speed, impact angle on erosion.
2. The erosion ratio is increasing as the replacement ratio increase.
3. The erosion rate of recycled concrete on sulfate attack is higher than normal recycled concrete.

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