The Mechanical Properties of Planting Concrete

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Abstract. Planting concrete has been widely used in river revetment engineering for its revetment stability, erosion resistance, landscape suitability and the ecological function. In this paper, the influences of water-cement ratio, cement content, aggregate size and curing period on the mechanical properties, apparent density and porosity of planting concrete were studied. Under the optimal water-cement ratio, the compressive strength, flexural strength and apparent density of planting concrete increase linearly with the increase of cement content, while the porosity decreases linearly. The compressive strength, flexural strength and porosity decrease linearly with the increase of aggregate size, while the apparent density increases linearly. The mechanical properties improve with the increase of curing period.

1. Introduction

Riparian zone is an ecological transition zone between river and upland vegetation. Riparian zone plays an important role in improving the self-regulation and self-restoration of river ecosystem and our living environment [1, 2]. Moreover, the ecological riparian zone provides a landscape transition platform for people to coexist harmoniously with the water, maintaining species diversity and dynamic balance of the ecosystem [3, 4].

In order to ensure the stability of the riparian zone, prevent the erosion and scouring of the bank slope soil by water and waves, and avoid the bank collapse, it is necessary to take revetment measures. The traditional revetment technology mainly considers the flood discharge speed, river erosion, slope stability and other factors, emphasizes the structural stability of the river bank. Thus, it has a certain degree of influence on the landscape and ecological environment. Therefore, the new ecological revetment technologies are urgently needed [5, 6].

Planting concrete is a new type of ecological concrete, which is prepared with cement, single graded coarse aggregate, admixtures and water. The planting concrete has a large number of interior connected pores, which are filled with vegetative soil. The planting concrete provides the mechanical properties, anti-erosion and durability needed for riverbank protection, which guarantees the safety of the river bank. The vegetation on the surface can not only maintain the soil and protect the bank, prevent water and soil loss, but also improve the ecological environment of the riparian area. Therefore, the planting concrete is widely used in the river bank protection engineering [7-9]. In this paper, the influences of water-cement ratio, cement content, aggregate size and curing period on the
mechanical properties, apparent density and porosity of planting concrete were studied.

2. Raw materials and mix proportion
The physical properties of 42.5R ordinary Portland cement (OPC) used are shown in Table 1, Blaine fineness is 3.9. The aggregates are single graded granite gravel, as shown in Table 2.

### Table 1. Physical properties of OPC

| Setting time (min) | Flexural strength (MPa) | Compressive strength (MPa) |
|--------------------|-------------------------|---------------------------|
| Initial            | Final                   | 3 d  | 28 d | 3 d  | 28 d |
| OPC                | 171                     | 241  | 4.9  | 8.4  | 23.6 | 46.0 |

### Table 2. Physical properties of aggregates

| Size /mm | Apparent density / (kg/m³) | Packing density / (kg/m³) | Water absorption / % | Crushing value / % |
|----------|---------------------------|---------------------------|----------------------|--------------------|
| 5~20     | 2650                      | 1460                      | 0.75                 | 9.6                |
| 16~31.5  | 2660                      | 1480                      | 0.67                 | 8.3                |
| 20~40    | 2660                      | 1480                      | 0.65                 | 8.2                |

The cement content is 150~270 kg/m³, and the dosage of gravel used for 1 m³ concrete is the mass of 1 m³ gravel with dry and dense state. The optimal water-cement ratio was determined by trial mix. Concrete specimens were made by hammering method, with two layers of charging, and each layer was hammered 10 times with a weight of 5 kg hammer. The size of specimens for compressive strength is 150 mm × 150 mm × 150 mm, and the standard curing (20 ± 2 °C, RH≥ 95%) is adopted. Each group has 6 specimens, and the arithmetic mean value is used as the test result.

3. Results and discussion

3.1 The effect of water-cement ratio
The relationship between the compressive strength and cement-water ratio of planting concrete is shown in Fig. 1. Apparently, the compressive strength decreases linearly with the increase of water-cement ratio. The lower the water-cement ratio, the lower the porosity of the hardened cement, thus the compressive strength is higher.

When the aggregate size is 5~20 mm, 16~31.5 mm and 20~40 mm, the relationship between the compressive strength and the cement-water ratio at 28 days is shown in Equations (1), (2) and (3), respectively.

![Fig. 1. The relationship between the compressive strength and cement-water ratio at 28 days.](image-url)
3.2 The effect of aggregate size

As shown in Fig. 2, with the same cement content of unit volume concrete, the optimal water-cement ratio increases with the decrease of aggregate size. This is mainly attributed to the decrease of aggregate particle size, and the increase of surface area and water requirement.

![Fig. 2. The effect of aggregate size on optimal water-cement ratio](image)

As shown in Fig. 3, with the decrease of aggregate size, the compressive strength at 28 days has a linear relationship with the average particle size of aggregate. As the decrease of aggregate size, the number of joints in the same volume concrete increases. And the bonding strength between the aggregate particles increases, therefore, the compressive strength of concrete increases.

![Fig. 3. The effect of aggregate size on the compressive strength at 28 days.](image)

When the water-cement ratio is 0.40 and 0.35, the relationship between the compressive strength at 28 days \( f_c \) and the average particle size of aggregate \( d \) is shown in Equations (4) and (5).

\[
f_c = 7.69 \times \frac{C}{W} - 15.54 \quad (1)
\]

\[
f_c = 7.99 \times \frac{C}{W} - 14.16 \quad (2)
\]

\[
f_c = 11.20 \times \frac{C}{W} - 18.21 \quad (3)
\]

3.3 The effect of cement content

With the same cement content, there is an optimal water-cement ratio in concrete, so that the cement...
paste has the appropriate flowability and the planting concrete has the highest strength. As shown in Fig. 4, the optimal water-cement ratio has a linear relationship with the cement content.

![Fig. 4. The relationship between the optimal water-cement ratio and cement content.](image)

As shown in Fig. 5-7, the compressive strength and flexural strength of planting concrete increase with the increase of cement content. With the comparable workability, the water-cement ratio of concrete decreases with the increase of cement content, and the mechanical strength increase.

![Fig. 5. The relationship between the compressive strength at 7 days and the cement content.](image)

![Fig. 6. The relationship between the compressive strength at 28 days and the cement content.](image)
3.4 The effect of curing period
With the same mix proportion, the compressive strength of planting concrete increases with curing period. And the ratio of the compressive strength of 7 to 28 days is between 0.79 and 0.83, with an average value of 0.80. After 1 year, the compressive strength is about twice as strong as that of 28 days, subsequently grows slowly.

3.5 Apparent density and porosity
Compared to ordinary Portland concrete, the planting concrete has larger porosity and permeability, particularly, plants can grow. As shown in Fig. 8 and 9, with the decrease of aggregate size, the apparent density of planting concrete decreases and the porosity increases.

Fig. 7. The relationship between the flexural strength at 28 days and the cement content.

Fig. 8. The effect of aggregate size on the apparent density.

Fig. 9. The effect of aggregate size on the porosity.
4. Conclusions
1) The optimal water-cement ratio of planting concrete decreases with the increase of cement content and aggregate size, showing a linear correlation.
2) With the optimal water-cement ratio, the compressive strength, flexural strength and apparent density of planting concrete increase linearly with the increase of cement content, while the porosity decreases linearly.
3) With the increase of aggregate size, the compressive strength, flexural strength and porosity decrease linearly, while the apparent density increases linearly.
4) The mechanical strength of planting concrete increases with curing period, and the compressive strength of 7 days is 0.8 times that of 28 days.

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