Mechanical and load transmission properties of soil-concrete block

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ABSTRACT

In order to recycle dredged soil, our research group developed interlocking blocks from dredged soil. Dredged soil interlocking blocks (350 mm in width, 350 mm in depth and 100 mm-150 mm in height) were made from soft clay dredged at the Kanmon run. They were produced with the constant dehydration pressure 5 MPa and cement content of 15%, 20% and 25% per the dry weight of clay. The unconfined compression test and bending test were carried out to investigate material characteristics of dredged soil interlocking blocks in the water for six months. On the other hand, in order to check the effect of interlocking blocks, a road was constructed by using interlocking blocks on the surface and, as a roadbed material, dredged and dehydrated soil and crushed stone for mechanical stabilization were used. Characteristics of dispersion of traffic load and settlement were evaluated by running experiments. Stress was measured by four earth pressure gauges and settlement was measured by surveying. The following conclusions are obtained: (1) There was close relationship between unconfined compressive strength and water-cement ratio. Therefore, it is concluded that unconfined compressive strength of dredged soil blocks are controlled by water-cement ratio. (2) Dredged and dehydrated soil can disperse traffic load effectively. (3) Soil-concrete blocks can’t disperse traffic load effectively, but have sinking suppressing effect when using dredged and dehydrated soil as roadbed material.

Keywords: soil, cement, unconfined compressive strength, bending strength, stress

1 INTRODUCTION

At the Kanmon run, an important international seaway, dredging work is carried out for deepening seabed every year. Dredged soil is transported to Shinmojioki disposal site, but the disposal capacity is little remained. New disposal sites are needed for dredged soil which will be generated in the future, but construction takes long time.

In order to recycle dredged soil, our research group has conducted basic study and Yamashita et al. (2011) succeeded making soil block (Φ53.4 cm x H50 cm) that has strength equals to concrete.

In this study, we developed interlocking blocks from dredged soil. Cement was mixed with soft clay dredged at the Kanmon run and dehydrated. To investigate mechanical properties, the unconfined compression test and bending test were carried out on interlocking blocks in the water for six months. A road was constructed by using interlocking blocks on the surface and characteristics of dispersion of traffic load and settlement were evaluated by running experiments.

2 EXPERIMENT OUTLINE

2.1 Material experiment

The material used in this study is soft clay dredged at the Kanmon run (called Kanmon clay). The physical properties of Kanmon clay is shown in Table 1.

| Physical Property       | Kanmon clay |
|-------------------------|-------------|
| Soil particle density $\rho_s$ (g/cm$^3$) | 2.697       |
| Liquid limit $w_L$ (%)  | 95.0        |
| Plastic index $I_p$ (%) | 59.1        |

Cement content is 15%, 20% and 25% of blast furnace slag cement type B per the dry weight of clay. The test conditions are shown in Table 2.
Table 2. Test conditions

| Material                  | Description                        |
|---------------------------|------------------------------------|
| Clay                      | Kanmon clay                        |
| Cement type               | Blast furnace slag cement type B    |
| Cement content            | 15, 20, 25%                        |
| Dehydration mode          | 2 MPa:30 min, 5 MPa:265~755 min    |
| Initial water content     | 300%                               |
| Curing condition          | Water curing (Temperature:20℃)     |
| Curing period             | 6 month                            |

Kanmon clay was prepared with initial water content of 300% and mixed with cement. The mixture was poured into the dehydration equipment (W350 mm×D350 mm×H1000 mm) shown in Fig. 1.

![Fig. 1. The dehydration equipment](image)

The mixture was dehydrated with dehydraion pressure of 2 MPa for 30 min, followed by constant dehydration pressure of 5 MPa. In order to investigate material characteristics, the unconfined compression test (JIS A 1216) and bending test (JIS A 1106) were carried out.

### 2.2 Running experiment

The sectional view of road is shown in Figure 2 and the horizontal projection of road is shown in Figure 3.

![Fig. 2. The sectional view of road](image)

![Fig. 3. The horizontal projection of road](image)

The earth pressure gauges were set in base course for measuring vertical earth pressure. After spreading each layer (20 cm), a pressure was given 8 times by rolling machine (4 t.). These works were continued 5 times and roadbed of 1 meter in height was constructed. Dredged and dehydrated soil (called “dehydrated soil”) and crushed stone for mechanical stabilization (called “crushed stone”) were used as roadbed materials. On the surface of the road, soil blocks were used as interlocking blocks. The earth pressure gauges were set in four points to investigate differences of roadbed materials and to check the effect of interlocking blocks.

![Fig. 4. Unconfined compressive strength, bending strength and cement content](image)

Figure 4 shows the relationships between unconfined compressive strength and cement content and between bending strength and cement content. Average unconfined compressive strength for cement content of 25% was 9.2 times than that of 15%. This is because of hydration reaction. Unconfined compressive strength varied greatly with the specimen cement content of 20%. The possible factor is water content dispersion. The dispersion occurred because the drainage time was not sufficient when making blocks. It can be seen that average bending strength doubles when cement content is increased by 10%.

3 **STRENGTH PROPERTY**

Figure 5 shows the relationships between unconfined compressive strength and water content and between bending strength and water content. Unconfined compressive strength decreased when water content increased. The reason is considered that water in specimen works as a gap, therefore, when water content is higher, specimen becomes frailer.
increased with decreasing water-cement ratio. It is found that, for high strength of soil blocks, it is necessary to decrease water-cement ratio.

![Unconfined compressive strength, bending strength and water content](image)

Figure 6 shows the relationships between unconfined compressive strength and dry density and bending strength and dry density. Unconfined compressive strength and bending strength increased when dry density increased. Unconfined compressive strength differed due to cement content with almost same dry density. Therefore, it can be suggested that increase of strength is related to the density increase and to the chemical reaction.

![Unconfined compressive strength, bending strength and dry density](image)

The relationships between unconfined compressive strength and water-cement ratio and between bending strength and water-cement ratio are shown in Figure 7. In this paper, the water-cement ratio is defined as weight ratio of water and cement. It can be seen that unconfined compressive strength decreases with increasing water-cement ratio. Following equation between unconfined compressive strength and water-cement ratio was obtained:

\[ q_u = 60.04(W/C)^{-2.061} \]  

(1)

\( q_u \) is the unconfined compressive strength and \( W/C \) is the water-cement ratio. The coefficient of correlation \( R \) in equation is 0.96. So, it is considered that there is close relationship between unconfined compressive strength and water-cement ratio. Also bending strength

![Unconfined compressive strength, bending strength and water-cement ratio](image)

The relationship between unconfined compressive strength and bending strength is shown in Figure 8. It is mentioned that bending strength is 1/5~1/8 (0.20–0.13) of compressive strength of concrete by Miyakawa and Okamoto (2009). The range is shown by oblique line in Figure 8. Average bending strength was 0.20 times as high as average unconfined compressive strength with cement content of 15%. With cement content of 25%, average bending strength was 0.04 times as high as average unconfined compressive strength. The value greatly differed from concrete. The maximum unconfined compressive strength and bending strength were 14 MPa and 0.8 MPa respectively. It is mentioned that compressive strength is 32 MPa and bending strength is 5 MPa in case of general interlocking blocks by Architectural Inst. of Japan (1988). So, it is necessary to improve strength of soil interlocking blocks.

![Bending strength and unconfined compressive strength](image)

4 LOAD TRANSMISSION

Figure 9 shows the relationship between height of roadbed and vertical stress measured in base course when constructing roadbed. As the height of roadbed grew, vertical pressure increased linearly. Increasing...
rates of stress were 27.96 kPa/m (crushed stone) and 3.91 kPa/m (dehydrated soil). The increasing rate of crushed stone was 7 times higher than that of dehydrated soil. The increasing rates of stress calculated by wet unit weight were 17.36 kPa/m (crushed stone) and 11.23 kPa/m (dehydrated soil). Therefore, it is considered that dehydrated soil can disperse traffic load effectively.

The relationship between vertical stress and running frequency is shown in Figure 10. Vertical stress was about 30 kPa smaller when dehydrated soil was used as roadbed than crushed stone was used. And the vertical stress became large when using soil block on the surface of the road.

Figure 11 shows the relationship between traffic stress amplitude and running frequency. Traffic stress amplitude is defined as the gap of maximum stress and minimum stress measured by traffic load. It shows that traffic stress amplitude increases setting blocks on the surface. And traffic stress amplitude tended to decrease due to increase of traffic frequency. The traffic stress amplitude was smaller when dehydrated soil was used as roadbed than crushed stone was used. It should be mentioned that dehydrated soil can disperse traffic load effectively.

The relationship between vertical stress and running frequency is shown in Figure 12. The settlement increased with the increase of running frequency. Especially, the settlement was large when dehydrated soil was used as roadbed. The effect of soil block could not be confirmed when using crushed stone as roadbed material, but when using dehydrated soil, soil block reduced settlement more than 1 cm.

FIG. 12. Settlememt and running frequency

5 CONCLUSIONS

In order to investigate mechanical and load properties of soil interlocking block, the unconfined compressive strength and bending strength were examined and running experiments were carried out. The following conclusions are obtained: 1) There was close relationship between unconfined compressive strength and water-cement ratio. Therefore, it is suggested that unconfined compressive strength of dredged soil blocks are controlled by water-cement ratio. 2) Dehydrated soil can disperse traffic load effectively. 3) Soil-concrete blocks can’t disperse traffic load effectively, but have sinking suppressing effect when using dehydrated soil as roadbed material.

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