Mix proportion design of liquid soil material suitable for abutment back filling

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Abstract. To solve the uneven settlement between the structures such as comprehensive pipe gallery, abutment back and road, aiming at the problems of insufficient compactness and heavy self weight of backfill materials at the back of abutment, a new type of backfill material for gravity platform back, namely liquid soil, is proposed. Many tests have been carried out on the compressive strength and water stability of liquid soil. According to the test results, the mixing ratio of liquid soil suitable for abutment backfill is as follows: without adding additives, the mass ratio of cement to fly ash is 8:92, and the moisture content is 45% or 47%; when 1.5% water reducing agent is added, the mass ratio of cement to fly ash is 6:94 or 8:92, and the moisture content is 40%; when the maximum particle size is 5mm, the mass ratio of cement and fly ash is 4:96 or 6:94, the moisture content is 25%.

1. Introduction
The back filling of abutment refers to the backfilling at the structure, and the left part between the structure and the subgrade is filled with the materials meeting certain requirements in layers[1]. During the operation of the highway, the abutment backfill and the bridge deck are prone to different settlement, resulting in the subgrade staggering and so on, which leads to the jumping and impact of high-speed vehicles passing through the abutment backfill, which is called Bridgehead Bump[2]. How to effectively eliminate or reduce this phenomenon of "vehicle bump at the bridge head" has become a problem to be solved in the construction of high-grade highway[3]. How to improve the compactness of filling material behind abutment is the key to reduce the settlement of embankment behind abutment and solve the bump at bridge head. However, at present, the compaction degree of the part close to the abutment back is difficult to meet the specification requirements[4]. The traditional backfill material for abutment back usually adopts soil filler with good engineering performance, but the defects of traditional filling material are easy to cause large post construction settlement, slab fracture and other diseases[5]. In order to solve the problem of differential settlement in the transition section between fill and highway structure, a new type of abutment backfill material came into being.

2. Experimental scheme

2.1. Experimental materials
2.1.1. Cement
As one of the most important raw materials of liquid soil, the main contribution of cement to liquid soil is to enhance its strength.

2.1.2 Fly ash

| Project | Fineness | Loss on ignition | Specific surface area | Apparent density | The compaction density | Water content |
|---------|----------|------------------|-----------------------|------------------|------------------------|---------------|
| Parameters | ≤10% | 7.9% | ≥450m²/kg | 700kg/m³ | 1150Kg/m³ | 3% ~ 7% |

2.1.3. Admixtures
In liquid soil, there are three kinds of additives: water reducing agent, medium sand and active mineral powder. Their properties are as follows:

① Water reducing agent
The cement additive used in this test is the Nai series additive (liquid). Naphthalene series water reducer is the most widely used high range water reducer with the largest production volume in China at present. Its characteristics are high water reducing rate, no air entrainment, little influence on setting time, relatively good adaptability with cement, and can be combined with other admixtures, and the price is relatively cheap.

② Medium sand
The sand used in the test is to meet the requirements of test code for road inorganic materials, and the content of particles less than 5mm is more than 90%.

③ Active mineral powder
Mineral powder can be hydrated to form hydrated calcium silicate, filled in the pores of cement concrete, greatly increasing the density of cement concrete, and converting the calcium hydroxide crystal with lower strength into a calcium silicate gel with higher strength. The properties of active mineral powder used in the test are shown in Table 2.

| Project | Density g/cm³ | Specific surface area m²/kg | Moisture content | SO₃ content | Cl + content | Loss on ignition |
|---------|---------------|-----------------------------|------------------|-------------|-------------|-----------------|
| Parameters | 2.99 | 800 | 0.04% | 0.1% | 0.01% | 0.4% |

2.1.4. Water
The liquid soil can be treated with drinking water for human and livestock.

2.2. Experimental content
The compression strength of the liquid soil samples was formed by the triple test mold with the test mold of 100 mm × 100 mm × 100 mm. The specimens were cured under the standard curing conditions (temperature 20 ± 2 °C and relative humidity above 90%) for 28 days. The unconfined compressive strength test was carried out by ya-2000 electro-hydraulic pressure testing machine. The water stability of materials refers to the strength and stability of materials after meeting water. Using the same triple test mold as the strength test, 100 mm cube test block was made for testing, and the formwork was removed after curing for 28 days under standard curing conditions. Then, the test block is soaked in water for 24h at room temperature, and the water stains are wiped out, and cured for 48h under the standard curing conditions. Then the test block is soaked in water for 24h, and then taken out
and cured under the standard curing condition for 48h. This is repeated twice to measure the residual compressive strength of the test piece, and the ratio of the compressive strength of the specimen to that of the UN immersed specimen, i.e. the water stability coefficient.

3. Test results and discussion

3.1. Compressive strength

The compressive strength of liquid soil with different water content and cement content is shown in Figure 1 and Figure 2. With the decrease of water content and the increase of cement content, the strength of liquid soil increases. When the cement content is 4%, the strength of liquid soil is very low due to the low cement content, so the strength error measured is relatively concentrated. When the cement content is 4% and 6%, the strength of liquid soil is too low to meet the engineering requirements.

![Figure 1. Compressive strength of liquid soil under different water content.](image)

![Figure 2. Compressive strength of liquid soil with different cement content.](image)

3.2. Water stability

It is considered that the water stability is better if the residual strength is greater than 50% after water stability test. With the increase of water content, the water stability of liquid soil has a certain downward trend. The compressive strength of liquid soil with different water content and cement content is shown in Figure 3 and Figure 4. When the water content of liquid soil exceeds 47%, the water stability coefficient of liquid soil is low, and the water stability coefficient is less than 50%. At this time, its water stability is poor. The influence of cement content on water stability is not obvious enough, and the trend of first increasing and then decreasing appears. According to the test results, it is considered that the water stability is better when the cement content is 6% and 8%. This paper summarizes the following principles of proportioning, as shown in Table 3.

- Based on the compressive strength, the water content of liquid soil should be reduced, the cement content should be increased, and the admixture should be mixed with medium sand or water reducing agent.
- Based on the consideration of water stability, the water content of liquid soil should be reduced, and the cement content should be 6% or 8% as far as possible. In order to improve water stability, liquid soil should be mixed with active mineral powder.
4. Conclusion

- The lower the water content, the higher the strength of liquid soil, and the higher the cement content, the better the strength of liquid soil. In the absence of additives, the liquid soil with 8% cement content can not meet the strength requirements. On the other hand, medium sand can greatly improve the strength of liquid soil, followed by water reducing agent, and the strength of mineral powder is less.

- With the increase of water content, the water stability of liquid soil decreases, but the decline range is not large; the water stability of liquid soil with 6% and 8% cement is the best; the mineral powder can improve the water stability obviously, the water reducing agent can reduce the water stability, and the medium sand has little effect on the water stability.

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