Model tests of geotextile in collapse treatment of karst subgrade

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Abstract. Subgrade collapse is widespread in karst areas of south China, which is easily causing economic losses and casualties. Compared with the traditional treatment methods, using geotextile has obvious advantages in treating the subgrade after karst collapse. In this paper, two scale model tests with different laying depth of geotextile used to treat karst collapse were performed. Instrumentations and particle image velocimetry system (PIV) were applied to investigate soil pressure, vertical displacement of filling and tension distribution of geotextile. Following results were found: from the point of view of soil pressure, compared with deep buried, there had not enough stable soil under the shallow buried geotextile to improve the collapse treatment effect effectively; Compared with using deep buried geotextile, shallow buried geotextile would cause a larger overall settlement with the surrounding fill, which reduced the reinforced effect and had unsatisfactory treatment effect. Therefore, the geotextile with deep layout should be used in the collapse control and the soil beneath it should be compacted to achieve a good treatment effect.

1. Introduction
There is 346.3×104 km² of solvable rock area in China, which accounts for more than one third of the national territory. Due to the existence of voids, subgrade sinkhole occurs frequently under the dead weight of embankment and the load of vehicles, which has serious harm to road safety and economic construction [1].

There are various methods of karst collapse treatment in the actual projects, including backfilling, grouting and rigid plate crossing et al. However, some disadvantages such as recurrence of collapse, high costs, long construction period and other problems have emerged after using these methods [2-3]. Compared with traditional methods, geosynthetics have some advantages in the treatment of karst collapse, there are many research achievements in collapse treatment using geosynthetics at present [4-7].

In this paper, two scale model tests were carried out for geotextile treatment after karst subgrade collapse, and the effects of geotextile laying depth on soil pressure, vertical displacement of filling and tension distribution of geotextile were discussed.

2. Tests
The prototype void of sinkhole simulated in this test was from the road collapse treatment project of Xihuan Road in Hechi city, Guangxi, China. It had 1.5 m length, 1.2 m width on surface and 4 m...
depth, which was surrounded by sandy soil. A large model test box (150cm×60cm×150cm) was used in the scale model tests and allowed visual observation using Particle Image Velocimetry (PIV). Figure 1 shows the dimensions of the scale model with a similarity ratio of $n=5.0$.

The filling soil used in the tests was Li River sand in Guilin area with density, moisture content, cohesive force and internal friction angle of 1.68g/cm$^3$, 1.03%, 32.8˚ and 0.2kPa, respectively. The medical gauze was a rational substitute of the geotextile prototype which had tensile strength of 3.22kN/m and tensile modulus of 48kN/m according to the tensile tests. Table 1 lists the scale model tests conducted in this study.

Table 1. Test scheme.

| Case | Collapse width $B$ (mm) | Anchorage length $L$ (mm) | Filling height $H$ (mm) | Laying depth of geotextile $h/H$ |
|------|------------------------|--------------------------|------------------------|------------------|
| Z1   | 300                    | 600                      | 1000                   | 1                |
| Z2   | 300                    | 600                      | 1000                   | 1/2              |

Following steps were applied in the scale model tests:

1. Double Teflon sheets were laid out to the inside surfaces of box to reduce the friction between box and soil;

2. The soil pressure cells were fixed in place and covered with a layer of sand about 50mm thick. Then the model geotextile with strain gauges in place were laid on it;

3. The sand was filled by layers and each layer with 100mm thickness was compacted fully by electric plate compacting machine. The compaction coefficient was required to 96%. When the filling height reached 1000mm, it was allowed to rest for 60min;
(4) The PIV system was installed and debugged. And the settling device was controlled to make the movable bottom plate stop settling at 30mm with the rate of 2mm/min. The soil pressure, fabric tension and filling displacement were recorded by the data acquisition system and PIV system;

(5) During the tests, the fitting state between the movable bottom plate and model geotextile needed to be observed manually, and the settlement of plate during the separation was required to be recorded.

3. Results and discussion

3.1. Soil pressure

The relative settlement $d$ was defined as the ratio of settlement $S$ to width $B$ of the movable bottom plate. The horizontal distribution of soil pressure at measured position is shown in figures 2a and 2b for relative settlement $d$ at 1% and 5%. Figure 2a presents that the soil pressure in subsided area of Z1 is significantly lower than that of Z2 at the initial stage of collapse, indicating that the geotextile with deep laying had a good effect on treatment; while the soil pressure between the two cases had no significant difference in stable area. When the settlement entered into the middle stage ($d=5\%$), the soil pressure of Z1 in subsided area was close to zero (figure 2b). The reason might be that the geotextile with deep laying was separated from the collapsed soil beneath it, which formed a relatively stable treatment system. But the soil pressure of Z2 in subsided area was reduced but not to be zero, implying the collapse had further effects on treatment system. Compared with the soil pressure at the initial collapse ($d=1\%$), the T3~T6 soil pressure of 5% relative settlement in stable area was further increased, except that the T3 soil pressure of Z1 was decreased. It is indicated that the influence of deep laying geotextile on collapse and surrounding area was greater than that of shallow laying geotextile. From the point of view of soil pressure, compared with deep buried, there had not enough stable soil under the shallow buried geotextile to improve the collapse treatment effect effectively.

3.2. Vertical displacement of filling

Figure 3 shows the vertical displacement nephograms of filling for Z1 and Z2 acquired from PIV at the end of settlement. It can be seen that the filling displacement of Z1 with bottom reinforcement was significantly lower than that of Z2 with middle reinforcement. And the former ended due to the separation between reinforcement and soil when the settlement of active bottom plate was 22mm, while the latter settled until the settlement value of 30mm specified in the test.

The vertical displacement of different filling height in the center of subsided areas at end of settlement ($d=10\%$) is plotted in figure 4. The filling displacement of Z1 was lower than that of Z2 at various heights. At the settlement marker of $h=0\text{mm}$, the vertical displacement of Z1 was about 22mm, while that in Z2 was 30mm. That was to say, the geotextile with deep layout were separated from the collapsed soil when the active bottom plate settled until 22mm, and the filling displacement here did not change. In addition, the vertical displacement monitored by markers at $h=300\text{mm}$ and above it in Z1 was about zero, while that at $h=800\text{mm}$ and above it in Z2 was approximately zero. It can be seen that the deep buried geotextile could realize the separation between soil and itself through tensioned membrane effect, but perhaps the shallow cannot.

3.3. Tension distribution of geotextile

The tensile force-relative settlement characteristics of Y1, Y3, Y4, and Y6 in two tests are given in figure 5. The tension forces of each measured point between the two tests were obviously different expect Y6. In the test Z1, the tension force at Y1, Y3 and Y4 had all underwent three stages: smooth increase, rapid increase and relative stability. The generation of relative stability stage was due to the separation of geotextile from the collapsed soil so that the tension force did not increase. However, the tensile force of test Z2 using shallow buried geotextile had been rising without stability stage. Additionally, the tensile force of Y1 and Y3 in Z1 was significantly higher than that in Z2 at various stages of settlement. This was probably due to that the vertical load above the deep buried geotextile
of the deep buried group was larger than that of the shallow buried case. Moreover, perhaps the reinforced effect of the latter was not good, which caused the overall vertical displacement of the geotextile and filling above subsided area and stability area within a certain range. The tension force of Z2 at Y4 was greater than that of Z1, which was also related to the larger vertical deformation of Z1 with shallow buried geotextile. It was equivalent to that the subsided area with larger width brought the more vertical load born by geotextile, which caused the growth of tension force at collapse edge.

![Figure 3. Vertical displacement nephograms of filling: (a) Z1; (b) Z2.](image)

![Figure 4. Vertical displacement of different filling height at \(d=10\%\)](image)

![Figure 5. Comparison of tensile force-relative settlement between Z1 and Z2](image)

### 4. Conclusions

The karst subgrade collapse can be effectively treated by using geotextile. Two scale model tests with different laying depth of geotextile used to treat karst collapse were performed in this study. The following conclusions can be drawn:

1) From the point of view of soil pressure, compared with deep buried, there had not enough stable soil under the shallow buried geotextile to improve the collapse treatment effect effectively;

2) Compared with using deep buried geotextile, shallow buried geotextile would cause a larger overall settlement with the surrounding fill, which reduced the reinforced effect and had unsatisfactory treatment effect;

3) The geotextile with deep layout should be used in the collapse control and the soil beneath it should be compacted to achieve a good treatment effect.
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