Field Test and Numerical Analysis of Flexible Retaining Wall of Shoulder Geocell

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Abstract. In order to study the stress and deformation characteristics of the shoulder type geocell flexible retaining wall, a three-dimensional numerical model of the geocell flexible retaining wall is established based on the reconstruction project of Zichang County urban transit section of Provincial Road 205 in Shaanxi Province, and the numerical calculation results are compared with the field monitoring results. The results show that the base pressure of the flexible retaining wall of the shoulder geocell increases with the increase of the filling height of the retaining wall, and decreases slightly after the completion of the construction; the horizontal earth pressure on each layer of the retaining wall is not evenly distributed, the horizontal earth pressure in the middle of the retaining wall > the horizontal earth pressure inside the retaining wall > the horizontal earth pressure outside the retaining wall; the horizontal earth pressure and the horizontal deformation after the stability are along the height of the retaining wall The drum distribution is the largest at the height H / 2 of the retaining wall.

1. Introduction
The geocell flexible retaining wall is a kind of composite retaining structure composed of soil and lattice. The structural layer composed of geocell, baffle and filling material is stacked layer by layer according to a certain slope (generally 1:0.5 ~ 1:0.25). Compared with the stone masonry retaining wall, the cost can be reduced by 15% ~ 30% [1], which has the characteristics of beautiful appearance, low cost and good structural stability. Therefore, it has been recognized and widely used by the geotechnical community, and has achieved good economic and social benefits.

Geocell was born in the early 1980s. It was first developed by the road and bridge laboratory of France road and Bridge University [2]. At the end of the 20th century, geocell flexible retaining wall was used in the field of highway and railway construction. In recent years, the geotechnical and tunnel research group of Highway College of Chang'an University has carried out in-depth research and achieved some results. Xie Yongli [3] studied the flexible retaining wall of the embankment type geocell...
with the height of 12M, and gave the stress and deformation characteristics of the flexible retaining wall of the geocell. Yan Changgen et al [4] proposed to control the local deformation of retaining wall by laying reinforced layer. Qu Zhanhui [5] and Xu Weiqiang [6] proposed to use the slice element method and differential element method to calculate the horizontal earth pressure of the flexible retaining wall of the grovel. However, the application time of geocell flexible retaining wall in China is still short, and there are still many deficiencies in design and construction theory. Based on the field test and numerical analysis, this paper discusses the mechanical and deformation characteristics of the flexible retaining wall of the shoulder geocell with the height of 6m.

2. Project Overview

2.1. Project introduction
Model test and on-site monitoring rely on the reconstruction project of Zichang County urban transit section of Provincial Road 205 in Shaanxi Province. The section K11 + 850 ~ K11 + 880 of expressway is located at Chenjiawan gully mouth, and the west section is connected with a tunnel. The terrain fluctuates greatly. There are farmland and residential buildings in front of it that cannot be slope treated. The shoulder type geocell flexible retaining wall is adopted for slope protection, with a length of 30m and a height of 6m, the slope rate is 1: 0.5.

One main section and one auxiliary section are arranged on the ecological flexible retaining wall of the geocell, respectively at K11 + 860 and K11 + 870. The horizontal earth pressure and base earth pressure of the retaining wall are measured by 30 steel chord earth pressure boxes. The bottom pressure box is horizontally buried, and the stress surface is facing the soil body of the retaining wall, and the base earth pressure of the retaining wall is measured. The other pressure boxes are buried laterally, and the stress surface of the pressure box is facing the soil behind the wall. Measure the horizontal earth pressure of the retaining wall.

The horizontal deformation of the retaining wall is observed by flexible displacement meter, which is buried in the first, sixth, 12th, 18th, 24th and 30th floor cells respectively, with a total of 12 flexible displacement meters.

2.2. Engineering geological condition
According to the survey data, the terrain of K11 + 850 ~ K11 + 880 section of the expressway fluctuates greatly, which is now a barren terrace land, widely covered with Malan loess and aeolian sand, with a thickness of about 5m ~ 8m. The underlying bedrock is strongly weathered and moderately weathered siltstone with shallow buried depth and locally developed structure.

3. Numerical analysis

3.1. Model building
The numerical model of geocell flexible retaining wall is composed of retaining wall body, foundation and fill behind the wall [7]. After consulting the reference materials and trial calculation, the model size of each part is determined as follows: the length of retaining wall is 15m, the height is 6m, the thickness is 3M, and the design slope rate of retaining wall is 1: Zero point five; the width of foundation is 4m, the thickness is 1m, and the width of soil behind the wall is 15m. Its three-dimensional solid geometry model is shown in Figure 1.

3.2. Gridding
In the process of FLAC3D numerical analysis, the more units are divided, the more accurate the calculation results are [8]. However, too many units will increase the computer burden, resulting in slow calculation process. Considering all kinds of factors, this calculation unit grid division adopts "sweep" grid division, which takes retaining wall as the key research object and carries out grid encryption.
treatment; foundation part and soil part are non-research focus, and grid division is relatively sparse. See Figure 5 for the specific cell grid division [9].

Figure 1. Stereogram of geometric model

Figure 2. Gridding stereogram

4. Test results and analysis

4.1. Earth pressure of retaining wall base
As shown in Figure 8, during the filling process of the retaining wall, the earth pressure of the basement of the flexible retaining wall of the geocell increases rapidly, decreases slightly after the completion of construction, and then tends to be stable. There is a certain difference between the measured earth pressure at the base of the retaining wall and the numerical calculation results. At the construction stage of the project site, first of all, large construction machinery and packing have a great impact on the pressure at the base. Therefore, during the construction process, the measured earth pressure at the base of the retaining wall is greater than the numerical analysis. With the completion of the construction and the withdrawal of the construction machinery from the site, the pressure at the base of the retaining wall decreases slightly.

Figure 3. Field test and model test of shoulder type flexible retaining wall
The requirements of flexible retaining wall of geocell for foundation bearing capacity are not high. The foundation earth pressure measured on site or the numerical analysis value after the retaining wall is stable are less than the theoretical calculation value (the theoretical foundation earth pressure calculation directly uses the volume weight of filler multiplied by the height of retaining wall) [11]. The difference between the theoretical value and the measured value is not only caused by the consolidation of the soil around the earth pressure box, but also related to the lateral deformation constraint of the lattice on the filler, so how to reduce the vertical component of the lateral deformation constraint is worthy of further study.

4.2. Horizontal earth pressure of wall

The temperature of soil layer under different treatment of experimental plots was monitored and recorded in real time, and the difference of soil temperature under different treatments was analyzed. From Figure 1 and Figure 2, it can be seen that the surface temperature of the soil in TC and TFC both increased. The treatment of TC increased by 0.4 centigrade compared with T0 treatment, and the TFC treatment increased by 0.8 degrees. However, the TF treatment without adding fly ash increased 0.3 degrees. This may be due to the deeper color of the fly ash, which increases the absorptive capacity of the soil to solar radiation. In addition, during the main growth period of corn (June -10 months), the daily surface temperature distribution on the surface of the soil was mostly below 30 degrees. In this temperature range, the increase of soil temperature significantly increased the water uptake efficiency of roots.

![Figure 4. Lateral earth pressure of the stable retaining wall](image)

The characteristics of horizontal earth pressure distribution of the shoulder type flexible retaining wall are related to the physical and mechanical properties of the geocell, the mechanical properties of the fill, the compaction machinery and the compaction process. First of all, during the construction process, the geocell is paved in layers. When the first layer of geocell is paved and the loader is used for soil loading, the roller is used for rolling. When the roller is rolled to the position close to the wall panel and the inner side of the wall, in order to ensure the smoothness and beauty of the line, the peripheral edge of the roller wheel is about 20cm away from the inner side of the panel and the retaining wall. The compaction process determines most of the compaction work it is distributed in the middle of the width of the geocell layer, so the maximum tensile point of the geocell layer is in the middle. Secondly, it is related to the "effect" of the mesh pocket in the internal lattice layer of the retaining wall. When the horizontal earth pressure is transferred in the interior of the lattice layer, the lattice deforms. In the middle, the lattice deforms to the maximum, and it’s unloading and interception functions are fully exerted. Then, the earth pressure begins to decrease gradually, and when it reaches the edge baffle, there is basically no deformation. Therefore, the horizontal earth pressure outside the retaining wall and the inside of the retaining wall it is very different from the middle of the retaining wall and has a linear distribution, which is similar to the rigid retaining wall.
For the calculation of horizontal earth pressure on the wall of shoulder geocell flexible retaining wall, it is not involved in the code for design of highway subgrade. In this paper, the Coulomb active earth pressure method, slice element method and differential element method are used as the theoretical calculation methods to calculate the horizontal earth pressure of the wall. The vehicle dynamic load in the operation stage is also one of the important factors that cause the horizontal deformation of the shoulder type flexible retaining wall. This paper does not consider the impact effect of dynamic load on the retaining wall, but converts it into permanent uniform load.

4.3. Horizontal displacement of wall
Figure 9 shows the horizontal deformation curve of the flexible retaining wall with time. Figure 12 shows the comparison curve of horizontal displacement between the model test and the measured wall after the construction of the retaining wall with the height of 6m.

Figure 5. Lateral displacement-time curve of flexible retaining walls

Figure 6. Contrast curve for lateral deformation of flexible retaining walls of model test and field test
It can be seen from Figure 5 that the horizontal deformation of each layer of lattice is mainly caused during the filling period of the upper layer of soil in direct contact. It can also be seen in the construction site that when the upper layer of filler is rolled, the next layer of lattice body has significant horizontal displacement, and the outer baffle has significant bulging deformation. When the filling height of the retaining wall increases, the horizontal deformation of the filled wall cell increases slowly, or even slightly decreases. After the construction of the retaining wall, the deformation is basically stable. It can be seen that the deformation of retaining wall mainly occurs in the construction period, which is the key period to control the deformation of retaining wall.

It can be seen from Figure 6 that after the retaining wall is stable, the deformation of the wall increases nonlinearly with the height of the retaining wall. The maximum deformation is 5.32 cm at 3M of the wall height, reaching 1.77% of the wall thickness, and within the allowable design range (the design limit deformation is 5% of the wall thickness), indicating that the retaining wall is stable. The deformation of the retaining wall is in the middle of the boundary, and the horizontal deformation of the part below the boundary increases with the increase of the height of the retaining wall, while the part below the boundary is just the opposite. This is related to the earth pressure distribution of the retaining wall. At the bottom of the retaining wall, the earth pressure increases with the increase of the height of the retaining wall, resulting in the wall deformation also increases with the increase of the height of the retaining wall; when the retaining wall reaches a certain height, the earth pressure of the retaining wall begins to decrease, and the deformation of the retaining wall gradually decreases with the increase of the height.

5. Conclusion

(1) The requirement of geocell flexible retaining wall for foundation bearing capacity is not high. The base earth pressure increases with the increase of filling height, which is non-linear distribution. During the filling process of retaining wall, the earth pressure increases rapidly. After the construction, the base earth pressure decreases slightly, and then tends to be stable.

(2) The earth pressure on the same horizontal layer of the flexible retaining wall of geocell is not the same, among which the earth pressure in the middle of the retaining wall > the earth pressure inside the retaining wall > the earth pressure outside the retaining wall. After the wall is stable, the earth pressure between the inner side of the retaining wall and the middle of the retaining wall presents a drum distribution, while the outer side of the retaining wall presents a linear distribution.

(3) Due to the influence of the earth pressure distribution, the horizontal deformation of the flexible retaining wall of the geocell presents a drum shape distribution, and reaches the maximum in the middle of the retaining wall. In the design and construction process of 6m high geocell flexible retaining wall, in order to ensure the safety of the wall and save materials, it can be considered to set up a lacing cell at 3M high of the wall.

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