Study on seismic behavior of new self-embedded retaining walls

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Abstract: This paper aims to explore the seismic mechanism of new self-embedded retaining walls through analyzing its embedded structures and numerical simulations, thus providing guidance for engineering practice and further development of new retaining wall. This paper discusses the working characteristics of self-embedded retaining wall in earthquake by using different reinforced scheme to simulate its seismic performance. SLIDE stimulates different reinforced scheme, which shows that the slope stability coefficient of horizontal reinforcement is larger than vertical watch reinforcement. The length and space of the reinforcement all influence the stability of the slope. The structural characteristics of self-embedded retaining wall shows that self-embedded retaining wall posses good seismic load transmission path and good seismic capacity. Firstly, the new self-embedded geotextile can effectively absorb seismic energy. Secondly, the movement of blocks, gravel filter layer and reinforced soil also plays an important role in energy consumption. Thirdly, high strength weight ratio can also reduce the seismic forces. Fourthly, gravel filter layer, geogrid and anchor rod which have a certain amount of damping force also posses good isolation performance. What’s more, anchor rods and geogrid which has a certain flexibility can restore to its original state within a certain time after the earthquake.

1. Introduction

With high frequency seismic activity, high intensity, light source, wide distribution, China becomes a serious earthquake country. Practice shows that the prevention and treatment of landslide geological hazards must first find out the model of deformation and failure of the slope (landslide)11. The study of slope stability evaluation methods and theories can be roughly divided into mathematical and mechanical theory of quantitative calculation and qualitative comprehensive engineering geological analysis of two categories, the main geotechnical numerical analysis method and using the limit equilibrium method of slope stability calculation, analysis and evaluation2,3. The most common method is the limit equilibrium analysis method, which is characterized by convenient and fast, and then there is a finite element analysis software to analyze the stress and strain of the slope4,9. The earthquake retaining wall collapse and failure will not only block the influence of river discharge, but also pose a great threat to human life and property safety.

In this paper, through analyzing the structure of self-embedded retaining wall, we are going to explore the good seismic performance of reinforced retaining wall, and through the SLIDE software simulation of different reinforcement program, to optimize the layout, in order to provide some references for the engineering practice of the self-embedded retaining wall in earthquake zone.

2. Structure principle of self retaining wall

Since the embedded retaining wall is a new type of retaining structure, it is by self-embedding retaining
clods, geogrid and soil composed of wall, to buttress structure, caisson, gravity retaining soil structure wall formed by the same role. The caisson structure, gravity type retaining soil and buttress structure formation of wall reinforcement compound instead, which is self obvious characteristics of self-embedded retaining wall. Compared with the traditional gravity retaining wall, the structure of the embedded retaining wall is clear, isolation and energy dissipation, low engineering cost, good landscape effect, simple construction technology and short construction period. And because of the dry base type flexible structure, it has strong adaptability to the sinking of the foundation, and the seismic performance is good.

Since the embedded retaining wall is mainly composed of backfill and foundation, since the embedded retaining blocks and backfill of the geogrid is composed of four parts. Block type retaining wall in a broad sense is a reinforced earth technique, with geogrid as skeleton, by assigning appropriate geogrid the soil and combined into a composite structure, improve soil strength, resistance wall soil lateral pressure, so it has good mechanical properties. More and more widely used in urban construction, water conservancy, real estate development and roads and other industries. The basic principle of the interaction between the self-retaining wall and retaining wall can be classified as follows: the principle of friction and reinforcement and the principle of cohesion, or the principle of quasi cohesion. The mechanism of the action is to improve the shear strength of the backfill soil by means of the geo grid in the backfill soil. When the reinforcement work, if the backfill and the geo grid produce friction without relative sliding, then the soil particles will be connected with the earth grid through friction work together. Under the effect of friction between soil and geogrid and soil stress passed to geogrid, however geogrid tensile stress and the resistance of the horizontal displacement of soil, just like in the soil increased a cohesion, thereby improving the mechanical characteristics of the soil. Therefore, the friction between the backfill and the soil grid is an important factor for the stability of the reinforced soil, and the key factor to determine the seismic performance. To ensure that the friction force is effective and not to cause the slip between the backfill soil and the soil grid. It should satisfy the formula: \( f > \tan \theta \). In the formula, \( f \) represents the friction coefficient between the soil and the reinforced belt, and the \( \theta \) represents the sliding friction angle between the soil and the reinforced belt.

At the same time, in order to ensure the friction between the backfill and the geo grid, the Earthwork Grille should be enough in length, and can bear the stress in the soil.

When the condition is established, the geogrid stress through direct contact with the geogrid soil particles delivered to the periphery of the soil particles, the stress dispersed, and geogrid and backfill to form a whole structure. In order to prevent the geogrid end of soil from the geogrid prolapse and collapse in self-embedding retaining walls of soil anchor bar or other anchorage facilities set up. The sketch map of the self retaining wall structure is shown in figure 1.

![Figure 1 self-embedded retaining wallStructure 3 diagram](image)

While ensuring the internal stability of the self retaining wall, it is necessary to deal with and strengthen the foundation and bearing capacity or the groove along the base.
3. Numerical simulation of the seismic wave of self-embedded retaining wall

3.1. computational model
In this paper, by using SLIDE software to simulate the stability of the self-embedded retaining wall under seismic waves, and then to obtain the dangerous slip surface and the possible sliding zone. SLIDE is a two-dimensional limit equilibrium program for evaluating the safety factor and failure probability of rock or soil slope, and the program calculation method is based on the vertical slice limit equilibrium analysis method. In this paper, the numerical simulation based on the different limit equilibrium method, but the difference is not big, so using (Janbu) method[9] to analyze and calculate the results. In order to better verify the superior seismic performance of reinforced retaining walls, two cases of slope reinforcement and slope reinforcement by self reinforced retaining wall were simulated respectively. By China Seismological Bureau of earthquake prediction research institute is to provide local engineering site seismic safety evaluation report ", with slide software simulation in horizontal earthquake acceleration was 0.6 (on the degree of seismic basic intensity VI), the duration of seismic wave for 11s[10-12].

3.2. slope stability analysis
Calculation of the parameters of the model soil: the internal friction angle is 26°, bulk density is 19.5kN / m-3, cohesion is 25kPa.

Under ideal drainage condition, the slope stability factor is less than 1.3 and the dangerous slip surface is shown in Figure 2. From Figure 2 we can see, based on the limit equilibrium method is obtained to calculate the dump slope stability coefficient is 1.046, basically in the state of limit equilibrium, the most dangerous sliding surface is located in the first stage, the most dangerous sliding surface radius large sliding surface is basically the starting at the edge of the platform. Through the SLIDE software filtering smooth function, the stability coefficient of slope can be obtained second to approximately 1.27. According to the provisions of the code of geotechnical engineering investigation, the value of the stability coefficient of the slope, the important project should be taken 1.30~1.50. Slope at all levels are not satisfied with this requirement, there is a possibility of local sliding collapse.

First and second grade slope occurs through the instability of the stability coefficient is 1.59, which indicates that the overall instability are less likely to dump slope, only to prevent occurrence of slump in the local.

3.3. Reinforcement effect analysis of self-embedded retaining wall retaining wall
The first level slope is the focus of the slope treatment, the stability coefficient of the first and the two slope under different length, distance and direction is calculated, and the calculation results are shown in table 1. As can be seen from the table, under the condition of full reinforcement, the stability of the reinforced slope is larger than that of the vertical slope, and the stability of the slope can be improved more effectively. At the same time, based on the limit equilibrium method, when all the band all through the potential slip surface, the stability coefficient of the potential slip surface will no longer increase. In practice of reinforced earth retaining wall with reinforced soil retaining wall, it is appropriate to increase the width of the rib belt to better play the potential of the band.
Table 1 Calculated results of reinforcement schemes

| Reinforcement scheme | Length (m) | Spacing (m) | Reinforcement direction | The first level of slope stability coefficient |
|----------------------|------------|-------------|-------------------------|-----------------------------------------------|
| 1                    | 5          | 2           | Level                   | 1.06                                          |
| 2                    | 5          | 2           | Vertical                | 1.01                                          |
| 3                    | 10         | 2           | Level                   | 1.10                                          |
| 4                    | 10         | 2           | Vertical                | 1.02                                          |
| 5                    | 15         | 2           | Level                   | 1.13                                          |
| 6                    | 15         | 2           | Vertical                | 1.05                                          |
| 7                    | 5          | 1           | Level                   | 1.08                                          |
| 8                    | 5          | 1           | Vertical                | 1.04                                          |
| 9                    | 10         | 1           | Level                   | 1.17                                          |
| 10                   | 10         | 1           | Vertical                | 1.08                                          |
| 11                   | 15         | 1           | Level                   | 1.24                                          |
| 12                   | 15         | 1           | Vertical                | 1.13                                          |
| 13                   | 20         | 1           | Level                   | 1.31                                          |
| 14                   | 20         | 1           | Vertical                | 1.18                                          |

In the horizontal seismic acceleration of 0.6g (equivalent to the basic seismic intensity of simulated VI). The program 13 reinforced slope at the first level of the most dangerous sliding surface stability coefficient of 1.310. The most dangerous slip surface still appears in the first grade of slope, the stability coefficient of 1.310. Simulation results are shown in figure 3.

Through the SLIDE software filtering smooth function, obtained stable sliding surface coefficient is less than 1.5, see figure 4.

The stability coefficient of the one or two stage slope is 1.47. The simulation results show that the horizontal earthquake acceleration was 0.6 (equivalent to the basic earthquake intensity of degree VI) under the action taken since the embedded reinforced retaining wall is the most dangerous stability coefficient of the sliding surface and a secondary slope through the instability of stability coefficient are more than 1.3. Meet the safety requirements of Engineering construction.

4. Conclusion
Based on the numerical simulation analysis, the aseismic mechanism of the reinforced earth retaining
wall is preliminarily explored, which provides some references for the slope reinforcement in the earthquake zone. Due to the influence of accidental factors and the complexity of the mechanism of reinforced retaining wall, the corresponding relationship between the model and the application of reinforced earth retaining wall with self reinforced retaining wall remains to be further excavated. The seismic behavior of the reinforced retaining wall is obtained by numerical simulation:

1) ceiling earthquake characteristics: self block retaining wall with several key connection point, provides additional force transmission path of the earthquake, the seismic block, gravel anti filter layer and the reinforced soil absorb large energy, vibration when the micro collision and mutual restraint, mutual ceiling, thereby reducing the seismic response of the whole structure. Once a connection point overload, overload can by adjacent connection sharing.

2) load characteristics: reinforced soil has a high strength to weight ratio, because the self retaining wall structure is generally lighter than other types of retaining wall structure, light weight in the earthquake is a major advantage of retaining wall.

3) the isolation characteristics: the anti-filter layer, the earth grid and anchor bar of the self-embedded retaining wall structure has certain damping force, and the vibration response of the structure is reduced by the large damping force. Under the action of small earthquake, the retaining wall has enough initial rigidity, and the system can keep the normal use requirement in the elastic range. The strong earthquake, the horizontal stiffness is smaller, so the retaining wall structure of the isolation effect is stable and reliable.

4) the reset characteristic: after the earthquake, because the anchor and the soil grid has certain flexibility, can return to the initial state within a certain time.

5) the energy dissipation characteristics: the crushed stone filter layer can adapt to the deformation, and the toughness of the reinforced soil is good. During the earthquake, every part of the structure can play the role of the dissipation of seismic energy.

In this paper, there is a certain difference between the model and the actual engineering, but the seismic mechanism of the reinforced earth retaining wall is studied by numerical simulation. At the same time, the research on the relationship between the model and the actual engineering needs to be further deepened due to the influence of the accidental factors and the complexity of the mechanism of the reinforced earth retaining wall.

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