Numerical Simulation Study on the Dynamic Response Law of Gabion Wall under Horizontal Earthquake Action

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Abstract. As an important seismic resisting element, the dynamic response law of the lattice retaining wall is of great significance for its design and assessment of seismic performance. Therefore, a numerical computational model of the gabion retaining wall was established using particle flow software. The hori-zontal EI-Centro-NS seismic waves with different peaks were input to study the dynamic response of the gabion retaining wall under horizontal seismic loading. The results show that: the peak dynamic stress of the gabion retain-ing wall increases-decreases-increases with the height of the wall, and reach-es the maximum at 5H/6, forming a dynamic stress amplification zone, and the total dynamic soil pressure is distributed as an "inverted triangle"; the horizontal displacement of the retaining wall and the vertical displacement of the retaining wall are both larger with the peak acceleration, reaching the maximum at the bottom of the wall, and both of them reach the maximum at the bottom. The horizontal and vertical displacements of the retaining wall both increase with the peak acceleration, reach the maximum value at the bottom, and gradually decrease along the height of the wall, and the vertical displacement is less affected. Under the excitation of four peaks of horizon-tal seismic wave, the retaining wall did not show obvious damage, and the flexibility of the grid retaining wall can absorb the seismic energy well, thus improving the seismic performance of the retaining wall.

Keywords: Gabin retaining wall; granular discrete element; dynamic response; horizontal seismic wave; seismic performance.

1 Introduction

At present, earthquakes occur frequently all over the world, and a large number of engineering construction activities will affect the stable state of existing natural slopes, and at the same time generate a large number of new artificial slopes. The results of a large number of seismic investigations show that earthquake-induced slope sliding is one of the main types of seismic geological hazards. As a flexible structure with good seismic resistance and slope stabilisation capacity, the role of the grid retaining wall is

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important for landslide management and debris flow prevention in areas with frequent seismic activities.

Nesovié[1] found that flexible gabion wall structures have good seismic performance. Hiroshi Nakazawa [2] evaluated the seismic performance of road gabion retaining walls. Chen Li [3] discussed the critical overturning distance and factors affecting the stability of gabion walls. Carneiro D [4] numerically investigated the ground damping performance of gabion walls. Liu Huabei [5] proved that geosynthetics reinforced soil retaining wall possesses excellent seismic performance through tests. Cai Xiaoguang [6] proved that the deformation of reinforced soil retaining wall under seismic loading is much less than the code limit. All of the above studies adopt the continuity research method, but the soil particles are discrete, so this paper adopts the particle discrete element method to better study the large deformation problems of discrete media such as lattice retaining wall, such as cracking, separation and other destructive phenomena.

In this paper, a numerical calculation model of the lattice retaining wall is established by using the particle discrete element software, and different peak horizontal seismic wave excitation is carried out to study the dynamic response law of the lattice retaining wall under the horizontal seismic action, so as to provide a reference for the seismic design of the lattice retaining wall.

2 Numerical modelling

2.1 Determination of model contact eigenstructure and parameters

In this paper, the discrete element method is adopted, and the fine analysis software of (DEM) framework is used to take the particle of the lattice retaining wall as the research object, and the mechanical properties of the medium are analysed from the microscopic point of view by defining the surface characteristics and contact properties of the particles, and the real-time mechanical behaviours generated by the lattice retaining wall model under the physical interactions can be finally observed. Based on the results of the indoor tests, the corresponding numerical experimental simulation of particle flow was carried out. By continuously adjusting the fine-scale parameters of the particles and repeatedly debugging the model, the parameters required for the simulation were finally determined as shown in Table 1.

Table 1. Model parameter table

composition	Normal/tangential stiffness/N·m^{-1}	Normal/tangential bond strength/N·m^{-1}	Parallel bonding method/tangential strength/N·m^{-1}
foundations	5×10^8	1×10^7	
Backfill	1×10^7	1×10^6	
Gabion stone	1×10^9	1×10^9	
Grids	1×10^6	1×10^9	1×10^8

2.2 Model building

A model of a gabion retaining wall with a width of 19m and a height of 10m was built, which consisted of three parts: limited foundation, backfill and gabion retaining wall. The height of each layer of gabion is 1m, and each layer is staggered inward by 0.5m, with a total of 7 layers of masonry. The numerical calculation model of the gabion retaining wall is shown in Fig 1.

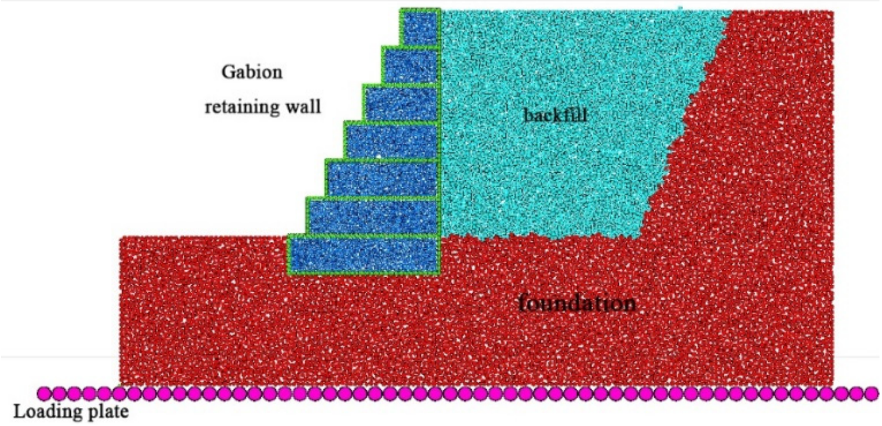

Fig. 1. Numerical calculation model of gabion retaining wall

3 Analysis of the dynamic response of the gabion retaining wall

3.1 Seismic Earth Pressure Calculation for Gabion Walls

Usually the horizontal seismic wave has a greater impact on the stability of the structure than the vertical, so only the impact of the horizontal seismic wave is considered here, the retaining wall force is the combined force of the horizontal seismic force and the gravity of the fill, and the seismic total dynamic soil pres-sure of the retaining wall of the latticework is calculated by the formula.

$$P_{E,a} = \frac{1}{2}\gamma H^2 K_{E,a} \tag{1}$$

$$K_{E,a} = cos^2(\theta \mp \alpha - \delta)/cos\delta cos^2\alpha cos(\varphi \pm \alpha + \delta) \cdot \left[1 \pm \sqrt{\frac{sin(\theta+\varphi)sin(\theta\mp\beta-\delta)}{cos(\varphi\pm\alpha+\delta)cos(\alpha-\beta)}}\right] \tag{2}$$

Formula: γ is the weight of the backfill behind the wall, H is the height of the retaining wall, and is the active earth pressure coefficient under horizontal seismic force.$K_{E,a}$ is the weight of the backfill behind the wall,β is the height of the retaining wall, δ is the active earth pressure coefficient under the action of horizontal seismic force.φ is the friction angle between the fill and the back of the retaining wall, and θ is the internal friction angle of the backfill.

As can be seen from Fig. 2, the peak dynamic stress intensity shows a nonline-ar variation with the increase of wall height, and the peak dynamic stress is the smallest at retaining wall H/2 and reaches the maximum at 5H/6, forming a stress amplification zone. With the increase of the peak value of the input horizontal seismic wave, the total dynamic soil pressure shows a tendency of decreasing and then increasing with the height of the retaining wall, and reaches the maximum at the top. The total dynamic soil pressure shows an "inverted triangle" distribution, and the maximum dynamic stress peak and total soil pressure both appear at the top of the retaining wall, which should be reinforced behind the wall in the de-sign to prevent the retaining wall from being damaged due to the amplification effect of the stress.

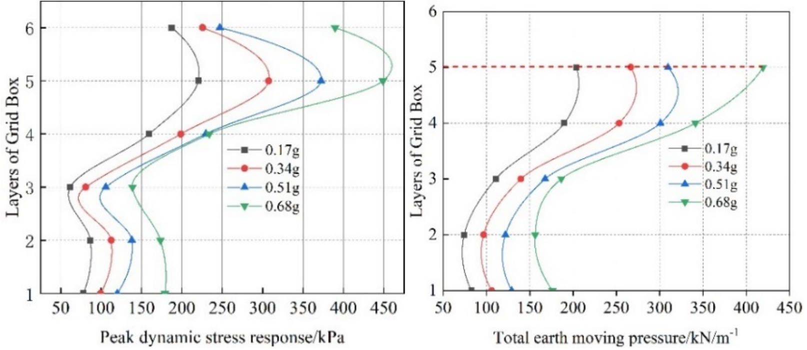

Fig. 2. Curves of peak dynamic stress intensity and total dynamic earth pressure versus wall height

3.2 Displacement analysis of gabion walls

The displacement response law of the gabion retaining wall under the action of different peak seismic acceleration is also an important index to study its seismic performance, as can be seen in Fig. 3.

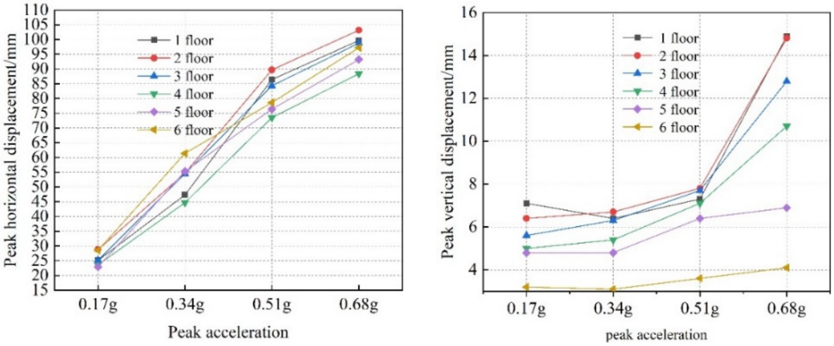

Fig. 3. Peak horizontal and vertical displacement response curves

with the increase of the input acceleration, the peak horizontal displacement of each layer of gabion mesh box increases accordingly. The maximum value appears at the bottom of the retaining wall, because under the action of horizontal seismic wave, the tendency of the gabion retaining wall to leave the fill behind the wall occurs, and the toe of the retaining wall rotates and translates in the direction of leaving the fill behind the wall, and the gabion retaining wall and the fill as a kind of elastic-plastic material, there is a cumulative effect of its seismic deformation, and the longer the seismic hold-up time, the larger its cumulative deformation will be. The trend of vertical dis-placement and horizontal displacement response law is basically the same, but the magnitude is much smaller than the horizontal displacement. The difference is that the peak of horizontal displacement increases more gently.

3.3 Analysis of the deformation of the gabion wall

The deformation maps of the lattice retaining wall after different peak seismic wave excitations are obtained, as shown in Fig. 4.

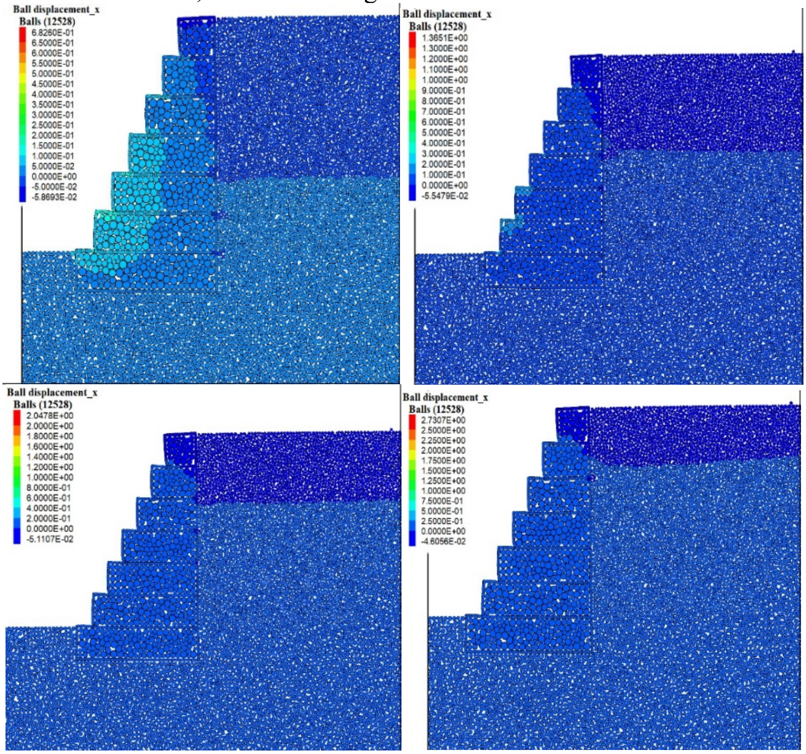

Fig. 4. Gabion retaining wall deformation diagram

The backfill behind the wall has a tendency to slide in the direction of the retaining wall under the action of horizontal seismic wave, especially in the top layer, where the tendency is most obvious. The damage form of the retaining wall under the action of horizontal seismic wave tends to overturning damage, but under the action of the four peak seismic waves, the retaining wall did not have obvious sliding, collapse, damage and other phenomena, indicating that the grid retaining wall has excellent seismic performance.

4 Conclusion

The dynamic response law of the gabion retaining wall under horizontal seismic wave excitation is as follows:

(1) The peak dynamic stress increases with the peak acceleration and reaches the maximum at 5H/6, forming a dynamic stress amplification zone, and the total soil pressure shows an "inverted triangle" distribution.

(2) Horizontal and vertical displacements increase with the peak value of the seismic wave, and the displacements are larger at the bottom and the top, and the longer the seismic time, the larger the cumulative deformation.

(3) Under the excitation of four kinds of peak horizontal seismic waves, the retaining wall did not have obvious misalignment, collapse and damage, and the seismic performance is good.

(4) This paper only discusses the dynamic response of the grid retaining wall under the horizontal seismic load, and the future research should focus on the mechanism of the joint action in the horizontal and vertical directions.

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