Seismic Performance Analysis of Highway Subgrade Retaining Structure

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Abstract. Subgrade retaining structure is the most common structure of highway, once it is damaged by earthquake, its damage is universal. Under the action of seismic load, whether the subgrade retaining structure cracks or collapses, and the failure mechanism is one of the key problems in the design of retaining structure in earthquake area. Therefore, it is necessary to systematically study the typical failure mode, failure mechanism and seismic earth pressure of highway retaining structures. In this paper, through the investigation and analysis of earthquake damage law and failure mode of highway retaining structure, combined with numerical model test, the seismic damage mode of highway retaining structure is summarized, and effective seismic reinforcement method is put forward, which provides a certain basis for post-disaster reconstruction of highway structure.

1. Introduction

Global plate tectonics and dynamic conditions determine that China is a country with high incidence of earthquakes. Subgrade retaining structure is the most common structure of highway, which was used with a wide range. Once damaged by earthquakes, its damage is also universal. But earthquakes themselves occur in a more frequent and violent manner all over the world. According to statistics over the past few years, after the Wenchuan earthquake, worldwide has occurred more than 100 strong earthquakes with magnitude 7.0, including Haiti earthquake and Yushu earthquake, which make us feel the pain of the skin.

As an important part of the life corridor, the subgrade retaining structure plays an important role in the emergency insurance after the earthquake. In order to meet the needs of disaster prevention and mitigation, we should fully respect earthquake damage, grasp the mode of earthquake damage of highway retaining structure on the basis of deep understanding and effective learning, so as to provide basic information and reference for earthquake resistance and prevention of highway retaining structure.

2. Earthquake Damage of Subgrade Retaining Structure

In earthquakes, the retaining structure of highway subgrade often suffers serious earthquake damage. Through the investigation of earthquake damage, the forms and characteristics of earthquake damage are as follows:
2.1 Seismic damage manifestations of retaining structures

2.1.1 Collapse of retaining wall
The sliding of the original slope where the retaining structure is located may cause the displacement and instability of the retaining structure, resulting in the collapse of the retaining structure (Fig. 1).

2.1.2 Shear failure of retaining wall
Shear failure of retaining wall is easy to occur in earthquakes for retaining structures built on fault fractured zones (Fig. 2).

2.1.3 Overturning of retaining wall
During earthquakes, slip and overturning of retaining structures are caused by fault rupture (Fig. 3).

2.1.4 Slip of retaining wall
Retaining structures are prone to slip due to shallow embedding depth of wall toes (Fig. 4).

2.1.5 Uneven settlement of retaining structure
Earthquake causes the change and decrease of bearing capacity of foundation of retaining structure, which leads to uneven settlement.

2.1.6 Outer drum of retaining structure
The earth pressure increases and the bulge of outer drum of retaining structure is caused by the change of filling property behind the wall, the increase of water pressure and the disturbance of retaining structure during earthquake.

Figure 1. Collapse of retaining wall

Figure 2. Shear failure of retaining wall

Figure 3. Overturning of retaining wall

Figure 4. Slip of retaining wall

(2) Main characteristics of earthquake damage of retaining structures are as follows:
- When earthquake occurs, the retaining structure moves with the surrounding soil. When the stiffness between the surrounding soil and the retaining structure does not match or the retaining structure has obvious inertia, excessive deformation will occur.
In the area where the stratum condition changes greatly, the retaining structure suffers more earthquake damage. The change of geological condition or topography results in the different vibration and displacement responses of stratum, which results in the large strain and the damage of the retaining wall structure.

It is easy to destroy where the thickness and height of the retaining wall section change obviously. The corner of retaining wall is easy to be destroyed, which is the weak point of earthquake resistance.

Retaining walls in liquefiable strata, faults and other adverse geological conditions are vulnerable to earthquake damage.

Retaining structures may cause cracks or even collapse and overturn due to earthquake damage, and interrupt traffic, resulting in huge economic losses.

3. Variation of Earth Pressure of Retaining Structure under Earthquake

The numerical model of retaining structure is shown in Fig. 5. The dynamic earth pressure variation along the height of retaining structure under EL-Centro and Wenchuan waves is simulated and analyzed. Tables 1 and 2 give the magnitude of seismic earth pressure under EL-Centro wave and Wenchuan wave respectively. The variation of dynamic earth pressure of retaining structure along height direction is shown in Fig.6. The horizontal axis is the measured value of dynamic earth pressure and the vertical axis is the height h of retaining structure. From Fig.6, it can be seen that the value under Wenchuan wave is larger than that under EL-Centro wave, and the change law of earth pressure under X-unidirectional excitation is consistent with that under XZ biaxial excitation. The normalized acceleration time history curves of EL-Centro wave and Wenchuan wave are shown in Fig.7, respectively.

![Figure 5. The calculation model of subgrade with retaining structure](image-url)

| value hight/cm | 0.1g | 0.2g | 0.3g | 0.5g | 0.6g | 0.7g |
|---------------|------|------|------|------|------|------|
| 0             | 11.13| 15.40| 19.99| 27.03| 30.28| 32.92|
| 11            | 8.13 | 11.40| 16.24| 20.78| 23.93| 26.97|
| 23            | 4.27 | 5.45 | 6.81 | 7.72 | 10.97| 12.86|
| 34            | 2.63 | 3.58 | 4.47 | 4.76 | 5.94 | 6.86 |
| 46            | 4.09 | 5.54 | 6.42 | 5.89 | 7.23 | 8.49 |
| 57            | 4.96 | 6.35 | 7.50 | 8.22 | 11.63| 13.86|

Table 1. The measured soil pressure under EL-Centro seismic waves (kpa).

| value hight/cm | 0.1g | 0.2g | 0.3g | 0.5g | 0.6g | 0.7g |
|---------------|------|------|------|------|------|------|
| 0             | 14.48| 20.36| 24.16| 31.42| 34.34| 37.45|
| 11            | 13.82| 18.04| 22.01| 25.23| 29.52| 32.13|
| 23            | 5.51 | 7.32 | 8.77 | 9.41 | 12.36| 14.66|
| 34            | 3.22 | 4.53 | 5.61 | 6.34 | 8.13 | 9.69 |
4. Conclusion
In this paper, the distribution of acceleration response of different models under different seismic waves is obtained by numerical simulation test of subgrade retaining structure model. The influence of different factors, such as type of seismic wave, intensity of seismic wave and multi-direction input, on the distribution of acceleration response is studied.

- The maximum acceleration response generally occurs at the top of the retaining structure. The type of seismic wave has an important influence on the acceleration response. The acceleration
response under Wenchuan wave is larger than that under EL-Centro wave. The larger the peak acceleration, the smaller the acceleration magnification.

- The acceleration amplification effect of the top of the subgrade, the top of the retaining structure and the upper and lower of subgrade slopes is obvious, which should be paid attention to in the seismic design of actual project.
- Through numerical analysis, it is found that if the top of retaining structure is strengthened by bolts, the peak acceleration of seismic waves will be greatly increased when earthquake damage occurs. The upper part of retaining structure is the key to seismic design.

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