Influences Analysis of Seismic Intensity on Dynamic Response of Slope Supported by Frame Structure with Pre-stressed Anchors

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Abstract. The mountainous area is wide in the western region of China, and there are many seismic zones. Due to the two factors, there are more and more slope projects in the western region, and the influence of earthquake also need to be considered into the relevant researches on anchored slope. The damage to the slope under the earthquake has attracted the attention of researchers. Therefore, there are many studies on slope support under the seismic action. However, there is little research on the influence of seismic intensity on the slopes supported with pre-stressed anchored-frame structures. This paper based on an engineering example in the northwest loess area, taking into account the synergy of the frame-anchor-soil, a three-dimensional finite element model of the slope system with pre-stressed anchored-frame structure under the seismic action was established. The dynamic response of the supported slope was calculated by the finite element software ADINA, and the impact of different seismic intensities on the slope displacement, acceleration, axial force of anchor, and earth pressure are analyzed

Keywords: Frame structure with pre-stresses anchors; supported slope; seismic action; dynamic response; seismic intensities.

1. Introduction

There is a large population, vast territory and complex terrain in China, but the land utilization rate is not very high, especially in the western region where there are many natural disasters. Due to the large number of mountainous areas in the west and the wide distribution of seismic zones, the development of urbanization has been relatively delayed. These earthquakes have caused great losses to people, so earthquakes are an inevitable factor in building infrastructure in the western region. The anchored-frame structures with prestress are widely applied in the northwest slope support because of many advantages, and there are many studies about the anchored-frame structures [1-2]. Mingxing Tao [3] found that the study of soil-structure interaction ignores the influence of soil-underground structure, and then discussed the reciprocity of soil-underground structure under earthquake by means of FEM. Shuaihua Ye et al [4-7] established a dynamic calculated model of slope with pre-stressed anchored-frame structures and structural dynamic control balance equation to study the dynamic response under seismic action, and the reliability of the anchored slope was analyzed by means of fuzzy
mathematics method. Meanwhile, the sensitivity analysis of the factors impact on the stability of the multi-level slope was also done by the improved gray correlation model. In the researches of Hongwei Zhu et al. [8], the axis force of anchors was significantly larger under earthquake, and the longer the length of rock bolt, the smaller the axial force under earthquake. Yuliang Lin et al. [9-10] found from the shaking table test that the magnification increases significantly at the toe of the frame structures, thus greatly enhancing the acceleration in response to seismic loads. On the one hand, the seismic load added the axial stress of the anchor in the free segment. On the other hand, the axial stress decreases rapidly at the anchoring segment, then goes to zero in the least time. Subsequently, the dynamic response of supported three-level slope with frame structures was researched by FLAC. Ying-jun Li et at [11] improved the displacement calculation about slope supported by nails after earthquake, which considered the real-time dynamic slip of slope sliding body under earthquake. Yingren Zheng et al. [12] used the FLAC to analyzed the failure principle of the slope when the seismic act on the slope system, thus clarified the location and nature of the fracture surface.

There are relatively few studies on earthquake intensity in previous studies, in this paper, a three-dimensional model of frame-anchor-soil cooperative work is established with the help of ADINA bases on a practical project in northwest China. At the same time, the response of the supported slope by anchored-frame structures with prestress is calculated and analyzed, in which the seismic response conditions of slope displacement peak, acceleration peak, anchor axial force and earth pressure peak under different seismic intensities are mainly studied.

2. Selection of Seismic Waves
The North-South acceleration record of the American El-Centro seismic wave is used to instead of seismic in this paper. It is divided into two seismic actions, namely X and Z directions in the ADINA model, as shown in Figure 1. Due to the limitation of calculation conditions, this paper only intercepts the part of the acceleration record containing its maximum peak value is intercepted as the input seismic acceleration record.

![EL-Centro oscillogram](image1.png)

(a) EL-Centro oscillogram in horizontal direction

![EL-Centro oscillogram](image2.png)

(b) EL-Centro oscillogram in vertical direction

**Figure 1.** EL-Centro oscillogram.

3. Establishing the Numerical Finite Element Analysis Model
The model size is 60m×12m×25m, and the supporting structure model is represented in Figure 2.
4. Influence of Intensity on Earthquake Response

The slope responses of seismic fortification intensity of 7 degrees 8 degrees and 9 degrees are calculated based on engineering examples. According to "Code for Seismic Design of Buildings" (GB 50011-2010), the maximum seismic accelerations used in the time history analysis of these three working conditions are 0.15g(55cm/s²), 0.30g(110cm/s²) and 0.40g(140cm/s²) respectively. The calculation results present that the influence of the intensity on the slope displacement peak, acceleration peak, axial force peak of each row of anchor rods, and peak earth pressure are relatively obvious. Figures 3~6 reflect the peak displacement, peak acceleration, peak axial force of each row of anchors and peak earth pressure of the supported slope system under earthquake when the intensity is 7 degrees, 8 degrees and 9 degrees respectively. It can be seen from the figures that the peak displacement, peak acceleration, peak axial force of anchors and peak earth pressure increase with the increase of the intensity. In addition, it can be found that the largest response values of the displacement, acceleration, axial force of anchors and earth pressure at the top of the slope. While, the smallest response values are at the toe of the slope. They gradually decrease from the top to the toe of the slope.

Figure 3. The displacement peak on the slope under different intensity.
5. Conclusions
Based on the project, the seismic response about the slope with pre-stressed anchored-frame structures under different seismic intensities is compared with each other and analyzed, therefore, it is easy to draw some conclusions with the analyses above. The peak displacement, peak acceleration, peak axial force of anchors and peak earth pressure increase with the increase of the intensity. In addition, the largest response values of the displacement, acceleration, axial force of anchors and earth pressure at the top of the slope, the smallest response values are at the toe of the slope. They gradually decrease from the top to the toe of the slope. The above shows that the seismic intensity plays an important role in the responses of the slope. It also provides reference for research about the dynamic response of slope in the northwest.

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