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METHODS FOR CALCULATING SEISMIC EFFECTS IN SLOPE STABILITY ASSESSMENT

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Abstract: This article provides general information on the methods for calculating the seismic impact in assessing the stability of slopes and covers the main methods used in this area. Methods for calculating the seismic impact in assessing the stability of slopes are of great importance in modern construction and geotechnical engineering. These methods are used to determine the movement of the soil during an earthquake and its effect on structures, as well as to ensure the safety and strength of structures. The development and improvement of methods for calculating the seismic impact will increase the safety of construction projects and create the possibility of implementing them in complex natural conditions. This article discusses the methods for calculating the seismic impact used in assessing the stability of slopes and their practical significance. The results of the study are presented based on the H/V method, i.e. the Response spectrum.

Introduction

Calculation of seismic impact and determination of slope stability, in turn, are of great scientific and practical importance. Slope stability allows us to assess how the layers of the earth's surface react to stress and shaking and how stable they are. This is necessary not only to ensure the safety of construction sites, but also to maintain their strength in the long term. When assessing slope stability, seismic impact calculation methods are used to determine the dynamic properties of the soil, earthquake forces and their impact on structures.

The stability of the soil is understood as the ability of the soil to resist movement. This property, in turn, depends on the physical and mechanical properties of the soil, such as density, moisture, composition and other parameters. Seismic impact refers to the static and dynamic forces acting on the soil and structures during an earthquake. Using methods for calculating the seismic impact, the movement of the soil during an earthquake and its effect on structures are determined.

At this point, the methods and technologies used to calculate slope stability and seismic effects are very wide and diverse. They are important not only for industry professionals, but also for improving the construction process and increasing safety.

Materials and methods

There are several methods for calculating seismic impact. The most commonly used methods are:

Static analysis method: This method is one of the simplest and most widely used methods for calculating seismic action in assessing the stability of slopes. In this method, the seismic action is considered as a static load and the stability of the soil is assessed under static conditions. In order to provide a complete overview of the characteristics, applications, advantages and limitations of the static analysis method, a detailed analysis of this method is presented.

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In the static analysis method, seismic action is modeled as static loads. In this method, the dynamic forces acting on the ground and structures during an earthquake are replaced by static equivalent loads. Static loads are used to assess the stability of the ground and are based on the properties of the ground, the earthquake parameters, and the geometric characteristics of the structure.

Seismic impact is considered as a static load. The stability of the soil is assessed under static conditions. Static loads are based on soil properties and earthquake parameters.

The static analysis method is carried out in several stages**:** Data collection: The study is based on the physical and mechanical properties of the soil (e.g., density, bond strength, angular internal friction) and earthquake parameters (magnitude, distance from epicenter, earthquake strength).

Static Load Determination: Seismic effects are modeled as static loads. These loads are based on the soil properties and earthquake parameters. Static loads are used to assess the stability of the soil. In this step, the soil resistance and the effect of the loads are compared. After the soil stability is assessed, the results are analyzed and conclusions are drawn about the safety and strength of the structure.

This method is much simpler and faster to implement than dynamic analysis methods. The static analysis method requires less resources and computing power. This method is widely used in various construction projects and is recommended in many standards and manuals.

In this method, the seismic effect is considered as a static load, so not all aspects of the dynamic effect are fully reflected.

Static analysis is a simple and effective method for calculating the seismic impact in assessing the stability of slopes. The importance of this method in the field of construction and geotechnical engineering is demonstrated by providing a complete description of its advantages, limitations, and practical applications. By improving the static analysis method and integrating it with dynamic analysis methods, it is possible to more accurately assess the stability of the soil and ensure the safety of structures.

Dynamic analysis method: In this method, the seismic effect is considered as a dynamic load and the stability of the soil is evaluated under dynamic conditions. This method allows for a more accurate representation of the ground motion during an earthquake.

Dynamic analysis is an important technical method used to assess the stability of landslides and the risk of soil and rock movement, displacement, or collapse. This method is widely used in civil engineering, geotechnical engineering, and mining. Dynamic analysis determines the dynamic properties of the soil, how the soil behaves and maintains or loses its stability under the influence of earthquake forces, water action, and other external forces.

Dynamic Properties of Soil: The dynamic properties of soil, such as the modulus of elasticity, viscosity coefficient, and density, play a key role in dynamic analysis. These parameters determine how the soil behaves under the influence of an earthquake or other dynamic forces. Dynamic analysis studies the effect of earthquake waves on the soil and how the soil responds to these forces. Earthquake forces can disrupt the stability of the ground and cause landslides. The saturation of the soil with water has a significant effect on its stability. Water can reduce the viscosity of the soil and cause subsidence. Dynamic analysis also takes into account water pressure and the permeability of the soil.

Construction work, mining, or other structures can cause additional loads on the ground. These loads can disrupt the stability of the ground and cause landslides.

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When applying the dynamic analysis method, data collection is carried out: physical and mechanical properties of the soil, earthquake history, water effects, and other important information are collected. Based on the collected data, a mathematical model of the soil is created. Through this model, the dynamic movements and stability of the soil are simulated.

The model assesses how the soil will behave and maintain or lose its stability under different conditions. It determines the level of risk of the soil under the influence of earthquakes, water impact, and other external forces.

Based on the results of the analysis, necessary measures are recommended to ensure soil stability. These measures may include soil reinforcement, creation of drainage systems, or changes to the building design.

The dynamic analysis method allows for a more accurate assessment of ground motion. The effects of various external forces (earthquake, water, loads) can be taken into account simultaneously. Based on the analysis results, risks can be identified in advance and measures can be taken to reduce them.

Numerical modeling methods: Modern computer technologies allow the creation of numerical models to assess the stability of soil to seismic action. These methods determine the movement of soil and its impact on structures under various scenarios. The dynamic properties of soil are important in calculating seismic action. The dynamic modulus of soil, viscosity coefficient, and other parameters determine how soil behaves under seismic action. These parameters are measured in laboratory conditions and used in calculations.

Response Spectrum Method: This method is a diagram showing the response at each frequency versus the maximum displacement, velocity, or acceleration. The maximum response at each frequency is found using the spectrum to determine how the system will respond to seismic action.

Response Spectrum - shows the natural frequencies of a system, how it vibrates (or other mechanical responses) when subjected to seismic forces. Spectra are usually plotted against the maximum displacement and maximum velocity or maximum acceleration of the system.

In seismic impact calculations, seismic forces are presented as time - varying forces, but the Response Spectrum Method calculates seismic forces simultaneously at all frequencies. For each natural frequency of the system, the maximum values of the displacement, velocity, or acceleration are taken from the spectrum and calculated for the system.

Dynamic analysis of a system determines its natural frequencies and modes. Once the frequency and mode of vibration of the system are determined, the response to seismic action can be calculated using the spectrum. The spectra are plotted against the highest displacement, velocity, or acceleration for each frequency.

To calculate the effects of seismic forces, the spectral forces that occur during a seismic event (e.g., earthquakes) are determined. These forces indicate how the system is affected at each frequency. Using the information in the spectrum, the maximum displacements or forces for each natural frequency of the system are calculated. By summing the responses from each model, the overall response of the system to seismic forces is calculated. The results obtained are used to calculate the forces and deformations of the system.

This method reduces the complexity of performing a full dynamic analysis of the system. Instead of analyzing over time in the response spectrum method, it is possible to obtain fast and efficient results by reading the spectrum. In this method, there is no need for time- based analysis, so the calculations are simplified and accelerated. This method is especially widely used in seismic analysis. It is very useful in assessing the seismic safety of buildings, bridges, reservoirs,

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slope stability and other structures. Due to its wide application, this method allows you to work according to many standards and regulations. The ability to calculate the system response for each natural frequency and model, as well as the system's response, helps to better understand the dynamics of the system.

Research results

The H/V method is used to determine the seismic properties of the ground, and the seismic response spectrum is mainly based on this method. This method helps to assess the resonance properties of the soil, that is, the frequency and amplitude relationships. At the same time, this method determines the seismic wave energy absorption properties of the soil. Seismometric studies are based on synchronous recording of natural noises. Their amplitude-frequency characteristics are analyzed and compared. Seismometric studies were carried out using a CMG-6TD seismometer (Guralp, UK). Seismic analysis was carried out using the HVSR (H/V spectral ratio) method. The Geopsy program was used for analysis. Using the soil response spectrum, the damping law was determined depending on which frequency and amplitude the soil corresponds to.

The damping law of the ground is determined using the following formula:

$$A=A_0 e^{-\xi t}$$

Here, A – vibration amplitude, A_0 – maximum vibration amplitude, ξ – damping coefficient, T – oscillation period, t – time, e – natural logarithm base (e=2.718).

In the law of decay, the oscillation frequency is expressed by the oscillation period to determine the duration of the oscillation. In this case, a decay graph is constructed from oscillation intervals with large amplitudes to small amplitude values over time.

The oscillation of a soil particle is equal to the sum of the periods of each oscillation according to the law of increasing time.

$$t_n = t_{n-1} + T_n$$

Here, t_n - the sum of the oscillation periods, T_n - is the oscillation period, and n - the number of corresponding values of frequency and amplitude.

Seismometric studies were used to determine the response spectrum of the soil to study the effect of railway transport on the seismic properties of the soil. First, seismometric studies conducted on the soil were interpreted with values measured in the absence of the influence of railway transport (Figure 1).

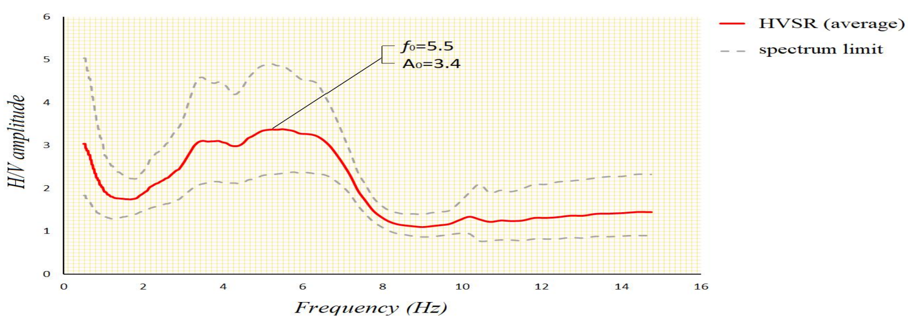

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Figure 1. Amplitude and frequency coupling spectrum in seismometric data measured in a quiet state

In the amplitude and frequency characteristics of the soil (Fig. 1), the value of frequency indicates that the resonance effects or vibrations in the soil are at their maximum. In the second case, the data obtained under the influence of railway transport showed a decrease in frequency and an increase in amplitude (Fig. 2).

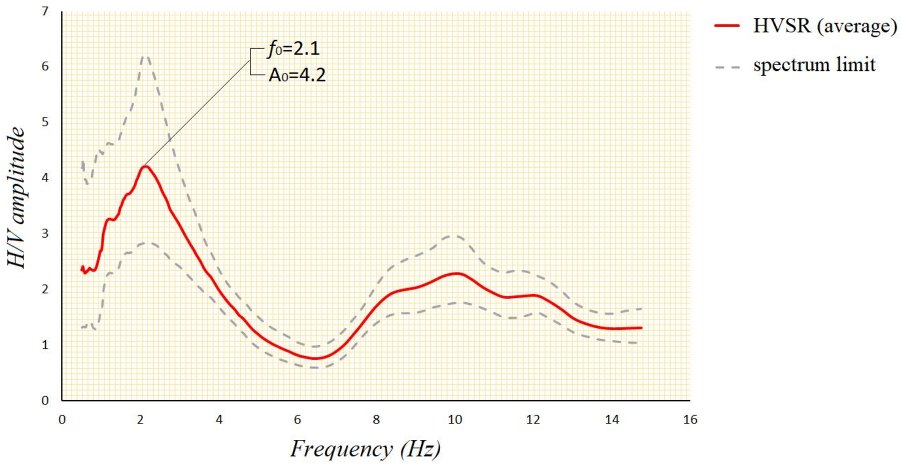

Figure 2. Amplitude and frequency coupling spectrum in seismometric data measured under the influence of railway transport

The vibration properties of the soil under the influence of railway transport are expressed in its increased vulnerability to seismic action. It turns out that the ability of the soil to absorb seismic wave energy is greater than in its quiet state. This means that the dislocation properties of the soil increase during an earthquake. An increase in the dislocation properties of the soil indicates the emergence of new discontinuities, an increase in forces in the seismic or dynamic direction.

The damping property in the response spectrum of the soil: The damping law of the soil is determined from the amplitude and frequency relationship of the soil particles. The damping coefficient determined for two cases in the soil showed that the ability of the soil to absorb seismic energy increased (Fig. 3)

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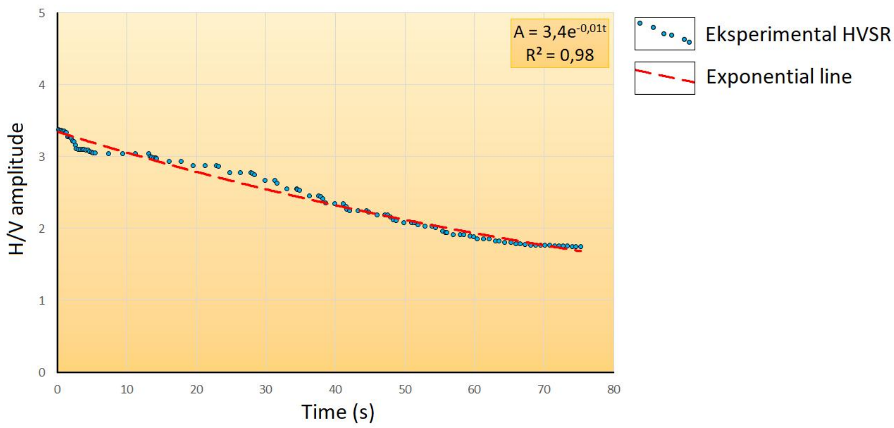

Figure 3. Soil damping pattern in seismometric data measured in a quiescent state

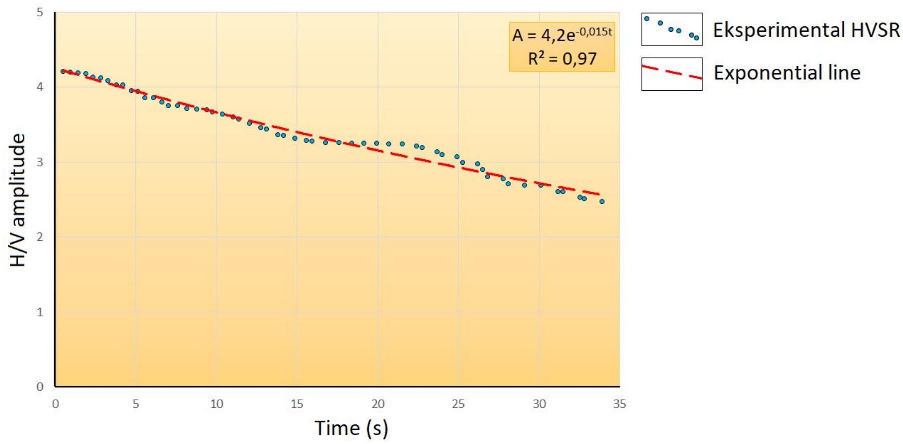

Figure 4. Soil damping patterns in seismometric data measured under the influence of railway transport

Analysis of the soil response spectrum showed that the absorption of seismic energy in a quiescent state was ξ = 1%, and under the influence of railway transport ξ = 1.5%. It can be observed that the overloading of railway transport increases the seismic impact of the soil by Δξ = 0.5% during an earthquake.

Railway transport imposes excessive loads on the landslide area. In modern geotechnical and construction engineering, various software products are used to calculate seismic effects. Among them are PLAXIS, GeoStudio, MIDAS and other programs. With the help of these programs, it is possible to assess the stability of the soil to seismic effects and check the strength of structures.

Methods for calculating seismic impact in assessing the stability of landslides are developing. With the help of modern technologies, artificial intelligence and big data analysis, it is possible to more accurately assess seismic impact and determine the stability of the soil with high accuracy. This creates new opportunities in the field of construction and geotechnical engineering.

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Conclusions

Changes in the vibration properties of the soil under the influence of railway transport can lead to an increase in seismic energy. This is expressed in a decrease in frequency (from 5.5 Gs to 2.1 Gs) and an increase in amplitude (from 3.4 to 4.2). According to the results observed through the seismic response spectrum of the soil, its reaction to seismic energy depends on the physical properties of the soil, and additional loads under the influence of railway transport play an important role in calculating the energy of the soil. The magnitude, epicenter and depth of the earthquake play an important role in calculating the seismic impact. Earthquake forces lead to soil movement and the emergence of dynamic loads affecting structures. Therefore, when calculating the seismic impact, it is necessary to correctly assess the characteristics of the earthquake. With the help of these methods, the strength and stability of structures during an earthquake are assessed, as well as the stability of the soil to seismic action is determined.

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