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Theoretical bases of vibration diagnostics of anchor against landslide constructions

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Abstract

The given work is devoted to development of theoretical bases of a new vibrating diagnostics method and evaluation a current condition of the anchor. The research of the pulse response of the anchor against landslide construction is a basis of vibrating diagnostics of a tension condition an anchor, detection of feature of abatement of a tightness, and definition of character of its dependence on a changing stretching force. The elastic body with the distributed parameters (a string) is used as the diagnostic model of the tense and fixed core of an anchor. Dependences of own frequencies changing of the pulse response of an anchor on a tightness changing at deformations and displacement of a place of fastening of an anchor are defined. The discrete model of an anchor against landslide construction is developed and researched for definition of dependences between parameters of an anchor condition and vibrating characteristics of a retaining wall, which is accessible to carrying out of measurements.

Keywords: sliding processes, anchor against landslide constructions, tension of anchors, vibrating diagnostics.

1. Introduction

The anchor against landslide constructions are used for the protection of territories and the located on them buildings from distribution and catastrophic consequences of the sliding processes. They are installed in potentially dangerous places with retaining walls. Practically, their original tension is a major factor, determining density of roof-bolt setting. The anchor tension is necessary constant over a long period of anchor construction operation. However, the tension of anchors can change in due course under influence of sliding processes. In some cases it can lead to that the anchor will be pulled out from a bedrock surface and will not carry out maintaining function without any visible external attributes of change of its technical functional condition. Therefore, it is necessary to spend periodically the control of a tension of anchors, that is the important information for an evaluation of a current condition of sliding processes and forecasting of their further development.

The anchor against landslide construction is offered by complex system enclosed a retaining wall (1), a tightener (2), a rod (3) and a locking device (4) as shown on Figure 1. A locking device serves for anchor fixation into rock, a tightener is used for stress making in an anchor rod for a decrease or elimination of a deformation and displacement of linked rocks. Practically, the steel wire rope or iron reinforcement constructions are used as a rod. Carried out theoretical researches of anchor constructions in the core touch problems of their strength and reliability for different operation phases [1]. These results allow to make demands to geometrical sizes and performances of used materials of elements of an anchor constructions, but are not sufficient for monitoring possible strains and offsets of rocks in a place of anchor fixation under natural excitation of land (for example, landslide).

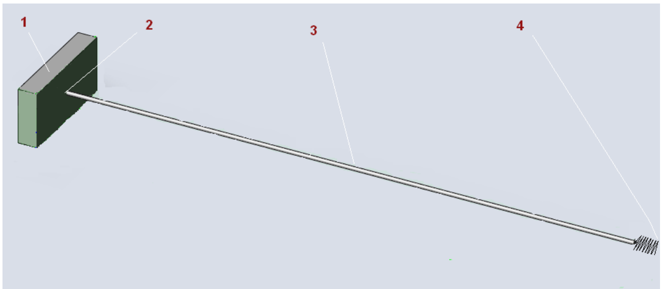

Figure 1. Configuration of an anchor against landslide construction: 1 - a retaining wall; 2 – a tightener; 3 - a rod and 4 - a locking device

The given work is devoted to development of theoretical bases of a new vibrating diagnostics method and evaluation a current condition of the anchor. The research of the pulse response of the anchor against landslide construction is a basis of vibration diagnostics of a tension condition an anchor [2], detection of feature of abatement of a tightness, and definition of character of its dependence on a changing stretching force.

2. Frequencies analysis

We use the elastic body with the distributed parameters (a string) for mathematical description of the tense and fixed rod of an anchor [3]. As a first approximation we'll not take into account a limitation of a string flexing by walls of an open test pit. String flexing (a deviation of a string in a cross plain) characterizes cross vibrations of a model. As is known, cross vibrations of a string under a influence of axial stretching force P are presented by expression

$$y = \sin\frac{n\pi}{l}x(A_n\cos\frac{an\pi}{l}t + B_n\sin\frac{an\pi}{l}t), \qquad (1)$$

where $a = \sqrt{Pgl/Q}$; g is gravitational acceleration; Q is string weight; l is string length; A_n, B_n are coefficients, which rate the amplitudes of a string oscillations on the main (n=1) and higher (n=2;3;...) oscillations shapes; x, y are axial and cross displacements.

The frequencies f_{no} of oscillations (1) are defined as:

$$f_{no} = \frac{an}{2l} = \frac{n}{2}\sqrt{\frac{Pg}{lQ}}. \qquad (2)$$

Let an axial stretching force P is changed at a strain and offset of a place of anchor fixation:

$$P_1 = P \pm \Delta P ,$$

where ΔP is changing value of stretching force; the sign "+" corresponds to increasing of stress in an anchor rod under landslide activity and the sign "-" corresponds to a case, when rod is pulled from rocks.

Let's consider coefficient of the relative tension changing $z = \Delta P / P$, therefore force $P_1 = P(1 \pm z)$. The frequencies f_{n1} in this case are:

$$f_{n1} = \frac{n}{2}\sqrt{\frac{P_1 g}{lQ}} = f_{no}\sqrt{1 \pm z} . \tag{3}$$

The factor R of nature frequencies changing at the tension changing can be defined from (3) as:

$$R = \frac{f_{n1}}{f_{no}} = \sqrt{1 \pm z} . \tag{4}$$

Table 1 presents dependencies of frequencies changing factor on coefficient of the relative tension changing at the increasing and decreasing of axial stretching force.

Table 1. Dependencies of factor *R* on coefficient *z* of the relative tension changing.

z	0,01	0,05	0,1	0,15	0,2	0,3
$R_{(+)}$	1,005	1,025	1,049	1,072	1,095	1,140
$R_{(-)}$	0,995	0,975	0,949	0,922	0,894	0,837

Apparently from the received results, small changing of force P ($z \le 0{,}1$) brings to changing of frequencies under all shapes of oscillations no more than 5 % both at increasing and at a decreasing of a tightness. The changing of axial stretching force in the range of $0 < z \le 0{,}3$ brings to changing of frequencies under all shapes of oscillations about 14-16%. Thus, changing of anchor rod frequencies can be used as diagnostic feature of tension of anchors.

3. Researches of anchor discrete model

As it was noted above, rod of an anchor is unapproachable to monitoring its tightness or own frequencies. Anchor against landslide constructions are mounted in such a way that retaining wall only is accessible to carrying out of measurements (see Fig. 2).

Therefore, it is necessary to determine influence of tension changing on performances of stress, displacements and strains of a retaining wall.

We use Finite Element (FE) Analysis for the design discrete model of an anchor against landslide construction which can be representative of an actual object. For this aim we consider anchor rod made from carbon steel rope with the following properties: Density 7850 kg/m^3; Modulus of Elasticity $2{,}05 \cdot 10^{11}$ N/m^2; Poison's ratio 0,29; Shear Modulus $8 \cdot 10^{10}$ N/m^2. Retaining wall is represented by concrete slab with the following properties: Density 2000 kg/m^3; Modulus of Elasticity $2{,}75 \cdot 10^{10}$ N/m^2; Poison's ratio 0,2. The developed discrete model consists of 8444 FE and 14572 nodes.

Figure 2. Photograph of anchor against landslide construction, installed in Crimea

The second goal was to understand the behavior of the vibrating characteristics of a retaining wall as a function of parameters of an anchor condition. For this study, rod rigidity value is changed (rigidity is decreased), relative rigidity changing ΔC is assigned of 0,15, that corresponds to R=0,97; 0,25 (R =0,87) and 0,5 (R=0,7). Figure 3 shows the example of modeling and estimation of wall displacement at the initial value of rigidity (ΔC =0).

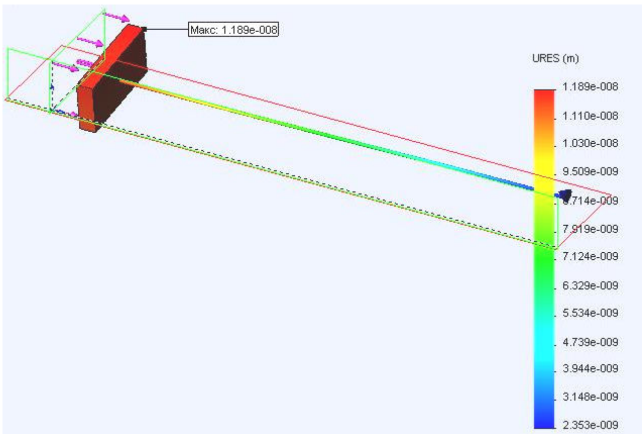

Figure 3. Example of modeling and estimation of wall displacement

As it is possible to see from the presented figure, the maximum displacement occurs on the slab and anchor rod has minimum displacement in the area of anchor fixation. Values of maximum and minimum displacement are change at a rod rigidity changing the means specified above. These values increase at the decreasing of rod rigidity.

Changing of minimum displacement can be interpreted as displacement of rocks and development of activity of landslide at the modeling and study diagnostic model of anchor against landslide construction. Relative rigidity changing of a rod and corresponding changing of frequencies are considered as parameters, which characterized functional condition of an anchor and its possibility to carry out maintaining function. Changing of maximum displacement is used in this study as a feature of changing of the anchor tightness or own frequencies. The relation between maximum and minimum values of displacement also depends on change of rod rigidity. The maximum value is different from minimum five times at the $\Delta C = 0$, and these values do not different among themselves at the $\Delta C = 0{,}5$, practically. In the latter case it means that the anchor against landslide construction practically does not carry out maintaining function.

Table 2 presents dependencies of relative values of maximum and minimum displacement (ΔD_{max} and ΔD_{min} , accordingly) on relative rigidity changing ΔC . The relative values are estimated by using the following expressions:

$$\Delta D_{max} = \frac{D_{max}(\Delta C)}{D_{max}(0)} \quad \text{and} \quad \Delta D_{min} = \frac{D_{min}(\Delta C)}{D_{min}(0)}, \tag{5}$$

where $D_{max}(\Delta C)$ and $D_{min}(\Delta C)$ are displacements at the rod rigidity changing ($\Delta C \neq 0$); $D_{max}(0)$ and $D_{min}(0)$ are displacements at the initial value of rod rigidity ($\Delta C = 0$).

Table 2. Dependencies of ΔD_{max} and ΔD_{min} on relative rigidity changing of a rod

ΔC	0	0,15	0,25	0, 5
ΔD_{max}	1	1,04	2,61	28,82
ΔD_{min}	1	1,79	9,15	143,41

The presented results show that evaluated values of minimum displacements increase too much at the decreasing of a rod rigidity. But we have not any possibility to measure these displacements. Value of maximum displacement increases slightly at the $\Delta C \leq 0{,}15$ (it corresponds to $R \leq 0{,}97$ and $z \leq 0{,}05$). Further decreasing of a rod rigidity causes a large increasing of values of maximum displacements. Since the mentioned displacements occurs on the slab, we can to measure these characteristics by using mounted on the retaining wall sensor.

4. Conclusions

The theoretical basis of development vibration diagnosis method is presented for monitoring and evaluation a current condition of the anchor against landslide constructions.

The elastic body with the distributed parameters (a string) is used as the diagnostic model of the tense and fixed core of an anchor, that allows to define and analyse dependencies of frequencies changing factor on coefficient of the relative tension changing at the increasing and decreasing of axial stretching force.

The discrete model of an anchor against landslide construction is developed and researched, that allows to understand the behavior of the vibrating characteristics of a retaining wall as a function of parameters of an anchor condition. The received results of anchor modeling and analysis show that decreasing of a rod rigidity causes increasing of displacements occurs on the slab and in the area of anchor fixation. Dependencies of relative values of displacements are researched on relative rigidity changing.

The received results are new and will be used for the further investigations and development of a new vibration method for monitoring and evaluation a current condition of the anchor against landslide constructions.

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