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EARTHQUAKE – RESISTANT SLOPE OF BULK STRUCTURES

ЕҢІСТІ ҮЙМЕРЕТТЕР ҮЙІНДІЛЕРІНІҢ СЕЙСМИКАЛЫҚ ТӨЗІМДІЛІКТЕРІ

СЕЙСМОУСТОЙЧИВЫЙ ОТКОС НАСЫПНЫХ СООРУЖЕНИЙ

Abstract. *The article results of various studies, currently the authors are engaged in research on the method of slope positioning, this method differs from others, since this method does not require expensive equipment and technologies for production, it is an economically very profitable method. The development of the slope position method is associated with the stability of the slope, where bulk structures are widely used in construction of various significance.*

This method has always been built under justification, and with various calculated steepness, has real resistances to various seismic impacts. The slope position method always has its own experience in dealing with antiseismic measures that are built with inexpensive technologies and equipment. Many experts thought that in this method it would be considered a very voluminous work, to the expected concussions, but this method was very relevant at this time and stable. Which were erected by this method (dams, dams, embankments, bridges, supports, etc.) were distinguished by seismic resistance, since the soils inside had different purposes and they should be resistant to various shocks.

The external factor is: the load on the slope surface and the dynamic impact (amplitude, frequency, period, duration of shaking, etc.). The stability of the slope steepness is also affected by: the height of the slope, the method of its construction, as well as the liquefaction of the soil that occurs under the influence of strong shocks. Taking into account all these factors allowed the authors to propose a computational method for assessing the seismic resistance of the slope slope structures. Comparison of the calculation data with the results of experimental studies showed good convergence.

Keywords: *slope, soil, antiseismic action, strength, load, diaphagram.*

Аңдатпа. *Мақалада әртүрлі зерттеулердің нәтижелері келтірілген, олар бұл әдіс басқалармен салыстырғанда қарапайымдылығымен, күрделі жабдықтар мен технологияларды қажет етпейтін экономикалық пайдасымен және т.б. бұл әдісті көлбеу тұрақтылығына әсер ететін факторларды есепке алу негізінде дамыту әр түрлі мақсаттағы үйінді құрылыстарын салуда кеңінен қолданылатындығын ескере отырып, көлбеу орналасу әдісін жетілдіру бойынша зерттеу жүргізуге болады.*

Сондықтан, негізделген және есептелген көлбеу, әсіресе сейсмикалық әсерлерге жақсы қарсылық көрсетеді деп есептейміз. Жоғарыда айтылғандай, бұл әдісті қолдану артық механизмдерден аулақ болуға мүмкіндік береді және құрылыстың жаңа технологияларын қажет етпейді және т.б. жеке мамандардың көлбеу орналасқан кезде объект көлемін ұлғайту туралы *пікіріне қайшы, бізге объектінің күтілетін әсерлерге қатысты тұрақтылығына қол жеткізу тек өтемақы ғана емес, сонымен қатар оның ұзақ мерзімді және мінсіз қызметімен ақталады. Ұсынылған әдіспен салынған құрылыстар (жол жағалаулары, бөгеттер, көпірлердің шеткі тіректері және т.б.) жер сілкінісіне төзімділігімен ерекшеленеді, өйткені олардағы грунт күтілетін сілкіністерге төзімді болады. Сыртқы фактор: көлбеу бетіндегі жүктеме және динамикалық әсер (амплитудасы, жиілігі, кезеңі, сілкініс ұзақтығы және т.б.). Көлбеудің тік тұрақтылығына да әсер етеді.*

***Түйін сөздер:**еңіс, грунт, антисейсмикалық іс-шаралар, беріктік, күшсалмақ, диафрагмма.*

***Аннотация.** В статье представлены результаты разных исследований, в данное время авторы занимаются исследованиями о методике оположение откоса, этот метод отличается от другими, так кака этот метод не требует дорогаценные оборудование и технологий для производства, экономически очень выгодный метод. Развитие метода оположение откоса, связано с устойчивости откоса, где широко пользуется насыпными сооружениями в строительстве различной значимости.*

Этот метод всегда возводился под обоснованием, и различными расчетными крутизнами, обладает реальными сопротивлениями к различными сейсмическими воздействиями. Метод оположение откоса всегда имеет свой опыт работам к антисейсмическим мероприятиями которые возводится недорогостоящими технологиями и оборудованиями. Многие специалисты думали что в этом методе считать будет весьма объемной работой, к ожидаемыми сотрясениями, но этот метод был очень актульным в данное время и устойчивым. Которые возводившие этим методом (плотины, дамбы, насыпи, мосты, опоры и т.д.) отличались сейсмостойкостью, так как внутри грунти имели различного назначения и они должны быть устойчивыми к различными сотрясениями.

Внешним фактором является: нагрузка на поверхности откоса и динамическое воздействие (амплитуда, частота, период, продолжительность сотрясения и т.п.). На устойчивость крутизны откоса также влияют: высота откоса, способ его возведения, а также разжижение грунта, возникающего в условиях воздействия сильных сотрясений. Учет всех этих факторов позволил авторам предложить расчетный метод оценки сейсмостойкости крутизны откосных сооружений. Сравнение данных расчета с результатами экспериментальных исследований показало хорошую сходимость.

***Ключевые слова**: откос, грунт, антисейсмические мероприятие, прочность, нагрузка, диафрагрaмма*

Introduction. In the plans of the state development of the Republic of Kazakhstan for the near future, special attention is paid to capital construction. It is planned to build main automobile and railway lines of national and international importance, as well as the development of 8 large, medium-sized and, especially, small hydroelectric power stations, etc. [1].

Thus, according to the program for the development of the transport infrastructure of the Republic of Kazakhstan until 2020, repair and reconstruction of highways with a length of 30 thousand kilometers are planned in the country. Km and railway lines – 8.2 thousand Km. The implementation of this program will not only significantly improve the condition of roads and railway lines, but also increase their seismic resistance [2]. Ground structures often turn out to be poorly resistant to earthquakes, and for this reason they require the use of various antiseismic measures.

Antiseismic measures should include: compaction of soil, replacement of weak soils with stronger ones, loading of the slope surface, slope alignment, changing the shape of the slope, drainage device, use of various fences in the slope (diaphragms, screens), etc. Analysis of these measures shows that each of them has certain disadvantages associated with limited use, not the perfection of technology, the high cost, and most importantly, with difficulties in achieving the goal. This circumstance dictates the conduct of additional studies, taking into account all possible factors that affect the dynamic stability of slopes.

Materials and methods of research. 1 picture showed the stability of a volume with a thickness of z1, which lies on a slope with a different slope a is expressed as:

$$кз = \frac{T}{Q}, \quad (1)$$

where T is the shear strength of the selected volume;

Q is the force shifting the selected volume.

This method has always been built under justification, and with various calculated steepness, has real resistances to various seismic impacts. The slope position method always has its own experience in dealing with antiseismic measures that are built with inexpensive technologies and equipment. Many experts thought that in this method it would be considered a very voluminous work, to the expected concussions, but this method was very relevant at this time and stable. Which were erected by this method (dams, dams, embankments, bridges, supports, etc.) were distinguished by seismic resistance, since the soils inside had different purposes and they should be resistant to various shocks.

(*ac*) in the form [3]:

$$\tau_с = 0{,}64\, \gamma_w H k_s, \quad (2)$$

where ks is the seismicity coefficient.

Soil shear resistance under the action of seismic acceleration ac is expressed as [4]:

$$S_{\sigma,w} = \sigma_{дин} tg\varphi_{w+} c_v, \quad (3)$$

where σdine are the dynamic stresses from the external load on the slope (p) and the ground's own weight (*ywH*).

In cases of concussion under conditions exceeding the threshold value, i.e.
as>*an* (where *as*, *an* - respectively seismic and threshold accelerations):

$$S_{\sigma,w}\ (t)= (\sigma_{dine} - \gamma_{в}.h_{z,t})\ tg\varphi_{w+} c_{v,t} \quad (4)$$

In the absence of an external load on the ground surface, i.e. (*p*=0):

$$S_{\sigma,w}(t) = (\gamma_w.H - \gamma_{в}.h_{z,t}) tg\varphi_{w+} c_{v,t} \quad (5)$$

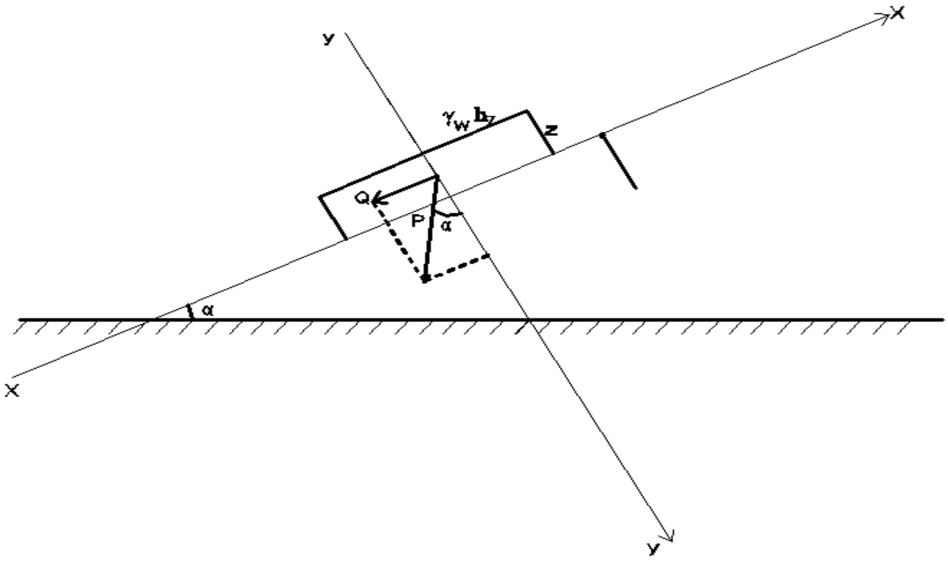

Figure 1. Calculation scheme of slope stability

Consequently, the coefficient of seismic stability reserve of slope structures in accordance with expression (1) is represented as [5]:

$$k_m = \frac{0{,}64\,\gamma_w H k_s}{\sigma_{din} tg\varphi_{w+}c_v} \quad (6)$$

If we denote the weight of the selected element by P, then the force Q shifting the element in accordance with Fig.1 will be written as:

$$Q \;\; = P.sin\ a \quad (7)$$

force T, ensuring the stability of the slope:

$$T = P.cosa \quad (8)$$

Under conditions of marginal equilibrium *as = an*, the ground shear resistance in its simplest form, i.e. in the absence of adhesion (*cv*= 0) according to (3), is represented as:

$$S_{\sigma,w} = T.tg\varphi_w, \quad (9)$$

where $T = \sigma_{dine}$.

If we take into account that

$$P.sina = P.cosa.\ tg\varphi_w \quad (10)$$

we have:

$$tga = tg\varphi_w \quad (11)$$

or

$$a = \varphi_w \quad (12)$$

Expressions (11) and (12) indicate the slope of the slope and the resistance of the soil under various conditions. This means that the slope stability coefficient:

$$k_m = \frac{tg\varphi}{tg\alpha}, \quad (13)$$

где α – the slope angle.

Based on the equalities (6) and (13), the earthquake-resistant steepness a of a slope structure can be defined as:

$$tga = \frac{(\sigma_{din} tg\varphi_{w+}c_v) tg\varphi_w}{0{,}64\,\gamma_w H k_s}. \quad (14)$$

(14) the formula determines the seismic slope steepness, in various seismic vibrations. Any steepness can withstand various seismic vibration vibrations, which may contain slope stability. In accordance with formula (14), the earthquake-resistant slope steepness, in general, depends on the intensity of the impacting earthquake (*ks*) and the strength characteristics of the soil (φ_w, c_v).. The second part of the dependence indicates the possibility of ensuring the stability of the structure at a given steepness by increasing the strength indicators of the soil.

In addition to the above, the role of the normal stress (σ_{din}), consisting of the external load (p) and the ground's own weight (*yw.H*), is also important. By adjusting the values of σ_{din}, it will also be possible to ensure a stable slope steepness.

In cases when there is no load on the slope surface, i.e. when p =0, formula (14) takes the form:

$$tga = \frac{tg\varphi_w}{0{,}64\,k_s}\left(tg\varphi_w + \frac{c_v}{\gamma_w H}\right) \quad (15)$$

It is known that under conditions of seismic impact at *as >an*, the parameters of soil strength change (decrease) due to a decrease in the connectivity of *cw,t* and as the weighing effect of dynamic pressure *h(z,t)* increases [6].

Dynamic pressure under certain conditions can have a catastrophic effect on the stability of the slope. Thus, under the condition *hz,t = σdin*, the value of *c(v,t*) will also be closer to zero. Such an extreme condition indicates that any slope steepness in the conditions under consideration will not be able to ensure the stability of the structure and as a result of soil liquefaction, landslides are formed, under certain conditions in huge sizes, with all the consequences that follow from this.

It should be noted that formula (14) forms the basis of the proposed method for assessing the seismic resistance of the slope slope structures. With its help, it is possible to predict the seismic resistance of any slope under the influence of earthquakes. This method is very simple and convenient in practical use.

The following are experimental studies of the factors determining the earthquake-resistant steepness of slope structures[7].

Results and their discussions. In accordance with expression (14), the earthquake-resistant slope of the slope depends on internal and external factors, such as: the strength parameters of the soil (φ_w, c_v); the vertical component of the stress from the ground's own weight and external load (*σdin*); density-soil moisture (n-w); dynamic pressure (*hz*); acceleration of oscillatory motion and its components (α_c,*A, f,T*). In addition, in cases where seismic acceleration (*ac*) prevails over the threshold value inherent in the soil (*an*), i.e. In the presence of the condition *as*>*an*, the change in soil adhesion (*cv,t*) and dynamic pressure (*hz, t*) during the shaking also affects the slope of the slope.

To confirm the dependence (14), experimental studies were conducted to study the above-mentioned factors, the results of which are given below.

The density of the soil. Experiments carried out on loess and sand slopes under various dynamic influences on them showed a direct dependence of the slope slope on the state of the soil density (Fig. 2). The expression of the soil density in its relative value allows us to extend the data to other similar soils, as shown in Figure tga=f (D), which indicates a stable the slope of the slope, consisting of soils of different densities [8].

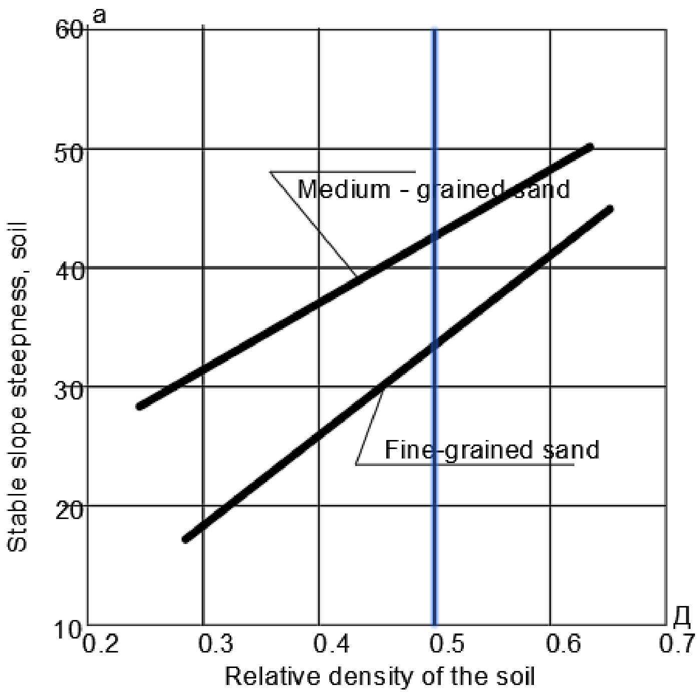

Figure 2. Dependence of the stable slope steepness on the porosity of loess soil

Soil adhesion. A violation of the slope stability under dynamic influences occurs only after a violation of the general adhesion of the soil, and, in cases when the soil is in a moistened state, plastic connectivity. In this case, the role of internal friction manifests itself only after a violation of the connectivity of the soil.

The relationship between the stable slope of the slope and the adhesion of the soil can be traced in Table.1., where are the vibrations of loess soils numbered 2, 4, 5 and 7 under shaking with an acceleration of 3000 mm/s2.

Table 1. Dependence of the stable slope slope on soil adhesion

Soil	Total coupling, Mpa						
	0,01	0,02	0,03	0,04	0,05	0,06	0,07
№ 2	0,19	0,20	0,24	0,27	0,29	0,36	0,45
№ 4	0,25	0,30	0,35	0,41	0,48	0,58	–
№ 5	0,13	0,16	0,18	0,22	0,32	0,37	0,50
№ 7	0,09	0,14	0,21	0,31	0,40	0,47	0,60

It should be noted that any increase in the amount of soil adhesion not only contributes to the stability of the slope, but also, by increasing the threshold acceleration, also increases the seismic resistance of soils in the body of the embankment (Fig. 3).

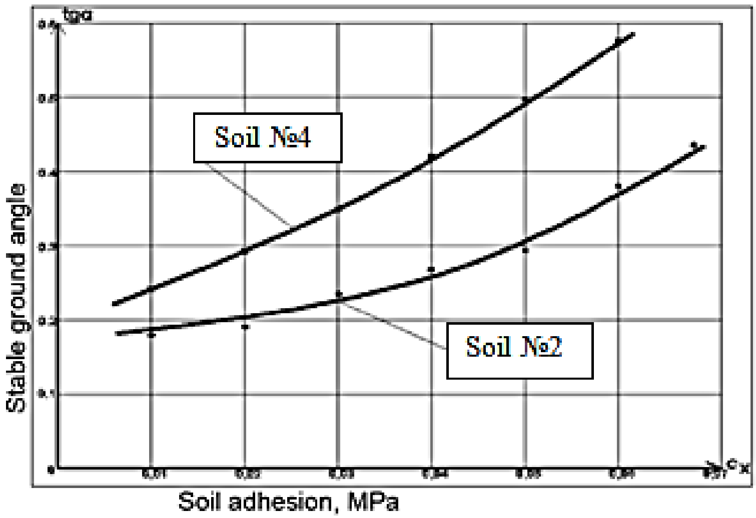

Figure 3. Dependence of the stable slope angle on soil adhesion

Dynamic impact. One of the main directions of our research was to clarify the role of dynamic impact (as) and its components in frequency (f) and amplitude (A) in the stable slope slope (tga).

The relationship between the steady slope of the slope and the intensity of the shaking can be seen from Fig.4, which illustrates the dependence of the steady slope of loess slopes on the intensity of vibrations. According to this figure, this dependence is represented as a curve *tga=f(ac)*. Hence, one can also see the role of soil density [9-12].

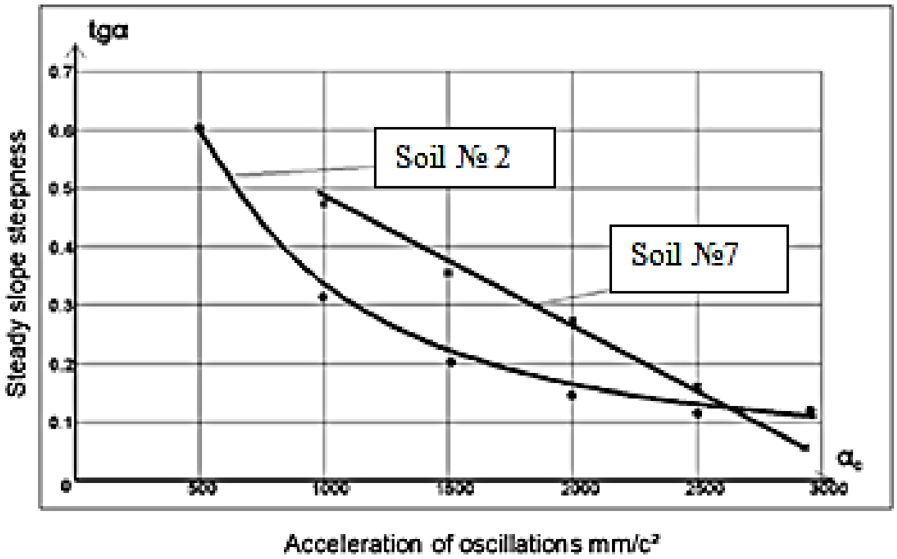

Figure 4. Dependence of the type *tga=f(ac)* for different soil

External load. We have also conducted a number of experiments to study the effect of external load on slope stability, some of the results of which are reflected in the table 3.

Table 2. Dependence of the stable slope slope on the external load (ac=2689 mm/s2)

Soil	External load, Mpa					
	5,0	10,0	15,0	20,0	25,0	30,0
№ 3	0,31	0,40	0,51	0,60	0,66	-
№ 6	0,44	0,46	0,53	0,57	0,63	0,68
№ 9	0,37	0,39	0,40	0,40	0,42	0,44

As follows from the data in the table, the external load on the slope surface in all cases has a positive effect on its stability during shaking.

Dynamic pressure. Many of the above data relate to slope fluctuations under $ac < an$ conditions and characterize stable slopes of slope structures. At the same time, we should not lose sight of the opposite case, i.e. $as>an$, when the soil composing the slope is represented by insufficient strength, moreover, it is saturated with water and is subject to strong fluctuations [13-16].

Table 3. The relationship between the steady slope of the slope and dynamic pressure

Soil	Dynamic pressure, cm				
	10	20	30	40	60
№ 3	–	–	0,58	0,36	0,25
№ 5	0,43	0,30	0,19	0,10	0,06
№ 7	0,52	0,21	0,08	–	–
№ 8	–	0,50	0,30	0,21	0,19

Conclusion. The proposed method "Earthquake-resistant steepness of slope structures" was confirmed by experimental studies conducted with various soils under various effects of seismic accelerations (ac), including:

1. Based on the consideration of the stress state of the soil layer from the condition of interaction of seismic waves and the surface of the elastic half-space, an expression is obtained for determining tangential seismic stresses in the conditions of a plane problem.
2. The earthquake-resistant slope steepness α primarily depends on the magnitude and components of the current seismic acceleration, as it increases, the slope steepness decreases;
3. The strength of soils is essential in the seismic stability of the slope steepness (φ, cv,t);
4. As a result of numerous experiments conducted on moistened loess soils, it was found that the earthquake-resistant slope steepness depends on internal, such as: strength indicators of the soil, its moisture density, dynamic pressure, and external, such as: the vertical component of stresses from the soil's own weight and external load, acceleration of oscillatory motion and its constituent factors.
5. The density of the soil and the presence of clay particles in its composition contribute to the stability of the slope steepness.
6. Any increase in soil moisture requires a slope position.

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