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A Brief Review on Strength Assessment of Earth Structures

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Abstract

The paper provides a brief review of the theories and methods for assessing the strength of earth structures and evaluation of slope stability of earth dams. For a reliable strength assessment of earth structures five criteria are proposed.

Keywords: Earth dam; Strength; Slope stability; Stress state

Introduction

It should be noted that the strength evaluation of earth structure and its elements using various theories of strength is one of the main tasks to ensure the safety and seismic stability of a structure. Basically, to assess the strength of earth structures, the Coulomb-More limit equilibrium conditions are used for elastic or elastoplastic strain in soil body [1-3].

For non-one-dimensional problems, these conditions are difficult to implement, since it is necessary to verify their realization over various slipping areas at different points of soil body [4,5]. When solving specific problems in cases of spatial stress state of soils considering their plastic strains, it is preferable to use the Mises -Schleicher-Botkin condition [6]. Recently, various authors are paying great attention to the study of the issues of strength reliability assessment of earth dams and their slopes. The theory of strength is developed in [7] for the general case of a plane strain state. In [8], existing methods for calculating soil slopes based on bearing capacity are analyzed. In [9], results of experimental studies of strain and strength of sandy soils under cyclic loading are presented.

An extensive review of the results obtained by various authors related to field observations, model studies and calculations of stress-strain state of dams is given in [10], it indicates the presence of tensile zones in dams, leading to the appearance of dangerous cracks. Along with the assessment of structure strength in general, no less important is the assessment of slope stability. As noted in [8,11-15] all existing methods in assessing the strength and stability lead to similar results. There are papers [16,17] devoted to the development of the methods of calculation and prediction of slope stability based on the analysis of soil stress state.

Methods for estimating slope stability of earth dams using the graph theory are presented in [18]. Results of analytical studies to assess the conditions that ensure long-term stability of slopes of soil structures are given in [19]. In [20], a methodology is presented to assess the stability of unsaturated soil slopes taking into account the limiting equilibrium of soil. In [21], mathematical models are proposed for the study of landslides caused by an earthquake. In [22], a method is developed to calculate soil stability, which, unlike the existing ones, takes into account the presence of the most probable surface damage. In [23], methods are developed to assess the stability of dam slopes of hydro-technical structures and ledges of pit walls.

In [24], two concepts of slope stability during the earthquakes are introduced: the stability factor and the dynamic stability overloading. Analysis of research results shows that the influence of dynamic overloading on seismic stability of slopes is rather high. In [25], it is noted that the computational analysis of slope stability is complicated by the unpredictability of inclination cracks and change in pressure. In [26-28], an assessment of strength and stability of the dam slopes with regard to plastic strains, gradual erection of structure and water seepage through the dam body is given.

The review of numerous papers shows that an assessment of slopes stability and earth structures strength in different papers is determined differently, each theory or method used has its own advantages and disadvantages [29]. It should be noted that at present a universal theory of strength assessment of soil structures that takes into account basic properties and features of various soils under intense dynamic (seismic) loads, as well as the method

for determining the strength properties of soils and structures based on the values of limiting strains under seismic effects are under development.

Therefore, at present this problem is relevant and it calls for a step-by-step solution. In [30-33] we have proposed five criteria to assess the strength of earth structures, some of them have been used in specific calculations to evaluate the strength of various earth dams.

The essence of these criteria is to assess the stress state of each point of the earth dams. They are:

I. At each point of the structure the values of horizontal and vertical stresses are checked, if at this point the horizontal stress is greater than the vertical one, it is assumed that at this point a shift of one part of the structure's soil relative to another may occur.

II. At each point of the dam, the signs of the components of normal (σ_1 , σ_2 , σ_3) and principal stresses (s_1, s_2, σ_3) are checked; their negative value means that soil at these points works on compression.

III. At each point of the structure, the fulfillment of the Coulomb-More limit equilibrium condition [3,16,29] is checked.

IV. In cases of spatial stress state, it is advisable to check the fulfillment of the Mises-Schleicher-Botkin condition [6,29] at each point.

The fulfillment of the above four conditions is necessary to ensure the strength reliability of earth structures. To ensure sufficient strength reliability of earth structures, along with the above four conditions, it is advisable that the greatest value of stress intensity at points of the structure, occurring under the most unfavorable operating conditions, should be less than the critical value of stress intensity that affects the strength of structure's soil..

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