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STABILITY OF RETAINING WALLS BY BEM

Materials are presented on finding active action of the soil on fencing. Location of the soil pressure on the retaining walls and the vector of stresses are calculated. The value of horizontal displacements of the retaining wall lateral surface is determined. Comparative analysis of calculations with the experimental investigation is performed.

Keywords: *retaining wall, soil pressure, the method of boundary elements.*

Introduction

Soil pressure on retaining structures depends on the shear resistance of soil masses supported by them. Shear resistance of soil is often the main factor that determines soil behavior under load since it determines the accuracy of engineering calculations on finding the limit load on soil, stability of the soil bodies and pressure on fencing. This is a variable quantity that depends on the pressure value and conditions at the contact points of the particles that resist shifting. In practical design limit shear resistance of the soil is considered.

In the applied problems of soil mechanics active soil pressure on fencing is determined by the methods of limit states. Classical theories of soil pressure are based on the fact of mobilization of active and passive soil pressures that actually emerge only in the case of full destruction. There is a necessity to find such models of soil that would reflect a great variety of its real properties.

The paper sets the task to elaborate the procedure of determining external horizontal load on retaining wall which, when exceeded, leads to breakdown of internal cohesion between the soil parts and causes their sliding and shifting.

Problem statement

Continuous regrouping of the particles due to the action of surface and volumetric forces is a characteristic feature of soils. Therefore, one of the basic problems of applied geomechanics is numerical prediction of the mechanism of geomechanical processes using mathematical modeling.

To solve the above problem, numerical realization of the design integral equation, that connects stresses and deformations at the retaining wall boundary with the soil, was conducted by BEM [1].

$$C_{ij}(\zeta)U_j(\zeta)+\int_i p^*_{ij}(\zeta,x)U_j(x)d\Gamma(x)=\int_i U^*_{ij}(\zeta,x)p_j(x)d\Gamma(x), \tag{1}$$

where $p_j(x)$ – vector of the stresses at the object boundary, which is to be found; $U_j(\zeta)$ – predefined vector of displacements at the object boundary; $p^*_{ij}(\zeta,x)$, $U^*_{ij}(\zeta,x)$ – fundamental functions of R. Mindlin for stresses and displacements.

For numerical realization of the problems of finding soil pressure (in this case it is sand) on the retaining wall by BEM (Fig. 1), lateral surface and the retaining wall base were divided into 5 boundary elements (BE) each; along the wall length 6 BE are taken. The stressed state $(\tau_s, \tau_r, \sigma_l)$ was determined in the central nodes of each BE along the length and approximated by a linear dependence.

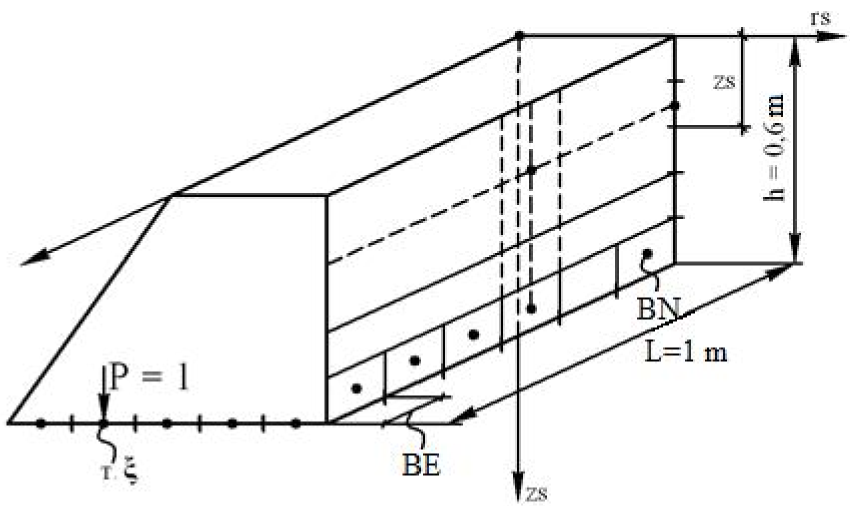

Fig. 1. Retaining wall discretization by boundary elements

Matrix form of the design equation is given by:

$$K\vec{Y} = F\,, \tag{2}$$

where $\vec{Y} = \begin{vmatrix} \tau_s \\ \tau_r \\ \sigma_l \end{vmatrix}$ – vector of the forces to be found (τ_s – tangential stresses at the boundary nodes (BN) of the lateral surface, τ_r – radial stresses at BN of the lateral surface; σ_l – normal stresses at BE of the retaining wall base; F – the vector of vertical and horizontal displacements; K – the matrix of BEM influence composed from the fundamental solutions of R. Mindlin [1, 2] for an elastic half-plane:

$$K = \begin{vmatrix} k_{ss} & k_{rs} & k_{bs} \\ k_{sr} & k_{rr} & k_{br} \\ k_{sb} & k_{rb} & k_{bb} \end{vmatrix}. \tag{3}$$

Components of K matrix: displacements of the lateral surface nodes and of the base under the influence of tangential stresses τ_s, radial stresses τ_r of the lateral surface and normal stresses σ_l of the base.

Double integration of the values of radial stresses τ_r along the retaining wall lateral surface, found from the system of linear algebraic equations (SLAE) (2), has given the value of active soil pressure on the retaining wall. The value of horizontal displacements of the retaining wall lateral surface, required for formula (2), is determined taking into account the following considerations [3]: if the wall is fixed, slides behind the retaining wall are impossible; lateral pressure of soil on the wall must depend only on elastic properties of the soil skeleton, which are restricted practically for all soils ≈ 10 kPa.

The vector of stresses $\vec{Y}$ calculated from (2) was compared with the value of the soil elastic stresses (8 – 12 kPa), which gave the possibility to determine the values of the corresponding horizontal displacements. Then maximal value of the soil active pressure on the retaining wall was found. Physico-mechanical properties of soils $(E,\ \nu,\ c)$, which measure quantitively the soil response to external influences, were used as the model input parameters. The paper presents BEM calculation of the lateral pressure of fine sand (the size of grains less than 0,25 mm) with the following physico-mechanical indices: specific cohesion of the soil (c = 3 kPa), Poisson's ratio (ν = 0,3), deformation modulus (E = 18 MPa) of the wall with L = 1 m, the height h = 0,6 m (Fig. 1).

The vector of radial stresses at the boundary nodes of the lateral surface was τ_r = {4,11 KPa, 3,92 KPa, 4,85 KPa, 2,51 KPa, 8,17 KPa}. Integration over the lateral surface has given the value of active pressure E_a = 2,828 KPa. In order to check the validity of the obtained results, BEM calculation data were compared with experimental research of I. V. Yaropolskiy [4], who noted that soil pressure on retaining walls depends on the wall displacement value (Fig. 2).

When the wall displacement exceeds the average value of the diameter of the soil granules (w> 0,2 mm), shifting of the soil particles occur. For the state of rest (w <0,2 mm) the active pressure value was 2,8 KN.

Active soil pressure on 1 running meter of the retaining wall length, calculated according to the current normative documents, is 2,828 KN [5].

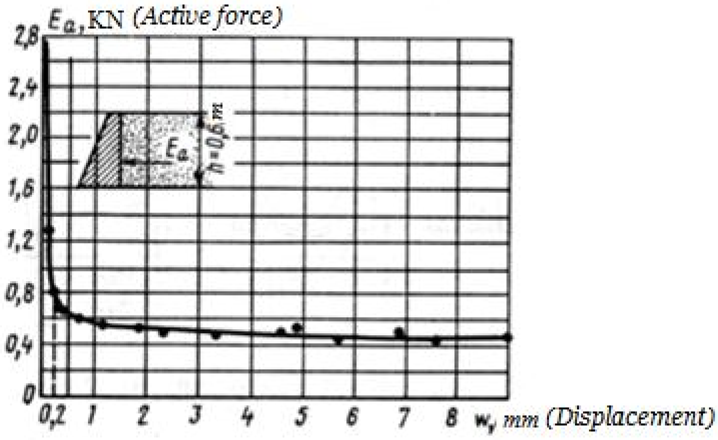

Fig. 2. The results of experimental research of I. V. Yaropolskiy on finding the dependence of active pressure on the retaining wall displacements

Conclusions

BEM procedure for determining active soil pressure on the fencing has been elaborated. The procedure corresponds to the experimental research of I. V. Yaropolskiy – E_a = 2,8 KN for the moment when elastic properties of the soil skeleton are exhausted and to the calculations performed using the normative documents (E_a = 2,828 KN) (ДБН В.2.1- 10-2009).

The proposed mathematical model makes it possible to determine lateral pressure of the soil with accuracy sufficient for practical purposes.

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