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On the Issue of Forming an Optimal Zone Placement of Reinforced Concrete Retaining Walls in the Body of the Road Embankment

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ABSTRACT: The process of designing retaining walls of highways includes a large number of tasks that have a geometric nature: the calculation of volumes and areas, determining the parameters of shape and position, subject to a number of restrictions. The article deals with the problem of forming a zone in the body of the highway embankment for optimal placement of thin-walled reinforced concrete retaining walls in it.

KEYWORDS: Geometric design, construction, unification, retaining walls, stability, placement, tipping.

I. INTRODUCTION

The key tasks of the process of optimal geometric design [1] are: - the formation of the zone of optimal design (ZOD);-the purpose of the optimal parameters of retaining walls (RW) and its elements (blocks, sections), taking into account regulatory technological and metric restrictions (including the desire to minimize the number of type elements); -optimal arrangement of RW in ZOD. Each of these tasks has an optimization character and can be considered as the subject of a separate study. In all cases of designing RW on roads, their main purpose is to ensure the stability of the subgrade. In this case, special attention is paid to ensuring the stability of the RW themselves, on which the stability of the structure as a whole depends. Therefore, it seems advisable at first on the road section where the location of RW is supposed to be determined, to determine the area of the subgrade, within which the stability of RW against tipping is guaranteed in accordance with applicable standards. This zone, together with the calculated surface for laying the foundation of RW and a number of other elements, forms ZOD of RW (Fig. 1), which serves as the basis for solving the main problem of optimal geometric design of retaining walls - placing RW and their elements in ZOD taking into account predetermined conditions.

The optimal design zone is a three-dimensional body bounded by surfaces of different dimensions (0÷ 3 -dimensional) that reflect a variety of factors that affect the position of RW. Changing the dimension of these surfaces is related to the specific design conditions of RW. In particular, the area of optimal design from above can be limited by the surface (plane) of the slope. At the same time, it is sometimes necessary to increase the ZOD from the slope surface to a certain level (see fig.1), associated with the possibility of the top line of RW beyond its limits. The bottom of the optimal design zone can be limited (depending on local soil and geological conditions) by the calculated surface (plane) of the Foundation or by some parallelepiped that limits the depth of the Foundation of the RW.

In General, the lower boundary of the optimal design zone may have a more complex structure. Depending on the shape in terms of curvature of the road section where the RW are designed, the optimal design zone behind and in front may be limited to vertical planes or cylindrical surfaces, and on the sides - either vertical planes or parallelepipeds that take into account the boundary conditions of the location of the beginning and end of the RW.

When placing RW in optimal design zones, the upper, lower, and side boundaries are the defining ones listed above. Therefore, when forming the ZOD special attention is paid to defining these boundaries, which are conventionally called areas of the ZOD (see Fig.1): Ω_B -upper, Ω_H - lower, Ω_1 - initial and Ω_m - final regions. In addition, in some cases, it is necessary to introduce intermediate areas - Ω_i, which limit the location of the junction of adjacent sections of RW that differ in the degree of penetration into the ground or include type elements of different classes.

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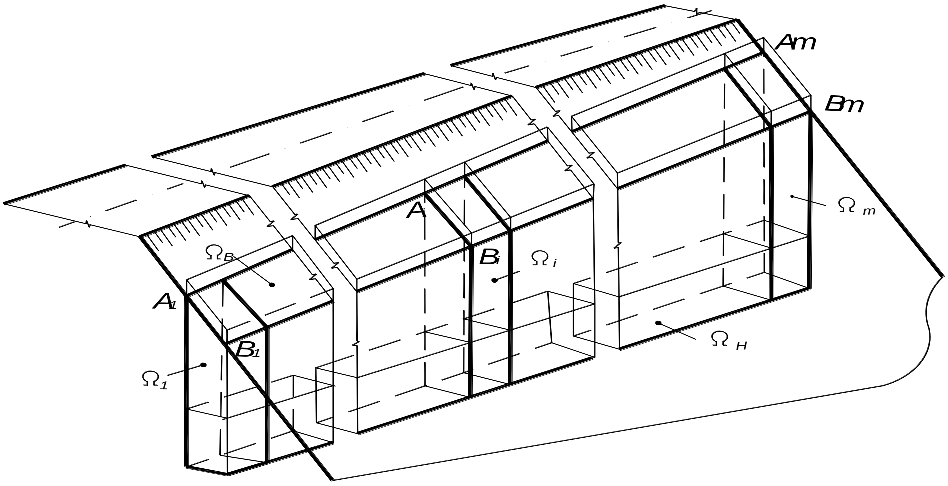

Fig.1 Zone of optimal placement of RW in the body of the road embankment

Thus, in the General area of ZOD can be considered as a combination of a number of constituent regions;

$$\Omega = \Omega_B + \Omega_H + \Omega_1 + \Omega_m + \sum_{i=2}^{m-1} \Omega_i \, , \qquad (1)$$

within which the required arrangement of the corresponding elements of RW should be provided, and its formation is reduced to some generalization of these areas.

The significance of each of these areas in the ZOD, from the point of view of placing RW in it, varies. Thus, the upper $\Omega_B$and lower $\Omega_H$areas are designed to accommodate the defining elements of RW -the top and bottom (sole). Therefore, they have the greatest influence on the nature of changes in the parameters of the shape and position of RW. The availability and dimensions of the initial Ω_1, final Ω_m, and intermediate $\Omega_i$regions, as noted above, depend on the specific design conditions. For example, if there is a significant slope of the top line of RW (with a small curvature of it), as well as a sharp change in the nature of soil stratification, the number of intermediate areas may increase. Or, on the contrary, in some cases, these areas may not exist at all, i.e., they may not exist at all.

$$\sum_{i=2}^{m-1} \Omega_i = 0 \qquad (2)$$

The upper $\Omega_B$and lower $\Omega_H$regions are determined based on stability calculations, while minimizing the area of fertile land and the amount of excavation work may be additional factors that influence the definition of these areas.

It should be noted that when determining the lower area $\Omega_H$along with others, the ground-geological conditions of the area are also taken into account, such as the depth of the Foundation, the depth of freezing, the thickness of the weathered rock layer, etc.

It is possible to consider in more detail the definition of the upper area $\Omega_B$the ZOD, the design scheme of which is shown in Fig. 2. The required calculation values are the boundary values of the lengths l_A and l_B distances of the l inner face of the RW from the edge of the roadbed, corresponding to the maximum permissible values of the working conditions coefficient - [m], which is accepted depending on the type of construction of the RW of its base.

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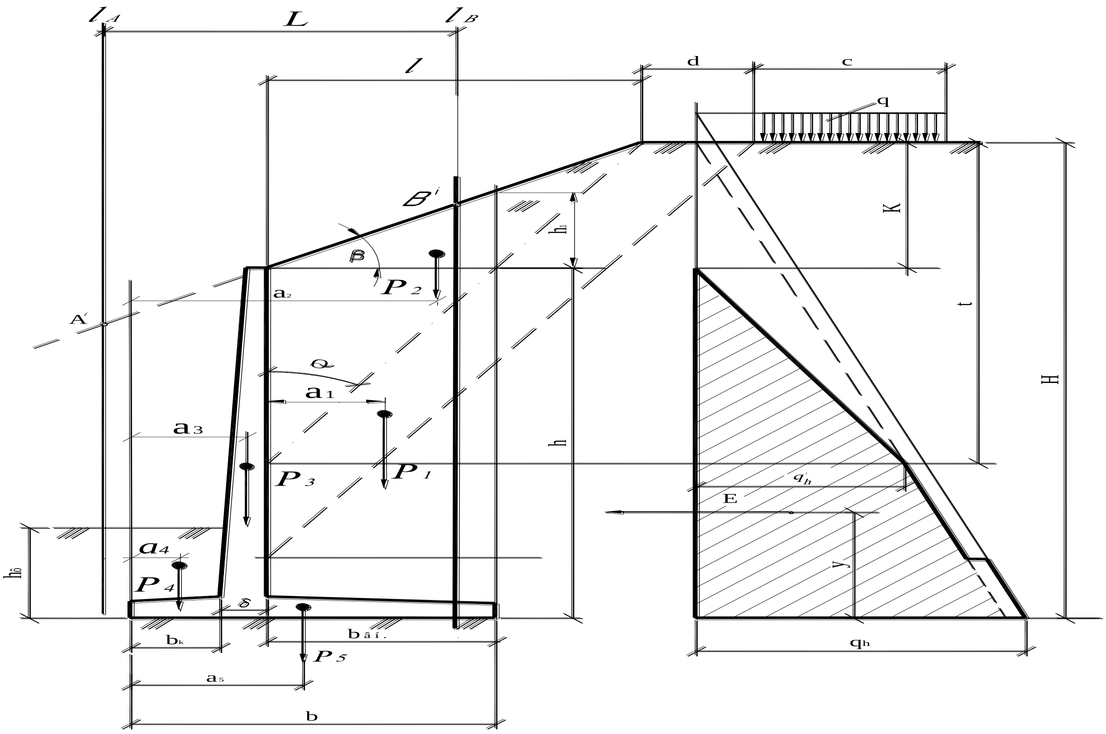

Fig. 2. Calculation scheme for determining the upper Ω_B and lower Ω_H areas of the ZOD

According to the calculated values of the coefficient of working conditions m find conditions of stability of RW against overturning, expressed formula:

$$M_{opr} / M_{pred} = E\ y / \sum_{i=1}^{n} P_1 a_1 < [m], \tag{3}$$

where,M_{opr} - is the calculated tipping moment relative to the plane of the Foundation sole: M_{pred} - is the limit tipping moment relative to point 0; E is the active (horizontal) ground pressure; y is the shoulder of force E relative to the plane of the Foundation sole;

P_1 - power adequate for the weight of the soil and elements of RW; a_1 - the shoulders of the forces P_1 - on the vertical line passing through the point 0; [m] - maximum allowable value of the coefficient m adopted, for example, for sections of reinforced concrete structures with foundations on the basis of mescaline - [0.7 ÷ 0,75].

II. MAIN CONTENT

The calculation begins with determining the active pressure of the soil E on the RW and constructing the corresponding pressure plot. To determine the effect of active soil pressure on RW, it is necessary to know the characteristics of the backfill soil, its own weight, the coefficient of internal friction of the soil $tg\ \varphi$ and other physical and mechanical parameters [3]. In the calculation, the section of RW with a length of 1 m is considered, for which the active ground pressureEand other loads are determined. The active ground pressure E is determined for the entire height of the RW, including the depth of the Foundation (see fig. 2).

The General formula for determining this pressure is as follows:

$$E = (\gamma h^2 \lambda) / 2, \tag{2.1}$$

The specific weight of the backfill soil; h - the height of the RW; λ - the coefficient of active soil pressure on the RW, the value of which depends on many factors, including the characteristics of the soil. As is known [4], when determining the proper weight of RW, as well as the weight of the soil located above the elements of RW, its cross section is divided into simple geometric shapes.

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In the center of gravity of each of these geometric shapes, forces P_i are applied, corresponding to the weight of the soil and elements of the RW

$$P_i = F_i\ y, \qquad (2.2)$$

Where,$F_i$is the cross-sectional area of the geometric shape.

When designing RW, it is often necessary to determine the ground pressure taking into account the time load located on the collapse prism. A uniformly distributed load located on the collapse prism, with an intensity of q (see. fig.2), replace with a layer of soil equivalent to the intensity of this load, having a height of:

$$h_0 = \frac{q}{\gamma}\ . \qquad (2.3)$$

The intensity of the soil pressure on the RW is determined by the formulas:

$$q_0 = \gamma h_0 \lambda \text{ and } q_H = \gamma (H + h_0)\lambda \quad . \qquad (2.4)$$

In different design situations, the calculated $M_{opr}$and limit M_{pred} tipping moments in (3) may vary depending on the angle of inclination β of the ground fill surface behind the RW relative to the horizontal plane at the top of the RW. For example, for the project case shown in fig. 2 and 2 when $\beta \neq 0$

$$M_{pred} = (P_1 a_1 + P_2 a_2 + P_3 a_3 + P_4 a_4 + P_5 a_5)n, \qquad (2.5)$$

$$M_{opr} = Eyn \frac{((H^2 + 2h_0)tg\vartheta - (2h_0 + 2h_0)\gamma)\ \mathrm{yn}}{2tg(\vartheta + \varphi)} \qquad (2.6)$$

Where, $tg\vartheta$ is the tangency of the angle of the sliding plane of the collapse prism, i.e.

$$tg\vartheta = -tg\varphi + (1 + tg^2\varphi) + \frac{4ch_0 + 2lk + 2dh_0}{(H^2 + 2h_0 H)\sin 2\varphi} \qquad (2.7)$$

Where, φ is the angle of internal friction of the soil; *n* - is the coefficient of overload of the soil or reinforced concrete. And in the case where β=0, the expressions (2.5) and (2.6) take the form.

$$M_{opr} = Eyn = \frac{(\gamma h^2 (tg\vartheta h^2 + 2h_0 c))yn}{4tg(\vartheta + \varphi)} \qquad (2.8)$$

$$M_{pred} = (P_1 a_1 + P_3 a_3 + P_4 a_4 + P_5 a_5)n \qquad (2.9)$$

However, for the case of β = 0, the task of determining the boundaries of the ZOD does not make sense, since l_i = 0, i.e. the RW is located at the edge of the roadbed, must be justified economically.

III. CONCLUSION

Thus, it is sufficient to use only the expressions (2.8) and (2.9) to calculate the M_{opr} and M_{pred}.The boundary values l_A and расстояния l_B of the distance l can be determined both numerically and analytically. An analytical method that involves the derivation and solution of a General equation may be acceptable in some particular design cases. In complex project situations, however, it is more appropriate to use a different numerical method, which requires separate studies.

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