Strength Stability of the roadbed reinforced by gabion structures

Farkhadjon Adilov[1], Mirzakhid Mirzahmov[1], RustamAbirov[1], Qodirjon Turajonov[1] and Akhrorbek Nomonov[2]

[1]Institute of mechanics and earthquake engineering, 100125 Tashkent, Uzbekistan, E-mail: [illegible]
[2]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan, phone: 998 (90) 918-68-25,
E-mail: [illegible]

Abstract. Stability of roadbed under dynamic (seismic) impact considered in this issue. For providing field tests, the road site was strengthening by gabion structures and its stability calculation by using finite element approaches used here.

Keywords: gabion, stress, deformation, stability, roadbed, seismic force

1. Introduction and primary calculation

Slopes of embankments and excavations, roads made of water-absorbing clay soils are often destroyed. The reasons may be a steep fall of a mountain valley, the presence of loose weathering products in the upper reaches of the valley within the drainage area as a result of heavy rainfall. Mountain mud-stone flows of great destructive power are of relatively short time [1-3].

Nowadays for roadbed in seismic prone areas wide spectra strengthening measures used and in some cases gabions also. In Uzbekistan local building codes for road structures we have not special approaches for calculation of stability so structures yet. Only in several cases field tests were provided. Our goal is propose the method for calculation roadbed strengthened by gabions.

It is required to carry out calculations of the external and internal stability of the gabion wall with a stepped front face (Fig 1), located on the left side of section of the highway of the category II. The wall consists of box-shaped gabions 1 m high, made of mesh with a wire diameter of 3.0 mm. The specific weight of the stone material of gabion structure filling is $\gamma = 26$ kN/m^3, the porosity is [illegible]. The soil of the roadbed is a loam with a calculated angle of internal friction $\varphi = 30$, cohesion $c = 8$ kPa, specific weight $\gamma = 18.9$ kN/m^3 and a strain modulus of 30 MPa. The width of the gabion wall base is B = 2m.

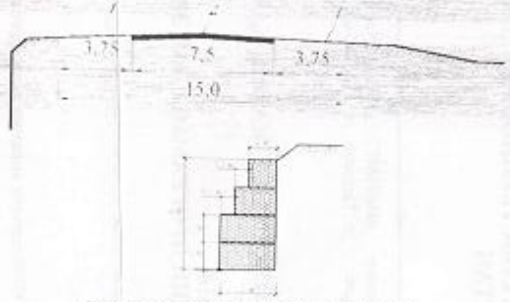


Figure 1 - Section of a road of category II and a gabion wall
1 - roadside; 2 - roadbed

The specific weight of the gabion structures of the retaining wall is determined by the formula

$$\gamma_s = \gamma_s \cdot (1 - n) = 26 \cdot (1 - 0.30) = 18.2 \text{ kN/m}^3$$

According to state standards (GOSTR 51285-99), the friction angle and specific cohesion of gabion structures on the calculated surface are determined by the formulas

$$\varphi_s = 2.5 \cdot \gamma_s - 10 = 2.5 \cdot 18.2 - 10 = 35.5$$

$$c_s = 3 \cdot \varphi_s - 5 = 3 \cdot 8.55 - 5 = 20.65 \text{ kPa}$$

In this case, the strain modulus of gabions is 420 MPa. The problem was solved by the finite element method ([illegible] = 867, [illegible] = 884). The boundary conditions are specified as follows: along the vertical boundaries of the calculated model there are no displacements in horizontal direction, there are no vertical displacements along the lower horizontal border, no restrictions are imposed on the displacements of other points.

When calculating the slope of the road, the load on the single, most loaded axle of a biaxial vehicle with a frame of 130 kN (13 tf) is taken into account, as well as the weight of the pavement and own weight of the roadbed and gabions. In this case, we will take into account the least favorable position of the transport load in the event of an emergency stop on the side of the road.

According to the developed methods, the external load from traffic is multiplied by a dynamic coefficient equal in the range of $\mu = 1.1 - 1.2$, the estimated seismicity of the area is 9 points, seismicity coefficient is $k^c = 0.1$

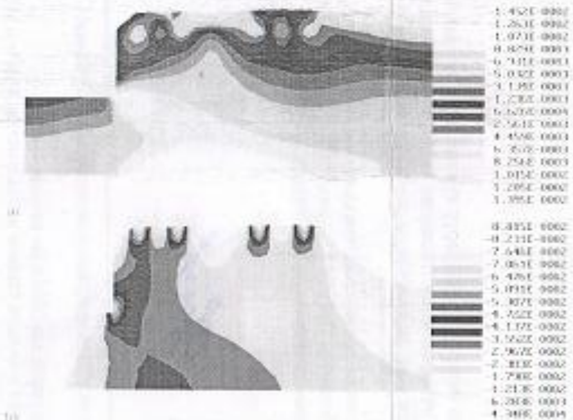
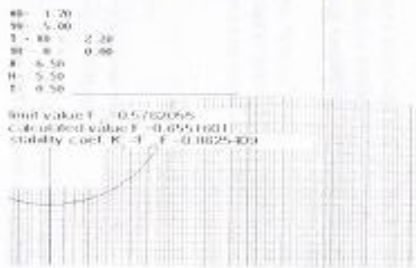


Figure 2 - Principal stresses, MPa
a- maximal principal stresses, b- minimal principal stresses



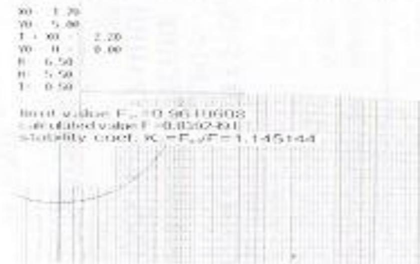


Figure 3 - Calculated stability coefficients of the slope

In the first case, the calculations were performed to assess the stability of the vertical slope, taking into account the effect of external load. Figure 2 shows the corresponding values for a given area, which can be used to judge the stress state of the array. Figure 3 shows graphical data on the stability state of vertical slope. However, the slope does not have a sufficient margin of stability, so it must be strengthened by gabion structures.

2. Results with using of gabions reinforcing

In this regard, calculations were carried out taking into account the vertical structure of the gabion. Calculations showed that this type of structure provides good strength of the slope (Figs. 1-5).

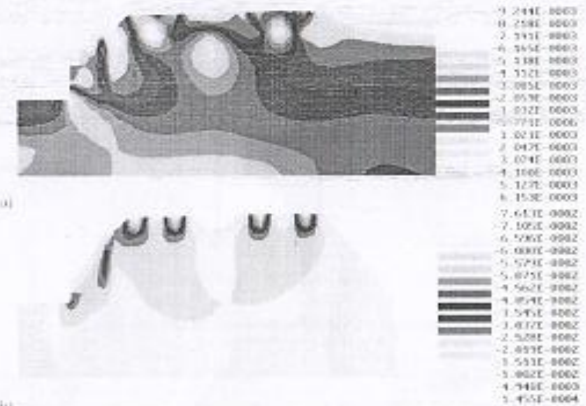


Figure 4 - Maximal and minimal principal stresses, MPa
a - maximal principal stresses; b - minimal principal stresses

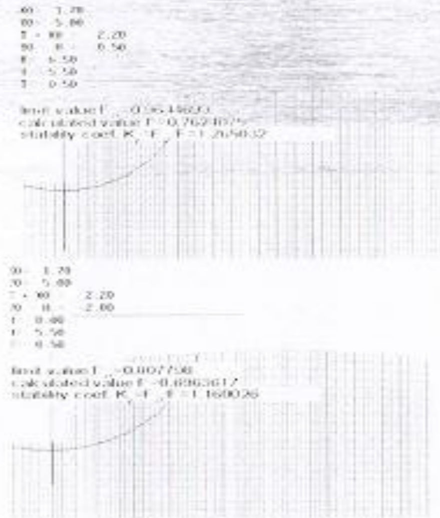


Figure 5 - Calculated coefficients of stability of the slope

Calculations show that the stability of the gabion wall against the shear along the base surface and turnover is provided. Therefore, the stability condition of the massive-volume gabion wall against shear is fulfilled.

Consider a section located between 3[d] and 4[th] layers of a gabion wall (Fig 6). The wall width in this section is $B_i = 2$ m:

$$\sigma_i = \frac{\sum G_{ni}}{B_i} = \frac{(18.2 + 27.3 + 36.4) \cdot 10^{-3}}{2} = 0.04095 \text{ MPa}$$

The value of permissible normal stresses on gabion structures is determined at a safety factor of $k_s = 1.15$ according to the formula

$$[\sigma_s] = \frac{50 \cdot \gamma_g - 300}{k_s} = \frac{(50 \cdot 18.2 - 300) \cdot 10^{-3}}{1.15} = 0.53043 \text{MPa}$$

The strength of the gabion structure under normal stresses is checked under the condition

$$[\sigma_s] = 0.53043 \geq \sigma_i = 0.04095$$

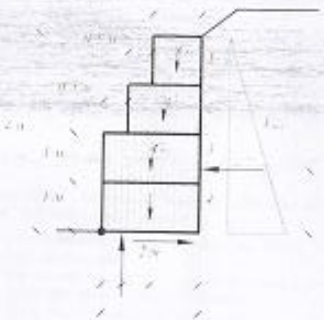


Figure 6 - Design scheme to calculate the internal stability of massive-volume gabion wall

So, the strength stability of the gabion structure of retaining wall in the considered section is sufficient. The strength of the remaining gabion structures is calculated similarly. Consider the same section between 3rd and 4th layers of the gabion wall. The magnitude of the horizontal shear force in the considered section is $F_{sh} = 0.02531$ MPa.

The acting tangential stresses are determined by the formula [2]

$$\tau_i = \frac{F_{sh}}{H_i} = \frac{0.02531}{2} = 0.01266\ MPa$$

The mass of the mesh of a box-shaped gabion structure in the considered section made of mesh with a wire diameter of 3.0 mm according to the appendix [4,5,6]. The allowable value of tangential stresses is determined with a safety factor of $k_s = 1.15$ according to the formula

$$[\tau_{sh}] = \frac{\sigma_i \cdot tg\varphi_g + c_g}{k_s} = \frac{0.04095\ tg35.5^{\circ} + 0.0203}{1.15} = 0.04336\ MPa$$

The possibility of shear of individual layers of the gabion wall is checked from the condition

$$[\tau_{sh}] = 0.04336\ MPa > \tau_i = 0.01266\ MPa$$

On analyses of above provided calculations the influence of basic parameters of gabions on road stability, its deformability was investigated. On these theoretical investigations and comparing with field tests results the approach will be propose for new building codes concern road structures.

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