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The Analysis of the Stability of the Communication Support Stabilized by Gabion Wall with Variable Configuration

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The subject of the article concerns the stabilization of communication earthworks using the so-called lightweight retaining structures. The stability of the embankment with the embankment built with the gabion wall is analysed, assuming a uniformly distributed load on the crown and a case of unilateral water pressure in the event of a flood. Final results of stability calculations made with the Fellenius and Bishop method in the form of slip surface with the smallest value of the coefficient were presented. Then, assuming the case of damming up of flood water, discretization of the filtration area, velocity distribution and hydrodynamic grating and slip surfaces were developed. The variable parameter is the wall configuration.

Keywords: communication embankment, gabion wall, water damming, stability.

1. INTRODUCTION

Light retaining walls belong to the relatively cheap, durable and uncomplicated protection in the construction of slopes of embankments and road and railway roadways [3-15, 21-22]. The functioning of these structures consists in switching on the ground centre for cooperation with the elements of the supporting wall in taking over the forces coming from the operational load. The principle of cooperation is based on the phenomenon of friction. In textbooks [7, 19], the most commonly used types of light retaining structures are specified: walls made of reinforced classical and geotextile reinforced soil, embankments reinforced by nailing technique, walls constituting a system of many horizontal shelves (made of prefabricated elements with angular cross-section), quasi-chest, shell walls , blinds, made from kaszyc, Fracasso sections, T-WALL elements and gabion. The latter are the subject of this article. The idea of contemporary walls made of mesh baskets filled with stone material comes from the late nineteenth century, when in the area of Cassalechio near Bologna, these buildings were used to remove damage resulting from the flood [8]. In Poland, this technology was disseminated after 1990, especially on the coast. In Lower Silesia, however, an acceleration of the rate of development of applications after the flood of 1997 is observed [14, 22]

Numerous publications have appeared on the subject of dimensioning, stability analysis, modelling, theoretical generalizations, experimental and polygonal research on gabion walls [4-15, 22], but few account for crisis situations, for example flood water [14-19]. When checking stability, damage mechanisms are commonly assumed, shown in Figure 1 [9].

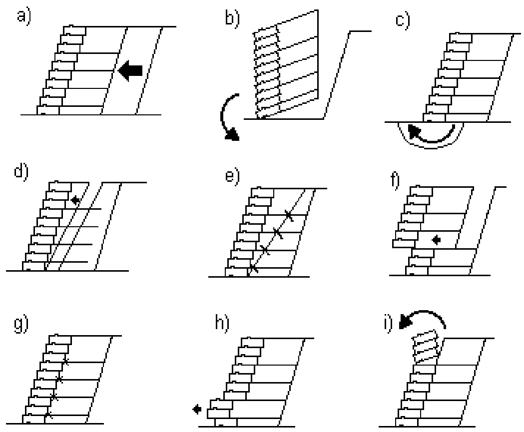

Fig. 1. Schemes of destruction of the retaining wall from gabions [9]: a - slip, b - rotation, c - displacement (exceeding the load capacity of the substrate), d - exceeding the limit tangential stresses ($\tau > \tau_{gr}$), e - exceeding of normal stresses (σ> σgr), f - inter-pole slippage, g - breaking connections; h - slip damage (bulge), and - apical destruction.

The article analyses (mainly in the aspect of stability) the behaviour of the embankment with an escarpment built on one side with a gabion wall. The effect of a uniformly distributed load on the crown of constant intensity and a case of water pressure in the event of a flood occurring was assumed. The damming up of water occurs on a slope without a gabion wall. In the first phase the embankment without load on the crown is considered. Taking the case of flood water damming, discretization of the filtration area, velocity distribution and hydrodynamic grating as well as slip surfaces were developed. The values of stability coefficients and geometrical parameters of the determined slip surfaces were also calculated. The variable parameter is the wall configuration. In the second phase, the embankment slope is not subjected to the pressure of water but there is a service load on the crown. The slip surfaces were determined for the smallest value of the stability coefficient calculated by the Fellenius and Bishop method. The software [1, 2] was used: the SZMFiB-Stability program of the slopes using the Fellenius and Bishop method as well as the FILTER-FILTRATION program established in the ground embankments that accumulate water.

2. CALCULATION DIAGRAM

The assessment of the stability of the communication embankment of the earth structure was made on the example of a homogeneous embankment, located on a deformable base with parameters identical to the embankment. The height of the embankment is H = 5 m, slope of slope 1: 1.5; volumetric weight of the soil material γ = 17.0 kN / m3. Geometric features of the object and effective strength parameters are given in Fig. 2.

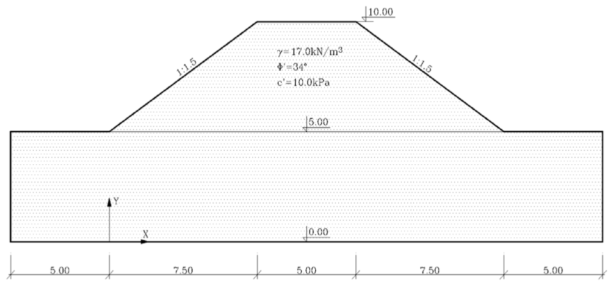

Fig. 2. The calculation scheme of the embankment [14].

3. EMBANKMENT WITH A SURGE OF A BUILT-IN GABION WALL, DAMMING WATER

The analysis assumes the stabilization of one-sided embankment, using a vertical wall made of gabion baskets, constructed in three variants: 2 (variant I), 3 (variant II) and 4 (variant III) gabions set on each other. Using the FILTER program [2, 14], the filtration field in the embankment was determined at the damming of water at a level equal to the height of the embankment. Discretization of the filtration area, velocity distribution and hydrodynamic grating at the maximum level of damming in the embankment Hg = 10.0 m, for the scheme consisting of variant I shown in Fig. 3–5.

Fig. 6 and 7 illustrate slip surfaces with the lowest stability coefficient determined by the Fellenius and Bishop method for a wall composed of two layers of gabions. In contrast, tables 1 and 2 summarize the values of stability coefficients and geometric parameters of the determined slip surfaces for all three variants of the gabion wall structure. In the first rows of tables, the results for a conventional embankment are given for comparison with the maximum water levelling.

Fig. 8 shows a summary of the results of calculations. For all designated slip areas, the values of stability coefficients are greater than the permissible values, which indicates that the overall stability of the analysed gabion wall structures at the maximum water accumulation is ensured.

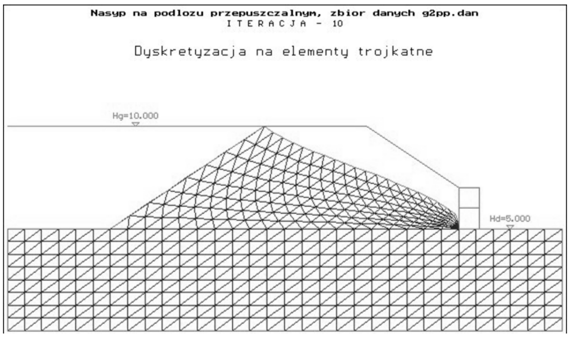

Fig. 3. Discretization of the filtration area at the maximum level of damming in the embankment with an escarpment built a gabion wall composed of two layers [14].

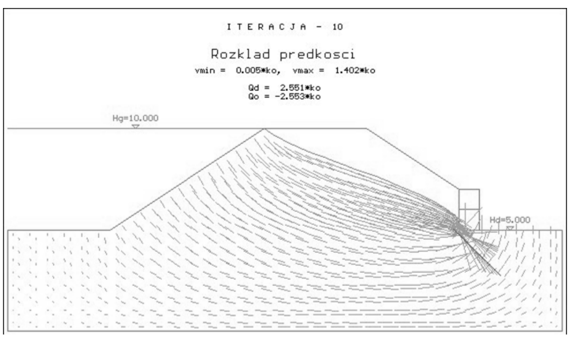

Fig. 4. The speed distribution at the maximum level of damming in the embankment with the escarpment built-up gabion wall composed of two layers [14].

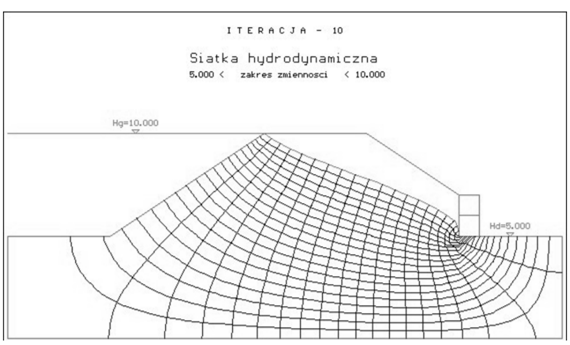

Fig. 5. Hydrodynamic net at the maximum level of damming in the embankment with an escarpment built a gabion wall composed of two layers [14].

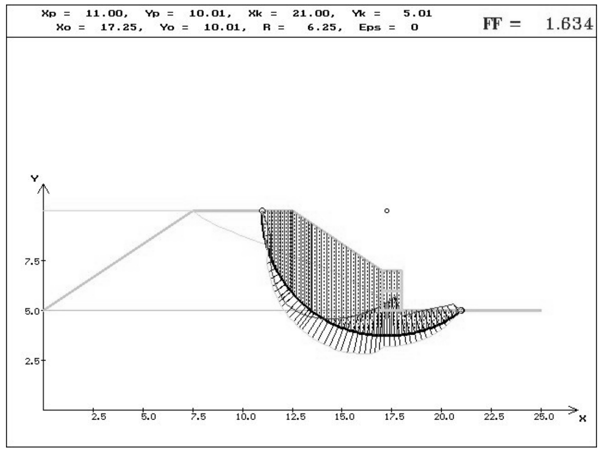

Fig. 6. Slip area with the lowest stability coefficient calculated Fellenius method in an embankment built with a gabion wall composed of two layers at maximum stacking [14].

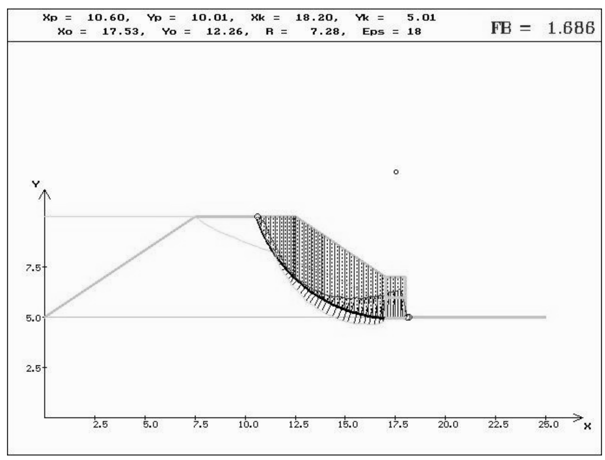

Fig. 7. Slip area with the lowest stability coefficient calculated using the Bishop method in a built-up embankment with a gabion wall composed of two layers with maximum damming [14].

Table 1. List of parameters regarding the smallest slip area the stability coefficient calculated by the Fellenius method for the embankment slope built with a gabion wall, with maximum water damming [14].

The number of gabions piled one on top of the other	**Stability Coefficient FF**	Coordinates of the characteristic points of the circular slip surfaces						surface radius of the slip R [m]
		start		end		middle		
		Xp[m]	Yp[m]	Xk[m]	Yk[m]	Xo[m]	Yo[m]	
0	**1.564**	10.9	10.0	20.9	5.0	17.823	11.356	7.052
2	**1.634**	11.0	10.0	21.0	5.0	17.250	10.010	6.250
3	**1.543**	11.3	10.0	18.4	5.0	16.611	10.010	5.311
4	**1.459**	10.5	10.0	17.7	5.0	15.836	10.010	5.336

Table 2. List of parameters regarding the smallest slip area the stability coefficient calculated using the Bishop method, for the embankment slope built with a gabion wall, with maximum water damming [14].

The number of gabions piled one on top of the other	**Stability coefficient FB**	Coordinates of the characteristic points of the circular slip surfaces						surface radius of the slip R [m]
		start		end		middle		
		Xp[m]	Yp[m]	Xk[m]	Yk[m]	Xo[m]	Yo[m]	
0	**1.605**	10.9	10.0	20.1	5.0	18.137	12.361	7.609
2	**1.686**	10.6	10.0	18.2	5.0	17.525	12.260	7.281
3	**1.609**	11.0	10.0	17.7	5.0	16.580	10.498	5.601
4	**1.522**	10.3	10.0	17.1	5.0	15.538	10.010	5.238

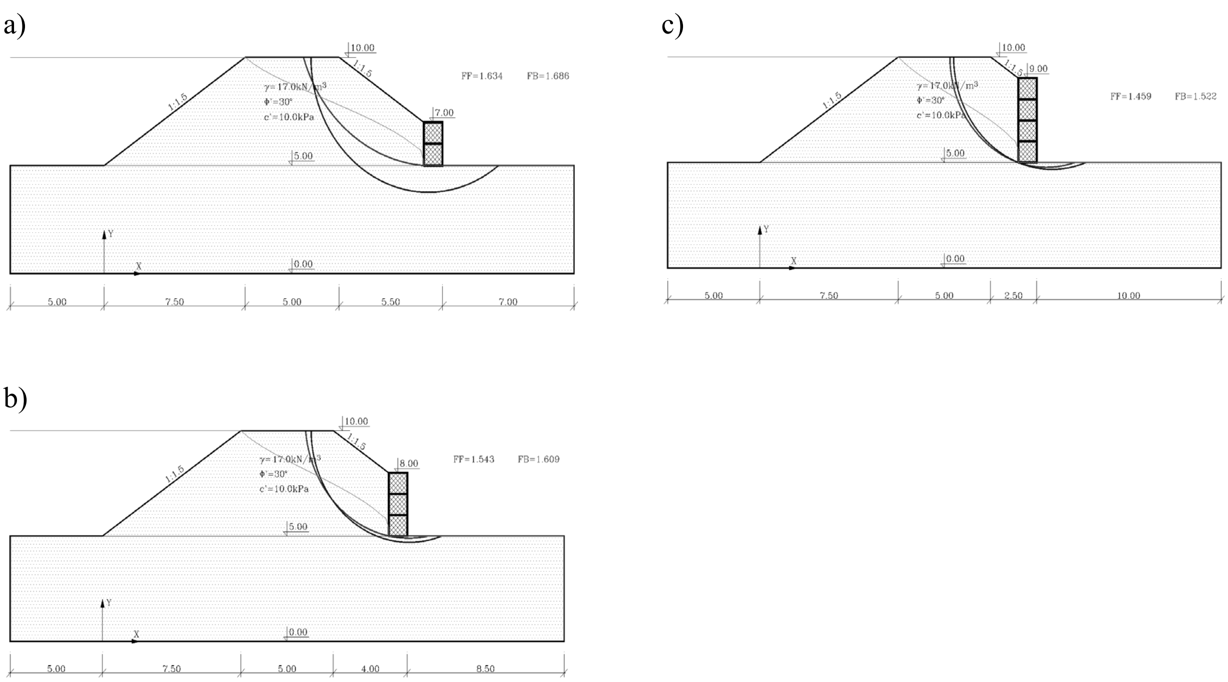

Fig. 8. Slip surfaces with the lowest stability coefficient at the maximum level of damming for the gabion wall [14]: a) composed of two layers of gabions, b) composed of three layers of gabions, c) made of four layers of gabions.

4. EMABNKMENT WITH A SURGE OF A BUILT-IN GABION WALL, LOADED ON THE CROWN

Schemes of gabion structures constituting variants I, II and III were loaded on the crown in a uniformly distributed manner with an intensity of q = 100kPa. The task consisted in estimating changes in the stability coefficient value depending on the wall configuration.

Figures 9-14 show the final results of the stability analysis in the form of estimating the slip area with the lowest coefficient. They are the result of a cycle of calculations of several hundred surfaces with different positions of the starting point, end point and radius of curvature.

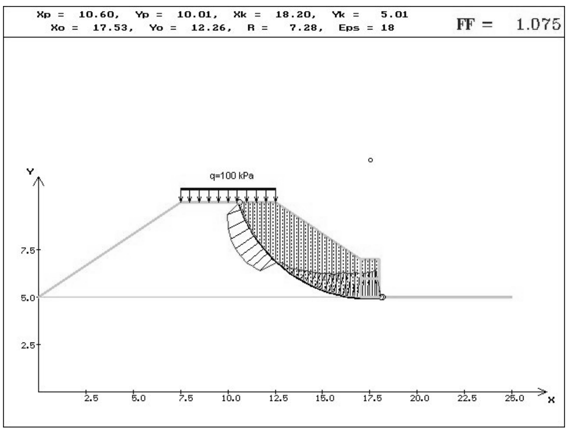

Fig. 9. Slip area with the lowest stability coefficient calculated by the Fellenius method in an embankment built with a gabion wall composed of two layers with a load of q = 100 kPa [14].

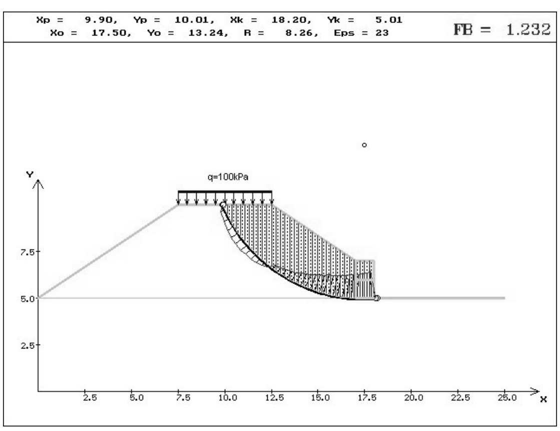

Fig. 10. Slip surface with the lowest stability coefficient calculated using the Bishop method in an embankment built with a gabion wall composed of two layers with a load of q = 100 kPa [14].

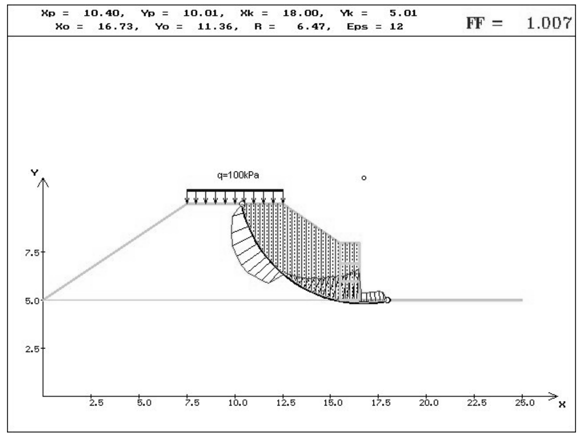

Fig. 11. Slip area with the lowest stability factor calculated by the Fellenius method in an embankment built with a gabion wall composed of three layers with a load of q = 100 kPa [14].

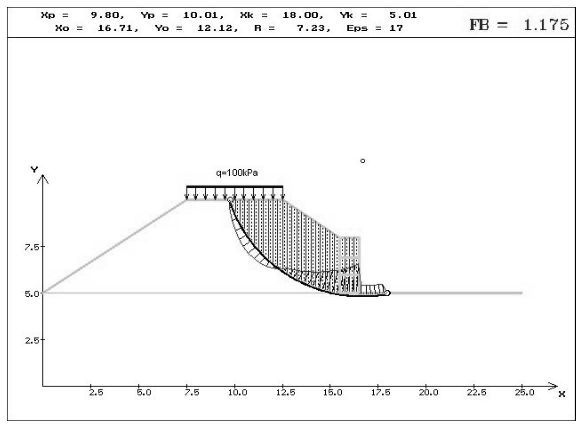

Fig. 12. Slip area with the lowest stability coefficient calculated using the Bishop method in an embankment built with a gabion wall composed of three layers with a load of q = 100 kPa [14].

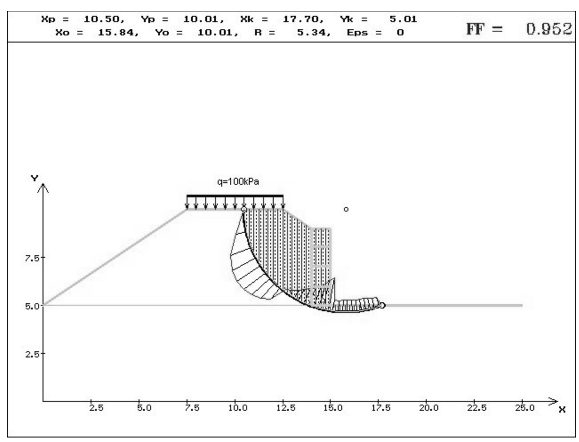

Fig. 13. Slip area with the lowest stability coefficient calculated by the Fellenius method in an embankment built with a gabion wall composed of four layers with a load of q = 100 kPa [14].

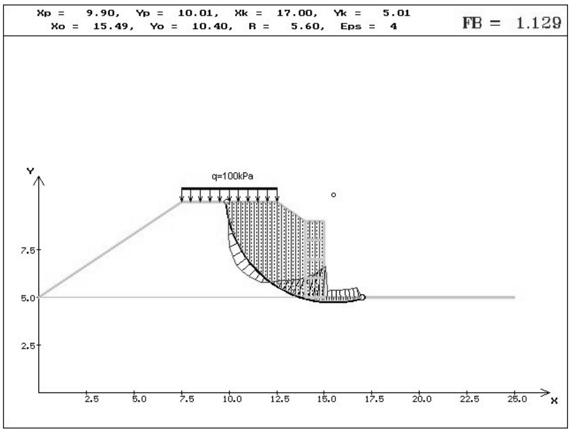

Fig. 14. Slip surface with the lowest stability coefficient calculated using the Bishop method in an embankment built with a gabion wall composed of four layers with a load of q = 100 kPa [14].

Tables 3 and 4 present the values of stability coefficients and geometrical parameters of the determined slip surfaces. In the first rows of these tables, analogous results for a conventional embankment (without a retaining wall) are given for comparison. If the conventional embankment slope is considered as stable (FF = 1,159 > FF_{dop} = 1,1÷1.3 i FB = 1,299 ≈ FB_{dop} = 1,3÷1,5), then the modelled gabion wall structures do not meet these conditions, i.e. their overall stability is not provided.

In Figures *15a, b, c* the potential slip surfaces of the embankment part together with the gabion wall are shown.

Table 3. List of parameters regarding the slip area with the lowest stability coefficient calculated using the Fellenius method, for the slope of the embankment built with a gabion wall at a distributed load with an intensity of q = 100 kPa [14].

The number of gabions piled one on top of the other	**Stability coefficient FF**	Coordinates of the characteristic points of the circular slip surfaces						Surface radius of the slip R [m]
		start		end		middle		
		Xp[m]	Yp[m]	Xk[m]	Yk[m]	Xo[m]	Yo[m]	
0	**1.159**	10.2	10.0	20.0	5.0	18.083	13.356	8.563
2	**1.075**	10.6	10.0	18.2	5.0	17.525	12.260	7.281
3	**1.007**	10.4	10.0	18.0	5.0	16.730	11.355	6.471
4	**0.952**	10.5	10.0	17.7	5.0	15.836	10.010	5.336

Table 4. List of parameters regarding the slip area with the lowest stability coefficient calculated using the Bishop's method, for the slope of the embankment built with a gabion wall at a distributed load of intensity q = 100 kPa [14].

The number of gabions piled one on top of the other	**stability coefficient FB**	Coordinates of the characteristic points of the circular slip surfaces						surface radius of the slip R [m]
		start		end		middle		
		Xp[m]	Yp[m]	Xk[m]	Yk[m]	Xo[m]	Yo[m]	
0	**1.299**	10.0	10.0	20.0	5.0	19.430	16.371	11.375
2	**1.232**	9.9	10.0	18.2	5.0	17.499	13.236	8.255
3	**1.175**	9.8	10.0	18.0	5.0	16.713	12.124	7.229
4	**1.129**	9.9	10.0	17.0	5.0	15.486	10.401	5.599

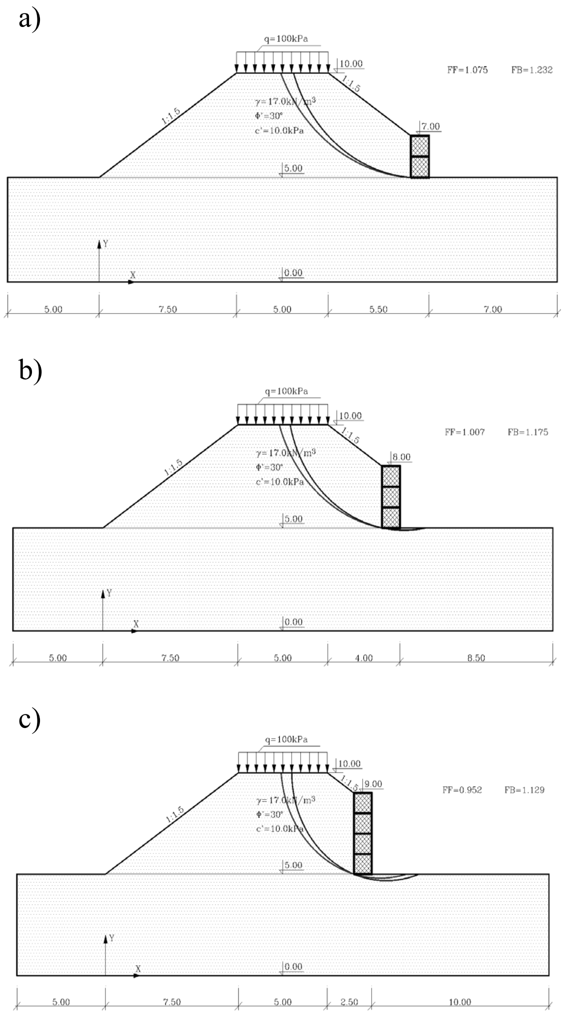

Fig. 15. Slip surfaces with the lowest stability coefficient with a load of q = 100 kPa for the gabion wall: a - consisting of two layers of gabions, b - consisting of three layers of gabions, c - consisting of four layers of gabions [14].

5. CONCLUSION

The usefulness of the FILTER numerical program [2] has been confirmed to determine the filtration field in the embankment at the damming of water at a level equal to the height of the embankment.

Stability analysis is of comparative nature: the values of stability coefficients calculated using the Fellenius and Bishop method, as well as geometrical parameters of the determined slip surfaces were compared with the values analogously calculated for a conventional embankment (without a retaining wall) with maximum water damming. From the summary of the results of calculations it follows that in all types of embankment with the gabion wall the condition of general stability at the maximum water damming is fulfilled.

However, it can be seen from tables 3 and 4 that in the case of an embankment with a gabion wall, the general stability laden in the crown is not ensured.

In the analysed cases of water-bearing embankment and operationally loaded, the values of stability coefficients depend on the configuration of the gabion wall.

The geometry of the gabion wall adopted in the models under consideration does not ensure the increase of the stability coefficient value. The disadvantageous phenomenon is particularly visible in the case of the embankment subjected to the operational load. The above statement may trigger discussion on the quality of the analysed models of the embankment supported by the gabion wall. As is known, the task of the retaining wall is to increase the value of stability coefficients, so the problem is located in the models. The constructed models are characterized by the same slope of both slopes (1: 1.5), while the width of the analysed slope is uneven and it is shaped:

- in a model without a gabion wall: 7.5 m,
- on models with a gabion wall composed of two, three and four modules successively: 5.5 m; 4 m and 2.5 m.

If the 7.5 meter-wide escarpment were left, then the grading slope of the models would be more gentle than the standard 1: 1.5 and would be advantageously reduced as a function of the height of the gabion wall. In such arrangement of models, the trend of changes in the values of stability coefficients (magnification) would be generated by the slope change. In conclusion, it is necessary to emphasize the basic character of research and the necessity of their continuation on appropriately modified models.

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