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STUDY ON THE ECONOMIC EFFICIENCY OF SLOPE CONSOLIDATION BY DIFFERENT METHODS

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Abstract

Slope instability and erosion of the soil by water and wind are major environmental hazards. Although they are result of natural geomorphological processes, they are both affected by and have consequences for human activity often incurring economic and social damage. The main objective of this study is to determine the costs of slope consolidation by using different methods. There were studied four techniques for slope consolidation: vegetation, gabions, nets biodegradable jute expanded clay and vegetation, respectively geotextiles. The economic efficiency was determined on an area of 100 m^2 for each case under study. Based on the obtained results, the variant represented by nets biodegradable jute expanded clay and vegetation had a total cost of 4735.12 lei, the cost per square meter of consolidated area being of 47.35 lei. This variant offers a pleasant aspect of the slopes and does not involve very high costs, compared to the variant represented by the arrangement of slopes with gabions.

Key words*: slope, economic efficiency, cost, consolidation techniques, vegetation.*

INTRODUCTION

Slope instability and erosion of the soil by water and wind are major environmental hazards. Although they are result of natural geomorphological processes, they are both affected by and have consequences for human activity often incurring economic and social damage (Morgan and Rickson, 1995). Slope failures are the movement of soil, and they occur on both artificial and natural slopes. Potential causes for slope instability range from deep-scared failures (such as with landslides) to surface erosion (such as when steep slopes cause water to travel in concentrated flows, eroding a series of gullies). There are many types of slopes failures, including rockfalls, rockslides, debris avalanches, debris flows and slumps, earth flows (Fay et al., 2012).

Human-induced modifications that may adversely affect external loads to slopes include grading of the existing slope or adjacent slope, construction adjacent to the slope, construction damage caused by blasting, and vibration of passing vehicles (Turner and Schuster, 1996). Slope regrading can create an over steep toe, or base of the slope, or an accumulation of material at the crest, which can lead to erosion. The shape of the slope can be a defining factor in its stability.

Natural slopes are generally concave, which is the most stable type of slope and experiences the least erosion (Schor and Gray, 2007). Many man-made slopes are linear and research has found that in many cases a linear slope will erode until it becomes concave (Fay et al., 2012). Mechanical stabilization techniques utilize non vegetative or nonliving components such as rock, gabion baskets, concrete, geosynthetics, and steel pins to reinforce slopes. These techniques can provide stability to both cut and fill slopes. Structures are generally capable of resisting much higher lateral earth pressures and shear stresses than vegetation. Mechanical stabilization techniques include retaining walls, mechanically stabilized earth, geosynthetically reinforced soil and other in-situ reinforcement techniques. For anchoring shallow soils, use of *in situ* earth reinforcements and recycled plastic pins has been reported in slope stabilization (Fay et al., 2012).

MATERIALS AND METHODS

The consolidation of slopes is very important in our country as well as worldwide. Nowadays there are numerous different slope stabilization methods but unfortunately many of them are unesthetic and very expensive. The study area is represented by slopes located in Cluj-Napoca.

In order to be able to calculate the economic efficiency, both classical and modern techniques were considered. The calculations were performed on an area of 100 m^2 for each studied variant: using vegetation, gabions, net biodegradable jute + expanded clay + vegetation, geotextiles, geocells and grass.

To consolidate the degraded slopes with vegetation we used the following species *Hedera helix*, *Campsis radicans*, *Cotoneaster horizontalis*, *Euonymus fortunei* and *Chaenomeles japonica.* 150 plants were used, 30 pieces of each species. The expenses for a plant varies between 19 and 35 RON. The planting of the species was done manually in pits of 15 x 15 x 20 cm and 30 x 30 x 35 cm. In order to carry out this work, two workers were needed, who dug, planted and watered the plants.The plants were planted with the root ball in ground. To consolidate the degraded slopes with gabions (Figure 1), in order to carry out this work, an excavator was needed to dig the foundation where the gabions will be located. The following materials were used: galvanized wire mesh with 2 mm wire diameter and 40 x 40 mm eye dimensions - 891 m^2; steel bar with 16 mm diameter - 1188 m; galvanized wire with 2 mm wire diameter - 600 m, broken stone with 44 mm diameter - 223.08 m^3. In order to carry out this work, three workers were needed, who worked 120 hours to complete the task.

Figure 1. Gabions

To consolidate the degraded slopes with neds biodegradable jute, expanded clay and vegetation (Figure 2), was needed nets biodegradable jute having the technical data: 290 g/ml 101 cm x 1 ml. 110 m^2 of biodegradable jute were needed, 100 liters of expanded clay and 100 pieces of stakes to support the nets biodegradable jute on the ground.

Also, the folowing ten species of ornamental shrubs both through the leaves and flowers were used: *Juniperus horizontalis, Forsytia suspensa, Lonicera pileata, Syringa vulgaris, Viburnum opulus, Buxus sempervirum, Weigela florida, Kerria japonica, Cedru feeling Blue, Betula pendula*. In order to carry out this work, two workers were needed, who worked 36 hours to complete this work.

The plants were planted with the root ball in ground. The planting of the species was done manually in pits of 15 x 15 x 20 cm and 30 x 30 x 35 cm.

Figure 2. Neds biodegradable jute, expanded clay and vegetation

To consolidate the degraded slopes with geotextile (Figure 3), were used 110 m^2 of geotextile and 150 pieces of stakes to support the geotextile on the ground. A worker worked 12 hours to complete this work.

Figure 3. Geotextile

To consolidate the degraded slopes with geocells and grass, 100 m^2 of geocells and 5 kg seeds of grass were needed. In order to carry out this work, two workers were needed, for 16 hours.

RESULTS AND DISCUSSIONS

In Table 1 was calculated the economic efficiency for the consolidation of the degraded slope, using vegetation. The total cost for the purchase of the 150 plants was 3420 RON and the total cost of this variant of the study was 4593 RON.

In Table 2 was calculated the economic efficiency for the consolidation of the degraded slope using gabions. Expenses for excavation are 1700 RON.

The material needed for the arrangement slope cost 20159.75 RON and labor cost 3760 RON. So the cost of arranging a slope area of one m^2 is 256.19 RON.

This method of arranging the slopes is the most expensive of the ones presented in this study.

Table 1. The cost of arranging a degraded slope using vegetation (RON)

Costs	Materials (RON)	Manual labor (RON)	Equipment (RON)	Total (RON)
Employee				
Gross salary	-	661	-	-
Direct costs	3420	661	-	4081
Contributions to social insurance (25%)	-	165	-	-
Social Health Insurance (10%)	-	66	-	-
Personal deduction	-	510	-	-
Income tax	-	0	-	-
Net salary	-	430	-	-
Employer				
Insurance Contribution for Work 2.25%	-	15	-	-
The difference in CAS, CASS to their value for minimum salary				
Social insurance (CAS) 53.71%	-	355	-	-
Social Health Insurance CASS 21.48%	-	142	-	
Total taxes				
The employee pays the state	-	231	-	-
The employer pays the state	-	514	-	-
Total taxes collected by the state	-	743	-	-
Full salary	-	1173	-	-
To pay a net salary of 430 RON, the employer spends 1173 RON				
TOTAL COSTS	**3420**	**1173**	**-**	**4593**

Table 2. The cost of arranging a degraded slope using gabions

Costs	Materials (RON)	Manual labor (RON)	Equipment (RON)	Total (RON)
Employee				
Gross salary	-	3677	-	-
Direct costs	20159.75	3677	1700	25536.75
Contributions to social insurance (25%)	-	919	-	-
Social Health Insurance (10%)	-	368	-	-
Personal deduction	-	0	-	-
Income tax	-	239	-	-
Net salary	-	2151	-	-
Employer				
Insurance Contribution for Work 2.25%	-	83	-	-
The difference in CAS, CASS to their value for minimum salary				
Social insurance (CAS) 15.75%	-	0	-	-
Social Health Insurance CASS 6.27%	-	0	-	-
Total taxes				
The employee pays the state	-	1526	-	-
The employer pays the state	-	83	-	-
Total taxes collected by the state	-	1609	-	-
Full salary	-	3760	-	-
To pay a net salary of 2151 RON the employer spends 3760 RON				
TOTAL COSTS	**20159.75**	**3760**	**1700**	**25619.75**

In Table 3 was calculated the economic efficiency for the consolidation of the degraded slope using nets biodegradable jute, expanded clay and ten species of ornamental shrubs both through the leaves and flowers. Total expenses for the consolidation of 100 m^2 of slope were: the net biodegradabile jute cost 1309 RON, the expanded clay cost 163 RON, vegetation cost 1684.12 RON and the pieces of stakes to support the net cost 250 RON, and the labor was 1329 RON.

Table 3. The cost of arranging a degraded slope using nets biodegradable jute, expanded clay and vegetation

Costs	Materials (RON)	Manual labor (RON)	Equipment (RON)	Total (RON)
Employee				
Gross salary	-	893	-	-
Direct costs	3406.12	893	0	4299.12
Contributions to social insurance (25%)	-	223	-	-
Social Health Insurance (10%)	-	89	-	-
Personal deduction	-	510	-	-
Income tax	-	7	-	-
Net salary	-	574	-	-
Employer				
Insurance Contribution for Work 2.25%	-	20	-	-
The difference in CAS, CASS to their value for minimum salary				
Social insurance (CAS) 33.26	-	297	-	-
Social Health Insurance CASS 13.33%	-	119	-	-
Total Taxes				
The employee pays the state	-	319	-	-
The employer pays the state	-	436	-	-
Total taxes collected by the state	-	755	-	-
Full salary	-	1329	-	-
To pay a net salary of 574 RON, the employer spends 1329 RON				
TOTAL COSTS	**3406.12**	**1329**	**0**	**4735.12**

In Table 4 was calculated the economic efficiency for the consolidation of the degraded slope using geotextiles. The necessary for the material amonunted to 1154.9 RON, as follows 7799 RON cost 100 m^2 of geotextile, 375 RON cost 150 pieces of stakes to support the geotextiles and the labor was 950 RON. So the total cost of consolidation of 100 m^2 of slope was 2104.9 RON and the cost for 1 m^2 of consolidation with this material is 21.04 RON.

Table 4. The cost of arranging a degraded slope using geotextiles

Costs	Materials (RON)	Manual labor (RON)	Equipment (RON)	Total (RON)
Employee				
Gross salary	-	331	-	-
Direct costs	1154.9	331	-	1490.9
Contributions to social insurance (25%)	-	83	-	-
Social Health Insurance (10%)	-	33	-	-
Personal deduction	-	510	-	-
Income tax (10%)	-	0	-	-
Net salary	-	215	-	-
Employer				
Insurance Contribution for Work 2.25%	-	7	-	-
The difference in CAS, CASS to their value for minimum salary				
Social insurance (CAS) 132.02%	-	437	-	-
Social Health Insurance CASS 6.27%	-	175	-	-
Total taxes				
The employee pays the state	-	116	-	-
The employer pays the state	-	619	-	-
Total taxes collected by the state	-	735	-	-
Full salary	-	950	-	-
To pay a net salary of 215 RON, the employer spends 950 RON				
TOTAL COSTS	**1154.9**	**950**	**-**	**2104.9**

In Table 5 was calculated the economic efficiency for the consolidation of the degraded slope using geocells and grass. The expenses for the material are 2207 RON and the labor cost 1025 RON for the 16 working hours. The cost for consolidation of one m^2 slope is 32.32 RON.

Table 5. The cost of arranging a degraded slope using geocells and grass

Costs	Materials (RON)	Manual labor (RON)	Equipment (RON)	Total (RON)
Employee				
Gross salary	-	441	-	-
Direct costs	2207	441	-	2648
Contributions to social insurance (25%)	-	110	-	-
Social Health Insurance (10%)	-	44	-	-
Personal deduction	-	510	-	-
Income tax (10%)	-	0	-	-
Net salary	-	287	-	-
Employer				
Insurance Contribution for Work 2.25%	-	10	-	-
The difference in CAS, CASS to their value for minimum salary				
Social insurance (CAS) 92.97 %	-	410	-	-
Social Health Insurance CASS 6.27%	-	164	-	-
Total taxes				
The employee pays the state	-	154	-	-
The employer pays the state	-	584	-	-
Total taxes collected by the state	-	738	-	-
Full salary	-	1025	-	-
To pay a net salary of 287 RON, the employer spends 1025 RON				
TOTAL COSTS	**2207**	**1025**	**-**	**3232**

CONCLUSIONS

Among the presented arranging techniques for the degraded slopes, the less costly technique is the one that use geotextiles in the amount of 2104.9 RON.

The most expensive alternative arrangement for the degraded slopes was the gabions variant, amounting to the sum of 25619.75 RON.

Based on the obtained results, the variant represented by nets biodegradable jute expanded clay and vegetation had a total cost of 4735.12 RON. This variant offers a pleasant aspect of the slopes and does not involve very high costs, compared to the variant represented by the arrangement of slopes with gabions.

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