# USE OF GABIONS AND VEGETATION IN EROSION-CONTROL WORKS

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*Abstract* — Heavy winter and spring rainfall during the years 2005, -06, -07, and -08 brought about numerous torrential floods and landslides throughout the world and in Serbia. They endangered people, animals, settlements, fields, and roads. This reminded us of a readily available, cheap, and efficient material: stone in wire baskets of doubly galvanized wire of various sizes and forms – gabions – which are also long-lasting, flexible, and ecological. If made according to prescribed standards, they offer a permanent solution for many erosion-control problems. In addition, they can be used in urgent interventions to protect the lives of humans, animals, and plants and prevent of immense material losses. This paper calls attention to an unjustifiedly neglected but important material, easily manipulated and with significant advantages compared to other structural materials, as well as to the possibility of its successful combination with vegetation, viz., willow (*Salix* sp.) cuttings and grasses.

Key words: Erosion-control materials, ecological materials, gabions, erosion, vegetation, metals, wire, stone

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## INTRODUCTION

Gabions, wire or synthetic baskets of different forms and sizes filled with stone, can be widely used in erosion-control works. Compared to other materials and elements, they possess significant advantages, and they are often combined with forest vegetation.

The construction of gabions follows certain established norms. They are used in:

- closing of river banks and breakthrough of embankments;
- 2. landslide consolidation;
- 3. road construction;
- 4. protection of settlements on sloped terrains;
- 5. hydrotechnical forest or agricultural works, i.e., for channel improvement;
- reclamation of hilly terrains in hydrotechnical forest or agricultural works, building of structures for slope management, and maintenance of these structures;

- 7. protection of roads against rockfall by the application of highly resistant wire;
- 8. river and torrent watershed management in support of dams and groynes and as longitudinal structures; and in catchments for protection of biological erosion control works with the species *Salix*, *Pinus*, *Rubus*, etc.

# MATERIAL AND METHOD

Used in river bank protection and for closing the breakthrough of embankments, gabions are often combined with forest species that tolerate moisture and light.

Such use is especially significant in situations such as those that occurred last spring in Banat, Southern Serbia, and elsewhere. Meeting of 100-year snow and abundant spring rain caused the breakthrough of a dam in Romania and flooding of the river Tamiš. To aggravate matters, long-lasting rains of high intensity also caused the flooding of other watercourses in Vojvodina, in the neighborhood of Vučje, and in the Resavski and Jablanički Districts. This flooding required an urgent reaction involving elevation of embankments and the closing of breakthroughs, tasks which can be best achieved by gabions, especially if they have already been formed and stored near the critical settlements. They provide good ground for the line planting of cuttings of those species that are readily propagated by vegetative methods.

The collapse of banks and breakthrough of slopes usually occur gradually and are a consequence of permanent limited erosion in the form of shell slippage, mass movements, etc. The consequences of river bank collapse are disastrous, and it is necessary to intervene on time in order to prevent them. For this reason, we emphasize the significance of materials and works which prevent the occurrence of such phenomena.

Previous experience indicates that the most efficient means for closing and blocking crevices and rockfall are wire baskets of the parallelepiped type. The advantage of such gabions is that they can be used everywhere throughout the course of a river, from its source to its mouth, either as an intervention of a temporary character or as a permanent protection structure.

The method of working with gabions in the improvement of river banks and in earth dams

consists of riprapping ready-made elements into the river channel, i.e., along the endangered river bank. The number and quantity of gabions depends on the extent of rockfall, and they should reach an elevation which completely protects the critical place on the river bank or embankment.

In such a situation, ready-made smaller parallelepiped elements measuring  $2 \ge 1 \ge 0.5$  m and  $2 \ge 1 \ge 1$  m or cylindrical ones measuring  $2 \ge 0.8$  m are used at the moment of intervention.

It is easier to manipulate smaller-sized elements, which also allow for better piling. The rolling down and piling of gabions is performed from the edge towards the center, and this prevents widening of the opening and protects riparian vegetation (*Salix* sp., *Alnus* sp., *Populus* sp., etc.).

Similar experience is reported from the surrounding countries of Southeast Europe. Such interventions are frequently performed in Italy, especially along the river Po and its tributaries, as well as along other watercourses.

In rivers with high velocity, the greatest danger for works on river bank protection and gabions arises from removal of materials below the structure. This is where the flexibility of gabions becomes useful because they sink and move, thus checking the river's flow and stopping the further removal of materials. The great capacity for alteration of



Fig. 1. Gabion matress.

the form and position of gabion elements and their ability to adapt to all possible deformations are essential factors of structural stability, even under the action of the strongest currents. The installation of ready-made gabions is performed in several ways: by rolling down a wooden or iron inclined plane; by throwing or tipping from trucks; etc. It can be readily combined with planting of tree cuttings and seeds of hygrophilous trees and shrubs, as well as grass species.

The filling of gabion elements with fragments (bulk) provides good conditions for the building of a super-constructed structure of regular geometrical shape. A rockfill can be formed subsequently by supplying additional gabion elements, which strengthens the entire structure, especially if it is reinforced by tree and shrub roots.

Thus, it can be claimed that the collapse and breakthrough of river embankments, which are to be expected in critical sections of flood-prone watercourses, can be effectively solved by gabion instalment at the endangered places using already prepared gabions in sufficient number, together with fascines made of willow elements (Fig. 1).

It should be noted that in gabion construction and deployment along rivers, seashores, roads, and various structures, it is necessary to satisfy certain established norms regarding the thickness and quality of wire, method of mesh preparation, composition and joining of gabion elements and the gabions themselves, and their filling with different stone fractions. Here it is recommended that the piling be filled with as few gaps as possible. This prevents potential natural sinking with undesired consequences, which can occur in time. It is obligatory to apply wire trusses in the longitudinal, transverse, and (when necessary) vertical directions.

Gabions should be securely joined by the wire prescribed for the mesh before or during the filling. This contributes to monolithism of the structure and prevents the danger arising from greater deformations of the substrate.

Project managers need to predict the wider foundations and most vulnerable sections of the structure in order to prevent the consequences of pressure and thrust of the terrain and reduce the danger of erosion and water impact.

During transport, care must be taken to ensure that the gabions (their galvanized layer) are not damaged in any way.

To counter the action of erosion by abrasion, the face of gabions is protected with wooden strips longitudinal to the structure or by roundwood stakes driven into the ground. Gabions in contact with sea water should be controlled at least once in six months. These structures can also be protected by driving in wooden pilots with boards placed between them, which prevents the removal of finer fractions. The minimal free height of the pilots is 25-30 cm.

## **RESULTS AND DISCUSSION**

Load testing of gabions measuring  $3 \ge 1 \ge 1$  m, having wire opening of  $8 \ge 10$  cm and wire diameter of 2.7 mm, filled with  $3 \le 10$  cm and wire diameter of mass of 5.400 kg, and loaded with 7.800 kg of zinc and lead plates shows that there was no wire breaking or any other damage (Fig. 2).



Fig. 2. Technical testing of gabions.

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$$f_{p} = F/P$$
  
$$f_{p} = 0.26 \text{ kg/cm}^{2}$$
  
F- load (kg)  
R - area (cm<sup>2</sup>)

Thanks to this property and their drainage capacity, gabion structures are the most economical of all known systems and types of works on landslide rehabilitation.

The low cost of gabions makes them feasible for a wide range of applications, such as:

- drainage of retaining walls;
- canal revetment;
- damming of watercourses; etc.

Gabions are often used for landslide consolidation. It is known that attempts have been made to solve the problem of landslides by erecting massive retaining walls, whose mass should resist the thrust of earth in movement.

The frequent failures of such anti-landslide walls made of concrete and stone masonry caused by their cracking and disfunction led to the construction of drainage systems to remove water as the main cause of landsliding, as well as to combinations of retaining walls and drainage systems.

The result of such experience is the application of gabion structures, which have the capacity for drainage and the efficacy of a retaining wall, but eliminate all the disadvantages of both systems. They also improve the environment because they are often combined with vegetation (willow, poplar, alder, etc.).

The ideal solutions are gabion structures in situations such as the spring of 2005, when a long and cold winter with heavy rainfall brought about the mass occurrence of landslides on the territory of Serbia, especially endangering roads.

Gabions adapt exceptionally easily to the changed conditions and forces acting in landslides,

they are elastic, and there is no threat to stability and functionality of the entire solution, whereas concrete walls can crack and stone masonry can crash and fall to pieces.

Practice shows that a gabion structure reacts well to all forces (pressure, stress, torsion, etc.), so it is difficult to find ones which have failed, even if they are poorly constructed. It should be pointed out that established norms must be strictly respected regarding quality of material used and the method of fixing the elements and their further securing by additional trusses.

The effectiveness of gabions lies in the fact that deformations are transmitted to their individual elements and the structure takes on the characteristics of a reinforced whole with a wide capacity for automatic adaptation of both individual baskets and the stones in them.

This quality and their capacity for drainage give the structures an advantage over all other systems of landslide reclamation, especially since they can be beneficially combined with forest and grass vegetation of hygrophilous species, thus improving the environmental conditions.

It should be noted that in landslide drainage by gabions, a flume made of perforated concrete elements is installed in the solid terrain below all possible sliding planes. In this way, the bottom of the drainage is rendered impermeable. On a rocky substrate, the riprapping of stones is sufficient. Autochthonous tree and shrub species can be introduced in the interspaces, depending on the ecotope.

# CONCLUSIONS

Gabions can replace retaining walls founded on stable ground or smaller walls in a landslide area with foundations in the landsliding body. Such structures can be deformed, but they do not lose their efficacy, except in the case of catastrophes.

A characteristic feature of a retaining-drainage gabion wall is that it allows for non-resistant air circulation ensuring drainage of land behind the structure. It withstands changes of forces and pressures and is elastically deformed in extreme cases, as opposed to other structures, which fail as a rule. It also permits the development of vegetation.

Gabions can also be used to strengthen surface structures such as cunettes and canals for accumulation and drainage of water from the sliding body for the reasons already mentioned. A gabion revetment is an economical structure, with low cost of wire and stone materials from a building site and its surroundings. Its deployment is cheaper than the construction of mortarless stone walls. Moreover, such a structure represents favorable ground for the autochthonous flora.

A gabion revetment can be covered with soil and seeded, or it can be left for spontaneous vegetation to form a plant cover and protect the soil against erosion for a long period of time, which ensures significant ecological and esthetic effects.

Gabions are also used in canal revetments and for sills, especially when a canal has a steep slope. Their presence decreases water velocity, abrasion forces, and damage to the structures.

In landslide reclamation, the most frequent application of gabions is in the management of minor watercourses flowing at the foot of the landsliding body. In such an environment, rigid transverse dam constructions break and thus lose their function, as opposed to elastic gabions. Gabions can be employed in the systems of dams, where they achieve the desired effect. It is very important that the gabion wire be of good quality and durable, since it is exposed to abrasion by sediment. This is demonstrated by the existence of structures more than a hundred years old. These structures adapt readily to the terrain and are soon covered and fixed by vegetation, even before the action of abrasion processes, and such places can be easily and cheaply improved and maintained in good condition. Frequently planted species are willow, poplar, and pine.

After final sinking of the structure, the overflow is covered with a thin layer of concrete, and a reinforced structure is achieved in this way.

Thus, gabion structures are useful in many situations and possess numerous specificities and advantages, including a great potential for combination with autochthonous tree and shrub species.

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# КОРИШЋЕЊЕ ГАБИОНА И ВЕГЕТАЦИЈЕ У ПРОТИВЕРОЗИОНИМ РАДОВИМА

## ВЈАЧЕСЛАВА МАТИЋ

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Крутепротиверозионе, регулационе изаштитне грађевине од класичних конструкцијских материјала (бетон, камен, дрво и др.), због промене природних услова и реагујућих сила и чинилаца: земљишних, водних режима, притисака, потисака, поткопавања, клижења, урвања, неједнаке отпорности обала и др. по правилу пуцају и губе функцију. Само еластичне, флексибилне, трајне и еколошке габионске грађевине, које се брзо уклапају у природу и препуштају вегетацији (јединој природној противерозионој заштити), а поред тога су и јефтине, представљају права, трајна и ефикасна решења многих проблема еколошког инжењеринга. То је материјал који заслужује ширу примену, поготову што се лако комбинује са вегетацијом: врбовим резницама, за бујичне регулације, озелењавање потпорних зидова и угрожених косина са *Salix* L., *Populus* L., *Robinia* L., *Pinus* L. и др., као и семеном одговарајућих трава, са развијеним кореновим системом и надземним делом, који ове грађевине штите од спољашњих утицаја и учвршћује их. Комбинација вегетације и ових елемената,представља трајно решење проблема, које још и оплемењује средину и одлична је еколошко-инжењерска заштита земљишних и водних ресурса.