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RESEARCHES CONCERNING THE CONFIGURATION OF GEOTEXTILES IN THE EXECUTION OF REGULATORY WORKS IN THE RIVERBEDS

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ABSTRACT

The paper deals with the behaviour at hydrodynamic action of the geotextiles used in carrying out the regularization and shore defence works located in riverbed. The geotextiles have lately presented applications for the execution of bottom thresholds, of the management dams in riverbed. Also, geotextiles have become an important component in the structure of river defence works on riverbeds. The research was carried out on the lower course of the Moldova River in the area of Pildesti, Neamț County. The dynamic action of the floods, through the liquid and solid flows, influences the stability and the resistance over time of the constructions made from geotextiles. The researchers analysed the behaviour of the geo-bags made of polyester bags filled with local materials (sand and gravel stabilized with cement), used in the structure of the bottom thresholds, steering dams and in the shore defence works. The research results indicate a differentiated behaviour of the geo-bags depending on the location (in the water, or on the shore) and the mode of action of the water (dynamic or static). The action of the water, through the liquid and solid flow, degraded the structure of the geo-bags by breaking and emptying the filling material. The geo-bags showed a reduced resistance to the action of the alluvial material, especially when the dosage of cement indicated by the design was not achieved. The research highlighted the good behaviour of the geo-bags in the erosion phenomenon of the riverbed, when they were mulched on the erosion zones and ensured the continuity of the constructions in the riverbed (bottom thresholds and shore defences).

KEYWORDS: bottom threshold, degradation, erosion, geo-bag, steering dam

1. Introduction

The river regularization works are part of the watercourses to ensure the stability of the hydrological and hydraulic parameters on a well-determined sector. The design of the works of regularization and defence of the bank in the riverbed is realized with hydrological parameters (flows, levels, levels of defence, protected surfaces, etc.) obtained by the statistical processing of the data collected over large intervals [1, 4, 7].

The hydrological changes of the last time period influence the behaviour of the regularization and shore defence works located in the erodible riverbeds [12]. The morphological change in time of the riverbed determines new actions on the stability of the hydrotechnical constructions with the role of shore defence [5, 10, 9].

The shore defences are made of natural materials (wood, stone), artificial materials (plain and reinforced concrete, plastics) and composites. The shore defence works can be rigid (reinforced concrete slabs, stone) and elastic (stone gabions, geo-bags). The rigid-type defence does not behave effectively in erodible beds [10].

Geotextiles are used in the execution of bottom thresholds, steering dams and river bed crossings. Geotextiles have become an important component in the structure of shore defence works on riverbeds formed in weakly cohesive rocks [3, 10].

The paper deals with the behaviour of water geotextiles used in the regularization and shore defence works located in the riverbeds.

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2. Material and research method

The research was carried out in two areas located on the lower course of the Moldova River (Figure 1). The riverbed in the two areas consists of alternating layers of ballast, dusty sand and clay sand from the alluvial transport. The river foundation is weakly cohesive, which favours erosion of the riverbed and the banks [4, 9, 14].

The research areas are located on the lower course of the river Moldova, as follows (Figure 2):

- zone I is located near the town of Soci, Mirosloveşti commune, Iaşi county;
- the second zone is located downstream of the town of Pildesti, Neamţ county.

A condition for selecting the research areas was given by their endowment with works to regulate the riverbed executed from geo-bags. Also, the shore defence works should be made of concrete slabs and geo-bags. This situation is present on the lower course of the river Moldova.

The Moldova River presents in the research area a characteristic route of the lower course located in a low slope field area (Figure 3). The direction of flow of the river is NW - SE. The river Moldova presents the following characteristics up to the hydrometric station (SH) Tupilati: length - 176.60 km, surface of the river basin - 3951 km^2, slope - 1.30‰, average altitude - 236 m, average multiannual flow - 32.9 m^3/s, solid flow in suspension - 43.2 Kg/s [11, 13].

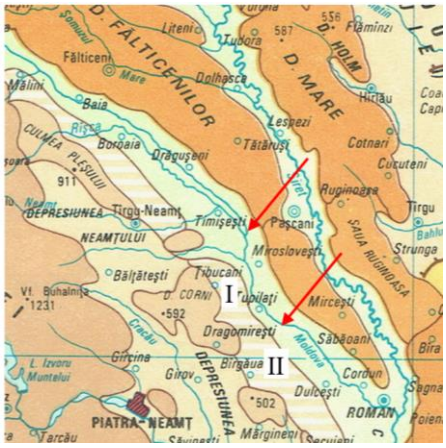

Fig. 1. *Location of the research areas on the physical map of the Moldova River: I - Soci area; II - Pildesti area* [14]

The research used hydrological data taken from the Tupilaţi Hydrometric Station, Neamţ County (average and maximum flows) [10].

Theoretical and experimental research was carried out in the following directions:

1. Researche regarding the modification of the constructive parameters of the regularization and shore defence works existing in the study areas.
2. Research on the behavior of the regularization works in time on the erosive action of water.
3. Research on the behavior of geotextiles in natural and anthropic actions in the site.
4. Analysis of solutions to improve the regularization solutions made with geotextiles in riverbeds.

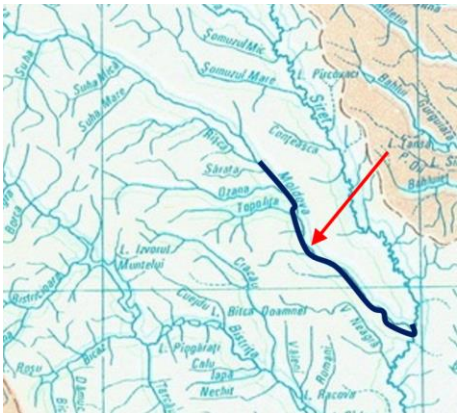

Fig. 2. *Localization in the hydrographic network of the lower course of the Moldova River* [13]

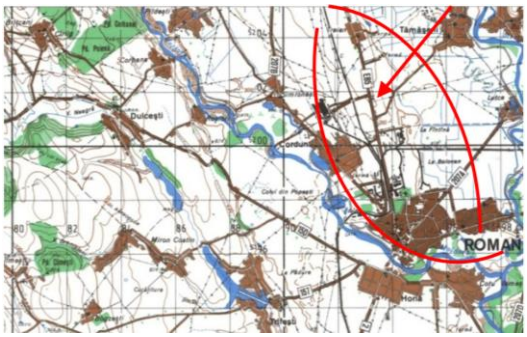

Fig. 3. *Location of the research area 2, Pildesti area, on the lower course of the Moldova River*

3. Results and discussions

3.1. Geotextiles used in the work of river regularization

Plastics are used in the construction of river defence works due to the high mechanical resistance to stretching. Some plastics are impermeable to very small thicknesses and have great flexibility. The realization of materials with large lengths and surfaces, with reduced weight, contributes to the increase of the execution efficiency [3, 10].

The introduction of the plastics materials in the structure of the hydrotechnical works is made with an

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easy technology and at relatively low costs. From the plastics used in river defence works, the geotextiles are detached. They are made in a wide range of types and have applicability under various geotechnical conditions. However, plastics are difficult to degrade over time or can hardly degrade [3]. Lately, biodegradable materials such as geotextiles, which replace part of plastics, have been used.

Geo-synthetic materials are flat structures of polymeric materials. The most commonly used types of geo-synthetics are geotextiles, geomembranes and geogrids. The functions performed by these are the following: separation, filtration, reinforcement, drainage, sealing and erosion protection [3].

Fig. 4. *Shore protection from non-woven geotextile mounted on the profiled slope of the river* [10]

Fig. 5. *Protection from geogrid + geotextile mounted on the profiled river bank* [9]

Geotextiles are materials made of polyester or polypropylene, woven or non-woven, being presented in a variety of thicknesses and strengths, depending on the scope. Geotextiles are classified according to their fabrication / non-woven, thermofixed and special type. Geotextiles are combined with geogrids for making ballast layers or reinforced earth walls. Geotextiles are flexible, which allows them a very good moulding on the mounting surface [3, 10].

A variety of geotextiles are used in the execution of the river bank consolidation works, at the embankment of dams and dams, at land masses, at drainage works and at support walls.

Biodegradable geotextiles are made in the form of textile fabrics, they are flat structures of plant (e.g. jute, coconut fibres) or animal (e.g. wool) materials. The most widely used biodegradable geotextiles are in the form of fabrics, seams and pressed bands [10].

Fig. 6. *Geotextile wool fabric mounted on the bank of a river as a support for the defence of the river* [9]

The woollen fabric is geotextile made from natural, non-reinforced wool fibres, which are biologically degraded in about 2-3 years. Grass seeds are placed over the woollen fabric placed on the river bank, and above these a filling with vegetable soil is performed. By using this composite, the sliding planes on the slope are avoided and the conditions for the protection with vegetal layer are ensured.

Over the last 25 years, work has begun to regulate rivers in geo-bags filled with ballast or ballast mixed with cement. Geo-bags are bags or mattresses made of polyester fabric stuffed with local materials [10]. Geo-bags are used for the protection of the river or lake shore, at the embankment dam etc.

Geo-bags have limited mobility on the three directions. Also, the commissioning technology is accessible and at a reduced price. The main disadvantage of the geo-bags is given by the mechanical resistance reduced to the action of the alluviums carried by the water.

The geo-bags are made for riverbed, steering dams, bottom thresholds, closing sleepers and mainly shore protection [10].

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a

b

Fig. 7. *Protection from geo-bags mounted on the river bank: a - bag/mattress-type geo-bag; b - shore defence from geo-bags* [9]

3.2. The result of the researches regarding the geo-bags behaviour in the works of river regularization

The studies and researches were carried out on sectors of the Moldova River located on the lower course, where regularization of the riverbed and shore defence works were performed using geo-bags. The river of Moldova in the two research areas presents a foundation formed by weakly cohesive rocks [4, 6].

Table 1. *Maximum flow rates (Qmax) with calculation probability (p (%)) for the study sector on the Moldova River* [3]

p (%)	2	5	10	20	50	95
Q_{max} (m^3/s)	1650	1275	1.000	558	31.0	2.13

The analysis of the structural and functional status of the geo-bags type works was carried out by in situ inspection, topographic measurements, visualization of the degradation forms, measurement of the geometrical parameters of the degradations, realization of photo and video surveys, etc. The data taken from the field were compared with those existing in the technical design documentation, or in similar works performed internally and externally.

The hydrological data analysis has revealed a high frequency of floods in the last 20 years in the study area. The hydrological studies carried out in the study area indicated the calculation and verification rates considered when designing the regularization and shore defence works (Table 1) [4].

A. Analysis of the behaviour of the shore defence works in the 1st research area, Soci area

In the Soci research area there is the hydrotechnical construction of the Moldova River sub-crossing by the Timisesti-Iasi adduction pipes (three steel pipes, of which two with a diameter of 1000 mm and a third with a diameter of 800 mm). The riverbed was calibrated, and the bank was protected with concrete slabs on the river's sub-crossing sector. The hydrotechnical work was executed between 1969 and 1971.

Between 2004 and 2012 there were a series of major floods on the river Moldova [4, 6], which partially and totally degraded the defences on some sections (Fig. 8.a).

a

b

Fig. 8. *Shore protection in the Sochi area: degraded concrete slabs (year 2008)* [4]*; b - defence from geo-bags (photo Sion, 2019)*

The technical expertise carried out in 2012 highlighted the state of degradation of the shore protection as a result of the action of water at floods, but also of the absence of maintenance works [4]. In 2015 the pipelines located in the subversion of the Moldova River were rehabilitated. Also, the shore

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defence was rehabilitated by using geo-bags as a solution to the instability of the foundation ground (Figure 8.b).

The shore defence is made of a structure of rectangular-shaped geotextile mattresses with a length of 1.50 m, width 0.80 m, height 30-40 cm and filled with ballast (Figure 8.b). The geotextile mattresses are placed with the long side parallel to the shore. Laying the mattresses horizontally was done in chess. Geo-bags in contact with water were filled with ballast mixed with cement [4].

The research was carried out between 2017-2019 and analyzed the behaviour of the shore protection executed from geo-bags. Field analysis and data processing indicated the following results:

- the shore defence behaved well in the action of the floods of 2016 and 2018, without showing significant degradation (Figure 8.b);
- a small number of geo-bags placed in the water contact layer were degraded by breaking down by the alluviums; the ruptures are in the direction of the water and have lengths of 3.0 - 8.0 cm;
- there was no movement of geo-bags vertically and horizontally.

B. Analysis of the behaviour of the regularization and shore defence works in the II research area, Pildesti area

The works of regularization and defence of the shore on the Moldova River in this area have the role of ensuring the optimal functioning of the underground water catchment in Pildesti. The riverbed was moved to the left bank. And through the bottom thresholds, the water level was raised to ensure the conditions of water capture.

The works of regularization and defence of the shore were executed from 1996. They were executed of reinforced concrete and stone. The floods on the river Moldova in 1994-2006 progressively degraded the works from the riverbed and from the shore. In order to remedy the works, consecutive renovations were carried out until 2006. The 2006 flood partially destroyed these works. The rehabilitation works of 2006 used in parallel geo-bags for the execution of the works of the river and the protection of the shore [10].

The shore protection and regularization works initially performed were made up of the following [8]:

- regularization works: moving the minor riverbed near the left bank through steering dams and closing sleepers; calibration of the flow section to a width of 90 m;
- shore defence works: reinforced concrete slabs supported on a simple concrete beam.

After 2006, works were carried out on the bank and on the shore, defence using geo-bags (geotextile bags filled with ballast) (Figure 9). Subsequent works carried out in 2017 (steering dock, closing dock, shore defence) were performed only with geo-bags [10].

The research was carried out between 2015 and 2019 and analyzed the behaviour of the shore protection executed from geo-bags. The analyzes performed in the field were realized at intervals of 3-5 months, or after passing a flood. The data processing and interpretation indicated the following results:

- the works made from geo-bags behaved differently depending on their location (in the riverbed and on the shore) and the complex of natural and anthropic actions;

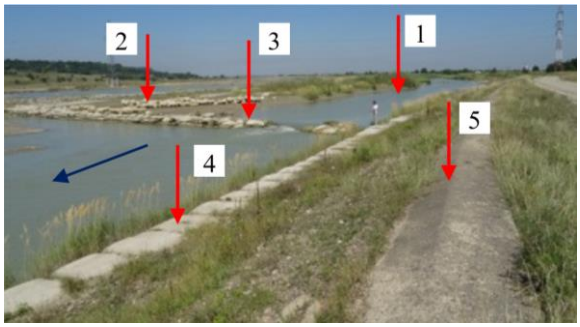

Fig. 9. *Works with geo-bags in the riverbed: 1 - diverted riverbed; 2 - steering dam; 3- bottom threshold; 4 - shore defence; 5 - old shore defence (photo, Sion, 2019)*

- the floods of 2006, 2008, 2016 and 2018 broke the submersible water steering dam to the river bank on the left bank; the phenomenon was determined by the maximum flow and the action of the alluviums (Figure 10);

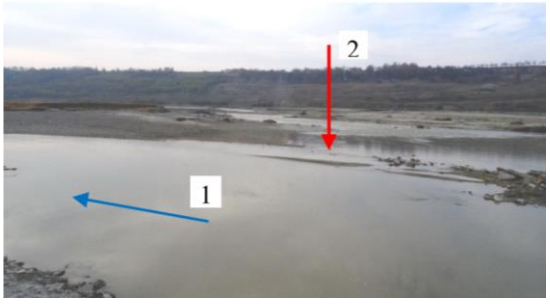

Fig. 10. *View of the branching area of the riverbed: 1 - deviated riverbed; 2 - steering dam (photo, Sion, 2015)*

- the destructive influence of the alluviums is relatively intensified by the presence of a ballast

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located at a distance of about 200-300 m from the area of technological change of the riverbed;

Fig. 11. *Structural degradation of a bottom threshold made from geo-bags (photo, Sion, 2018)*

- the closure cross executed from geo-bags was broken at the 2016 flood, which caused the main river to be moved to the right bank: the geo-bags were displaced by the action of the water from the site;
- the bottom thresholds made on the deflected bed and executed from geo-bags have the role of raising the water level; the bottom threshold is made of 2–4 rows of vertical geo-bags; the height of the bottom thresholds is 0.60-1.60 m;
- the degradation of the bottom thresholds by the hydrodynamic action is differentiated along the riverbed; degradation is manifested by moving geo-bags horizontally and vertically (Figure 11);
- some of the bottom thresholds analyzed were degraded by partially destroying a variable number of geo-bags and moving some downstream, or at the base of the threshold (Figure 12);

Fig. 12. *General view of the structural degradation of a bottom threshold made from geo-bags under hydrodynamic action (photo, Sion, 2019)*

- the analysis carried out in the field showed the total degradation of the geo-bags by breaking and evacuating the filling material; geo-bags partially emptied of material were moved from the downstream position, which changed the water discharge positions;

Fig. 13. *Degradation of works from geo-bags on water action on the Moldova River: 1 - bottom threshold; 2 - shore defence (photo, Sion, 2019)*

- the shore defence made from geo-bags is located at a variable distance from the old shore defence executed from concrete slabs (Figure 13 and 14);
- shore protection from geo-bags is located at a variable distance from the old shore protection work carried out from concrete slabs (Figure 9, 13 and 14);
- a limited number of shore protection geo-bags are degraded by rupture as a result of flooding carried by floods (Figure 15);

Fig. 14. *General view of the left bank defence works: 1 - old concrete slab work; 2 - new work from geo-bags (photo, Sion, 2018)*

- the analysis in the field showed that some of the geo-bags are degraded by local rupture and tearing by the flocks of sheep and goats passing through the shore area;

Research conducted on the lower course of the river Moldova has shown that the presence of weakly cohesive rocks in the bedrock foundation in time determines the loss of the stability of the regularization and defence works of the rigid type. A great influence on the degradation of the works is the action of the high frequency floods and important alluvial transport.

The results of the researches carried out in the two areas showed a satisfactory and differentiated behaviour of geo-bags at the action of the water

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depending on the location of the site (on the bank or on the shore), the way of completion and the quality of the filling.

Fig. 15. *Details on forms of degradation of geo-bags under natural and anthropic actions (photo, Sion, 2019)*

The works of regularization and defence of the elastic type bank work efficiently with the erodible riverbeds, they behave well in the settlements and movements in vertical and horizontal plane. Works in geo-bags do not affect the environment through the contribution of concrete and metal.

The morphological changes of the riverbed imply the modification of the calculation parameters when designing the regularization works regarding the hydrological data and the mechanical characteristics [4, 8].

An important conclusion is represented by the ecological behaviour of the geo-bags. Shore defence in geo-bags allows fine alluvium to be deposited on mattresses, thus forming areas for aquatic flora and fauna growth [2].

4. Conclusions

The studies and researches carried out on the lower course of the Moldova river revealed the different degradation of the old shore defence works following the hydrodynamic erosion of the foundation and the concrete slabs.

Studies and research carried out in recent years have highlighted the possibility of using geo-bags when carrying out regularization works subject to frequent action of floods with important solid transport.

The research carried out in two study areas revealed a variable behaviour of the geo-bags in the action of the water depending on the location (river / riverbed), their mode of accomplishment and the filling quality.

Elastic-type shore defence works, geo-bags type, work effectively with erodible riverbeds, behave well in vertical / horizontal settlements and displacements and do not affect the environment.

Ensuring optimal environmental protection conditions in the watercourses area requires the use of biodegradable geotextiles when carrying out regularization works.

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