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MONITORING OF DEGRADATION PROCESS OF THE SHORE DEFENCE WORKS IN ERODABLE RIVERBEDS

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ABSTRACT: *The paper presents the results of the research on the monitoring of the degradation of the shore defence works located in the Moldova riverbed, in the area of Soci, Iasi County. In the research area there are located three potable water pipelines that undercrossing the river Moldova. Monitoring was carried out by performing topographical measurements at predetermined time intervals as well as following hydrological risk events. Topographic measurements have been materialized by realizing topographical plans for the study area, transverse profiles and longitudinal profiles through the riverbed. The processing of topographic plans and cross-sections has resulted in the degradation of shore defence works under the influence of natural and anthropogenic risk factors. The analysis of the cross-sectional profiles indicated the hydrodynamic erosion over time of shore defence works. The analysis of the longitudinal profiles indicated the process of deepening the riverbed of the Moldova River on the researched section. The results of the research have allowed the design of river bedside and shore defence in the study area.*

Keywords: *hydrodynamic erosion; longitudinal profile; risk factors; topographic measurements; transverse profile;*

1. Introduction

Global climate changes also occur in Romania. These are present in the regional and local climatic evolution in Romania, respectively in the evolution of the temperatures and the distribution of the precipitations, the intensification of the desertification process, the degradation of the environmental conditions, etc.

A direct influence is felt on the hydrological cycle at the basin level and mainly on the annual distribution of precipitation and flow. Climate change determines a number of risk factors in the monthly and annual evolution of hydrological and hydraulic parameters on rivers in a hydrographic basin.

Risk factors are natural and anthropic, and their effect has become extremely potent in the natural and human environment.

In the last period of time, the influence of the anthropogenic risk factors on the local climate evolution is felt. Studies and researches conducted internationally and nationally confirm this hypothesis (Luca M., 2012, Romanescu G., Stoleriu C., 2013).

The hydrological regime of the rivers in Romania is characterized in the last period by the presence of maximum flows with high frequency of occurrence. Hydrological changes influenced the behaviour of shore defence works located in riverbeds (Luca M, Stoenescu I, 2007, Romanescu G., Stoleriu C., 2008). The aim of the paper is to analyse and investigate on the ground the way of behaviour of the bank defence works located on the Siret River basin. The purpose of the paper is to investigate the phenomenon of degradation of shore defence works on the Moldovan River protecting river sectors with important hydrotechnical and civil works.

2. Characteristics of the study area. Research methodology

The studies and researches were carried out on a Moldavian river sector located between Moţca and Mirosloveşti area. The detailed researches were carried out in the locality of Soci, Iaşi County (Fig.1).

The Moldavia River has a length of 160 km up to the research area, 3.567 km2 hydrographic area and 1.30% slope on the study sector. The river sector in the study area has a NW - SE orientation. The geographic coordinates of the analysed sector are: latitude 47010'50.00 "N, longitude 26037'10.11" E. The Moldova River presents a sinuous route with multiple morphological changes in the study area. In the research area in detail, where the construction of the underflow of the Timişeşti - Iaşi pipeline is located and the river presents a straight track made through regularization works.

The Moldova River presents two arms of different length (380-400 m), of which the left is more developed in cross-section and longitudinal section. The undercrossing area of the adduction pipelines is equipped with shore defence works over a length of 400 - 500 m.

The study section has a length of 420.0 m. The study sector has three steel pipes with a diameter of 1000 mm, which undercrossing the river bed. The river section presents an island in the study area that changes the layout of the bed in a horizontal plane. The surveyed river area comprises the two arms of the river separated by the island and the connecting area of the two arms downstream of the island. The width of the minor bed ranges from 260 m upstream to 127.0 m on the left arm, 74.0 m on the right arm and 141.0 m downstream of the island. The maximum depth of the river bed ranges from 4.74 m to 4.32 m along the studied river section. The Moldavian River presents in the study area a talvheg consisting of massive ballasts with thicknesses of 15 ... 20 m. The ballast layer extends into the major bed at distances of 100 ... 200 m. The non-cohesive material of the bed enables the formation of active hydrodynamic erosion processes.

On the Moldova River there is a number of ballasts in the study area. Most ponds are located on the left bank of the river

The research material consists of hydrological, hydraulic, topographic, geotechnical studies, safety in exploitation of hydrotechnical constructions, environment, etc. Studies have been conducted over a

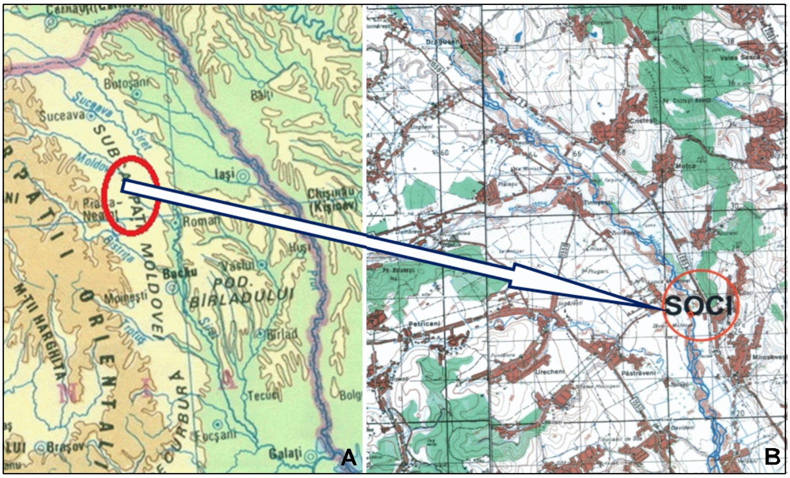

Fig. 1. Location of the research area on the Moldova river
A - the map of the river basin of the river Moldova; B - the research area of the degradation phenomenon of the riverbed.

period of about 30 years. Detailed research was carried out between 2004 and 2016.

Primary data was processed using statistical, hydrological, hydraulic calculation programs as well as special programs on the field of study.

3. Results and discussions

The flow regime in the river basin of the Moldavian River presents particularly great variations in time and space, with a high degree of torrentiality. The high degree of torentiality is highlighted by the extreme multi-annual values of the flow on the Moldova. The ratio between the maximum historical and historical flows is about 1000. High values of the torrential coefficient are also present for the average monthly flows (about 170 ... 175) and even the annual ones (about 5-6). Extreme values of rainfall occurred in different periods of the year: May -1972, June and July-1969, July and August 1991, September-2001, April-2005, July-2008, etc. The high degree of torrential influence has influenced the behaviour of shore defence works.

Hydrological risk factors are represented by high-flowing flows that reach and exceed the calculus probabilities imposed on the design of bed constructions (bridges, adjustments) and shore (shore defence works, dykes). Hydrological risk factors affect locally, but also along the river bed morphology and indirectly, the habitat existing in the minor and major river bed (Luca M., 2016).

The theoretical studies pursued the following objectives:

- processing hydrological and hydraulic data specific to the river section considered in the research;
- determination by calculation of lengths and depths of erosion in the transverse and longitudinal sections located on the analysed river sector;
- comparative analysis of the topographical plans drawn up for defined periods of time;
- processing and interpretation of the measurements by qualitative and analytical highlighting of the morphological changes of the river bed.

Experimental field research presented the following steps:

- drawing up the basic topographic plan of the river sector considered in research;
- topographic measurements for the realization of the basic transverse profiles through the river bed in characteristic sections of research; measurements for updating the transverse profiles (Fig. 2);

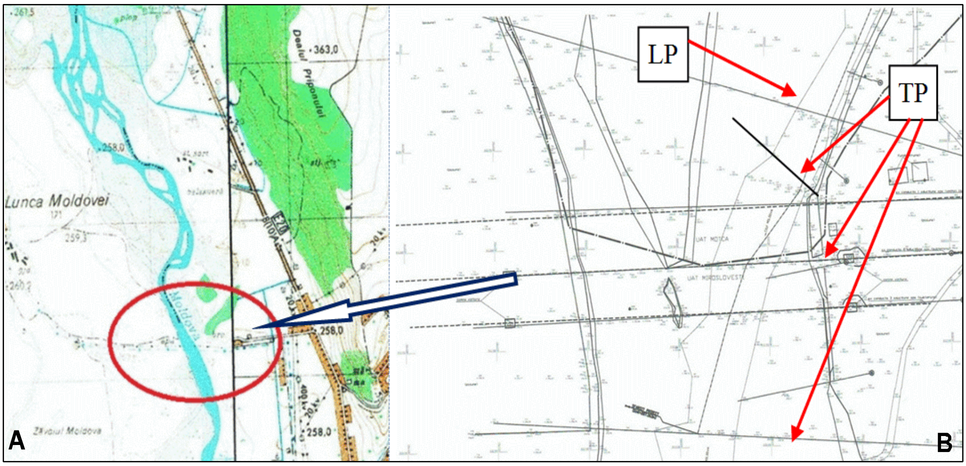

Fig. 2. Situation plan of the research area on the Moldova River

A - location of the study area; B - location of transverse and longitudinal profiles on the research sector.

- topographic measurements for the longitudinal profile of the river bed and its updating at time intervals, or the important modification of the river bed configuration;
- topographic surveys at time intervals to assess the morphological changes of the riverbed.

A main component of field research is the taking of photographic and video images in the analysis sections of the morphological changes of the riverbed.

By means of the measurements, transverse and longitudinal profiles are formed in characteristic sections through the minor and the major ones. The hydrodynamic erosion value of the bed is measured on the longitudinal and transverse profiles. Measured values are compared to those calculated according to standardized or considered significant research relationships.

The shore defence on the Moldova River was carried out in two different stages, depending on the period of execution of the undercrossing of the pipelines. The first shore defence was carried out in 1911. The second shore defence was carried out in the 1970s - 1971, with the execution of the underflow of adduction pipes AdIIa and AdIIb (Fig. 2). Four types of shore defence (code A1, A2, A3 and A4) were made on the study area. Type A1 shore defence consists of two overlapping constructive structures (Fig. 3.a, 3.b).

The first structure (the basic structure) is a massive stone with a height of 1.80 m and a width of 2.90 - 1.50 m, which is placed on a fascia mattress. The second structure consists of concrete slabs (50x50x10 cm) mounted on a ballast bed and supported on a simple concrete beam. The tile pillar has tilting inclination 1: 1.5 and is mounted at a height of 1.70 m.

Field research has analysed how the coastal defence construction works in time to the natural and anthropic factors of the site.

The degradation of the shore defence works was carried out by destructive processes during the years 2000 - 2015. The degradation process included the following steps: a - washing the alluvial offshore defence (Fig. 4.b); b - removing the cement mortar from the joints and washing the ballast layer under the tiles (Fig. 4.c); c - cracking and cracking of concrete slabs; d - the entrainment of the rock from the supporting mass and the collapse of the defence building; e - breaking of the support beam and the collapse of the concrete slabs (Fig. 4.d); f - the drilling of concrete pieces in the riverbed and the erosion of the bank (Luca 2012, Luca 2016).

Shore defence works on the Moldova River were clogged with alluviums during the first years of operation. Between 2000 and 2016 the hydrological and hydraulic regime on the researched river sector has changed.

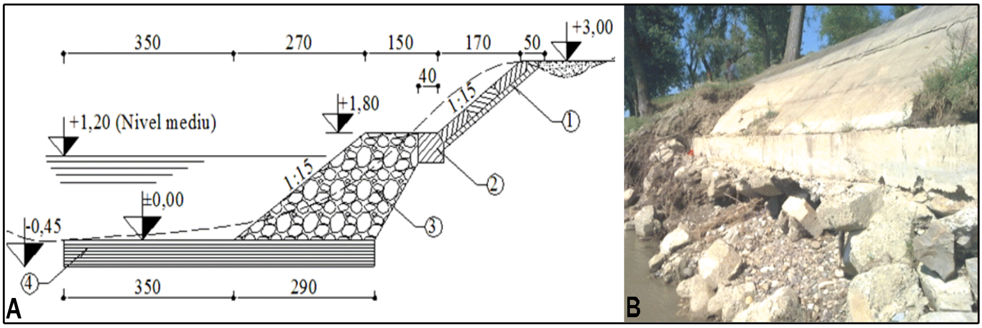

Fig. 3. Images of the shore defence on the Moldova River
A - execution pattern for type A1; B - detail on the state of exploitation of shore defence on the Moldova river, Soci area in 2010.

Fig. 4. State of decay in time of the bank protection
A – the situation of defence works in 2005 year of the left transversal profile number 10, TP10lf;
B – silt washing in the 2008 year; C – degradation of tiles, 2010; D – training tiles and collapse into bed in the 2012 year.

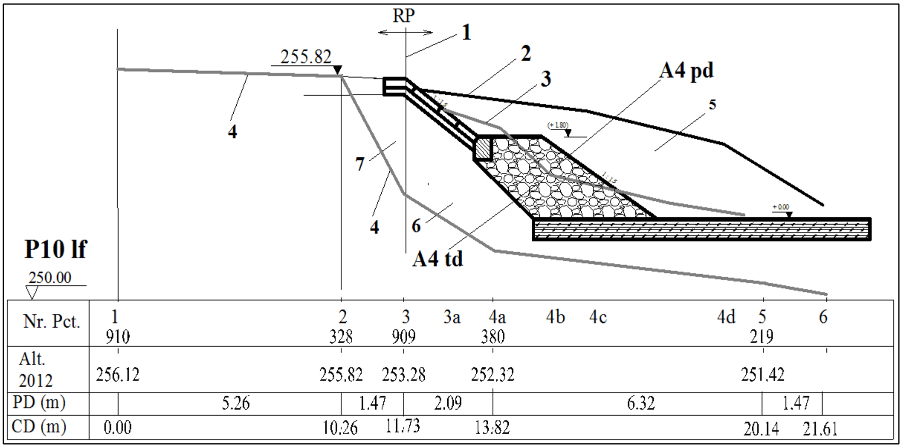

Fig. 5. Analysis and calculation scheme of the erosion phenomenon in the left bank of the Moldova river, transversal profile TP10 left
1 - reference point 2; 2 - shoreline in 2006; 3 - the bank line in 2008; 4 - shoreline in 2012; 5 - layer of alluviums; 6 - shore erosion area; 7 - erosion area in minor bed; A4 – type A4 bank of defence; A4 pd - partly degraded shore defence; A4 td - total degraded shore defence.

Natural risk factors, corroborated with those of anthropogenic risk, have accelerated the degradation of shore defence works until their total destruction. The shore defence works were more degraded on the left bank, where the phenomenon was accelerated by two anthropogenic risk factors: a - exploitation of river bed ballast in the upstream section of the research sector; b -

absence of maintenance and repairs works of the shore defence.

The monitoring of the shore erosion phenomenon and the degradation of shore defence was carried out periodically and in imposed situations (floods), in the research sections (transverse and longitudinal profiles). Topographic measurements have been transposed across the cross-sectional profile assigned to each research section. Topographic measurements were completed with photo and video capture. Topographic measurements had two reference points: the first is installed on the CV4 vane pit (Fig. 2); the second is fixed to the shore defence crown of the considered cross-sectional profile (Fig. 5 and Fig. 7).

The topographic monitoring mode for a research section is presented in Figure 5, where three topographical measurements made in 2004, 2005, 2006, 2008 2010 and 2012 in the TP10lf transverse profile are highlighted.

A series of lengths and depths were measured using a laser type telemetry. The processing of the experimental data for the Pt10st transverse profile is presented in Table 1.

The analysis of the data in Table 1 and Figure 1 shows the influence of the floods on the erosion of the left bank of the Moldova River. The processing of data taken from topographical measurements results in lengths and depths of erosion at the bank of the Moldova River, including bank protection in the TP10lf cross section. The bank of the bank in 2006 (line 2, Fig.5) resulted from the embankment of the shore defence works carried out in 1970. The alluvial deposit was eroded by the floods produced on the Moldova River in the years 2005, 2006, 2008, 2010, 2012, determining the situations presented by lines 3, 4 and individual measurement points (Fig. 6), Table 1).

Similarly, the data for the other cross-sections were processed. Some profiles were recorded during the research period only by the erosion of the alluvial deposit, for example the TP11lf profile (Fig. 7).

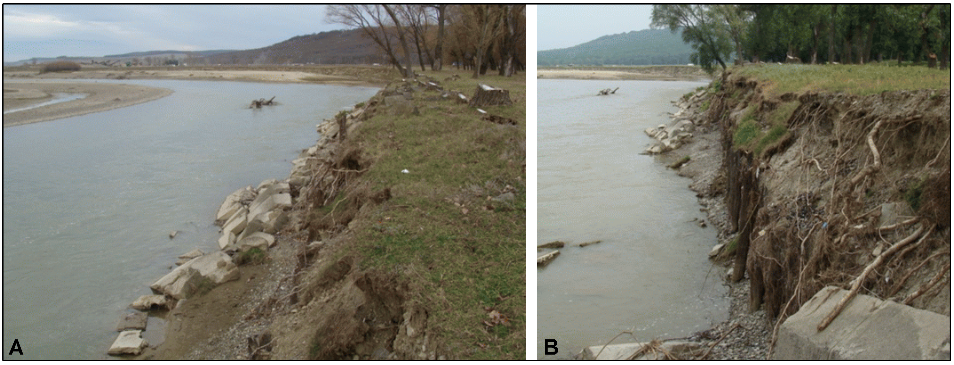

Fig. 6 - General view of the total degradation of shore defence and left bank erosion of the Moldova River in the research area

A - the left bank, the upstream area, the year 2014, the profiles TP1lf -TP6lf; B - left bank, central area, 2014, profiles Pt8l - Pt11l.

Table 1. Monitoring of erosion parameters - TP10lf Moldova River

Period	**2004**	**2005**	**2006**	**2008**	**2010**	**2012**	**2014**
L (m)	18.42	17.21	16.11	13.91	12.88	- 1.47	- 1.92
*H*er (m)	-	-	0.42-0.69	1.76-1.93	2.27-3.05	2.88-4.12	3.28-4.80
Obs.	-	-	-	D.p.ap.m	D.p.ap.m	D.t.ap.m	Er.m.
D.p.ap.m. - partial shore defence degradation; D.t.ap.m - total shore defence degradation; Er.m. - the river bank erosion							

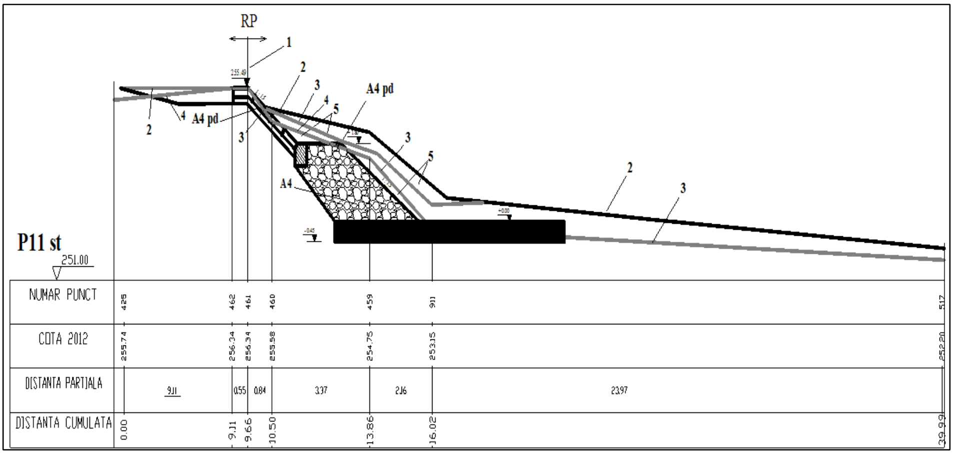

Fig. 7. Scheme of analysis and calculation of the erosion phenomenon on the left bank of the Moldova river, cross-section TP11lf:

1 - reference point 2; 2 - shoreline in 2006; 3 - the bank line in 2008; 4 - shoreline in 2012; 5 - layer of alluviums; 6 - shore erosion area; A4 - type A4 bank of defence; A4 pd - partially degraded shore defence.

The data collected from the longitudinal profiles were processed by drawing up the graphical diagram and tables with erosion depths. The analysis of erosion depths is difficult to achieve due to the change in time of the bed valley.

This is evident in the left bed, where the talhveg in 2004-2006 was positioned on the island and in 2010 it was positioned to the left bank (Fig. 1.b).

The displacement of the trough is determined by upstream flow conditions where the anthropic risk factor dominates the natural factor.

The main anthropic factor influencing the current flow on the Moldavian River upstream of the research area is the exploitation of the ballast at a distance of about 150 - 200 m.

4. Conclusions

• The comparative analysis of initial and after floods topographical plans indicates a number of significant morphological changes in the riverbed, with particular impact on the dynamics of solid and liquid flows.

• The undercrossing area through minor riverbed the river has two branches generated by the presence of alluvial formations (an island) that modifies the configuration of solid and liquid flows and levels in flood value.

• Longitudinal sections have revealed the deepening of the riverbed as determined by hydrodynamic erosion. Values increased in the last 15 years and influenced the stability of the construction of transmission pipes undercrossing.

• Lack of flow control works in the riverbed led to the formation of currents that influence and generate hydrodynamic erosion, with significant effects on bank protection works.

• The floods from 2006 and 2008 intensified a series of morphological changes in the river channel, particularly in the left bank, a situation that resulted in partial and total degradation protection works.

• Transport capacity of the Moldova's minor riverbed in the undercrossing area need to be restored by recalculating and updating the topographic geometrical parameters as planned.

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