REMARKS CONCERNING UNDERMINED TRANSVERSE HYDROTECHNICAL STRUCTURES USED FOR TORRENTIAL WATERSHED MANAGEMENT IN CRIS RIVER CATCHEMENT

Davidescu Şerban Octavian* Davidescu Adriana Agafia* Ungurean Cezar*
Tudose Nicu Constantin * Adorjani Andrei*

*Forest Research and Management Institute, Braşov Station, 13 Cloşca St., Braşov, Romania,
E-mail: s_davidescu@icas.ro
E-mail: agafiadavidescu@yahoo.com
E-mail: ucezar@yahoo.com
E-mail: cntudose@yahoo.com
E-mail: adorjaniandrei@yahoo.com

Abstract

The paper presents some research results regarding one of the most important damage that occur during torrent control hydrotechnical structure service. First, it refers to the occurrence frequency of undermining in the environmental conditions of Cris catchment area. In 10 torrential watersheds and improvement perimeters 315 transverse hydrotechnical works were studied. The paper analyzes the influence of structure elevation height and the influence of structure's downstream sustainability by another hydrotechnical work; over the frequency rates of the event, trying to establish what kind of structures are more vulnerable to be undermined. After a short presentation of the undermining characteristics, it is presented how this behavioural event influence the general condition of the structure through its impact over the ruptures that occurred and over structures condition rate. Finally the role of the riverbed lithological structure, the sediment size grading and the sustainability of the structure over the intensity of undermining were studied.

Key words: undermining, torrent control, condition rate, hydrotechnical structure

INTRODUCTION

During a long period of time, more than 100 years, within Cris river basin limits, 1175 transverse hydrotechnical structures have been built (Adorjani et al., 2008), being used 39 different types and more than 50 constructive variants (Lazăr, Gaspar, 1994). All these structures were placed on very different environmental condition (relief, lithology, climate, land use), leading to various reactions, materialized in many behavioural events (damages and dysfunctions).

Undermining is a damage that consists in unveiling the foundation of the structure's body, mainly by water and sediment flow. The phenomenon progresses to full uncover of the foundation and laterally it can develop to the full width of it. Due to loss of front support, as a result of floods or due to the dynamic action of floating, transverse work may fall, may break, or suffer ruptures of fragments of its body. It represents an important damage of torrent control structures that leads to entire construction overthrow, or to ruptures affecting the structure body (Clinciu et al., 2010, Clinciu, 2011).

Taking into account these implications and its frequent appearance, following body breaking, undermining is the most important damage possible to occur during torrent control structures service (Davidescu et al., 2012 a).

The experience gained in the research of natural events and the importance of torrent control structures to mitigate riverbed erosion and to prevent downstream sediment deposits (Mircea et. al., 1992, Lazăr, Gaspar, 1994, Conesa-Garcia, Garcia-Lorenzo, 2008, Clinciu et al. 2010, Clinciu 2011, Garcia et al., 2011) led to a better understanding of the behaviour and benefits of torrent control structures and to the substantiation of a complex research methodology regarding their reactions to environmental and human challenges.

Factors that favour this event are sill spacing, sediment size grading, riverbed slope (Marion et al., 2004), but the land lithology has also a decisive impact over the torrent control structure behaviour. Apart these factors, structure age, watershed area among other morphometric parameters and land use within watershed boundaries have a special role in how hydrotechnical works behave.

MATERIAL AND METHOD

The subjects of the research are hydrotechnical transverse structures made during time in order to improve torrents within Criş River Catchment. They are 73 traverses (structures with no elevation on spilled area), 172 sills (structures having an elevation between 0.1 to 2.0 m) and dams (structures having over 2.0 m elevation) placed on 52 streams located in the upper Cris River Basin (Tisa tributary). Those 52 streams are part of 10 torrential watersheds or improvement perimeters, as shown in table 1.

Table 1

Location of the studied transverse torrent control structures

River basin	Torrential watershed or improvement perimeter	No. of torrential streams	No. of transverse structures inventoried
Criş Alb	Şipot Stream	9	35
Criş Negru	Băiţa Poiană Perimeter	9	23
	Sălişte de Vaşcău Perimeter	9	21
	Crăiasa Valley	4	51
	Aleşdului Valley	1	8
Criş Repede	Bociu Valley	4	59
	Iadului Valley (origins)	3	15
	Bisericii Valley	6	33
	Rachiţa Valley	4	52
	Marghiţa Valley	3	18
TOTAL		**52**	**315**

Each studied torrent control structure was assessed from a behavioural point of view, meaning that all damages and dysfunctions were inventoried and measured. For every hydrotechnical work the condition rate was calculated (Davidescu et al., 2012 a) based on the most important damages occurred during their service. Using this method of quantifying the cumulative effect of the most important damages occurred in service it is possible to substantiate an objective system to establish the repair order of damaged structures (Davidescu et al. 2012 b).

To assess the undermining and to classify structures according to the intensity o this damage, the maximum depth of the unveiled foundation (in cm) was measured and the proportion of its affected width (in %) was evaluated. The intensity of the undermining was established based on the product of measured and evaluated parameters.

Depending on the distance between two successive works, the slope of the riverbed and the height of downstream structure siltation; 4 categories of influence of downstream structure were established for each assessed transverse work. These four categories were rated from 0 to 3, where 0 represents the situation "no support from downstream structure" and 3 represents "fully supported work" (the siltation of downstream structure is reaching the elevation of the studied structure). To these four categories a new one (4), that include transverse works capturing water for a drain channel, was added.

RESULTS AND DISSCUSIONS

On the riverbed of the 52 torrential streams improved using torrent control structures, 58 undermined structures were found, which represents 18% from the total amount of studied works. They are 56 structures without apron, representing 29% of the structures in this category. Two structures have the apron destroyed this failure being the triggering reason of the undermining.

Undermining was mentioned at 24 transverses (representing 33% from the total amount of them), 25 sills smaller than 1 m height (24%), 6 sills having a height between 1 and 2 m (9%) and 3 dams with a height between 2 and 3 m (8%), in this last category being included both structures with an apron, mentioned above. Excluding from the analysis those hydrotechnical works having an apron, the proportion of undermined traverses is 38%, of 1-2 m sills is 37%, of 1-2 m sills is 20% and of 2-3 m dams is 4%; resulting a significant reverse correlation between the occurrence frequencies of undermining and the structure height (fig. 1), the regression indicating a lower risk of undermining as structure height increases.

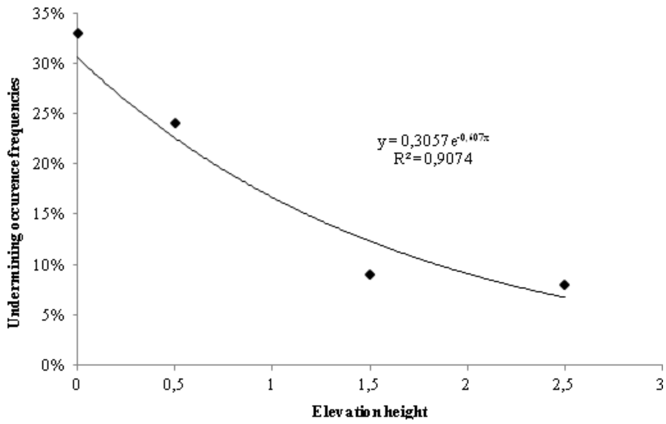

Fig.1 The occurrence frequencies of body undermining depending on elevation height

Referring to the influence of downstream structures over the occurrence frequencies of this behavioural event, a larger proportion of structures without support or with a small support from downstream (categories of downstream structure influence 0 and 1) are affected comparing to the others categories. As illustrated in figure 2, 24% from structures not benefiting from downstream support are undermined, the same percentage of affected structures being in category 1 of influence from the downstream structure; while the structures included in category 2 of downstream support being affected in 22% of cases and the fully supported hydrotechnical works (category 3) being undermined only in 2% of cases. The structures that capture water for a drain channel are not affected by undermining.

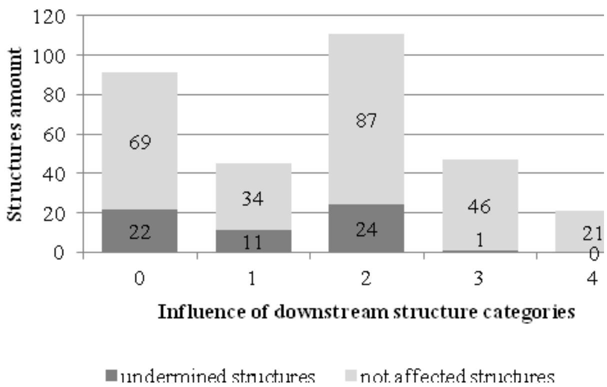

Fig.2 Transverse works with undermined body related to downstream sustainability

The damage characteristics (depth, proportion of the structure width affected and the undermining intensity) presented in table 2, reveal that 10% of these structures are endangered due to the very high intensity of the studied behavioural event; 38% having more than 80% of their width unveiled. In terms of depth, at 47% of the undermined structures the undermining depth is less than 0.5 m.

Table 2

Amount of undermined transverse works depending on undermining characteristics

Undermining depth			**Proportion of the affected structure width**			**Undermining intensity**		
Category	**Structures amount**	**%**	**Category**	**Structures amount**	**%**	**Category**	**Structures amount**	**%**
≤0.5m	27	47	≤20%	3	5	very low	4	7
0.5-1.0m	22	38	20-40%	10	17	low	15	26
1.0-1.5m	7	12	40-60%	10	17	average	17	29
>1.5m	2	3	60-80%	13	22	high	16	28
			>80%	22	38	very high	6	10

Mentioning that 22% of undermined structures are not affected by other damages, we have noticed that undermining is linked especially with ruptures, 48% from these structures having fragments of their body detached. The close connection between those two behavioural events is also highlighted by the significant correlation between the undermining intensity (expressed by the product between undermining depth and the proportion affected) and the percentage of the detached fragments from the spilled area, respectively from the whole structure body (spilled area and body wings), as shown in figure 3.

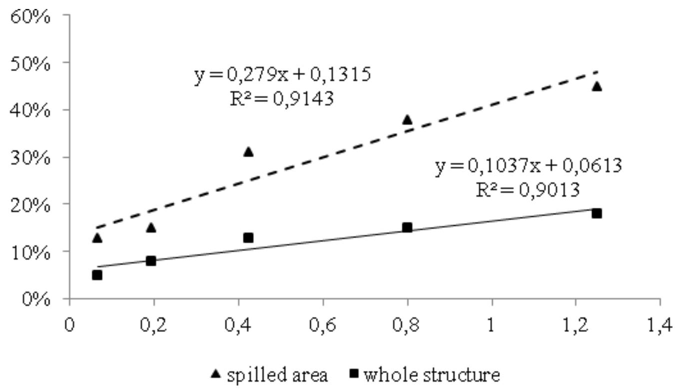

Fig. 3 Correlation between body undermining intensity and the proportion of body structure broken, in case of transverse works affected by both damages

The average condition rate for undermined structures is 70.2, being with 18% lower than the condition rate of not undermined structures (86.0) and 15% lower than the average condition rate of structures within Cris catchment (83.1). This indicator varies significantly according to the this particular damage intensity (fig. 4)

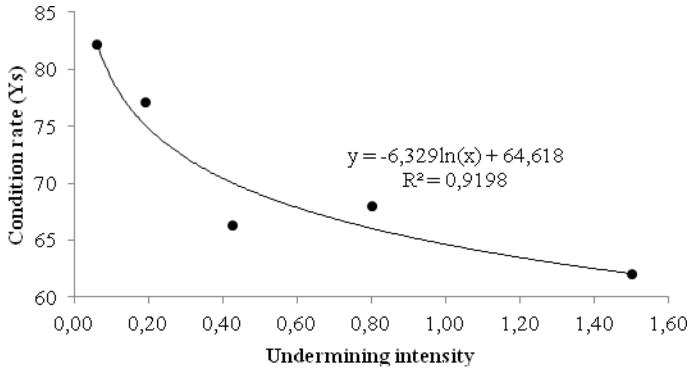

Fig. 4 Structures condition rate (Y_s) depending on body undermining intensity

As regards to triggering or favouring factors of undermining the influence of following elements was studied: the terrain lithology, the sediment size grading on the riverbed and the downstream sustainability of the structures.

Lithological substratums that characterize riverbeds with undermined torrent control structures are included in 11 categories. The highest incidence of the studied phenomenon has been reported if substratum is formed by rhyolites (46%) and by rocks belonging to amphibolites, micashists and parageniss facies (37%), even if these rocks are very rough. The average depth of the undermining recorded is reduced (54 cm for rhyolites and 78 cm for the second category). The variance analysis did not reveal any significant differences regard to undermining characteristics (depth proportion affected and intensity) between lithological categories of the riverbeds.

Sediment size near undermined structure does exert some influence on undermining characteristics, especially on the intensity of the damage. The results are inconclusive, only qualitative information on alluvia grading being taken. Still the undermining average intensity values indicate an increase of the behavioural event impact over the structure with an increasing alluvia granulometry as follows: 0.53 for fine alluvia, 0.58 for medium size alluvia and 0.79 for gross alluvia, the differences being insignificant in conformity with variance analysis.

The support of a downstream structure is important not only in terms of the risk of developing the damage but also in terms of its intensity. Thus the event intensity is much lower when undermined structures are fully supported by downstream structure (0.24) comparing to the rest of undermined structures for which the average intensity is 0.57 (fig.5).

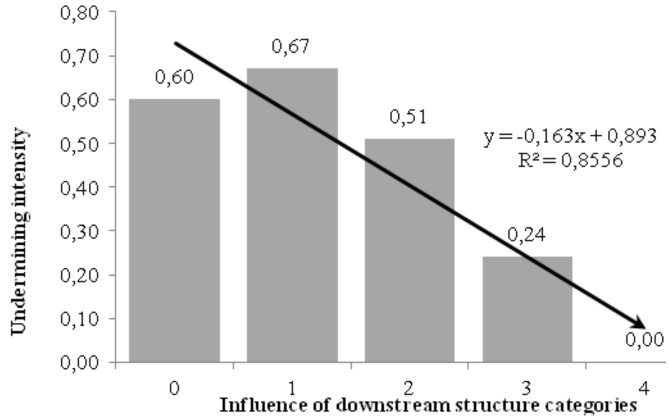

Fig.5 Body undermining intensity depending on downstream sustainability

CONCLUSIONS

Undermining is a behavioural event that affects almost the third part of torrent control structures without an apron, therefore being one of the most important damage types occurred during hydrotechnical works service. In case of structures having an apron, undermined structure bodies seldom are reported, but in case of apron failure unveiling the foundation is unavoidable.

Risk of developing this damage is in inverse relation with elevation height, traverses being the most vulnerable transverse hydrotechnical works to be undermined. The risk is very low if hydrotechnical structures support each other, fact actually achievable by positioning them in sustained systems. To achieve this goal, a review of the methodology torrent control structures designers use to adopt siltation slope is required.

Undermined foundation depth for the affected structures in Cris River Basin is reduced, but the affected with of the body is high. Event intensity is worrying for more than 35% of the structures, being necessary to strengthen them soon.

If undermined hydrotechnical works are not consolidated in time, damage evolution can lead to further degradation through detachments from the body, ruptures being the final stage in hydrotechnical construction deterioration. Those two damage types are linked one to another undermining trigger breaking of structure body, almost half of undermined works having ruptures of parts from their bodies. In the same time a higher intensity of the undermining leads to a bigger part detached from the body. The most vulnerable part to ruptures if the foundation is been undermined is the spilled area of the body.

Analysing the correlation between the condition rate and the intensity of the undermining the influence of this event over the general status of the structure was emphasized again. A logarithmical inverse regression reveals that if the intensity of the event increased, structure condition decreased.

The support of downstream structure is the most significant influencing factor that was studied, the intensity of undermining being much lower if the structures are sustained.

Even if the results are inconclusive, they allow us to state that riverbed sectors with gross alluvia and rougher rocks in the lithological substratum are more vulnerable to develop this kind of event.

REFERENCES

1. Adorjani A., Davidescu Ş., Gancz C. 2008. Combaterea eroziunii solului şi amenajarea bazinelor hidrografice torenţiale în patrimoniul silvic al României, Silvologie vol. VI – Amenajarea bazinelor hidrografice torenţiale – Editura Academiei Române, Bucureşti pp. 169-192. (in Romanian)
2. Clinciu I., 2011. Cercetări privind lucrările de amenajare a reţelei hidrografice torenţiale din bazinul superior al Tărlungului (amonte de acumularea Săcele). "Transilvania" University Press. Braşov. 400 pp. (in Romanian).
3. Clinciu I., Petriţan I.C., Niţă M.D., 2010. Monitoring of the Hydrotechnical Torrent – Control Structures: a Statistical Approach. Environmental Engineering and Management Journal vol. 9, nr. 12: pp. 1699-1707.
4. Conesa-García C., García-Lorenzo R., 2008, Effectiveness of check-dams in the control of general transitory bed scouring in semiarid catchment areas (South-East Spain), Water and Environment Journal, pp. 1-14.
5. Davidescu, S.O., Clinciu, I., Tudose, N.C., Ungurean, C, 2012 (a). An evaluating methodology for hydrotechnical torrent control structures condition. Ann. For. Res. 55 (1), pp. 125-143.
6. Davidescu Ş.O., Niţă M.D., Clinciu I., Adorjani A., Tudose N.C., Ungurean C., 2012 (b). Monitorizarea stării lucrărilor hidrotehnice utilizate în amenajarea bazinelor hidrografice torenţiale şi stabilirea urgenţelor de intervenţie cu reparaţii. Revista Pădurilor. vol. 127, nr. 3.
7. Davidescu Ş.O., Clinciu I., Tudose N.C., 2012 (c). Factors influencing torrent control structures condition in a torrential improved watershed. Proceedings at International Symposium "Forest and Sustainable Development" 2012. (Soon to be published).
8. Garcia J.L., Garcia F., Ciulianu A., 2011. The works in the torrential correction and their effect after a century. Proceedings of the Biennial International Symposium "Forest and Sustainable Development". Transilvania University Publishing House. pp. 415-420.
9. Lazăr N., Gaspar R. et al., 1994: Cercetari privind stabilitatea, rezistenta si functionalitatea lucrarilor hidrotehnice de amenajare a torentilor. final report I.C.A.S. Bucharest: 120 pp (in Romanian)
10. Marion A., Lenzi M.A., Comiti F., 2004. Effect of sill spacing and sediment size grading on scouring at grade-control structures. Earth Surf. Process. Landforms 29, p. 983–993.
11. Mircea S., Vasilescu C., Mircea A., 1992: Observaţii asupra modului de comportare a lucrărilor hidrotehnice transversale executate pe formaţiunile torenţiale din b.h. Olăneşti, Buletin Ştiinţific, Seria E, Vol 34, U.S.A. Bucharest (in Romanian)