RESEARCHES REGARDING THE COMPRESSION RESISTANCE ON EARTH CUBES AND CYLINDERS STABILISED USING HYDRAULIC BINDING AGENTS

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Abstract
Romania holds one of the richest hydrographic networks in Eastern Europe, network which is composed of rivers which have their springs in the Carpathians and which cover approximately 30% of the country, natural and artificial lakes which occupy 1.1% of the country and also a rich network of underground waters which supply the areas deficient in running waters. The major problems of waters courses are extreme meteorological phenomena, namely when their speed exceeds the resistance limits of the soil occurring therefore erosions which lead to the degradation and instability of the river bank leading therefore to it caving in. In order to reduce erosion and render the households safe, hydro-technical protection works of the banks have been carried out for ages, using local materials such as earth, wood or stone, or materials manufactured in preparation plants such as concrete or asphalt. Thus, in order to reduce the costs and materials in the field, an experimental sector was built on the river Căpuș in Cluj department, built with local materials and stabilised with hydraulic binding agents in order to reduce the active erosion phenomenon. The present paper brings forward the results of the laboratory trials regarding the compression resistance of cubes and cylinders of stabilised earth with hydraulic binding and offers solutions for the use of these earths for the reinforcement of the banks of Căpuș River.
Key words: *earths, hydraulic bindings, resistance, compression, stability.*

1. Introduction

The earth stabilisation process dates back more than 5000 years according to the reports carried out by McDowell in 1959 which proves the fact that roads made of stabilised earth were discovered to have been built in ancient Egypt and Mesopotamia, while the Greeks and the Romans used lime as the stabilising hydraulic binding agent.

The first test for the stability of the ground were carried out in the United States, starting with the year 1904, America finding itself during the peak of its industrialisation, tests meant to stabilise the local earths using concrete in order to produce a base layer (foundation) for the roads, being an alternative for the importation of gravel.

Concrete was used as a binding and stabilising agent for the first time in 1925 in order to build a street in Sarasota, FL, while lime was applied on short highway areas for the first time in 1924 due to the increase of automotive traffic.

During the 1940's, the AAMT (The American Association for Materials Testing) uses several research projects carried out on PCA (Portland Cement Association).

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In 1951, during the construction of several earth dams in the central area of the United Stated of America (the U.S. Department of the interior-Bureau of Reclamation) proposes the adoption of a new technical solution to protect the upper slope of the dams, due to the increase cost of transport and quality ripraps.

Therefore, the Bureau of Reclamation decided to realise a scale experimental model for the Bonny accumulation in eastern Colorado to research the resistance in time of a soil-cement mixture which came into permanent contact with water. The chosen section was placed on the left bank of the accumulation, separate from the body of the dam, the section undergoing extreme conditions, such as waves, ice and a number of 100 cycles frost-defrost per year.

The model consists in the protection of a dam with a 105 m length, with a mixture of soil=cement, in compact layers of 15 cm thick and 2.13 m wide, the slope of the being 1:2 (H/V) while the height of the dam is 6.8 m.

The technical solution using concrete stabilised earth was considered a success for the protection upper wall of the dams against waves and extreme meteorological conditions for most dams, the observations during the years are satisfactory, the interventions and the repair works being carried out on short or local sections. The engineers have transferred all this knowledge to the protection of the banks against lateral erosion and phenomena which lead to the increase of flows due to flooding events. This type of technical solution was useful during the Tucson and Arizona flooding in 1978 and 1983. Even if the safety flows have exceeded the protective height, it wasn't substantially affected and prevented damages of millions of dollars. In Tucson, more than 74 miles (119 km) of banks are now protected with cement stabilised earth. In 2002, The District in Los Angeles, California, officially adopted the technical solution using cement stabilised earth for the protection of river banks. A pilot project, namely West Creek next to Santa Clarita, was finalised and considered to be the first project to use stabilised earth where the district actually committed to carry out this type of work. The first river bank protection in Palmdale, California was finalised in 2003 on Amargosa Creek.

The research group composed of doctoral students and faculty of the University of Petrosani, The Technical University of Cluj – Napoca in collaboration with Romanian Waters – Somes-Tisa Water Basin Administration carried out an experimental research on a sector using stabilised material on Căpuș River in Gilău.

Fig. 1. *Active erosion in the area of the assessed location*

2. Laboratory studies and the design of the hydro-technical works

2.1 Designing and choosing the best solution

The location of the work is in Căpus Valley – territorial code II.1.31.10., Gilău, Cluj, between hm 262-263 (stereo coordinates 70 between x=587589.82, y=373017.33 and x=587512.17, y=373116.42) and was designed to protect against the effects brought forward by increased intensity frequent precipitations, these types of mudslides wearing away the river banks and endangering the access to the agricultural fields.

The following basic principles were respected when choosing the technical solutions for the improvement of the water course of Valea Căpuș:

- The significant flood risk areas were first identified as well as the main causes which lead to the occurrence of the said flooding on the assessed water stream;
- The type of materials existent in the area were also considered when choosing the technical solution in order to reduce costs as much as possible;
- The diversification of the type of reinforcement depending on the morphological characteristics of the river bed.

Technical, constructive and technological description - Characteristic indexes of the proposed protective works:

a) Protective dam

- The surface of the occupied land St=100 sm
- Height H=1.5 m
- Width B=6 m
- Crown b=3 m
- Length L=15 m

b) River bank protection

- The surface of the occupied land St=100 sm
- Height H=2.4 m
- Width B=6 m
- Crown b=3 m
- Length L=15 m

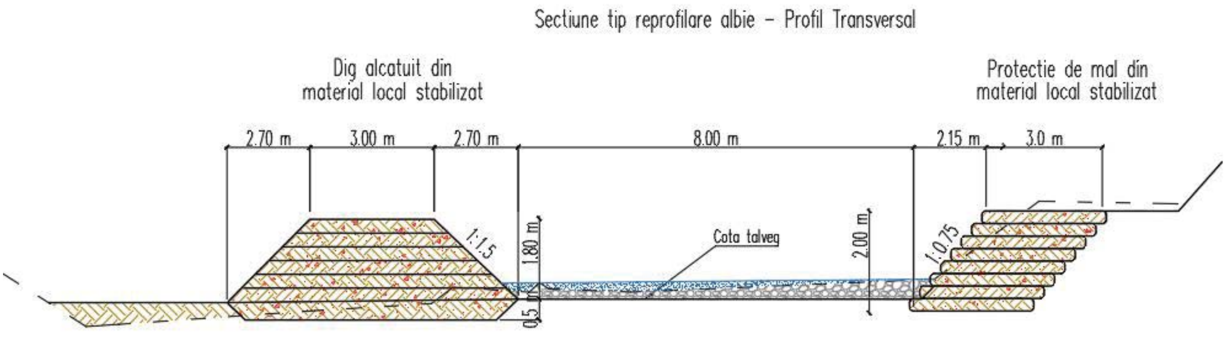

Fig. 2. *Cross-cut section of Căpuș River*

The hydraulic binding agents were bought from Lafarge Holcim România and were selected considering the work experience and the results of laboratory tests. The left bank provided enough space for a small dam to be built, stabilising the local soil with Doroport TB25 © [3]. The right side of the river was considerably steeper; therefore the technical solution chosen was the protection of the embankment. The local material was a mixed with Dorosol C30.

2.2 Laboratory tests

Granulometric curve

The determination of the granulometric curve and the type of earth - Carrying out the granulometric analysis:

a. Scope of the analysis: - the determination of the dimension of the particles of a poli-disperse mixture and the repartition of different sizes of particles in the mixture;

b. Analysis preparation: a sifting device was used in order to analyse the aggregate grading, device which is composed of several sifting surfaces with a decreasing size of the openings through which the material to be analysed is fed (manual sieves with different openings were used). Each dimension obtained was separately collected.

c. The evolution of the analysis:

- The actuating motor of the sieve is connected to the network
- The mixture to be analysed, the weight *m* of which is known is fed to the sieve with the largest holes;
- The machinery is kept into operation until the total separation of the fractions occurs;
- The motor is disconnected and each granulometric fraction is weighed.
- If 3 sieves were used then 4 classes shall be obtained with the weights *m1, m2, m3, m4*.
- The diameter of the hole of each sieve is measured, *l1 > l2 > l3*
- The weight of the resulted fraction is reported to the initial weight of the mixture, obtaining thus a percentage of the total weight of the mixture, and the repartition of the particles on granulometric fractions
- The fraction repartition, % =m1/m2 x 100

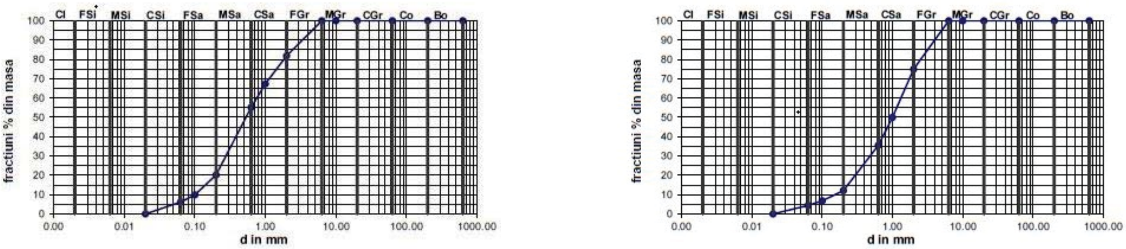

Fig. 3 *Granulometric curves of the left and right bank of Căpuș River*

The determination of the optimum humidity of the earth using the Proctor method

A series of normal Proctor tests were carried out on both types of soil, both in their natural state as well as in a mixture with hydraulic binding agents. It has been considered a 3% and respectively 5% binding agent in soil dry mass, while the final recipe was chosen after having correlated the results and the laboratory analysis, such as direct shear test and odometer tests. The compression curves resulted are presented in Figure 4.

The optimum humidity of the local material found on the left bank is 11% while that on the right bank is 13%. The effect of having stabilised the local material with 5% hydraulic binding agent was that the humidity on the left bank remained at 11% while that of the right bank decreased by 2%, reaching therefore 11%, the experimental sector being realised according to the laboratory trials.

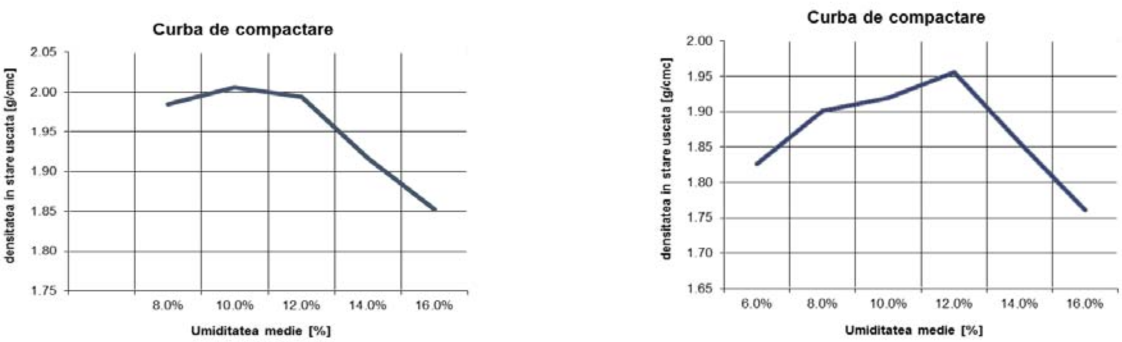

Fig. 4 *The compression curves of the local material from the left and the right bank of Căpuș River*

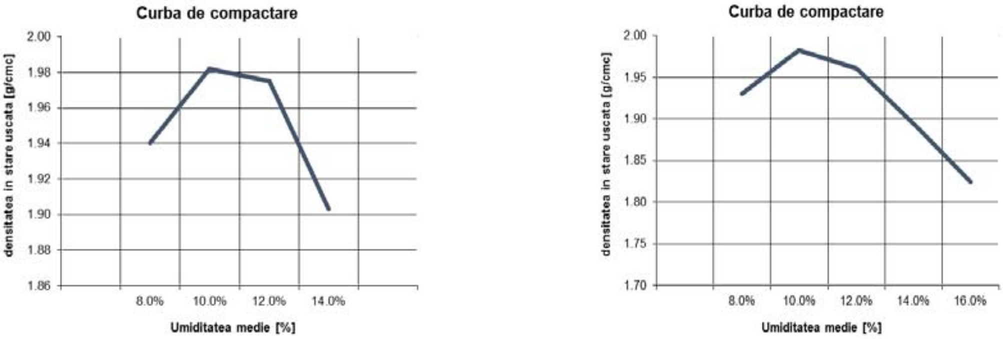

Fig. 5 *The compression curve of the stabilised material from the left bank (5% Doroport) and right bank (5% Dorosol) of Căpuș River*

Determining the resistance to compression

The study has also analysed the 7 days and 28 days tearing regime of the earth material mixed with 3% and respectively 5% dorosol and doroport, under the compression action on different types of samples (cube of 10x10x10 – manually compacted and a 10 cm cylinder compacted using a proctor machine) experimentally determining the resistance to compression values. Following the experiments, the material was analysed and compared with other materials such as concrete, considering STAS 0107/0-90.

The resistance of the material is defined by the basis of the characteristic resistance, which is the resistance to compression expressed in N/mm^2 determined using cubes with a side of 100 mm and cylinders with a diameter of 100 mm for an age of 7 and respectively 28 days.

The samples were kept until the cast came off:

- In a room where the temperature was 20±4°C and the humidity 60±5% and the cast came off after 20±4 hours from being taken / manufactured and kept (depending on the side of the sample) in a certain humidity regime for a certain period of time;
- Next to the construction element, in identical humidity and temperature conditions, both before as well as after the cast came off.

The numbers for the samples were assigned on the front of the cast or on the opposite side immediately after the cast came off and comprises: the short code of the unit, the series and the manufacture date. The samples to be sent to a laboratory are packed in wooden boxes filled with wood shavings well moisturised or with a natural humidity and are sent at least 3 days before being tested.

The trial of the samples was carried out perpendicularly in their casting direction.

The resistance to compression was determined using the following relation:

$$F_{ck} = P/A \; [N/mm^2]$$

Fig. 6. *Determining the compression resistance of a 10x10x10 cm cube*

Fig. 7. *Determining the compression resistance of a 10cm diameter cylinder*

Tables 1 and 2. *The values of the resistance to compression of the cubes*

Nr. proba	Dozaj Doroport (din masa materialului in stare uscata)	Rezistenta la compresiune (7 zile)	Rezistenta la compresiune (28 zile)	U.M.
1	3%	2.36		MPa
2	3%	2.12		MPa
3	5%	1.71		MPa
4	5%	2.45		MPa
5	3%		2.35	MPa
6	3%		2.69	MPa
7	5%		3.45	MPa
8	5%		3.93	MPa

Nr. proba	Dozaj Dorsol (din masa materialului in stare uscata)	Rezistenta la compresiune (7 zile)	Rezistenta la compresiune (28 zile)	U.M.
1	3%	2.78		MPa
2	3%	2.53		MPa
3	5%	2.68		MPa
4	5%	2.9		MPa
5	3%		4.29	MPa
6	3%		2.79	MPa
7	5%		4.92	MPa
8	5%		5.28	MPa

Tables 3 and 4. *The values of the resistance to compression of the cylinders*

Nr. proba	Dozaj Dorsol (din masa materialului in stare uscata)	Rezistenta la compresiune (7 zile)	Rezistenta la compresiune (28 zile)	U.M.
1	3%	1.1		MPa
2	3%	1.05		MPa
3	5%	1.45		MPa
4	5%	1.38		MPa
5	3%		1.2	MPa
6	3%		1.08	MPa
7	5%		1.5	MPa
8	5%		1.41	MPa

Nr. proba	Dozaj Dorsol (din masa materialului in stare uscata)	Rezistenta la compresiune (7 zile)	Rezistenta la compresiune (28 zile)	U.M.
1	3%	1.19		MPa
2	3%	1.25		MPa
3	5%	1.49		MPa
4	5%	1.52		MPa
5	3%		1.29	MPa
6	3%		1.15	MPa
7	5%		1.55	MPa
8	5%		1.52	MPa

3. Conclusions

After having stabilised the earth, an increase of the resistance to compression of the laboratory samples may be observed; therefore, resistance increases together with the increase of the dosage of the binding agent and the passing of time, the most obvious results being the 28 days old samples, where resistance increased by roughly 50% compared to non-stabilised earth. Therefore, the dosage of the binding agent is chosen depending on the necessities in the field, the specific conditions, and the forces which act upon a work. Considering the use of local materials, the costs may be considerably reduced and they obtain a bank or dam protection with characteristics and resistance to superior erosion which comply with the perfect design parameters.

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