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GEOTECHNICAL BEHAVIOR OF AN EXPANSIVE SOIL IMPROVED WITH WASTE TYRE CRUMB RUBBER DETERMINED BY LABORATORY TESTS

BY

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Abstract. The present study focuses on the sustainable solution for the improvement of expansive soils behavior using scrap tyre rubber. With the alarming increase of tyre wastes, the researchers world-wide are looking for sustainable methods to include all types of scrap tyre materials in civil engineering structures. This type of waste is very hard to dispose and its clearly unwanted in any kind of urban-industry. Expansive soils are well known for their problematic behavior and have always caused geotechnical problems causing different types of structural damage at light weight buildings and roads. The expansive soil used in this experimental study is the Bahlui Clay which is analyzed in various conditions and in different mixtures with the waste tyre crumbs. In the laboratory tests different percentages of scrap tyre crumbs along with rubber powder have been used aiming to see some improvements of physical parameters. Results have shown that the waste tyre crumbs can be used as a method of soil stabilization, but only in certain conditions. The 30% scrap tyre addition proved to have a positive

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influence on the geotechnical properties of the active clay, improving the physical soil parameters such as Atterberg limits, linear contraction, and plasticity index.

Keywords: Expansive soil, waste tyre crumbs, Bahlui Clay, sustainable solution.

1. Introduction

Investigation tests have been carried out to observe the behavior of Bahlui clay improved with tyre crumb rubber in different states. The expansive soils have a very complex behavior and are wide spread around Iași city and other regions of Romania. The expansion and contraction of this type of clay affects light infrastructures like roads, parking lots, highways causing permanent damage.

Through the laboratory test performed, we aimed to obtain suitable dimensions and proportions of material for the improved Bahlui clay, without endangering its structural integrity causing considerable changes in other parameters. We also noticed the behavior of the mixtures in different laboratory conditions and aimed on finding a suitable mixture depending on the workability, the method of sorting the rubber material and the homogeneity.

2. Bahlui clay description

The Bahlui clay is a soil with high swellings and contractions, that can be found in the Iași area. The Bahlui clay has a high potential for swelling and contraction; structures build on this type of soil can suffer significant damages, which can become very expensive to repair later;

To make the comparison between Bahlui clay and the improved clay, we made the same set of determinations on simple clay, without added rubber.

Table 1
Bahlui clay parameters

	Plastic limit w_p *[%]*	*Liquid limit* w_L *[%]*	*Plasticity index* I_p *[%]*	*Linear shrinkage* C_L *[%]*	*Volumic shrinkage* C_V *[%]*	*Shrinkage limit* w_s *[%]*
Bahlui Clay	*26,67*	*75,88*	*49,21*	*23,4*	*117,35*	*10,69*

3. Experimental methodologies

SAMPLE PREPARATION

In scientific articles we noticed rudimentary mixing methods for laboratory tests, most common by hand (Deepanshu Solanki, 2017) or by using a blender (Soltani, 2018) without using water in order to avoid separation of the clayey soil fragments from the rubber crumbs.

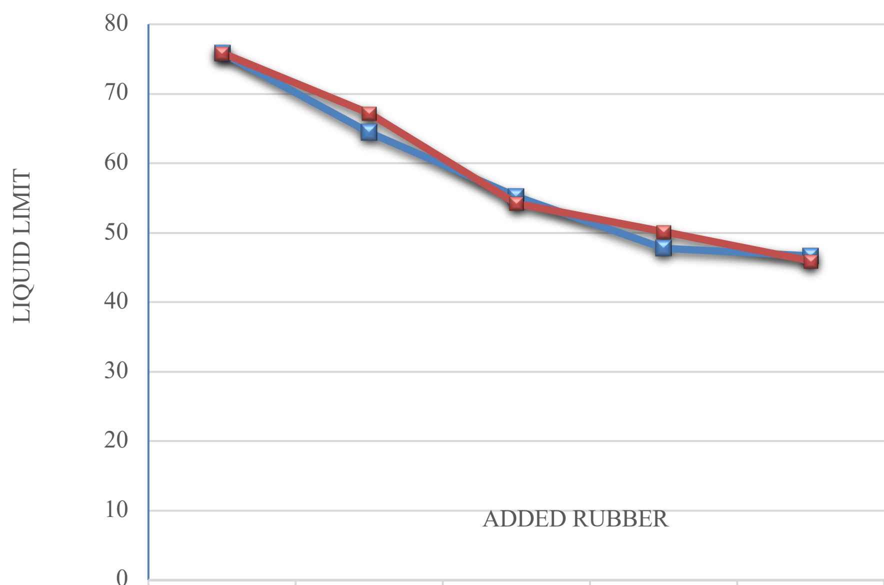
In order to achieve a homogeneity, it was selected the method of drying and grinding Bahlui clay from the article "Experimental Investigation on Soil Stabilization Using Rubber Crumbs on Expansive Soil" (Ms.L.Kokila, 2017) resulting in small soil fragments allowing a manual mixing without any difficulties.

Added rubber percentages were also chosen based on scientific papers (Davood Akbarimehr, 2018, Purushotham G. Sarvade, 2012), performing tests on mixtures with: 5%, 10%, 20% and 30% added rubber crumbs with dimensions between 0.5mm and 1mm. The rubber crumbs were sorted by using a sieve.

Expansive soils are well known for their problematic behavior and have always caused geotechnical problems including high liquid limit, high plasticity index, high linear and volumic shrinkage and caused different types of structural damage at light weight civil engineer works.

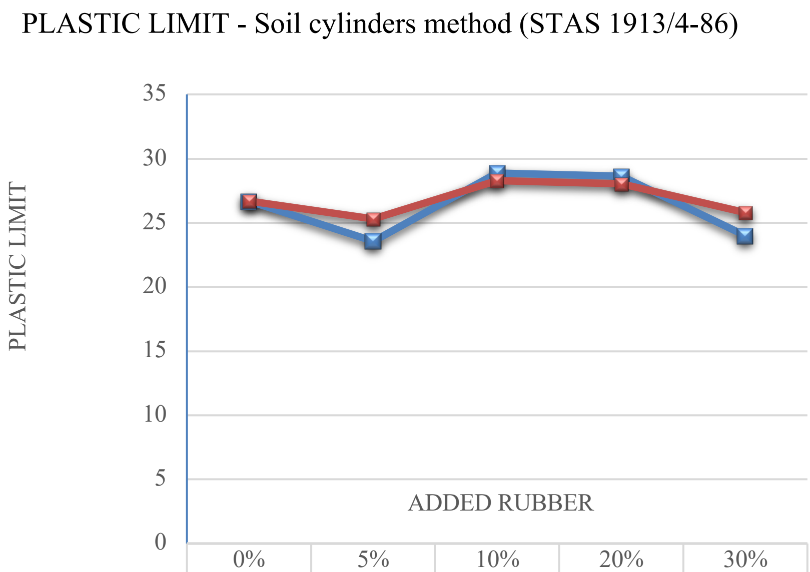
Following the sample preparation, the geotechnical tests of particular interest were performed to obtain the physical parameters for the characterization of the active clay: liquid limit, plastic limit, linear shrinkage, volumetric shrinkage and shrinkage limit.

LIQUID LIMIT - Casagrande cup method (STAS 1913/4-86)



	0%	5%	10%	20%	30%
0.5-0.8mm	75.88	64.45	55.23	47.79	46.66
0.8-1mm	75.88	67.23	54.23	50.15	45.94

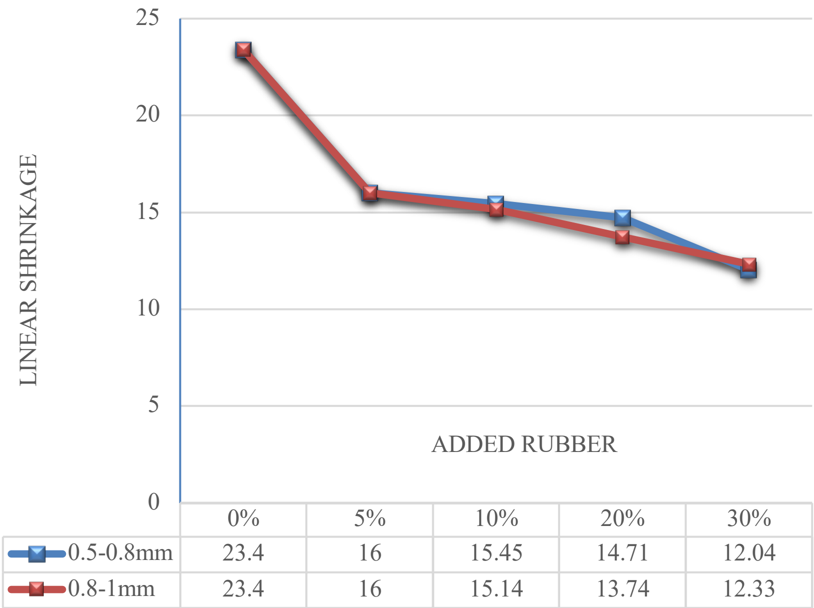
Fig. 1 – Liquid limit variation with the percentage of rubber crumbs.



	0%	5%	10%	20%	30%
0.5-0.8mm	26.67	23.56	28.87	28.61	23.99
0.8-1mm	26.67	25.3	28.28	28.04	25.8

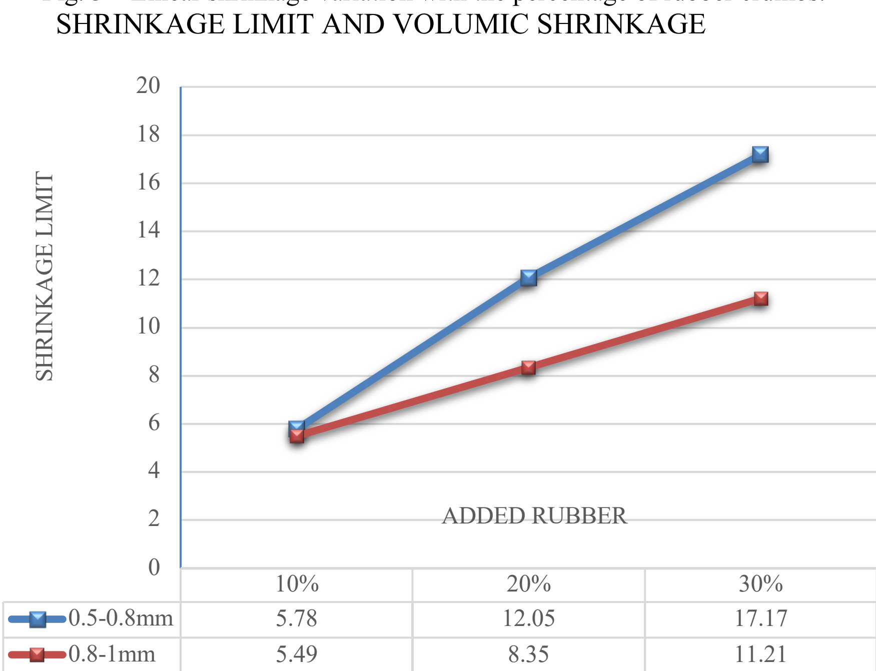
Fig. 2 – Plastic limit variation with the percentage of rubber crumbs.

LINEAR SHRINKAGE



	0%	5%	10%	20%	30%
0.5-0.8mm	23.4	16	15.45	14.71	12.04
0.8-1mm	23.4	16	15.14	13.74	12.33

Fig. 3 – Linear shrinkage variation with the percentage of rubber crumbs.



	10%	20%	30%
0.5-0.8mm	5.78	12.05	17.17
0.8-1mm	5.49	8.35	11.21

Fig. 4 – Shrinkage limit variation with the percentage of rubber crumbs.

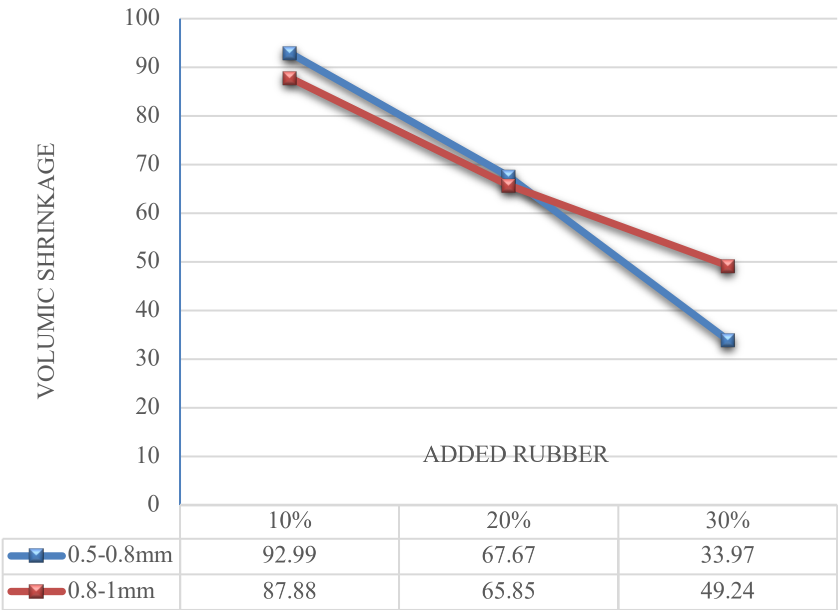


Fig. 5 – Volume shrinkage variation with the percentage of rubber crumbs.

4. Results and discussions

The obtained results are presented below, following the classification criteria in the present norms and standards.

PLASTICITY INDEX

Table 2
Plasticity index assessment

Plasticity index	*Soil state*
0	*non-plastic*
≤ 10	*low plasticity*
11 ... 20	*medium plasticity*
21 ... 35	*high plasticity*
> 35	*very high plasticity*

Table 3
Plasticity index assessment

PERCETAGE OF RC ADDED	*10%*	*20%*	*30%*
0.5-0.8mm rubber crumbs	*26.36*	*19.18*	*22.67*
0.8-1mm rubber crumbs	*25.95*	*22.11*	*20.14*

The improved soil obtained values of the plasticity index between 19% and 26%, changing the state from very high plasticity to high plasticity.

LINEAR SHRINKAGE

Table 5
Linear shrinkage assessment

Linear shrinkage	*Swelling-shrinkage index*
0 ... 12	*non-critical*
12 ... 17	*marginal*
17 ... 22	*critical*
> 22	*critical high*

The improved soil mixture obtained values of linear shrinkage between 15.45% and 12.04%, the swelling-shrinkage index being marginal but with a clear decreasing trend considering the value 23.4% of Bahlui clay in the natural state.

SHRINKAGE LIMIT

Table 6
Shrinkage limit assessment

Shrinkage limit	*Probable swelling percentage, from dry to saturated for 6.9 kPa vertical load*	*Swelling potential*
< 11	*> 30*	*Very high*
7 ... 12	*20 ... 30*	*High*
10 ... 6	*10 ... 20*	*Medium*
> 15	*< 10*	*Low*

The results obtained from the laboratory tests revealed values between 5.49% and 17.17%, indicating a change in the swelling potential from very high to low.

VOLUMIC SHRINKAGE

Table 7
Volumic shrinkage assessment

Activity	*Shrinkage limit*	*Volumic shrinkage*
Less active	*> 16*	*< 55*
Medium active	*16 ... 12*	*55 ... 75*
Active	*12 ... 10*	*75 ... 100*

Very active	*< 10*	*> 100*

Following the results of the volume shrinkage and the shrinkage limit highlighted above, we observed changes in activity, from active to less active, the clay improving with increase in percentage of rubber in the mixture.

Table 8
Swelling potential assessment

		SWELLING POTENTIAL			
		low	**medium**	**high**	**very high**
WL (%)	Chen, 1975	< 30	30 - 40	40 – 60	> 60
	IS, 1498	20 – 35	35 – 50	50 – 70	70 – 90
	Mohan and Goel, 1959	20 – 35	35 – 50	50 – 70	70 – 90
	Daksanamurthy and Raman, 1973	20 – 35	35 – 50	50 – 70	> 70
I_P (%)	Chen, 1975	0 – 15	10 – 35	20 – 55	> 55
	Holtz and Gibbs, 1956	< 20	12 – 34	23 – 45	> 45
	Holtz, 1959	< 18	15 – 28	25 – 41	> 35
	Williams and Donaldson, 1980	< 12	12 – 24	24 – 32	> 32
	Mohan and Goel, 1959	< 12	12 – 23	23 – 32	> 32
	IS, 1498	< 12	12 – 23	23 – 32	> 32
	Seed et al., 1962	< 10	10 – 20	20 – 35	> 35
	Holtz, 1959	> 15	10 – 16	7 – 12	< 11

The results showed for the addition of 10% rubber, depending on the liquid limit and the plasticity index, reveal a high swelling potential. For the mixture with the addition of 20% rubber, the swelling potential falls in the medium to high column and for the 30% rubber addition, the swelling potential can be considered medium.

Table 9
Swelling potential assessment

		SWELLING POTENTIAL			
		low	**medium**	**high**	**very high**
[C_L] (%)	Mckeen, 1976	< 5 (non-critical)	5 – 8 (marginal)	> 8 (critical)	
	Altmeyer, 1955	< 5 (non-critical)	5 – 8 (marginal)	> 8 (critical)	
[ws] (%)	Holtz and Gibbs, 1956	> 13	8 – 18	6 – 12	< 10
	Holtz, 1959	> 15	10 – 16	7 – 12	< 11
	Altmeyer, 1955	> 12 (non-critical)	10 – 12 (marginal)	< 10 (critical)	
	Bureau of Reclamation	> 15	10 – 16	7 – 12	< 11
	Sowers and Sowers, 1970	> 12	10 – 12	< 10	

The results of the test for an 10% added rubber, depending on the linear shrinkage and shrinkage limit, reveal a high to very high swelling potential. For the mixture with 20% added rubber, the swelling potential falls to medium-high column and for the 30% added rubber, the swelling potential can be considered medium.

5. Conclusions

Following the laboratory tests for the liquid limit, for two dimensions (0.5-0.8mm and 0.8-1mm), we obtained relatively close results for the same added rubber (10%, 20% 30%).

The decreasing trend of the liquid limit value is visible and we can conclude that even up to an 30% added rubber, the mixture obtains values of 46.66% and 45.94%, compared to the value for natural Bahlui clay (75.88%) which indicates an improvement.

Regarding the plasticity limit, the results obtained did not reveal a change of trend that can be classified as improvement, but the values were used to calculate the plasticity index.

The linear shrinkage value decreased significantly from 23.4% (Bahlui clay) to 12.04% (30% added rubber mixture).

The shrinkage limit is one of the parameters that registered the biggest improvements, resulting values from 5.49% to 17.17%, indicating a change in the swelling potential from very high to low. Together with the volume shrinkage, the mixture of clay with different sizes and additions led to the change in activity from active to less active.

During the laboratory tests I noticed that the 30% added rubber mixture has a high difficulty of homogenization compared to 20% or 10% mixtures; the sample preparation is difficult and has a high risk of errors.

We dried the samples at different temperatures of 60ºC and 100ºC, in order to observe if there are remarkable differences in the structure of the dry samples or if a high temperature could lead to the melting of the rubber crumbs. Following the analysis of the results, it was concluded that there is no additional disturbance due to drying at the mentioned temperatures.

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EVALUAREA COMPORTAMENTULUI GEOTEHNIC AL UNOR PĂMÂNTURI CU UMFLĂRI ȘI CONTRACȚII MARI ÎMBUNĂTĂȚITE CU GRANULE DE CAUCIUC ÎN CONDIȚII DE LABORATOR

În cadrul prezentului articol de cercetare am urmărit comportamentul argilei de Bahlui îmbunătățită cu granule de cauciuc de diferite dimensiuni, în cantități diferite și condiții cu caracter distinct. Pământurile cu umflări și contracții mari (PUCM), sunt pământuri cu comportament complex, cu o răspândire relativ mare în zona municipiului Iași precum și în alte zone ale țării, care acționează defavorabil asupra numeroaselor lucrări de infrastructură, provocând degradări cu caracter permanent.

Prin analizele de laborator realizate, am urmărit obținerea unor dimensiuni și proporții de material potrivite pentru o îmbunătățire a argilei de Bahlui, fără a periclita integritatea structurală a acesteia provocând modificări considerabile ale altor parametri. De asemenea am remarcat comportamentul amestecurilor în diferite condiții de laborator și am urmărit realizarea unui amestec în funcție de lucrabilitate, metoda de sortare a materialului din cauciuc și omogenitatea obținută.