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The use of fly ash and volcanic tuff for the construction of the mixed road pavements

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Summary

The paper presents the research results on the properties of the various sorts of fly ash and volcanic tuff, extracted from Eastern Carpathian Mountains, in order to be use for stabilization of local materials, at the construction of mixed road pavement structures. This research has been undertaken in the frame of the Department of Transport Infrastructures and Foundations from Technical University "Gh. Asachi" Iasi. The results obtained on experimental sectors equipped with such mixed road pavements, constructed on the Accelerated Loading Testing Facility " Professor Dimitrie Atanasiu" and specific technical recommendations are also presented .

KEYWORDS: mixed road pavement structures, fly ash, volcanic tuff, alt-accelerated, loading testing.

1. INTRODUCTION

In the context of the actual economic and energetic crisis, it is necessary to apply new constructive solutions, capable to bring energy savings, reduction of deficient materials and to use, on a larger scale, of the local byproducts and materials. In the same time, the rational use of local materials involves the use, to a larger extent, of the stabilized aggregate mixes, as specific materials included in the composition of the mixed road pavements.

2. MATERIALS USED FOR THE STABILIZED MIXES

Romanian technical specifications [5] for the design and construction of road pavement layers stabilized with pozzolanic binders provide the use of natural aggregate (sand, ballast) and of the quarry aggregates including quarry byproducts. As binders, these specifications are recommending the use of various sorts of fly ash and of volcanic tuff.

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3. POZZOLANIC BINDERS

The use of puzzolanic binders, of some industrial byproducts and of volcanic rocks such as tuffs, largely spread in many countries such as France, Belgium, USA, etc, has reached now, in our country, an operational status. Pozzolanic binders are siliceous and silico-aluminaceus materials containing chemical compounds which are able to combine with some additives like lime, so that, in the presence of water , at the usual temperature to be able to give birth for new formations , less soluble in water and manifesting binder properties.

3.1. The thermo industrial fly ash

Fly ash is an artificial pozzolanic binder which results as a byproduct at the burning in air suspension of the fine grinded carbon, at temperatures varying between 1200 to 1500 ^{0}C. The ash is obtained on dry procedure, by using specific separators and electro-filters, after which is stored in big deposits. The fly ash involved in our experiment has resulted from inferior carbon combustion and is looks like a gray color fine powder.

The grading curves of fly ash, produced in Iasi and Vaslui are presented in Fig.1. In relation with this figure, one may observe that the Vaslui ash is finer than that of Iasi (75% passing through sieve 0.071mm, in comparison with 57%)

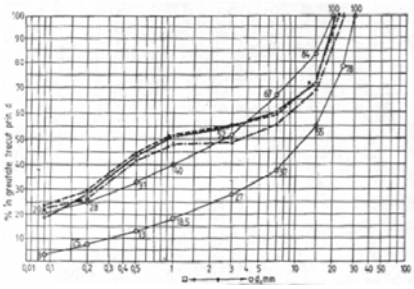

Fig.1. The grading of two sorts of fly ash

Physical characteristics of these two sorts of fly ash are presented in Table 1.

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Table1. Physical characteristics of the investigated sorts of fly ash

		Fly ash from sources :		Grinded volcanic tuff
		Iasi	Vaslui	
Blaine specific surface , cm2/g		3490	3800	3620
Apparent density , g/cm3		2.209	2.349	2.289
Bulk apparent density	Loose state	0.735	0.819	0.785
	Compacted state	0.947	0.958	0.978

The chemical composition of the fly ash from those two sources and the technical conditions recommended by Romanian norms are presented in Table 2, from below:

Table 2. The chemical composition of the investigated sorts of fly ash

Chemical composition, %	MgO	2.20		2.10		3.40	Max 5.0
	PC	2.29		2.18			≤ 10
	K_2O						1.3
	Na_2O						1.3
	SO_3	3.76		3.05		2.72	Max 3.0
	CaO	5.60		4.06		5.40	Min 5.0
	Fe_2O_3	Σ = 90.05 %	7.58	Σ = 88.76 %	7.98	Σ = 89.70 %	5.48
	Al_2O_3		32.42		27.50		34.62
	SiO_2		50.05		53.28		49.20
							$SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70$ %
Name and source of the investigated binder		Fly ash from Iasi (lignit)		Fly ash from Vaslui (lignit)		Grinded volcanic tuff Harghita	Technical conditions according Romanian specifications

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3.2. Grinded volcanic tuff

Tuff is a volcanic-sedimentary rock resulted from deposition and cementation of the volcanic ash. The main source from Eastern Charpatian Mountains is the Santdominic quarry. The raw material is presented under the form of a quarry aggregate, size 8-20mm. This aggregate is then grinded to obtain finer material, with a grading, similar to that shown in Fig.2. the grinding fineness, being of 67%. The chemical composition of the grinded volcanic tuff is given in Table 2. In relation with Table two, one may observe that this composition meets the technical conditions specified in the Romanian norms [4].

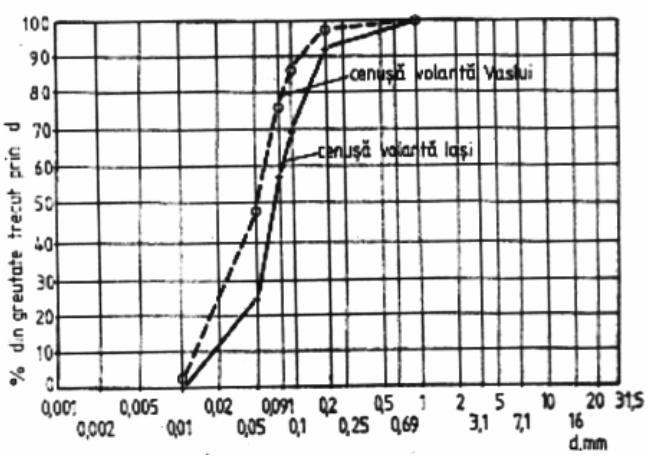

Fig.2. Grading of the grinded volcanic tuff

3.3. The hydraulic lime

The hydrated lime, furnished by the Bicaz factory, under the form of a fine powder has a content of calcium oxide (CaO) of 60,7% and a grading with a rest of 12,3% on the 0,09 sieve.

4. EVALUATION OF THE POZZOLANIC ACTIVITY

4.1.,[4]/ The modified ASTM Method

In accordance with this method the resistance to compression is determined on specimens realized from a mix of calcium hydroxide (one part) and uniform sand (two parts), compacted in cylinder molds having 5 cm diameter and 10 cm

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height, after curing in water at the temperature of 23 ^{0}C for 24 hrs and then at the temperature of 55 ^{0}C for six days.

The compression resistance, determined on cylinders, in these conditions , at the age of seven days , must be at least 0,55 N/mm, in order the ash to be considered as an active one. The laboratory positive results obtained by testing hose three types off pozzolanic binder investigated are presented in Table 3:

Table 3 the mechanical characteristics of the investigated pozzolanic binders

The type of the pozzolanic binder	R_c 7 at 7 days, N/mm^2
Fly ash / Iasi	0.96
Fly ash /Vaslui	0.90
Volcanic tuff /Harghita	0.67

5. A PROPOSED METHOD FOR EVALUATION OF THE ACTIVITY OF POZZOLANIC BINDERS

This method consist in determining the compression resistance at 28 days on specimens stored in wet atmosphere and at seven days for specimens stored one day in wet atmosphere and then on accelerated dry at 55 0C for the rest of 6 days. Test specimens are realized from mixes of 90% pozzolanic binder and 10% hydrated lime , brought at the optimum moisture content established according AASHTO (modified) Proctor procedure, on cylinders having the same dimensions as in the ASTM method. In both cases, according ASTM recommendations the resistance value has to be of at least 0.55 N/mm. The results obtained on these tests are presented in Table 4:

Table 4. Compression resistance for the investigated specimens

The type of mix	Curing conditions		
	normal		thermo-accelerated
	R_c (N/mm^2)		
	Age , in days		
	7	28	7
Fly ash/ Iasi (90%) + hydrated lime (10%)	0.37	0.58	0.55
Fly ash/ Vaslui (90%) + hydrated lime (10%)	0.37	0.55	0.54
Volcanic tuff Sindominic (90%) + hydrated lime (10%)	0.26	0.61	0.57

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6. NATURAL AGGREGATES

Natural aggregates of ballast type extracted from the Pascani quarry and quarry byproducts from Santdominic, Suseni and Chileni sources, complying with the Romanian technical conditions [5] have been used in the experiment.

7. THE STABILIZED MIXES

Four types of stabilized mixes have been used, as follows:

-Ballsat/ Siret stabilized with 25% Iasi/ flying ash

-ballast /Siret stabilized with 25% Vaslui/flying ash

-quarry byproduct/Sandominic stabilized with 8% volcanic tuff

-quarry byproduct/ Suseni-Chleni stabilized with 8% volcanic tuff

Grading curves of these mixes are presented in Fig. 2 the Proctor compaction characteristics are presented in Table 5 from below:

Table 5 . The Proctor compaction characteristics obtained for the four types of stabilized mixes

The type of mix	$\gamma_{d\ max}$, (g/cm^3)	W_{opt}, (%)
Siret ballast + 25% Iasi flay ashe	1.89	9.5
Siret ballast + 25% Vaslui fly ashe	1.863	9.5
Sindominc quarry by product + 8% volcanic tuff	2.345	8.5
Suseni - Chileni quarry byproduct + 8% volcanic tuf	2.283	9.98

The results obtained on compression tests, performed on cylinders prepared from these mixes and tested at 14, 28, 60, 90, 180 and 360 days are given in Table 6.

8. RESULTS OBTAINED ON ALT PILOT TESTS

Three types of road pavement structures has been conceived by using Siret ballast stabilized with 25%Valsui fly ash and used for the construction of thre experimental ALT sectors as follows:

-sector 1: foundation layer /20 cm ballast; base layer / 10 cm stabilized ballast; wearing course: 5 cm rough asphalt concrete ;

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-sector 2: foundation layer /20 cm ballast; base layer / 15 cm stabilized ballast; wearing course: 5 cm rough asphalt concrete ;

-sector 3: foundation layer /20 cm ballast; base layer / 20cm stabilized ballast; wearing course: 5 cm rough asphalt concrete.

These sectors were exposed to the accelerated traffic after a period of 60 dyes necessary for the curing of the stabilized mixes with fly ashes.

Permanent deformations under ALT tests have been recorded at various stages and the results are presented in Fig. 3.

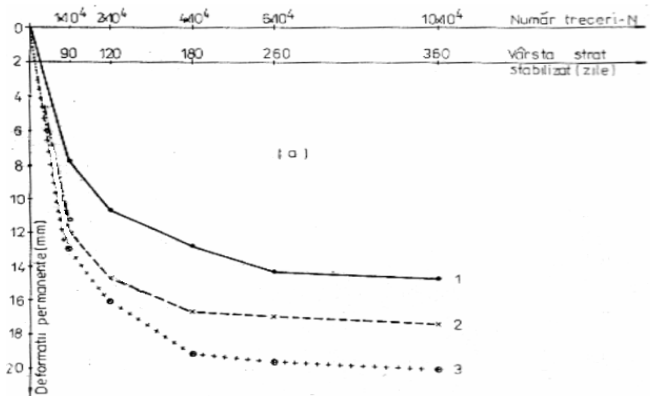

Fig.3 Permanent deformations under ALT tests, recorded at various stages of the experiment

In relation with Fig.3, one may observe that the more rapid accumulation of the deformation in the initial loading period till reaching the number of 4x10^6 passes of the standard axle load (11.5 kN), this limit corresponding with the age of 60…180 days , necessary for the complete curing of the stabilized mixes.

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Table 6. Results obtained on compression tests, performed on cylinders prepared from these mixes and tested at 14, 28, 60, 90, 180 and 360 days

Technical conditions	R_{tg} N/mm^2	-	-	-	-	-	-	-
	R_c N/mm^2	Base course	1.3	2.2	-	-	-	-
		Foundation course	0.7	1.2	-	-	-	-
Suseni - Chileni quarry byproduct + 8% volcanic tuff		R_c N/mm^2	0.2	0.3	0.34	0.40	0.50	0.80
		R_c N/mm^2	2.3	2.5	3.5	3.9	4.2	6
Sindominc quarry by product + 8% volcanic tuff		R_c N/mm^2	0.2	0.3	0.35	0.4	0.7	0.75
		R_c N/mm^2	2	2.5	3.3	4	4.6	5.9
Siret ballast + 25% Vaslui fly ash		R_c N/mm^2	0.2	0.25	0.3	0.4	0.45	0.5
		R_c N/mm^2	1.6	2.2	2.75	3.2	3.7	5
Siret ballast + 25% Iasi flay ash		R_c N/mm^2	0.2	0.3	0.4	0.5	0.6	0.75
		R_c N/mm^2	1.4	.2.2	3.2	3.3	3.8	6.2
Age in days			**14**	**28**	**60**	**90**	**180**	**360**

8. CONCLUSIONS

- The fly ashes from sources Iasi and Vaslui used for the stabilization of the Siret ballast may be an alternative solution for the construction and rehabilitation of roads in this region of Romania;

-The grinded volcanic tuffs from eastern Carpathian Mountains (Harghita county) is also a good alternative for the realization of the stabilized mixes for stabilization of the quarry byproducts from sandominic and Suseni-Chileni, in order to be used for the construction of road pavement structures in the region ;

- The mixed road pavement structures realized with Siret ballast stabilized with Vaslui fly ashes have a satisfactory behavior under accelerated traffic , and thus they could be used for the modernization of the roads subjected to low and medium traffic.

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ISSN 1582-3024