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STUDY ON THE POSSIBILITY OF USING PORTLAND CEMENT WITH ADDITIVES FOR ROAD CONCRETE

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Abstract: *This paper presents a possible development direction in terms of concrete road implementation to achieve road structures, as rigid ones, main feature consisting in the use of Portland cement with additives compared to the same product without additives.*

Key words: *concrete, cement, fly ash.*

1. Introduction

The need to develop a suitable transport infrastructure and modernizing existing one require funding and also the most advantageous choice in relation to local materials, knowing that the magnitude of this kind of programs demands large materials consumption, difficult to ensure by traditional sources.

A report by the Ministry of Transport, Posts 2007-2013 shows:

- Transport infrastructure is underdeveloped and requires significant investment to bring it up to European standards;
- The access to Western European corridors, as well as the east and south Europe is limited by the transport capacity and low quality of certain infrastructure elements [1].

Currently, in Romania, road concrete industry is governed by laws (NE 014-2002, 589-2004 DNA) under certain peculiarities in the composition design, execution and quality check. On this context, the choice of different cement types is made in accordance with road concrete classes, knowing that they are unitary Portland cement, CD 40 or CEM I 42.5 R, CEM I 42,5 N or CEM I 32.5 R.

In addition with the above, there is the urgent problem of analyzing the possibility of using cement with additives for concrete road, in order to achieve the model from countries in which these technologies have been successfully applied (Table 1).

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Technology applied in different countries Table 1

Nr.	Application	Cement type	Description
1	Asphalt pavement M0 Highway (Ring road Budapest)	CEM II/A-S 42,5N	Reinforced slab
2		CEM II/B-S 32,5R	
3	Asphalt pavement Ring road Antwerp/Anver (Belgium)	CEM III /A 42,5N-LH, LA	Continuously reinforced concrete
4	Crossing barrier Estern Scheldt (Holland)	CEM III/B	
5	A10-E40 Highway Brussels-Ostend(Belgium)	CEM III/A 42,5N-LA	Reinforced slab
6	Ring road Ghent (Belgium)	CEM III/A 42,5N-LA	Reinforced slab
7	N49(E34) Road, Antwerp/Anver, Knokke (Belgium)	CEM III/A 42,5N-LA	Continuously reinforced concrete
8	E25-E40 Connection Highway, Liege(Belgium)	CEM III/A 42,5N-LA	Reinforced slab
9	N50 Road, Froyennes(Belgium)	CEM III/A 42,5N-LA	Whitetopping

Following the example of developed countries, correlated with EU environmental regulations, Romania will have to quickly find alternatives to recycling of waste from industrial activities, of which fly ash is and will be in the future the main source of pollution by large quantities resulted, but also land areas that are necessary to store it as a waste dump. A report of the European Coal Combustion Products Association (ECOBA) shows the areas and utilization of fly ash, in which road construction, along with cement industry and concrete production hold the most important market share in recycling this valuable product:

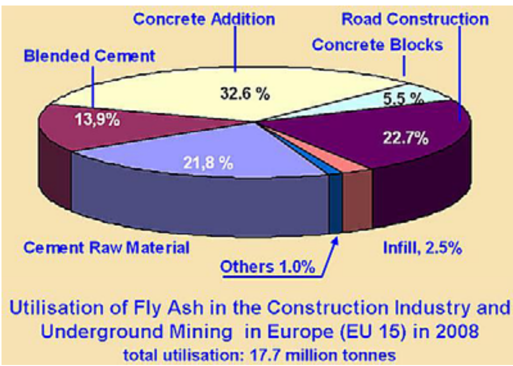

Fig. 1. *Utilisation of fly ash in the construction industry. ECOBA*

2. Road concrete with Portland cement and fly ash addition binders

2.1. Problem description

Given the difficult conditions faced by road structures with cement concrete pavement, both in terms of traffic and climatic factors, this question can be formulated: "Is the fly ash able to partially and successfully substitute cement in road construction?" To answer this question, we must follow a really long way. It is well known that thematic research on the use of fly ash to build road structures (in form, foundation or base layers) were been made in Romania, leading to PhD thesis and experimental areas, but practical application remained only at limited, episodic level, in present being abandoned.

This paper aims to present a comparative study related to mechanical performances of road concrete, designed for cement layers for rigid road structures designated to a medium traffic class (national and county roads, streets, service roads, industrial sites).

It should be noticed, from the beginning, that the study was made with dry fly ash, obtained from CET Govora power plant filters. Today, this power plant (being also the first and only in Romania), has implemented a system to certify the ash as for concrete category A, N, certified construction product according to SR EN 450-1 + A_1: 2007, addition type II for concrete production".

ROMCEN (Professional Association of Producers and Users of Ash in Romania), have as main objective to promote the use, as raw material in road, industrial construction industry, of the ash obtained from cogeneration technological processes of thermo-electrical power plants (CET).

Fly ash, as a secondary product of energetically activities of thermo-electrical power plants, is a fine powder consisting essentially of spherical vitreous particles, originating from the combustion of pulverized coal in SiO_2 and Al_2O_3, with SiO_2 content of at least 25 % by weight, as defined in EN 197-1 and the amount content of SiO_2, Al_2O_3 and Fe_2O_3 should not be less than 70 % by weight.

2.2. Experimental conditions

In order to determine the binder capacity of the fly ash from CET Govora and the possibility of obtaining road concrete with a low cement dosage, three concrete compositions were made, with the same mix of binder and water/binder ratio, in order to ensure a fresh concrete with consistency determined by slump test and corresponding to 30 ± 10 mm value.

Therefore, the control samples were according to the concrete composition with Portland cement CEM I 42,5R binder and other two compositions aimed to replace cement quantities with fly ash equivalents (50 kg, respectively 100 kg of fly ash for 1 m^3 concrete, as cement replacement).

The composition used was one that ensures, by design, a BcR4,0 concrete type, if using a cement type CEM I 42,5R (control sample), as is shown in Table 2.

Calculating concrete composition Table 2

Components [Kg/m^3]	Concrete with CEM I 42,5R (RM) cement		Concrete with CEM I 42,5R cement and fly ash addition 50g (R1)		Concrete with CEM I 42,5R cement and fly ash addition 100g (R2)	
	[%]	[Kg/m^3]	[%]	[Kg/m^3]	[%]	[Kg/m^3]
Sand 0-4	40	793	40	783	40	773
Chippings 4-8	20	396	20	392	20	388
Chippings 8-16	25	495	25	489	25	483
Chippings 16-25	15	297	15	294	15	291
Binder - cement		335		285		235
- ash CET		–		50		100
Superplasticizer additive	1,1	3,685		3,685	1,1	3,685
Air entraining additive	0,04	0,134	0,04	0,134	0,04	0,134
Water		147		147		172

The materials used in the experimental program can be characterized briefly as follows:

- Sand: sort 0-4 representing the fine mineral part, with the origin from river pit;
- Chippings sorts 4-8 / 8-16 / 16-25, andesite, from Malnaş career;
- Holcim Cement I 12.5 R, Câmpulung
- Dry fly ash from CET Govora S.A. power plant approved as type II addition for concrete (SR EN 450-1 + A_1: 2007).

Fig. 2.a. *Concrete components*

Fig. 2.b. *Dry concrete mixture*

- Superplasticizer type SIKA-ViscoCrete 1040 policarboxilateter;
- Air entraining additive SIKA-LPS A-94 synthetic surfactants;
- Water from the drinking water network.

In the experimental program all three concrete composition were tested, both in fresh and hardened state (at the age of 7 and 28 days).

2.3. Laboratory test results

Therefore, with those three designed mixtures, concrete compositions were prepared, having low slump test value, corresponding to S1 class and 335 kg of CEM I 42,5R dosage for control sample and 285 kg cement and 50 kg fly ash for R1, respectively 235 kg cement and 100 kg fly ash for R2, their characteristics being presented in Table 3.

Results obtained on fresh concrete Table 3

	Binder type	Dosage [Kg/m^3]	W/Binder ratio	Compaction [cm]	Density [Kg/m^3]
RM	Cement CEM I 42,5R	335	0,44	3,0	2425
R1	Cement Fly ash	285 50	0,44		2415
R2	Cement Fly ash	235 100	0,51		2351

The slump test is presented in figure 3:

Fig. 3. *Concrete consistency by slump test*

According to laboratory protocol, carried out tests on the samples aimed:
- Bending strength (it defines concrete road class);
- Compressive strength;
- Determination of permeability P_8^{10};
- Determination of resistance to repeated freeze-defrost cycles, G100.

For the big picture of the physical and mechanical characteristics highlighted as a result of determinations made on the control sample and the other two – with 50 kg (R1) and 100 kg (R2) fly ash addition, below are presented (Table 4) the performance of the three concrete samples, compare with technical regulations (NE 014-2002).

Concrete mechanical resistances Table 4

Binder dosage [Kg/m^3]	W/C	Designed concrete class	28 days R_{inc} NE 014 [MPa]	28 days R_{inc} Laboratory [N/mm^2]	28 days R_e NE 014 [MPa]	R_e laboratory 7 days [MPa]	28 days [MPa]
Cement I 42,5 335 Fly-ash -	0,44	BcR 4,0	4,0	7,1	35	51	60
Cement I 42,5R 285 Fly-ash 50	0,44	BcR 4,0	4,0	7,0	35	43	58
Cement I 42,5R 235 Fly-ash 100	0,51	BcR 4,0	4,0	6,8	35	32	57

Bending and compressive strengths are presented in figure 4a and 4b.

Fig. 4.a. *Bending test*

Fig. 4b. *Compressive test*

The results of permeability test P_8^{10} and frost criterion are presented in table 5.

Permeability test and frost criterion Table 5

Binder type/dosage [Kg/m^3]	W/C	P_8^{10} [cm]	NE 014-2002	Frost criterion resistance
Cement I 42,5 335 Fly-ash -	0,44	0,6	G100	G150
Cement I 42,5R 285 Fly-ash 50	0,44	0,6	G100	G150
Cement I 42,5R 235 Fly-ash 100	0,51	0,7	G100	G150

3. Conclusions

Bending resistance R_{inc} indicates high values for both control sample (RM-CEM I 42,5R), namely 7 N/mm^2 as well as for ash addition samples, the differences being practically negligible (7.0 N/mm^2 for R1 and 6.8 N/mm^2 for R2 respectively).

These values are also well above those according to NE 014-2002 for BcR 4 class (namely $R_{înc}^{28\ days} = 4.0\ N/mm^2$). Moreover, these values exceed even the BcR 5 class, for which. $R_{înc}^{28\ days} = 5.0\ N/mm^2$.

Compressive strength (indicative) also shows values far beyond those provided in the technical regulations for BcR 4 concrete class.

Higher levels of resistance to bending, compression and good behaviour to frost criterion, highlight a compact concrete, with good distribution of the minerals, homogeneous, as evidenced by the results obtained in determining the degree of permeability.

Given these results, another study would be the way to further research the abrasion resistance and to defrost action.

An economic analysis shows that we can achieve significant reductions in the price of concrete and even in terms of the price for road structures with concrete pavements, by reducing slabs thickness, due to good behaviour and characteristics significantly increased compared with normalized values, and all this thorough the use of fly ash addition (SR 450-1 + A_1: 2007).

Reducing the amount of cement from 335 kg to 285 kg and 235 kg per m^3 by replacing with addition of fly ash to have the same content of binder (i.e. 50 kg/m^3 and 100 kg/m^3) in terms of obtaining the performance gap compared to normalized values, clearly confirms the above statement.

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