Waste Materials Used For Building Construction

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Abstract: - The fly ash is an industrial waste which produces environment problems because contaminates lands and water with heavy metals. The ultra fine fly ash is captured with cyclones help. There were made experimental researches on mixtures realized with ultra fine fly ash (from Timisoara Power Plant-Romania), classical mineral binder (lime and cement), sand, water and super plasticizer. The testes made were concerning to: apparent density, bending tensile and compression strengths and thermal conductivity. The new building materials have the same properties like ordinary concretes, mortars, bricks etc. The technical efficiency, thermal efficiency, economic efficiency and sustainability index were established for new materials, classical building materials and Reference Materials. It was obtained building materials with over 25% economy versus materials with superior characteristics. By using an industrial waste (ultra fine fly ash) will result a good impact on environment. The materials with industrial waste (ultra fine fly ash) are recommended to be used as prefabricated slabs for pavement.

Key-Words: - Ultra fine fly ash, efficient building materials, environment protection, industrial waste, sustainability, friendly environment building materials

1 Introduction

The XXI [st] century has a big problem to solve: to reduce the environmental problems that appeared during the big industrial development in the past century. This leads to important problems regarding the design and preparation of the building products and materials, so that finally to obtain an economic cost of the product, on short and long time periods, also a "friendly with the environment" during its fabrication process.

Romania it is one of the world's biggest fly ash producers, this is because of burning a low quality of coals. In the 1980 year, 15 millions tones of fly ash were produced.

The fly ash it is an important industrial waste that resulted from the burning of powder coal at temperatures between 1.200 – 1.600 °C. From each tone of coal it results 0.15 – 0.6 tones of fly ash.

In our days, in Romania there are recorded 951 industrial waste deposits that cover a surface over 11000 hectares.

Table 1 present the industrial waste deposits as they are presented by Government Department.

The reuse of fly ash as an engineering material primarily stems from its pozzolanic nature, spherical shape and relative uniformity. Nearby Timisoara City at Utvin, there it is one of the biggest air pollution sources from west Romania: the fly ash deposit of Power Plant South Timisoara. This deposit covers 50 hectares and it was started since 1987. In this moment, special equipment is in function which produces dense slurry. This dense slurry is and admixture of fly ash and water in 1:1 proportion.

Table 1. Industrial waste deposits

Industrial deposit	Number	Occupied Surface (ha)
Decantation ponds	209	2466
Waste dump	251	5932
Fly ash and slag dumps	108	2823
Simple deposits	354	748
Underground deposits	29	17

The recycling of fly ash has become an increasing concern in recent years due to increasing landfill costs and current interest in sustainable development.

Fly ash utilization, especially in concrete, has significant environmental benefits including:

- increasing the life of concrete roads and structures by improving concrete durability;
- net reduction in energy use and greenhouse gas and other adverse air emissions when fly ash is used to replace or displace manufactured cement;
- reduction in amount of coal combustion products that must be disposed in landfills;
- conservation of other natural resources and materials.

2 Experimental programme

Experimental determinations were made on new building materials realized with ultra fine fly ash (from Timisoara Power Plant) classical binders and sand.

There were realized mixtures with the following compositions:

- **G1** materials group (1-5 batches):
  - water=20%;
  - dry material=80%:
    - sand 0-4 mm=40%;
    - blended binders=60%;
- **G2** materials group (6-9 batches):
  - water=15%;
  - dry material=85%:
    - sand 0-4 mm=60%;
    - blended binders=40%.
- **G3** materials group (10-12 batches):
  - water=15%;
  - dry material=85%:
    - sand 0-8 mm=60%;
      - ► 0-4 mm = 40%
      - ► 4-8 mm = 20%
    - blended binders=40%.

To establishing the blended binders compositions was used the next model:

$$\%\Sigma\text{Blended binders}=\%\Sigma(\text{classic binders}+\textbf{UFA})=100\% \quad (1)$$

where:

- classic mineral binders=cement (**C**)+lime (**L**);
- **UFA**=ultra fine fly ash from Power Plant.

The blended binder compositions were fixed by using 10%, 20% and 25% of lime (L), 5%, 10% and 20% of cement and ultra fine fly ash (UFA) was obtaining from relation:

$$\%\text{UFA}=100\%-\%\Sigma\text{Blended binders} \quad (2)$$

During the compound mixing the superplasticizer (polycarboxylatether) was added in 0.5% from blended binder's mass proportion.

The prismatic samples have been made with 40x40x160 mm dimensions.

The samples were realized in two steps:

- first was prepared a manual dry mixture from sand, ultra fine fly ash, lime/cement;
- second, water was added, the mixture was 2 minutes mechanical mixed, superplasicizer was added and 2 minutes mechanical mixed again.

The compactness was performed on jolting table in two sequences: 30 jolts in 30 seconds for the first half fresh material and 30 jolts in 30 seconds for the steel mould filled with all fresh material quantity.

The samples were kept into wet air box until 28 days age.

The materials composition is showed in table 2.

Table 2 The materials composition

Group	BATCH	Water [%]	Lime [%]	Cement [%]	Ultra fine Fly Ash [%]	Sand 0-4 mm [%]	Sand 4-8 mm [%]
G1	Series 1 L10 C10	20	4.8	4.8	38.4	32	-
	Series 2 L20 C5	20	9.6	2.4	36.0		
	Series 3 L20 C10	20	9.6	4.8	33.6		
	Series 4 L10 C20	20	4.8	9.6	33.6		
	Series 5 L25 C10	20	12.0	4.8	31.2		
G2	Series 6 L10 C10	15	3.4	3.4	27.2	51	-
	Series 7 L20 C5	15	6.8	1.7	25.5		
	Series 8 L20 C10	15	6.8	3.4	23.8		
	Series 9 L10 C20	15	3.4	6.8	23.8		
G3	Series 10 L10 C10	15	3.4	3.4	27.2	32	19
	Series 11 L20 C10	15	6.8	3.4	23.8		
	Series 12 L10 C20	15	3.4	6.8	23.8		

3 Experimental results

Apparent density, bending tensile strength and compression strength are present into Table 3.

The apparent density at 28 days age for different batches, presented in Table 3, have a value between 1762 kg/m^3 and 1987 kg/m^3 which framed the materials in medium heavy mortars category or cell concretes.

Table 3 Physical and mechanical characteristics of hardened mixtures

BATCH	Apparent density ρ_a, [kg/m^3]		Bending tensile strength f_{ct}, [N/mm^2		Compressive strength f_c, [N/mm^2]	
	7 days age	28 days age	7 days age	28 days age	7 days age	28 days age
Series 1 L10 C10	1855	1762	4.42	2.76	19.76	30.01
Series 2 L20 C5	1813	1766	3.61	1.87	15.75	28.91
Series 3 L20 C10	1853	1773	4.07	2.50	19.28	32.56
Series 4 L10 C20	1850	1780	3.01	2.57	19.33	32.43
Series 5 L25 C10	1840	1790	3.63	1.98	17.05	30.01
Series 6 L10 C10	2017	1987	4.36	3.51	16.44	24.26
Series 7 L20 C5	1965	1940	3.06	3.40	12.63	24.93
Series 8 L20 C10	1989	1896	3.69	3.21	14.51	27.29
Series 9 L10 C20	1938	1839	3.92	3.28	14.43	28.17
Series 10 L10 C10	1932	1822	2.90	2.92	11.80	19.01
Series 11 L20 C10	1920	1805	2.35	2.57	11.85	22.75
Series 12 L10 C20	1906	1820	3.27	3.04	15.66	27.83

For materials of G1 group

Mechanical strength obtained at 7 and 28 days age, have the optimal behaviour for series 1 L10 C10 and series 3 L20 C10.

Although have obtained high levels of f_c to 28 days (> 30 N / mm^2), f_{ct} presents a decrease for the age of 7 days to 28 days. These characteristics are proper for small items such as paving plates.

For materials of G2 group

By increasing the amount of classic binder over the 20% (reported to blended binders), f_{ct} have decreased from the age of 7 days to 28 days but f_c presents increases.

Comparing the results with those obtained on the materials of G1 group we can say that by using a higher percentage of sand, the f_{ct} decreasing was less up to 19%.

For materials of G3 group

The bending tensile strength has the values between 2.57 N/mm^2 and 3.04 N/mm^2 and f_c between 19.01 N/mm^2 and 27.83 N/mm^2 which are comparable to that of concrete class C 8/10 - C16/20. Regarding f_{ct}, we observe that series 9 L10 C10 and series 10 L20 C10 present increasing for 7 days to 28 days and series 11 L10 C20 has a smaller decrease of 4.6%.

For a constant percentage of 10% cement, the increase of the percentage of lime of 10% (series 6 L10 C10) to 20% (series 8 L20 C10) led to lower f_{ct} with 0.35 N/mm^2, representing 12.0% and to increase f_c with 3.74 N/mm^2.

For the case of constant quantity of lime (10%) and increasing the proportion of cement to 10% (Series 6 L10 C10) at 20% (series 9 L10 C20) an increase of f_{ct} with 0.12 N/mm^2 (4.1%) and of f_c with 8.82 N/mm^2 (46.4%).

The thermal conductivity coefficient was determinate with Almemo 2290-8 device for series 1 L10 C10 and the values obtained was λ = 0.70 W/(m●K). This coefficient is the same like brick and less than concrete thermal conductivity.

The technical efficiency, thermal efficiency, economic efficiency and sustainability index are presented into Table 4.

A reference Materials was chosen as an ideal material for comparison with classical as well as with new materials.

The technical, thermal and economic efficiency was express taking into account three coefficients as follow:

$$\beta_1 = \frac{R}{C} x100 = \frac{1}{\lambda x C} x100 \quad (3)$$

$$\beta_2 = \frac{f_c}{C} x100 \quad (4)$$

$$\beta_3 = \frac{f_c}{\rho_a} \quad (5)$$

From Table 4 and Fig. 1 it can be concluded:

1. The thermal efficiency β_1 as the ratio between the thermal resistance R and the cost C, has the maximum value for Reference Material (25) and for cell concrete (10.8). The new materials are characterized by thermal efficiency between 2.2 to 3.4. The small value were obtained for ordinary concrete β_1=1.0 and solid brick β_1=1.2.
2. The economical efficiency β_2 expressed by the ratio between the compressed strength and cost has the minimum values are for cell concrete (8) and solid brick (9) due to smaller value of the compressive strength. Economical efficiency for new material with the values between 45 and 62 is very similar with the Reference Material (50).
3. Technical efficiency, as ratio between the compressive strength and the apparent density is with the maximum value for the Reference Material (33). From the new materials the Series 3 (18.4) and Series 4 (18.2) are characterized with the higher value. The ordinary concrete as well as the cell concrete has obtained the smaller values (11 and 8.9); the minimum value is for solid brick β_3=5.9.

Table 4 Technical characteristics, sustainability index and coefficients of efficiency

Materials	f_c N/mm^2	λ, W/(m K)	ρ_a kg/m^3	E, MJ/m^3	C, €/m^3	S	S_1	β_1	β_2	β_3
Series 1	30.01	0.7	1762	1106	48	0.785	0.723	3.0	62	17.0
Series 2	28.91	0.7	1766	1335	53	0.703	0.599	2.7	54	16.4
Series 3	32.56	0.7	1773	1581	59	0.671	0.506	2.4	55	18.4
Series 4	32.43	0.7	1780	1550	58	0.679	0.516	2.5	56	18.2
Series 5	30.01	0.7	1790	1804	64	0.612	0.444	2.2	47	16.8
Series 6	24.26	0.7	1987	928	45	0.817	0.862	3.2	54	12.2
Series 7	24.93	0.7	1940	1080	48	0.757	0.741	3.0	52	12.9
Series 8	27.29	0.7	1896	1271	52	0.709	0.630	2.7	52	14.4
Series 9	28.17	0.7	1839	1196	49	0.745	0.669	2.9	57	15.3
Series 10	19.01	0.7	1822	869	42	0.817	0.920	3.4	45	10.4
Series 11	22.75	0.7	1805	1224	50	0.692	0.653	2.8	45	12.6
Series 12	27.83	0.7	1820	1196	49	0.743	0.669	2.9	57	15.3
C 16/20	26.5	1.6	2400	2408	63	0.531	0.332	1.0	42	11.0
Solid brick	10.0	0.8	1700	5080	108	0.271	0.157	1.2	9	5.9
Cell concrete	5.0	0.15	560	2198	62	0.478	0.364	10.8	8	8.9
Reference Material	20.0	0.10	600	800	40	1.000	1.000	25.0	50	33.3

S = Sustainability Index; S_1 = Energetic sustainability; E = Energy; C = Cost; f_c = Compressive strength;
λ = Thermal conductivity (average); ρ_a = Apparent density; R = 1/λ = Thermal transfer resistance
β_1 = Thermal Efficiency; β_2 = Economical Efficiency; β_3 = Technical Efficiency

4 Sustainability of new materials

According to the paper [1] the sustainability index was calculated by formula:

$$S = 0.4\frac{E^R}{E} + 0.3\frac{C^R}{C} + (0.15\frac{R}{R^R} + 0.15\frac{f_c}{f_c^R}) \quad (6)$$

This index refers to four components of the sustainability dimensions: ecological (by E=energy), economic (by C=cost) and social (by R=thermal transfer resistance and f_c=compressive strengths).

The results of the analysis of sustainability are presented into Table 4 and Fig. 2. Reference material was chosen to have the maximum value of sustainability index (S=1).

The solid brick is characterized by a minimum value of S=0.271 as well as cell concretes with S=0.478 due to of high energy included for obtaining, a higher cost and a small compressive strength. The new materials have a sustainability index of S=0.612-0.817 which is higher as compared with ordinary concrete S=0.53.

The sustainability was expressed, too, by the energy only with the next relation:

$$S_1 = \frac{E^R}{E} \tag{7}$$

were: E^R is the energy of the Reference Material and E is the energy incorporated by the other materials. The energy sustainability index was obtained as S_1=0.444-0.920 for new materials with ultra fine fly ash and of S_1=0.364 for cell concrete as well as of S_1=0.332-0.388 for ordinary concrete. The minimum values has the solid brick S_1=0.271.

The index S is a global characterization of sustainability as compared with energy sustainability S_1.

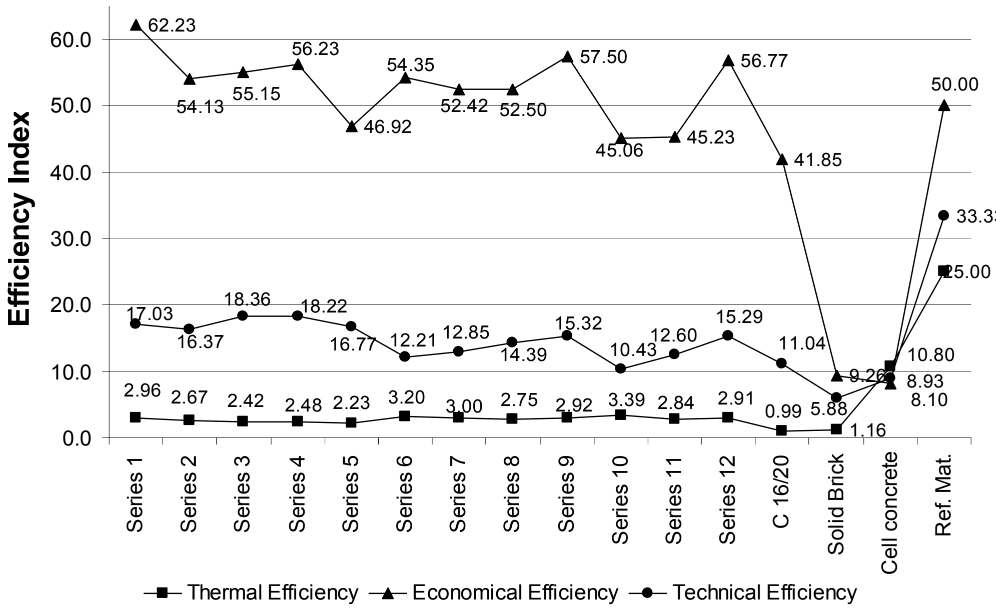

Fig.1 Technical, Thermal and Economical efficiency

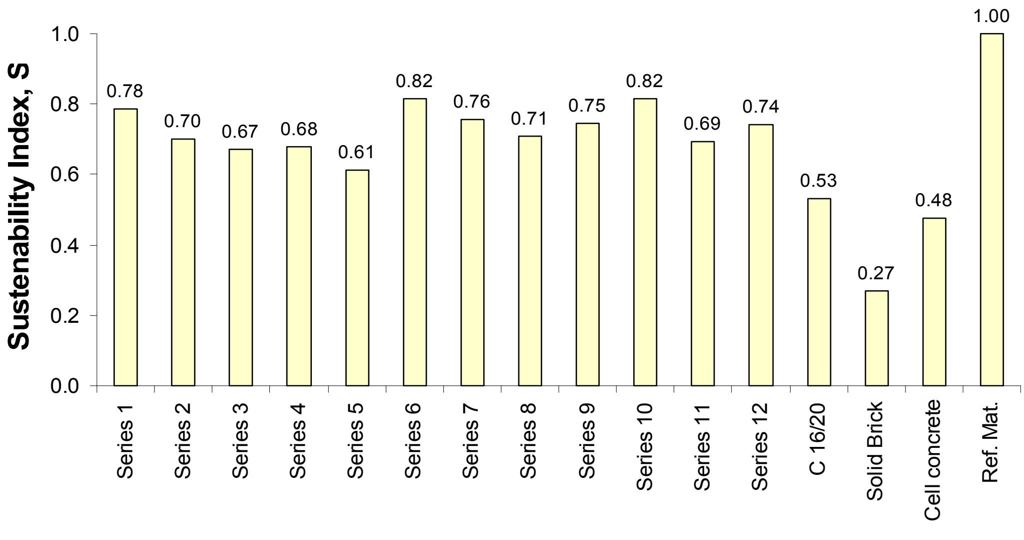

Fig.2 Sustainability Index of Reference Materials and new materials

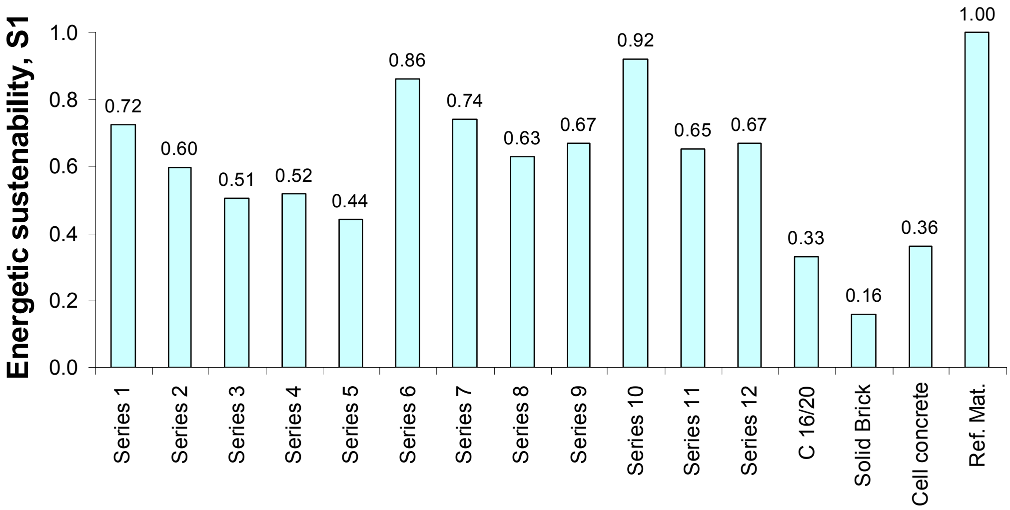

Fig.3 Energetic sustainability of Reference Materials and new materials

4 Conclusion

From the theoretical studies and experimental determination some conclusions are underlined below.

The new materials are characterised by an important economical efficiency like Reference Materials.

Technical efficiency, as a ratio between the compressive strength and apparent density is a high one as compared with reference Material.

The thermal efficiency expressed by the thermal efficiency index b1 as well as by energetic sustainability index S1 of the new materials is much better as compared with ordinary concrete (the best value were obtaining for series 6 and 10).

A comprehensive characterisation of the new materials was defined by a new concept: sustainability index S (see formula 6). According to this index the new materials (especially series 6 and 10) are very close to Reference Material which means they are sustainable.

Taking into account the characteristics presented before, the new materials with industrial waste (ultra fine fly ash) are recommended to be used as prefabricated blocks for masonry and slabs for pavement.

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