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Barite Mortar with Fluid Fly Ash as Shielding Material

David Procházka[1], Dalibor Beneš[2]
[1]Institute of Technology of Building Materials and Components, Brno University of Technology, Brno, 602 00, Czech Republic
[2]Institute of Technology of Building Materials and Components, Brno University of Technology, Brno, 602 00, Czech Republic

Summary

This short article handles about the possibility of utilization of the fluid fly ashes in shielding materials. Because fluid fly ash is a waste and is being produced in large quantity, there is searched for alternatives in its usage. One of possible ways is e.g. its admixing into building materials. This is possible mainly due to chemical composition similarity between fly ash and some building materials. Scores of the time the fly ash is being added to the binder. In this work the fly ash was admixed to calcium hydrate and the resulting mixture was then used as a binder. But firstly it was necessary to ascertain chemical composition of the fluid fly ash and then to compute appropriate relation fly ash:calcium hydrate. After it, the designed binder was used into shielding mortar, which was subsequently tested on X-rays.

KEYWORDS: barite mortar, ionizing radiation shielding

1. INTRODUCTION

Loading of the environment by the human being is big problem todays. The major polluter is still energetic industry, especially burn coal power plants. About 80 % of solid combustion products makes the fly ash. The world-wide ash production (fly ash and bottom ash) is estimated to about 500 Mt/year [1, 2, 3]. The largest producers are China, USA, Russian Federation, India [4]. The most frequent treatment is the waste disposal. But that is discriminating for appropriation of land. But there is also the possibility to add the ash into hydraulic binders, because of its pozzolanic properties (it depends on combustible and burning process quality). Furthermore it can be used as a filler in concrete, e.g. for high performance concrete production. But always it is necessary to watch for its chemical and mineralogical composition. Together with mentioned, there is searched for another exploitation ways. In this paper the ash was tested in a shielding matter.

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2. FLUID FLY ASH

For purposes of this work it was used the fluid ash from Hodonín power plant in Czech Republic. As a fuel there is being used lignite (young solid fossil fuel with low heating power). The power plant produces filter ash (granulity 0 – 0,7 mm), dry bed ash (granulity 0 – 1,9 mm) and a stabilisate (mixture of filter ash, bed ash and batch water – it is in point of fact ash mortar; granulity 0,036 – 1,8 mm; it can not be stored). The annual yield of entire ash matter reaches to circa 100 000 tonnes. The price depends on the taken quantity and makes 5 – 30 Kč/t (0,2 – 1,1 euro/t) [5]. The ash attributes determined by the power plant are in the table 1 and 2.

Table 1. Ash matter – Hodonín power plant

		Bed Ash	Filter Ash	Stabilisate
Assesment	Unit		Value	
Ash matter	%	2,70	4,76	3,24
Apparent Density	$kg \cdot m^{-3}$	1014	638	-
Specific Weight	$kg \cdot m^{-3}$	-	2568	-
Total Sulphur Content	%	4,30	4,46	2,30
Specific Activity ^{226}Ra	$Bq \cdot kg^{-1}$	71	163	-
SiO_2	%	28,80	29,00	-
AL_2O_3	%	12,90	14,90	-
CaO	%	26,40	23,00	5,58
K_2O	%	0,58	0,58	-
SO_4	%	-	-	11,69
CO_2	%	-	-	3,82

Table 2. Hodonín ash chemical analysis

Oxid [%]	Filter Ash	Bed Ash
SO_3	7,840	13,400
P_2O_5	0,341	0,142
SiO_2	31,600	30,400
MnO	0,103	0,048
Fe_2O_3	6,640	3,590
MgO	3,720	1,990
Al_2O_3	17,000	13,900
TiO_2	0,541	0,467
CaO	29,400	32,900
Na_2O	0,326	0,258
K_2O	1,170	1,020

Next to the chemical analysis there was done RTG analysis too (see Figure 1,2).

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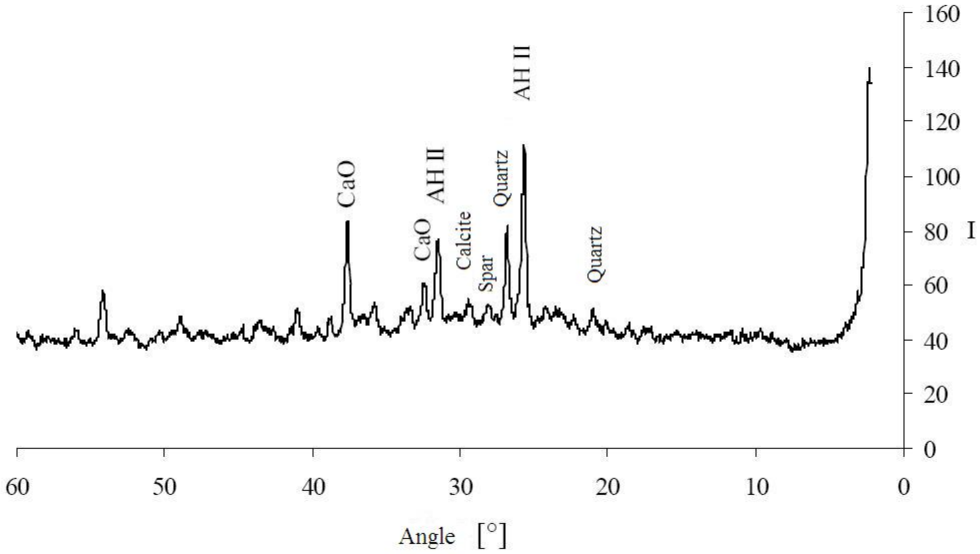

Figure 1. Hodonín filter ash RTG

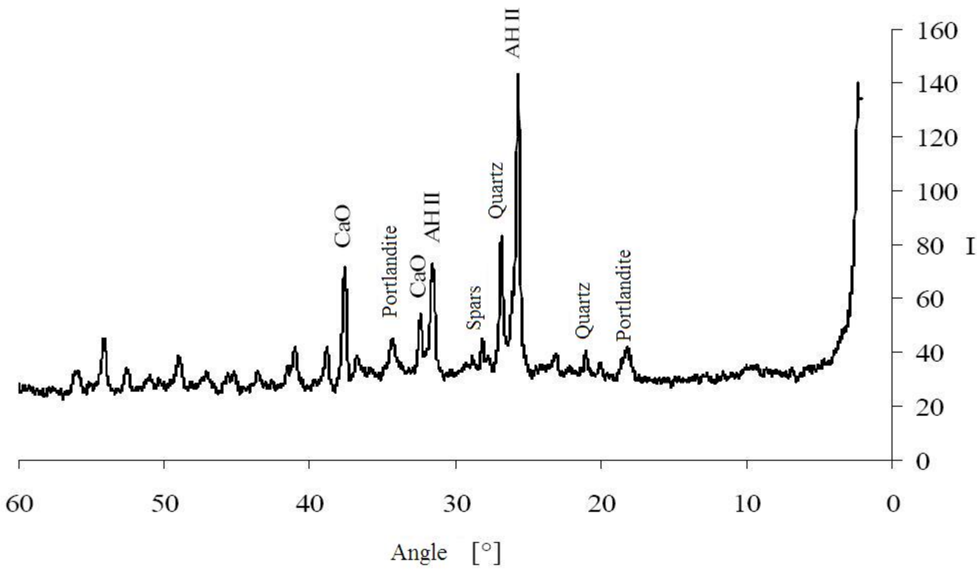

Figure 2. Hodonín bed ash RTG

From the tables 1 and 2 it is evident, that both types of ash are not too different. Because of relative high CaO content, it can be presumed on higher calcite dosage.

As regards to the mineralogy there were identified quartz and spar as rests of combustion, next anhydrite II and calcite as desulfphatation products. After the ash properties verification it was approached to the blended binder design.

3. BLENDED BINDER DESIGN

The blended binder was designed as ash and calcium hydrate mixture according to hydraulic modulus on 1,0 value.

$$M_H = \frac{[CaO]}{[SiO_2]+[Al_2O_3]+[Fe_2O_3]} \quad [-] \qquad (1)$$

M_H ... hydraulic modulus. It is relation of mass fragments of single hydraulic oxides. The 1,0 value signifies high hydraulic binder.

The dosage relation of ash and calcium hydrate was computed just at this modulus, see table 3.

Table 3. Mixing relation between ash and calcium hydrate

Parameter	Filter Ash	Bed Ash
Ash Content [%]	61,5	61,5
Calcium Hydrate Content [%]	38,5	38,5
Hydraulic Modulus	1,03	0,92
Ash : Calcium Hydrate	1 : 0,625	1 : 0,625

From both ashes and from the calcium hydrate were then prepared trial mixes and proven on shrinkage and strengths. Both mixtures characteristics were nearer more likely to hydraulic binders than to the aerial binders. Even if he had lower strenght values, for research purposes it was used the filter fly ash.

4. SHIELDING MIXTURE DESIGN

At the design it was resulted from already known formula for cement mortar (see Computational Civil Engineering 2008), which was shown itself as viable. As a filler it was used the barite dust. On the ground of its different granulity first several designs were unsatisfactory in comparison with previously used aggregate. The final composition determines table 4.

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Table 4. Blended mortar composition

Parameter		Value
Composition [%]	blended binder	12
	barite dust 0-0,063 mm	88
	admixture B	1
	admixture F	0,12
Dry mass Volume weight of the dry mixture in shaked state [$kg \cdot m^{-3}$]		2 760
Water-cement ratio [-]		0,45
Bulk density of concrete [$kg \cdot m^{-3}$]	fresh mixture	3 040
	after 28 days of maturing	3 100

After the design it was approached to the testing of technological properties (standardly on prisms 40 x 40 x 160 mm), see table 5.

Table 5. Technological properties

Parameter		Value
Water-cement ratio [-]		0,45
Bending tensile strength [MPa]	after 1 day	0,7
	after 28 days	1,9
Compression strength [MPa]	after 1 day	4,1
	after 28 days	13,3

Relatively low strength values are given by high dose of too fine aggregate – the baryte dusts. The strength values could be possible heigthen e.g. by addition of coarse aggregate and using of superplasticizer. After strength parameters verification it was approached to the final phase of the project – to the findings of shielding abilities.

5. THE SHIELDING PROPERTIES

The ability to shield the ionizing X-ray radiation was checked on tablets 10, 20 ,30, 40, 50 mm and compared with referential lead tablets. The radiaton intensity increased gradually. The results are shown in table 6 and in the figure 3.

Table 6. Shielding ability of barite tablets with blended binder

Voltage U [kV]	Dose rate D [pGy/s] Slab 10 mm	Slab 20 mm	Slab 30 mm	Slab 40 mm	Slab 50 mm
60	18 200	70	48	39	31
80	122 000	240	67	61	56
100	762 000	8 950	791	173	144
135	4 340 000	530 000	80 300	12 700	2 520

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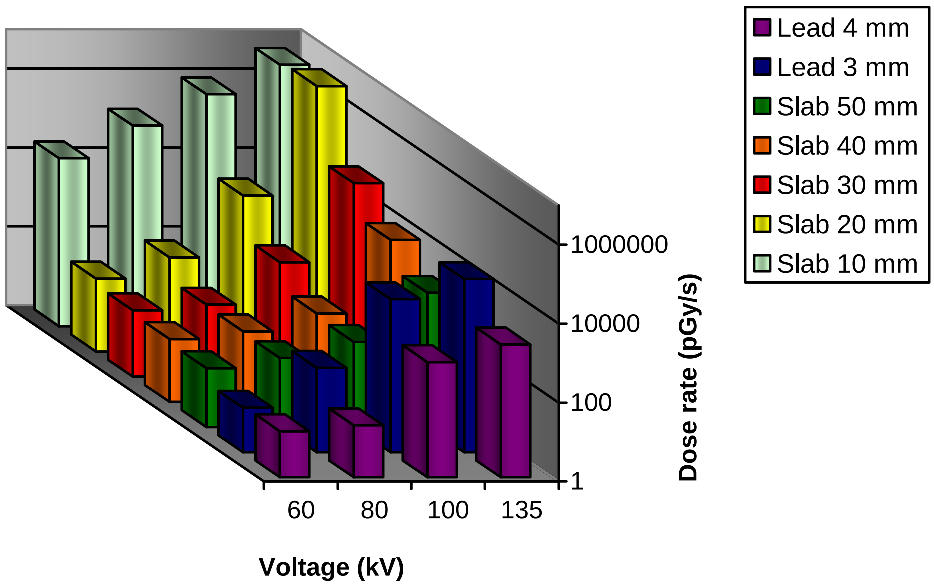

Figure 3. Shielding comparison of barite dust slabs and lead (logarithmic scale)

From the graph it is evident that shielding ability of the barite mixture equalizes to the shielding of 4 mm lead at 50 mm of its own thickness. It is difference around one order. When compared the barite mixture volume weight with the lead density, it is clear that thicker lead must shield more. Seeing that dose input growth exponentially with higher intensity, it is clear that the needed shielding material thickness will be not higher about multiple of density rates, but will increase exponentially too.

CONCLUSION

The performed tests have shown applicability of waste ashes even in so problematic sphere as the ionizing radiation shielding is. Though the ash alone do not administrates to the shielding, the barite is the shielder, he is usable as a bonding component.

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Low strength values predestinates the mixture more likely to nonbearing purposes. Yet it is possible to heighten them through formula optimalization and by using of superplasticizer.

If would be compared the shielding of barite dust with blended binder on the one hand and barite sand with cement binder on the other hand (see [6]), the shielding will be higher in case of barite sand say on the ground of higher volume weight. When it is wanted to reach better shielding, the mixture of cement and sand is more suitable to use. On the other side, when there is need to save money, it is possible to use mortar with the barite dusts and blended binder.

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