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DURABLE EXTRUDED AND SELF-HARDENING LOAM BRICKS BASED ON FLY ASH FROM LIGNITE


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Abstract

The basis of the primary energy supply in the Czech Republic is mainly lignite combustion. Power plants are for example Chvaletice, Melnik, Pocerady, Porici, Prunerov, Ledvice, Tusimice, Tisova and Hodonin [1,2]. Accordingly, there is a large amount of fly ash with its latent hydraulic and puzzolanic properties, depending on the composition. In terms of sustainability, such industrial residues offer huge potential for conversation of resources and often connected with it, a CO_2-reduction. Especially lime-rich fly ashes offer a variety of possibilities in the high quality production of self-hardening loam-bricks, having an improved durability. Different clays/loams were mixed with fly ashes (10 to 30 wt-%) and homogenized by addition of water. Out of these mixtures, samples were moulded in different dimensions by using an extruding press. After curing under different humidity conditions at room temperature, the samples were tested for their strength and their durability. The investigations showed, that the choice of the starting materials has significant impact to the workability and the development of the strength. Furthermore, there is an optimal amount for the ash in the recipes to prevent a rapid destruction by capillary water absorption. The modified clay bricks could make a decisive contribution to the improvement of weather resistance e.g. in tropical areas with sudden rain showers.

Keywords: Waste materials, Fly ash, CO_2-reduction, Resource conservation, Durability

1 Introduction

The aim of the project was to develop a material-technical process without drying and firing based on clay-ash-bound fine grain systems. The base were chemical and mineralogical interactions between the ashes and clays. Fly ash has self-hardening characteristics due to its latent hydraulic properties and its content of active glass (calciumaluminate-silicate glass) [3, 4], but also, it is important to have a little bit of soluble sulphate for the self-hardening process. For this reason, ashes with a certain proportion sulphate were used and the clays and the loams delivered the reactive aluminum. The ash is important for the workability, connected to the extrudability, because of the supply of non-plastic components. Further, the durability is greatly improved by the addition of ashes in the system. These facts result in an enormous potential for the use of the accumulating fly ash. This paper represents a small overview of obtained results of a project which was funded by German Federation of Industrial Research Associations (AiF) [5-7].

2 Materials

Clays or loams consist of typical alumina silica constituents, which can react under certain conditions (mechanical activation by the extrusion process) with more or less calcium and sulphate from the ashes. Five different clays (c1 to c5) were chosen and combined each with three fly ashes (A, B and C). Regarding the clays, a wide possible range was selected, see Tab. 1. Loam 1 and clay 2 are very plastic, what is good for the workability.

Tab. 1 Mineral composition of the clays and loams

	Clay / Loam	**Fireclay**	**Illite / Mica**	**Illite / Smectite**	**Smectite**	**Chlorite**	**Quartz**	**rest**
C1	Illite-kaolinite-loam	35	15	3	3	2	40	2
C2	Kaolinite-clay	74	9	3	4	1	9	n.e.
C3	Kaolinite loam	32	15	2	1	n.e.	45	5
C4	Illite-kaolinite-loam	21	33	7	n.e.	n.e.	29	9
C5	Argillite	n.e.	58	n.e.	n.e.	9	25	8

Table 2 shows the composition of the ashes. Ash A and B come from a powerplant in Poland with the same origin, ash B was crushed by a mechanical impact, thus C_2AS phase and amorphous phases could be formed. Ash C is from Germany and has the highest amount of sulphate, free lime and melilite in summary.

Tab. 2 Mineral phases of the ashes [wt%]

Ash	**amorphous**	**Anhydrite**	**CaO**	**C_2AS**	**C_4AF**	**C_3A**	**C_2S**	**CAS_2**	**Quartz**	**[Mg,Fe]O**	**Mullite**
A	44.7	7.4	10.2	0.0	1.8	0.0	2.6	9.7	11.2	1.8	5.6
B	57.2	5.1	5.0	10.7	0.0	0.0	0.0	4.1	5.3	2.0	5.0
C	34.2	11.9	8.2	11.2	10.8	3	5.8	0	13	1.9	0

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3 Manufacturing process and methods of investigation

3.1 Production of the specimens

The clays were crushed < 1 mm and from the now fine-grained raw material 10, 20 and 30 wt% were substituted by fly ash, additionally pure clay samples were still produced. The mixture was homogenized in an Eirich-mixer by adding water, see Fig.1. Initially, samples were moulded in a small format (approx. 32x14x80 mm^3) by using an extrusion press, see Fig. 1. Thus, differences in workability and later to the strength and durability could be obtained.

Fig. 1 Eirich-mixer,extrusion press and specimens

3.2 Storage of the specimens

To get information about the impact of fluctuating humidity influences the samples were stored in a closed container over 20 % sulfuric acid (88 % RH), over magnesium chloride hexahydrate (33 % RH) and also in a room with 65 % RH. The selected temperature was 20 °C.

3.3 Investigations

After 28,70 and 105 days, the strength was determined in reference of two samples with same composition and curing under same conditions. With the most promising mixtures, phase analytical studies (XRD) were done on samples with c1 and c2 combined with ash A and C (30 wt%) after 105 days of curing. Out of this tests and in combination with the results of the workability (see [4-6]), it leaded to two very good blends for investigations for the durability. The destruction has been documented under capillary water absorbtion. Furthermore, the dynamic modulus of elasticity was calculated from bending-frequency measurements. This was done before and after 24 hours of water saturation, which corresponds to 1 cycle. Thereafter, the samples were carefully dried (40°C) and a new cycle began.

4 Results

4.1 Compressive strength

The effect of ash addition on the strength development is very differently. Mixtures with clay 1 and 2 deliver the best results, in combination with 30 wt% of ash C, there is achieved an increase in strength of approx. 75 – 80 % (16 MPa). The other clays/loams either have no increase in strength due to an addition of ash compared with the pure clay/loam, or it increases with rising content of ash, but it does not exceed 6 MPa.

4.2 Durability

Pure clay/loam-bricks are not weatherproof and lose strength or they are destroyed when they are exposed to excessive moisture. In tropical regions with strong sudden rain it is a recurring problem. The results of the investigation to durability show that an ash addition considerably improved the durability of clay samples.

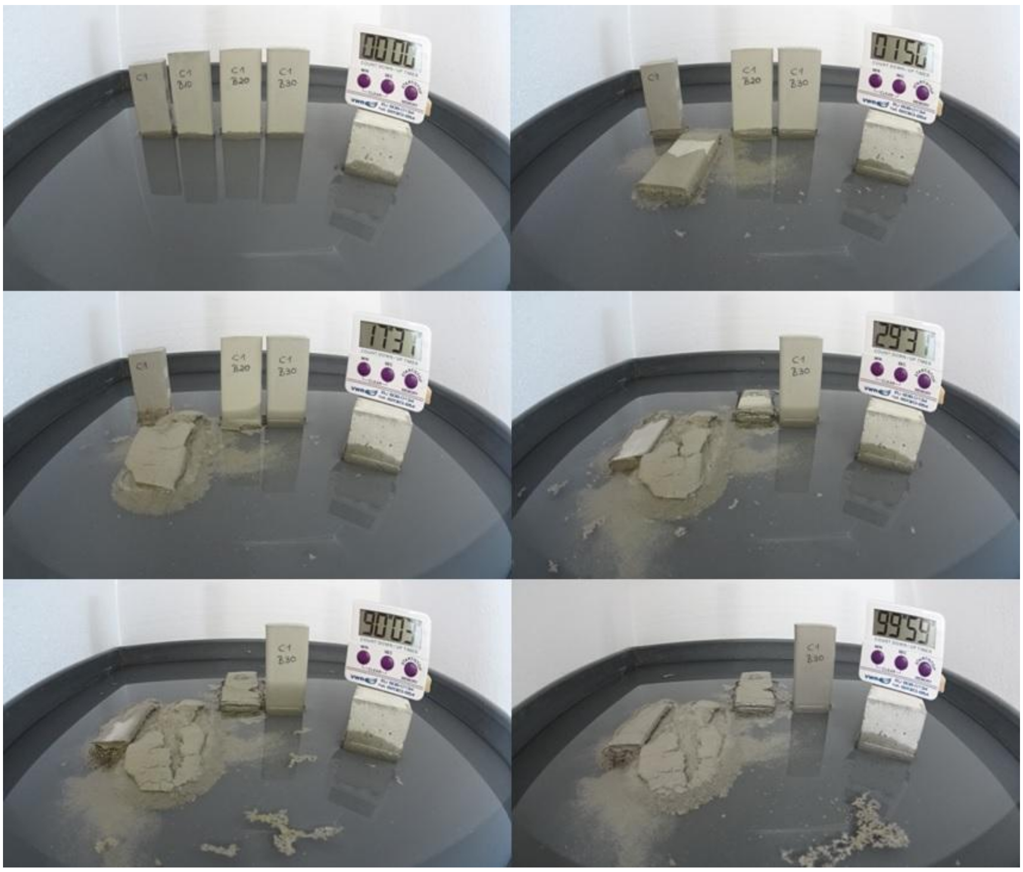

Fig. 2 Capillary water absorption of loam-ash-samples (c1 and ash B) in fast motion

Fig. 2 shows a series of images in fast motion of samples with clay 1 and ash B under capillary water suction. The sample with a content of 10 wt% ashes is so badly damaged after almost 2 minutes that it is overturning. This is confirmed by the studies on strength, 10 wt% ash even reduce the strength in the mixtures. After 17 minutes the pure loam sample is then destroyed and after approx. 30 minutes the specimen with an ash content of

20 wt%. With substitution from 30% of clay by ash the sample is still undamgaed even after complete saturation and it is still the same after 24 h.

Further investigations, based on a subsequent drying (40 °C) to constant mass after 24 hours water absorption and renewed water storage, confirm the improved properties of samples with 20 to 30 wt% ash, see Tab. 3. The samples are not destroyed with a content of 30% ash even after 3 cycles. Furthermore, the calculated dynamic modulus of elasticity indicates no relevant changes in strength by repeated water absorption and subsequent drying.

Tab. 3 Dynamic modulus of elasticity for blends with clay 2 and ash C after water absorption

Cycles	**Pure clay sample**	**10 wt% ash**	**20 wt% ash**	**30 wt% ash**
Before water absorption	7.94	5.06	5.73	8.11
1 st cycle	destroyed	destroyed	5.65	8.28
2 st cycle	-	-	destroyed	8.27
3 st cycle	-	-	-	8.30

5 Conclusion

Based on the results of the project it can bee pointed out, that it is possible to add fly ashes with high amounts of calcium and also sulphate to certain clays or loams to produce extruded bricks in a good quality. It enhances the workability and the strength rises, if ash amounts up to 20 wt% were use. Further, the durability regarding the influence of moisture is greatly improved. From these results it can be noted, that calcium rich ash from lignite can make a contribution to conserving resources and reducing CO_2 emissions. Especially in terms of improving the durability of self-hardening bricks, there are still further potential for this industrial residue.

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