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THEORETICAL AND EXPERIMENTAL STUDIES UPON TO USE OF FLY ASH AS RAW MATERIAL IN CEMENT MANUFACTURING PROCESS

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ABSTRACT

Cement manufacturing process relies mainly on raw materials containing the four essential elements for its creation: calcium oxide, silica oxide, aluminum oxide and iron oxide. On the cement plant those elements are taken from limestone, clay, pyrite and sand. Each raw material used for the cement raw mixture provides mainly one chemical compound; getting the required composition of the meal can be achieved with different mixes of raw materials.

The use of new raw materials will not require higher storage capacity on the plant, only new installation will have to be done to the existing clay silo for sand storage and one of the cement silos changed into fly ash silo to feet with new material specific flow ability.

The cement manufacturing process has to deal with many environmental issues. The use of natural mineral resources is part of this and being able to replace those raw materials with wastes from industrials processes is of great importance for a cement plant. Fly ash has proven its reliability as raw material, with a main issue on this study is to keep the level of supplies from the thermal power station Mintia, which will have to increase its electricity production.

1. INTRODUCTION

Cement manufacturing process relies mainly on raw materials containing the four essential elements for its creation: calcium oxide, silica oxide, aluminum oxide and iron oxide. On the cement plant those elements are taken from limestone, clay, pyrite and sand. Each raw material used for the cement raw mixture provides mainly one chemical compound; getting the required composition of the meal can be achieved with different mixes of raw materials.

Those materials can be either from a natural origin or resulting of different industrial processes, preferably available near a cement plant. Investigation studies on a technical and economical point of view are done

to replace existing raw materials, respectively to use of fly ash from a thermal power station as raw material in cement manufacturing process.

2. NECESSITY AND ADVANTAGES OF THE USE OF FLY ASH

In cement manufacturing process, today is used limestone and clay extracted from their own quarries and pyrite ash as a corrector for cement production.

The use of fly ash as silica-alumina component would be beneficial regarding the following points:

- Lack of homogeneity in the current clay deposit due to sandstone inclusions that create difficulties both in exploitation of the deposit and in the technological process of raw mixture fabrication.
- Present clay has disadvantageous ratio between silica modulus (M_{Si}=2.08-2.19) and the alumina modulus (M_{Al}=2.58-2.7), which leads to a low clinker silica modulus (M_{Si}<2).
- Improvement of clinker's compositional range, and implicitly cement quality, including the possibility to diversify cement types range, produced at lower costs.
- Improvement of environmental protection.
- Conservation of natural resources.

Using fly ash as a raw material for clinker fabrication allow to eliminate; future investments related to updating clay use such as an efficient de-dusting system and also the cost of clay with extraction, crushing, drying, transporting and filling.

3. MATERIALS USED AND THEIR CHARACTERISTICS

3.1 Physical and chemical composition

For this study, the raw materials used are limestone, pyrite ash which are already used today on the plant as raw materials, and it will be add two other raw materials: **fly ash** and **sand**.

The chemical compositions averages are given in Table 1 and Table 3, respectively, the physical characteristic average, in Table 2 and Table 4.

Fly ash is a waste from electricity production in un thermal power station situated at 16 km from the cement plant. It is used as a raw material to increase the silicate modulus and to assure an optimal mineralogical clinker composition.

Table 1. Fly Ash chemical composition average

Chemical compound	SiO_2	Al_2O_3	Fe_2O_3	K_2O	CaO	MgO	Lost of Ignition
Composition (%)	55,84	27,88	8,10	1,97	1,87	1,44	*1,63*

Table 2. Fly Ash physical characteristics average

Volumetric weight (kg/m^3)	RO_2 (%)	Blaine Specific Surface (cm^2/g)	Particle size Granular (%)			
			< 12 μm	< 32 μm	< 48 μm	< 192 μm
870	5,9	2035	16,4	37,8	49,9	93,45

Sand is also used as a raw material to increase silicate modulus because a three raw materials mixture cannot lead to an optimal clinker composition as we can see further.

Table 3. Sand chemical composition average

Chemical compound	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	SO_3	Lost of Ignition
Composition (%)	94,6	2,7	0,99	0,31	0,25	0,03	*0,24*

Table 4. Sand physical characteristics average

Volumetric weight (kg/m^3)	Maximum aggregate moisture (%)	Particle size
1460	26,81	0-1 mm; Fract. > 1 mm = 2 %

3.2. Weighing dosage of raw materials

The dosage calculus (weighing dosage for four raw materials: limestone, fly ash, pyrite ash and sand) is done according to the method on raw meal dosage currently in used in Romania. It's based on clinker-required characteristics influencing the raw materials dosage such as:

- Lime Saturation Factor: to attain complete lime saturation in the clinker, chemical transformations as follow occur:
  - Silicate (SiO_2) in C_3S and C_2S;
  - Al_2O_3 and Fe_2O_3 combined in C_4AF;
  - Remaining alumina in C_3A.

  $Sk = C_0 / (2{,}8.S_0 + 1{,}1.A_0 + 0.7.F_0)$
- Silica ratio: $M_{Si} = S_0 / (A_0 + F_0)$
- Alumina ratio: $M_{Al} = A_0 / F_0$, with $S_0 : SiO_2$; $A_0 : SiO_2$; $F_0 : SiO_2$; $C_0 : SiO_2$

Weighing dosage conclusion: A four raw materials mixture allows giving three modulus conditions on clinker, Lime Saturation Factor, Silicate modulus and Alumina modulus. This is the main difference with the existing three raw materials dosing for which only two conditions are possible to give either Lime Saturation Factor and Silicate modulus or Lime Saturation Factor and Alumina modulus.

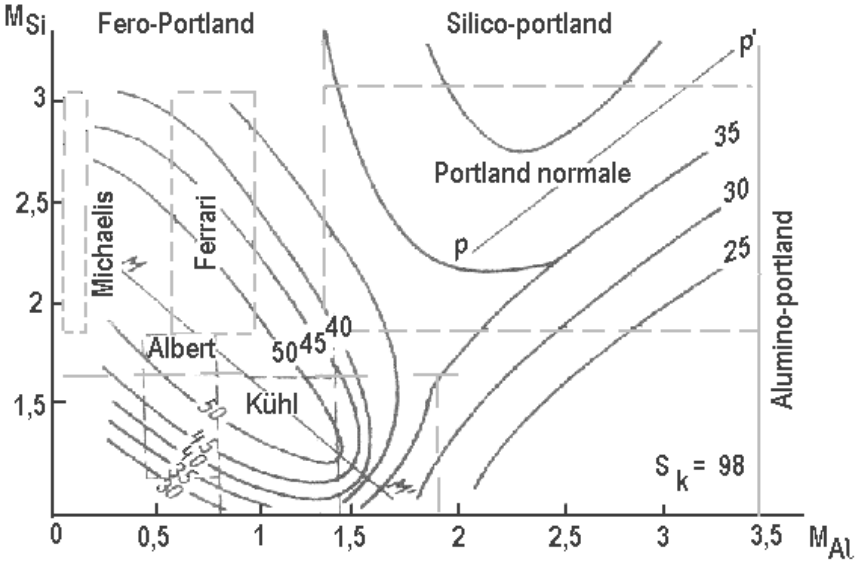

Figure 1. Type of Clinker according to Silicate and Alumina Modulus

Present clay ratio between silica modulus (M_{Si}=2.08-2.19) and alumina modulus (M_{Al}=2.58-2.7) leads to a low clinker silica modulus (M_{Si}<2). On the plant, today the clinker produced average modulus are M_{Si}=2.0-2.1 and M_{Al}= 1.7-1.8 which just matches the minimal required in terms of modulus for Normal Portland cement type (Figure 1).

With the new dosing of raw material, clinker silica and alumina modulus will be increased and lead to an easier clinkerisation process and cement with compression strength higher than 52,5 MPa.

Therefore clinker chemical dosage relies on the type of raw materials used; it means that using limestone, fly ash, pyrite ash and sand the range of cements will increase from today's products with limestone, clay and pyrite ash as raw materials and also the clinker's quality will increase.

3.3. Technological flow for the use of fly ash as raw material

3.3.1. Transport and storage for fly ash: Among other things, the stable operation of a cement plant decisively depends on the reliability and safe functioning of its conveying and storage processes.

Frequent breakdowns and unexpected failures may become serious dangers for maintaining production and may lead to considerable economic consequences. Raw materials transport and storage must be adequately designed according to the cement plant capacity.

The thermal power station situated aprox. 7 km from the cement plant by road provides fly ash today as an additive to clinker and in the near future as a raw material.

Annual fly ash supplies as raw material are based on: Raw meal production relies on cement sales, proportioning of each type of cement with particular clinker percentage; Raw meal dosage characteristics, the amount of fly ash fluctuates with raw meals regarding the raw materials used and clinker-required characteristics.

For an annual production of 500000 tones of raw meal composed of limestone, fly ash, pyrite ash and sand with 11% average weight proportion of fly ash, the annual needs in fly ash as a raw material are of 55000 tones.

Raw meal required characteristics can fluctuates in order to produce different types of clinker; therefore fly ash proportion in raw meal can fluctuate from 10 to 12 %. Adding the annual 30000 tones of fly ash used as additive to clinker, it leads overall to 85000 tones annual fly ash consumption on the cement plant.

Today the 30 000 tones annual consumption is stored in a 600 tone silo. The new utilization of fly ash will require a higher storage capacity which as to be situated close to the actual raw materials dosage workshop and also close to the railway and road access.

If we consider existing storage facilities acceptable for the above conditions, a cement silo matches the best with a road and railway access. It is necessary to use an existing silo connected with railway, fly ash is now transported to the plant by truck but railway access is necessary for future possible transport facilities.

***Capacity of the future fly ash silo**:* Volume capacity: 6000 m^3; Fly ash volumetric weight: 0.8 t/m^3; Weight capacity: 4800 tonnes of fly ash.

***Raw mill capacity for fly ash**:* With a maximum of 12% of fly ash in raw materials weighting dosage: Raw mill general capacity – 260 tonnes/hour; Raw mill fly ash capacity – 31 tonnes/hour; Daily capacity (for a 16 hours run)- 500 tonnes/day.

Cement mill capacity for fly ash. With a maximum of 18% of fly ash in raw materials weighting dosage: Cement mill general capacity – 100 tonnes/hour; Cement mill fly ash capacity –18 tonnes/hour; Daily capacity (24 hours run) – 432 tonnes/day.

Table 5. Raw meal production characteristics

Characteristics	Raw meal	Limestone	Fly Ash	Pyrite Ash	Sand
Weighing dosage (%)	100	80,5	10,5	1,9	7,1
Annual consumption (t)	500000	402500	52500	9500	35500
Raw mill capacity (t/h)	260	210	27	5	18,5
Daily raw mill capacity (t/d)	4160	3360	432	80	296

The existing cement silo, which will be changed into fly ash silo, must be restructured with mainly new input and output device.

3.3.2 Transport of fly ash from silo to dosing system and dosing system

The entire conveying line from the silo to the dosing system for the raw mill will be a pneumatic conveyor, which is suitable for fine particles such as fly ash and also with an easy installation on an existing plant. It will be designed for a maximum capacity of 50 tonnes/hour, considering a raw mill fly ash capacity of 31 tonnes per hour and future higher capacity due to mill general capacity increase or fly ash higher proportion in weighing dosage.

4. ECONOMIC EFFICIENCY OF THE USE OF FLY ASH AND SAND INSTEAD OF CLAY. CONCLUSIONS

For an annual production of 500000 tones of raw meal, we compare the consumption of clay in the three raw materials dosage to the consumption of fly ash and sand in the four raw materials dosage. We consider for the four materials weighing dosage as considered in [1], an equivalent amount of clay instead of sand and fly ash.

Table 6

Type of meal	3 Compounds raw meal	4 Compounds raw meal	
Raw material	Clay	Sand	Fly Ash
Cost of material (Euro/tonne)	4	8	4
Weighing dosage (%)	17.6	7.1	10.5
Annual cons. for 500000 t. of raw meal	88000	35500	52500
Annual cost for each raw material (Euro)	332000	284000	210000
Annual cost (Euro)	332000	494000	

The annual cost of sand with fly ash is 50% higher than the cost of clay in raw meal if we consider replacing the entire clay consumption. In this study a small amount of clay will be firstly replaced by fly ash and sand that will not increase to an important extent the price of cement. We also have to consider that necessary investments related to updating of clay handling are going to increase the material cost. The benefit of replacing clay is to obtain a much better quality of clinker with higher silica and alumina modulus. Thus more additives can be used with this clinker from 35% today up to 60% with the new clinker, which will lower the final cost of cement.

The use of new raw materials will not require higher storage capacity on the plant, only new installation will have to be done to the existing clay silo for sand storage and one of the cement silos changed into fly ash silo to feet with new material specific flow ability. Conveying of raw materials will be done via existing conveyors for fly ash and sand; only fly ash will require a new pneumatic piping line, which has the advantage to be able to be easily shaped to feet with the actual structures on the plant.

The cement manufacturing process has to deal with many environmental issues. The use of natural mineral resources is part of this and being able to replace those raw materials with wastes from industrials processes is of great importance for a cement plant. Fly ash has proven its reliability as raw material, with a main issue on this study is to keep the level of supplies from the thermal power station Mintia, which will have to increase its electricity production.

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