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THE INFLUENCE OF CLINKER DUST ON BLAST FURNACE CEMENT PROPERTIES

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ABSTRACT

Clinker dust or cement kiln dust (CKD) is fine granulated material which generate during the thermal treatment of raw meal and during the clinker cooling process. By applying different methods in certain stages of the technological process it is possible to extract the mentioned dust. The chemical composition of the clinker dust depends on type and composition of raw material, fuel and specific material flow from the kiln system. Increasing the content of alkali, chlorine, sulphate and other raw materials and fuels constituents results in significant increasing of these constituents in the kiln dust structure. Generally it can be said that the formation of clinker dust in the kiln system is undesirable and it is therefore necessary to periodically release the CKD from the mentioned kiln system. On this way it is possible to use clinker dust as a cement additive. In this article has been conducted research of using mentioned kiln dust as blast furnace cement additive where the focus was on influence of CKD on physical-mechanical properties of cement.

1. INTRODUCTION

Clinker dust is a chemical byproduct of the cement production. More precisely, clinker dust accrues during the clinker burning process in the kiln. The dust-polluted kiln gases are discharged at different spots of the kiln system and dedusted in various filter systems. The chemical composition of the clinker dust strongly depends among other factors on the raw materials and fuels used, on the kiln system and on where the gas is discharged (within the kiln system). The amounts of clinker dust are considerable and generally pose the question of utilization for the cement plants.

If one looks at generation and disposal of clinker dust under the cost aspect, it becomes clear that this dust is generated from precious raw materials with high grinding energy consumption. Burning the thus generated kiln meal uses up a large amount of heating energy. If the discharged clinker dust is then landfilled, this means an economic loss due to:

- loss of precious raw materials,
- loss of energy,
- costs of operation, storage and transportation

Moreover, landfilling of clinker dust is not in line with environmental protection with regard to:

- conservation of primary resources (raw materials and fuels),
- climate protection by reduction of CO_2 emissions generated during burning of limestone,
- conservation of valuable landfilling areas.

Chemical construction of clinker dust depends on a number of factors. In principle it can be said that in different kiln systems different types of clinker dust arise. From a general point of view the following factors are decisive:

- **Used materials**: Different amounts of alkalis, chloride, SO_3 and volatile heavy metals can be transferred into the kiln system via the used raw materials and fuels. The relative contents of these substances have significant impact on the composition of the clinker dust. However, volatility of a salt does not only depend on the metal ion, but also on the anion. Chlorides, for example, increase the volatility of alkalis and thus smaller amounts can be integrated into clinker despite the same ambient conditions.

- **Temperature and retention time**: The hot kiln area represents a barrier for the volatile constituents. At a certain temperature a given amount of potassium, for example, can be integrated into clinker and by this break the barrier. The remaining amount vaporizes and is transported with the kiln gas in cooler areas where it recondenses. The higher temperatures are in the sintering zone and the longer retention times are, the higher is the barrier and consequently only few volatile constituents can be integrated into the clinker. This supports the creation of circulations. As extreme example white cement can be named which is burned at very high temperatures. Consequently, the alkali content of the clinker is very low.

- **Circulations**: If less volatile constituents are transferred outwards by the clinker than moved in by the raw materials, circulations may build up and influence the burning process (for example in kilns with cyclone preheater without bypass alkali circulations can appear at the kiln inlet → formation of coating and blocking of the cyclone). If alkali-contaminated dust is unlimitedly used as raw meal, outer circulations are formed. By vaporization/sublimation in hot areas and condensation/resublimation in cooler areas the thermal balance of the kiln is influenced in a negative way.

The European cement standard EN 197 allows utilization of clinker dust as secondary component in cement of up to 5%. Due to the chloride content in the dust this proportioning cannot be attained in many cases, as the limit value of 0.1% of chloride is usually reached with lesser quantities. Besides chloride the alkali content of clinker dust may be the reason for a lower proportioning. This might be the case if certain requirements regarding alkali content, heat of hydration and sulfate resistance are to be met.

The utilization in cement thus depends on the contents of chloride and/or alkalis in the clinker dust. In some cases the contents of trace elements might also be of importance, if, for example, the eluate of cement-containing material must meet certain requirements.

In comparison to the use in Portland cements the clinker dust's activating effect is stronger in CEM II and CEM III cements that contain fly ash and/or slag. It has a positive effect especially on the early strengths. Measurements of a CEM III/A 42.5 showed an early strength increase of up to 4 MPa after 7 days. On the other hand, there are only minor changes as to the final strengths. This is an advantage insofar as the cement must not be sorted into the next higher strength class.
A prolongation of the setting time (initial and final setting time) is sometimes observed when utilizing clinker dust. The initial setting time is merely prolonged by 10-15 minutes, whereas the prolongation of the final setting time might amount to between 40 and 80 minutes. In some cases, however, prolongation of the processing time can indeed be of advantage.

Bhatty (1983, 1984a-c, and 1986) found that the addition of CKD with fly ash and slag produced cement with improved strength while not impacting other properties. It was reported that cements containing only CKD had reduced workability, setting times, and strength. The loss of strength was attributed to alkalies in the dust. It is believed that the use of fly ash with CKD diluted the alkalies and thus improved the strength.
Bhatty found that the use of slag may reduce the workability of the cement, but when CKD was added, the strength increased due to the activation of the slag by the alkalies. It was found that blended cement with high sulfate produced the greatest strength, and that the impact of the alkali in the dust could be negated by the fly ash and/or slag. Overall, the ratios of alkali, chlorides, and sulfates in the dust impacted the performance of the blended cements.

Researches of many studies were shown that the water for normal consistency increases with the quantity of CKD. This is due to the presence of high amount of alkalis, sulfates, volatile salts, and lime in cement dust, as well as the high surface area leading to high water demand. The setting times are shortened with an increase in the quantity of CKD. This may be attributed to the high alkalinity of the CKD that accelerates the hydration of cement.

The free lime content increases with curing time up to 7 days. This is mainly attributed to the hydration of slag portion that begins with slow rate and increases with time. Therefore, the consumption of the liberated lime increases with time. The hardened slag cement pastes with the CKD give higher values of free lime than only slag cement paste. This is due to the fact that there are two main sources of lime, the hydration of cement clinker phases and the residual lime containing CKD. Therefore, the free lime is increased with CKD content. At a given age, the free lime content increases with the quantity of CKD.

The compressive strength increases with curing time for all hardened cement mortars. This is due to the continuous hydration and accumulation of hydration products in water filled pores to form a more compact body. At a given time, the hardened slag cement mortar with 5% CKD gives higher values of compressive strength than slag cement mortar. 5% CKD is the optimum amount to activate the hydration of slag while the compressive strength decreases slightly with CKD content of up to 10 mass%. It can be concluded that, the substitution of slag cement with 5 to 10% CKD has a slight effect on the compressive strength. As the CKD content increases up to 20 mass%, the compressive strength decreases significantly.

2. EXPERIMENTAL TECHNIQUES

For this research 18 laboratory samples were prepared with different amount of clinker and granulated blast furnace slag while the content of clinker dust and gypsum was fixed on 4%. Since there are three types of blast furnace cements according to standard EN 197-1 (CEM III/A, CEM III/B and CEM III/C) it was prepared 6 samples of CEM III/A, then 6 samples of CEM III/B and 6 samples of CEM III/C.

For each type of blast furnace cement was prepared samples with minimum, maximum and average content of granulated blast furnace slag and clinker with and without clinker dust. For all mentioned samples was followed the compressive strength durring the time as physical-mechanical parameter.

Table 1 shows the content of granulated blast furnace slag, clinker, gypsum and clinker dust for CEM III/A type of cement.

Table 1. Composition of CEM III/A cement

	Sample name	**Clinker (%)**	**Granulated blast furnace slag (%)**	**Gypsum (%)**	**Clinker dust (%)**
CEM III/A	**U 1 -** CEM III/A	**35.00**	**61.00**	**4.00**	**X**
	U 2 - CEM III/A	**57.00**	**39.00**	**4.00**	**X**
	U 3 - CEM III/A	**46.00**	**50.00**	**4.00**	**X**
	U 4 - CEM III/A	**35.00**	**57.00**	**4.00**	**4.00**
	U 5 - CEM III/A	**57.00**	**35.00**	**4.00**	**4.00**
	U 6 - CEM III/A	**46.00**	**46.00**	**4.00**	**4.00**

Table 2 shows the content of granulated blast furnace slag, clinker, gypsum and clinker dust for CEM III/B type of cement.

Table 2. Composition of CEM III/B cement

	Sample name	Clinker (%)	Granulated blast furnace slag (%)	Gypsum (%)	Clinker dust (%)
CEM III/B	**U 10 -** CEM III/B	**20.00**	**76.00**	**4.00**	**X**
	U 11 - CEM III/B	**28.00**	**68.00**	**4.00**	**X**
	U 12 - CEM III/B	**24.00**	**72.00**	**4.00**	**X**
	U 13 - CEM III/B	**20.00**	**72.00**	**4.00**	**4.00**
	U 14 - CEM III/B	**28.00**	**64.00**	**4.00**	**4.00**
	U 15 - CEM III/B	**24.00**	**68.00**	**4.00**	**4.00**

Table 3 shows the content of granulated blast furnace slag, clinker, gypsum and clinker dust for CEM III/C type of cement.

Table 3. Composition of CEM III/C cement

	Sample name	Clinker (%)	Granulated blast furnace slag (%)	Gypsum (%)	Clinker dust (%)
CEM III/C	**U 19 -** CEM III/C	**5.00**	**91.00**	**4.00**	**X**
	U 20 - CEM III/C	**14.00**	**82.00**	**4.00**	**X**
	U 21 - CEM III/C	**10.00**	**86.00**	**4.00**	**X**
	U 22 - CEM III/C	**5.00**	**87.00**	**4.00**	**4.00**
	U 23 - CEM III/C	**14.00**	**78.00**	**4.00**	**4.00**
	U 24 - CEM III/C	**10.00**	**82.00**	**4.00**	**4.00**

3. RESULTS AND DISCUSION

In the following figures (diagrams) are presented the values for compressive strength for three types of cement in function of time. The Figure 1 refers to cement CEM III/A, while Figure 2 refers to CEM III/B and figure 3. is related to CEM III/C.

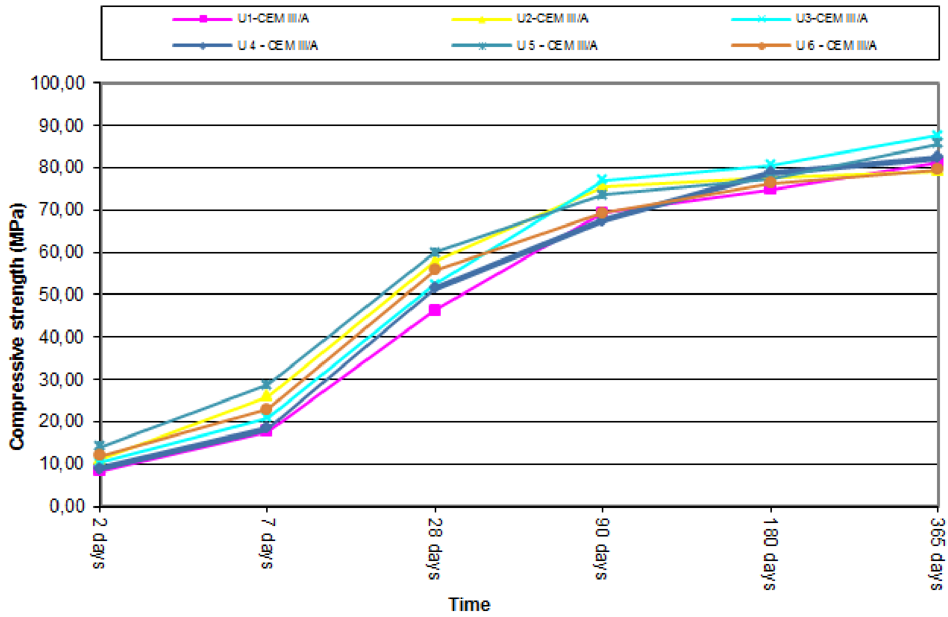

Figure 1. Compressive strength for CEM III/A cement

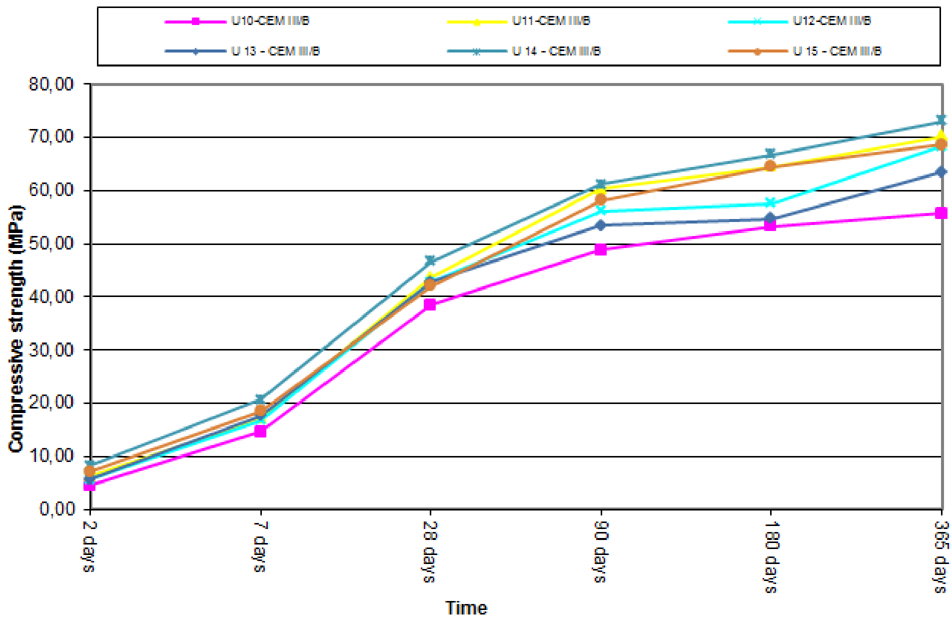

Figure 2. Compressive strength for CEM III/B cement

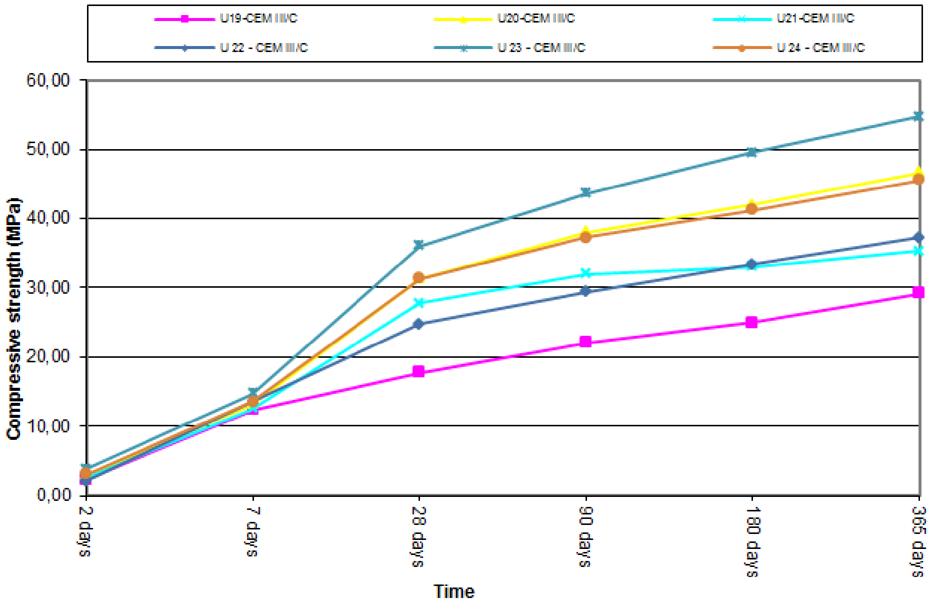

Figure 3. Compressive strength for CEM III/C cement

4. CONCLUSION

From the presented results it can be concluded that:

- Cement type CEM III/A has the biggest values for compressive strength during the whole period of examination (2, 7, 28, 90, 180 and 365 days). The reason for this is the largest quantity of clinker.
- As the amount of clinker decreases and the granulated blast furnace slag increased, the compressive strength in the early period is decreased while in the later period is increased.
- The presence of clinker dust (CKD) has positive effect on compressive strength in all period of examination.
- Clinker dust with low alkalis and chlorine content is desirable because of positive influence on cement compressive strength.
- Generally on the one hand clinker dust is the material which is necessary to release from kiln system from time to time in order to prevent blockage of kiln and on the other hand clinker dust with good quality is acceptable for cement production.

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