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THE EFFECT OF CEMENT KILN DUST ON THE PROPERTIES OF CEMENT

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ABSTRACT

Due to the nature of the technological process, the cement industry is a significant source of dust. Managing industrial waste is a global problem worldwide; cement kiln dust is an example of such waste. The dust from the cement kiln is a by-product of the cement production process obtained during the grinding and burning of the raw materials inside the cement kiln. Still, due to its high alkaline content, it cannot be returned to the kiln, but its disposal and landfill can cause many environmental problems. It is necessary to find alternative methods for its utilization. Due to its fineness and composition like that of cement, there is a growing interest in the use of this powder as a partial substitute for ordinary Portland cement. The purpose of this paper is to investigate the influence of dust obtained during the production of cement clinker on the properties of cement (specific surface area, standard consistency, setting time, and compressive strength) and its implications in the conditions of its application.

Keywords: cement kiln dust, mechanical properties, cement, water requirement.

INTRODUCTION

The production process of Portland cement clinker, a semi-finished product in cement manufacturing, results in the release of significant amounts of dust, including dust from the kiln dedusting installation (referred to as CKD - Cement Kiln Dust) and dust from bypass installation (referred to as CBPD - Cement By-Pass Dust). While CKD is consistently released in the cement production process, CBPD is only used in specific cases to reduce chlorine and alkali [1 - 4].

The impact of bypass dust on cement properties has been the subject of investigation in various papers [3]. The addition of CBPD dust to cement results in an increased water requirement to achieve standard consistency in the cement paste. When 10 % of CBPD is added, the water demand increases by approximately 22 % compared to ordinary Portland cement paste [3]. According to the study reported by El-Didamony et al., the initial setting time of cement paste with 10 % CBPD is shortened by about 45 % [3]. Additionally, the compressive strength of cement mortar containing CBPD is similar to that of ordinary Portland cement, as long as the CBPD dust content does not exceed 6 %. The quality of CBPD is influenced by the clinker-burning technology, the type of raw materials and fuels used, and the dust removal method. CBPD varies in chemical and mineral composition as well as physical properties [5, 6].

The chemical and mineral composition as well as the physical properties of the CBPD differ from those of CKD [7 - 10].

The primary component found in bypass dust is CaO, with a concentration ranging from 40 to 60 % [7]. Additionally, it contains SiO_2, Al_2O_3, Fe_2O_3, K_2O, and Na_2O. Unlike Portland cement clinker, bypass dust is distinguished by its high levels of alkalis, particularly K_2O, chlorides, and SO_3. The concentration of these oxides in bypass dust is dependent on the type of fuel used in cement production, particularly alternative fuels like plastics, bone meal, and sewage sludge. The high levels of alkalis, chlorine, and sulfur significantly restrict the use of cement bypass dust in cement production [8].

CBPD is characterized by a high concentration of chlorine in comparison to CKD, where the concentration of chlorine is minimal. Another notable difference is the content of K_2O and SO_3. The content of potassium and sulfur in CBPD can be as much as 2 - 2.5 times higher than that in CKD [11 - 13]. As the production of Portland cement clinker continues to rise, the amount of emitted cement dust is also increasing. As a result, there is growing discussion about the broader utilization of bypass dust in various industries. Currently, bypass dust is being used in the production of cement and glass, for building roads and highways, and in the manufacturing of concrete. There is also significant interest in utilizing this waste for solid stabilization purposes [14, 15].

Numerous studies have delved into the characteristics of cement containing CBPD dust. This paper aims to analyse the properties of a cement binder that incorporates cement dust from a cement kiln (CKD).

EXPERIMENTAL

In the experimental part, cement using varying proportions of clinker, dust from a rotary cement kiln (CKD) (Fig. 1), and industrial gypsum dihydrate, as detailed in Table 1 was produced. The clinker and dust were sourced from the same cement plant, and their composition is provided in Table 2. For industrial experiments, a vertical roller mill with a maximum grinding pressure of 155 Bar and a highly efficient dynamic separator. The following analyses were performed on the obtained samples:

The particle size analysis of the feed and ground products was conducted using a Laser Diffraction Particle Sizer Mastersizer 3000 (Malvern Instruments). The specific surface area was determined using the Blaine air-permeability apparatus and expressed as the total surface area in square centimeters per gram, or square meters per kilogram, of cement. Please take note of the following procedure for the determination of standard consistency: Combine 300 g of ground cement with 75 g of tap water in a vessel and mix with a spoon

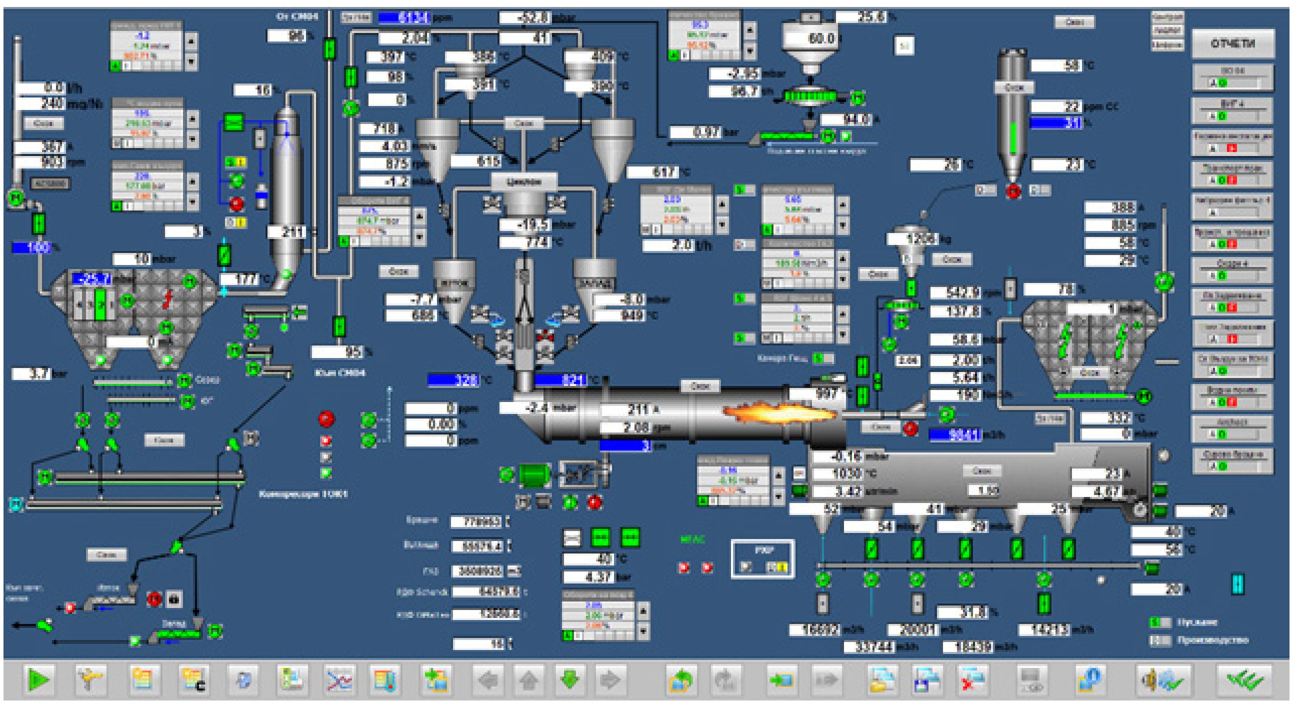

Fig. 1. Rotary cement kiln for the production clinker (dry method) with a preheater tower.

for 3 min. Fill the cement paste into a Vicat ring on a glass plate. Allow the tip of the plunger to fall onto the top surface of the cement paste and then set freely. If the water used is sufficient for a normally consistent paste, the plunger should fall to 5 - 7 mm from the glass plate within 30 sec. The Vicat apparatus was used to determine the water quantity required for cement, using a cylindrical plunger. The compressive strength of mortar was determined following standard EN 196 - 1:2016 Method of testing cement - Part1: Determination of strength, by placing prepared mortar in prismatic molds with dimensions of 160 × 40 × 40 mm. The molds were cured at a temperature of 20°C in a room with a relative humidity of 90 % for 24 h, followed by cured in tap water at 20°C for 1, 2, and 28 days. After the specified durations, the prismatic specimens were split and broken using Toni Technik 2020 equipment. Each test was repeated three times, and the reported values represent the mean average.

RESULTS AND DISCUSSION

The results of the experiments that were conducted are detailed in Table 2. Introducing bypass dust into the cement results in an increased water requirement to achieve standard consistency in the cement paste (Fig. 2), aligning with findings in existing literature. The incorporation of bypass dust into the cement reduces the initial setting time of the cement paste (Fig. 3). Furthermore, an increase in dust content in the binder further reduces the initial setting time, consistent with findings in the literature. This can be attributed to the high alkali content in bypass cement binders, which may activate the hydration of the cement fraction, primarily alite (C3S). The higher the dust content in the binder, the greater the water demand, likely due to the increased specific surface area of the cement binder resulting from the incorporation of bypass dust, which is characterized by very high Blaine's surface area (Fig. 4). As indicated

Table 1. Mix proportions of raw materials subjected to grinding.

	Clinker, %	Gypsum, %	CKD, %
Blank	96.0	4.0	0.0
Recipe 1	95.0	4.0	1.0
Recipe 2	93.0	4.0	3.0
Recipe 3	91.0	4.0	5.0

Table 2. Results of the investigated cement pastes.

	OPC , %	CKD, %	W/C, %	Setting time, min	Compressive strength [Mpa]			
					1 day	2 day	7 day	28 day
Blank	100	0	28.00	200	17.3	30.00	46.80	55.20
Recipe 1	99	1	29.10	195	16.5	29.50	44.90	54.80
Recipe 2	97	3	29.60	190	17.3	30.80	46.70	53.50
Recipe 3	95	5	30.20	180	17.7	32.00	47.30	52.60

in Table 2, the initial setting time of the reference paste (recipe 1) is 200 min.

The presence of cement bypass dust hurts the strength of cement mortars as shown in Fig. 5. The strength of mortars in Recipe 1 to Recipe 3 is lower than that of the reference mortar (Blank) after each analysis period. This decrease in compressive strength may be attributed to the higher content of free CaO in dust-containing binders due to the introduction of CKD, which represents a high concentration of free CaO. Moreover, the cement binder containing bypass dust requires more water to achieve standard cement paste consistency, potentially leading to increased microporosity, especially in the content of capillary pores and macropores in the microstructure [15]. This increase in microporosity consequently adversely affects the strength properties of the mortar, resulting in reduced resistance to compressive forces.

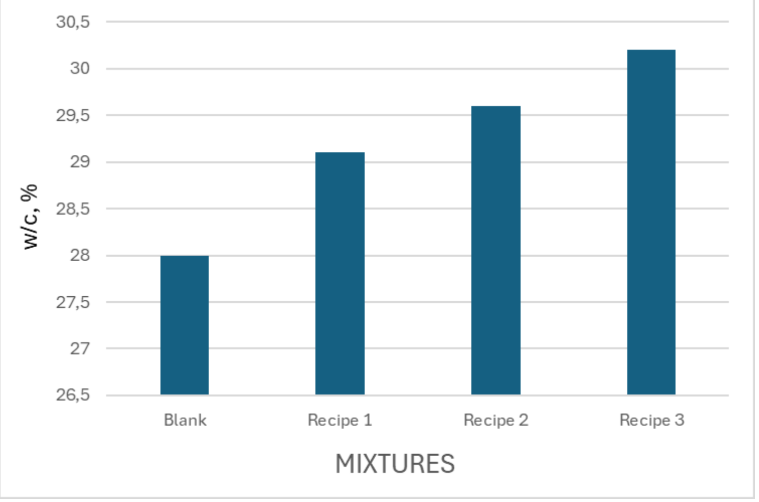

Fig 2. Water/cement ratio of cement mixtures.

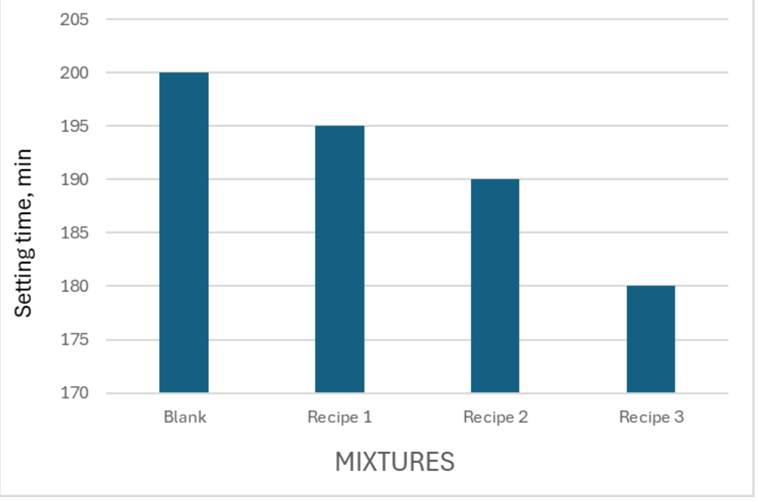

Fig. 3. Setting time of cement mixtures.

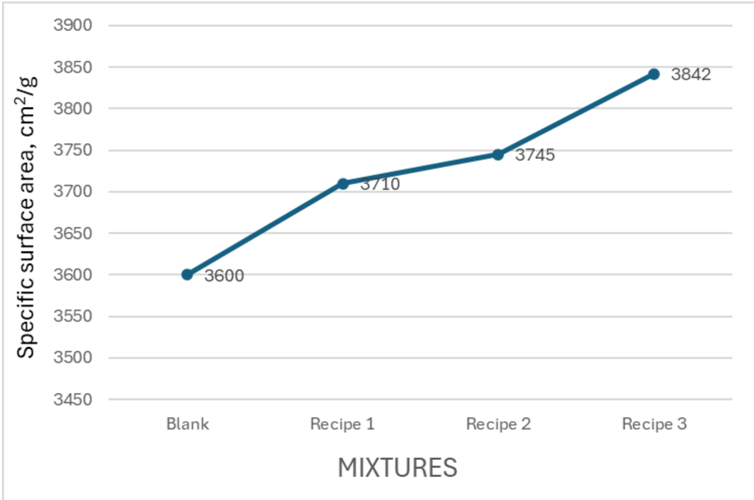

Fig. 4: Specific surface area of cement mixtures.

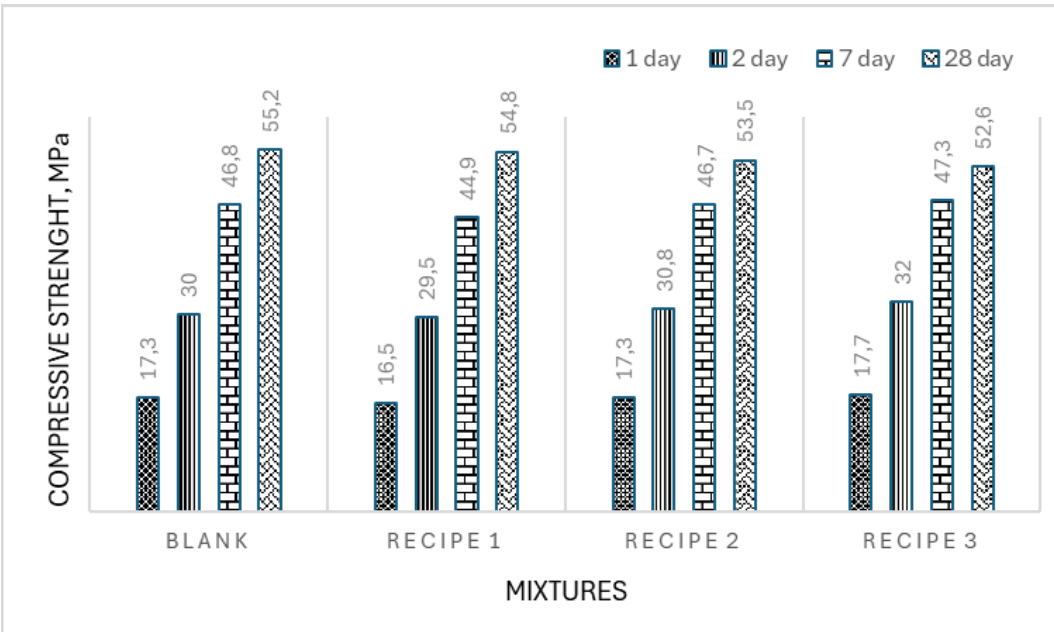

Fig. 5. Compressive strength of cement mixtures.

CONCLUSIONS

Incorporating cement kiln dust into the cement mix increases the water requirement to achieve standard consistency. For samples analysed, the water requirement for full hydration increases by up to 8 % with 5 % dust entrainment. A higher dust content in the mix accelerates the setting of the cement paste. Specifically, the cement paste containing 5 % dust begins to harden 20 min earlier than the control mixture. Adding CKD to the cement mix enhances early strength compared to samples without but diminishes ultimate strength by up to 4.5 % at day 28. The inclusion of small amounts of dust from a rotary cement kiln has no significant impact on the physical-mechanical properties of the cement.

REFERENCES

1. K. Al-Jabri, R. Taha, M. Al-Ghassani, Use of copper slag and cement by-pass dust as cementitious materials, Cement Concrete Aggregates, 24, 2002, 7-12.
2. K.S. Al-Jabri, R.A. Taha, A. Al-Hashmi, A.S. Al-Harthy, Effect of copper slag and cement by-pass dust addition on mechanical properties of concrete, Construction and Building Materials, 20, 2006, 322-331.
3. H. El-Didamony, I.M. Helmy, A. Amer, Utilization of cement dust in blended cement, Pakistan Journal of Scientific and Industrial Research, 35, 1993, 304-308.
4. S. Pavía, D. Regan, Influence of cement kiln dust on the physical properties of calcium lime mortars, Materials, and Structures, 43, 2010, 381-391.
5. W.S. Adaska, P. Works, D.H. Taubert, Beneficial Uses of Cement Kiln Dust, Proc. Cem. Ind. Tech. Conf. Rec., Miami, FL, USA, 2008, 210-228.
6. H.A. Todres, A. Mishulovich, J. Ahmed, Cement kiln dust management: permeability, Research and Development Bulletin RD 103T, Portland Cement Association, Skokie, 1992.
7. M. Maslehuddin, O.S. B. Al-Amoudi, M. Shameem, M. K. Rehman, M. Ibrahim, Usage of cement kiln dust in cement products - research review and preliminary investigations, Construction and Building Materials, 22, 2008, 2369-2375.
8. S. Peethamparan, J. Olek, J. Lovell, Influence of chemical and physical characteristics of cement kiln dust (CKDs) on their hydration behaviour and potential suitability for soil stabilization, Cement and Concrete Research, 38, 2008, 803-815.
9. R. Siddique, Utilization of cement kiln dust (CKD) in cement mortar and concrete - an overview, Resources, Conservation and Recycling, 48, 2006, 315-338.
10. M. Khudhair, A. Elharfi, Formulation of the cement kiln dust (CKD) in concrete: Studies of the physical-chemical and mechanical properties, Int. J. Chem. Tech. Res., 9, 2016, 695-704.
11. M. Heikal, I. Aiad, I. M. Helmy, Portland cement clinker, granulated slag and by-pass cement dust composites, Cement and Concrete Research, 32, 2002, 1805-1812.
12. H.M. Mostafa, E.M. Rashed, A.H. Mostafa, Utilizations of by-pass kiln dust for treatment of tanneries effluent wastewater, 9th International Water Technology Conference, 2005, Sharm El-Sheikh, 2005, 133-141.
13. Y. Keerthi, P.D. Kanthi, N. Tejaswi, K.S. Chamberlin, B. Satyanarayana, Stabilization of clayey soil using cement kiln waste, Inter. J. Adv. Str. Geo. Eng., 2, 2013, 2319-5347.
14. G.A. Miller, S. Azad, Influence of soil type on stabilization with cement kiln dust, Construction and Building Materials, 14, 2000, 89-97.
15. B.S. Albusoda, L.A.K. Salem, K. Salem, Stabilization of dune sand by using cement kiln dust (CKD), Journal of Earth Sciences and Geotechnical Engineering, 2, 2012, 131-143.