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UTILIZATION OF CEMENT DUST IN BLENDED CEMENT

H. EL DIDAMONY, I. M. HELMY AND A. A. AMER

Faculty of Science, Zagazig University, Zagazig, Egypt

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Cement plants generate cement dust during the manufacture of portland cement. The present work aims to study the utilization of this waste product to prepare some blended cements. The results revealed that the substitution of portland cement clinker as well as slag with cement dust decrease the hydration and mechanical properties of portland and portland slag cements.

Key words: Cement dust, Granulated slag, Portland cement.

Introduction

The utilization of by-products, from the various sectors of industry, is a present-day concern involving the problem of energy and sometimes even ecology. The cement industry usually uses mechanical collectors, electrostatic precipitators filter baghouse collectors, or combinations to control the particulate. In fact, approximately 12% of the kiln feed exists from the kiln with the gas throughout the industry, roughly 73% of the kiln dust is recycled to the cement-making process [1].

Cement kiln dust blends with slag fly ash were investigated by Bhatti [2]. Compressive strength, slump and initial setting time were measured. The amounts of sulphates, volatiles, free CaO as well as CaCO₃ affected the properties of the blends.

Daugherty and Funnell [3] investigated a variety of slags, fly ashes, and kiln dust in combination with normal portland cements from a number of cement plants. The object of the study was to determine the effect of cement quality when low levels of by-product additives are incorporated into portland cement.

The effect of 10% kiln dust on the properties of fly ash-slag portland cement blends were examined [4]. The kiln dusts used were categorized as low alkali-low chloride-high sulphate, and high alkali-high chloride-low sulphate. The blends were studied for strength, shrinkage, autoclave expansion, sulphate expansion and alkali aggregate expansion.

The aim of the present work is to study the effect of cement dust as an ingredient for the preparation of blended cement. The blends were prepared from portland cement clinker, granulated slag, cement dust and raw gypsum. The hydration as well as the compressive strength were investigated.

Experimental

The materials used in this work were ordinary portland cement clinker, cement dust, granulated slag and raw gypsum.

The chemical composition of these materials is given in Table 1. The surface area of the cement clinker, granulated slag, cement dust and gypsum were 3200, 3380, 3180 and 2750 cm² g⁻¹, respectively. The determination was carried out by the air permeability according to ASTM method [5]. Blended cements were prepared from the above materials as shown in Table 2.

TABLE 1. CHEMICAL OXIDE COMPOSITION OF STARTING MATERIALS, % (wt).

Material	Oxides, %						
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	L.O.I
P.C.Clinker.	21.40	5.10	3.20	63.80	2.50	1.50	0.90
S.R. Cement.	20.90	4.02	5.14	64.10	1.90	2.36	0.60
C.K. Dust*.	16.16	4.71	2.83	53.85	2.18	4.79	9.10
B. F. Slag	35.00	13.00	0.50	45.00	2.60	0.50	0.20
Gypsum	2.00	1.80	0.20	33.00	0.70	40.00	20.00

*Sol. salt K₂O and Na₂O 3.66%, Cl 8.70% and free lime 14.12%.

TABLE 2. MIX COMPOSITION OF DIFFERENT CEMENTS, % (BY WEIGHT).

System	O.P.Clinker	C.Dust	G. Slag	Gypsum
I.1	95	00	00	5
I.2	80	15	00	5
I.3	75	20	00	5
I.4	65	30	00	5
II.1	60	00	35	5
II.2	50	10	35	5
II.3	40	20	35	5
II.4	30	30	35	5
III.1	65	00	30	5
III.2	65	10	20	5
III.3	65	15	15	5
III.4	65	20	10	5

Each dry mix was homogenized for 1 hr. in a porcelain ball mill using two balls to assure complete homogeneity. The mixing of the paste was done as described in a previous work [6]. The pastes were mixed using 0.28 W/C and moulded in one inch cubes. The moulds were cured in a humidity chamber at $23 \pm 1^\circ$ for 24 hr. then demoulded and cured under water until the time of testing.

The kinetic of the hydration was followed by the determination of free lime as well as chemically-combined water contents after 3, 7, 28, 90, 180 and 360 days. The compressive strength was also determined at these intervals. After measuring the compressive strength the hydration was stopped [6]. The free lime content was determined as described elsewhere [7]. The combined water content was estimated by the ignition loss of the dried sample at 1000° for 30 min. The combined water contents of the hardened cement pastes containing cement dust were corrected.

$$\% \text{ Combined water content} = \text{Ignition loss of hydrated sample} - \text{ignition loss of raw mix.}$$

Results and Discussion

Substitution of portland cement clinker with cement dust in portland cement. This series deals with the effect of cement dust on the hydration characteristics of portland cement paste. The combined water contents of kiln dust blended cement pastes are graphically plotted as a function of curing time in Fig. 1. The chemically-combined water contents increases gradually with increasing curing time for all cement pastes. The results illustrate that portland cement paste gives the higher values of combined water. On the other side, as the

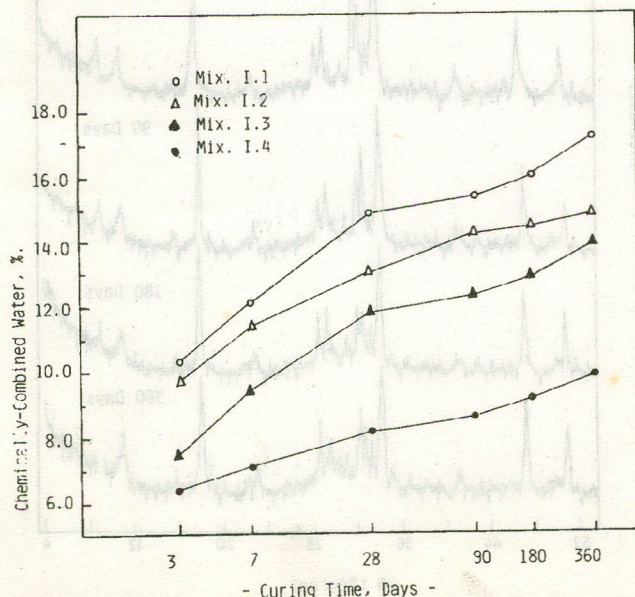


Fig. 1. Chemically-combined water for different cement pastes immersed in tap-water up to one year, %.

cement dust increases, the combined water contents diminish. This is mainly due to the decrease of the amount of cement clinker with increasing the cement dust. Accordingly, the portland cement phases such as C_3S , $\beta-C_2S$, C_3A and C_4AF are diminished. These phases with their hydraulic characteristics certainly influence the chemically-combined water. The cement dust on the other hand has no hydraulic characteristics, it consists mainly of $CaCO_3$ with some alkalis and quartz [8].

Although the combined water content has been used to study the kinetics of hydration of blended cement pastes, interpretation of the results on the basis of liberated free lime during the hydration has been found to be complex. In such cements, pozzolana (quartz) reacts with calcium hydroxide, therefore, the $Ca(OH)_2$ content at any time is not only dependent upon how much portland cement has been reacted, but also upon the extent of pozzolana interaction. There are two opposing processes, one tends to increase calcium hydroxide content (hydration of silicate phases) and the other tends to decrease (reaction of pozzolana with lime).

The results of free lime contents of the blended cement pastes as a function of curing time is represented in Fig. 2. The free lime contents increase with curing time for all cement pastes. At a given time, the free lime content decreases with the increase of cement dust in the blends. This decrease is mainly due to either the decrease of the amount of clinker which liberates the lime during hydration or to the interaction of the liberated lime with the cement dust.

Knowledge of the degree of hydration is an essential step towards understanding the rate of strength development. The compressive strength of the hardened cement pastes cured

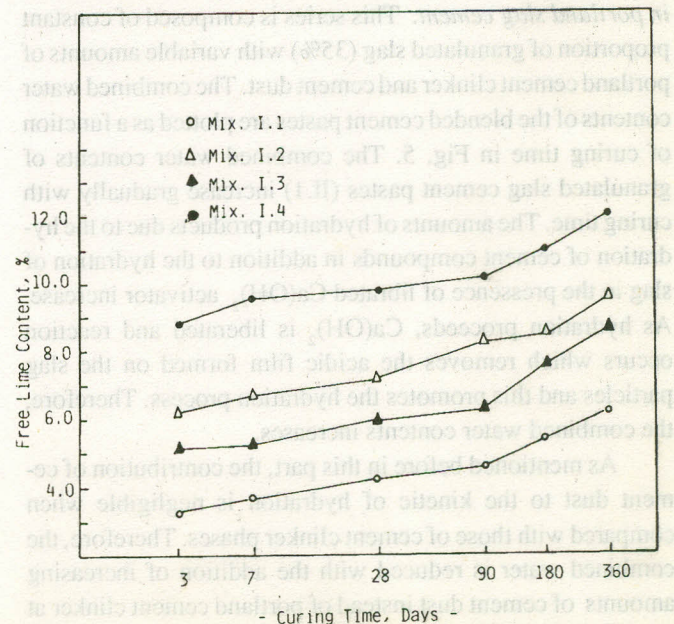


Fig. 2. Free lime content for different cement pastes immersed in tap-water up to one year, %.

under tap water up to one year is represented in Fig. 3. Portland cement paste exhibits the higher values of compressive strength at all ages. As the cement dust increases, the compressive strength falls. This is due to the replacement of cement clinker which is mainly responsible for the strength development with cement dust. In addition, the larger amounts of chloride present in cement dust cause a sort of crystallization of the hydration products which result in a opening of the pore system of the paste leading to a reduction of strength.

The chloride ion takes part in chemical reactions similar to those of involving the sulphate ion and yields chloroaluminate hydrate $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaCl}_2 \cdot 12\text{H}_2\text{O}$ which is analogous to $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaSO}_4 \cdot 12\text{H}_2\text{O}$ [9]. However, the action of the chloroaluminate is different from that of sulphoaluminate in that the former does not cause expansion but softening [10]. Therefore, the compressive strength of kiln dust blended cement pastes decreases. Also, the reduction of the compressive strength of the paste is due to the decrease of clinker portion in the blende. Imam *et al.* [11] reported that in the presence of alkalis the microstructure of CSH phases becomes heterogeneous and that lowers the strength. The formation of chloroaluminate hydrate can be seen in the XRD patterns of the hydrated samples of mix 1.2 cured in tap water up to one year in Fig. 4. The XRD patterns illustrate the formation of calcium chloroaluminate hydrate with ettringite at three days. The unhydrated $\beta\text{-C}_2\text{S}$ and C_3S decrease with curing time whereas the intensity of $\text{Ca}(\text{OH})_2$ enhances. The formation of chloroaluminate hydrate is mainly due to presence of chloride in cement dust.

Substitution of portland cement clinker with cement dust in portland slag cement. This series is composed of constant proportion of granulated slag (35%) with variable amounts of portland cement clinker and cement dust. The combined water contents of the blended cement pastes are plotted as a function of curing time in Fig. 5. The combined water contents of granulated slag cement pastes (II.1) increase gradually with curing time. The amounts of hydration products due to the hydration of cement compounds in addition to the hydration of slag in the presence of liberated $\text{Ca}(\text{OH})_2$ activator increase. As hydration proceeds, $\text{Ca}(\text{OH})_2$ is liberated and reaction occurs which removes the acidic film formed on the slag particles and this promotes the hydration process. Therefore, the combined water contents increases.

As mentioned before in this part, the contribution of cement dust to the kinetic of hydration is negligible when compared with those of cement clinker phases. Therefore, the combined water is reduced with the addition of increasing amounts of cement dust instead of portland cement clinker at all ages of hydration.

The free lime contents of the hardened blended cement

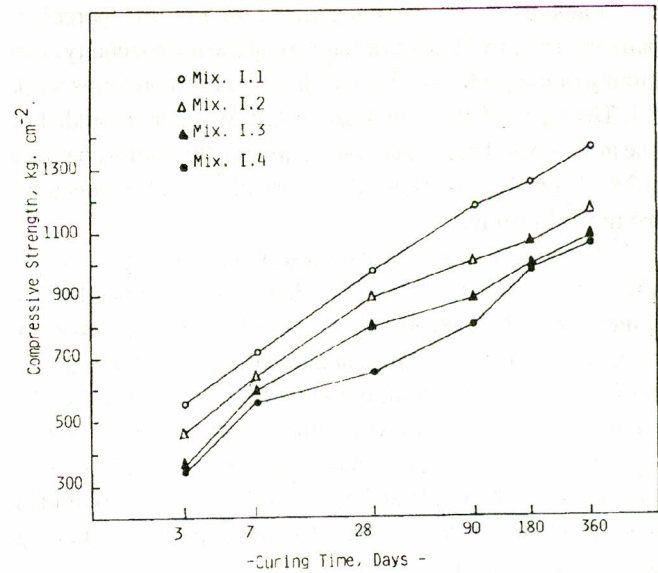


Fig. 3. Compressive strength of different cement pastes immersed under tap-water up to one year, kg. cm².

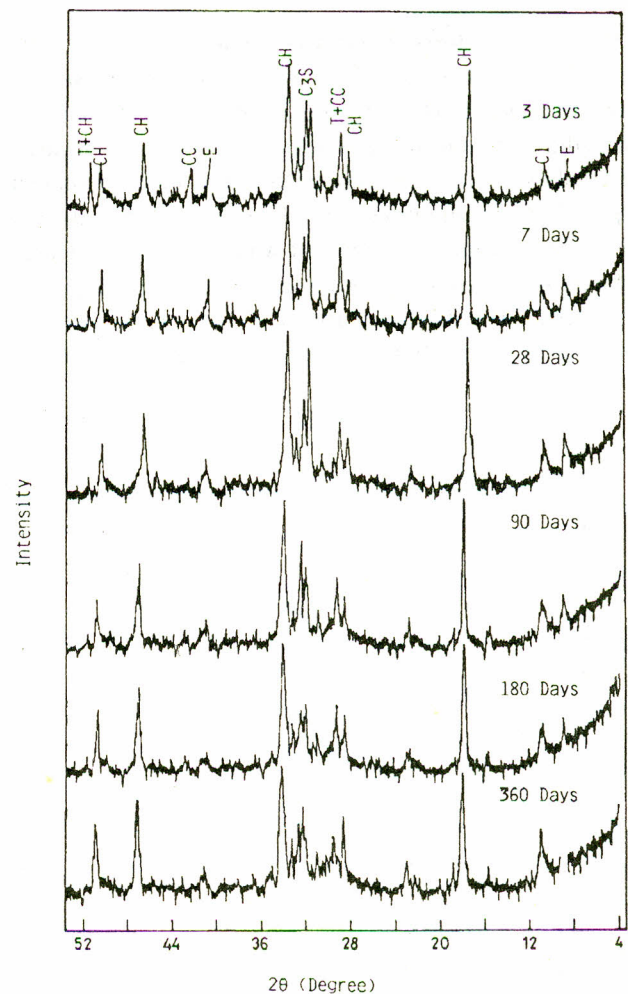


Fig. 4. XRD patterns of hydrated pastes of mix 1.2 hydrated up to one year.

pastes are plotted in relation to curing time in Fig. 6. The free lime contents increase with the increase of curing time for all cement pastes. At a given age, the free lime decreases with the increase of cement dust. This can be due to two factors, first, the presence of slag which reacts with free lime, so, the amount of free lime decreases. The second factor is that the increase of cement dust with the decrease of cement clinker results in the reduction of liberated $\text{Ca}(\text{OH})_2$ during hydration.

The compressive strength values of these blended cement pastes are plotted as a function of curing time in Fig. 7. The strength increases with curing time for all blended cement pastes. Generally, the addition of cement dust reduces the compressive strength. The strength development depends primarily on the formation of calcium silicate hydrates as the main hydration products which precipitate in the water-filled space to form a more compact body. It is well known from the hydration kinetics that cement dust has no hydraulic proper-

ties. Therefore, the hydration products are reduced progressively with the increase of the substituted amounts of cement dust and accordingly the strength decreases. Also, the dust contain alkalis which form compounds with low strength [2,11].

Substitution of granulated slag with cement dust in portland slag cement. This series is composed of a constant amount of cement clinker (65%) with variable proportions of granulated slag and cement dust. The combined water contents of the blended cement pastes were plotted as a function of curing time in Fig. 8. Generally, the combined water content increases gradually with curing time for all cement pastes. Cement paste (III.1) gives higher values of combined water than those of other blends in the same series. The substitution of cement dust for equal amounts of slag reduces the combined

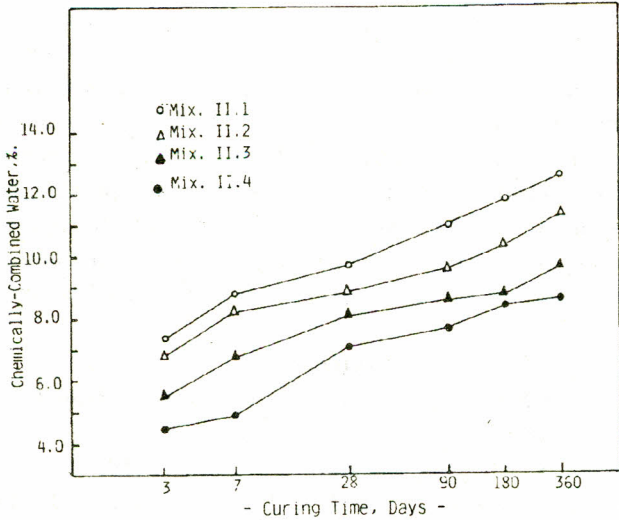


Fig. 5. Chemically-combined water for different cement pastes immersed under tap-water up to one year.

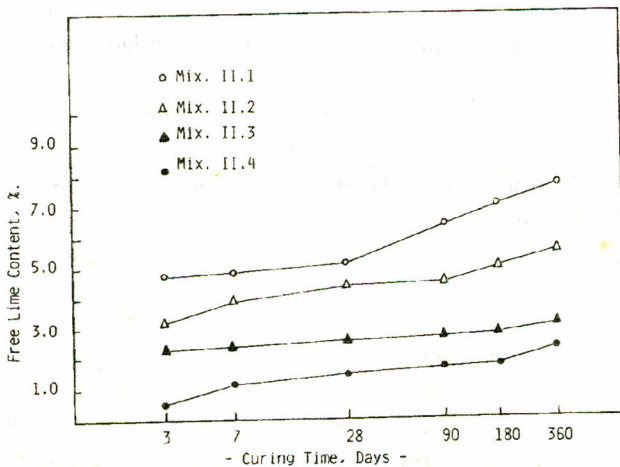


Fig. 6. Free lime content of different cement pastes immersed under tap-water up to one year, %.

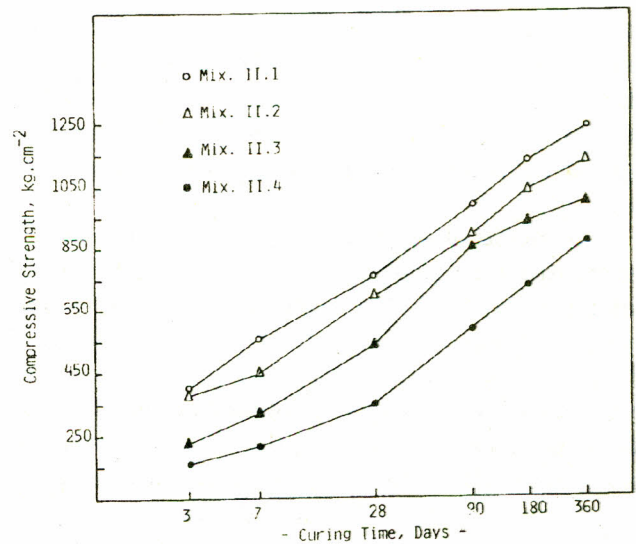


Fig. 7. Compressive strength of different cement pastes immersed under tap-water up to one year, kg. cm^{-2} .

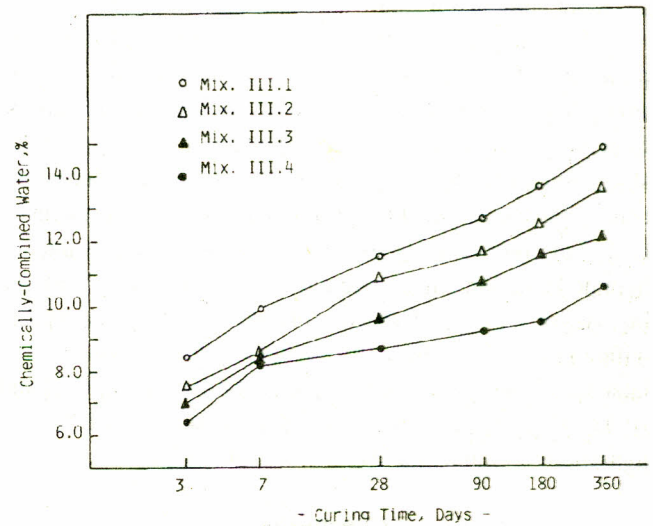


Fig. 8. Chemically-combined water of different cement pastes cured under tap-water up to one year.

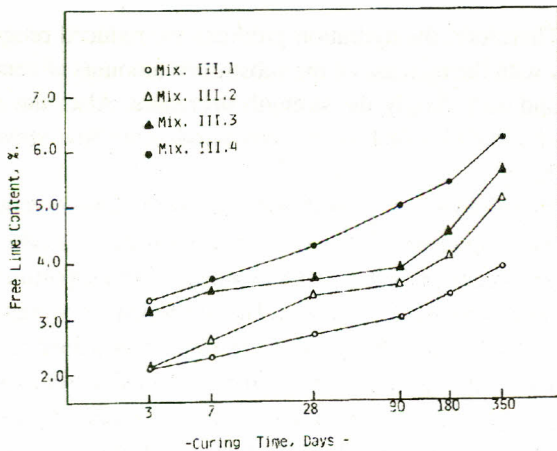


Fig. 9. Free lime different blended cement pastes cured under tap-water up to one year.

water contents at all ages. As mentioned before, the contribution of cement dust to the kinetics of hydration is negligible when compared with that of clinker or slag. The latter have the greatest influence on the extent of hydration and accordingly on the combined water content with respect to cement dust.

The results of free lime contents of hardened blended cement pastes are graphically represented in relation with curing time in Fig. 9. The results show that the free lime content increases with the increase of curing time for all blended cement pastes. At a given age, the free lime content increases with the increase of substituted amount of cement dust at the expense of granulated slag. Granulated slag consumes some $\text{Ca}(\text{OH})_2$ in activation but cement dust has no such hydration characteristics. Therefore, the replacement of dust for slag tends to increase the amounts of free lime. So, the free lime is accumulated and its amount is increased with substituting more amounts of slag with cement dust.

The compressive strength of hardened blended cement pastes in relation to curing time is plotted in Fig. 10. The strength increases with curing time for all cement pastes. Cement dust is added to replace equal amounts of granulated slag. Generally, the addition of cement dust reduces the compressive strength of the pastes. When cement dust with no cementing properties is substituted for slag, the amounts of hydrated calcium silicate are reduced progressively with the increase of substituted amounts of cement dust. Cement paste without dust (III.1) shows the higher compressive strength at later ages than those made with cement dust (III.2, III.3 and III.4). This increase is mainly due to the higher rate of hydration of granulated slag at later ages [12].

Conclusion

From the above findings, it can be concluded that: (i)

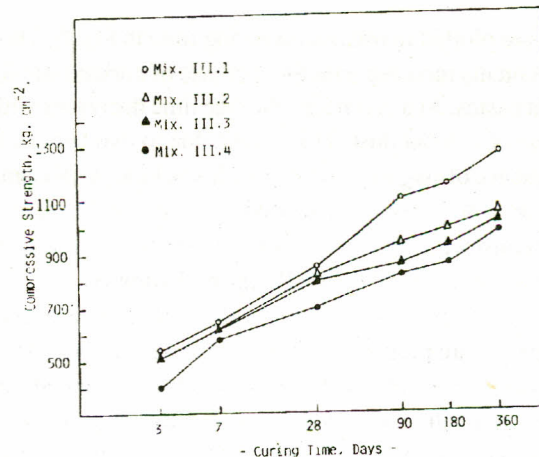


Fig. 10. Compressive strength of different blended cement pastes cured under tap-water up to one year.

Addition of cement dust to either ordinary portland or portland slag cement certainly adversely affects the physico-mechanical as well as chemical properties of the cement pastes. The magnitude of this effect is generally proportional to the amounts of substituted dust. (ii) Production of blended cements containing cement dust must conform to strict specifications bearing in mind the expected daily changes in chemical and mineralogical compositions of cement dust especially its contents of alkali sulphates and chlorides which imposes certain limitations on its production. (iii) The amount of cement dust must not exceed than 5-8% of portland cement.

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