PROPERTIES AND USAGE OF CEMENT KILN DUST IN CONCRETE

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ABSTRACT

During the manufacture of portland cement clinker a portion of the products is carried by the kiln gases as a dust and it is called "cement kiln dust". This paper presents an investigation into the ability of using cement kiln dust as a partial replacement of cement by analyzing and characterizing its effect on cement paste, mortar and concrete properties. For analyzing cement paste and mortar properties, the percentages of cement replacement with cement kiln dust by weight were 0, 10, 20, 25, 30, 40, 50, 60, 70, 80, 90 and 100 percent, while for analyzing concrete properties, the percentage of replacement were 10, 20, 25 and 30 percent. A natural fibers (chopped wheat straw) were used in concrete mixes to overcome the undesirable side effects of cement kiln dust. The chemical analysis of cement kiln dust shows that it is an alkaline waste material and the major percentage of its components are calcium carbonate, oxide clays, and some alkali salts. The results of using cement kiln dust as a partial replacement of cement show that the percentage of 25 is considered to be the maximum ultimate percentage which could be used in concrete mixes within the Egyptian Standard Specifications. The results of this research also show that the cement kiln dust acts as a cementitious material, but it has a negative effect on concrete properties. It decreases the compressive, splitting, flexural strength, modulus of elasticity and ultimate impact resistance by about 9, 26, 19, 9 and 20 percent respectively for 20% replacement of cement with cement kiln dust by weight at 28 days. Conversely, the shrinkage of concrete was increased by about 43% at 28 days , therefore it was tried to add a cheap material as the chopped wheat straw to offset the effect of cement kiln dust. The results due to adding 2% chopped wheat straw fibers was very satisfying. The chopped wheat straw fibers increase the splitting tensile strength by about 9, 6 and 10 percent at ages of 28, 56 and 91 days respectively for 20% replacement of cement. Also increase the impact resistance for both first visible crack and ultimate impact resistance (N1 and N2) by about (180%, 150%) and (20%, 45%) at 3 and 91 days respectively and decrease the drying shrinkage by about 9% at 28 days for 20% replacement of cement with cement kiln dust by weight compared to the same mix without fibers.

Keywords: Cement kiln dust, Portland cement clinker, Chopped wheat straw.

INTRODUCTION

In Egypt many cement factories suffer from bounteous of cement kiln dust (by product), for instance AL-AMERYA cement plant has about 400 ton by-product of cement kiln dust each 10000 ton cement, thereby the accumulation of about 1.5 - 2 million ton/ year of cement kiln dust represents not only a significant loss of money, energy, and raw materials but also a negative impact to the environment. Likewise, many observations and statistics proved that about 50% of the inhabitants near the cement factories suffer from many diseases such as catarrh, chronic throat inflammation, sinusitis and bronchial asthma.

This paper reports the results of an experimental investigation into the use of cement kiln dust as a partial replacement of cement by weight in concrete mixes. To achieve the previous aim the following targets had been carried out:-

1- Identify the chemical and physical properties of cement kiln dust.
2- Determine the maximum permissible

percentage of cement kiln dust which could be replaced by cement within the Egyptian Standard Specifications.

3- Study the effect of cement kiln dust on concrete properties and try to improve the bad side effects of the cement kiln dust by using natural fibers called chopped wheat straw which is a natural cellulose annual plant.

EXPERIMENTAL PROGRAM

The experimental program was divided into two main sections, in the first section, the characteristics of the cement kiln dust itself and the effects of partial replacement of portland cement with cement kiln dust on cement paste and mortar properties were investigated. In the second section, the effect of cement replacement with cement kiln dust on the concrete properties were studied and the trial to over come the undesirable side effects of cement kiln dust by using natural fiber (chopped wheat straw) in concrete mixes.

In the first section the percentage of replacement of portland cement with cement kiln dust by weight were (0%, 10%, 20%, 25%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100%), while in the second section the percentage of replacement were (10%, 20%, 25%, and 30%).

Materials And Mix Proportions

The cement kiln dust used in this study was supplied by a local cement factory in Alexandria, AL-AMERYA Cement Plant, no pretreatment of material was carried out and representative samples were obtained directly from the supply. Locally manufactured AL-AMERYA Ordinary Portland Cement was used. Natural silicious sand passing through a BS 4.75mm sieve was used as fine aggregate and crushed pink lime stone having a nominal maximum size of 19mm was used as coarse aggregate for making concrete. Table (1) summarizes the compositions of the concrete mixes used.

The used chopped wheat straw was a natural cellulose annual plant. In order to have almost equal clean fibers, the selected fibers were sieved on sieve No.(7) and the retained fibers on the sieve were used while fibers passing from the sieve ignored. The fibers were seated in potable water for 24 hours to allow for dissolving the biochemical materials, (biochemical materials tends to retard the hydration of cement and the fibers may be susceptible to microbiological deterioration), then the fibers soaked in saturated lime solution for at least one hour with continuous stirring. The fibers then dried naturally in the sunlight and air flow.

Setting time of the mixture of cement and cement kiln dust samples were carried out in accordance with ASTM C 191-82 [1] and the pastes were made with necessary water content to produce standard consistence as defined by ASTM C 187-83 [2]. Tests were carried out to determine the soundness of cement and cement kiln dust samples separately according to BS 4550 [3]. Specific surface area of cement and cement kiln dust was determined, using blaine air permeability apparatus. The compressive strength of cement and cement kiln dust was carried out in accordance with ASTM C 109-92 [4]. The design of all concrete mixes is based on preliminary trial mixes, the cement content was assumed to be 300 kg/m3 and the water content was chosen so as to give constant slump of 10 cm.

Slump test on fresh concrete was carried out in accordance with ASTM C 143-78 [5]. Testing of hardened concrete was performed at 3, 7, 14, 28, 56, and 91 days. Compressive strength was carried out in accordance with ASTM C 39-83 [6], Splitting tensile strength in accordance with ASTM C 496-79 [7] using cylindrical specimens 75mm diameter and 150mm height, Modulus of elasticity according to ASTM C 469-83 [8], Flexural strength in accordance with ASTM C 293-79 [9], Impact resistance as recommended by ACI committee 544-1988 [10] and length change measurements in accordance with ASTM C 490-83 [11].

Casting And Curing Of Concrete Specimens

Concrete was mixed in a pan mixer. Ingredients were weighed to the correct amount and fed into the mixer in the following sequence: coarse aggregate, fine aggregate, cement, kiln dust and water. Dry mixing was carried out for 2 minutes followed by wet mixing for 3 minutes .A vibrating table was employed to compact the molded specimens. All specimens were remolded after 24 hours and cured in water until testing. The length change specimens were cured for 28 days in water and then left to dry in air until the day of testing.

Table 1. Mix proportions of concrete mixes.

Type of mix		Mix proportions for one cubic meter in kg					
Dust	Fibers	Cement	Water	Dust	Fibers	Sand	Coarse
0.0%	0.0%	300	195	0.0	0.0	811	1025
10%	0.0%	270	196.5	30	0.0	807	1025
10%	2%	270	199.5	24	6	800	1025
20%	0.0%	240	201	60	0.0	795	1025
20%	2%	240	204	54	6	788	1025
25%	0.0%	225	204.6	75	0.0	786	1025
25%	2%	225	205.5	69	6	783	1025
30%	0.0%	210	208.5	90	0.0	777	1025
30%	2%	210	214.5	84	6	760	1025

RESULTS AND DISCUSSION

Characteristics Of Cement Kiln Dust:

The general appearance of cement kiln dust is light brown in color. The color varies in shade from batch to batch for the same source. It has observed that coarser particles are darker in color than the finer particles.

Chemical Composition of Cement Kiln Dust

Table [2] shows a typical composition of cement kiln dust used in this study together with the cement dust produced in the UK [12], the USA [13] and Malaysia [14]. For the purpose of comparison, composition of the used Egyptian Ordinary Portland Cement, a mixture of raw materials used in portland cement production [15] and other waste materials having cementitious properties such as granulated slag and fly-ash of UK origin [16] are included .

The cement kiln dust basically consists of partially processed raw materials used for the production of cement, for this reason, the chemical composition of the dust depends on the quality of raw materials and the cement making process. Where the cement kiln dust produced by dry process is definitely different from cement kiln dust produced by wet process (AL-AMERYA cement plant uses the dry method).

From table [2] it could be deduced that cement kiln dust shows a considerable amount of loss on ignition. The analysis of cement kiln dust also indicates that the alkali and sulphur contents are considerable. Although the raw materials are low in sulphur, the cement kiln dust contains a significant amount of sulphur possibly originating from the oil used for heating.

Physical Properties Of Cement Kiln Dust

Specific gravity: The specific gravity determination was carried out by means of standard specific gravity bottle and kerosene oil. The specific gravity value was (2.92). When comparing this value with the specific gravity of ordinary portland cement (3.15), it is clear that the specific gravity of cement kiln dust was lower than ordinary portland cement by 7.3%. Therefor any replacement of cement with cement kiln dust on the basis of weight will decrease the total weight of the mix when compared with the control mix.

Specific surface area: The average specific surface area of the cement kiln dust was determined by Blain's air permeability method in accordance with ASTM C 204 [17]. It was (4440 cm2/gm) , comparing this value with that of cement (2550 cm2/gm), it is clear that the surface area of cement kiln dust is mush higher than that of cement.

Fineness: The cement kiln dust was sieved on sieve no.170, the fineness was 1%, comparing this value with that of cement (7.5%), it is obvious that the fineness of cement kiln dust is relatively greater than the fineness of cement.

Table 2. Chemical composition of cement kiln dust and other cementitious materials.

Compound	Cement Kiln dust				O.P.C	R.M [15]	G.S [16]	Fly ash [16]
	Egypt	UK [12]	USA [13]	Malaysia [14]				
Silica	15.5	15.3	11.1	12.2	20.0	14.3	34.7	49.1
Alumina 0	4.2	2.1	5.5	5.8	4.9	3.0	13.6	28.7
Ferric Oxide	2.3	1.7	2.9	2.3	3.0	1.1	0.3	9.5
Calcium Oxide	47.6	43.0	44.0	42.7	62.9	44.4	38.4	1.8
Magnesium oxide	2.3	0.9	2.5	1.3	2.6	0.6	10.2	1.7
Sulphate	3.1	6.2	5.6	6.5	2.4	0.1	0.2	0.3
Sodium	6.11	0.7	0.9	0.8	-	0.1	0.4	1.8
Potassium	5.8	6.0	6.0	4.3	-	0.5	0.8	3.7
Free Lime	4.8	ND	ND	6.1	-	-	-	-
Loss on ignition	7.2	ND	21.5	22.1	2.2	35.9	35.9	3.0

Soundness: The soundness tests on cement kiln dust and cement samples indicated that the expansions of cement kiln dust and cement specimens were 1.5 and 1.0 mm. respectively. As expected,the cement kiln dust has a higher expansion than that of cement due to the presence of sulphate. Although the observed expansion of cement kiln dust is much below the specified maximum value of 10mm by ESS [18] for portland cement, but the cement kiln dust may be considered as a high expanded material. Table [3] shows the physical properties of cement kiln dust and ordinary portland cement.

Properties Of chopped wheat Straw

Density measurements: The density of dry fibers was found to be 0.42 t/m3.

Water absorption: Figure (1) shows the relationship between the time and the percentage of water absorbed for cured and non-cured natural fibers. It is clear that the non cured fibers absorb more water than the cured fibers, that is because during the treatment (curing) of chopped wheat straw, the lime solution fill the voids of the fibers and decrease its porosity which leads to the decrease of the water absorption.

Fiber length and aspect ratio: Observations and measurements revealed that the average aspect ratio of about 100 samples is (31.9). This ratio fall in the range recommended by ACI committee 544-1988 [10].

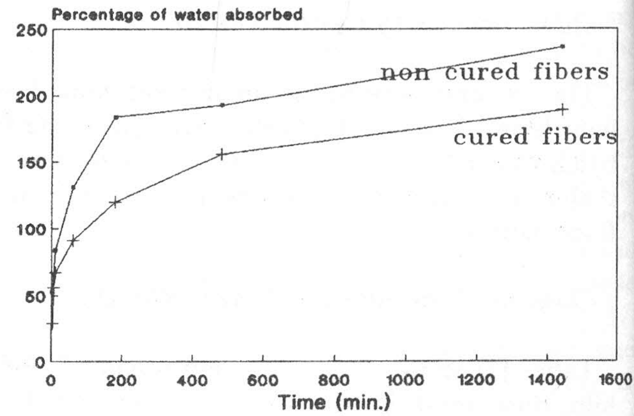

Figure 1. Relationship between time and percentage of water absorbed by fibers.

Effect Of Cement Replacement With Cement Kiln Dust On Cement Paste Properties

Water demand to determine standard consistency: Figure (2) shows the relationship between the ratio of water to the mixture of cement and cement kiln dust, by weight, required to produce a paste having standard consistence as defined by BS 12 [19], as a function of the percentage of cement replacement. It is observed from the figure that the water demand increases with high percentage of cement replacement. This manner is due to that the cement kiln dust has a specific surface area much higher than cement. This reason may explain the extra water that required to produce the same consistency.

Table 3. The physical properties of cement kiln dust and ordinary portland cement.

Property	Results of cement kiln dust	Results of ordinary portland cement
Bulk specific gravity	2.92	3.15
Specific surface area (cm2/gm)	4440	2550
Fineness (%)	1	7.5
Soundness(mm)	1.5	1

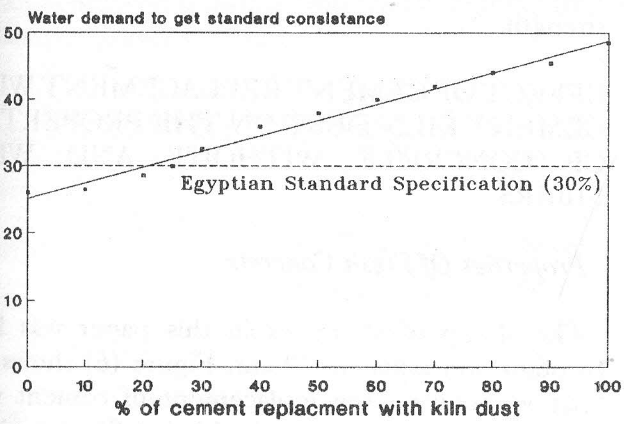

Figure 2. Water demand to produce the standard consistence.

Setting time: Figure (3) shows the relation between the initial and final setting time and the percentage of cement kiln dust replacement .It is obvious from the figure that the relation between the kiln percentage and the setting time consists of two stages. In the first stage it is clear that increasing the cement kiln dust directly increased the setting time up to 60% respectively. This phenomenon is owing to that the cement kiln dust acts as a barrier between the cement particles and water, hence causes a delay in setting. In the second stage it is clear that increasing the cement kiln dust inversely affect the setting time. This phenomenon is owing to that when the ratio of the cement kiln dust particles exceed the ratio of the cement ratio in the same paste that means that there is an excessive amount of alkalies in the paste and the alkalies promotes the setting of cement. The reason for quick initial and final setting times of cement kiln dust at 100% replacement is due to that the particles of cement kiln dust were collected before the step of adding gypsum to the cement during the manufacturing so the cement kiln dust does not contain any particles of gypsum.

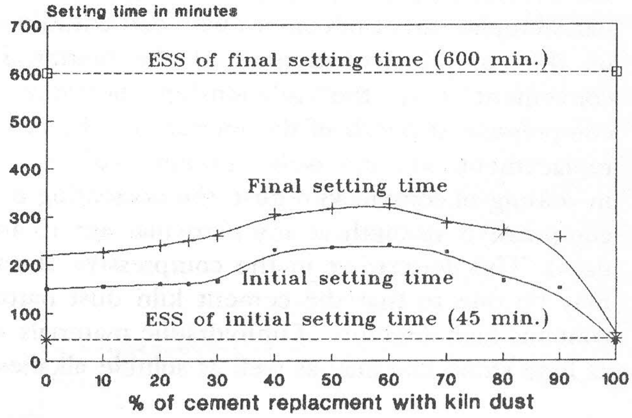

Figure 3. Effect of partial replacement of cement with cement kiln dust on setting time.

Soundness: Figure (4) shows the effect of partial replacement by various percentages of cement kiln dust on the soundness of the pastes. Comparing the soundness of various cement kiln dust replacement with the Egyptian Standard Specification ESS [18], it could be extracted that the ratio of 25% of cement kiln dust falls within the ESS (not exceed 10mm). So it may be mentioned that the ultimate ratio of cement kiln dust replacement which could be used is 25% from the point of view of soundness.

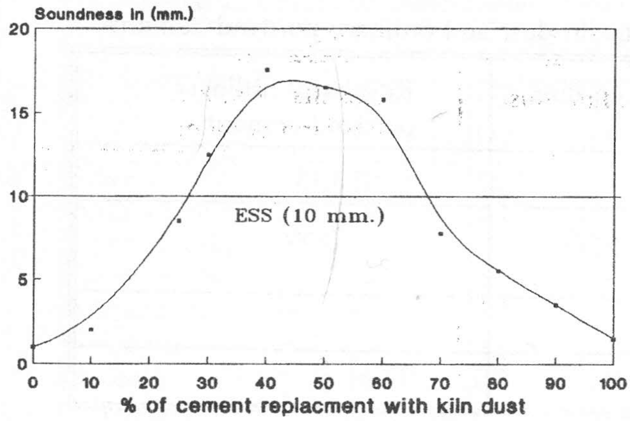

Figure 4. Effect of partial replacement of cement with cement kiln dust on soundness.

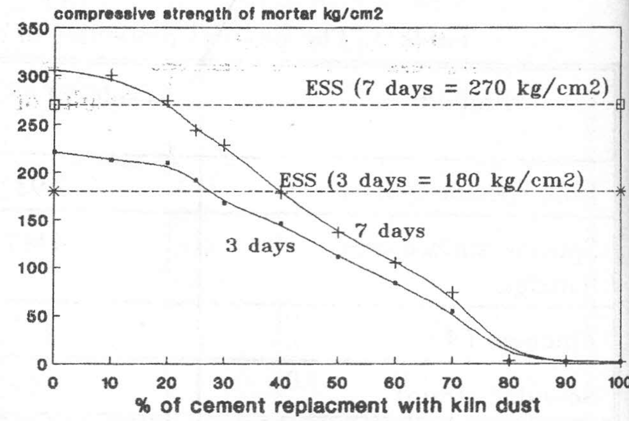

Figure 5. Effect of partial replacement of cement with cement kiln dust on mortar cube compressive strength.

Effect Of Cement Replacement With Cement Kiln Dust On Mortar Properties

Compressive strength: The compressive strength of cement kiln dust was carried out in accordance with BS 8110:1986 [4]. Figure [5] shows the effect of partial replacement of cement with cement kiln dust on the compressive strength of the mortar. It is convenient that the relationship between the compressive strength of the mortar and the cement replacement is inversely proportional ie. the increasing of cement kiln dust, the decreasing of the compressive strength at any particular age (3 and 7 days). The decreasing in the compressive strength may be due to that the cement kiln dust particles contains high amounts of unhydraulic materials such as lime stone and clay as well as soluble alkalies.

Selection of best adequate percentages: In order to estimate the best sufficient and adequate percentage of cement kiln dust which could be used in concrete mixes, it must be compared between the different cement kiln dust percentages and the Egyptian Standard Specification. Likewise it should be tried to give a compromise between the Egyptian Standard Specifications and economic requirements in order to get integral compatible optimization. From figure [1] to figure [5], It could be deduced that the percentage of cement kiln dust which conform with the Egyptian Standard Specifications are (10%, 20%, 25%, and 30%)

EFFECT OF CEMENT REPLACEMENT WITH CEMENT KILN DUST ON THE PROPERTIES OF CONCRETE WITHOUT AND WITH FIBERS

Properties Of Fresh Concrete

The slump of all mixes in this paper was kept constant and equal to 10 cm. Figure (6) shows the relation between the replacement of cement with cement kiln dust (with and without) fibers and the water cement ratio. It is clear that increasing the percentage of cement kiln dust affects the slump inversely, so that, the water cement ratio increases with increasing cement kiln dust content to keep the same slump of 10 cm. This phenomenon may be due to the increase in the solid volume of the dust (as the density of cement kiln dust is lower than that of cement) and to the increased portion of the finer particles in the dust which lead to the increase in the specific surface area, and therefore increasing the water demand to maintain the same workability.

Effect of adding fibers : From figure (6), it is obvious that the presence of fibers increases the water cement ratio required to have the same slump, regardless the percentage of kiln dust replacement. The explanation of this manner is owing to the porosity of the fibers so it tends to absorb water as soon as it is added to the matrix.

Table 4. Cylinder compressive strength for concretes without and with fibers.

Mix		cylinder compressive strength kg/cm2					
Fibers	Dust	3 days	7 days	14 days	28 days	56 days	91 days
0.0%	0.0%	111.1	147.3	160.5	195	245.3	291
	10%	105.5	136.7	150	175.1	222.6	256.8
	20%	100.3	133.3	148.9	160.4	209.9	232
	25%	88.8	118.6	137.1	158.8	191.3	205.1
	30%	79.9	110.9	130.5	140.2	170.4	195.5
2%	0.0%	111.1	147.3	160.5	195	245.3	291
	10%	102.1	133.3	147.8	164.6	210	246.2
	20%	90.3	122.9	129.7	151	198.1	220.1
	25%	80.6	115.6	123.5	145.1	170.2	195.9
	30%	73.9	91.1	121.3	133.3	150.1	176.6

Modulus of elasticity: Table (5) and Figure (9) show the relation between the modulus of elasticity in compression and percentage of replacement of cement with cement kiln dust without fibers at different ages. From the figure it is clear that the relation between them is inversely proportional. The reduction in modulus of elasticity may be attributed to the reduction in compressive strength. At 28 days the percentage reduction in modulus of elasticity for 10%, 20%, 25%, and 30% replacement with cement kiln dust, was 8%, 9%, 12%, and 16% respectively when compared with 0.0% replacement and 0.0% fibers.

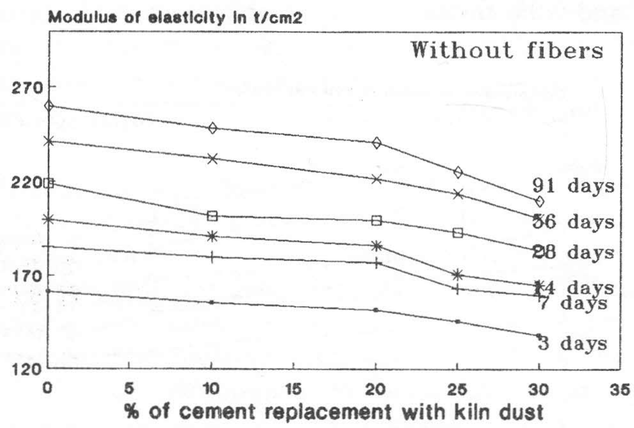

Figure 9. Effect of partial replacement of cement with cement kiln dust on modulus of elasticity for concretes without fibers.

Effect of fibers: Table (5) and Figure [10] show the relation between modulus of elasticity and percentage of replacement of cement with cement kiln dust with 2% fibers at different ages. It is obvious that the inclusion of fibers decreases the modulus of elasticity. This reduction in modulus of elasticity because chopped wheat straw fibers were considered to fall in the category of law modulus of elasticity fibers which reduce the modulus of elasticity of the mix. The reduction in modulus of elasticity indicate the concrete to have the capacity to sustain and resist such impact loads, therefore the reduction in modulus of elasticity may considered to be an advantage. At 28 days the percentage reduction in modulus of elasticity due to adding 2% fibers at 10%, 20%, 25%, and 30% replacement with cement kiln dust, was 13%, 18%, 20%, and 23% respectively when compared with 0.0% replacement and 0.0% fibers.

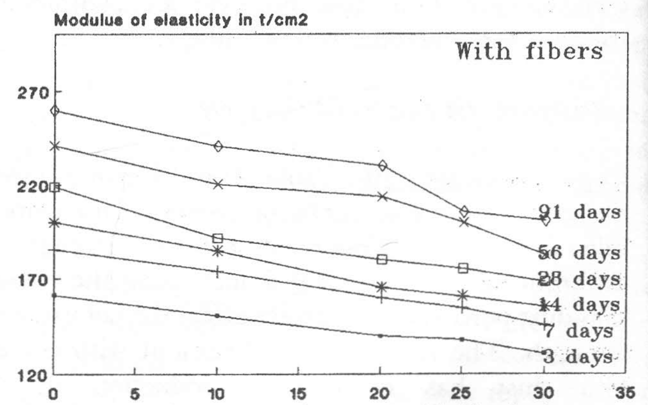

Figure 10. Effect of partial replacement of cement with cement kiln dust on modulus of elasticity for concretes with fibers.

Table 4. Cylinder compressive strength for concretes without and with fibers.

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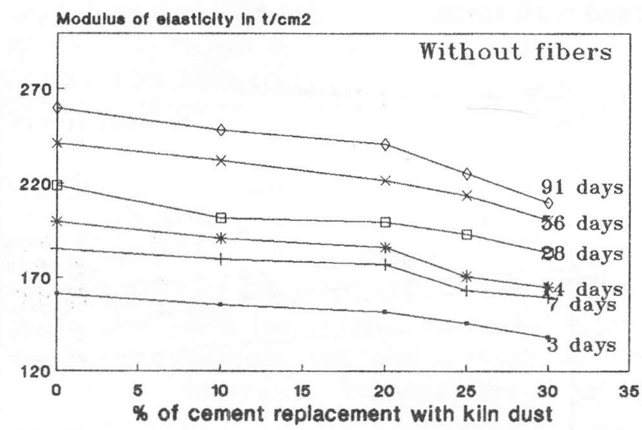
2%	0.0%	111.1	147.3	160.5	195	245.3	291
	10%	102.1	133.3	147.8	164.6	210	246.2
	20%	90.3	122.9	129.7	151	198.1	220.1
	25%	80.6	115.6	123.5	145.1	170.2	195.9
	30%	73.9	91.1	121.3	133.3	150.1	176.6

Modulus of elasticity: Table (5) and Figure (9) show the relation between the modulus of elasticity in compression and percentage of replacement of cement with cement kiln dust without fibers at different ages. From the figure it is clear that the relation between them is inversely proportional. The reduction in modulus of elasticity may be attributed to the reduction in compressive strength. At 28 days the percentage reduction in modulus of elasticity for 10%, 20%, 25%, and 30% replacement with cement kiln dust, was 8%, 9%, 12%, and 16% respectively when compared with 0.0% replacement and 0.0% fibers.



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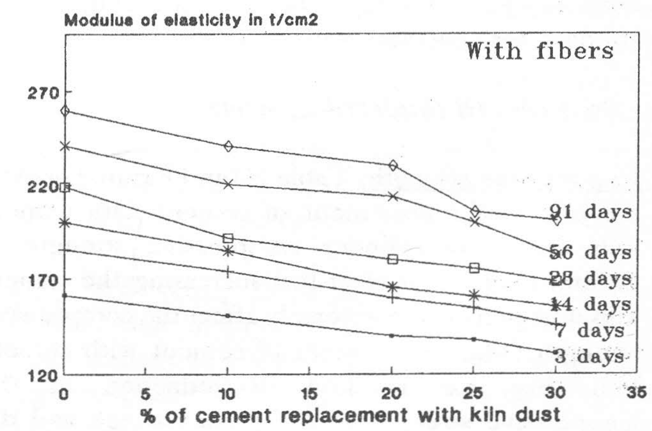

Figure 10. Effect of partial replacement of cement with cement kiln dust on modulus of elasticity for concretes with fibers.

Table 5. Modulus of elasticity for concretes without and with fibers.

Mix		Modulus of elasticity t/cm2					
Fibers	Dust	3 days	7 days	14 days	28 days	56 days	91 days
0.0%	0.0%	161.3	185.4	200	219	241.2	260.1
	10%	155.6	180.1	191.2	202.1	232.2	248.3
	20%	151.7	177.1	186.5	200	221.9	240.7
	25%	145.6	163.3	170.9	193.6	214.1	225.4
	30%	138.1	159.6	165.1	183.8	201.1	210.3
2%	0.0%	161.3	185.4	200	219	241.2	260.1
	10%	150.4	173.7	184.8	191.4	220.6	240.9
	20%	140.1	159.9	165.4	180	213.6	230.4
	25%	138	154.4	160.7	175.2	199.7	205.3
	30%	130.6	145.7	155.1	168.3	182.3	200.8

Table 6. Splitting tensile strength for concretes without and with fibers.

Mix		Splitting tensile strength kg/cm2					
Fibers	Dust	3 days	7 days	14 days	28 days	56 days	91 days
0.0%	0.0%	17.18	25.9	27.9	31.7	35.8	42.2
	10%	16.3	20.3	22.8	24.8	26.5	30.5
	20%	13.1	17.6	20.6	23.5	25	27.3
	25%	12.7	15.8	18	19.6	24.5	26
	30%	10.1	12.2	13.9	16.8	20.5	23
2%	0.0%	17.18	25.9	27.9	31.7	35.8	42.2
	10%	16	19.6	22.6	26.5	27	31.5
	20%	12.8	17.2	19.1	25.5	26.5	30
	25%	12.5	14.7	18	21.7	25	27.5
	30%	10	12	13.5	17	21	25

Splitting tensile strength: Table (6) and Figure (11) show the relation between splitting tensile strength and the percentage of replacement of cement with cement kiln dust by weight at different ages. It is clear that adding cement kiln dust affect the splitting tensile strength inversely. The reduction in splitting strength may be due to that the bond strength between the cement paste and aggregate could be further weakened if the cement kiln dust particles are present in the interfacial zone, thereby the splitting tensile strength of the concrete decreases. At 28 days the percentage reduction in splitting tensile strength for 10%, 20%, 25%,and 30% replacement with kiln dust, was 22%, 26%, 38%, and 47% respectively when compared with 0.0% replacement and 0.0% fibers.

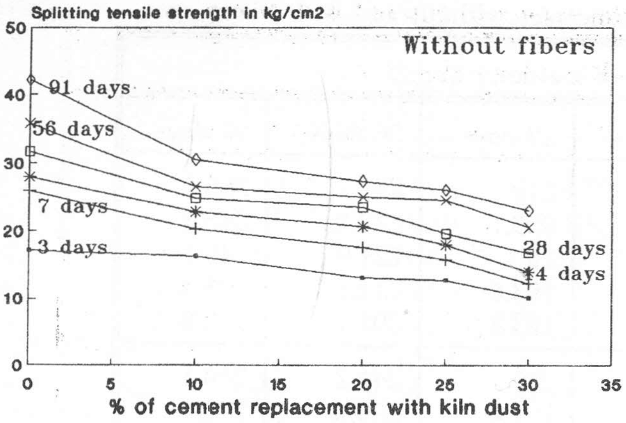

Figure 11. Effect of partial replacement of cement with cement kiln dust on splitting tensile strength for concretes without fibers.

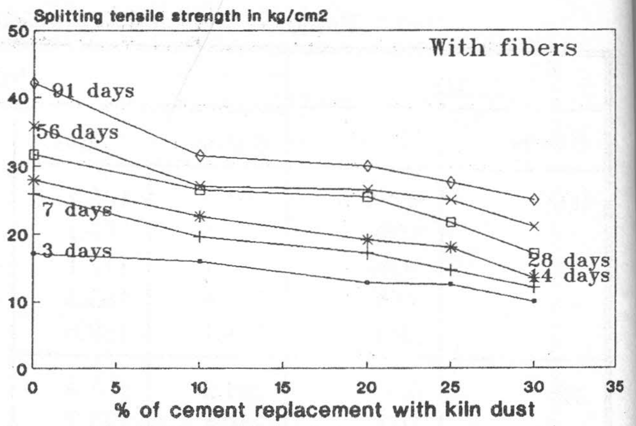

Figure 12. Effect of partial replacement of cement with cement kiln dust on splitting tensile strength for concretes with fibers.

Effect of fibers: Table (6) and Figure (12) show the relation between splitting tensile strength and the percentage of replacement of cement with cement kiln dust with 2% fibers at different ages. From the results it could be deduced that adding fibers reduced the splitting tensile strength until before 28 days, but conversely at 28 days the splitting tensile strength increased by adding 2% fibers. At 28 days the percentage reduction in splitting tensile strength due to adding 2% fibers at 10%, 20%, 25%, and 30% replacement with cement kiln dust, was 16%, 20%, 32%, and 46% respectively when compared with 0.0% replacement and 0.0% fibers. Comparing these values with that without 2% fibers, it could be deduced that the splitting strength increased by adding 2% fibers. The considerable explanation of this phenomenon may be due to that the reduction of splitting tensile strength of fibrous concrete mixes is owing to fiber modulus of elasticity, fiber volume fraction and interfacial bond between fibers, since the used fibers have a modulus of elasticity lower than that of the matrix, hence a reduction should be expected for all mixes at early ages but with increasing time (curing time) the interfacial bond between fiber and the matrix will increase the tensile strength of the composite, hence the concrete mix be able to sustain tensile stresses

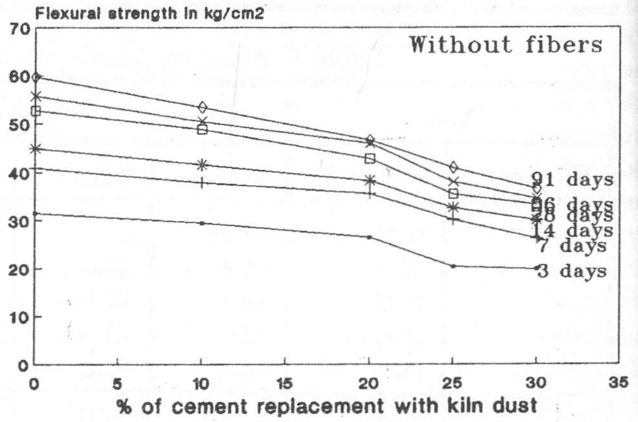

Figure 13. Effect of partial replacement of cement with cement kiln dust on flexural strength for concretes without fibers.

Flexural strength: Table (7) and Figure (13) show the relation between flexural strength and percentage of replacement of cement with cement kiln dust at different ages. it is clear that the relation is inversely proportional. The reduction in flexural strength is due to the reduction in the interfacial bond acting between cement paste and aggregate particles. At 28 days the percentage reduction in flexural strength for 10%, 20%, 25%, and 30% replacement with kiln dust, was 7%, 19%, 33%, and 37% respectively when compared with 0.0% replacement and 0.0% fibers.

Table 7. Flexural strength for concretes without and with fibers.

Mix		Flexural strength kg/cm2					
Fibers	Dust	3 days	7 days	14 days	28 days	56 days	91 days
0.0%	0.0%	31.5	40.95	44.9	52.7	55.7	59.7
	10%	29.5	37.91	41.6	48.9	50.5	53.4
	20%	26.46	35.6	38.3	42.7	46	46.6
	25%	20.4	30.2	32.6	35.5	38	40.9
	30%	19.9	26	30.1	33.3	34.5	36.6
2%	0.0%	31.5	40.95	44.9	52.7	55.7	59.7
	10%	29	37.3	40.93	46.1	47	50
	20%	24.1	31.6	33.4	39.4	42	44.1
	25%	20.2	28.8	31.8	34.8	35.7	38.9
	30%	19.7	25.5	29.5	32.1	34	36

Effect of adding fibers: Table (7) and Figure (14) show the relation between flexural strength and the percentage of replacement of cement with cement kiln dust with 2% fibers at different ages. It is obvious that adding fibers decreases the flexural strength. At 28 days the percentage reduction in flexural strength for 10%, 20%, 25%, and 30% replacement with kiln dust and 2% fibers, was 13%, 25%, 34%, and 39% respectively when compared with 0.0% replacement and 0.0% fibers.

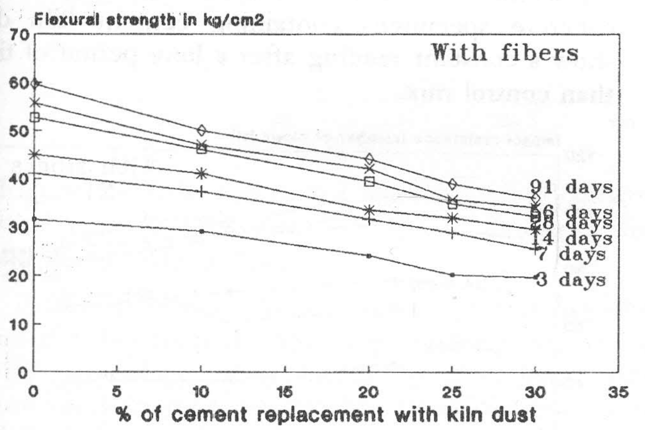

Figure 14. Effect of partial replacement of cement with cement kiln dust on flexural strength for concretes with fibers.

Impact resistance: Table (8), Figure (15) and Figure (16) show the relation between impact resistance as a number of blows (N1 and N2) and percentage of replacement of cement with cement kiln dust at different ages. It is clear that adding cement kiln dust decreases the impact resistance for both first visible crack and ultimate impact resistance (N1 and N2). The explanation of this manner may be due to the fact that the cement kiln dust is a brittle material, since the concrete is fairly strong in compression and has a brittle failure mode, thus replacement of cement by kiln dust increases the brittleness of the concrete and make it much lower crack resistance.

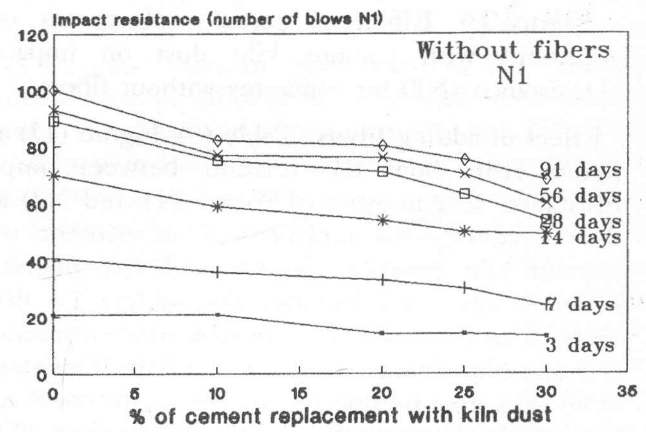

Figure 15. Effect of partial replacement of cement with cement kiln dust on impact resistance (N1) for concretes without fibers.

Table 8. Impact resistance (as a number of blows) for concretes without and with fibers.

Mix		Impact resistance (as a number of blows) N1 and N2											
Fibers	Dust	3 days		7 days		14 days		28 days		56 days		91 days	
		N1	N2	N1	N2	N1	N2	N1	N2	N1	N2	N1	N2
0.0%	0.0%	21	27	41	47	70	75	89	93	93	101	100	106
	10%	21	26	36	40	59	65	75	80	77	84	82	78
	20%	14	18	33	35	54	60	71	75	76	80	80	84
	25%	14	17	30	33	50	51	63	70	70	76	75	80
	30%	13	17	24	28	49	51	54	57	60	64	68	74
2%	0.0%	21	27	41	47	70	75	89	93	93	101	100	100
	10%	46	51	65	69	75	80	95	105	99	116	105	125
	20%	39	45	60	66	70	75	90	98	91	115	95	121
	25%	39	42	70	75	67	73	84	92	87	108	95	119
	30%	38	42	67	73	64	68	80	88	85	104	86	110

N1 = First visible crack, N2 = Ultimate impact resistance.

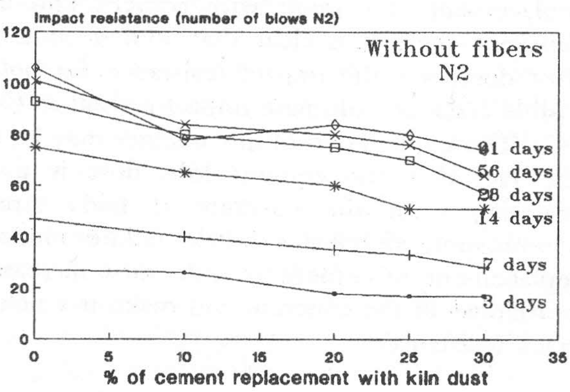

Figure 16. Effect of partial replacement of cement with cement kiln dust on impact resistance (N2) for concretes without fibers.

Effect of adding fibers: Table (8), Figure (17) and figure (18) show the relation between impact resistance as a number of blows (N1 and N2) and the percentage of replacement of cement with cement kiln dust by weight (with 2% fibers) at different ages. It is obvious that adding 2% fibers leads to an extremely considerable improvement in (N1 and N2). The great increase of impact resistance at all ages may be due to that the inclusion of such natural fibers reduce the modulus of elasticity of the matrix and increase the composite impact resistance, likewise, the improvement in ultimate impact resistance in the presence of fibers further validate the hypothesis that natural fibers inclusion help to enhance the fracture energy and toughness characteristics on concrete material through bridging across cracks.

Length change measurements: The length change specimens were cured for 28 days in water and then left to dry in air until testing. Figure (19) shows the relation between the shrinkage measurements and percentage of replacement of cement with cement kiln dust at different ages. It is clear that adding cement kiln dust increased the shrinkage of the concrete specimens. For example the shrinkage of 30% replacement with cement kiln dust was about two and half times the shrinkage of 20% replacement at 80 days. It is also obvious that the concrete specimens containing cement kiln dust show a constant reading after a long period of time than control mix.

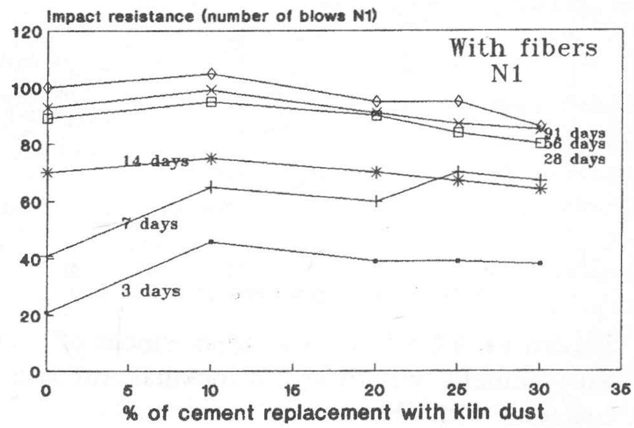

Figure 17. Effect of partial replacement of cement with cement kiln dust on impact resistance (N1) for concretes with fibers.

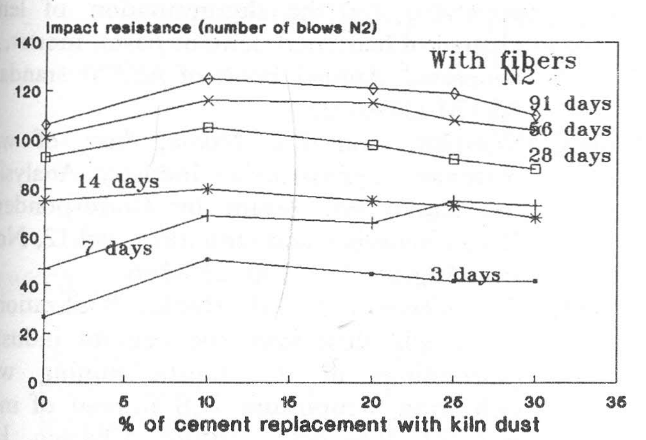

Figure 18. Effect of partial replacement of cement with cement kiln dust on impact resistance (N2) for concretes with fibers.

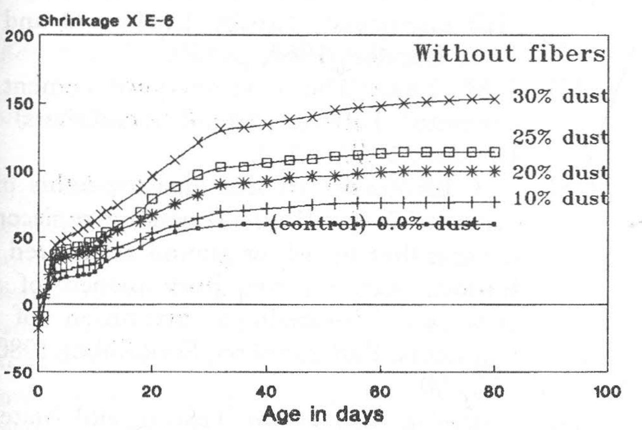

Figure 19. Effect of partial replacement of cement with cement kiln dust on drying shrinkage for concretes without fibers.

Effect of adding fibers: Figure (20) shows the relation between the shrinkage measurements and the percentage of replacement of cement with cement kiln dust by weight (with 2% fibers) at different ages. It is obvious that adding fibers to concrete mixes cause a noticeable reduction in shrinkage measurements. It is also clear that the concrete mixes containing fibers show a constant reading at earlier times than concrete mixes without fibers. This phenomenon may be attributed to the inclusion and random orientation of fibers within concrete matrix which leads to restrain the contraction of concrete specimens therefore the shrinkage may be reduced. The shrinkage of 30% replacement with cement kiln dust and 2% fibers was about 80% the shrinkage of 30% replacement without fibers at 80 days.

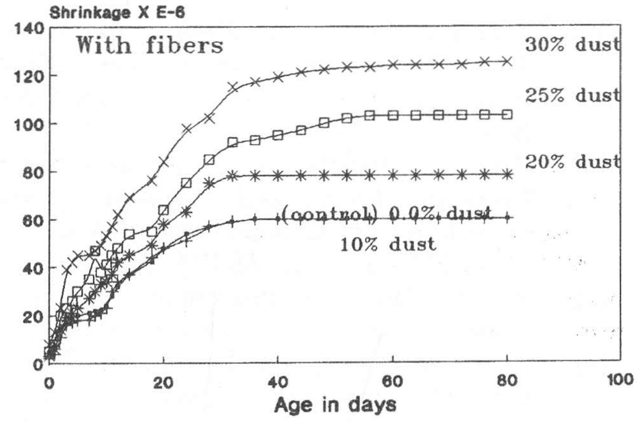

Figure 20. Effect of partial replacement of cement with cement kiln dust on drying shrinkage for concretes with fibers.

CONCLUSION AND RECOMMENDATIONS

Cement kiln dust is considered to be an alkaline waste material containing processed raw materials and acts as a cementitious material, since it contains a certain degree of cementitious property. The specific gravity of cement kiln dust was 2.92, its specific surface area was 4440 cm2/gm and its soundness was 1.5 mm. To achieve the requirements of Egyptian Standard Specifications, the maximum permissible percentage of cement kiln dust could be used in mortar and concrete mixes was 25%. From the limited research reported here, it may be stated that ordinary portland cement in concrete could be safely replaced by weight up to 25% of cement kiln dust with 2% natural fibers (chopped wheat straw) from the point of view of short term strength and this can result in saving in construction cost. further tests on the durability of kiln dust in severe conditions are needed to establish the effectiveness of the replacement. Cement kiln dust may be used in a relatively important manufacture such as hollow cement blocks, concrete curbs, paving , and tiling. The egyptian cement factories must deal with cement kiln dust as a valuable material because the considerable economical gains to the national income which will result from the partial replacement of cement with cement kiln dust. The using of cement kiln dust in construction industry will undoubtedly alleviate the consequent damage to the local ecology.

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