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Residues of the Cement Industry and Its Return to the Production of Concrete to Produce the Concrete

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Abstract: *The presented work investigates the effect of addition admixture (cement kiln dust) to concrete as a partial replacement of cement weight. Cement kiln dust was added by (10,30,50)% of cement weight.Four mixes were selected, three of them contain cement kiln dust (CKD) and one reference mix without any admixture for ages (7,28,90) days. Compressive strength ,flexural strength, ultra-sound velocity (UPV), slump, splitting tensile strength and static modulus of elasticity were tested.The test results indicated that the use of (CKD) led to significant decreasing in concrete strength in general and this decreasing increases with the increasing of (CKD), for example at 28 day the compressive strength of reference concrete (A) was 35 MPa, while the compressive strength of (B,C,D) contain (10,30,50)%CKD were (28,25,22) MPa respectively.*

Keywords: *waste concrete, Cement kiln dust, Admixture, Concrete, Cement industry.*

1. INTRODUCTION

To reduce the problem of waste material dumping, it is imperative that waste materials showed be utilize in an environmentally safe manner either as raw materials for other products or for some other beneficial purposes. While such large quantities of waste material get accumulated facing very serious problems of safe disposal, it could be possible with the help of the building material industry to sensibly put to use such waste products into very useful, interesting and cast effective item. The idea of " no waste" that is accepted and followed in the developed countries can be transferred to our situation [1]. Cement kiln dust (CKD) is a by-product from cement manufacturing. Cement kiln dust is a fine powdery material similar in appearance to Portland cement. It is composed of micron sized particles collected from electrostatic precipitators during the production of cement clinker [2].

2. LITRERATURE REVIEW

El-Sayed et al. [3] investigated the effect of CKD on the compressive strength of cement paste and on corrosion behavior of embedded reinforcement. They reported that up to 5% substitution of CKD by weight of cement had no adverse effect on cement paste strength and on reinforcement passivity. It was reported that when CKD and blast furnace slag are added in proper ratio to ordinary Portland cement , the compressive strength and the corrosion resistance of the mix increase.

Salem and Ragai [4] investigated the electrical conductivity of granulated blast furnace slag, CKD,silica fume cement pastes at different porosities. Blended cement pastes containing granulated blast furnace slag and CKD and made with or without silica fume, were prepared using the initial water to solid (w/s) of 0.3, 0.4 and 0.5 to produce low, normal and high porosity pastes respectively. The variations of electrical conductivity with hydration time were measured at $30C^{o}$ and $50C^{o}$ for each paste during setting and hardening processes after gauging with deionized water.

Shoaib et al. [5] evaluated of the influence of CKD substitution on the mechanical properties of concrete. Materials used in that research were untreated raw CKD ,ordinary Portland cement (OPC) , blast furnace slag (BFC) and sulfate resisting Portland cement (SRPC). It was reported that with increasing quantity of CKD , generally, the ultimate compressive as well as tensile strengths decreased for OPC concrete specimens, slight increase in strength was observed for BFSC and SRPC.

3. EXPERMENTAL WORK

3.1 Materials.

3.1.1 Cement.

Ordinary Portland cement was used throughout this work. The physical and chemical test results of the used cement are given in table (1) and table (2). It conforms to Iraqi specification No. 5/1984 [6].

3.1.2 Fine Aggregate.

Sand of 4.75 mm maximum size was used for concrete mixes of this investigation. The specific gravity , absorption and sulfate content were (2.65 , 0.67% , 0.15%) respectively.

3.1.3 Coarse Aggregate.

The washed coarse aggregate of 10 mm size were used. The specific gravity , absorption and sulfate content were (2.68 , 1.06% , 0.06%) respectively.

3.1.4 Mixing Water.

Potable water was used for mixing and curing purposes.

3.1.5 Cement Kiln Dust (CKD).

Cement kiln dust was used in this work of which the chemical composition is shown in table (5).CKD used in this work was brought from Falluja factory of cement as a by- product of cement industry and it was grinded to obtain toughness equal to 4500 cm^2/gm to be finer than the toughness of cement used to achieve homogenous matrix.

4. EXPERMENTAL PROGRAM

The experimental program is planned to investigated the effect of cement kiln dust (CKD) as admixtureon the compressive strength , flexural strength , slump , ultra-sound velocity and modulus of elasticity of concrete . Table (6) shows the details of reference and admixture CKD concrete mixes used throughout this work.

5. MIXING PROCEDURE

A mechanical mixer of (0.1) m^3 capacity was used . The interior surface of mixer was cleaned and moistured before placing the materials. The raw materials such that gravel , sand , cement and CKD were first mixed dry for about one minute then water was added to the mixer. After that mixing continued for about three minutes until the concrete becomes homogenous in consistency.

6. CASTING COMPACTION AND CURING

The molds were lightly coated with mineral oil before use , concrete casting was carried out in different layers each layer of 50 mm . Each layer was compacted by using a vibrating table for (15-30) second until no air bubbles emerged from the surface of the concrete , and the concrete is level off smoothly to the top of the molds . Then the specimens were kept covered in laboratory for about (24) hours . After that , the specimens remolded carefully , marked and immersed in water until the age of test .

7. TESTING OF HARDENED CONCRETE

7.1 Slump Test.

This test was done according to ASTM C 143-89 [7] to find the workability of reference and admixture concrete.

7.2 Compressive Strength Test.

The compressive strength was determined according to B.S.1881.Part 5 , 1983 [8]. The average of compressive strength of three cubes was recorded for each testing age (7,28,90) days.

7.3. Flexural Strength Test.

(100*100*500) mm concrete prisms were prepared. The test was carried out using two point load according to ASTM C 78-84 [9] . The average modulus of rupture of three prisms was obtained for each testing age

(7,28,90) days . The ultimate tensile strength in flexural was calculated by using the following formula

$$Fr = PL/bd^2 \quad (1)$$

7.4. Splitting Tensile Strength Test.

(100*200) mm concrete cylinder were prepared according to the ASTM C 496-86 [10]. The average of splitting tensile strength of three cylinders was recorded for each testing age (7,28,90) days. The splitting tensile strength was calculated as follows:

$$Ft = 2P/\pi dL \quad (2)$$

7.4 Ultra Sound Velocity Test.

PUNDIT was used to determine UPV. The frequency of PUNDIT used is 54 KHz. Frequency of 54 KHz was used according to B.S:1881:Part 203:1986[11]. Velocity of ultra sound was determined from this formula :

$$V=L1/T \quad (3)$$

7.5 Static Modulus of Elasticity

The static modulus of elasticity was calculated at age (28) day according to ASTM C 469-87a [12]. 3

8. RESULTS AND DISCUSSION

8.1 Slump Test

The slump was determined at age (7,28,90) day for fresh concrete specimens. The test results are summarized in table (7). It is shown that the slump was decrease with increasing of (CKD%). The test results illustrated that the slump of mix A (reference concrete) was higher than the slump of admixture mixes (B,C and E) as shown in Fig. (1). This is

due to the toughness of (CKD)which leds to increasing of specific surface area then the workability of mixes will be decrease.

8.2 Compressive Strength.

The compressive strength was determined at age of (7,28,90) day for moist cured concrete specimens. The test results are summarized in table (8). It is show that the compressive strength was increase with age for all types of concrete and the compressive strength for concrete contain (CKD) decreases appreciably with adding of (CKD) as shown in Fig. (2). For example, the 28 day compressive strength decreased from (30) MPa of reference concrete mix No.1 to (24,21 and 18) MPa for mix No. 2,3 and 4 respectively. While Shoaib et al. [5] used percentages of replacement of CKD ratio to cement 0%,10%,20%,30%,and 40%.The mixes have the same mix proportion (1 cement:1.9sand:3.52 gravel and 0.5 w/c ratio), and the cement content used in the mixes was 350 kg/ m^3. Compressive strength was determined at the age of 1,3and6 months. Based on the test results, they reported that control mix (0%CKD) achieved compressive strengths of 27,28.5 and 32 MPa at the ages 1,3 and 6 months respectively. Compressive strengths of concrete mixes decreased with the increase in CKD percentage at all ages (1,3 and 6 months),approximately 44%,reduction in strength was observed at 40% CKD content, with 10%CKD content the percentage reduction in compressive strength was 15%,3.5% and 1.6% at 1,3 and 6 months. Al-Harthy et al [13] used seven different concrete mixtures were made by replacing cement with 0%,5%,10%,15%,20%,25% and 30% CKD by total weight of the cement. For each of the mixtures ,three water –to- binder ratios of 0.5, 0.6, and 0.7 by weight were used . Based on the investigation they reported that there was generally a reduction in compressive strength with increasing in CKD replacement for cement. More reduction in compressive strength was observed in mixtures with higher water – to binder ratio (0.7) than in mixtures with low water to binder ratio (0.5) . For all blends the control mix (no CKD) generally produced the highest compressive strength. At the age of 28 days, control mixtures (no CKD) with water- to-binder ratio of 0.7,0.6 and o.5 achieved compressive strengths of 34.4;37.5 and 55 MPa,respectively.

However, small amounts of replacement up to 5% did not seem to have an appreciated adverse effect on the compressive strength, especially at low water-to-binder ratio (0.5). At 5% and 10% CKD substitution for Portland cement, the reductions in 28 day compressive strength values were 1.8% and 4.5% respectively. A water-to-binder ratio (0.6), 28 day strength reductions were 12.4% and 18% for 5% and 10% CKD replacement. At maximum level (30%) of CKD substitution, the reductions in strength were 31%,29% and 22% for water-to-binder ratios of 0.7,0.6 and 0.5 respectively.

The test results illustrated that the compressive strength increase with age for all types of concrete used because of the closer microstructure of cement paste and completion of hydration process , on the other hand the decreasing in compressive strength with increasing of (CKD%) is due to the replacement of cement clinker , which is mainly responsible for strength development. In addition , the larger amount of chloride present in cement kiln dust cause assort of crystallization of hydration products which results in an opening of the pore system of hardened samples leading to a reduction of strength.

8.3 Flexural Strength.

The flexural strength was determined at ages (7,28,90) days for concrete specimens. The results are given in Table (9) and plotted in fig. (3) show that the flexural strength increased with age for all mixes in this research while it was decreased with addition f (CKD) to the mix and this decreasing increases with the increasing of (CKD) added to the mix.

For example, the 28 day flexural strength decreased from (4.3) MPa of reference concrete mix No.1 to (3,2.5 and 2.4) MPa for mix No.2,3 and 4 respectively due to the replacement of cement clinker , which is mainly responsible for strength development. In addition , the larger amount of chloride present in cement kiln dust cause assort of crystallization of hydration products which results in an opening of the pore system of hardened samples leading to a reduction of strength.

8.4 Splitting Tensile Strength.

The splitting tensile strength was determined at ages (7,28,90) days. From these results which are presented in Table (10) and plotted in fig. (4) it is found that the splitting tensile strength of all concrete mixes increase with age and decrease in mixes contain (CKD)% with increasing of this admixture in mix . For example, the 28 day splitting tensile strength decreased from (3.51) MPa of reference concrete mix No.1 to (3.46,3.43 and 3.37) MPa for mix No.2,3 and 4 respectively. Shoaib et al [5] concluded that splitting tensile strength of concrete mixes decreased with increase in CKD percentage .Maximum reduction occurred at 40% CKD and it was 39%,41% And 41% at the ages of 1,3 and 6 months. However, at 10% CKD reduction in strength was nominal (13% at 1 month ,12% at 3 months , and 13% at 6 months).This reduction in strength in the research is due to poor bond between aggregate and cement mortar. Thus, the concrete sample gives lower bond between the aggregate particles and that lowers tensile strength.

8.5 Ultra Sound Velocity(UPV) Test .

The UPV was determined at age of (7,28,90) day for moist cured concrete specimens. The test results are summarized in Table (11). It is show that the UPV was increase with age for all types of concrete and decreases with adding of (CKD) as shown in Fig. (5). For example, the 28 day UPV decreased from (4.53) km/sec. of reference concrete mix No.1 to (4.5,4.4 and 4.2) km/sec. for mix No.2,3 and 4 respectively due to the replacement of cement clinker , which is mainly responsible for strength development. In addition , the larger amount of chloride present in cement kiln dust cause assort of crystallization of hydration products which results in an opening of the pore system of hardened samples leading to a reduction of strength.

8.6 Static Modulus of Elasticity.

The static modulus of elasticity(MOE) was determined at age (28) days. The test results are given in Table (12) for all concrete mixes . From this table it can be seen that the MOE decreases with addition of CKD. The percentage decreases of MOE relative to reference concrete (A) were (5.31,9.67 and 77.87)% for mixes (B,C and E) respectively. Generally, the content of CKD in concrete is the principle factor that affects the value of MOE as shown in Fig. (6). The decreasing of MOE with increasing of CKD is due to the replacement of cement clinker, which is mainly responsible for strength development. In addition, the larger amount of chloride present in cement kiln dust cause assort of crystallization of hydration products which results in an opening of the pore system of hardened samples leading to a reduction of strength.

9. CONCLUSIONS

Depending on the results of the investigation, the following conclusions can be drawn:

1. The compressive strength decreases with the increasing of CKD. The reduction of compressive strength range between (6.12% to 15.55%).
2. The flexural strength decreases with the increasing of CKD. The reduction of flexural strength range between (5.61% to 45.96%).

3. The splitting tensile strength decreases with the increasing of CKD. The reduction of splitting tensile strength range between (1.38% to 7%).

4. The UPV decreases with the increasing of CKD. The reduction of UPV range between (2.24% to 4.11%).

5. The slump decreases with the increasing of CKD. The reduction of compressive strength range between (2.36% to 8.33%).

6. The MOE decreases with the increasing of CKD. The reduction of MOE range between (5.31% to 77.87%).

10. TABLES AND FIGURES

Table (1) : Physical properties of cement (Turabat al-Sabia)

Physical properties	Test result	Limits of Iraqi spec. No.5/1984
Specific surface area Blaine Method , m^2/kg	380	≥230 m^2/kg
Setting time , Vicat's method : Initial setting hrs : min Final setting hrs : min	 3 : 52 1 : 22	 ≥1 hour ≤10 hours
Soundness	0.3%	≤ 0.8%
Compressive strength of mortar , N/mm^2 3 – day 7 - day	 21 26	 ≥ 15 N/mm^2 ≥ 23 N/mm^2

Table (2): Chemical properties of cement used.

Chemical components	Percent(%)	Limits of Iraqi spec. No 5/1984
CaO	62.72	-
SiO_2	21	-
Al_2o_3	3	-
Fe_2O_3	5.4	-
MgO	2.37	< 5%
SO_3	2.82	< 2.5%
Loss of ignition	2.5	< 4%
Inseluble residual	1.22	< 1.5
Lime saturation factor	0.83	0.66-1.02
C_3S	41.33	
C_2S	29.1	
C_3A	9.25	
C_4AF	9.12	

Table (3): Grading of fine aggregate.

Sieve size (mm)	A cumulative passing (%)	Limits of Iraqi spec. No 5/1984 for zone (3).
4.75	100	90-100
2.36	91.6	85-100
1.18	80.1	75-100
0.6	70.8	60-100
0.3	24	12-40
0.15	7.6	0-10

Table (4) : Grading of coarse aggregate.

Sieve size (mm)	Accumulative passing(%)	Limits of Iraqi spec. No .45/1984 for zone (3).
14	100	100
10	89.2	85-100
5	16.6	0-25
2.36	0	0-5

Table (5) : Chemical composition of CKD

Chemical components	Percent (%)
SiO_2	14.82
Al_2O_3	5.52
Fe_2O_3	1.98
CaO	49.65
MgO	3.35
SO_3	6.33

Table (6) : Details of the experimental program

N0. of Mix	Mix Des.	W/C ratio	Admixture(%) by weight of cement	Mix proportions by weight cement:sand:gravel:CKD
1	A	0.4	0	1:1.5:3:0
2	B	0.4	10	1:1.5:3:10
3	C	0.4	30	1:1.5:3:30
4	E	0.4	50	1:1.5:3:50

Table (7) : Slump results of concrete mixes

No. of Mix	Mix Des.	Slump (mm)
1	A	130
2	B	127
3	C	120
4	E	120

Table (8) : Average compressive strength results of various types of concrete

No. of Mix	Mix Des.	Compressive strength (Mpa)		
		7 day	28 day	90 day
1	A	24	30	35
2	B	21	24	28
3	C	20	21	25
4	E	15	18	22

Table (9) : Average flexural strength results of various types of concrete.

No. of Mix	Mix Des.	Flexural strength (Mpa)		
		7 day	28 day	90 day
1	A	3.4	4.3	5
2	B	2.7	3	3.6
3	C	2.3	2.5	3
4	E	1.2	2.4	2.8

Table (10) : Average splitting tensile strength results of various types of concrete

No. of Mix	Mix Des.	Splitting tensile strength (Mpa)		
		7 day	28 day	90 day
1	A	3.45	3.51	3.67
2	B	3.38	3.46	3.62
3	C	3.32	3.43	3.5
4	E	3	3.37	3.43

Table (11) : Average pulse velocity results of various types of concrete

No. of Mix	Mix Des.	Pulse velocity (km/sec.)		
		7 day	28 day	90 day
1	A	4.51	4.53	4.56
2	B	4.43	4.5	4.46
3	C	4.3	4.4	4.1
4	E	3.8	4.2	4.38

Table (12) : Static modulus of elasticity (MOE) results of various types of concrete

No. of Mix	Mix Des.	Static Modulus of Elasticity (Gpa) at 28 day
1	A	23.8
2	B	22.6
3	C	21.7
4	E	13.38

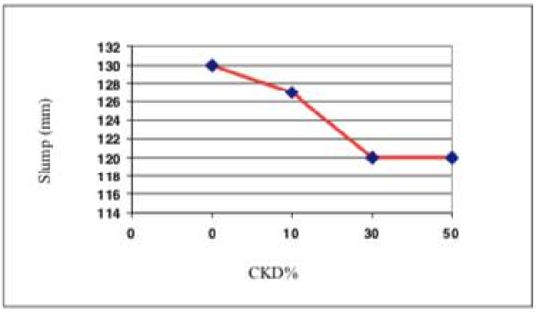

Fig.(1): Relationship between (CKD)% and slump for different types of concrete.

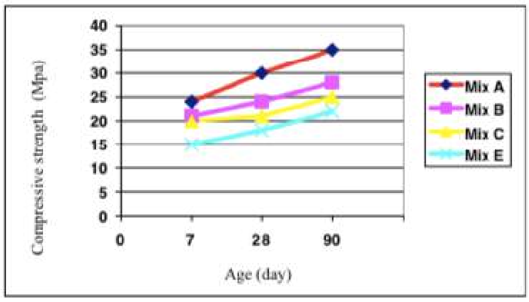

Fig. (2) : Relationship between age and compressive strength for different types of concrete

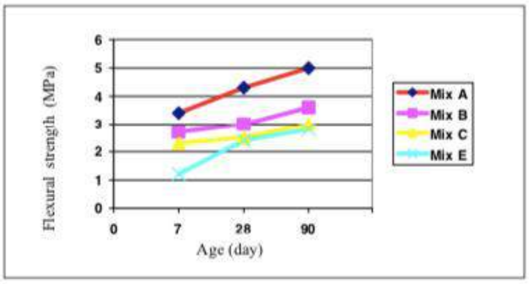

Fig.(3) : Relationship between age and flexural strength for different types of concrete

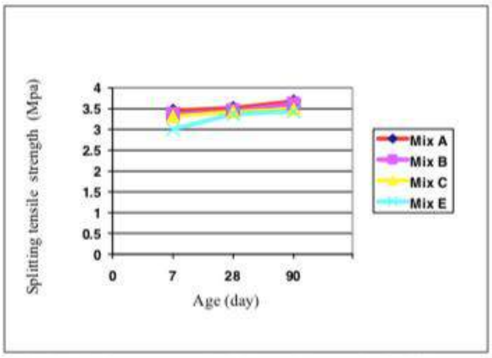

Fig.(4) : Relationship between age and splitting tensile strength for different types of concrete

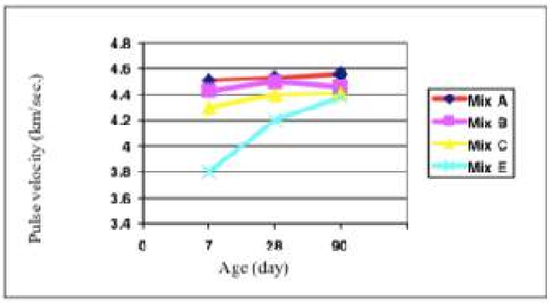

Fig.(5) : Relationship between age and pulse velocity for different types of concrete.

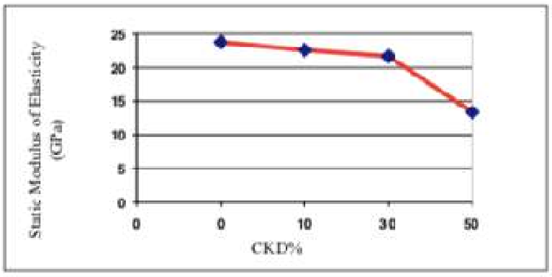

Fig.(6) : Relationship between CKD% and static modulus of elasticity.

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