Evaluation The Effect of Cement Kiln Dust on Some Mechanical Properties of Self Compacting Concrete

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Abstract

In this paper, it was aimed at studying the influence of cement kiln dust (CKD) on workability of fresh concrete and some mechanical properties of self compacting concrete, CKD is by product from the cement factory. The work consist of using different mixtures having CKD of (10,20,30%) by weight of cementations materials .

Different test was used to study the different workability parameters. The mechanical properties studied in this work, are compressive strength, splitting tensile, flexural strength, and modulus of elasticity at ages 7 to 60 days. Furthermore the ultrasonic pulse velocity was used to assess the properties of the SCC. It was possible to produce SCC with CKD add on which satisfies the requirement of this types of concrete, however the compressive strength was ranged (32 - 60) MPa, splitting tensile ranged (2.1- 3.4)MPa , modulus of rupture ranged (3.75- 7.5)MPa.

Keywords: self compact concrete, cement kiln dust properties of self compact concrete

الخلاصة

يهدف هذا البحث إلى دراسة تأثير إضافة غبار مرسبات السمنت المنتج من معامل السمنت بنسب مختلفة من (10−30%) من وزن المواد السمنتيه إلى الخلطات الخرسانية ودراسة تأثيره على قابلية تشغيل الخرسانة الطرية وكذلك دراسة الخواص الميكانيكية (مقاومة الانضغاط، مقاومة الشد, مقاومة الانحناء،معامل المرونة) , للأعمار من 7إلى 60 يوم بالإضافة إلى فحص سرعة الموجات فوق الصوتية لتقييم خواص الخرسانة ذاتية الرص. من الممكن أنتاج خرسانة ذاتية الرص مع إضافة غبار مرسبات السمنت ضمن متطلبات هذا النوع من الخرسانة, كذلك تراوحت قيم مقاومة الانضغاط بين (32−60)نيوتن/مم^2, مقاومة الشد بين نيوتن/مم$^{-2}$(2.1−3.4), مقاومة الانحناء بين نيوتن/مم^2 (3.75− 7.5) .

Introduction

The use of self - compacting concrete (SCC) is spreading worldwide because of its very attractive properties in the fresh state as well as after hardening. The principal reasons for this interest concern the ease of placing this type of concrete in heavily reinforced areas difficult to access , the reduced effort in accomplishing some of the casting tasks and the significant reduction of the construction period. Along with these advantages, in terms of environment, this technology will enable a considerable reduction of the acoustic noise levels and the use of secondary. The use of SCC will lead to a more industrialized production, reduce the technical costs of in situ concrete constructions, improve the quality, durability and reliability of concrete structures and eliminate some of the potential for human error. It will replace manual compaction of fresh concrete with modern semi- automatic placing technology and in that way improve health and safety on and around the construction site. However, this type of concrete needs a more advanced mix design than traditional vibrated concrete and more careful quality assurance with more testing and checking *(Selvamony et al. 2010)*.

Large quantities of industrial by-products are produced every year by various industries. The main goals of environmental protection agencies and governments are to seek ways to minimize the dual problems of disposal and health hazards of these by-products. For many years, by-products such as fly ash, silica fume, slag, copper slag (CG) were considered as waste materials. Moreover, new byproducts are being generated by various industries, which could have a promising future for partial

replacement of Portland cement. cement by-pass dust (CBPD) (also known as cement kiln dust) are by-products of the cement industries, this material use in many applications as follows*(Al – Jabri, et al. 2006)*:
(a) pozzolanic base stabilization
(b) a filler in asphalt concrete mixtures
(c) wet soil conditioning and waste stabilization and solidification
(d) an amendment in neutralizing acidic soils
(e) a partial replacement for ordinary Portland cement (OPC) in concrete

The Experimental Program

Different workability test were adopted such as slump- flow, T50, L- box, V- funnel. The mechanical properties studied were, compressive strength, splitting tensile strength, flexural strength, and static modulus of elasticity. The ultrasonic pulse velocity test, was used to determine the properties of the hardened concrete. The properties of concrete mixes are summarized in Table (1).

Table (1) Mix proportions

Mix Designation	Cement kg/m^3	CKD kg/m^3	Sand kg/m^3	Gravel kg/m^3	SP l/m^3	Water kg/m^3	w/p ratio
R 0%	500	-	775	825	6.25	200	0.4
D5 10%	450	50	775	825	6.25	200	0.4
D10 20%	400	100	775	825	6.25	200	0.4
D15 30%	350	150	775	825	6.25	200	0.4

Note: R: Reference concrete (without filler). D5 : Concrete with 10% cement kiln dust. D10: Concrete with 20% cement kiln dust. D15 : Concrete with 30 % cement kiln dust ,all these percents are with respect to cementations materials.

Materials

1- Cement:

Ordinary Portland cement (O.P.C) manufactured by united cement company commercially known (Tasluja- Bazian) was used throughout this study. This cement compared with the Iraqi specification NO.5 /1984. The chemical composition and physical properties are presented in Table (2).

Table (2) Physical analysis and chemical composition of the cement

Physical Properties	*Test Results*	*I.O.S.5: 1984 Limits*
Setting Time : Initial hrs ; min Final hrs ; min	 2;00 6.0;00	 ≥45 min ≤10hrs
Compressive Strength MPa 3-days 7-days	 18 26	 ≥15 ≥23

Oxide	*%*	*I.O.S. 5: 1984 Limits*
CaO	62.5	_
SiO_2	20.30	_
Al_2O_3	5.55	_
Fe_2O_3	4.20	_
MgO	2.5	< 5.0
K_2O	0.75	
Na_2O	0.35	
SO_3	2.41	< 2.8
Loss On Ignition (L.O.I)	1.7	< 4.0
Lime Saturation Factor (L.S.F)	0.81	0.66 - 1.02
Insoluble residue (I.R)	0.4	< 1.5 %
Free lime (F.L)	0.67	_
Total	99.92	
Compound Composition	*%*	*I.O.S. 5: 1984 Limits*
C_3S	50	_
C_2S	20.48	_
C_3A	4.0	_
C_4AF	13.17	_

2- Fine Aggregate: Natural sand from Baher _ al Najaf region was used. The results of physical and chemical properties of the sand are listed in Table (3). Its grading is conformed to the IQS No. 45/ 1984. Zon.3.

Table (3) Grading and physical properties of the sand

Sieve size (mm)	*Passing %*	*I.O.S.45:1984 Limits Zone (3)*

10 5 2.36 1.18 0.6 0.3 0.15	100 96 89 80 75 29 7	100 90-100 85-100 75-100 60-79 12-40 0-10
Physical Properties	*Test Results*	*L.O.S.45 1984 Limits*
Specific gravity Absorption % Sulfate content (SO_3) % Clay %	2.65 1.6 0.324 2.3	_ _ ≤ 0.5 ≤3.0

3- Coarse Aggregate: The coarse aggregate was AL- Nibee crushed gravel with a maximum site of 14 mm. The coarse aggregate is complying with IQS NO. 45 / 1984. Table (4) show the grading and some physical properties of the coarse aggregate.

Table (4) Grading and physical properties of the coarse aggregate.

Sieve size (mm)	*Passing %*	*I.Q. S NO 45 : 1984 Limits*
14 10 5 2.36	100 35 0.15 0	90 – 100 10 – 40 0 – 5 0
Physical Properties	Test Results	I.Q. S NO 45 : 1984 Limits
Specific gravity (S.G) Absorption % Sulfate Content (SO3) % Clay %	2.6 1.1 0.06 0.5	_ _ ≤0.1 ≤1.0

4- Super- Plasticizer: Super-plasticizer were used to achieve high workability needed to produce SCC. A chemical admixture based on modified poly carboxylic either which is known commercially (Glenium51)was used in this work to produce SCC. Glenium 51 is considered one of a new generation of copolymer based superplastizer that complies with ASTM C494 Types A &F. For this work ratio 1.25 liter for each 100 Kg of cement was used. Table (5) show the properties of superplastizer.

Table (5) properties of superplastizer

Form	Viscous liquid
Color	Light brown
Relative density	1.1 @ 20ºC
pH value	6.6
Viscosity	128+/-30 cps @20ºC
Transport	Not classified as dangerous
Labeling	No hazard label required

5- Water:- Tap water was used for mixing and curing of the concrete.
6- Cement Kiln Dust (CKD):- Cement kiln dust was collected from Kufa cement factory and used to produce SCC. Three ratio (5,10,15%) by weight of cement were used. The dust was stored in dry place and passed through U.S. sieve N.300 (0.6mm) before used. The chemical properties of the dust are shown in Table(6).

Table (6) Chemical properties of CKD

Oxide	%
CaO	42.02
SiO_2	14.1
Al_2O_3	4.20
Fe_2O_3	2.50
MgO	2.45
K_2O	3.23
Na_2O	1.66
SO_3	8.47
Cl	4.12
Loss On Ignition	17.15

Mixing procedure

Mixing procedure is important to obtain the required workability and mixer, with a capacity of $0.05m^3$. Before starting to mix, it is necessary to keep the mixer clean, moist and free from previous mixes.
The procedure used for mixing the batches was as follows:

1- adding the fine aggregate to the mixer with 1/3 water, and mixing for minute.
2- Adding cement with another 1/3 mixing water, and mixing for 1 minute.

3- After that, the coarse aggregate is added with the last 1/3 mixing water and 1/3 of superplasticizer, and mixing for 1.5 minute then the mixture is left for 0.5 minute for rest.
4- Then, the filler (cement kiln dust) and remaining 2/3 of the superplasticizer is added and mixed for 1.5 minute .

The mixture is then discharged, tested and cast; the total time of mixing was about 5 minutes .

Test Procedures.

1- The workability of SCC can be characterized by the following properties:-
*Filling ability
*Passing ability
*Segregation resistance

In order to evaluate the filling ability, passing ability and segregation resistance of the fresh concrete, slump- flow, T50, L-box and V-funnel tests were conducted in this research according to EN 12350-1,2 requirements.

2- *Hardened concrete tests.*

2-1 Compressive strength

Compressive strength was carried and tested according to BS. 1881: part 116 :1983 a total number 36 cubes of 100 mm were tested by using a hydraulic compressive machine of 2000 KN.

All specimens were cured in water until testing age to investigate the effect of (CKD)on the mechanical properties of SCC. Each result of compressive strength was average for three specimens.

2-2 Splitting Tensile Strength.

The splitting tensile strength was determined according to the procedure outlined in BS. 1881:PART 117:1983. A total number of 24 cylinders were cast, demolded and cured in a similar way as the cubes. Each splitting tensile strength result was the average of strength for two specimens . The splitting tensile strength calculated from the equation:-

$$f_t = 2P/D\times\prod\times L \text{ -----(1)}$$

Where:
f_t = tensile strength (MPa)
D and L = the cylinder diameter and length (mm)
P= the applied compressive load (N)

2-3 Flexural Strength

Concrete prisms of dimension (100*100*400)mm were cast according to BS.5328:y1990 procedure.

Modulus of rupture tested according to BS.1881:118:1983 using two point load test and calculated from the simple beam bending formula:

$$f_r = PL/bd2 \text{-------(2)}$$

where:
P= maximum applied load (N)
L= span length (mm)
b and d= specimen width and depth (mm).

2-4 Static Modulus of Elasticity :

The static modulus of elasticity was determine according to BS.1881:121:1983 specifications. A total number of eight cylinders (150*300)mm were tested. All specimens were cast, demolded and cured as for the compressive strength cubes. A hydraulic compression machine of 2000 KN is used to apply a compression load until 40% of the ultimate load. The proving ring used which have length of 200mm and gauge with an accuracy of 0.1mm,is made according to BS.1881:121:1983.The record results were the average of reading for two Cylinders : the modules of elasticity calculated as follows:

$$E_c = (S_2 - S_1) / (\varepsilon_2 - \varepsilon_1) \text{ --------- } (3)$$

Where :

Ec : modules of elasticity GP

S2: stress corresponding to 40 of ultimate load MPa .

S1 : stress corresponding 60 to longitudinal of 50 X10 – 6 MPa.

ε2 :Longitudinal strain produced by S2

ε1 : 50 X 10^{-6}

2 – 5 Ultra – sonic pulse velocity : This test was carried out according to BS 1881 : Part 203 : 1986 using the (PUNDIT) with frequency of 36 KHZ to determine wave velocity in concrete specimens .

Results and Discussions

The properties of fresh concrete are presented in Table (7) . These results show that the SCC produced by the addition of CKD is complying with the requirements of SCC and it is found to have a good consistency and workability at fresh state compared to reference concrete (R) with zero addition of (CKD).

The results tests and development of compressive strength gain shown in Table (8)and Fig (1) . it is clear that the increase in CKD ratio leads to increase the compressive strength due to the early pozalanic action of the CDK , However this behavior was true for 28 days age for all ratios , on the other hand at 60 days age results shows that there is a decrease in the compressive strength with the increasing of CKD ratios (10– 30 %) , by about (5 – 18 %) . This can be attributed to the adverse effect of CDK which contain.

From the results shown in Table (9) and Fig(2) . it can be observed that increasing the CKD ratio from zero to 15% by weight of the cement leads to the decreasing the splitting tensile strength by about (1 – 15 %) at ages from 7 to 60 days. This is due to the low initial volume of capillary voids in the mixes which decrease when increasing the CKD content.

The addition of CKD to the mixes (10 – 30%) by weight of the cement leads to decreasing the flexural strength by about (19 – 33%) for ages from 7 to 60 days as shown in Table (10) .

Results of the modules of elasticity Ec show in Table (11)and Fig(3) similar pattern as for compressive and splitting, there was decrease in the values of the modules of Elasticity ranged (27 – 34 %) . This behavior is due to the large early volume of voids in concrete in higher ratio of CKD. On the other hand , the accelerating effect of CKD increase the pore size . the inclusion of CKD filler powder in the voids among and between cement particles makes weak , non homogenous and less dense interface zone between matrix and aggregate .

From the results shown in Fig (4) , it can be seen that increasing the CKD ratios from (0 – 15 %) by weight of the cement lead to a reduction in the pulse velocity by (10 – 13 %) at 7, 28, 60 days. This reduction in U.P.V with the increase in CKD is due to the large early volume of voids in concrete body , which abstract the pulse transition and prolong the transit time .

Table (7) Fresh Concrete Results

Mix Nation	Slump-flow	T50	V-funnel	V- funnel at $T_{5\ min}$	L-Box H2/H1	T200	T400
R	735	3.6	7	9.25	0.96	3.25	4.8
D5	775	2.2	6	8	0.989	1.5	2
D10	745	3	6.5	9	0.971	2.3	3.5
D15	743	3.2	6.8	9.2	0.964	3	4.2
Acceptance Criteria	650-800	2-5	6-12	0-3	0.8-1	-	-

Table (8) Compressive Strength Results

Mix Nation	Compressive Strength (MPa)			Density Kg/m^3 at 28 days	UPV Km/s at		
	7	28	60		7	28	60
R	32.40	39.08	60.30	2500	4.35	4.67	5.3
D5	32.30	42.60	57.00	2540	4.22	4.58	4.7
D10	33.97	42.24	49.70	2490	4.0	4.48	4.5
D15	32.30	42.60	48.90	2500	3.8	4.3	4.6

Table (9) Splitting Tensile Strength Results

Mix Nation	Splitting Tensile Strength (MPa)		
	7	28	60
R	2.52	3.05	3.36
D5	2.31	2.91	3.1
D10	2.25	2.79	3.40
D15	2.13	2.81	3.30

Table (10) Flexural Strength

Mix Nation	Flexural Strength (MPa)

	7	28	60
R	4.63	5.05	7.05
D5	4.41	4.60	5.36
D10	4.24	4.40	4.95
D15	3.75	4.18	4.7

Table (11) Modulus of Elasticity

Mix Nation	Ec (GPa)		
	7	28	60
R	28	30	35
D5	27	29	32
D10	25	27	30
D15	23	25	28

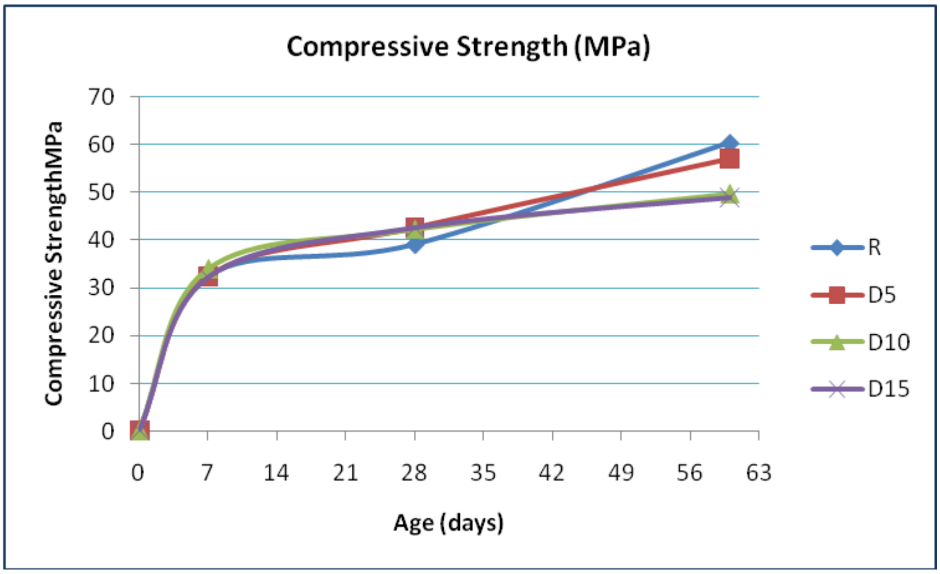

Figure (1) Development of Compressive Strength of Mix Nation

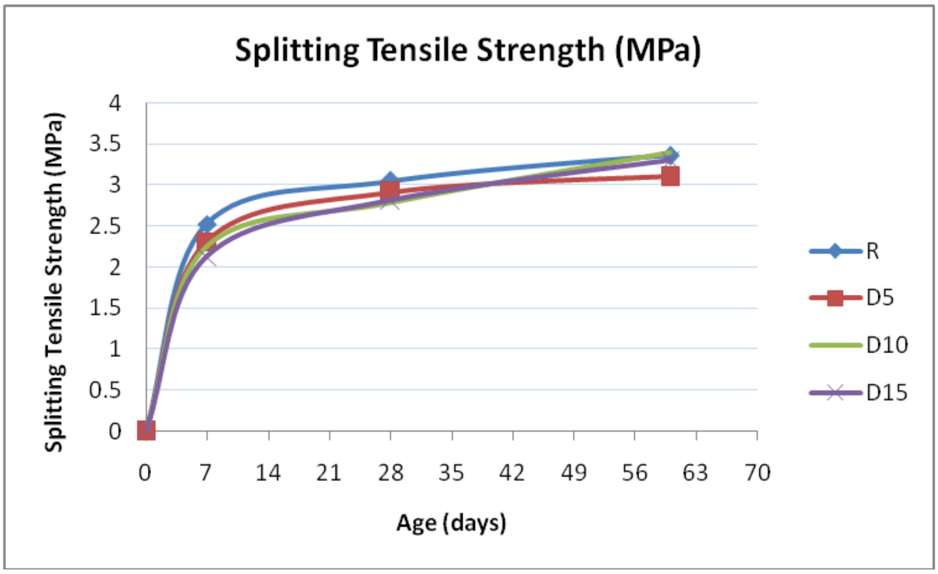

Figure (2) Development of Splitting Tensile Strength of Mix Nation

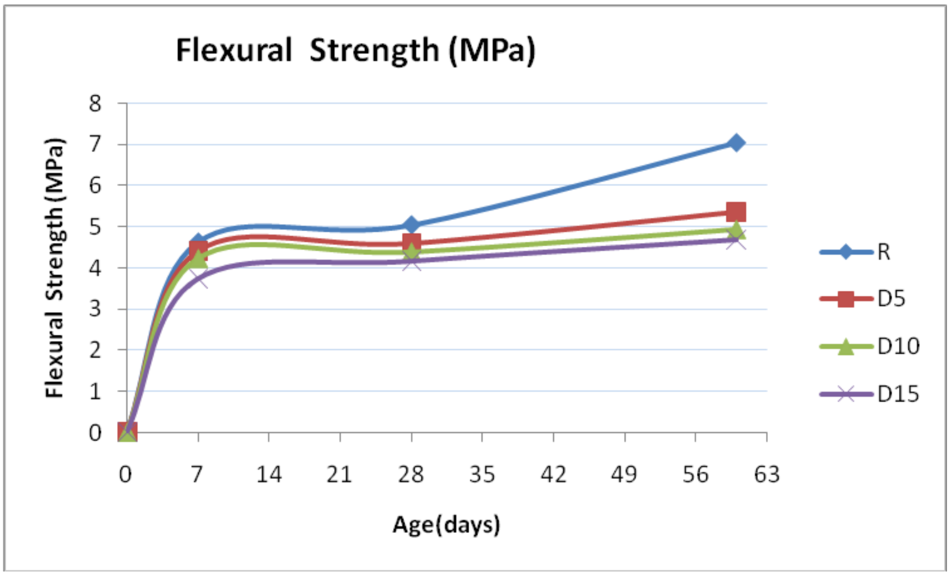

Figure (3) Development of Flexural Strength of Mix Nation

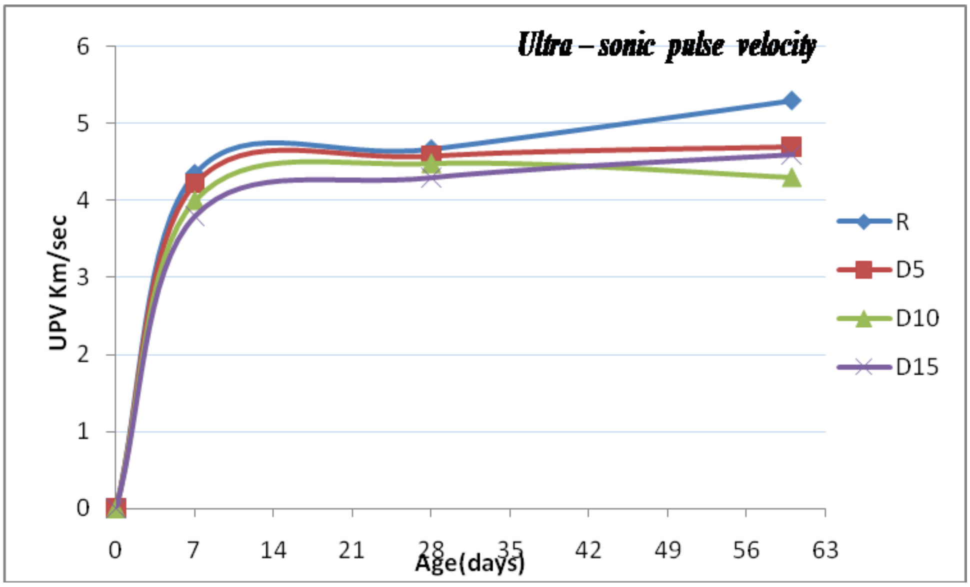

Figure (4) Development of *Ultra – sonic pulse velocity* of Mix Nation

Conclusions

Based on the tests results of the present study the following conclusions can be drawn:

1- Increasing the CKD addition ratio from (10-30%) by weight of cement results to a slight increase the compressive strength at early ages up to 28 days up to <10% , while there was a decrease at 60 days age may reach by about 18%.

2- Splitting and flexural strength show a decreases for all ratio of CKD at age 7 to 60 days.

3- At 7 to 60 days Ec ranged between (28- 35) GPa for reference mixes and ranged between (23-32) GPa of CKD mixes.

4- There was a reduction in UPV value for all ratio of CKD at different ages by 4-17%.

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