Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.6, No.10, 2016

The Effect of CKD Fineness for Karbala Cement Plant on the Engineering Properties of Cement When add it as a Partial Replacement

Yousif, A. Al-Mojamai[1*], Hamed, H. Abdullah[2], and Faizah, A. AI-Barazinjy[3]
[1,2]Department of Geology , College of Science ,Baghdad University ,Baghdad ,Iraq
[3]Building Research Directorate, Ministry of Construction and Housing, Iraq.

Abstract

Cement kiln dust (CKD) is a waste of cement manufacture. The disposal CKD management has becomes an environmental challenge. In order to overcome this problem, researchers are carried out to find out active means to utilize it in various applications .One of these applications is adding it as partial substitution of cement. The aim of this study is investigating the effect of CKDs fineness on the engineering properties of cement, when utilized as a partial replacement. the CKD was grind by jet mill and classify into 4 groups according fineness (3000 , 6000 , 8000 ,10000) cm^2/gm then prepared blends with (5 ,10 , 15 , 20 , 25 , 30 , 35 and 40) % replacement by CKD for each fineness ,.The results showed that increasing of fineness lead to increasing of water demand for consistency,. Setting time(initial and final) retarded with increase fineness of CKD, and the compressive strength of samples contain CKD up to 20% in fineness more than 6000 cm^2/gm are enhanced. These results may came from the increasing specific area activity of CKD compounds which affected on cement hydration and improve in the cement hydrated particles packing and more denser and compact of cement hardened.

Keywords: Cement, CKD, fineness, consistency, setting time, compressive strength, Karbala

1- Introduction

Cement kiln dust is a waste of cement manufacturing which is collected at kiln exhaust gases of cement plant and disposal and accumulation in irregular piles in open land. In Iraq cement kiln dust accumulates usually found around the plants, most of these piles are unlined and uncovered(Al-Shadeed 2009).

The significant properties of CKD are affected by design of kiln ,raw materials and the used fuel in the cement plant (Saddique 2006 and Khanna 2009).The consistence of CKD are generally silicates, chlorides, carbonates ,various metal oxides and oxides of potassium ,calcium and sodium (USEPA 1993).

CKD are used in various engineering purpose, one of these is the partial replacement of cement to produce cement mortars and concrete in order to benefit and reduced of negative effects of high quantities of CKD on environment.

In this study CKD is used in differences percentages as partial replacement after grinding to reach for advance fine of grain size of CKD.

2- Aims of study

The aims of this study is to investigate the effects of using different fineness of CKD in different percentages added as partial replacement of cement on engineering properties of cement , using CKD of Karbala plant in Iraq.

3- Methodology

The source of CKD are used in this study is Karbala cement plant. The chemical analysis of CKD is carried out as the first step in this study as shown (Table. 1).

Table 1. The chemical composition of CKDs samples

Oxides	L.O.I	SiO_2	Al_2O_3	Fe_2O_3	SO_3	CaO	MgO	K_2O	Na_2O	CL
Percent	24.05	14.01	4.04	3.06	3.77	44.13	1.97	1.50	3.30	0.16

The (Table.2) shows the physical analysis and chemical composition of Ordinary Portland Cement OPC (AL-Mass), which it results are conformed to IQS. No.5 /1984.

Table 2. Physical analyses and chemical composition of OPC (Al- Mass)

Test		Test result	I Q S . No.5 /1984 limits
Setting time	Initial	132	≥ 45 min
	Final	270 min	≤ 10 hours (600min)
Compressive strength(MPa)	3 days	22.52	≥ 15
	7 days	30.24	≥ 23
Fineness(cm^2/gm)		3160	≥ 2300
Soundness		conform	< 0.8
Chemical composition	CaO	62.21	-
	SiO_2	20.76	-
	Al_2O_3	4.10	
	Fe_2O_3	3.30	
	MgO	2.46	< 5.0
	K_2O	-	
	Na_2O	-	
	SO_3	2.76	< 2.8
	L.O.I	2.75	< 4.0
	L.S.F	o.94	0.66 – 1.02
	I.R	0.94	< 1.5%
	F.L	1.12	-
	C_3S	57.15	-
	C_2S	16.65	-
	C_3A	5.28	-
	C_4AF	10.03	-

The grinding CKD samples were carried out using jet mill grinder methods, which depending on collisions granular of materials into each other to obtain finer grins size.

The CKD samples are classifying into 4 groups according to the fineness test which is carrying out by using, Blain permeability method according to IQS.No.8/1984.The groups are 3000, 6000, 8000, 10000 cm^2/gm. The preparation blends have OPC with replacement 5 , 10 , 15 , 20 , 25 , 30 , 35 , 40 % of CKD from each fineness group. The effect of fineness and percentages of CKD replacement on water demand of cement paste to reach the standard consistency, which means the degree of paste plasticity (Bhatty 1984) where consistency test carried out for all blends according to IQS. No.8 /1984 using Vicat apparatus.

The initial and final setting time are determined for all blends to evaluate the effect of CKDs fineness on these properties and indirect of development hydration reactions of cement, which is performed using Vicat apparatus according IQS. No. 8/1984. The compressive strength test carried out for all blends according to IQS.No.8 /1984 which depend on mortar cubes (7.07 × 7.07 × 7.07) cm.

4- Results and Discussion

4-1- Consistency test

The amount of water demand for reach blend (cement) to normal consistency is 132 mL, while The amount of water demand for reach blend (cement + CKD of Karbala) to normal consistency are shown in (Table . 3)

Table 3. The consistency tests results.

fineness cm^2/gm / CKD percent	3000	6000	8000	10000
5%	132	138	145	147
10%	135	140	150	150
15%	135	140	150	155
20%	140	145	155	167
25%	145	145	160	165
30%	145	150	160	170
35%	150	150	158	170
40%	153	153	164	172

The maximum water amount values required to reach for normal consistency appears when the fineness is 10000 cm^2/gm for all percentages of replacement of CKD ,and the minimum values are appear when the fineness of CKD 3000 cm^2/gm for all percentages of CKD replacement of CKD .

The relationship between fineness and water amount which is required to obtain normal consistency are shown in (Fig.1). Which explains clearly that increasing in fineness leads to increasing in water amount for each percentage of CKD replacement.

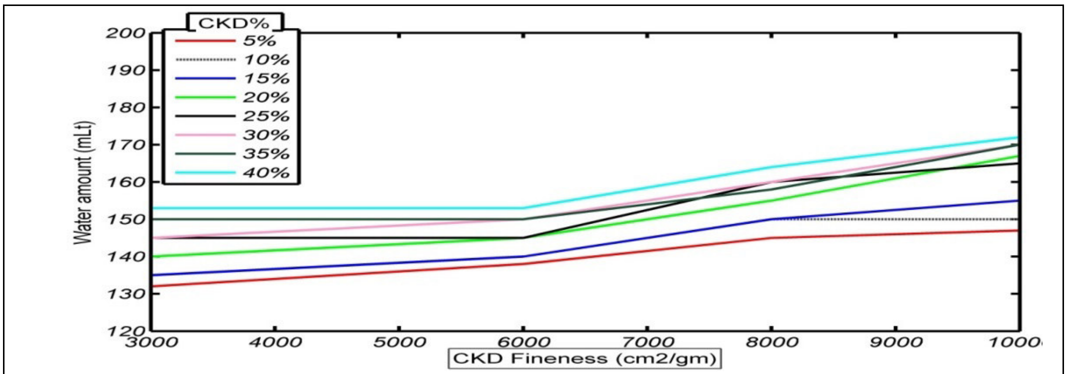

Figure 1. Effect of fineness of CKD on the water amount for consistency

From (Fig.1) and (Table.3) shows it can be illustrated that the increasing of percentages of CKD replacement lead to more water required to reach for consistency for all CKD fineness examined which used in this study . Where the increasing CKD fineness lead to increasing of CKD compounds activity by increasing surface area. These compounds are most probably responsible for the high water demand by react directly with it as CaO, or by enhanced hydration of cement compounds as alkalis.

4-2- Setting Time Test Results

The initial setting time of OPC paste was 132 minutes and final setting time was 270 minutes within the limits of Iraqi standers specifications (IQS.No.5 /1984). The initial and final setting time of (cement+ CKD of Karbala)are shown in the(Table .4)

Table 4 . Results of Initial and Final setting time for cement +CKD of Karbala

CKD percent \ Fineness cm^2/gm		3000	6000	8000	10000
5%	Initial setting	130	125	120	125
	Final setting	270	280	270	280
10%	Initial setting	110	135	130	135
	Final setting	240	280	275	275
15%	Initial setting	120	130	130	130
	Final setting	245	280	285	295
20%	Initial setting	115	130	140	135
	Final setting	220	275	280	300
25%	Initial setting	100	120	140	135
	Final setting	200	265	290	300
30%	Initial setting	90	130	135	140
	Final setting	180	275	300	330
35%	Initial setting	75	130	135	150
	Final setting	170	270	290	350
40%	Initial setting	73	135	143	150
	Final setting	160	270	300	355

All data of initial and final setting time in (Table .4) are with the limits of IQS.No.5/1984.

The maximum value of initial setting 150 minutes appears at 35 & 40 % CKD replacement in fineness at 10000 cm^2/gm while the minimum value 73 minutes appears at 40% CKD in fineness 3000 cm^2/gm.

The maximum value of final setting 355 minutes time appears at 40% of CKD replacement at CKD fineness is 10000 cm^2/gm and minimum values (160 minutes) appears at 40% of CKD replacement in 3000 cm^2/gm of CKD fineness .

The effect of CKD fineness on initial setting time is explain in (Fig.2), which is showed that percentages more than 15% with increasing of fineness lead to increasing (retarder) time of setting. while the percentages of replacement less than 15% are slightly or had not effect with increasing fineness.

The (Table.4) and (Fig.2) shows that the fineness 3000 cm^2/gm are accelerates or minimizes setting time with increasing of CKD while the fineness 8000 to 10000 cm^2/gm are shows retarding effect.

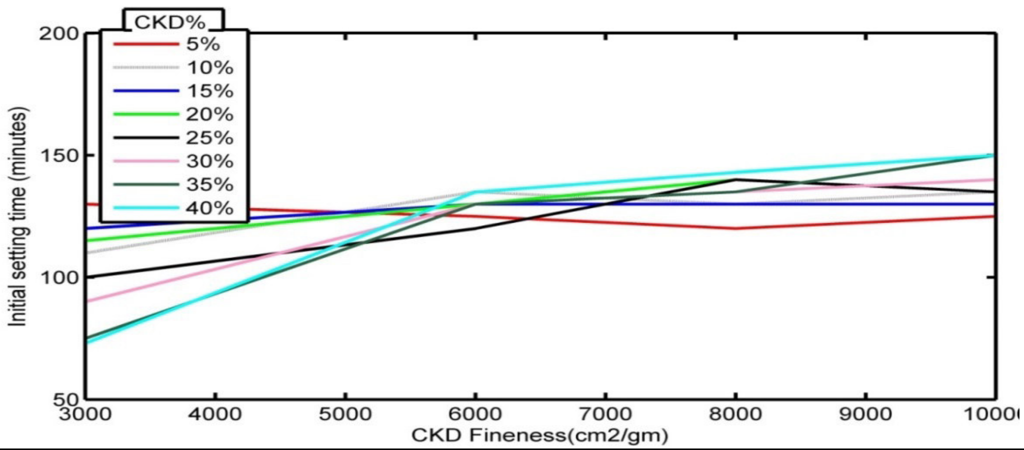

Figure 2. Relationship between fineness of CKD replacement & initial setting time

The relationship between fineness and final setting time (Fig.3) showed that percentages of CKD replacement shows clearly effect of increasing fineness which leads to increasing (retarding) time and the maximum values appear at high fineness tested.

The (Table.4) and (Fig.3) explain that the fineness 3000 cm^2/gm are accelerates reactions with increasing of CKD replacement while the fineness 8000 to 10000 cm^2/gm are shows retarding effect with increasing of CKD replacement.

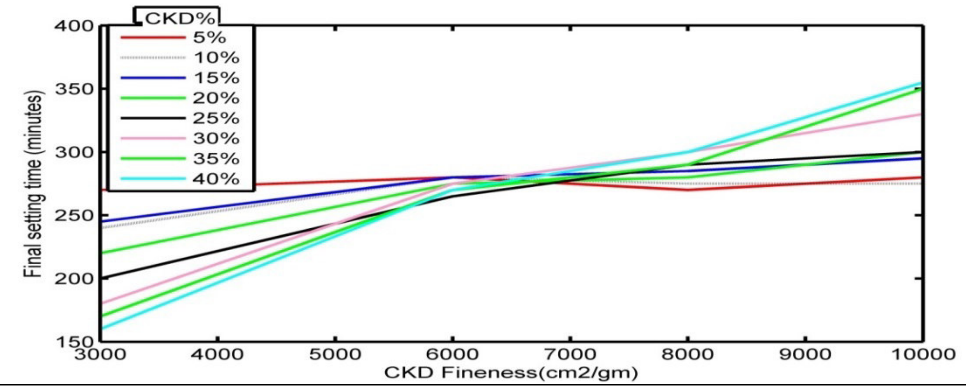

Figure 3. Relationship between fineness of CKD replacement &final setting time

The retardation of initial and final setting indicates the fineness is changing the behavior of setting time by increasing the active surface area of some active compounds , especially SO_3 which increasing it activity with increasing fineness and leads to effect on reaction in first moments of hydrations by the enhanced the productions of Ettringite which responsible for retarding of cement, by prevents water to reach and react with cements compounds , especially C_3A and finally retarded time of setting .

4-3- Soundness Tests Results

The soundness tests is the one of cement test which important to assessment for agreement or refuse the cement products .The results of soundness for OPC (zero mix) and all replacement by CKD (at all CKD fineness are examined in this study) shows in (Table.5), where the all CKD replacement up to 20% is conform to IQS. No. 5/ 1984 while all replacement more than 20% are unconformity, which indicated to negative effect of CKD replacement more than 20%.

Table 5. Soundness results test

Fineness cm^2/gm / CKD percent	3000	6000	8000	10000
5%	∠	∠	∠	∠
10%	∠	∠	∠	∠
15%	∠	∠	∠	∠
20%	∠	∠	∠	∠
25%	×	×	×	×
30%	×	×	×	×
35%	×	×	×	×
40%	×	×	×	×

∠ = conform with in IQS ×= unconformity with in IQS

4- 4- Compressive strength

The results of compressive strength of zero CKD mortars (zero mix) are listed in Table. 6).

Table 6. Compressive strength of OPC without CKD(Zero mix).

Curing time	3days	7days	28days	90days	180days
Compressive strength (MPa)	22.52	30.24	43.62	50.47	61.31

The results of compressive strength OPC with partial replacement by CKD explained below for each fineness test:

4 -4-1- Compressive strength of cement with CKD at fineness 3000 cm^2/gm.

The (Table.7) shows the result of compressive strength (MPa) of OPC with different CKD replacement at 3000 cm^2/gm of CKD fineness.

Table 7 .The result of compressive strength (MPa) of OPC with different CKD replacement at 3000 cm^2/gm of CKD fineness.

Curing time / CKD%	3days	7days	28days	90days	180days
5%	21.98	30.96	42.92	52.54	60.93
10%	22.86	31.03	41.94	50.99	61.78
15%	20.08	29.99	37.33	40.82	46.93
20%	17.36	26.03	30.86	37.99	36.23
25%	15.24	19.83	25.36	33.39	36.72
30%	15.82	18.65	21.40	29.00	23.83
35%	13.92	17.40	20.18	18.18	15.88
40%	12.31	17.01	16.36	14.02	12.67

The maximum values appears at 5 and 10 % CKD replacement and minimum values appears at 40% CKD replacement (for each curing time).

The relationship between the curing time with compressive strength for each CKD replacement is plotted in (Fig.4) , where The strength values are developed with curing time for all mixes except 30%,35% and 40% of CKD content where these values drops down at 180 days age for 30% , and 90 days age for 35% and 40%. The strength increase with 5% and 10% of CKD and are the same of zero mix values of strength. And increasing CKD percentages to 15% it decreases but yet higher at 180 days age .When CKD contain reaches 20% and 25% strength values decreases more but still improving with curing time. 30%, 35% and 40% of CKD in the mix causes a great decrease of strength and for 40% addition reaches 12.67 MPa at 180 days age.

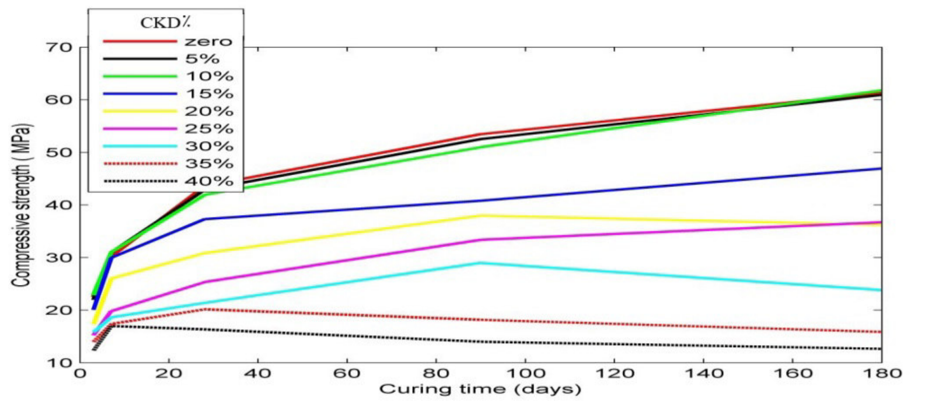

Figure 4.Compressive strength of OPC development with curing time, for each CKD replacement at 3000cm^2/gm fineness

4- 4-2 - Compressive strength of cement with CKD at fineness 6000 cm^2/gm

The (Table.8) shows the compressive strength of OPC with different CKD replacement at 6000 cm^2/gm CKD fineness.

Table 8. Result of compressive strength (MPa) of OPC with different CKD replacement at 6000 cm^2/gm of CKD fineness

Curing time / CKD%	3days	7days	28days	90days	180days
5%	19.91	32.02	40.78	53.58	59.93
10%	20.18	28.97	39.97	52.76	61.00
15%	21.86	30.90	42.32	53.03	59.32
20%	21.91	29.87	43.90	50.80	61.03
25%	18.03	23.39	35.48	37.11	52.09
30%	17.92	22.44	33.22	36.67	39.26
35%	13.33	21.78	31.49	30.23	40.82
40%	13.87	18.59	26.22	23.22	19.19

The maximum values appears at 5, 10 ,15 and 20 % CKD replacement and minimum values appears at 40% CKD replacement.

The relationship between the curing time with compressive strength for each CKD replacement is plotted in (Fig.5) where this figure shows that compressive strength values increases with curing time for mixes containing 5%,10%,15% and 20% and are similar to the values of zero mix.

Increasing CKD percentages up to 25% in the mix decreases these values to be less than values of zero mix , and for the mixes containing 30% CKD compressive strength increases steadily , then with 35% increases sharply at 180 days ages reaching 40% content strength drops down sharply at 180 days age.

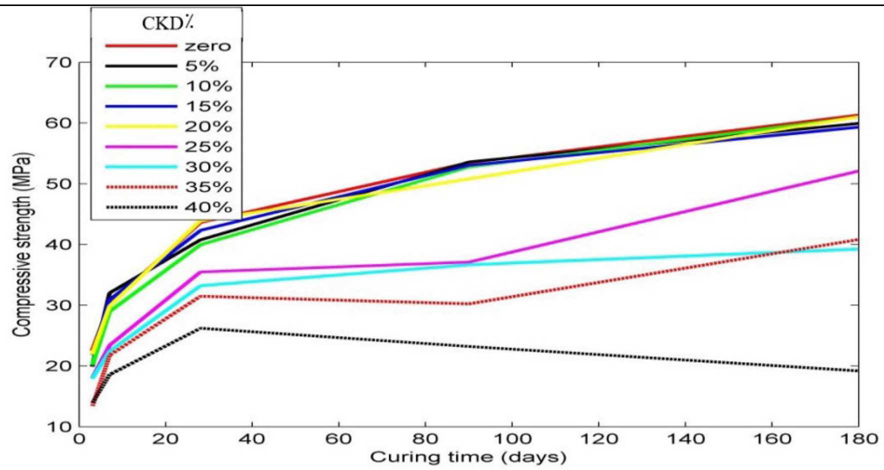

Figure 5. Compressive strength of OPC development with curing time, for each CKD replacement at 6000cm^2/gm fineness.

4-4-3- Compressive strength of cement with CKD at fineness 8000 cm^2/gm

(Table.9) shows The result of compressive strength (MPa) of OPC with different CKD replacement at 8000 cm^2/gm of CKD fineness. The maximum values appears at 5, 10, 15 and 20 % CKD replacement and minimum values appears at 40% CKD replacement.

Table 9 . The result of compressive strength (MPa) of OPC with different CKD replacement at 8000 cm^2/gm of CKD fineness.

Curing time / CKD%	3days	7days	28days	90days	180days
5%	19.91	29.32	41.01	52.93	59.97
10%	20.63	31.59	39.99	50.97	61.78
15%	22.01	29.34	42.21	52.98	60.98
20%	22.03	31.88	42.36	51.11	58.99
25%	16.31	27.29	37.36	44.04	53.32
30%	18.92	25.40	33.49	40.86	51.71
35%	14.84	23.62	31.58	33.73	46.92
40%	12.21	18.33	30.28	27.33	31.77

The relationship between curing time with compressive strength for each CKD replacement at 8000 cm^2/gm is plotted in (Fig.6). Here it can seen that there is a little enhancement in strength values increasing with curing time and are close to those numbers of zero mix for 5%,10%,15% , 20% addition of CKD and the strength decreases when this addition reaches 30%,35% and 40%.

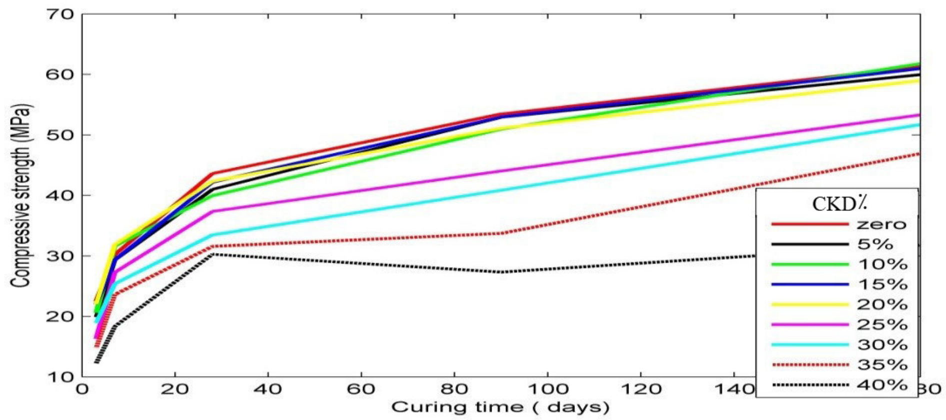

Figure 6. Compressive strength of OPC development with curing time, for each CKD replacement at 8000cm^2/gm fineness.

4-4-4 – Compressive strength of cement with CKD at fineness 10000 cm^2/gm

The (Table.10) shows the compressive strength of OPC with different CKD replacement at 10000 cm^2/gm of CKD fineness. The maximum values appears at 5 , 10 , 15 and 20 % CKD replacement and minimum values appears at 40% CKD replacement (for each curing time).

The relationship between compressive strength with curing time for each CKD replacement is plotted in (Fig.7). In this figure it is quite obvious to notice that compressive strength values for all mixes contain CKD up to 20% shows that does not records a big difference with those of 8000 cm^2/gm in values and shows almost the same behavior which means that fineness didn't make a big difference when compared with zero mix development strength, while the CKD percentages more than 20% shows decreases and not conformed with zero mix strength values.

Table 10. The result of compressive strength (MPa) of OPC with different CKD replacement at 10000 cm^2/gm of CKD fineness.

Curing time / CKD%	3 days	7 days	28 days	90 days	180 days
5%	22.67	30.92	42.87	52.73	60.03
10%	21.93	31.96	43.29	53.23	62.00
15%	23.80	33.03	43.01	51.88	61.87
20%	22.81	30.99	42.87	52.03	62.63
25%	23.07	32.46	42.39	52.83	54.03
30%	17.13	27.09	36.73	41.32	54.33
35%	17.64	24.71	32.96	34.87	48.63
40%	13.87	23.32	32.29	31.32	33.63

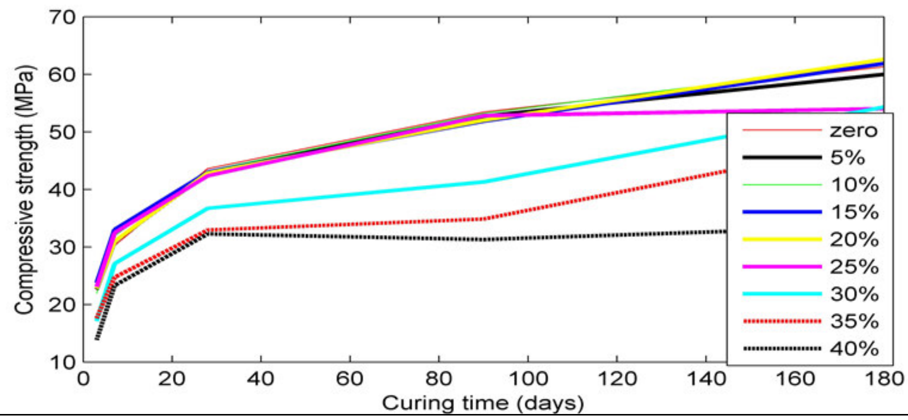

Figure 7. Compressive strength of OPC development with curing time, for each CKD replacement at 10000 cm^2/gm fineness

The (Tables . 6 , 7 , 8, 9 and 10) and (Figs. 4 ,5 ,6and 7) shows the increasing of CKD fineness affects positively on the compressive strength for all percentages of replacements , but this increasing varies from fineness to other. Where the fineness of CKD has no significant effect on strength for CKD replacement 5% and 10% when fineness is greater than 3000 cm^2/gm and lesser than 6000 cm^2/gm . Increasing fineness to be more than 6000 cm^2/gm ,effect positively on samples content CKD up to 20% replacement of cement ,while the increasing CKD percent more than 20% weakens the structure .

Increasing fineness could cause this improvement due to increasing active surface areas of granules of some compounds (Silica and CaO) which are the main constituent for the formation of pozzolanic materials responsible for pozzolanic bond , Khanna (2009) explained increasing strength with increasing surface area of CKD that these particles acts as active sites of nucleation of OPC hydration products and more increasing of ion dissolution which leads to increasing the chemical activity.

Second reason is physical effect of CKD on cement structure , where the initial framework of paste established at the time of setting affects to a large degree the subsequent structure of the products hydration which influences the development of strength (Neville 2011), therefor the increasing in the activity of cement –CKD due to CKD fineness leads to influence on the hydration rate and effect directly on the framework of hydrated cement and finally on the strength.

The increasing of fineness of CKD where the SiO_2 (Quartz) and calcium carbonate $CaCO_3$ particles will fill the gaps among cement particles there for improves particles packing which attributes in higher compressive strength (Hawkins at el.2005 and Sprung at el.1991)

There for the increasing of fineness of CKD attributes in:

1- Changing of activity of compounds which improved hydration .

2- Attributed on limitation of negative effect of other component's.

3- Improve in the cement hydrated particles packing and more denser and compact.

5- Conclusions

1-Increasing CKD fineness improved to some extend mechanical properties of (cement +CKD) mortars.

2-Using of CKD in mixes as a replacement for cement materials caused a loss of mixes plasticity with increasing of CKD fineness and also with increasing of CKD replacement.

3- The normal consistency of cement paste requires more water demand with increasing CKD fineness and percentages.

4 - The setting time of mixes containing CKD up to 40% at all CKD fineness are within limitations of IQS .No.8/1984, and the soundness results conforms up to 20% for all CKD fineness were examined in this study.

5. Increasing fineness more than 6000 enhanced compressive strength of CKD replacement up to 20% and up to 10% at CKD fineness less than 6000 cm^2/gm. these results are within the limitations of IQS. No.8/1984

References

Al-Shadeed, S. O. (2009), "Investigation of cement dust from Iraqi factories ", PhD. Thesis University of Technology,Iraq, 101p.

Saddique,R. (2006), "Review utilizing of cement kiln dust (CKD) in cement mortar and concrete – an overview ", Resources, Conservation and Recycling 48 315–338.

Khanna,O. (2009), "Characterization and utilization of cement kiln dust (CKD) as partial replacement of Portland cement ", Thesis ,university of Toronto ,323p.

USEPA .(1993), "Report to Congress on Cement Kiln Dust" www.epa.gov/epaoswer /other/ckd.

Iraqi Organization of Standards: I.O.S., 5/1984, for Portland cement.

Iraqi Organization of Standards: I.O.S., 8/1984, for Portland cement.

Neville, A. M. (2011), “Properties of Concrete: 5th Edition”,. John Wiley & Sons Inc.2866p.

Hawkins, P., Tennis, P., and Detwiler, R.J. (2005), “The Use of Limestone in Portland Cement: A State of the Art Review”, Portland Cement Association, Research &Development Serial No. 2052b, Skokie, IL.

Sprung, V.S., and Siebel, E. (1991), “Assessment of the suitability of limestone for producing Portland limestone cement”, ZKG International, 3, 43-48.