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Formulation of the cement kiln dust (CKD) in concrete: Studies of the physical-chemical and mechanical properties

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Abstract : This present work aims to valorize a solid waste produced by the cement kiln,such asthe cement kiln dust (CKD) generated from the cement plant of Amran - Yemen during the production of cement.Which we substituted the clinker (cement) by the weight of it at different percentage to achieve the following objectives:
*Minimize the emission of CO_2 into the atmosphere which is the main cause of the greenhouse effect and reduce the solid waste "cement kiln dust (CKD)" that were generated by the cement kiln during the production,while elaborating a new hydraulic binder friend of the environment;
*Gain a percentage of energy and raw material consumed.
In this paper, the possibility of using the cement kiln dust (CKD) as an addition in the production of cement and concrete has been studied. We studied the effect of adding of CKD on the physical-chemical characteristics as well as its influence on the physical properties of cement-based of CKDon one hand. In addition the effect of the CKD on the compression strength mechanical has been studied on the other hand.
The obtained results showed that the solid waste (CKD) and the emissions of CO_2were reduced according to the use of the percentage of cement kiln dust in the formulation matrix. The fineness by sieving and by the Blaine Specific Surface Area (BSSA) augmentedwhin the percentage of adding CKD also increases. The quantity mixing water is growing in function of the increase in the percentage of addition of CKD in cement. In more expansion rises when the content of the CKD increases. The setting time increases with the increased of the percentage of the CKD also. Similarly, the mechanical strengths at 2/7 and 28 decrease with the percentage of cement kiln dust in cement was augmented.
Key words : Greenhouse gas, cement kiln dust, composite cement, new formulation, physical-chemical characteristics, mechanical strength.

1. Introduction

In Yemen, the production of different types of cement had reached about 20 million tonnes per year, generated around of 2 million tonnes of waste cement kiln dust (CKD). This significant quantity of CKD provokeof the environment pollution.

The CKD is a mineral by-product collected via the electrostatic filters during the process of the production of clinker[1,2,3,4,5]. It consists essentially of four main elements which are the raw calcined crude which has not reacted with the clinker; the free lime dust, enriched salts of alkali sulfates, halides and other volatile compounds[6,7], They are dependant on the location of the collection system, the methods of the manufacturing, the installation of the electrostatic filter and also the type of fuel used[8]. It is a highly alkaline material, which are not used before, then, in our work we will introduce it in the formulation of cement to minimizing the use of the raw material, the emission of Co_2 which is the main cause of the greenhouse on one hand and gain a percentage of the energy consumed on the other hand[9,10].

This experimental work has been done to the laboratory of cement and quality control of Amran cement plant (Yemen) in collaboration with the laboratory of agro resources polymers and process engineering in the faculty of science, Ibn Tofail University (Kenitra- Morocco), to evaluate the influence of this mineral in the form of powder, finely divided by-product on the physical - chemical properties cement[11,12,13,14,15], such as the fineness by Blaine specific surface area, the loss on ignition, the setting time, the water content, the expansion and on the mechanical properties of concrete of the formulations with the different mass fractions of CKD have been studied.

2. Materials and Methods

2.1. Materials

Formerly to evaluate the influence of the addition of cement kiln dust (CKD) in the production of cement on the physical, chemical characteristics of cement and the mechanical properties of mortar and / or concrete in fresh and hardened state, we proceeded to the characteristics of the materials used in our work to understand the phenomena that occur during the hydration of the mixture.

2.1.1. The cement

The type of cement used in this work is (CMI / 42.5) from the plant of AMRAN - Yemen with 95% of clinker and 5% of gypsum. The composition chemical determined by X-Ray Fluorescence (XRF), mineralogical and the physical properties,are legendary in tables (1), (2) and (3):

Table1: Elementary chemical compositions of clinker, gypsum and cement

Content (%)	Cao	SiO_2	Al_2O_3	Fe_2O_3	Mgo	SO_3	K_2O	Na_2O	CL
Clinker	62.76	21	5.84	3	1.96	0.9	1.21	0.2	0.02
Gypsum	33.4	0.7	0.36	0.09	0.63	47.2	0.03	0.1	0.01
Cement	61.35	19	5.87	2.97	2.01	2.4	1.17	0.1	0.02

Table 2: Mineralogical composition of the clinker

C_3S	C_2S	C_3	C_4AF
47.7	25.1	10.4	9.1

Table 3: Physical properties of the clinker and cement

Physical properties	Units	Values	
Blaine specific surface area	Cm^2/g	Clinker	3360
		Cement	3240
Density	G/cm^3	Clinker	3.17
		Cement	3.14

2.1.2. The sand

To prepare our mortar, we used normalized sand conforming to the norm EN 196-1, delivered by the French society Nouvelle of Littoral, its particle size analysis is illustrated in figure (1).

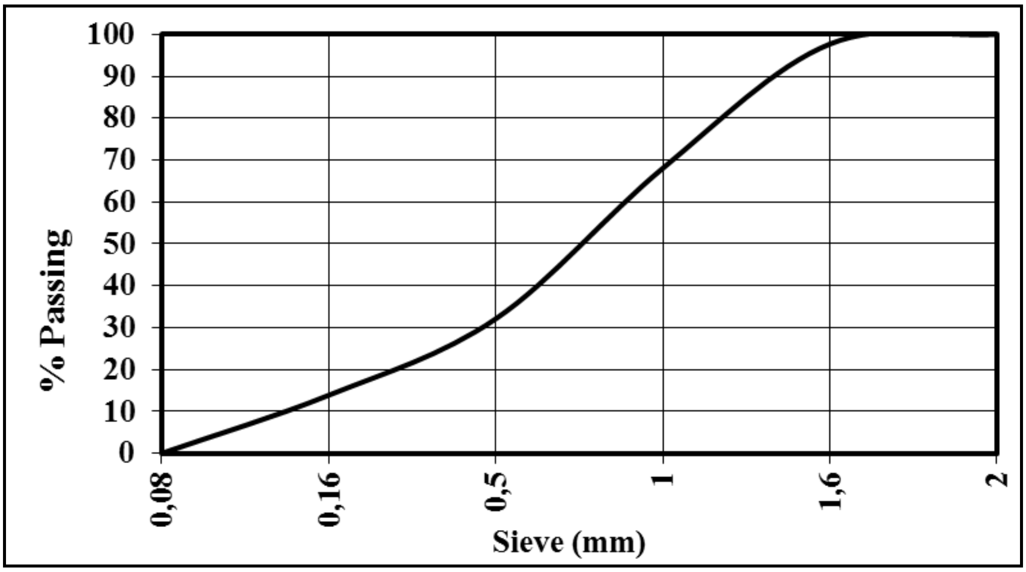

Figure 1: Gradingcurve of sand

The particle size analysis presented in figure (1) there is that used sand grains are distributed in a systematic way according to the specifications of the normEN 196-1[15].

2.1.3. The cement kiln dust (CKD)

The cement kiln dust (CKD) is recuperated by the electrostatic filters from the kiln of Amran - Yemen at in the course of the production of clinker. The chemical analysis of its major components prepared by X-Ray Fluorescence (XRF)[12], are celebrated at the table (4).

Table 4: Elementary chemical compositions of CKD determined by XRF

Content (%)	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	K_2O	Na_2O	CL
CKD	45.91	12.66	1.57	0.81	1.43	0.14	0.23	0.03	0.039

In conformity to the table (4) we find that the constituted essentially of the CKD are the calcium oxide (CaO), the silicon dioxide (SiO_2), the alumina (Al_2O_3), the iron oxide (Fe_2O_3) and the magnesium oxide (MgO).

2.1.4. The water for mixing

To spoil our mix, we used tap water (wells), its main characteristicsare collected in the table (6).

Table 6: Main characteristic of the mixing water

Components	PH	T, D, N	CO_3^{-2}	HCO_3^-	Calcium	Magnesium (Mg^{+2})	Conductivity
Unit	**-**	**(Mg/L)**	**(Mg/L)**	**(Mg/L)**	**(Mg/L)**	**(Mg/L)**	**Ms/cm**
Value	7.0	450	216.0	0.0	56.4	52.4	692,0

2.2. Methods

We studied the influence of the addition of cement kiln dust in the manufacturing of cement while partially substituting the clinker by CKD at different percentages ranging from 0% to 5% and 10% by weight of the clinker with a fixed the rate of gypsum in all formulations achieve on the physical chemical properties of the cement, the physical property of fresh cement paste and the mechanical property of concrete in the hardened state. The different formulations were prepared in a standard mixer EN-196-1[20] following the procedure indicated by the norm EN-196-3 [18,19,20,21]relative to the normal consistency of pure paste[18,19,20]. The tables (6), (7) and (8) have different formulations produced.

Table 6: Composition of the mixture used to prepare 500 g of cement with the different percentages of CKD

%		CT	CCKD1	CCKD2	CCKD3	CCKD4	CCKD5	CCKD10
Cement	%	100	99	98	97	96	95	90
	Mass (g)	500	495	490	485	480	475	450
CKD	%	0	1	2	3	4	5	10
	Mass (g)	0	5,000	10,000	15,000	20,000	25,000	50,000

Table7: Matrix of formulation of fresh cement paste at base of CKD

%		PT	PCKD1	PCKD2	PCKD3	PCKD4	PCKD5	PCKD10
Cement	%	100	99	98	97	96	95	90
	Mass (g)	500	495	490	485	480	475	450
CKD	%	0	1	2	3	4	5	10
	Mass (g)	0	5,000	10,000	15,000	20,000	25,000	50,000
Water	Mass (g)	140.00	141.41	142.86	144.33	145,83	147.37	155,56
W/C	%	0.280	0.283	0.286	0.289	0.292	0.295	0,311

Method of preparation of mortar of cement with addition

The method consists of the determination of the mechanical compressive strength of the prismatic specimens of dimensions 40 mm × 40 mm × 160 mm. These specimens were collected from a batch plastic mortar according to the norm EN 196-1[20]. The matrix of the formulation containing one part of a cement + addition of CKD and three parts of sand normalized with a report of water and cement varies from 0.50% to 0.56% according to the percentage of CKD as indicated in the table (8).

The mortar is prepared by mixing and putting into a mold using a standardized shocked device[18,19,20,].

The mold containing the test sections is kept in a humid atmosphere for 24 hours and then removed from the mold is stored under water pending the moment of the strength tests. At the required age, the samples are removed from their wet preservative medium, they are broken into two halves by bending and each half is subject to the compression test [18,19,20].

Table8: Matrix of formulation of the mortarin hardened state at base of CKD

%		MT	MCKD1	MCKD2	MCKD3	MCKD4	MCKD5	MCKD10
Cement	%	100	99	98	97	96	95	90
	Mass (g)	500	495	490	485	480	475	450
CKD	%	0	1	2	3	4	5	10
	Mass (g)	0	5,000	10,000	15,000	20,000	25,000	50,000
Sand	Mass (g)	1350	1350	1350	1350	1350	1350	1350
Water	Mass (g)	140.00	141.41	142.86	144.33	145,83	147.37	155,56
W/C	%	0.500	0.505	0.510	0.515	0,521	0.526	0.556

3. Results and Discussion

3.1. Physical-Chemical properties of cement at base of CKD

3.1.1. The loss on ignition

The measuring of the loss on ignition was made in oxidizing atmosphere (air) by calcination in the air at (1000 °C.) for the purpose of giving an indication of the presence of water and organic material in the particular mixture in the cement based to CKD[22,23], is illustrated in the figure (2).

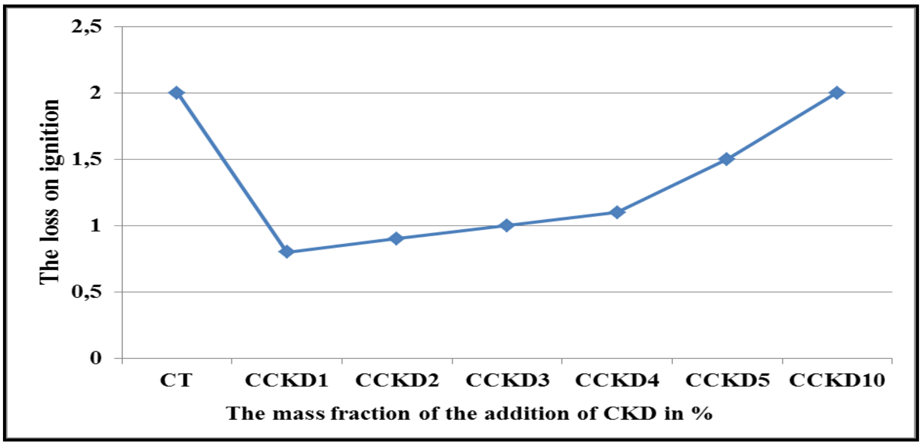

Figure 2:Variation of the loss on ignitionof cement with the mass fraction of the addition of CKD in (%)

Conferring to the figure (2) we observe that the rate of loss on ignition increases with the addition in the percentage of CKD, this is essentially increase due to the chemical composition of our addition that was rich in CaO.

3.1.2. The fineness of cement in base CKD

The fineness of cement is an important characteristic that has to be determined to see their influence on cement in base CKD in the concrete at fresh and hardened state during the mixing, it is measured either by sieving or by the method of the Blaine specific surface area, when the surface of cement is big, it is more contact with water as well as the hydration is rapid and complete mixture[23,24,25]. It is determined according to the specification of the standard[16,18,19,20].

3.1.3. 3.1.2.1 The fineness of cement in base CKD by the method of sieving: particle size analysis

It is a measure of the percentage of the weight of a sample of cement atthe base of CKD when it is sifted to the total mass of the sample, present in figure (3).

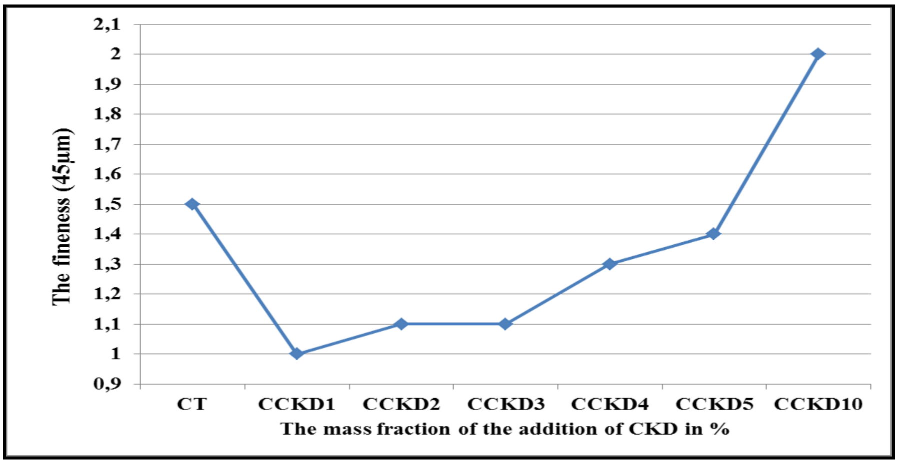

Figure 3: Variation of the fineness of cement at base of CKD with the mass fraction of the addition in (%)

In conformity with the figure (3) that illustrates the result of the fineness of cement by sieving 45 µm depending on the addition of CKD, we note that the fineness of cement onthe base of CKD increases in the percentage of addition of CKD. This increase is mainly due to the fineness of CKD.

3.1.4. 3.1.2.2 Finesse by the method of air permeability (Method of Blaine Specific Surface Area)

The fineness of cement by Blaine Specific Surface (BSS) is measured using the Blaine of permeability to air. And after the figure (4) which shows the result of the fineness of the cement in base CKD by the method of Blaine specific surface, indicates that there is an increase in fineness with a cement control and the cement atthe base of CKD. This increase generally due to the fineness by SSB of our adding CKD, which assures us largest cement grain contact, a high reactivity during hydration and subsequently an improvement in mechanical properties.

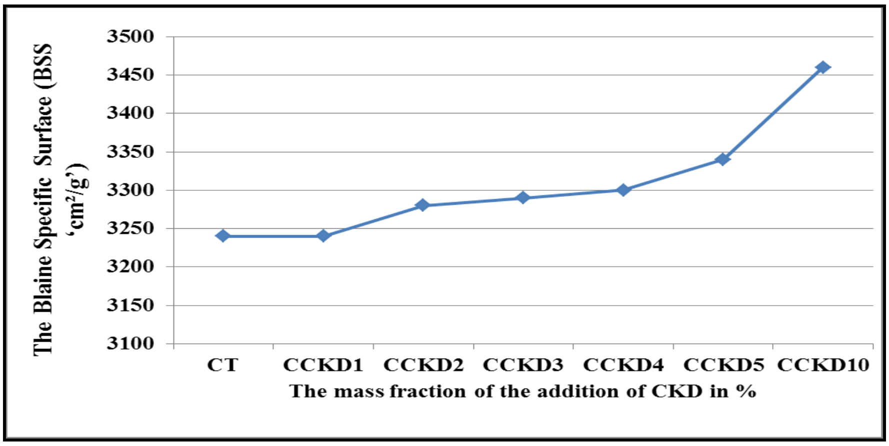

Figure 4: Variation of the Blaine specific surface of cement at the base of CKD with the mass fraction of CKD

Corresponding to the figure (4) we note that the BSS of cement with the addition of the CKD increases in function of the percentage of adding ofCKD. This increase is generally due to the specific surface of CKD.

3.2. The influence of the addition of CKD on the physical properties of fresh cementpaste

3.2.1. The influence of the addition CKD on the consistency of cement

The consistency of the cement paste is a characteristic which evolves over time. In order to study the evolution of the consistency according to the different parameters, it must go to a consistency that is the same for all paste studied[25,26,27]. The purpose of this test is to determine the optimum quantity of mixing water for obtaining a good mortar. This test is performed with the Vicat devise according to EN 196-3[18,20], is shown in the figure (5).

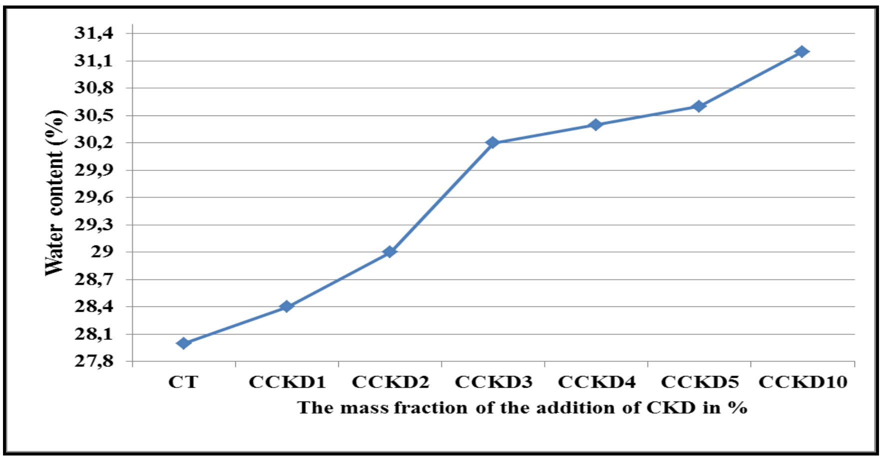

Figure 5: Variation of the quantity of water necessary for mixing the cement with the mass fraction of the addition of CKD in %

After the figure (5),which shows the evolution of water content of fresh cement paste at the base of the different percentages of adding in CKD? We perceive that the cement paste atthe base of CKD needs a more water compared with the control paste and significantly increases with the increases in the percentage of addition of CKD. This increase is mainly due to the chemical and mineralogical CKD compositions which is rich in CaO.

3.2.2. 3.2.2 Influence of CKD on the physical property of fresh cement paste (setting time)

For observe also the influence of the cement kiln dust on the physical property of fresh cement paste, such as the initial and the final time of setting is determined using of Vicat device according to the specification of the European norm EN196-3[18,20], are displayed in the figure (6).

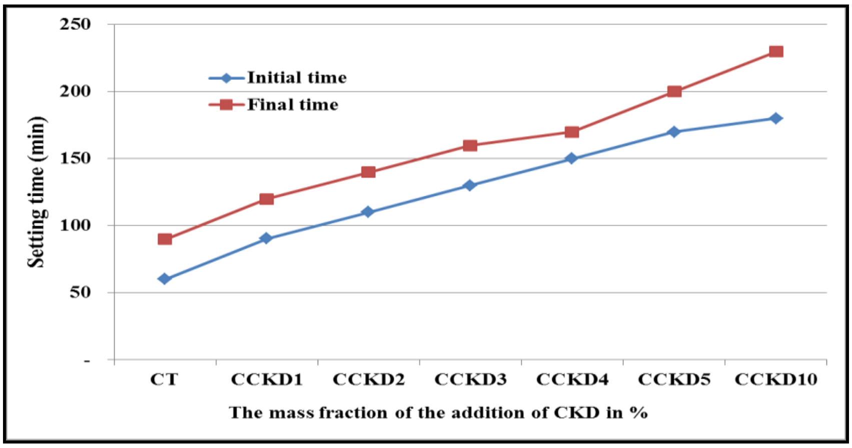

Figure 6: Variation of the setting time of the cement paste in function with different percentage of the addition of CKD

After the figure (6) which contains the time variation of the initial and final time of the cement paste with the different percentages of CKD, we notice that the setting time of paste cement at the base of CKD increases according to the addition of CKD. This increase is generally due to the chemical compositions and mineralogical of CKD, on one hand and grace to the high fineness of cement based on the CKD on the other hand.

3.2.3. 3.2.3 The effect of the addition of CKD on the expansion

This test is used to discover the presence of the expansive material in cement at the base of CKD, especially the gypsum and the magnesia contained in this binder[25,26]. These undesirable elements can lead to serious threats to the sustainability of constructions. It is measured using the Le Chatelier device according to the norm EN196 / 3 are presented in the figure (7).

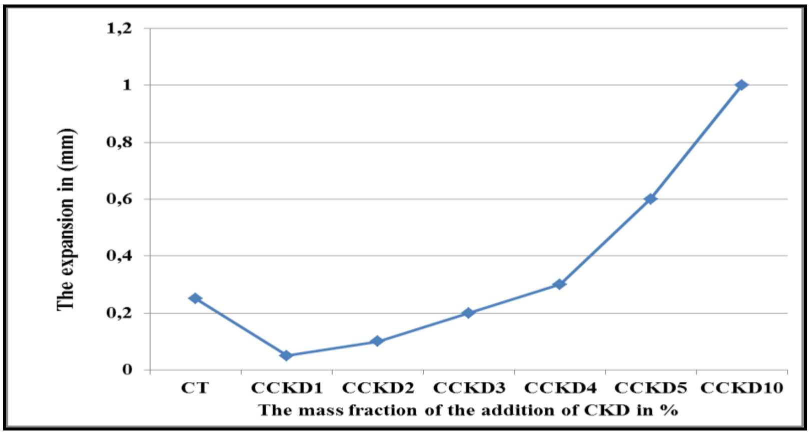

Figure 7: Variation of the expansion of cement with the mass fraction of the addition of CKD in %

According to the figure (7) we note that there is an increase of expansion based on the percentage of CKD addition, but it does not exceed the limit set by the norm NF EN 196-3 + A1 [13]which is 5 mm.

3.3. The influence of the addition of CKD on the mechanical strength of mortar or concrete in the hardened state

Finally, we also evaluated the influence of CKD on the mechanical performance of concrete in its hardened stateusing the mechanical resistance of the compressive strength results on 3 samples (40 X 40 X 160) mm^3 of mortars in the base of CKD for each compression time (2 / 7 and 28) days is prepared and kept according to the norm EN 196-1[19,21].

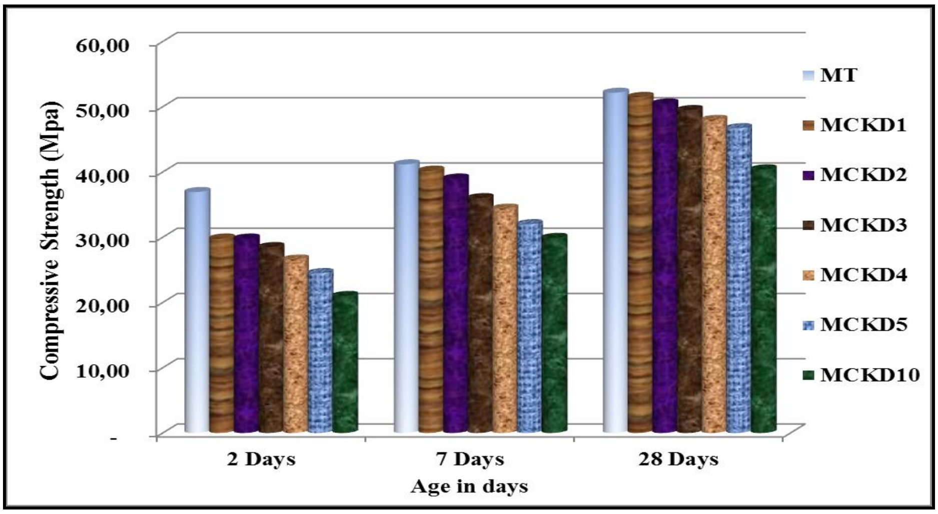

Figure 8: Variation of the mechanical compressive strength in function of age in days

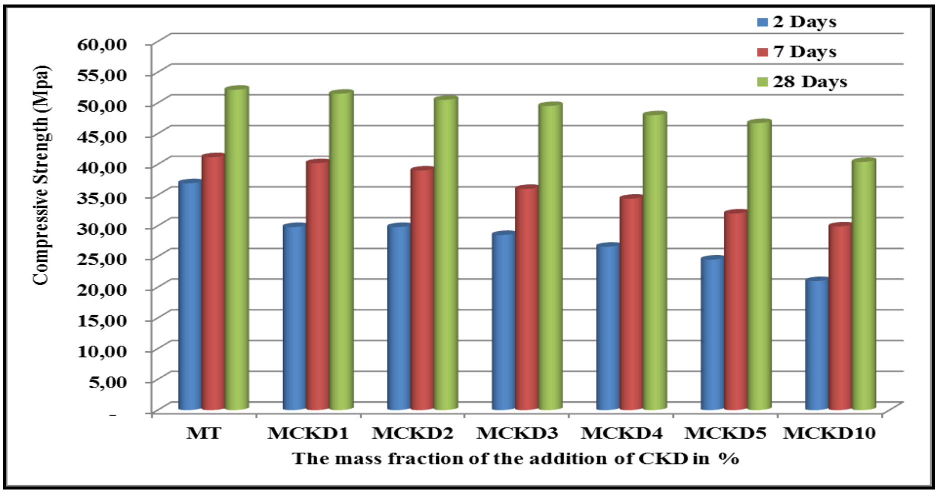

Figure 9: Variation of the compression strength in function of the mass fraction of CKD

According to the figure (8) which celebrates the evolution of the mechanics of compressive strengths in function on the age and figure (9) that illustrates the evolution of the compressive strength, we found that the compressive strengths of all mortars at based on CKD increase regularly with age and have no fall[28,29,30,31,32], however the compressive strengths have considerably decreased with the increasing the percentage of the addition in CKD 2/7 and 28 days. This reduction in the compressive strengths is usually due to the mineralogical chemical composition, and also the crystalline form of alkali present in adding CKD. It plays the role of accelerating reactions during the hydrations of the mixtures of cement[33,34,35].

4. Conclusion

After the experimental study, we can allurement the following conclusions:

The addition of (CKD):

- Gives a very fine powder with an improved in the specific surface, which varies between 3240 m²/g and 3460 m²/g, that ensures ease of the hydration of the cement at mixing;
- Increases the setting time of mortar which allowed us to use it as a retarder.

To these effects, the cement kiln dust (CKD) can be effectively used as a corrector of the physical - chemical properties of cement.

The introduction of CKD in the matrix of formulation of the cement reduced the energy consumed and the raw materials used during the production of clinker which reduces the cost of production on one hand and minimizes the percentage of the carbon dioxide (CO2) in the atmosphere on the other hand.

5. References

1. karagooly, YahyaH.Jebur Al. Effect of Cement Kiln Dust on Some Properties of soil. Journal of Babylon University/Engineering Sciences, (2012), pp.1150-1156.
2. SulaphaPeethamparan a, b, Jan Olek b, Janet Lovell c, Influence of chemical and physical characteristics of cement kiln dusts (CKDs) on their hydration behavior and potential suitability for soil stabilization, Cement and Concrete Research, (2008), pp. 803-816.
3. A.A. Amadi a, A.S. Osu b. Effect of curing time on strength development in the black cotton soil – Quarry fines composite stabilized with cement kiln dust (CKD). Journal of King Saud University – Engineering Sciences, (2016), pp. 165-176.
4. M.KHUDHAIR; and al., Formulation of solid Waste of cement kiln dust (CKD) in concrete. Studies of the physical-chemical and mechanical properties. International Conference on the Environment and the Impact of the Pollution (Water, Air, Ground) on the Population and the Global warming (JEIPPRC-03), May, the 23rd -24th,2016, Faculty of Sciences Ibn Tofail University, Kenitra, Morocco.
5. M. KHUDHAIR; and al., Impact of the use of Cement Furnace Dust (CKD) as solid waste in the formulation of concrete on the emission of CO2 into the atmosphere. International Conference on the Environment and the Impact of the Pollution (Water, Air, Ground) on the Population and the Global warming (JEIPPRC-03), May, the 23rd -24th,2016, Faculty of Sciences Ibn Tofail University, Kenitra, Morocco.
6. W.M.Salem a, n, W.F.Sayed a, S.A.Halawyb, R.B.Elamary a. Physico-chemical and microbiological characterization of cement kiln dust for potential reuse in waste water treatment. Ecotoxicology and Environmental Safety, (2015), pp. 154-161.
7. Gerald A. Millera, Shahriar Azad b. Influence of soil type of stabilization with cement kiln dust. Construction and Building Materials, 30 March (2000), pp. 89–97.
8. S. Abd El-Aleem, M.A. Abd-El-Aziz, M. Heikal and H. El Didamony. EFFECT OF CEMENT KILN DUST SUBSTITUTION ON CHEMICAL AND PHYSICAL PROPERTIES AND COMPRESSIVE STRENGTH OF PORTLAND AND SLAG CEMENTS. The Arabian Journal for Science and Engineering. April (2005).
9. DAOUS, M. A. Utilization of Cement Kiln Dust and Fly Ash in Cement Blends in Saudi Arabia. Engineering Sciences Journal, 11, (2009), pp. 33-45.
10. R. Elmrabetand al. The Effect of Pozzolanic Addition on Expansive Portland Cement; International Journal of ChemTech Research, 2016,9(6),pp 392-399.
11. K.S. Al-Jabri, R.A. Taha, A. Al-Hashmi, A.S. Al-Harthy. Effect of copper slag and cement by-pass dust addition on mechanical properties of concrete. Construction and Building Materials, 12. (2006), pp. 322–331.
12. M. Maslehuddin a, O.S.B. Al-Amoudi b, M. Shameem a, M.K. Rehman a, M. Ibrahim a. Usage of cement kiln dust in cement products – Research review and preliminary investigations. Construction and Building Materials, (2008), pp. 2369–2375.

13. M. Maslehuddin a, O.S.B. Al-Amoudi b, M. Shameem a, M.K. Rehman a, M. Ibrahim a. Usage of cement kiln dust in cement products – Research review and preliminary investigations. Construction and Building Materials, (2008), pp. 2369–2375.
14. AnnaduraiA. and al., Strength Prediction of Hybrid Fiber Reinforced High Strength Concrete, International Journal of ChemTech Research; 2015,8(12),pp 675-681.
15. British standards institution, E.N.196-2: methods of testing cement- Part 2: chemical analysis of cement, 2005.
16. COMITÉ EUROPÉEN DE NORMALISATION, Méthodes d´essais des ciments Partie 1 : Détermination des résistances mécaniques. CEN NF EN 196-1. Août 1995, pp. 15-101-1.
17. Ravindrarajah, R. Sri. Usage of cement kiln dust in concrete. International Journal of Composite cements and Lightweight Concrete, May 1982, pp. 95-102.
18. British standards institution, E.N.196-3: methods of testing cement- Part 3: determination of setting time and soundness, 2005.
19. British standards institution, E.N.196-1: methods of testing cement- Part 1: determination of compressive strength, 2005.
20. COMITÉ EUROPÉEN DE NORMALISATION, Méthodes d'essais des ciments Partie 3 : Méthode d'essai standard pour consistance normale du ciment hydraulique, détermination du temps de prise et de la stabilité. CEN NF EN 196-3+A1. Janvier 2009, pp. 15-471-3.
21. COMITÉ EUROPÉEN DE NORMALISATION, Ciment Partie 1 : Composition, spécifications et critères de conformité des ciments courants. CEN, NF EN 197-1, Février 2001 pp. P 15-101-1.
22. Burning wastes as an industrial resource. Their effect on Portland cement clinker. M.A. Trezzaa, A.N. Scianb. (2000), Cement and Concrete Research, pp. 137–144.
23. Lipowski, StefaniaGrzeszczyk and Grzegon. EFFECT OF CONTENT AND PARTICLE SIZE DISTRIBUTION OF HIGH-CALCIUM FLY ASH ON THE RHEOLOGICAL PROPERTIES OF CEMENT PASTES., Cement and Concrete Research, (1997), pp. 907-916.
24. D.D. Bui a, J. Hu b, P. Stroeven b. Particle size effect on the strength of rice husk ash blended gap-graded Portland cement concrete, Cement & Concrete Composites, (2005),pp. 357–366.
25. T. Vuka, V. Tintaa, R. GabrovsÏekb, V. KaucÏicÏb. The effects of limestone addition, clinker type and fineness on properties of Portland cement., Cement and Concrete Research, (2001), pp. 135-139.
26. Maria S. Konsta-Gdoutos*, 1, Surendra P. Shah. Hydration and properties of novel blended cements based on cement kiln dust and blast furnace slag. Cement and Concrete Research, (2003), pp. 1269–1276.
27. Ion Teoreanu a, GrazielaGuslicov b. Mechanisms and effects of additives from the dihydroxy-compound class on Portland cement grinding, Cement and Concrete Research, (1999), pp. 9–15.
28. Bui, D. D., Hu, J., &Stroeven, P. Particle size effect on the strength of rice husk ash blended gap-graded Portland cement concrete. Cement and concrete composites, 27 (3), (2005), pp 357-366.
29. Bui, D. D., Hu, J., &Stroeven, P. Particle size effect on the strength of rice husk ash blended gap-graded Portland cement concrete. Cement and concrete composites, 27 (3), (2005), pp 357-366.
30. VivekS.S. and al., Effect of Silica Fume in Flow Properties and Compressive Strength of Self Compacting Concrete, International Journal of ChemTech Research,. 2015, 8 (1), pp 01-05.
31. Harshavardhan A. and al., A Review Report on Physical and Mechanical Properties of Particle Boards from organic Waste, International Journal of ChemTech Research, 2016,9 (1), pp 64-72.
32. Deepak M. andal., ANN Modelling for Prediction of Compressive Strength of Concrete Having Silica Fume and Metakaolin, International Journal of ChemTech Research; 2015, 81),pp 184-189.
33. Jaishankar P.andal., Experimental study on Strength of Concrete by usingMetakaolin and M-Sand, International Journal of ChemTech Research; 2016,9 (5), pp 446-452.
34. PriyaA.K. and al., Evaluation of Strength Properties of Pavement BinderReplaced with Waste Materials as Modifier, International Journal of ChemTech Research; 2016,9 (1), pp 248-252.
35. AbhilashP. and al., Strength properties of Fly ash and GGBS based Geo-polymer Concrete, International Journal of ChemTech Research; 2016,9 (3), pp 350-356.

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