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Production of Concrete Mixed with Cement Dust Using Pressure and Curing Methods

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Abstract

Cement kiln dust (CKD) is released as an accidental product in large quantities and is classified as solid waste and has negative effects on the environment to benefit from these wastes and achieve an environmental and economic return, this research was carried out to study the effect of cement dust produced from Kufa Cement Factory on the properties of concrete by preparing four concrete mixtures by adding cement dust as a partial substitute for cement in proportions: 5%, 10%, 15%, and 20% and comparing it with the reference mixture and conduct the ripening process for ages 7, 28, and 90 days, a set of tests were carried out: (compressive strength, slump, hardening time, density, absorption, porosity, The results of the tests showed, in general, a decrease in the compressive strength, slump and density of concrete, an increase in the water percentage, the initial hardening time, porosity and absorption with an increasing the percentage of addition of cement dust, but by a small amount to 10%, and the percentage of increase or decrease becomes more clear when the percentage of adding cement dust is increased by more than 10%. , on the level of laboratory application, a hollow block was produced by pressing method with an added percentage of cement dust (5%, 10%, 15%, and 20%) of the weight of the cement, a compression and absorption resistance test was conducted, and the results were in accordance with the approved specification and for all percentages of addition.

1. Introduction

Many countries of the world suffer from the problem of the accumulation of industrial waste and its negative effects on the environment, and these wastes include cement kiln dust It is an accidental product of the cement industry, as the cement plants release hundreds of thousands of tons of cement kiln dust annually, with the accompanying economic and environmental impacts, as most factories adopt traditional methods for the disposal of CKD On the site, where it is collected in heaps in the open, and in the presence of air, the cause of pollution is volatilized, and from an economic point of view, the safe disposal of it costs huge sums [1].

Cement kiln dust (CKD) can be defined as an alkaline solid substance in the form of a powder, similar in appearance to cement, and it is a partially burned raw material, the main components of which are calcium oxide, silica, Aluminum, iron, and cement dust becomes more cement as the concentration of calcium oxide increases [2].

The results of examining the internal texture of cement dust using a scanning electron microscope shown in Figure (1) indicate the presence of three phases, the predominant phase appears in the form of irregular clumps of crystals, Then the second phase is in the form of regular crystals with straight edges and its proportion is less than the irregular crystals and the third phase is crusty, which is a small percentage, and there is very little of the needling phase present in the composition of the internal structure of cement dust.

The results of the mineral composition of cement dust using X-ray diffraction indicate that the predominant phase is calcite (calcium carbonate), then the quartz and dolomite phase, as shown in Figure (2) [3].

When comparing the results of chemical analyzes between cement and its dust, we find that cement dust contains a high percentage of alkaline (Na_2O, K_2O), sulfates, chlorides, free calcium oxide, and a small percentage of silica and calcium oxide compared to cement.

The physical and chemical properties and mineral composition of (CKD) cement kiln dust vary from one plant to another depending on several factors, the most important of which are the type of raw materials used, the design of the kiln, the type of processes that occur inside the kiln, the method of cement dust collection, and the type of fuel used [2, 4].

For example, the results of the chemical analysis of cement dust for the Najaf Cement Factory, which adopts the dry method, indicate the percentage of sulfates in the range of (23.68%), calcium oxide (26,87%), and silica (8.16), while the results of the chemical examination of Kufa cement dust, which adopts the wet method (the subject of the study), the percentage of sulfate (8.37%), calcium oxide (43.14%) and silica (12.98%). were found Concerning the chemical properties of (CKD), it contains a high amount of alkaline, so it is considered a caustic substance, and the mixture of water with (CKD) gives a PH value of (12) or more [5].

One of the most important physical properties of CKD is the granular size distribution, where the Portland Cement Institute PCA indicates that the particles of CKD emitted with smoke are of uniform sizes, average in diameter of about (10) microns and that the granular size distribution of (CKD) It depends on several factors, namely the manufacturing technology, the method of dust collection, the chemical composition of (CKD), and especially its alkaline content. Concerning the effect of the type of furnace system used in the manufacturing process, the dust produced by the dry method is finer than the dust produced by the wet method [3].

Because it contains high alkaline substances, namely (Na_2O, K_2O) and other undesirable substances such as sulfates and chlorides, it cannot be returned to the furnaces as international standards specify the percentage of alkalines in the form of (Na_2O) that should not exceed (0.6%) due to its negative effects. The quality of the clinker is produced due to the reaction between the alkaline and the active silica in the aggregate [4].

There are modern techniques for removing alkali using the aqueous leaching method, followed by returning the washed cement dust to the kilns and using another technology, which is (a fluidized bed), where the alkali is removed through evaporation [4].

There are many studies by a group of researchers that dealt with the possibility of using cement dust as a partial substitute for cement, and they found in general that there are no significant negative effects on the strength of cement when using cement dust at a rate of 5% in concrete mixtures and a rate of (15%) [1] in the block industry.

Cement dust is used in various construction applications as a partial substitute for cement and to reduce its negative effects. Studies [2] and [4] indicated the possibility of using it in the concrete mix with other additives such as fly ash from electric power plants Coal-fired as fuel and (furnace slag is an accidental product of the sold industry) gives results similar or better than regular concrete because it prevents or reduces the interaction between alkaline and active silica in aggregates, and the possibility of using it by adding it to the cement product itself without grinding it and delivering it to the nano size [6], as well as using it after removing most of the alkali by washing[7], also, a study was conducted to know the effect of replacing cement with a large part of granular blast furnace slag (GGBFS) and cement kiln dust (CKD) on mechanical properties, durability and fine structure[8]. There are other uses for cement dust, including (soil stabilization, glass industry, water purification, filler, fine aggregate in concrete, and concrete mixes) [9, 10, 11, 12].

This research aims to study the possibility of benefiting from cement kiln dust as a by-product in the cement industry as a partial substitute for cement in concrete mixtures and the block industry to protect the environment from its negative effects in addition to the economic return in the production of concrete building units from available materials and at the lowest possible cost.

2. Experimental Procedure

The first stage is the preparing the mixtures. Materials used: Salt-resistant cement conforming to Iraqi Standard No. (5) of 1984, sand, coarse gravel conforming to Iraqi Standard No. (45) of 1984, with mixing ratios by weight (cement (1), sand (1.5), gravel (3))) and the ratio of water to cement (0.5) made four mixtures with an addition of cement dust (5%, 10%, 15%, 20%) And a reference mixture without cement dust, for the soft mixture pouring process, cube-shaped molds measuring (10 × 10 × 10) cm were used to check the absorption, density, porosity and measuring (15 × 15 × 15) cm to check the compressive strength, The samples were immersed in water to cure for the age of 7, 28, and 90 days and a set of tests were carried out: (compressive strength, slump, initial hardening time, density, absorption, porosity) and compared them with reference.

The second stage: An application was carried out on a laboratory level to produce a hollow block of dimensions (40 × 20 × 20) cm and the proportions of adding cement dust (5%,10%,15%,20%) to the weight of the cement, all laboratory conditions were adopted and the raw materials available in the laboratory were used. At mixing weight ratios (1: 1.7: 6) (cement: sand: gravel) using a pressure strength (175) kg/cm^2 and treating the produced block with water for (14) days, tests were conducted for its compressive strength and absorption strength according to the guideline No. (32/1989).

3. Results and Discussion

The results are shown in Table (1) and Figures (3 & 4) indicate that the workability of the concrete mixture decreases with the increase in the percentage of (CKD) added, as it came within 140 mm for the reference mixture and decreased to 136, 130, 125, and 122 mm when adding dust Cement in percentages (5%, 10%, 15%, and 20%) of cement weight, respectively, and that the required amount of water increases slightly by 2.7% when adding cement dust by 5% and 10% of the weight of cement and with an increase of (30) minutes in the initial hardening time when adding 5% and 10% of the weight of the cement and become 5.5% and 6.4% with an increase in the initial hardening time 40 minutes and 45 minutes. When cement dust is added at a percentage of 15% and 20% of the weight of cement, respectively, compared to the reference, the reason for this is due to the chemical composition of cement dust, as it contains a high percentage of alkaline and sulfates, as well as increasing its smoothness leads to an increase in the surface area and therefore there is a need to increase the percentage of water.

The results are shown in Table (2) and Figure (5) indicate that the compressive strength of concrete cubes at the aging age of 28 days' decreases slightly by the equivalent of 98.5% and 92.4%, respectively compared to the reference concrete when cement dust was added at a percentage of 5% and 10% of the weight of cement, and it decreased to 84.1% and 80.6% when adding 15% and 20%, respectively. This is due to the presence of a high percentage of sulfates in cement dust, as it came to a limit of 8.37% Which helps the reaction of these sulfates with calcium hydroxide $Ca(OH)_2$ to form calcium sulfate, which in turn reacts with calcium trialumina (C3A))($3CaO\ Al_2O_3$) to form hydrated sulfur calcium aluminate, and its symbol is called erosions ($3CaO.Al_2O_3$ $3CaSO_4.32H_2O$), which causes additional internal pressure that may lead to concrete cracking and damage, as well as the presence of a high percentage of alkaline, which led to an interaction between the effective silica in the aggregate and the alkaline, and this interaction resulted in gelatinous materials that increased in size when absorbing water, which led to the occurrence of additional internal stresses in the concrete and thus was reflected Negatively on low compressive strength

The results are shown in Table (2) indicated a small increase in porosity by 1.99% and 2.9% when adding 5% and 10% of cement dust, respectively, and the increase became more than 20.5 % and 21.9% when adding 15% and 20% of cement dust, respectively, as well as increasing the absorption by 3.3% and 4.7% when adding 5% and 10% of cement dust and increased to 24.7% and 26.7% when adding cement dust by 15% and 20%, respectively, while the density decreased by 1.26% and 1.69% when adding 5% and 10% of cement dust, respectively, and decreased to 3.38% and 3.80% when adding 15% and 20% of cement dust, respectively.

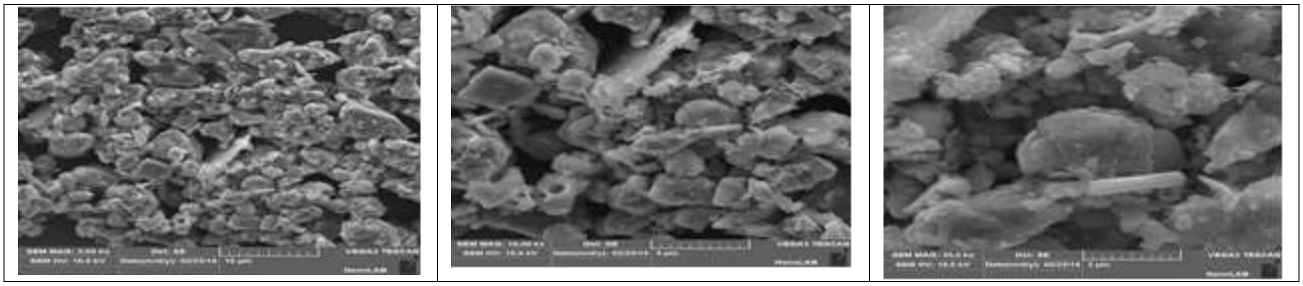

Figure (1). Electron microscope shows the inner texture of cement dust with different magnification power (5.00, 10.00, 25.00) KX.

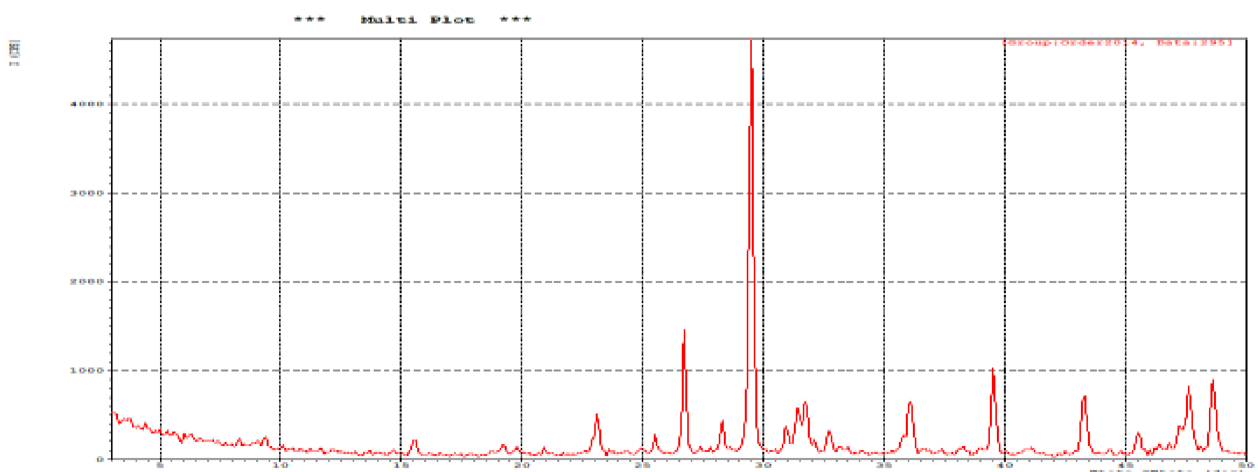

Figure (2). The phases of cement dust.

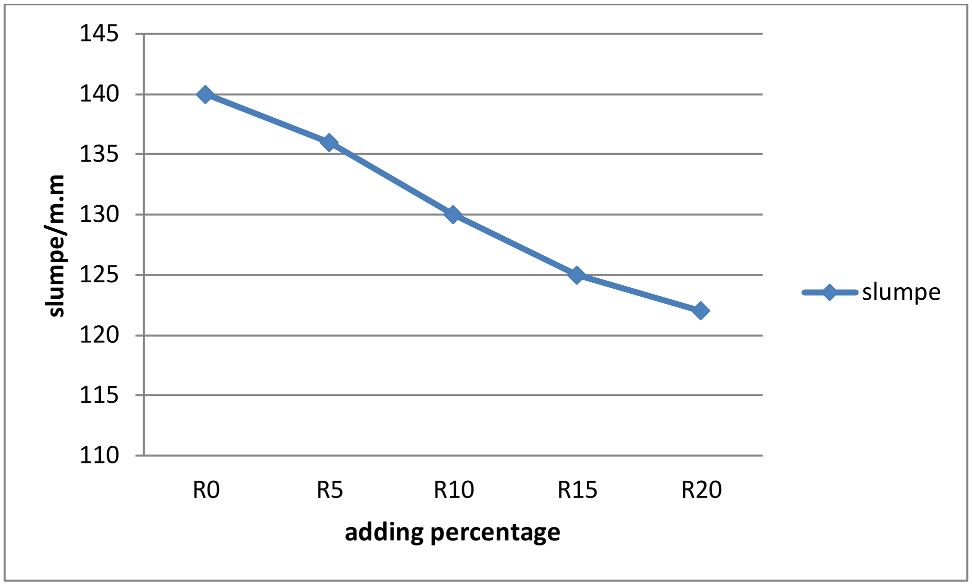

Figure (3). The relationship between the percentage of addition of cement dust and slumpe of the concrete mixture.

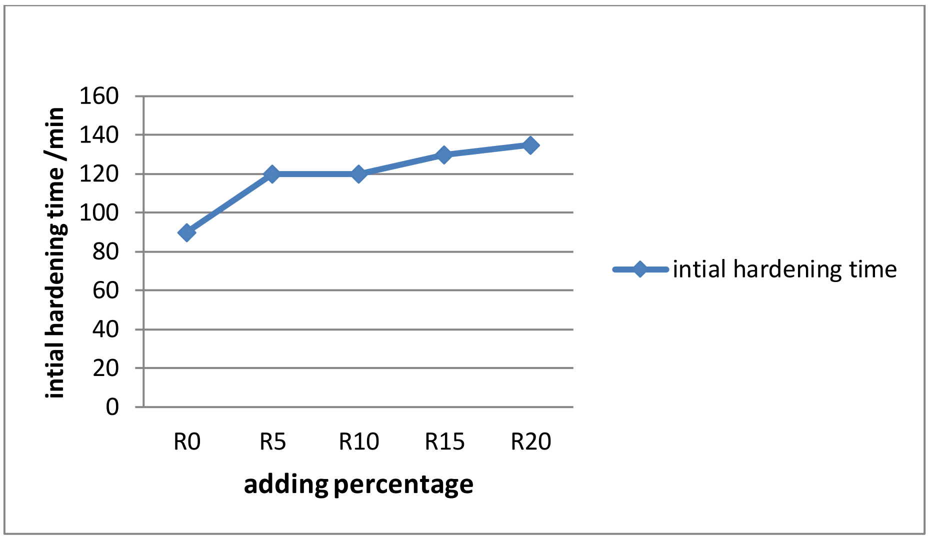

Figure (4). The relationship between the initial hardening time and the percentage of addition of cement dust.

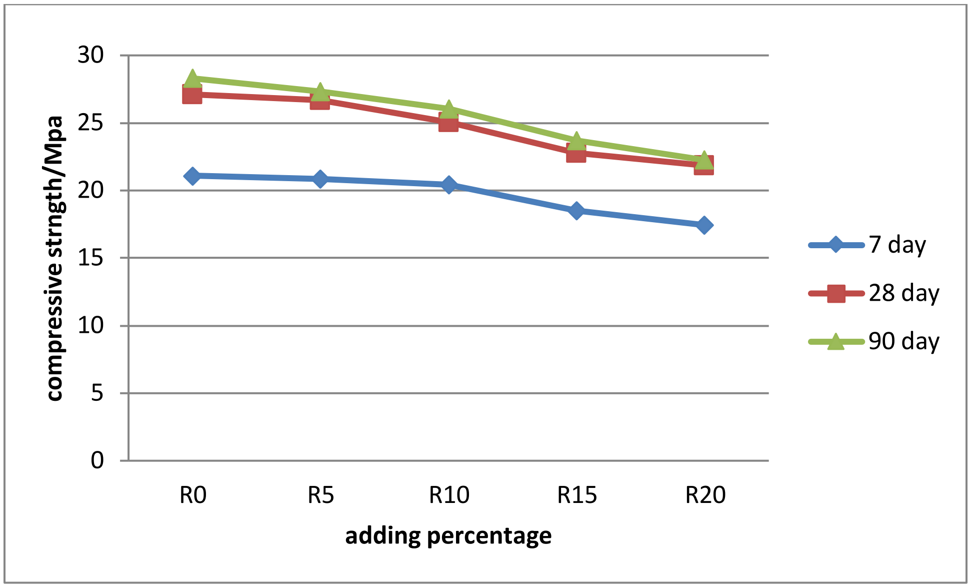

Figure (5). The relationship between the compressive strength and the addition rates of cement dust for different ages.

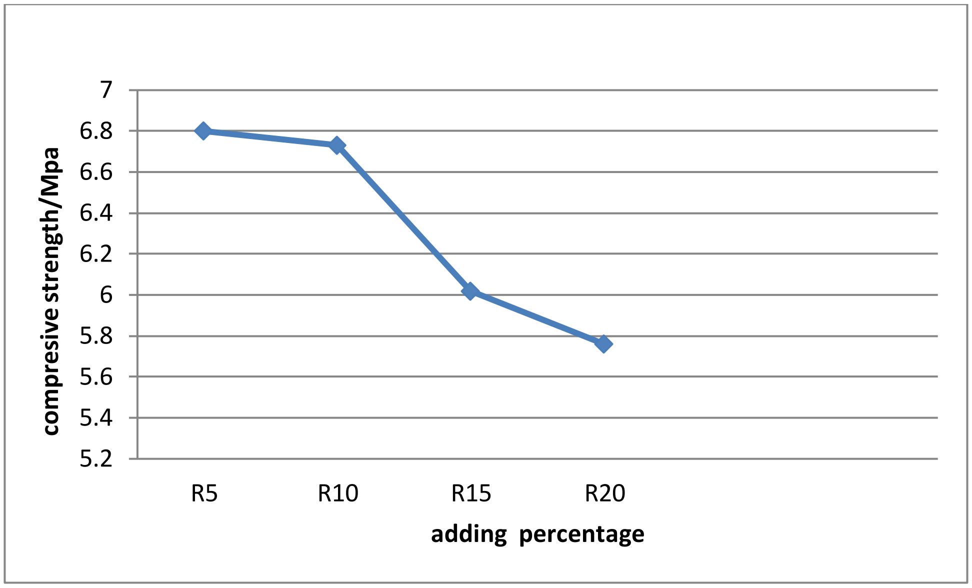

Figure (6). Results of the compressive strength of the laboratory-produced block.

Table (1). shows the initial hardening and Slumpe of concrete mixtures.

No.	Mix symbol	Added water volume (ml)	Initial hardening time (min)	Slumpe (mm)
1	R_0	109	90	140
2	R_5	112	120	136
3	R_{10}	112	120	130
4	R_{15}	115	130	125
5	R_{20}	116	135	122

Table (2). Results of the tests of compressive strength, density, porosity, and absorption of concrete cubes for a ripening age of 28 days.

No.	Mix symbol	Compressive strength Mpa	Density gm/cm^3	Porosity ratio %	Absorption rate%
1	R_0	27.11	2.37	8.53	3.6
2	R_5	26.7	2.34	8.70	3.72
3	R_{10}	25.05	2.33	8.78	3.77
4	R_{15}	22.79	2.29	10.28	4.49
5	R_{20}	21.85	2.28	10.40	4.56

Table (3). Results of chemical analysis of cement dust in Kufa Cement Factory.

NO.	The oxides involved in the formation of cement	Oxide symbol	Percentage %
1	Calcium oxide	CaO	43.14
2	Silicon dioxide	SiO_2	12.98
3	Aluminum trioxide	Al_2O_3	3.96
4	Iron trioxide	Fe_2O_3	2.4
5	Sulfur trioxide	SO_3	8.37
6	Magnesium oxide	MgO	2.09
7	Potassium oxide	K_2O	2.60
8	Sodium oxide	Na_2O	1.25
9	Chloride	Cl	0.22
10	Burning loss	---	22.94

Table (4). Compressive and Absorption Strength Test Results for Hollow Block.

NO.	Mix symbol	Compressive strength(Mpa)	Absorption %
1.	R_0	6.88	5.7
2.	R_5	6.8	5.87
3.	R_{10}	6.73	5.9
4.	R_{15}	6.02	6.7
5.	R_{20}	5.76	7.1

Table (5). Endurance and Absorption Requirements for Block Standard Specification No. (1077) for the year 1987.

<table>
<tr><th rowspan="2">Block type</th><th rowspan="2">degree</th><th colspan="2">Minimum pressure tolerance N/mm^2 calculated on average total area</th><th rowspan="2">Water absorption does not exceed (%)</th></tr>
<tr><th>3block rate</th><th>One block</th></tr>
<tr><td rowspan="2">Solid</td><td>A</td><td>13</td><td>11</td><td>10</td></tr>
<tr><td>b</td><td>9</td><td>7</td><td>15</td></tr>
<tr><td rowspan="2">hollow</td><td>A</td><td>7</td><td>6</td><td>15</td></tr>
<tr><td>b</td><td>5</td><td>4.5</td><td>20</td></tr>
</table>

4. Conclusions

It was observed from the above results that an increase in the percentage of CKD compared to the reference led to a decrease in density and an increase in porosity, and thus, the absorption rate increased, which negatively affected the compressive strength, due to the chemical composition of cement dust shown in Table (3), especially the presence of a high percentage of alkaline negatively affected the nature And the strength of hydration products and impede their work, which caused an increase in the percentage of pores and voids, and weak bonds between aggregates and cement, which was reflected in a decrease in density and strength, and an increase in porosity and absorption. The results of examining the pressure and absorption strength of the laboratory-produced block by pressure method, are shown in Table (4) and Figure (6), indicating that it conformed to the Iraqi standard whose requirements were set forth in Table (5) and for all additions of cement dust at rates of 5%, 10%, 15%, and 20% of the weight of cement.

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