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Utilization of Cement Kiln Dust with Local Ores to Prepare Ceramic Building Materials

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Abstract

Kiln dust material is collected during the manufacturing process of cement industry. It is considered as a waste material and poses environmental pollution. The properties of Kiln dust material depend on the kind of raw materials and fuel used. It is considered as a waste material This study focuses on the utilization the waste materials for ceramic products (bricks and tiles). The efficiency parameters (percentage of raw materials, additives, and firing temperature) during manufacture of the samples. Different amount of Kiln dust materials (20, 30 and 40) % were mixed with red kaolin clay and 10% (Na_2CO_3) is added to reduce firing temperature as a catalyst to prepare glassy phase. The samples were prepared by semi-dry press at a pressure 250 Kg/cm2 in two molds, cylinder (3.5 × 10 cm^2) and square (5 × 5 cm^2) for brick and tile respectively. Theses samples were dried at room temperature for 48 h. and at 110 °C for 24 hr. then, fired in muffle furnace at different firing temperatures (1050, 1100 and 1150 °C). The properties of ceramic materials after firing are produced a new material modifying in properties, and it is desirable stability of the product during the manufacture, as well as, firing temperature of the samples are very influential parameter on the physical and mechanical properties. Using kiln dust material with red kaolin clay, needs to high firing temperature up to 1150 °C, but the presence Na2CaCO3 in sample aid to decrease firing temperature to 1100 °C, with maintain requirement [1, 2, 3], fixing the addition of kiln dust material should not exceed 30%.

1. Introduction

Large amounts of kiln dust materials (KDM) are collected during the cement manufacturing process. It was supplied from Kaufa Cement factory, it is considered as a waste material, the positive uses of these wastes produces useful profitable products and decreases environmental problems.

Recycling of KDM appears solutions not only to solve such pollution problem but also to reduce cost, which is more important in economic design of buildings. Ceramic material industry constantly looking for a new technique and new raw material resources to improve the quality of their products and minimize their costs [4,5]

In this work, the influence of calcite (located in KDM) on sintering process of clays have been studied. Therefore, we selected kaolin, Red kaolin clay, Al-Hussainiyiat claystone as one of the most defined raw material used in ceramics [6]. Kiln dust material has not been efficiently utilized in the ceramic industry to prepare ceramic building materials like clay brick and tile. The technical properties of the ceramics as physical and mechanical properties were tested to get a suitable product for construction applications in Iraq and identical to standard specifications.

Increasing demand of the construction industry, the industrially developed world has attracted the attention of the Research and Development department of Iraq to study and evaluate the local raw materials for the production of ceramic materials, the regional studies put high necessity to develop ceramic material by using waste material like kiln dust material.

2. Theoretical Part

Different materials and methods have been used to prepare ceramic material, depending upon the chemical compositions of the raw materials and processing conditions. Number of studies [7, 8] tried to produce ceramic materials by using west material (kiln dust materials). They described the effect of KDM in variable percentages 2%--15% on the physical and mechanical properties and the effect of sintered in an electric furnace at (950oC – 1150℃). The results revealed that the bricks of 2% cement kiln dust fired at 1100℃ achieved the high resisting ceramic materials. Another researches, were studied the effect of calcite additives (from 5% up to 30%) to clay for prepare ceramic tiles and bricks [4, 5, 6, 9, 10]. It has been demonstrated that the calcite has a great reactivity, therefore it reacts easily with the phyllosilicates and quartz, providing better sintering of the starting powders at lower temperature degrees. The best additive percentage of calcite were defined at around 5%, and firing temperatures was exceeding 950℃. Affects positively on studied properties of the produced bricks which attained strength exceed 35 kg /cm^2.

Another study [5] used the addition of calcium carbonate residue to clay in different proportions (15, 20, 25, 30 and 35%) in a ceramic body. It has been demonstrated that the residue addition has great reactivity therefore, reacts easily with the phyllosilicates and quartz, providing better sintering of original powders. It has been possible to confirm that the new formulations subjected to the usual ceramic industry firing processes cause mineralogical compositions with similar properties to those obtained with marls or carbonated clays (wollastonite–anortite–Gehlenite).

3. Experimental Procedure

3.1. Materials

Kaolin: Five kilograms of Red Kaolin Clay was crushed by a jaw crusher, to a particle size of less than 1 mm, then grind by a ball mill in two fractions (-250+125) µm and (-125 +75) µm. The representative sample was send to chemical (wet analysis) and mineralogical composition by XRD (Type Shimadzu 7000 diffractometer) at GEOSURV, Iraq. The result of these analysis is listed in Table (1) and Figure (1).

Kiln Dust Material: Kiln dust material (KDM) was sieved to pass -106 µm to remove coarse particles. Table (1) and Figure (2) presents the chemical analysis and XRD pattern of KDM.

Additives: Sodium Carbonate (Na2CO3) with purity 99.5% from (THOMAS BAKER INDIA).

Table (1). Chemical analysis of Kaolin and Klin dust material (KDM).

Comp. %	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	L O I	SO_3	K_2O	Na_2O	TiO_2
Red Kaolin clay	45.66	9.45	25.85	1.62	0.85	11.34	0.08	0.47	0.65	1.13
Kiln dust material	11.82	1.57	2.83	44.43	2.80	21.95	10.55	0.95	1.00	0.25

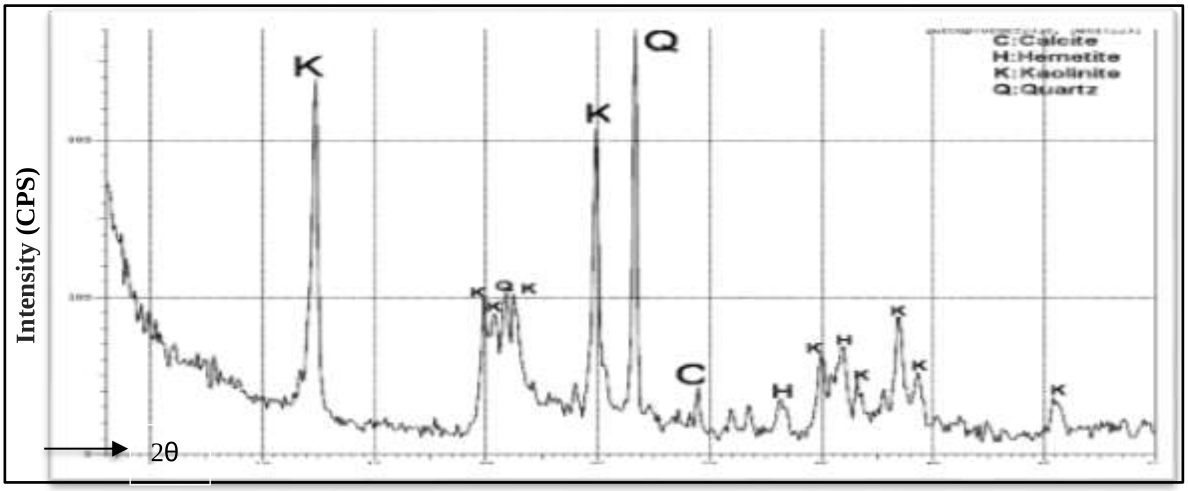

Figure (1). XRD pattern of red kaolin clay.

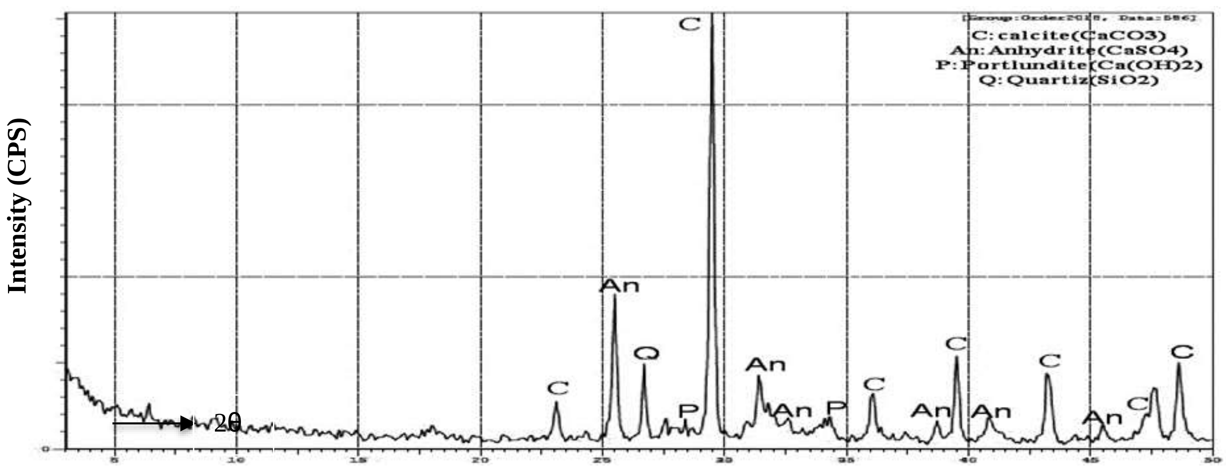

Figure (2). XRD pattern of Kiln dust material.

3.2. Method

3.2.1. Preparation of Ceramic Material (Bricks and Tiles)

Three experiments were designated for studying variable percentages of red kaolin clay (K) in two fractions (75% coarse and 25% fine) and kiln dust material (KDM), as well as, Na2CO3 was used as additive to form samples of bricks and tiles. The mixtures were included, red kaolin clay (K) and kiln dust material (KDM) in different percentages, as shown in Table (2). The mixture materials were thoroughly homogeneous and then moistened by spraying with distilled water (10–15 wt%). Each mixture was then uniaxial pressed in cylindrical mold dimensions (3.5*10) cm to prepare brick, and square mold dimensions (5*5*1) cm to prepare tile, then formed by dry press at

(25) N/mm2 for brick and tile. The samples were dried in furnace at 110˚C after remained at room temperature for 48 h., then fired in a muffle furnace at different temperatures (1050, 1100 and 1150) ˚C. The heating rate of the desired temperature was (5) C˚/minutes and soaking time (2) h. At the end of the firing program, the specimens were left inside the furnace to cool down. Then, mechanical, physical and mineralogical tests of the prepared samples were carried out.

Table (2). Preparation of mixing raw materials and additive.

Sample No.	**Adding by part % N**		**adding Na_2CO_3a%2**
	Kaolin	**Kiln dust material**	
Red kaolin clay: Kiln dust material	80	20	10
	70	30	10
	60	40	10

4. Results and Discussion

4.1. Characterization of Starting Materials

The chemical and mineralogical analyses of red kaolin clay and kiln dust materials used in this investigation are shown in and Figures (1 and 2) respectively. The chemical analysis results Table (1) show that the clay contains an appreciable amount of Al_2O_3 from kaolinite group. Further, these clays are rich in Fe_2O_3 which act as a fluxing agent, and low in alkaline oxides (Na2O and K2O, <1.02 wt.%). The kiln dust material had different amounts of calcite ($CaCO_3$), anhydrite ($CaSO_4$), quartz (SiO_2) and portlandite ($Ca(OH)_2$), and it is constituted mainly by CaO then SiO_2, accompanied by significant anions content of sulphate (about 10.55%) all these content leads to the high LOI value (21.95%). The oxiedes K2O, Na2O, Fe2O3, CaO, and MgO are considered as fluxing and can influence the densification behavior of the ceramic materials during firing [7,11].

4.2. Effect of Different Percentages of Kiln Dust and Temperature on Physical and Mechanical Properties

The properties of ceramic materials after firing are produced a new material modified in properties, and it is desirable stability of the product during the manufacture, as well as, the efficiency parameters (percentage of raw materials and additives, firing temperature) during manufacture of bricks and tiles.

The physical and mechanical properties of products (bricks and tiles) are shown in Tables (3 and 4) respectively, were calculated by depending on ASTM [12]. It can be seen the most important test for assuring the engineering quality of building materials. The physical and mechanical properties of the ceramic materials are inversely proportional to the quantity of kiln dust were added to the mixtures.

The proportion of kiln dust material (KDM), red kaolin clay, Na_2CO_3 10% and the firing temperature is controlling the bricks and tiles shrinkage, as shown in Table (3 and 4) during the firing process. Generally, a good quality of the building materials exhibits shrinkage below 8% as shown below in tables. The shrinkage lies in the scope of the good quality category, in order to yield a good quality brick.

5. Conclusions

The positive uses of these wastes, useful profitable products and decreases environmental problems for the neighbouring society. Therefore, the kiln dust materials can be used generally in manufacture of ceramic material applications as additives with keeping the acceptable percentage by no more than (30) %. The best results for preparation different ceramic materials were obtained as requested in ASTM standard by mixing (red kaolin clay: kiln dust material) in percentage (70: 30) % and firing at 1100°C. Exclude the preparation of bricks because, the use of kiln dust material needed high temperature (exceeded 1050°C) with other additives, that's not fit the brick industry, but fitting another ceramic industry.

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