The effect of scrap glass powder in traditional porcelain

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Abstract

In this work, Soda Lime Glass (S.L.G.) powder was used ,as fluxe in traditional porcelain instead of feldspar. Two ceramics porcelain were compared; commercial or traditional porcelain that content of 50wt % kaolin, 25wt % quartz, and 25wt % feldspar. Feldspar mass was substituted by scraps soda lime glass yielding a new porcelain composition, to determine the softening points and then the effect of glass addition on porcelain firing process.

Eight samples, for each patch, were prepared and 8wt % water was added. The resulting composite blends were then die pressed at 2N, to produce disk specimens with diameter of 1.5 cm, and then they were sintered at (1000, 1100, 1200, 1250,1300,1350,1400 and 1450) ˚C, for 2 hours in an electric furnace with a digital controller. Physical parameters, such as density, water absorption, and shrinkage were measured. It was concluded that the sintering process and physical properties were improved by heat treatment. However, the firing results showed that the addition of S.L.G. replacing feldspar lowers the melting points of porcelain and the addition of scrap powder has a positive effect on the quartz dissolution.

The purpose of the present work is to replace 25wt% of feldspar by soda lime glass in a standard porcelain composition and evaluate their differences in physical properties at different firing temperatures.

Keywords

scrap glass, new porcelain, S.L.G

Article info

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تأثير اضافة مخلفات مسحوق الزجاج على البورسلين التقليدي

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الخلاصة:

في هذا العمل ،استخدم مسحوق زجاج الصودا لايم (S.L.G) كمصهر في البورسلين التقليدي بدل الفلدسبار،حيث تم مقارنة نوعين من البورسلين السيراميكي. البورسلين التجاري او التقليدي والذي يحتوي على 50% كاؤلين, 25% كوارتز, 25% فلدسبار. عوضت كمية الفلدسبار بمخلفات زجاج الصودا لايم لأنتاج تركيب جديد من البورسلين وحساب درجة انصهاه ثم حساب تأثير اضافة الزجاج على عملية حرق البورسلين.

تم تحضير ثماني عينات من كل خلطة باضافة 8% من الماء ثم كبس المخلوط المركب بضغط مقداره 2 نيوتن للحصول على عينة قرصية بقطر 1,5 سم بعدها تم تلبيد العينات بدرجات حرارة (1000, 1100, 1200, 1250, 1300, 1350, 1400, 1450) م° لمدة ساعتين في فرن كهربائي. تم قياس المعاملات الفيزيائية مثل الكثافة, امتصاصية الماء, والتقلص. تم الاستنتاج ان عملية التلبيد والخصائص الفيزيائية قد تحسنت بالمعاملة الحرارية ,حيث اظهرت نتائج الحرق ان اضافة زجاج الصودا لايم بدل الفلدسبار قد خفض درجة انصهار البورسلين وان اضافة المسحوق المتخلف له تأثير ايجابي في ذوبان الكوارتز. الغرض من هذا العمل, هو استبدال 25% من الفلدسبار بمخلفات زجاج الصودا لايم في تركيب البورسلين القياسي ثم تقييم الاختلاف في الخصائص الفيزيائية بدرجات حرارية مختلفة.

Introduction

Porcelain has been used as an electrical insulating material for a long time, due to specific properties (mechanical strength, high-power dielectric strength and corrosion resistance [1]. It is a white, non-porous, and partially transparent ceramic material. It was first made by the Chinese to withstand the great heat generated in certain parts of their kilns. Today, porcelain is produced in many countries and its technology well known and described in different textbook and papers [2, 3].

The two natural substances, kaolin were used also known as china clay white clay free of impurities that melts only at very high temperatures [4]. Kaolin acts as a binder for the constituents in the raw materials mixture, and it confers plasticity to the body for shaping. The second minerals called feldspar or pertuntse that forms glassy cement, that binding the constituent permanently. Feldspar is a flux material that reacts with the other compounds, to forms a liquid phase in the system and leads to densification and shrinkage of the ceramics body during the thermal treatment. The final microstructure of the fired porcelain consisted of coarse aggregate particles held together by a finer matrix system that is easy dense [5].

Materials that used for lowering the softening point is important for reducing the firing temperature of ceramic products such as bricks, tiles, and porcelain through the chemical reaction [6]. The addition of glass reduces firing temperature, and the time resulting in a significant increase in production without additional heating capability of a plant[7]. Glass powder is a strong fluxing agent and has a capacity to form a lower melting point silica. Therefore, the firing temperature range was relatively narrow and different from that of traditional porcelain [17].

Experimental

The starting material have been used, in the work, were Duekhla kaolin, quartz and feldspar Iraqi raw materials supplied by (Ministry of Industry, General Company for Geological Survey and Mining). Also, the and Soda Lime Glass (SLG) taken from Al-Taji glass industry site, which is milled by blast method.

Two batches compositions were prepared. First one is the traditional porcelain (TP) which composed of 50 wt% kaolin, 25 wt% quartz, and 25 wt% feldspar. The second one, which namely new porcelain (NP), was composed of 50 wt % kaolin, 25 wt % quartz, and 25 wt % wasted soda lime glass powder. The glass powder have been used as fluxes agent in the second batch constituents and replaced feldspar(the melting point for S. L. G. was 690 ˚C). After the raw materials were selected and the desire amounts weighted, using a sensitive four-digit balance type (Precisa Instruments Ltd.). They have a series of preparation steps. First, the raw materials were dry milled in a ball mill during 10 minutes, using paddle mixer type (Willy- Wab-T_2), in order to homogenizing the mixture. The milling and grinding time are necessary achieved the optimum samples properties, and then sieved to obtained a desire particle size (>150μm).

The samples have been formed by combination of constituents with 8 wt % of distilled water, to produce the desired products. It is found that 8 wt % of distilled water gaive the best compaction results. Then the weighted mass (2gm of powder) is forced through a steel die to produce a disk samples with 1.5 cm in diameter. There are several types of pressing based on the direction of pressure. Uniaxial pressing type was used in this work. This process was described by applying pressure from only one direction. It is found that 2 N for 1 min press duration is the best load and time to obtain crack free green disk. Samples were dried for 48 hours in air and then at 110 ˚C for 24 hours in an electric oven.. The prepared samples have been sintered at different temperatures (1000, 1100, 1200, 1250, 1300, 1350, 1400 and 1450)˚C for 2 hr at a

heating rate of 10°C/min, in an electric furnace type Carbolite.

Density, water absorption, and shrinkage measurements were carried out. These parameters were very important for porcelain body. "Archimedes" principle. Where the difference between the sample weight in air (dry weight) W_d and its weight in a fluid W_i is divided by the density of the fluid ρ_f. That gives the volume of the liquid displaced, which is identical to the volume of the sample[8,9] . The density of the sample is given by:

$$\rho_a = \frac{W_d}{(W_d - W_i)/\rho_f} \quad \text{..... (1)}$$ Were

:ρ_a is the apparent density.

ρ_f is the fluid density.

The measurement procedure is obtained according to ASTM C373-88 by several steps[10]. Firstly the samples are dried in an oven at 110°C and then the dry weight, W_d, is determined. Then the specimens is placed in a baker filled with distilled water and boiled for 2 hr, then the specimens is allowed to soak for an additional 24 h, a second weight W_i is recorded while the sample is suspended in distilled water. After that, each specimen is lightly wiped with a moistened smooth cotton cloth, to remove all excess water from the surface, and the saturated weight, W_s, is recorded.

The Water Absorption expresses as a percent, is the relationship of the mass of water absorbed to the mass of dry specimen [11].

$$W.A\% = \{(W_s - W_d)/W_d\} \times 100\% \quad \text{.....(2)}$$ we

re: W.A: The Water Absorption of specimen.

W_d **:**Weight of the dry specimen.

W_i**:** Weight of the soaked immersed specimen.

W_s**:** Weight of the saturated specimen.

Shrinkage occurs because the particles agglomerate together. Linear shrinkage is necessary to fined out the amount of the decreasing or increasing in the dimension. The linear shrinkage, after drying and firing of ceramic specimen as a percentage of plastic length, as follows[12]:

$$Linear Shrinkage (L.S.) = \frac{L_\circ - L}{L_\circ} \times 100\% \quad \text{.....(3)}$$ We

re: L_0: is the original length

L: is the increasing or decreasing in length

The original and new length that obtained for linear shrinkage measurement were listed in Table (1).

Table (1)

Temp. (C)	L.S% New	L	L_o	L.S% Trad.	L	L_o
1000	7.90	0.561	0.601	7.9	0.510	0.564
1100	8.20	0.550	0.599	7.60	0.565	0.611
1200	8.60	0.571	0.624	8.70	0.530	0.580
1250	8.80	0.556	0.609	10.5	0.540	0.596
1300	7.45	0.520	0.562	12.5	0.500	0.571
1350	5.10	0.542	0.571	12.3	0.606	0.532
1400	4.64	0.553	0.592	12.8	0.520	0.596
1450	4.34	0.530	0.554	6.30	0.540	0.576

Result and discussion

The resulting of chemical analysis for Kaolin and S.L.G. were analyzed (Ministry of Industry, General Company for Geological Survey and Mining), are given in Table (2). It shows that the S.L.G. contains some other oxides in the higher level, such as Na_2O (16.4%), CaO (5%), MgO (3.45%), and SiO_2 (72.54%). These oxides may play a significant role towards vitrification, phase transformation, and growth of mullite crystals in soda lime glass [13].

Table (2): Chemical analysis of Duekhla Kaolin and Soda Lime Glass.

Kaolin Content	Weight wt %	S.L.G. Content	Weight wt %
Na_2O	0.25	Na_2O	16.4
CaO	0.15	CaO	5.0
K_2O	0.61	K_2O	0.35
MgO	0.38	MgO	3.45
Al_2O_3	34.84	Al_2O_3	1.45
Fe_2O_3	1.32	Fe_2O	0.6
SiO_2	47.26	SiO_2	72.54
TiO_2	1.4	TiO_2	0.01
L.O.I.	13.79	SO_3	0.15
		Cl	0.05

L.O.I: Loss on Ignition.

kaolin and soda lime glass samples were examined using X-ray diffractometer type Philips with CuKα (1.5406 A) radiation. The diffracted X-ray intensity is recorded versus the diffraction angle (2θ). The 2θ angles covered the range (10 to 60) degrees. The interplaner distance (d), corresponding to (2θ) of the diffraction peaks, is calculated using Braggs law (Eq.(4)). The ASTM diffraction standard is used to identify the probably existing phases [14,15].

$$n\lambda = 2d \sin\theta \quad \text{.....} \quad \text{...(4)}$$

Where:

n: is the order of reflection, which may be an integer (1, 2, 3 . . .) consistentin, with $\sin\theta$ not exceeding unity.

λ : is the X-ray wavelength.

d : is the interatomic spacing.

θ: is the angle of the diffracted beam.

X-ray diffraction (XRD) for both new and traditional samples are shown in Figures (1) and (2) respectively.

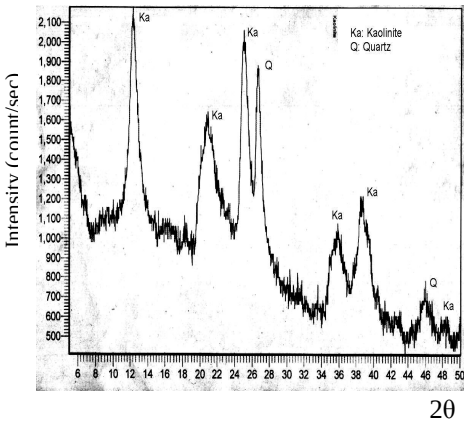

Fig. (-1) : XRD patterns of Kaolin

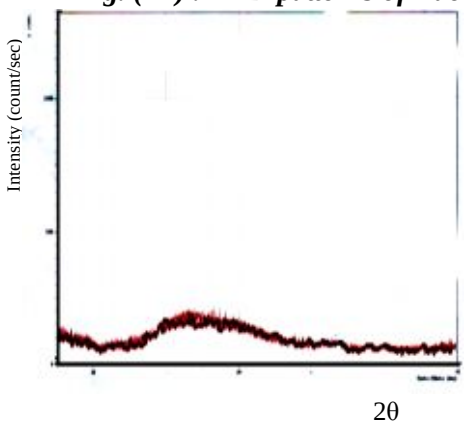

Fig.-(2) : XRD patterns for SLG.

The usual methods used, for the evaluation of the degree of sintering, are linear shrinkage and water absorption. These methods, however, give incomplete information about densification. The water absorption (W.A.) only measured the open porosity, while shrinkage is a function of the initial green porosity [16]. In order to obtained an additional information about the closed porosity, the density measurements were carried out.

Fig. (3) shows the values of density, that obtained versus temperature. It indicates clearly that the new porcelain have higher values of density than the traditional porcelain, for all the range of temperatures. At 1000 ˚C , it can be observed that the sintering process is in its initial stage and the values are closely for both products. This represents a clear demonstration , regardless of the presence of an existence glassy phase in the S.L.G., at this temperature. This may be explained by the high viscosity of the SiO_2–rich melting the constituent [16].

Above 1100 ˚C the sintering process is significant improved with increasing temperature. At 1250 ˚C, new porcelain composition have the highest value of density(2.257 gm/cm^3). However, the traditional porcelain have the highest values of density 2.321gm/cm^3 at 1350 ˚C . A continue increasing in temperature leads to decreasing density in new porcelain, due to increasing of the amount of glassy phase. This is a consequence of the fact , that the glassy structure always has a lower density than the corresponding mixture of crystal phase [17,16].

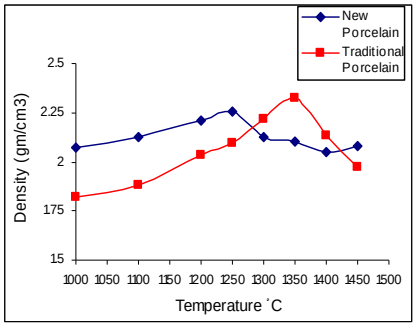

Fig. (3): Density for new and traditional porcelain at different temperature.

Fig. (4) show the variation of water absorption for new and traditional porcelain after sintering at different temperature. It have been observed that, at 1000 ˚C the traditional porcelain have water absorption values higher than new porcelain which seemed to have more of an effect on reducing water absorption . This is due to the inclusion of higher amount of open and closed porosity in traditional porcelain. With the increasing sintering temperature the open porosity transforms to closed porosity and leads to decreasing values of W.A. for both porcelain batches. It can be seen that the best value obtained for new porcelain sample at 1250 ˚C is 0.391%, while the best value for traditional porcelain occurred at 1400 ˚C is 0.28%.

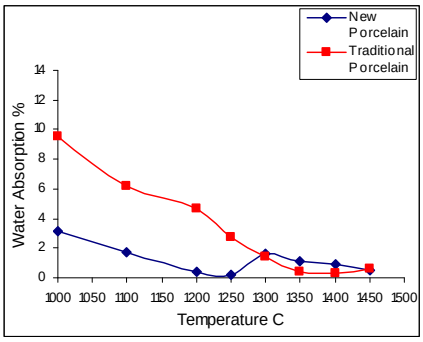

Fig. (-4): Water absorption as a function of sintering temperatures.

Variation of shrinkage as a function of temperatures was shows in Fig.(5). It has seen obviously that in the range 1000˚C - 1250 ˚C shrinkage values are similar for both traditional and new porcelain. This demonstrated that, at this temperature the scrap addition does not improve the densification process. It suggested that, in spite of, the heat treatment increased, the high melting temperature of quartz resist heating and the quartz remains without dissolving in porcelain constituents[13]. New porcelain have the best shrinkage value which obtained at 1250 ˚C is 8.8%, while the highest value attended for traditional porcelain is 12.8% at 1400 ˚C. The increasing temperature, above 1250˚C, leads to decreasing due to increasing closed porosity [5]. For traditional porcelain, it seems clearly that the increasing temperature above 1200 ˚C leads to higher values of linear shrinkage. This explained the transformation of open porosity to closed porosity [7].

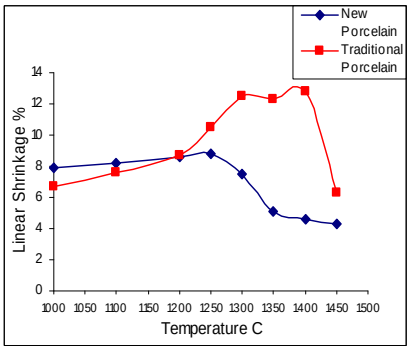

Fig. (5): Shrinkage curves for new and traditional porcelain at different temperature.

Conclusion

It is concluded that the eliminated whole the amount of feldspar by soda lime glass leads to decreasing the sintering temperature by 100-150 ˚C. An, addition of soda lime glass had a small influence on density ,water absorption, and shrinkage at temperature less than 1200 ˚C, due to difficult dissolution of glass constituents in porcelain composition. Due the increasing temperature, the glass addition results in improving physical properties, "larger shrinkage, and denser materials that absorbed less water.

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