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USING ARABIC GUM IN PRODUCTION OF REFRACTORY BONDING MORTAR

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Refractory bonding mortar is a specially-engineered blend consists of non-metallic materials that give the mortar unique heat-resistance and thermal characteristics for use in high-temperature applications. The goal of this study was to determine the performance of refractory mortar that produced from local raw materials in this study; Iraqi clays were utilized as raw materials while Arabic gum was used as adhesive materials. Three proportion mixes were applied, (96:4), (93:7), and (90:10) as (grog: kaolin binding material) and the burning temperatures for specimens were 1500^{o}C. In the present research, some physical test such as the percentage of apparent porosity, bulk density, and specific heat are studied. Also, some mechanical properties such as compressive strength, binding strength, and dimensional stability are investigated. Finally, thermal conductivity and thermal shrinkage as thermal properties are also surveyed. All refractory bonding mortar produced in this study which has been used local materials have a good quality and it has all the characteristics of an economical product.

Keywords: Kaolin, Strength, Grog, Thermal properties, Dimensional stability, Iraq.

1 INTRODUCTION

Refractories are made of inorganic, nonmetallic, porous and heterogeneous materials composedof thermally stabilized mineral aggregates, a binder phase, and additives. The principal raw materials used in the production of refractory are normally the oxides of silicon, aluminum, magnesium, and calcium (Agbajelola 2011, Kadhum and Jaffer 2013).

Refractories are ceramic materials designed to withstand very high temperatures (in excess of 540 °C) (Chukwudi 2008).

According to previous researches (Simon *et al.* 2003, Kadhum and Jaffer 2013) refractory materials must be chemically and physically stable at high temperatures. Depending on the effect of the environment, they must be resistant to thermal shock, be chemically inert, and/or have specific ranges of thermal conductivity and of the coefficient of thermal expansion.

2 THE OBJECTIVES OF RESEARCH

This study consists of the following objectives and significance:

A. Producing refractory bonding mortars from local materials such as Iraqi clay and Arabic gum that have properties comfortable to standard specification for refractory mortar which is utilized in fusion kilns building and lining.

B. This study is carried out to investigate some mechanical, physical and thermal properties of local refractory bonding mortar to encourage using Arabic gum as an adhesive material in refractory bonding mortar.

3 EXPERIMENTAL PROGRAMS

3.1 Materials

White kaolin was used as a granular product in this study. This clay was produced by crushing and grinding calcined refractory material (Al_2O_3-SiO_2 composition).

Kaolin clays were also utilized as a binder due to its good properties during molding without appearing of cracks. The white kaolin, which is utilized in this work, conformed to the chemical analysis requirements of (Iraqi Chemical Standard 2004), as shown in Table 1.

Table 1. Chemical analysis of white-kaolin.

Composition	**Al_2O_3%**	**SiO_2 %**	**MgO%**	**SO_3%**	**CaO%**	**Fe_2O_3%**	**L.O.I%**
White-Kaolin	42.90	42.96	Nil	Nil	0.76	0.32	13.06
Limit of (Iraqi Chemical Standard 2004)	32 (min.)	50 (Max)				1.4 (Max)	

Arabic gum was used as adhesive materials in this study, which were brought from local markets. Arabic gum is an organic material from the Iraqi acacia tree, which has adhesive properties when mixed with water and in high temperature.

Arabic gum is a natural exudate of acacia trees that is widely used in the food industry and has a unique combination of excellent emulsifying properties, low solution viscosity, and high molecular weight.

3.2 Preparation and Testing of Specimens

The procedures of preparation and testing of specimens processes include preparation of grog as refractory aggregates from kaolin clays and preparation of adhesive materials from Arabic gum solution or powder.

The following process results in the production of refractory bonding mortar:

A. Raw materials are crushed by the grinder and the powder was sieved to obtain the required sizes of the mixture. The purpose of the grinding process is to improve the physical and mechanical properties of materials.

B. The white kaolin clay formed in a rectangle mold at 20°C (room temperature) for one day to loss water, and later drying in dryer oven at (110°C) also for one day. The purpose of burnt clay was to reduce shrinkages cracks and deformations throw green stage.

C. The rectangular samples were burned for (2 hrs) at (1400°C) in a special kiln.

D. The burning samples were crushed by disc and finally, sieved by utilizing sieve No. (200) of seventy-five microns according to ASTM – C64 (1972) to make the grog.

E. The Arabic gum was crushed, sieved and dissolved in hot water to produce a solution with 1.5 gm/cm^3 density by using hot water.

F. All materials (Arabic gum with water as an adhesive material, kaolin grog, and kaolin as a binding material) were mixed by the electrical mixer. The details of the mix proportion are shown in Table 2.

G. After mixing, the mixtures were casted in the 2 cm cubic mold, pressing the mixtures to gain high density and lower porosities, placing at 20°C for one day, and then drying the specimens at 110°C for one day.

H. Finally, the specimens were burned at 1500°C in a special kiln for two hours.

Table 2. Mix proportion of all Iraqi refractory bonding mortar samples used in the study.

Mix No	Arabic Gum	Description (grog: binding material)	Mix proportion (grog: binding material)
Mix 1			96:4
Mix 2	(5%) % of water	Kaolin: Kaolin (K: K)	93:7
Mix 3			90:10

4 TEST RESULTS AND DISCUSSION

4.1 Mechanical properties

4.1.1 *Compressive strength (Crushing strength)*

The average value of compressive strength of the hardened samples was specified by using 2cm cubes according to ASTM C64 (1972).

The compressive strength of the Iraqi refractory bonding mortar was determined before and after burning at 1500°C and the results shown in Table 3.

Table 3. The cold and hot compressive strength of Iraqi refractory bonding mortar specimens.

Mix No	Mix proportion (grog: binding)	Mix Description (grog: binding)	Cold compressive strength (MPa) at 20°C before burning	Hot compressive strength (MPa) after burning
Mix1	(96:4)	Kaolin: Kaolin	4.47	85.29
Mix2	(93:7)	(K: K)	4.13	90.38
Mix3	(90:10)		3.16	116.61

Table 3 shows that the cold crushing strength of the mix (3) gives a minimum value of (3.16Mpa); which is within an acceptable range suggested for refractory. However, ASTM C64 (1972) recommended 1.3 Mpa as a minimum value of compressive strength for refractory materials. This shows that kaolin grog and local adhesive material can be used in refractory bonding mortar. It is also noticed that the cold compressive strength of specimens before burning was decreased whenever the kaolin grog content decreased, while the hot compressive strength of specimens after burning up 1500°C was increase when the kaolin grog content decreased.

4.1.2 *Bonding strength test*

This test was measured by using a flexural / tensile testing machine of ELE international company. The preparation of the specimens, included of cutting the fire brick into (40*40*160) mm^3 prism dimension by electrical hacksaw for concrete sawing, then bonding the two parts by refractory mortar products in this study according to ASTM C 198-02 (2002). The specimens were tested before burning and after burning and the results showed in Table 4.

From the Table 4 that mentioned below, it was noticed that the mix (2) gave higher cold bonding strength and followed by mix (1) and mix (3) respectively. While when comparing the values of cold bonding strength with hot bonding strength the mix (1) gave higher hot bonding strength and followed by mix (2) and mix (3).

Table 4. The cold and hot bonding strength of Iraqi refractory bonding mortar specimens.

Mix No	Mix proportion (grog: binding)	Mix Description (grog: binding)	Cold bonding strength (MPa) at 20°C before burning	Hot bonding strength (MPa) after burning
Mix1	(96:4)	Kaolin: Kaolin	2.38	12.31
Mix2	(93:7)	(K: K)	3.39	12.13
Mix3	(90:10)		1.19	9.39

4.2 Physical Properties

The physical properties of refractory mortars included bulk density, specific gravity, the percentage of the apparent porosity and water absorption. The results of physical properties of Iraqi refractory mortars are shown in Figure 1. The bulk density of the mixes that burned at 1500°C showed an increment whenever the kaolin (binding material) content increased while specific density, percent of apparent porosity, and percent of water absorption decreased whenever the kaolin (binding material) content increased.

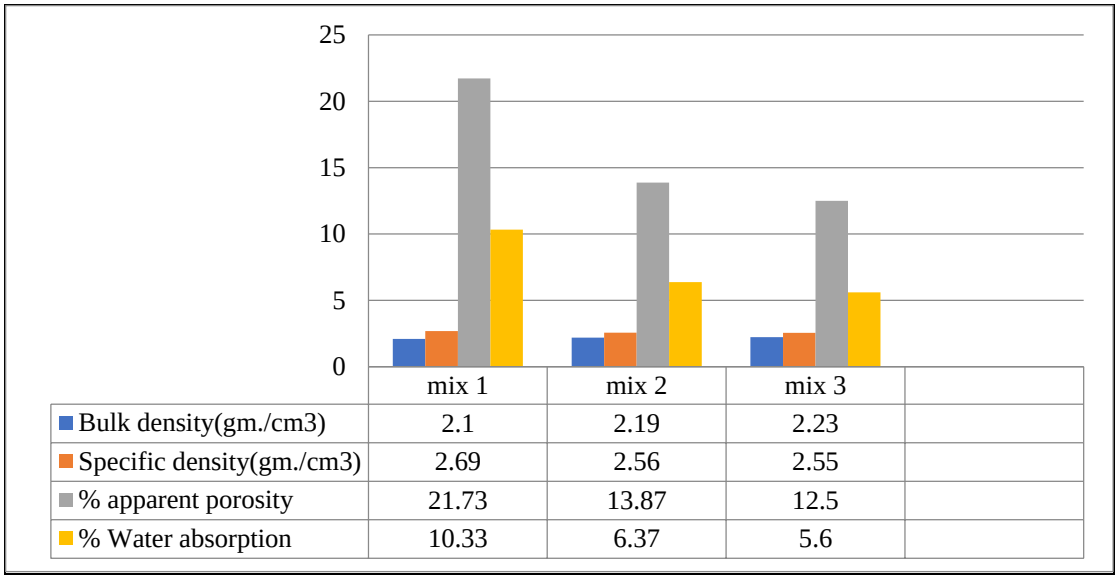

Figure 1. Physical properties of Iraqi refractory mortars burning at 1500°C.

4.3 Dimensional Stability Tests

These tests included linear thermal shrinkage and reheating expansion which were measured according to ASTM C 179–04 (2004) by using the electronic digital caliper tool before and after burning the specimens to 1500°C. The linear thermal, shrinkage of the refractory mortar was evaluated for three mixes after burning the specimens to 1500°C.

The results were illustrated in Table 5 to range from (5% to 10 %). It was also noticed from Table 5 that re-burning the specimens at 1500°C was led to expand only mix (2) and mix (3), that's due to the phase of Mullite is seen as a binding phase in most of the refractory brick and it has a high resistance to melting and minimum thermal expansion as well as low thermal conductivity as stated by (Al-Amer and Al-Kadhemy 2015).

Table 5. Linear thermal shrinkage and reheating expansion of specimens after burning to 1500°C.

Mix No	Mix proportion (grog: binding)	Mix Description (grog: binding)	linear Thermal shrinkage%	Reheating expansion %
Mix1	(96:4)	Kaolin: Kaolin	5	0
Mix2	(93:7)	(K: K)	9.5	5.3
Mix3	(90:10)		10	5.9

4.4 Thermal Properties

The thermal conductivity and specific heat of the mixes that burned at 1500°C showed an increment whenever the kaolin (binding material) content increased while thermal diffusivity decreased whenever the kaolin (binding material) content increased as shown in Figure 2. Moreover, these results have a lower than the value was stated (2.1w/m.K) by (Rasin *et.al.* 2009).

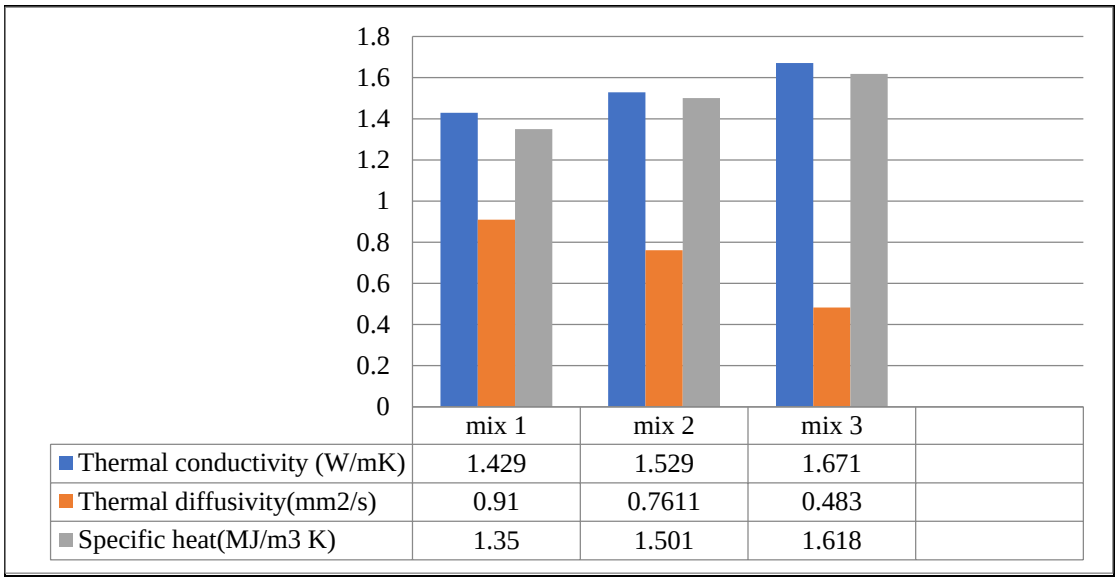

Figure 2. Thermal properties of Iraqi refractory mortars burning at 1500°C.

5 CONCLUSIONS

From the experimental results presented in this research, the following some conclusions are drawn:

A. Results indicated that hot compressive strength increased when the kaolin grog decreased while the cold compressive strength decreased when the kaolin grog decreased for all mixes.
B. Increasing binding material content caused a considerable increase in the bulk density, thermal conductivity, and specific heat while specific density, percent of apparent porosity, thermal diffusivity, and percent of water absorption decreased with the increment of kaolin (binding material) content.
C. Finally, refractory bonding mortar can be produced by using local materials such as Iraqi clay and Arabic gum as adhesive material with good properties.

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