



USING LOCAL IRAQI MATERIALS IN PRODUCTION OF REFRACTORY BONDING MORTAR

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<http://dx.doi.org/10.30572/2018/kje/090207>

ABSTRACT

The Iraqi kaolin clay was used as a raw material in this research. three mix proportion was applied, (96:4), (93:7) and (90:10) as (kaolin grog: kaolin binding). The specimens of mortar were burning at 1500°C, after producing a refractory aggregate (grog) by preparation process mixing with sodium silicate solution as adhesive material with 5% by weight of the mix. The mechanical tests were carried (compressive and bonding) strength, durability investigations (thermal shrinkage, and reheating expansion), and the physical investigation was carried (bulk density, specific gravity, apparent porosity and water absorption). It was found the first mix (96:4) recorded the highest compressive strength befor burning and bonding after burning, and the best physical properties after burning at 1500 °C, with mix proportion (96: 4), while the highest compressive strength after burning were the mix three (90: 10).

KEYWORD: kaolin, sodium silicate, reheating expansion, grog, compressive strength.

1. INTRODUCTION

The local production of refractory binding materials has become necessary because of its increasing needs. It will also reduce the cost and quantity of imported refractory materials from the other country (Agbajelola, 2011). The refractory mortars may be purchased either ready for use, in the wet condition, or requiring only the addition of water, in the dry condition. Preliminary to the recent study, it was deemed advisable to determine suitable soaking and mixing periods after adding the water required for bring the mortar to the necessary consistency for use Refractory materials. The mortars used to install brick and holding together in kiln building and lining, or are chosen so that thermal expansion will the goal to achieve a lining that comes as close as possible to being a monolithic and continuous refractory structure (Refractories institute, 1987). their compounds between metallic and nonmetallic element; they most frequently are nitrides, oxides, and carbides. The wide range of materials that fall within this classification includes ceramics that are composed of clay minerals, cement, and glass (Kadhum and Jaffer, 2013). A refractory material is a type of engineering ceramic called an 'industrial ceramic'. Refractory materials, however, have coarser grain size and higher porosity than engineering ceramics and consist of aggregate particles held together by a bonding (matrix) phase, where both the aggregate and the binding material can be multiphase. The particle size distributions are carefully controlled in order to control the microstructure, which directly influences porosity and density, strength, corrosion resistance and thermal shock resistance Al-(Tememy, 2014). The refractory mortars are consisting of a ground dry refractory material which becomes plastic when mixed with water and it is air or heat settable as well as it is suitable for use in laying refractory brick of the type used in making the lining of furnaces such as those used in refining metals (Sullins, 1988). The bonding mortar may require an adjusted balance of properties to meet the extremely exacting conditions while in service. Also, the working properties of the mortar should be good for both economy and convenience in the laying when mixed to either dipping or troweling consistency (Harbison-Walker, 2005).

The objective of this research to producing the local refractory binding mortars that have specification comfortable to standard specification for refractory mortar which is using in refractory and fusion kilns building and lining, and prepared three percentages of mortar mix to choose the optimum percentage of material to produce refractory binding mortar with good properties.

2. EXPERIMENTAL PROGRAMS

2.1. Materials

2.1.1. Raw material:

The kaolin clay was used as a raw material of the refractory aggregate (grog) was provided from AL-Anbar City. Granular product produced by crushing and grinding and calcined or burned the refractory material, usually of alumina-silica composition. Chemical analysis of kaolin according to Iraqi Chemical Standard illustrated in [Table 1](#), and chemical analysis for raw materials were carried out in ministry of construction and Housing and Municipalities & Public Works \ Building Research Directorate.

2.1.2. Binding material:

The kaolin clay was used too; as a binding material the granular product produced by crushing, grinding and sieving by sieve No.200, usually of alumina-silica composition ([Harbison-Walker 2005](#)).

Table 1. Chemical analysis of raw materials.

Chemical Composition	Kaolin	Kaolin Specific limits*
$\text{Al}_2\text{O}_3\%$	42.90	32 (Min.)
$\text{SiO}_2\%$	47.95	50 (Max.)
$\text{MgO}\%$	Nil	----
$\text{CaO}\%$	0.76	-----
$\text{Fe}_2\text{O}_3\%$	0.32	1.4 (Max.)
L.O.I %	13.06	-----
$\text{SO}_3\%$	Nil	-----

* Iraqi Chemical Standard

2.1.3. Adhesive material:

Sodium silicate (Na_2SiO_3) solution was used as adhesive material in this work. It is locally named as water glass which has been produce in Iraq.

It is dissolved in water to mix easily with components during mixture preparation. The sodium silicate solution density ranged between (1.2-2.4) gm/cm^3 Refractory materials. The Sodium silicate solution used in this work has a density of (1.5 $\text{gm.}/\text{cm}^3$).

Water glass (Na_2SiO_3) is a useful adhesive of solids due to many causes as flowing:

- a) Because it is using in forming samples.
- b) Helps significantly reduce porosity for the product, therefore, it is used with most ceramic products.
- c) Is responsible for hardening the mixtures.
- d) Sodium silicate is inexpensive and abundantly available, which makes it is used popular in many refractory applications Refractory materials.

2.2. Preparation processes

The kaolin clays are crushed and sieved to remove the impurities, the purpose of this process to increase the particles surface area and contact points between grains, and that will tend to increase the adhesive among grains and increase its ability to react with each other or with the binding materials during burning and leading to improve the physical and mechanical properties Refractory materials.

kaolin clay was formed as a thin rectangle shape and thermal treatment was done by remaining at room temperature for (24 hrs.) to loss the formation water, and finally dries in dryer oven at (110°C) for (24 hrs.). Then the kaolin clay form was burned in a special kiln at (1450°C) for (2 hrs.) in the Ceramic Department Laboratory of Materials Engineering College in Babylon University. Then, used in the mixtures after jagging and grinding by disc mill in ministry of construction and Housing and Municipalities & Public Works Central Baghdad Laboratory. The purpose of burnt clay was to reduce shrinkages cracks and deformations throw green stage. Finally, it was sieved by using sieve no. 200 ($75\mu\text{m}$) according to (ASTM C 64-72, 1972) to make the grog.

Mixing of sodium silicate solution (5%) by weight as an adhesive material with water and kaolin grog and kaolin as a binding material was done by electrical mixer Science Journal, 9, pp. 10 (2001). Mix proportion as illustrated in Table 2. Casting cubic specimens ($20 \times 20 \times 20$) mm was done by the ramming method by a steel rod in three layer as concrete cube.

After that, specimens treated thermally in room conditions for (24 hrs.) and dried in an oven at (110°C) for (24 hrs.); finally, specimens burned at (1500°C) for (2 hrs.). The burning was carried out in Laboratories of Materials Engineering Department at the University of Technology. Table 3 shows the detail of burning.

Table 2. mix proportion.

Mix No.	Mix proportion (kaolin grog: kaolin as a binding material)
1	96:4
2	93:7
3	90:10

Table 3. Burning treatment temperature.

Materials	Burning Temperature (°C)
Raw materials	1450
Thermal bearing	1500

3. RESULT AND DISCUSSION

3.1. Physical properties

For physical measurement, water displacement method has been used according to (ASTM C 20-00, 2000). This method consists of boiling the specimens in water for (2 hours) and emersion it for (12 hrs.) before calculating the weights. After that using three weights for the specimens dry, saturated and suspended in water calculated these weights were used in the equations (1) and (2) to calculate the physical properties which are the bulk density, specific gravity, apparent porosity, and water absorption.

The results of physical properties were illustrated in Table 4 for mortars burning at 1500 °C.

A. Bulk density

The bulk density of refractory mortars specimens decreased whenever the kaolin grog content decreased for all mixes. The results in Table 4 and Fig. 2 show that the mix No.1 has a higher bulk density, than the other mixes.

For many refractories materials, the general indication provides from bulk density of the product quality; the refractory with higher bulk density (low porosity) it is considered that will be better in the quality. When the bulk density increase the volume stability increases, the capacity of heat, as well as the abrasion Introduction to refractory and insulating materials. (24/3/2017).

$$\rho_b = D / (S - W) \times 100$$

1

Where;

ρ_b = Bulk density

D = dry weight.

S = Suspended weight in distilled water.

W = Weight in air.

B. Apparent porosity

The apparent porosity of kaolin mixed results [Table 4](#) gave values between (6.45-19.23) percent. Which are within the acceptable range (10-30%) suggested for refractory clays by ([Chester, 1973](#)) and ([Chukwudi and Eng, 2008](#)), except mix No. 3 which fell outside the acceptable range. Moreover, the porosity of mixes was decreased when the kaolin (binding material) content increased. The increase in bonding material reduces the porosity due to the increase in the degree of phase transformations with high temperatures between 1400 and 1500, which results in an increase in the liquid phase that fills the existing vacuum and which solidifies after cooling ([Saife, 2003](#)).

The High porosity materials tend to be highly insulating as a result of the high volume of air they trap because air is a very poor thermal conductor. As a result, the materials have a low porosity are used in the hotter zones generally, while the materials have a more porous are usually used for the thermal backup ([Abdul-Hamead, 2011](#)).

$$\rho P = (S - D) / (S - W) \times 100 \quad 2$$

Where;

ρP = Apparent Porosity

D = dry weight.

S = Suspended weight in distilled water.

W = Weight in air.

C. Water absorption

The results showed that the apparent porosity decreased with decreased of kaolin grog content and decreased the water absorption as shown in [Table 4](#).

Table 4. Physical properties of mortar specimens after burning at 1500°C.

Mix No.	Mix proportion (grog: binding)	Bulk density (gm./cm ³)	Specific gravity (gm./cm ³)	% apparent porosity	% Water absorption
1	96:4	2.26	2.4	19.23	9.52
2	93:7	2.24	2.5	11.21	5.08
3	90:10	2.22	2.5	6.45	2.86

3.2. Compressive strength

The compressive strength test was measured by using a digital compressive machine of ELE international company with loading rate (1.5000 KN/min) according to (ASTM C 64-72 1972).

The compressive strength of the refractory mortar was evaluated for three mixes before and after burning at (1500°C). Fig. 1 explained the results.

From Fig. 1 shows the results of the compressive strength at room temperature the mix No.3 gave a minimum strength of (2.83Mpa); which is within an acceptable ASTM recommended (1.3Mpa) as the minimum value for refractory materials (ASTM C 64-72 1972). This shows that kaolin grog can comfortably withstand impacts at low temperature (Chukwudi and Eng., 2008).

It was noticed before burning has the highest compressive strengths occur in mix No.1 and No.2. But, the compressive strength after burning was showed the opposites behavior than compressive strength before burning. The highest compressive strength after burning was achieved in mix No.3.

At the same time, the compressive strength of specimens before burning was decreased when the kaolin grog content decreased, while the compressive strength of specimens after burning at 1500°C was increase when the kaolin grog content decreased.

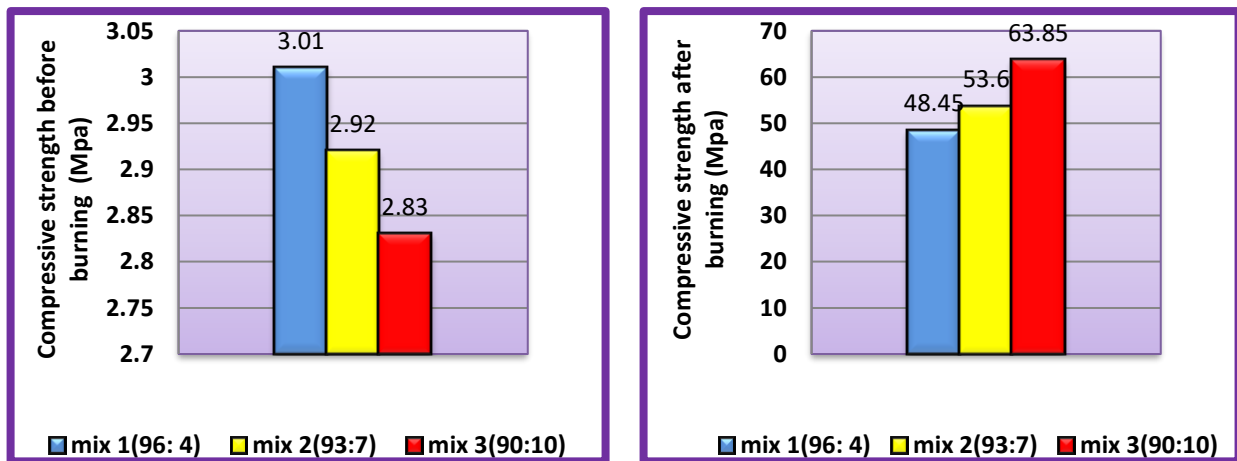


Fig. 1. compressive strength of refractory mortars.

3.3. Bond strength test

This test was applied to the fiery brick specimens after preparation by cutting the fiery brick into prism (40*40*160) mm³ dimension by electrical hacksaw for concrete sawing, then bonding the two parts by refractory mortar products according to (ASTM C 198-02., 2002).

Remained specimens into room temperature for (24 hrs.), dried in dryer oven at (110 °C) for (24 hrs.) the specimens were tested after burning at (1400°C) [not (1500 °C) due to no kiln reach to this temperature in test time] and measured by using flexural/tensile testing machine of ELE international company as in Fig. 2.

The results of bonding strength after burning at 1400°C were Fig. 3 explained the results and show that the mix No. 1 gives the highest value. On the other hand, the hot bonding strength decreased with increased kaolin (binding material) content.



Fig. 2. Flexural/ tensile testing machine of ELE.

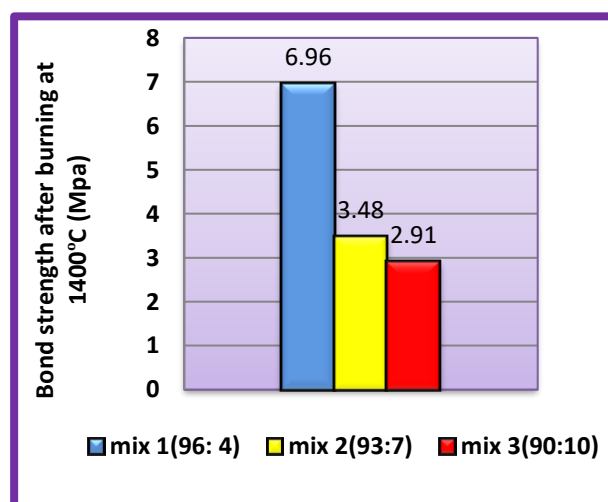


Fig. 3. bond strength of refractory mortars after burning at 1400°C.

3.4. Thermal shrinkage

Table 5 shows details of thermal shrinkage test conditions, it was measured according to (ASTM C 179-04. 2004) by using the (electronic digital caliper) tool before and after burning the specimens at 1500°C.

The linear thermal shrinkage of the refractory mortar was evaluated for three mixes before and after burning the specimens at 1500°C. The results were illustrated in Table 6 and ranged from (9.5% to 10.5%).

It was noticed that the highest value of the linear thermal shrinkage occurred in mix No.3, which fell outside the recommended range. While the linear thermal shrinkage for mix No.1 and No.2 was within the recommended range. (Chester, 1973), recommended that linear shrinkage range of (7%-10%) for refractory clays.

3.5. Reheating expansion test

This test was consisted of measuring the dimensions of specimens after burning at (1500°C) and after re-burning at (1400°C), details of reheating test conditions are shown in Table 5. It was measured according to (ASTM C 179-04. 2004).

In Table 6 results for specimens were illustrated. It was noticed that re-burning the specimens at 1400 °C was led to expand the specimens for the three mixes. Moreover, the specimens were given same values of expansion for mixes No.1 and No.2 that containing low and medium content of kaolin (binding material) but mix No.3 has a lower expanded. that's due to the phase of Mullite is considered as a binding phase in most of the refractory materials and it has a high resistance to melting and minimum thermal expansion as well as low thermal conductivity (Al-Amer and Al-Kadhemy, 2015).

Table 5. Details of thermal shrinkage and reheating test conditions.

Test specimens conditions	Temperature (°C)
grog burning	1450
Before burning	110
After burning	1500
After re-burning	1400

Table 6: Linear thermal shrinkage and reheating expansion

Mix No.	Mix proportion (grog: binding)	Linear Thermal shrinkage%	Reheating expansion % at 1400°C
1	96:4	9.5	6.3
2	93:7	10.0	6.3
3	90:10	10.5	5.6

4. CONCLUSIONS

At the end of this research about the production of refractory mortar from local Iraqi materials some conclusions are reached:

1. The bulk density was decreased whenever the kaolin grog decreased for burnt refractory mortars at 1500°C by about (0.9%) for three mixes.
2. The apparent porosity was decreased with the decrement of kaolin grog content, and the mix one has the highest apparent porosity.
3. Compressive strength at room temperature for refractory mortar mixes was increased with kaolin grog content increased, and mix No.1 has the highest cold compressive strength.
4. The compressive strength after burning at 1500°C was decreased with the increment of kaolin grog content in the mix, and the mixed No.3 has the highest hot compressive strength.
5. The bonding strength at 1400°C of refractory mortar for fiery brick specimens was increased when the kaolin grog content increased, and the first mix showed the highest value.
6. The refractory mortars were showed a decreased in thermal shrinkage since the kaolin grog content increased.
7. Thermal expanded of refractory mortars was constant in mix No.1 and No.2 and decreased with the decrement of kaolin grog content for mix No.3.
8. At the end the Mix No. 1 (96: 4) has met the requirements of the specification for refractories in terms of density, porosity and compressive resistance before and after burning, although mixture 3 gave resistance after burning higher than mix 1, also has a lower reheating (re- burning) expansion.

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