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# Study the preparation of alkaline mortar and conduct some physical and mechanical properties

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# Study the preparation of alkaline mortar and conduct some physical and mechanical properties

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**Abstract**: Alkaline mortar samples were prepared with four mixtures of local materials to be suitable for smelting iron, smelting furnaces or manufacturing ceramic crucibles. The physical and mechanical tests of the prepared models gave good results in comparison to the standard specifications, depending on the proportions of the samples prepared for the tests. The density, compressive strength, compressive strength of the Brazilian method and size of shrinkage were measured.

**Keywords: refractories, magnesium oxide, silicon oxide, aluminum oxide, and linings.**

## 1. Introduction

Considering the great development that takes place in the casting of different metals, and therefore the urgent need for furnaces and foundries especially, so it is necessary to provide different types of refractories and depending on the type of metal required for casting or fusion. Refractories are used either as linings or bricks for the construction of furnace structures or ceramic crucibles for metals fusion [1-3]. Refractories are generally ceramic materials, mostly non-metallic that withstands or resist at high temperatures, and may withstand molten metal and slag as well as gases released from the furnace [4].

Classification of refractories: Refractories are classified according to their properties as follows: **First**; the degree of resistance to fusion or heat resistance, known as the material's ability to maintain its mechanical strength at high temperatures without shedding load. Refractories are classified according to their properties as follows: [2,5]: (i) Refractories with common thermal resistance to temperatures 1580-1770°C. (ii) Refractories with high thermal stability for the thermal range 1770 - 2000 °C. (iii) Refractories with higher thermal resistance to temperatures above 2000° C. **Second**; Chemical and mineral composition, can be classified as follows: (i) Silicate and be based on silicon oxide such as silica - quartzite refractories. (ii) Silicate - Alumina, where the main components of the aluminum oxide and silicon oxide, such as clay refractory with high concentration of alumina. (iii) Which are based on magnesium oxide, and these refractories such as magnetite, dolomite and talc. (iv) Chromic, which is based on chromium oxide as well as magnesium oxide such as magnetite, chromite, chromium - magnetite. (v) Carbon refractories, which are carbon-based such as graphite and carbon refractories. (vi) Zirconium refractories based on zirconium oxide, such as zirconia and zirconium refractories. (vii) Refractory carbides, which are based on various carbide minerals. (viii) Oxide refractories, containing pure oxides such as magnesium oxide, aluminum oxide, beryllium oxide, zirconium oxide and silicon oxide. **Third**; Refractories are classified as acidic, neutral and basic oxides. (i) Acid oxides such as silicon oxide. (ii) Neutral oxides such as aluminum oxide. (iii) Basic oxides such as magnesium oxide. Table (1) shows the degree of melting points for some refractory materials [5].

**Table (1) show some refractories materials [5]**

| Refractory materials | Melting Temperatures (°C) |
|---|---|
| **Pure Graphite C** | **3482.2** |
| **Pure Sintered Magnesia, MgO** | **2798.9** |
| **Pure Sintered Zirconia, $ZrO_2$** | **2698.9** |
| **Pure Sintered Alumina, $Al_2O_3$** | **2048.9** |
| **Silica, $SiO_2$** | **1715.6** |

To obtain magnesium oxide from magnesium salts and solutions, which are usually magnesium carbonate, dolomite or sea water containing chloride and magnesium sulfide. For example, to obtain magnesium oxide from magnesium carbonate, the raw material is heated at a temperature 510- 750°C, according to the following interaction [6,7]:

$$MgCO_3(s) \overset{heat}{\Longleftrightarrow} MgO(s) + CO_2(g) \quad \dots\dots\dots (1)$$

When adding 5-10% of the aluminum oxide to magnesium oxide, it leads to increased thermal stability and slag resistance. The compound is composed of alumina-magnesia (MgO-$Al_2O_3$) [8].

The aim of this study is to study the preparation of refractory samples from most of the materials available locally. It can be obtained as a byproduct of some factories, and has been taken advantage of the rubble of the mines that went out of service as well as Iraqi mud.

# 2. Experimental work

## 2.1 Materials used

- Magnesium oxide (MgO) from ENGLISH CO. - BDH

- Grog from crushed or broken magnesium oxide (MgO) brick (Waste furnaces).

- Aluminum oxide ($Al_2O_3$ ) from ALM-41-SUMITO-CHEMICAL-COMPANY-U.K.

- Silica ($SiO_2$), locally from Dweikle Anbar province.

- Kaolin ($Al_2Si_2O_5(OH)_4$), locally from Dweikle mines in the western desert of Anbar province.

- Polyvinyl alcohol (PVA) as a binder with 1%wt, from CHINA /e-chem.com.cn.

## 2.2 Machines and the equipment used

- Ball milling.

- Sieves.

- Hydraulic press.

- Controlled furnaces up to 1700 °C.

- Molds for forming.

## 2.3 The method of work

Do a good cleaning of the crushed magnesia bricks and then grind it to sizes that can be milling within the equipment available in our laboratories. After grinding, we were sieved the powder to obtain particle size less than 75 µm. Table (2) represents the weight ratios prepared from four samples of alkaline mortar. These ratios were mixed for each sample using a ceramic ball mill for 24 hours, for the purpose of good mixing of components.

**Table (2) Weight ratios of different samples**

| Material | Weight percent (wt %) | | | |
|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
| Grog | **50** | **50** | **50** | **50** |
| MgO | **27** | **27** | **38** | **38** |
| $Al_2O_3$ | **10** | **-** | **8** | **-** |
| $SiO_2$ | **13** | **-** | **4** | **-** |
| Kaolin | **-** | **23** | **-** | **12** |

## 2.4 Method of forming

Two types of metal molds were used for the purpose of formation. The first is used to obtain a cylindrical model with a diameter of 3cm for the purpose of measuring density and compressive strength (Brazilian test method). While the second mold to form a cube with length 3cm for the purpose of calculating the compressive strength according to the standard used in the *Research Center of Construction and Glass*. The pressure used for compaction of the samples was 2.5ton. In both molds, the amount of shrinkage was calculated.

## 2.5 Sintering

All the samples were sintered at temperatures of 1200°C - 1300°C for the purpose of measuring density and shrinkage. After obtaining encouraging results, samples were presented in the form of cubes of the four species in table (2), for the purpose of measuring compressive strength. A rigorous heat treatment program was used for this purpose:

- Sintering temperature is 1200-1300 °C.
- Heating rate 3 °C/min.
- Retention time is 2 hours.
- Cooling rate 5 °C/min.

## 2.6 Laboratory tests

### 2.6.1 Density

Samples prepared in the form of a cylinder were used to measure the density by using equation (2).

$$\boldsymbol{\rho} = \frac{\mathbf{m}}{\mathbf{V}} \quad \dots\dots\dots(\mathbf{2})$$

Where: m; the mass of the sample, V; the volume of the sample and $\boldsymbol{\rho}$; the density of the sample.

### 2.6.2 Shrinkage

The shrinkage of the cylindrical and cubic shape of all the samples was calculated by measuring the dimensions before and after the thermal treatment and using equation (3).

$$\boldsymbol{shrinkage}(\%) = \frac{\boldsymbol{V_1} - \boldsymbol{V_2}}{\boldsymbol{V_1}} \times \mathbf{100}\% \;\dots\dots\dots(\mathbf{3})$$

Where: $V_1$; the volume before heat treatment and $V_2$; the volume after heat treatment of the sample.

### 2.6.3 Compressive strength

The cubic shape was used for the purpose of measuring compressive strength at the *Research Center of Construction and Glass*.

### 2.6.4 Splitting strength

Which is called the Brazilian method, can be calculated by equation (4) [9].

$$\boldsymbol{\sigma_D = \frac{2F}{\pi d D}} \quad \dots\dots\dots (4)$$

Where: F; meted force (N), D; diameter of Sample (m), d; thickness of sample (m) and $\sigma_D$: diametrical strength or splitting strength (N/m² or Pa).

## 3. Results and discussion

Table (3) represents the results of the tests carried out on the samples for mixtures (1, 2, 3 and 4) and standard of the *Research Center of Construction and Glass,* since the standard represent the specification of alkaline mortar. The difference between green density for all the samples prepared and the standard was very small, there is a slight difference in the use of kaolin instead of alumina and silica. But the green compressive strength for the samples prepared was greater than the standard because of good compaction of the samples.

After the thermal treatment of the samples at 1200°C, we note that the density increased by 1.62% for the first sample-1, 1.08% for the sample-2, 39.4% for the sample-3 and 37.3% for the sample-4, because of the loss of all the water molecules in the samples after burning, note that the density values we obtained are very close to the standard specifications for sample-1 and sample-2. But when increasing the magnesia ratio from 27% to 38%, there may be an increase in the density after the burning to 1300°C for sample-3 and sample-4. The compressive strength for all the samples prepared was greater than the standard except sample-1 was less than the standard. The values of compressive strength for sample-3 and sample-4 were very large comparison to the standard because of good heat treatment at 1300°C. The behavior of splitting strength was the same for compressive strength but different in values.

As for the shrinkage in size, the samples (1,2) note that the quantity of shrinkage in size is slightly higher than that required by the standard specifications. This is probably due to the presence of bonding material and the presence of kaolin in sample (2) instead of alumina and silica. Kaolin loses the water molecules present in the process of burning. As for samples (3,4), the amount of shrinkage are greater than to the standard specifications, this is due to the increase in the percentage of magnesium oxide, lowering the proportion of kaolin and increase in temperature of heat treatment at 1300°C.

Figure (1) represents the histogram of green density for the samples-1, samples-2 samples-3 samples-4 and standard, the difference in values for all the samples and standard was very small. Figure (2) represents the histogram of green compressive strength for the four samples and standard, the difference in values for all the samples and standard was very small. Figure (3) represents the density for the four samples and standard, the figure shows the values of samples-3 and samples-4 was greater than sample-1, sample-2 and standard, this increase was due to suitable heat treatment. Figure (4) and Figure (5) represents the histogram of compressive strength and splitting strength respectively, the figures shows the values of samples-3 and samples-4 was greater than sample-1, sample-2 and standard, this increase was due to suitable heat treatment for the samples-3 and samples-4. Figure (6) represents the histogram of shrinkage for the samples and standard, the shrinkage for samples-3 and samples-4 was greater than others samples due to heat treatment to 1300°C.

**Table (3) Physical and mechanical properties of the mixtures and Standard specifications of the *Research Center of Construction and Glass***

| Property | Sintering at 1200°C | | Sintering at 1300°C | | Sintering at 1200°C |
|---|---|---|---|---|---|
| | Sample-1 | Sample-2 | Sample-3 | Sample-4 | Standard |
| Green density (g/cm3) | 2.11 | 2.08 | 2.18 | 2.11 | 2.13 |
| Green compressive strength (MPa) | 1.37 | 1.43 | 1.45 | 1.42 | 1.40 |
| Density (g/cm3) | 1.88 | 1.87 | 2.58 | 2.54 | 1.85 |
| compressive strength (MPa) | 1.84 | 2.05 | 2.78 | 2.38 | 2.00 |
| Splitting strength (MPa) | 90.5 | 98 | 129 | 113.8 | 95 |
| Shrinkage (%) | 2.5 | 4.5 | 5.3 | 5.8 | 2.3 |

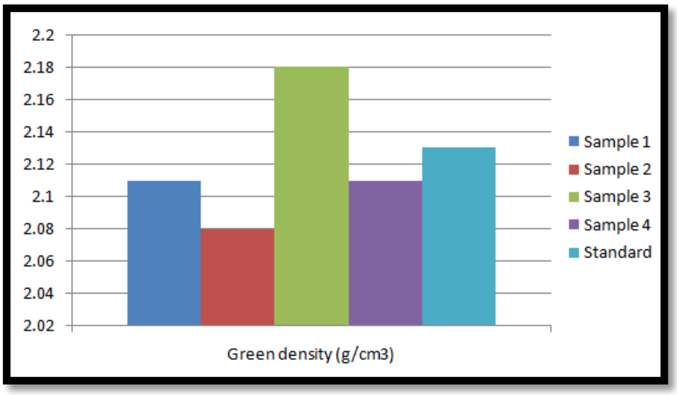


Figure (1) represents the histogram of green density for the samples and standard

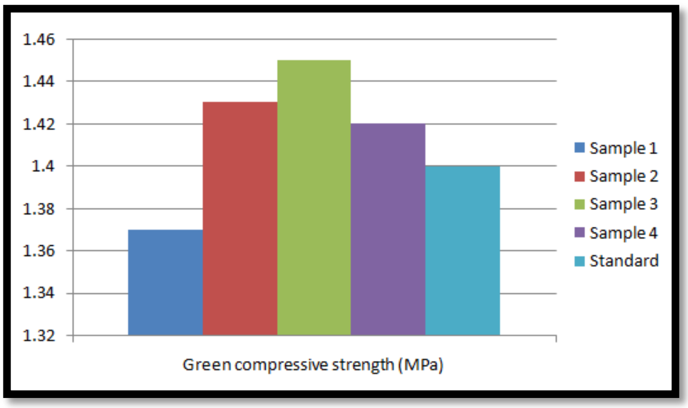


Figure (2) represents the histogram of green compressive strength for the samples and standard

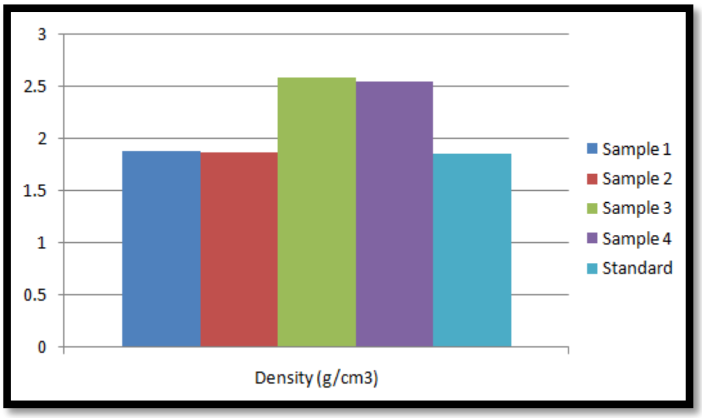


Figure (3) represents the density for the samples and standard

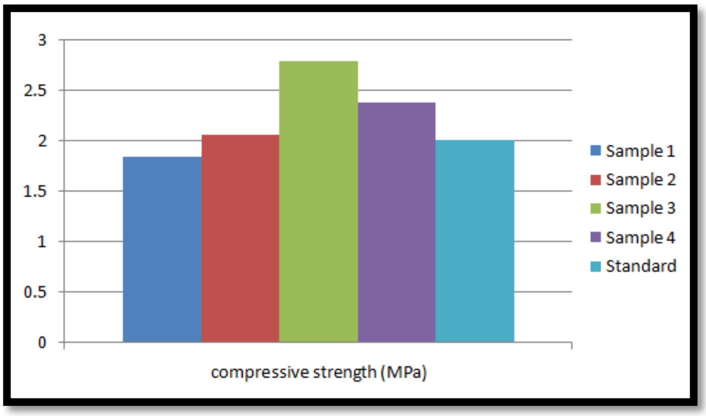


Figure (4) represents the histogram of compressive strength for the samples and standard

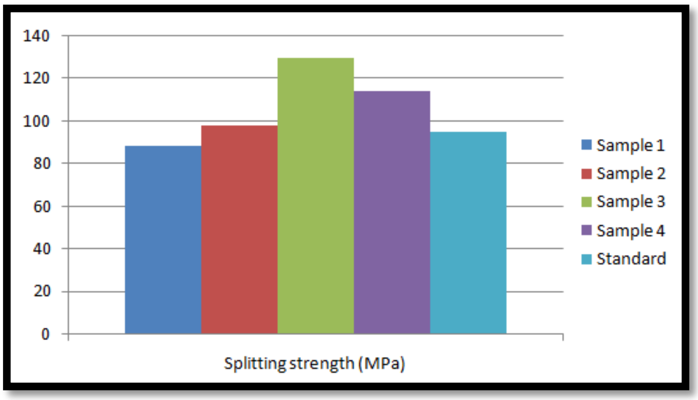


Figure (5) represents the histogram of splitting strength for the samples and standard

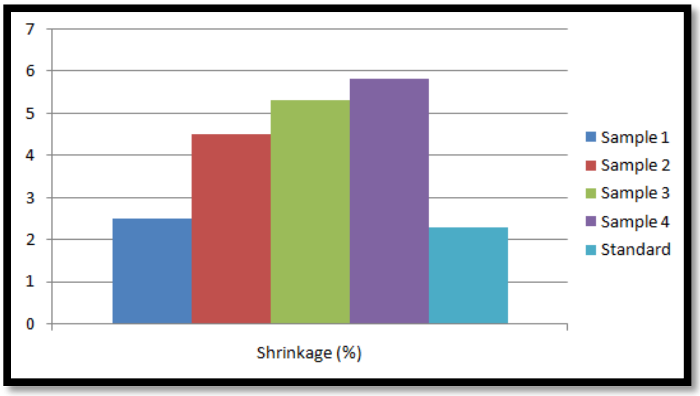


Figure (6) represents the histogram of shrinkage for the samples and standard

## 4. Conclusion

We conclude from the above that it is possible to prepare a alkaline mortar of materials, most of which are local. The best mixtures was found for samples-3 and samples-4. The results proved that the specifications of this alkaline mortar are good compared to the required specifications. It can be used to pack iron-melting furnaces. As well as furnaces which are used alkaline mortar, such as cement furnaces. It is also used in the manufacture of iron nozzle for corrosion resistance from molten iron flow. In addition to the possibility of manufacturing crucible ceramics bear or resist high temperatures and good physical and mechanical characteristics of smelting many metals and others industrial applications.

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