

INVESTIGATION THE MECHANICAL AND PHYSICAL CHARACTERISTICS OF SUSTAINABLE REFRACTORY CONCRETE

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Abstract

This paper is about using waste refractory bricks as aggregate (WRBA) instead of natural bauxite aggregates (NBA) to produce refractory concrete that is environmentally friendly and low-cost. Two types of WRBA from two different sources were used: RBA-1 obtained from the grinding of alumina bricks and RBA-2 obtained from magnesite bricks. For each of the three types of aggregate used, refractory concrete mixes are made with 14% water content and 1:3 cement\Agg. At room temperature and 100% relative humidity, the cast samples were kept for twenty-four hours. They were then opened and allowed to cure for seven days in water. After seven days of curing in water, the specimens were put in an oven to dry at 110 °C for twenty-four hours. The samples were burned at a rate of 3.33 °C/min for two hours at temperatures between 1000 and 1100 °C. They were then tested after being cooled to 25°C. Refractory concrete made from WRBA was evaluated by bulk density, shrinkage, compressive strength, Modulus of Rupture, and Weight change and compared to those obtained on conventional refractory concrete. According to the results and compared with ACI 547, refractory concrete made from WRBA can be produced with good high-temperature properties; at these temperatures, refractory concrete made from WRBA shrinks less than that made from NBA.

Keywords:

Refractory concrete.
 High alumina cement.
 Bauxite aggregate.
 Alumina brick as aggregate.
 Magnesite brick as aggregate.

1 Introduction

As the world's population grows and civilization advances, more concrete is consumed, putting tremendous strain on natural resources. Moreover, a significant portion of concrete waste from construction and demolition is dumped in landfills, which is a great reason to recycle and reuse these wastes. Several studies have evaluated the use of construction and demolition wastes as aggregates in the production of concrete, showing that they can be substituted for natural aggregates [1].

Refractories are defined as "non-metallic materials with physical and chemical properties that allow them to be used as parts of systems or as structural elements in environments that are heated above 1000 °F (811 K; 538 °C)." Both normal weight aggregate and lightweight aggregate can be used in refractory concretes; the former is known as "heavy refractory concretes," while the latter is frequently referred to as "insulating refractory concretes" ACI 547-2008[2]. Joseph F. Lamond and James H. Pielert [3] showed that refractory concretes with high-alumina cement and common refractory materials such as aggregate, like crushed firebrick, can be used to withstand extended high temperatures, as in the case of monolithic kiln linings. When exposed to dry heat temperatures as high as 1300°C (2372°F), this kind of concrete will not degrade because ceramic bonds will take the place of the hydraulic bonds that were lost during desiccation. Refractory concrete can have service temperatures as high as 1800°C (3272 °F) when aggregates like fused aluminum oxide are used with a cement that is essentially calcium aluminate [3]. Hosseini et al [4] studied refractory concrete and described it as a unique kind of concrete intended for use at high temperatures. It is made up of binders, plasticizer liquid, refractory aggregates, and, if necessary, additional special admixtures. This type of concrete uses special binders, which are not used in regular concrete structures. The reaction between the plasticizer liquid and the binder hardens the mixtures at normal or low temperatures. Similar to other varieties of concrete, these also

require water for the forming and setting processes. Since the extra water will evaporate from the concrete during the heating process, the water content in the mixture design needs to be carefully considered. Admixtures and additional chemical compounds can be used to enhance the curing process and achieve certain unique qualities. Refractory concrete that is made without cement by using additives and alternative material bonds is known as free cement refractory concrete or FCRC. It exhibits good volume stability and is less susceptible to chemical attack, molten metals, and slags the three main destructive forces. Badiie and Sasan [5] concluded that because colloidal silica content increases the liquid content in the refractory concrete composition, adding colloidal silica to refractory concrete reduces the bulk density of refractory concrete at all temperatures. Consequently, as the body dries, the moisture is removed, increasing the body's porosity. Additionally, they discovered that because of a higher degree of sintering and a higher ceramic bond, higher contents of colloidal silica have disadvantages in the strength development where the mechanical strength increases and the highest strength value was at 1500 C°. R. K. Dickuviene et al [6] showed that it was found that the density of refractory concrete supplemented with micro-silica and reinforced with steel fibers increased by approximately 2% to 7% at 100°C to 800°C, respectively. Furthermore, it is stated that the addition of steel fiber reinforcement and micro-silica raises cold-crushed strength from 22% to 47% at 100°C. When steel fiber and micro-silica are added, this increase decreases and becomes 9% at a high temperature of 1000 °C. Newman[7] proposed that the occurrence of abnormal or unusual cracks in refractory concrete after the first firing. These fractures could be caused by shrinkage from dehydration or by high-temperature ceramic reactions between the cement and aggregates. These cracks will seal when the concrete reaches the temperature required for normal operation. After the first firing, thermal expansion can be reversed by cooling and reheating the material. There shouldn't be a problem with these cracks unless debris is allowed to accumulate inside them in between firings. Subsequent firings may cause the crack's width to increase.

Waste material generated during the last stages of brick and tile production that is damaged is referred to as "waste material from the brick and tile industry". Because they are unfit for sale, prefabricated bricks and tiles that are damaged beyond tolerance limits are crushed near the factory. This type of waste material is widely used in sports terrain as filler in both the upper and lower layers. But according to research conducted worldwide, crushed brick could be utilized as a concrete aggregate [8]. This study attempts to investigate how the properties of high alumina cement refractory concrete are affected by three different types of aggregates: bauxite, alumina brick, and magnesia brick.

2. Raw Materials

Refractory concrete properties are mostly determined by the characteristics of the raw materials and the synthesis or processing method.

2.1 High Alumina Cement

Neville 2011[9] shown that while the concreting techniques are similar, high alumina cement's structural use is severely limited due to its very different composition and some of its properties from Portland cement and Portland blended cements. Given the cement's name, "high-alumina," one can assume that a significant amount of alumina is present in it. Typically, alumina and lime make up 40% of the mixture, while 15% of ferrous and ferric oxides and 5% of silica are also present. There may also be trace amounts of the alkalis, magnesia, and TiO₂. Typically, bauxite and limestone are used as the raw materials. Bauxite is a residual deposit made of hydrated alumina, iron and titanium oxides, and trace amounts of silica that is left over after weathering of rocks containing aluminum in tropical climates.

The results of the chemical analysis for high alumina cement are displayed in Table 1, where the major constituents are silica SiO₂ (35.29%) and alumina Al₂O₃ (62.34%). Additionally, a small number of fluxes like Fe₂O₃, CaO, and MgO are present. This test was conducted in the General Direction of Geological Survey and Mining Laboratories.

Table 1: Analysis of chemicals for alumina cement

Oxides	Percent
Al ₂ O ₃	62.34
SiO ₂	35.29
SO ₃	0.02
CaO	0.14

TiO ₂	0.49
Fe ₂ O ₃	0.83
L.O. I	0.15
Total	99.13

2.2 Bauxite Aggregate

The Fallujah Refractories Company and the Building Research Center provided the fine aggregate depicted in Fig.1A, which was used in the refractory production process. It might exist in the western region of Iraq. Tables (2 and 3) present the chemical and sieve analysis results of the bauxite aggregate. According to ACI Report 547–2008 specifications, the sieve analysis reveals that the aggregate's composition is primarily made up of impurities (MgO, CaO, and F₂O₃) and alumina silicate, with size ranging from (0.1 to 4.75) mm, while powdered bauxite comes from crushed bauxite aggregate in size 100 µm, as seen in Fig.1B.

Table 2: Analyzing the sieve of bauxite aggregate.

Size of sieve	%Passing
4.75 mm	100
2.36 mm	60
1.18mm	43.2
100 µm	9.5
Specific gravity	2.49

Table 3: Analysis of chemicals for bauxite aggregate.

Oxides	Percent
Aluminum oxides (Al ₂ O ₃)	91.8
Silicon dioxide (SiO ₂)	5.60
Potassium oxide (K ₂ O)	0.27
Carbon oxide (CaO)	0.19
Titanium dioxide (TiO ₂)	0.96
Ferric oxide (Fe ₂ O ₃)	0.98
L.O. I	0.14
Total	99.82



a) The bauxite aggregates



b) Bauxite aggregate as powder

Fig.1: Bauxite as fine aggregate and powder used in this research

2.3 Alumina Brick

Alumina brick is widely used in steel metallurgical equipment, including electric furnace roofs, blast furnaces, furnaces for non-ferrous smelting, chemical industries, cement industries, and other applications. It has high refractories under load, good thermal shock resistance, spalling resistance, erosion resistance, and other advantages. In this search using tandem with high alumina cement, two types of aggregate and as aggregate to provide an excellent complete solution for refractory applications.

Crushed alumina brick as aggregate with different grades ranging from 0.1 to 4.75 mm, in accordance to the requirement of ACI report 547-2008 [2], and as shown in Fig. 2. Table 4 and Table 5 show the sieve analysis and chemical analysis of high alumina brick as aggregate.

Table 4: Analyzing the sieve of alumina brick used as an aggregate.

Size of sieve	Passing [%]
4.75 mm	100
2.36 mm	60
1.18mm	43.2
100 μ m	9.5
Specific gravity	2.49

Table 5: Analysis of the chemical makeup of bricks made of alumina.

Oxides	Percent
Aluminum oxides (Al_2O_3)	84.07
Silicon dioxide (SiO_2)	8.450
Potassium oxide (K_2O)	0.389
Carbon oxide (CaO)	2.660
Titanium dioxide (TiO_2)	0.099
Ferric oxide (Fe_2O_3)	3.46
L.O. I	0.15
Total	99.13



Fig. 2: Crushed alumina bricks as fine aggregate

2.4 Magnesite Brick

Magnesite brick is an alkaline refractory brick made of magnesite as the main component and periclase as the main crystal phase. Its magnesium oxide content is 91%-97%. Magnesite bricks have high refractoriness, and have good corrosion resistance to iron oxides, alkaline slag and high-calcium fluxes. But the thermal shock resistance is poor. In this searched used in tandem with high alumina cement, two types of aggregate and as aggregate to provide an excellent complete solution for refractory applications. Magnesite bricks can be broadly classified into two types: chemically bonded magnesite bricks, which are also referred to as unfired magnesite bricks, and sintered magnesite bricks. Magnesite bricks with high purity and high firing temperature become directly bonded magnesite bricks due to direct contact with periclase grains. Bricks made by fused magnesite as raw materials are called fused combined magnesite bricks. Sintered magnesite bricks are sintered at a high temperature of 1550~1600°C after crushing, batching, mixing and forming. The sintering temperature of high-purity

products is above 1750°C. Unburned magnesia bricks are made by adding proper amount of chemical bonding agent to magnesia. It is made by mixing, molding and drying [10].

Crushed magnesia brick as aggregate with different grades ranging from 0.1 to 4.75 mm in accordance to the requirement of ACI report 547-2008 [2], and as shown in Fig.3 . Table 6 and Table 7 show the sieve analysis and chemical analysis of high alumina brick as aggregate.

Table 6: Sieve analysis for magnesia brick as aggregate.

Size of sieve	Passing [%]
4.75 mm	100
2.36 mm	60
1.18mm	43.2
100 μ m	9.5
Specific gravity	2.49

Table 7: Magnesite brick aggregate chemical analysis.

Oxides	Percent
Al ₂ O ₃	67.79
SiO ₂	14.33
K ₂ O	0.174
CaO	1.75
Fe ₂ O ₃	12.23
L.O. I	0.13
Total	96.27

No	Mix details (Cement /Aggregate (1:3))		Mix designation	water
1	Alumina cement	Bauxite aggregate	Mix 1	14%
2	Alumina cement	Alumina brick recycle as aggregate	Mix 2	14%
3	Alumina cement	Magnesite brick recycle as aggregate	Mix 3	14%

Table 8: The percentages of materials in mixture as % of weight of aggregate.



Fig.3: Crushed magnesite bricks as fine aggregate

3. Experimental Laboratory Program

3.1 Preparation of Refractory Concrete

In order to achieve a uniform mixture and good workability, the materials in this research were mixed for three minutes during the drying state. The materials were first mixed with aggregate, then high alumina cement was added, and finally water (14% of the weight mixture) was added. The percentages of materials and water for each mixture are displayed in Table 8. According to ASTM C860 2019[11],

Fig.4 illustrates that the amount of water/dry weight for hand mixing, also referred to as "Ball-in-Hand," should be kept to a minimum.



Fig.4: Ball-in-hand test

3.2 Molding and Compaction Models

After the mixture is finished, it is poured into molds with dimensions of 285*75*75 and 40*40*160 mm for prism specimens, and 70.5*70.5*70.5 mm for cubic specimens, as shown in Fig. 5. A thin layer of oil must be applied to the molds from the internal interface in order to stop the mixture from sticking to certain parts of the mold. The mixture compacts in two-layer molds using a tiny steel hammer to produce specimens with a uniform frame and two distinct shapes for prisms and cubes, shown in Fig.6. The ASTM C862-2020 [12] is followed in this process.



Fig.5: Casting specimens into molds.



Fig.6: By using a tiny steel hammer to compacts specimens.

3.3 Drying and Firing

Upon curing in water for 7 days and in order to dry them out, the samples were next placed in an oven set to 110 C° for an entire day, following the instructions provided by ASTM C865-2022 [13].

The specimens are fired, in accordance with ASTM C865-2022 [18], at a burn rate of 3.33 C°/min after drying at temperatures between 1000 C° and 1100 C°. The samples are then allowed to remain at this temperature for two hours, or "socking time," so that they can tolerate high temperatures without sintering, as shown in Fig.7 .



Fig.7: Preheat the oven to 1000°C and 1100°C while the models are inside.

4. Experimental Tests

The tests are due to American Standard for Testing and Materials, where the Bulk Density was made according to ASTM C 20[14], the compressive strength due to ASTM C133[15], Modulus of Rupture was carried out with center point loading according to ASTM C133 [15], shrinkage was done according to BS1902: section 5.10-1987[16] and weight change test.

5. Result and Discussion

Three types of aggregate used with aluminum cement in percentage 3:1 by high volume, and study the effect of three types of aggregate on properties of refractory concrete.

5.1 Bulk Density

The results of the bulk density for all refractory concrete mixes were listed in table 9 and fig.8. One of the most crucial characteristics of refractory concrete is its bulk density, which inductor for internal structure of refractory concrete. Whereas bulk density indicates whether the mix will meet the requirements of refractory concrete to be used withstand extended high temperatures, it also provides an early expectation of all the hardened properties of concrete. Furthermore, it provides a preemptive means of overcoming any unsatisfactory property. For all mixes, the bulk density falls between (2.13 and 2.49) gm/cm³ at 25 C° to 1100 C°.

Using recycled (magnesia or alumina) brick as aggregate exhibits a reduction in bulk density compared with natural bauxite aggregate. This reduction is because the refractory concrete that made from recycled magnesia bricks as aggregate has a higher percentage of voids and pores that retain water (mixing water + curing water). Bulk density will be more reduction for refractory concrete made from recycled magnesia brick as aggregate when compared with using recycled alumina brick as aggregate, which conform to refs [17,18 and 19].

For all refractory concrete mixing that made from different types of aggregate, when preheated at 1000 C° and at 1100 C° temperature has led to abrupt drop in bulk density, mainly due to the dehydration.

Table 9 :Test result of bulk density for refractory concrete.

Set No	Bulk Density g/cm ³		
	At 25 C°	At 1000 C°	At 1100 C°
Mix 1	2.39	2.24	2.23
Mix 2	2.28	2.14	2.13
Mix 3	2.21	2.12	2.10

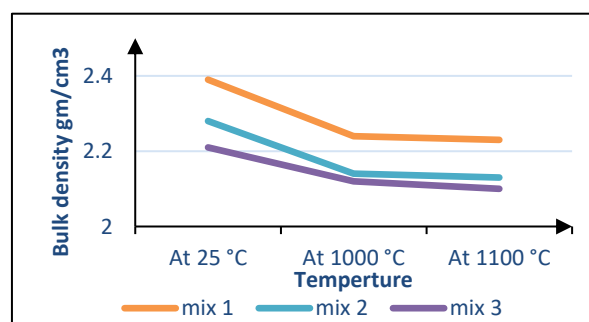


Fig. 8: Bulk density of refractory concrete at different temperature.

5.2 Shrinkage and expansion

The average change in specimen length per unit length resulting from the loss of free water under typical circumstances is known as drying shrinkage. Both moisture loss and chemical structure changes cause refractory concrete to permanently change in volume. It is possible to categorize this volume change as temperature-dependent or temperature-independent. Initial drying and curing phases involve temperature-independent volume change. It is usually much less critical than temperature-dependent volume change, and it can be controlled appropriately. The combination of the refractory concrete's reversible thermal expansion and contraction behavior and the irreversible effects of moisture loss and

chemical metamorphosis results in temperature-dependent volume changes. At high temperatures, these irreversible effects intensify, resulting in a significant, long-term volume change, in accordance with the reference [20]. All refractory concrete mixes, including the standard mixture, were successful in reaching their target typical drying shrinkage values of less than 0.5 percent permanent linear shrinkage after firing at 2000 F (1090 C), that conforming to the ref [2].

Referred to the table 10, and the Fig .9 and Fig.10, contraction or expansion of the refractory concrete can take place during service. From results shrinkage for refractory concrete, it was observed that shrinkage for the refractory concrete with two types of aggregate (bauxite and magnesia brick) increases with the increasing temperature Fig. 2. The shrinkage during the dehydration was little but increases at high temperature depending on the chemical structure and composition during firing and forming vitreous phase at high temperatures. While expansion happened in refractory concrete that made from alumina brick as aggregate, where this expansion increases with the increasing temperature. Volume increases of refractory concrete explained mainly by oxidation of the unreacted aluminum metal, and recrystallization processes.

But, before exposure to high temperature shrinkage would happened for all types of aggregate used in making refractory concrete and for all ages Fig. 3, due to high speed rate of hydration, which can cause issues with early age cracking, in accordance with the reference [21].

Table 10 :Test result of shrinkage for refractory concrete.

Set No	Shrinkage [%]					
	At air temperature				At different temperature	
	1 day	3 days	7 days	14 days	1000 C°	1100 C°
Mix 1	-0.0594	-0.0629	-0.1118	-0.1258	-0.2341	-0.2691
Mix 2	-0.0175	-0.0279	-0.0454	-0.1118	0.0279	0.0768
Mix 3	-0.0351	-0.0596	-0.1087	-0.1683	-0.1928	-0.2010

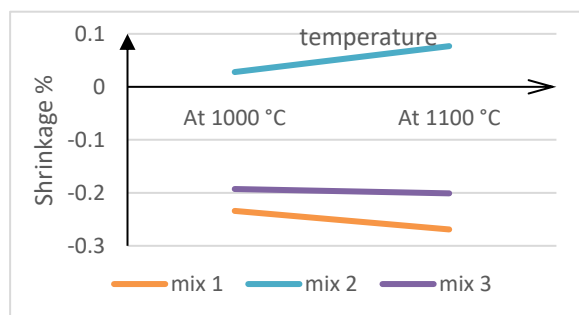


Fig. 9: shrinkage and expansion of refractory concrete at different temperatures.

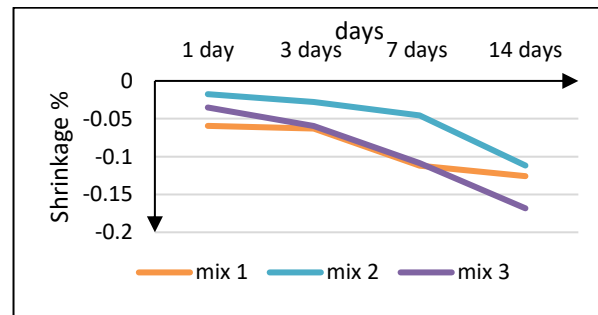


Fig .10: shrinkage of refractory concrete at different ages.

5.3 Compressive Strength

Table 11 and Fig.11 showed the compressive strength for refractory concrete, while Fig.12 showed the test method of compressive strength for samples. The compressive strength for refractory concrete containing (Alumina brick or magnesia brick) as coarse aggregate was lower than refractory concrete made of natural coarse aggregate (bauxite aggregate). This is due to recycle refractory bricks as aggregate, had lower strength and hardness than bauxite aggregate. Therefore replacement of bauxite aggregates by should be done with caution as it can adversely affect the compressive strength, which conform to refs [22,23 and 24]. As well as the reduction in strength may be attributed to six reasons: (i) The crushed bricks failed to develop proper / adequate bond with refractory concrete and alumina cement matrix. (ii) Because of high porosity of the surfaces of the crushed bricks, the mixture needs more water to get the required slump. (iii) The crushed bricks made the mixture unworkable because of roughness of the surfaces of crushed bricks aggregates affecting the compaction distribution upon the refractory concrete layers. (iv) Recycled brick aggregates have a lower rigidity than the natural aggregate. (v) Due to the structural qualities of bauxite and improved compaction. (vi) When crushed bricks are used as aggregate, the porosity of the refractory concrete increases, resulting in a decrease in compressive strength. When comparing the results obtained by replacing bauxite aggregate with recycled alumina bricks as aggregate or recycled magnesia bricks as aggregate, it was found that the strength of concrete was lower when using recycled magnesia bricks as aggregate.

But, at temperature (1000 and 1100) °C would happen a reduction in compressive strength for all types of refractory concrete used in this research. The reduction in strength may be attributed to four reasons: (i). attributed the physicochemical degradation of cement paste and aggregate at elevated temperatures. (ii) During heating the refractory concretes dehydrate causing microstructural changes that can improve or reduce the mechanical strength of the refractories. The behavior of the materials as a function of temperature can be divided into two groups. The quasi-brittle behavior at lower temperatures (from 29 to 300) °C and the visco-plastic behavior at higher temperatures (600–1200) °C, as also observed by other studies. The loss of strength during the conversion process can be explained by the fact that hydrated aluminate products become denser. The conversion, with the release of water, results in an increase in the porosity of the matrix. Thus, the increase in porosity contributes to the damage to the microstructure of the material during compression, generating a larger number of microcracks, which causes a decrease in the mechanical properties, which conform to ref (26). (iii) The aluminum oxide aggregate and high alumina cement do not react at room temperature. Only at temperatures higher than 1350 °C does the reaction with the aggregate begin. (iv) Moreover, the porosity and type of aggregate minerals play an important role in the strength and loss of heated concrete. This indicates that the introduction of excessive water into the refractory concrete based on high-alumina cement, regardless of the type of aggregate, led to deterioration in the concrete's properties. Therefore, the level at which an aggregate type (recycled refractory brick as aggregate) replaces another type (bauxite aggregate) can lead to different values for the strength loss of heated refractory concrete, which conform to ref (26).

Table 11: Test result of compressive strength for refractory concrete.

Set No	Compressive Strength MPa		
	At 25 °C	At 1000 °C	At 1100 °C
Mix 1	13.50	3.26	2.41
Mix 2	11.20	2.41	2.28
Mix 3	9.50	2.39	2.19

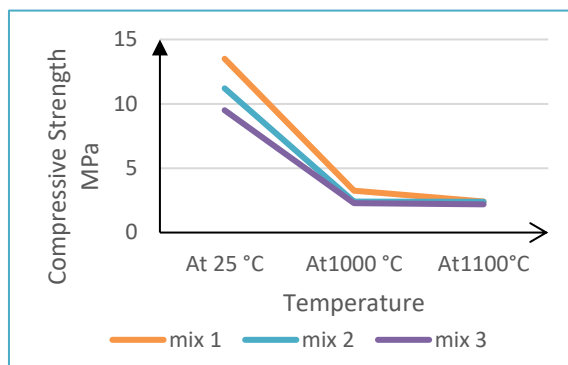


Fig. 11: compressive strength of refractory concrete at different temperature.



Fig.12: Compressive strength testing mechanism.

5.4 Modulus of Rupture

From table 13 and Fig.13 showed the results for modulus of rupture, while Fig.14 showed modulus of rupture test. It can be seen that the modulus of rupture was reduced when replaced natural coarse aggregate (bauxite aggregate) by (Alumina brick or magnesite brick) as coarse aggregate. According to the obtained results, concrete containing on (Alumina brick or magnesite brick) as coarse aggregate has a decreased modulus of rupture, in accordance with references [22, 23 and 24]. The reduction in modulus of rupture may be attributed to the same causes that were mentioned previously in compressive strength with replacement bauxite aggregate with crushed refractory bricks as aggregate. Additional causes were discovered, including, the refractory bricks as aggregate produced by crusher have a lot of mortar on the surface, and micro-cracks on the inside the recycled refractory bricks as aggregate may have significantly changed physical properties, such as absorption and porosity, by either the micro cracks, or the old cement mortar. It was identified that mechanical properties, such as modulus of rupture, were deteriorated severely by the shape and amounts of micro-cracks.

At high temperatures (1000 and 1100)°C would reduction in modulus of rupture for all types of refractory concrete used in this research. The reduction in modulus of rupture may be attributed to the same reasons mentioned previously in the compressive strength test as the temperature increased, and further cause was found, such as: (i) The drop of modulus of rupture as a temperature more than 25 °C was attributed to the weakening of the bonding as a result of microcracks from expansive phase formation. (ii) Metastable (CAH_{10} and C_2AH_8) and stable (C_3AH_6 and AH_3) hydrates are produced when the anhydrous active phase is hydrated. When hydrated at a temperature below 15 °C, the metastable calcium aluminate decahydrate CAH_{10} ($\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 10\text{H}_2\text{O}$) is formed. This material cures isothermally and transforms into dicalcium aluminate octahydrate C_2AH_8 ($2\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 8\text{H}_2\text{O}$) and aluminium trihydroxide (AH_3), which is also referred to as gibbsite, when the temperature rises. But when the temperature rises above 27 °C, these metastable calcium alumina hydrates change into stable tricalcium aluminate hexahydrates, or C_3AH_6 ($3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O}$), which is also referred to as katoite, and AH_3 , which releases water. This reaction, also referred to as a conversion reaction, is dependent on the rise in temperature and moisture content, in accordance with ref [25]. The following equations, (3) and (4), explain this reaction, which is unavoidable. The mechanical and physical characteristics of the high alumina cement -based binder system is impacted by this conversion reaction. Porosity is formed when water is released from the matrix, hydrating the anhydrate phases and causing a decrease in strength. However, after the formation of stable denser cubic C_3AH_6 , the long-term strength gain is stable, in accordance with ref [25].

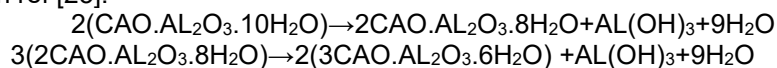


Table 12: Test result of modulus of rupture for refractory concrete.

Set No	Modulus of rupture MPa		
	At 25 °C	At 1000 °C	At 1100 °C
Mix 1	4.45	1.17	1.05
Mix 2	3.52	0.82	0.77
Mix 3	3.05	0.73	0.7

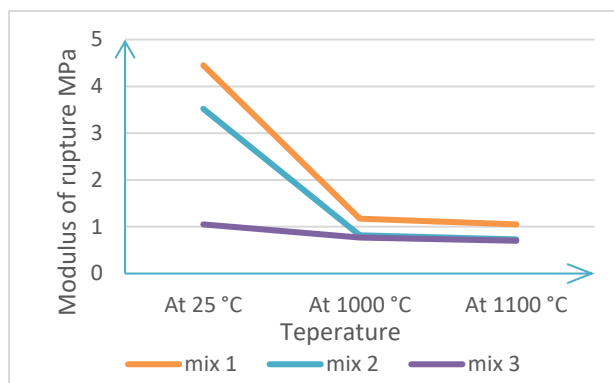


Fig .13 :modulus of rupture for refractory concrete. at different temperature



Fig .14: Modulus of rupture testing mechanism.

5.5 Weight change

From table (14), and Fig.15 showed the results of weight change. where increased in weight of refractory concrete before heating can be attributed to the pores remaining from the excess water in the concrete. Overall, when the free-water content of the refractory concrete increases, the drying of the liquid leaves behind empty voids without free water that led to reduction in weight of all mixes refractory concrete used.

While the weight change that happened in refractory concrete containing (Alumina brick or magnesia brick) as coarse aggregate was lower than refractory concrete made of natural coarse aggregate (bauxite aggregate), this is due to more voids that content on excess water.

Table 13: Test result of Weight change for refractory concrete.

Set No	Weight change%	
	At 1000 °C	At 1100 °C
Mix 1	-6.32	-6.68
Mix 2	-10.18	-10.42
Mix 3	-10.04	-10.39

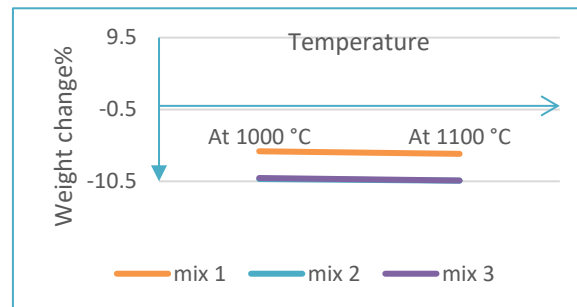


Fig .15 :Weight change for refractory concrete at different temperature

6 Conclusion

The following inferences can be made in light of the testing method used:

- 1.The hardened properties compressive strength, modulus of rupture and bulk density for refractory concrete produced by demolished brick (alumina or magnesia) as coarse aggregate were less than that of refractory concrete produced by natural crushed aggregate (bauxite).
- 2.Results indicated to increase in loss the weight of refractory concrete with demolished brick (alumina or magnesia) as coarse aggregate. This is mainly due to the high porosity content on free water.
- 3.Shrinkage decreased when using demolished brick (alumina or magnesia) as aggregate compared to bauxite aggregate at normal temperature.
4. At high temperature (1000 and 1100) °C, compressive strength, modulus of rupture, bulk density and weight change would reduce.
- 5.Refractory concrete that produced by bauxite and magnesia brick as aggregate happened shrinkage, while that produced by alumina brick would happen expansion at high temperature (1000 and 1100) °C.
6. According to the results, recycled brick (alumina or magnesia) can be used as aggregate in refractory concrete.
7. In future research, can study the effects of slag application or white kaolin on the characteristics of refractory concrete that is manufactured from alumina cement with crushed refractory bricks as aggregate

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