# INVESTIGATION OF POROUS LIGHTWEIGHT AGGREGATES

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## Abstract

Research on the production of lightweight refractory concrete using Mongolian raw materials was carried out in collaboration with scientists from the Freiberg Mining Academy in Germany. Two different manufacturing processes were used for sample preparation. The monocalcium aluminate (CA) and calcium dialuminate ($CA_2$) offsets were burned at 1000°C, 1100°C, 1200°C and 1300°C. The holding time of the samples was 3 hours for all fires without any special requirements for the heating rate. After the burning, tests were carried out on the samples (determination of bulk density, measurement of splitting tensile strength, determination of thermal conductivity, SEM, etc.)

## Introduction

In 2020, Mongolia produced 16.7 thousand tons of steel products, 1182.2 thousand tons of cement, 70.2 thousand tons of lime and 20 million pieces of ceramic bricks [1]. These are industries that use fire-resistant thermal insulation materials.

G.Saran and Ts.Jadambaa conducted a study of thermal insulation foam bricks using refractory kaolin from Mongolia and produced foam chamotte bricks with a bulk density of 500, with a compressive strength of 1.84 MPa and a thermal conductivity of 0.28 W/(m·K) at 1000 °C [2]. However, no study of calcium aluminate-based thermal insulation materials has been conducted in Mongolia.

The compounds of calcium alumina were used for microporous insulation materials. The microporous insulation materials have extremely low thermal conductivity values of 0.02-0.03 (W/m·K). This is achieved by pore sizes less than 0.1 µm, which hinders the transfer of heat through convection and radiation [3].

Porous lightweight thermal insulation materials are obtained by the foaming and the gas-driven method. With the two processes, porosities are preferably 75 to 85%, in special cases up to 95%. In the foaming process, stable foams are first produced from about 99% water and 1% organic foaming agents.

To produce the lightweight refractory brick using the foam method, the raw material must be mixed with water in a fine-grained form with a grain size of less than 0.1 mm to form a slip [4-7].

## Methods And Materials

Monocalcium aluminate and calcium dialuminate were produced using aluminum hydroxide of AlCOA company in Germany and lime obtained from Mongolian Khutul limestone. Due to the uneven extinguishing behavior of quicklime, were decided to use calcium hydroxide. This counteracts the regrowth effect on the test samples caused by free calcium oxide. First, burning experiments were carried out with the limestone from Khutul. The limestone was burned at 950-1000 degrees Celsius for 4,5 and 6 hours. Lime reactivity was 89.56-93.12. Therefore, we burned limestone at 1000 degrees for 4 hours and used it for testing. The use of alumina ($Al_2O_3$) in the two-component system ($CaO - Al_2O_3$) has not proven itself due to poor reactivity to the hydroxide hydrargillite ($Al(OH)_3$). Three types of foaming agents were used, and cellulose was added as a foam stabilizer. The slurry was prepared using the ingredients given in Table 1 and autoclaved. The hydrothermal hardening was carried out at 191°C and 1.3 MPa with a hard ening time of 10 hours. The test sample was dried quickly and burned at 1000- 1300°C. The pore characteristics of the raw materials and calcium aluminate were investigated by scanning electron microscopy analysis (Zeiss GeminiSEM-500, Germany), by thermal conductivity meter (G HP500, Netzsch, Germany) and by mercury porosimeter (Autopore IV 9510, Micromeritics, USA).

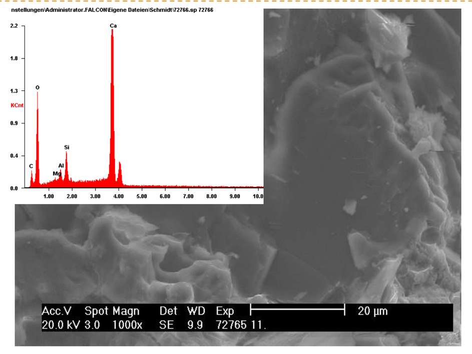


**Figure 1.** SEM images of limestone from Khutul

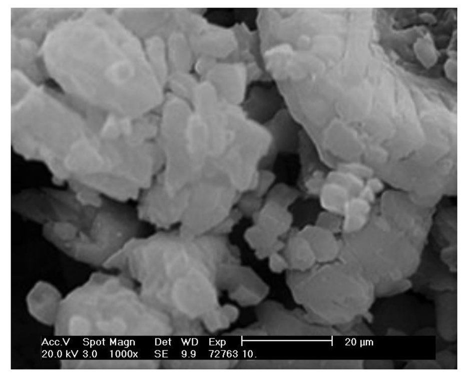


**Figure 2.** SEM images lime from Khutul

## Results

The calculations of offsets CA and $CA_2$, which should correspond to the stoichiometric ratios of these compounds formed after the high-temperature treatment, have been calculated based on the reaction equations for a complete conversion. The offsets CA and $CA_2$ were thermally treated at burning temperatures of 1000 to 1300 degrees Celsius with a holding time of 3 hours, because sintering phenomena were noticeable in these offsets from 1200 degrees Celsius. The bulk density of the samples increases with the increasing burning temperatures. In offset CA, the bulk densities were between 0.26-0.59 g/cm$^3$, depending on the composition and firing temperatures. And in offset $CA_2$ the bulk densities were between 0.25-0.79 g/cm$^3$. The X-ray examinations allow the conclusion that a desired or expected mineral formation according to the given combinations of substances such as tobermorite and xonotlite has occurred at high temperatures.

**Table 1.** Combination of foamer and offsets

| Offsets | moisture content, [%] | W 53 (%) | W53+Z (%) | G1010 (%) | G1010+Z (%) | 285 (%) |
|---|---|---|---|---|---|---|
| CA | 150 | 3.00 | 3.00+1.50 | 0.05 | 0.05+1.50 | 1.00 |
| $CA_2$ | 150 | 3.00 | 3.00+1.50 | 0.05 | 0.05+1.50 | 1.00 |

**Chart 1.** Thermal conductivity values of CA offsets , W/(m·K)

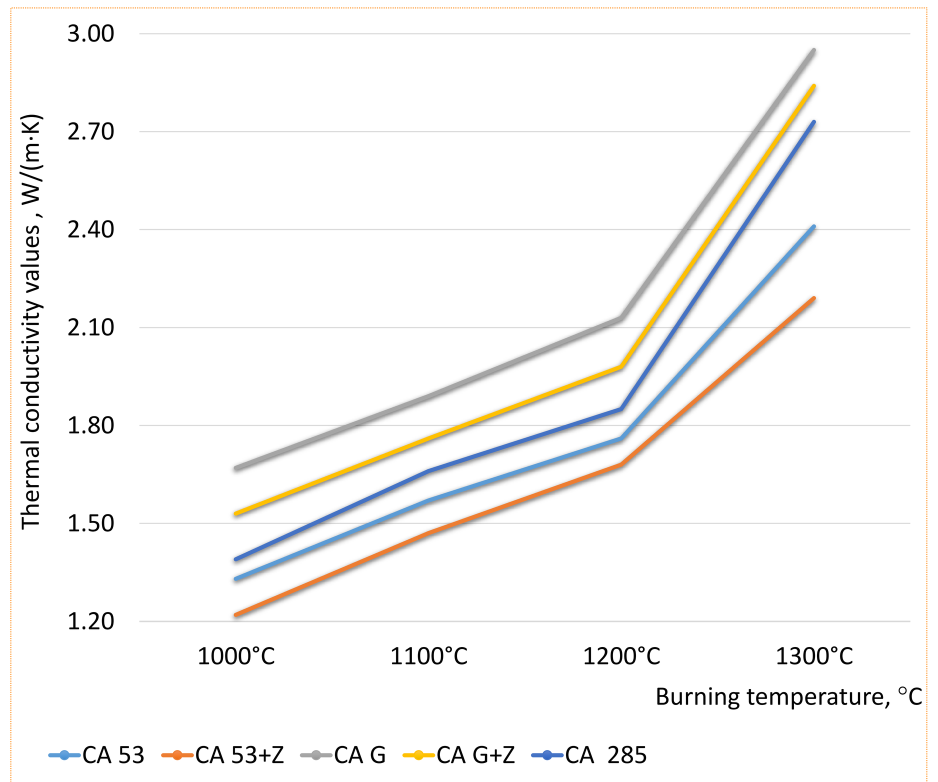



**Chart 2.** Thermal conductivity values of $CA_2$ offsets , W/(m·K)

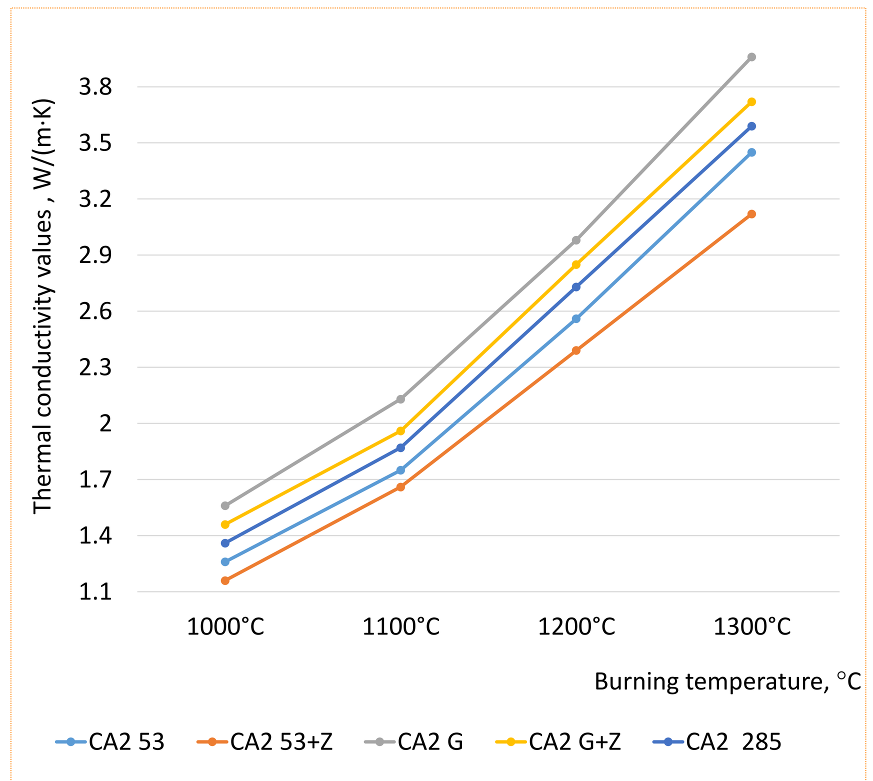



**Figure 3.** X-ray diffraction patterns of CA at 1000°C

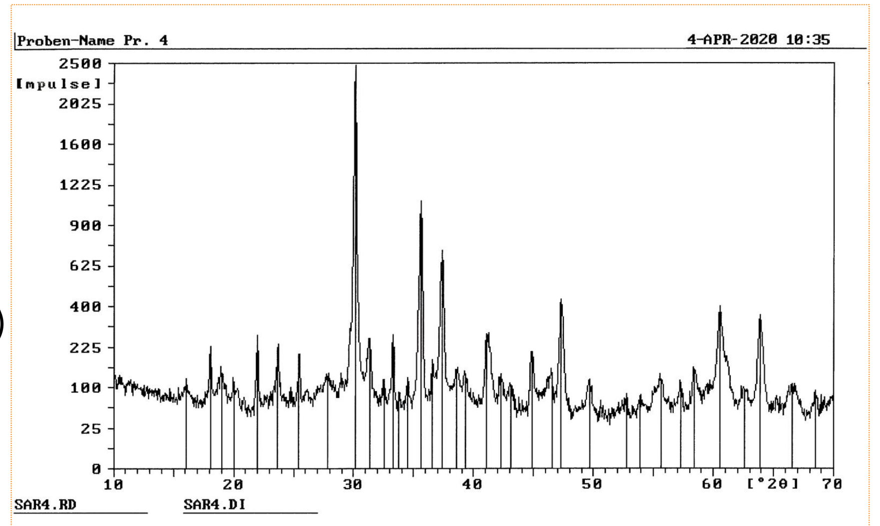
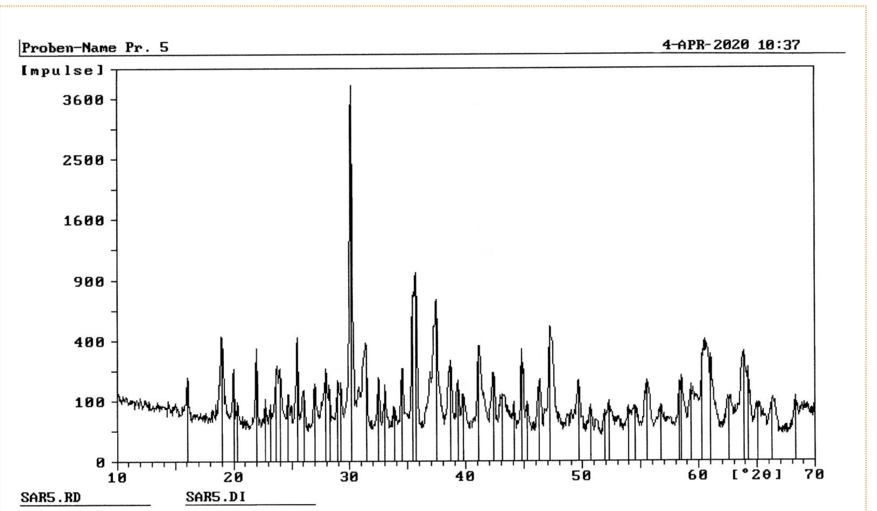


**Figure 4.** X-ray diffraction patterns of CA at 1300°C



## Discussion

The total porosity of offset CA was between 78-85%, depending on the temperature. The total porosity decreases with increasing temperature. This sample showed a decrease in porosity with increasing temperature, which can also relate to the formation and regeneration of minerals of the compound CA and the resulting changes in the microstructure.

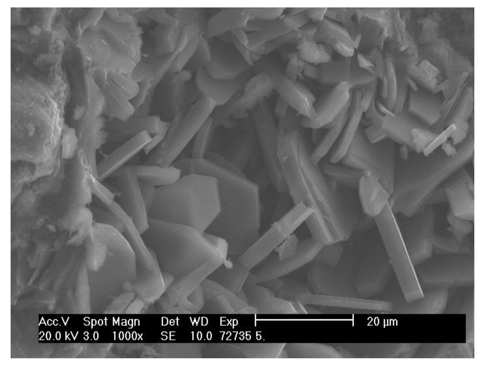


**Figure 5.** SEM of CA at 1000°C

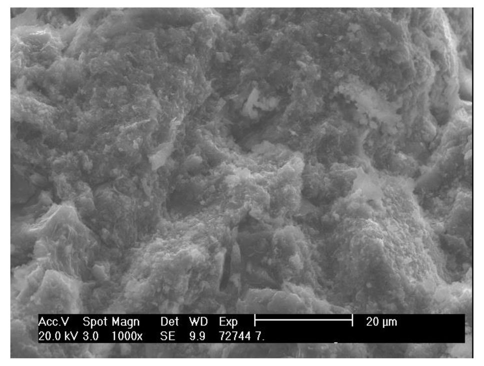


**Figure 6.** SEM of CA at 1300°C

## Conclusions

Lightweight aggregates produced and hydrothermal hardened using foam technology had low bulk densities, above all very low thermal conductivity, favorable splitting tensile strengths and high porosity. CA offsets showed tensile strengths of 1.22-1.67 MPa at 1000°C, 1.47-1.89 MPa at 1100°C, 1.68-2.13 MPa at 1200°C and 2.19-2.95 MPa at 1300°C. $CA_2$ offsets showed tensile strengths of 1.16-1.56 MPa at 1000°C, 1.66-2.13 MPa at 1100°C, 2.39-2.98 MPa at 1200°C and 3.12-3.72 MPa at 1300°C. The offset with monocalcium aluminate (CA 53) shows the lowest thermal conductivity values. The thermal conductivity values for this offset were 0.099 W/(m·K) at room temperature and 0.234 W/(m·K) at 1169 degrees Celsius. The tensile strength values of the samples, which were burned at over 1100 degrees Celsius, meet international standards for lightweight refractory bricks.

## Future Directions

In this study, only light refractory concrete aggregates could be produced. In the future, it is necessary to produce high-temperature equipment and other thermal insulation boards and materials from domestic raw materials. It is also necessary to import and use aluminum oxide to produce calcium aluminates. It is also necessary to study the possibility of replacing it with domestic raw materials.

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