

## Influence of Zeolite on the Mineralogical Properties Autoclaved Aerated Concrete

Mustafa Albayrak

Mineral Research and Exploration General Directorate (MTA), 06520, Turkey

and

Turhan Ayyildiz\*

Ankara University, Faculty of Engineering, Department of Geological Engineering, 06100, Turkey

Received: 10 December 2002; accepted: 05 March 2003

Tobermorite family to cement chemistry exhibits base exchange behavior. Zeolite (clinoptilolite) is synthesized for Al-substituted tobermorite ( $11^0\text{A}$ ), 90  $\mu\text{m}$ , instead of quartz around 50  $^{\circ}\text{C}$  for 4 h and autoclave at 200  $^{\circ}\text{C}$  produces smaller crystallites and exhibited larger radial platelets. Tobermorite content material show that bulk density increases sharply with decrease in Al. Bulk density values increase regularly with increase in compressive strength values. Porosity diameter of the samples increase with increases in quantity of aluminum, however, strength of material decreases. As a result, it is shown that use of clinoptilolite, instead of quartzite saves energy and has industrial application.

**Keywords:** Zeolite, Autoclaved aerated concrete, Concrete, Cement chemistry, Clinoptilolite, Tobermorite, Mineralogical properties

### Introduction

Tobermorite is a hydrous calcium silicate, which occurs as a platy mineral in calcium silicate rocks. During steam curing, C-S-H aggregates are formed initially and later by reaction with dissolved silica from quartz, tobermorite ( $5\text{CaO}\cdot 6\text{SiO}_2\cdot 5\text{H}_2\text{O}$ ) is formed as a main binder. Some workers have shown that the hydrothermal reactions in the  $\text{CaO-SiO}_2$  systems are controlled by the dissolution of quartz<sup>1,2</sup>. Tobermorite is technologically important because it is binding agent for autoclaved concrete. Megaw and Kelsey<sup>3</sup> have determined the crystal structure of a naturally occurring tobermorite. It has been found that the tobermorite family, fundamental to cement chemistry can exhibit base exchange behaviour. Several Al-substituted tobermorites were synthesized with silica, kaolinite, and clinoptilolite<sup>4,6</sup>. Mitsuda and Taylor<sup>7</sup> have pointed out that with clinoptilolite (siliceous zeolite) the formation of tobermorite was fast.

In this investigation the effect of Al on the formation of Al-substituted tobermorite from C-S-H was investigated using clinoptilolite. Mineralogical and mechanical properties of material with tobermorite are presented.

### Material and Methods

Zeolite, used in this study, was obtained from G\u00f6rdes (Manisa-Turkey) Zeolite Works. XRD analyses were studied by Rigaku Geiger Flex X-ray Diffractometer (MTA) and chemical analyses was determined by XRF technique (Rigaku RIX 3000 Spectrometer-MTA). Mineralogical analyses was also carried out by Scanning Electron Microscope (SEM)-LEO 435 at Turkish Cement Cooperation. Considering the proportions of the raw mixtures,<sup>2,8,9</sup> block samples were prepared with mean ratio of  $\text{Ca}/(\text{Al}+\text{Si}) = 0.48$ . In all the samples, clinoptilolite (90  $\mu\text{m}$ ) was used, instead of quartz. The mixtures were cast in a 16x4x4 cm mold, hardened at atmospheric pressure at 50  $^{\circ}\text{C}$  for 4 h and later autoclaved at 200  $^{\circ}\text{C}$  under saturated steam pressure of 11.5 bars for 12 h.

\*For correspondence  
Email: ayyildiz@eng.ankara.edu.tr

**Results and Discussion**

*Mineralogical and Chemical Analyses of Zeolite and AAC Samples*

The samples were performed using XRD analyses. Clinoptilolite and cristobalite minerals were determined from ASTM Card (Figure 1). Samples were heated to 800 °C, clinoptilolite shows durability behavior up to 750 °C, over 750 °C structure of the clinoptilolite was deformed and became amorphous. At the 1150 °C, it was amorphous, light brownish to yellow in colour, consisting opal CT, quartz, and

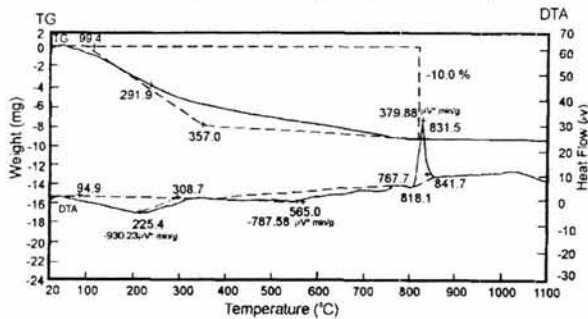


Figure 1— X-ray diffractometer (XRD) pattern of clinoptilolite

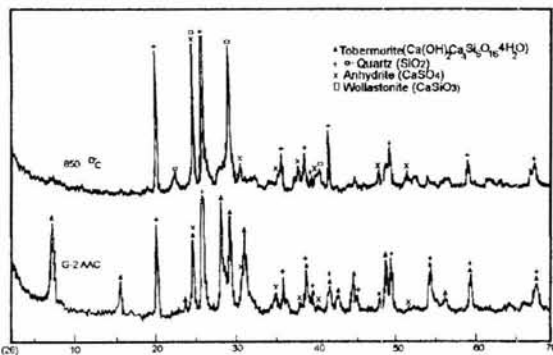


Figure 2 — X-ray diffractometer (XRD) pattern of clinoptilolite after treatment between 900 and 1300 °C

some feldspar (Figure 2). Opal CT and quartz were observed at 1300 °C and its colour changed from dark gray to leaden. Anhydrate, amorphous, clinoptilolite, tobermorite (11A<sup>0</sup>) and calcite minerals were determined by XRD, using casting and the autoclaved aerated samples by using clinoptilolite. The major and minor elemental analyses of zeolite samples are shown in Table 1 and 2.

Scanning Electron Microscopy (SEM) studies were done for samples, including clinoptilolite and autoclaved aerated samples. Different grain sizes of zeolite samples were investigated (Figure 3 a, b). SEM photographs of Al-substituted tobermorites produced by clinoptilolite syntheses are shown in Figure 3 (c-f). Al-substituted tobermorite exhibited small lathlike crystallites. On the other hand, some samples exhibited larger radial platelets, which are the typical morphology. Energy Dispersive Analyses (EDS) results of zeolite and tobermorite are given in Figure 4 and 5.

Table 2 — Minor element analyses results

Sample No.	Per cent Ti	Per cent Ag	Per cent Ni	Per cent B
S1	0.01	N d	N d	N d
S2	0.01	N d	N d	N d
S3	0.007	N d	N d	N d
S4	0.02	N d	N d	N d
S5	0.02	N d	N d	N d
S6	0.015	N d	N d	N d

Detection limits: 0.0004 per cent 0.004, 0.01

n d: Not determined

Table 1— Major element analyses results

Sample No.	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	K <sub>2</sub> O	CaO	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	L.O.I
S1	0.3	1.1	12.5	71.5	3.8	2.0	1.3	-	7.10
S2	0.5	1.5	13.2	70.5	3.3	1.9	1.9	-	7.15
S3	0.5	0.8	12.6	70.5	5.0	2.2	1.5	-	6.75
S4	0.9	0.9	12.7	70.7	3.5	2.5	1.4	-	7.35
S5	0.5	1.0	11.9	72.0	4.2	2.0	1.3	-	7.20
S6	0.4	2.0	14.5	67.0	1.7	3.1	0.7	-	10.55
S7	0.6	0.8	12.0	73.0	3.6	1.8	1.0	0.1	6.75

*X-ray Diffraction and Thermal Analyses of Products*

Typical TG/DTA curve of commercial G-2 grade AAC is shown in Figure 6. Two endothermic reactions observed for AAC between 95 – 309 °C and at 565 °C are due to loss of molecular water and conversion of  $\alpha$ - SiO<sub>2</sub> to  $\beta$ - SiO<sub>2</sub>, respectively. The sharp exothermic reaction at 831 °C is associated with crystallization of wollastonite. These changes are in good agreement with the XRD pattern,

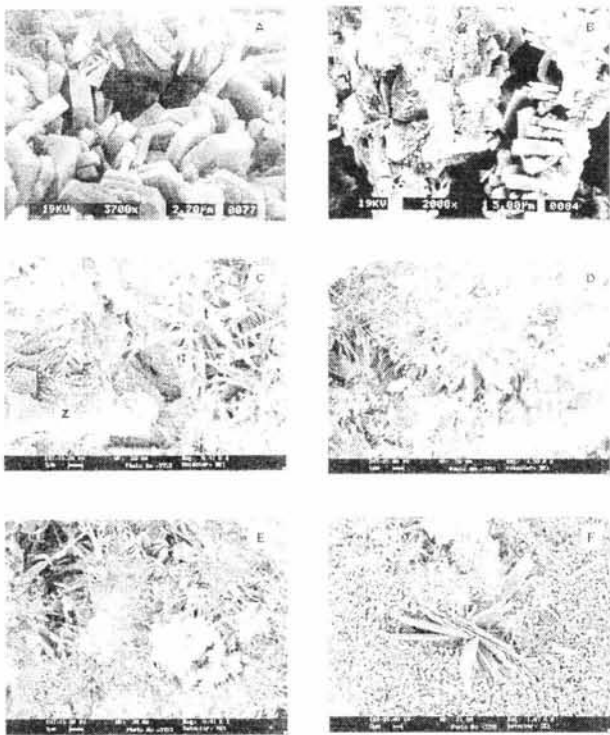


Figure 3 (a, b) — Scanning Electron Microscopy (SEM) photomicrograph of the different sizes clinoptilolite, (c) Scanning Electron Microscopy photomicrograph of tobermorite (t) and zeolite (z), (d, e, f) Scanning Electron Microscopy photomicrograph of Al-substituted tobermorites

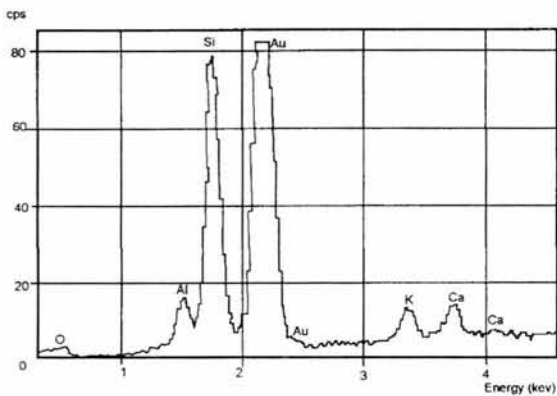


Figure 4 — Energy Dispersive Analyses (EDS) diagram of zeolite

obtained for AAC at 25<sup>0</sup>C and 850 °C, respectively (Figure 7).

*Mechanical Properties*

Autoclave samples were analyzed for bulk density, compressive strength, flexural of strength, and elasticity modulus method. It has been observed that bulk density values were between 0.2 g/cm<sup>3</sup> – 0.6 g/cm<sup>3</sup>, while compressive strength values were between 2 kgf / cm<sup>2</sup>-33 kgf / cm<sup>2</sup>. Bulk density values were shown to increase with rising compressive strength values. The porosity diameter of the produced samples changes due to aluminum quantity and porosity diameters of the material varied between 0.5 and 3 mm. Porosity diameter of the samples increased with rising in aluminum quantity, however, strength of material decreased. In addition, constants for heat conductivity were calculated. As a result, constant of the heat conductivity were similar to those produced by zeolite and quartz material<sup>10</sup>.

**Conclusion**

In conclusion, Al-substituted tobermorite (11A<sup>0</sup>) is produced, using zeolite (clinoptilolite). However,

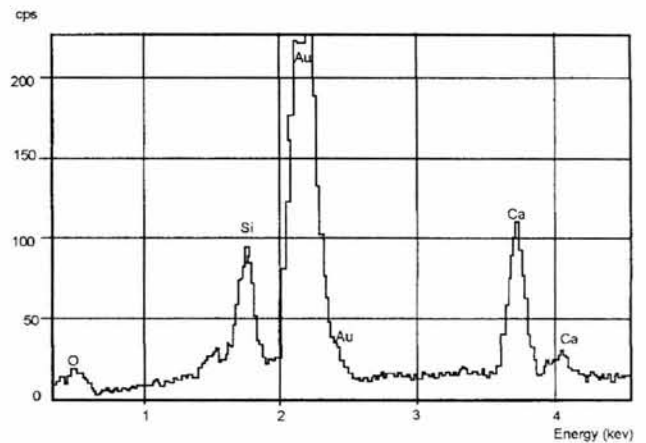


Figure 5 — Energy Dispersive Analyses (EDS) diagram of tobermorite

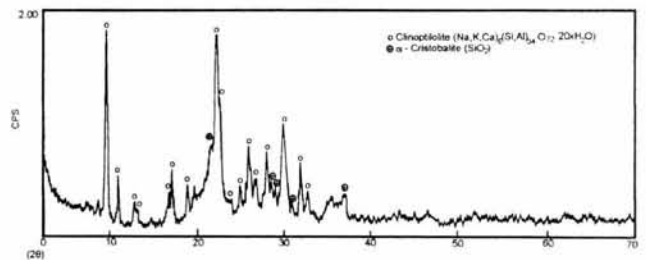


Figure 6 — TG/DTA curve of commercial G-2 grade AAC

