

Investigations of Chrysotile Asbestos Application for Sintered Ceramics Obtaining

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Abstract

Asbestos is a serious health hazardous substance and its removal is a priority for pollution prevention. The destruction of the tubular structure of asbestos can be achieved by means of thermal treatment. In order to characterize the changes accompanying thermal treatment, both natural chrysotile asbestos and calcined asbestos were subjected to the thermogravimetric and differential thermal analysis, X-ray diffraction phase analysis and examination by scanning electron microscopy. The results of laboratory investigations of using calcinated chrysotile asbestos to production of sintered ceramics (stoneware) are presented.

Keywords: Asbestos, Calcination, Chrysotile, Sintered ceramics, Microstructure – final

BADANIA NAD ZASTOSOWANIEM AZBESTU CHRYSOTYLOWEGO DO WYTWARZANIA CERAMIKI SPIEKANEJ

Azbest jest substancją bardzo niebezpieczną dla zdrowia i jej usunięcie jest priorytetem w przypadku zapobiegania zanieczyszczeniu środowiska. Rozpad rurkowej struktury azbestu można wywołać za pomocą obróbki cieplnej. Azbest, zarówno naturalny chrysotylowy jak i kalcynowany, poddano termogravimetrycznej i różnicowej analizie termicznej, rentgenowskiej analizie fazowej i oględzinom z użyciem skaningowego mikroskopu elektronowego, aby scharakteryzować zmiany towarzyszące obróbce cieplnej. Przedstawiono wyniki badań laboratoryjnych nad wykorzystaniem azbestu chrysotylowego do wytwarzania ceramiki spiekanej (wyroby kamionkowe).

Słowa kluczowe: azbest, prażenie, chryzotyl, Ceramika spiekana, mikrostruktura finalna

1. Introduction

Asbestos minerals have been used for a number of applications due to their excellent physical properties that include non-flammability, high tensile strength, heat and electrical insulation and resistance to chemical and biological attack. They were widely used as components of buildings and materials including insulations, acoustic and thermal sprays, pipe and boiler wraps, plasters paints, flooring products, roofing materials, and cementitious products [1–4].

The word „asbestos” refers to several types of fibrous minerals. There are many different types of asbestos fibres, divided into two main categories: amphibole and serpentine asbestos. The group of serpentine includes only chrysotile. Others belong to the group of amphiboles; they are: crocidolite, amosite, tremolite, antophyllite, and actinolite. Chrysotile (white asbestos), crocidolite (blue asbestos) and amosite (brown asbestos) have the widest industrial applications [1, 5, 6]. The evidence concerning the asbestos carcinogenicity began to accumulate in the sixties. The first ban on the use of the material started in eighties. Asbestos is considered to be extremely hazardous for people, causes lung diseases, like asbestosis or lung cancer [1, 5–11].

The tendency to limit the use of asbestos appeared in Poland several years ago. At present there is one method of

depositing asbestos containing products. Asbestos products and asbestos wastes are packed into polyethylene foil bags and stored in special stockyards designated for dangerous wastes [2, 3].

However, such a procedure does not represent a final solution of the problem of disposal of asbestos wastes.

1.1. Methods of rendering asbestos and the asbestos containing materials harmless

In the UE countries the regulations of the asbestos wastes recycling are obligatory in order to reduce their hazardous influence on the environment.

The professional literature presents a number of ways, mainly the patented ones that concern the utilization and neutralization of asbestos and the asbestos products. Most literature reports concerning both the basic research as well as the utilitarian one, concern the chemical treatment of the waste, where the compounds from the serpentine and amphiboles group are decomposed using strong bases and inorganic as well as organic acids [12].

One of the patents presents treating asbestos with a concentrated solution of NaOH in a reactor – autoclave at 175–200°C and under the pressure of 0.3 to 1.0 MPa. The

waste obtained after the decomposition may be utilized for the production of cement [13].

A lot of literature reports concern the destruction of asbestos using strong inorganic acids (for example sulphuric acid) and various organic acids [14–17]. The next method [18] consists of treatment with acid in the presence of the fluorine ions. The secondary products of utilization, emitted in a solid form are then utilized as fillers in the production of the fireproof materials or in the building industry.

A new method elaborated in [12] consist in the digestion of the asbestos wastes in a strongly acidic environment of the phosphoric acid. After the neutralization with calcium hydroxide or calcium carbonate the solution can be processed to phosphate fodders or to phosphate fertilizers and silica which will be examined in respect to its potential application as an active material or a filler in the building and the plastic industries.

Other suggested methods to render harmless toxic asbestos materials are: mechanochemical treatment [19], vitrification [20, 21] as well as thermal treatment and recycling in the clinker burning process and traditional ceramics (refractories and building materials).

Chrysotile asbestos was the subject of present paper which was supplied to the chlorine industry.

We describe the recycling of thermally treated asbestos as a raw material for the production of sintered ceramics (stoneware).

2. Experimental

During the first stage of investigation the changes proceeding at temperatures up to 1000°C for asbestos fibres were determined. The testing methods applied:

- differential thermal analysis (DTA) and thermogravimetry (TG, DTG),
 - X-ray diffraction phase analysis (XRD),
 - scanning electron microscopy (SEM).
- DTA, TG and DTG, were performed using a Paulik-Paulik-Erdey (MOM, Hungary) type derivatograph within the range of temperature 20–1000°C. The conditions: air atmosphere, heating rate 10 Kmin⁻¹, alumina crucible, mass of sample 500 mg, Al₂O₃ as the reference material.

X-ray powder diffraction analysis of the examined samples was carried out using a XRD-3003TT type X-ray diffractometer (Seifert), equipped with a copper anode generating Ni – filtered CuK α radiation. ICDD files were used to identify the crystalline phases.

The microstructure of samples was examined by scanning electron microscope (Tesla BS 340, the Czech Republic and Hitachi S-3400N).

The aim of second the stage was the examination of the possibilities of using asbestos calcinated at 700°C (soaking time at this temperature was 3 h) for the manufacture of sintered ceramics. Standard mixtures for stoneware were prepared, *i.e.*, calcinated asbestos or quartz sand (the component which reduces shrinkage) was mixed with “Zapniów” clay (plastic component) and “Strzeblów” feldspar – quartz material (flux). The mixtures were homogenized in a ball – mill for 40 min. The composition of mixture of raw materials: clay – 60 mass.%, calcinated asbestos or quartz sand – 30 mass.%, feldspar – 10 mass.%. There were raw materials

differing in grain size, first with the grain size 0.2–1 mm and the second: < 0.2 mm. In the second case calcined asbestos was subjected to short – time (30 min) homogenisation in a laboratory vibration mill. The green compacts of 30 mm in diameter and about 30 mm in height (8–10 % of water, uniaxial pressing of 40 MPa) were fired at 1150, 1200 and 1250°C for 1 h. Linear shrinkage, water absorption, open porosity, apparent density and compressive strength were measured on representative samples, following standard laboratory procedures. Microstructure was also observed via SEM.

3. Results and discussion

Within the range of temperatures from 600 to 800°C chrysotile Mg₃(Si₂O₅)(OH)₄, loses its chemically bonded water (endothermic peak with a minimum at 710°C on DTA). Crystallization of forsterite Mg₂SiO₄ is observed on DTA curve as an exothermic peak of T_{max} = 840°C (Fig. 1). The presence of forsterite has been confirmed by X-ray analysis of calcined asbestos (Fig. 3).

SEM image of natural chrysotile asbestos (Fig. 4) shows the typical bundle of long chrysotile fibres. As a result of calcination at 700°C for 3 h the fibres are converted into strips of forsterite of various sizes (Fig. 5). Homogenization in a vibration mill generated the material of a more uniform size (Fig. 6).

The use of calcined asbestos, as a non plastic component of ceramic mass, instead of quartz sand, has decreased sintering temperature of ceramics and caused that more dense bodies were obtained (Tables 1 and 2). Microstructure of chosen ceramic samples is presented in Figs. 7 and 8.

The best results were obtained when the samples containing calcinated asbestos were sintered at 1200°C, and grain size of raw materials was below 0.2 mm: high compressive strength equal to 145 MPa, low water absorption and open porosity equal to 1.7 % and 7.9 %, respectively

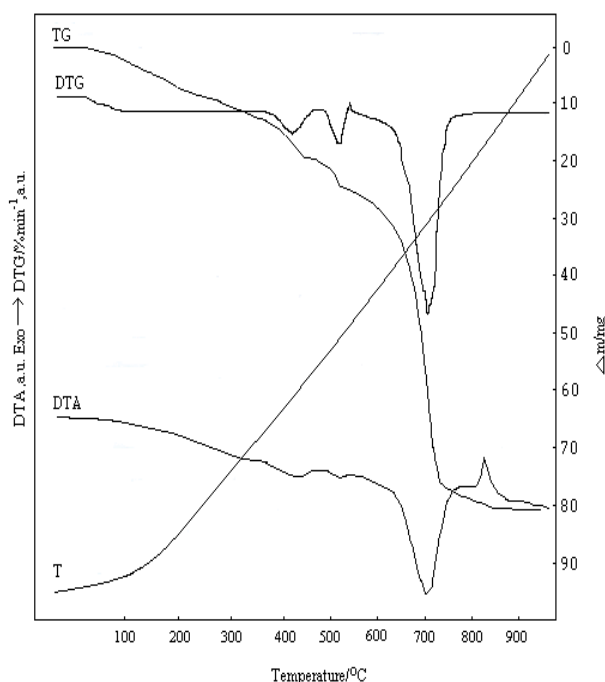


Fig. 1. DTA, TG and DTG curves for chrysotile asbestos.

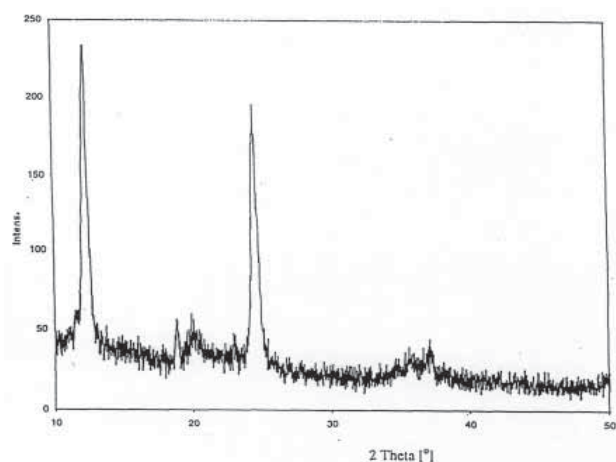


Fig. 2. XRD profile of chrysotile asbestos.

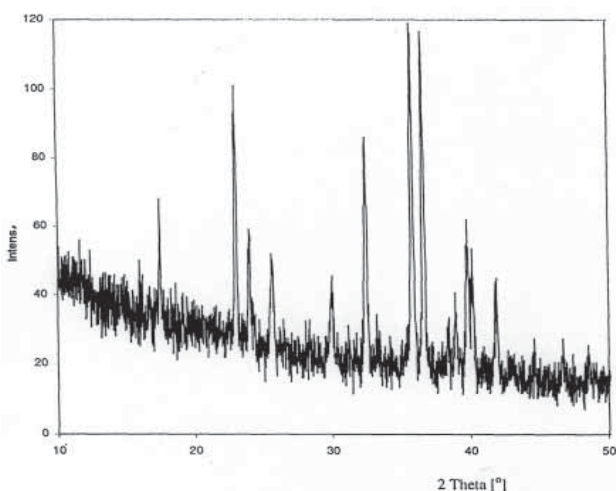


Fig. 3. XRD profile of chrysotile asbestos calcined at a temperature of 700°C (forsterite).

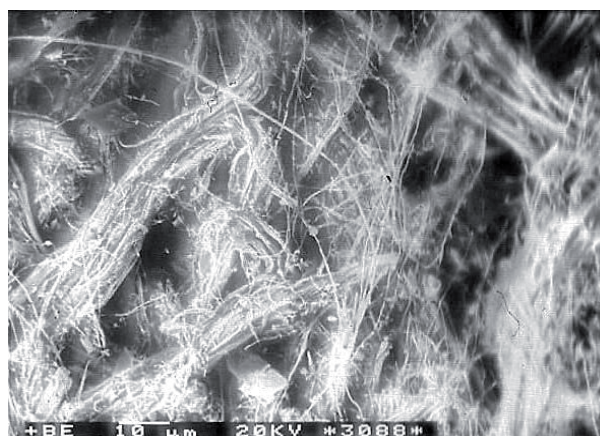


Fig. 4. SEM image of chrysotile asbestos.

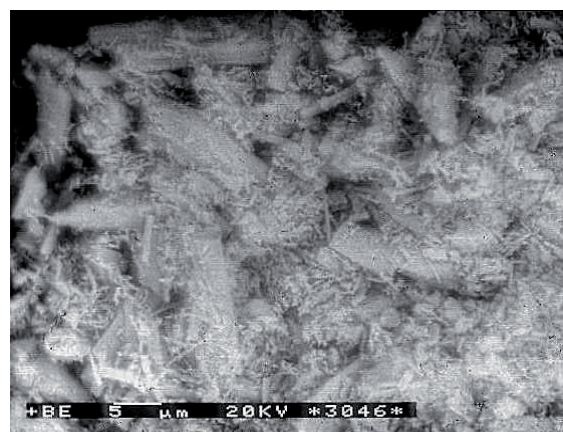


Fig. 5. SEM image of chrysotile asbestos after heating at 700°C, transformation into forsterite.

Table 1. Physical properties of test ceramic products (grain size of raw materials: 0.2–1 mm).

	Ceramic mass with quartz sand			Ceramic mass with calcined asbestos		
Calcination temperature [°C]	1150	1200	1250	1150	1200	1250
Linear shrinkage [%]	0.1	0.6	1.8	6.4	7.0	6.0
Water absorption [%]	8.9	7.5	6.6	9.3	5.1	7.4
Open porosity [%]	19.4	16.4	14.7	20.5	11.9	16.0
Apparent density [g/cm ³]	2.13	2.20	2.22	2.19	2.30	1.83
Compressive strength [MPa]	50	63	83	60	79	17

Table 2. Physical properties of test ceramic products (grain size of raw materials < 0.2 mm).

	Ceramic mass with quartz sand		Ceramic mass with calcined asbestos	
Calcination temperature [°C]	1150	1200	1150	1200
Linear shrinkage [%]	0.4	0.9	8.1	10.4
Water absorption [%]	9.6	8.1	7.9	1.7
Open porosity [%]	20.6	17.9	17.8	3.9
Apparent density [g/cm ³]	2.08	2.15	2.24	2.39
Compressive strength [MPa]	39	77	91	145

(Table 2). Water absorption is one of the most important parameters to determine the technical properties of ceramic products. Water absorption and open porosity provide an immediate indication of the sintering degree of the material. An example of properties which depend on the porosity is constituted by mechanical resistance. Linear shrinkage is related to the compactness resulting from the degree of sintering and development of a glassy phase during firing. A consequence of a high temperature firing process is that material undergoes considerable shrinkage (10.4 %, Table 2). Increase of sintering temperature from 1200 to 1250°C causes worsening of properties of ceramic samples containing calcined asbestos. The samples have expanded what resulted in the increase of open porosity and water absorp-

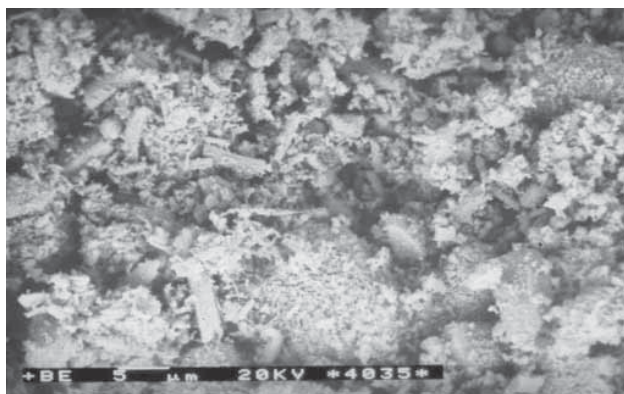
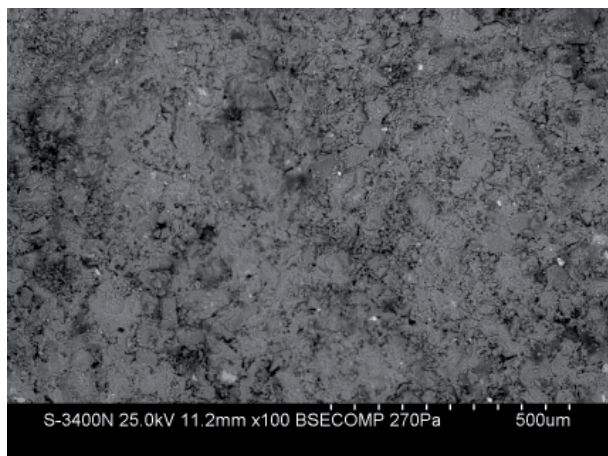
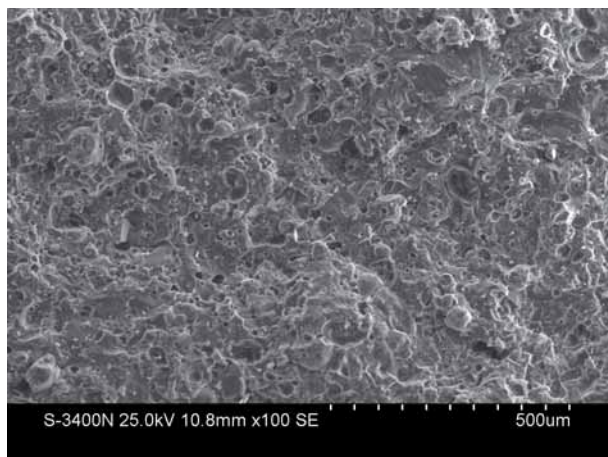


Fig. 6. SEM image of chrysotile asbestos after calcination at 700°C and milling in a vibration mill.



a)



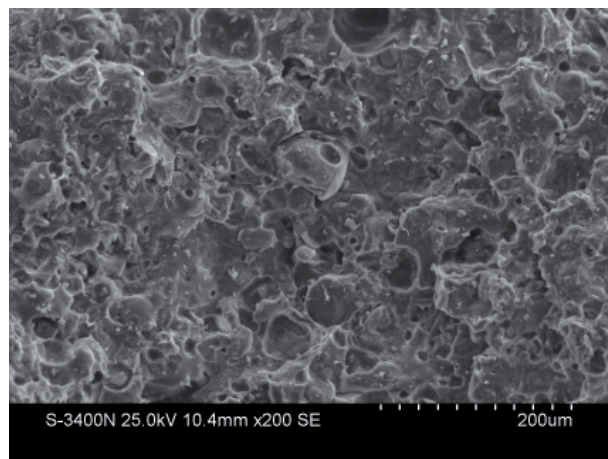
b)

Fig. 7. SEM image of fracture ceramics (based on calcinated asbestos; grain size of raw materials < 0.2 mm) sintered at: a) 1150°C, b) 1200°C.

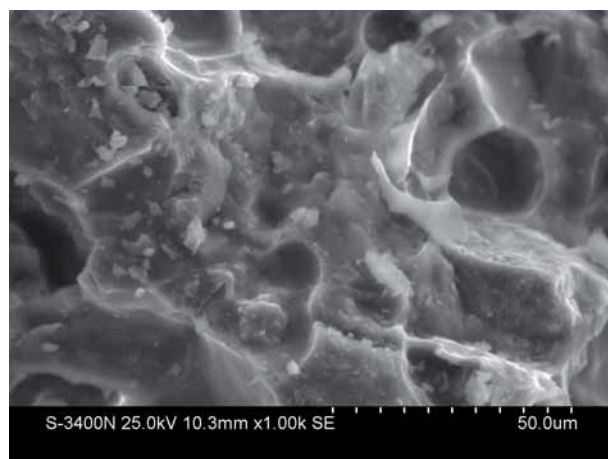
tion and the decrease of apparent density and compressive strength (Table 1).

4. Conclusions

As a result of chrysotile asbestos calcination at 700°C its microstructure changes, *i.e.*, chrysotile fibres, are converted into forsterite strips. Forsterite is harmless magnesium silicate. On the basis of preliminary results it may be suggested



a)



b)

Fig. 8. SEM image of fracture of ceramics (based on calcinated asbestos; grain size of raw materials < 0.2 mm) sintered at 1200°C: a) mag. x 200; b) mag. x 1000.

that calcined chrysotile asbestos can be used as one of raw materials for the production of sintered ceramics (stoneware), substituting quartz sand. Despite of high energy consumption, the thermal decomposition method could be applied instead of storage and can enable recycling asbestos wastes.

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