Development of Material Design Method for Autoclaved Lightweight Aerated Concrete

Analysis of formation mechanism of crystalline component tobermorite

Achievements

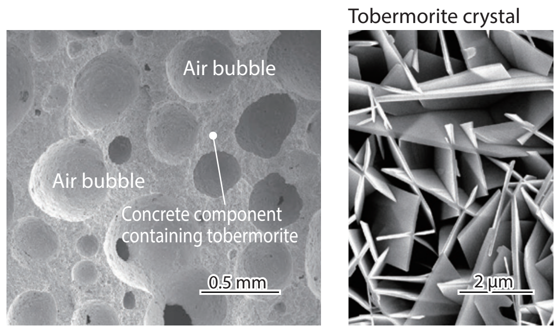
- Clarification of formation mechanism of crystalline component **tobermorite*** by in-situ observation of synthesis reaction of **autoclaved lightweight aerated concrete (ALC)****
- Paving the way for material design of ALC and control of its synthesis reaction

R&D facilities: Asahi Kasei Corporation and Asahi Kasei Construction Materials Corporation

***Tobermorite:** This is a crystalline calcium silicate hydrate, which forms the framework of ALC. It has high strength and durability in that it does not chemically change under heat or water. Tobermorite was first discovered in Tobermory (Scotland) in 1880 as a mineral, and it was named after the town. After that, the crystals existing in concrete produced under steam were found to be the same as those of the naturally occurring tobermorite.
****Autoclaved lightweight aerated concrete (ALC):** When a main material composed of silica, cement, and quick lime (calcium oxide) is mixed with water and a foaming agent (aluminum), the mixture foams and hardens similarly to a sponge cake and produces a porous concrete. The weight of ALC is one-fifth that of conventional concrete, and ALC has a high heat insulation and a high fire resistance. In Japan, ALC has become widespread since the 1960s as a building material. Nowadays, it is used for various purposes in many buildings as wall, floor, and partition materials.

Structure of ALC

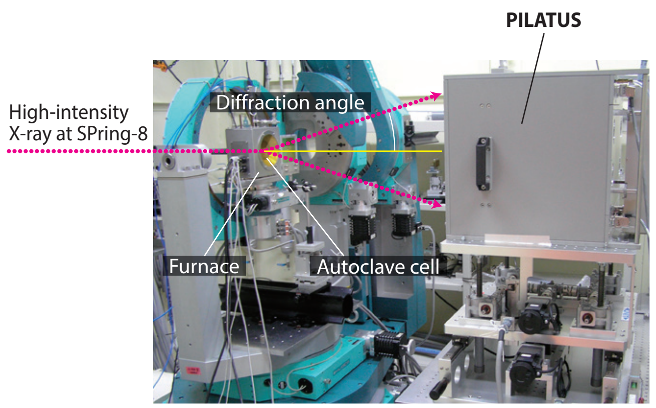
In ALC, many air bubbles are dispersed and they are connected by fine pores. The air bubbles and fine pores comprise 80% of the total volume. Because ALC contains much air, similar to a down jacket, it has a high heat insulation capability. Tobermorite crystals grow at the surface of the air bubbles and fine pores.

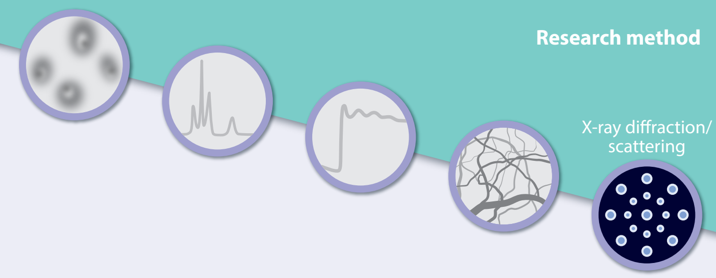


X-ray diffraction experiment at SPring-8

Two-dimensional pixel detector, PILATUS

PILATUS measures the X-rays diffracted by the material produced in the autoclave cell with a high time resolution.
PILATUS is a highly sensitive two-dimensional X-ray detector jointly developed by the Japan Synchrotron Radiation Research Institute (JASRI) and the Paul Scherrer Institute (PSI) in Switzerland.





Role of SPring-8

Background

The quality and quantity of tobermorite crystals determine the strength and durability of ALC. To grow platelike large crystals, the heat and water should be uniformly distributed in the material, and a condition under which the many air bubbles are generated as a space for crystal growth is necessary. To this end, ALC as a building material is produced using a high-temperature and high-pressure steam sterilizer (autoclave).

Recently, significantly increased performance of ALC has been demanded. However, as the chemical reaction occurring in the autoclave cannot be observed from the outside, changing the mixing ratio of the raw materials and synthesis conditions through trial-and-error was the only method adopted to improve the performance of the ALC.

Results

An autoclave cell was placed in the experimental hutch of a SPring-8 beamline. By irradiating the high-intensity X-rays on the material produced in the autoclave cell, the diffraction angle was measured to examine the contents of the synthesized material.

From the above examination, the formation mechanism of the tobermorite has been gradually revealed. It was considered that tobermorite was generated from calcium silicate hydrate (CSH) synthesized as a result of the reaction between silica and quick lime. In addition to this process, the existence of a route for generating tobermorite from monosulfate, a sulfate compound, via hydroxyl ellestadite (HE) was clarified. Furthermore, the timing at which the raw materials change into tobermorite was determined.

It became possible to proceed with the material design of ALC using the results obtained in this study as a guideline.

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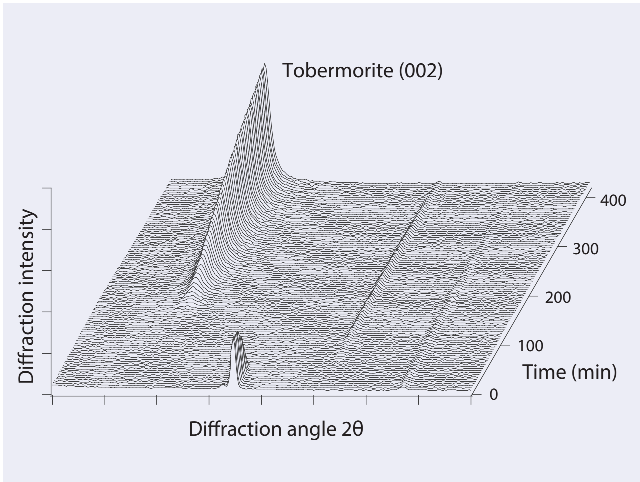
X-ray diffraction pattern observed in formation reaction of ALC

The X-rays diffract upon irradiation on a sample product. Each material has a unique diffraction angle, which can be used for identification. By observing the X-ray diffraction pattern, it is possible to identify when tobermorite is generated.



Change in mineral phase in formation reaction of ALC

As the amounts of silica and slaked lime (calcium hydroxide) decrease, more tobermorite is generated. This finding supports the CSH synthesis route, which is known conventionally. In addition, the existence of an intermediate product called monosulfate was revealed. A route in which the monosulfate disappears in an intermediate stage and tobermorite is then synthesized through hydroxyl ellestadite (HE), was found.