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# AAC with low thermal conductivity

**ABSTRACT:** The structure of this optimized autoclaved aerated concrete (AAC) consisting essentially of calcium silicate hydrate phases, especially of 11 Å tobermorite does not contain inorganic filler like calcite. The absence of quartz and crystalline fillers ensures lower thermal conductivity values even though the crystal structure of the silicate hydrate phases (CSH) phases. According to the tests, the calcium silicate hydrate pore structure with the residual quartz grain contents below 10% by mass is producible by ensuring that the $SiO_2$ component in the hydrothermal process reacts fully or nearly fully (< 10% by mass of residual quartz grains) with the CaO component to give CSH phases, especially crystalline CSH phases, preferably to give 11 Å tobermorite which crystallizes out particularly efficiently. In terms of production, this is achieved by a common autoclaving process and by the use of very fine quartz flour as the $SiO_2$ component. The production is not possible using cryptocrystalline or amorphous silica, for example with fumed silica or precipitated silica or with microsilica (amorphous $SiO_2$ which forms in the preparation of silicon metals from ferrosilicon).

## 1. Introduction

Autoclaved aerated concrete (AAC) is produced of natural inorganic raw materials such as sand, lime, cement, water and the rising agent aluminium. AAC has an unique structure, formed by millions of small air pores, which leads to an optimum correlation between compressive strength and low materials weight. Moreover, air has a low thermal conductivity which makes AAC one of the best insulating building materials. The main topic in research is the reduction of thermal conductivity.

## 2. Fundamentals

Figure 1 shows the development of the λ-value in the history.

This was mainly achieved by reducing the dry density (fig. 2). Unfortunately the compressive strength also decreases.

Autoclaved aerated concrete consists mostly of calcium silicate hydrate phases, especially plate like 11 Å tobermorite and residual quartz grains. Other minerals from the raw material sand occur in small amounts. The thermal conductivity of various mineral phases is documented in table 1 [1, 2].

The most promising way for lowering the thermal conductivity is the reduction of residual quartz, since quartz has a very high thermal conductivity.

There are different ways to achieve the goal:

- application of special filler,
- exchange quartz by high soluble, cryptocrystalline $SiO_2$-minerals,
- combination of special raw materials.

Table 1

THERMAL CONDUCTIVITY OF NATURAL MINERALS.

| mineral | thermal conductivity [W/(mK)] | |
|---|---|---|
| quartz (single crystal) | ⊥ c 7,2 | \|\| c 13,6 |
| calcite | 2,6 | |
| dolomite | 4,9 | |
| feldspar | 2,4 | |
| tobermorite | 0,18 – 0,2 | |

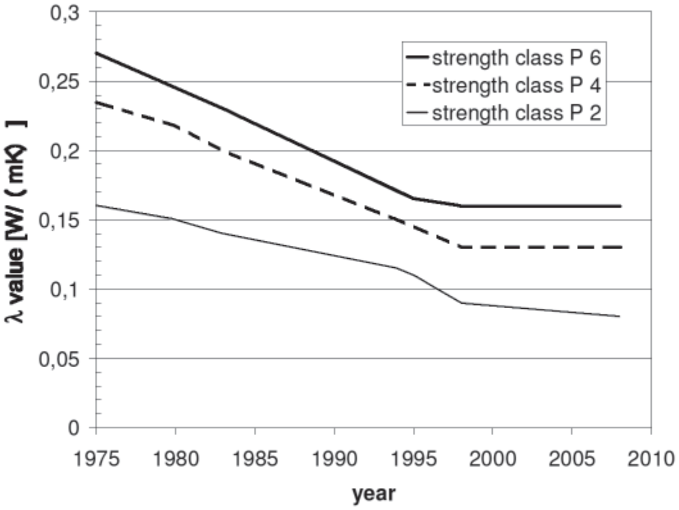

Fig. 1. Thermal conductivity of AAC in the history.

## 3. Results

### 3.1. Filler

A lower thermal conductivity of AAC may be achieved by adding special micro-or nanoporous fillers like zeolite or foamed glass [3]. Our experiments with foamed glass show, that foamed glass reacts during the autoclaving process and the mineral phase content is

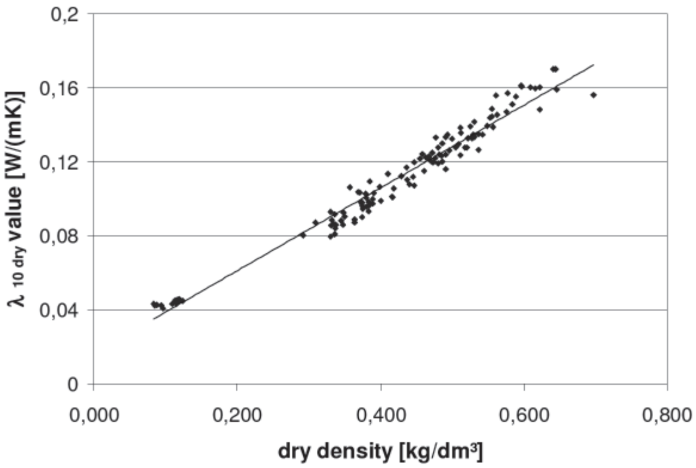

Fig. 2. Correlation between dry density and λ-value.

influenced. The amount of 11 Å tobermorite decreases and C-S-H (I) increases. C_S_H (I) is from the structural point of view, between C-S-H gel and 11 Å tobermorite,. Consequently the compressive strength decreases in the same way like the thermal conductivity. Furthermore, the shrinkage of this AAC is very high.

The application of calcite with different concentrations as a filler was investigated. The samples are compared with their compressive strength as well as with their so called A-value. The A-value represents a relative level of the strength of AAC. The A-value depends on the raw density and the compressive strength and can be described as followed: A-value = CS / RD$^2$ x 0.016; with: CS = compressive strength [N/mm$^2$], RD = raw density [kg/dm$^3$], 0,016 = const. [4].

With increasing the calcite content the A-value and the thermal conductivity decrease (figure 3).

The compressive strength is more influenced than the thermal conductivity. For this reason this way is not practicable.

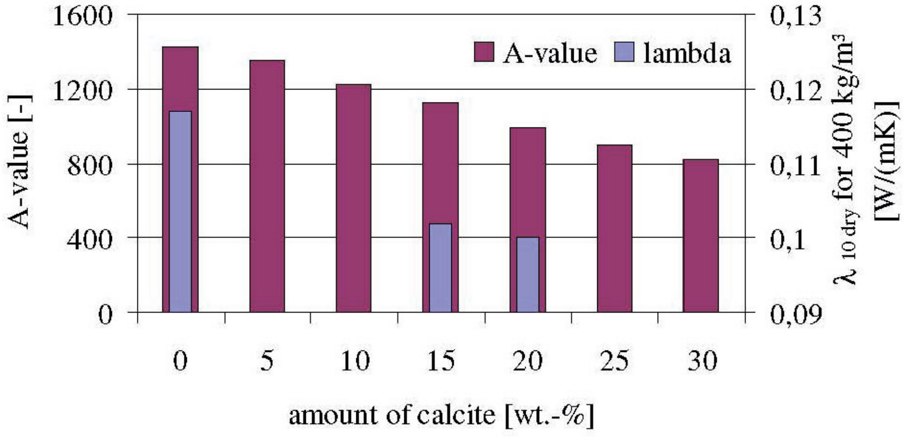

Fig. 3. Influence of calcite on the A-value and the thermal conductivity.

## *3.2. Replacement of quartz by cryptocrystalline SiO$_2$ minerals*

Cryptocrystalline SiO$_2$ minerals have a better solubility than quartz during the autoclaving process. This point was intensively investigated by ZÜRN [4]. Opal and diatom earth were used. He found that those minerals completely dissolve during the autoclaving process. The compressive strength was higher than in samples without cryptocrystalline SiO$_2$ minerals. But the shrinkage was very high, compared to the results from the experiments with foam glass. Consequently it is not possible to replace quartz by cryptocrystalline SiO$_2$ minerals for practical AAC application.

## *3.3. Selection of special raw materials*

A lot of experiments were done with different quartz powders and various Portland cements. The specific surface area of the quartz powder varied between 6000 and 12.000 cm²/g measured according to Blaine [5]. The composition range of the investigated AAC mixtures is shown in table 2.

Table 2

COMPOSITION RANGE OF AAC MIXTURES.

| Ingredient | Amount in % by mass |
|---|---|
| Quartz powder | 25 – 45 |
| Rock powder | 0 – 20 |
| Cement | 15 – 45 |
| Quicklime and/ or lime hydrate | 10 – 30 |
| Sulphate carriers | 2 – 8 |
| Recycled aerated concrete | 0 – 20 |

Table 3

TEST RESULTS.

| | Tobermorite % by mass | Quartz % by mass | λ 10 dry W/(mK) |
|---|---|---|---|
| GV 06 | 63.4 | 2.9 | 0.0758 |
| GV 07 | 68.9 | 2.8 | 0.0761 |
| GV 08 | 62.7 | 2.6 | 0.0759 |
| W 76 | 57.0 | 4.7 | 0.0754 |
| GV 108 | 58.5 | 4.8 | 0.0756 |
| GV 126 | 66.0 | 3.8 | 0.0761 |

The samples were mixed and autoclaved by the same procedure like ordenary AAC. Table 3 shows the test results of the AAC with a quality class P2/035.

That means, that the values of the compressive strength are ≥ 2.7 N/mm², measured on cubes (dimension 100 mm x 100 mm x 100 mm). The dry density is ranged between 330 – 350 kg/ m³. The content of residual quartz is lower than 5% by mass calculated by the Rietveld analysis. The reduced amount of residual quartz is the reason for the low thermal conductivity.

## 4. Summary

As a result of the research work it is possible to produce an AAC with a compressive strength ≥ 2.7 N/mm², a dry density of 330 – 350 kg/m³ and a thermal conductivity lower than 0.08 W/(mK). It was achieved by using fine ground quartz and the adaption of binder content. Therefore residual quartz in AAC is very low. A change of the production process is not necessary.

## Bibliography

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