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3D ANALYSES OF THE AIR VOID STRUCTURE IN HIGH STRENGTH FOAM CONCRETE

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Summary: Foam concrete is a lightweight material with dedicated properties with regard to thermal insulation, as well as to mechanical properties. The spatially resolved analyses of the air void geometry allow a correlation with the mechanical properties. In the analyses shape (elongation, sphericity) and orientation (euler angles) are evaluated for different air void volumes.

1. INTRODUCTION

In recent years, the development of a new generation of foam concrete has started at TU Dortmund University [1] and was continued at University of Kassel [2]. Commercially available foamed concrete has instable properties [3] or consumes high amounts of energy due to the required autoclaving process [4]. The developed foam concrete is air cured and shows stable properties, especially for bulk density and compressive strength. To achieve comparable or better properties than commercial products like autoclaved aerated concrete (AAC), the new material is based on the principles of ultra-high performance concrete (UHPC). These UHPCs reach compressive strengths higher than 160 MPa. The foaming process of the UHPC mix is a chemical reaction of aluminium powder with calcium hydroxide. As a result hydrogen gas will be produced. The hydrogen gas forms the pores and as a consequence the low bulk density. The densities of different mix designs can vary between 0.5 to 1.3 kg/dm³, as well as, the compressive strength (2.5 to 18.0 MPa). This range could be reduced by using lightweight aggregates (e. g. perlite and/or foam glass) to decrease density and increase thermal insulation. Basalt fibres and redispersible polymer powders are used for stabilisation.

Investigations of cut surfaces showed that the air voids had differences in size and shape distribution due to the used raw materials, e. g. aluminium powder or superplasticizers [1]. These differences have a great influence on the compressive strength of the foam concrete. The difficulty with cut surfaces is the two-dimensional investigation of spatial objects. Furthermore, the sample sizes limits the quantity of the analysed air voids and the statistical error could have a great influence on the data. With 3D analyses these problems could be solved. The 3D shape factors elongation and sphericity, as well as, the euler angles are used to describe a specimen.

2. EXPERIMENTAL METHOD

The 3D pore analyses of different foam concrete mix designs were done with a high resolution CT system, Zeiss Xradia Versa 520 (µ-CT). Cubes with lengths of 5.0 cm were used for investigation. The resolution was chosen between 20 – 30 µm. The reconstruction of 1601 projections was done with the Zeiss-software XMReconstruction. The further investigations were done by using FEI-software Avizo 9.2.0. With this software the data were filtered, the air voids were segmented and analysed in shape (elongated shape and sphericity), size (volume) and position properties (angel of the largest extension).

Samples from the same production series were tested acc. to DIN EN 12390-3 for the compressive strength in different loading directions. Both data sets were correlated to find the parameters that influences the properties.

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3. RESULTS

The spatial investigation of air void shapes was more precise and allows a much better correlation with the mechanical properties of foamed concretes than the 2D analyses. Materials with different raw materials, thus different bulk densities and mechanical properties, showed a similar behaviour under biaxial loading when lager pores are present. A more even distribution led to a more homogenous material behaviour.

For example the air voids with a volume > 3 mm^3 had a large influence on the compressive strength. In the analyses these air voids tend to more elongated forms. Moreover, the position properties showed that the alignment of the air voids in loading direction led to higher results in compressive strength tests. Improvements of up to 50% are possible.

One analysed foam with a bulk density of about 0.5 kg/dm^3 (Fig. 1a) was produced with lightweight aggregates. The air void structure was quite homogenous, only 9.6% of the air voids were larger than 3 mm^3 (Fig. 1 b), but these had a significant effect on the compressive strength. The orientation distribution function (Fig.1 c) shows that in the area of euler angles $\varphi < 30°$ the air voids with an elongation factor below 0.2 are mainly located.

The air void structure has a larger effect when the bulk density, thus the compressive strength, of a foam concrete is low. That is due to the fact that the tensile strength as well reduced. When the specimens are loaded the thin concrete structures fail because of lateral strain. This strain is larger if the euler angle φ is smaller.

To conclude a small euler angle φ, an elongated shape and a volume > 3 mm^3 have an influence on the mechanical properties.

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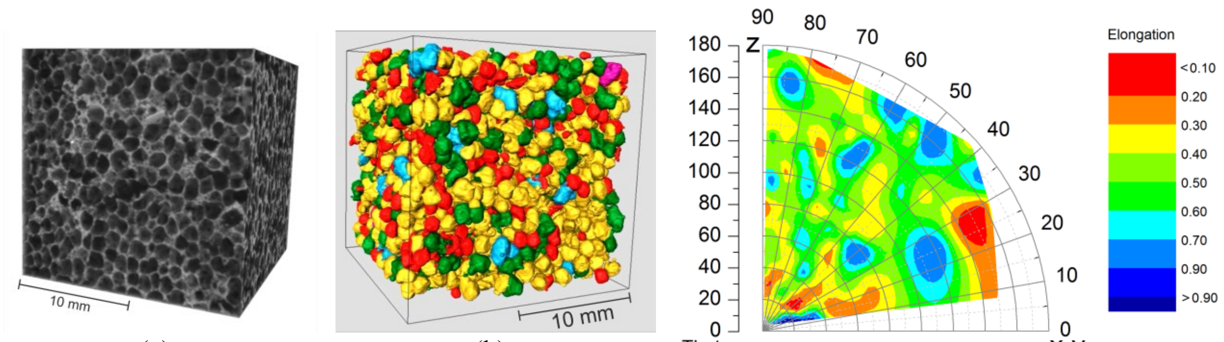

(a) (b) (c)

Figure 1: (a) 3D reconstruction of a foam concrete with a bulk density of 0.5 kg/dm^3. (b) Air void model: red < 1 mm^3; yellow = 1 – 2 mm^3; green = 2 -3 mm^3; blue = 3 -4 mm^3; pink > 4 mm^3. (c) Orientation distribution function (ODF) of the air voids shown in (b) with the angles $\varphi$and ϕ and the elongation.