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Using of Cavitation Disperser, for Porous Ceramic and Concrete Material Preparation

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***Abstract*—**Present paper describes method of obtaining clay ceramic foam (CCF) and foam concrete (FC), by direct foaming with high speed mixer-disperser (HSMD). Three foaming agents (FA) are compared for the FC and CCF production: SCHÄUMUNGSMITTEL W 53 FLÜSSIG (Zschimmer & Schwarz Gmbh, Germany), SCF-1245 (Sika, test sample, Latvia) and FAB-12 (Elade, Latvija). CCF were obtained at 950, 1000°C, 1150°C and 1150°C firing temperature and have mechanical compressive strength 1.2, 2.55 and 4.3 MPa and porosity 79.4, 75.1, 71.6%, respectively. Obtained FC has 6-14 MPa compressive strength and porosity 44-55%. The goal of this work was development of a sustainable and durable ceramic cellular structures using HSMD.

***Keywords* —**Ceramic foam, foam concrete, clay foam, open cell, close cell, direct foaming.

I. Introduction

ENVIRONMENT, energy, health and transport issues are dominating our modern daily live. The complex interactions of these problems can only be solved by sustainable processing and the development of improved porous components. The design of lightweight (porous or cellular structures), cheap but durable materials is one of the modern trends in material design [1]. Number of investigations in the fields of energy efficient light-weight building materials, ceramic and metal porous materials constantly increases in the last years [2]. Clay is one of the most available and cheap natural materials which can be sued for production of construction and insulation materials. Several papers describe the production of porous components based on geopolymers, made by direct foaming, typically following approaches similar to those employed in the cement industry (i.e. in situ generation of gas [3], [4]), leading to the creation of mainly closed cell foams. Method of foaming by the gas forming in the process of reaction, e.g. oxygen, is known as well [5]. Biological foaming technique through reaction of yeast with starch in aqueous ceramic suspension was studied as well [6].

In this work clay ceramic foam (CCF) and foam concrete (FC) wear obtained with high speed mixer-disperser (HSMD). The method is based on the multiple impacts in a liquid media by dispersing elements in the presence of cavitation effects. In this research porous clay ceramic foam and foam concrete production method by direct foaming, using high speed mixer - disperser with cavitation effect was studied. For foamed concrete and ceramics three foaming agents FA are used.

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II. Materials and Methods

A. High Speed Mixer - Disperser

For experimental studies we have used of a HSMD described in previous works (Fig. 1) [7]–[9] with two modifications: involving air (valve 4), and graded ready-mixture tank (1), Fig 1. Rotational frequency of rotor up to 6000 rpm is used.

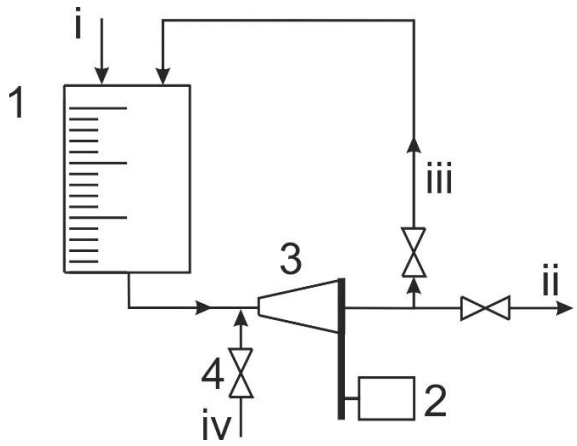

Fig. 1 The high speed mixer-disperser set-up. 1 – reservoir with suspension, 2- electro motor, 3 - mixer-disperser, 4 – valve for air supply. i – ingredient supply, ii - product output, iii – recirculation way, iv – air supply

B. Reagents and Raw Materials

SCHÄUMUNGSMITTEL W 53 FLÜSSIG (Zschimmer & Schwarz Gmbh, Vācija), SCF-1245 (Sika, test sample, Latvia) and FAB-12 (Elade, Latvija) were used as foaming agents. For CCF preparation homogenized clay from Liepa deposition (Latvia) was used. Clay was dried at 105C for 24h, milled in a ball mill for 15 min and refined (for particles size < 150 um). Tap water - Riga municipal water supplement system [10] and DOLAFLUX B 11 ((Zschimmer & Schwarz Gmbh, Germany) as dispersant were used for CCF production as well. The following materials were used to produce cellular concrete: Portland cement CEM I 42.5N, RW-Fuller silica fume, Sika ViscoCrete D 132-2 plasticizing agent, and tap water (water/cement ratio 0.43).

C. CCF Obtaining Method

HSMD operated at 500 rpm and reservoir was filled with 300 ml of tap water and dispersant (1% from clay mass – 6.5 g). Gradually 650 g of dry clay powdered clay was added and HSMD speed also gradually changed to 4000 rpm. After that FA (5% from clay mass – 32.5 g) was added, mixer speed was set to 6000 rpm and at the same time air was supplied through the valve 4, Fig. 1. When mix volume increased twofold the foamed mixture was held in HSMD for 1 min in recirculation mode and then ceramic foam was transferred into the corrugated board and corrugated board with gypsum bottom cast and dried for 72 hours at 20°C. After that sample was burned in muffle oven (LH 11 by Nobertherm) at 1050, 1100, 1150°C (heating rate of 5°C/min) for 30 min.

D. FC Obtaining Method

The FC preparation consists in two steps. At the first water with plasticizer and silica fume were used to prepare mortar of cement. The consistence of mortar mix should be ductile, not crumbly, at the lowest water content as possible. This is necessary to provide maximum water volume for circulation in HSMD (from total calculated amount of water according to recipe). Experimentally established optimal water amount for mortar preparation and stable circulation – 45% and 55% respectively. The addition of prepared mortar started at 800 rpm. During addition of mortar mixer speed changed to 5000 rpm, then FA was added (5% from dry concrete and silica fume mass) and thoroughly mixed. Mixer speed was increased to 6000 rpm and time air was supplied through the valve 4, fig.1. When mix volume increased for 100% for FC-1 and for 80% for FC-2, the foamed mixture was held in HSMD for 1 min in recirculation mode and then foam was transferred into the casting forms.

E. Characterizations of Porous Samples

The as-burned for CCF and aged for 28 days FC porous samples were physically characterized in terms of bulk density, powder density, total porosity, open porosity (via the Archimedes method), and closed porosity. These properties of porous samples were individually determined in three replicates and the average value was reported. To determine the total porosity for both materials (CCF and FC), the bulk density of the porous sample was determined by measuring the lateral dimensions and their respective weights. Subsequently, the total porosity, N, was calculated from the bulk density, ρ, using:

$$N = (1-(\rho / \rho_0))*100\% \quad (1)$$

where ρ_0 is the picnometric density of powdered material. The theoretical density of the dried porous samples was determined by picnometerically. The theoretical density for the burned/aged sample was determined. The open porosity of the samples was measured by the Archimedes displacement method [11] using distilled water according to:

$$P = (m_1-m) / (m_1-m_0) \quad (2)$$

where P is the open porosity of the sample, m is the sample weight in air after complete drying, m_0 is the sample weight in distilled water, and m_1 is the sample weight measured after immersing it in boiling water for 4 h and wiping off the water on the surface. Obviously, the closed porosity is the difference between total and open porosity, i.e.

$$N_{closed} = N - N_{open} \quad (3)$$

For Microstructural characterization a Keyence corporation (Japan) VHX-2000 optical microscope with lenses VH-Z20R/W and VH-Z500R/W was used for optical imaging. The Compression tests of sintered cubic shape samples (50mm X 50 mm X 50 mm) were carried out using Universal Testing Machine (UTM) (Instron: 8801) at room temperature by strain rate 0.01/s. The tests were carried out for a set of five samples in each category.

III. Results and Discussions

All three FA were tested for foaming clay and concrete slurries. Visual observation of foaming process results are presented in Table I.

TABLE I
FOAMED MATERIALS VISUAL OBSERVATION

Foaming agent	Clay foam	Foamed concrete
W 53	Stable foam, minimal crack.	Poor foaming.
FAB-12	Poor foaming, fast foam coalescence.	Good foaming, stable foam, fine pores.
Sika	Fast foam coalescence, big cracking during drying.	Poor foaming, fast foam coalescence.

Taking in account preliminary results FA W 53 has been applied for foaming clay slurry and FA FAB-12 has been applied for foaming cement mortars.. The FA SCF-1245 produced by Sika has been excluded from further investigation tests.

Water amount has been taken in mass % for ceramic slurry characterization. Rely to the previous investigation [12] water content was 37% for preparation clay ceramic slurry. Cement mortar is characterized by water/cement ratio (W/C). Rely to the investigation [13] W/C 0.43 has been used for cement mortar respectively. Performed testing results of obtained samples are shown in Table II.

Microscope investigation has shown open cell structure of CCF (Fig. 2). It may be explained by properties of FA W 53 to create stable foam and save this stability in interaction with clay slurry. In case of use corrugated board with gypsum bottom cast, the bottom layer of CCF (1.5-2.0 mm) has gradient porosity (Fig. 5). It may be explained by rapid water absorption by gypsum cast from slurry and clay ceramic foam densification. Size of the pores isn't possible to define due feature of CCF structures. Decreasing bulk density of CCF by increasing temperature of burning may be explained by melting part of clay creating more strength matrices (Table II).

TABLE II
OBTAINED MATERIALS PROPERTIES

Sample	Bulk density, g/cm^3	Porosity %	Compression . str, MPa	Open porosity, %
FC-1	1.10±0.02	55±0.5	8.5±0.6	12
FC-2	1.30±0.02	45±0.5	14±1.0	8
CCF 950°C	0.43±0.02	79±1.0	1.2±0.1	98
CCF 1000°C	0.52±0.02	75±1.0	2.5±0.1	96
CCF 1150°C	0.57±0.02	74±1.0	4.3±0.1	93

Fig. 2 CCF structure micrograph, optical microscopy, at X200 magnification

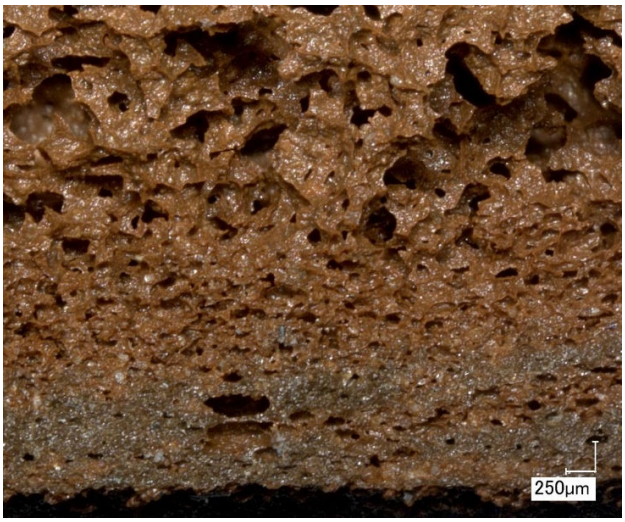

Fig. 3 CCF bottom part structure micrograph, optical microscopy, side cross-section at X50 magnification

The FC structure contents closed cells (Fig. 4). The results of investigation the pore distribution in FC are shown in Fig. 5. The pore sizes are in the range from 25 to 275 µm with two peak maximums of pore size: at 100-125 µm and 150-175 µm. The obtained porosity and density of FC can be explained physical-chemical interaction between FA FAB-12 and cement mortar, taking in account that part of the applied water becomes chemically bonded.

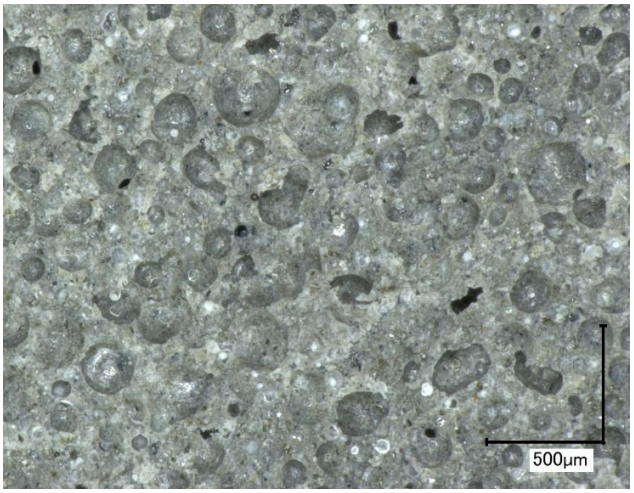

Fig. 4 FC Srtucture micrograph, optical microscopy, magnification at X200 magnification

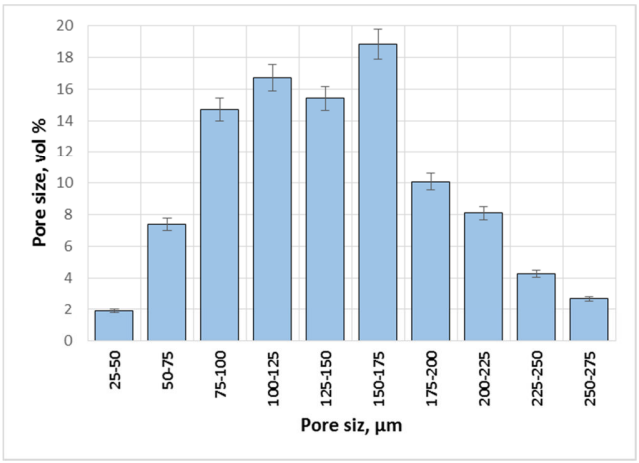

Fig. 5 The pore distribution in FC-1.

IV. CONCLUSION

Three different FA have been evaluated and two of them SCHÄUMUNGSMITTEL W 53 FLÜSSIG and FAB-12A have been investigated for foaming clay slurry and cement mortar. W 53 is more applicable FA for CCF production since at the drying stage cracking was pronounced the least. For the FC production better results were achieved applying FAB-12A - less pore size gradient in volume and higher foam stability were noted.

Obtained CCF samples have bulk density in the range 0.43-0.57 g/cm^3, high porosity (74-79%) and according compression strength 1.2-4.3 MPa. CCF has open-cell structure. Obtained FC samples have bulk density in the range 1.13-1.3 g/cm^3, porosity in the range 55-45%) and according compression strength 8.5.-14.0 MPa FC matrices has closed cell structure.

Instantly after foaming both materials have shown good workability, stabile to vibration and steadily fill mold. When HSMD was used for foamed ceramics production suspension leaves the reactor at the pressure sufficient for cast filling and does not require additional pumping.

Obtained CCF is can be used for cheap filter production, e.g. for preliminary water filtration. Obtained FC is proposed as low-cost, low weight filler in construction work for volume filling heat and sound insulation in floor pouring or in any other case where block FC cannot be used.

HSMD application is promising technology for self-hardening foamed materials and ceramic foams production.

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