COMAT

The 9th International Conference on Advanced Composite Materials Engineering

Transilvania University of Brasov
FACULTY OF MECHANICAL ENGINEERING

17-18October 2022

FOAMED CEMENT VIBRATION TESTING

Péter B.*[1], Péter B.[2], Alexandra H.[3] István K.[4]

1. Department of Fluid and Heat Engineering, University of Miskolc, Miskolc, Hungary, peter.bencs@uni-miskolc.hu
2. Department of Fluid and Heat Engineering, University of Miskolc, Miskolc, Hungary, peter.bozzay@uni-miskolc.hu
3. Institute of Ceramic and Polymer Engineering, University of Miskolc, Miskolc, Hungary, femhamza@uni-miskolc.hu
4. Institute of Ceramic and Polymer Engineering, University of Miskolc, Miskolc, Hungary, istvan.kocserha@uni-miskolc.hu

*Corresponding author: peter.bencs@uni-miskolc.hu

Abstract: *In this study, cement foams prepared using hydrogen peroxide were investigated with the aim of determining the effect of this lightweight additive on the physical and mechanical properties of cement foam. As a primary objective, preliminary experiments were carried out to develop a specific test system suitable for the determination of the parameters to be tested. The cement foams to be tested had an average body density ranging from 300 to 600 kg/m^3 and a compressive strength ranging from 2 to 3.19 MPa at 28 days of age, and the specimens were prepared by layered casting of two cement foams with different body densities. Based on the primary results, a suitable system for vibration testing of the hydrogen peroxide-expanded cement foam was developed and the primary vibration tests showed good resistance of the specimens to standard vibration excitation.*

Keywords: *cement foam, vibration, fracture.*

INTRODUCTION

Foamed concrete, also known as foam cement, is a type of ultra-lightweight concrete, which is produced by introducing gas bubbles into fresh cement paste using different types of foaming agents [1]. Foamed concrete is a combination of hardened cement paste and a number of small, closed pores, which has excellent properties [2, 3]. It has the advantages of minimum aggregate requirements, high flowability, fire resistance, and low thermal conductivity, density and overall mass [4]. Due to these properties, it is used in a very wide range of applications compared to conventional concrete [1, 2]. Up to 400 kg/m3 cement foams are used for thermal insulation, grouting, 600 kg/m3 for road construction, pipe embedding in utility sewers, trench filling and backfilling in contact with building walls. It can also be used in other areas, such as fire protection, sound and heat insulation, vibration damping [5]. Foam concrete does not usually contain coarse additives. However, several studies have reported on the substitution of

sand with other materials of similar fine grain size [6, 7]. Amorphous expanded perlite can be used as an alternative to sand [4] and can also improve the mechanical properties and resistance of concrete [8]. Perlite is a naturally occurring glassy igneous rock found in many countries: Japan, the United States, Turkey and Hungary. One of the characteristics of perlite is that it grows to five to eight times its original volume when exposed to the right temperature (870 °C) and transforms into a low-density cellular material. This expansion process is due to the fact that the raw rock contains between 2-6% of chemically bound water, which swells on rapid heating to produce a foam-like microstructure [9, 10]. Expanded perlite can be used in lightweight mortars and concrete to increase the thermal insulation properties of the materials. It is also used in brick manufacture and for building elements that require thermal and acoustic insulation [9, 11].
Similar foaming can also be achieved using various chemicals. In this study, cement foam test specimens prepared using hydrogen peroxide were used and tested on the shaker test rig presented later.

1. MEASUREMENT SYSTEM

At the core of the shaker system is the Brüel&Kjaer 4818 shaker head, which, by being horizontally aligned and extended with a uniquely designed and manufactured shaker table, has been able to significantly increase the shaker's limited (in practice up to 15-20 kg) capacity. The new device is essentially a table on a steel stand, moving on linear ball bearing guides, which, with the structural elements used, is capable of moving (shaking, excitation) specimens of up to approx. several hundred kilograms in one direction horizontally. The upper limit in this case is not so much the mass as the physical dimensions, the limited size of the table (400 x 220 mm). The range of movement is 30 mm, which allows the shaker's 19 mm p-p max amplitude to be fully utilized.
With the earlier modification of the shaker support stand, the spring-supported 1 m^3 concrete block that provided its vibration-free base had a greater potential for oscillation than before, which in some cases could have a negative effect on horizontal (shaker table) excitations. In order to keep the vibration within reasonable limits, vibration damping elements were designed and installed between the concrete block and the shaft walls, which proved to be sufficiently effective.
The table material was chosen as a test, after considering several uncertainties, and was 10 mm thick plywood, which is sufficiently heavy-duty, sufficiently rigid for the given size, cheap and easy to replace due to the linear conductor design. The position of the table was set far enough away from the excitation point due to the extent of the shaker's vibration-free base, so we tried to make the excitation transmission rod relatively rigid to the extent possible, but at the same time adjustable and safe (Figure 1).
The first task to be carried out with the shaking table is to test foam concrete specimens of special materials and designs. This is a cube with an edge length of 100 mm, made of lightweight concrete with different degrees of foaming (thermal insulation gradient) with hydrogen peroxide. The purpose of the test is, in this case, firstly to try to determine how, in the

case of a specimen made by a layered combination of two materials (in this case 600 and 900 kg/m^3), the boundary layer of the two materials behaves under vibration at different frequencies and accelerations (essentially shear stress), what the vibration characteristics of the specimen are, and what the excitation is that causes the specimen to split in the interface environment (or possibly other locations).

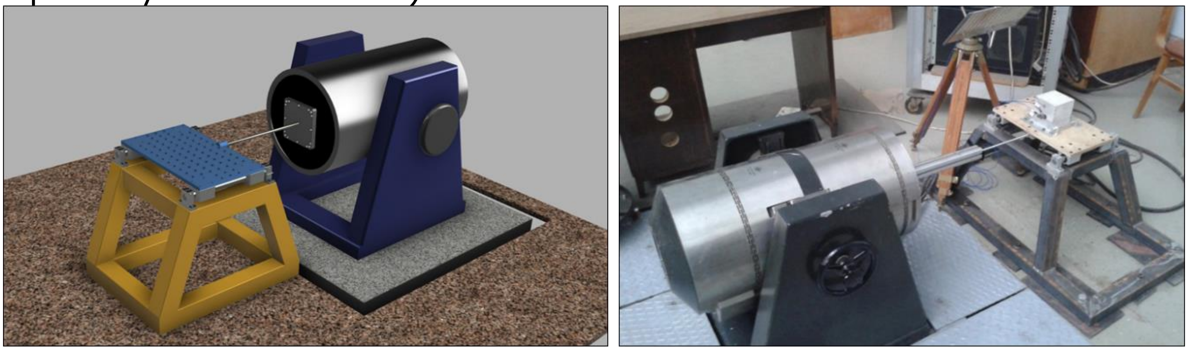

Figure 1: Shaker table designed and built with the B&K 4818 shaker

For the test, a clamping frame was mounted on the shaking table, in which the sample was fixed between thin rubber plates to prevent the fracture of the brittle concrete under compression, so that the boundary layer was parallel to the table and free above the clamping frame, so that shear loading could be well controlled.

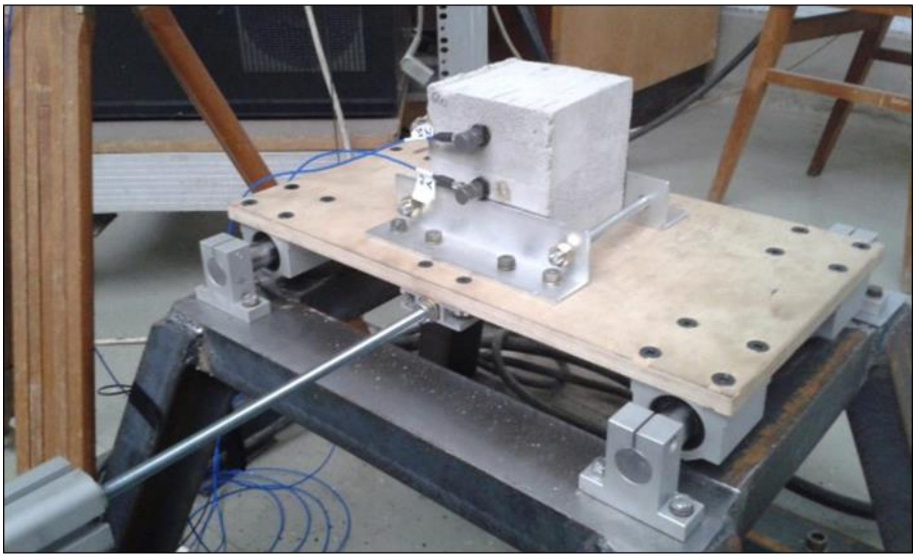

Figure 2: Shaking table with clamped sample and accelerometers

An accelerometer was mounted on each half-frame (Figure 2), connected to a National Instruments CompactDAQ instrument, and data was acquired using a program created in NI SignalExpress running on a computer. The sample was excited in two ways: with white noise or with a sinusoidal sweep signal with an increment of 1 Hz/s between 10 and 500 Hz, with feedback to maintain a constant acceleration level [12, 13].

According to the standards for concrete walls, the acceleration limit value that can be generally used, including in the present case, and which the wall must withstand without damage, is in the range 5 - 15 mg between 5 and 100 Hz. Such a low acceleration value cannot be produced by this B&K device, our measurements show that the vibration of its own cooling system is in the order of 100 mg, however, due to the geometry of the test specimen it was expected that much higher acceleration values in the range already under investigation could be used.

2. RESULTS

Based on the first results, it became necessary to apply an additional load to increase the shear stress on the sample, given that the geometry and mass of the sample did not produce the expected result (separation along the boundary layer) even under the increased stress provided by the excitation system (acceleration above 10 g and longer duration), although the load values available in the literature and standards (which are not too numerous) were already exceeded by orders of magnitude.

One of the main reasons for this is the low shear stress and the resulting low shear mass due to the geometry of the concrete, compared to the structural properties of the concrete. In order to increase this, an additional possibility was considered to apply an additional load, which could be most easily applied in the following three ways for the given shaking device:

1. by layering and bonding several concrete blocks (the structure is too weak, unstable),
2. attaching a heavy metal "cap" to the top of the sample (additional bending load).
3. Clamping the top of the test sample down with known force to the test stand resting on the shaking table.

Solution 3 was chosen with the following design and 2 x 75 N clamping force (Figure 3).

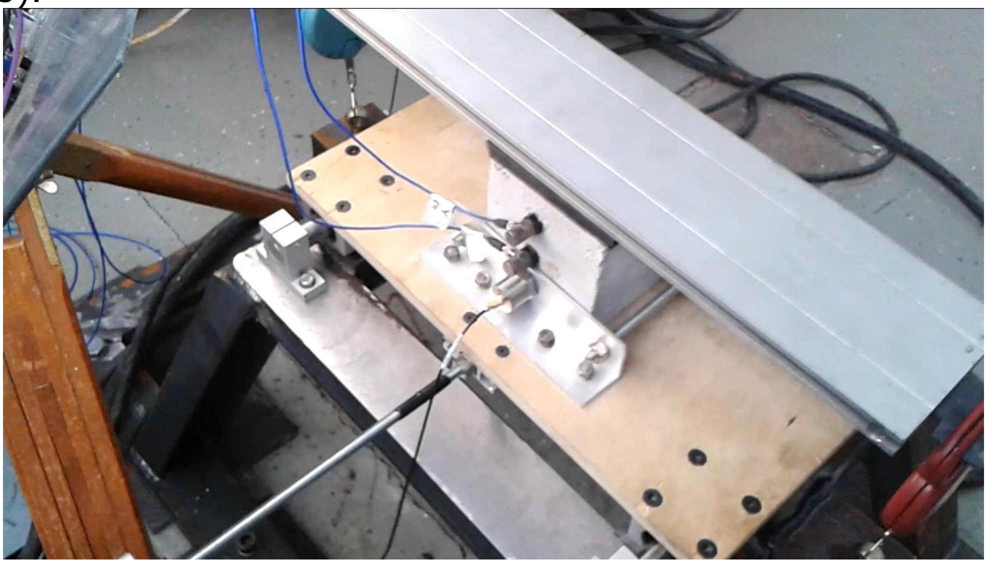

Figure 3: Shaking table with clamped sample and accelerometers

As in previous tests, an accelerometer was used to measure the acceleration and the response signal on each of the two half-frames, and in this case the constant acceleration feedback accelerometer was placed directly on the clamp (Figure 3). The acceleration data were recorded from the National Instruments CompactDaq instrument by a program written for the SignalExpress software, and their spectra and frequency response were calculated. For example, the variation in natural frequencies and amplitudes was observed for the same sample during subsequent sweep measurements of 1 g and then 4 g constant acceleration (Figure 4).

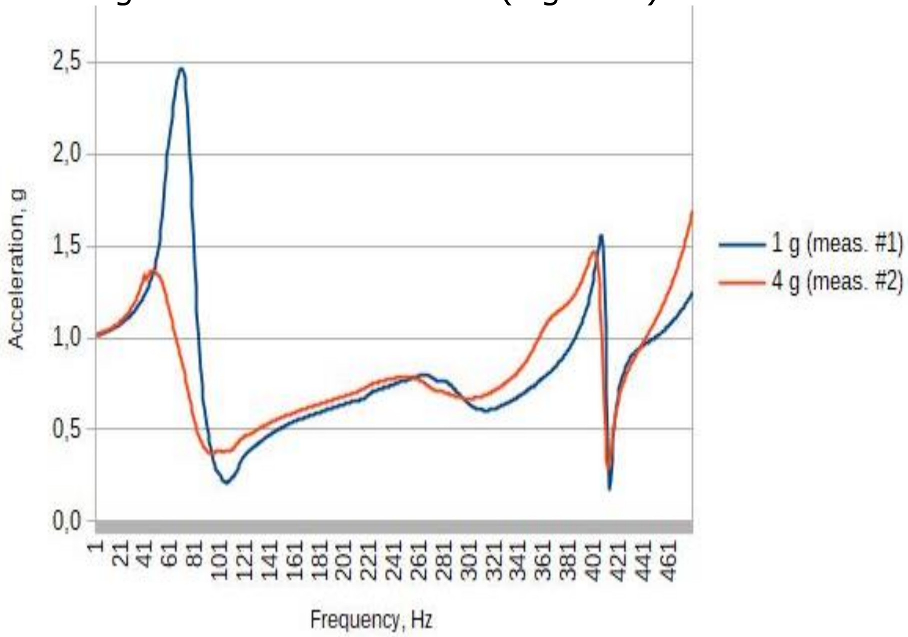

Figure 4: Frequency response, sweep 10-500 Hz, 150 N press

As the test sample still had not split, we tried to remove the upper half-block by hand, carefully and with moderate force, which was successful after a few pulling and twisting movements. The fracture surface shows a characteristic pattern (Figure 5).

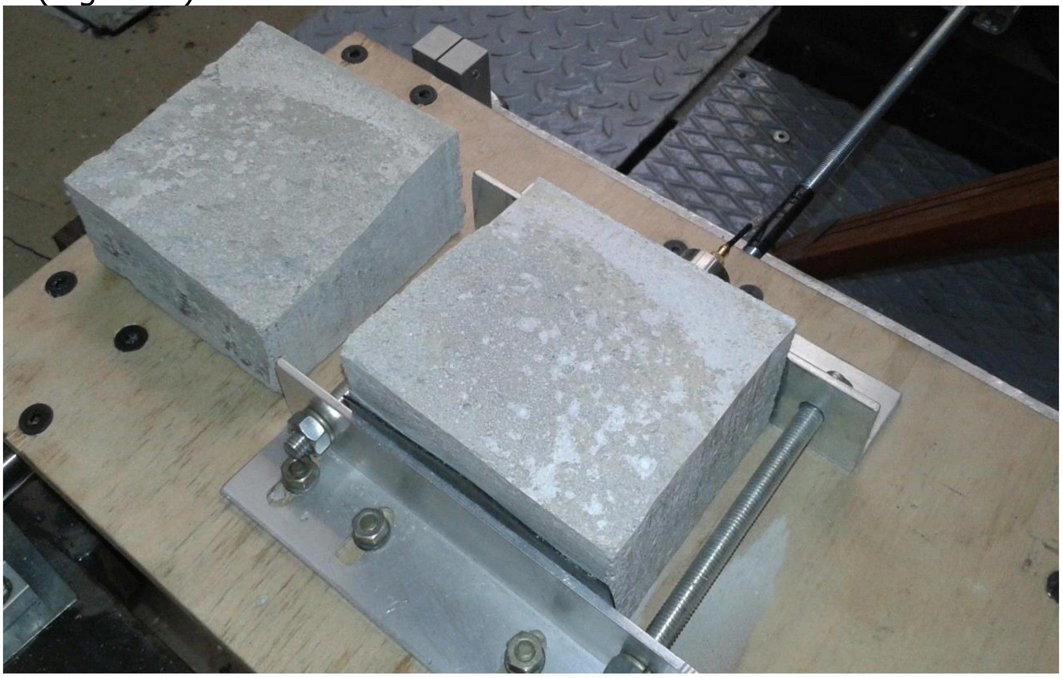

Figure 5: Split sample

3. CONCLUSIONS

To summarize the measurement and development process, the vibration data collection and evaluation process involved firstly building, installing and developing a multi-purpose vibration measurement system, then training in the use of the necessary sensors, instruments, management, data collection and evaluation software, and creating software components that can serve as flexible templates for further tasks. This provides for example the possibility of participating in vibration and even thermal tests of innovative wall elements of the PCM (Phase Change Material) type, as well as other types of test samples of foam and composite materials.

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