



## MECHANICAL PROPERTIES OF FOAM CONCRETE AS A CONSTRUCTION MATERIAL IN CYCLE PAVEMENT STRUCTURES

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### Abstract

The structural layers of cycle pavements are currently being optimised regarding their individual layer composition. Currently, the material composition of the layers is not made of the highest quality materials in terms of stiffness and strength. The aim is to achieve a gradual gradation of the stiffness of the individual layers in relation to the load on the road. The new material foam concrete is used in cycle pavements. Its tensile mechanical properties are significant for the design of structural blocks, contraction, and expansion joints and especially the thickness of the foam concrete layer. This paper discusses a simplified tensile test of foam concrete on specific specimens. It also includes the evaluation and determination of the basic tensile properties of one type of foam concrete - FC500. The conclusion of the paper presents practical examples of the use of this material in concrete cycle pavements in Slovakia.

*Keywords: foam concrete, tensile strength, modulus of elasticity*

### 1 Introduction

In the first phases of the development of foam concrete, non-structural use of this material was expected. The basic composition of foam concrete is water, binder, filler, and foaming component. Due to the foaming agent is foam concrete characterized by low volume weight and porosity. Its application in buildings was therefore predicted to be a filling material with suitable thermal insulation properties. Further development and research of this material has given rise to the possibility of using this material in other areas of construction engineering. One of the possibilities is to use this material in the layers of the cycle pavements structures. The advantage is, besides the low volume weight (100 -1600 kg/m<sup>3</sup>), low density, the good workability of the foamed concrete mixture and the minimal consumption of aggregate [1]. For the design of the overall composition of the structure of cycle pavements, its construction blocks, contraction and expansion joints, it is important to define the appropriate mechanical properties of the foam concrete. In this paper, we will focus on determining the material characteristics of foam concrete type - FC500 in tension using a simplified tensile test. For this purpose, it was necessary to design a measuring line suitable for determining the necessary mechanical properties [2].

#### 1.1 Foam concrete FC-500

Foam concrete is also known as Lightweight Cellular Concrete (LCC). It is defined as a cement-based slurry, with a minimum of 20% (per volume) foam entrained into the plastic mortar. The basic components of foam concrete are water, binder, filler and foam-forming

particles. The individual components added to the mix will determine the strength and durability of the concrete. The basic properties and conditions of use of the individual components are as follows:

**Water:** The water should not contain any chemical additives, damaging admixtures and organic solvents that may disturb the structure of the pores formed.

**Binder:** The most used binder is Cement Class I- IV 32.5R,N to 42.5R,N. The use of cement must have low carbon content and good reactivity, which can improve the properties of foam concrete.

**Foaming agent:** two basic groups of foaming agents are Natural foaming agents and Synthetic foaming agents. FC-500 foam concrete uses Synthetic foaming agents' technology. Synthetic foaming agents are produced based on technical requirements, which allows to improve their quality in terms of durability and usage.

**Filler** Crushed or quarried aggregate of 0-2mm or 0-4mm fraction can be used as filler. Other alternatives are various inorganic waste materials such as limestone, finely ground slag, fly ash [3, 4].

## 1.2 Mechanical tests

The testing methods can help analyse different mechanical properties of materials or components. There are many different methods of testing, and the tensile test is one of the basic tests for determining basic mechanical characteristics in the field of materials science and engineering Fig. 1. A specimen of the material under test is subjected to tensile stress until a limit of failure. The values obtained through tensile test are tensile strength, breaking strength, maximum elongation, and area reduction. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. The most used is the uniaxial tensile test, which has also been used in the present case. The experimental testing process is described below. Another method of measurement is the biaxial tensile test. The main difference is in the way the materials are loaded [5].

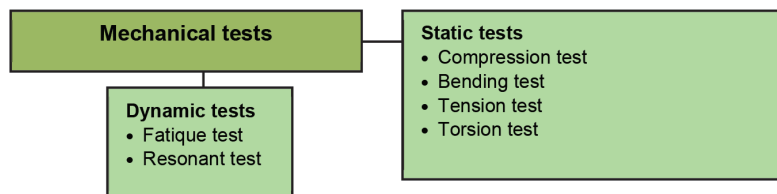


Figure 1 Classification of the mechanical tests

## 2 Experimental measurements

### 2.1 The process of the tensile test

The purpose of the experimental test in simple tension is to determine the maximum force required to break the test specimen. The test specimen shall have a specific shape - dog-bone-shaped specimens. This shape is important because of the proper grip of the specimen in the test assembly. The cross-sectional area of the measured part is reduced compared to the cross-sectional area of the remainder Fig.2. The taper will ensure that the deformation and ultimate failure of the specimen will be oriented in the measured part of the specimen [5]. The length of the transition area should be at least as large as the thinnest part.



Figure 2 The test specimen of foam concrete FC-500

For the implementation of the tensile test, a special measuring mechanism was prepared in the university's measuring laboratory. The measuring line and its parts are specified in more detail in the following Figure 3.

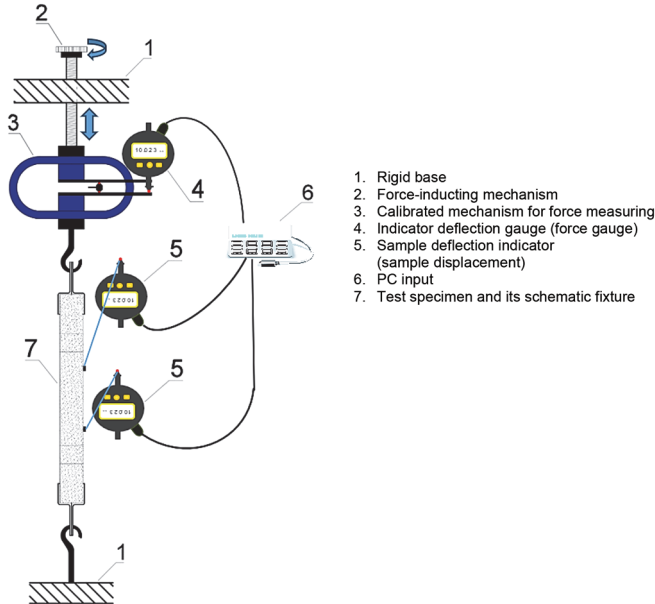


Figure 3 Tensile test measurement assembly

Tensile response is influenced by various factors such as type of the material, construction technology, compaction and fixing of specimens, testing speed and the others. The test specimen was loaded with uniaxial tension during the test. In this case, we can consider that the stress state in each cross-section is a simple tension, and we can use the dependence between the stress and deformation in the x-axis direction (1),(2).

$$\sigma = \frac{F}{A_0} \text{ [MPa]} \quad (1)$$

$$\varepsilon = \frac{\Delta l}{l_0} = \frac{l - l_0}{l_0} \text{ [-]} \quad (2)$$

Deformation is an important parameter monitored during loading. We calculate its value as the ratio of the change in the length of the specimen  $\Delta l$  and its original length  $l_0$ . The measurement was realized with two screws attached to the foam concrete specimen. The screws were used to connect the test fixture to the deflection indicator gauges by means of a steel wire. Determining the tensile strength is relatively simple.

For brittle materials such as foam concrete, tensile strength is a valid design criterion. Tensile strength  $\sigma_{max}$  is the maximum load  $F_{max}$  divided by the cross-sectional area  $A$  of the specimen (3).

$$\sigma_{max} = \frac{F_{max}}{A} \text{ [MPa]} \quad (3)$$

The advantage of this type of solution is the independence of the stress-strain curve from the dimensions of the specimen [5].

## 2.2 Results of experimental measurements

Experimental measurements were carried out in the laboratory on samples with a hardening and stiffening time of 28 days. The specific property of foam concrete is moisture content, which has a positive effect on its final properties. Therefore, the samples were exposed to higher moisture content than under normal conditions for 24 hours before measurement. After measuring the necessary data, it was possible to create a stress-strain diagram and then to read the modulus of elasticity  $E$ . Young's modulus of elasticity is defined as the rela

$$E = \frac{\sigma}{\varepsilon} \text{ [MPa]} \quad (4)$$

To compare the values of Young's modulus of elasticity, experimental measurements were measured on 6 specimens of the same material - foam concrete FC 500. The individual curves of the stress-strain diagrams for all 6 measured samples can be seen in the following Fig. 4. The character of the individual curves is approximately the same. The same applies to the calculated values of the modulus of elasticity.

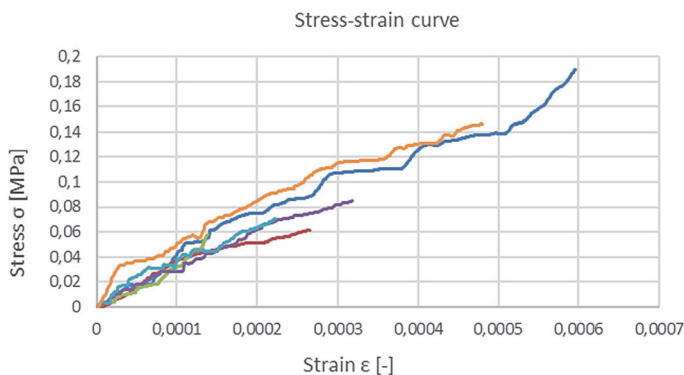


Figure 4 Stress-strain diagrams of foam concrete specimens

By comparing the individual results shown in Tab.1, it was found that the average modulus of elasticity of FC-500 foam concrete is 276 [MPa]. The measurements indicate that during the execution of the test on specimen number 3, eccentric loading, or slippage of parts of the measuring assembly may have occurred. The modulus of elasticity is greater than that of the other specimens. Therefore, the measurement in question is excluded from the statistical set.

**Table 1** Measuring results

Number of test specimen	Fmax	$\sigma$ [MPa]	E [MPa]
1	303	0,19	272
2	100	0,07	282
3	95	0,06	377
4	156	0,09	271
5	113	0,07	287
6	262	0,14	271

### 3 Application of foam concrete in practice

Further extensive research on the use of foam concrete in cycle pavement is currently underway. The focus is not only on the mechanical properties, but mainly on the effect of weather conditions on the performance of FC 500 in the structural layers of the pavements. Moisture and temperature changes have a considerable influence on the properties of foam concrete. Foam concrete is very absorptive, but this does not reduce its mechanical properties. In the dry state it appears to be a fragile material and therefore cannot be used as a load-bearing layer. A base layer of this material appears to be particularly suitable for sites frequently underwater. It has excellent retention properties. Individual studies can be found in the available literature.

Currently, the first structural layers containing foam concrete have been used in a part of the Zemplin cycling route in the east of Slovakia. The design of the pavement layers was made in accordance with the relevant provisions of the Road Act No 135/1961 Coll. concerning the design of roads. In this case, the foam concrete layer was reinforced with ORLITECH basalt reinforcing mesh. In this case, a computational model was also developed to solve the spatial stresses based on the finite element method [6, 7]. The composition of this pavement is as follows:

- Single-layer cement concrete pavement cover CB III, thickness - 180 mm
- PE film
- FC 500 foam concrete base layer with ORLITECH reinforcing mesh, thickness - 100 mm
- uncemented gravel layer, thickness - 150 mm

The total thickness of the pavement was 430 mm. In addition to this type, other compositions containing a semi-rigid asphalt pavement with a base member were also proposed for sections with different types of loading (for emergency vehicles, for machinery or maintenance vehicles). The FC 500 base layer appears to be particularly suitable for sites frequently flooded with water, because of its excellent retention properties.

### 4 Conclusions

The trend of using new materials to replace commonly available concrete can also be applied to the optimisation of the structural insertion of cycle pavements. The increasingly used foam concrete is offered as an alternative. To be able to realise and design such structures, its tensile properties are significant. Therefore, the aim of this work was to find out the basic material characteristics of foam concrete from the tensile testing. From the tests we can conclude that it is not equal to conventional concrete in strength. However, this cannot be considered as a bad property. The foam concrete has already found use in many building structures and its application succeeds in reducing the cost and thickness of cycle pavement

structures. As a result, its use is more economically advantageous. It also has the advantage of being able to be applied in flood plain areas without reducing the mechanical efficiency of the pavement structure. Its ability to gradually release trapped water to improve the microclimate of the cycleway will also be beneficial from an ecological point of view.

## Acknowledgments

This research was funded by the Ministry of Education, Science, Research and Sport of the Slovak Republic, grant number VEGA 1/0552/24 “The Dynamic Effects of Transport on Historic Structures and the Possibility of Their Mitigation by Innovative Materials in Transport Engineering”.

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