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Experimental Investigation of Properties of Foam Concrete for Industrial Floors in Testing Field

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Abstract. Foam concrete (FC), as a mixture of cement, water, additives and technical foam, is well known for more than 30 years. It is building material with good mechanical properties, low thermal conductivity, simple and even high technological treatment. Foam concrete contains closed void pores, what allows achieving low bulk density and spare of raw materials. Thanks to its properties, it is usable as a replacement of conventional subbase layers of the industrial floors, the transport areas or as a part of the foundation structures of the buildings. Paper presents the preparation of the testing field (physical model) which was created for experimental investigation of the foam concrete subbase layer of the industrial floor in a real scale.

1. Introduction

Foam concrete (FC), as a mixture of cement, water, additives and technical foam, is in principle well known for more than 30 years. It is building material with good mechanical properties, low thermal conductivity, simple and even high technological treatment. Foam concrete contains closed void pores, what allows to achieve low bulk density and spare of input materials, [1]. Thanks to its properties, it is usable as a replacement of conventional sub-base layers of the industrial floors, the transport areas or as a part of the foundation structures of the buildings. Mixture for the foam concrete can be prepared for various bulk densities. Today, we deal with bulk densities 300, 400, 500, 600 and 700 $kg.m^{-3}$, [2-4].

According to the bulk density, the foam concrete is designated FC 300, FC 400, FC 500, FC 600 and FC 700. For application in the industrial floors, the foam concrete layer is equipped with non-woven separation geotextile at the bottom of the FC layer.

Physical modelling represents verified and reliable method for observation of behaviour of the examined structure. Together with computational simulation, it represents the powerful tool not only for the research but also for designing of these structures, [4, 5].

Series of observations of the real scale physical model in the testing field are proposed to verify the functionality of the sub-base layer of the foam concrete in the industrial floor structure. Experiments are prepared and realized in cooperation of University of Žilina (UNIZA) and the company iwtech Ltd, [6], figure 1.

2. Testing field

Testing field represents the subbase of real industrial floor structure on the subgrade. Testing field is located in outer environment closed to laboratory of faculty of Civil Engineering (Uniza), where other special monitoring of structures are provided side-by-side, egg. permanent temperature and moisture content monitoring in railway track subbase layers, [7-9]. Observation can be performed at defined boundary conditions what allows to obtain relevant outputs.

Figure 1. Testing field – concreting of FC reinforced layer

Configuration of the subsoil and the embankment is showed on figure 2. Subsoil of the testing field consists of antropogenous clay of intermediate plasticity and stiff consistency (table 1). Embankment was made from compacted fill of different fractions, with the separation and filtration geotextile covered on the subsoil. The thickness of floor subbase layers was selected in four variants, in order to have different subgrade stiffness under the foam concrete layer (table 2). Sections A. and B. represents the subgrade with higher bearing capacity and the sections C. and D. the subgrade with lower bearing capacity. This division allows to investigate the response of the foam concrete constructed on the subgrade with different stiffness.

Geotextile Filtek 200 of weight 200 g.m^{-2} was used as separation and filtration layer on the surface of subgrade. Additionally, the basalt reinforcing mesh type ORLITECH MESH [12] with aperture dimensions of 100 × 100 mm was placed in the sections B. and C. (figure 2). Foam concrete is then pour out on this compound. Testing field then consists of four segments with different stiffness properties (A., B., C. and D.).

Table 1. Strain modulus E_{V2} for the clayey subsoil

Section	**Average strain modulus E_{V2} [MN.m^{-2}]**
A, B	5
C, D	5

Table 2. Strain modulus E_{V2} for the embankment on the subsoil

Section	**Average strain modulus E_{V2} [MN.m^{-2}]**
A, B	29
C, D	16

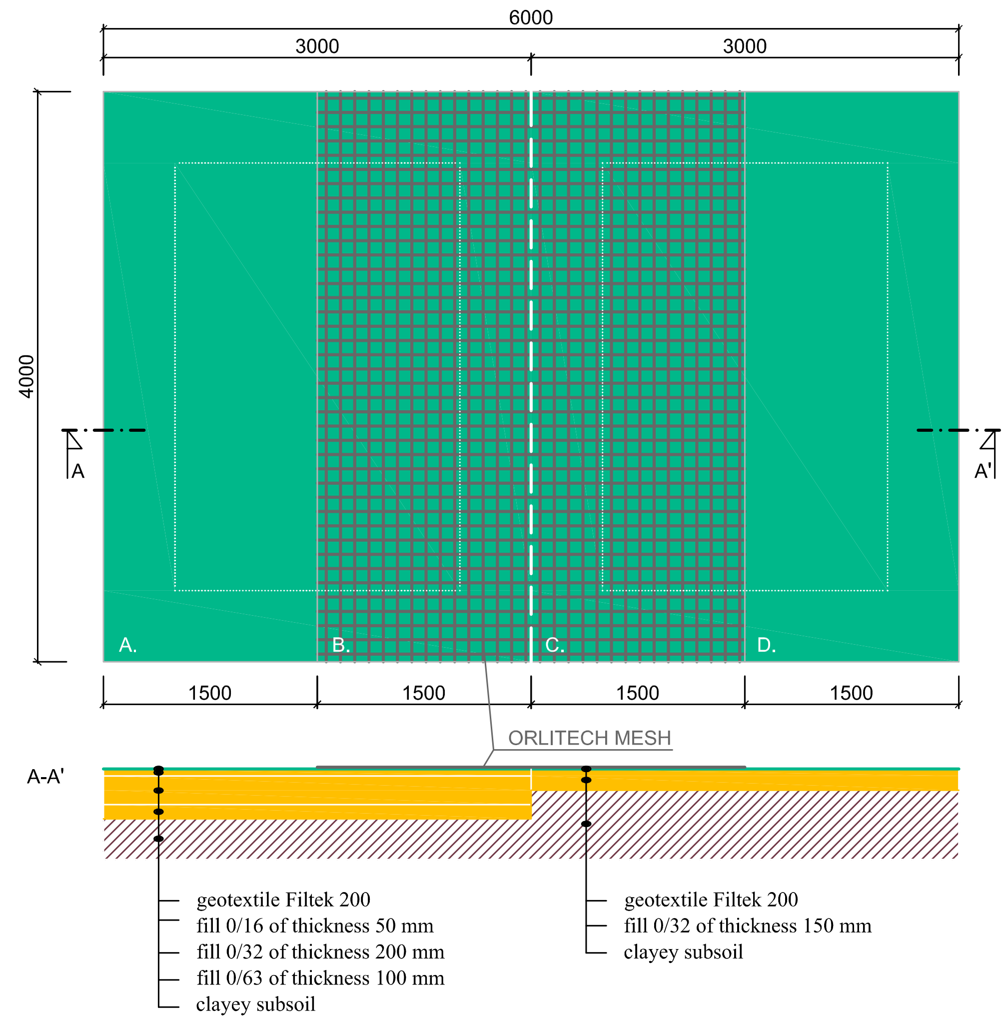

Figure 2. Testing field layout for the embankment and the subsoil (Dimensions in mm)

3. Experimental procedure

Beside the laboratory tests of mechanical properties of the foam concrete, physical modelling in the test field to observe the behaviour of the foam concrete in the floor structure will be a part of the research activities. Aim is to verify the outputs of the analytical methods and computer simulations. Collected data will serve as a base for understanding the foam concrete layer behaviour in the industrial floor what allows to realize effective design of the subbase layers from the foam concrete to achieve the safety and the serviceability of created floor using all of the benefits of the foam concrete.

3.1. Verification of response of the foam concrete subbase layer

The response is investigated using PLT apparatus. Plate Load Test represents one of the most widely used method for sub-base layer quality control of communications, traffic areas or floor structures. Surcharge effect on the tested layer is simulated during the test. Several characteristics describing deformation properties of the finished sub-base layer, such as modulus of subgrade reaction, modulus of elasticity or strain modulus, can be derived from outputs in form of relationship between the load and the plate settlement. Plate load tests (PLT), according to the scheme in the figure 3, will be carried out on the first layer of the foam concrete FC 500 of thickness of 120 mm after 28 days to determine the strain modulus E_{V2}, the reaction modulus k and the modulus of elasticity E.

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After testing, first layer of the foam concrete will be covered with second layer of thickness of 100 mm. Plate load tests will be also carried out on this layer after 28 days. After realization of the third layer of the thickness of 100 mm, the final thickness of the foam concrete will be 320 mm. Plate load tests will be also carried out on this final layer after 28 days. Performed tests will be helpful to understand the behaviour of the subbase layer from the foam concrete with different thickness, reinforcement and subgrade stiffness.

3.2. Measured quantities
Experimental measurement on the testing field consist of the plate load tests (PLT) which allow obtaining several quantities characterizing the deformation properties of the sub-base of the industrial floor. These quantities are used to set the criterions for the safe and economical design of the industrial floor. Besides, these criterions are also used for quality assessment during the construction. The characteristics of the sub-base layer from the foam concrete FC 500, such as modulus of subgrade reaction k, modulus of elasticity E and strain modulus E_{V2}, will be determined.

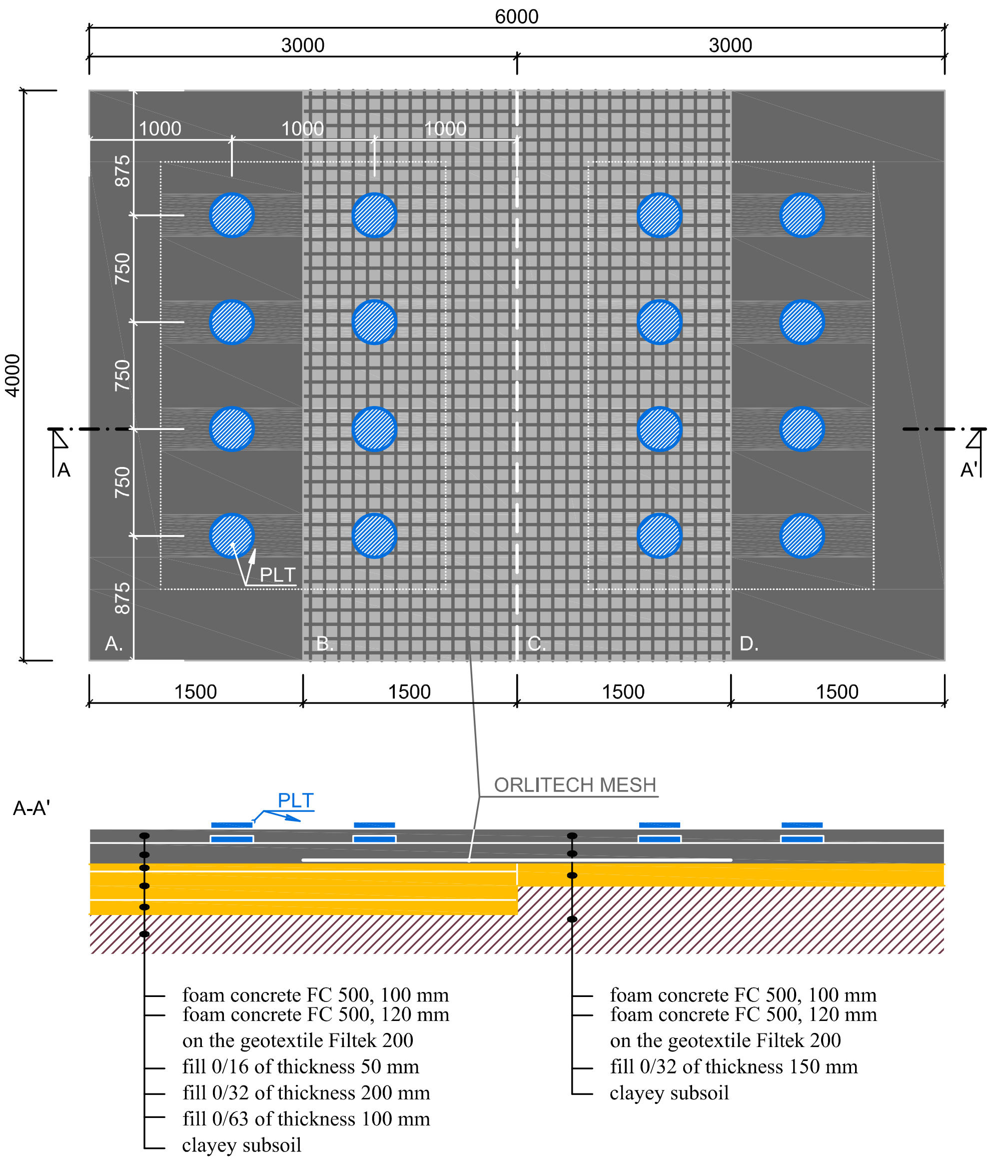

Figure 3. Testing field layout for the measurement, (dimensions in mm)

Reaction modulus of the sub-base k is determined according to the following equation using large loading plate with diameter of 762 mm in terms of the German standard DIN 18134, [11]:

$$k = \frac{p}{s} \quad (\mathrm{MN.m^{-3}}), \tag{1}$$

where: p is contact stress under the loading plate ($\mathrm{MN.m^{-2}}$),
s loading plate settlement ($= 1.25 \times 10^{-3}$ m).

Measurements on the testing field was performed by using the plate with the diameter of 300 mm in order to reduce the required stress acting on the test framework, so the values of the modulus of subgrade reaction should be reduced according to the Stratton theory, using the following equation:

$$k_{762} = \frac{k_{300}}{2.3} \quad (\mathrm{MN.m^{-3}}), \tag{2}$$

Static modulus of elasticity E is calculated by using the results of the plate load test as:

$$E = \frac{\pi}{2} \cdot \left(1 - \nu^2\right) \cdot \frac{p \cdot r}{s_e} (\mathrm{MN.m^{-2}}), \tag{3}$$

where ν is Poisson's ratio of the tested layer (= 0.2 for the foam concrete FC 500),
p contact stress under the loading plate ($\mathrm{MN.m^{-2}}$),
r loading plate diameter (m),
s_e average elastic plate settlement (m).

Static strain modulus E_v is calculated using the output of the plate load test in terms of the German standard DIN 18134:

$$E_v = 1.5 \cdot r \cdot \frac{\Delta p}{\Delta s} \quad (\mathrm{MN.m^{-2}}), \tag{4}$$

where r is loading plate diameter (m),
Δp stress interval in which the modulus is determined ($\mathrm{MN.m^{-2}}$),
Δs average plate settlement for given contact stress interval (m).

Beside the modulus values, the ratio of the modulus values from both load cycles designated as α is important indicator of the quality of the tested layer:

$$\alpha = \frac{E_{v2}}{E_{v1}} \quad (-), \tag{5}$$

where E_{V2} is strain modulus from second load cycle ($\mathrm{MN.m^{-2}}$),
E_{V1} strain modulus from first load cycle ($\mathrm{MN.m^{-2}}$).

The ratio should not exceed the given value defined in dependence on the load of the layer and the importance of the structure and usually is selected from interval 2.0 to 2.5.

4. Results

The benefit of the layer of the foam concrete FC 500 is significant at all observed quantities, where increase of the values is visible. The layer of the foam concrete FC 500 even with small thickness allows to achieve larger increase of the values of the deformation characteristics in comparison to the conventional subbase layers (figure 4 to 6).

The ratio of the strain modulus α from both load cycles is also important parameter. The value of the ratio reached 1.0 to 1.3 what meets the criteria for the sub-base layers of the industrial floors set to 2.0.

Utilization of the reinforcing mesh ORLITECH MESH [12] not only increases the values of the deformation parameters but also improves the homogeneity of the finished layer what was confirmed by the smaller dispersion of the measured values of the observed parameters.

The layer of the foam concrete FC 500 with thickness of 12 cm reinforced with the basalt reinforcing mesh ORLITECH MESH realized on the subgrade with the strain modulus 29 MN.m^{-2} allows to achieve the final strain modulus E_{V2} = 80 MN.m^{-2}. The layer of the foam concrete FC 500 with thickness of 22 cm reinforced with the basalt reinforcing mesh ORLITECH MESH realized on the subgrade with the strain modulus 16 MN.m^{-2} allows to achieve the final strain modulus E_{V2} = 102 MN.m^{-2}. Such a layers can be already used as a final sub-base layer under the floor slab.

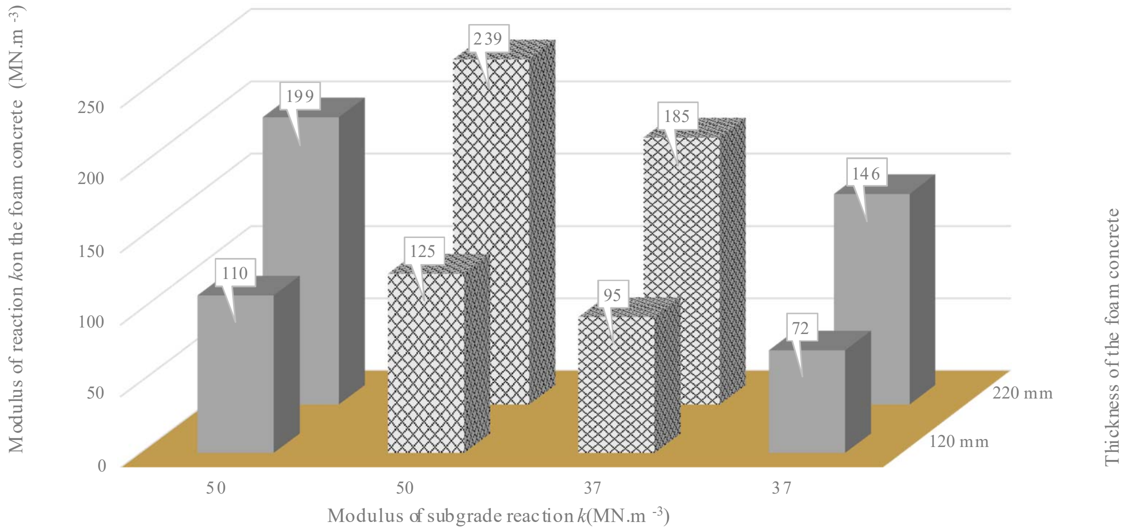

Figure 4. Measured values of the modulus of subgrade reaction *k*

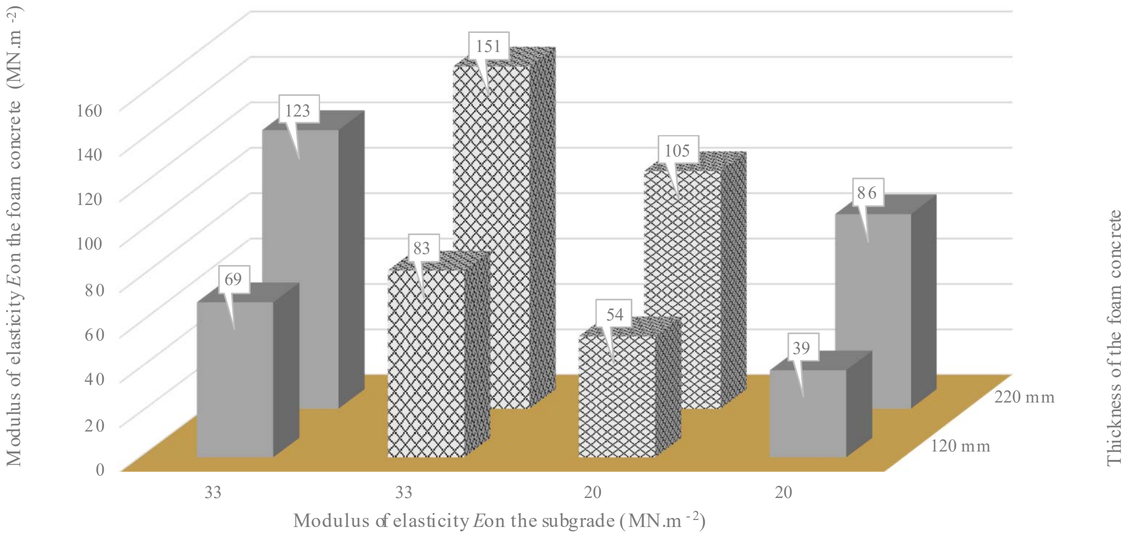

Figure 5. Measured values of the modulus of elasticity *E*

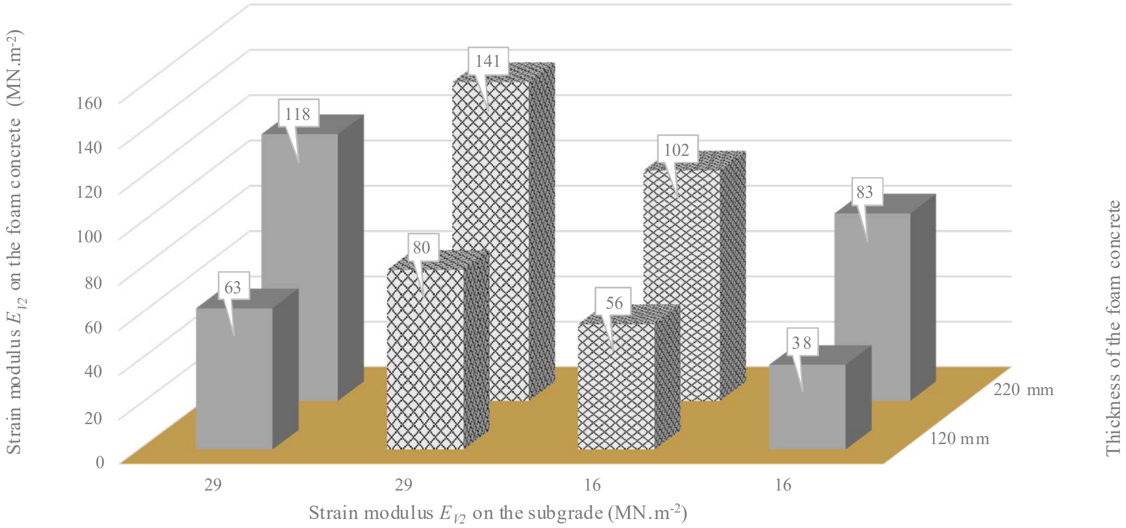

Figure 6. Measured values of the strain modulus E_{V2}

5. Conclusions

The current possibilities of foam concrete are not only in its traditional uses in building construction, but also in transport constructions and special engineering constructions or geotechnical applications or special remediation works. Foam concrete produced by the technology of iwtech Ltd, allows to produce variety of bulk density of FC with different strength and thermal parameters, [13, 14]. Similar research and testing is being carried out in Poland [4, 5, 15], Switzerland and many other countries. The most reliable results can be achieved on physical models or real models of structures, which allow to calibrate numerical analyses at design stages, [16-20],

The presented physical models of subbase structure from FC, realized in the testing field, was used for calibration of the numerical and analytical models for design and verification of the industrial floors. Same boundary conditions are set for the foam concrete layer, which allows the direct comparison of both conventional fill and foam concrete subbase layers. Physical modelling in real scale is suitable to obtain relevant outputs, which are necessary to propose appropriate implementation of the foam concrete material to the industrial floor structure.

Combination of the physical modelling and computer simulation allows to create effective tool for design of the industrial floors with subbase layer from the foam concrete. The transfer of the knowledge to the practical application and the realization of the floor structures with use all of the benefits of the foam concrete, which will be next research. The aim is to create safe, economic and effective design of the floor structure.

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