EXAMPLE OF ALTERNATIVE DESIGN OF INDUSTRIAL FLOOR USING FOAM CONCRETE FC 500

Technical report No. 07

THE FOAM CONCRETE IN FLOOR CONSTRUCTION ...

The Foam Concrete (FC), the mixture of the binder, the water, additives and the technical foam, has been known for over thirty years. It´s a building material with good mechanical properties and low thermal conductivity and at the same time with high-tech processing.

The foam concrete contains closed air pores, what achieves its low volume weight (density) and saving of material inputs.
Due to its properties the foam concrete is usable as a substitute of the conventional sub-base layers of an industrial floor and also of transport areas, or as a part of foundation structures of buildings.

Foam concrete FC 500 as the sub-base layer of an industrial floor

Nowadays the foam concrete with densities 300 – 400 kg/m^3 is most often used as a floor levelling layer of civil buildings. Research and development realized by iwtech s.r.o. in partnership with University of Zilina and other partners shows that its use can be much wider.
Benefits of using the foam concrete as a sub-base layer improving the properties of the subgrade of the industrial floor will be presented with an example of the floor of the storage space of the hall object (**fig. 1**).
The sub-base layer of aggregate will be replaced with the layer of the foam concrete FC 500 with density 500 kg/m^3.

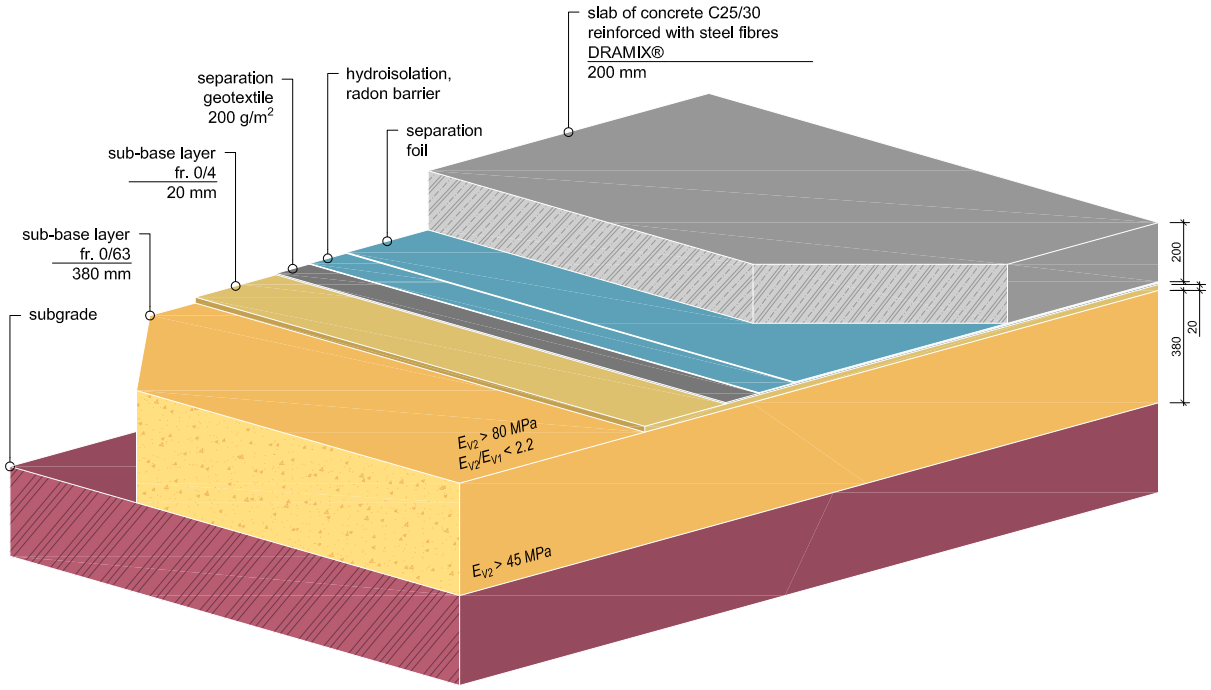


Fig. 1 The usual design of the industrial floor of the storage hall

The alternative design considers two alternatives of the sub-base layer of the foam concrete:
Alt. I. foam concrete FC 500 with the separation geotextile with unit weight 200 g/m^2
Alt. II. foam concrete FC 500 with the separation geotextile with unit weight 200 g/m^2 reinforced with basalt mesh ORLITECH MESH with aperture size 100x100 mm

I. Static calculation

Static analysis of particular variants of the floor structure was carried out in accordance with the regulation Concrete Society TR34.

To show the possibilities of FC 500 as a layer improving properties of the subgrade, the example of the heavy loaded industrial floor was selected with the service load:

- uniform distribution load with characteristic intensity q_k = 100 kN/m^2,
- point load simulating the forklift load with intensity 56 kN per one wheel,
- point load 75 kN per 1 rack stanchion with layout 1.1 x 2.8 m, with spread foot with dimensions 150x150 mm; rack distance is 300 mm.

Floor slab of concrete C25/30 with thickness of 200 mm is reinforced with steel fibres DRAMIX® (L = 60 mm, D = 0.9 mm, R_m = 1160 MPa).
Slab is designed as a joint-less with dilatation joints layout 30 x 30 m.

Design of the sub-base layer of the foam concrete FC 500 and also the concrete slab reinforced with the steel fibres is based on the conditions imposed on the conventional compacted sub-base layer (**fig. 2**):

- E_{V2} > 80 MPa
- E_{V2} / E_{V1} < 2.2

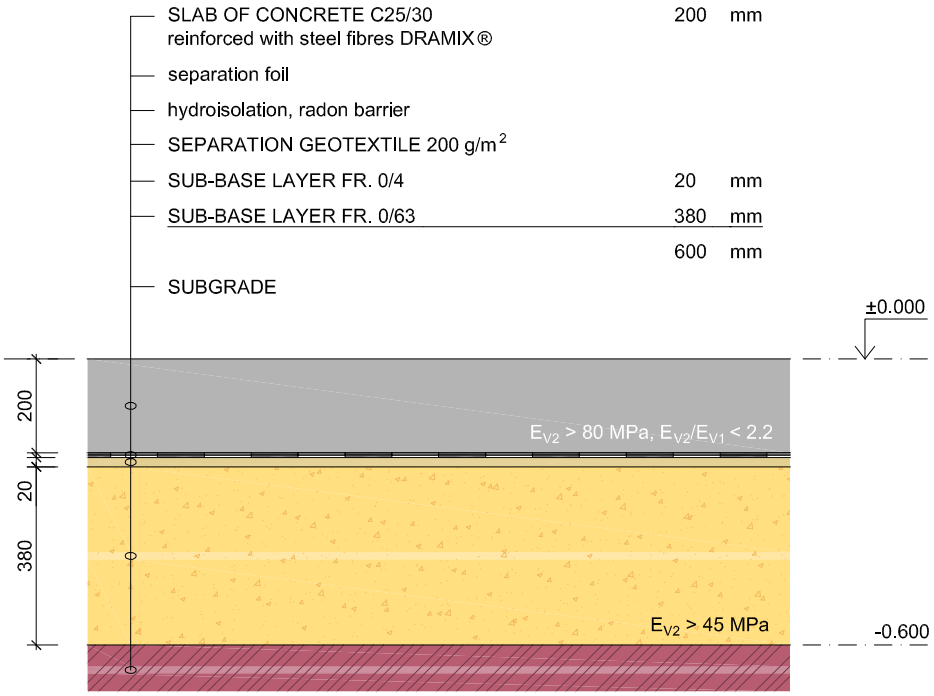


Fig. 2 The usual design of the industrial floor

Alt. I. Foam Concrete

Experimental measurements of the foam concrete layers in real scale in the experimental field of University of Zilina (UNIZA) were the base for the design of the thickness of the sub-base layer of the foam concrete FC 500.

Due to the favourable physical-mechanical properties of the foam concrete FC 500, the total thickness of the floor structure can be reduced at significantly lower demand on the subgrade preparation (**fig. 3** and **4**). In addition of the minimum required strain modulus E_{V2} fulfilment, the ratio of modulus from both load cycles during the plate load test carried out on the foam concrete FC 500 lied in the interval **from 1.0 to 1.3**.

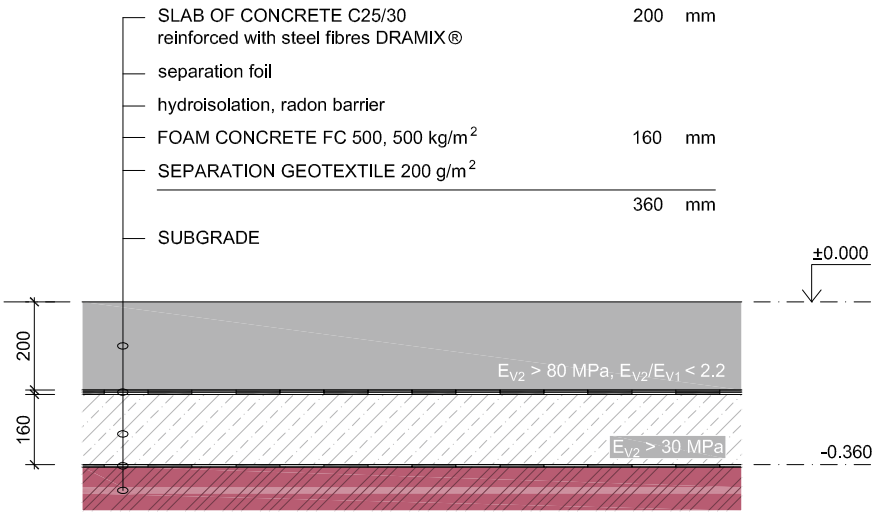


Fig. 3 The alternative design of the floor structure I.
without the reinforcement of the foam concrete FC 500

Alt. II. Foam Concrete with basalt mesh ORLITECH MESH

Application of the basalt mesh ORLITECH MESH allows the reduction of the sub-base layer of the foam concrete (**fig. 4**).

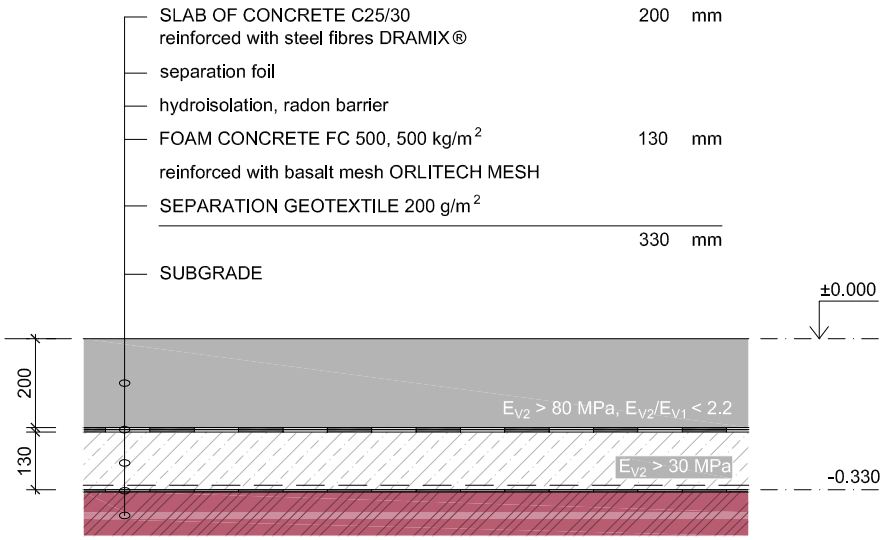


Fig. 4 The alternative design of the floor structure II.
with the reinforcement of the foam concrete layer FC 500 with the basalt mesh ORLITECH MESH

II. Thermal consideration – comparison of alternatives

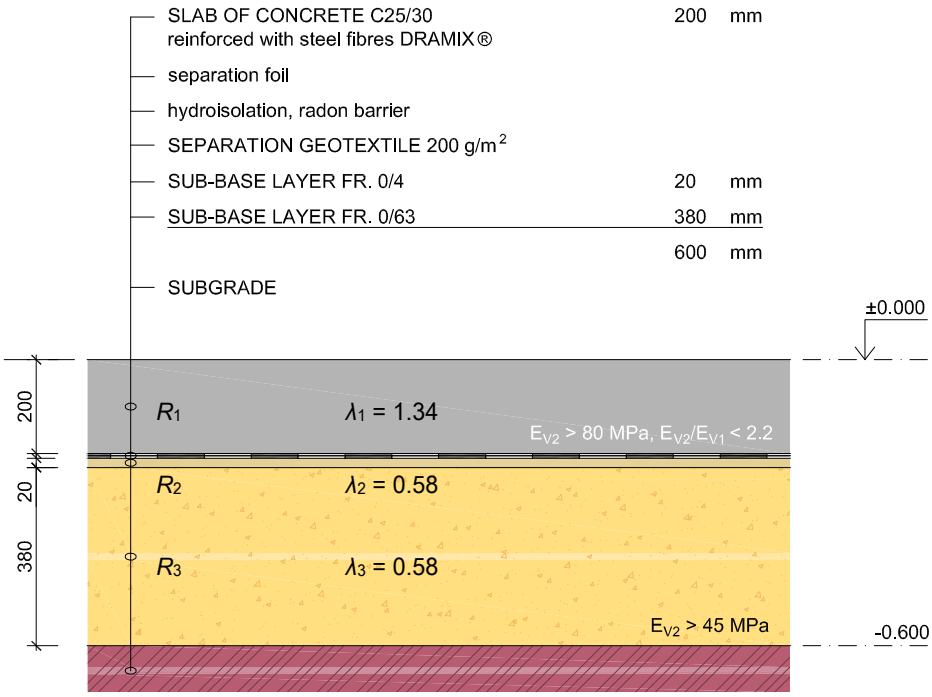
For the evaluation of the thermal properties of the alternative compound using the foam concrete FC 500, the calculation of the thermal resistance was performed for original and alternative floor designs.

Stabilized moisture content of 15% for the environment of the aggregate of fraction 0/63 was considered. The thermal conductivity λ = 0.19 W/m·K was set for this moisture content. These assumptions are valid in case of no influence of the groundwater or the flooding water on the foam concrete moisture.

Thermal resistance R of the compound (1) is determined as a sum of the ratios of the thickness of the particular floor layer d_i and the corresponding coefficient of the thermal conductivity λ_i.

$$\boldsymbol{R}\ (\mathrm{m^2 \cdot K/W}) = \Sigma\ R_i = \Sigma\ [d_i\ (\mathrm{m})\ /\ \lambda_i\ (\mathrm{W/m \cdot K})] \qquad (1)$$

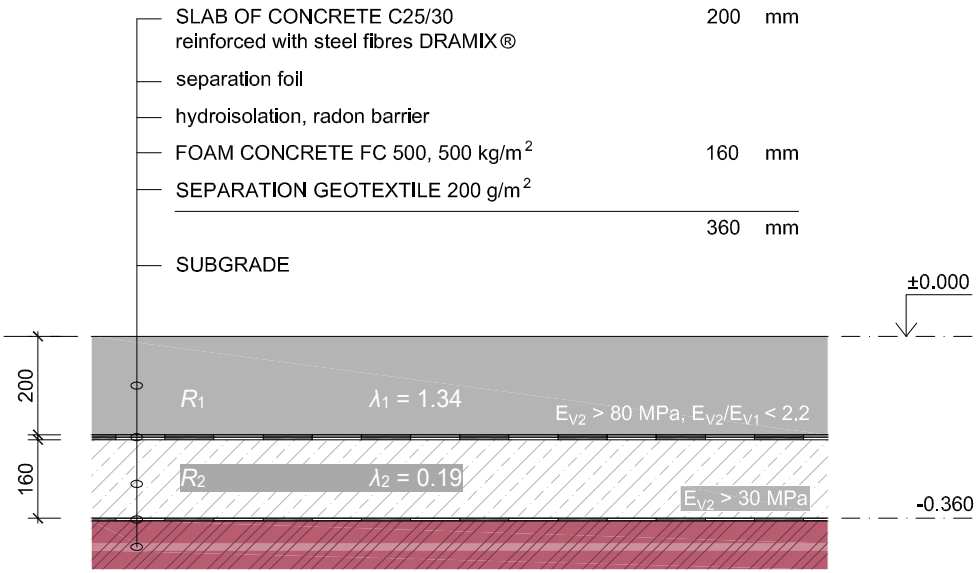
The usual design of the industrial floor



$$\boldsymbol{R} = R_1 + R_2 + R_3 = (0.20 / 1.34) + (0.02 / 0.58) + (0.38 / 0.58) = \mathbf{0.839\ m^2 \cdot K/W}$$

The design of the alternative floor compositions did not accent the thermal resistance of the floor structure.

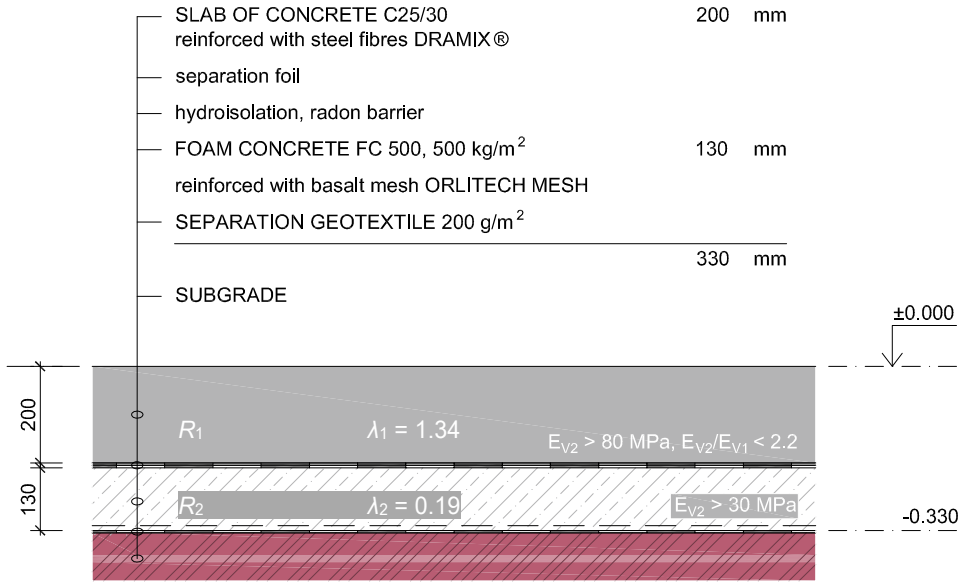
Alt. I. Alternative design of the floor using the foam concrete FC 500



$\boldsymbol{R} = R_1 + R_2 = (0.20 / 1.34) + (0.16 / 0.19) =$ **0.991 m²·K/W**

0.991 m²·K/W (alternative design I.) > 0.839 m²·K/W (usual design)

Alt. II. Alternative design of the floor using the foam concrete FC 500 reinforced with the basalt mesh ORLITECH MESH



$\boldsymbol{R} = R_1 + R_2 = (0.20 / 1.34) + (0.13 / 0.19) =$ **0.833 m²·K/W**

0.833 m²·K/W (alternative design II.) < 0.839 m²·K/W (usual design)

III. Economic aspects

Benefit of the foam concrete FC 500 in the floor structure is demonstrated by the example of the **heavy loaded industrial floor of the storage hall**. This benefit can be expressed as a financial savings during the floor structure realization. Mentioned prices does not include costs related to the subgrade improvement. Another **significant savings** can be achieved using the foam concrete FC 500 as a sub-base layer and **lower demands on the subgrade preparation** that can be compensate by the thickness of the foam concrete layer.

The usual design of the industrial floor:

thickness of the concrete slab reinforced with the steel fibres DRAMIX®	**200 mm** (fibre type see page 3)
total floor thickness	**600 mm**
floor thermal resistance	**R = 0.839 m²·K/W**

Price based on the CZ price level valid for 2017 for 1000 sq. m area:
53 407 EUR excl. VAT

Alt. I. Alternative design of the floor using the foam concrete FC 500:

thickness of the concrete slab reinforced with the steel fibres DRAMIX®	**200 mm** (fibre type see page 3)
total floor thickness	**360 mm**
floor thermal resistance	**R = 0.991 m²·K/W**

Price based on the CZ price level valid for 2017 for 1000 sq. m area:
48 407 EUR excl. VAT

Alt. II. Alternative design of the floor using the foam concrete FC 500 reinforced with the basalt mesh ORLITECH MESH:

thickness of the concrete slab reinforced with the steel fibres DRAMIX®	**200 mm** (fibre type see page 3)
overall floor thickness	**340 mm**
floor thermal resistance	**R = 0.833 m²·K/W**

Price based on the CZ price level valid for 2017 for 1000 sq. m area:
48 296 EUR excl. VAT

Comparison of the usual and alternative floor designs:

	Usual floor design	Alt. design I. without reinforced foam concrete FC 500	Alt. design II. with reinforced foam concrete FC 500
Realisation time without earth works:	up to 4 days	up to 2 days	up to 2 days
Usability of layer after finishing:	immediately	+3 days @ 15 – 20 °C	+3 days @ 15 – 20 °C
Usability of sub-base layer for further works:	limited	up to 30 days	up to 30 days
Realisation costs per 1000 m^2 (EUR):	53 407	48 407	48 296
Cost reduction per 1000 m^2 (EUR):	---	5 000	5 111
Cost reduction per 1 m^2 (EUR):	---	5.0	5.1

Notice:
Mechanized excavations, purchase costs of materials including transport costs, staff and machinery including transport are included in the mentioned prices.
The price does not include the contractor's margin, budget reserve and also costs related to the subgrade improvement (these costs vary depending on the specific locality). Prices may vary depending on the transport zone of the materials.
Transport distance of 30 km for all materials is considered in the costing.

Attention:
Presented comparison only relates to the presented examples. Every industrial floor is situated in a certain environment at corresponding design conditions and final costs. Therefore, it is essential that the design of the floor structure with the foam concrete has to be carried out by the authorized specialist with the appropriate qualification and knowledge.

EVALUATION AF AN ALTERNATIVE SOLUTION USING FOAM CONCRETE

Proposed alternative floor designs using the foam concrete FC 500 meet the required criteria in terms of static analysis.

Alternative floor designs using the foam concrete modify the usual industrial floor design as follows:

- reduction of the total floor thickness from **600 mm** to **360 mm** or **330 mm** respectively
- reduction of the sub-base layer thickness from **400 mm** to **160 mm** using unreinforced foam concrete or **130 mm** using reinforced foam concrete
- lower demand on the subgrade improvement – required strain modulus E_{V2} is **reduced from 45 MPa to 30 MPa**
- financial savings ca. **5 100 EUR per 1000 m²**

Due to the high level of physical-mechanical parameters and their rapid increase over time, the foam concrete FC 500 can be successfully used as a replacement of the conventional sub-base layers.

The biggest benefits of the foam concrete FC 500 as the sub-base layer of the industrial floors are …

- reduction of the floor thickness and lower demand on the subgrade preparation, what allows to reduce the extent of the earthwork
- variability of the floor composition using the foam concrete FC 500 reinforced with the non-corrosive basalt mesh ORLITECH MESH and various subgrade criteria
- excellent thermal properties
- a high level of homogeneity of the FC 500 layer and compliance with the quality standard for each realisation, especially when the reinforcing mesh ORLITECH MESH is used in this layer

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