SOME PROPERTIES OF FOAM CONCRETE

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Summary: *In this paper materials which can be ingredients for foam concrete are given. The most important properties of foam concrete are presented. Also, the results of our own investigation are shown.*

Key words: *Foam concrete, properties, polypropylene fibres*

1. INTRODUCTION

Aerated concrete is lightweight concrete which contains stable cells of air or gas evenly distributed in mixture. Depending on the bulk density aerated concrete can include use of natural or artificial aggregates. Foam concrete can be defined as concrete made with or without adding aggregates to Portland cement, water and ingredients for creating pores of air in concrete, whose bulk density in dry condition does not exceed 800 kg/m. In this paper we will show possibilities of use of certain materials, the properties of foam-concrete, as well as the results of our own investigation of foam-concrete manufactured by adding ammonia-based foam.

2. MATERIALS USED FOR FOAM-CONCRETE PRODUCTION

2.1. CEMENT

The cement has to confirm to the requirements prescribed by EN196 and EN197 standards or some other standard, e.g. ASTM C150. Besides the pure Portland cement, cements may contain slag, pozzolanic, and even metallurgical cement can be used. Cements with additions may have lower strengths in first 3 to 5 days. Use of cements with high early strengths can increase early strengths of concrete.

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2.2. AGGREGATE

The aggregate which is used for production of foam-concrete must confirm to the requirements from European standards or standards of some other area where the foam-concrete is produced. The practice has shown that many kinds of aggregate which did not confirm the standard requirements, gave satisfactory results in foam-concrete.

2.3. WATER

Conditions for water are the same as for conventional concrete. Care should be taken that the water does not contain large quantities of acids, alkalis, salts, oils and organic matter that could have damaging effect on concrete setting time, concrete strength and other properties of concrete.

2.4. FOAM

Prefabricated foam is produced by mixing foam concentrate and water with compressed air. This mixture is put in the blender which increases the volume up to 30 times. Bulk density of the foam obtained in this way is between 34 and 64 kg/m^3.This method is called foam generator in practice and is often different depending on the producer. Foam concentrate must have properties which enable it to produce stable cells of air in concrete. If the foam is not stable it could cause the degradation of foam structure and consequently considerable increase of foam-concrete bulk density in dry condition. There are many foam concrete producers on the market. In this case we used foam concentrate produced by a German company „Neopor“. The base for this concentrate is completely natural (the basic ingredient is ammonia). Foam concrete produced in this way can be considered as a completely ecological product.

2.5. ADMIXTURES

Air entrainments are often used but only for aggregate concrete. Use of other admixtures, like superplasticizers and accelerators, is possible but their effect should be confirmed in trial mixtures in order to avoid possible damaging effect on foam-concrete.

2.6. FIBRES

The improvement of low tensile strengths of foam-concrete may be achieved by use of fibres in concrete. It is especially important to enhance concrete properties which are the result of considerable concrete shrinkage. Most frequently used are polypropylene and glass fibres. Polypropylene fibres can be used in cases of very low bulk densities of concrete while glass fibres are used when bulk density in dry condition is not of crucial importance and some other properties of concrete are required like strength or thermal coefficient of conductivity.

3.MAIN PROPERTIES OF FOAM-CONCRETE

3.1. BULK DENSITY IN DRY CONDITION

Bulk density in dry condition is used for predicting the physical properties of foam concrete. This property is determined according to procedure described in standard SRPS U.N1.300 or according to American standards ACTM C495 or ASTM C513. The usual procedure prescribes drying of samples up to constant density during 24 hours at temperature of 110 ± 10 °C.

3.2. BULK DENSITY OF GREEN CONCRETE

Bulk density of green concrete is usually measured on building site. If some of parameters like aggregate moisture and volume of foam concrete are known, bulk density in dry condition can be predicted. It can be calculated easily using the following formula:

$$O_c=(W_{da}+1.2W_{ct})/S \qquad (1)$$

Where is: O_c – approximate value of bulk density in dry condition, W_{da} – mass of dry aggregate in mixer in kg, W_{ct} – mass of cement in mixer in kg, S – volume of foam concrete produced in one mixer in m^3, $1.2W_{ct}$ – mass of cement plus mass of water needed for hydratation in kg

3.3.COMPRESSIVE STRENGTH

The ratio of compressive strength of foam concrete and bulk density in dry condition is an important indicator of the quality of foam concrete. According to ASTM standards strengths lesser than 0.48 MP are not suitable for use in constructions but only for separate elements in constructions, e.g. for pipes, heat insulation of walls, tunnels etc.

3.4. MODULUS OF ELASTICITY

Testing of modulus of elasticity module of foam- concrete is very complex because of low compressive strengths of foam concrete. Testing of this property requires very precise equipment. According to ACI data, its value is from 0.14 to 0.69 GP.

3.5. SHRINKAGE

Shrinkage of concrete and consequent cracking of foam-concrete due to shrinkage is usually not of critical importance for foam-concrete used for thermal insulation. But in case of foam-concrete used for constructions, shrinkage must be taken into account. Shrinkage is determined according to standard SRPS U.N1.300. Our standard prescribes shrinkage independently of used aggregate, while American practice shows that the difference in shrinkage of foam concrete is related to use aggregates.

3.6. THERMAL MOVEMENT

Foam concrete can be exposed to a wide range of temperatures. Thermal movement of foam-concrete must be taken into account in places where great variations of temperature are expected during foam-concrete exploitation. This expansion of foam-concrete is important when foam-concrete is used for roofs, power plants and similar constructions. Coefficient of thermal movement primarily depends on foam concrete's bulk density as well as the used aggregate.

3.7. WALKABILITY

Ability of foam concrete to endure a normal pedestrian load without considerable damage is called walkability. The best way to assess this ability is to measure indentations of steps on the surface of foam-concrete. This ability can be improved by increasing the bulk density of foam-concrete.

3.8. NAILABILITY

Foam concrete can be nailed to any adequate surface without damage and this property is called nailability. This is very important when the of facade wallboard are planted by nails or screws. This method of facade covering with foam-concrete wallboards should be done only if the product is 7 days old or older.

3.9. THERMAL CONDUCTIVITY

Thermal conductivity of foam-concrete depends on many factors. The greatest influence on thermal conductivity has the moisture of foam-concrete at the moment of testing. Also, very important influence has the bulk density. Based on investigations a formula was proposed for K-value of foam-concrete. These formulas are given for foam-concrete in dry condition (2) and foam concrete kept in air with relative humidity of 50 to 60% (3), where r is the bulk density of foam-concrete in kg/ m^3, and e=2.718.

$$K=0.072 \text{ x } e^{0.00125r} \quad (2)$$
$$K=0.087 \text{ x } e^{0.00125r} \quad (3)$$

3.10. REACTION TO FIRE

According to SRPS standards testing for reaction to fire is obligatory if the material contains organic materials. Also, according to EN standards foam concrete containing a mass or volume fraction of ≤ 1,0 % (whichever is the most onerous) of homogeneously distributed organic materials the declaration may be fire Class A1 without the need to test.

3.11. WATER VAPOUR PERMEABILITY

Very important property of foam-concrete is its ability to conduct steam through its structure. It is an important property because the structure of foam-concrete allows the soaking of steam from the environment and its retention until the conditions are adequate for its release into surroundings. The testing of water vapour permeability is carried out according to SRPS U.J5.600. The lesser water vapour diffusion coefficient is the greater is its ability to soak the humidity from the surroundings and to release it.

4. THE RESULTS OF TESTING

4.1. COMPRESSIVE STRENGTH

The testing was carried out according to SRPS standards. Great number of samples was tested while varying bulk density in wet and dry condition based on the quantity of cement in concrete. Only one type of cement was used in order to make the comparison of the results easier. Water-cement ratio was not varied but was kept on the level needed to make the most of the foam present in the foam-concrete production. The following table shows the results for six batches of samples. Each batch had 9 samples.

Table 1. Compressive strength of foam concrete

Batch	Date of production	Bulk density of green concrete (kg/m^3)	Bulk density of dry sample (kg/m^3)	Average compressive strength (N/mm^2)
Batch 1	22.08.2006.	568	522	2.4
Batch 2	23.08.2006.	517	479	2.0
Batch 3	12.09.2006.	445	427	1.2
Batch 4	14.09.2006.	396	351	0.8
Batch 5	14.09.2006.	646	583	2.5
Batch 6	15.09.2006.	406	357	1.0

4.2. COEFFICIENT OF THERMAL CONDUCTIVITY

The testing was carried out according to SRPS standards. This information is very important for foam-concrete because one of the main uses of this material is for thermal insulation. This is especially property for foam-concrete with low bulk density. Since our standards require that certain bulk densities of foam-concrete are matched with certain compressive strengths, this property was tested on foam concrete with bulk density of circa 420 kg/m which was considered satisfactory compressive strength.

Table 2. Coefficient of thermal conductivity

t_{sr} (°C)	20	30	40
λ (W/(m•K))	0.0823	0.0850	0.0880

To illustrate this data we can use the example of an ordinary brick whose coefficient of thermal conductivity is 8 times higher.

4.3. WATER VAPOUR DIFFUSION COEFFICIENT

The testing was carried out in accordance with SRPS standards. It showed that the water vapour diffusion coefficient of foam concrete was 1.9. The same standard defines approximate values of water vapour diffusion coefficient for foam concrete between 5 and 7. The analysis leads to conclusion that the results which were got are the same as for thickly pressed insulation materials with fibres. Such small water vapour diffusion coefficient tells us that walls made of these materials 'breathe'. This is good because the use of these materials can efficiently solve the problem of increased humidity in rooms.

4.4. SHRINKAGE

Volume strain of foam-concrete is manifested as its shrinkage. Shrinkage of foam-concrete can be considerable, depending of materials used for its production. Materials used for production of foam-concrete showed major shrinkage strains in the beginning of testing. To prevent this polypropylene fibre were used. Polypropylene fibres are light which means that their use in production does not crucially change the bulk density. In this way the resistance of foam concrete to shrinkage was considerably improved and initial shrinkage of 2.6 mm/m (foam-concrete without polypropylene fibres) was reduced to under 1mm/m (foam-concrete with polypropylene fibres).

5. CONCLUSION

Based on everything said about foam-concrete and the results of testing it is clear that foam concrete is one of better thermal insulation materials. The fact that its coefficient of thermal conductivity is up to 10 times smaller than of some commonly used materials in our country speaks for itself. Consequently, it can be concluded that the thickness of the wall made of foam-concrete can be far lesser, which increases the useful living space as well as the profit made from residential buildings. In industrial sector, the advantage of using foam-concrete is larger useful space, too. Even during the building phase it is easily possible to count on energy efficiency of the finished structures (i.e. reduced expenses for heating).

NEKA SVOJSTVA PENO-BETONA

Rezime: *U radu su navedeni materijali koji se mogu koristiti za spravljanje peno-betona. Prikazana su najvažnija svojstva peno-betona. Takođe, dati su i rezultati sopstvenih istraživanja.*

Ključne reči: *Peno-beton, svojstva, polipropilenska vlakna*