Heat-insulating foam concrete based on microsilica reinforced with fiber

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Abstract. The article presents the results of the study of mechanical properties of heat-insulating foam concrete based on microsilica with different percentages of fiber made of different materials. It is experimentally established that the optimal amount of basalt and steel fibers in non-autoclaved foam concrete is 2 % by weight of solids, polypropylene fiber – 3 %. The best strength characteristics of foam concrete based on microsilica were produced using basalt fiber; therefore its application to reinforced foam concrete is the most preferable as compared to the others.

Heat-insulating foam concrete of non-autoclave hardening is an energy-effective building material. However, besides to good thermal insulation properties, it is characterized by low mechanical properties, large shrinkage deformations and small crack resistance.

From literature sources [1÷14] it is known that the reinforcement of foam concrete with fibers compensates for the above disadvantages.

The purpose of this work is to study the effect of the amount and type of fibers on the mechanical properties of thermal insulation foam concrete made with microsilica.

The following materials were used in the research:
- Portland cement CEM I 42,5 H (PC 500 D0) production of JSC “Angarskecemment”;
- microsilica from dust collecting filters of the JSC “Kremniy”;
- a hyperplasticizer based on polycarboxylates “MC-Power-Flow-3100”;
- a synthetic foaming agent Penta Pav 430A;
- basalt fiber;
- steel fiber;
- polypropylene fiber.

The research method was as follows. Foam concrete mixes for foam concrete D500 control composition (without fibers) and with fibers were prepared by classical technology: mix of Portland cement (PC), microsilica (MC), fibers (reference composition without fibres) with water and hyperplasticizer and the foam (water+foaming agent) were prepared separately. Then everything was mixed to obtain a homogeneous mass.

From the previously performed works it was found that the optimal ratio of the Portland cement to the microsilica in foam concrete is 1:1 [15] and the quantitative range of fibers in concrete based on microsilica is from 1 to 3% by weight of solids [16].

From foam concrete mixes with different amount and type of fiber samples sized 40x40x160 mm were molded. After 28 days of normal hardening samples were dried to constant weight at a temperature of 105±5 °C and tested for compressive and flexural strength in according with GOST 10180-2012 “Concretes. Methods for strength determination using reference specimens”. The test results are shown in Table 1.

Table 1. Physical and mechanical characteristics of fiber-foam concrete.

| №  | Amount of fiber, % by weight of solids | Average density of dried samples, g/sm³ | Humidity, % | Compressive strength, MPa | Flexural strength, MPa |
|----|--------------------------------------|----------------------------------------|-------------|---------------------------|-----------------------|
| 1  | 1                                    | 0.458                                  | 35.1        | 0.29                      | 0.47                  |
| 2  | 2                                    | 0.576                                  | 35.2        | 1.99                      | 2.1                   |
| 3  | 3                                    | 0.482                                  | 33.2        | 0.64                      | 1.16                  |
|    | Fiber-foam concrete with the content of steel fiber | | | | |
| 4  | 1                                    | 0.451                                  | 36.4        | 0.25                      | 0.29                  |
| 5  | 2                                    | 0.542                                  | 32.2        | 0.65                      | 0.61                  |
| 6  | 3                                    | 0.514                                  | 34.9        | 0.43                      | 0.42                  |
|    | Fiber-foam concrete with the content of polypropylene fiber | | | | |
| 7  | 1                                    | 0.403                                  | 27.2        | 0.09                      | 0.12                  |
| 8  | 2                                    | 0.477                                  | 26.7        | 0.42                      | 0.54                  |
| 9  | 3                                    | 0.561                                  | 35.0        | 1.27                      | 1.17                  |
|    | Control composition (without fiber content) | | | | |
| 10 | -                                    | 0.471                                  | 28.4        | 0.45                      | 0.41                  |
To assess the effectiveness of the reinforcement of heat-insulating foam concrete with fiber was used indicator, called the specific strength ($R_{sp}$) or the coefficient of constructive quality ($S.S.Q.$) of material. Specific strength or $S.S.Q.$ – this is the ratio of the compressive strength ($R_{comp}$) or flexural strength ($R_{flex}$) of material to its relative density $d$ (formula 1 and 2).

$$R_{sp}^{comp} = \frac{R_{comp}}{d}$$  \hspace{1cm} (1)

$$R_{sp}^{flex} = \frac{R_{flex}}{d}$$  \hspace{1cm} (2)

Dependences of specific strength of heat-insulating foam concrete D500 based on microsilica on quantity and a type of fiber are represented in Figures 1÷6.

**Figure 1.** Dependence of the specific compressive strength of foam concrete D500 on the amount of basalt fiber.

**Figure 2.** Dependence of the specific flexural strength of foam concrete D500 on the amount of basalt fiber.
Figures 1 and 2 show that the greatest strength characteristics of foam concrete using basalt fiber are obtained with its content in the amount of 2% by weight of solids: specific compressive strength increased 3.6 times and specific flexural strength – 4.2 times as compared to the control composition (without fiber).

**Figure 3.** Dependence of the specific compressive strength of foam concrete D500 on the amount of steel fiber.

**Figure 4.** Dependence of the specific flexural strength of foam concrete D500 on the amount of steel fiber.
Figures 3 and 4 show that the greatest strength characteristics of foam concrete using steel fiber are obtained with its content in the amount of 2% by weight of solids: specific compressive strength increased by 25% and specific flexural strength – by 30% as compared with the control composition (without fiber).

**Figure 5.** Dependence of the specific compressive strength of foam concrete D500 on the amount of polypropylene fiber.

**Figure 6.** Dependence of the specific flexural strength of foam concrete D500 on the amount of polypropylene fiber.
Figures 5 and 6 show that the greatest strength characteristics of foam concrete using polypropylene fiber are obtained at its content in the amount of 3% by weight of solids: specific compressive and flexural strengths increased 2.4 times as compared to the control composition (without fiber).

Thus, it is experimentally established that the optimal amount of basalt and steel fibers in foam concrete is 2% by weight of solids, polypropylene fiber – 3%. The highest values of compressive strength and flexural strength of heat-insulating foam concrete based on microsilica were obtained using basalt fiber, so its use in foam concrete is more preferable as compared to polypropylene and steel fibers.

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