TECHNICAL NOTE

HEAT-CONDUCTING PROPERTIES OF SMALL-POWER-HUNGRY CELLULAR CONCRETE

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ABSTRACT

One of the most effective thermal insulation materials is unautoclave cellular concrete in modified cement. The laboratory scientific research on composition developments and technology of unautoclave cellular concrete fabrication were carried out. In the composition of elaborated concrete, the modified cement mix, gas making substance, structure formation additives, setting accelerators, polymeric admixtures and filler from coarse-ground quartz sand were used. Elaborated material has the density 180…400 Kg/m³, compressive strength 0,3…0,53 Mpa, coefficient of heat conductivity 0,07…0,105 W/m. K.

Keywords: unautoclave cellular concrete, heat conductivity, thermal insulation, compositions, polymeric admixtures

1. MIX DESIGN

The creation of new thermal insulation materials on the basis of mineral binding remains one of the main directions, enabling to solve the problem of thermal insulation of buildings under the conditions of power crisis in Russia.

The diminution of the density of especially lightweight concrete (ELC) up to 150-300 Kg/m³ favors to hold coefficient of heat conductivity within 0,05-0,08 W/m.K. Constructions, made of ELC, equally with high thermal-insulating properties should meet the requirements of non-combustibility, toxicology and longevity.

In our laboratory the scientific research of ELC compositions with the bindings on the basis of modified Portland cement and gyps-cement-molding flask (GCF). The elaborated compositions represent high porous (the pores volume to 94%) concrete stones, making by means of air curing of specially mix design, consisting of binding fine-ground quartz sand, water and adjusting admixtures.

Depending on the kind of pores-forming admixture, the elaborated ELC compositions are gas or foam concretes. In order to get especially lightweight gas concrete we used the standard gas-forming admixture-aluminium powder and alkali additions regarded as gas formation and setting accelerators. In the process of making the ELC the fine-ground quartz sand and binding mixture, containing the foam-forming admixtures were mechanically air-entrained. The peculiarity of all elaborated compositions is air curing (t=+18-20°C, relative humidity φ=90-98%).
The optimum ELC compositions with the use of Portland cement, tested at the age of 7 days have the compression strength 0.25-0.6 MPa and density in dry state 150-300 Kg/m³. Under favorable conditions the rise in strength for investigated materials continues even after 7 days. Their density-strength relation is shown in Figure 1.

![Density-strength relation](image)

1- Strength of gas concrete; 2- strength of GCF binding; 3- strength of foam concrete.

2. APPLICATIONS

In regard to structure formation peculiarities and physical-mechanical properties of elaborated ELC one can suppose that their most preferable field of application is cast-in-situ thermal insolation of the buildings.

In the course of researches the possibility to use GCF binding for the making of ELC was revealed. The composition of that binding is a special mix design on the basis of gyps (A), portland cement (B) and molding flask admixture (C). The most valuable properties of GCF binding for the manufacturing of ELC are rapid hardening (due to gyps hardening) and high water-resisting property (is secured by cement component).

As active mineral admixture locally procurable rocks (Sureck molding flask) were used. The molding flask, that is deposited in Penza region, consists on the whole of opal silicon dioxide ($\text{SiO}_2 \cdot n\text{H}_2\text{O}$) with clay slip additions. The activity of used admixture in respect to calcium oxide, determined in conformity with the recommendations TY21-32-62-89 «Gyps-cement-molding flask binding», is within the limits of 210-240 mg/gram.

On the initial stage a work on the binding proportioning was accomplished with a view to find the optimum composition of ELC on the basis of GCE binding. Compression strength and water-resisting property served as the criterions of the optimum binding composition. In Figure 2,3 the relations of compression strength-coefficient of water resisting $K_w$ (after 48 hours curing by ponding) component parts (on mass: A-gyps mark “Г-5,” B-Portland cement mark “ПП-400,” C-Sureck molding flask) are shown. These relations were defined by the use of equation (1) with coefficients, determinated with the help of statistic treatment of empirical date.
\[ R_{\text{com}} = 10.8 A + 12.0 B + 13.6 C - 2.4 A B - 18.4 A C + 3.2 B C \]

where \( (0.5 \leq A \leq 0.6); (0.2 \leq B \leq 0.3); (0.2 \leq C \leq 0.3) \)

Figure 2 Compression strength (Mpa) – component parts relations of GCF binding

Table 1 Physical – mechanical data of cellular concretes

<table>
<thead>
<tr>
<th>Kind of ELC</th>
<th>Density, Kg/m³</th>
<th>Porosity, %</th>
<th>Compression strength, Mpa</th>
<th>Coefficient of heat conductivity, W/m.K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas cement concrete</td>
<td>200</td>
<td>93</td>
<td>0.11</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>90</td>
<td>0.19</td>
<td>0.069</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>88</td>
<td>0.25</td>
<td>0.075</td>
</tr>
<tr>
<td>Foam cement concrete</td>
<td>200</td>
<td>93</td>
<td>0.27</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>90</td>
<td>0.38</td>
<td>0.069</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>88</td>
<td>0.45</td>
<td>0.075</td>
</tr>
<tr>
<td>Foam GCF binding</td>
<td>260</td>
<td>90</td>
<td>0.21</td>
<td>0.07</td>
</tr>
<tr>
<td>concrete</td>
<td>300</td>
<td>88</td>
<td>0.32</td>
<td>0.078</td>
</tr>
</tbody>
</table>

The results of laboratory investigations point out that the majority of tested GCF binding compositions, containing Sureck-molding flask, can be regarded as the water-resisting materials \( (K_{w} > 0.8) \)

The optimum binding composition using the above-mentioned criterions has A, B, C ratio 2.08:1:1 (on mass). The GCF binding test samples, possessing such a ratio, assume compression strength 11MPa at the age of 5 days and a quantity of \( K_{w} \) equal 0.82. In order to raise the tensile strength by bending, this GCF binding composition was modified by means of polymeric admixtures-carbamide resin and dispersion polyvinylacetate. As it was found out, polyvinylacetate dispersion admixture is more effective and also its optimum quantity makes up 5% of GCF binding mass (it ensures the rise of bending strength by 41%). As further increasing polyvinylacetate admixture content, the considerable diminution of compression strength (by
60 %) as well as bending strength (by 7.5 %) takes place. On the basis of elaborated GCF binding composition, the cellular foam concretes were made and researched (table 1). The relation compression strength-density of ELC with the use of GCF binding is shown in Figure 1 (curve 2).

One of the principal quantitative factors relating to the thermal insulation materials is the coefficient of heat conductivity $\lambda$, therefore it is important to secure the process of ELC designing and composition development by the prognostication of their heat-conducting properties. The calculating heat conductivity value of two-ingredient (air + binding) cellular materials can be determined by consideration of a number of proposed heat conductivity models [1,2]. Regarding as an elementary accounting ELC cell the most simple two-ingredient model with closed air space of cubic form, there was received for ELC the following relation

$$\lambda = \frac{\lambda_{\text{bin}} \lambda_{\text{air}}}{\lambda_{\text{air}} \left(1 - \frac{2}{3} \nu_{\text{air}}\right) + \lambda_{\text{bin}} \left(1 - \frac{2}{3} \nu_{\text{air}}\right)} + \lambda_{\text{bin}} \left(1 - \frac{2}{3} \nu_{\text{air}}\right)$$

(2)

Where $\lambda_{\text{bin}}, \lambda_{\text{air}}$ - the coefficient $\lambda$ of binding and air

$\nu_{\text{air}} = 1 - \frac{\rho_{0}}{\rho}$ - material porosity

Assuming, that for unautoclave cellular cement concrete the value $\lambda$ of air by bore of pore to 2 mm is within the limits of 0.025-0.027 W/m. K and that of cement (for lack of pores) - 0.85 W/m. K, the equation (2) takes on an air:

$$\lambda = \frac{0.0212 \left(1 - \frac{\rho_{0}}{\rho}\right)^{\frac{2}{3}}}{0.025 \left(1 - \frac{2}{3} \left(1 - \frac{\rho_{0}}{\rho}\right)\right) + 0.85 \left(1 - \frac{2}{3} \left(1 - \frac{\rho_{0}}{\rho}\right)\right)} + 0.85 \left(1 - \frac{2}{3} \left(1 - \frac{\rho_{0}}{\rho}\right)\right)$$

(3)

According to our laboratory research coefficient $\lambda$ of GCF binding without pore formation make up the mean quantity 0.75 W/m. K. The equation (2) for ELC on the basis of GCF binding assumes an air

$$\lambda = \frac{0.0187 \left(1 - \frac{\rho_{0}}{\rho}\right)^{\frac{2}{3}}}{0.025 \left(1 - \frac{2}{3} \left(1 - \frac{\rho_{0}}{\rho}\right)\right) + 0.75 \left(1 - \frac{2}{3} \left(1 - \frac{\rho_{0}}{\rho}\right)\right)} + 0.75 \left(1 - \frac{2}{3} \left(1 - \frac{\rho_{0}}{\rho}\right)\right)$$

(4)
By equation (3.4) $\lambda$ calculation values, were determined which have shown a quite good similarity with that of empirical findings for ELC with the use of different cement density, (Figure 4)

Figure 4 Coefficient of heat conductivity of cellular concrete
1- calculating $\lambda$ values of cement ELC; 2.- empirical $\lambda$ date of cement ELC; 3. calculating $\lambda$ values of ELC on the basis of GCF binding.

Presently the materials studied in this paper are being put into production at one of Penza precast. Their techno-economic efficiency and competitiveness with heat insulators made from expanded polystyrene and mineral wool are evident.

REFERENCES