Energy efficiency improvement of aerated concrete block wall fences

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Abstract. The development of effective protecting structures is currently one of the most popular areas in the construction industry. In order to ensure energy efficiency and environmental safety in the construction of civil buildings, masonry made of aerated concrete blocks with high thermal protection properties is used as protecting structures. As glue and cement-sand solutions in masonry have low thermal conductivity and are temperature bridges, the issue of filling through seams of aerated concrete masonry is very acute. The authors have developed a double row of concrete masonry, having a minimum number of cross-cutting horizontal seams, which not only improves thermal insulation properties, but also reduces material consumption and, consequently, the complexity of the arrangement of protecting structures of civil buildings. The influence of through horizontal seams made of cement-sand grout and block binding on the resistance to heat transfer of masonry made of aerated concrete blocks is considered.

1. Introduction
Reducing the material intensity and, consequently, the labor intensity of construction while maintaining the operational characteristics of buildings and structures has become the main direction of construction development. In order not to increase material consumption at increasing thermal protection properties new construction materials, products and structures are developed and introduced, the emergence of which allows combining the main trends of joint construction: reducing material consumption as the main economic task, and increasing the thermal protection properties of protecting structures as a component of the overall task of improving energy efficiency of buildings [1-4].

Cellular concrete is one of the main effective building materials used in the construction of external walls of buildings [5-9]. Construction systems made of cellular concrete blocks provide the required thermal insulation with a minimum thickness of the structure. However, the factor that reduces the energy efficiency of protecting structures made in the form of masonry of cellular concrete blocks is the filling of masonry seams with heat-conducting materials [10].

At arranging masonry from cellular concrete blocks, three main variants of masonry seams are used: on polyurethane glue, cement-sand grout and cement glue [11, 12].

The use of polyurethane glue as a joint filler for cellular concrete masonry is the most cost-effective due to the higher performance of work during installation and a lower cost of construction in the ratio of the cost of filling masonry seams. This type of masonry allows for high thermal uniformity...
due to the small thickness of the horizontal seam (less than 1 mm) and high thermal conductivity of the seam material. However, due to the low shear stiffness and high deformability, polyurethane adhesive can only be used when installing curtain walls of buildings.

Masonry on a cement-sand grout is the most material-intensive due to the arrangement of seams with a thickness of 8...10 mm, while this material is the least heat-conducting, which reduces the heat-protective properties of the entire enclosing structure.

Cement glue as a filler for masonry seams is the most optimal material due to its high thermal uniformity with a seam thickness of 1...2 mm, while having a low deformability and high strength.

The presence of heat-conducting inclusions, which are temperature bridges, in the protecting structures leads to additional losses of heat energy during the operation of buildings during the heating period and, as a result, to additional operating costs. However, failure to take these factors into account may lead to an unjustified underestimation of the design capacity of heating devices.

Taking into account the fact that the main heat losses occur through the through seams of wall structures, the development of cellular concrete masonry walls with a minimum number of through seams is one of the main tasks of ensuring the efficiency of buildings.

As the protecting structure of one-dimensional cellular concrete blocks, the most common masonry with cross-binding of blocks through a row is used (Fig. 1, a). However, this masonry is not energy efficient enough due to the presence of a large number of through horizontal seams that reduce the thermal uniformity of the protecting structure.

The authors developed an energy-efficient double row aerated concrete masonry walls (Fig. 1, b), which is characterized by high thermal uniformity due to reducing the number of through horizontal seams [13].

![Figure 1](image.png)

**Figure 1.** Cross section and general view of cellular concrete block masonry.  
(a) masonry with cross-binding of blocks in a row (b) double row cellular concrete masonry.

Energy-efficient double row aerated concrete masonry consists of two vertical rows of one-size blocks and is represented by alternating tiers made in the form of two sections with a die binding between them. The lower section is represented by an internal vertical row of blocks laid down with a stretcher, and an external row of blocks laid down with a bedside. The upper section is represented by an inner row of blocks laid with the bedside down, and an outer row laid with the stretcher down.

This technological solution allows reducing the number of through horizontal seams by 5.6 times, thereby increasing the thermal uniformity, and reducing the material consumption and, as a result, the labor intensity of the masonry device by 20% due to the lower thickness of the protecting structure.

2. Methods
The study of the thermal properties of aerated concrete masonry, taking into account heat-conducting inclusions in the form of through seams, is quite important for the effective use of masonry, often as the only thermal insulation layer of a wall structure. Therefore, increasing the thermal uniformity of masonry from aerated concrete blocks while ensuring the required performance characteristics
determines the energy and economic efficiency of the arrangement of double row cellular concrete masonry developed by the authors.

As part of a comprehensive study of the types of masonry and their performance characteristics the authors conducted computational and experimental studies of the effect of through seams on thermal performance [14-20].

For the calculation and experimental evaluation of the thermal performance of the wall structure, the authors considered fragments of aerated concrete masonry, represented as a section of through seam and a section of block binding. By mechanical processing, models of masonry (Fig. 2) with dimensions of 250×250×50 mm are made, consisting of two rows of fragments of aerated concrete blocks connected with a cement-sand grout. Models a and c (Fig. 2) are represented by sections of binding of fragments of blocks, models b and d (Fig. 2) are represented as one and two through seams, respectively. All seams are 5 mm thick.

\[ R_{oc} = \frac{\Sigma A_i}{(\Sigma A_i/R_{oc,i} + \Sigma L_j/\psi_j + \Sigma N_k K_k)} \]  

where 
- \( A_i \) – the area of the structure of the i-th type in the fragment under consideration, m²;  
- \( L_j \) – the length of all j-type joints in the fragment under consideration, m;  
- \( N_k \) – the number of point thermal inhomogeneities of the k-th type in the considered fragment, PCs;  
- \( R_{oc,i} \) – heat transfer resistance of a homogeneous part of the i-th type structure, (m²·°C)/W;  
- \( \psi_j \) – additional specific linear heat loss through the junction of the j-th type, W/(m·°C);  
- \( K_k \) – additional specific heat losses through point heat engineering inhomogeneity of the k-th type, W/°C.

The fragments under consideration are represented by three types of homogeneous part of the structure:  
- masonry section in the form of a through seam (Fig. 2, pos. 1);  
- masonry section in the form of a layered structure consisting of two vertical rows of fragments of aerated concrete blocks connected by a layer of cement-sand grout (Fig. 2, pos. 2);  
- section of binding of seams of masonry fragments (Fig. 2, pos. 3).
3. Results and discussion
Experimental studies were conducted on the thermal conductivity meter ITP MG-4. The temperature difference between the refrigerator and the heater of the device during the experiment was 30 °C. The results of the computational and experimental evaluation, including the determination of the reduced resistance to heat transfer, linear losses through the joint and the coefficient of thermal conductivity, are shown in Fig. 3.

Figure 3. Average values of the main heat engineering indicators.

From the data presented in Fig. 3, it can be concluded that the best thermal performance of the masonry model \( a \) that is due to the absence of through seams in this model, which are heat-conducting inclusions, by 10...30% compared to the masonry model \( b \), which has a single through seam. It should be noted that the thermal performance of the masonry model \( c \), which has three sections of block binding, is comparable to the performance of the masonry model \( b \) with a single through seam. Also, according to the research, the least energy-efficient model is the masonry \( d \), whose thermal characteristics are inferior to the model of masonry \( c \) with non-through seams by 10...25%.

4. Summary
Energy-efficient double row aerated concrete masonry for the construction of protecting wall structures with a minimum number of through seams has been developed and designed. To determine the effect of through seams on the thermal performance of masonry, construction models were erected on the through seam section and on the block binding section. After conducting computational and experimental studies and processing the results, it was found that reducing the number of through horizontal seams increases the energy efficiency of wall structures by 10...30%.

The use of the energy-efficient double row aerated concrete masonry developed by the authors allows to increase the thermal protection properties of the wall structure by reducing the heat-conducting inclusions in the form of through seams, as well as to reduce the material consumption and, consequently, the labor intensity of the construction of the protecting structure by reducing the thickness of the masonry while ensuring the required performance characteristics.

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Acknowledgements
This work was realized in the framework of the Program of flagship university development on the base of the Belgorod State Technological University named after V G Shukhov, using equipment of High Technology Center at BSTU named after V G Shukhov.