

Study of the thermal protection characteristics of composite aerated concrete lintels when optimizing the life cycle of a building

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Abstract. The article is devoted to the study of the effectiveness of various methods of reinforcing composite aerated concrete lintels intended for window and door openings in the construction of civil buildings. The authors have developed a composite aerated concrete lintel for window and door openings, which includes two or three aerated concrete blocks and a seam at the ends made with polyurethane glue. The lintel reinforcement is made in the form of tape and parts of carbon fiber tape attached to aerated concrete blocks. The article provides a comparative analysis of various methods of reinforcing lintels made of aerated concrete, including steel rods and glass-composite reinforcement, as well as external tape reinforcement using carbon tapes. The results of the study allow us to conclude that external tape reinforcement with carbon fiber tapes is the most effective method. The most thermally efficient type of lintel reinforcement is external tape reinforcement with carbon fiber tapes, since the reduced heat transfer resistance is 6-10% higher than that of similar lintels with another type of reinforcement, and 10-28% higher than traditionally used lintels (reinforced solid lintels and composite U-shaped lintels).

1 Introduction

Laying walls from cellular concrete blocks is one of the most effective ways to construct external walls of civil buildings. This is explained by the high thermophysical characteristics and mechanical strength of this material [1-4]. Blocks made of cellular concrete provide high energy efficiency of buildings, as well as their durability and reliability [5-7]. However, the high energy efficiency indicators of masonry made from aerated concrete blocks when assessing the thermal insulation properties of external wall structures are significantly reduced due to the lintels of window and door openings, which have higher thermal conductivity rates. When managing the life cycle of a building, it is of

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great importance to ensure that the building envelope meets the requirements for thermal protection, ensuring comfortable walking of people in the room. To reduce the thermal conductivity of the ceiling of openings, reinforced lintels made of autoclaved aerated concrete [8, 9] and U-shaped aerated concrete blocks are used, however, the steel reinforcing frame inside the lintels reduces the thermal uniformity of the entire wall structures, and the large weight of the lintel relative to aerated concrete blocks increases the labor and machine intensity of installing the structural element.

To ensure the required thermal uniformity of the design of the overlap of window and door openings without increasing labor intensity, an aerated concrete composite lintel was developed [10], including three aerated concrete blocks (Fig. 1, pos. 1) and a seam (Fig. 1, pos. 2) at the ends, made on polyurethane glue. The lintel reinforcement is made in the form of a tape (Fig. 1, pos. 3) and parts of the tape (Fig. 1, pos. 4) made of carbon fibers attached to aerated concrete blocks.

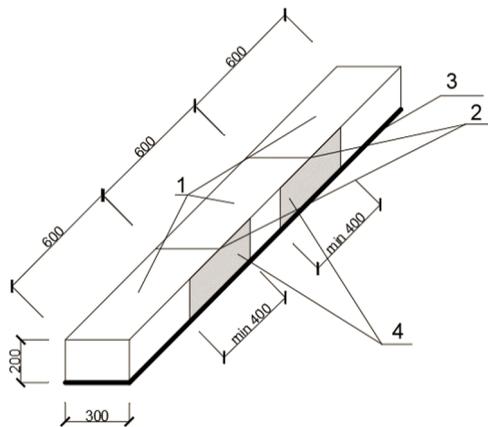


Fig. 1. Composite aerated concrete lintel for window and door openings: 1 – aerated concrete blocks; 2 – vertical seam; 3 and 4 – carbon fiber tapes

On the lower side of the composite jumper along the entire width and length with the direction of the fibers parallel to the longitudinal axis of the composite jumper, a tape (Fig. 1, pos. 3) of carbon fibers is attached using epoxy glue. Also, using epoxy glue, parts of the tape (Fig. 1, pos. 4) made of carbon fibers are attached along the flange sides of the aerated concrete block elements, along the entire height of the aerated concrete block and symmetrically relative to the vertical seam with the direction of the fibers perpendicular to the longitudinal axis of the composite lintel.

To increase the strength characteristics, a through longitudinal groove is made in the lower part of the lintel with a longitudinal steel or glass-composite rod installed in it.

2 Materials and methods

To justify the choice of the type of reinforcement that increases the strength properties of the composite lintel without significantly reducing the heat-shielding properties, the reduced heat transfer resistance of the enclosing structure was calculated taking into account heat-conducting inclusions. For the calculation, we consider a fragment of a composite aerated concrete lintel reinforced with one rod (Fig. 2, a), a fragment of a lintel reinforced with two rods (Fig. 2, b), a fragment of a lintel reinforced with carbon fiber tapes

along the seam

(Fig. 2, *c*), a fragment of a lintel reinforced with one rod and carbon fiber tapes along the seam (Fig. 2, *d*), a fragment of a lintel reinforced with two rods and carbon fiber tapes along the seam (Fig. 2, *e*), with an area of 1 m² each. The fragments in question consist of three D600 aerated concrete blocks measuring 200×300×600 mm. The blocks are connected at the end sides with polyurethane glue 1 mm thick. Rod reinforcement is made with steel or composite rods with a diameter of 10 mm. Carbon fiber strips attached to the underside of the composite aerated concrete lintel were not taken into account in the calculation, because are located outside the body of aerated concrete blocks and their influence on the heat transfer resistance and ventilation of the structure is absent. The width of the tapes attached to the flange sides of the blocks in the places of vertical seams for all types of composite lintels is 400 mm.

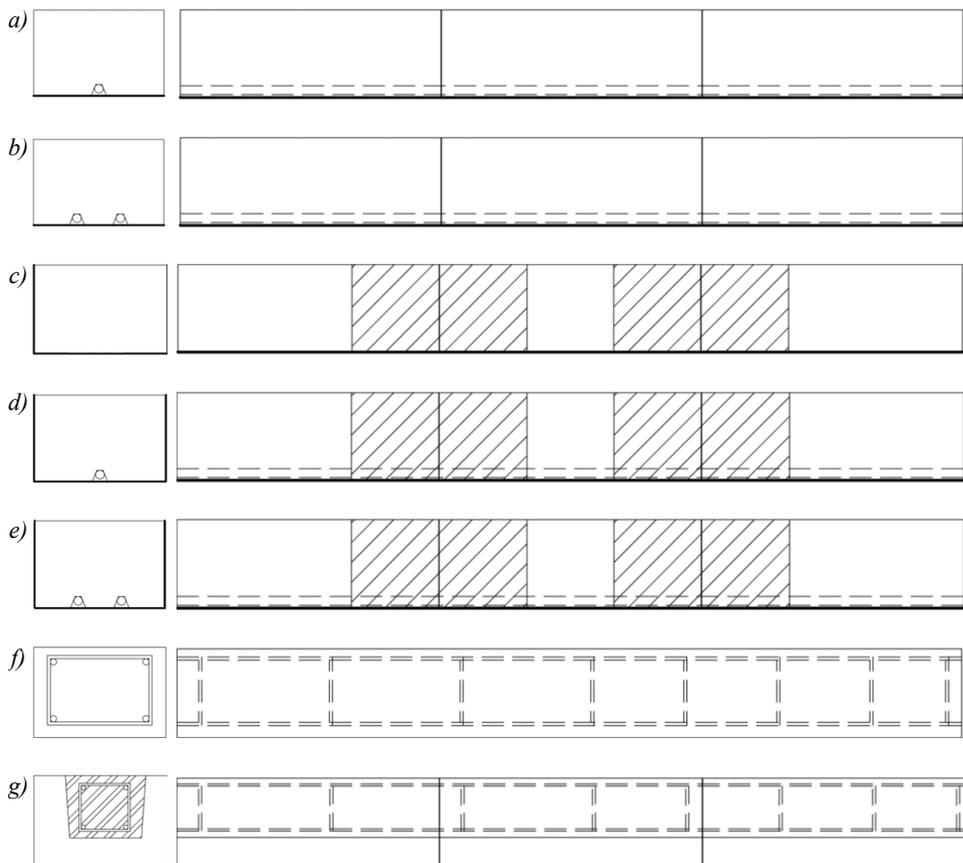


Fig. 2. Cross section and general view of fragments of composite lintels made of aerated concrete blocks to determine the reduced resistance to heat transfer: *a* – lintel reinforced with one rod; *b* – lintel reinforced with two rods; *c* – lintel reinforced with carbon fiber tapes along the seam; *d* – jumper reinforced with one rod and carbon fiber tapes along the seam; *e* – jumper reinforced with two rods and carbon fiber tapes along the seam; *f* – reinforced aerated concrete continuous lintel; *g* – reinforced lintel made of U-shaped blocks

Also considered within the framework of the study are a reinforced solid lintel made of aerated concrete of medium density grade D600 (Fig. 2, *f*), a lintel made of U-shaped

blocks (Fig. 2, g) with a reinforcement frame located in a recess, filled with concrete of the M100 grade.

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 40 °C.

3 Results and discussion

The considered fragments of lintels are represented by the following types of a homogeneous part of the structure:

- section of aerated concrete block;
- a section of a vertical through seam on polyurethane glue;
- a section of rod reinforcement in the form of an aerated concrete block with reinforcing bars built into it;
- a section of external strip reinforcement in the form of an aerated concrete block with a carbon fiber strip attached to the tray side of the block;
- the excavation area for a lintel made of U-shaped blocks, consisting of walls made of aerated concrete, a reinforcement frame made of steel rods and heavy concrete poured into the excavation;
- a section for excavating a lintel made of U-shaped blocks, consisting of walls made of aerated concrete and heavy concrete poured into the excavation.

The reduced heat transfer resistance of the structure of each of the calculated fragments is determined by formula (1) [11, 12]:

$$R_{o}^r = \sum A_i / (\sum A_i / R_{o,i} + \sum L_j \psi_j + \sum N_k K_k) \quad (1)$$

where A_i – the area of the i -th type of structure in the fragment under consideration, m²;
 L_j – length of all joints of the j -th type in the fragment under consideration, m; N_k – number of point thermal inhomogeneities of the k -th type in the fragment under consideration, pcs.; $R_{o,i}$ – heat transfer resistance of a homogeneous part of the structure of the i -th type, (m²·°C)/W; ψ_j – additional specific linear heat losses through a joint of the j -th type, W/(m·°C); K_k – additional specific heat losses through point thermal heterogeneity of the k -th type, W/°C.

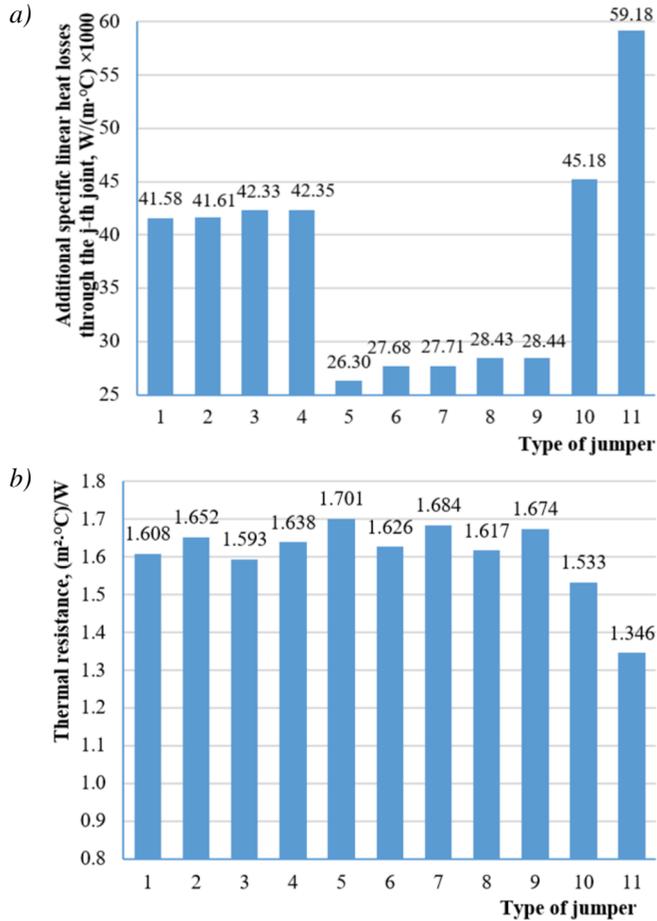
Since there are no point thermal homogeneities in the structures under consideration, N_k and $K_k = 0$.

The reduced heat transfer resistance of a fragment of an aerated concrete lintel reinforced with one rod, a fragment of a lintel reinforced with two rods, a fragment of a lintel reinforced with carbon fiber tapes along the seam, a fragment of a lintel reinforced with one rod and carbon fiber tapes along the seam, a fragment of a lintel reinforced with two rods is determined. and carbon fiber tapes along the seam, a fragment of a reinforced solid lintel and a fragment of a reinforced lintel made of U-shaped blocks. of studies of thermophysical characteristics are presented in Fig. 3.

From the data presented in Fig. 3, a, it can be seen that the maximum additional specific heat losses are for fragments of lintels without external strip reinforcement, since carbon fiber tapes attached to aerated concrete blocks in places of vertical joints reduce the airflow of the composite structure. The smallest value of additional specific heat losses is for the lintel reinforced with carbon fiber tapes, which indicates the influence of rod reinforcement on the thermal uniformity of the structure despite the fact that reinforcement with steel and glass composite rods has different thermal conductivity indices. It should also be noted that

fragments of lintels with an identical type of reinforcement have practically equal specific heat losses, which indicates that thermal homogeneity is affected by the ratio of areas of homogeneous parts of the structure.

A composite lintel made of U-shaped blocks has the greatest additional specific heat losses, since the design of this lintel contains a homogeneous part of the structure, presented in the form of a recess with a reinforcement frame, filled with heavy concrete, of a sufficiently large area, due to which the length of the joints of homogeneous parts of the structure increases, facilitating loss of heat (Fig. 3, *b*).



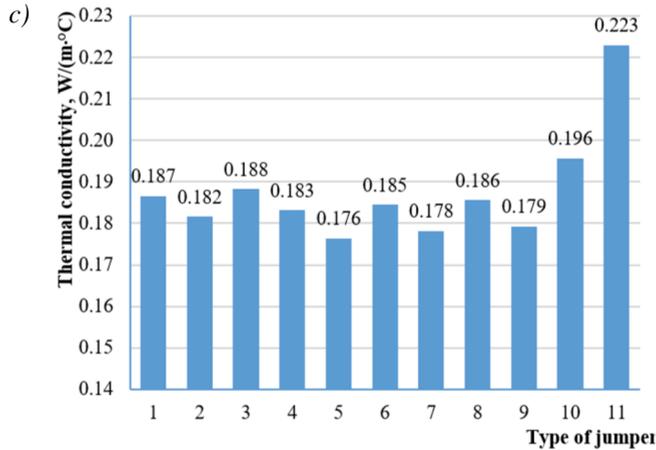


Fig. 3. Results of studies of thermophysical characteristics: *a* –additional specific linear heat losses through the joint of the *j*-th type; *b* – thermal resistance; *c* – thermal conductivity of lintel fragments; 1 – lintel with one steel rod; 2 – lintel with one glass-composite rod; 3 – lintel with two steel rods; 4 – lintel with two glass-composite rods; 5 – lintel with carbon fiber tapes along the seams; 6 – lintel with one steel rod and carbon fiber strips along the seam; 7 – lintel with one glass-composite rod and carbon fiber tapes along the seam; 8 – lintel with two steel rods and carbon fiber tapes along the seams; 9 – lintel with two glass-composite rods and carbon fiber tapes along the seam; 10 – reinforced solid lintel; 11 – composite lintel made of U-shaped blocks

From the data presented in Fig. *c*, it follows that rod reinforcement as a heat-conducting inclusion reduces the thermal characteristics of the structures under study. At the same time, reinforcement with steel rods reduces the heat-shielding properties of lintels by 5-7% compared to rod reinforcement with glass-composite reinforcement due to the high thermal conductivity of steel. The most thermally efficient type of lintel reinforcement is external strip reinforcement with carbon fiber tapes, since the reduced heat transfer resistance is 6-10% higher than that of composite lintels with another type of reinforcement. However, if it is necessary to increase the strength characteristics of a composite lintel by installing rod reinforcement in the body of aerated concrete blocks, glass-composite reinforcement with high thermal protection should be used.

In relation to a solid reinforced lintel, a composite lintel made of aerated concrete blocks, reinforced with carbon fiber tapes along the seam, has thermal conductivity rates that are 10% higher; in relation to a composite lintel made of U-shaped blocks – by 28% due to the absence of heat-conducting inclusions in the form of a reinforcement frame and heavy concrete in the body of the lintel.

4 Conclusion

The authors have developed an energy-efficient composite aerated concrete lintel for window and door openings with various types of reinforcement, which makes it possible to reduce the deformability of the enclosing structure using polyurethane adhesive due to the installation of steel and glass-composite rods and external strip reinforcement. To determine the effectiveness of a composite lintel, the reduced heat transfer resistance is calculated; a fragment of an aerated concrete lintel reinforced with one rod, a fragment of a lintel reinforced with two rods, a fragment of a lintel reinforced with carbon fiber tapes along the seam, a fragment of a lintel reinforced with one rod and carbon fiber tapes along the seam

are considered. , a fragment of a jumper reinforced with two rods and carbon fiber tapes along the seam and the terminals were installed.

External strip reinforcement, made in the form of a tape of carbon fibers, rigidly attached to the underside of a composite cellular concrete lintel along the entire width and length, with the direction of the fibers parallel to the longitudinal axis, makes it possible to provide the required strength characteristics required for cellular concrete lintels, without reducing its heat-shielding properties, since The carbon fiber tape is located outside the body of the composite bridge and is not a temperature bridge. The use of polyurethane glue as a filler for vertical joints at the ends of a composite lintel is due to its low thermal conductivity and high thermal uniformity in relation to cellular concrete, which increases the efficiency of the lintel.

Parts of the tape made of carbon fibers, rigidly attached to the flange sides of the bar elements in the place of vertical seams, in addition to increasing the shear rigidity of the seams made with polyurethane glue, reduce the airflow of the composite lintel, increasing its heat-shielding properties.

The most thermally efficient type of lintel reinforcement is external strip reinforcement with carbon fiber tapes, since the reduced heat transfer resistance is 6-10% higher than that of similar lintels with another type of reinforcement, and 10-28% higher than the indicators of traditionally used lintels (reinforced solid lintel and composite U-block lintels).

The greatest additional specific heat loss has a composite lintel made of U-shaped blocks, since the design of this lintel contains a homogeneous part of the structure, presented in the form of a niche with a reinforcement frame, filled with heavy concrete, from a fairly large area, due to which the length of the joints of homogeneous parts of the structure increases, contributing to heat loss, which negatively affects the heat-protective characteristics of the enclosing wall structure at the life cycle stage of the construction project.

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