Experimental determination of the minimum allowable thickness of the external decorative layer of the silica-granite block under exposure to a radiant heat from the base of the fire

S V Sharhun¹, O A Mokrousova¹, A Y Koshelev¹, E A Ojegov¹, N F Sirina²

¹Ural Institute of State Fire Service of EMERCOM of Russia, Mira str., 22, Yekaterinburg, 620062, Russia
²Ural State University of Railway Transport, Kolmogorova st., 66, Yekaterinburg, 620034, Russia

E-mail: S_sharhun@mail.ru

Abstract: The paper presents the results of the full-scale tests that determine the minimum permissible thickness of the protective outer decorative layer of a silica-granite wall block when exposed to radiant heat flux from a fire source, taking into account the location of the constructed object at the standardized distance between buildings and structures. The article presents an analysis of the fire safety regulatory requirements applicable to the Russian Federation, in terms of the location of buildings and structures of various fire resistance levels in the territories of gardeners’ and allotment non-profit associations or on land plots intended for individual housing construction in urban and rural settlements.

1. Introduction
Currently the construction industry has been actively developing in the Russian Federation. In large cities there is an active development of both central, already existing areas, and the integrated development of new territories - the creation of new neighborhoods with their own infrastructure. A separate direction has been taken in the construction industry which is the construction of the so-called “nearest suburb” in close proximity to major cities and centers of the constituent entities of the Russian Federation.

It is worth noting that the construction of multi-storey buildings is currently quite well regulated and is subject to constant monitoring from the stage of issuing a design permit to the commissioning of the object, and after that it is also inspected by state fire supervision authorities. The private sector is currently being built often, without any permits (for land plots of certain categories, the construction permits are not provided for at all) and without the proper oversight by the regulatory authorities. What ultimately, as fire statistics show, leads to rather dire consequences.

In the original edition of the Federal Law No. 123 "Technical Regulations on Fire Safety Requirements" dated July 22nd, 2008 [1], there was the article 75 that stated. "Fire safety distances on the territories of garden plots, allotments and household plots", which determined the fire safety distances between buildings and constructions on the territories of garden plots, allotments and...
household plots. However, later this article was excluded and now in [1] there are no requirements for the placement of buildings and structures in the territories of garden plots, allotments and household plots. These requirements are contained within SP 53.13130.2011 [2].

So according to article 6.5. [2] fire safety distances between residential buildings or residential houses located in adjacent areas, depending on the material of the bearing and enclosing structures, should not be less than the distances illustrated in the table No. 1. At the same time, fire safety distances between the buildings and structures within one garden plot are not standardized.

Table 1. Minimum fire safety distances between the outermost residential buildings (or houses) and groups of residential buildings (or houses) on plots

| The material of bearing and enclosing structures of a building | Distance, m. |   |   |   |
|---------------------------------------------------------------|--------------|---|---|---|
| A Stone, concrete, reinforced concrete and other non-combustible materials | 6 8 10       |   |   |   |
| B The same, with timber frames and floors, protected by non-combustible and slow-burning materials | 8 10 12      |   |   |   |
| C Timber, framed enclosing structures made of non-combustible, slow-burning and combustible materials | 10 12 15     |   |   |   |

The placement of buildings within the same land plot and the distance between neighboring households in modern gardeners’ partnerships and allotment associations, as well as on land plots intended for individual housing, is currently rather chaotic. That being said, we can’t speak here about any compliance with the requirements set forth in [2] in regards to the gaps between the buildings at all.

Most studies on this topic, for example [3,4,5], are devoted specifically to issues of preventing the spread of fire to neighboring buildings, and the issues of damage to neighboring objects without the spread of fire are not considered in principle. Figure 1 shows the graphical dependence of the heat flux at a distance from the fire source during the burning of buildings of I-III degree of fire resistance.

Figure 1. Graphic dependence of the heat flux at a distance from the base of fire during the burning of buildings I-III degree of fire resistance
Analyzing the graph data, we can conclude that even while maintaining the required distance of 10 meters between the buildings, the value of heat flux that will affect the next building will amount to about 42 kW/m². This means the value will rapidly increase with decreasing distance between buildings.

Considering the characteristics of modern building materials (including those used in thermal insulating layers), it can be safely assumed that the effect of heat flux, even if it did not spread the fire, can have a significant impact on the thermal performance of materials used in the construction of buildings.

Currently the so-called multi-layer structures consisting of bearing, thermal insulating and facing layers are widely used. However, if non-combustible thermal insulation is used as a heat-insulating layer in the construction of multistory buildings, then individual residential construction focuses primarily on cost-effective materials, most of which are combustible in their fire performance characteristics. One example of such materials is a silica-granite wall block manufactured according to TU 5835-002-99461491-2008, which are four-layer blocks with an outer textured (silica-granite) layer of heavy and dense concrete, outer undertextured and inner layers of a block of fine-grained dense concrete, connected by plastic, basalt plastic or fiberglass ties. The middle layer is a thermofiller made of expanded polystyrene.

2. Methods and materials

To assess the degree of influence upon the thermophysical properties of an object constructed of such blocks, the heat flux from a fire in a building located in the immediate vicinity, the series of tests were carried out. For this purpose, the device was used, which is a supporting structure housing the following equipment:

- source of thermal radiation (gas infrared burner B64-2 SX SBM);
- the measuring unit moved along the guides with a stand for placing the sample, equipment for measuring the temperature at five points of the sample under study;
- manual drive to move the unit during the experiment;
- equipment control panel;
- working table to accommodate the recording PC;
- gas cylinder with a capacity of 50 liters;
- shut-off and control valves to connect the gas cylinder to the device;

In order to carry out the laboratory tests, a block sample with different thicknesses of the outer layer of 46, 65, 70 and 73 mm. was used.

![Figure 2](image1.jpg) **Figure 2.** The visual appearance of the sample for testing

![Figure 3](image2.jpg) **Figure 3.** The sample on the laboratory setup
The prepared samples are alternately installed on the device; in order to protect against heat exposure from the sides they are wrapped with thermal insulation material MBOR-16 (Figure 2); to record the data 3 thermocouples are installed: the 1st one on the front surface, the 2nd one behind the facing layer and the 3rd one behind the thermal insulating layer (Figure 3).

After that, the sample was installed at a distance from the heat source at which the value of the heat flux acting on the surface at 42 kW / m² was ensured, which, according to the Figure 1, corresponds to the location of buildings at the distance of 10 meters from each other. The time of the test is 60 minutes.

3. Results
The test results, graphical dependences of temperature and the appearance of the sample after the test for block No. 1 (thickness of the outer layer 46 mm) are shown in Pictures 4, 5, for block No. 2 (thickness of the outer layer 65 mm) are shown in Pictures 6, 7, for block No. 3 (outer layer thickness 70 mm) are shown on Pictures 8, 9, for block No. 4 (outer layer thickness 73 mm) are shown on Pictures 10, 11.

Figure 4. The visual appearance of the block No. 1 after the test

Figure 5. Graphical dependence of temperature according to indicated values of thermocouples No. 1 – No. 3

Figure 6. The visual appearance of the block No. 2 after the test

Figure 7. Graphical dependence of temperature according to indicated values of thermocouples No. 1 – No. 3
Figure 8. The visual appearance of the block No. 3 after the test

Figure 9. Graphical dependence of temperature according to indicated values of thermocouples No. 1 – No. 3

Figure 10. The visual appearance of the block No. 4 after the test

Figure 11. Graphical dependence of temperature according to indicated values of thermocouples No. 1 – No. 3

4. Discussion
Analyzing the results we can draw the following conclusions:

1. When locating the building having a protective facing layer of a thickness 46 mm. and made out of multilayer thermal blocks at a distance equal to 10 meters from the fire source, the maximum temperature (thermocouple No. 2) behind the facing layer will amount to 128 °C within 60 minutes after the start of exposure to radiant heat flux, which leads to the destruction (melting) of 50% of the thermal insulating layer. Consequently, the thickness of the facing coating amounting to 46 mm is not enough.

2. With an increase in the thickness of the protective layer by about 50% to 65 mm, and when locating the building made out of the multilayer thermal blocks at a distance equal to 10 meters from the fire source the maximum temperature (thermocouple No. 2) behind the facing layer will amount to 117 °C within 60 minutes after the start of exposure to radiant heat flux, which leads to the destruction (melting) of 13% of the thermal insulating layer. Therefore, the thickness of the facing coating amounting to 65 mm is also not enough.
3. With an increase in the thickness of the protective layer to 70 mm, and when locating the building at a distance equal to 10 meters from the fire source the maximum temperature (thermocouple No. 2) behind the facing layer will amount to 70 °C within 60 minutes after the start of exposure to radiant heat flux, which leads to the destruction (melting) of 5% of the thermal insulating layer. Therefore, the thickness of the facing coating amounting to 70 mm is also not enough.

4. With an increase in the thickness of the protective layer to 73 mm, and when locating the building at a distance equal to 10 meters from the fire source the maximum temperature (thermocouple No. 2) behind the facing layer will amount to 49 °C within 60 minutes which does not lead to the destruction (melting) of the thermal insulating layer. Consequently, the minimum value of the thickness of the facing coating required for the protection of the thermal insulating layer amounts to 73 mm.

5. Conclusion
During laboratory testing it was discovered that when using expanded polystyrene as a thermal insulating layer and insufficient thickness of the outer (facing) layer of a silica-granite wall block, a concealed damage to the insulating layer is possible even if the buildings are located at a standardized in [2] distance from each other. As a consequence, the thermal conductivity of this construction will be reduced and in the absence of external damage, the thermal performance of the building as a whole will be reduced. The repair of the thermal insulating layer in this case will require significant financial expenses. This can be considered as a hidden damage in the event of a fire, and it may not be discovered during the investigation in the event of a fire, but much later, which in turn in some cases can make it impossible to recover it.

References
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