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EXAMINATION OF CONDITION OF HISTORICAL TRANSPARENT STRUCTURES OF THE PUSHKIN STATE MUSEUM OF FINE ARTS

Alexander V. Spiridonov, Nina P. Umnyakova, and Boris L. Valkin

Research Institute of Building Physics of Russian Academy of Architecture and Construction Sciences (NIISF of RAACS), Moscow
E-mail: spiridonov@aprok.org

ABSTRACT

The article describes the results of the second part of examination related to transparent structures of the Pushkin State Museum of Fine Arts: the lantern lights. The structures are cultural heritage of federal importance and are subject to state preservation. Based on the results of comprehensive examination, the conclusions were made that these structures are in unsatisfactory condition and materials were prepared for development of recommendations concerning their restoration.

Keywords: transparent structure, lantern light, heat transmission resistance, thermal behaviour, condensate, metal structures

In the first half of 2018, the Structure Physics Research Institute (NIISF) conducted examination of historical windows of the 1st floor of the main building of the Pushkin State Museum of Fine Arts (hereinafter referred to as Pushkin Museum) [1–3]. This article describes the next stage of examination of the museum's historical transparent structures, namely assessment of conditions of the lantern lights [4].

Fig. 1. illustrates the scale of the transparent structures of the Pushkin Museum.

Such complex roofs are rather common for art museums. Fig. 2, for example, demonstrates the building of the Lille Palace of Fine Arts (France) built in 1897 (15 years before the main building of the Pushkin State Museum of Fine Arts). In the 1990's, the museum successfully undergone restoration and was opened again in 1997. Therefore, the Lille museum somehow becomes a reference point

Fig. 1. Model of the main building of the Pushkin State Museum of Fine Arts

Fig. 2. Lille Palace of Fine Arts

Fig. 3. Systems of natural lighting of museums: *a* – one of the halls of the Pushkin State Museum of Fine Arts; *b* – similar hall of the Lille Palace of Fine Arts

Fig. 4. Roof beam joint with traces of corrosion

Fig. 6. Exterior of the transparent structure in 2018

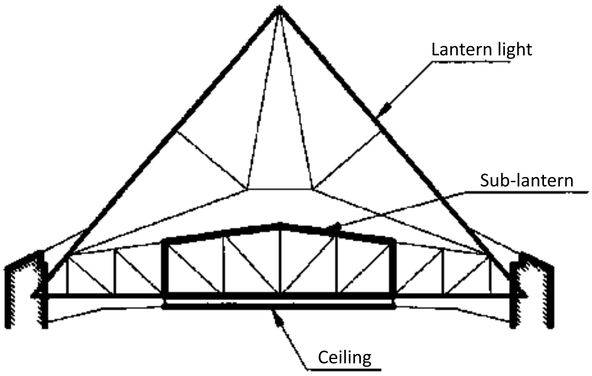

Fig. 5. Cross-section of the transparent structure

for restoration the Pushkin State Museum of Fine Arts on Volkhonka street.

Necessity of such transparent structures in museums of fine arts is substantiated by the fact that most of fine art works look the best way under natural lighting [5]. The basics of natural lighting of buildings (including museum buildings) were developed back in the middle of the previous century [6, 7] and virtually all modern galleries are equipped with lantern lights to the largest extent possible. Fig. 3 demonstrates the halls of the Pushkin State Museum of Fine Arts and the Lille Palace of Fine Arts. General trends in lighting of exhibits in these buildings are obvious.

Due to the decision of establishment of the Museum Quarter on Volkhonka street and adjacent streets, the adjacent buildings were signed over to the Pushkin State Museum of Fine Arts, and, like the main building, these buildings are currently undergoing serious reconstruction, and restoration of working efficiency of transparent structures (lantern lights) should be a part of this process.

The studies, performed by the specialists of N.M. Gersevanov NIIOSP in 2014–2015 [8], have shown that the transparent structures of the main building of the Pushkin State Museum of Fine Arts are in unsatisfactory condition. In particular, 65 dangerous to use sections and 11 sections with limited operating capacity were identified.

The dangerous to use sections are primarily the areas of strong (up to 100 %) corrosion of joint plates, angle legs and inclined elements connecting the frame work to the walls of the building as well as thread stripping of bolts. Such areas are located primarily at corners of the buildings, in the vicinity of neck gutters and ridge part of frame works.

For illustration of the conclusions of the study [8], only one example is presented below (Fig. 4).

The museum's transparent structures consist of three main elements: the main element (lantern light); the sub-lantern element; the lower element (ceiling of diffuse glass above the exhibition halls).

Nowadays all these elements are made of one glass pieces attached to metal T-profiles (Fig. 5). All

Fig. 7. Elements of the lantern light structure in 2018

Fig. 8. Ridge of the lantern light transparent structure and traces of repairs

the structures were installed during construction of the museum in the beginning of the previous century (some restoration works were performed in the 1960–1970's). Fig. 6 shows contemporary exterior of the transparent structures of the museum.

The transparent structures (at least those of the lantern light and the ceiling) installed in the main building of the Pushkin State Museum of Fine Arts, like most of its other structures, are subject to state supervision and their full replacement is prohibited by law. Each element of the transparent structure is analysed separately.

The current state of the structural elements of the main element of the museum's transparent structure (***lantern light***) is shown in Fig. 7.

Briefly summing up the results of our examination, the following may be noted:

– The roof pitches are made of glass fragments with thickness of 4 mm (average dimensions of glass fragments are (415×1110) mm), the pitch is 50°;

– The glass fragments are installed on T-profiles (35×35×3) mm which are supported by horizontal steel angles (90×10) mm;

– The main frame works are made of two welded (bolted?) beam channels so that they actually have a profile of an I-beam;

– Dimensions of the frame work cross-section are as follows: width of 150mm, height of 140 mm, thickness of 5 mm to 7 mm (depending on thickness of the coating applied over the previous 100 years);

– Spacing between the frame works is not uniform and its average value is 2,850 mm;

– The height of the ridge of main element of the triangular lantern light from the floor of the roof space is about 8,000 mm and that of the semi-cylindrical lantern light is 10,000 mm;

– The glass fragments are installed with higher fragment overlapping the lower one (like roof tiles) with a small spacing providing both additional ventilation and natural removal of condensate generating on the inner surface of glass (V.G. Shukhov's idea);

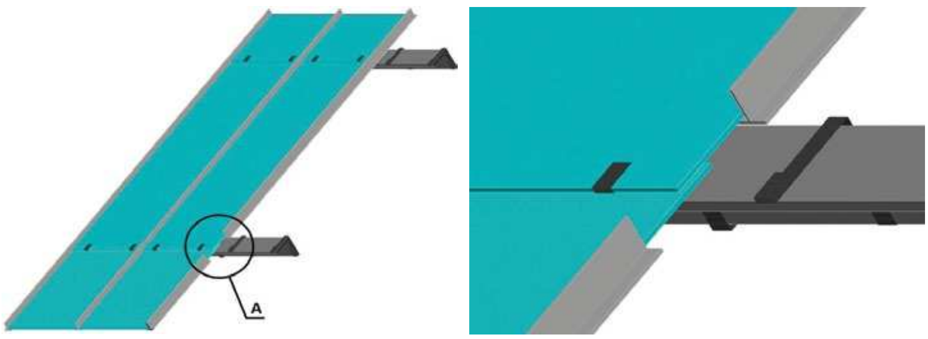

Fig. 9. Fixation of the lantern light glaring elements to horizontal guides

Fig. 10. Inner space and exterior of the sub-lantern

– The glass fragments are fixed to the horizontal steel angles by means of clips made of sheet steel;

– The joints of glass and T-profiles are sealed with joint sealer (with caulking compound in some places) with poor quality: there are holes admitting precipitation;

– Ventilation of the space beneath the glass is performed by means of airways made of sheet steel and located in the upper part of pitches (in each next but one segment);

– The ridge of the roof has numerous traces of leakages and patching up with poor quality (Fig. 8);

– There are numerous traces of leakages as well as broken glass fragments in the lantern light glaring;

– In the course of maintenance of lantern light glaring, glass was replaced by plywood sheets and/or galvanised steel sheets (Fig. 8);

– Lantern light glaring is dirty and was not maintained for a long period of time, which significantly reduces its lighting properties.

The scheme of lantern light glaring is shown in Fig. 9.

The second element of the transparent structure (***sub-lantern***) consists of triangular structures and has the following dimensions: lower width – from 4,000 mm to 7,000mm, edge height – 970 mm, centre height – 1,410 mm. The size of sub-lantern is a little smaller in semi-cylindrical lantern lights. Glazing of sub-lanterns is made of one glass pieces with thickness of (5–6) mm installed in T-profiles similar to those used in the main element of the transparent structure.

The pitch of the horizontal glaring of the sub-lantern is equal to (10–15) angular degree.

Current state of the sub-lantern glaring absolutely does not comply with its intended use, i.e. provision of natural lighting of exhibition halls. That is why there are numerous additional light sources installed in the space between the diffuse ceiling and the sub-lantern (Fig. 10).

Fig. 11. Exterior of the diffusing ceiling with the lighting devices

For prevention of leakages to the main halls, the sub-lantern is currently covered by fabric, polymer film, etc. (Fig. 10).

Due to the constant leakage, the profiles on which the glazing of the side panel is corroded and need to be replaced and or deep cleaned and coated with special compounds

Diffusing opaque glass (with rather dense frosting) in the ***ceiling*** is installed horizontally on the same metal T-profiles with cross-section dimensions of (35×35×3) mm as the other elements of the transparent structure (Fig. 11). Its view from the exhibition halls is shown in Fig. 3, *a*.

To define the areas with uniform heating performance of the examined transparent structure and to discover the ingress zones, thermal imaging inspection was performed. For this purpose, *NEC TH-9100* thermal vision camera and a pyrometer were used. The inspection was performed with consideration of requirements of GOST R [9].

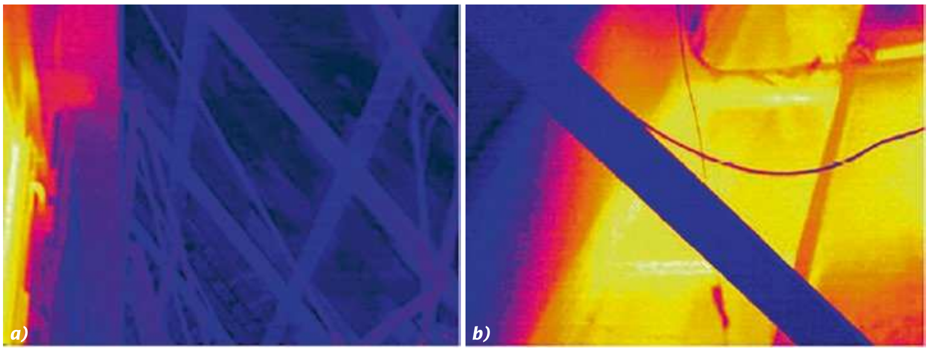

Fig. 12. Thermographics of the transparent structures:
a – the lantern light;
b – sub-lantern and the ceiling

The thermal imaging inspection of the examined structure was performed at ambient temperature of t_a= –4.5 °C and internal air temperature of t_i = +20 °C (Fig. 12).

The temperatures of the transparent structure were measured in some areas above the exhibition halls (27 and 29) and in these premises themselves (with lighting devices on).

Ambient temperature: – 4.3 °C.

The area above Hall No. 27 – temperature under the outer lantern light: (3–5) °C; temperature under the sub-lantern: (9–10) °C; temperature of sub-lantern side glazing: 8,6 °C.

The area above Hall No. 29 – temperature under the outer dome: (3–5) °C.

Fig. 13 shows the layout of sensor positioning and Fig. 14 shows the values of temperature and heat current at different points of the transparent structure.

One of the main conclusions of the examination which may be used for planning of thermal behaviour of the transparent structures during their restoration is that the difference between the ambient temperature and the temperature under the main lantern light in the roof space is (8–10) °C.

In order to define reduced total thermal resistance R_o, the inspection was performed by means of heat current and temperature meters. The measurements were performed in accordance with recommendations [10, 11].

The obtained values of R_o of the lantern light glazing and sub-lantern + ceiling glaring: (0.18–0.20) (m^2·°C)/W and (0.40–0.45) (m^2·°C)/W respectively.

The important result of this part of inspection, which may be used for planning of thermal behaviour of the transparent structures in the course of their restoration, is that R_o increases by (0.20–0.25) (m^2·°C)/W if glazing of the sub-lantern and the ceiling is assessed together.

Based on the numerous on-site investigations of the historical transparent structures of the main building of the Pushkin Museum, the following major conclusions were made:

1. The transparent structures are in a very bad condition (non-repairable in some cases): there is rust on nearly all structures, holes, non-working hardware, etc;
2. The characteristics of the transparent structures (reduced total thermal resistance, air permeability) do not comply with the applicable regulatory documents;
3. The condensate generated on the inner surfaces of the transparent structures in cold periods causes negative impact on durability of the structures;
4. It is necessary to provide special sun-protecting devices and curtains diffusing direct sunlight for the structures of the lantern lights facing the East, the South and the West facades of the main building of the Pushkin Museum;

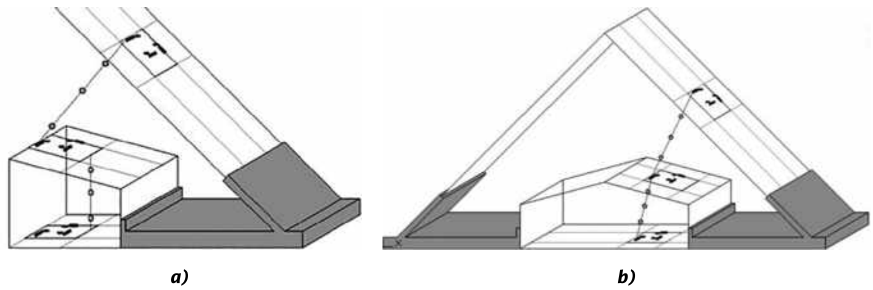

Fig. 13. Scheme of positioning of temperature and heat current sensors:
a – above Hall No. 27;
b – above Hall No. 29

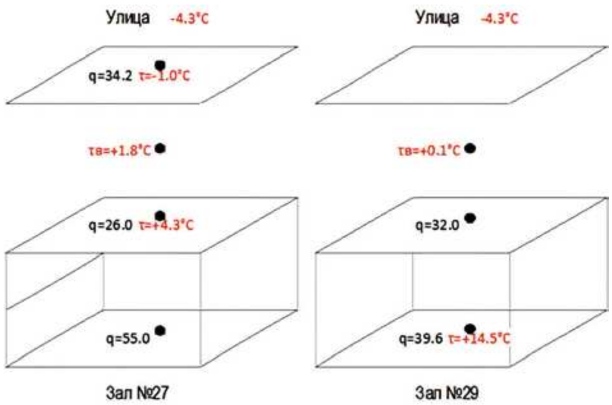

Fig. 14. Values of temperature τ and heat current q (W) at the main points of the selected premises

5. In view of the planned comprehensive reconstruction of the museum, establishment of the Museum Quarter on Volkhonka street and impossibility of replacement of historical transparent structures, which are cultural heritage subject to state supervision, it is necessary to develop the measures aiming at increase of their efficiency.

The results of heat engineering calculations of different variants of transparent structures efficiency increasing and recommendations for their restoration will be presented in the following article by the authors.

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Alexander V. Spiridonov,
Ph.D. in Technical Sciences, graduated from the Moscow Power-Energy Institute (MPEI) in 1975 on specialty "Lighting and Light sources". At present, he is the Fellow in Chief of Research of the NIISF of RAACS, President of the Association of Manufacturers of Energy Efficient Windows (APROK), Laureate of the RF Government Prize in Science and Technology

Nina P. Umnyakova,
Ph.D. in Technical Sciences, Associate Professor. She graduated from the Moscow Civil Engineering Institute. At present, she is Deputy Director of the NIISF of the RAACS. Her research interests are thermal protection of buildings, energy saving, evaluation of thermal protection qualities of cladding in the presence of reflective thermal insulation

Boris L. Valkin,
Dr. of Architecture. In 1974, he graduated from Moscow architecture institute (MARhi). At present, he is Professor of International Academy of Architecture, Moscow and Associate Professor of MGSU