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Temperature-humidity regime in the operation of the roofs of historic buildings

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The article presents the experience of developing engineering solutions for the restoration and preservation of cold pitched attic structures on the example of a historic building in Poltava. A preliminary design solution for the thermal modernization of the attic floor was analyzed, which included the placement of mineral wool insulation in the attic in accordance with requirements of DBN V.2.6-31:2016 with a thickness of 250 mm. Increasing the thickness of the insulation to modern requirements for energy efficiency on a reinforced concrete floor could lead to a decrease in the temperature in the attic, which, in turn, would not contribute to the melting of snow on the roof, which occurred in the last 70 years of the building's operation. A possible increase in snow load along with cooling of the steel truss elements to -20°C can cause brittle fracture of truss elements made of boiling steel. The thickness of the insulation along the attic floor should be taken no more than 100 mm in order to reduce transmission heat losses and maintain a positive temperature in the attic space.

Keywords: attic floor, insulation, temperature and humidity conditions

Температурно-вологісний режим при експлуатації дахів історичних будівель

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В статті представлено досвід розробки інженерних рішень з відновлення та збереження конструкцій холодного скатного горища на прикладі історичної будівлі в м. Полтава, які дозволять попередити втрату несучої здатності конструкцій та уникнути теплових відмов у горищному просторі. Було виконано обстеження несучих та огороджувальних конструкцій горища, несучими конструкціями покриття є сталеві ферми, елементи яких з’єднані за допомогою заклепок. За час експлуатації практично кожна з ферм зазнала значних деформацій окремих елементів, ймовірніше за все під час пожежі у 1943 році, які були локально підсилені. Для подальшої безаварійної експлуатації сталевих ферм покриття було рекомендовано антикорозійну обробку всіх відкритих сталевих елементів покриття, виконання страхувального підсилення спирання на нижній пояс ферм збірних залізобетонних набірних плит, прибирання старого утеплювача з горищного перекриття Було проаналізовано попереднє проектне рішення термомодернізації горищного перекриття, яке включало розміщення мінераловатного утеплювача на горищі згідно вимог ДБН В.2.6-31:2016 товщиною 250 мм. Збільшення товщини утеплювача до сучасних вимог з енергоефективності на залізобетонному перекритті могло привести до зниження температури на горищі, що, в свою чергу, не буде сприяти таненню снігу на покрівлі, яке відбувалося останні 70 років експлуатації будівлі. Можливе збільшення снігового навантаження разом із охолодженням сталевих елементів ферми до -20^{0}С може викликати крихке руйнування елементів ферми, виготовлених з киплячої сталі. Товщину утеплювача по горищному перекритті слід прийняти не більше 100 мм з метою зменшення трансмісійних тепловтрат та підтримання позитивної температури у горищному просторі. Також для збереження існуючого тепловологісного режиму горищного простору рекомендується відновити аераційні щілини на рівні карнизів та гребеневої планки.

Ключові слова: горищне перекриття, утеплення, температуровологістний режим

Introduction

Recently, historical buildings older than 100 years have become objects of restoration. But not a professional approach to conducting a technical survey of a building and developing project documentation in most cases leads to a loss of performance characteristics of structures.

The article presents the experience of developing engineering solutions for the restoration and preservation of cold-pitched attic structures on the example of a historic building in the city of Poltava, which made it possible to prevent the loss of the bearing capacity of structures and avoid thermal failures in the attic space.

Review of the research sources and publications

The issues of surveying the structures of historical buildings and making decisions regarding measures for the reconstruction of buildings, including roofs and attic spaces, were considered in [1-4]. The reconstruction of historical buildings from an energy-efficient point of view is considered in detail in [5]. Features of the temperature and humidity regime of the attic space and its influence on structures are considered in [7-8]. To determine the actual temperature and humidity regime of the attic space, the authors in the work [6] performed monitoring of changes in temperature and humidity and their distribution in space. For flat roofs, the authors carried out surveys and gave recommendations for repair and reconstruction in [9-10].

Definition of unsolved aspects of the problem

When restoring historical buildings, modern means of insulation, which are typical for new construction, cannot be used. It is not only about external enclosing structures that are the object of protection, but also about structures that do not have architectural or historical value. For example, the attic floor or the foundation zone of a building can be insulated, but only after studying the thermal and moisture regime of structures in the existing operating mode and modeling the thermal and moisture regime after thermal modernization. When performing restoration work, there are many cases when insulation led not only to thermal failures in the structure, but also to a loss of bearing capacity.

Problem statement

The purpose of the work is to analyze the temperature and humidity regime of the attic space and simulate it after the insulation of the attic floor of the building, to prove the need for an individual approach to the development of measures for insulation in historical buildings.

Basic material and results

The historic building was built in 1902-1908 in the style of Ukrainian modern. During the Second World War in September 1943, the building was looted and burned (Fig. 1). The building was restored only in 1964.

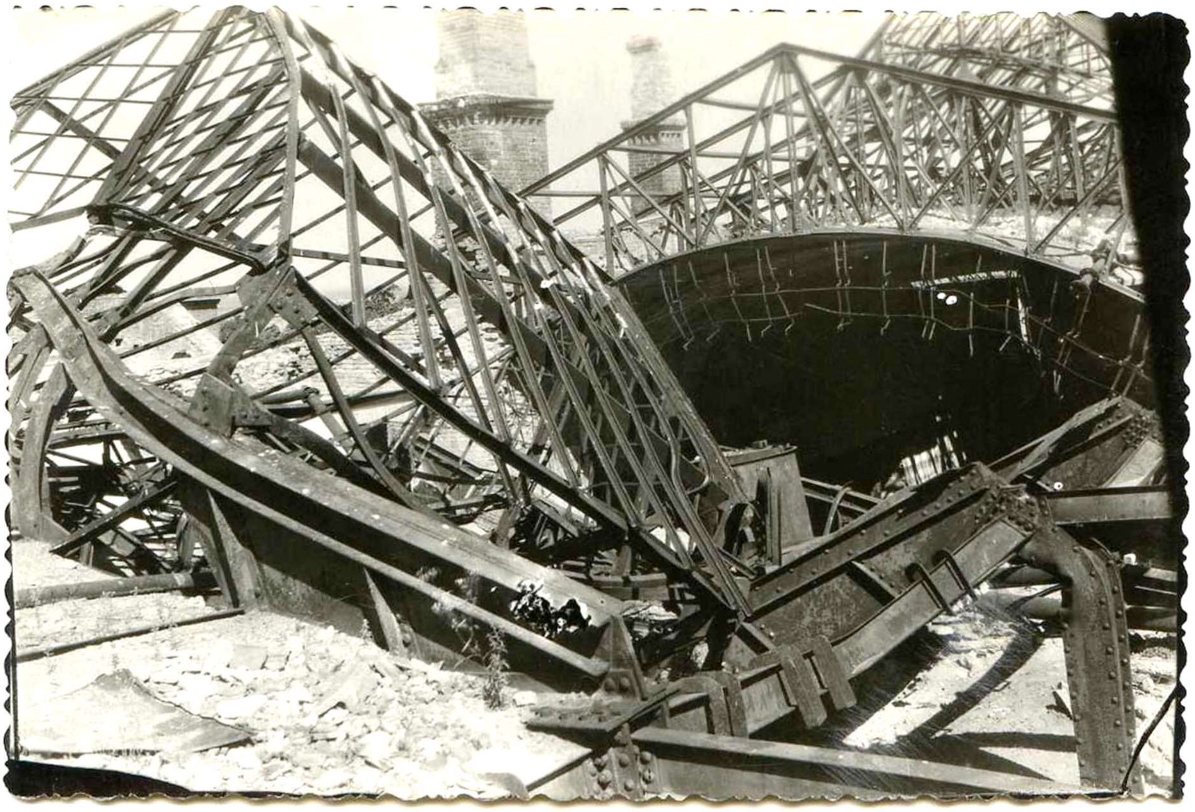

Figure 1 – Metal roofing trusses of a historic building after a fire

The need to determine the technical condition of the metal trusses of the ceiling of a part of the building arose in connection with the reconstruction work. The area covered by the building with an overall dimension of 23.5×12.5 m was subject to survey. From the inside of the room (from the hall), the examined section of the coating looks like a concrete vault with a span of about 12 m with a lifting boom of about 2.25 m with a translucent lantern measuring 4.55 × 8.0 m in the middle part of the hall (Fig. 2). The curvature of the concrete vault along the width of the span (width of the room) is different; closer to the bearing longitudinal walls, the curvature increases.

The visual survey was preceded by the collection of data on the architectural, planning, and structural design of the building, as well as familiarization with the technical and reference documentation of analogue buildings and structural elements. When examining the technical condition, in addition to examining structures and elements, detecting visible defects and damage, measurements of violations of geometric dimensions, drawing up diagrams, sketches, photographing damage, cracks, steel corrosion, mechanical and physical damage to structures, existing strengthening of damaged structures were carried out.

The load-bearing structures of the hall cover are steel trusses, the elements of which are connected with rivets. According to visual inspection, steel trusses have been preserved in almost original form since the construction of the building - approximately in 1908. Over the years of operation, almost each of the trusses has undergone significant deformations of individual elements. Most likely, the deformations occurred during a fire inside the building in 1943, as evidenced by the historical information and photographs of that time provided by the Customer. Separate deformed truss elements were locally reinforced. A general view of the steel structures of the coating at the time of the survey is shown in Figure 3.

The technical survey included the execution of drawings of each truss (Fig. 4), fixing defects, damages, and strengthening of its elements, instrumental studies, and verification calculation of the bearing capacity of metal structures.

Recommendations for the further trouble-free operation of steel roof trusses included anti-corrosion treatment of all exposed steel elements of the roof, the implementation of safety strengthening for supporting precast concrete slabs on the lower belt of trusses, and the removal of old insulation from the attic floor.

It was necessary to determine in more detail the restoration of the heat and moisture regime of the attic floor since the preliminary design solution included the placement of mineral wool insulation in the attic in accordance with modern requirements of DBN V.2.6-31:2016 [12] to minimize heat loss. From the standpoint of energy efficiency, the maximum insulation of the attic floor is the right decision. In most historical buildings, this is perhaps the only possible measure to reduce energy costs for heating, since other building envelopes are the object of protection.

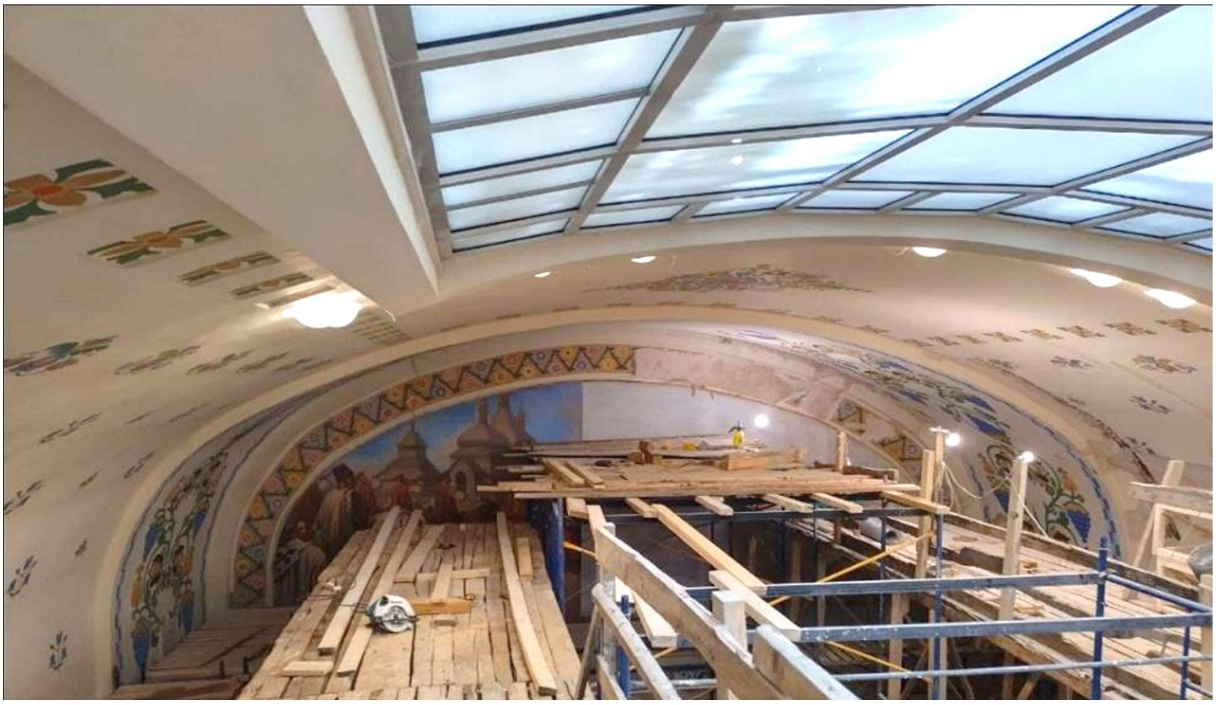

Figure 2 – General view of the ceiling of the hall from below from inside the room

Figure 3 – General view of the steel structures of the roof of the hall at the time of the survey: ordinary load-bearing trusses of the concrete vault

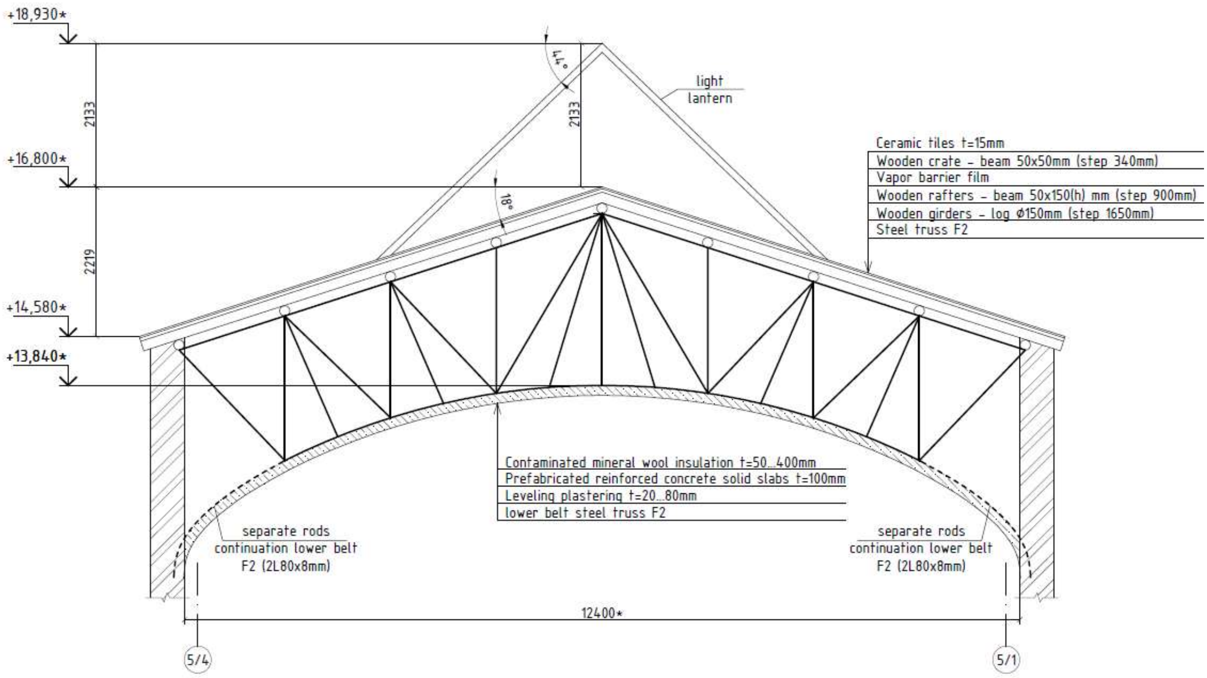

Figure 4 – Schematic drawings of ordinary trusses type F2

But at this facility, given that the steel structures of the roof are made of boiling steel, it is not recommended to change the existing temperature regime for the operation of the attic. The production method of the rolled steel used for coating structures is not known for certain. To determine the chemical composition of the steel used and its physical and mechanical properties, it is desirable to conduct chemical analysis and mechanical testing of steel samples cut from unloaded fragments of elements of the roof truss system. But for more than 100 years of operation of metal structures, its fragments were replaced and strengthened so many times that everything had to be submitted for chemical analysis.

Increasing the thickness of the insulation to modern requirements for energy efficiency on a reinforced concrete floor will lead to a decrease in the temperature in the attic, which in turn will not contribute to the melting of snow on the roof, which has occurred in the last 70 years of the building's operation. A possible increase in snow load along with cooling of steel truss elements to -20°C can cause brittle destruction of truss elements made of boiling steel.

In connection with the above, the thickness of the new insulation along the attic floor should be taken no more than 100 mm in order to reduce transmission heat losses and maintain a positive temperature in the attic space. In the case of insulation of the attic floor in accordance with the requirements of DBN V.2.6-31:2016 [12] (up to 250 mm of insulation), condensation will form in the nodes of the lower truss belt, accelerating metal corrosion.

According to modern technology for covering a pitched roof, it includes a waterproofing membrane, which is an additional protection against climatic moisture, but when it is installed, it is necessary to arrange aeration holes. Old pitched roofs without a membrane were ventilated due to the leaky roofing material - ceramic tiles, asbestos-cement or metal sheets. Aeration functions are also performed by dormer windows, which, during repairs, are mistakenly closed with metal-plastic windows or even dismantled. The design of the attic roof of the building where the study was conducted did not include dormer windows since construction. Therefore, in order to preserve the existing thermal regime of the attic space, it is recommended to restore the aeration slots at the level of the cornices and the ridge strip.

Conclusions

As a result of visual inspections, instrumental measurements, and verification calculations of steel trusses covering the hall of a historical building, the following conclusions can be drawn:

1. Coating steel trusses due to corrosive wear, fire exposure, deformation of elements, etc., are in state 3 "unsuitable for normal use".

2. The results of the calculations show that the trusses, taking into account significant corrosion damage (especially the closed lower belt) and strengthening, are on the verge of exhausting the bearing capacity σ_{max}=167 MPa, which does not allow increasing the loads existing at the time of the survey.

3. When carrying out restoration work, it is not recommended to change the existing temperature and humidity regime of the attic in order to prevent brittle fracture of trusses made of boiling steel when the attic cools and the snow load on the roof increases. Therefore, it is impossible to insulate the attic floor in accordance with modern energy efficiency requirements.

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