Wooden roof structures of the Moberg house

Liubov Seliutina[1], *Elena* Ratkova[1*], and *Ekaterina* Okulova[1]

[1]Petrozavodsk State University, 33, Lenin str., 185910 Petrozavodsk, Republic of Karelia, Russia

Abstract. The preservation of cultural heritage sites is an important task. Historical monuments are a reflection and documentary evidence of the past, information about which must be preserved and passed on to future generations. One of the most vulnerable and fragile structures in a building is the roof. This work provides historical information and presents the results of a survey of the structures of the building of engineer Moberg in the urban-type settlement of Kalevala in the Republic of Karelia of the Russian Federation. The structural system of the roof and the joint work of its elements have been studied. The expediency of preserving the structural system, shape and geometric parameters of the roof, as well as replacing the existing structures before the reconstruction with new elements from modern sawn timber has been substantiated. The cultural heritage site "House of Engineer Moberg" is an architectural monument of regional significance of the early 20th century and the main historical building of the urban-type settlement of Kalevala, built under the influence of the ideas of Finnish national romanticism. According to archival sources, the house was built in 1906 and renovated in 1925-1926 with the participation of engineer Eduard Moberg and builder Tuomas Waller. Nowadays, the building houses the ethnocultural center kalevalatalo. Keywords: Reconstruction of the Moberg house, inspection of building structures, structural roof system.

1 Introduction

Historical monuments preserve the history, traditions and life of people of previous generations. They are a reflection and documentary confirmation of the past, information about which must be preserved and passed on to future generations. The preservation of cultural heritage sites is an important task, it allows preserving the connection between the past, present and future. Historic buildings are an important asset of any country, primarily for illustrating its history, not for making a profit through promotion in the tourism industry [1].

The topic of research on structures and buildings constructed in previous years is widely presented in the technical literature. Examples are studies by many authors [1-27]. Scientists note that in order to preserve the cultural heritage, a unified approach to the monuments of wooden architecture is needed, in particular, conservation on the spot with the preservation of all latest changes [26]. However, historic buildings are unique and require a personal touch.

* Corresponding author: ratjkova@mail.ru

One of the most vulnerable and fragile structures in a building is the roof. Its service life is influenced by the effects of atmospheric precipitation, wind, ultraviolet radiation, temperature difference, chemical and organic substances, and mechanical stress.

This work presents information about the rafter and under the rafter systems of the building of engineer Moberg in the urban-type settlement of Kalevala in the Republic of Karelia of the Russian Federation. The study of building structures was carried out with the aim of studying the structural system of the roof, the joint work of elements, determining the possibilities of replacing existing structures with new elements before reconstruction, acquiring the skills of examining wooden structures using modern equipment.

2 Materials and Methods

The cultural heritage site "House of Engineer Moberg" is an architectural monument of regional significance of the early 20th century and the main historical building of the urban-type settlement of Kalevala, built under the influence of the ideas of Finnish national romanticism (see Fig. 1).

Fig. 1. Moberg House, August 2015. Photo by T. Berdasheva.

It is known from archival sources that the house was built in 1906 for the logging engineer G. Vendelin as a private dwelling house. Later, in 1925-1926, it was reconstructed into the main building of the Ukhta district executive committee. The engineer Eduard Moberg, who came from Sweden, and the builder Tuomas Waller, who came from the USA, took part in its reconstruction. It is currently not established which of them was the author of the project. Eduard Moberg was appointed as an engineer in the utilities subdivision and was involved in the construction of the house at the initial stage. This is indirect evidence that it is he who is the author. The name of Eduard Moberg is also associated with the construction of the Ukhta hydroelectric power station, the first electric mill in Ukhta, a mechanical workshop, a canal and bridges.

The House of Engineer Moberg was inaugurated on May 29, 1926. For more than 70 years, the premises of this building have housed the authorities of various levels and the administration of various institutions. From 2006 to 2016, the restoration of the house was carried out. The draft design of the restoration and fittings was carried out by ZAO "LAD".

Nowadays, the building houses the KALEVALATALO ethnocultural center with an exposition of the local history museum, a fund storage, a department of folk traditional crafts, workshops, a conference hall with an exhibition hall, a folk theater, and an ensemble of kantele players.

The House of Engineer Moberg is a two-story wooden building, without a basement, with unused space in the tower at the third floor level. The layout of the premises is of a corridor type, with the arrangement of rooms on two sides, in the exhibition halls of the museum – enfilade.

The dimensions of the building in terms of plan are 25x25 m, the height of the first floor is 2.8 m, the height of the second floor is 2.6 m.

The main requirement when choosing survey methods is to extend the service life of a historic building due to its timely and high-quality reconstruction. The main provisions governing the composition and scope of complex engineering and technical surveys necessary to determine the technical condition, carry out repair and restoration projects, preserve and adapt for the modern use of cultural heritage sites, as well as to obtain reliable data on the occurrence of physical causes and develop recommendations for their conservation, are presented in the work of V. Acristini [3]. In the study of the structures of the Moberg house, the methodology of preparation for technical complex analysis was used. Comprehensive analysis includes building a team of consultants, collecting data, preparing the analysis, and submitting the report to the party ordering due diligence preparation [7].

An important task during reconstruction is the assessment of the physical condition of the object, which includes an assessment of the degree of damage to structures based on expert assessment. A novel approach to prioritizing the severity of physical defects is visual inspection using a multi-criteria decision analysis approach [13]. Methods of laser scanning and photogrammetry are also widely used [5, 9]. There is a known method of complex chronological attribution of monuments of wooden architecture, including architectural and dendrochronological studies [24]. This method is used by scientists [24, 25]. The use of a set of special measures aimed at eliminating the causes of destruction allows preventing the deterioration of the condition of a wooden building and significantly reducing the degree of necessary restoration intervention [23].

The authors performed an external examination of structural elements, with selective fixation on a digital camera, which meets the requirements of clause 7.2 of the Russian State Standard SP 13-102-2003, according to which the survey is an examination of the building and individual structures using measuring instruments and devices (binoculars, cameras, tape measures, calipers, probes, etc. other).

Measurement work was carried out in accordance with the requirements of clause 8.2.1 of the Russian State Standard SP 13-102-2003. The purpose of the measurement work was to clarify the actual geometric parameters of building structures, to determine their compliance with the project or deviation from it. Instrumental measurements clarified the spans of the structures, their location and pitch in the plan, the dimensions of the cross sections, the height of the rooms, the marks of the characteristic nodes, the distance between the nodes.

The measurements were carried out using a construction measuring tape TL5M (Russian State Standard GOST 7502-98) and a laser rangefinder inclinometer Bosch GLM. A large amount of photographic material of the rafter system and assemblies was also filmed.

Based on the results of the survey, it was decided to restore the building by hanging the log house on grips without dismantling the walls and floor beams. Only the elements and structures of the building that require replacement are fully disassembled: wall cladding, floors and ceilings, stoves, windows, doors, roof, and porch.

The existing walls from hewn logs on two edges are preserved. Rotten lower and upper timber sets will be replaced with new ones. Logs affected by rot and house fungus are cleaned and treated with an antiseptic.

Flooring and ceiling are wooden. The basement and attic floors have been completely replaced.

The roof is gable over the main premises, gable with a kink in decorative attics, hipped with curvilinear profile over the central tower.

The rafter system was restored according to the existing model from layered plank rafters along a ridge beam on racks with struts. Seam roof made of galvanized steel with a colored polymer coating, attached to a wooden lathing.

According to the results of measurements, the rafter structures were taken as bar with a section of 150x150 mm and 150x200 mm, the rafters - a board of 50x175 mm with a step of 550 mm. The lathing is taken as a 125x32 board with a step of 350 mm.

The load-bearing structures of the roof take on sufficiently large loads from snow and their own weight and must meet the requirements for load-bearing capacity. Replacing old structures with new ones without design justification can lead to deformations, and in some cases, to collapse of the roof.

This paper presents the results of a study of the structural system of the roof of the Moberg house, the joint work of its elements. On the basis of calculations, the possibility of replacing existing structures with new elements from modern sawn timber is determined. The calculations were performed according to the regulatory documents in force in the Russian Federation (SNiP II-25-80. Wooden structures. Updated edition of SP 64.13330.2017).

Calculation of the lathing

The performed calculation of the lathing at an angle of inclination of the roof of 27° and a rafter pitch of 0.55 m confirmed the correctness of the selected section of the lathing 125ˣ32 mm and a pitch of 350 mm. The design scheme of the lathing is shown in Figure 2. The standard load per 1 m^2 is 2,236 kPa.

The design resistance of pine was determined according to SP 64.13330-2017, taking into account the coefficients of long-term strength m_{lt}=0,8, corresponding to the load duration mode "G", the coefficient of the operating condition of the structure m_s=0,9, the coefficient depending on the service life m_{sl}=1. The scheme for calculating the lathing and the cross-section of the roof is shown in Figure 3.

$$R^P = R^A \cdot m_{lt} \cdot P \cdot m_s \cdot m_{sl} = 19{,}5 \cdot 0{,}8 \cdot 0{,}9 \cdot 1 = 14{,}04 \; MPa \,,$$

where R^A = 19,5 MPa – designed resistance of wood with moisture content of 12%, note of table 3 of the Russian State Standard SP 64.13330.2017;

$m_{lt} = 0{,}8$ – coefficient of long-term strength;

$m_s = 0{,}9$ – coefficient of the operating condition of the structure (table 9 of the Russian State Standard SP 64.13330.2017);

$m_{sl} = 1$ – coefficient depending on the service life (table 13 of the Russian State Standard SP 64.13330.2017).

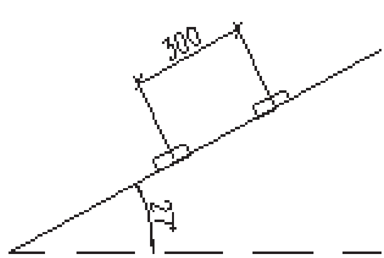

Fig. 2. Design scheme of the lathing.

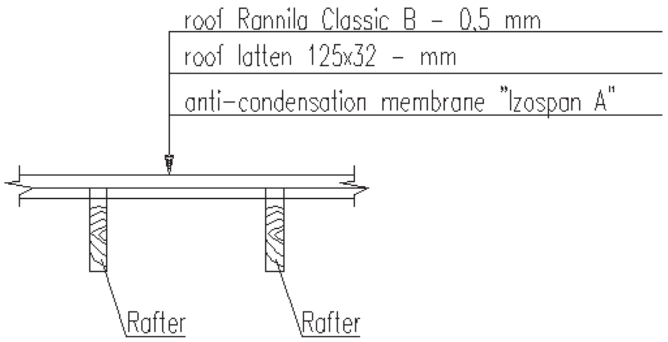

Fig. 3. Scheme for calculating the lathing and the cross-section of the roof.

Calculation of the rafter system

The calculation of the rafter spars is carried out for two types of structural systems of the roof of the house (see Fig. 4):

Type 1 - gable roof with a kink over decorative attics;

Type 2 - gable roof over the main premises;

Type 3 - hipped roof curvilinear profile over the central tower.

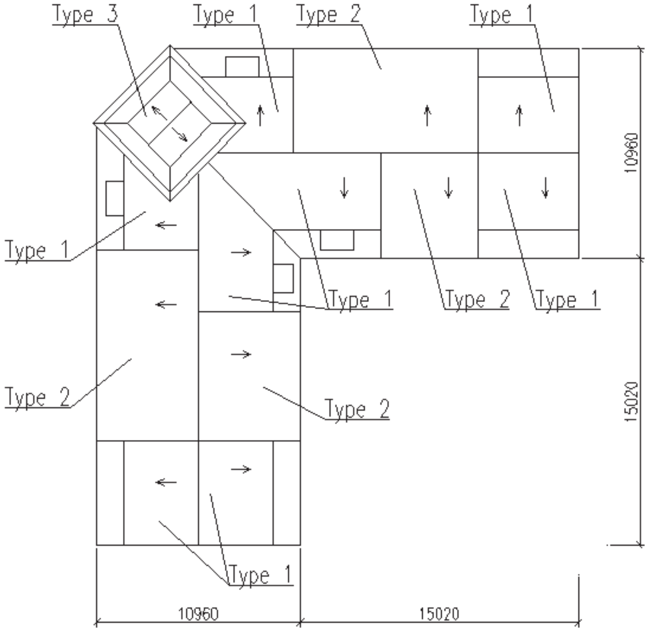

Fig. 4. Roof plan showing types of roof structural systems.

According to the results of measurements, the distance between the axes of the longitudinal walls was taken to be 3.57 m, the roof slope α = 27°.

Fencing structures: seam roofing «Rannila Classic B» on the lathing made of boards 125*32 mm.

Material: 2 grade coniferous wood (pine). The geometric dimensions of the elements of the rafter system of type 1, type 2 are shown in Figures 5, 6.

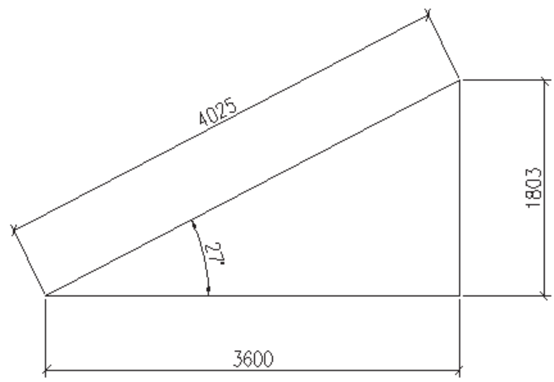

Fig. 5. Rafters, type 1.

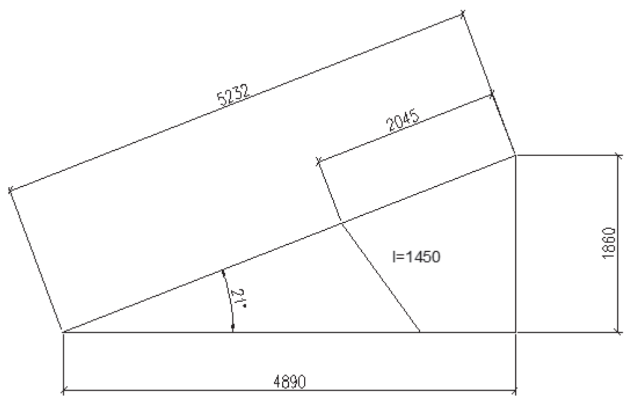

Fig. 6. Rafters, type 2.

The calculation of the rafter spar is carried out according to the I and 2 groups of limiting states

The rafter spar is designed as a beam with an inclined axis on two supports (see Fig. 7).

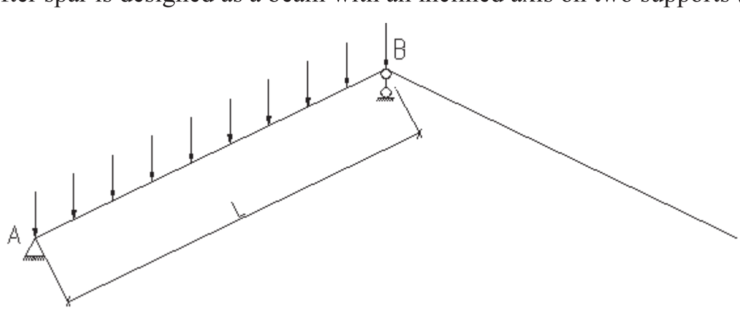

Fig. 7. Design scheme of the rafter.

The moment of resistance of rafters from 1 board with a section of b×h=175×50 (see Fig. 8):

$$W = \frac{5 \cdot 17{,}5^2}{6} = 255{,}21\ cm^3.$$

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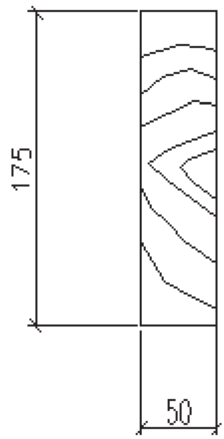

Fig. 8. Section of the rafter.

The results of calculating the rafter spars are shown in the table.

Table 1. Stresses and deflection of rafters.

Type of rafters	Stresses, MPa			Deflection, cm	
	Normal stresses	Shearing stresses	Design resistance (SP 64.13330.2017)	Design	Vertical limiting deflection (SP 20.13330.2016)
Rafter, type 1	9.01	5.01	11.583	1.3	1.96
Rafter, type 2	11.386	7.56	11.583	0.97	2.09
Rafter, type 3	6.54	3.84	11.583	0.59	1.62

Conclusion: the cross-section of boards 175x50 from grade 2 wood fully satisfies the stiffness condition.

Calculation of the under the rafter system

The under the rafter system consists of racks, ridge beams and braces. The beam is designed from a solid bar. Racks are bolted with beams with diagonal braces. The distance between the racks is 3.5 m, between the rafters - 0.55 m.

Beams of five sections are calculated (see Fig. 9-13).

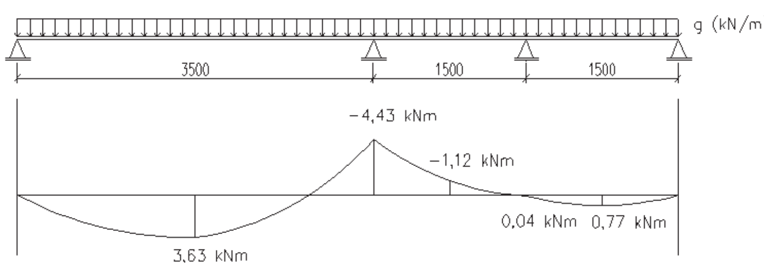

Fig. 9. Layout of section No. 1.

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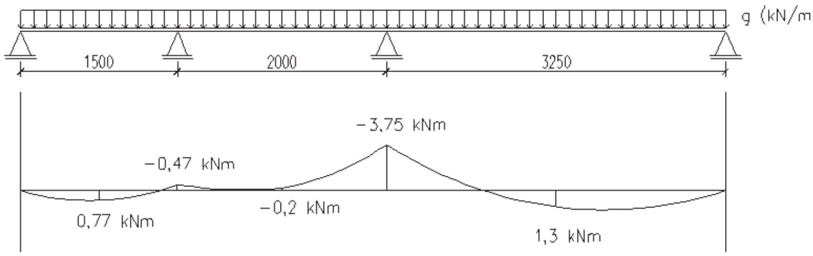

Fig. 10. Layout of section No. 2.

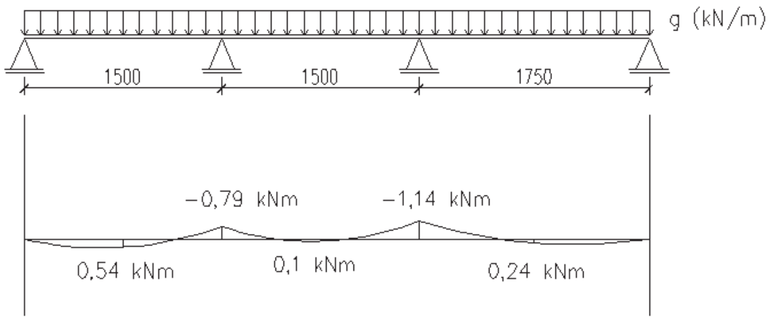

Fig. 11. Layout of section No. 3.

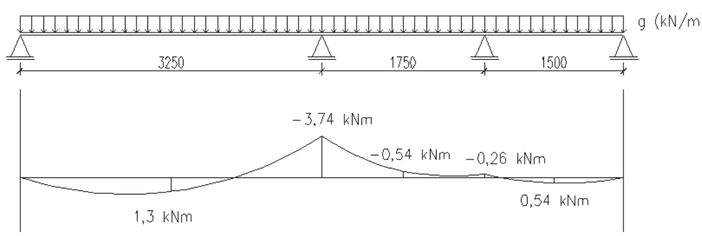

Fig. 12. Layout of section No. 4.

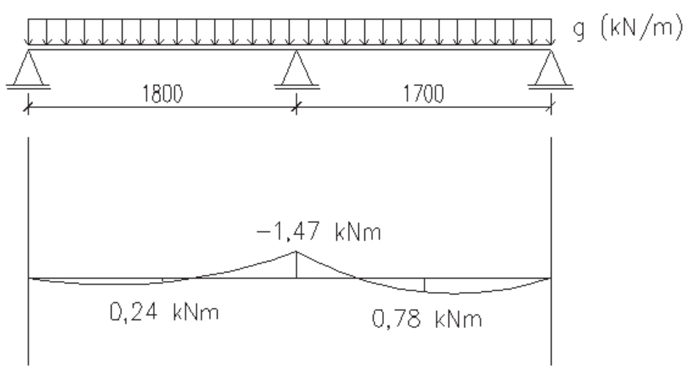

Fig. 13. Layout of section No. 5.

Calculation of the cross-section of the beam

The cross-section of the beam is taken from a bar of 150x200 mm. Material: 2 grade coniferous wood.

The maximum torque is taken equal to M_{max} =4,43 kN·m.

Stresses:

$$\sigma = \frac{M}{W} = \frac{443}{1000} = 4{,}43\ MPa < R = 11{,}583\ \text{MPa}.$$

Strength condition for the 2nd group of limiting states:

$$f = \frac{5}{384} \cdot \frac{q^s \cdot l^4}{E \cdot I} = \frac{5}{384} \cdot \frac{0{,}81 \cdot 3500^4}{10^4 \cdot 10^8} = 1{,}59\ \text{sm},$$

where $\text{q}^{\text{s}} = 0{,}81 \frac{\text{kN}}{\text{m}^2}$ - standard load.

Vertical limiting deflection, taken according to table D1 of the Russian State Standard SP 20.13330.2016:

$$f_{ld} = \frac{350}{166{,}5} = 2{,}1\ \text{sm}$$

$f = 1{,}59\ \text{sm} < f_{ld} = 2{,}1\ \text{sm}$. The condition is met, the maximum deflection does not exceed the maximum permissible value.

Conclusion: a bar with a section of 150x200 mm made of wood of the second grade fully satisfies the stiffness condition.

3 Results

In the course of studying the possibility of replacing the existing roof structures of the Moberg House with new elements with the same geometric parameters, which existed before the reconstruction, the calculations of the lathing, rafter spars and elements of the under the rafter system were performed for two groups of limiting states: according to bearing capacity and deformations. The loads acting on the structure were determined, design schemes were made, moment diagrams were built, the conditions of strength and rigidity were checked.

Based on the calculation results, the following structural elements were chosen:

- lathing made of boards 125*32 mm with a pitch of 350 mm;
- rafter spars made of boards 175x50 with a pitch of 550 mm;
- ridge beam from a bar with a section of 150x200 mm.

Material of all structural elements: 2 grade coniferous wood.

4 Discussion

The performed calculations of the load-bearing structures of the roof of the Moberg House, taking into account the preservation of its shape and geometric parameters, confirmed the possibility of using wooden lumber with a cross-section and pitch taken based on the results of measurements.

5 Conclusions

During the reconstruction of the architectural monument of the early twentieth century “House of Engineer Moberg” in the urban-type settlement of Kalevala, it was decided to replace the roof in compliance with its shape and size. In the work, the structural system of the roof of the house was studied, measurements were made, calculations of the load-bearing elements were made, which confirmed the expediency of preserving the structural system of the roof and replacing the existing structures with elements with the same geometric parameters.

The technical condition of the supporting and enclosing structures of the house after reconstruction in accordance with the provisions of SP 13-102-2003 can be assessed as serviceable, in which the building structures are characterized by the absence of defects and damages that affect the decrease in the bearing capacity and serviceability. Threats to the life and health of people staying in the building have not been identified.

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