

Problems of Forecasting the Resource of Buildings of the Historical Construction of the Resort Region of the Caucasian Mineral Waters

V A Pshenichkina¹, D V Shchitov², P A Sidyakin²

¹ Volgograd state technical University, Akademicheskaya, 1, Volgograd, 400074, Russia

² North-Caucasus Federal University, Prospect 40 let Oktyabrya, 56, Pyatigorsk, 357500, Russia

E-mail: vap_hm@list.ru, pgtugsh@mail.ru, sidyakin_74@mail.ru

Abstract. The problems of ensuring the safety and durability of the exploited buildings of the historical construction of the resort region of the Caucasian Mineral Waters are considered. These buildings are the face of the city-resorts of the CMW, so the issues of their preservation are necessary to pay special attention. The analysis of architectural and structural features of buildings, technical condition of their structures and bases is given. A technique for predicting the durability of buildings with wear damages of structures, as well as failure-free operation in relation to possible extreme seismic influences, is proposed. The implementation of these tasks helps to preserve the unique appearance of the resort region.

1. Introduction

The Caucasian Mineral Waters region has a number of significant advantages that are unique and require constant attention and preservation.

At present, we are carrying out a complex of construction, technical and environmental studies of the construction complex, territories and municipal facilities of the resort region of the Caucasus Mineral Waters [1-5]. The main objectives of these studies are to identify the problems of construction, technical and environmental character and, if necessary, the development of specific activities and recommendations aimed at their solution. In this paper, we consider issues related to ensuring the durability of buildings in the historical development of the resort region of the Caucasus Mineral Waters, while two important points are reflected in [1]:

- in connection with a number of reasons, the number of historical buildings is constantly decreasing;
- the technical condition of a significant number of historical buildings, for which no measures are taken to preserve and reconstruct, is deteriorating every year.

On the territory of the Caucasian Mineral Waters, there are special objects of a particularly valuable historical heritage relating to the initial period of the development of resort towns from 1800 to the 1920s worthy of special attention. The rich past of the buildings of the towns of Kislovodsk, Pyatigorsk, Essentuki, Georgievsk and Zheleznovodsk is associated with historical events and legendary personalities. Classics of art, poets and writers, musicians and artists, creative people and



outstanding citizens of Russia Lermontov M.Y., Tolstoy L.N., Pushkin A.S., Ermolov A.P., Shalyapin F.I. and many others lived, created and performed their duty in the Caucasus. Thanks to them both the real history of Russia and the rich creative heritage reflected in widely known works with literary and artistic images permeate and fill these picturesque houses, streets and parks.

Almost all the buildings and structures of this period have unique architectural elements that echo the stylistics of the construction of a similar period in St. Petersburg. Thanks to the attraction of the leading European architects, in particular the Bernardazzi brothers, to the signing of the contract for the design and construction of the necessary buildings in the Caucasus, the technologies and constructive forms of the best European buildings could be realized in architectural masterpieces at the CMW. The Bernardazzi brothers began their creative career in the Italian part of Switzerland, since 1820 the existing architects continued to create in Russia, originally participated in the creation of St. Isaac's Cathedral and in the reconstruction of the Anichkov Palace in St. Petersburg. Over the next 20 years, the Bernardazzi brothers designed and built in the resort towns of the Caucasian Mineral Waters, Georgievsk and Stavropol. The draft general plan of Pyatigorsk, developed by Bernardazzi, was approved in 1827 by G.A. Emanuel. Thanks to the formed generic architectural talent of the Bernardazzi brothers, the facades of the buildings preserved the unity of style with the classical facades of the government buildings of the resort towns. Masters of work with travertine (Mashuk stone - tuff limestone) taught soldiers and peasants stone art, which admires and fascinates attentive connoisseurs of architecture during walks in the towns of the Caucasian Mineral Waters 200 years ago. Facades, pediments, bay windows, cornices and socles of pre-revolutionary buildings, created by Italian masters and their students, strikingly resemble the facades of Italian and Spanish houses made with brickwork using travertine. On the slopes of Mount Mashuk numerous careers with traces of the extraction of this elegant natural stone material are preserved.

2. Analysis of applied building materials and technologies

General constructive typologies of historical buildings of the Caucasian Mineral Waters and adjacent territories are reduced to several solutions, which are discussed below.

The foundations of buildings are tape, made of the following materials:

- rubble (natural stone - beshtaunit, dense sedimentary rocks, travertine);
- blocks of natural stone (travertine).

Socle of buildings:

- masonry of natural stone (beshtaunit, travertine)
- blocks of natural stone (travertine, sandstone)

Wall constructions include jumper windows and doorways, as well as arches are made of:

- blocks of natural stone with a lock stone;
- sloping brickwork with a lock stone of travertine or sandstone;
- sloping brickwork with a brick lock.

Facades and building elements are made of:

- Whole travertine or sandstone blocks;
- mixed masonry of bricks and blocks of natural stone;
- brickwork from all sides;
- rubble masonry from all sides;
- brickwork on the facade, butts are made with butov.

Overlapping of buildings:

- wooden;
- metal beams;
- arched concrete with metal beams.

Balconies of buildings are made with the use of fences in the form of wrought-iron grids, supporting structures cantilever or with support on columns:

- wooden beams
- metal beams.

At the same time, in the resort towns of Kislovodsk and Yessentuki, surfaces of stones and blocks of sandstone and travertine predominate, with insignificant inclusion of volcanic stones of Beshtaunit. In the resort town of Zheleznovodsk, beshtaunit and travertine were used. In the resort town of Pyatigorsk, which is the capital of the North Caucasus Federal District, almost all the preserved historic buildings are made using travertine.

The total number of especially valuable historic buildings, built before 1920 and preserved to the present day in the towns of the Caucasian Mineral Waters, is:

- Pyatigorsk has more than 500 multi-apartment houses and about 100 public buildings;
- Yessentuki has more than 50 multi-apartment houses and about 50 public buildings;
- Kislovodsk has more than 300 multi-apartment houses and about 100 public buildings;
- Zheleznovodsk, Georgievsk, Novopavlovsk have more than 50 multi-apartment houses and about 30 public buildings.

Thus, more than 1000 historic buildings located on the territory of the specially protected resort region of the Caucasus Mineral Waters, need constant monitoring of their construction and technical condition, in order to ensure their durability, reliability, as well as aesthetic appeal to residents and visitors of the resort region.

3. Ensuring the durability of buildings

According to our research, by now the technical condition of historical buildings is significantly different, a number of factors affecting their safety have been considered in [1,6,7]. In order to ensure the preservation of historical buildings for present and future generations, it is necessary to develop and implement measures aimed primarily at increasing their durability. At the same time, it is necessary to take into account that the seismic impact areas under consideration are regions where the intensity of seismic impacts reaches 8-9 points on a 12-point macroseismic MSK-64 scale [8].

Consequently, ensuring the durability of buildings of historical development of the resort region of the Caucasus Mineral Waters is associated with the solution of the following tasks:

- forecasting the residual life of buildings that are currently in satisfactory technical condition, as well as buildings whose structures have been damaged as a result of uneven deformations of the base. Such damages include power cracks in the necrotic bridges, sections of external walls, weathering of mortar from masonry seams and others.
- risk assessment in relation to extreme seismic influences and development of measures to improve the safety of buildings at the end of their future operation.

At the first stage of forecasting the individual resource of the maintained building, an assessment of the technical condition of its structures and foundations, the detection of defects and damage by methods of nondestructive testing are made. The second stage determines the actual load and the actual operating conditions of the structures under study. At the final stage, the actual resource is reconciled with the reliability indices laid down at the design stage, the forecasting of the optimal residual life on the basis of the data obtained, as well as an assessment of the probability of failure of structures during normal operation. At the third stage, the actual earthquake resistance of buildings and the likelihood of failure in the implementation of an earthquake of design intensity are estimated.

For load-bearing structures of buildings, the parameters determining their performance are the load-carrying capacity and rigidity, by the change of which, during the technical examination, it is possible to judge the course of the process of wear and tear. It should be borne in mind that the design is influenced by many random factors that are difficult to describe. Therefore, a reliable prediction of the residual life of the building as a whole and its structures is possible only on the basis of probabilistic methods of reliability theory.

With the joint effect of gradual failures and failures associated with extreme seismic loads, the probability of failure-free operation of the structure is considered as a complex event, consisting in the joint fulfillment of two conditions: failure-free operation with wear damages and failure-free operation from extreme impacts. The probability of failure-free operation of the structure, provided that these failures are independent, is equal to the product of the corresponding probabilities:

$$P(t) = P_1(t) \cdot P_2(t) \quad (1)$$

Reliability is determined by the degree of seismic hazard of the construction area as the probability of exceeding the estimated earthquake for a time at least once and is calculated according to Poisson's law with a constant intensity:

$$H(t) = 1 - \exp(-\Lambda t) \quad (2)$$

where is $\Lambda = 0,02 \text{ years}^{-1}$ the frequency corresponding to the period of 500-year-old earthquake frequency on map A of OSR-97.

The necessary level of safety in relation to seismic impacts is provided by the choice of an extreme computational earthquake, based on seismic risk assessment [9]. The maximum estimated acceleration of the earth during an earthquake depending on the service life T and the specified maximum permissible risk is given by the following formula:

$$a^* = \omega_0^2 \sigma / \mu \left[2 \ln(\omega_0 \tau_E \Lambda T / \pi H^*) \right]^{\frac{1}{2}} \quad (3)$$

where is ω_0 - the natural frequency of the system; τ_E - the duration of the intensive phase of the earthquake; T - service life; μ - is the damping parameter; σ - is the standard for moving the system.

The required amount of risk H^* or security P^* must be consistent with some optimum for this class of buildings optimum reliability. The considered buildings of historical development belong to systems with non-economic responsibility, high reliability of which can be provided by purely constructive measures that do not lead to high costs. In this case, the criterion of maximum reliability is freed from the cost limitation [10], and the optimal values P^* are H^* either determined without economic criteria, but based on the maximum reliability criterion dual to the minimum cost criterion.

A significant advantage of the criterion of optimization based on reliability is that constraints such as strength or rigidity conditions are replaced by a single restriction on the reliability index P^* . During operation, the total resistance of buildings to intensive impacts is reduced due to accumulation of damage, wear, plastic residual deformations, uneven deformation of the base. The risk factors for such buildings are related to the duration of operation: on the one hand, extreme impacts are functions of time, on the other hand, resource development, accompanied by wear and damage accumulation, reduces resistance to seismic influences. In this case, the safety requirements act as limitations on the service life T , when the required safety level is violated before reaching the limit state due to accumulated damage. Then the reliability criterion is taken in the following form:

$$P(T^*) \geq P^* \quad (4)$$

where is T^* - the established service life; P^* - the maximum allowable value of the reliability criterion for the expiration of the specified period.

The conclusion.

Thus, the implementation of a qualitative assessment of the technical condition of historical buildings will allow selecting the most optimal and economically justified measures for their preservation.

References

- [1] Shebzukhova T A , Sidyakin P A , Shchitov D V , Vartumyan A A 2016 *Environmental safety of engineering infrastructure of cities and recreational areas of the North Caucasus*. Pyatigorsk, Part 1. - 144 p
- [2] Pshenichkina V A , Ekba S I , Sidyakin P A , Shchitov D V 2017 *Vestnik MGSU*. **4** pp 452
- [3] Azarov V, Sergina N, Sidyakin P, Kovtunov I 2017 *IOP Conf. Series: Earth and Environmental Science* **90** 012015
- [4] Khorzova L I, Sidyakin P A, Yanukyan E G 2016 *Procedia Engineering* **150** pp 2031

- [5] Sidyakin P A, Yanukyan E G, Fomenko N A, Vahilevich N V 2016 *News of higher educational institutions. Geology and exploration* **1** pp 66
- [6] Shchitov D V, Shchitova T V 2014 *Modern science and innovations* **4** pp 72
- [7] Politov S I, Sidyakin P A, Palatov R R 2015 *Civil safety technologies* **2** pp 64
- [8] SP 14.13330.2014 Construction in seismic regions SNIIP II-7-81 * (updated SNIIP II-7-81* Construction in seismic regions (SP 14.13330.2011)) (with Change No. 1)
- [9] Bolotin V V 1984 *Forecasting the resource of machines and structures* 312 pp.
- [10] Bolotin VV 1982 *Methods of probability theory and reliability theory in the calculation of structures*. 350 pp.