Inspection of sugar factory brick wall

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Abstract. Nowadays a huge number of industrial buildings constructed in the last century need restoration. Structures with brick walls are in the list. The reason for this is the appearance of cracks, breaks, spalls, cavities, holloes and other discontinuities of brickwork; wall deformations; stratification of brickwork rows; humidification of walling, weathering and leaching of mortar; loss of individual bricks; damage to protective and finishing layers; efflorescence on the surface of brickwork and many other things.

The causes of such defects can be the following: unsatisfactory operating conditions; errors at the design stage; low quality of the used construction material; substandard work; differential settlement of walls foundation; violation or lack of wall waterproofing; natural aging of masonry and other negative factors.

In this work the object of the inspection was a brick wall of the main building of the sugar factory, which was put into operation in 1962. The inspection results showed that the condition of the load-bearing brick wall of the sugar factory main building, taking into account the scope and danger of defects, the degree of physical and moral wear of structures, as well as a number of other factors, can be considered unsatisfactory (limited working capacity) and the building can be regarded suitable for reconstruction and further operation.

1. Introduction

Nowadays a huge number of industrial buildings constructed in the last century need restoration. Structures with brick walls are in the list. The reason for this is the appearance of cracks, breaks, spalls, cavities, holloes and other discontinuities of brickwork; wall deformations (deflections, verticality deviation); stratification of brickwork rows; humidification of walling, weathering and leaching of mortar; loss of individual bricks; damage to protective and finishing layers; efflorescence on the surface of brickwork and many other things.

The causes of such defects can be the following: unsatisfactory operating conditions (aggressive environment; wetting, humidification); errors at the design stage (inaccurate account of loads, insufficient quantity of bonds, poor quality or incomplete geotechnical evaluation of foundation soils); low quality of the used construction material (low strength and frost resistance, deviations in dimensions); substandard work (violation or absence of bonding, verticality or horizontal deviation); differential settlement of walls foundation; violation or lack of wall waterproofing; natural aging of masonry and other negative factors.

Any of the above-mentioned defects can cause a decrease in the strength characteristics of the masonry structure, reduce the period of its operation, which can ultimately lead to serious consequences. In order to guarantee the reliability, durability, safety and survivability of the structure it is necessary to perform a thorough inspection of such buildings, eliminate the causes of damage and then carry out full or partial reconstruction of the damaged areas [1-4].
In our opinion the works of V.I. Kolchunov, N.V. Klyueva [5], I.T. Mirsayapov and A.G. Tamrazyan [6] deserve special attention in the field of reliability and survivability of buildings and structures. In the above works great attention is paid to evaluating the performance of structures after beyond design impacts (fire, explosion, negative weather conditions).

In the studies [7-9] the main causes of structures failures at all stages of work are investigated, their analysis is carried out and the methods for their further prevention are suggested. The authors conclude that in the recent years their number has not decreased because of insufficient number of measures to prevent emergencies. Therefore, there is a need to carry out expert examination of such objects to determine their current technical condition and the possibility of their safe operation.

The works of O.M. Donchenko and I.A. Degtev [10-13] are devoted to the peculiarities of brickwork in various conditions. In the above studies attention is mostly focused on the stress and strain state of the stone structure at various stages of its performance. The authors conclude that the destruction of masonry functioning in a complex stress state occurs, when the limit state of strength in the individual components is reached as a result of the combined action of compressive and tensile stresses.

In this work the object of the inspection was a brick wall of the main building of the sugar factory with a height of 19.5 m and a brickwork thickness of 510 mm. All the building structures were installed in accordance with the project. The sugar factory building was put into operation in 1962 and the operation continued until 2006. In 2006 a partial overhaul was carried out with reconstruction of the finishing coat.

The reason for the inspection was doubtful reliability of the brickwork of the main building of the sugar factory, the non-compliance of the structures with the requirements of normal operation of the building and their significant physical wear due to the failure to fulfil previously recommended measures and the ongoing process of corrosion and deformation destruction of the structures.

Thus, the purpose of the inspection was to determine the technical condition of the brick wall and the possibility of further operation taking into account the actual condition.

2. Methods and materials

The choice of methods for reconstruction and restoration of operational qualities of damaged brick wall areas is primarily based on a qualitative assessment of the technical condition of the object being inspected. This procedure is based on scientific diagnostics that allows identifying signs and causes of damage. Relying on the parameters of the technical condition, taking into account their normative values and permissible deviations, methods and means for the parameters analysis and assessment are developed.

When assessing the condition of the brickwork, the following three methods were used: 1 – visual determination of the structures wear by external signs; 2 – instrumental assessment of the structures condition; 3 – engineering analysis of the diagnostic data.

During the inspection by means of viewing and special instrumental methods the structures were examined, the actual loads, impacts, operating conditions and material properties were determined; measurement drawings and diagrams, a list of defects and other necessary materials were prepared.

When assessing the technical condition of the masonry structures, verification calculations were made, which necessarily took into account the defects and damages detected during the inspection, the actual properties of the materials, the predicted loads, impacts and operating conditions. This assessment was made on the basis of theoretical and experimental studies in order to determine and further use the reserves of the load-bearing capacity of the masonry structures.

Expert-technical inspection of the brick wall was carried out by the following program: 1 – analysis of design, as built and operational documentation; 2 – physical inspection of structures and elements (visual examination of all structural elements of the site; internal inspection of load-bearing structures; evaluation of technical condition of building structures); 3 – instrumental examination of the site structures (determination of the strength and condition of materials by nondestructive methods of control, sampling and laboratory testing; measurements of temperature-humidity and operational parameters,
heat and dust release of the environment; 4 – calculations of load-bearing structures taking into account the identified defects and damages of hazard category A; 5 – determining the causes of damage; 6 – drawing up a conclusion based on the results of examination of the structures technical condition, developing recommendations for structures operation.

3. Results and discussions

When checking the actual height, it was found out that it basically corresponds to the design values with deviations within the limits of the permitted tolerances.

The external and internal walls have vertical cracks up to 6 cm wide and 2–4.5 m long. The biggest crack opening is observed in the upper and middle parts of the building. The reason for their occurrence is uneven deformations of the sub-base under the foundations. Despite the fact that their development has almost stopped, they are dangerous. Besides, the walls have a large number of small cracks up to 0.4 mm wide that penetrate two or more bricks.

On the external surfaces of the walls a significant decrease in the strength of the masonry mortar and its pouring out to a depth of 4 cm were determined. Severe damage is found between the marks on the height of 16.0 m and 19.2 m: punching of masonry, mortar leaching out of masonry joints, loss of strength, efflorescence and wetting. Besides, on this site the collapse of more than 1 m² of brickwork was revealed, as well as the wobbling of bricks with 100% loss of strength (defect of A category) (Fig. 1).

![Figure 1. The condition of defects in the load-bearing brick wall.](image-url)

The quality of masonry is low with poor bonding and low quality filling of joints with mortar (Fig. 2). Bricks with a large number of small cracks, chipped edges and corners are used for masonry. On the inner side of the walls there are a lot of randomly located cracks and wetting. Due to long-term moistening of masonry structures with atmospheric water and process fluids there are traces of leaching on the structures surfaces in the form of light and dark-colored blooms. This is the consequence of dissolution and removal to the surface of the hardened cement paste components of the masonry mortar, which was undoubtedly a catalyst for a certain decrease in strength.

Inside the building at the level of 7.2 m a metal beam resting on a brick wall suffered significant corrosion damage. Moreover, the area of its support is not sufficient. In the place of its support on the brick wall the masonry was pushed and sagged as a result of the loss of masonry mortar strength.
Delamination and rotting of the rolled carpet due to humidification by atmospheric precipitation for a long time, as well as local uneven surfaces, affected the condition of the parapet section of the masonry. The degree of the parapet destruction along its length varied: from leaching to destruction, especially in the northern part of the building (defect of category A).

Considering the results of the inspection, the brick wall reinforcement is calculated. Reinforcement is performed with prestressed steel tie rods along the outer contour of the walls at the level of floor slabs. The force that is supposed to be perceived by one tie rod under condition of preventing further deformations with the calculated resistance of the masonry to the section of M 75 bricks on M 50 mortar, $R_{st} = 1.6 \text{ kg/cm}^2$, length of the cross wall $l = 36.0 \text{ m}$ and its thickness $d = 51 \text{ cm}$:

$$N = 0.02\cdot R_{st}\cdot l\cdot d = 0.02\cdot 1.6\cdot 3600\cdot 51 = 5875.2 \text{ kg}.$$  

The required area of steel tie rod St 3 (A 240) when $R = 2150 \text{ kg/cm}^2$:

$$A = \frac{5875.2}{2150} = 2.73 \text{ cm}^2.$$  

The same calculations are for the cross wall $l = 48 \text{ m}$:

$$N = 0.02\cdot 1.6\cdot 4800\cdot 51 = 7833.6 \text{ kg};$$  

$$A = \frac{7833.6}{2150} = 3.64 \text{ cm}^2.$$  

The force that is supposed to be perceived by one tie rod under condition of compensation of masonry tensile work in a crack, which is 51 cm deep and 4.50 m high, and the calculated tension resistance of the masonry is $R_t = 0.8 \text{ kg/cm}^2$:

$$N = 51\cdot 450\cdot 0.8 = 18360 \text{ kg}.$$  

The required area of one tie rod:

$$A = \frac{18360}{2150} = 8.54 \text{ cm}^2.$$  

For a larger value of the required area it is accepted 3 Ø 20 A 240 ($A = 9.42 \text{ cm}^2$).

The value of tie rod elongation when prestress value $\sigma_{sp} = 1000 \text{ kg/cm}^2$, elastic modulus $E = 2\cdot10^6 \text{ kg/cm}^2$:

for the cross wall –

$$l = 36.0 \text{ m}, \Delta l = (\sigma_{sp} / E) l = (1000 / 2\cdot10^6) 36000 = 18 \text{ mm}$$  

for the longitudinal wall –

$$l = 48.0 \text{ m}, \Delta l = (1000 / 2\cdot10^6) 48000 = 24 \text{ mm}.$$  

4. Summary

The inspection results showed that the condition of the load-bearing brick wall of the sugar factory main building, taking into account the scope and danger of defects, the degree of physical and moral wear of structures, as well as a number of other factors, can be considered unsatisfactory (limited working capacity) and the building can be regarded suitable for reconstruction and further operation. At the same time individual structural elements do not have the required operating characteristics. Therefore, in order to prevent further destruction of the masonry structure it is necessary to take measures to strengthen it, restore it or improve the operating conditions.

It was recommended to restore the brickwork from 0.00 m up to 7.2 m and between the marks of 16.0 m and 19.2 m, with the joints being bonded. If possible, new brickwork should be carried out. All works are supposed to be performed only after the wall deformations are stopped.
It is necessary to unload the brick wall at 7.2 m mark with additional posts for metal beams in the middle of the span, as well as to perform reinforcement of the brick wall with metal one-sided tie rods. Anchoring of tie rods is performed at a distance of at least 2 meters from the cracks and only to the bearing wall.

All walls cracks should be propped with steel pins Ø10 A 400 with a length of 150 mm and a step of 500 mm along the crack. After propping the crack should be filled with M100 cement mortar to a depth of at least 5 cm. Along the entire height of the wall overcoating on the fixed grid is supposed to be carried out on the outer and inner sides. On the outer surface the brick walls small cracks should be cleaned of dust, moistened and sealed with a cement-sand mortar. Through cracks in internal walls with normal air humidity (60 %) should be sealed by injecting polymer-modified cement mortar. In external and internal walls with high humidity cement mortar should be used. The sections of brick walls with through cracks should be disassembled to a width of 1.5 – 2 bricks for the entire thickness of the wall and then sealed with full bricks in compliance with bonding joints of old and new masonry.

After repairs it is necessary to eliminate the increased humidity of the wall material, which was the result of damage to technological equipment and various engineering devices.

It is necessary to perform major repairs of the parapet section of masonry and monitor the roof condition.

Normal operation of the sugar factory main building is possible only after all the recommendations given as a result of the inspection are fulfilled.

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