A new method for assessing the physical wear of apartment buildings with defects included

Asadulla Khotamov[1*], *Shakhnoza* Kadabayeva[1]

[1]Tashkent Institute of Architecture and Construction, 100011 Tashkent, Uzbekistan

Abstract. The article proposes a new method for assessing the physical deterioration of residential buildings, taking into account not only the physical deterioration of structures, but also the accumulated defects in buildings. The composition of operational wear, methods for their assessment and assessment of the real technical condition of structures and buildings as a whole are analyzed. At the same time, operational wear is considered as a combination of physical and moral wear. If physical depreciation is presented as a category of technical and economic, then the assessment of the degree of this depreciation is associated with the costs spent on its elimination. The technical condition of the building structure is also affected by defects accumulated at different stages (pre-project, design stage, prefabrication stage, storage and transportation of the structure, construction and installation and operation stage) of the existence of the building. The elimination of accumulated defects also requires corresponding costs. Therefore, in the article the accumulated defects are referred to as functional deficiencies and it is accepted as functional wear and tear. And the assessment of cumulative wear in determining the real technical condition, the inclusion of this wear is necessary. This article presents an algorithm and a mathematical model for accounting for this type of (functional) wear.

1 Introduction

Researches of all leading architectural and construction universities and research centers of the world are aimed at organizing the optimal operation of multi-apartment buildings (MAB). In particular: the problems of regional factors, the appearance of defects, types and their significance during operation, issues of premature wear, etc., which negatively affect the durability and safety of the MAB, also on the timing of scheduled repair and restoration work, the rationale for the overhaul, relation to the standard service life, ensuring durability and, as a result, organizing the optimal operation of MAB. In this direction, it is important to predict the durability of MAB through its physical wear and tear over time, monitoring the technical condition of MAB based on an electronic passport for digital management of the city cadastre.

In the Russian Federation, 10% of the total housing stock amounted to 290 million square meters, which was built in 1959-1985 (mainly a 5-storey large-panel "Khrushchevka"),

* Corresponding author: loyiha_ks@mail.ru

where the level of physical deterioration is from 40% to 80% [8]. In Western European countries, such as: Russia, France, Poland, within the framework of renovation programs to determine the technical condition of MAB, it was revealed that 20-30% of the total funds allocated for construction is spent on new construction, and the rest, 70-80% for overhaul, reconstruction and renovation [8]. In Japan, South Korea, Singapore and Hong Kong, research is underway to identify the origin of defects during the commissioning of objects and operation during the warranty period, their analysis and elimination, and to improve the quality system [3]. A specific "German school" has been formed in Germany. For example, 70% of the total housing stock in Berlin is 34 million apartment units, of which 24 million were reconstructed [8]. These MABs in Germany were built in the 1980s, and yet they were not in a normal technical condition.

In the Republic of Uzbekistan, over the past 30 years, the intensity of physical wear has increased as a result of a strong change in hydrogeological conditions due to an increase in groundwater. The salt-alkaline composition of groundwater is increasing, which is dangerous for building structures. The geography of aggressive environments in the republic is increasing. The reason is the drying up of the Aral Sea, which was the largest water basin while maintaining climate stability in Central Asia.

Assessment of the degree of physical wear and tear intensity is an urgent task, however, in this article we will give one more point, which is considered important when assessing the technical condition of MAB.

2 Main part

In Uzbekistan, in particular Tashkent, the first one-story MABs were built in 1926 in the town of May 1 (in the center of Tashkent) [2]. To this day, all these houses have been demolished. In the early 1930s the first MAB two and three-story with communal amenities were built. The oldest generation have an actual service life of about 90 years. They are physical and morally obsolete. Many of them have been demolished, the rest are still in operation. The second generation of MAB includes residential buildings built in the period 1940-1966. those. before the Tashkent earthquake. MAB, belonging to the second generation, also has significant physical and moral deterioration. The distinctive features of these MABs are as follows: they were built of burnt bricks, the width of the enclosing walls was at least 2 bricks, with wooden ceilings. The foundations are tape made of concrete, rubble or burnt bricks. Thanks to the width of the sole and the foundation strip, the enclosing walls and the brand of mortar and brick, they survived the Chatkal (1945) Tashkent (1966) earthquake. However, MAB related to the second generation requires serious attention in relation to the expediency of further operation based on the current state [7].

The third generation of MAB includes residential buildings built after the Tashkent earthquake, the so-called industrial period, 1966-1990. They were built according to standard projects, based entirely on factory production, according to new standards, taking into account seismic resistance. Fig. 1 shows the dynamics of the construction of MAB in Uzbekistan, and the largest number of MAB were built in this industrial period. The states of these MABs are completely different. In addition, unsatisfactory operation, the lack of scheduled preventive repairs led to an overestimation of physical wear and tear. On a number of physical, they have significant obsolescence.

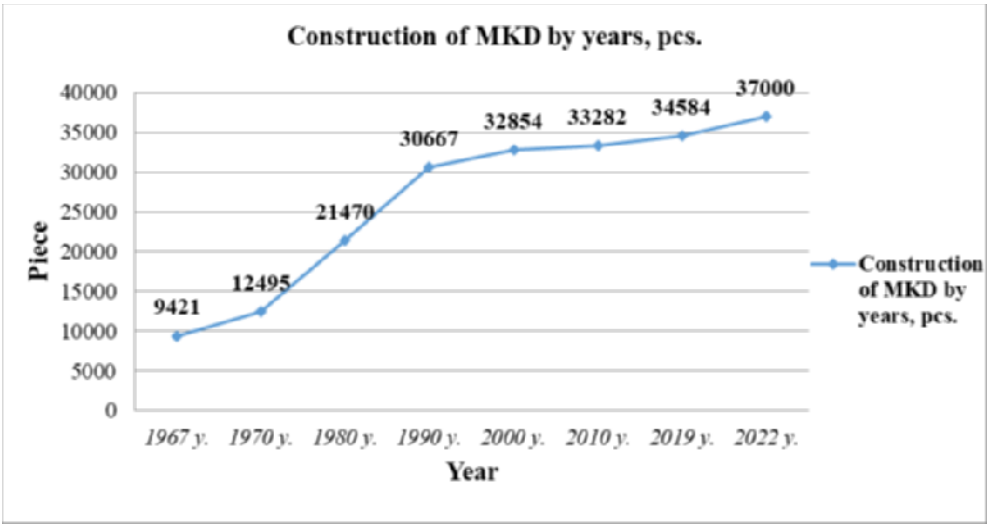

Fig. 1. The dynamics of the construction of MAB in Uzbekistan.

The fourth generation of MAB included residential buildings built after 1990. Many of them were built on the basis of individual projects, the so-called "complex construction", i.e. they have structures made of a monolithic reinforced concrete frame with brick infills, made of prefabricated reinforced concrete in one building.

However, this article discusses the assessment of the degree of physical deterioration of MAB, which is an important point in the overhaul, modernization, reconstruction or renovation of residential areas.

Existing methods for assessing the physical deterioration of residential buildings are far from perfect and give a clear result due to the subjectivity of decisions. Moreover, the existing methods and current regulations in this area are far from perfect.

Assessment of the physical deterioration of residential buildings, in particular MAB, is carried out on the basis of the normative document VSN 56 (p). According to this document, the physical wear of structural elements, engineering equipment and buildings as a whole is determined. Depreciation of engineering equipment is shown in graphs that take into account the service life (the so-called normative method of calculation).

The wear of structural elements is determined by the following formula.

$$\Phi_k^e = \sum_{i=1}^{n} \Phi_i^e \cdot \frac{P_i}{P_k} \quad (1)$$

The general degree of physical deterioration of the building is determined by the following formula.

$$\Phi_{Б}^e = \sum_{i=1}^{n} \Phi_{ki}^e \cdot l_i \quad (2)$$

where: : $\Phi_i^e -$ wear of the structure, element or engineering equipment, %, $P_i -$ size of damaged areas, sq.m., or m. P_k - total dimension of the structure, sq.m., or m; n is the number of damaged areas. $\Phi_{ki}^e -$ wear of individual structures, elements or engineering equipment, %. $l_i -$ coefficient taking into account the share of the structure, element or engineering equipment relative to the replacement cost of buildings.

It should be noted that according to VSN, only physical wear is determined. However, the building material is still subject to aging, i.e. a structural change, for example, associated with a loss of strength or rigidity of an element or structure! According to VSN, wear is determined mainly by external signs of a damaged element or structure. The appearance of the structure does not always give the proper result on the technical condition of the structures (keeping the appearance in its original form, for example, concrete can lose its modulus of elasticity over many years of operation in a dry hot climate up to 25-30% [5]. The same, burnt brick may lose strength in an unfavorable environment (for example, increased moisture) without changing their appearance, i.e. without signs of any damage or wear of an erosive nature). And the aging of building materials is determined only on the basis of a detailed examination using diagnostic methods. This is done primarily by determining the strength characteristics of the construction materials.

Based on the foregoing, the aging of the main parts of the building structure according to the following formula [8]:

$$\Phi_k^{э} = \sum_{i=1}^{n} \Phi_i^{э} \cdot \frac{P_i}{P_k} \quad (3)$$

The total aging of the building is written as follows:

$$\Phi_{Б}^{э} = \sum_{i=1}^{n} \Phi_{ki}^{э} \cdot l_i \quad (4)$$

where: $\Phi_i^{э} -$ aging of a part of the structure,%, $P_i -$ dimension of obsolete parts, sq.m., or m. P_k - total dimension of the structure, sq.m., or m; n is the number of areas subject to aging; $\Phi_{ki}^{э}$- aging of individual structures, %. $l_i -$ coefficient taking into account the share of the structure, element or engineering equipment relative to the replacement cost of buildings.

Based on formulas (1) and (3), the wear and aging of individual structural parts is written as follows:

$$\Phi_k = \sum_{i=1}^{n} \Phi_i^{e} \cdot \frac{P_i}{P_k} + \sum_{i=1}^{n} \Phi_i^{э} \cdot \frac{P_i}{P_k} \quad (5)$$

Based on the formulas (2) and (4), wear and aging in the building as a whole is recorded as follows:

$$\Phi = \sum_{i=1}^{n} \Phi_{ki}^{e} \cdot l_i + \sum_{i=1}^{n} \Phi_{ki}^{э} \cdot l_i \quad (6)$$

Thus, according to formulas (5) and (6), the physical wear (taking into account the wear and aging of the material) of individual structural parts and buildings as a whole is determined. Depreciation is determined on the basis of the current VSN, and the aging of the material of the structure and buildings as a whole is determined by an expert, based on diagnostic assessment methods using technical expertise.

The current standards cannot take into account the “aging” indicator in tables consisting of 72 names, showing all signs of damage in the main structural parts of buildings.

The existing normative methods for assessing the physical deterioration of buildings, based on the service life, have a very large error in relation to the results obtained by expert methods (the above method).

In the works [3, 9] at the stage of erection of a building or structure by strengthening the control of the requirements of the technology of construction production in order to minimize defects associated with the quality of the materials used, products, structures and the quality of the construction and installation, finishing, etc. works physically wear is modeled with probable deformations of foundation bases. However, this approach is typical for a specific case, related to the engineering-geological and hydrological conditions of the construction site and from the existing loads on the foundation by the time construction is completed, and can continue for a long time up to the entire period of the life cycle of the object.

Classical methods according to the service life of the architect Rossi, S.K. Balashov, V. Srokovskiy, V.V. Anisimova, V.E. Nikolaytsev, Litver, V.K. Sokolova, N.V. Nechaev [1], as well as the method of determining physical wear and tear, taking into account the age of buildings and major repairs carried out, has its drawbacks, the method of V.S. Bashkatova, A.V. Belykh also has its drawbacks, since if the buildings have not been repaired and built, then the use of these methods is not possible or they take into account the specifics of the region.

We have developed formulas for determining the physical deterioration of residential buildings, the operation of which was considered unsatisfactory. For this, the wear and tear of more than 300 buildings in different regions of the republic was analyzed. As a result of field experiments, the predicted values of physical wear were established, taking into account regional characteristics:

1) predictive model for brick MAB with unsatisfactory operation:

$$y = 0.207\ (0.1x\text{-}6)\ 3 + 44.8 \tag{7}$$

where, y is physical wear, Фў, % = y = 48.9%.);

x-period of building operation, Te, year (Te = x = 65 years);

2) for MAB from a prefabricated reinforced concrete panel in case of unsatisfactory operation:

$$Ф = 0.21\ (0.1\ Te\ \text{-}6.1)\ 3 + 47.7 \tag{8}$$

3) wear of the foundation of brick structures during unsatisfactory operation:

$$Ф\ (T) = 0.27 \cdot T + 6.42 \tag{9}$$

where T is the standard service life of buildings; Te is the actual service life.

If there are no signs of wear in the structural elements (according to external signs), then formulas (7,8,9) can be applied. However, these formulas are regional in nature, taking into account the specifics and depend on the operating conditions, more precisely, the formulas are developed for those buildings in which the operation was carried out in unsatisfactory conditions.

Also, the classical formulas recommended by the architect Rossi, further S.K. Balashov, V. Srokovskiy, V.V. Anisimov, V.E. Nikolaytsev, Litveram, V.K. Sokolov, N.V. Nechaev is used mainly in the mass assessment of buildings, for an approximate determination of their degree of wear and the category of technical condition.

For isolated cases when it is necessary to assess the real technical condition of buildings, an assessment of the degree of accumulated wear and tear will be required.

The above formulas (5) and (6) are modified, taking into account both wear and aging, however, they cannot determine the real technical condition of structures or buildings as a whole.

To determine the real technical condition of the building, formulas (5) and (6) need to add all sorts of defects and shortcomings, which can be attributed to the functional deterioration of buildings.

Defects, as you know, can occur even in the pre-design stages. Then, design errors, factory manufacturing defects, defects made in the processes of construction and installation works, as well as in the operation processes. The accumulation of defects worsen the quality and reduce the cost of MAB. Therefore, they must be taken into account when determining the degree of operational wear as functional wear and tear (see Picture 2).

Picture 2 shows the value of the impact of defects on the cost of a building as functional wear.

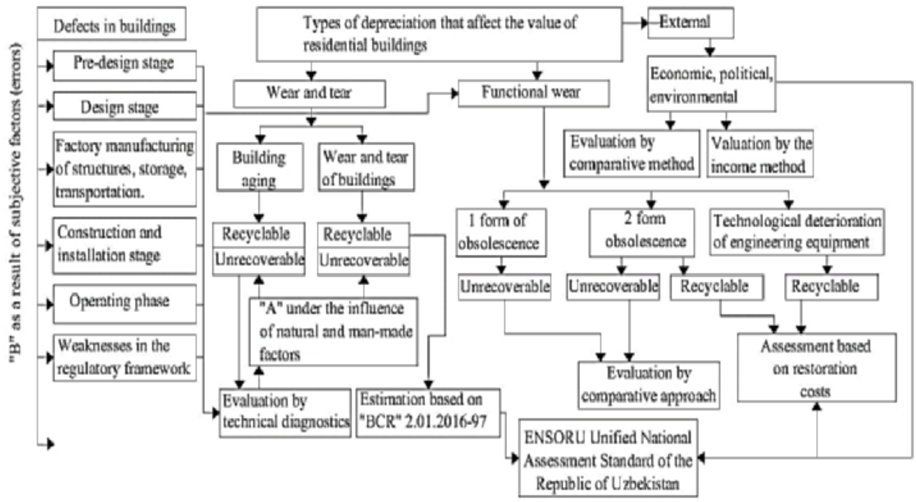

Fig. 2. Types of wear that affect the cost, serviceability of MAB [7].

As you know, physical wear is an indicator that combines the technical and economic conditions of building structures, i.e. the value of physical wear and tear show the deterioration of the technical condition, respectively, requiring adequate compensation for the restoration of material losses.

Based on the above consideration, it follows that the elimination of existing defects, as well as accumulated physical wear and tear, requires adequate costs. Therefore, in order to assess the real technical condition of buildings, it is proposed that, along with the accumulated physical wear and tear, it is also necessary to determine the accumulated defects, the so-called functional deficiencies of buildings.

Accordingly, Pic. 2 - the technical condition of the MAB is measured in the aggregate of wear, aging of materials and accumulated defects, i.e.,

$$\mathrm{T_c} = f(\Phi^{\mathrm{e}} + \Phi^{\text{э}} + \Phi_{\mathrm{y}}^{\text{д}}) \leq [\mathrm{T_c}] \qquad (9)$$

where: T_c – technical condition of MAB; [Tc] – normative technical condition of MAB; f(x)- function that satisfies the technical condition of the MAB; Φ^{e}- wear of the building, %; $\Phi^{\text{э}} -$ aging building; %, $\Phi_{\mathrm{y}}^{\text{д}}$ – building defects (related to functional wear).

$$\mathrm{T_c} = f(\Phi^{\mathrm{e}} + \Phi^{\text{э}} + \Phi_{\mathrm{y}}^{\text{д}}) \leq [\mathrm{T_c}] \qquad (9)$$

We display defects that occur at all stages of the life cycle (pre-design stage, design errors, factory manufacturing errors, transportation, construction and installation defects, and defects that arose during the operation processes) of the building as follows:

$$\Phi_{\text{ук}}^{\text{д}} = \sum_{i=1}^{n} D_i \cdot \frac{P_i}{P_k} \qquad (10)$$

where: $D_i -$ defects of a part of the structure, $P_i -$ dimension of the defective parts, sq.m., or m. P_k total dimensions of the structure, sq.m., or m. n - number of defective parts.

The amount of defects that have arisen in the life cycles of buildings is formulated as follows.

$$\Phi_{у}^{д} = \sum_{i=1}^{n} D_{ki} \cdot l_i \qquad (11)$$

where: D_{ki} – defects in individual structures, %;

Mean, wear, aging and accumulated defects in individual structural elements is determined on the basis of formulas (5), (10) according to the following formula:

$$\Phi_k = \left(\sum_{i=1}^{n} \Phi_i^e \cdot \frac{P_i}{P_k} + \sum_{i=1}^{n} \Phi_i^э \cdot \frac{P_i}{P_k}\right) + \sum_{i=1}^{n} D_i \cdot \frac{P_i}{P_k} \qquad (12)$$

Wear, aging and accumulated defects building on the basis of formula (6), (11) - will look like this:

$$\Phi = \left(\sum_{i=1}^{n} \Phi_{ki}^e \cdot l_i + \sum_{i=1}^{n} \Phi_{ki}^э \cdot l_i\right) + \sum_{i=1}^{n} D_{ki} \cdot l_i \qquad (13)$$

Formula (13) reflects the actual technical condition of the building. When determining the technical condition of the MAB, VSN 56 (r), BCR 2.01.16-97 is used to assess the wear and tear, to assess the aging of materials of the main load-bearing structures (non-restorable - base physical wear of materials) and accumulated defects are determined by expert basis of technical expertise of buildings.

3 Discussion

From all the previous it follows that the assessment of the real technical condition of residential buildings is a difficult task. Therefore, in recent years, a new term has appeared in the theory of depreciation of building structures of buildings, as "operational depreciation", which includes the physical, moral depreciation of buildings. Obsolescence is also typical for residential buildings, in particular for MAB. However, the evaluation of the form of obsolescence is a more time-consuming process compared to physical deterioration. If physical and two forms of obsolescence together constitute wear, the so-called "operational", then functional wear can be initial, associated with design errors, factory manufacturing of elements, structures or engineering equipment, especially errors made at the stage of the construction and installation stage (deviations from design decisions, poor-quality construction work, lack of proper control of construction processes, participation of incompetent specialists ...). As a functional disadvantage, they strongly influence the change in the work of the design calculation scheme of the building structure. This is due to the appearance of additional eccentricities, misalignment of vertical and horizontal elements of load-bearing structures, etc. Buildings, such initial defects functional worn out, the elimination of which requires significant capital investment, that the equivalence is taken as functional deficiencies. For regions where territories are included in high seismic activity, these shortcomings of the building can cause an emergency state or end with collapses. Regulatory documents as do not take into account these factors.

4 Conclusion

The correct assessment of accumulated wear and tear is an important point in determining the technical condition of buildings. Because, the actual technical condition of the building, in addition to wear and tear and aging of construction materials, depends on the defects accumulated in it. Based on all the previous considerations, it follows that the assessment of

accumulated wear and tear requires a detailed survey of the building, if necessary, the use of diagnostic methods. In conclusion, the following can be noted:
- an algorithm and a mathematical model of the sequence for assessing the cumulative wear and tear, taking into account accumulated defects, was developed;
- a scheme was developed for the interconnection of types of wear that affect the cost, operational suitability of MAB.

The recommended method for assessing cumulative wear contributes to determining the actual technical condition of building structures and possible costs to eliminate physical and functional wear.

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