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INFLUENCE OF THE INTENSITY OF PHYSICAL WEAR AND TEAR ON THE DURABILITY OF MULTI-APARTMENT RESIDENTIAL BUILDINGS

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Abstract: Determining the level of reliability in relation to the operation of multi-apartment residential buildings (MMARB) and determining the intensity function of the accumulation of physical depreciation are important issues regarding the renovation strategy. The distribution of the service life of residential buildings, the function of their reliability and the distribution of depreciation of the buildings under study are interdependent concepts. The deterioration of the object will be the higher, the longer the period of its operation. However, this is not an increase that reflects the life span of the building, nor is it a cost that is directly proportional to its age. The article presents a model and methodology for checking the level of deterioration and reliability of MARB, operated in different regions of the Republic of Uzbekistan, built in the period 1967-2019. The main conclusion was made regarding the mechanism of damage to residential buildings: during the period of operation of the facility, in which the uptime to failure has an exponential distribution, the average remaining uptime does not change at any time. It has been confirmed that after a certain period of non-failure operation, the tested MARBs perform their functions as new buildings.
Key words: apartment buildings; physical wear and tear; wear intensity; reliability; durability; operational wear; lifetime.

Introduction: Damage is an event that includes the loss of operability of an element or building [1,2,3,4,5]. This is due to their reaching the limit state. Exceeding the limit state corresponding to the subsequent utility functions of individual elements of the MARB reduces their operational potential [6]. The building structure, their elements lose various utility functions when it reaches the limit state of serviceability and goes into a state that is defined in reliability theory as faulty (but usable). This state lasts until all its functions exceed this limit state. After that, the element becomes unusable. The limit state for serviceability is a number of indicators that are regulated in the standards. The stimuli that cause the successive functions of the element to exceed the limit states can be sudden (accidental damage), gradual (aging damage) or have a relaxation extortion character (gradual aging of the element and its sudden transition to the unusable state occur together) [7]. Aging processes that occur gradually are usually caused by damage of a deterministic nature (predictable at a given time) [8].
Accidental damage occurs suddenly (damages, accidents) or caused by accelerated physical wear and tear. It should be noted that the intensity of physical wear is affected by defects that can be very diverse in time: defects of the pre-design stage (engineering surveys, incorrect choice of territory ...), design defects, defects in the manufacture of building structures, defects arising from

improper storage for a long time , transportation, construction and installation defects, as well as defects that arose during operation) [9].

If the design, element and engineering equipment contains an initial defect, the limit state of its individual functions is reached faster. Subsequently, there is a clear decrease in the resistance of the material to external factors. Sudden damage causes unexpected changes in the basic physical parameters that determine the performance of the main function of the element.

In case of failure, the limit values of the safety functions of the element design are not exceeded, and in case of an accident, the parameters change beyond the values allowed by the requirements.

Gradual damage is the result of physical aging. Aging processes are associated with irreversible structural changes in materials used in building components.

The accumulation of the effects of these interactions causes structural changes in the material. The result of these external and internal destructive processes is a decrease in the resistance of the material to damage that occurs during various periods of operation [10]. Consequently, there is a gradual increase in physical wear and loss of the functional properties of the element, which leads to its inoperability, and then to unsuitability for operation. Exceeding the limit state of serviceability by individual operational functions of the element does not mean its complete physical wear. The issue of safety is determined here by the relevant standards, technological instructions, conditions for admission to use, approvals and technical certificates [11]. Therefore, the criterion of safe operation is absolutely necessary during operation, regardless of the nature of the causes of damage to building elements [12].

The so-called Lorenz curve illustrates the typical course of the process of wear of building elements during their operation [13,14]. In this process, we can distinguish the following three main intervals of the age of the building "T" and the corresponding intervals of technical wear and tear "F" - Figure 1:

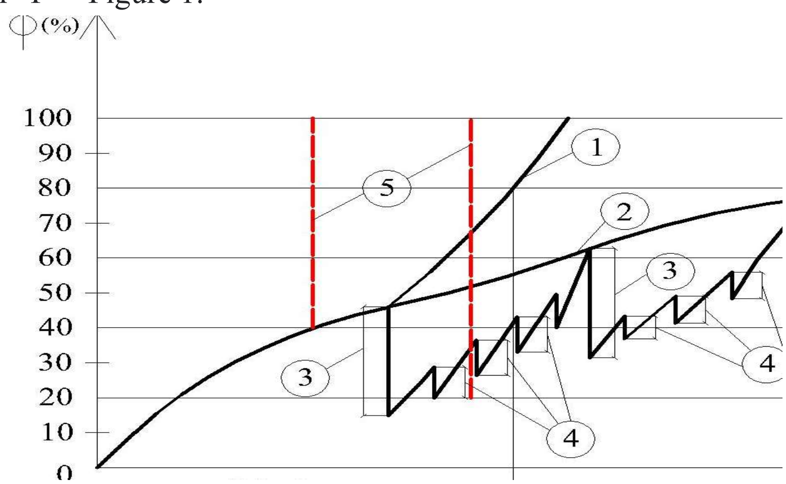

Figure 1. The aging process of MARB, taking into account repairs during operation.
1-natural aging (without repairs); 2-process aging in normal operating conditions; 3-reduction of physical wear and tear during major repairs; 4- reduction of physical wear and tear during current repairs; 5-sudden failure (accidents caused by natural or man-made factors).

• warranty and post-warranty period within 0.10-20 of the age of MARB Te, during which the building, as it were, "adapts" and accumulates operational wear "F" of approximately 20%;
• the period of normal operation within 0.60-0.75 of the age of the building Te, during which the object is in proper condition and shows operational wear "F" at the level of 50%;
• the period of planned operation until the full age of the building T, which is equal to its expected durability D, and during which the object must be repaired / modernized until it reaches the level of operational wear and tear of 80-90% [15,16,17,18,19].

The last period of planned operation and the period of unscheduled operation of multifamily residential buildings, whose age exceeds the service life in the literature [12], is the subject of research and analysis regarding the intensity of damage and changes in the state of reliability of buildings that meet the criteria of the target research sample described below.

Literature review

During operation, construction objects are subjected to continuous destructive processes from various internal and external factors. Over time, their functional properties decrease, and as a result of repair, they are partially restored [14]. However, choosing the type of repair is not an easy task. To this end, many models and methods have been developed to support policy makers and building administrators. They include a computer decision model for selecting repair options [13]; a simplified method for assessing technical degradation using artificial neural networks [11]; and technical and economic evaluation of works using fuzzy stochastic networks. In the proposed models and methods, an important element is the correct assessment of the size and intensity of defects in structural elements. A significant problem in the problem under discussion is an increase in physical wear and tear and partial defects, that is, a change in the state of the reliability of the building during operation. Analysis of the technical condition and intensity of damage to the MARB requires appropriate modeling. To model this phenomenon, one can use the Rayleigh distribution [7,8] or the Weilbull distribution [9].
The exponential Weibull distribution is often used to estimate the distribution of normal operation time [10] because it assumes that failures are caused only by external random events. However, in reality, such an exponential model of reliability distribution does not exist. Significant approximations, in which the influence of wear processes is assumed to be negligible, are made in the exponential distribution. A special example of a Weibull distribution is the Rayleigh distribution. This distribution, in turn, occurs when the wear of the element increases over time, i.e. is the main cause of failure over time. Appropriate modeling of operating scenarios helps to select the optimal planning for building renovations.
The aim of the study was to determine, using the example of more than 312 inspected apartment buildings, how the intensity of damage affects the reliability of construction projects.

Research method.

The subject of the study [18,19] is MARB in various regions of the republics. The buildings have completely different periods of construction. The buildings were built of brick, natural stone, precast concrete panels and wood. Sample numbers are shown in the table below.

Table.

Region	The composition of the MARB according to the applied design solution										Sum	%
	2-3 storey wooden	prefabricated reinforced concrete panel			9 storey frame	brick			Natural stone			
		*2	4*	5*		*2	4*	5*	2*	3*		
Tashkent region	16	1	10			7	2	4			**40**	12,82
Karakalpak AR	14			1		24					**39**	12,50
Khorezm region	1		2			5					**8**	2,56
Bukhara region	4					6					**10**	3,21
Navoi region	1					4	1		12	2	**20**	6,41
Surkhandarya reg.	2	1				5					**8**	2,56
Jizzakh region	2	17				23			4		**46**	14,74
Fergana region						3					**3**	0,96
Namangan region	2		1			9					**12**	3,85
Sirdarya reg.						47	2				**49**	15,71
Kashkadarya reg.	3	2	5			31	5				**46**	14,74
Samarkand region						6	3				**9**	2,88
Andijan region						18					**18**	5,77
Tashkent city					1	2		1			**4**	1,28
Total	**45**	**21**	**18**	**1**	**1**	**190**	**13**	**5**	**16**	**2**	**312**	**100**
Total**, %**	14,42	6,73	5,77	0,32	0,32	60,90	4,17	1,60	5,13	0,64	**100**	
Total**, %**	**14.42**	**13.14**			**0.32**	**66.67**			**5.77**		**100**	

The main selection criterion for the sample was the low-quality (unsatisfactory) operation of the MARB.

The methodology for selecting the study sample at the level of detail was based on the mutual similarity of all technical solutions for MARB in the country.

The selected research sample, according to the criteria presented above, is representative in relation to one of the concepts (specific to the accepted research goal) of representativeness [11,12]. It contains all variable values that could be reconstructed from a previous study that had a different objective function than that adopted in this study. However, these values have been compiled and processed in such a way that inferences can be drawn about causal relationships between them in the general population. Thus, we can assume the typological representativeness of the sample into which the desired types of homogeneous variables are classified. Since the structure of the population and its properties were well known before, such selection of the research sample can also be considered deliberate. The sample may not be representative in terms of the distributions of the variables under study, which may, for the assumed level of significance, not correspond to similar distributions in the population. At this stage of the study, it is also unknown whether the selected sample is representative due to the correspondence between its variables and identically defined variables in the entire set of DCs across regions.

The concept of MARB reliability is always associated with the performance of operational tasks [7,8]. The fulfillment of the task of the MARB implies the correct performance of certain functions by it under certain operating conditions and within the established time limits. If this function is denoted as ϕ, the operating conditions of the building as χ, and the operating time of the building as T, then the task that the object must perform can be written as an ordered triple $[\phi, \chi, T]$. Knowing the function that the building should perform, it is possible to establish such a set of requirements ($\omega\phi$) for the characteristics of MARB that their fulfillment is a necessary and sufficient condition for the correct performance of the functions assigned to it (ϕ). It was assumed, with some simplifications, that the estimated MARB from the point of view of the theory of operation is an object with two states. This means that it may be suitable for its function or unsuitable for its function. The task of the object, which is then understood as an event (Z), is written as the following ordered triple: $[\omega\phi, \chi, T]$. Further, it was assumed that the requirements for the MARB and the conditions of its operation are known, i.e. the pair $[\omega\phi, \chi]$ is fixed, and therefore it was assumed that the reliability of residential buildings can be estimated as a function of time (t).

Thus, the concept of reliability of MARB is defined as follows: the reliability of a residential building is its property, which is considered as its ability to meet the requirements ($\omega\phi$) within the established limits of suitability and unsuitability for operating conditions, certain specified service conditions (χ) and operating time (T).

The above considerations made it possible to determine the measure of reliability according to the general formula [7,9]:

$$R(t) = P\{\tau > t\} \tag{1}$$

where:

τ - time of failure-free operation of the element;

R (t) is a reliability function describing the probability of failure-free operation of an element during a period of time t, which can also be expressed as $\lim \{t \to \infty\} R(t) = 0$.

More precisely, the reliability function R(t) denotes the probability of correct operation of the object in the interval [0, t]. For the considered MARB with repairable elements, index (1) characterizes their reliability up to the first defect. The course of the reliability curve coincides with the change in the value of health due to the fact that they are also complex objects.
The R(t) function is also a transformed distribution function having the following form:

$$F(T)=P\{\tau>T\}=1-R(T) \quad (2)$$

F (T) determines the probability with which the correct operation of the MARB will be less than the expected service life (T). If we assume that such an event occurs at time t = 0, i.e. the object is suitable for use at the time of its commissioning, then it can be assumed that it will also perform this task at any time ti (with the interval $0 < Ti \leq T$, where i = 1,2). Then the overall reliability of a residential building is equal to the product of reliability:

$$R = R\ (T)\ R\ (0) = R\ (\omega\varphi, \chi, T)\ \Delta P\ \{Z\ (\omega\varphi, \chi, 0)\} \quad (3)$$

The symbol R (0) denotes the so-called initial reliability of the element, that is, the probability that it will be good at the time the task is started (T=0). Therefore, the definition of the concept of reliability was used and as a result the following was obtained:

$$R\ (0) = P\ \{Z\ (\omega\varphi, \chi, T)\} \quad (4)$$

and then:

$$R\ (T) = P\ \{Z\ (\omega\varphi, \chi, Ti)\},\ 0 < Ti < T\ /\ Z\ (\omega\varphi, \chi, 0) \quad (5)$$

Further, it was assumed that the event Z ($\omega\phi$, χ, 0) is undoubted, i.e., there is no doubt that if the MARB during operation performs all the specified functions, then it will fulfill all operational requirements. In this case, R (0) = 1, and expression (5) takes the following form:

$$R\ (T) = P\ \{Z\ (\omega\varphi, \chi, Ti)\},\ 0 < Ti \leq T \quad (6)$$

Ultimately, the overall reliability of the MARB can be expressed by the function R (T), which may have a different distribution in different periods of the facility's operation. Most often, the variable (T) can be considered as a random variable of continuous type, and then the density function is the derivative of the distribution function F (T):

$$f\ (T) = F'\ (T) = -\ R'(T) \quad (7)$$

It should be noted that the reliability function is a decreasing function. This means that, for example, R (Ti) <R (Ti−1), and in extreme cases for Ti=0 and Ti=∞, the reliability function takes the values R(0)=1 and R(∞)=0. This contradicts the distribution function F(T), also called the unreliability function, for which Ti: F(0)=0 and F(∞)=1 for the same values.
Based on the results obtained as a result of the inspections carried out, we will list the work carried out in capital repairs in the buildings, the percentage of reduction in the level of physical degradation in them after capital repairs and the amount of expenses spent on these capital repairs in percentages. For this purpose, the share value of the constructive parts of the buildings in the building was taken according to the "torn indicators of the restoration values of buildings and structures" [7].

THE RESULTS AND DISCUSSION.

This means that after capital repair work in 2-storey wooden building, the level of physical wear on the building can be reduced by 10.43-13.23%, the rate of residual absorption is 33.57-42.77%.

In 2-storey residential buildings, these indicators could decrease by 8.57-11.31%, while the survival rate was 29.03-38.29% by Regions. In 4-5-storey residential buildings, these indicators could decrease by 7.27-7.45%, while the survival rate was 26.44-30.74% in the regions. In residential buildings with 2-4 storey prefabricated reinforced concrete panels, these indicators could decrease by 8.77-10.6%, while the residual absorption rate was 26.44-42.4% by Regions. And finally, after capital repair work on 2-3-storey natural stone residential buildings, the level of physical wear on the building can be reduced by 9.38-9.75%, the level of residual absorption is 31.22-32.45% [20-21].

Apparently, as a result of the capital repairs carried out, the level of physical wear and tear is maintained around 7.27-13.26%. The depreciation rate, also called base wear, remains around 26.44-42.77%.

The technical condition of residential buildings with 2-storey timber construction, although their resource over time was exhausted, the coefficient of physical wear rate relative to the normative wear was 1.3-1.56. Such a coefficient indicates that the Houses of this type of construction are more likely to be exploited in practice than the normative service life. Absorption intensity λ_{av}=0.00517-0.00915;

In the technical situation of 2-storey residential buildings, this was observed. The coefficient of physical wear rate relative to normative wear by Regions was 0.85-1.02. This is evidenced by the fact that the premises of this type are out of work ahead of schedule. The intensity of absorption is λ_{av}=0.00803-0,01158, the maximum indicator belongs to KKR;

The coefficient of physical wear rate of 4-5-storey residential buildings in relation to the normative wear was 0.964-1.057. This is an indication that the wear in buildings of this type is uniform. will be damned. The intensity of absorption is λ_{av}=0.00803-0,01158, the maximum indicator belongs to KKR; In other respects, the examination was conducted only in the city of Chirchik. Absorption intensity λ_{av}=0,00760-0,00975;

The coefficient of physical wear rate of 2-4-storey prefabricated reinforced concrete panel residential buildings over 3 provinces was 0.951-0.803 compared to the normative wear rate. Burst intensity λ_{av}=0.00955-0,01225, the maximum indicator belongs to Tashkent region;

The coefficient of physical wear rate of 2-3-storey natural stone residential buildings in Navoi and Jizzakh regions in relation to normative wear was 0.978-1.229. These types of construction houses, like yohoch buildings, are more likely to be exploited in practice than the normative service periods. The intensity of absorption is λ_{av}=0,00597-0,01056, the maximum indicator belongs to the Jizzakh region;

From the results of the analysis, it is known that the intensity of absorption was observed in residential buildings with 2-storey brick and reinforced concrete panels (λ_{av}=0,01158-0,01225);

The intensity of the depreciation of houses in relation to the normative service life in average wooden houses λ_{av}=0,00716, in natural stone houses λ_{av}=0,00826, in 2-storey buildings λ_{av}=0,00980, in 4-5-storey houses λ_{av}=0,0086 and the largest indicator in houses with reinforced concrete panels λ_{av}= 0,0114;

CONCLUSION. The results of the conducted examination confirm that the actual service life of the building, its designations and materials does not always correspond to the normative service life established in the norms for them. During the period of the design of buildings for the proper use of housing stock in urban planning, it is necessary to take into account the specific details of the territory in the selection of construction materials used in the construction industry, their capital groups, their life expectancy indicators, their function in the network of the economy. As a result of the analysis of natural observation and inspection works carried out in different regions of the Republic, the following can be cited in terms of multi-apartment houses in the exploitation:

- When using natural materials as a floor covering in buildings and structures, the need of the designer to know the intensity of the absorption of materials in terms of the full use of the reserves of these materials in order to plan the capital repair work in them is considered a prerequisite;
- This information is evidence that capital repairs in multi-apartment residential buildings are not carried out at the required level.
- Complex in buildings the difficulty of carrying out capital repairs is that the structures that make up the premises, the elements, engineering equipment, the elements of external landscaping are very diverse, they are made up of different building materials, the service life of which is different. At the same time, the conduct of capital repairs in the building complex is therefore not economically feasible.
- Therefore, in the process of designing buildings, it is desirable to use the standard types of structures, elements, engineering equipment, elements of external improvement, which make up them for the service life. Only then there will be an opportunity to predict even the intensity of their depreciation. This is an important factor in the monitoring of housing stock.
- There is an opportunity to predict their actual service life according to these indicators;
- As a result of the observations, there is an accelerated depreciation of relatively new buildings, and over time, a decrease in the intensity, which in this way provides an opportunity to create a graph of physical wear from the climatic conditions of the Republic and the Capital Group of buildings;
- Once again, the factors known to us in the growth of the intensity of the general wear of the material, constructive parts and the building the quality of the exploitation, in addition to the quality of the project, preparation and construction have proved to be an autonomous factor.

REFERENCES

1. Merminod P. Study of wear and damage to old buildings; Chantiers Revue du Batiment du Genie civil et de la Securite: France, 1984
2. Zaleski J. Repair and modernization of residential buildings. Arkady: Warsaw, Poland, 1995.
3. Zimmermann, G. The destruction of structures - the destruction of buildings, damage, wear and aging; Deutsches Architektenblatt, Ausgabe Baden: Wuerttemberg, Germany, 1976
4. Novogonskaya, B. Forecast of the technical condition of the masonry walls of residential buildings. Bud. archit. 2014, 13, 27-32.

5. Macarulla M., Forcada N., Casals M., Gangolells M., Fuertes A., Roca X. Standardization of housing defects: classification, validation and benefits. J. Constr. English Manag. 2013, 139, 968-976.
6. Kim Y., Oi S., Cho Y., Seo J. PDA and a wireless web-based integrated system for quality assurance and defect elimination in apartment building designs. Machine. Features 2008, 17, 163-179.
7. van Breugel K., Koleva D., van Beek T. Aging of materials and structures; Springer International Publishing: Delft, The Netherlands, 2018
8. Sugier J., Anders G. Modeling and evaluation of the wear process during repair work. maint. Reliable. 2013, 15, 305-311.
9. Novogonskaya B. The intensity of damage in the process of aging buildings. Arch. civileng. 2020, 66, 19-31.
10. Cordeiro G., Ortega E., Lemonte A. Exponential Weibull lifetime distribution. J. Stat. Comput. Simul. 2014, 84, 2592-2606.
11. Conior J. Technical assessment of old buildings using a fuzzy method. Arch. civileng. 2019, 65, 129-142.
12. Martsinkovskaya E. Technical and functional requirements for assessing the wear of buildings. Arch. civileng. 2002, 48, 125–134.
13. Pihlayavaara S. Background and principles of long-term performance of building materials, durability of building materials and components; Sereda P., Litvan G., eds.; ASTM International: West Conshohocken, PA, USA, 1980; pp. 5-16.
14. Wolff R., Dike P. Maintenance and modernization; Beton: Germany, 1988.
15. Collection of aggregated indicators of the rising cost of residential buildings and structures. Book I. Apartment buildings in cities and urban settlements of the Republic of Uzbekistan. GKKINP-18-076-03, Tashkent 2003.
16. Records LLC “LOYIHA KONSALT SERVIS”. Technical conclusions on the result of a General survey of the technical condition of building structures. Dog No. 70-85 from 26.07.2019.
17. BCR 1.04.03-98-Regulations on the organization and conduct of reconstruction, repair and maintenance of residential buildings, public and socio-cultural facilities. Usedvehicle umitaka, Tashkent-1998. 53 p.
18. On the results of the correspondence on the technical cases of multi-apartment housing funds, on the shortcomings, problems and violations of the law identified in this process, as well as on the measures taken by the “Uyjoyfondinspection” on their elimination. Information on control over the use of multi-apartment housing fund under the Ministry of Housing and communal services of the Republic of Uzbekistan. Tashkent, April, 2019.
19. Khotamov A.T. Assessment of regional factors influencing residential quarters through the intensity of the aging of buildings. Journal "TEST" Engineering & Manajement (USA) included in the SCOPUS database. March-April 2020. ISSN: 0193-4120. Page No. 8756-8764.

20. Khotamov A.T. Statistical analysis of forecasting physical wear and tear of multi-family residential buildings/ Journals/Scienific Journals in Palaeontology and Egyptology/ Pal.Arch`s Journals of Archaeology of Egypt/ Egyptology – pjaee, 17(9) (2020) входящие в базу СКОПУС ISSN: 1567-214X/ Page No.10003-10013.

21.Khotamov A.T. New methodology for assessing damage to residential buildings and neighborhoods caused by natural disaster. International Conference «Scientific research of the sco countries: Synergy and integration». Infinity publishing. Haidian, Beijing, PRC. China-2020, Page No.174-180.