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Methodology remaining lifetime determination of the building structures

Yuriy Otrosh[1,*], *Andrii* Kovalov[2], *Oleg* Semkiv[1], *Irina* Rudeshko[2], and *Valentin* Diven[2]

[1]National University of Civil Defence of Ukraine, Chernishevska str., 94, 61023 Kharkov, Ukraine
[2]Cherkassy Institute of Fire Safety of National University of Civil Defence of Ukraine, Onoprienko str., 8, 18034 Cherkassy, Ukraine

Abstract. The paper proposes an approach to determining the increase of the normative lifetime of building structures on the basis of the algorithm of numerical calculation of the residual life of structures, which is performed on the basis of the results of defining parameters obtained during the technical examination and evaluation of defects, failures and structural damage. To calculate the structures, the simulation of the stress-strain state of the building structures with the involvement of OK LIRA was used. Simulation allowed performing optimization of technical solutions and strengthening of structures for buildings. The methodology is used to design elements for strengthening the structures of buildings and structures. Reliable estimation and forecasting of the technical condition enables to prevent the occurrence of accidents of structures and their associated losses, to use rational use of funds for current and capital repairs, and to regulate the technical condition in such a way as to achieve the most effective use of fixed assets.

1 Introduction

The growth of the risk for technogenic emergencies in Ukraine is due to the fact that in the recent years, in most important industries, design service life of the high-risk facilities and potentially dangerous objects have expired by 50-70%, sometimes reaching the pre-emergency level. If structural measures on protection against differential settlement of the foundation are not available (which is typical of buildings built in the postwar period), the cracks and other defects appear caused by differential deformations of the foundation [1-3].

The security means the absence of unacceptable risk associated with the possibility of causing any harm to people's life, health and property, as well as for the environment [4-5]. The unsatisfactory technical state of many construction facilities is a consequence of their dilapidation and needs a rapid assessment of the technical state of the structures in order to prevent the occurrence of emergencies [6].

Based on the above, an important task is to create an appropriate, available and simple, but effective approach for determining the increase in the normative useful life of building structures or their reassigned lifetime based on their remaining lifetime calculation, since in the country with a difficult economic situation, the task of extending the service life of

[*] Corresponding author: yuriyotrosh@gmail.com

building structures is possible up to two or three warranty operation lives or service lives, specified in the documentation. This is important and requires clarification of the known methods.

2 Unsolved issues

In Ukraine, an emphasis is given to the problem of determining the remaining lifetime of building structures, especially within the comprehensive program “Problems of Lifetime and Safe Operation of Structures, Constructions and Machines” of the National Academy of Sciences in Ukraine, which coordinates the works of both as the high-risk facilities, so the ordinary buildings and structures. The program was launched after the publication of the relevant resolution of the Cabinet of Ministers of Ukraine.

Within the framework of this program, approaches are known for determining the remaining lifetime and increase in the normative operation life of high-risk facilities, for example [7-9]. But this approach does not provide objective information on the use of such methods in the construction industry.

There are also many methods for determining the remaining lifetime of steel structures, one of which, for example, is described in a scientific article of the following authors [10]. This approach for determining the remaining lifetime of construction facilities includes an algorithm for numerical calculation of the remaining lifetime of construction facilities based on the results of the constitutive parameters obtained in the course of technical inspection and evaluation of defects, failures and damages of construction facilities. On the basis of this approach, the physical and mathematical models of facilities are constructed, the constitutive parameters of which have temporal development t, or on the basis of measurements of constitutive parameters in-situ in different time intervals. It is proposed to take into account the development in time of the identified defects and to take into account the defects and damages of steel structures, which were not identified during the technical inspection. The differentiation of threats is performed in the models, that make up a certain types of hazards (local risks), as well as the threats of a complex hazards according to the appropriate combinations and types of hazard (global risk). In these approaches for calculating the remaining lifetime, the occurrence and development of unfavourable events are used as assigned at different time moments, and the calculated and postulated dangerous processes having a development in time t. With this approach, the time scales of risks $R(t)$ are used. But such calculations algorithms are designed to be used for calculating steel structures, such as pipelines, and they do not meet the requirements of the analysis of the remaining lifetime of building structures operation. Thus, their use in the construction industry is not appropriate.

3 The purpose of the work

The work suggests an approach for determining an increase in the standard term of building structures operation based on the algorithm for numerical calculation of the remaining lifetime of construction facilities, which is performed on the basis of the results of constitutive parameters obtained in the course of technical inspection and evaluation of defects, failures and damages of building structures. The calculation is performed on the basis of constructed physical and mathematical models of facilities, the constitutive parameters of which have temporal development, or on the basis of measurements of constitutive parameters in-situ in different time intervals.

4 Main part

The methodology of the element lifetime reassignment should:

- assess adequately the changes in assessment parameters of the technical state in time (reaching by the dilapidation parameter of the value corresponding to the limiting one is considered as a reaching by the element of the limiting state);
- assess the probability of reaching the limiting state for the period of lifetime reassignment.

The methodology of lifetime reassignment should be substantiated with:

- the accuracy and reliability of the initial data and the results being obtained;
- the methodology of experimental data collection and processing;
- measurement accuracy of dilapidation parameter;
- reliability requirements to the value of the element lifetime;
- availability of an appropriate diagnostic and control system.

In accordance with the requirements of the valid normative documents, the element (construction) is considered in operating condition, and its technical state is normal or satisfactory, if it is not met:

– the failure condition of the structures (the reaching of the limiting states of the first group)

$$F \geq F_u, \tag{1}$$

– the condition when the structure reaches the limiting states of the second group

$$f \geq f_u, \qquad a_{crc} \geq a_{crc,u}. \tag{2}$$

The functions of the load-bearing capacity can be accepted in accordance with the applicable regulatory documents.

In as much as the changes in time happen in the junction nodes, concrete and reinforcement, the base metal, welded joints, the nodes of the elements connection due to the corrosion processes, the effects of radiation and elevated temperatures, and also mechanical stresses, some (or all) of the above inequality components are functions of time. Each of the inequalities (1) and (2) can be transformed to:

$$\Phi_u[x_1(t),x_2(t),..,x_m(t),y_1,y_2,..,y_n] < \Phi(t), \tag{3}$$

where $\Phi_u[x_1(t),x_2(t),..,x_m(t),y_1,y_2,..,y_n]$ is the function of load-bearing capacity (deformability) of elements (structures), which is determined according to recommendations valid normative documents, with account of changes in time of the input parameters;

$\Phi(t)$ is the acting maximum force (deformation) in the element (structure). The form of the functional dependence should be determined after algebraic transformations of inequalities of the form (1), (2) with integrating, if it is possible, of all time-dependent variables into the set of arguments.

Accordingly, in the inequality (3) the function arguments $\Phi(t)$ are divided into two groups. The arguments of the first group x_1, x_2 ,.., x_m depend on time and are called constitutive parameters. The arguments of the second group $y_1,y_2,..,y_n$ do not depend on time and are constants.

The assessment of the possibility of lifetime reassignment is carried out in accordance with the physical (deterministic) model developed on the basis of data on dilapidation parameters and reaching the limiting values by the elements, analysis of failures and damages of the studied elements, states and operating conditions that obtained in the course of inspection and evaluation of the technical state.

The model for assessing the possibility of lifetime reassignment should provide:

adequate assessment of changes in time of the technical state parameters;

possibility of reaching the limiting state.

When assessing the possibility of increase in the service life by the condition of the load-bearing capacity preserving, use the representation of inequalities in formula (3). The dependence of the constitutive parameters on time is recommended to accept linear form:

$$x_i(t)=x_i^0+s_i t \quad (i = 1, 2,..,m), \tag{4}$$

where x_i^0 - value of the constitutive parameter with the number i at the moment of examination; s_i - rate of the constitutive parameter change with the number i; t - time, calculated from the examination moment.

For the constitutive parameters, take up the rates of their change (linear or nonlinear) on the basis of an analysis of behaviour and operating conditions of the structures.

The rate of the constitutive parameter change should be determined on the basis of measurements of this parameter in-situ at two different moments of time t_1 and t_2. To obtain reliable results, the time base:

$$\Delta t=t_2 - t_1, \tag{5}$$

should be significant (measured in years).

The rate of the constitutive parameter change x_i should be calculated by the formula

$$s_i = \frac{x_i^2 - x_i^1}{\Delta t} \quad (i = 1, 2,..,m), \tag{6}$$

where x_i^1 - the value of the constitutive parameter x_i at the time moment $t = t_1$, x_i^2 - the value of the constitutive parameter x_i at the time moment $t = t_2$.

It is recommended to perform as many independent measurements of the same constitutive parameter as possible. In this case x_i^1 - is the arithmetic average of the measurement results of the parameter x_i at the time moment $t = t_1$, x_i^2 - is the arithmetic average of the measurement results of the parameter x_i at the time moment $t = t_2$.

If it is impossible to make the measurements, the rate of the constitutive parameter change can be determined on the basis of theoretical or laboratory studies.

The assessment of the possibility to increase the service life according to the load-bearing capacity should be made in the following sequence:

- estimate the load-bearing capacity of the element (structure) according to the designing data F_{pr};

- based on the inspection, determine the parameters of the load-bearing capacity function $\Phi_u[x_1(t),x_2(t),..,x_m(t),y_1,y_2,..,y_n]$ for a particular element (structure) and determine the loadbearing capacity of the structure $F_{cr}=\Phi_u[x_1(t),x_2(t),..,x_m(t),y_1,y_2,..,y_n]$;

- from the calculation results, estimate maximum forces F in the element (structure). Compare

$$F_{cr} \geq F, \tag{7}$$

if the inequality is met, the service life has not run off;

- the lifetime reassignment t_R should be determined using the supposition with respect to a linear dependence of the controlled parameters change in time

$$t_R = \Delta t \frac{F_{cr} - F}{F_{pr} - F_{cr}}, \tag{8}$$

If a failure is possible for two or more elements of a statically indeterminate system, the calculation of the system should be made with account of the redistribution of forces after the elimination of the ruined elements from the computational scheme.

For reinforced concrete structures, along with the strength, deformability and crack resistance calculations, it is allowed to use the methods of mechanics of concrete deterioration, which consider the structural concrete changes in time [3, 11].

The need for inspection of the building structure of Imeni Gagarina Cinema at 5 Shchusev St. in the Shevchenkivsky district in Kiev, arose as a result of the termination of the building use for its intended purpose without the development and implementation in-situ of measures for conservation of the building. The most probable cause of damage in the walls is considered the unsatisfactory performance of drainage from the roof of the building, the termination of the building operation without the development and implementation of conservation measures, the unsatisfactory state of the blind area, and the lack of drainage of precipitation from the site.

To determine the minimum required reinforcement of structures, it is necessary to determine the stress-strain state of the building as a whole (forces that arise in the building structures, as well as the structures movement). To achieve this purpose, a finite element model of the building in one-dimensional problem setting has been developed (fig.1). The calculations of the building were made with account of yielding of a foundation and the stiffness coefficient of the monolithic foundation plate and the frame structures. The purpose of the complex calculation was to obtain the stress-strain state of the building and foundation structures, as an integrally working system.

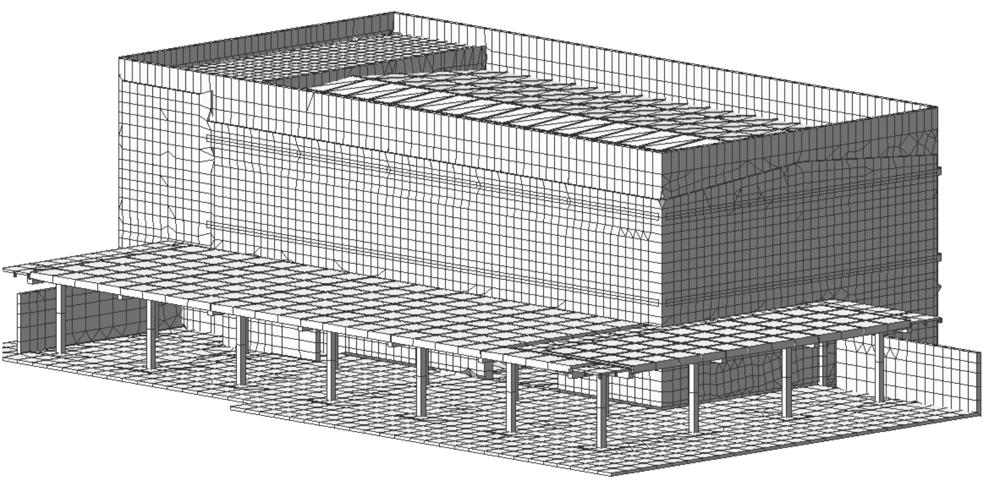

Fig. 1. Finite element model of the superstructure of the building.

Based on the results of the performed calculations of the system, the greatest deformation of the foundation soils is 22.19 mm under the walls of the hall part of the building. According to the recommended normative document, for multistoried frameless buildings with load-bearing walls of brickwork with the armor-clad belts, the average yieldings of the building foundation should not exceed 18 cm, that is, the calculated yieldings of the building do not exceed the limiting values.

Based on the results of the performed calculations of the system, it was established that the main stress N_1 and N_3 have the highest values (both compression and tension) in the wall of the first floor in the local zones of the areas of window apertures and door apertures location. The greatest value of the main stresses N_1 and N_3 is 4.03 MPa (compression) and 2.51 MPa (tension). In other parts of the walls of the first, second and third floors, the main stresses have significantly lower values of compression against the strength of the brick and mortar solution.

In the development of thereconstruction project, it is necessary to make such decisions which will contribute to a uniform loadingon the foundation structures.When working on the serviceability restoration of the building structure of Imeni Gagarina Cinema, it is necessary to perform the reinforcement of structures that have significant dilapidation (floor slab, partition walls, external staircases on steel stringboards, etc.), as well as the wall insulation and roof coating replacement. You need to install the windows and doors assembly, to perform the replacement of the floor and interior decoration in the premises.

5 Conclusions

A methodology has been developed for diagnosis of the technical state and determination of the remaining lifetime of the building structures, which is used when designing reinforcement elements of buildings and structures. For the calculation of structures, the modelling of the stress-strain state of the building structures with the use of LIRA software has been used. This allowed by way of calculation to perform optimization of technical solutions and to ruggedize structures of the houses, which are in operation, and to perform the further strengthening with minimal costs. An approach for determining the remaining lifetime of structures depending on operating conditions has been developed. The reliable assessment and forecasting of the technical state makes it possible to prevent the occurrence of structural failures and related losses, to use rationally the funds for performing current and capital repairs, as well as to regulate the technical state in such a way as to achieve the maximum efficiency in the use of basic funds. Since the service life of most residential, public and industrial buildings exceeded the duration of effective operation prior to capital repair, the methodology has been developed for remaining lifetime assessment of such buildings on the basis of modern concepts of the building materials and structures performance under loading with the aim of deciding on possible further operation or setting the buildings for major repairs (reconstruction) under the combined action of force, deformation and high-temperature effects.

References

1. M.I. Vasiliev, I.O. Movchan, O.M. Koval, Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, **5**, 106-113 (2014)
2. Y. Abramov, V. Borisenko, V. Krivtsova, Eastern European Journal of Enterprise Technologies, **5**, 16-21 (2017)
3. O. Nekora, V. Slovynsky, S. Pozdieiev, MATEC Web of Conferences, **116**, 02024 (2017)
4. S. Vambol, V. Vambol, O. Kondratenko, Y. Suchikova, O. Hurenko, Eastern European Journal of Enterprise Technologies, **3**, 63-73 (2017)
5. S. Vambol, V. Vambol, Y. Suchikova, N. Deyneko, EasternEuropean Journal of Enterprise Technologies, **1**, 27-36 (2017)
6. V.V. Tiutiunyk, H.V. Ivanets, I.A. Tolkunov, E.I. Stetsyuk, Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, **1**, 99-105 (2018)
7. Patent Ukrainy na KM # 18066, MPK G01N 3/00 *Protses vyznachennia zalyshkovoho*

resursu naftohazoprovodiv ta zbilshennia normatyvnoho terminu yikh ekspluatatsii

8. Patent Ukrainy na KM # 9473, MPK G01 N3/00, G01 M3/22 *Protses vyznachennia zalyshkovoho resursu obiekta pidvyshchenoi nebezpeky ta zbilshennia normatyvnoho terminu yoho ekspluatatsii*
9. V. Andronov, B. Pospelov, E. Rybka, Eastern European Journal of Enterprise Technologies, **4**, 38-44 (2016)
10. S. V. Kolesnichenko, Yu. V. Seliutin, I. Yu. Chernykh, K. B. Mnatsakanian, Scientific Journal «ScienceRise», **11**, 37-42 (2017)
11. S. Pozdieiev, O. Nuianzin, S. Sidnei, S. Shchipets, MATEC Web of Conferences, **116**, 02027 (2017)