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Building Residual Life Calculation at Hazardous Production Facilities

Mikhail Borisovich Permjakov

Director of Institute of Construction, Architecture and Art, Nosov Magnitogorsk State Technical University, Head of the Building Manufacture and Highways, associate professor, candidate of Technical Sciences

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ABSTRACT

This work proposes the author's method of building residual life calculation with metal frames. A flowchart on resource assessment and the calculation of emergency collapse risks was developed. The technique allows to set a term of building residual resource prior to overhaul or decommissioning.

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INTRODUCTION

The construction industry, like any other industry, is characterized by the presence of emergencies. Statistics show that approximately 80% of construction accidents with the destruction of an object bearing structures is the result of human errors during design, construction and operation of buildings. These errors form the inner (object) risk of an accident, the level of which influences not only an object service life (resource), but also the extent of damage in the event of an accident.

The task of building structure residual life assessment, including the cases of specific loads impact (e.g., seismic ones), is currently one of the urgent tasks to ensure the safe operation of buildings and structures, requiring the permission to implement the prediction of this resource value during a period until the use value exhaustion by building (construction).

Methods:

By this paper we propose an author methodology (developed by Permjakov M.B.), which contains the fundamental provisions of the methodology for residual resource determination, establishes the requirements to determine the projected life of buildings. The methodology is intended for diagnostic purposes and object technical state determination for the objects the projected life of which is exhausted, set by a project, regulatory documents and also after disasters and repairs.

As a basic concept for the calculation of building residual life, an approach is proposed based on "safe operation by technical condition" principle. According to this approach, the evaluation of an object technical state is carried out by technical condition parameters ensuring its safe and reliable operation in accordance with the technical and (or) design (project) documentation, and is residual life in accordance with the main parameters of technical condition. The parameters the change of which (separately or in a certain set) may lead to inoperable or extreme condition are accepted as technical condition parameters.

Main part:

There are the following technical condition parameters depending on extreme state criteria and an object operation conditions:

- characteristics of materials (mechanical characteristics: yield stress, stress limit, hardness, fracture toughness, endurance, long-term strength, creep limits, chemical composition, microstructure characteristics, etc.);
- safety factor (by yield strength, durability, long-term strength, creep, fracture toughness, stability, by the number of cycles or stresses at cyclic strength calculations);
- technological parameters (temperature, vibration parameters, operation modes, etc.).

Corresponding Author: Mikhail Borisovich Permjakov, Director of Institute of Construction, Architecture and Art, Nosov Magnitogorsk State Technical University, Head of the Building Manufacture and Highways, associate professor, candidate of Technical Sciences.

The estimation of technical condition parameters and the criteria selection is performed according to technical documentation analysis results, operational (functional) diagnostics data, expert examination.

The prediction of residual life or the establishment of an assigned resource is carried out in accordance with the change principles of core parameters obtained at the analysis of damage development mechanisms and (or) the functional parameters measurement results.

One of the solutions is accepted on the basis of obtained estimates:

- continuation of operation on the basis of established parameters;
- continuation of operation with parameter limitation;
- repair;
- improvement (reconstruction);
- use for different purpose;
- decommissioning.

It should be noted that there is no single approach to calculate and estimate the residual life of buildings and constructions.

We offer the author's scheme of building residual life determination, which demonstrates all the basic steps to determine the residual life of potentially dangerous objects (Fig. 1.).

СТРУКТУРНАЯ СХЕМА ОПРЕДЕЛЕНИЯ ОСТАТОЧНОГО РЕСУРСА ЗДАНИЙ / DIAGRAM OF BUILDING RESIDUAL LIFE DETERMINATION

Объект, здание – Object, building

Анализ технической документации: - Technical documentation analysis:

- проектной; - project;
- монтажной; - mounting;
- эксплуатационной; - operational;
- ремонтной – repair

Анализ условий эксплуатации: - Operation condition analysis:

- технологические режимы; - technological modes;
- режимы нагружения; - modes of loading;
- температурные воздействия; - temperature effects;
- эксплуатационная среда - operational environment

Оперативная диагностика – prompt diagnostics

Определение уровня надежности и риска аварии: - Reliability level and accident risk determination:

Продление эксплуатации на установленных параметрах - Operation extension within established parameters

Прибрежимый (ничтожно малый) - Negligible

Приемлемый – Acceptable

Предельно допустимый - Maximum allowable

Чрезмерный - Excessive

Вывод из эксплуатации - Shutdown

Экспертное обследование здания: - Expert examination of building:

- визуальный осмотр; - visual inspection;
- измерительный контроль; - Measuring control;
- механические испытания свойств материалов; - Mechanical testing of material properties;
- дефектоскопия – defectoscopy;

Продление эксплуатации – operation prolongation;

Экспертная оценка остаточного ресурса - Expert evaluation of residual life

РАСЧЁТ ОСТАТОЧНОГО РЕСУРСА - Residual life estimate

Выбор критериев и предельных состояний: - Criteria and extreme states selection:

- статическая прочность с учетом дефектов; - Static strength with defects consideration;
- коррозия; - corrosion;
- усталость; - Fatigue;
- температурные воздействия - Temperature effects

Экспериментальные исследования: - Experimental studies:

- тензометрия; - Strain measurement;
- акустическая эмиссия – acoustic emission

Расчёты по предельным состояниям – Extreme conditions calculation

Оценка ресурса: - Resource estimation:

- отдельных конструктивных элементов здания; - of separate structural elements of a building;
- частей здания; - building parts;
- здания в целом – building in general;

Принятие решения: - Solution acceptance:

- Продление эксплуатации по установленным параметрам – Operation prolongation according to set parameters
- Продление эксплуатации с ограничением параметров - Operation prolongation with parameters limitation
- Ремонт - Repair
- Реконструкция - Reconstruction
- Использование по иному назначению – Use for other purposes
- Вывод из эксплуатации – Decommissioning

Fig. 1: Diagram of building residual life determination.

Technical documentation analysis shall include:

- regulatory and technical, engineering (design) and operational, including installation and repair documentation;
- technical documentation and scientific and technical information on the failure and damage of facilities and similar equipment.

The following things are inspected at technical documentation analysis:

- Building and (or) construction passport;
- The set of civil drawings showing all changes made during the works, and marks on these changes agreement with the project organization which developed the project;
- Acts of building (structure) acceptance for operation, indicating defects, acts of defects elimination;
- Acts of acceptance tests conducted during the operation;
- Technical journal of building (structure) operation;
- Hidden works acts and the acts of provisional acceptance for separate critical structures;
- Work performance and author's supervision logs;
- Geodetic survey materials;
- Work quality control logs;
- Certificates, technical certificates certifying the quality of constructions and materials;
- Acts of anticorrosive and paint works;
- Acts of structure periodic inspection results;
- Acts of accidents and technological processes violations affecting the operating conditions of a building (structure);
- Reports, documents and opinions of specialized organizations concerning the performed surveys;
- The determined standard operation terms;
- The documents on current and capital repairs, structure strengthening;
- Documents describing the actual technological loads and impacts and the influence of their changes during operation;
- Documents describing the actual parameters of shop environment (composition and concentration of gases, humidity, temperature, heat and dust release, etc.);
- Technological rules and other documentation;
- Reports on engineering-geological conditions of a building (construction) location area;
- Declaration of industrial safety for hazardous production facilities (in the cases provided by the Russian Federation legislation).

The following aspects are considered during operation terms analysis:

technological modes;

- loading modes;
- temperature effects;
- operating environment;
- the factors affecting safe operation (accident risk factors).

Accident risk factors include:

- close location of other hazardous production facilities;
- closely located underground utilities, gas mains and power lines;
- closely located railway stations (railways), roads, airfields;
- territorial engineering-geological and climatic factors.

On-line diagnostics is aimed on data acquisition concerning the technical condition of an inspected object.

The following procedures are performed during on-line diagnostics:

- ranking of building elements within the group of structures;
- structure survey conduct with the assessment of structure states.

The main groups of structural elements for a metal building frame of single-storey industrial buildings are:

- Columns (constant or variable by section height (step ones), separate ones in the form of two loosely linked columns);

- Supporting elements of cover (frames and secondary trusses, light frames, beams);
- Constructions under crane (beams (trusses) under crane, brake beams or trusses)
- Connections (connections between columns, cover connections).

The diagnostics result is the defective statement specifying the structure technical state.

The purpose of an expert survey is the obtaining of information concerning the actual technical state of an object, the presence of object damages, the revealing of causes and mechanisms of their formation and development.

Expert examination of the building includes:

1. Construction survey:

- 1.1 Determination of structures and joints cross section actual size of structures, their spatial position;
- 1.2 verification of structure compliance with design documentation, the actual geometrical stability, identification of deviations, defects and damage of components and structure assemblies with the statements of defects and damages drawing up;
- 1.3 specification of actual and projected loads and impacts;
- 1.4 establishing the physical and mechanical properties of structural materials;
- 1.5 foundation, building frame deformation and the bearing capacity of soil when foundation sediments are revealed.

2. The following works shall be performed during test calculation:

- Choose a construction design scheme taking into account the deviations defects, and damages, the actual loads and structural properties of materials identified during survey;
- Check the load-bearing capacity of elements, assemblies and joints. Identify the ones which do not satisfy the conditions of strength, stiffness and stability.

The technical condition of structures and expert evaluation of residual life is performed according to expert survey results.

An expert assessment is based on:

- the analysis of technical and operational documentation;
- operating conditions analysis;
- obtained data results concerning visual measuring control, instrumentation control, non-destructive testing, the determination of structure spatial position;
- verification calculation results.

The structure technical state is divided into five levels: serviceable; operational; limited use; prohibited or abnormal.

The decision to extend the operation of a building with the determination of its residual life, or the need to calculate residual life is based on obtained results and operation experience analysis. The residual life of an object must be set on the basis of aggregate information by the prediction of its technical condition according to main parameters till the attainment of an ultimate state.

The following conditions (simultaneous) shall be provided during the residual life prediction:

- the parameters of a building technical condition are known;
- the determining parameters of technical condition, varying according to identified mechanism of object elements damage are known;
- the criteria of an object extreme states are set the attainment of which is possible at the identified damage development.

The criteria for the metal frame building residual life calculation are:

- wear and tear;
- static strength taking into account defects and temperature effects;
- corrosion;
- fatigue.

Results:

The residual life calculation may be performed by one or several criteria. In general the choice of calculation method for residual life on a particular criterion should be justified by the accuracy and reliability of the obtained data, as well as the requirements of accuracy and reliability of projected object resource and the risk of its further operation. Experimental research of designs, namely strain measurement and (or) acoustic emission may be performed if necessary for the more accurate calculation of residual life.

The residual life calculations by extreme state criteria are performed according to the following methods:

- depending on physical wear and tear;
- according to building corrosive wear;
- by static strength;
- by cyclic performance (fatigue).

Conclusions:

According to the results of residual life calculation the assessment of building structural elements of the building or the building as a whole is performed. When the residual life is calculated on several criteria the resource is assigned by the minimum value. On the basis of an object technical condition evaluation and the residual life evaluation a reasoned decision is taken concerning the possibility of an object further operation in accordance with the residual or assigned life or its repair, operating parameters reduction, a different purpose use or decommissioning.

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