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Issue of the use of construction objects in the point of view of the safety engineering

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Abstract

During periodic inspections, the technical condition and assessment of the suitability of the building object for further safe use are checked by: identification of symptoms of technical wear of the facility and estimation of the impact of this consumption on the functional properties and technical efficiency of the building. The paper proposes an assessment of the technical condition of buildings based on a four-valued logic.

Keywords: safety engineering, four-valued logic

1 Introduction

The subject of interest of this study are building objects that are designed, built and operated to meet various human needs. They most frequently fill the environment in which man functions and according to the works [2–5, 10] determine in the long term their existence the conditions of human life safety.

Construction objects in the operation process lose their properties of functional features as a result of the impact of various internal and external factors. In most cases, these impacts are unfavorable and, over time, lead to a loss of performance of the building. Therefore, the owner (manager) of a building object in the process of its operation should take measures to minimize the effects of these impacts subjecting the building object to the renovation process.

One of the initial stages of the process of renewal of exploited building objects are periodic inspections constituting the first stage of technical diagnostics of the states of an operated building object. This stage defines activities related to the identification of technical conditions in the facility in use for the occurring set of events or operational situations.

During periodic inspections, the technical condition is checked and the building object is evaluated for further safe by:

- identifying the symptoms of the technical wear of the facility;
- estimation of the impact of this consumption on the performance and technical efficiency of the building.

The paper proposes a method of assessing the technical condition of buildings, based on four-valued logic used in the assessment of the state of technical objects [1, 6, 8, 9, 11–21, 23–30].

2 The issue of changing the state of a building object

Knowledge about the nature of the change in the state of the building (in the period of its expected existence) regarding the physicochemical and technical aspects of the aging processes and the consumption of materials and construction of building objects is necessary in solving most of the problems of their design, construction, manufacture and operation. It allows for rational behavior in the abovementioned scope, including the selection of appropriate manufacturing technology and optimization of the operational properties of complex structures of various building structures.

The aging and wear processes are inherent in the existence of buildings, destructively affecting their technical condition and inevitably leading to their degradation manifested in the emergence and development of observable

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types of damage that may interrupt the proper functioning of the structure and even loss of physical form of the object. In a technical sense, the degradation of a building object is associated with the physicochemical changes of this object as a result of its use, and is the result of a process of deterioration of the strength and performance of individual elements of the object, and thus the entire building object. It occurs both as a result of their intensive exploitation and aggressive environmental impact - which are two basic factors conducive to premature wear of a building. In the common understanding, the degradation of a building object is equated with:

- **the concept of aging of a building** -inextricably linked to a significant lapse of service life,
- **the impact of all exogenous factors** creating the building environment.

In fact, building structure degradation is a more complex process, because it depends not only on operational impacts but also on the accumulation of effects of various processes such as fatigue wear, cracking, abrasive, deformation and creep. Each of these processes is inseparably connected with the design, implementation and operation of a building, in particular with the change in external load carried by the building in the process of its operation.

3 The problem of assessing the technical condition of a building

3.1 Used assessment methods

As it results from works [2–5, 10], there are no unified rules for formulating assessments of the technical condition of structures and construction elements of buildings, they are adopted differently and are characterized by a different level of generalization, which raises a number of problems related to the use of the effects of technical diagnostics of these objects. The assessment of the technical condition, structure or structural elements is the result of qualifying the examined structure or its element to an adequate group with parameters and properties to the standards describing a given state (group).

In the process of diagnosing the technical condition of building objects, it is known that the greater the number of distinguished object states, the more information obtained about the object will be more reliable. The problem of conducting multi-valued classification of technical conditions of objects, and thus of multi-valued diagnostics, although currently feasible, requires deep technical and economic analyzes. The expediency of using multi-valued diagnostics of technical objects of different classes requires separate technical and economic justifications.

Currently, the most commonly used description of these states, according to logic: two-, three- and four- valued logic:

1) Two - valued logic

According to the works [7, 22], the description of these states is most often used according to two-valued logic, assuming that building objects in the process of use may be in one of two (mutually exclusive) technical states:

- Fit status (1), when the object performs the purpose function as intended;
- Failure status (0), when the object does not perform the objective function.

The bivalent classification of building objects means that only part of the diagnostic information obtainable in the diagnostic process is used. This type of diagnostic classification is appropriate for technical and technological processes as well as for repairable and non-repairable technical facilities. The purpose of this kind of diagnosis is to recognize the state of failure (failure) and locate the element generating such state. When organizing maintenance activities, it is important to recognize in the facility the conditions that immediately precede the occurrence of the state of unfitness, which is the condition of incomplete suitability. Therefore, the application of bivalent logic for the needs of organization of the service process is insufficient.

2) Three-valued logic

To increase the amount of diagnostic information obtained during the diagnosis of a building object, diagnostics began using trivalent logic developed in [22]. Three-valued classification of technical conditions of an object automatically imposes the use of three-valued logic (0,1,2) assuming that building objects in the process of use may be in one of three (mutually exclusive) technical states:

- Fit status (2) for use, when the building performs the purpose function in accordance with its intended purpose;

- Incomplete fit status (1) for use, when the facility performs with a limited purpose the purpose function as intended;
- Failure status (0) for use, when the object is unable to perform the purpose function as intended.

The introduction of an additional state allows to increase the diagnostic information obtainable, which in the context of operational maintenance services supports this process and additionally also increases the value of the average time of failure-free operation of the facility. The diagnoses developed in this way are mainly used in the process of locating damage to a technical object.

Although the problem of diagnosing in trivalent logic is currently intensively developed, the developed issues and rules of diagnostic inference do not fully solve the problems of modern technical objects. Their high complexity and responsibility of tasks requires providing the user with fast and reliable information about the technical condition of these facilities. One way to counteract the above problems is to introduce multi-valued diagnostics with more conditions.

Four-valued logic

In order to clarify the process of diagnosing the technical condition of technical objects, in [7] a description of the state of these objects in the so-called tetravalent logic (0,1,2,3), which, like trivalent logic, is a special case of n-value logic. It is characterized by the fact that its functions and arguments can take one of four values determined by the symbols 0,1,2,3. Similar to two-and three-valued logic, the area of specificity of any four-valued function is limited. In four-valued logic, it stands out:

- Fit status (3), defines the state of the object in which it performs tasks as intended, assuming that the values of the characteristics of the input signals are within the allowable change ranges X_j. In this state of the object, the values of the characteristics of the Y_i signal are in the range called the insignificant change range;
- Incomplete fit status (2), defines the condition of an object with the ability to perform an incomplete task, assuming that the input signals are in the range of changes in the permissible values of the X_j signal features. In this state, a change in the value of at least one feature of the Y_i signal must fall within the range called the significant change range;
- Critical fit status (1) defines the condition of the object characterized by the ability to perform some but not all of its functions, assuming that the input signals are within the range of changes in the permissible values of the X_j signal features. In this state, a change in the value of at least one feature of the Y_i signal must fall within the range called the critical change range;
- Failure status (0) defines the state of the object having complete inability to perform its tasks, assuming that the input signals are in the range of changes in the permissible values of the X_j signal features. In this state, a change in the value of at least one feature of the Y_i signal must fall within the range called the range of unacceptable changes.

Based on the scheme of classification of object states in the four-valued logic presented in Fig. 1, the following assumptions were made:

- the object's transition from the "3" state to the "2" state, from the "2" state to the "1" state and from the "1" state to the "0" state occur with the same probability;
- the simultaneous occurrence of the states of unfitness and critical condition or the state of incomplete condition and critical condition of the elements of basic technical objects is below 0,1;
- the object can be at a given time t only in one of four states: "3", "2", "1" or "0";
- the states of suitability, incomplete suitability and critical suitability belong to the range of permissible changes which allows to comply with two- and three-valued logic.

The introduction, in four-valued logic, of an additional state characterizing the technical object, in addition to increasing the available diagnostic information, also increases the range of significant changes. Identification of one of the partial or critical fitness conditions belonging to this range should result in the decision to carry out preventive technical renewal. This action is aimed at bringing the exploited technical object back to the condition of being fit, i.e. to the range of insignificant changes.

The four-state model with an additional critical condition determines the condition of an object capable of fulfilling some, but not all, of its functions, assuming that the input signals are within acceptable change ranges. The

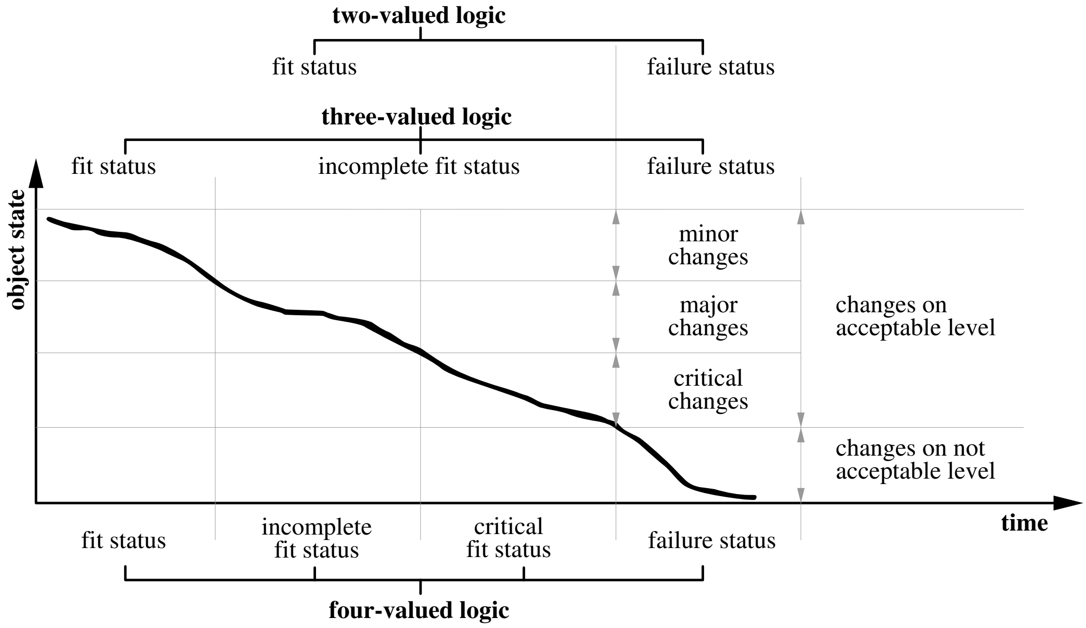

Figure 1. Scheme of classification of building structure states in four-valued logic, in relation to classification in two- and three-valued logic - according to [7]

introduction of an additional state characterizing the technical object, in addition to increasing the available diagnostic information, also increases the range of significant changes. Identification of one of the partial or critical fitness conditions belonging to this range should result in the decision to carry out preventive technical renewal. This action is aimed at bringing the exploited technical object back to the condition of being fit, i.e. to the range of insignificant changes.

3.2 A proposal to use four-valued logic to diagnose the technical condition of buildings

Using four-valued logic to diagnose the technical condition of buildings, I present a proposal for general descriptions of the above. states (which should be determined according to the specifics of the functional and material-structural solution of a given building object): 1) The state of fitness of a building (3) is a state in which the building has full capacity to perform its tasks in accordance with its intended use, i.e. it has the technical and functional properties required for a given building. In this condition, the technical parameters and operational parameters of the object characterizing the properties related to the basic requirements and operational properties resulting from the purpose of the object are within the range of permissible values even in the event of changes in the building resulting from damage to elements (structural, non-structural and installation), such as however, they do not endanger the safety of use. Therefore, a building subject to airworthiness is an object that has the required (for a given purpose) technical and functional properties. It maintains these properties even in the event of changes occurring as a result of non-significant damage to the abovementioned elements of the building and is useful for specified safe use. 2) The incomplete condition of a building (2) is a state in which the building has limited ability to perform its tasks, i.e. it has deteriorated, compared to those required for a given building, technical and functional properties resulting from damage to (structural, non-structural and installation) that may hinder or prevent safe use of the facility.

In such a state, at least the value of one of the parameters (technical or functional) of the object characterizing the properties related to the basic requirements and functional properties resulting from the purpose of the object exceeds the range of permissible values and falls within the range called the range of significant changes. When reducing the value of technical and functional features of a building object to minimum (boundary) values, it is necessary to undertake renovation works involving the restoration of the original values of these features to these objects. In this case, use is necessary to ensure safe use appropriate countermeasures, including but not limited to:

- introducing restrictions on the use of the building, consisting of on reducing the intensity of use, changing the way of use that reduces the amount of loads transferred to the structure, etc., and
- undertaking preventive actions aimed at the renovation of the facility consisting in restoring the original technical

parameters and utility parameters of the object. (in accordance with the PN-ISO 15686-1:2005 standard. Buildings and structures. Service life planning. Part 1: General principles - "renovation is to restore the building or part of it to an acceptable condition by renewing, replacing or repairing worn elements, or which degraded"). 3) The condition of critical fitness of a building (1) is the state in which the building is in a state of ultimate load-bearing or serviceability threat, in which certain parameters (technical or functional) have reached values deemed unacceptable for technical, functional and (or) economic reasons . It is such a state in which the object does not have the ability to perform the full range of tasks assigned to it, i.e. it has unacceptable, compared to those required for a given building, technical and functional properties resulting from damage to elements (structural, non-structural and installation) that limit safe use of the facility. The threat of the ultimate limit states and the usability limit states may refer to individual elements or the whole structure of a building object may be manifested by the occurrence of a state of danger of a construction failure (or a state of construction failure) or a state of danger of a construction disaster. External symptoms of the construction structure reaching limit states are the occurrence of damage constituting external symptoms of the state of emergency of building structures, such as: deformations, deformations, scratches and cracks in the structure and elements of the structure adjacent to the structure. The term limit state here means such a situation in the structure that even a slight increase in loads disqualifies it from the point of view of the requirements. After exceeding the limit state, the object cannot be used due to the lack of physical possibilities of functioning or as a result of the decision on decommissioning.

A building in critical condition requires:

1) maximum limitation of its use or cessation of use in order to reduce the amount of loads transferred to the structure and

2) to take measures to secure the building, which, according to section 2 of chapter 9, include, depending on the needs:

- provisional (temporary) support of inclined vertical structure elements (walls, posts);
- provisional (temporary) reinforcements of other elements of the structure;
- dismantling fragments of the object that threaten security or dismantling the whole building facility;
- fencing of the object preventing access to the danger zone;
- land drainage changes.

4) The state of unfitness of a building object (0) is a state in which the object has complete inability to perform its tasks in accordance with its intended purpose. It is a state in which a building object has exceeded the ultimate bearing capacity limit or a serviceability limit state in which certain parameters (technical or functional) have reached values deemed unacceptable for technical, functional and / or economic reasons. This is a condition resulting from the destruction of components (structural, non-structural and installation) that prevent the safe use of the object. In this condition, the object may at any time go into a state of construction disaster due to the destruction of individual elements or the whole building object. The issue of limit states of a building structure discussed in point 10.1.1 of Chapter 3 based on the PN-EN 1900: 2004P standard.

4 Technical conditions of the building

As it results from Fig. 2, a construction object subjected to various influences due to reasons P (t) during its operation may be in one of the following four states:

1) The state of fitness to which they belong:

- S_{b1}-the object is undamaged in a condition suitable for safe use;
- S_{ub1}-object in a state of damage that does not threaten security.

2) The incomplete condition to which they belong:

- S_{ub2}– object in a state of damage that does not threaten security and is suitable for safe use;
- S_{uz1}– object in a state of damage that threatens security.

3) The critical fitness state to which it belongs:

- S_{uz2}– an object in the ultimate limit state that threatens safety and cannot be used as intended;
- S_{uz3}– an object in a serviceability limit state that endangers safety and cannot be used in accordance with its intended purpose;

4) The condition of disability to which it belongs:

- S_{z1}– the object in the state of exceeding the ultimate or serviceability limit states is unusable
- S_{z2}– object in a state of destruction unusable;
- S_{z3}– object in a state of construction disaster unusable.

A building damage event can be considered a construction disaster if it meets the definition of a construction disaster in Art. 73 of the Construction Law. The GUNB data shows that in the years 1995-2017 (23 years) there were 7669 construction disasters in the country (on average 333 disasters / year).

Possibilities of changing the condition of the building given for damages u (t) and damages due to (t) caused by technical reasons P(t), internal and external origin are illustrated in Fig. 2.

From the above the drawing shows that: 1) An object in S_b state for safe use after a period of time may be in undamaged condition suitable for safe use and requiring only maintenance, maintaining its technical and operational features at the required level or passage:

- into a state of damage S_{ub} , which does not threaten security,
- into a state of damage S_{uz} , that threatens security;
- directly into a state of destruction S_z without going through the above-mentioned states damage

2) An object in damaged condition S_{ub}, who does not threaten security can change:

- into a state of damage S_{ub1} ,fit for safe use and security,
- into a state of damage S_{ub2} ,incomplete fitness for safe use,
- into a state of damage S_{uz},that threatens security,
- directly into a state of destruction S_z,

3) An object in damaged condition S_{uz}, that threatens security can change:

- into a state of damage S_{uz1} ,with limited fitness for safe use,
- into a condition of critical fitness for safe use S_{uz2} ,in relation to reaching the ultimate limit state,
- into a condition of critical fitness for safe use S_{uz3},in relation to reaching the serviceability limit state,
- directly into a state of destruction S_z,

4) An object in a state of destruction S_z, that threatens security may go into a state of inability to use safely:

- state S_{z1} ,expressed by exceeding the ultimate or serviceability limit states,
- state S_{z2} ,expressed in the destruction of the object or part of it, and
- state S_{z3}, expressed disaster of the object or part of it.

5 Conclusions

1) There are no unified rules for formulating assessments of the technical condition of structures and construction elements of exploited building objects, they are adopted differently and are characterized by a different level of generalization, which causes specific problems with the use of the results of inspections of these buildings.

2) In the technical diagnostics of a building, the following should be considered very important:

- actions aiming at reliable determination of the technical condition of a given object and possibilities of its further safe use and,

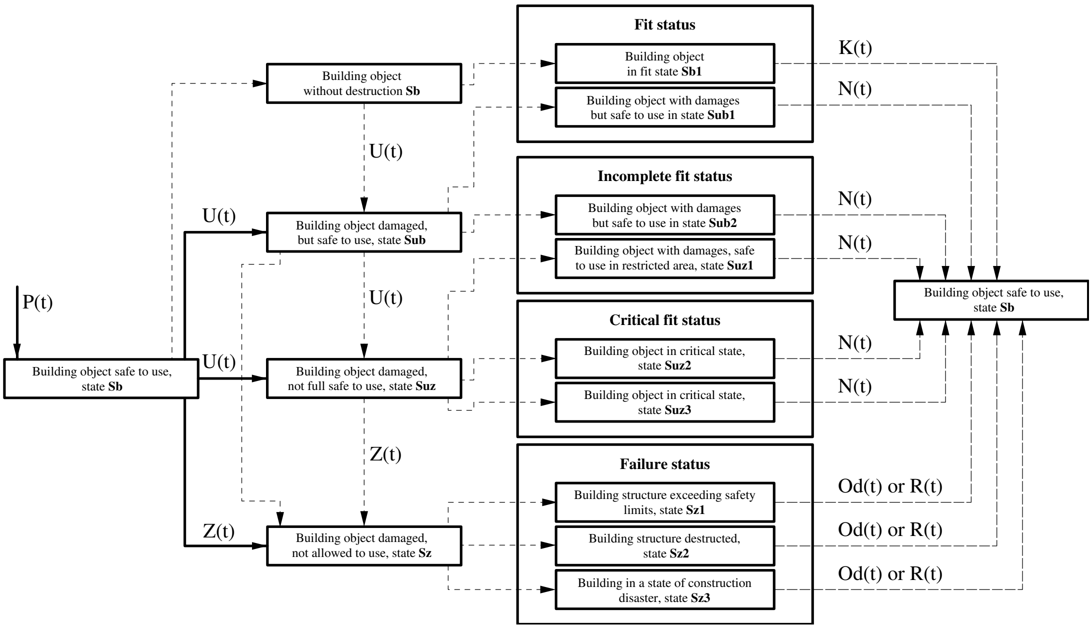

Figure 2. Diagram illustrating the conditions of a building resulting from technical wear characterized by events of damage and destruction of its elements. P(t) – technical reasons for the change in the condition of a building, U(t) – damage caused by causes of internal and external origin, Z(t) – damage caused by causes of internal and external origin, K(t) – maintenance process, N(t) – repair process (including renovation activities), Od(t) – object rebuilding process, R(t) – object demolition process

- assessment of the impact of damage and destruction of the object or part of it on the possibility of safe use of the object or part of it;

3) Determinants of safety and economics of building works are the reasons for improving the methods used to assess their technical condition and seeking new methods to assess their technical condition.

4) The need for credibility in determining the technical condition of a given object and the possibility of its further safe use results from the need for security of the building and economic conditions.

5) Diagnosis of the technical condition of the object, taking into account the causes of damage and destruction and the anticipated further time of use is the basis for a rational assessment of the possibilities and purposefulness of repairing the structure of the object.

6) In the event of a threat to the safety of a building, it is necessary for the owner (manager) to take urgent measures to remove any damage or destruction of the object or parts of it affecting that threat.

7) Lack of corrective action may lead to the construction object or part of it to destruction (construction disaster).

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