Investigation of the process organization of identifying an invalid test during construction expertise

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Abstract. This article discusses the mechanism for studying the functional position of building structural units of a structure and identifying symptoms if there is a suspicion that the identifier influencing the building structure destruction was determined incorrectly. Approaches to determining the degree of damage to a building structure can use the methods based on mathematics and statistics. Calculated determination of a building structure failure degree cannot replace an expert-civil engineer, but provides significant assistance to him. The paper discusses the mathematical methods for determining the building structures’ failure degree from both mathematical and technical points of view. Defect dynamics trend in a building structure in time is taken into account - a cardinal indicator when establishing the problem of finding the amount of working capacity loss. The stochastic methods of probability theory used with the fund recuperation of information about the work carried out to restore the building structures and their return to a working state provide a high level of determining defects in building structures. It has been proved that the policy of choosing a further examination reduces the total number of the studies performed, as well as reduces the examination duration, the moment of establishing the destruction degree determination of the building structure, which is important in some cases. The developed algorithm reduces the subjective moment both when establishing further examination and when determining the destruction degree of a building structure.

1. Introduction
Over the course of a certain period of building operation, under the climatic factors’ dangerous moments influence and the technological processes distinctiveness, a regression of the structures’ work occurs and there is a threat of deviation, in relation to the quality level set by the project [7]. Atmospheric phenomena, technological environment, man-made influences, factors influencing the building from the underground part are the reasons influencing the loss of the primary technical and operational properties of a construction. These processes increase the mechanical wear of the structure, thereby reducing the operational reliability reserve of the building, which can lead to the limiting state of the structure. The listed moments can cause an accident and destruction of the entire building [2, 3]. The performance of the survey, as a part of the technical and construction expertise, provides an opportunity to obtain technical information about the reliability level of building structures [11].

2. Approaches to determining a damage degree to a building structure
The intention of the technical survey is the synectics of the technical condition on a construction site, as well as the general operational activity, the synectics of the extensional absolutely necessary recreational
developments, the pragmatisation and feasibility of restoration, the express analysis of the root causes of defectiveness and malfunction or accidental damage to the construction site [4]. Obligatory nature of the work on the construction objects’ functioning inspection, their extension, technical composition and purposefulness are determined by certain established intentions. Each stage of the survey includes a certain scope of work and a sequence of actions.

In approaches to determining the degree of damage to a building structure, discriminant analysis, Bayesian, neural networks, calculation trees based on the definitions of statistics and mathematics can be used [1]. These methods do not take into account the competence of an expert-civil engineer in matters of a building structure behavior during its destruction, the correlation of technological processes and identifiers that have an impact on destructuring. In the format of connecting stocks of technical and construction information into entirely mathematical methods, it is recommended to use the above-mentioned technical knowledge to ensure the detail and diversification of the statistical data, concretized by the accumulated knowledge base.

The information available for the civil engineer performing the examination makes it possible to supplement and concretize the distribution data. By such concretization and replenishment, in the mathematical approach, the statistics about the work of a building structure and the laws of the occurrence, development and outcome of technological processes that affect its reliability; timely assess the technical condition of the building structures of the technical facility; carrying out an express forecast about the existing possibility of the formation of malfunctions in construction facilities; developing procedures to eliminate or prevent these defects are included in the stock of information of an expert civil engineer [5, 6].

The maximum likelihood method is injected into the concept of probabilities as a generalized method for calculating the dominant complexity values by creating maximizing accepting of perception. The conclusion on the building structure reliability state is based on the time of the most probable destruction, and the probability of destruction is calculated according to the signs affecting this destruction.

In order to detect the certain parameters’ probabilities of the present values that have an effect on the destruction of a building structure in any appearance of a flaw, the primary basis of information took place, and on this basis, rankings of a separate identifier that have an effect on destruction have been developed. The rankings of discrete properties influencing the destruction and dislocation consistency of these properties during fracture have been established. That is, the ranking and features affecting the structure destruction are well known $a_{0j} = 1, 2, 3, \ldots, n$

$$Q_{j}^{\gamma}(a_{j}) = \{Q_{j}^{\gamma 1}(a_{j}), Q_{j}^{\gamma 2}(a_{j}), Q_{j}^{\gamma 3}(a_{j}), \ldots, Q_{j}^{\gamma t}(a_{j})\}$$

where $Q_{j}^{\gamma}(a_{j})$ – is the probability density value of the $j$-th feature affecting the destruction of a building structure with its value $a_{j}$ and $\gamma$ - m defect;

$t = 1, 2, 3, \ldots, \tau(j)$ – define the moment (day) counted from the beginning of the change in the structure’s properties.

Thus, according to the above-mentioned initial data for a separate identifier that influenced the failure of a building structure, it is possible to calculate the probability of an identifier that affects the building structure destruction - $Q_{j}^{\gamma_{l}}(a_{0j})$ [10].

We will use the Bayes formula to determine one once-defined identifier affecting the destruction of a building structure [9]:

$$d_{\gamma} = \frac{a_{\gamma}Q_{j}^{\gamma}(a_{0j})}{\sum_{\gamma}a_{\gamma}Q_{j}^{\gamma}(a_{0j})} \quad (1)$$

where $d_{\gamma}$ – is the probability distribution of detected defects in a building structure,

$\sum_{\gamma}$ - defines the summary note of generalization $\sum_{\gamma=1}^{\tau}$ for each defect identified by an expert.

In the highlighted Bayes formula $d_{\gamma}$ the objective possibility of a building structure failure in the right and left sides of the equation is interpreted in the same way.

With regard to $d_{\gamma}$ the formula is solved (1).
To make the overview of this formula clearer, we will write it down for a pair of signs that destroy the structures: $\gamma = 1$ and $\gamma = 2$. Then the probability of the first sign of the building structure destruction has the form:

$$d_1 = \frac{d_{ij}^1q_{f1}(a_{ij})}{d_{ij}^1q_{f1}(a_{ij}) + d_{ij}^2q_{f2}(a_{ij})} \quad (2)$$

Let us provide that in an expanded union of a pair of features $d_1 + d_2=1$. It is noticeable that the equality (2) has only two ways to resolve:

$$d_1 = 0, \quad d_2 = 1 \quad \text{or} \quad d_1 = 1, \quad d_2 = 0$$

The intention is to find a way to solve the problem, adequate from the point of view of finding a clear identifier that influences the destruction of the building structure. An iterative combination is recommended for the solution method. This iterative combination was used for the empirical formulation of the identifier determined by the formula (1) written in the form

$$d_{\gamma}^{m+1} = \frac{d_{\gamma}^m q_{f\gamma}(a_{ij})}{\sum d_{\gamma}^m q_{f\gamma}(a_{ij})} \quad (3)$$

The correlation index $m$ used in the format of the quantitative parameter of the join of two variables. This indicator has the parameters from -1 to +1. If the indicator approaches zero, this indicates that there is no linear relationship. The linear relationship of the variables will be much closer than the indicator will approach $m + 1$ or $m - 1$. The result of the recommended iterative algorithm in practical application invariably converged; accordingly, the conditionality of determining the identifier that affects the destruction of the building structure was high [8].

The prerogative of the method lies in the fact that the iterative algorithm is unambiguously converged and this makes it possible to establish the sought probabilities with a range of calculus to a lesser extent.

3. Revealing the wrongly defined identifier

However, it happens that after the construction expertise and after the repair and restoration work, the defects similar to those that were found during the survey, continue to appear. This may mean that the cause of the defects was identified incorrectly [12]. In order to identify an invalid test, it is necessary to solve the following problem. One by one, tests or a group of tests are gradually removed from the previous surveys. After that, the most required survey is searched.

Let us introduce the $S$-operating time notation of a building structure without destruction. $S_{max}$ can be achieved by applying the preventive measures for the existing technologies for the elements’ recovery. The optimization problem is $S_{max}$, and the variable indicator is the number of the criterion (identifier), which influences the building structure destruction. The analogue of the functional purpose of the benchmark is $\Delta S$, and a similar goal of improving - $\Delta S$, where $\Delta S$ – defines increase $S$ as a result of the next survey; $d$ – is a probability distribution of a diagnosed reduction in bearing capacity in a structure; $\gamma = 1, \quad 2, \quad 3, ... , \quad n$ – denote the number of the process destroying the structure; $a$ – is a survey value, is interpreted as a parameter $k$ (variable) and is an identical expression of any of the probable parameters of a feature that destroys the structure. The initial segregation of building structure defects was accepted by the consequential appraisal based on $b$ – the previously diagnosed studies. The numbers of properties that destroy the structure are denoted by the letter $j$: $1 \leq j \leq b$. $a_{ij}$ – is a specific meaning of the $j$-th identifier influencing the destruction of the building structure, obtained as a result of the survey. Let us suppose the conversion range is also known $V a_m$, i.e. $a_{m\text{min}}$ and $a_{m\text{max}}$. The idea is to bring the non-destructive time of the building structure ($S$) to the maximum value. To do this, we (as a result of surveys) have to identify the signs that affect a building structure destruction.

If there is a suspicion that the identifier influencing the destruction of the building structure was determined incorrectly, then the data from the already carried out studies are removed. Its assumed parameter determines the total probability formula.

$$ae_{aj}^{j=dt} = \int_{a_{j\text{min}}}^{a_{j\text{max}}} a_j q(a_j) f a_j, \quad (4)$$

where

$$q(a_j) = \sum_{\gamma} p_{\gamma} q_{\gamma}(a_j). \quad (5)$$
With the given $a_{oj}^{dl}$ there is $d_{y}^{\text{new}}$.

$$\begin{align*}
\sum_{j=1}^{b-1} a_{oj} j = 1, 2, 3, \ldots, b, b - 1, j \neq d_{l} \to d_{y}^{\text{new}}.
\end{align*}$$  

(6)

Following this, we will rename $d_{r} = d_{y}^{\text{new}}$ and circularly reproduce the calculations by the formulas (4) - (6) until determining $a_{oj}^{dl}$ and $d_{r}$. Found $a_{oj}^{dl}$ and $d_{r}$ (more precisely, a comparison of these values with the verified test values and with the resulting failure probabilities) convincingly explain the reason and need for re-verification of the tests $j = d_{j}$.

![Survey control algorithm](image)

Figure 1. Survey control algorithm.

Rechecking is performed when specifying if the criterion $S$ changes dramatically. For example, provided that after the suspicious estimate was excluded, and the $S$ value (calculated by this method) has changed significantly, in this case it is necessary to double-check the survey. Whether the tests need to be repeated or not, can be decided in the same way as it had been found out, which test is the most important to perform. The survey control algorithm (Figure 1) has been designed to remove stochastic errors and to increase the surveys’ reliability.

4. Calculating the likelihood of re-examination

The probability of re-examination $j$ is calculated taking into account the previous surveys $j$. In some examinations, the tests that need to be repeated are identical to the primary ones, in other examinations the tests that need to be carried out are completely different. When answering the question of what further research should be done, those that have not been conducted yet and those that have already been completed, are taken into account. For those that have already been fulfilled, the need to repeat them again is determined. This is done for control, to remove stochastic errors, as well as to increase the surveys’ reliability. A problem, which consists in answering the question at what point it is necessary to stop the measurement process of the next survey, or it should be continued, appears. Provided that the number of checks is not fully used, it is possible to develop the conditions for interrupting the procedure for finding the $k$ calculation. In the event that the number of surveys is completed, and the specified criteria are incomplete, all this raises doubts whether the full composition of the applied surveys was really selected.

Sometimes the developed criteria depend on the price of the survey, as well as on what profit we will have after the building structure is restored. The recommended criteria do not depend on prices. In the form of a mandatory requirement to terminate the search for further examination, let us consider the correlation:

$$\begin{align*}
\sum_{r} \frac{|d_{y}^{\text{new}} - d_{r}|}{d_{r}} \leq \varepsilon_{d}, \\
\Delta S \leq \varepsilon_{\Delta S}.
\end{align*}$$

(7)

(7a)
Inequality (7) reflects the stabilization process of refining the destruction degree determination (7a) and demonstrates that the additional examinations’ profitability turned out to be small.

Since S has the moment dimension, therefore, we can solve the problem of the validity of the quantities ∆S. Another limitation of the smallest value ∆S and other criteria represents the correctness of the S, d, calculation and other parameters. The limiting conditions for the completion of calculations can be obtained by comparing with a building structure that does not have defects:

$$\frac{S_{\text{new}}-S_{11}}{S_{11}} \leq \varepsilon_S.$$  (7b)

Where S11 is the S value for an ideal structure, since the initial index of the first matrix refers to the fact that there are no defects, and the second index is one to the building structure restoration.

Another requirement is the greater reliability of the diagnosis:

$$\left(1-\max d_i\right) < \varepsilon_d.$$  (7c)

A series of features can be obtained by comparison with the ideal restoration of a building structure. A stricter rule is applicable to the fulfillment of the inequality conditions (7) - (7c) in a series of, for example, 3 calculations k performed one after the other. It is important that the k value found in a fragment of these calculations, for example, in 2 calculations, should be used.

**Summary**

The developed policy for selecting the next survey reduces the number of surveys performed, reduces the survey period, the duration of determining the destruction degree of a building structure, makes it possible to determine the identifier affecting the destruction of a building structure, which is fundamentally important for preventing a building accident. The developed algorithm allows minimizing the subjective factor when appointing the next examination, as well as when determining the destruction level of the examined structure.

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