SCHEME OF CONTROL OF ENGINEERING STRUCTURES' TECHNICAL CONDITION

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ABSTRACT

Reliability of artificial structures on the railways is directly related to safety of life of passengers and cargo. The proposed scheme of control of technical condition of the span allows to calculate with a great precision design reliability and to predict its changes, to respond flexibly to the dynamics of the operating conditions, as well as to control optimally the processes by the criterion «reliability–cost».

Keywords: railway engineering structures, span, reliability, security, recursive algorithm, optimal interval.

Background. *In accordance with GOST R54257–2010 [1], the reliability of the construction object is defined as its ability to perform its required function over the estimated useful life and estimated lifetime is a set in the building code or the design assignment period of use of the construction object according to its purpose until overhaul and (or) reconstruction with prescribed maintenance. Design life is measured from the start of operation of the facility or resumption of its operation after major repairs or reconstruction.*

Consequently, the expected lifetime is determined a priori, i.e. before the start of operation, based on average data. Therefore, elements of artificial structures are replaced or repaired through the normalized period between repairs.

Objective. *The objective of the authors is to consider a scheme of control of technical condition of artificial structures.*

Methods. *The author uses general scientific and engineering methods, mathematical calculation, evaluation approach, graph construction.*

Results. *To account for changes in operating conditions (varying train load, non-constant traffic intensity, changing climatic conditions) in order to ensure the required security artificial structures should be used on railways according to the actual technical condition.*

To determine the service life and other indicators of reliability of artificial structures by not normalized period between overhaul, and based on the actual technical state it is necessary to build a probabilistic model of an artificial structure as of a complex technical system. The probabilistic model will allow to predict the service life of an artificial structure with a certain probability of failure-free operation.

For efficient operation of artificial structure it is necessary to carry out replacement or repair of elements not according to the normalized terms, but in accordance with the results of calculations on a probability model considering the actual technical condition.

Since the service life of artificial constructions is less than the life of any of its elements, it is necessary with the probalistic model to calculate, that is, to predict service life of the entire man-made structure.

Calculation of reliability of the entire man-made structure as complex technical systems can be built on the built recursion method described in the article [2].

For railway bridges the probability of failure-free operation of elements of metal spans, given the high safety requirements for operation, should not fall below 0.9845 [3]. Therefore it is necessary to determine the moment of the operating time for the entire superstructure, or what is the same, passed train load, when the probability of failure-free operation reached 0.9845.

Since the terms of replacing the entire superstructure comes earlier than the period of repair (replacement) of its elements, to extend the life of the entire man-made structure it is necessary to replace its individual elements. First of all those elements, the repair time (replacement) of which comes earlier than others. For cumulative purposes here it is best to use the algorithm for calculating the optimal range of preventive replacements [4]. Further, of all optimal intervals it is necessary to use the smallest interval, that is, to select the element, which is scheduled to be replaced before all elements.

For the calculation by the method of optimal intervals of preventive replacements an artificial structure should be represented as a complex technical system, consisting of a large number of interrelated elements that can be done as follows.

For each element, its function of distribution of probability of failure-free operation is set:

– distribution function of such probability is selected by the principles set out in article [5], the best choice is a distribution function of Weibull for which it is necessary to set two parameters; in the absence of survey data parameters are selected according to a recommended theory;

– according to the survey data the parameters of the selected function of distribution of probability of failure-free operation is calculated for each element of the metal superstructure.

In determining the parameters of distribution function of probability of failure-free operation it is necessary to conduct a survey of artificial constructions. In the course of the survey for each element of artificial constructions numerical score of its technical condition is calculated with the help of special instruction [6]. Then numerical score can be transferred into a measure of damage following the procedure laid down in article [5]. The dependence of probability of failure-free operation on the measure of damage, according to the procedure in the monograph [3], is built on the normal law:

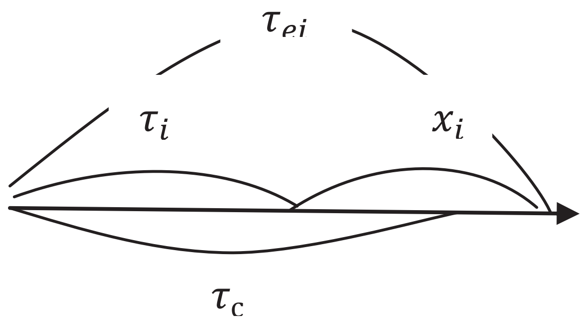
$$F(\nu)=\frac{1}{\delta\sqrt{2\pi}}\int_{-\infty}^{\nu}\frac{e^{-(\nu-m)^2}}{2\sigma^2}d\nu, \qquad (1)$$

where ν *– measure of damage of the element of the artificial structure;*

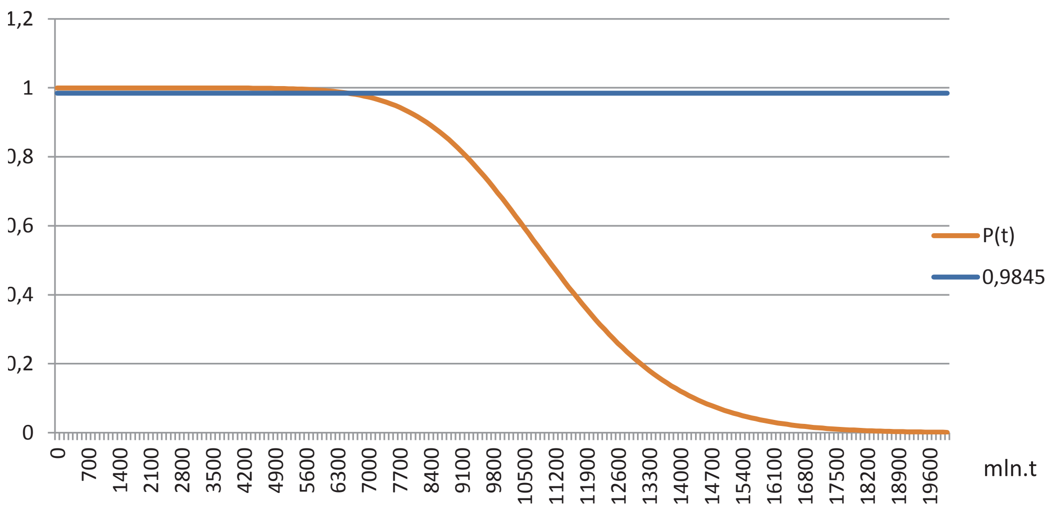
m – mathematical expectation of the damage measure at which the failure occurred;

σ *– standard deviation of the measures of damage, at which the failure occurred.*

By the probability of failure-free operation obtained after a survey in such a way and passed load to the time of the survey one of the parameters of the distribution function is calculated. During two surveys both parameters of the distribution function of the probability of failure-free operation can be calculated, which during future surveys will only be specified.



Pic. 1. The ratio of intervals τ_{ei}, τ_i, τ_c, x_i.



Pic. 2. Probability of failure-free operation of the superstructure of the bridge over the river Nerussa.

Thus, for each element of the artificial structures the parameters of the Weibull distribution function are selected and subsequently refined.

Then, using the recursive method [2] the probability of failure-free operation of all facilities at a given time, or what is the same, for a given value of missed load is calculated. Consequently, we obtain the dependence of the probability of failure-free operation of the entire artificial construction from the passed load. According to the found dependence can be calculated time τ_c, at which the critical level of probability of failure-free operation P = 0.9845 is reached.

Let's consider the metal superstructure of artificial structure, in which the number of elements is denoted by n. To operate the artificial construction on the criterion of the minimum economic costs with a maximum of reliability, it is necessary to carry out repairs (replacement) of individual elements of artificial structures through optimal intervals τ_1, τ_i,..., τ_n, calculated using the method of optimal intervals of repair (replacement) of elements [4].

Optimal interval of repair (replacement) depends on time during which the element must be guaranteed to work in order to carry out during this time its repair or replacement with a view of possible delays, i.e. duration of the alert interval x. For optimal operation, the smallest of these intervals should be selected.

For any i-th element of the artificial facility the following inequation is fair:

$$x + \tau_i = \tau_{ei} > \tau_c, \qquad (2)$$

where x_i – preventive interval for the i-th element;

τ_i, i = 1,...n – optimal interval for the i-th element;

τ_{ei}, i = 1,...n – sum of the optimal interval τ_i and preventive element x_i for the i-th element;

τ_c – interval of repair (replacement) of the artificial structure;

n – number of elements in the artificial structure.

This inequation is represented graphically in Pic. 1.

In order that the artificial structure corresponds with the requirements of reliability, it is necessary to begin to replace the elements of the artificial structure with the smallest optimal intervals τ_{min} and, consequently, with the smallest interval τ_{emin} equal to the sum τ_{min} and x_{min}, for these elements during the interval x to the time when it is necessary to replace the entire artificial structure, i.e. the optimum interval for these elements is reduced by the time $\tau = \tau_{emin} - \tau_c$. Thus, we obtain:

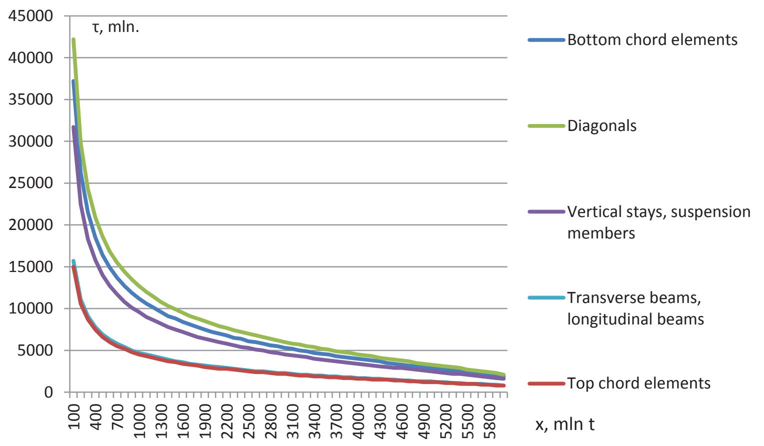
$$\tau_{min} + x_{min} - \tau = \tau_{emin} - \tau \le \tau_c, \qquad (3)$$

where x_{min} – preventive interval for this element;

τ_{min} – the lowest optimal interval;

τ_{emin} – sum pf the optimal interval τ_{min} and preventive interval x_{min} for the element;

τ_c – interval of repair (replacement) of the artificial structure.



Pic. 3. Dependence of the optimal interval τ_i on preventive interval x_i.

Let's build a scheme of control of technical condition for the entire period of operation of the bridge on the river Nerussa, located at 478 km of II track of the section Bryansk–Suzemka of Bryansk–Lgov maintenance section. The bridge has metal spans roadway on bottom boom designed by Giprotrans of People's Commissariat for Lines of Communication of 1931, under the design load H-7.

The calculated interval of repair (replacement) under the recurrence method for the metal superstructure of the bridge overlooking a river Nerussa is τ_c= 6536 mln t at a probability of failure-free operation

For different types of elements of the metal superstructure of the bridge under consideration optimal replacement intervals were calculated. The dependence of the optimal interval from preventive intervals for different types of elements of the metal superstructure is shown in Pic. 3.

Of the elements for which the optimal intervals of replacement were calculated, elements with the least optimal intervals were selected. These elements are the elements of the upper zone, the optimal replacement interval for which is τ_{min} = 6000 mln tons with a preventive signal x_{min} = 600 mln tons.

Thus, an optimal replacement interval of the metal superstructure, i.e. the entire system, τ_c= 6536 mln tons less than the lowest interval τ_{emin}, equal to the sum of τ_{min} = 6000 mln tons and x_{min} = 600 mln tons. Therefore, the optimal interval for the top chord elements should be reduced by time equal to τ = 6600–536 = 64 mln tons That is, it is necessary to start repairing elements of the top chord of the metal superstructure must be in τ_{min} = 6000–64 = 5936 mln tons and τ_{min} and x_{min} = 600 mln tons.

Conclusion. *The proposed scheme of control of the technical condition of the superstructure allows more accurately to calculate its reliability and to predict its changes, to respond flexibly to the dynamics of the operating conditions, as well as to carry out the optimal control by the criterion of «reliability–cost».*

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