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APPLICATION OF INFORMATION MODELING TECHNOLOGY AT THE OPERATIONAL STAGE BRIDGE STRUCTURES

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Annotation. The article discusses the application of information modeling technology at the stage of operation of bridge structures. It is shown that the introduction of Building information modeling (BIM) makes it possible to create a digital twin of an object that provides comprehensive data management on its design, technical condition, load conditions and maintenance plans.

Key words: Building information modeling, bridge structures, operation, digital twin, condition monitoring.

FOYDALANISH BOSQICHIDAGI KO‘PRIK INSHOOTLARIDA AXBOROT MODELLASHTIRISH TEXNOLOGIYASINI QO‘LLASH

Jumabayev Adilbek Bazarbayevich
iqtisod fanlari falsafa doktori
QQDU “Shahar qurilishi va xo‘jaligi” kafedrasi katta o‘qituvchisi

Annotatsiya. Maqolada ko‘prik inshootlaridan foydalanish bosqichida axborot modellashtirish texnologiyasidan foydalanish ko'rib chiqiladi. BIMning kiritilishi ob’ektning dizayni, texnik holati, yuklanish sharoitlari va texnik xizmat ko'rsatish rejalari to‘g‘risidagi ma’lumotlarni har tomonlama boshqarishni ta’minlaydigan raqamli juftlikni yaratishga imkon beradi.

Kalit so‘zlar: Binolarni axborot modellashtirish, ko‘prik inshootlari, foydalanish, raqamli juftlik, holatni kuzatish.

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Analysis Current trends in the construction and operation of transport infrastructure require the introduction of innovative approaches that ensure high efficiency in managing the life cycle of facilities. One of these technologies is information modeling of buildings and structures, which was initially used mainly at the design and construction stages, but is now being actively integrated at the operational stage. The operation of bridge structures is a key stage of their life cycle, which determines the safety, durability and cost-effectiveness of further use. Traditional monitoring and maintenance methods often do not provide sufficient accuracy and timely detection of defects, which leads to increased repair costs and reduced safety. The introduction of BIM technologies allows you to create a digital twin of a bridge facility, including data on its design, technical condition, operating conditions and maintenance plans.

The use of information modeling at the bridge operation stage ensures:

integration of project, construction and operation data into a single digital platform;

monitoring the condition of structural elements in real time;

wear forecasting and repair planning;

improving the accuracy of calculations of operating costs and optimizing the timing of maintenance.

Thus, the use of information modeling technology is an important tool for improving the efficiency of bridge management, extending their service life and ensuring transport safety. Assessing the reliability of bridge elements during operation is a difficult and time-consuming task. To solve it, it is necessary to establish patterns of change in various characteristics of the elements, to accumulate the necessary statistical data. The methodology is based on a model according to which fatigue failure occurs if the amount of accumulated damage reaches a certain limit (in the general case, a random value). When using this model, the uptime condition of the bridge element can be represented as:

$$\nu \leq \nu_{OH}$$

ν - estimated value of the damage measure; ν_{OH} - the value of the damage measure at which the specified reliability is ensured.

In the model under consideration, the probability of failure-free operation of the element P(v) is related to the damage measure according to the normal law.

The accumulation of damage in the elements of bridges occurs for various reasons: fatigue damage to the elements, corrosion, disorders of bolted joints and other factors. Let's consider a model where the advanced accumulation of damage occurs mainly in one of the elements of metal trusses (strut, suspension, lower belt), and the operability and safety of the structure is controlled by two levels of limiting conditions. Let's assume that the accumulation of damage in the element is monotonous and is reflected by the parameter v(t) (Figure 1). When the parameter reaches the ν_{OH} level, a fatigue crack appears, and when the v_P level is reached, fatigue failure of the structural element occurs.

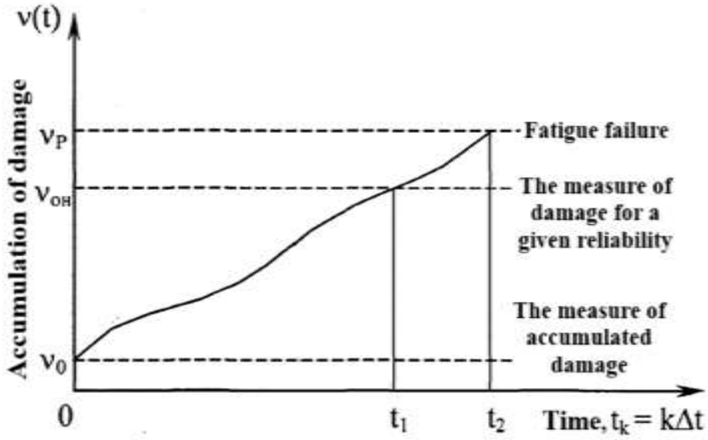

Figure 1: The scheme of accumulation of damage in the element

Let's consider a mathematical model for managing the technical condition of the bridge, taking into account fatigue damage. The reliability of the endurance element is assessed by comparing the calculated damage measure ν with ν_{OH}. Taking into account the high requirements for the safety of bridge operation and the nature of the development of post cracks, the probability of trouble-free operation of metal superstructure elements is assumed to be at least 0.98, which corresponds to $\nu_{OH} \leq 0.3$.

Table 1.

Examination results

ν_0	0,10	0,15	0,20	0,25	0,30	0,35	0,40	0,45
$P(\nu_0)$	0,9990	0,9979	0,9955	0,9924	0,9845	0,9712	0,9515	0,9236

The durability of bridge elements is determined from the condition of equality of the calculated damage measure ν_{HAK}, determined from the total impact of the load from the beginning of operation, and ν_{OH}, corresponding to a given reliability. In this case, the durability of a resource can be expressed in the number of trains or cars of certain types or in time [1,2].

In accordance with this methodology for assessing the fatigue life of elements of metal bridge spans, the residual resource, expressed in the number of cars, is:

$$N = \frac{\nu_{OH} - \nu_{HAK}}{\nu'}$$

where ν_{HAK} - a measure of accumulated damage from passing cars; ν' - a measure of damage from one reference vehicle.

Based on the methodology, the dependences of the accumulated damage measure and the probability of trouble-free operation of the superstructure elements on the number of vehicles, taking into account the current and prospective load, are obtained. The results obtained by this method are presented in Table 2.

Table 2.

Results obtained by this method

Span length, m	**Element**	**The measure of damage during the period of operation**	**Residual fatigue life, thousand. conditional cars**	**The measure of damage from one conditional machine**
110	H0-1	0.00088	271805	$1.1001*10^{-6}$
	H1-2	0.05566	3101	$7.4122*10^{-5}$
	H2-3	0.03737	5035	$4.9732*10^{-5}$
	H3-4	0.05434	3303	$7.2411*10^{-5}$
	H4-5	0.04898	3564	$6.5234*10^{-5}$
	P1-1	0.02565	12251	$3.4116*10^{-5}$
	P2-2	0.02939	8202	$3.9056*10^{-5}$
	P3-3	0.02484	8025	$3.3061*10^{-5}$
	P4-4	0.01080	7922	$3.3703*10^{-5}$
	P5-5	0.01777	6781	$2.3608*10^{-5}$

The accumulation of damage in the elements of bridges occurs for various reasons: fatigue damage to the elements, corrosion, disorders of bolted joints and other factors. The experience of operating bridges in modern conditions shows that an increase in traffic intensity and an increase in the carrying capacity of transport also reduce the likelihood of trouble-free operation of the elements. Damage accumulation is assessed by monitoring the number of vehicles passing over the bridge. Monitoring the technical condition of bridges is an urgent task that allows for rapid monitoring and analysis of data for proper and effective management of bridge behavior. The technology of normalization modeling is not only a technology for designing bridge structures from scratch. The created information model of the bridge is very useful for existing facilities, since it contains all the necessary information about them, and the task of service organizations is to manage this information competently. With an efficient data transmission network from sensors mounted on the bridge structure, it is possible to quickly transfer information immediately to the information model, updating it (Figure 2).

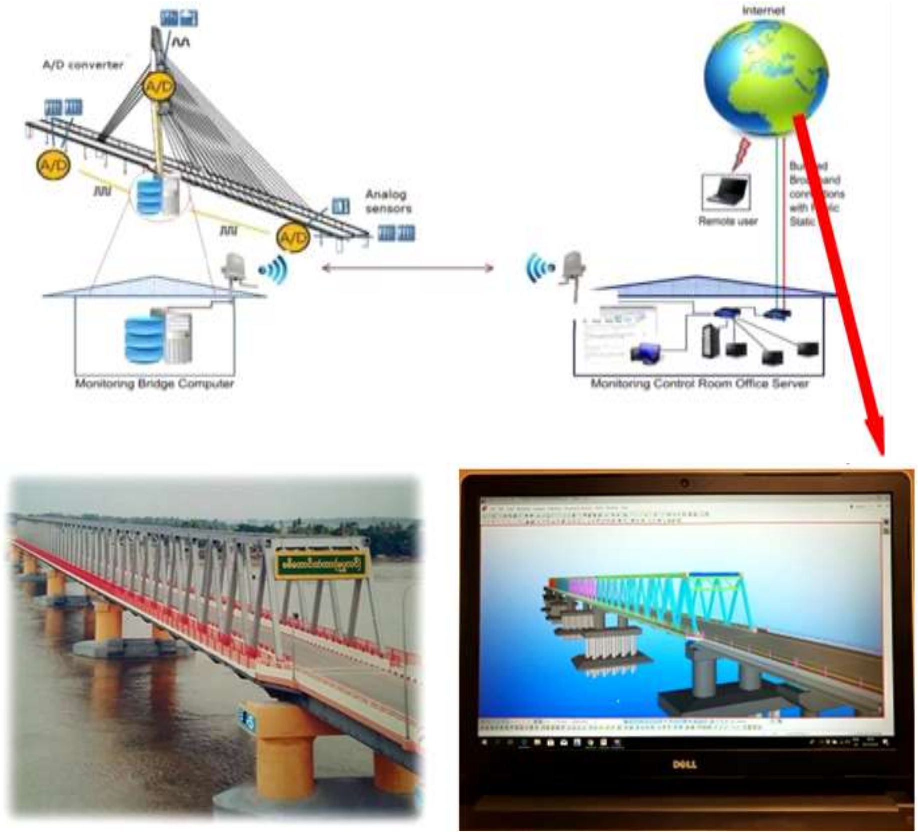

Figure 2: Transfer of monitoring results to the information model

The use of information modeling technology makes it possible to expand the base of properties of model elements by adapting software using plugins, which are application software operating in the information modeling environment. Plugins are a powerful tool that can significantly improve the operation of a certain type of structure. To ensure the specified reliability of metal bridge spans, it is necessary to reduce the period between repairs of damaged elements or to strengthen them. To determine the period between repairs of damaged elements, we will consider the bridge as a complex technical system. Then the optimal repair interval can be determined based on the model of preventive replacements of "weak links" in a long-term operating system. Consider an element operating in the system with an increasing failure rate function [3,4]. For example, such an element would be the slant of the metal truss of the bridge superstructure. Let's make the obvious assumption that aging elements have a negligible probability of failure in the absence of a moving load. Let's introduce the designation: T_0 is the average uptime of the element, i.e. the time from the start of operation to reaching a given maximum reliability level v_{OH} <0.3 (until the probability of uptime is reached $P(T_0)$ = 0.98). The element can be replaced with another serviceable one in the order of preventive maintenance or in an emergency. Let's denote the replacement time of the functional element by T_1, and the replacement time of the failed element by T_2. We assume T_1 is less than T_2. Time in this mathematical model is calculated in conventional units: as a unit, we will take the time interval during which 1000 conventional cars pass over the bridge. For bridges with different traffic intensity, this interval, expressed in years, will be different, and expressed in thousands of conventional cars – the same. Let's define the interval of preventive element replacements – the time after which the element must be replaced (repaired). The indicator by which the optimal value of the interval of preventive substitutions of a given element is selected is the probability p(x, t). This indicator has the following meaning: the probability of finding an element in working condition at an arbitrary moment *t* and working flawlessly after the moment *t* for time *x*. In practice, it is recommended to choose the interval *x* as the shortest time exceeding the sum of T_2 and possible delays. Let's assume that the times of planned element replacements are realizations of some random variable T having a distribution G(t).

The intervals between repairs (replacements) of the element form in time a sequence of independent, identically distributed random variables with a distribution function F(t). The element is replaced (repaired) prophylactically after a random time distributed according to the distribution function G(t), or immediately after failure:

$$G(t) = \begin{cases} 0 & by \quad t \le \tau \\ 1 & by \quad t > \tau \end{cases}$$

Let's consider the implementation of a mathematical model for determining the optimal interval for preventive replacement of metal truss elements.

The time after which the element must be replaced is determined by the formula:

$$a\tau \int_0^{\tau} e^{-\frac{at^2}{2}} dt + e^{-\frac{at^2}{2}} - 1 = C$$

$$C = \frac{T_1}{T_2 - T_1 + x}, \quad a = \frac{\pi}{2T_0^2}$$

To determine the optimal interval of preventive substitutions T_0 using the equation, it is necessary to know the numerical values of the constants T_0, T_1, T_2 and *x*. The slant was used as the investigated element of the farm.

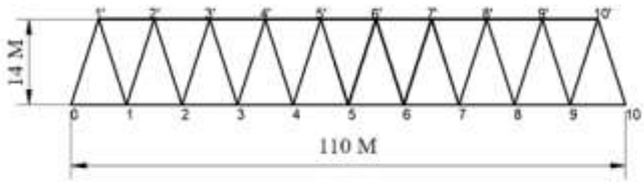

Figure 3: The superstructure of a metal bridge (truss).

T_0 is the total fatigue life of the element, i.e. operating time to failure at a given probability of uptime. Let's denote this value, expressed in conditional terms, by N_0. Then the total fatigue life can be determined as follows.

– the developed fatigue life, i.e. the number of passed conditional machines;

– residual fatigue life, i.e. the number of conditional machines remaining until the full resource is reached.

The value depends on the design span of the truss, the type of element, and the type of conditional machines.In particular, for the braces P5'-5 of the superstructures of the farm in question, 6,780 thousand conventional machines.To process the monitoring results in the information model, a problem-oriented plug-in was written that implements a model for assessing the reliability of an operational bridge based on two levels of limit states. Recall that when the parameter reaches the level, a fatigue crack appears, and when the level is reached, fatigue failure of the structural element occurs.The program monitors the accumulation of damage to prevent these extreme conditions, and uses a color scale to show the extent of accumulated damage to individual elements. Data entry for the demo version is performed manually through the dialog box (Figure 4). In practice, information enters the program from sensors mounted on the elements or from sensors that count passing cars.

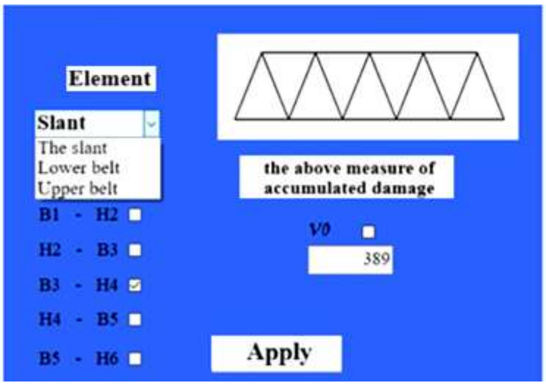

Figure 4: The dialog box of the element reliability assessment program.

The result of the plug-in is a three-dimensional image of a metal truss with a color image of the degree of accumulated damage (Figure 5).

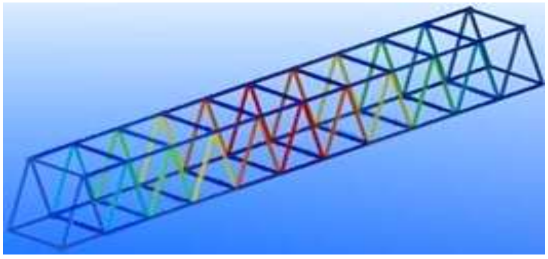

Figure 5: The result of the work: color display of the degree of accumulated damage in the bridge elements.

Thus, the integration of monitoring results into the information model of the bridge at the operational stage helps to timely monitor the degree of accumulated damage for individual elements, which will increase the reliability and durability of the bridge structure. Based on the research carried out by the author, the article proposes new scientifically based technological solutions to improve the quality of design and operation of bridge structures, which are essential for the country's transport system. They are listed below in the form of results, recommendations and prospects for further development:

The conducted research has shown that currently the most effective means of achieving high construction speeds and increasing the reliability of bridge structures during operation is the use of information modeling technology in bridge construction. This technology is a very useful tool at all stages of the life cycle of bridges. Separate families of supports and girder spans for the bridge have been developed. A family of bolted metal bridge trusses has been developed. A software implementation has been performed that expands the functionality of the program at the design stage, using problem-oriented plug-ins to select different types of metal truss sections. A software implementation has been performed that expands the functionality of the program at the design stage, for automatic placement of bolts in nodal joints. A plugin has been created for the automatic generation of spatial farm calculation schemes, which performs the preparation of a farm calculation scheme for a strength analysis system. A plugin has been created that integrates monitoring results into an information model to track the degree of accumulation of fatigue damage to selected bridge structure elements, which makes it possible to increase the reliability of the bridge structure during operation by improving the reliability assessment of individual elements and integrating existing monitoring techniques and results with the bridge information model.

An information model of the bridge in the Republic of Uzbekistan has been created using reverse engineering and developed programs. Her example shows the effectiveness of information modeling technology not only for the bridges being designed, but also for the bridges being operated. It is recommended to use information modeling technology at the operational stage to reduce the number of errors by performing the necessary calculations at any stage of the facility's operation, taking into account the monitoring results. The prospect of further development of the dissertation research topic is to expand the use of information modeling technology to improve the reliability of operational bridges based on the integration of new monitoring technologies by means of non-destructive testing into the digital model of bridge structures.

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