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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
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STRESSES IN ELEMENTS OF METAL RAILWAY BRIDGES UNDER THE ACTION OF THE CREW

Abstract. The necessity of application of mobile measuring and computing systems during the examination of extended metal span structures of railway bridges is justified in the article, and also the stresses appearing in the elements of the structure of the farm under the influence of different types of rolling stock are presented.

Keywords: bridge, crew, metal truss, span structure, reliability, voltage.

Now in the countries of Europe, Asia and the USA numerous researches are carried out for an estimation of a technical condition and diagnostics of maintained artificial constructions on dynamic parametres. A particularly noticeable breakthrough in this direction occurred in the 90's. of the last century, when powerful portable computers were created, and an evaluation of the stress-strain state of the system under the influence of external loads became an affordable and accessible tool for practical engineers.

Thus, the use of automated measuring systems (AIS) for the collection and processing of data in the testing process is becoming increasingly important. If monitoring is required, i.e. long-term monitoring of the condition of the facility under construction, AIS proves to be the only acceptable one, since it allows not only to completely abandon numerous observers, but can also be equipped with a decision-making system for automatic prevention of emergency situations.

Thus, at the current stage, a VAT study of bridge structures is most effective using AIS. This allows you to more deeply analyze the experimental data and find the best solutions to improve their reliability

When determining the load capacity of span structures, they are tested in accordance with [1] to refine the actual stress state of the elements, especially in the presence of defects and damages, the influence of which on load-carrying capacity is difficult to take into account theoretically.

Professor N.G. Cooper [2] defined the primary task to be studied within the framework of the interaction of bridges and rolling stock: the identification and analysis of the conditions under which dynamic deformations and movements in the "bridge-train" system have the most unfavorable combination during operation.

Since the load from the rolling stock is concentrated at the locations of the axles of the trolleys, the deflections of the span structure at each moment of time will correspond to the flexural deformations and it is always possible to find its two positions giving the greatest and the least static deflections of the span structure.

From measured values of flexural deformations, knowing the design modulus of elasticity of the construction material, according to Hooke's law, one can make a transition to the actual stresses in the bridge structure. Periodic measurement of deformations (stresses) of a span structure under a mobile load for 2-3 years will make it possible to predict the change in its state in time and determine the remaining life by carrying capacity and carrying capacity [3, 4].

The calculated values of the controlled parameters, for example, the stresses in the elements of the span structure, can be determined both by engineering methods and by means of specialized computational software that implements the finite element methods (MIDAS Civil, APM Civil Engineering, APM Structure3D module, Cosmos M).

The advantage of using finite element models is the ability to simulate various malfunctions in a design, adapting the calculation results to actual operating conditions. By deviating the actual stresses from the calculated values, it is possible to judge the degree of damage to the structures of the span structure of the bridge.

At the present time, the planned transition to an automated control system for the maintenance of artificial structures (ACS ISSO) with a database (including in digital form) of the results of surveys, tests, diagnostics and monitoring is becoming more urgent.

In this paper, the results of full-scale measurements of stresses from the train load in the elements of the span structures of a railway metal bridge across the Irtysh River at 657 km of the single-track section of Semipalatinsk-Zhana-Semey constructed in 1929 are presented. Span structures are represented by metal trusses with a polygonal outline of the upper belt. Figure 1 shows the scheme of the bridge transition.

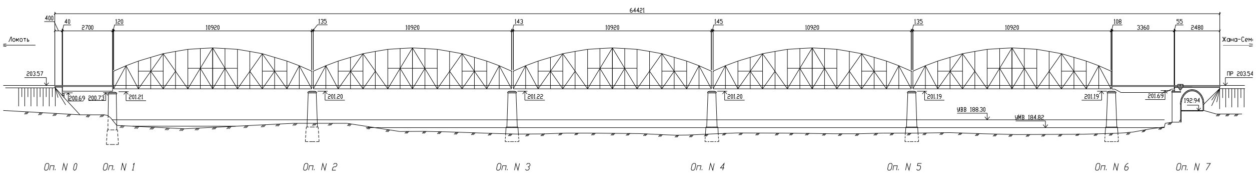

Figure 1 – Scheme of railway metal bridge across the Irtysh River in the city of Semey

On the bridge on the supports there are five metal trusses in the channel part of the Irtysh River with a calculated span Lp=109.2m with a ride down. The riveted metal trusses were made in 1928 from Art.3 according to the norms of 1921. Farms - with polygonal upper belt and triangular lattice with springs, are combined by means of longitudinal and transverse connections and a beam cage of the carriageway.

In the eighth panel of each channel span structure, a deformation (temperature) rupture of the longitudinal beams of the carriageway is carried out, with the end of the longitudinal beam supported on a metal "table" attached to the wall of the transverse beam. Each farm consists of 16 equal panels with a length of 6.825m, the height of the truss on the support is 7.8m, in the middle of the farm is 18.2m, the distance along the axes of the farms is 6.1m, the distance between the axes of the longitudinal beams is 2.0m. The joints of the elements are made on rivets.

The diagram of the span structures 1-5 is shown in figures 2 and 3 shows the arrangement of strain gauges on the elements of the structure of span structures 1 and 5.

The measurements were carried out in accordance with the requirements of [1] using a tensometric measuring and computing system consisting of certified and certified measuring instruments of the world's leading manufacturers. The complex makes it possible to produce precision (high-precision) measurements of stresses and relative deformations in elements of the track and span structures of bridges from the impact of rolling stock simultaneously in 16 sections with a total length of up to 500 m.

The accuracy class of the measuring equipment is 0.1, the error of the measurement results given in this study was in the range from 5 to 7%.

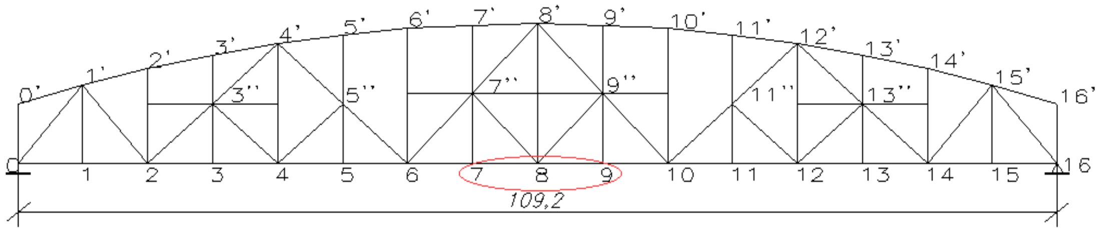

Figure 2 – Schematic of span structures 1-5

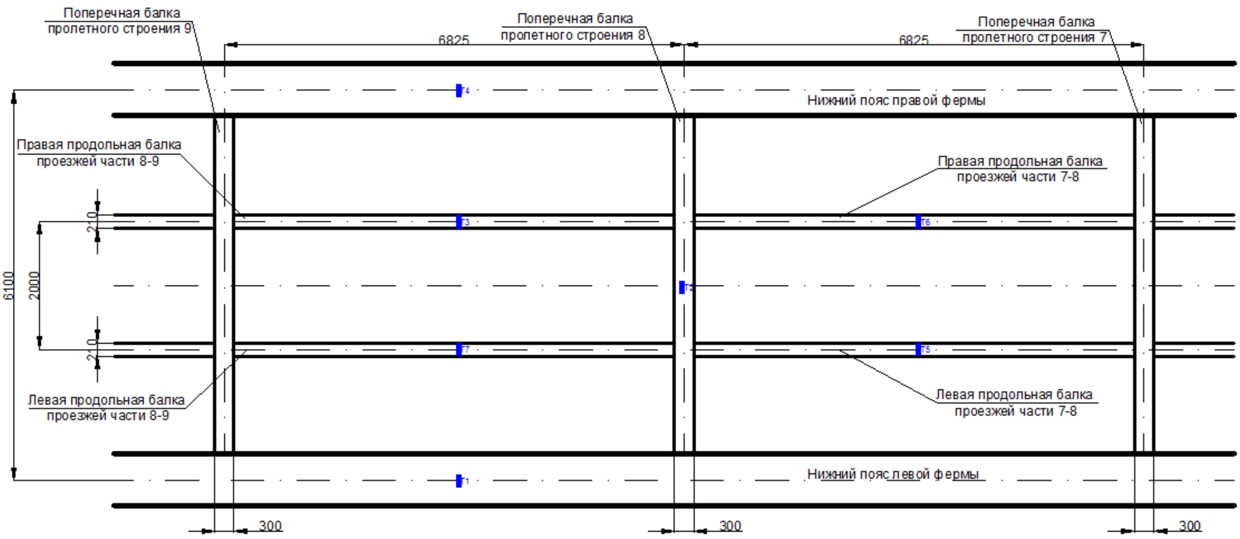

Figure 3 – Scheme of arrangement of strain gauges on span structures 1 and 5:
T1 - Strain gauge №1, on the lower belt of the left farm; T2 - Load cell №2, on transverse beam №8 of the span structure;
T3 - Load cell №3, on the right longitudinal beam of the roadway 8-9; T4 - Strain gauge №4, on the lower belt of the right farm;
T5 - Strain gauge №5, on the right longitudinal beam of the roadway 7-8; T6 - Strain gauge №1, on the left longitudinal beam of the roadway 7-8; T7 - Strain gauge №1, on the left longitudinal beam of the roadway 8-9

The complex was tested at a number of facilities of JSC "NC" KTZh "and showed good results in evaluating the effectiveness of reinforcing railway bridge structures with a composite material [5-6] and determining the impact of dynamic rolling stock impact on the railway track and span structures of bridges [7-15].

As an example, figures 4-7 show diagrams of stress changes in the elements of the span structure 1 when passing through the span structure of locomotive TEZ3A with cargo composition ("assembly") at a speed of 25 km/h.

From the diagrams shown, it is seen (figure 4a, b) that the stresses in the left and right belts of the trusses differ insignificantly (within 2 MPa). This circumstance indicates a uniform distribution of the movable load in the plane across the bridge and the absence of displacement of the axis of the path relative to the axis of the span structure.

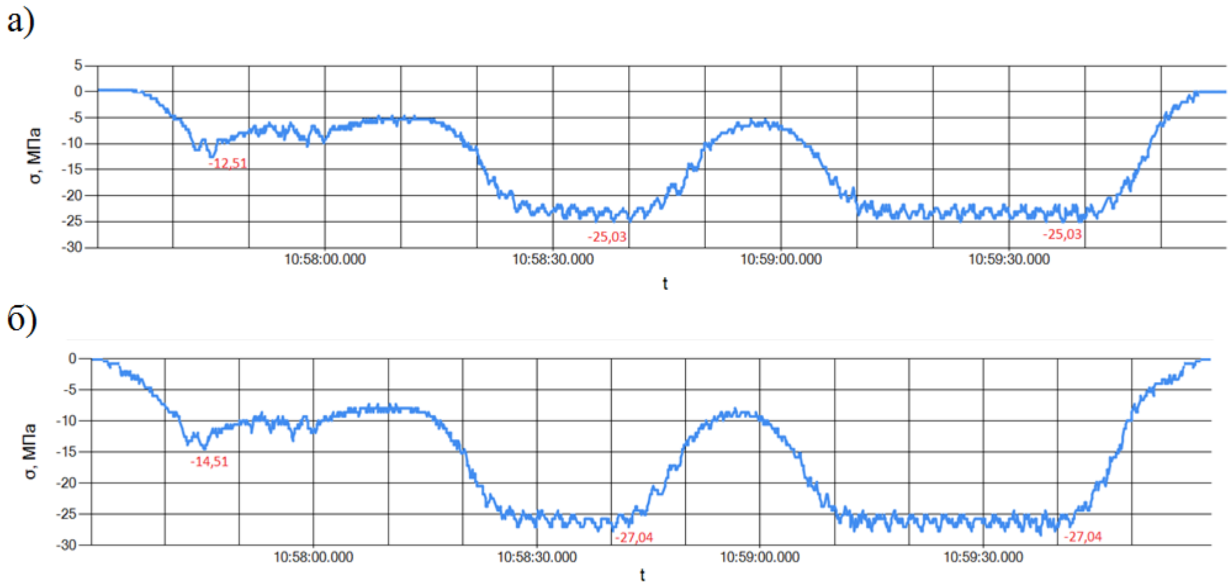

Figure 4 – Variation in stresses in the left (a) and right (b) lower belts of the trusses (panel 8-9) of the span structure 1 when the locomotive TEZ3A is passed with the freight train ("assembly")

The stress diagrams in the belts of the trusses differ significantly from the stress diagrams in the elements of the carriageway, both in appearance, and in terms of the quantitative characteristics of the stresses and their qualitative composition. In particular, the greatest stresses in the left and right longitudinal beam of the carriageway (panel 7-8) of the span structure 1 are observed from the action of the locomotive when entering the bridge and from the impact of the loaded bunkers in the middle and loaded gondolas at the end of the composition (figure 5a, b), and they are almost equivalent in quantitative characteristics.

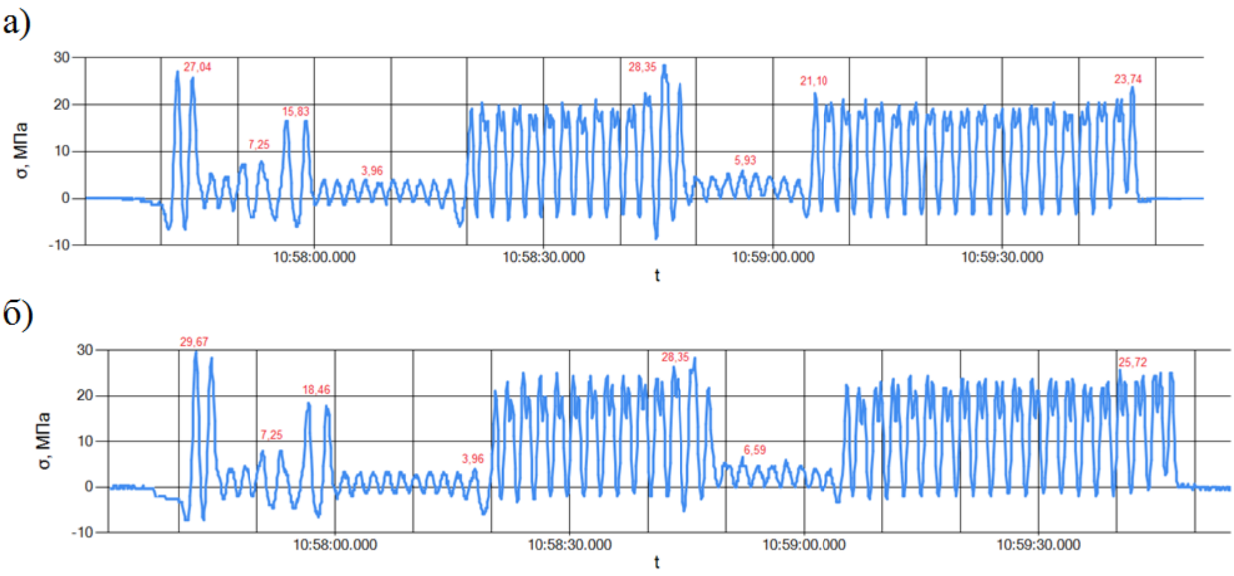

Figure 5 – Variation in the stresses in the left (a) and right (b) longitudinal beams of the carriageway (panel 7-8) of the span structure 1 when the locomotive TEZ3A with the freight train ("assembly") passes

The greatest stresses appearing in the belts of the trusses when exposed to the same loaded bunkers in the middle and loaded gondola cars at the end of the composition, are 2 times higher than the stresses from the locomotive effect (figure 4a, b).

This is explained, firstly, by the fact that empty tanks and gondola cars are located in the head of the convoy, and secondly, when the vehicle is moving at a low speed (25 km/h), the span structure is not fully loaded yet.

The stresses in the transverse beam (8) of the carriageway of the span structure 1 when passing the loaded bunkers in the middle and the laden open-top wagons at the end of the composition (figure 6) do not fall below 12 MPa.

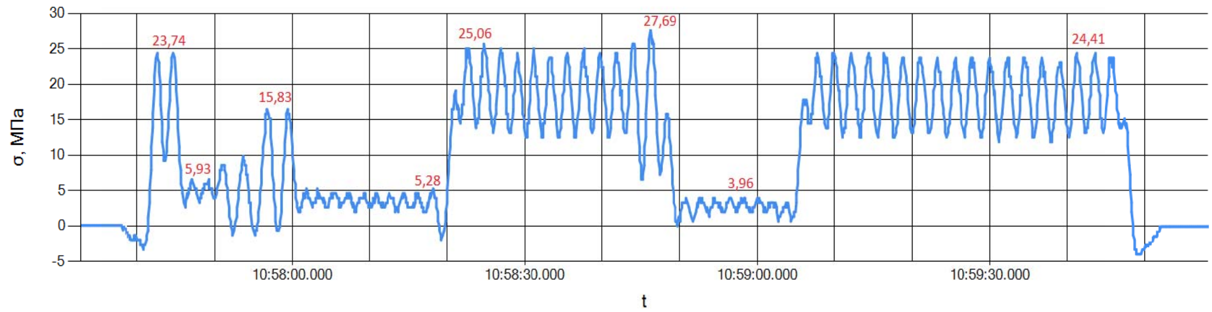

Figure 6 – Variation of stresses in the transverse beam (8) of the carriageway of the span structure 1 when the locomotive TEZ3A is passed with the freight train ("assembly")

It should be noted that the maximum stresses at the passage of this composition are fixed in the left and right longitudinal beams of the carriageway (panel 8-9) of the span structure 1 (figure 7a, b).

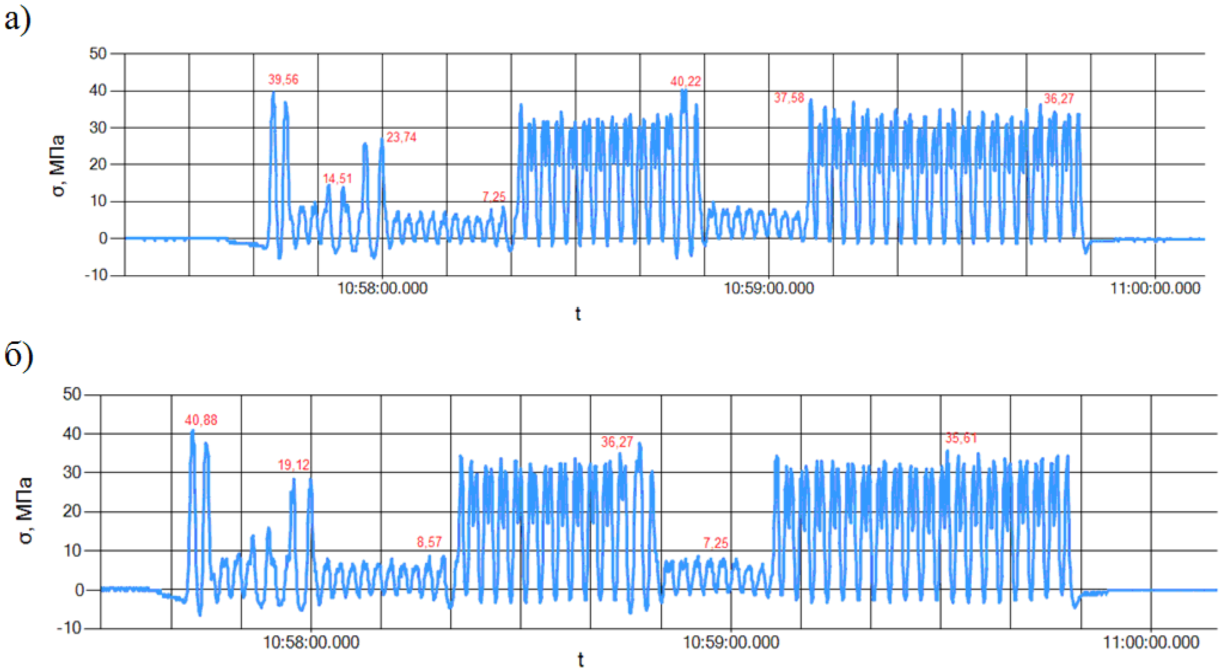

Figure 7 – Change of stresses in the left (a) and right (b) longitudinal beam of the carriageway (panel 8-9) of the span structure 1 when the locomotive TEZ3A is passed with the freight train ("assembly")

Extremes of measured stresses in elements of the structure of trusses

# p.	Type of rolling stock	Lower Belt of the Left Truss T 1	Lower Belt of the Right Farm T 4	Right longitudinal beam of the roadway (7-8) T 6	Right longitudinal beam of the roadway (7-8) T 5	Right longitudinal beam of the roadway (8-9) T 3	Left longitudinal beam of the roadway (8-9) T 7	Cross beam of the roadway (8) T 2
1	2	3	4	5	6	7	8	9
Measured stresses in structural elements of PS 1, MPa								
1	Single SKD6	-10	-10	28	27	39	38	23
2	Single TE33A	-9, -9	-10, -9	32, 29	28, 30	42, 41	39, 41	25, 26
3	Talgo	-14	-14	31	28	38	41	26
4	Passenger	-12, -12, -12, -14, -12, -12	-12, -12, -12, -9, -12, -12	30, 30, 30, 30, 31, 32	28, 26, 27, 28, 27, 28	40, 41, 40, 40, 43, 41	41, 40, 38, 38, 40, 40	26, 26, 26, 27, 26, 26
5	Empty Cargo	-19, -11, -12	-19, -11, -11	27, 30, 28	28, 26, 28	39, 42, 40	40, 39, 41	28, 26, 27
6	Cargo laden	-26	-28	29	27	38	41	29
7	Cargo prefabricated	-25, -22, -24, -25, -28	-28, -21, -25, -24, -28	30, 31, 30, 28, 29	28, 28, 28, 25,27	41, 41, 42, 38, 39	40, 40, 39, 37, 42	28, 28, 29, 28, 30
Measured stresses in structural elements of PS 5, MPa								
8	Single SKD6	-10	-10	33	32	25	28	25
9	Single TE33A	-10, -10	-10, -11	34, 34	34, 34	28, 25	29, 30	26, 27
10	Single 2ТЭ10М	-16	-16	33	32	24	27	27
11	Cone of locomotives ТЭ33А and СКД6	-16	-17	34	34	26	29	26
12	Talgo	-12, -12	-13, -12	34, 34	34, 34	27, 26	27, 29	26, 26
13	Passenger	-13, -14, -12, -12, -12	-13, -12, -12, -13, -13	32, 33, 33, 34, 33	35, 32, 36, 32, 36	27, 26, 23, 26, 23	28, 29, 26, 28, 28	28, 26, 26, 26, 26
14	Empty Cargo	-26, -23	-27, -23	34, 33	33, 33	27, 26	24, 25	27, 28
15	Cargo laden	-27, -27, -27, -26, -26	-27, -26, -29, -27, -26	32, 34, 33, 33, 34	32, 33, 35, 32, 32	23, 26, 25, 25, 26	29, 30, 27, 28, 28	28, 28, 26, 29, 29
16	Cargo prefabricated	-28, -26	-28, -26	35, 33	34, 35	27, 25	30, 26	29, 28

As is known, the bridge class (load-carrying capacity of the bridge) is determined by the weakest element of the defective span structure itself. Table shows the extremes of the measured stresses in the elements of the structures of span structures 1 and 5 that arise when different types of rolling stock are exposed. It can be seen that the stresses in the longitudinal beams of the carriageway of the span structure 1 considerably (by 30-35%) exceed the stresses in similar beams of the span structure 5.

Conclusions. Analysis of the measured stresses in the elements of the span structures under the rolling stock, in general, showed the joint work of the structural elements of the trusses, the uniform distribution of the mobile load in the plane across the bridge and, accordingly, the absence of displacement of the track axis relative to the span axis.

However, from the analysis of the stresses presented in table 1 (columns 7.8), it can be concluded that the stresses in the longitudinal beams of the carriageway of the span structure 1 are significantly (by 30-35%) higher than the stresses in similar beams of the span structure 5. Consequently, the longitudinal beams of the carriageway of the span structure 1 have a lower margin of strength, and, correspondingly, of a bearing capacity than the longitudinal beams of the span structure 5.

The use of digital technologies in the measurement and analysis of stresses in the elements of trusses from the impact of various rolling stock made it possible to identify the most faulty span structure and significantly reduce the labor costs for conducting a survey of the structure.

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ЭКИПАЖ ӘСЕРІНДЕГІ МЕТАЛДЫ ТЕМІРЖОЛ КӨПІРІ ЭЛЕМЕНТТЕРІНДЕГІ КЕРНЕУЛЕР

Аннотация. Мақалада теміржол көпірінің металды аралық құрылымынын зерттеу кезінде мобильді өлшеуші-есептеуші кешенді қолдану қажеттілігі негізделген, сондай ақ жылжымалы құрамның әртүрлі типтерінің әсер ету кезіндегі ферма конструкциясы элементтерінде пайда болатын кернеулер келтірілген.

Түйін сөздер: көпір, экипаж, металды ферма, аралық құрылым, сенімділік, кернеу.

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НАПРЯЖЕНИЯ В ЭЛЕМЕНТАХ МЕТАЛЛИЧЕСКИХ ЖЕЛЕЗНОДОРОЖНЫХ МОСТОВ ПРИ ВОЗДЕЙСТВИИ ЭКИПАЖА

Аннотация. В статье обоснована необходимость применения мобильных измерительно-вычислительных комплексов при обследовании протяженных металлических пролетных строений железнодорожных мостов, а также представлены напряжения, возникающие в элементах конструкции фермы при воздействии различных типов подвижного состава.

Ключевые слова: мост, экипаж, металлическая ферма, пролетное строение, надежность, напряжения.

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