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JUSTIFICATION OF CAPITAL REPAIR OF A HIGHWAY BRIDGE WHEN CHANGING THE LOAD

Purpose. The purpose of the scientific article is to substantiate the implementation of capital repairs of a road bridge that has been significantly damaged as a result of hostilities. The achievement of this goal is based on numerical analysis of the model using the finite element method, taking into account recommendations for reinforcing bridge elements. **Methodology.** Loads and impacts gathered during numerical analysis ensure the verification of bridge structures and elements for strength, stability, and durability according to the first group of limit states criteria, as well as stiffness and crack resistance according to the second group of limit states criteria. Temporary loads and impacts for structures calculating for all groups of limit states are taken with reliability factors for loads γ_f and dynamics factors (1+μ). The structure utilizes standard I-section beams for the superstructure with lengths of 22.16 m and 32.96 m, designed according to the working drawings and calculations developed by "International Design Institute" LLC and modeled in the professional structural analysis software Lira-CAD. **Findings**. The calculation of the beams was performed in two stages, reflecting their work: Stage 1 – Concreting the slab, the slab is not included in the structural analysis; Stage 2 – The slab is included in the span work, concreting of sidewalks without inclusion in the structural analysis, laying of asphalt concrete pavement, barrier railing, guardrails and expansion joints. The structure of the temperature-continuous monolithic slab, calculated using the Lira-CAD structural analysis software, has been reinforced considering the entire range of loads. **Originality**. The originality of the study lies in the scientific substantiation of carrying out major repairs on the bridge, which provides the possibility of the passage of temporary vertical loads according to H-30 and NK-80 schemes and pedestrian load on the sidewalks. **Practical value.** The practical value lies in the justification of the works on the restoration of the bridge design characteristics. Moreover, the calculations of the loads and impacts provide verification of the structures and elements of the bridge as well as the sequence of work operations during construction.

Keywords: road bridge; capital repairs; load change; hostilities; load capacity

Introduction

Restoration or capital repairs is an important task for any structure built in the previous century. Each structure has a period of normal operation, after which the care of such a structure becomes more laborious and requires intervention in the structure itself by replacing a large part of it or even the entire structure.

The bridge is an extremely critical structure both on the highway and on any other transportation routes. It is designed for constant operation with extreme loads, which subsequently lead to failure.

With the beginning of the Russia-Ukraine war, another factor was added to all the others that affect it throughout the entire service life, which is capable of destroying the bridge in a matter of seconds, namely hostilities.

A large number of bridges in Ukraine have been damaged as a result of hostilities. Moreover, one part of the bridges has suffered minor damage and can be operated after survey and inspection of the bridge by specialists. The costs of their restoration are relatively small (Кваша, & Салійчук, 2013). The second part of this number is partially destroyed: blown up supporting parts, damaged span structures, destroyed supports, unsuitable access roads, etc. In this case, the bridge is surveyed and inspected by certified experts (Davis, Hoomaan, Agrawal, Sanayei, & Jalinoos, 2019). The experts provide a technical report based on the results of the inspection, and also prepare conclusions and recommendations for the further operation of the structure (Тютькін, & Остапенко, 2020). In this case, the question arises (Yardim, Periku, & Köroglu, 2022): does it make sense to restore the old bridge or is it better to build a new bridge, since repairing the bridge crossing will take a lot of time and resources (Zhou, J., Lu, & Zhou, Z., 2022). The third part of the set of bridges is completely destroyed: there is nothing to inspect, therefore specialists are needed who will design a new bridge along the old axis or choose an alternative crossing point over the obstacle. All three scenarios have been analyzed before, during wars and military conflicts around the world (Gega, & Bozo, 2017).

Bridge restoration or capital repairs are always carried out in accordance with current regulations, with a reserve to increase load capacity or traffic for the duration of its service life (Ding, Hao, Xia, & Deeks, 2012).

Purpose

The purpose of the scientific article is to substantiate the implementation of capital repairs of a road bridge that has been significantly damaged as a result of hostilities. The achievement of this goal is based on numerical analysis of the model using the finite element method, taking into account recommendations for reinforcing bridge elements.

Methodology

The bridge under study is located on a highway on the border of the settlement of Bogorodichne. The bridge was used for traffic in both directions and for pedestrians. The bridge was partially destroyed as a result of military aggression by the russian federation, and traffic across the bridge is currently impossible (Fig. 1).

Fig. 1. Fragment of the general view of the destroyed bridge crossing

The bridge was built in 1972, it crosses the non-navigable Siverskyi Donets River. The width of the channel is 91 m, the depth is 2.5 m. The bridge is located on a straight line in plan and is a nine-span section prefabricated girder reinforced concrete bridge. The bridge layout is as follows: 5×22.16+3×33.0+22.16 m.

In 2019, the routine maintenance and medium repairs of the structure were carried out without increasing the load-bearing capacity.

During the routine maintenance of the structure, all supports were repaired with the restoration of the protective layer of concrete and the application of a hydrophobic protective coating.

Bridge spans 1-2, 5-6 and 9-10 are reinforced concrete simply supported prefabricated girders, in cross section they consist of 6 beams, made according to the standard design 122-62. The length of the beams is 22.16 m, the height is 1.2 m, the distance between the beams axes is 1.67 m. The beams are connected using diaphragms.

Bridge spans 6-7, 7-8, 8-9 are reinforced concrete simply supported prefabricated beam structures, in cross section they consist of 6 beams, made according to the standard design 149-62. The length of the beams is 32.96 m, height is 1.7 m, the distance between the beams axes is 1.67 m. The beams are connected using diaphragms.

The results of the survey indicate the following: 1) the bridge deck is effectively completely destroyed; 2) bridge spans No. 4-5, 5-6, 6-7, 7-8, 8-9, 9-10 are destroyed and require replacement; 3) complete destruction of supports No. 6, 7, 8 is noted; 4) the percentage of the approaches wear is 20 %.

Due to military aggression by the russian federation, the bridge has become inoperable, traffic across it is impossible. Due to significant destruction, the remaining resource of the bridge has been exhausted, although the surviving elements are in good condition. Thus, capital repairs require scientific research, which is necessary to justify the change in load.

Loads and impacts gathered during numerical analysis ensure the verification of bridge structures and elements for strength, stability, and durability according to the first group of limit states criteria, as well as stiffness and crack resistance according to the second group of limit states criteria (Xin, Li, Wang, & Hampson, 2022).

The loads taken into account in this analysis are combined into several groups (Chase, & Gáspár, 2000).

Permanent:

- self-weight of the structures;
- soil pressure of the embankment.

Temporary from rolling stock and pedestrians (Kim, Heo, You, & Choi, 2017):

- vertical loads;
- horizontal transverse impacts of rolling stock;
- horizontal longitudinal loads from braking or traction.

Others:

- wind loads;
- temperature and climate loads;
- friction in the bearings.

It should be noted that some of the loads for the restorable structures of the bridge are insignificant and are not included in this calculation. Such a load, for example, is an ice load that acts below the lines of installation of new support structures and does not have a direct impact on them.

During the structural analysis of the bridge according to the first and second reliability classes, a reliability factor for responsibility γ_n is applied to the design load values. This factor is used as a multiplier for the effect of the action (deflection, force, stress), except for cases when this effect is unloading.

According to DBN V.1.2-15:2009 (ДБН В.1.2-15:2009, 2009), the determination of forces in bridge elements when restoring its original load-bearing capacity, temporary moving loads and its location scheme are taken according to the standards by which the bridge was first designed, namely SN 200-62 for the time of bridge construction in 1962-1986.

Therefore, temporary loads and impacts for calculating structures for all groups of limit states are taken with reliability factors for loads γ_f and dynamics factors (1+μ) (Fu, & You, 2009).

The structure utilizes standard I-section beams for the superstructure with lengths of 22.16 m and 32.96 m, designed according to the working drawings and calculations developed by "International Design Institute" LLC and modeled in the professional structural analysis software Lira-CAD (Fig. 2).

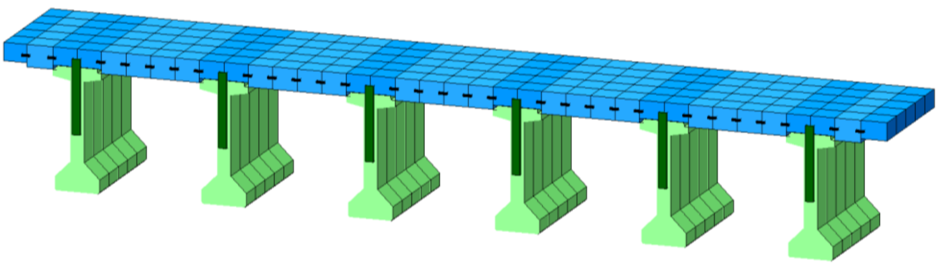

Fig. 2. Visualization of the calculation model of the span in Lira-CAD

Findings

The calculation of the beams was performed in two stages, reflecting their work.

Stage 1 – Concreting the slab, the slab is not included in the structural analysis.

At this stage, the self-weight of the monolithic concrete slab, not included in the work and the prefabricated beam itself is taken into account (Fig. 3).

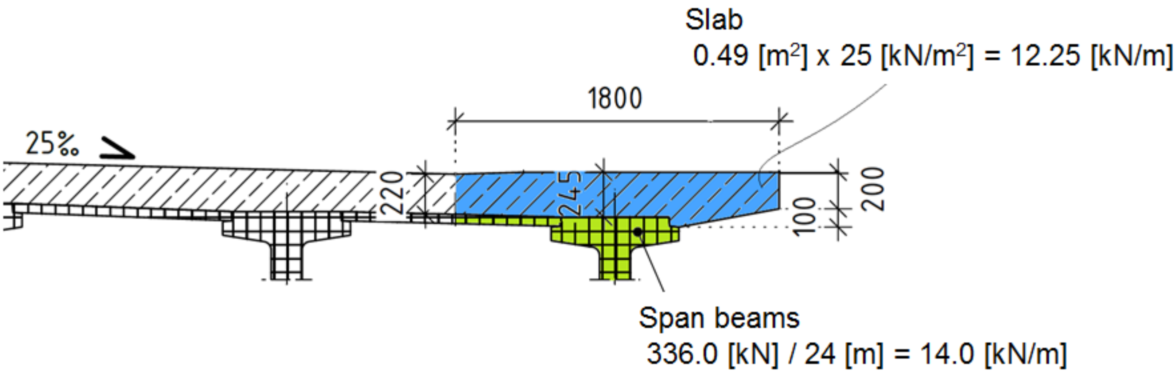

Fig. 3. Load on the beam according to stage 1

Stage 2 – The slab is included in the work, concreting of sidewalks without inclusion in the structural analysis, laying of asphalt concrete pavement, barrier railing, guardrails and expansion joints.

The calculation of the temperature-continuous monolithic slab was performed. The following initial data was accepted for the calculation.

Materials:

- longitudinal main reinforcement of grade A400C;
- transverse main reinforcement of grade A400C;
- concrete of B35 class.

Concrete cover to the main reinforcement:

- monolithic slab – top 55 mm / bottom structural;
- sidewalk slabs – top 55 mm / sides 40 mm;
- prefabricated formwork slab – top structural / bottom minimum of 20 mm.

The structure of the temperature-continuous monolithic slab, calculated using the Lira-CAD structural analysis software, has been reinforced (Fig. 4) considering the entire range of loads. (Fig. 5-6).

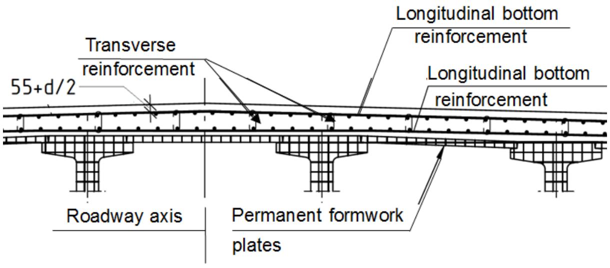

Fig. 4. Slab reinforcement scheme

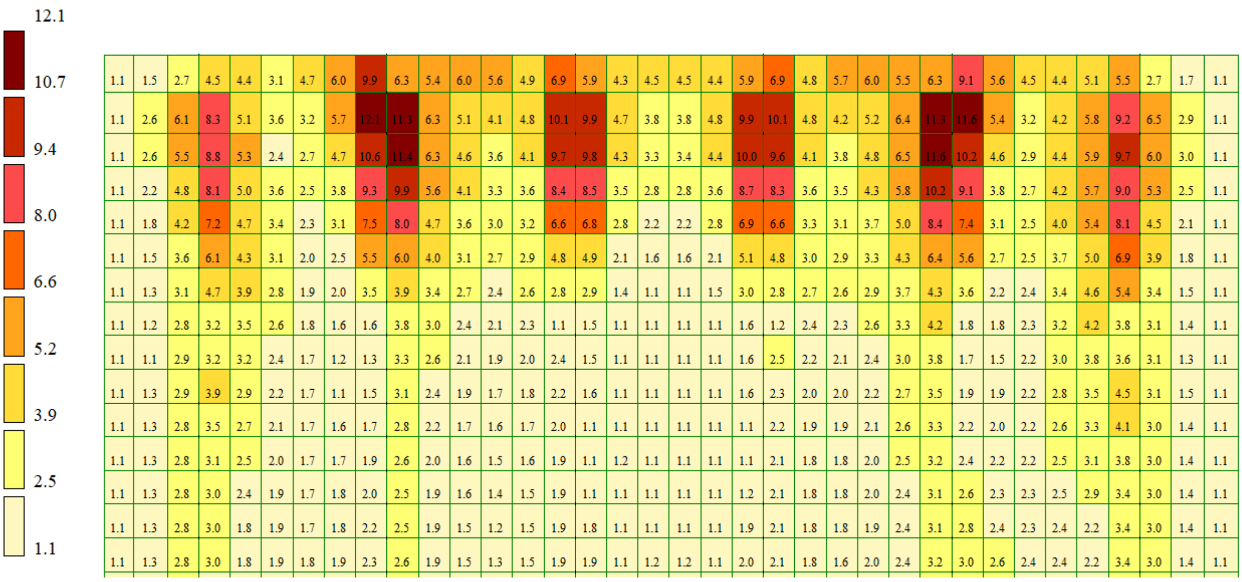

Fig. 5. Maximum required reinforcement across the bridge above the support

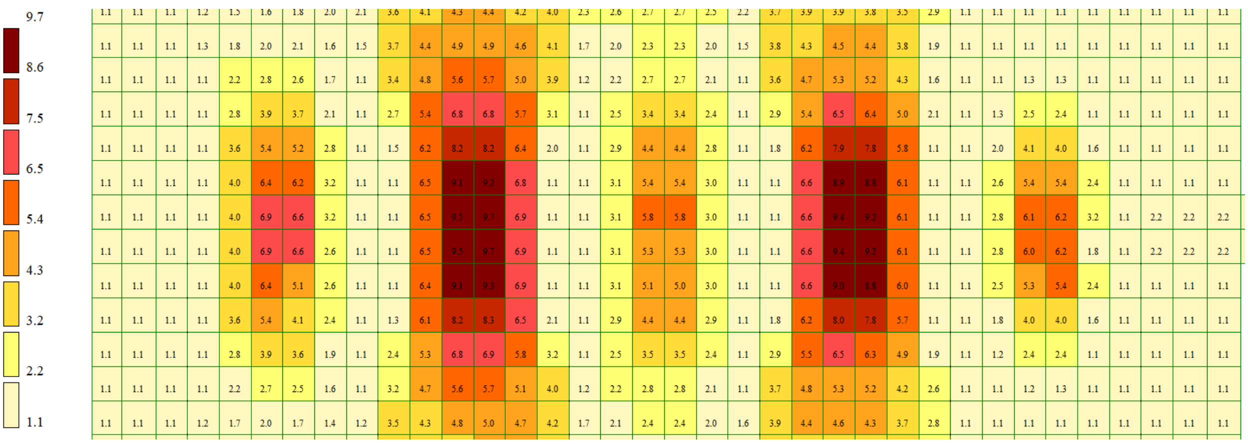

Fig. 6. Maximum required reinforcement across the bridge in the span

We adopt the upper and lower main reinforcement of the slab in the spans:

- across the bridge as equal to Ø16 mm;
- along the bridge – at least Ø12 mm.

Reinforcement of continuous parts above the supports: additional bottom and top reinforcement along the bridge of Ø16 mm (*L*=4 m).

The bridge supports were also calculated, for which the following initial data were accepted.

Materials:

- main longitudinal reinforcement grade – A400C;
- transverse reinforcement grade – A240C;
- concrete class:
- pier column – B35;
- pier cap – B35.

Protective concrete layer to the clamps:

- pier column – minimum of 40 mm;
- pier cap – 40 mm.

The calculation is carried out for intermediate piers with the options for supporting the span structures of 32.96 + 32.96 and 22.16 + 32.96 m (Fig. 7). The option 22.16 + 22.16 m is not considered, since it is not decisive.

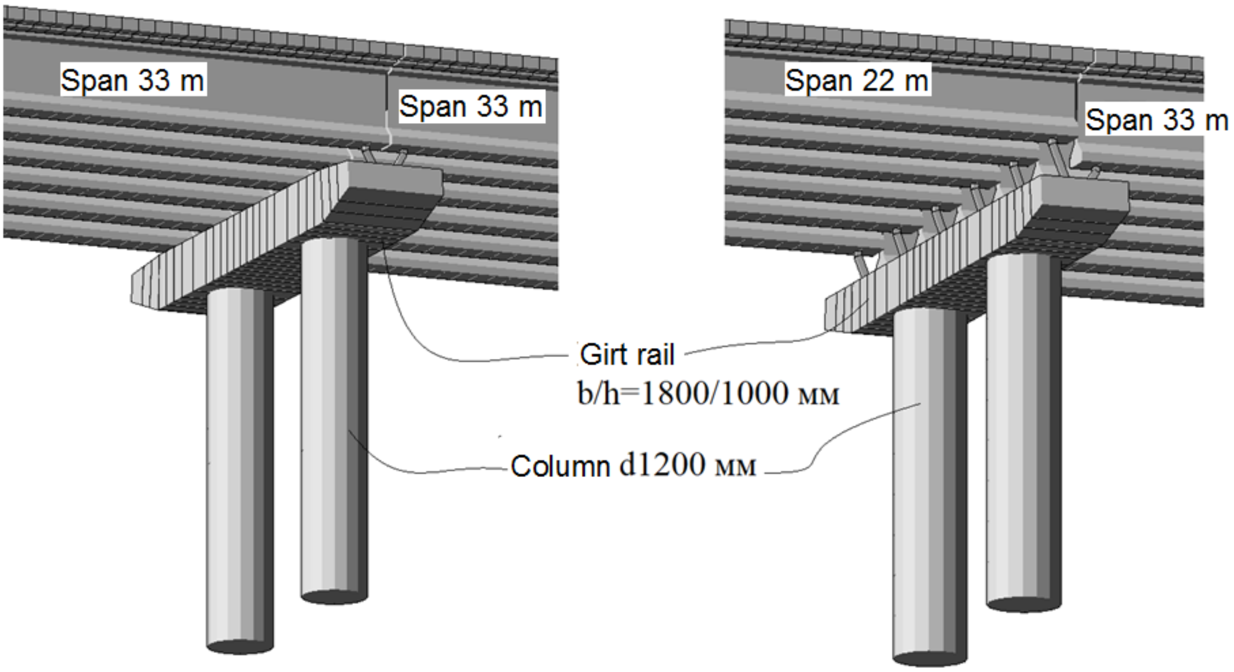

Fig. 7. Visualization of the calculation model of piers with Lira-CAD

The reinforcement of the supports was performed using the professional Lira-CAD complex (Fig. 8-9).

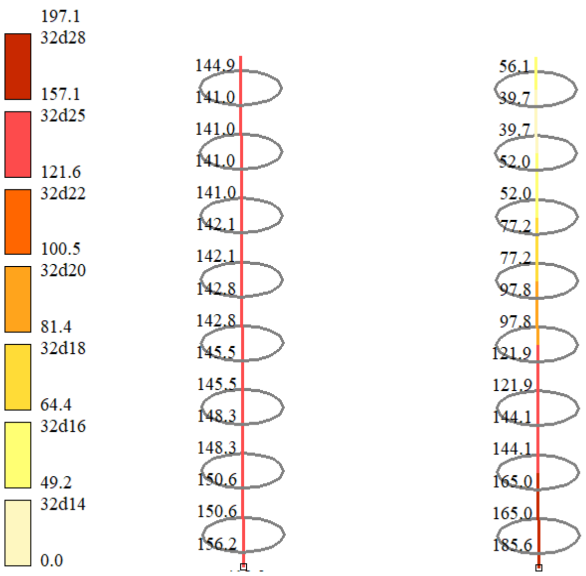

Fig. 8. Required longitudinal reinforcement of pier columns

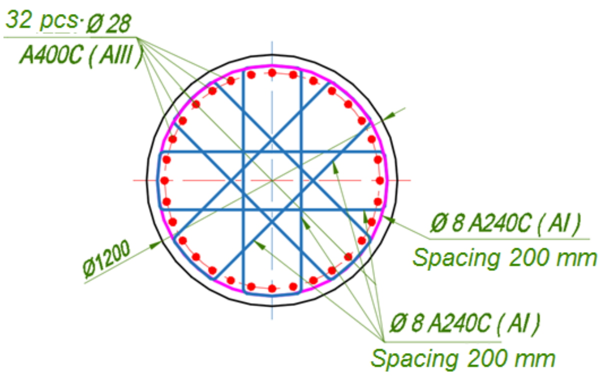

Fig. 9. Reinforcement scheme of columns

Thus, a comprehensive set of studies of the bridge subjected to capital repairs with a change in load has been carried out.

Originality and practical value

The originality of the study lies in the scientific substantiation of carrying out major repairs on the bridge, which provides the possibility of the passage of temporary vertical loads according to H-30 and NK-80 schemes and pedestrian load on the sidewalks. The practical value lies in the justification of the works on the restoration of the bridge design characteristics. Moreover, the calculations of the loads and impacts provide verification of the structures and elements of the bridge as well as the sequence of work operations during construction.

Conclusions

After analyzing the technical condition of the bridge, it can be concluded that it is advisable to carry out repairs by restoring the design characteristics of the structure. Based on the calculations performed in the Lira-CAD software complex, a decision was made to carry out capital repairs with a change in load. To withstand the loads for which the structure is designed, it is necessary to carry out repairs, which include the following operations: 1) complete restoration of supports No. 6, 7, 8; 2) repair of caps, bearing pedestals and installation of new bearings on supports No. 5, 9, 10; 3) installation of new beams of span structures 4-5, 5-6, 6-7, 7-8, 8-9, 9-10; 4) dismantle the sidewalk blocks, the guardrail and barrier rail, install new sidewalks and new elements; 5) install a new drainage from the bridge and a drainage collector; 6) install new lighting poles; 7) install new waterproofing of the roadway; 8) install a new road surface structure.

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ОБҐРУНТУВАННЯ КАПІТАЛЬНОГО РЕМОНТУ АВТОМОБІЛЬНОГО МОСТУ ПРИ ЗМІНІ НАВАНТАЖЕННЯ

Мета. Метою наукової статті є обґрунтування проведення робіт з капітального ремонту автомобільного мосту, який отримав значні пошкодження внаслідок бойових дій. Досягнення цієї мети ґрунтується на чисельному аналізі моделі методом скінченних елементів із врахуванням рекомендацій з армування елементів мосту. **Методика.** Зібрані під час чисельного аналізу навантаження і впливи забезпечують перевірку конструкцій та елементів мосту на міцність, стійкість і витривалість за першою групою граничних станів, а також жорсткість і тріщиностійкість за другою групою граничних станів. тимчасові навантаження і впливи для розрахунку конструкцій за всіма групами граничних станів приймаємо з коефіцієнтами надійності за навантаженням γ_f та коефіцієнтами динаміки (1+μ). В конструкції використані типові І-подібні балки прогонової будови довжиною 22,16 м та 32,96 м, розроблені відповідно до робочих креслень та розрахунків розроблених ТОВ «Міжнародний проектний інститут» та змодельовані в професійному розрахунковому комплексі Ліра-САПР. **Результати.** Розрахунок балок виконувався в два етапи, що відображають їхню роботу: Етап 1 – Бетонування плити, плита не включена в роботу; Етап 2 – Плита включена в роботу, бетонування тротуарів без включення в роботу, вкладання асфальтобетонного покриття, бар’єрне огородження, поручневе огородження та деформаційні шви. Конструкція температурно-нерозрізної монолітної плити із армуванням з допомогою розрахункового комплексу Ліра-САПР заармована із врахуванням всього комплексу навантажень. **Наукова новизна.** Наукова новизна дослідження полягає в науковому обґрунтуванні проведення робіт з капітального ремонту мосту, що надає можливість пропуску по ньому тимчасових вертикальних навантажень за схемами Н-30, НК-80 та пішохідного навантаження на тротуарах. **Практична значимість.** Практична значимість полягає в обґрунтуванні виконання робіт з відновлення проєктних характеристик мосту. Причому проведені розрахунки навантаження і впливів забезпечують перевірку конструкцій та елементів мосту та послідовність виконання робіт під час будівництва.

Ключові слова: автомобільний міст; капітальний ремонт; зміна навантаження; бойові дії; вантажопідйомність

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