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SOME ASPECTS OF THE RESTORATION OF TRANSPORT INFRASTRUCTURE FACILITIES

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This paper examines certain aspects of the restoration of damaged transportation infrastructure facilities. A study to select the rational bridge structural system in which its elements damage does not lead to the destruction in whole and the structure will be capable to restoration was done. The article examines issues related to the expropriation of land plots for the construction and reconstruction of bridges in Ukraine, as well as the legislative acts governing these activities.

Keywords: land alienation, public need, public necessity, bridge restoration, rational structural system, arch bridge, truss bridge.

Introduction

As of early 2022 (prior to the full-scale invasion), Ukraine's bridge infrastructure had a stable structure and was undergoing active modernization [1,2]. According to data from the State Agency of Motorways of Ukraine [3], there were 16,155 bridges under the jurisdiction of the state and local communities (table 1).

Table 1

Type of control	Quantity	Part (%)
State significance	5 845	36%
Local significance	10 310	64%

The issue of wear and tear was a key one. According to the results of a large-scale survey conducted in 2020–2021:

- 27% of bridges (approximately 4,300) were deemed to be "partially operational",
- 12% of bridges were in "inoperable condition" (fifth service condition—emergency).

The average age of most bridges was 55–60 years, and a significant number of them were designed to withstand loads that do not meet current standards. These past two years have seen a record number of repairs ahead of the full-scale invasion [3]:

- 2020 – 158 bridges on state highways were renovated and constructed,
- 2021 – 345 bridges were renovated and constructed (an all-time record since independence).

By 2025, the plan was to renovate at least 1,385 structures. The highest concentration of bridges was observed in regions with rugged terrain and a complex river network:

- Ivano-Frankivsk Oblast - ~1,400 structures,
- Zakarpattia Oblast – ~1,200 structures,
- Lviv Oblast - ~1,100 structures.

Apart from roadways, the Ukrzaliznytsia infrastructure included more than 7,000 engineering structures (including bridges and overpasses), of which approximately 3,500 were railway bridges.

The state of the bridge infrastructure in the wake of a full-scale invasion

Due to the full-scale invasion, Ukraine's transportation infrastructure has suffered unprecedented damage. As of early 2026, the total number of destroyed or damaged bridges and overpasses exceeded 346 (in government-controlled territories). On public roads, particularly on major routes, 157 bridges

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were destroyed. To maintain logistics, approximately 100 temporary crossings and modular bridges were constructed.

The regions that suffered the most severe damage were those located in areas of active combat or under occupation. The brunt of the damage fell on eight regions (table 2). The data is based on reports from the State Agency for Infrastructure Restoration and Development of Ukraine [4].

Table 2

Oblast	Estimated number of destroyed bridges	Key Objects / Notes
Kharkiv	~90	The most damage was caused by intense fighting
Donetsk	~70	Constant destruction due to the proximity of the front line (in particular, the bridges in Bakhmut and Lyman)
Kyiv	49	Most were blown up to halt the advance on the capital (Irpin, Stoyanka)
Kherson	~40	Including the strategic Antonivsky Bridge and the crossings over the Ingulets River
Chernihiv	31	In particular, the key bridges across the Desna River
Mykolaiv	28	Most of them were destroyed during the defense of Mykolaiv and the offensive on Kherson
Sumy	~25	Damage in border areas and on major highways (Highway H-12)
Zhytomyr	~10	Mainly in the northern areas (Route M-07)

In recent years, the State Agency for Infrastructure Restoration and Development of Ukraine has been actively working on the major repair and reconstruction of transportation infrastructure:

– 2022 – 41 bridges were repaired (8 of which were destroyed by the war, and the rest were in disrepair),

– 2023 – 45 structures were rebuilt (21 of which had been destroyed by the war),

– 2024 – approximately 40 bridges fully rebuilt (including 20 structures on state highways in the Kyiv, Chernihiv, and Kharkiv regions).

The installation of six more modular bridges is planned for 2026 [5,6] (with support from international partners, including UK Export Finance).

Even without taking military operations into account, the condition of the bridges remains critical [4]:

– About 10% of bridges are inoperable or in a state of disrepair.

– More than 3% have limited load-bearing capacity.

– The largest number of bridges is concentrated in Ivano-Frankivsk (over 1,400), Lviv, and Khmelnytskyi regions.

Determining Rational Structural Systems for Bridges

In view of the road bridges destroyed as a result of shelling, paying the attention to the nature of the damage and taking into account the probability of repeated attacks on new structures, it is necessary that the new bridges that will be built to replace the destroyed ones be designed with such structural system, in which its elements damage does not lead to the destruction in whole and the structure will be capable to restoration. This objective can be achieved by chose of a rational structural system, in which the failure of its elements leads to formation of such systems of the damaged structure that would be geometrically stable.

Considering the arch bridge with element configuration shown in Fig. 1(a) during the kinematic analysis we can see that when the some elements at various positions have been excluded, the damaged structures have been formed, which are geometrically stable (Fig. 1(b-e)). Therefore, such initial system meets the specified condition.

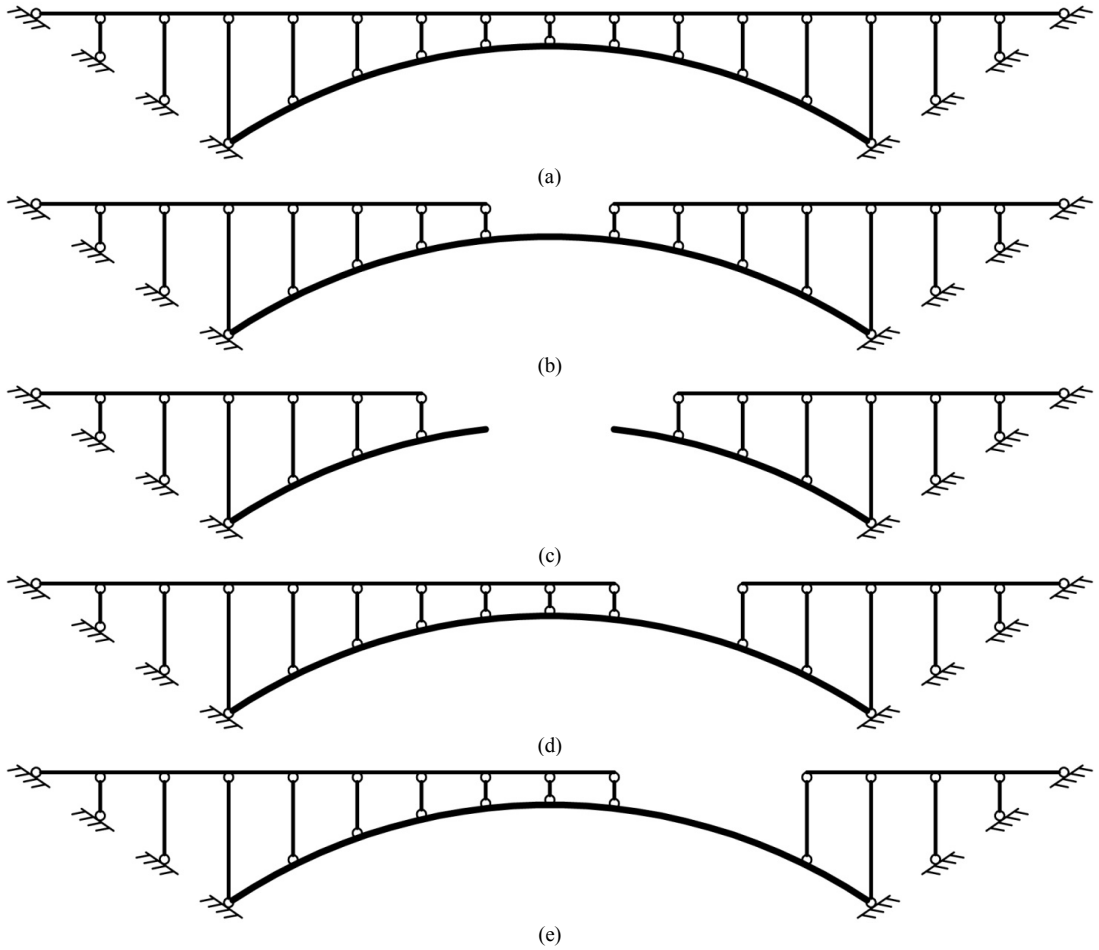

Fig. 1. Arch bridge system: (a) initial; (b) destruction case 1; (c) destruction case 2; (d) destruction case 3; (e) destruction case 4

Also, considering the truss bridge, shown in Fig. 2(a), in form of arch bridge like as Fig. 1(a), in this variant we can see, that when the some elements at various positions have been excluded, the damaged structures have been formed, which are geometrically stable, too (Fig. 2(b-e)). As a result the initial structure remains capability to be restored.

To reach a final conclusion as to which of the proposed systems is more rational, taking into account the possible destructions, it is necessary to make a comparative analysis of internal forces values in structural elements depended on external loads for both in the initial (Fig. 1(a), 2(a)) and in the damaged (Fig. 1(b-e), 2(b-e)) systems. For such a comparison, it is necessary to consider the structural model of compared structures, with the same loading scheme and draw forces diagrams (Figs. 3, 6).

The calculations results in form of axial force N and bending moment M diagrams for arch bridge and axial force N diagrams for truss bridge are shown in Fig. 4, 5 and 7, respectively.

The obtained results let make the conclusion that, if the probability of bridge structures destroying by shelling is absent, the compared variants are acceptable both. However, when consider the most dangerous positions of moving loads and their combinations (Figs. 8–10), will be seen, that truss bridge scheme is more acceptable.

Taking into account the damages of future structures under the possible shelling, from the analysis of the force diagrams for considered destruction cases can be seen, that the significant factor is the large bending moments in the arch bridge structural elements, compared to the truss bridge structure, where bending moments in its elements are nulled. The cross-section dimensions of structure elements are directly depended on this, and as a result, the material costs in their production.

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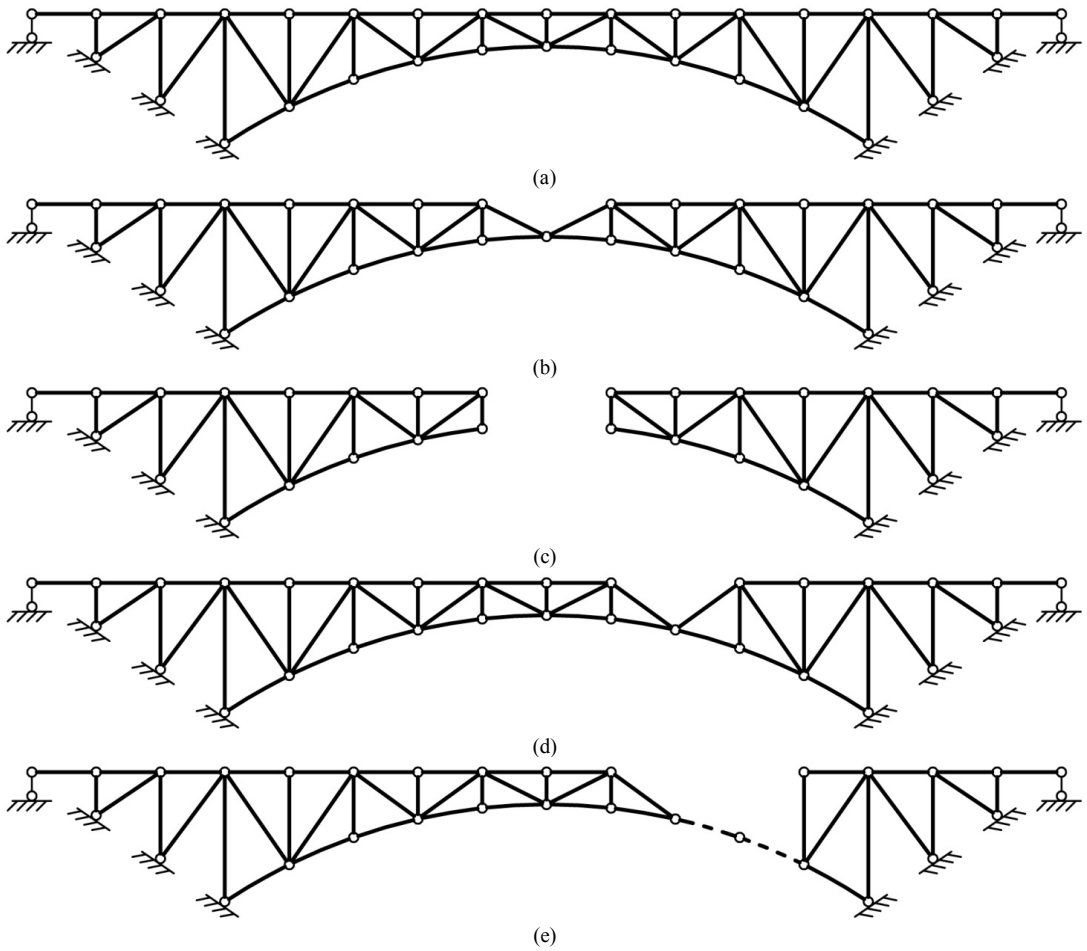

Fig. 2. Truss bridge system: (a) initial; (b) destruction case 1; (c) destruction case 2; (d) destruction case 3; (e) destruction case 4

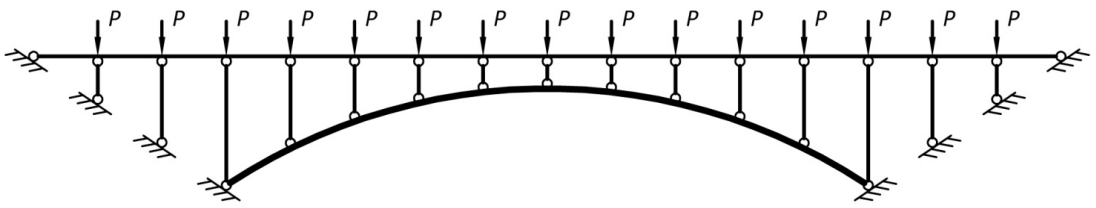

Fig. 3. Arch bridge, initial structural model

Summarizing, based on the results of the study to select the rational structural system, we can draw a final conclusion that for the construction of new road bridges instead of destroyed ones, the most acceptable is a truss bridge system with polygonal bottom chord along the outline of an arch, shown in Fig. 2(a).

Alienation of land plots during the construction and reconstruction of bridges

Bridges are classified as linear transportation infrastructure facilities; to construct them, government authorities have the right to purchase private land plots with the owner's consent. The alienation of land plots for the construction and reconstruction of bridges in Ukraine is governed by legislation, specifically the Law of Ukraine “On the Alienation of Land Plots and Other Real Estate Objects Located Thereon That Are Privately Owned for Public Needs or on Grounds of Public Necessity, etc., as a measure to meet public needs or for reasons of public necessity. The construction,

major repair, and reconstruction of bridges and overpasses are expressly defined by law as grounds for the purchase or compulsory acquisition of property.

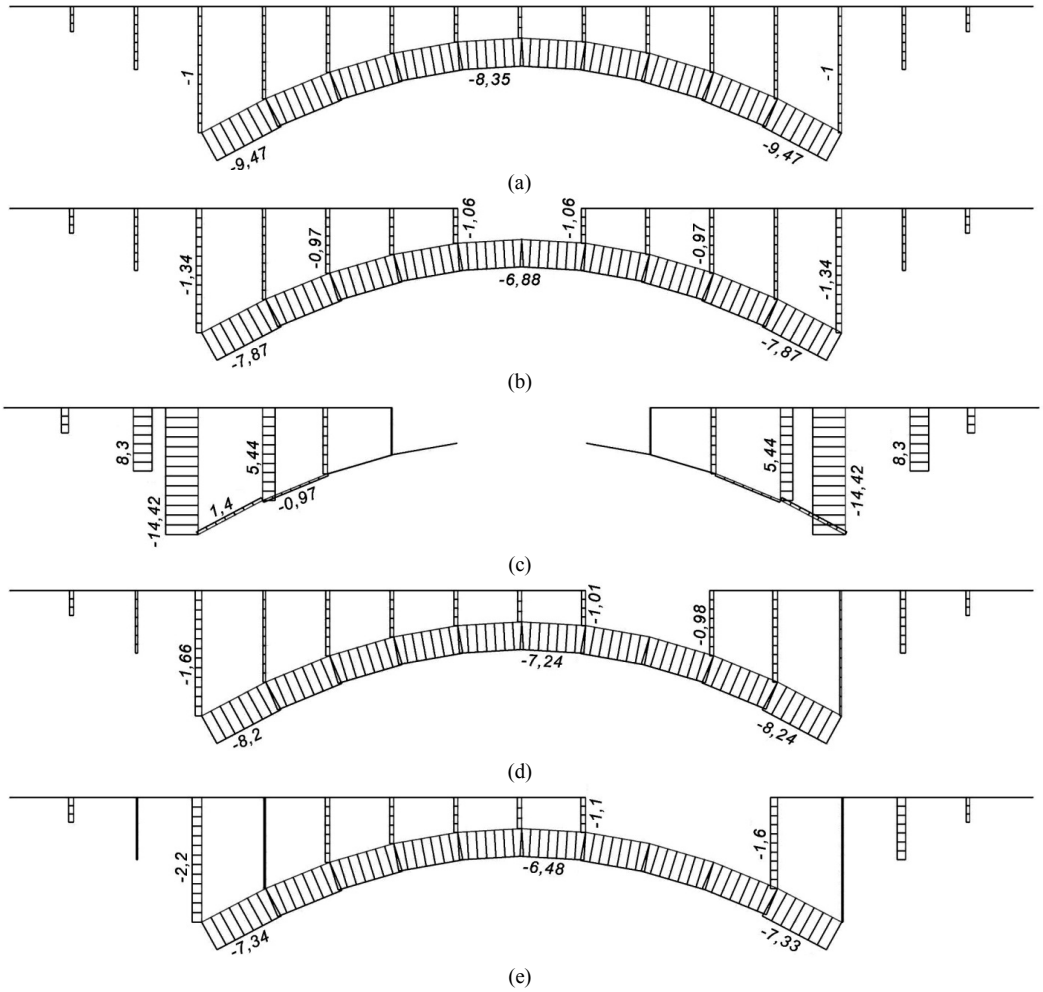

Fig. 4. Axial force diagrams *N*, 1·P (arch bridge): (a) by initial structural model; (b) destruction case 1; (c) destruction case 2; (d) destruction case 3; (e) destruction case 4

If the owner does not consent to the purchase, the land may be compulsorily acquired by court order on grounds of public necessity [7] (table.3). In particular, this is permitted for the construction of bridges on public roads or those built under concession agreements.

Table 3

Comparison criterion	Public need	Public necessity
1	2	3
Basis for application	Construction of roads, bridges, overpasses, protective structures, and energy facilities	Exclusive necessity for national security facilities, linear infrastructure, and airports
Method of transfer of ownership	Contractual: transfer of ownership through a legal transaction (sale, exchange)	Compulsory: carried out exclusively by decision of an administrative court
Role of the owner's consent	Decisive. Alienation is possible only by voluntary consent	No consent is required; the property is alienated against the owner's will, provided that compensation is paid

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1	2	3
Special conditions (concession)	General procedure	For bridges/roads under concession agreements, a 6-month window for voluntary consent is established prior to filing a lawsuit

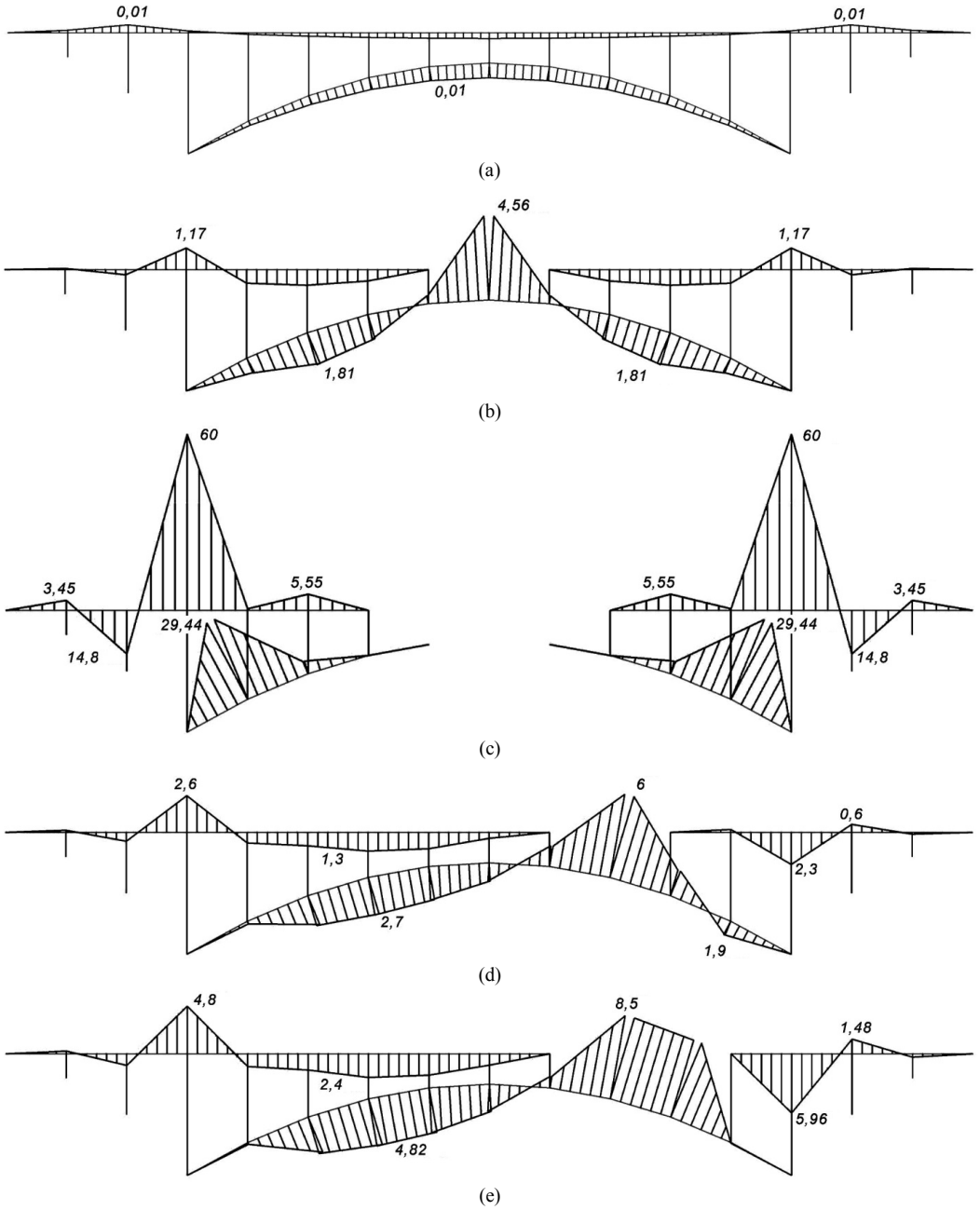

Fig. 5. Bending moment diagrams M, P·m (arch bridge): (a) by initial structural model; (b) destruction case 1; (c) destruction case 2; (d) destruction case 3; (e) destruction case 4

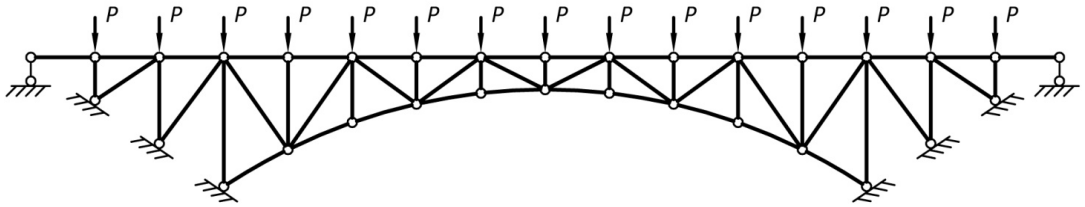

Fig. 6. Truss bridge, initial structural model

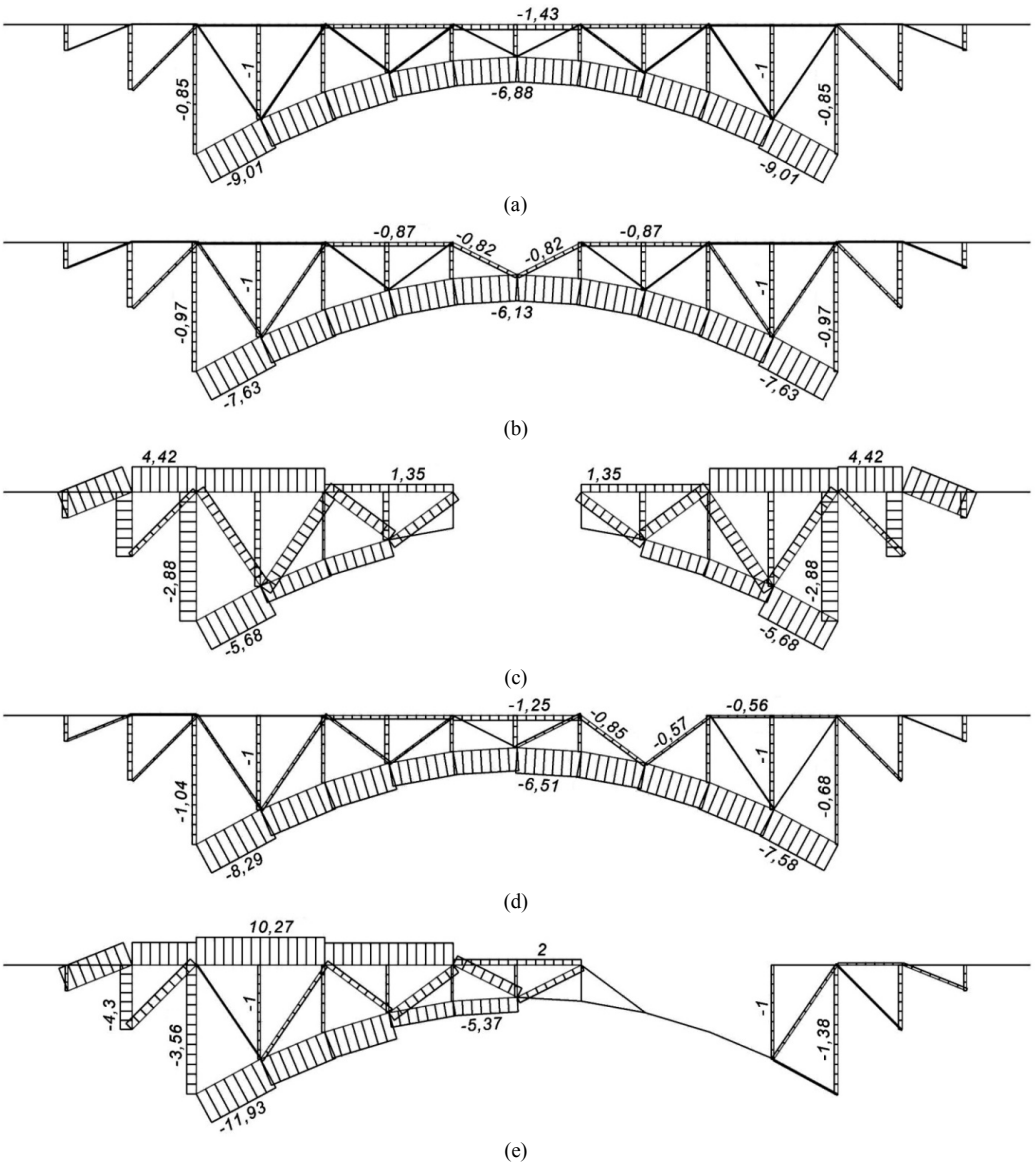

Fig. 7. Axial force diagrams *N*, 1·P (truss bridge): (a) by initial structural model; (b) destruction case 1; (c) destruction case 2; (d) destruction case 3; (e) destruction case 4

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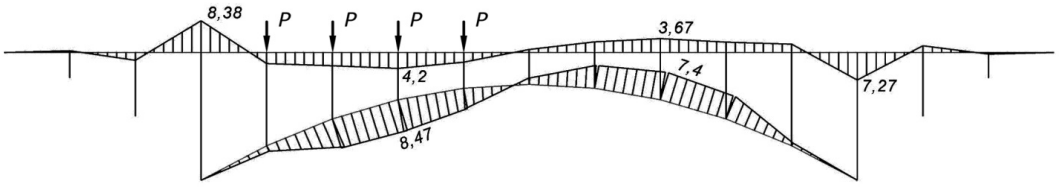

Fig. 8. Bending moment diagram M, P·m (arch bridge)

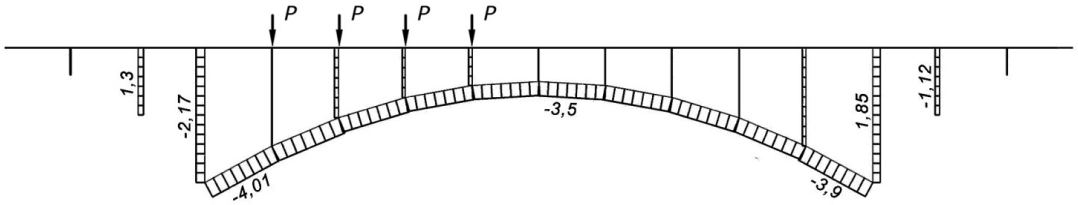

Fig. 9. Axial force diagram *N*, 1·P (arch bridge)

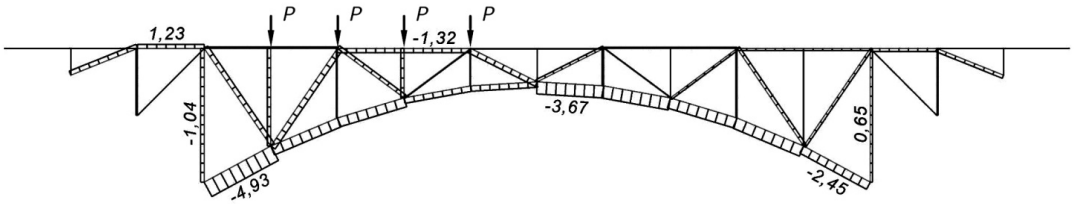

Fig. 10. Axial force diagram *N*, 1·P (truss bridge)

Compulsory alienation is an exceptional measure, the legality of which is based on proving that the "optimal option" for construction (due to economic and technological factors) cannot be implemented on other sites [7]; in a lawsuit filed with the administrative court, the government agency must prove that the reconstruction of the bridge is objectively impossible without terminating the defendant's property rights.

The Law of Ukraine "On the Expropriation of Privately Owned Land Plots and Other Real Estate Objects Located Thereon for Public Needs or on Grounds of Public Necessity" establishes specific provisions concerning the construction and reconstruction of bridges:

– generally, a decision to expropriate a plot expires after one year, however, for the construction and reconstruction of bridges, overpasses, and facilities for their operation, this period is three years;

– if only part of the land is needed for the bridge, but the owner believes that the remainder cannot be rationally used for its intended purpose, the entire land plot is subject to expropriation at the owner's request;

– in addition to the land, any buildings, structures, and perennial plantings located on it are subject to expropriation.

The constitutional principle of "prior and full compensation" is implemented through a complex structure of the redemption price [7]. The redemption price includes the market value of the land and real estate, as well as all losses incurred by the owner (including lost profits and the costs of processing documents for the new plot). Compensation may be paid in cash or by providing another plot of land or real estate of equivalent value. The value is determined based on an expert monetary appraisal. The owner has the right to hire their own appraiser if they disagree with the proposed price. The owner has the right to challenge in court both the decision to expropriate the property and the assessed value of the property. The state does not reimburse the owner for any repair or construction costs incurred after receiving notice of the expropriation.

Under martial law [8], property may be compulsorily alienated by decision of the military command for the needs of the state, with full compensation for its value [9] (either in advance or subsequently). During the special period of martial law, a special regime applies to the Uzhhorod District (Transcarpathia) [9]. Special regulations apply to the construction of bridges and overpasses in

this area. Compensation for property is paid at three times its value. If a voluntary agreement is reached, the owner receives an additional bonus equal to 20% of the triple value. The return of land plots to their former owners after the war is prohibited, which guarantees the stability of investments in strategic facilities. These provisions remain in effect until the state of martial law is lifted, but no later than January 1, 2027. In the case of a special regime in the Uzhhorod district, an administrative appeal against the decision does not suspend its effect.

Conclusions

The resilience of Ukraine's transportation infrastructure will be based on a combination of unique experience in the rapid restoration of structures—through the selection of rational designs and a flexible legal framework (as in Zakarpattia). The lawful and expeditious acquisition of land is the foundation of reconstruction. This will enable the transformation of ruins into modern infrastructure meeting EN (European Norms) standards.

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ДЕЯКІ АСПЕКТИ ВІДНОВЛЕННЯ ОБ'ЄКТІВ ТРАНСПОРТНОЇ ІНФРАСТРУКТУРИ

В статті розглядаються питання, пов'язані з відновленням об'єктів транспортної інфраструктури, а саме: відчуження земельних ділянок для будівництва транспортних споруд та вибором раціональних схем конструкцій автомобільних мостів. Станом на початок 2022 року (до моменту повномасштабного вторгнення) мостове господарство України мало сталу структуру в стані активного оновлення в межах програми «Велике будівництво» (2020–2021 рр.).Через повномасштабне вторгнення транспортна інфраструктура України зазнала безпрецедентних руйнувань. На початок 2026 року загальна кількість зруйнованих або пошкоджених мостів та мостових переходів перевищувала 346 одиниць (на підконтрольних територіях). На державних дорогах, безпосередньо на ключових трасах, було зруйновано 157 мостів. Для забезпечення логістики було зведено близько 100 тимчасових переправ та модульних мостів. З метою вибору раціональних схем конструкцій мостів, які мають бути зведені на заміну зруйнованих, здійснено дослідження і запропоновано схеми споруд, для яких пошкодження їх елементів не призводило до руйнування всієї споруди, а сама конструкція була спроможною до відновлення. Такими є конструкції, в яких виведення з ладу ряду складових елементів вихідної схеми призводить до утворення таких схем пошкодженої конструкції, які залишаються геометрично незмінюваними. Запропоновано два ключових варіанта: арковий міст та фермовий міст з полігональним нижнім поясом за обрисом арки. Шляхом аналізу епюр внутрішніх зусиль для вихідних розрахункових схем та розглянутих варіантів схем пошкоджених конструкцій, зроблено висновок про найбільш прийнятну схему. Оскільки мости належать до лінійних об'єктів транспортної інфраструктури, для розміщення яких органи влади мають право викуповувати приватні земельні ділянки за згодою власника, розглянуті питання відчуження земельних ділянок для будівництва та реконструкції мостів в Україні та законодавчі акти, які регулюють ці дії.

Ключові слова: відчуження земельних ділянок, суспільна потреба, суспільна необхідність, відновлення мостів, раціональна схема споруди, арковий міст, фермовий міст.

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SOME ASPECTS OF THE RESTORATION OF TRANSPORT INFRASTRUCTURE FACILITIES

This article examines issues related to the restoration of transportation infrastructure, specifically: the acquisition of land parcels for the construction of transportation facilities and the selection of optimal structural designs for road bridges. As of early 2022 (prior to the full-scale invasion), Ukraine's bridge infrastructure had a stable structure and was undergoing active modernization as part of the "Great Construction" program (2020–2021). Due to the full-scale invasion, Ukraine's transportation infrastructure has suffered unprecedented damage. As of early 2026, the total number of destroyed or damaged bridges and overpasses exceeded 346 (in government-controlled territories). On state roads, specifically on key routes, 157 bridges were destroyed. To ensure logistics, approximately 100 temporary crossings and modular bridges were constructed. In order to select rational bridge structures, that will be built to replace the destroyed ones, the structural systems in which its elements damage does not lead to the destruction in whole and the structure will be capable to restoration were studied and proposed. These are structures in which the failure of its elements leads to formation of such systems of the damaged structure that would be geometrically stable. Two key variants have been proposed: an arch bridge system and a truss bridge system with polygonal bottom chord along the outline of an arch. By analyzing the internal force diagrams for initial analytical models and the considered destruction cases, the conclusion about the most acceptable system was drawn. Since bridges are linear transport infrastructure objects, for the construction of which authorities have the right to purchase private land plots with the owner's consent, the issues of land alienation for the construction and reconstruction of bridges in Ukraine and the legislative acts regulating these actions were examined.

Keywords: land alienation, public need, public necessity, bridge restoration, rational structural system, arch bridge, truss bridge.

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Розглядаються деякі аспекти відновлення зруйнованих об'єктів транспортної інфраструктури. Здійснено дослідження і запропоновано схеми споруд, для яких пошкодження їх елементів не призводило до руйнування всієї споруди, а сама конструкція була спроможною до відновлення. Розглянуті питання відчуження земельних ділянок для будівництва та реконструкції мостів в Україні та законодавчі акти, які регулюють ці дії.
Табл. 3. Іл. 10. Бібліог. 9 назв.

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Tabl. 3. Figs.10. Refs. 9.

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