10.26411/83-1734-2015-2-55-5-23

Supports Used in Makeshift Reconstruction of Railway Bridges

Zenon Zamiar
The International University of Logistics and Transport in Wroclaw, Poland

Andrzej Surowiecki
The International University of Logistics and Transport in Wroclaw, Poland

Abstract
The topic of the article concerns supports (abutments and pillars) used in makeshift reconstruction of railway bridges. The causes determining difficulties in the construction of supports for makeshift bridges are listed. The following supports are discussed in terms of construction and assembly technology: wooden supports (from the so-called cages, piles, frame and frame-pile, flat and flat and frame as well as wooden splines), steel (pile, frame), as well as concrete and reinforced concrete. Attention was drawn to the necessity of making attempts to use the remaining supports, or fragments of permanent supports to the greatest possible extent.

Keywords: railway bridges, bridge supports, makeshift reconstruction

1. NOTES ON THE PROBLEMS OF RECONSTRUCTION OF DAMAGED BRIDGES

Destruction or partial damage to bridges may occur due to natural accidents (such as ice jam, washing supports, hurricane) or by deliberate destruction with explosives, or due to faulty workmanship, which in turn causes damage to the load-bearing structure or supports and loss of operational viability. the bridge [13 ÷ 16, 18 ÷ 19].

In any case, it is important to quickly restore train traffic on the destroyed or damaged bridge. Since permanent restoration usually takes a considerable amount of time, provisional restoration is used in critical cases as much faster [1, 6, 8, 11, 12–17].

Provisional reconstruction of bridges can be carried out on an ad hoc or temporary basis. The method of the adopted reconstruction of the bridge structure depends on the type of destruction, the date of reconstruction, the expected period of operation and the materials of the folding bridge structure [2 ÷ 5, 8 ÷ 10].

Ad hoc reconstruction is generally used in wartime conditions in order to quickly launch railway traffic routes, to ensure continuous operational and rapid military operations. Such bridges are made without clearing the river bed of fragments of a damaged bridge, and without taking into account the flow conditions of high water and ice [8].

The purpose of the temporary bridge reconstruction is to resume and maintain train traffic for at least 3 years. This method of reconstruction is used when there is a shortage of time, materials and equipment enabling the construction of a permanent bridge. The temporary restoration mode allows for the application of lighter technical conditions and the incorporation of materials with reduced strength properties [8].

When designing a provisional bridge reconstruction, first of all, attempts should be made to use the surviving supports or parts of the fixed supports.

This article presents the issues of supports used in makeshift reconstruction of railway bridges. In particular, the following supports were discussed in terms of construction and technology: wooden supports (from the so-called cages, piles, frame and frame-pile, flat and flat-frame, and wooden splines), steel (pile, frame), as well as concrete and reinforced concrete.

2. SUPPORTS USED IN MAKESHIFT RECONSTRUCTION OF BRIDGES

In the case of temporary or makeshift reconstruction of bridges, the supports are difficult and time-consuming elements of these structures. How quickly they can be made determines the date of launching traffic over the bridge. Difficulties in the construction of supports for makeshift bridges result, among others, from the following reasons [8]:

- an increased number of supports in relation to the number of supports for a permanent bridge,
- construction of foundations at the bottom of watercourses covered with scrap of fallen load-bearing structures and damaged supports,
- making supports in periods unsuitable for construction and assembly works,
- fabrication of structures not normally used for large support reactions (makeshift structures are generally light),
- shortening to a minimum the duration of traffic interruptions on railway routes.

The basic structural parts of the supports for temporary bridges are the foundation and the load-bearing core of the supports.

Due to the material, there are several types of supports [3, 4, 6 ÷ 11]: wooden, metal, concrete, reinforced concrete and supports made of various materials.

Due to the period of execution of the supports and the method of their additional use when lifting fallen bridge spans, three groups of supports are distinguished [8]:

- supports built only to take over the reactions from temporary spans,
- supports built during the lifting of fallen spans and constantly loaded with them during this time,
- supports built immediately to their full height and used to lift fallen spans.

The supports for provisional reconstruction of bridges can be made in a new place (often not in the axis of the damaged structure), or built on the salvaged parts of fixed bridge supports. One of the main rules for temporary reconstruction of bridges is to use the salvaged parts of supports and spans to the maximum extent [8].

3. WOODEN SUPPORTS

Characteristics and Application [3, 7, 8, 17, 20]

Wooden supports are used in the case of urgent and quick, immediate or temporary bridge construction, usually with steel spans [3]. The design dimensions of such supports are different from those normally constructed in wooden bridges. The advantages of wooden supports include the ease of processing wood, the possibility of prefabrication and the possibility of using local material. These advantages are of great importance, especially when it is necessary to quickly restore damaged bridges. The disadvantages of wooden supports are: a significant volume of the wood used for their construction, low stiffness and flammability. Wooden supports used in the provisional reconstruction of bridges are built in the form of [mycelia]: cages, pile structures, frame and pile-frame structures, and cassette-frame structures.

Each of the specified types of supports may have variations resulting from construction details, depending on the height of the embankment and the type and span of the spans. Wooden supports for railway bridges must ensure the constancy of the structure under load as well as the safety of train traffic.

Supports Made of Cages [3, 8, 17, 30]

A structure called a cage is a temporary structure, consisting of horizontal layers of railway sleepers or bridge decking (bridgeheads are elements of the railway track on bridges without ballast ballast) or wooden beams, placed in horizontal layers on top of each other and fastened with steel clamps. Cage supports made of sleepers are the most provisional type of bridge supports. In these supports, the sleepers are usually placed 5 pieces in one layer.

Before laying the first layer of underlays, the ground surface should be properly prepared. Therefore: the ground of the subgrade must be leveled (leveled) and reinforced with a natural stone rip-rap (e.g. nearby the construction site) or a crushed stone rip-rap (being the material of the surface ballast) with a layer thickness of at least 0.30 m.

The first layer of the cage is placed tightly, one undercoat adjoining the other. If the water depth does not exceed 1.0 m and the speed of the current is not greater than 0.5 m / sec - the cages are placed on dry soil or on a stone throwing in rivers. In the case of deeper water or its higher velocities, the base of the cage is protected against washing by building a sheet piling around it or placing the cage on a previously made porridge.

Fig. 1 shows a schematic view of the cage from wooden railway sleepers [8]. Each of the sleepers of one layer should be connected with the sleepers of the underlying layer using two cross clamps - with the ends at an angle of 90^0 – with bridge girders resting on wooden or steel joists placed on the upper layer of sleepers forming a cage (Fig. 1) [8].

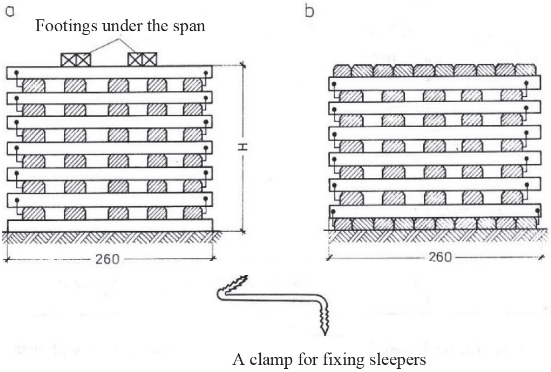

Fig. 1. Cage made of wooden railway sleepers [8]: a - side view (longitudinal direction of the bridge spans, b - front view (in the cross-section of the bridge span)

Cages up to 3.0 m high are placed without widening in the transverse direction - which means that the length of the cage is equal to its width. Cages over 3.0 m high are widened at the bottom in order to reduce the pressure transmitted to the ground (Fig. 2) [8]. With a wide spacing of the main girders of the bridge, to save money, supports made of separated cages, i.e. two sets of cages (Fig. 3) [3, 8]. Both units are connected with horizontal tongs made of long wooden beams or steel I-sections. In order to stiffen this structure, cross braces are mounted between the tongs (Fig. 3).

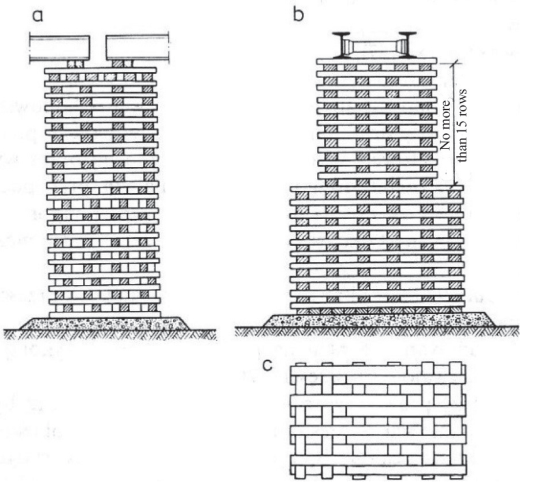

Fig. 2. Bridge pillar constructed of cages composed of railway sleepers [3, 8]:
a - longitudinal view of the bridge spans' ends and side view of the pillar,
b - view of the main spans in the cross section of the span and front view of the pillar,
c - top view of the lower part of the pillar

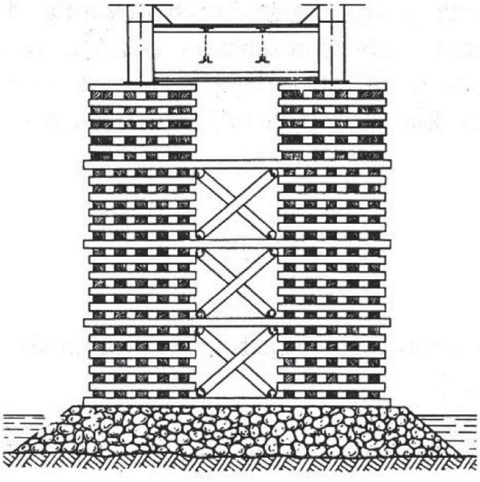

Fig. 3. Cross-section through the bridge span on a pillar constructed of two sets of cages composed of railway sleepers [3, 8]

Abutments of provisional bridges are also built from cages made of railway sleepers (Fig. 4) [3, 8]. Each of the successive layers of sleepers must be properly matched to the previous one, and the sleepers from the successive layers must be connected to each other with two steel staples. The maximum height of cage supports should not exceed 10 ÷ 12 m. The advantage of bridge supports made of cages is the speed and ease of installation, which sometimes takes place simultaneously with the process of lifting the damaged span of the bridge from the bottom of the river. The disadvantage of wooden cages is their flammability, significant settling under load and the need to use a large amount of wood. In order to reduce the risk of fire, the cages are secured by placing a steel sheet on the roof of the structure.

The settlement Δh of a cage structure can be approximated according to the classical formula derived from Hooke's law, as follows [8]:

$$\sigma = E \cdot \varepsilon = E \cdot \Delta h / h \quad (1a)$$

$$\varepsilon = \Delta h / h = \sigma / E \quad (1b)$$

$$\Delta h = \varepsilon \cdot h = \sigma / E \cdot h \quad (1c)$$

where:

σ - stress of the clamp at the crossing points of the cage elements [kN / m2],

E - modulus of cage elasticity as a whole structure, adopted according to [miclin] of 13,0 kN/10^{-4}m;

ε - unit deformation (shortening or elongation) of a structural element sub jected to stress σ;

h - height of the cage constructed of sleepers, [m].

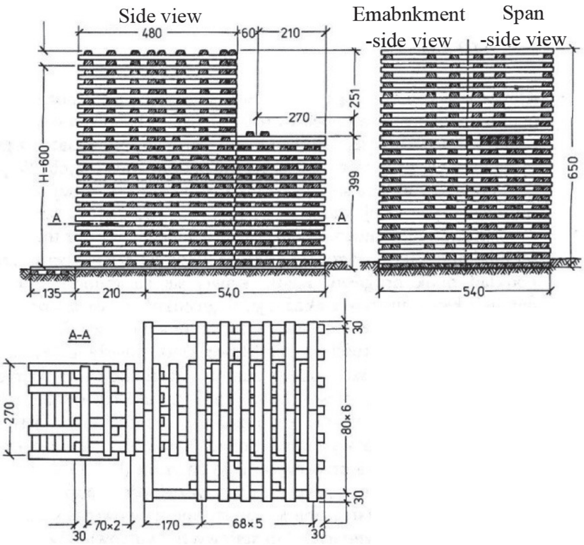

Fig. 4. Bridge abutment, constructed of cages composed of railway sleepers [3, 8]. An example for a railway span of a bridge with a span of 27.0 m with an embankment height of 6.0 m

<u>Pile Supports</u> [3, 8, 17, 20]

The pile supports are usually made of pine, less often of spruce and fir, and exceptionally - oak. The foundation of the pile supports (pillars) are piles driven into the ground. The pillars of the pile supports are an extension of the driven piles. Piles with a length of up to 8.0 m should not be „joined", i.e. shorter sections should be joined. In the case of a length of more than 8.0 m, the contacts below the ground surface should be placed at different levels simultaneously, below the soil frosting depth.

Pile pillars (so-called pile yokes) are used in bridges with low and medium support heights and in flyovers, where it is possible to drive the piles.

In pillars, the number of rows of supporting piles and the number of piles in a row depends on:

- vertical and horizontal reactions of adjacent spans,
- pile bearing capacity,
- pillar height,
- conditions for the flow of ice after winter.

The spacing of piles in rows depends on the spacing of the bridge girders (i.e. main beams). In the spans of double-girder bridges, piles are driven in two sets, symmetrically in relation to the longitudinal axis of the girders (Fig. 5) [3, 8]. In multi-girder spans, single or twin piles are driven under the individual girders. The struts in the pillars are made of logs, caps and bearing beams - of square timber or two-sided logs, while horizontal and diagonal tongs - of half-logs or logs (Fig. 6) [8].

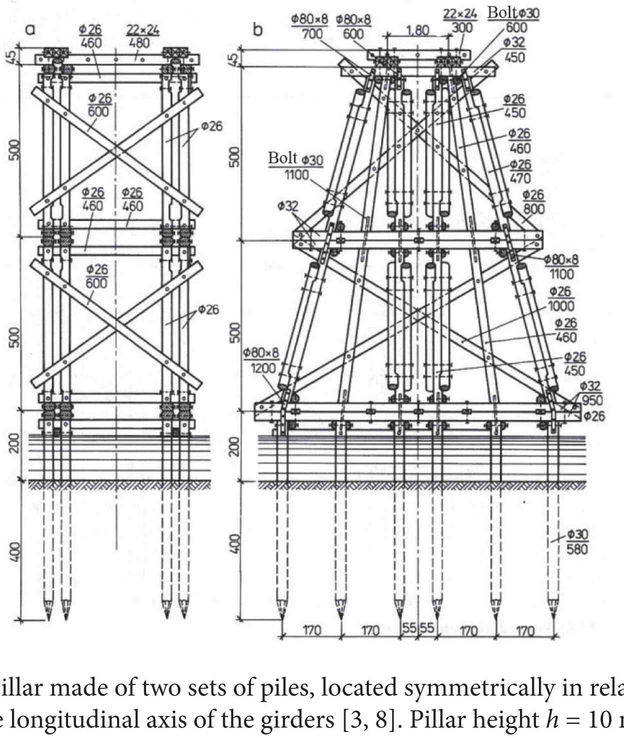

Fig. 5. Pillar made of two sets of piles, located symmetrically in relation to the longitudinal axis of the girders [3, 8]. Pillar height h = 10 m;
a - view of the pillar along the bridge structure;
b - view of the pillar in the cross-section of the bridge span

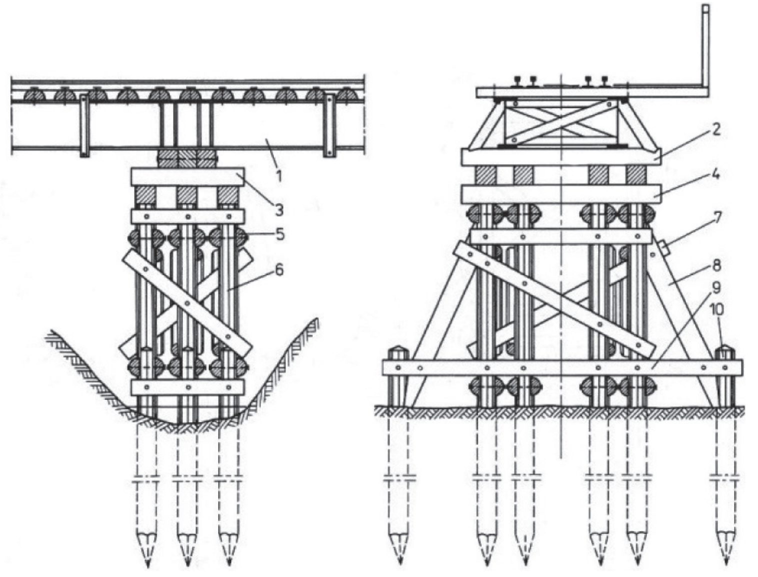

Fig. 6. Pillar of the provisional bridge [8]: left - in the longitudinal section through the bridge structure; right - in the cross section through the bridge structure; 1– bridge span, 2 - bearings, 3 - beamssubstrate, 4 - cap, 5 - horizontal brace, 6 - main piles, 7 - oblique clamp, 8 - braces, 9 - horizontal clamps, 10 - strut piles

In heavily loaded pillars, tops made of steel C-sections, laid flat or made of I-sections, are also used. Wooden abutments usually consist of two parts: the lower front part (and in some cases wider), intended to support the span from the side of the obstacle, and the rear, higher and narrower part - which is a transition from the front part to the embankment and is actually a flyover, partially located on the embankment. The transverse dimensions of the rear section depend on its height and the width of the bridge. The dimensions and number of piles in the front part of the abutments depend on the value of the vertical and horizontal reaction (Fig. 7) [3, 8].

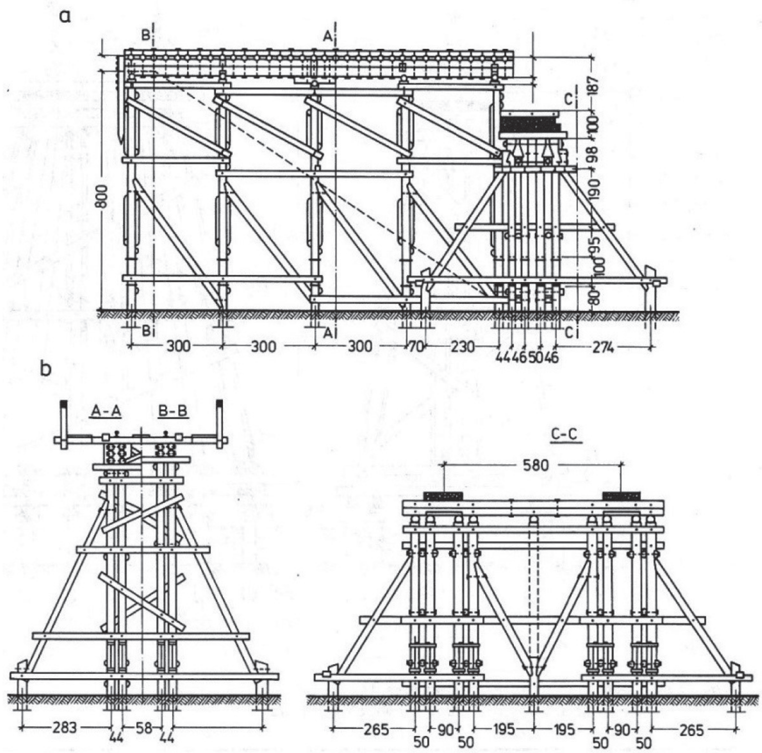

Fig. 7. Wooden abutment, consisting of two parts [3, 8]: a - longitudinal view, b - cross sections of the abutment A-A and B-B, c - cross-section view of the support C-C bridge span

Frame and Frame-Pile Supports [3, 8, 17, 20]

Supports consisting of frames, made regardless of where they are placed, are called frame supports. These supports are made of single frames, prepared in the factory. The frame consists of poles connected at the top with a cap, and at the bottom - with a sill. Depending on the height and width of the frames, they are tied together with oblique or both horizontal and oblique tongs (Fig. 8) [3, 8].

Frame supports can be placed directly on a layer of wooden sleepers, situated on: a concrete foundation, a quarry, porridge, cages, a pile grate and on the surviving parts of permanent bridge supports. Frame supports on a layer of wooden sleepers situated on a stone grate, as well as on grooves and cages are used only in temporary, short-term bridges.

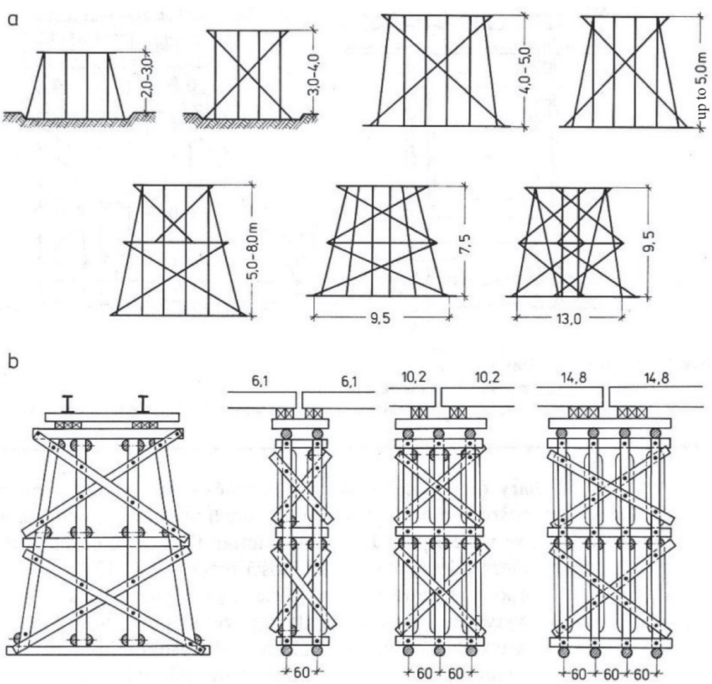

Fig. 8. Frame supports [3, 8]: a - cross-section diagrams of the bridge carriageway, b - support structure in the cross-section of the bridge carriageway and view of the supports (two-row, three-row and four-row) in the longitudinal direction of the bridge spans

Due to the value of the vertical and horizontal forces acting on the frames, frame supports were divided into [8]:

a) single-series flat,
b) two and more spatial serials.

Due to the height of the support, there are [8]:

- single-story frames,
- two- and multi-storey tower frames.

Most often, the frame and pile supports are used in bridges, i.e. frame supports mounted on a pile grate (Fig. 9) [3, 8]. The construction of these supports consists in the fact that the pile grate (driven into the ground or in the river bed) is cut above the water table and connected with caps. A significant advantage of the frame and pile supports is the possibility of carrying out piling works with the parallel - simultaneous - execution of frames on the construction site or in the enterprise's auxiliary production plant located outside the construction site. The ready frames are delivered to the construction site individually - or as combined spatial elements of the entire support or its half.

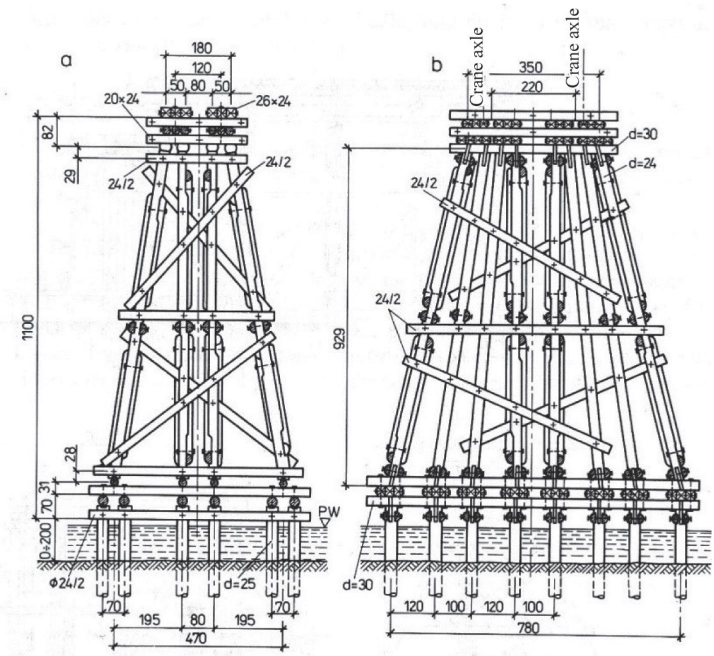

Fig. 9. Frame-pile support 11.0 m high [3, 8]: a - side view of the pillar (in the longitudinal direction of the bridge spans), b - front view of the pillar (in the cross-section of the road set on two main girders)

Cribwork and Cribwork-Frame Supports [3, 8, 17, 20]

Cribwork supports are used in cases where:

- the ground of the river bed makes it impossible to drive the piles,
- the bottom of the watercourse is stony or rocky,
- there are layers of weak soils in the river bed of considerable thickness, and the bearing capacity of the piles would be insufficient to transfer the loads on the support,
- the water depth is more than 1.5 m (up to 10 m), the speed is high and there are large ice parades in winter.

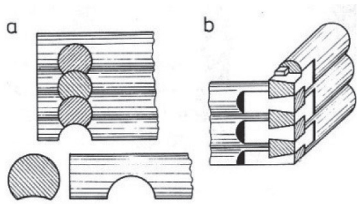

Fig. 10. Connection of corners in cribwork [3, 8]: a - normal connection, b - connection on rivers with high ice floe flow

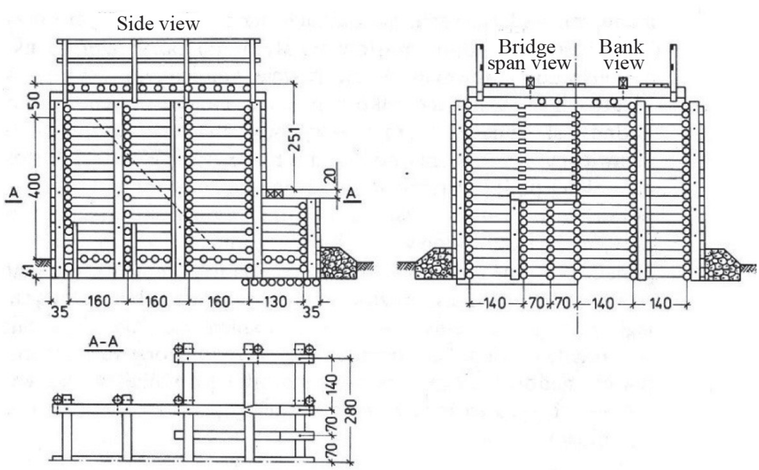

Fig. 11. Cribwork abutment [3, 8]: upper left - side view (along the bridge span), upper right - front view (in the cross-section of the bridge span), bottom left - horizontal A-A section

Cribwork is a wooden box without a bottom or with a bottom. The walls of the cribwork are made of round logs with a diameter of 18 ÷ 25 cm, forming a box-shaped framework in order to be stiffened with internal transverse and longitudinal walls. The chest divided into chambers is filled with a stone rip-rap. The walls can be tight or leaky with a clearance ranging from 5 cm to half the log diameter between the rims. The corners of the wreaths are connected with cuts as shown in Fig. 10 [3, 8]. The bottom of the cribwork is set at the height of one to three lower rims, depending on the hardness of the soil. The lower rims form a kind of a cribwork knife, which sinks into the ground of the river bottom under load and prevents the support from moving. In order to protect against washing, the base of the grits is covered with a stone rip-rap, minimum 0.5 m high, with a slope of 1: 1. Cribwork supports can be used as abutments (shown in Figure 11 [3, 8] or as pillars.

Cribwork pillars on rivers with weak water current may have a rectangular shape in plan (in the top view). On the other hand, on rivers with strong water current and flow of ice - cribwork sharpened at an angle of 45^0 in the front part should be used. The cribwork is usually mounted on the bank, then it is lowered down the scaffolding to the river, towed to the right place and immersed with a stone riprap. After placing on the bottom, the cribwork is built up to the designed height.

When it is necessary to build high supports, in order to save material and labour, cribwork is built only up to a height of about 1.0 m above the high water level. Higher, on the battens, frame supports (Fig. 12) [3, 8] are placed, on which the bridge spans rest. Such supports are called cribwork-frame supports. Frame supports can also be placed on cages made of sleepers.

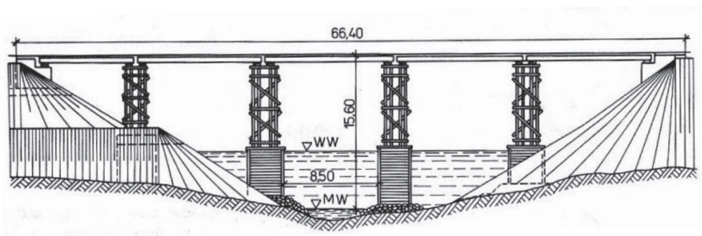

Fig. 12. Cribwork-frame supports [3, 8]

In makeshift reconstruction of bridges, frame supports are widely used when the bridge is rebuilt in the previous longitudinal axis and the supports rest on fragments of damaged walls of abutments or pillars (Fig. 13) [3, 8].

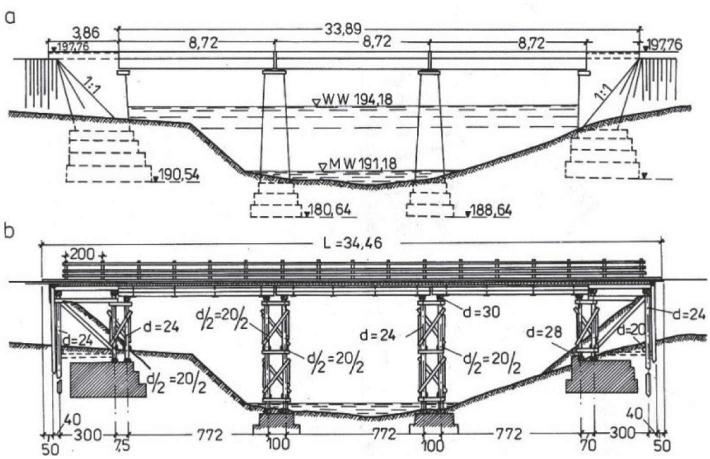

Fig. 13. Provisional reconstruction of the road bridge on frame supports [3, 8]: a - view of the bridge before destruction, b - provisionally rebuilt bridge

When reconstructing damaged bridges, it is necessary to arrange the spans with girders with the lower carriageway instead of the upper carriageway. In order to equalize the height of the supports, then a frame structure is placed in the bearing niche, on which the bearings rest (Fig. 14) [3, 8]. The frame is attached with steel anchors to the wall of the abutment and supported with braces.

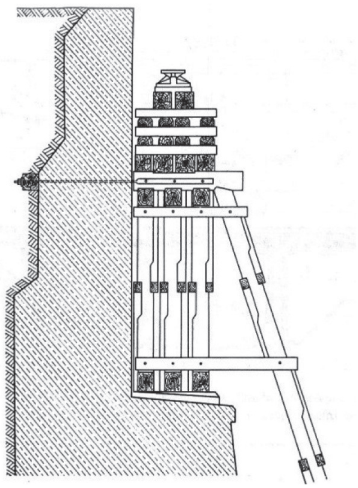

Fig. 14. The structure of the frame support in the abutment niche, attached with steel anchors to the abutment wall [3, 8]

Ice Aprons [3, 8, 17, 20]

In the construction of a makeshift bridge, the riverbed becomes narrowed by installing more supports than in the construction of a permanent bridge. As a result, the conditions for the flow of water and ice floe deteriorate. Therefore, wooden pillars are protected against the impact of ice floes and flowing solid objects (such as: tree trunks, logs, etc.) by building ice aprons in front of the pillars at a distance of 1.5-5.0 m. The dimensions of the ice aprons depend on: the width of the pillars, the level of ice runoff (in high water) and the size and thickness of ice floes. In the construction of ice aprons, a distinction is made between single (Fig. 15) [3, 8] and tented (Fig. 16) [3, 8]. A single ice aprons is made of one row of piles driven into the bottom soil at a minimum depth of 3.0 ÷ 4.0 m from the bottom blur level (Fig. 15). This type of ice aprons is used when there is a weak ice floe and low water velocities. Side impacts of ice floes are dangerous for single ice aprons, as they are not stiff in this direction. The more rigid type of single ice aprons are those consisting of two or more series of piles suitably braced with each other.

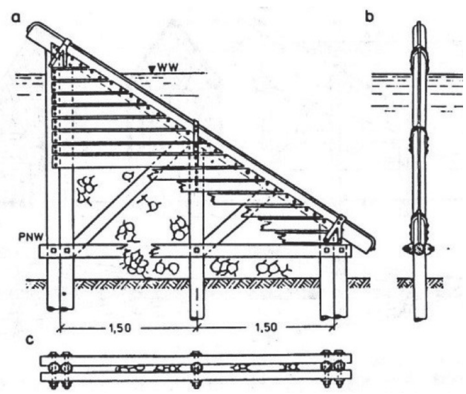

Fig. 15. Single ice apron [3, 8]: a - side view (in the plane of the vertical cross-section of the bridge span), b - front view (along the bridge span), c - top view

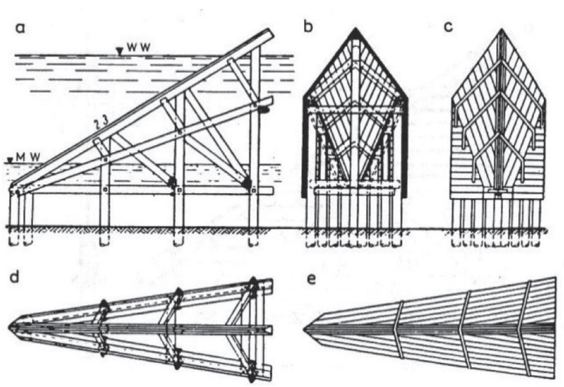

Fig. 16. Tent ice aprons [3, 8]: a - side view of the ice apron frame (without formwork), b - rear view (in the direction opposite to the water current vector), c - front view (in the direction of the water current vector), d - top view of the ice apron frame, e - top view of the ice apron with formwork

Tent ice apron - significantly spatially shaped in relation to the single ice apron, it consists of three rows of piles (Fig. 16) [3, 8], the middle one of which is hammered in the extension of the pillar axis (perpendicular to the longitudinal axis of the bridge span), and two lateral the series form a certain angle in relation to the middle row [3, 8]. Three or more piles are hammered in at the front of the firehouse, where all three rows meet. Piles in rows are connected with caps. The middle row lug has a suitable slope and constitutes a cutting edge and is covered with a steel section (usually - angular) or a railroad rail. The piles are reinforced with braces in the direction of ice floes. Before the pressure of the thick ice floe and the fast water current - the interior of the chambers is filled with a stone rip-rap. Outside, an ice apron is covered with a 2 mm thick steel sheet in order to force ice to slide along the walls of an apron, and to prevent damage to the 32 mm thick planks. On wide rivers with a thick ice floe and with a significant water flow velocity, in front of the main ice aprons, additionally preliminary ice aprons are set up at a distance of 30 ÷ 50 m.

4. STEEL SUPPORTS

Steel supports are used in the construction of temporary long-term bridges and in conditions where the construction of wooden supports is difficult or impossible [3 ÷ 6, 8 ÷ 12, 17]. Such conditions include [8]:
- significant values of support reactions,
- the need to drive piles to a great depth,
- great water depth,
- the ground is difficult to drive wooden piles.

Steel supports are classified as pile and frame supports. The pile structure is made of piles made of steel pipes. Due to construction problems, they are used only in bridge structures with a low support height.

Frame supports can be dismantled (folded) and non-dismountable. The structure of these supports may consist of flat or three-dimensional elements. The structure of the folding support is made on the foundation block. These supports include: cap elements, support load-bearing elements, elements connecting the load-bearing structure with the foundation (Fig. 17) [8].

The elements of the cap in steel folding supports - in various structural arrangements of the mounted supports - usually constitute identical solutions. The arrangement of load-bearing elements usually varies, depending on the required height of the support. The elements connecting the load-bearing structure with the foundation are most often suitable for foundations on a flat base or on piles. The structure of folding supports can be made of basic (load-bearing) elements in the following form: linear, flat or spatial. The choice of the form of the load-bearing elements depends on the intended assembly technology and the intended means of transport.

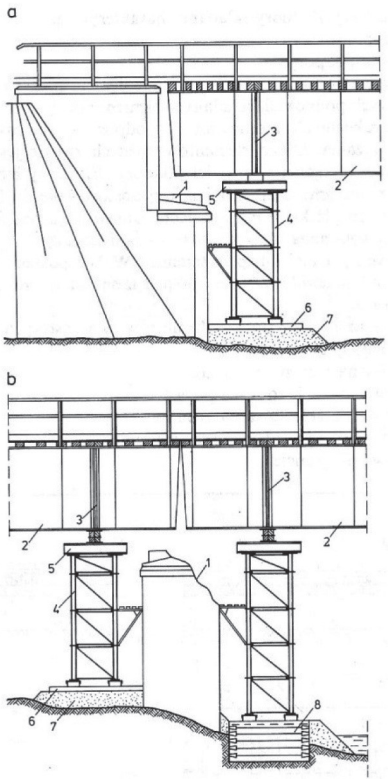

Fig. 17. Schemes of structural systems of the steel folding support [8]: a - folded support in the process of reconstructing the abutment, b - folding supports during the pillar reconstruction; 1 - damaged support elements, 2 - ends of the bridge spans (in the longitudinal view), 3 - reinforcement of the webs of the main beams in the bridge spans, 4 - support bearing element, 5 - cap elements, 6 - support elements, 7 - direct foundation (a layer of stone aggregate), 8 - wooden cribwork

The spatial form of the steel supports is created by frames that are demountable and non-demountable. Demountable supports are used in the Roth-Wagner and Callender-Hamilton systems [8]. Depending on the values of the reactions acting on the supports and the height of the supports, various installation methods are possible. An example of a folding frame support is a pillar of a single-track railway bridge, shown in Fig. 18 [8]. The pillar consists of 6 columns arranged in two rows, three columns each on one bottom cap. The horizontal brace is made of sections with a channel section. Diagonal braces (braces) are angles fixed at the ends to the gusset plates with bolts. This type of support can be used for spans with a span of up to 18.0 m in floodplains.

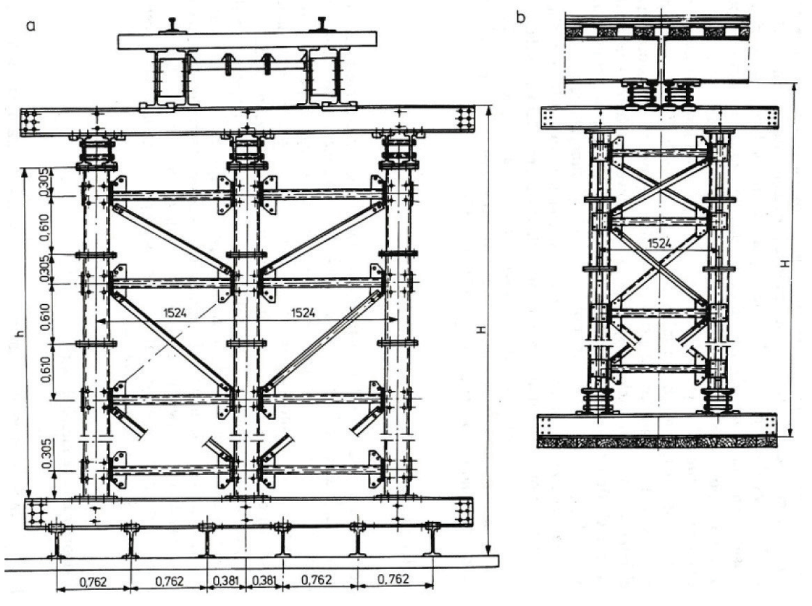

Fig. 18. Collapsible frame support (pillar) of a railway bridge on a single track line [8]: a - view of the pillar in the cross-section of the bridge span, b - pillar in the longitudinal view of the bridge spans

Non-demountable frame supports may be built on previously made or existing foundations, of the same elements as steel piles and pile supports, or of elements prepared outside the construction site, and then transported and set on the foundations.

5. CONCRETE AND REINFORCED CONCRETE SUPPORTS

Reinforced concrete pillars are most often used for the temporary reconstruction of high viaducts, especially for lifting fallen spans and then supporting them [6, 8, 11]. These are the cases where the production of wooden supports would require a lot of wood and would be time-consuming. Concrete and reinforced concrete supports (for the construction of makeshift and temporary railway bridges) can be effective in practice if they are constructed as prefabricated structures, not monolithic ones.

6. CONCLUDING REMARKS

The provisional reconstruction of bridges is to restore traffic that was interrupted due to damage to the bridge structure as soon as possible. When designing a provisional reconstruction of a bridge, first of all, attempts should be made to use as much as possible the surviving supports or some of the fixed supports. The reconstruction of the bridge discussed in this article should generally be carried out in a way that allows permanent reconstruction in the next phase, without the need for a longer break in train traffic. The exception may be the temporary reconstruction of bridges during military operations, when first of all it is necessary to open up train traffic on the damaged railway lines as quickly as possible.

The method of reconstruction depends on many factors, including: the type and degree of damage to the bridge, the conditions in which the reconstruction takes place (e.g. war conditions), the required deadline for the completion of works, the type of materials and equipment owned, the number of qualified personnel, etc. In the event of reconstruction, the rules of statics, train traffic safety, and savings in materials and labour apply.

The aforementioned issue of train traffic safety concerns provisional bridges (in this case called relief structures), built along the track axis, in a way that allows the damaged elements of the bridge to be rebuilt under them. Such provisional (relieving) structures "surround" the body of the damaged object and enable its reconstruction without interrupting train traffic. The use of such temporary bridge structures is recommended on active railway lines [3, 8, 17].

REFERENCES

[1] Białobrzeski T., *Mosty składane*, Wydawnictwa Komunikacji i Łączności, Warszawa 1978.

[2] Bień J., *Uszkodzenia i diagnostyka obiektów mostowych*, Wydawnictwa Komunikacji i Łączności, Warszawa 2010.

[3] Cholewo J., Sznurowski M., *Mosty kolejowe i fundamentowanie*, Wydawnictwo Komunikacji i Łączności, Warszawa 1970.

[4] Hydzik J., *Mosty kolejowe. Część II*,Wydawnictwo Komunikacji i Łączności, Warszawa 1986.

[5] *Warunki techniczne dla kolejowych obiektów inżynieryjnych. Id-2 (D2)*, PKP Polskie Linie Kolejowe S.A., https://www.plk-sa.pl/files/public/user_upload/pdf/Akty_prawne_i_przepisy/ Instrukcje/Wydruk/Id/wydr._Id-2.pdf [dostęp: 14.05.2022].

[6] Madaj A., Wołowicki W., *Budowa i utrzymanie mostów*, Wydawnictwo Komunikacji i Łączności, Warszawa 2013.

[7] Marszałek J., Chmielewski R., Wolniewicz A., *Mosty kolejowe*, PKP Polskie Linie Kolejowe S.A., Warszawa 2010.

[8] Miklin A., Sawicki M., *Mosty kolejowe. Część 1*, Wydawnictwo Komunikacji i Łączności, Warszawa 1993.

[9] Miklin A., *Stalowe podpory prowizoryczne mostów kolejowych*, „Drogi Kolejowe", 5-6 (1980).

[10] Miklin A. *Zniszczenie i odbudowa elementów przęsła kolejowego mostu kratowego*,„Drogi Kolejowe", 7 (1984).

[11] Rybak M., *Przebudowa i wzmacnianie mostów,* Wydawnictwo Komunikacji i Łączności, Warszawa 1982.

[12] *Projekt techniczny konstrukcji odciążających z wiązek szyn – typ szwajcarski*, Centralne Biuro Projektowo-Badawcze Budownictwa Kolejowego, Warszawa 1991.

[13] Surowiecki A., Zamiar Z., *Teoria i praktyka bezpieczeństwa ruchu drogowego i kolejowego*, Wydawnictwo Wyższej Szkoły Oficerskiej Wojsk Lądowych im. gen. Tadeusza Kościuszki, Wroclaw 2014.

[14] Surowiecki A., Zamiar Z., *Infrastruktura transportu lądowego a bezpieczeństwo przewozów*, Wydawnictwo Wyższej Szkoły Oficerskiej Wojsk Lądowych im. gen. Tadeusza Kościuszki, Wroclaw 2015.

[15] Surowiecki A., Zamiar Z., Saska P., *Bezpieczeństwo w projektowaniu konstrukcji inżynieryjnych*, Wydawnictwo Wyższej Szkoły Oficerskiej Wojsk Lądowych im. gen. Tadeusza Kościuszki, Wroclaw 2016.

[16] Surowiecki A., *Ogólne zasady prowizorycznej odbudowy mostów,* Materiały wykładowe, Wydział Nauk o Bezpieczeństwie, Akademia Wojsk Lądowych, Wroclaw 2021.

[17] Sznurowski M., *Utrzymanie mostów kolejowych, przepustów i tuneli,* Wydawnictwo Komunikacji i Łączności, Warszawa 1989.

[18] Zamiar Z., *Infrastruktura transportu jako element infrastruktury krytycznej,* CL Consulting i Logistyka, Oficyna Wydawnicza NDiO, Wroclaw 2011.

[19] Zamiar S., Surowiecki A., Saska P., *Infrastruktura transportowa*, Oficyna Wydawnicza Atut, Wroclawskie Wydawnictwo Oświatowe, Wroclaw 2020.

[20] Zobel H., Alkhafaji T., *Mosty drewniane. Konstrukcje przełomu XX i XXI wieku,* Wydawnictwa Komunikacji i Łączności, Warszawa 2006.

Zenon Zamiar
The International University
of Logistics and Transport in Wroclaw, Poland
zzamiar@msl.com.pl
ORCID: 0000-0001-9887-0183

Andrzej Surowiecki
The International University
of Logistics and Transport in Wroclaw, Poland
andrzejsurowiecki3@wp.pl
ORCID: 0000-0003-4080-3409