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Overview of the organisation and technology of portable panel bridges

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Abstract

The article presents examples of the use of portable bridge structures in civil engineering. Due to the possibility of combining elements of these structures into a variety of complex spatial arrangements, they could be widely used. Various technologies and principles of organisation of the construction of engineering structures of pre-fabricated bridges are presented. The presented solutions are both technologies known and used since the beginning of the history of panel bridges, as well as new technologies, developed on the basis of practical experience of engineers. The article presents selected scientific principles of work organisation, influencing the maintenance of a high rate of implementation of the construction project. The article also analyses the influence of location conditions, different from typical standard assembly stations, on the technology and organization of construction.

Keywords: folding bridges, construction technology, construction organization

1 Introduction

Military bridges have a very universal application. Except for the direct military application, these structures can also be used in peacetime. Military Reconstruction Units (MRU) were established on the basis of existing engineering units, deployed in garrisons located in the areas of the threats. They carry out tasks within the framework of disaster management and construct temporary bridges from panel structures when dealing with the consequences of natural disasters (Fig. 1a). Another example of the use of pre-fabricated military structures is their use as scaffolding during construction or repairs of buildings, or as support structures. An example of such use is the use of the folding span structure of the L-36 railway bridge [3,4] as scaffolding during the construction of the stadium roof in Poznań (Fig. 1b).

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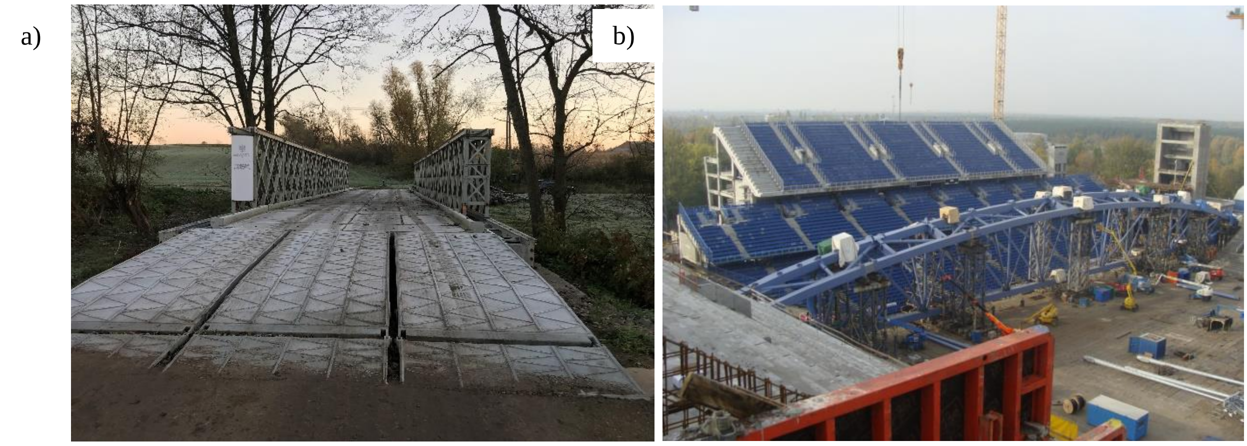

Fig. 1. Examples of the use of panel structures, a) liquidation of the effects of natural disasters - DMS 65 bridge - Szeligi near Płock (2021), b) L-36 bridge structure as support scaffolding for the lattice girder of the Poznań stadium roof (2011).

A common application of panel bridge is the construction of temporary diversionary crossings to provide continuity of passage during repairs or reconstruction of existed bridges (Fig. 2 a, b). Subdivisions of the engineering forces, as part of specialised military services, (or civilian construction companies) construct the temporary bridges, thus allowing spare time for the manager to carry out repair activities of the permanent engineering structures, or to procedure the formation of new ones.

Fig. 2. Use of military collapsible bridge structures as diversion structures,
(a) Ostrołęka bridge (2017), (b) Kiezmark bridge (2002).

A decisive factor in making crossings from panel structures is generally the short construction time. Often, the rate of construction of a pre-fabricated bridge is dependent on the time taken to build the intermediate supports. If the construction time of the intermediate beam support determines the construction time of the entire bridge, then we speak of a critical point. It is not possible to slide the span structure if the next support is not completed. The length of the shore bridge span to be installed is limited by the site conditions - the length of the installation site. This condition requires detailed selection of the optimum work organisation and construction technology.

The pace of construction of the supports as well as the bridge spans depends on many factors, such as:

- terrain conditions (terrain and river banks),
- ground conditions,
- water conditions,
- weather conditions,
- type of span structure and support structure adopted,
- professional background of the contractor,
- type and efficiency of equipment [9].

The article presents the known technologies for the construction of portable bridges and the organisation of construction works. The methods presented are those that have been in use since the inception and development of collapsible bridges, as well as new methods, developed on the basis of the practical experience of the soldiers of the engineering forces. The experience of the team carrying out the construction work is an important element that determines the rate of construction of the structure [1,2].

2 The organisation and technology of folding bridges

Typically, the construction of portable, pre-fabricated bridges involves three main stages:

a) preparatory work,
b) basic assembly work,
c) finishing work.

The basic method of assembling the bridge structure is to assemble the span structure in the assembly yard and cantilever it onto the supports along the axis of the bridge [9]. Structural stability is ensured by the construction of counterweights. This method is universal for the construction of bridges with different static schemes.

The supports of panel bridges are made in two variants. For their construction, the support structures can be used or their use can be omitted. In the first variant, a pile or slab support foundation is built and then the folding support structure is superstructed. In the second variant, the support structure consists of piles braced together to form the foundation and the support core, ending in a cap.

The scope of work in the construction of the spans of the panel bridges will vary depending on the technology and organisation of construction used, the construction conditions, the structural solutions adopted and the contractor's equipment capabilities.

Pile foundation construction

A critical process during the construction of panel bridges is the construction of the pile foundation of the support. The work is usually carried out on water, necessitating the use of floating equipment and the installation of pile driving equipment on these means. When constructing a pile foundation on land, the pile driving equipment is usually set on frames that allow the equipment to move in the axis of the bridge and along the longitudinal axis of the support. Generally, two types of pile foundations are adopted in the construction of panel bridges - timber pile foundations and steel pipe pile foundations. The most commonly used pile driving equipment is pile drivers with combustion hammers or vibratory hammers.

Combustion hammers are used to work in loose as well as cohesive soils. The carrying structure of the combustion hammer is the pile driver. The pile driver ensures that the movement of the hammer and the driven pile are concentric. The hammer and pile driver, as a unit, are mounted to work on a rigid foundation or on a pile ferry if the foundation is made on water. The disadvantage, due to the fixed length of the pile driver's guide on which the hammer travels, is the limitation of the pile driving depth. A solution to this problem may be to extend the pile ('stiffening'). The use of combustion hammers for driving steel pipe piles is less effective than for wooden piles, due to the elastic interaction of the hammer's impact part with the pipe pile.

Another device for driving piles is electrically driven vibratory hammers. These operate at high vibration frequencies and low amplitudes. Vibrohammers operate most effectively in loose soil. Vibro-hammers are carried to the pile by cranes or are mounted on self-propelled means, then pressed against the pile with handles. Vibratory equipment is very sensitive to the characteristics of the soil, so its use must be preceded by a thorough investigation of the soil substrate [11].

Assembly of folding support structures

The superstructure is installed using lifting equipment. Manual assembly is possible, but this is regarded as a back-up solution. Assembly is carried out by joining individual or integrated elements. When the superstructure is assembled with integrated elements, an additional yard is required for joining the elements. This reduces the amount of time spent on assembly shuttles. This method carries with it the need to use lifting equipment with considerable overhang and lifting capacity [11].

In the construction of supports, a minimum of two teams of fitters are most often organised. The first team is responsible for driving the piles, while the second team is responsible for installing the superstructure of the supports or, when no superstructure is used, for bracing the piles and preparing the substructure. Pile driving, due to its labour-intensive nature, can be carried out on a wide front by multiple teams.

Assembly of the span structure using the cantilever method

The method is characterised by the addition of successive segments of the bridge span from the front, with the stability of the span being safeguarded during the assembly work. The assembly work has to be carried out in one place, which limits the speed of the structure's assembly. Once assembled, the span structure can be lifted and placed on intermediate supports or slid over. With the second method, a difference in support height is required, due to the deflection of the cantilevered portion of the span [11].

Assembly of the structure in the axis of the bridge with sliding of the spans onto the supports

The method is based on mounting the span structure in the axis of the bridge on one bank of the water obstacle. The structure is then slid along the axis onto intermediate supports. The essence of the method is the assembly of the span structure on a previously prepared assembly yard. The assembly yard requires a leveled area, located at least on one bank of the water obstacle, in the axis of the bridge. This area should meet the conditions for shape, bearing capacity of the ground and surface requirements. A system of assembly rollers is built on the assembly track, placed on wooden or other shims. Articulated rollers (bearing elements) are used at the abutments. The front of the structure to be assembled is the mounting bow. Using additional elements, such as inserts and stays in the bow, the bow is raised so that the structure can be slid over the intermediate supports of the longest span [11]. In this method, the stability of the structure to be slid over is required to be maintained by building a counterweight of sufficient length.

Installation using temporary supports

The essence of the method is the use of additional assembly supports when constructing the span structure of a bridge using cantilever or slip-on techniques. The temporary supports can be installed on the ground or on ferries or barges. Secondary supports are made of rectangular cages, which are arranged as a panel structure. Existing support structures, such as the SPS-69B support, can also be used.

Ground-mounted auxiliary supports are built immediately in the axis of the bridge. The height of the support is adjusted by appropriate ground levelling or by using wooden shims. The structure of the auxiliary support must be secured against displacement by driving stabilising piles or placing the support on a substrate of sufficient rigidity, using, for example, reinforced concrete slabs.

Floating supports on barges or ferries are assembled off the axis of the bridge, close to the shore at a convenient location. Once the support structure is assembled, it is positioned in the axis of the bridge and the means of floating is fixed in the water by anchors. In this case, the matching of the height of the auxiliary support and the span structure is achieved by levelling the support structure and using wooden shims for the assembly rollers [11].

Installation on full scaffolding

The essence of the method is the assembly of the bridge span structure on cages supported on scaffolding, which is made in the axis of the bridge. The span thus assembled is lowered onto the supports. In this method, steel or wooden scaffolding is used. The scaffolding is supported on previously driven piles [8, 12].

Positioning of bays delivered fully assembled

The method involves the complete construction of the span section at the pre-assembly site and then transporting the completed span by rail, water or land to the site for erection. The complete bridge span structure delivered in this way limits the assembly work in the bridge axis to only placing the structure on the supports (Fig. 3). In order to use this method, specialised equipment must be available, namely means of transport (e.g. barges of the required displacement) and handling (with adequate capacity) [11].

a) b)

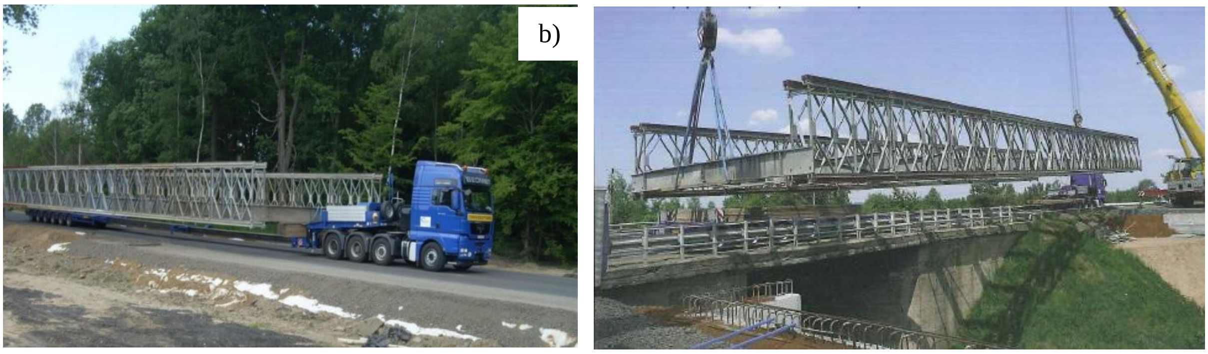

Fig. 2. Positioning of spans delivered fully assembled, (a) transport of fully assembled span structure, (b) installation of structure on obstruction [14].

Method of bridge abutments by crane

The method can be used in the construction of bridges in a single-span arrangement with a span length of 6 to 30 meters. Assembly is carried out on both banks of the water obstacle. Groups of assemblers build sections of the bridge girders. The assembled sections are carried from the shore over the obstacle using cranes. Joining them is done when each girder section is supported on the abutment on one side and suspended and held by a crane device on the other. The connection of the segments over the water obstacle is carried out with bolts. Analogously, the installation of sections of the second girder is carried out. Thus, in the first instance, the abutments are connected by girders. Then the assembly groups add the remaining girder elements, between the trusses they fasten the transverse beams, wind girders and other elements of the platform and equipment. In the last phase, the entrance elements of the structure are installed [14].

Connecting abutments for crossing with a short assembly site

The method can be used for the construction of bridges in a single-span arrangement with a span length of 6 to 30 meters. In this technology, assembly groups supported by a crane device operate on both sides of the river. Short assembly yards (about 10 meters long) built with four assembly rollers and two abutment bearings are rolled out on both banks. The aforementioned elements are arranged in the axes of the girders. Bearings in the line of the abutment, further rollers at equal distances. Such a planned arrangement of rollers is placed on wooden sleepers of the appropriate height, so that the height of the assembly site is equal on the elements on which the truss chords will slide. Each assembly group on both sides of the crossing assembles parts of one girder wall on a shortened assembly yard. It then partially extends the trusses thus connected over the water obstacle, maintaining the stability of the structure. After partially extending the girder, a group of assemblers adds a short counterweight, cyclically extending the structure. The spar segments slid on both sides of the water obstacle are fastened in the middle by the fitter with bolts. After the two edges are thus joined, the counterweight is removed. The second girder is pinned in the same way. The counterweight used to connect one wall, is used as a counterweight to connect the girder of the other wall. Subsequently, the assembly groups add the remaining elements of the girder, between the trusses they fasten the transverse beams, wind girders and other elements of the platform and equipment. In the last phase, the driveway elements of the structure are installed [14].

The construction of a bridge from folding elements can be carried out in several stages or in one. Variant one consists of carrying out various works at different times, that is, for example, the assembly sites are prepared, the structural components are brought to the storage yards, and only after the entire structure is brought in does the bridge assembly begin. The second variant, i.e. construction on the march, is organized in such a way that an appropriate order is established in the column of vehicles transporting the bridge elements. Construction elements are brought in the axis of the crossing, then they are taken from the transport vehicle and directly built into the structure [11]. It is extremely important in this variant to take into account in planning the implementation of the task the principle of alignment of logistics processes with the core processes. It is necessary to consider in detail the needs of construction supply and establish a supply system so that the essential construction process can be carried out continuously. In planning, special attention must be paid to the available transportation means, their loading capacity and supply needs [8].

3 Discussion

The prerequisite for achieving a high rate of construction, and thus reducing the working time on the water obstacle, is to harmonize two essential construction processes:

- support construction work [5, 8],
- assembly of the span structure [9].

The principle of harmonization of work is to optimally match the cooperating assemblies with each other and precisely determine the times of their operation.

An extremely important factor is the selection of the structural layout and the organization and technology of folding bridge construction to the conditions at the site. Optimal selection can greatly reduce not only the construction time, but also its cost. The contractor should be familiar with each construction method, knowing its advantages, disadvantages, requirements and possibilities. Proficiency in the organization and technology of the construction of panel bridges makes it possible to reduce the need for a lot of preparatory, basic and finishing work. We are talking about the principle of applying research and experience, which improves the organization through the use of practices acquired in previously performed tasks [1, 8].

Each of the described assembly methods has different field requirements, and it is the field conditions that determine the capabilities of the contractor. A wide range of methods of assembling bridges makes it possible to vary and rationalize the execution of selected construction tasks. Thus, it allows rational scheduling of the construction of crossings from panel structures [6].

4 Conclusions

Folding structures are successfully used not only for military purposes, but also for civilian purposes. Their use is versatile, ranging from replacing existing bridges during their repair or reconstructing engineering structures destroyed by natural disasters. Folding structures are also used as technological supports, scaffolding, overpasses and temporary platforms. The use of collapsible structures in civil construction helps ensure the capacity of the road network in Poland.

The presented technologies and organizations for the construction of folding bridges do not exhaust the issue. The need to build crossings in conditions different from typical ones determines the need to improve technological solutions, the detailed selection of technologies for the construction processes carried out in the given conditions, the design of new technologies.

Currently, the most widely used structure for the construction of temporary crossings is the DMS-65 structure [4,9]. It is on the equipment of engineering troops and is most abundant in depots. However, this structure and the others used in our country (MS 22-80 and MS-54) do not meet modern road serviceability and technological requirements [5, 9]. Therefore, it is reasonable to develop a new folding bridge design that would meet the following requirements [13]:

- capacity,
- load capacity,
- traffic speed on the object,
- permissible weight of components,
- minimization of structural components,
- uncomplicated assembly method,
- equipment and method of rainwater drainage.

In addition, the new structure should meet the requirements for maintaining an appropriate pace of its assembly, the possibility of transportation by available means (dimensions and weight of the structural components), durability [12].

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