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Proposal for new technologies of DMS-65 folding bridge construction

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Abstract

The paper presents two new technologies for the construction of single-span road bridges using the DMS-65 folding bridge structure. These technologies have been successfully applied in practice and resulted in savings in bridge construction time and cost. The presented technological solutions allow to organize the construction of small bridges in conditions of limited space for the construction yard.

Keywords: folding bridges, emergency situations, construction technology

1 Introduction

Folding bridges, which are structures made of previously prepared elements, have the properties of their repeated use in various assembly systems. For technological reasons, folded bridges have spar elements in their structural connections, the so-called assembly clearances, which significantly distinguishes them from monolithic structures used in other types of bridges for civilian application [1, 6].

Folding bridge elements are also used in other areas of civil engineering, not only as bridges themselves. Folding bridge structures are often used as technological bridges, relief supports or all kinds of scaffolding [7, 12]. The most interesting examples include the assembly of the roof of the Central Railway Station in Warsaw, where, on the 15-meter MS 22-80 structure over Aleje Jerozolimskie, girders weighing 40 tons were transported without stopping traffic, the construction of temporary supports to facilitate the assembly of the supporting structure of the Siekierkowski Bridge in Warsaw in 2002, or use of the KD-66C and SPS structures to make technological supports and two access flyovers for the construction of a permanent bridge over the Vistula River in Płock in 2003-2004. An interesting example of atypical use of structures provided by engineering troops in a crisis situation was the construction of a floating bridge after the failure of the Czajka sewage treatment plant in 2019 [2].

The construction of folding bridges from the DMS-65 structure with the use of the assembly site and sliding the structure onto the supports along the bridge axis is suitable for the construction of multi-span bridges. However, when it is necessary to build a single-span bridge in a free-support system, this method significantly extends the time of bridge construction due to a large scope of preparatory and finishing works, compared to the main works. The article presents two new construction methods based on the DMS-65 construction, which were developed on the basis of practical experience of soldiers of the 2nd Inowrocław Engineering Regiment.

2 Principles of crossing construction from the DMS-65 folding bridge structure

The DMS-65 folding road bridge is the most commonly used structure in contemporary military bridge construction in Poland - figure 1. This structure enables the rapid reconstruction of the bridge infrastructure in the event of natural disasters or failure of existing fixed structures. Sometimes also military bridges of this type are used for long-term operation.

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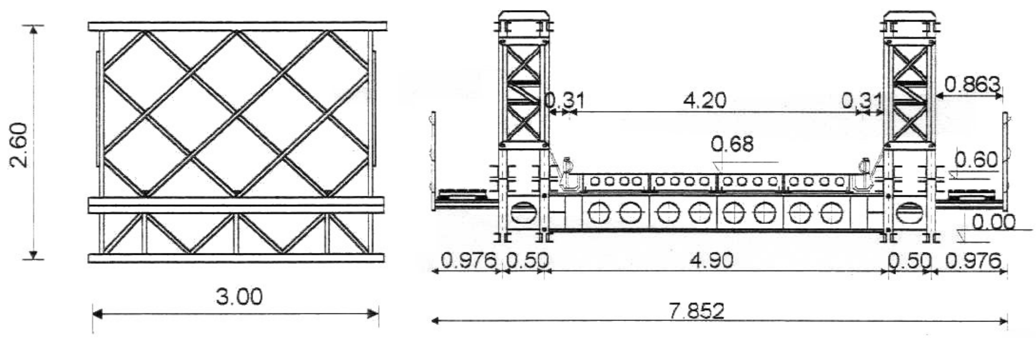

Figure 1. DMS-65 folding bridge: a) side view, b) span cross-section

According to the military instruction "DMS-65 road folding bridge - Construction and operation" [4], the construction of a bridge from the DMS-65 structure consists of three main stages:

a) preparatory works,

b) basic assembly works,

c) finishing works.

The basic method of assembly of the bridge structure is the assembly of the span structure on the assembly site and sliding it on supports along the bridge axis. The stability of the structure is ensured by the construction of a counterweight. Such a method is universal for the construction of bridges with different static schemes, activities at particular stages of construction include:

Re: a) Preparatory works:

- reconnaissance, technical measurements of the area and site of the bridge construction, as well as the selection of the bridge axis;
- execution of the field bridge crossing design;
- development of a project for the organization of works,
- grouping and preparation of construction elements, materials, equipment and assembly devices at the construction site,
- preparation of the river banks and the assembly site,
- reconstruction and fixation the situational and high-altitude elements of the bridge crossing in the field.

Re: b) Basic assembly works:

- developing and setting at workstations: machines and mechanical devices for the execution of foundations, supports, installation of supports and span structures,
- alignment of the stacks and assembly rollers,
- execution of foundations for supports,
- assembly of the supports' superstructure,
- assembly of the span structure and sliding it onto the supports.

Re: c) Finishing works:

- dismantling of the bridge launching nose,
- execution of direct access to the bridge,
- execution of commuting,,
- setting up road signs, signalling devices and traffic regulation,

- execution of handrails on the approaches to bridge sidewalks,
- dismantling and transporting the basic and auxiliary assembly devices,
- tidying up the surrounding area,
- handing over the bridge for operation to a unit designated for the operational maintenance of the bridge crossing.

The standard stages of a bridge construction involve many varied and complex steps and require field space for the assembly track. This area should meet the conditions regarding the topography, bearing capacity and surface requirements. The assembly site requires a levelled area, located at least on one side of the water obstacle. This area should be not less than 7 m wide, although for full freedom of movement and folding of structural elements, a width of 25 m is suggested. The length of the assembly site, counting from the abutment line, should be such that the length of the assembled structure and put out on supports is equal to always not less than 1.5 times the length of the first span that the assembled structure is to cover, plus at least 12 m to provide adequate counterweight. The counterweight should be at least 1.5 times the weight of the structure supporting the bridge when sliding it over the supports. For example, when the first span is 30 m, the counterweight should be about 45 m. So the entire span structure assembled on the assembly site would consist of the 30 m launching nose of the bridge structure extended onto the support and 45 m of counterweight.

The length of the assembly site can be reduced by periodically erecting the structure above the water obstacle, while maintaining the stability of the structure (the appropriate length of the assembled span structure at the assembly site - counterweight). However, with each slide-on cycle, assembly will be interrupted and the bridge construction time will lengthen.

The field conditions do not always make it possible to prepare an assembly site with the required dimensions in the geometry plan, therefore it becomes advisable to use other technological solutions. For example, the DMS-65 structures can be built on additional temporary supports, the avanbeck structure (launching nose of the bridge) can be used or the spans delivered fully assembled can be erected [8]. However, these solutions require additional specialized equipment or additional structural elements, which in the construction of single-span crossings with a small span generates significant financial outlays or additional time for implementation. Later in the article, two new technologies for the construction of the bridge span from the DMS-65 folding structure will be presented, which were developed on the basis of practical experience of the engineering troops of the Polish Armed Forces.

3 Proposals for new technologies for the construction of short spans from the DMS-65 structure

The first of the new proposed technologies was developed as part of the military task involving the construction of seven lines of the crossing in the form of single spans of the DMS 65 structure as part of the engineering support for the World Youth Day Krakow 2016 [9]. The construction of the spans would require a significant amount of earthworks to complete the assembly site due to the location of abutments on the flood embankments - Fig. 1 a), b).

The assembly of the structure with the cantilever method would involve the transport of additional elements of the structure that would be necessary for the construction of the avanbeck structure (launching nose of the bridge) and the counterweight structure. All these issues prompted the development of an innovative assembly technology, which in the end significantly accelerated the pace of construction works and additionally reduced the final costs of the task. This technology was called the "method of bridge abutments by crane".

There are two assembly groups of eight people on the construction site, one on each side of the obstacle to be overcome. The composition of one group with the list of activities performed by individual group members is presented in Table 1. Construction elements are delivered to each group independently. The bridge is assembled directly from the vehicles, or the elements can be assembled next to an obstacle (on a previously prepared storage yard).

Both assembly groups are involved in assembling the lower part of the girder sections and laying it over the obstacle. On each of the banks, three spatial trusses were connected, in the WYD 2016 task, the spans had a total length of 18 m. The assembled sections are transferred from the shore to the obstacle with the use of cranes. They are connected when each part of the girder rests on the abutment on one side, and on the other side is suspended and held by a lifting device.

The connection of the segments over the water obstacle is made by means of pins. The fitter connects the spatial trusses, first by installing the bolts of the lower chords of the space truss, then mounting the pins of the upper chords.

Figure 2. Assembly of the structure during the World Youth Day in 2016, a) view of bank supports, b) assembly of the span structure.

Table 1. Technology of works, "method of bridge abutments by crane"

No.	Group	Listing of activities	Equipment
1	1+1+6 (commander, operator, fitter)	Restoration and stabilization of the bridge axis.	Total station, wooden pegs, rope
2.		Preparation of workstations and storage yards.	Lifting device - Jelcz 862 D.43 with HIAB type device, socket wrench 30, socket wrench 50, hammer, crowbar, hooks
3.		Installation of sections of spatial trusses on the shore (connection by means of pins).	
4.		Assembly of the lower parts of the girder (placing spatial trusses on abutments, connecting them with pins over the obstacle).	
5.		Installation of the second girder (as above)	
6.		Installation of crossbeams.	
7.		Assembly of the remaining elements of the first carriageway of the bridge, except for the deck plates.	
8.		Installation of other girders, transverse beams and other elements of the next roadway, except for the deck plates.	
9.		After finishing the last carriageway, assembly of the deck plates.	

Similarly, sections of the second girder are assembled, thus, in the first place, the abutments are connected with the lower parts of the girders made of spatial trusses. Then, the assembly groups between the trusses fix the transverse beams, wind girders and build up the girders with flat trusses connected with trusses, the assembly begins from the middle of the span. In the last phase, the deck plates and the entry elements of the structure are assembled.

The described assembly technology can be used in the construction of single-span bridges in a free-supported system. The span of bridges constructed in this way, with the use of full-time lifting devices (JELCZ 862 D.43) ranges from 6 to 24 meters, with the use of mobile cranes up to 30 Mg. It is possible to install spans with a span of up to 30 meters. It should be noted that with the span of more than 24 meters, the deflection of the structure (kinematic - from assembly play in joints) is significant, which makes the installation of flat gratings difficult. In such a situation it is necessary to lift the lower parts of the girders with the use of hydraulic jacks or lifting devices. This allows for the leveling of the kinematic deflection of the structure of the lower part of the girder and facilitates connection with flat gratings. Any such necessity will extend the assembly time, but this time will still be much shorter than in the case of traditional construction technology.

The second technology presented in the article was developed by the co-author of the article. This technology was used for the first time for the reconstruction of the crossing after the failure of the road bridge in Szeligi town - Fig. 2.

Figure 3. Crossing after the failure of the road bridge in Szeligi town.

The conditions of the crossing were determined by the occurrence of a crisis situation, i.e. the passage of the flood wave in July 2021. As part of the support provided to public administration by the Polish Armed Forces, the engineering troops were tasked with supporting the crossing on the Biskupka River. The terrain conditions around the water obstacle were unfavorable, and the abutments of the destroyed structure were washed out. On the lower bank of the crossing there were wet floodplains, on the side of the higher bank the difficulty was caused by the narrow access road leading to the crossing - Fig. 3.

To overcome the obstacle and clear the crossing, it was necessary to use the span structure with a span of 24 meters. In the first phase, the civil services secured the washed out abutments by stabilizing them with steel poles and reinforced concrete slabs. The area along the bridge axis on both sides of the river did not allow for the development of the assembly site. On one side of the Biskupka river, there was a swampy floodplain in close proximity, while on the other side the bituminous access road was about 4 meters wide and it additionally ran in a significant longitudinal slope. These conditions made it impossible to build a folding bridge in the classic technology of cantilever sliding of the structure. There was also no space for placing the lifting devices in a manner other than perpendicular to the water obstacle - this eliminated the possibility of building a bridge in the above-described "crane abutment connection" technology. In connection with the above, the co-author of the article has developed a new technology for the assembly of the DMS-65 bridge, the proposed name of the technology is "connecting abutments for crossings

Figure 4. Field conditions at the crossing point.

with a short erection site". Also in this technology, assembly groups supported by a lifting device operate on both sides of the river, the composition of one group with a list of activities performed by it is presented in Table 2.

Table 2. Technology of works "connecting abutments for crossings with a short assembly site"

No.	Group	Listing of activities	Equipment
1	1+1+6 (commander, operator, fitter)	Restoration and stabilization of the bridge axis.	Total station, wooden pegs, rope
2.		Preparation of workstations and an assembly site	Lifting device - Jelcz 862 D.43 with HIAB type device, socket wrench 30, socket wrench 50, hammer, crowbar, hooks
3.		Installation of sections of spatial trusses on the assembly site. Mounting the counterweight.	
4.		Installation of the first girder (extension of the girder section, connection of trusses with bolts over the obstacle).	
5.		Dismantling the counterweight from the first spar. Installation of the second girder (as above).	
6.		Installation of transverse beams, flat trusses.	
7.		Installation of plates and other elements of the bridge's roadway.	

In this technology, a temporary assembly site is developed on both sides. In the case of the presented crossing in Szeliga, the assembly sites were about 10 meters long and consisted of six assembly rollers arranged in the axes of the girders. The first rolls are placed in line with the abutment, the next ones are placed every 5 meters. The mounting rollers are placed on concrete slabs or on piles of wooden logs. Lifting devices are positioned between the spans' axes. Each of the assembly groups on both sides of the crossing mounts the lower parts of the spar from four spatial gratings on bearings. Then, it partially extends the connected trusses over the water obstacle, maintaining the stability of the structure. After the spar is partially extended, a group of fitters adds a short counterweight, cyclically extending the structure. The counterweight consists of three segments of spatial trusses (one segment consisting of a single space truss, the next two segments of stacked trusses), which allows the stability of the structure to be maintained. The spar segments slid on both sides of the water obstacle are fastened in the middle by the fitter with bolts. It is important that the installer first connects the lower chords of the trusses, then the upper chords. The use of transport belts by the fitter can be a significant help when connecting spatial trusses. Fastening the trusses with a belt allows the fitter to level the trusses and adjust the joints, thus making it easier to drive the pin. Fig. 4 shows the joining of the lower part of the spatial lattice spar.

Figure 5. Connecting sections of the structure in the described technology.

After connecting the spatial trusses, the counterweight is disassembled. The second girder is clamped in the same way. The counterweight used in joining one wall is used as a counterweight to the spar joining of the other wall. Next, the soldiers assemble the transverse beams, wind girders, flat trusses and braces. In the last phase, the deck plates and the driveway are built in.

4 Discussion

Time saving is undoubtedly the biggest advantage of the indicated new technologies and construction organization. It is often a decisive factor in construction, especially in military operations. Based on the experience of practical construction sites implemented by the 2nd Engineering Regiment, it was found that the construction of DMS-65 bridges with the use of new technologies shortens the time of their implementation by about 40% compared to the time allocated to the implementation of crossings using traditional technology.

New technologies significantly reduce the need to carry out many preparatory, basic and finishing works, such as:

- grouping and preparation of the additionally required structural elements, materials, equipment and assembly devices at the construction site;
- preparation of the assembly site;

- stacking and assembly rolls;
- sliding the span structure over the supports;
- dismantling of the mounting bow and counterweight.

The costs of using the equipment are lower by about 20% (eliminated transport of additional elements to the assembly site, launching nose of the bridge and counterweight). Personnel costs are reduced by nearly 60% due to the shorter duration of the task.

It should be emphasized that in the presented solutions, the entire assembly site has been abandoned and its length has been shortened to the necessary minimum. Earthworks are required for the entry and setting of lifting devices and means of transport. However, these robots are also required in the traditional assembly method. The minimization of the assembly area reduces the terrain requirements in the vicinity of a water obstacle. This is an important factor when it is necessary to build a bridge in unfavorable and demanding terrain conditions (terrain with longitudinal and transverse slopes, limited area of land).

5 Conclusion

The use of folding bridges to secure the needs of civil communication in crisis situations and as logistic bridges in military operations is necessary to ensure the capacity of the road network in Poland [5, 10, 12]. These structures are intensively used for the construction of detour bridges during the renovation of permanent structures. Folding bridge structures available in Poland have a limited load capacity in relation to the requirements of modern standards [3, 5], however, they still play an invaluable role in the case of the necessity to ensure quick construction of crossings. The DMS-65 folding bridge is the most numerous in the warehouses, and it is this structure that is currently most often used for the construction of temporary crossings.

The limitation in the use of the described new technologies for the construction of crossings from the DMS-65 folding bridge structure is their use only in single-span structures. However, when building crossings of this size, they can be an invaluable tool for reducing construction time and costs. An example of such a reduction in construction time and costs may be the task related to the construction of bridge structures as part of the World Youth Day Krakow 2016, when the realization time was reduced by almost 60% and costs by almost 40%.

Currently, none of the structures in stock is produced, which means that the existing reserves are decreasing every year as a result of wear resulting from their ongoing operation. In addition, it should be noted that the structures of the DMS-65 or MS-54 type do not meet modern requirements regarding the load bearing capacity, capacity and horizontal gauge to secure both military crossings for the equipment currently used by the Polish Armed Forces and for the heaviest vehicles that we meet in civil transport. Hence, it becomes expedient to develop a new folding bridge structure that meets modern technical and operational requirements [11].

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