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SUPPORT BRIDGES

PART 1 - EUROPEAN SUPPORT BRIDGES WITH A SPAN OF 40 m

Abstract. The article presents European bridges designed to act as support bridges, which can also serve as line-of-communication bridges. The designs presented enable construction of bridges with a span of at least 40 m for MLC 70 class tracked loads. Tactical and technical specifications of the individual designs are presented. Particular attention is paid to the construction materials for essential components, structural design, assembly process, logistic systems of transport and deployment.

Keywords: military bridge, support bridge, bridge layer, bridge span, launching beam.

1. INTRODUCTION

Military bridges are very important in maintaining the mobility of the army, as well as for the national economy (civilians) in order to quickly reconstruct the road infrastructure in crisis situations (failures and collapses of bridge structures resulting from the action of natural forces or terrorism). According to the defence standard [1], and in the opinion of military experts in many countries, bridges can be classified with regard to the function of negotiating obstacles into three basic groups:

- Tactical Bridging - Close Support Bridges¹,
- Support Bridging - General Support Bridges,
- Line of Communication Bridges.

Regardless of the originally adapted function, tactical bridges can act as support or line-of-communication bridges, and support and line-of-communication bridges can complement each other. However, the most appropriate for the purposes of support and logistics are structures specifically designed for those purposes which, in addition to the short deployment time, also ensure high traffic capacity and safe passage of heavy vehicles. The development of military bridges is mainly aimed at introducing structural and technological changes ensuring increase in load capacity and length, while facilitating the process of bridge deployment.

The requirements on the length of bridge spans depend on the widths of the terrain obstacles. Studies carried out by the US Army [2] show that 24-m bridges enable crossing of 73% of encountered obstacles, while 18-m bridges have the capacity to negotiate 54% of the obstacles. Similarly, Europe, including Central and Eastern Europe [3], is characterized by a large number of various natural and artificial obstacles (rivers, canals, sinks, deep valleys, etc.) that can not be crossed without the use of specialized equipment. Note that in Poland waters occupy 8265 km², which constitutes 2.6% of the total country area. Of prime significance is the fact that gaps wider than 10 m occur every 6 to 7 km on the average, and 70% of these gaps are up to 50 m wide [4].

¹ Close Support Bridges and General Support Bridges are preferred terms in the NATO nomenclature

Requirements and development plans for bridges have been conceived in several armies (among them: US [2], Canadian [4], Polish [5], [6], Russian [7]), where geographical considerations and needs of the armed forces were taken into account. These requirements take into account the specificity of the tasks of the individual armies. The solutions sought currently include structures that can act as support bridges and replace foldable bridges along the lines of supply and during a crisis in the national economy. Classical folding bridges (such as Bailey, MGB, DMS-65) are too laborious to erect and require a large operating crew.

The technology of constructing military bridges has evolved over many years, mainly due to the use of new materials and mechanization of operations [8]. The gradual progress in reducing the workload during the erection of folding bridges with a span of 30 m is shown in Fig. 1. The solutions analyzed in this figure were developed over the first eighty years of the last century. In the 1990s and at the beginning of the 21st century, significant progress was achieved in the speed of erection of support bridges with a span of approximately 40 m. During the last six decades there has been an exponential improvement in the efficiency of the structure. As yet there is no tactical support bridge with a span of ca. 40 m in the Polish Army, and the design of the DMS-65 folding bridge is outdated and fails to meet the requirements on load and traffic capacity.

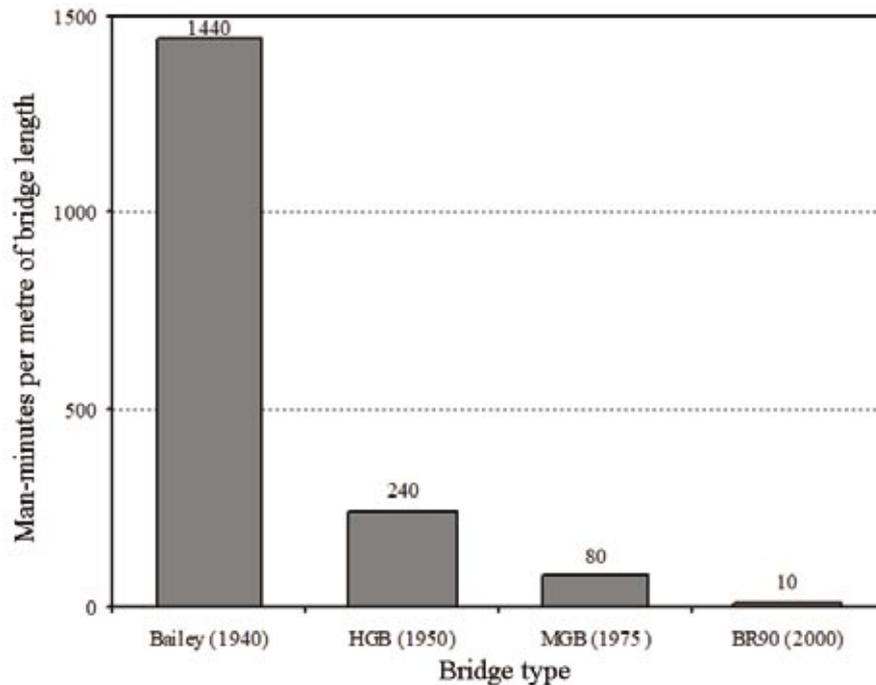


Fig. 1. Improvements in construction efficiency for a 30m MLC70 bridge. [8]

According to [6], the design of modern folding support bridges for the Polish Armed Forces should enable:

- negotiating an obstacle at least 39 m wide,
- erection of the bridge in no more than 1 hour,
- transfer of loads above MLC 70 for tracked vehicles and above MLC 110 for wheeled vehicles,
- filling of spaces between treadways.

Further in the article, European bridges are presented which were designed to act as support bridges and which fulfil the above requirements. In addition they can replace foldable

bridges used in logistics along communication lines. Bridges of other design, the additional purpose of which is acting as support bridges, are not discussed here.

2. REVIEW OF 40m SUPPORT BRIDGES

2.1. DoFB - DORNIER bridge

The German DoFB system is the oldest design of a support bridge with the required span of 40 m for MLC 70 load. Its first concepts were conceived in the 1980s as part of a three-party (USA, UK, West Germany) project "Bridges for the 80s". Based on the experience gained in this project, Dornier developed a "DORNIER FALTBRÜCKE" concept (Dornier Foldable Bridge - DoFB), also known as "Faltfestbrücke" (FFB). This concept has been very positively received by the Bundeswehr and was improved in the years 1984-1987 until the fabrication of the first prototype made at the request of the German Ministry of Defence. Further development of the structure, using modern materials [9] and computational methods [10], and successful tests resulted in the signing, in September 1994, of contracts for the purchase of 10 bridges. The bridge assemblies, that enabled erection of 40-m long bridges, were delivered in the years 1998-2000. The bridge is manufactured by the German company Eurobridge Mobile Brücken GmbH of Friedrichshafen, which is a subsidiary of Dornier GmbH, which in turn in 2006 was integrated with the international company European Aerospace and Defence Company (EADS).

The DoFB bridge span consists of a modular deck and support girders. The structure includes drive-on and middle segments and approach ramps (short and long), as well as a launching beam and ground beams (supports). The deck is solid. The bridge with a span of 40 m consists of 4 middle segments and 2 drive-on segments (Fig. 2), the number of middle segments used determines the length of the bridge. The launching beam (Fig. 3), 40 m long, also consists of 4 middle sections and 2 drive-on sections of the launching beam.

The launching beam with a rectangular cross-section is an element that allows extending the bridge supporting structure over an obstacle. It therefore must be relatively lightweight. For this reason composite materials have been used for its construction.



Fig. 2. Erection of the DoFB bridge; lifting of the drive-on segment and setting of a segment on the launching beam

The main span consists of two girders with a box section (Fig. 2), open at the bottom and stiffened with transverse diaphragms, hinged to the middle roadway. For transportation, both girders are folded under the roadway, forming a rectangular prism ($2.75 \times 1.0 \times 7.0$ m).

Supporting elements of spans and support beams are made of aluminium alloys connected by riveting and by bolts.

The bridge segments are set on the launching beam in the unfolded arrangement (Fig. 2), they are then interconnected and then, by means of the bridge drive, they are moved towards the opposite bank, and the ends of lower chords of the drive-on segments are set on the ground beams. The ground beams are the proper supports of the bridge and are the only elements that contact the ground.

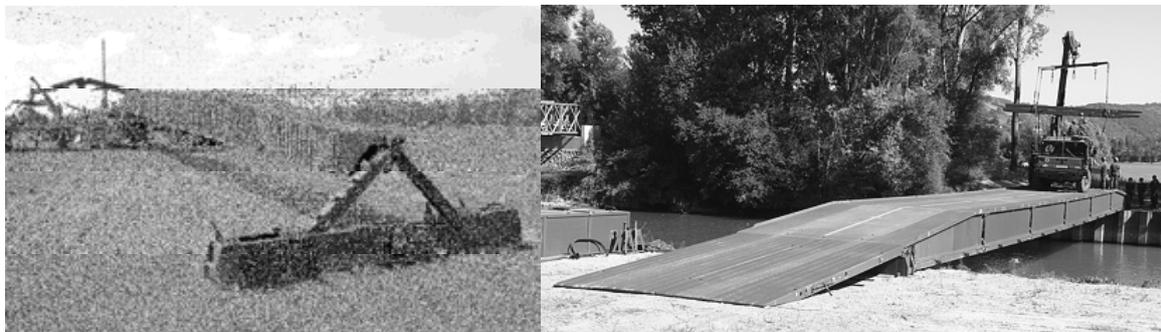


Fig. 3. Launching beam with ground beam and complete bridge with drive-on section [13]

The modular design concept of the supporting structure and auxiliary elements allow construction of bridges of different spans. The complete bridge with a span of 40 m is transported on a bridge-launching vehicle and four transport vehicles. Standard trucks are used for carrying the bridge elements. The original transport vehicle and the chassis of the launching vehicle was MAN A1 (8×8) with a load capacity of 15 t. Bridges supplied to foreign armies used other, "local" vehicles. The weight and dimensions of the vehicle, except the width of 2.75 m, are in accordance with the German regulations on vehicle approval for road traffic. The exceedance of the permissible width by 10% is no limitation for military vehicles. Such vehicles can be driven on public roads also during peace time.

EUROBRIDGE also delivers vehicle trains of total length 54 m, which enable simultaneous erection of two bridges in the following arrangements: 40 +14, 34 + 20 and 27 +27. Such a train comprises two launching vehicles, five transport vehicles, each with a capacity of 15 t, and one 10-t vehicle for carrying equipment.

The option to erect two bridges is also the purpose of the other support bridges described further in this article. That option requires additional sets of drive-on segments and appropriate number of approach ramps. Usually, only one launching vehicle is used, as it is the most expensive component, which prevents the simultaneous construction of two bridges, but still significantly increases the efficiency of using the set in an area with a large number of obstacles of narrow or medium width.

Current DoFB models enable erecting spans up to 46 m in length for MLC 70 T and MLC 110W loads. A 46 m long and 4.4 m wide DoFB set is launched over an obstacle by a crew of 6 during a time of one hour. The driving speed on the bridge is specified at up to 25 km/h.

In 1999 the Polish Army expressed interest in purchasing this bridge. The Military Institute of Engineer Technology, commissioned by the Ministry of National Defence, drew up Technical Requirements [11] for the bridge and conducted tests in Germany [12]. The bridge passed the tests, however, the purchase was not concluded, and work began on a proprietary design of a support bridge.

DoFB is now in service in the armies of the following countries: Spain, Austria², Singapore and Slovenia. Other countries, including USA, UK, Sweden, Russia, have created their own systems based on the design principles of DoFB.

2.2. DSB Bridge

The Dry Support Bridge (DSB) was developed and improved by Williams Fairey Engineering Ltd (England), which in 2006 was transformed into WFEL Ltd³. WFEL started the production of bridges in 1977, after winning a contract with the British Ministry of Defence for the Medium Girder Bridge (MGB). The work on DSB design lasted from 1997 to 2003, and were concluded in a contract for the delivery of these bridges to the US Army.

DSB was originally designed for the US Army as the successor of MGB, classified as a support bridge [14], with a 40-metre gap-crossing capability. Its catalogue designation was M18 DSB, and its nominal load capacity for the maximum span was as follows: MLC 70T (tracked) and MLC 96W (wheeled).

The US Army Tank Automotive Command Centre (TACOM) commissioned WFEL to upgrade the bridge to enable crossing gaps up to 46 m wide, without sacrificing the load capacity of the bridge. New bridges have been delivered to USA since 2013, the US Army having purchased so far 108 sets of DSB. In 2016 a contract was concluded to upgrade 97 bridge sets to meet new requirements [15].

The upgrade included the delivery of an additional middle span and a new launching beam. The upgrade kit also included additional items to strengthen the launch vehicle.

Every new M18 DSB set consists of an Oshkosh M1075 (10x10) launch vehicle towing a M1076 trailer with a PLS (Palletized Load System) carrying the launching beam elements, and three Oshkosh M1077 (8x8) Common Bridge Transporter trucks towing a similar trailer carrying the remaining bridge elements (Fig. 4). The bridge can be transported by C-17 and C-5 aeroplanes.



Fig. 4. Schematic drawing of the M18 DSB set, CBT Oshkosh M1077 transport vehicle with M1076 trailer and IVECO 8×8 transport vehicle [16]

The bridge span consists of two U-shaped aluminium girders combined with the roadway panel forming a 4.3 m wide bridge surface. A single bridge girder module is 6 m long, 1.19 m high and 4.3 m wide.

² In Austria the structure is called Pionierbrücke 2000

³ In 2012 WFEL was acquired by Krauss-Maffei Wegmann of Germany, manufacturer of Leguan assault bridges.

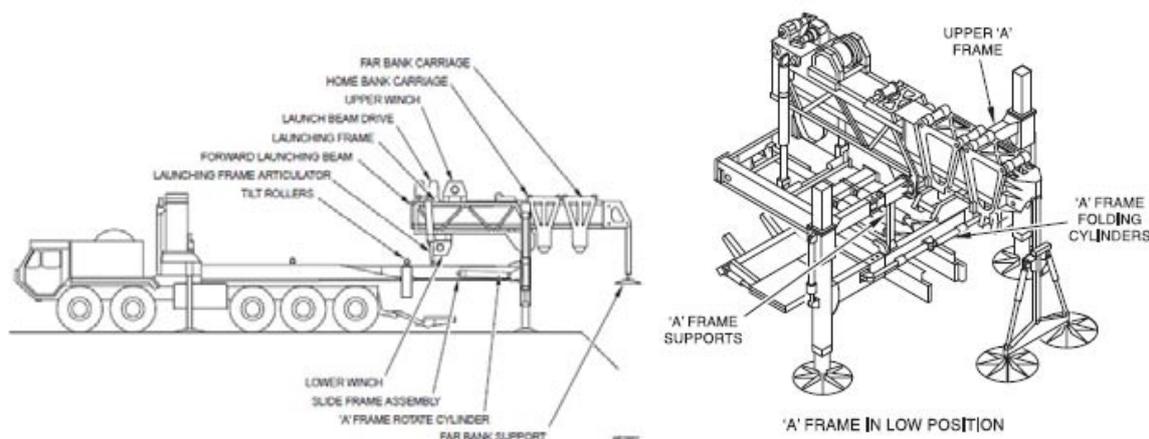


Fig. 5. Launch vehicle with extended launch frame and the launch frame [17]

The bridge is erected using a launcher the task of which is the construction of a launch frame and extending onto the opposite bank a launching beam with carriages for moving the bridge elements (Fig. 5). A 46 m long bridge can be erected by a crew of 8 soldiers within 90 minutes [17], retrieval takes about 150 minutes and can be performed on either end of the obstacle.

DSB bridges are now in service also in the armies of the following countries: Australia, Switzerland and Turkey. In general these are identical structures, possibly mounted on different means of transport. Only the Swiss version is equipped with sidewalks and handrails (Fig. 6), which increases the safety of operation when used in a civilian environment during various types of crises.



Fig. 6. Span of the "Swiss" version of DSB with sidewalk and handrails with a launch vehicle on a IVECO Trakker 10×8 chassis

2.3. FB 48 Bridge

The development of a new support bridge for the Swedish Armed Forces was initiated in 1986 in cooperation between the government's Defence Materiel Administration (Försvarets materielverk, FMV) and the Karlskrona shipyard⁴. The army needed a new type of bridge that could act as a support bridge and a folding logistic bridge in the relatively rich in water obstacles area of Sweden. In the Swedish nomenclature the bridge was codenamed Krigsbro 5 (KB5), with its English equivalent being Fast Bridge 48 (FB 48). Project development and structural tests supervised by the FMV agency led to the ordering of 10 bridges in 1993, with an option for a further 10 to 20 bridges.

⁴ In 1989 the Karlskrona shipyard was taken over by Kockums AB, then by Thyssen Krupp Marine Systems AB, and in 2014 the Swedish SAAB purchased the Thyssen Krupp Marine Systems AB plants in Sweden.

The FB 48 has a modular span with a maximum length of 48 m, which enables crossing gaps up to 46 m wide. The span length ranges from 32 to 48 m, the span consisting of four to six 8 m long, 4 m wide and about 1.5 m high sections. 15 m long ramps enable smooth entry onto the bridge. The bridge set is transported by six standard 12-t trucks and one trailer with the launch system. The launcher is fitted with a hydraulic power system for the crane and a ram for moving the span modules. During launching the launch beam is the first to be extended towards the opposite bank. Then supporting segments are mounted on the beam, connected and moved to the opposite bank (Fig. 7). The total deployment time by a 7-person crew is 75 minutes. The area required for bridge assembly is 6×30 m.



Fig. 7. View of the launch beam extended to the opposite bank and the complete FB 48 bridge set over an obstacle (launch beam between lattice girders) [18]

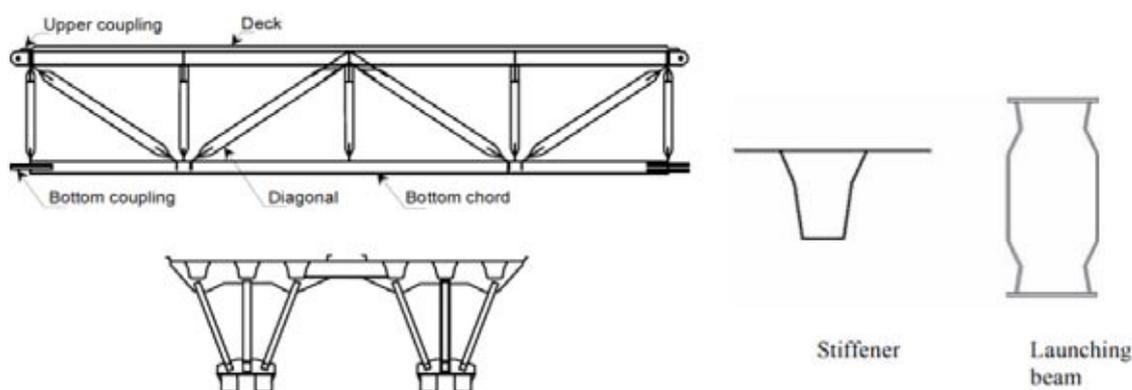


Fig. 8. View of the FB 48 span segment and the cross section of the launching beam [19]

The bridge span module consists of two U-shaped treadway lattice girders with the deck plate at the top. The dimensions of the bridge module are $8 \times 4 \times 1.5$ m, its weight is 5.5 t, while the launch beam weighs 1.7 t. The deck is made of 5-mm thick S1100 steel plate stiffened with cold-formed longitudinal braces (Fig. 8). The bottom girder is made of cold-bent sections, while the truss cross braces are made of S460 rectangular hollow sections. Segment connectors are made of 50 mm S960 steel plates. All essential elements of the bridge are made of high-strength steel with a yield point of 1100 MPa and impact strength of 40 J at -40°C . Since the use of such steel was not covered by the existing regulations and was new in the 1990s, it was necessary to carry out many detailed material tests. Extensive tests of elements regarding local buckling and deformation were carried out. Fatigue and static tests were also carried out on welded parts and welding procedures were checked. These tests, together with the optimization of the structure with regard to the weight, have shown that high-strength steel is a material competitive to aluminium alloys.

In September 1996, Kockums AB, as one of the two competing main contractors, received an order from the US Army Tank Automotive and Armaments Command (TACOM) to develop a heavy bridge as part of the Heavy Dry Support Bridge (HDSB) program. The contract for HDSB was finally awarded to Williams Fairey Engineering Ltd, now WFEL Ltd., for the DSB bridge described here before.

At the beginning of 1994, after completing the feasibility study, FMV began discussing the expansion of the FB 48 design to enable erecting a multi-span bridge up to 200 m long. The span had a maximum length of 32 m between the two-column intermediate supports and provided load capacity of up to MLC 70. The program was named Krigsbro 6 or FB 200. Use was to be made of the key elements of the FB 48: launcher, span segments and ramps. As part of the research program, as early as 1996, a new span assembly system was developed without the use of a launch beam and a system of integrated supports [20].



Fig. 9. The FB 200 bridge over an obstacle and launching of the span segments and of the support by means of a special launcher [18]

The span is installed by means of an ordinary FB 48 launcher which moves the segments from the transport means to the place of assembly. Then a new launcher with a crane moves on the top chord of the span and installs subsequent segments and supports (Fig 9). The span segments and supports are conveyed on a special assembly carriage. In the assembly phase, the span supports the launcher and at the same time acts as a launching beam as in FB 48. The supports are designed as two columns connected to support footing. The support columns are hydraulically extendible from 2 to 12 m.

Although the structure passed tests, the FB 200 program was not completed and deployed to the Swedish army because of the Swedish army reductions and defence cost cuts.

2.4. MMK mechanized bridge

In 1998 the engineering company KBTM⁵ (Конструкторское бюро транспортного машиностроения) at Omsk commenced work on mechanized bridge codenamed "Писк". It was aimed at filling the gap in the capabilities of negotiating medium-sized water obstacles. The existing mechanized bridges (ТММ-3 or ТМР-6) allow fast direct crossing of several dozen metres wide gaps, but require additional supports. They enable crossing of relatively shallow obstacles, ТММ3 up to 3 m deep, and ТММ6 up to 5 m deep. The goal of the project was to create a single-span bridge that enables making a 40-metre-long crossing under various terrain conditions. Studies conducted by KBTM engineers assumed that this length was sufficient to negotiate 87-97% of the obstacles encountered in the battlefield.

The research work on the new design was completed in 2008, and the first bridges were delivered to the Russian army in 2013. The new MMK mechanized bridge (Мостовой механизированный комплекс ММК) can erect spans 16, 22, 28, 34 or 41 m long or two bridges with a total length of 60 m [21]. The entire set comprises four to six transport vehicles⁶, and one or two launching vehicles. The basic version, designed to erect a 41-m bridge, consists of: launching vehicle, four vehicles carrying main span segments and launching beam, and vehicle carrying approach ramps. All the vehicles are based on Ural-532361-1012 8×8 chassis. The structure of the bridge spans and of the launching vehicle was granted a patent in 2010 [22].



Fig. 10. Launching vehicle (MCM) of the MMK bridge [21]

The launching vehicle (Мостосборочная машина – МСМ) consists of chassis and working attachments (Fig. 10), which include:

- mechanism for extending the launching beam over an obstacle;
- loading crane;
- winch;
- hydraulic power unit and equipment;
- supports for stabilizing the launcher.

Bridge launching is based on a procedure that is completely different from those of former Russian bridges. It is similar to that of DoFB, where use is made of a launching beam. In the first stage, six segments of the launching beam are assembled and extended over the obstacle using a winch and a hydraulic system. Then, six segments of the span are moved

⁵ In July 2014 KBTM was transformed into „Омсктрансмаш”, and since 2010 it is part of the УралВагонЗавод concern.

⁶ Various versions of the set are presented at the manufacturer's website <http://www.kbtm-omsk.ru/node/239> and in the concern's catalogue.

along the launching beam to the opposite bank by means of the launching mechanism and the winch (Fig. 11).



Fig. 11. View of the segments of the bridge and of the launching beam in the transport position and assembly of the MMK span segments on the launching beam [21]

The supporting structure of the spans consists of two steel plate girders of triangular cross-section, connected by deck plate. In the transport arrangement the span segments are 3.3 m wide, when assembled over an obstacle they are 4 m wide. The load-bearing capacity of the bridge is 60 tons, with a travel speed of up to 20 km/h, and 80 tons when speed is reduced to 5 km/h. The practical traffic capacity of the bridge is from 340 to 380 vehicles per hour. The greatest advantage of MMK is its short deployment time: 11-person crew builds a 40-metre bridge within 60 minutes.

The first public appearance of the bridge was at the Armia 2016 exposition at Kubinka near Moscow, where it was also offered to foreign customers.

2.5. Support bridges under development

The British Armed Forces are also in the process of replacing and supplementing the BR 90 system bridges, which was created in the 1980s. The increased weight of the army vehicles means that the BR90 requires upgrading the spans and replacing obsolete transport vehicles. Since 2014, the British Army has been working on defining the path for modernization or possible replacement of the BR90 system components. This program was called TYRO Project, its main goal being putting into operation a new bridge system in 2022. It will have to meet the needs of the army at least until 2040.

The first phase of the program, initial analyzes and evaluations, was carried out by BAE Systems in 2016, and in April 2017 a tender was announced for the implementation of the new TYRO bridge project [23]. The contractor is to be selected in 2019.

The TYRO project calls for the delivery of new Close Support Bridges and General Support Bridges in place of the existing BR90 system bridges. There is also an option for modernizing the bridges of the current system and increasing the load capacity to the MLC 100 class for tracked vehicles. The General Support Bridge should provide a span length of at least 30 m with the possibility of negotiating a 60-m obstacle with the use of additional equipment [23].

The most notable bidder is BAE Systems, which plans to design and manufacture the new system together with General Dynamics [24, 25]. As regards the general support bridge, BAE propose to improve the capacity of the existing General Support Bridge (GSB) to extend its length to 44 metres by means of a bridge strengthening kit (Fig. 12) and the possibility of

building two-span bridges up to 62 m long, with floating or fixed support. Span prototypes are currently undergoing tests [26].

In Poland, research work on a new support bridge, with a minimum span of 40 m, was started in 2008. A development project titled "MLC 70/110 mobile folding bridge for negotiating medium-sized wet and dry gaps" is implemented by the Research and Development Centre of Mechanical Devices "OBRUM" Ltd [27, 28].

As part of the project, a bridge set was developed under the name MS-40, whose essential element is a launching vehicle installed on a special semi-trailer. The launcher is equipped with a crane, designed to take up segments of the launching beam and of the bridge, and with a launching mechanism, designed for deploying and retrieval of the bridge over an obstacle. All structural components of the spans and of the equipment are transported on trailers of one type, compatible with trucks used by the Army.

The segmented span is made of high-strength steel in the form of two-girder boxes of trapezoidal cross-section with a deck plate. Maximum length of the span is 45.5 m. The outermost segments have supports and are connected with approach ramps by means of 12 m long drive-on sections. The bridge's load capacity corresponds to MLC 70 for tracked vehicles and to MLC 110 for wheeled vehicles, at permissible driving speed of 20 km/h. The roadway is 4.5 m wide, 3.0 m wide in transport arrangement. The MS-40 project is currently in the final phase of MOD approval procedures. It should fill the gap between assault bridges and obsolete folded bridges of the DMS-65 type.



Fig. 12. GSB construction with strengthening system under the span [26]

3. SUMMARY

In modern armies, there is a tendency to blur the differences between traditional support bridges and folding bridges. Examples of such solutions include support bridges: German DoFB (Dornier Folding Bridge) and British DSB (Dry Support Bridge) manufactured for the US Army, as well as the Japanese Type 07, which have spans of ca. 45 m length and

load capacity MLC 70 T. The Polish MS-40 will have similar specifications. The main problem is the continuous increase in the required load capacity of bridges. In the last 5 years, the load capacity requirement has increased to a minimum of the MLC 80T class, and in the latest British program this requirement is specified as MLC 100T [25].

The following critical requirements are always taken into account when specifying the capabilities of new bridge systems: mobility (in the sense of inherent ability to negotiate difficult terrain), ability to be transported by various means, load capacity, span length and survivability. These requirements vary depending on the function that a given bridge is supposed to meet in securing the mobility of troops.

A military bridge consists of: span structure (possibly with a support), launch system (launcher), chassis for carrying the launch system and means for transporting span structures and equipment components. Designing such a military bridge system is definitely a different process from the designing of civilian bridges.

The traditional optimization of the span structure aims at achieving the maximum load capacity for the assumed span length with minimal use of the weight/cross-section of the construction material. This is not the case when designing military bridges, because the transport and launching means decide about the future operational possibilities of the structure in a significant, if not major, degree. The use of standard or dedicated transport means limits and imposes dimensions and weight of the components of the bridge structure. Modular configuration of the structure must take into account the carrying capacity of the transport vehicles and the ability of the launcher in the individual deployment phases.

When designing a support bridge, its required load capacity and span length must be taken into account. The division of the supporting structure of the span into elongate assembly elements depends on the length of the transporting means, and the transverse division depends on the permissible width and height of the transport means in road traffic. The permissible width of 3 m specified for civilian vehicles is usually exceeded, only the permissible transport height (4 m) is rarely exceeded (e.g. French EFA (Engin de Franchissement de l'Avant): 4.09 m). The military project should not be limited by civilian requirements that do not guarantee the achievement of the objective and make it impossible to create a solution at an appropriate cost to effect ratio. The unique nature of "war actions and needs" should allow for deviations from the civilian requirements to satisfy the military functions of military equipment, including bridge systems. With the implied increased load capacity of bridges, it is not possible to adhere to the old transport requirements. Even the use of modern aluminium alloys or polymer composites reinforced with carbon (or other) fibres will not significantly reduce the cross-sections of supporting elements of the span and launcher, that are necessary to design a bridge for new loads. It should be emphasized once again that a small transport dimension means a small/short structural element, requiring a greater number of assembly elements and operations (time) needed to deploy a long and adequately strong span. Difficult and ineffective will be the search for new design solutions, ensuring high load capacity and span lengths, designed for transportation on standard vehicles with civilian limitations.

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