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## New Modular Bridges Solutions

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# New Modular Bridges Solutions

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**Abstract.** The present paper describes new modular bridges solutions developed by MBSbyBERD, with higher range of spans and load capacity, fast assembly and smart packing. As an upgrade of the Bailey bridges type, MBSbyBERD's developed new structural solutions thought to be launched by increment launching.

Natural disasters, conflicts between peoples and the aging of existing infrastructures have been the main causes for the search of modular bridges as a solution for the rapid reestablishment of interrupted roads. MBSbyBERD solutions aims to accelerate the reestablishment of the connections comparing with the existing market solutions. Designed to be pre-assembled and containerized in order to minimize assembly time, 4 different models of modular bridges have been developed, optimized to cover a range of spans from 15m to 120m. The new range of spans up to 120m offered by BERD, open new possibilities of bridging further margins reducing distances between populations and so social and economic impact.

## 1. Introduction

The modular bridges Bailey type were developed during World War II to be used as logistical bridges with a recognized structural efficiency that has allowed them to be durable with slight geometric adjustments and improved class of materials and accessories. However, these bridges have limitations for spans greater than 60m, namely load capacity, high deformability and assembly time. Nowadays modular bridges are used to respond as a rapid reestablishment solution of disrupted roads in several situations such as natural disasters, conflicts or aging of existing bridges. MBSbyBERD developed new structural solutions that aim to accelerate the reestablishment of the disrupted connections comparing with the existing modular bridges solutions on the market and overcome spans up to 120m, fulfilling the current load parameters for this type of bridge - HL-93 (AASHTO) and MLC80T / 110W (STANAG). Designed to be pre-assembled and containerized in order to minimize assembly time, 4 different models of modular bridges have been developed and optimized to cover a range of spans up to 120m.

## 2. Modular bridges – conventional solutions

### 2.1. Background

The prompt reestablishment of connections is often ensured through the installation of temporary bridges. Mostly of these solutions are based in Bailey Bridge - modular panel bridge – invented during the World War II by Donald Bailey and widely tested and implemented all over the world.



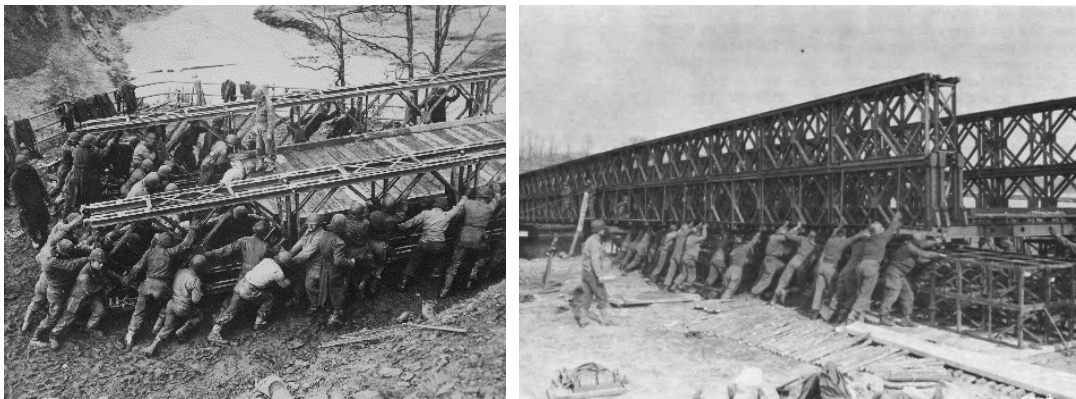


Fig. 1. Bailey bridge - incremental launching during WWII [1] [2];



Fig. 2. Bailey bridge for route reestablishment during the collapse of a section of Highway A14 – Figueira da Foz/ Coimbra, Portugal (2016);

Bailey bridge type is based in two trusses constituted by modular panel pinned between each other. For longer spans (up to 70m) or heavy loads, truss reinforcement can be reached simply by joining more layers or levels of modular panels. The solution achieved, more than 70 years ago, is still being applied. However, the response capacity of the existing solutions is currently limited - in many situations the installation of a modular bridge is not a viable alternative to minimize the impact caused by the lack or loss of circulation. This is due to the limitations of the existing solutions, within which were identified as the most relevant [3]:

- For spans longer than 60m, the existing solutions impose incrementally operative constraints (vehicle weight and traffic speeds);
- There are no solutions for spans larger than 90m;
- For long spans (80 to 90m), assembly times are very long and need very significant human and mechanical means;

## 2.2. Logistic and bridge assembly

Modular panel bridges are usually transported in containers. As so panel measures (10feet long by 7feet height) were limited to fit in containers since their invention. If by one hand light panels were achieved allowing the bridge assembly without mechanical and/or lifting equipment, by the other hand results in a limitation of stiffness that for long spans (>50m) is not solved with the two level panel truss girder.

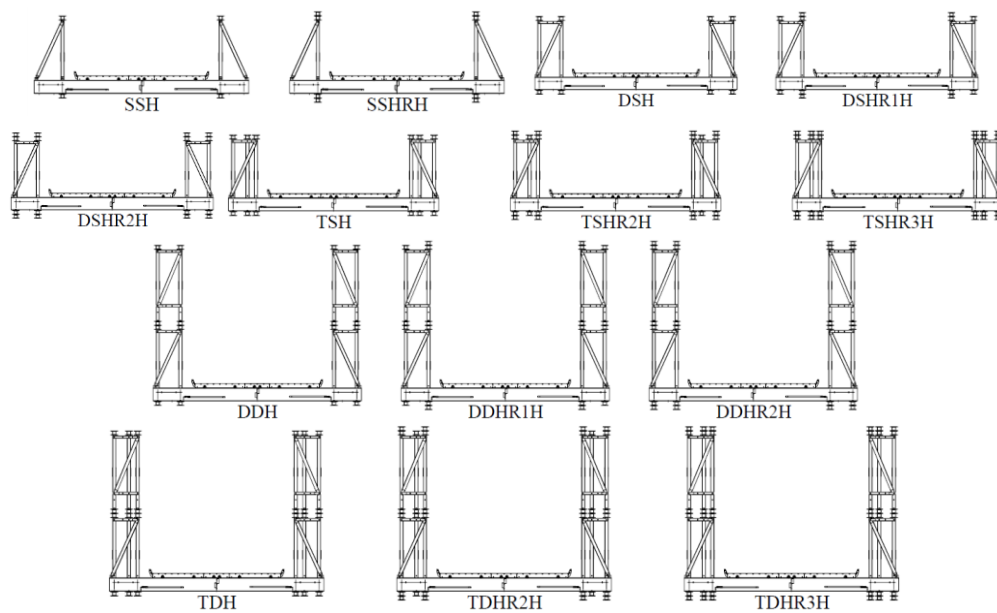


Fig. 3. Bailey bridge – cross sections types – panel combinations [3];

Modular bridges are assembled in one of the margins and then placed using cranes (allowable for spans up to 30m) or using incremental launched construction process. For the launching operation is used a lighter structure “launching nose” to reach the opposite margin. During the bridge launching pavement panels are located in the back of the bridge. This permits to have a lighter structure during launching operation and the needed counterweight to keep the static equilibrium.

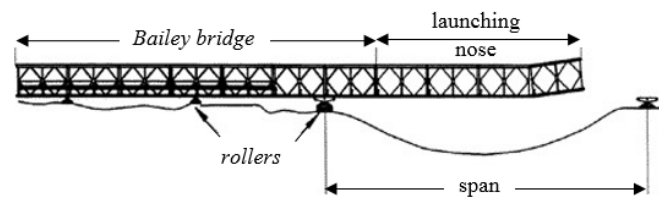


Fig. 4. Bailey bridge - incremental launching [3];

### 3. Design criteria for modular bridges

#### 3.1. General parameters

The design of modular bridges is strongly conditioned by a set of parameters, namely geometric requirements (span, number of lanes, width of the deck), assembly (topographical conditions and accessibility of the margins), transport, connections and modularity, among others. The deck width is standard and depends from the number of lanes: 1 lane normal width - 3.15m; 1 lane extra width - 4.20m; 2-lanes - 7.35m.

Since modular bridges had their backgrounds in the military area, the main guidelines to design are also military. The Trilateral Design and Test Code for Military Bridging (TDTC) [4], developed by the US, UK and Germany, provides recommendations on the several parameters that should be considered in the design of temporary bridges, where modular bridges can be included.

#### 3.2. Loads

Apart the conventional loads normally considered in bridge design, in the case of vehicle loading there are some particularities that depend of the bridge application - civil or military. It has been found that in general the main manufacturers of modular bridges (Mabey, Acrow, Wagner-Biro among others) use the load model defined by AASHTO (USA) - HL-93 (or previous versions) for civilian applications and

STANAG2021 (NATO) for military applications. In the case of civilian application, the vast majority of countries that regularly acquire modular bridges, namely Peru, Colombia, Chile, Indonesia, among many others, have based their codes in AASHTO, being therefore deprived the EC1, even by the European manufacturers.

In the case of military actions, NATO developed the STANAG standard on the military load class of bridges, barges and vehicles. The NATO classification system considers 32 classes (MLC) of vehicle type - VT (16 wheeled vehicles and 16 tracked vehicles): 4, 8, 12, 16, 20, 24, 30, 40, 50, 60, 70, 80, 90, 100, 120 and 150 [5]. Besides vehicle loading defined by STANAG, TDTC introduces other loads that should be considered during modular bridges design.

1	2	3	4	5	6	7
MLC	Tracked Vehicles	Wheeled Vehicles				
		Axle Load [Tonnes] and Spacing [m]	Maximum Single Axle Load	Tyre Load and nominal Ground Contact Width [m]	Axle Load and nominal Ground Contact Length [m]	Axle Wheel Spacing and nominal Ground Contact Width [m] (1)
100						
120						

Fig. 5: Characteristics of the vehicles used in the MLC category system of STANAG (extract for MLC100 and MLC120) [5]

In case of bridges to be used temporarily in the construction of other infrastructure works, namely works involving the movement of large volumes of land in places with crossings of valleys and / or water courses, design must be done considering the specific vehicle to be used in that work, like high load capacity dumpers.

Vehicle loads should also be increased by impact factors - 15% for bridge and 20% for access ramps in the case of TDTC and 1.33 in the case of AASHTO [4].

## 4. New modular bridge solutions

### 4.1. General

The main challenge associated to the development of a modular bridge is the combination of the conditions that must be met in the replacement or materialization of a connection between two margins in one of the scenarios identified above.

In addition, to the necessary study of the structure of the modular bridge and the particular aspects of this type of bridges, namely the constitution of the modular elements with fast connections to one another, ease of transportation, new configurations, material efficiency, etc. there are important challenges associated with the construction/ assembly of a modular bridge. In case of underdeveloped countries, the reestablishment time of a collapsed or damaged bridge is relevant but might have a low social-economic impact. In developed countries the time for a bridge reestablishment have a high social-economic impact. In order to respond to these issues, MBSbyBERD developed new modular bridge solutions that were designed considering several core aspects, namely:

- Load capacity required by main standards;
- Service limitations defined by standards (for example deflection);
- Enable the pre-assembly of the most part of the pieces in factory and the final assembly in the site become much faster than the traditional solutions;
- The pre-assembled module is containerized (20 or 40feet);



- The “wrap effect” condition the geometry of longitudinal truss. Geometry is also conditioned by internal forces.;

MB60, MB80 and L-MB120 (spans up to 120m) are bridges with faster assembly<sup>2</sup> combining modularity with high load capacity ASSTHO HL-93 and STANAG MLC110W/80T. The modular bridges use common material (steel S355), pinned and bolted connections and the same construction process – increment launching, as Bailey bridges type.

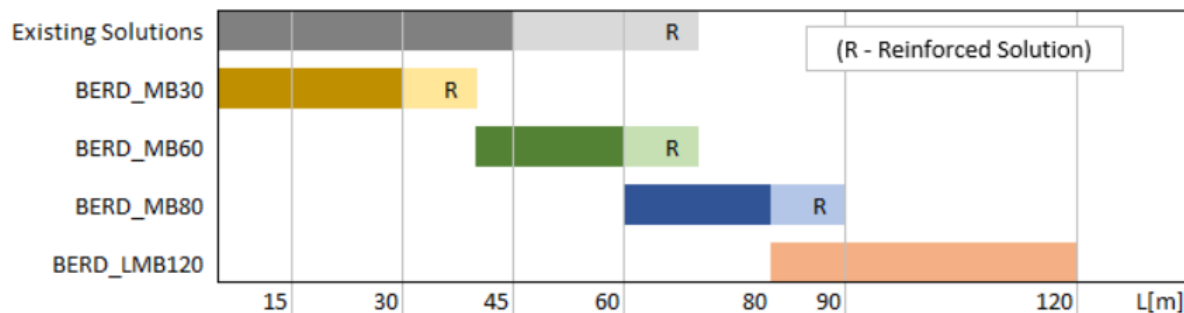


Fig. 6. Bailey bridge - incremental launching [6];

#### 4.2. Solutions to spans up to 60m

For spans up to 60m two solutions were developed, the MB30 optimized for 30m spans, and the MB60 for 60m spans. In the case of the MB30, it was decided to place the deck on the top of the truss beam thus taking advantage of the transversal beams and deck panels in controlling the instability of the upper chord under compression. This solution allows you to adjust the load capacity as well as the width of the deck by adding new planes of longitudinal trusses. MB30 can also be assembled without the use of mechanical lifting equipment like the Bailey bridges type.

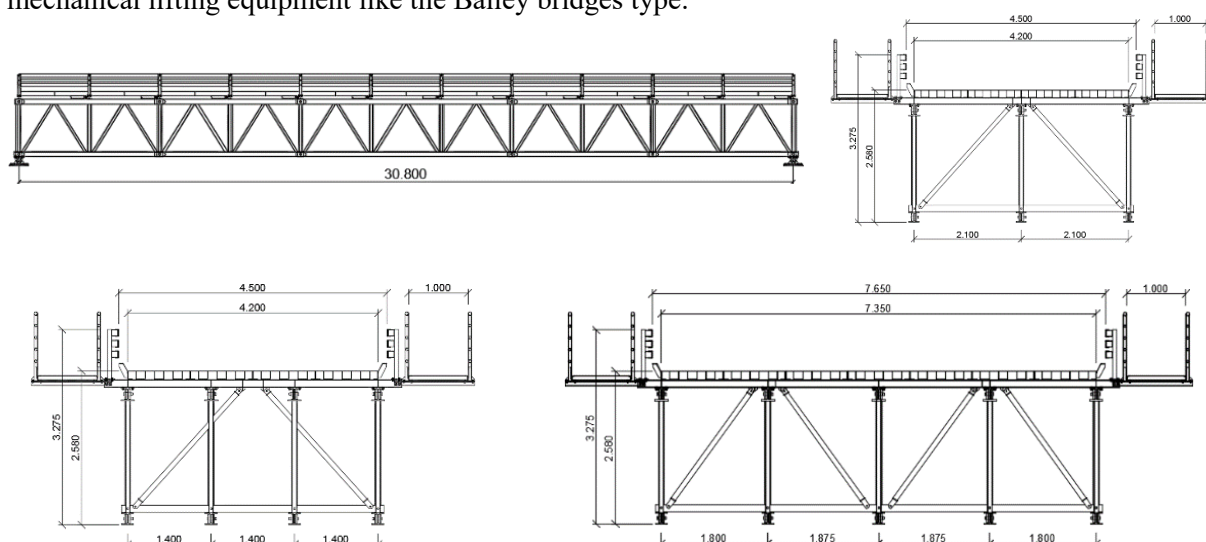


Fig. 7: MB30 – Elevation and cross sections corresponding to different deck widths and load capacity.

<sup>2</sup>

When compared with main market players (Mabey and Acrow) with similar spans (60m and 90m). No cases are known of modular bridges for spans longer than 90m

The MB60 has a high load capacity and meets the deflection limits of AASHTO. To do so, the height of the trusses was increased to 4.1m which implied the impossibility of producing welded modules by containerization reasons. Thus, a new concept was developed of articulated modules, pre-assembled in the factory and optimized for containerization and rapid assembly on site.

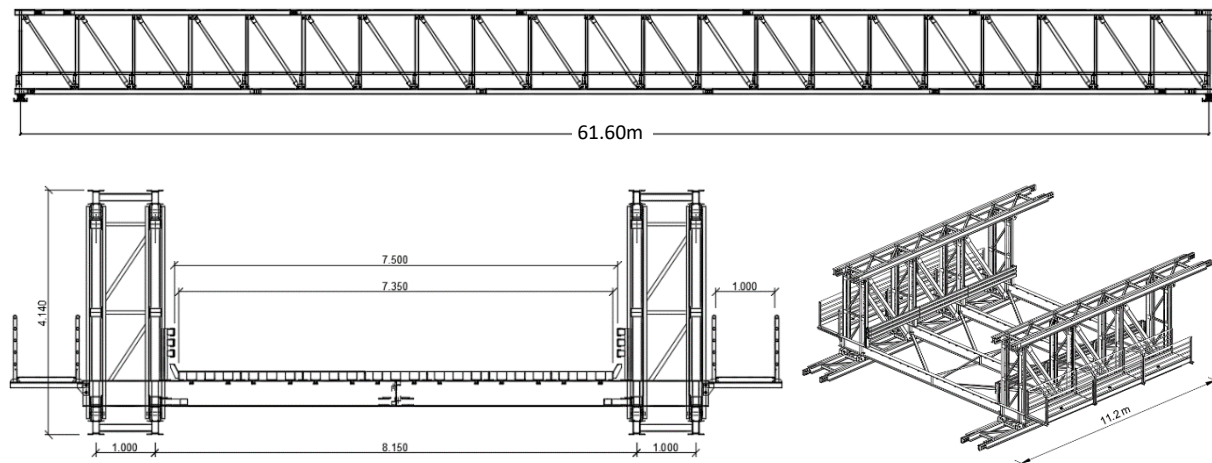


Fig. 8: MB60 – Elevation, cross sections and perspective for two lanes solution

#### 4.3. Long span solutions (up to 120m)

For spans longer than 60m, the modules developed for the MB60 have limitations, mainly in the deflection. The possibility of applying reinforcements in the truss chords allows some flexibility for spans up to 70m. However, for longer spans these reinforcements are ineffective. Thus, it was designed specific modules for this range of spans (MB80 and LMB120), with a height of 8.84m, which from 80m are reinforced with the inclusion of an upper bow-shaped chord. The significant height of the modules allows creating a closed cross-section with clear benefits in controlling instability phenomena. These modules are also articulated to be containerized.

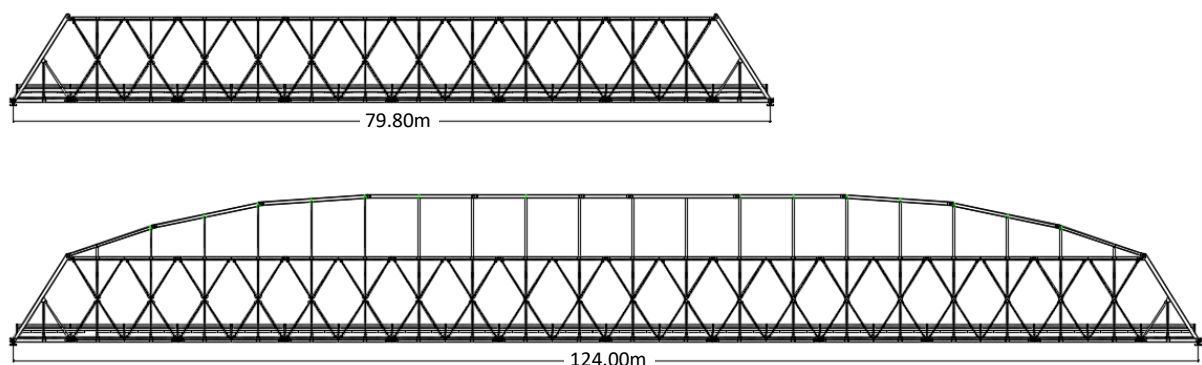


Fig. 9: MB80 and LMB120 elevations

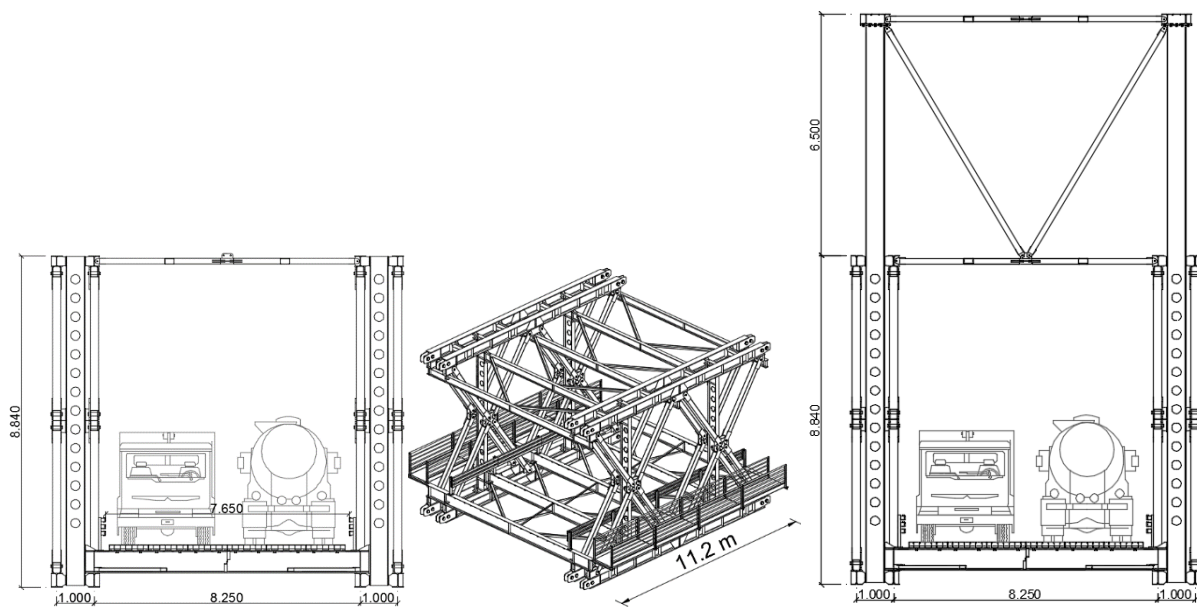


Fig. 10: MB80 and LMB120 cross sections

#### 4.4. Logistic and bridge assembly

New bridge solutions have modules that are packed for being easily removed from containers and are partially pre-assembled in order to accelerate assembly process (see Fig. 5 and 6). The reduction of number of assembly connections on site and longer modules (5.6m or 11.2m) than Bailey bridge type (3.05m- 10feet) are crucial aspects to reduce the global duration assembly time.

MB60 and MB80/LMB120 modules types are longer and heavier and common pulling and lifting equipment is required on assembly operations. Although Bailey bridge modules are lighter, the use of mechanical equipment on lift and launching operations is also common.

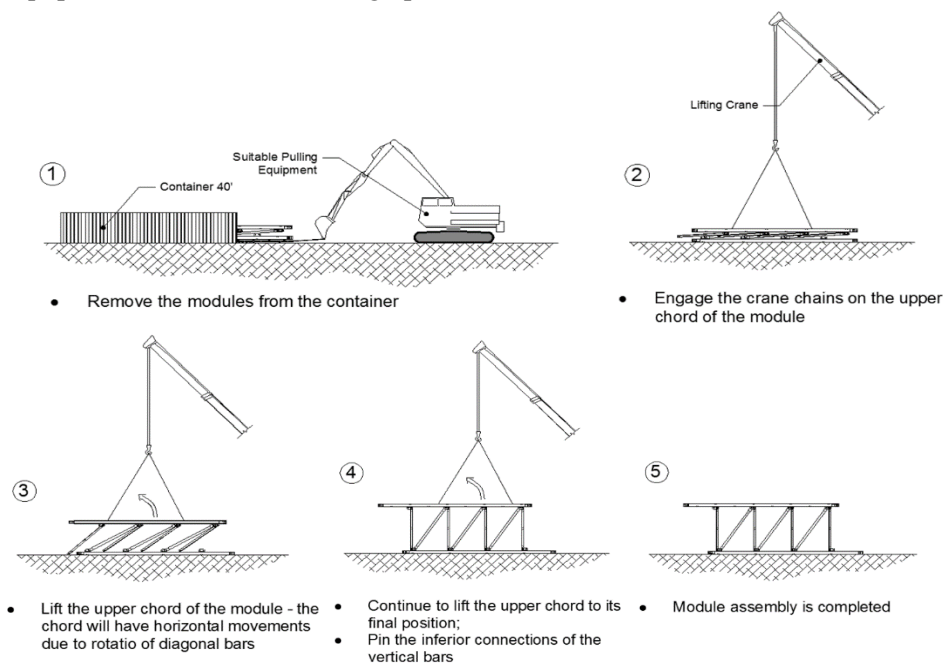


Fig. 11: MB60 – Module type assembling;



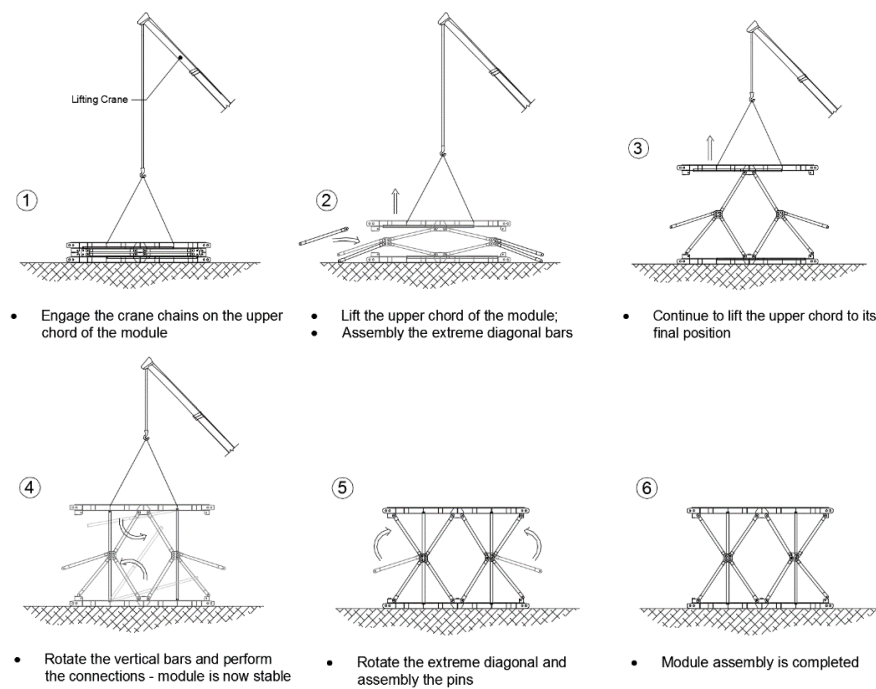


Fig. 12: MB80/LMB120 – Module type assembling;

Both module types were designed considering the scissor opening movement.

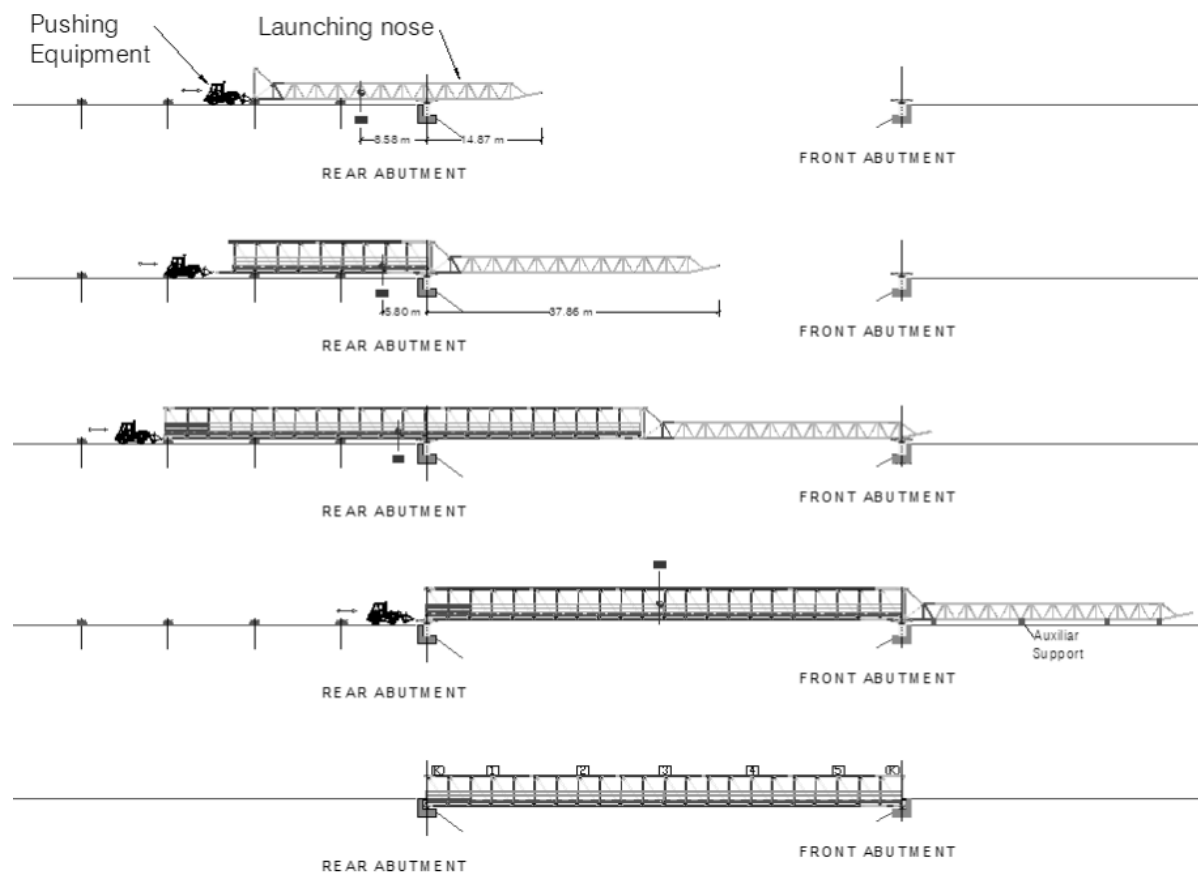


Fig. 13: MB60 – Incremental launching;

As already mentioned before, MB60 and MB90/LMB120 are installed in the final position using incremental launching method, similar to the common modular bridges installation. MBSbyBERD kinematic studies point out to a global assembling time reduction up to 40% [6].

## 5. Conclusions

Modular bridges are being used as fast reestablishment solutions for routes disruption and to the reduction of social-economic impact. However, this impact can be even more reduced if the installation of the modular bridge becomes faster and if longer spans are available. As so, MBSbyBERD developed new modular bridge solutions to accelerate the reestablishment of routes in different scenarios and for different levels of need.

## 6. References

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