M1-70-S MOVABLE SCAFFOLDING SYSTEM (MSS)

FOR THE D4R7 DANUBE BRIDGE

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Figure 1: Construction of West approach Viaduct to the Danube Bridge (Photo Credit D4R7)

THE DANUBE BRIDGE

The Danube Bridge (Bratislava Bypass), currently under construction, is a highway bridge, with a total length of 2,934.5m, part of it spanning over the Danube River, 10km from Bratislava city centre.

In structural terms, it comprises the 900m long central main bridge and two access viaducts – 784m long West viaduct (span arrangement of 53m + 10x67.5m + 53m) and 1,250.5m long East viaduct (span arrangement of 62.5m + 16x70m + 65m).

In order to simplify the construction, the bridge superstructure was built in two different stages: the central box girder and the lateral wings were built in different stages by different equipment.

Figure 2: West viaduct construction: M1-70-S Movable Scaffolding System at the 9th span and wing traveller at the 1st span (Photo Credit D4R7)

The viaducts central box girder was built as a full span continuous beam using movable scaffolding systems, while the main bridge central box girder was built by the balanced cantilever technique using form travellers.

In both cases (main bridge and viaducts), the lateral wings were built in a second stage by auxiliary equipment designated as wing travellers.

The cross section of both viaduct decks is very similar.

They were designed to be built by similar movable scaffolding systems.

The construction method valued the following criteria: fast construction cycle, minimizing interference with the ground (only longitudinal access near the piers alignment was provided), minimizing the need for external auxiliary machinery, timely planning and organization of tasks and last, but not least, maximizing safety.

M1-70-S MOVABLE SCAFFOLDING SYSTEM (MSS)

The movable scaffolding systems (MSS) applied in the construction of the approach viaducts are designated as M1-70-S (Figure 3) since they are a version of the larger span overhead MSS family from BERD named as M1, already successfully used in construction of 4 prestressed concrete viaducts with 90m long spans.

In this specific application, the M1-70-S span range is limited to 70m.

In generic terms, the M1-70-S comprises the following components:

1) Main Girder;
2) Transversal Structures;
3) Supporting Frames;
4) Formwork;
5) Platforms, and
6) Equipment (hydraulic and electrical components).

Figure 3: BERD'S MSS M1-70-S, West viaduct construction (Photo Credit D4R7)

The Main Girder is the key structural component, capable of spanning the distance between the supports loaded by its self-weight and by the weight of the deck under construction.

Structurally, the Main Girder is a variable depth steel trussed box section with an arched upper chord in the central part and suspension ties for the front cantilever.

The Transversal Structures support the Formwork and include the necessary kinematic mechanisms for Formwork adjustment and for bottom part rotation needed to pass through the front pier section during longitudinal movement between adjacent spans (Figure 4).

There are 3 types of Supporting Frames depending on the specific position/function:

1) Pier Frame is placed on the zero-segment fixed to the pier cap and is used during the entire construction cycle;
2) Concreting Frame is fixed to the Main Girder and is the rear support during the MSS fixed phase (usually called Concreting);
3) Launching Frame is assembled on the span, being used only during the Launching.

The Platforms provide the access and safe working conditions on all working areas.

Finally, the Equipment is distributed along the MSS to accomplish the several kinematic functions of the MSS, namely the load transportation (with chain winches), the longitudinal launching (with hydraulic winches), the Main Girder vertical movement and opening/closing of Transversal Structures (with hydraulic cylinders).

The electrical energy is supplied by a diesel generator placed on the Main Girder rear area for better access to the refill tasks.

In Figure 4, the M1-70-S transversal section is presented in two different configurations: configuration for concrete pouring with transversal structures closed (left side) and configuration for MSS launching with transversal structures open (right side).

This figure highlights one of the advantages of using M1-70-S in this particular application – it allows construction of decks very close to the ground, therefore minimizing interference and excavation volumes.

This feature was essential while the MSS was operating over the dike in the West side of the Danube Bridge.

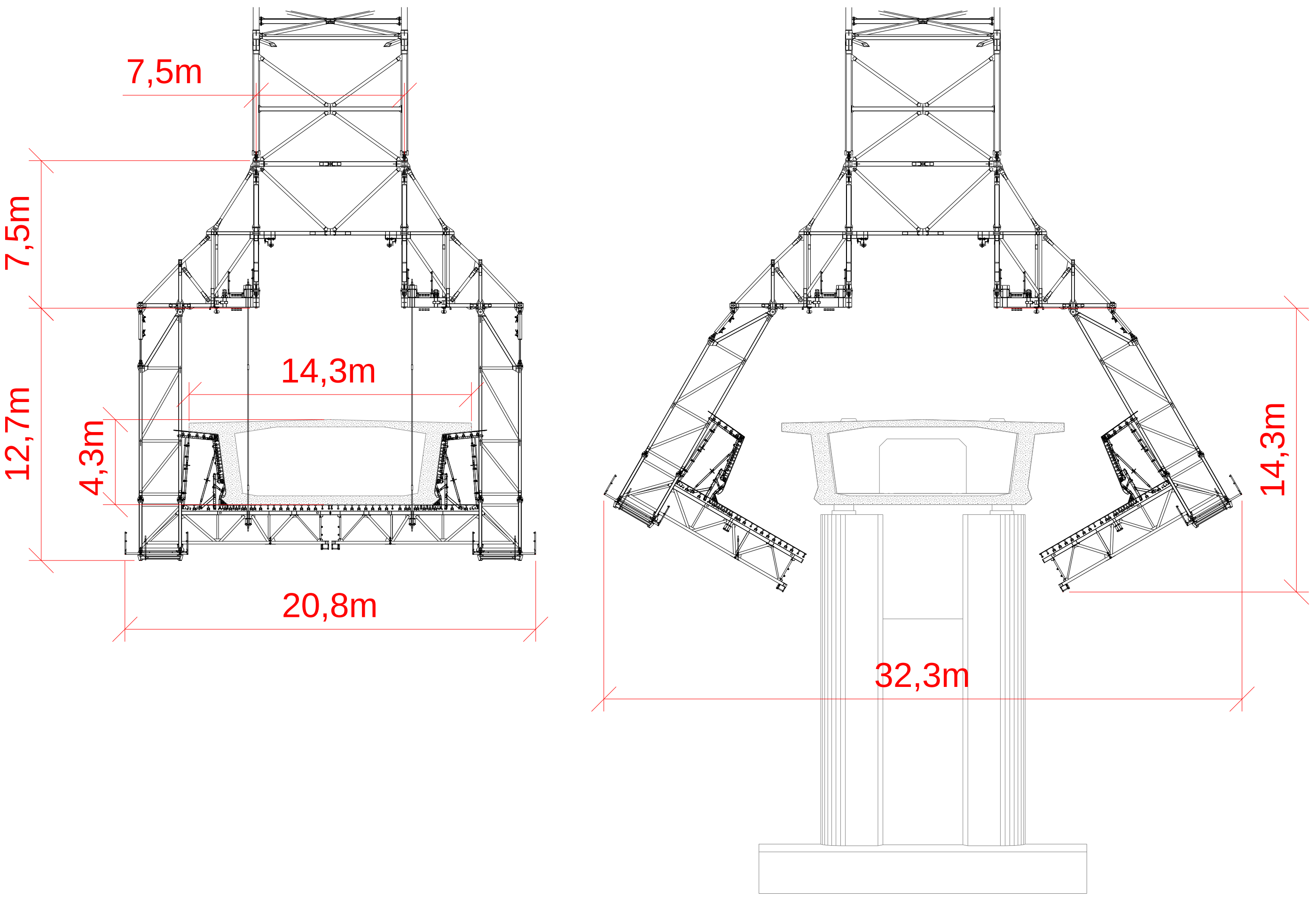

Figure 4: Transversal section of M1-70-S: Concrete Pouring (left) and Launching Configuration (right)

MONITORING PROVIDED BY OPS (ORGANIC PRESTRESSING SYSTEM)

In both MSS used for construction of the viaducts, the main girders are strengthened by an active prestressing system – OPS - patented by BERD, featuring a continuous mid-span deflection monitoring and compensation system.

For the Main Girder deflection measurement, a system based on the "communicating vessels principle" with pressure transducers at the supports and at mid-span is used.

The deflection at mid-span causes pressure variation on the mid-span transducers from the reference defined by the alignment of transducers at the supports.

When the mid-span deflection of the MSS reaches a predetermined threshold, the OPS algorithm transmits to the OPS hydraulic cylinders instructions to compensate the deflection.

To avoid uncontrolled loss of force on the OPS hydraulic cylinders, lock nuts are used to ensure a mechanical retention of force if the hydraulic circuit bursts.

For appropriate operation, the OPS measures continuously several variables, including the mid-span deflection, pressure and stroke of hydraulic cylinders, lock nut position and temperature of the

Figure 5:- Transversal section of M1-70-S

cabinets and of the oil in the deflection measurement circuit and the hydraulic cylinders circuit.

These variables are recorded on files that allow the analysis of any anomalies and malfunctions.

Furthermore, the OPS ensures additional safety during concreting by real time MSS monitorization, emitting warnings and alarms if an anomaly is detected.

The OPS layout is presented in Figure 6, which shows the different components of the system, namely:

1) Active anchorage (hydraulic actuator);
2) Hydraulic unit;
3) Prestressing tendons;
4) Main board including the rear pressure transducers;
5) Mid-span pressure transducers;
6) Front support pressure transducers;
7) Passive anchorage.

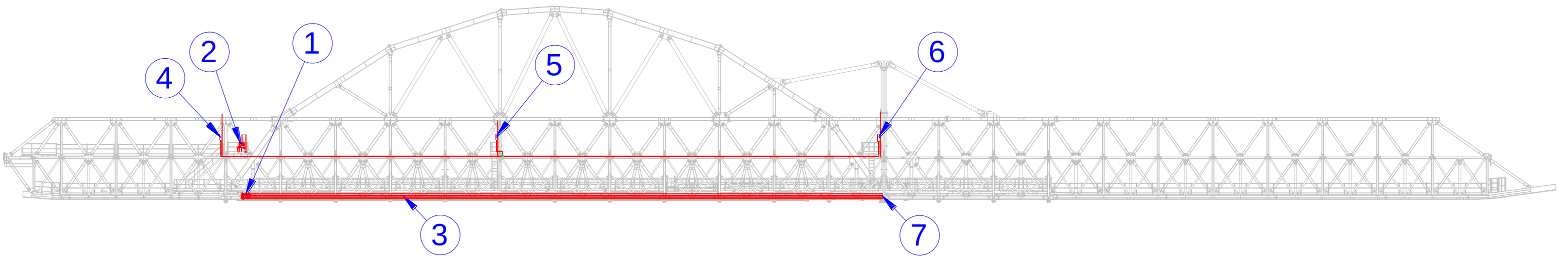

Figure 6: OPS layout

COMPLEMENTARY MONITORING SYSTEM

While the OPS provided continuous and real time monitoring for both MSS, a complementary monitoring system was installed exclusively for the West side MSS, covering the 12 spans to be built.

This complementary system gathered and analysed data with the intention of further development of the OPS into a Smart OPS.

The complementary monitoring includes three subsystems, comprising sets of anemometers, strain gages and accelerometers.

Together, these subsystems allow the characterization of loadings.

Wind is the most important variable load.

The permanent loads are obtained by the sum of the weight of the individual elements.

The static structural response is determined by measurement of strains on representative elements and the dynamic response (vibration) is measured by accelerometers.

The monitoring of wind characteristics provides validation of design assumptions and the correlation between the structural response and the excitation, to better define the interaction between the air flow and a flexible structure.

The time series are processed by algorithms that allow the real time identification of the dynamic modal parameters that define the dynamic response of the structure.

Since the natural frequencies are a function of the structure stiffness, any damage, incorrect assembly or structural deterioration that imply a reduction of the stiffness is identified by a reduction of the natural frequency.

The precise measurement of the natural frequency variation with time enables the detection of small structural changes.

However, since natural frequencies are also affected by the temperature, wind speed and operation conditions, these effects have to be mitigated with statistical models.

The measurement of strains at fast sampling rate is also a tool used for structural monitoring, namely for the stress state and fatigue assessment.

This last component of the monitoring system is very important in the determination of the residual life of the structure.

Figure 7: MSS M1-70-S in the last span construction

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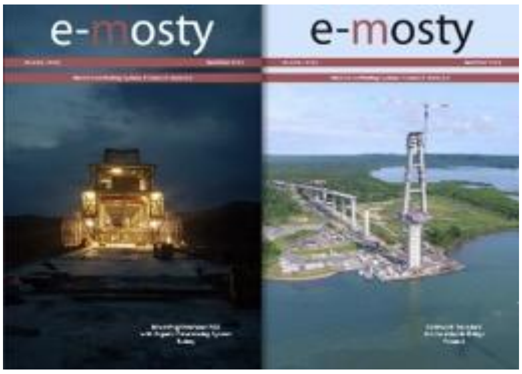

More information about MSS with OPS can be found in e-mosty – click on the image to open the magazine as pdf