Unusual constraints for the assembly of the cable-stayed Kaiser-Otto-Bridge in Magdeburg – Special features and answers

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Abstract:
With the construction of the new cable-stayed Kaiser-Otto-Bridge in Magdeburg was created a new trafficroute for streetcars and tramway across the river „Alte Elbe". The total length of the threespan structure is 248 m. The mainspan with a width of 158 m is spanned by a 63 m high pylon and strand-based-cable-systems. The location blocked the design of an ordinary construction method for this type of structure.
In relation of an high-ambitious schedule solutions for fabrication, assembly and the integration of the pylon-erection were developed and demonstrated.
The transverse oriented steel structure of the one-piece composite box girder in the mainspan was manufactured by SEH Engineering in Hanover and assembled in balanced cantilever method. The following article article reports on the special features of the production and assembly of the steel structure, in particular with regard to the selected component structure in the transverse direction and measures for accelerated assembly in balanced cantilever method.

Keywords: Cabled-stayed bridge, Composite Bridge, Fabrication, balanced-cantilever-method

1 Introduction

In the center of Magdeburg, the curved all-steel bridge built in 1965, known as the new Strombrücke, spans the Elbe River. This combined road and tram bridge (heavy traffic, trams, and private vehicles) did not have an adequate continuation to the east, so the traffic from the new Strombrücke had to be diverted over a historic arch bridge, the Anna-Ebert-Brücke, with traffic restrictions.
Attempts were made to eliminate this bottleneck during the former GDR era, but they failed due to a lack of funds for infrastructure improvements. However, there was actually a new route available on the eastern bank of the Elbe that crossed the so-called "Alte Elbe" (Old Elbe).
After flood damage to the Anna-Ebert-Brücke, it was repaired and, at the same time, the planned construction of the continuation of the route specified by the new power bridge was pushed ahead.
As a result of a competition, it was decided to build two bridges, one a single-span frame structure spanning the marina and the other a pylon bridge over the Alte Elbe.
This decision was accompanied by the decision to reinforce the now holistic "power bridge" in the Elbe area to the current traffic load level.
This is because this structure, the aforementioned new power bridge, also had four major handicaps:

1. Structural damage
2. Unfavorable support span ratios
3. Damage to the surface and corrosion protection
4. Undersized structural components

In order to ensure that the route could continue to be used, these deficiencies also had to be remedied in the short term. This was reported in [5] Bundesingenieurkammer (Hrsg.) Ingenieurbaukunst 2025: Made in Germany
The following section describes the assembly of the pylon bridge resulting from the construction site areas designated as no-go zones and the component layout resulting from the assembly.

2 Structural Design, regulations and static analysis

The cross-section of the Kaiser-Otto Bridge consists of a single-cell steel-box-girder with a composite slab on top and crosses 2 tramway tracks, 2 lanes for vehicle traffic as well as facilities for pedestrians, cyclists and various media lines (Fig. 1). The construction height is 2,50 m and the concreteslab is 30 cm thick. The box girder is accessible with corresponding passage heights, walkways and lighting.

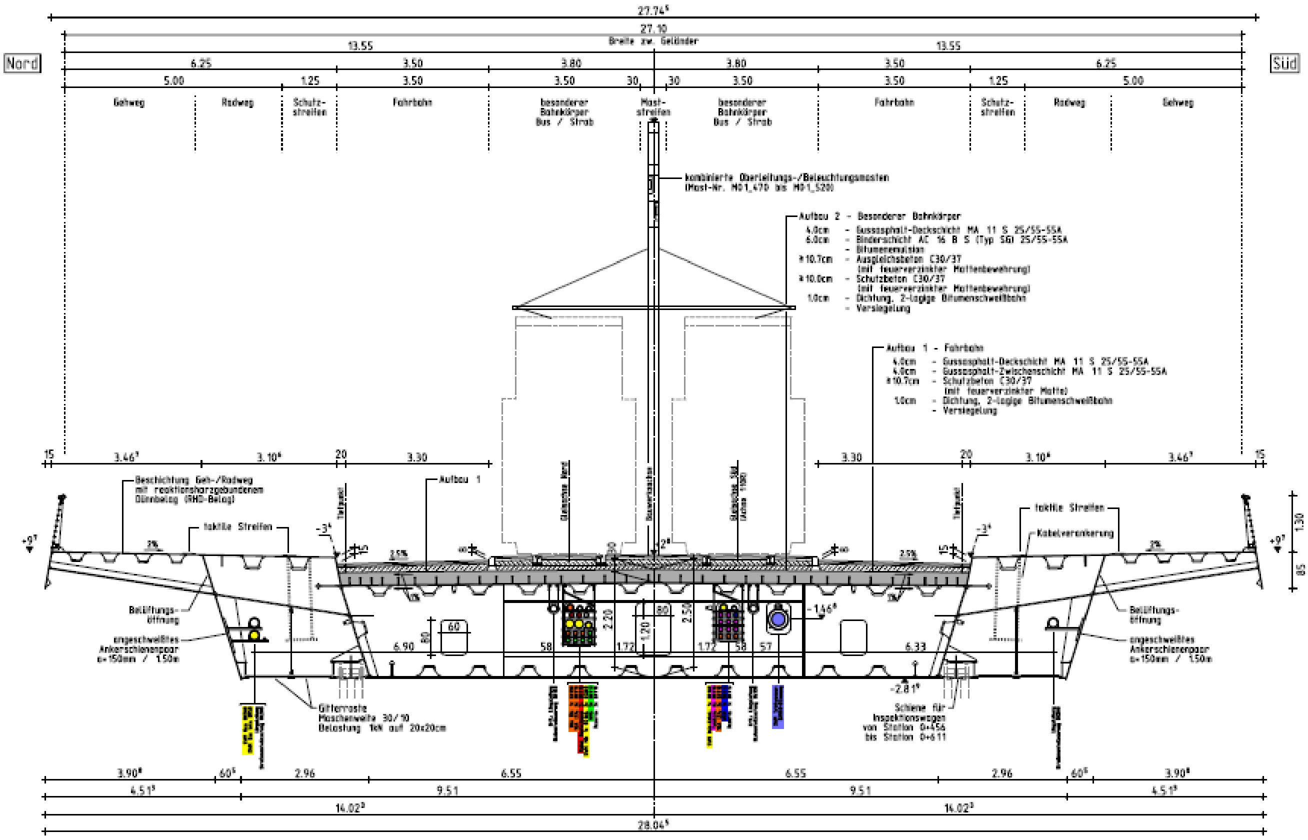

Figure 1: Cross section

The Kaiser-Otto Bridge was designed as a cable-stayed bridge (see Fig. 2) to guarantee the flow cross-section in the event of flooding and to take into account the protection zones of the FFH area below the route.

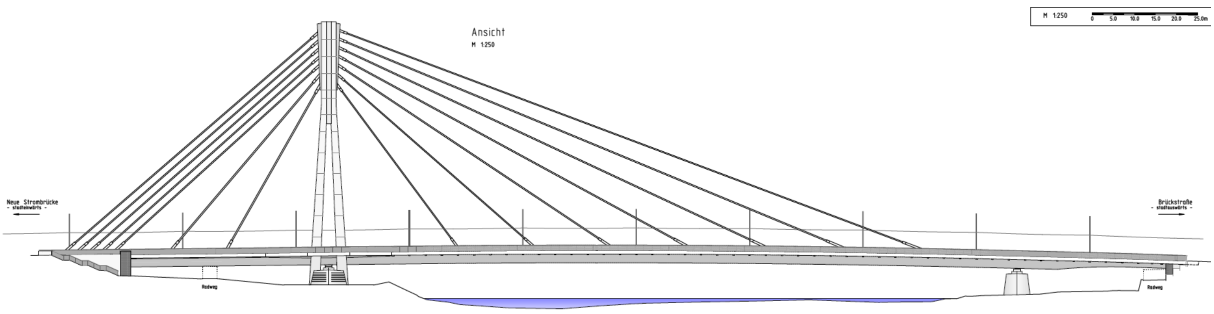

Figure 2: View of the Kaiser-Otto bridge

In order to protect the flora and fauna, the use of land for the foundations of the bridge structure was kept to a minimum.
The total length of the structure is 248 m with a main span of 164 m and a pylon height of 63 m.
Due to the dominant appearance of the pylon, its architectural design (see Fig. 3) was determined in a multi-stage study.

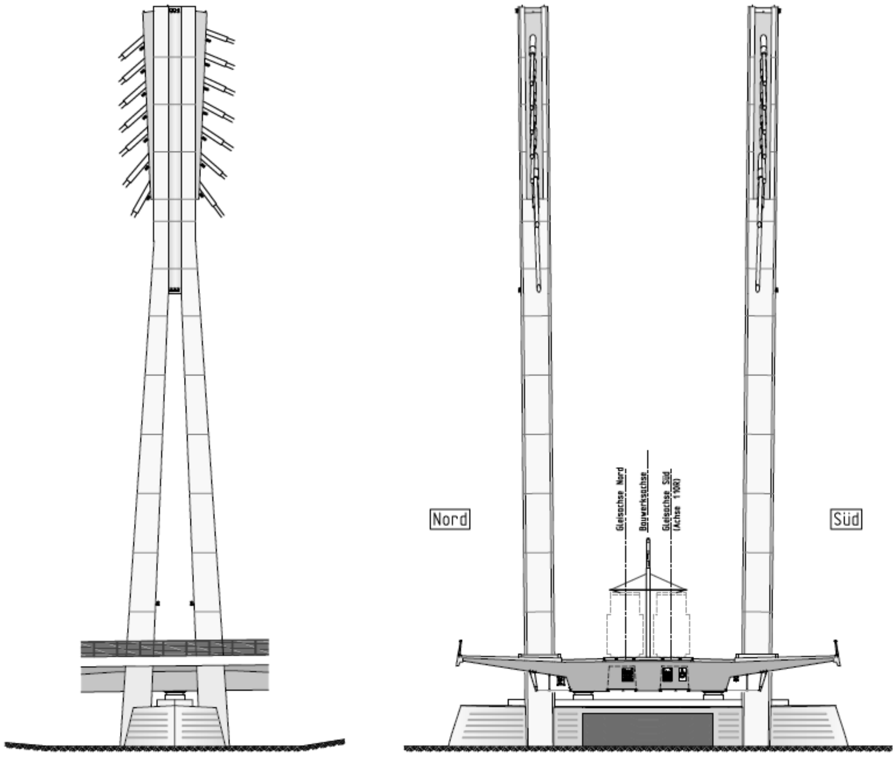

Figure 3: Pylon

The lower section of the A-shaped pylons consists of 2 reinforced concrete columns, each split longitudinally. In the upper section, the columns merge and form a composite cross-section with hollow steel boxes for cable anchoring. The spanning was carried out via 2 lateral cable levels made of strand-based cables.

The structural analysis, execution and quality assurance were carried out on the basis of German and European regulations in particular:

- ZTV-ING (additional contract conditions for civil engineering structures in Germany)
- DIN EN 1990 to 1999 (calculation standards)
- DIN EN 10025 (Technical delivery conditions for structural steels)
- DBS 918002-02 (Technical delivery conditions for structural steels)
- DIN EN 1090 (Execution and quality assurance of steel structures)
- etc.

The global analysis in the longitudinal direction was carried out for all construction stages using a spatial-framework-model. The calculation in the transverse direction and local load applications were analyzed on partial models. The effective widths of the superstructure cross-sections were determined using the moment lines in the serviceability limit state.

The client had the approval- and execution-planning for the structure drawn up in advance and handed over the associated checked documents to the contractor when the contract was awarded. Any possible effects of construction-related issues (e.g. changes to the construction process, assembly loads, etc.) on the advanced planning were to be subsequently supplemented by the contractor. However, optimisation of the sheet thicknesses according to technical requirements were not allowed.

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3 Manufacturing- and assembly-concept

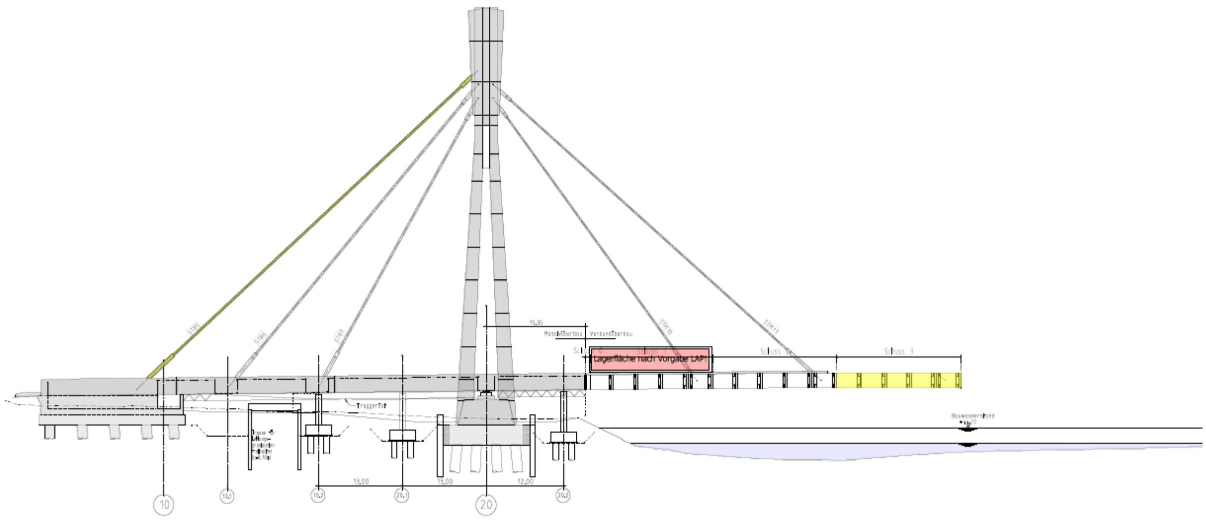

Figure 4.1: procedure-example for the assembly of one deck-sequence

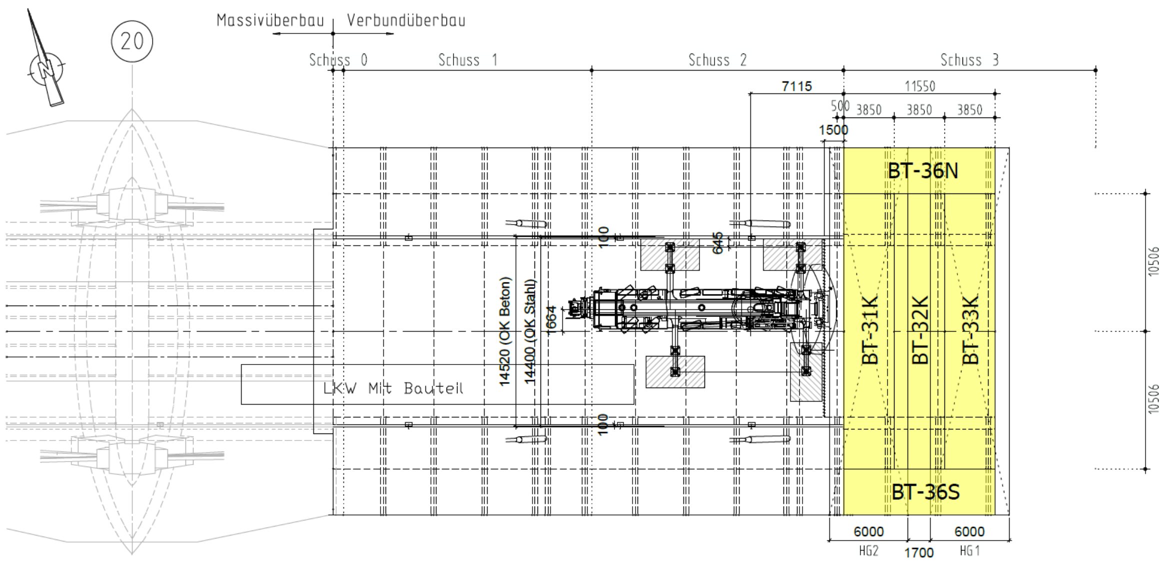

Figure 4.2: assembly segments BT-31K to BT-33K, BT-36N/S

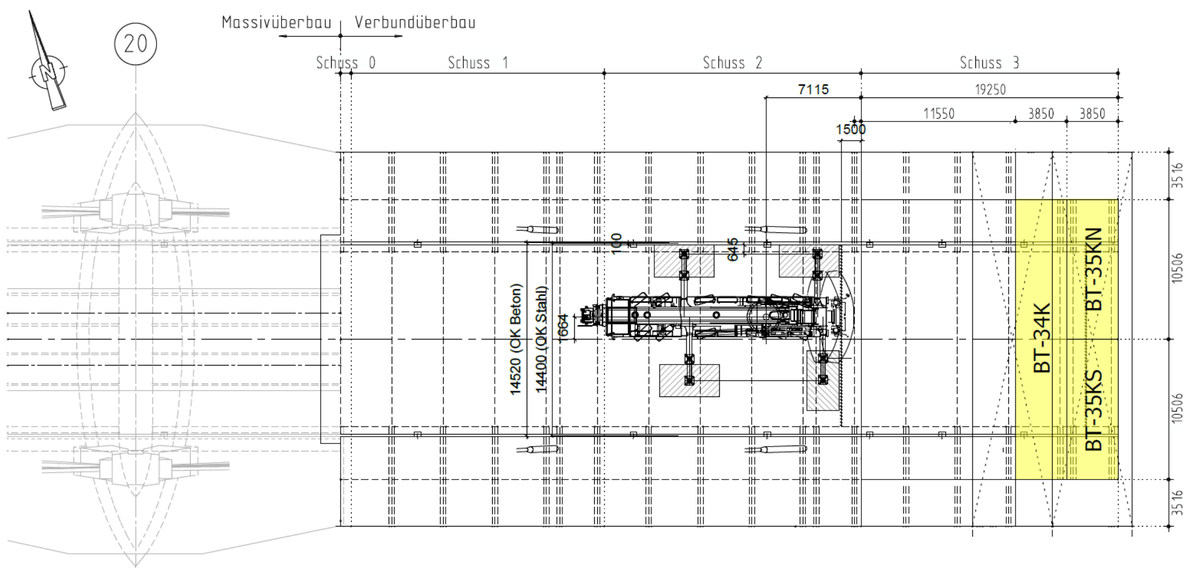

Figure 4.3: assembly segments BT-34K, BT-35KN, BT-35KS

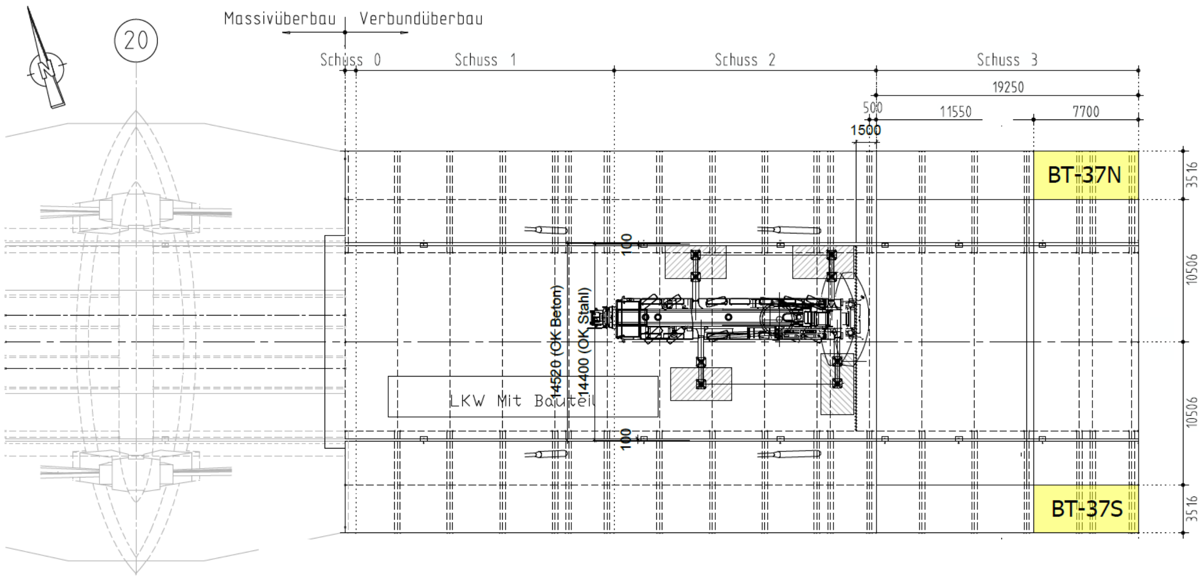

Figure 4.4: assembly segment BT-37N/S

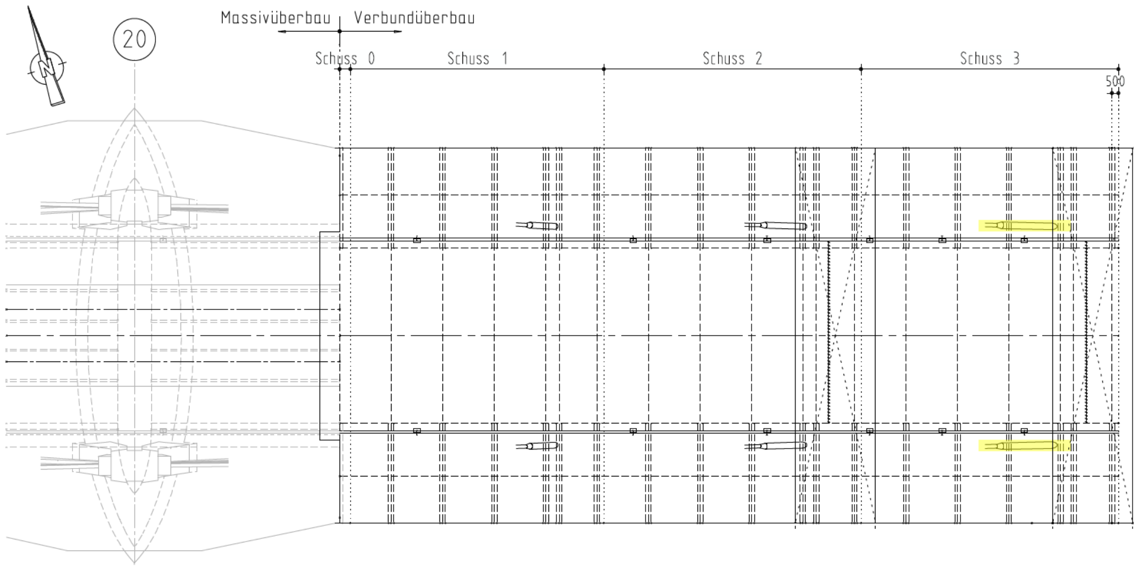

Figure 4.5: assembly cable

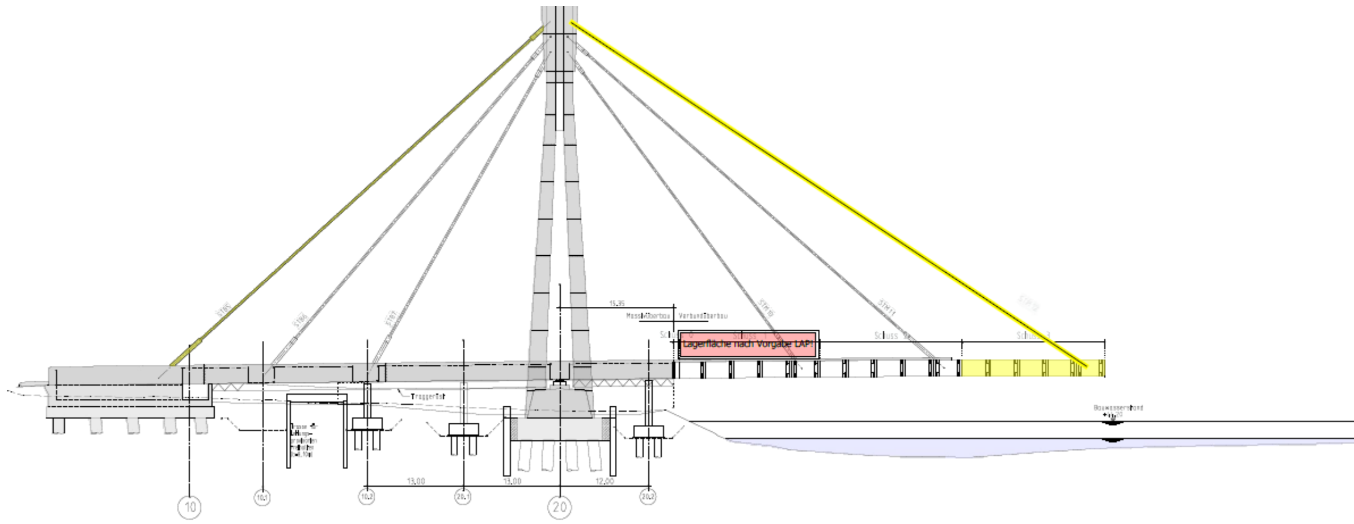

Figure 4.6: assembly cable

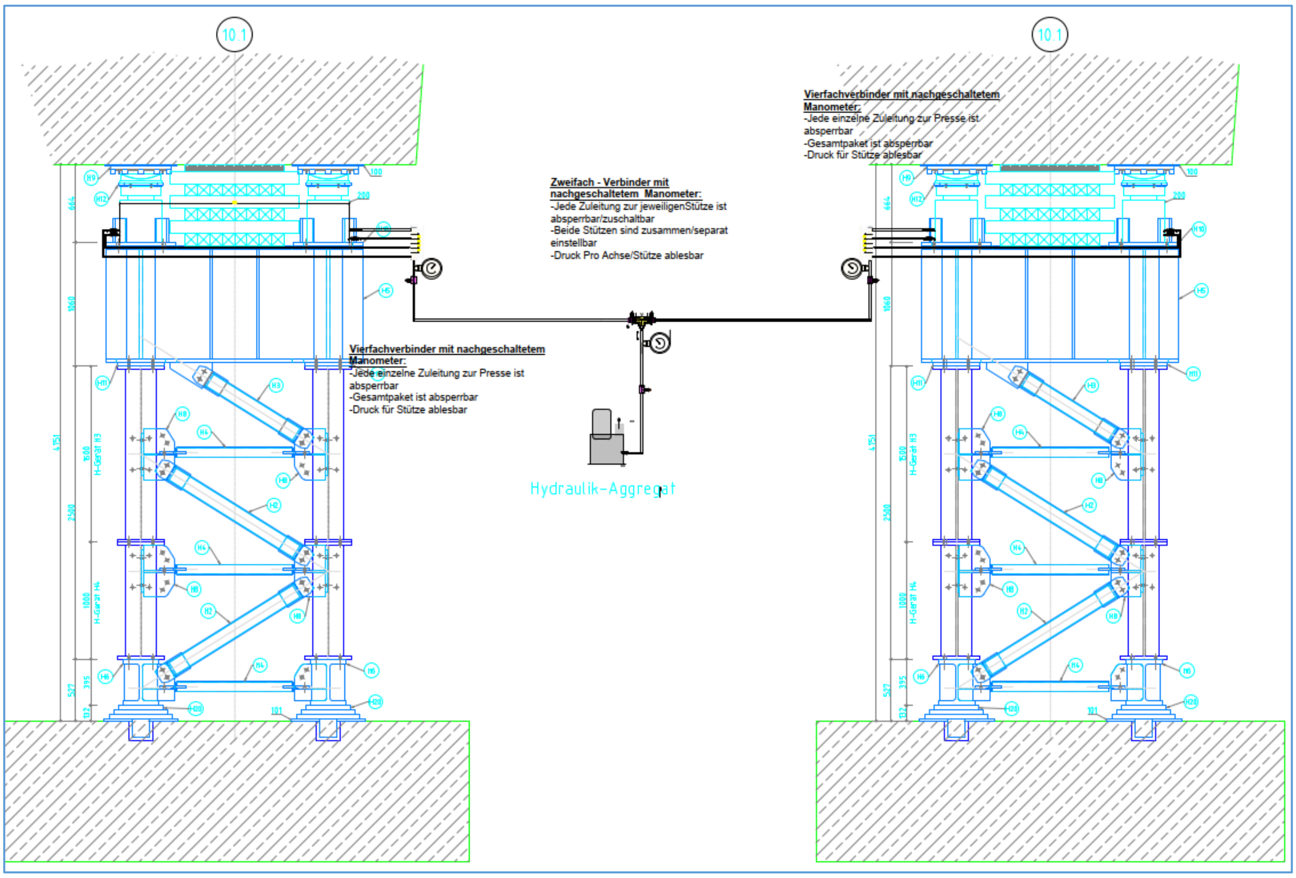

Figure 5: temporary adjustable pillars for the use of different loading requirements

The main-span was produced in 8 assembly sections, each with a length of 19,250 mm.
For each assembly section, 6 transversely orientated workpieces were produced in the workshops in Hanover, delivered to the installation site via the public roads and the already completed part of the bridge, unloaded there with a mobile crane standing on the bridge, lifted directly into the final position and fixed. After fine adjustment and measurement of the workpieces, all transverse joints of an assembly section were welded, the strand cables installed and tensioned in the first step (Fig. 4).
This was followed by the reinforcement and concreting of the in-situ concrete and the tensioning of the cables in the second step.
For each subsequent shot (19.25 m), the rear anchoring field, which was supported on heavy-duty supports, had to be manipulated using hydraulic presses to compensate for the asymmetrical interaction between the back span, pylon, and main span. (Fig. 5)

In the event of deviations in the final cable forces or the nominal gradient after completion of the bridge, the cables were to be re-tensioned in the third step. This was not necessary.

Figure 6: first shot installed under the use of combined welding and painting platforms

4 Challenges in the assembly of a cable-stayed bridge in balanced-cantilever-method

The greatest challenge when constructing a cable-stayed bridge in balanced-cantilever-method is achieving the required nominal-gradient while maintaining the cable forces. The problem lies in the dependence on a large number of factors, all of which are subject to unavoidable variations, particularly:

- the variation of properties of the materials
- the limits of the accuracy of static-analysis-models
- the correspondence of the theoretical calculation assumptions with reality (e.g. the actual load conditions of the construction company with the assumed load conditions)
- unavoidable manufacturing tolerances in the factory and on the construction site
- inaccuracies when tensioning the ropes
- influences from temperature
- limits of measurement accuracy during surveying
- etc.

Mastering this complex issue requires close cooperation between the planners and the contractor during the installation process. In the case of the Kaiser Otto Bridge, the deformations of the superstructure were measured during each individual assembly process, the actual conditions were recorded on site and handed over to the planner for evaluation. In the event of deviations between the TARGET and ACTUAL conditions, appropriate compensatory measures were immediately defined for the next work step. With this procedure, the TARGET gradient and the TARGET cable forces could be achieved excellently.

5 Construction time

Mainspan:
February 2022 - March 2023:

1st shot: 3 months
2nd shot: 2 months
3rd shot: 1.5 months
4th shot: 1.3 months
5th shot: 1.3 months
6th shot: 1.3 months
7th shot: 1.3 months
8th shot: 1 month

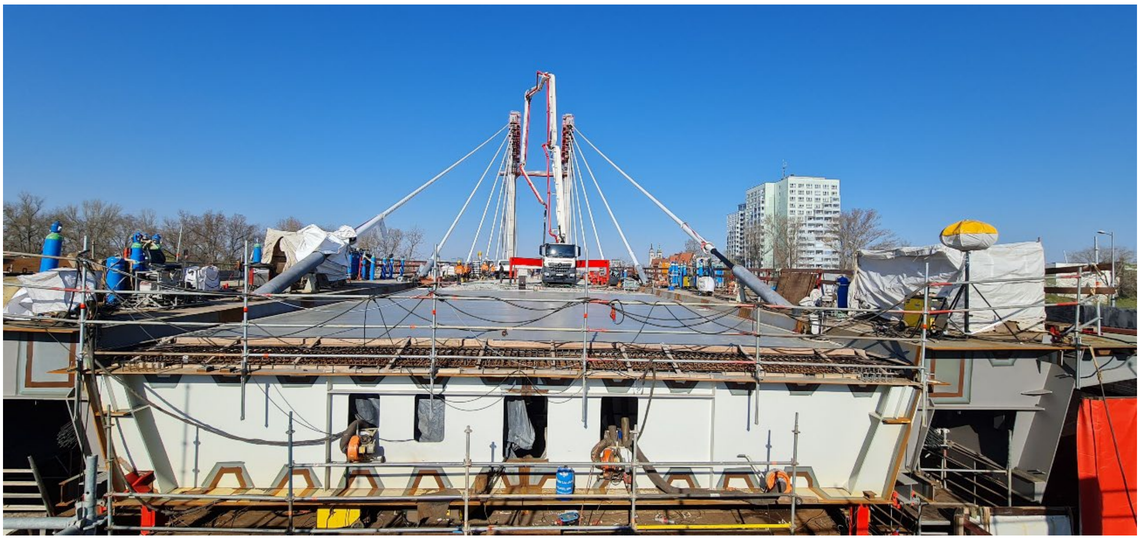

Figure 7: bridge-deck-segment after the concrete installation

6 Conclusion

The construction of the Kaiser Otto Pylon Bridge in Magdeburg was characterized by unusual constraints for the assembly of the bridge deck in its component structure. The section-by-section construction of the composite roadway had to be integrated into the complex assembly process. The planned assembly speed of the steel construction segments in conjunction with the cable assembly and concreting of the composite roadway was achieved with high precision after two sample segments.
The bridge was put into operation at the turn of the year 2023/2024.

7 References

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