Aerial view showing the steel beams in place above the bridge deck *(Nürnberg Luftbild, Hajo Dietz)*

CHOREOGRAPHY IN BIM

Engineers in Germany rebuilding a pair of highway bridges within a tight footprint have successfully removed the old superstructure by deploying parts of the new bridge to serve a dual purpose – all within a BIM environment. Helena Russell explains how

An ongoing scheme of improvements to the Schwelmetal Viaduct on the A1 motorway in Germany will see the replacement of bridges from the early 1960s that no longer meet modern standards. But the two somewhat modest structures being replaced are flanked by a pair of more modern bridges which will remain, severely restricting the space available for site operations. The bridges carry the motorway over the Schwelme River, a series of high-speed railway lines and a highway in a congested urban setting near Wuppertal in west Germany. The four structures sit shoulder to shoulder, with just a few centimetres separating the decks.

The outer bridges are to remain unaltered, while the inner structures have to be demolished and removed from site, and new bridges rebuilt within the existing footprint. Work will be carried out on one bridge at a time, to maintain maximum capacity for motorway traffic throughout.

Main contractor Hochtief Infrastructure won the US$36-million contract to replace the 207m-long bridges in July 2018, with construction starting on site in January 2019 for client DEGES, Deutsche Einheit Fernstraβenplanungs-und-bau (German Road Planning & Construction Unit). DEGES took the decision that this should be a BIM pilot project – claimed to be the first time that BIM has been used in the detailed design of a major highway bridge in Germany.

Hochtief's consultant Arup Deutschland is responsible for detailed design and temporary works design across all the site operations, fleshing out and implementing the ingenious demolition and construction procedure that was first proposed in the scheme design as a solution to the tight physical constraints of the site.

In short, this sees the steel beams that will form the longitudinal girders of the permanent structure being assembled above the deck of the existing bridge ahead of its demolition. The beams are initially positioned 5m above their final elevation, supported on temporary trestles and configured to act as rails for three movable gantry carts. These carts support, transport and lower segments of the old bridge deck as they are cut out and removed one by one; when demolition is complete and the new piers have been built, the steel beams are lowered into their final position so that construction of the composite concrete deck can proceed in the conventional way.

However in order to implement this imaginative solution, the engineering team went through a great deal of analysis and preparation to ensure that the procedure goes to plan.

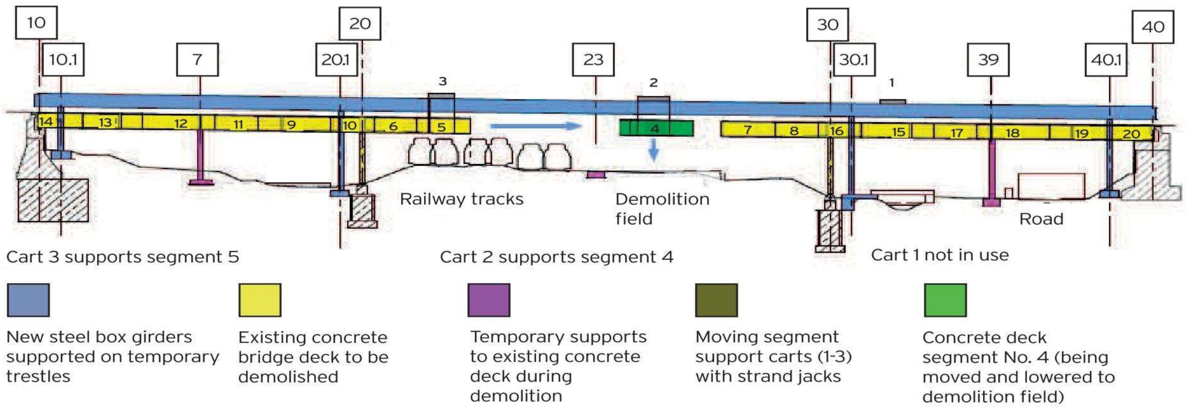
Design of the steel box girder beams has to take account of their role in the demolition process as well as the loading they must accommodate in the final structure; additional restraints are needed to prevent longitudinal movement of the beams during the construction phases; the old bridges have to be strengthened in order to undergo demolition safely; additional temporary piers are necessary to support the changing articulation of the old bridges as they are deconstructed, and the whole procedure must be executed within the footprint of the existing structure.

Although the concept of the demolition procedure had been sketched out at tender stage, it was down to Hochtief and Arup to carry out the detailed design and ensure it could be delivered safely and efficiently. According to Hochtief Infrastructure design coordinator and site manager Norbert Nelz, the first challenge was to assess the condition and verify the behaviour of the existing concrete bridges.

Arup Deutschland design team leader Robert Meyer explains that design drawings showed the extent and positioning of reinforcement and post-tensioning ducts, but the quality of the latter posed a question mark. "We didn't know how well the ducts would be grouted," he says, "and so in our analysis we had to consider the two extreme case scenarios – best and worst. In fact it turned out that the grouting was very good."

Nevertheless the analysis revealed the need to strengthen the existing ▶

The concrete box girder deck is cut into 20 segments and lowered using strand jacks mounted on gantry carts, with the steel beams acting as rails



▶ bridge to enable it to be safely demolished. Although designed to the relevant codes when built, and capable of supporting itself in the static condition, this was no longer the case once the structure was severed for demolition and loads were redistributed. Its shear capacity had to be increased by strengthening, to enable the demolition to proceed.

The physical constraints mean that the replacement bridges will follow the same alignment and span arrangement of the existing bridges, each having an 87m-long main span with 60m-long side spans forming a total of 207m. They will be conventional structures, with new concrete piers built on the existing foundations and composite superstructure formed of twin steel box girders with a 15.5m-wide concrete deck.

As well as the difficulties of building within a restricted footprint, Nelz highlights the presence of the road and railway corridors that the bridge crosses. So far in the programme the railway has only been closed three times – for five hours at a time overnight – to allow the contractor to perform critical operations that could not be carried out over live railway lines, such as removing the segments of deck directly overhead.

Before any severance of the main structure could take place, a great deal of preparation was necessary. Temporary supports (shown in pink on the diagram) were erected at each midspan to support the existing bridge as it went through the demolition process, as well as temporary trestles (in blue) which support the new steel beams while they act as gantry crane rails. New foundations had to be built for the trestles to accommodate the existing piers and other physical constraints.

The first cut to the bridge deck was made near the centre of the main span, with demolition progressing towards the abutments in a tightly controlled procedure. Once freed, each of the 20 segments was transported by the gantry carts and lowered to the ground to be broken up. The size and weights of the segments varied, depending on their position in the span, being between 8m and 13.5m long, and weighing up to 500t. The thickness of the webs on the box girder units above the piers was up to 1m; this reduced to 300mm elsewhere.

The removal operation had to be carefully choreographed for each unit, confirms Nelz, to address the continuous changes in load distribution and the need to monitor and adjust these as conditions changed. Some units, such as those over the piers, were tricky to extract due to physical constraints and two carts had to be employed. Hebetech Engineering assisted in the demolition work, with strand jacks mounted on the carts. At time of writing, the removal of the first bridge had been completed and the construction of the new piers and adaptations to the abutments was in progress. The next major operation, planned to take place at the end of March, will be to lower the steel box girders by 5m to their permanent position so that deck construction can start. This is a tricky operation, says Meyer, due to the need to lower the girders simultaneously across the full length of the bridge. It will be carried out using strand jacks, and with a weekend closure in place. A special steel guide has been designed by the site team to fix the beams in the longitudinal direction at one abutment while lowering takes place.

Working within the BIM environment proved beneficial in planning the demolition and identifying potential clashes. Three-dimensional models were created of the existing bridges, and also of the new bridges in two configurations – one during demolition and one in the final position. Using BIM had notable benefits, explains Meyer. The 3D model of the existing bridge was sufficiently detailed to enable the geometry, weight, centre of gravity and so on of each segment to be extracted directly from it. If the segment sizes or shapes were adjusted, these key characteristics were automatically updated saving a great deal of time. Design drawings of the original structures were used to generate this model, with key dimensions and concrete density confirmed on site, Meyer adds.

Nelz agrees that the process of clash detection was made considerably easier with BIM, in particular given the extent of the temporary works. However, he notes that additional resources are needed at the beginning. "In the starting phase of a project, you need to put more effort into elaborating the BIM model. But once it is complete, you can work more efficiently as the model is linked to drawing management, schedule, process and cost monitoring, quantities, forms and reports and so on."

"Sufficient time has to be allowed for the preparation of permanent as well as temporary works design ahead of the start of construction, to enable detailed and conclusive clash detection, for example, with a fully-detailed model," Nelz adds. "Detailed design needs to be handled before construction begins; currently, it more often starts at the same time as the ground-breaking."

Once the first replacement bridge has been completed, traffic will be redirected onto it and the process will be repeated for the second structure. Full completion of the project is scheduled for June 2023 ■

Schwelmetal Viaduct

Client: DEGES (Die Deutsche Einheit Fernstraßenplanungs-und-bau)
Client's engineer: Inros Lackner SE Group
Main contractor: Hochtief Infrastructure
Contractor's consultant: Arup Deutschland
Heavy lifting subcontractor: Hebetech Engineering
Client's BIM manager: Albert Ingenieure
Contractor's BIM manager and 4D/5D coordination: Hochtief Vicon