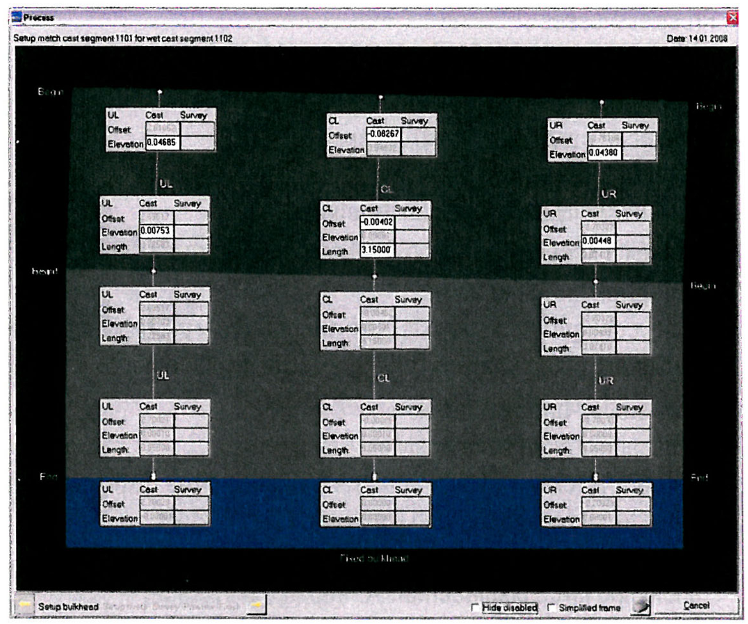
THE FULL STORY

Construction of precast segmental and balanced cantilever bridges can be made easier with appropriate software, say **Andreas Domaingo** and **Dorian Janjic**

Precast segmental techniques are becoming more and more widely used for construction of all types of bridges. Their enormous success is due to the wide range of benefits they offer to bridge owner, designer and contractor. One major aspect is economic reasons; overall costs can be reduced by accelerating the construction on the one hand, and by minimising non-permanent material costs, such as falsework, on the other hand.

Another important point is the issue of quality; since the segments are produced in the controlled environment of a casting yard, an increased and balanced quality of the single segments can be achieved. Finally, precast segmental methods are 'low impact' as far as the construction site is concerned. With respect to reduced construction time and set up of falsework, there is less impact on other infrastructure already present at the site, for example if the new bridge crosses an existing one. There is also less waste material, and the risk of water courses being polluted by wet concrete is greatly reduced. For these reasons precast segmental construction is much preferred by contractors and designers. The only drawback – if it can be said to be such – is that they are very demanding from a technical point of view. The erection procedure must be based on complex geometric calculations, and during casting, permanent surveying is necessary to keep errors with acceptable limits. This is of particular importance at the casting yard where small errors can add up rapidly – in the worst case making proper closure impossible. To overcome this difficulty, the structural analysis software suite RM2006 from TDV, which is now part of Bentley Systems, has been expanded to provide complete modelling of precast segmental bridges from the definition of the bridge geometry right up to the final assembly and survey of the segments. This enables the same model data to be used for all design and construction phases. Since all calculations are based on the same data pool, less additional data input must be provided which reduces the time effort, loss of data and errors. Since all the software tools involved are able to communicate with each other, complicated data transfer and storage format is not an issue.

At the begin of the project the designer creates a geometrical model of the final bridge in the geometric pre-processor GP. Within this tool it is now possible to define the absolute or relative segment lengths and casting sequence by labelling the different structural elements either as starter, intermediate or closer segment. Once this information is provided, the segmentation of the bridge is determined by taking into account the constraints imposed by the fixed bulkhead on the casting yard. This complicated 3D geometry calculation includes horizontal and vertical curvature of the bridge as well as twisting of the main girder. Furthermore, the future positions of the casting control rivets for the match-cast segment setup and survey are determined by drawing directly into the cross-sections that are used. Finally the structural model can be exported to the structural analysis tool RM. Within RM the static analysis of the bridge can be performed as usual, including a camber calculation to compensate the deformation due to permanent load. The camber line is used to calculate the theoretical casting curve of the elements without load. RM provides all possibilities to model the application of new segments to the static system, for example balanced cantilever erection with cranes or lifting frames.

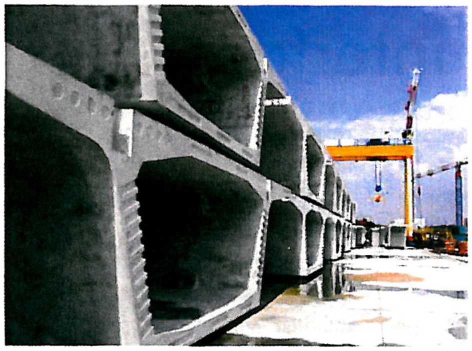


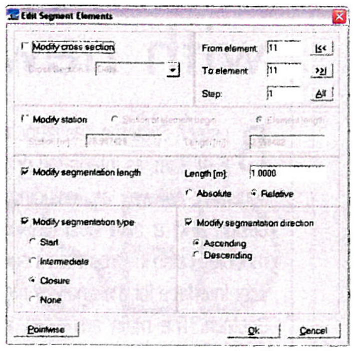
Set-up of match-cast segment as displayed by RMCast tool

In this context the input procedure and modelling of construction stages can be reduced by the RM pre-processor for balanced cantilevers. This tool takes advantage of the repetitive construction sequence and the similar tendon layout for the erection of the cantilevers at different piers. Respective tendons are stored in groups, which can easily be copied and adapted for each pier. The construction sequence is set up in a schematic schedule, which then generates all necessary load cases and calculation actions for the construction stages automatically, such as assembling new elements, calculation of self-weight, weight of the wet concrete and movement of travellers.

When the analysis is finished, a new module 'Do Cast' is available to generate the necessary casting yard geometry. To this end the theoretical casting curve is combined with the final bridge geometry and position of control rivets to obtain the 3D positions of the rivets within the casting geometry. This casting geometry is exported together with the camber lines at the different construction stages to a newly-created tool named RMCast.

This tool can be used to manage the casting process. For each cast segment, RMCast provides the following steps: first the match-cast segment, or the floating bulkhead for a starter segment, is positioned according to the rivet positions calculated by RMCast. Then the rivets for the new segment are positioned and the segment is cast. Finally the rivet positions are surveyed to calculate the necessary corrections for the following casting sequence and the modified camber lines. In the next step the match-cast segment is





Far left: Storage of cast segments with notches for carrying shear clearly visible *(Finley Engineering Group)*
Centre: Not much data is needed to define the casting sequence in the geometric preprocessor GP
Left: Match-cast segment and mould at casting yard

transported to stock or construction site and the newly cast segment becomes the new match-cast segment, and so on. Reports of each casting step can be generated automatically.

The most important point in the procedure set out above is an accurate survey of the cast geometry. Small errors which occur, for example for elements at the beginning of the casting sequence, can cause serious problems when it comes to the application of a closing segment. But an accurate survey and consequent correction allow small errors to be immediately rectified when casting the next segment. The corrections needed to stick as close as possible to the theoretical casting curve are automatically calculated and updated by RMCast between the casting steps.

Finally, the precaster delivers the segments together with the updated camber lines – with small kinks compared to the original ones due to corrections – to the contractor so that at the construction site a survey of the actual casting geometry becomes possible.

The RM structural modelling, static analysis and camber calculation is for example currently being used by the Finley Engineering Group to design six precast segmental bridges for the Road 431 project in Israel. More than 500 segments with a total deck area of more than 18,000m^2 are needed to erect the bridges, and they have spans ranging from 30m and 66m. The use of external tendons allows precast segments to be simplified, and the number of stressing operations to be reduced. Precast segmental construction is ideal for the tight construction schedule demanded by the contractor in this case.

Finley is also using RM's cantilever and camber line features for design of the bridge over the Kanawha River in West Virginia. This structure will have the longest concrete span in the USA built by balanced cantilever. It has seven spans ranging from 50m to 230m and a deck width of just over 22m. The software solution was used from the detailed 3D model design in the geometric pre-processor, right up to camber line calculations and design checks according to AASHTO in the static analysis part RM ■

Andreas Domaingo and Dorian Janjic work for TDV