Jointless bridges in France
Innovation for the year 2016

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Abstract:
Maintenance of bridges is an increasing topic for all different owners in France. Decreasing budgets for infrastructure maintenance are growing demand in innovation for maintenance-free structures. Approximately half of the maintenance budget on bridges is currently used to replace joints with a short lifetime.
The purpose of this article is to present the main jointless bridges built in France during the year 2016.
The first one, called OA34, is part of the southern ring road of Strasbourg. It has been designed as a semi-integral bridge. The deck is a composite steel concrete with two weathering steel main girders and a slab in reinforced concrete. The full length is 85 meters, divided into 3 spans (27 m - 35 m - 27 m).
The second one is about rebuilding an old bridge, located near the small town of Boncourt in Lorraine, with a new integral one. The full length is about 35 meters in a single span. The deck use UHPFRC multi-girders with some piers in reinforced concrete.
However, innovation does not only concern semi or integral design to minimize future maintenance. Thus, weathering steal has also been used for main girders of OA34 and UHPFRC girders have been used for Boncourt’s bridge.
Design, calculation according to Eurocode and site aspect will be processed in this paper.
1 INTRODUCTION

Today, there are about 270,000 road bridges in France. This designation is reserved for structures that have more than 2m of opening. Smaller ones are generally hydraulic structures in the form of nozzles or scuppers and are not considered as bridges. The bridges are distributed according to the following types of structure [1]:

<table>
<thead>
<tr>
<th>Type of Bridge</th>
<th>Number</th>
<th>Surface</th>
<th>Average age</th>
<th>Estimated life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masonry Bridge</td>
<td>10%</td>
<td>3%</td>
<td>135 y</td>
<td>250 y</td>
</tr>
<tr>
<td>Reinforced concrete</td>
<td>49%</td>
<td>25%</td>
<td>33 y</td>
<td>80 y</td>
</tr>
<tr>
<td>Prestressed concrete</td>
<td>18%</td>
<td>48%</td>
<td>34 y</td>
<td>70 y</td>
</tr>
<tr>
<td>Steel and composite</td>
<td>5%</td>
<td>15%</td>
<td>30 y</td>
<td>75 y</td>
</tr>
<tr>
<td>Concrete nozzle</td>
<td>7%</td>
<td>3%</td>
<td>28 y</td>
<td>70 y</td>
</tr>
<tr>
<td>Steel nozzle</td>
<td>9%</td>
<td>3%</td>
<td>36 y</td>
<td>45 y</td>
</tr>
<tr>
<td>Special bridge (other)</td>
<td>1%</td>
<td>2%</td>
<td>40 y</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Bridges in France

The vast majority of bridges uses reinforced or pre-stressed concrete. The small structures (spans less than 15 meters approximately) are integral bridges. Beyond these spans, the design of bridges in France uses expansion joints and bearings for dilatation (thermal action, shrinkage and creep).

These non-integral bridges account for 60% of the surface area of all French road bridges. Its need a lot of maintenance specially to change expansion joints.

To optimize the maintenance cost of bridges, engineers in France are increasingly trying to design integral or semi-integral bridges to remove the expansion joints. In this paper, we present two innovative bridges built in the east of France:

- OA34 of the southern ring road of Strasbourg;
- rebuilding of an old bridge in Boncourt

2 OA34 of the southern ring road of Strasbourg.

The OA34 allows the crossing of the Ehn and the Ergelsenbach rivers as well as two farm tracks in Geispolsheim (near Strasbourg) with 3 spans: 27m; 34.5m; 27m. The skew is about 70°. For an easier maintenance, bridge deck is designed with 2 separate ones. Each deck is steel-concrete composite two-girder bridge (weathering steel S355W). The widths are 11.83m and 12.83m. The curvature is about 1050 m and there are deep foundations (4 piles 1000mm diameter per piers). The 2 decks are semi-integral, without expansion joint but with reinforced elastomeric. The retaining walls are made of reinforced earth because of jointless bridge and seismic analysis.

All the analysis uses Eurocodes rules [2].
Figure 1: site plan

Figure 2: longitudinal section

Figure 3: cross section
The main advantage of building semi-integral-bridges with bearing pad and without expansion joint (jointless only) is to limit the risk. Integral bridges (jointless and bearingless) are innovative structures but with some risks. French owners like innovation but hate risks it. If there is a problem in the expansion of the deck, it is possible to use an expansion joint at a lower cost. The risk associated with the removal of joint expansion is low. The removal of bearing pad is riskier and a dysfunction of this removal may result in demolition of the structure (deck, pier and foundation). The risk of removal support devices is very high.

Also, the main cause of deterioration of the reinforced elastomeric bearing is the water at the abutments. Removal of the expansion joints allows stopping water in the abutments and preserves the reinforced elastomeric bearing. The single removal of the expansion joint eliminates the maintenance cost of the joint but also the replacement of bearing with a low risk.

The design of the jointless abutment is inspired by the Swiss standards of the FEDRO [3] [4]

Figure 4: detail jointless abutment
The analysis of the abutment could be very complex. In this project, we have adopted simplified and security hypothesis to facilitate analysis of the structure:

- Isostatic analysis of the approach slab;
- Horizontal analysis of the abutment slab;
- Vertical analysis of the abutment slab;
- Analysis of the break of slope of the approach slab;
- Analysis of the junction transition slab / slab of the deck under thermal action.

The first analysis does not bring any particularity. For the analysis of the abutment slab, the 2 main girders are some simple bearing and the slab is studied like a beam. The passive earth pressure $K_p$ is taken to 3. Total expansion of the structure is 3cm (thermal expansion -40°C +30°C, no shrinkage because of the 2 steel main-girders).
For the analysis of the junction approach slab / slab of the deck under thermal action, the main reinforcement is the bar E in figure 5. It is impossible to consider the deck completely blocked in the approach slab (tensile force under thermal action is 10 MN). We analyze the bars E by considering the friction of the approach slab on the earth (C=1). The friction is considered on 4 faces (2 lateral, top and bottom faces). In this case, tensile force under thermal action is 3 MN.

For the analysis of the break of slope of the approach slab, we check that the bridge is not too flexible. The main consideration is the hinge of the transition slab with the deck. The deck is isolated from settlement and other parasitic effects of the approach slab.

Figure 7: analysis of the break slope

For OA34, the break slope with LM1 loading is 0,12% < 0.8%.

Figure 8: pictures worksite
3 Rebuilding of an old bridge in Boncourt

The bridge of Boncourt allows the crossing of the Orne river in single span of 30m. The skew is about 70°. The deck is a jointless open frame bridge beams ITE® in UHPFRC. The width is 13m. The deck is integral, without expansion joint and without reinforced elastomeric bearing. All the analysis uses the Eurocode 2 [5] and the UHPFRC French standard [6].

Figure 9: site plan and picture of the new and old bridges

Figure 10: longitudinal section

Figure 11: cross section
The design of integral open frame (jointless and without bearing) is very common in France for a range of 15-20m. France also owns double open frames with a total length about 40 m without problems at the junction with the road. We know that our open frame design in UHPFRC will work with dilation/expansion action (thermal, shrinkage and creep). The particular analysis in this bridge concern the fixing restraint between beams and supports with higher restraint bending moment than in conventional reinforced concrete open frame designs.

In order to reduce the risk of innovation, we realize 2 analyses:

- The first one is “hyperstatic” (indeterminate): this analysis model restraint moment between beams and supports.
- The second one is “isostatic” (determinate): this analysis add robustness to the structure. Restraint moment between beams and supports are neglected and abutments are just simple bearing for the beams.

In the hyperstatic analysis, we use strut and tie model for the fixing restraint.

The beam abutment is elongate at 30 cm and grill of reinforcing are placed under the beam.

REFERENCES


