DESIGN OF HIGH SPEED TRACK ON LONG BRIDGES

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Samenvatting

Als gevolg van temperatuurvariaties kunnen aanzienlijke railkrachten en verplaatsingen ontstaan in voegloos spoor (CWR) op bruggen of viaducten met grote overspanning. Grote relatieve verplaatsingen tussen dwarsliggers en ballastbed verstoren de stabiele ligging van het spoor in de ballast hetgeen resulteert in een lagere schuifweerstand. In het algemeen worden deze problemen opgelost door het aanbrengen van compensatieinrichtingen in het spoor. Voor hoge snelheidslijnen vormt dit echter geen aantrekkelijke oplossing omdat deze voorzieningen een lokale verstoring veroorzaken van de verticale spoorstijfheid en spoorgeometrie waardoor intensief onderhoud nodig is. Naar aanleiding van een spoorbrugsituatie nabij Antoing, België, heeft de Technische Universiteit Delft een theoretische studie uitgevoerd, met financiële ondersteuning door de Nationale Maatschappij van de Belgische Spoorwegen (NMBS), teneinde de mogelijkheid te onderzoeken of compensatielassen kunnen worden vermeden op lange spoorbruggen [1].

Abstract

Due to temperature variations, considerable longitudinal rail forces and displacements may develop in continuous welded rail (CWR) track on long-span bridges or viaducts. Excessive relative displacements between sleepers and ballast bed may disturb the stable position of the track in the ballast which results in a lower frictional resistance. Generally, these problems are solved by installing rail expansion devices in the track. For high-speed track, however, this is not an attractive solution as these devices cause a local disturbance of the vertical track stiffness and track geometry which would require intensive maintenance. Initiated by a railway bridge situation near Antoing, Belgium, Delft University of Technology carried out a theoretical study, sponsored by Belgian National Railways (NMBS), to assess the possibility of avoiding expansion joints on long bridges [1].

CONTENTS

1. INTRODUCTION

The bridge, which is being built as part of the high-speed line Brussels - Lille (junction for Paris/London), has a length of 438 m and consists of 7 spans, which are supported by 6 piers and 2 abutments (Fig. 1). The main span, i.e. span no. 6, which crosses the river Scheldt, is 120 m long and is reinforced by two steel arches. The bridge carries two parallel ballasted tracks with UIC 60 rails laid on concrete sleepers. Throughout this article the following values apply:

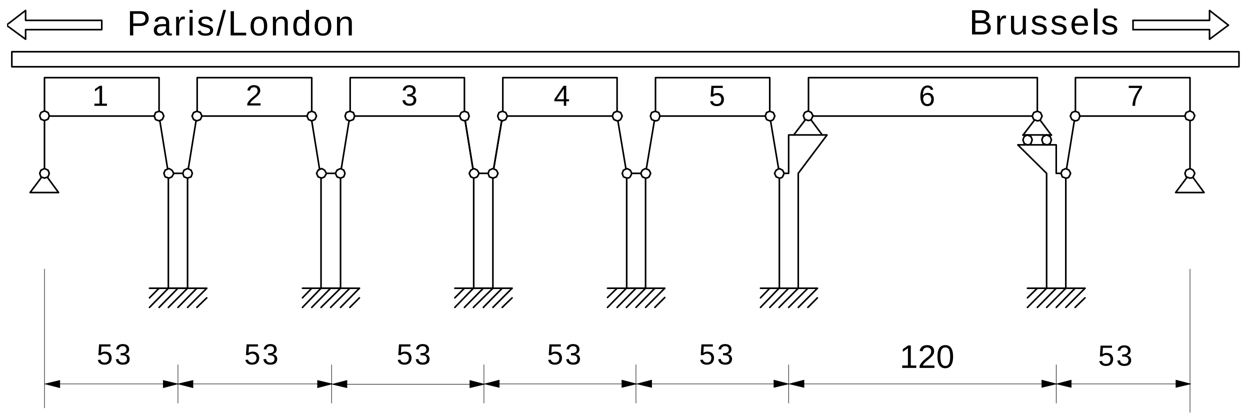

Figure 1 Schematic overview of the bridge configuration

Rails/track:	A = 15372 mm² (2 x UIC60), E = 210 kN/mm². α = 1.2 E10^{-5} °C^{-1}, ΔT = +40°C;
Span 1-5,7:	A = 26 E10^{6} mm², E = 34.75 kN/mm², α = 1.2 E10^{-5} °C^{-1}, ΔT = +30°C, longitudinal support stiffness 15 kN/mm;
Span 6:	A = 10.13 E10^{6} mm², E = 34.75 kN/mm², α = 1.2 E10^{-5} °C^{-1}, ΔT = +30°C, longitudinal concentrated load = -1350 kN (acting at the location of the roller support , due to friction);
Ballast/track:	F_{max} = 20 kN/mm, u_0 = 2 mm (bilinear characteristic);
Piers:	longitudinal support stiffness = 15000 kN/mm;
Braking load:	8 kN/m/track over 400 m track including span 6.

2. COMPUTER MODELLING OF CASE WITH FULL CWR TRACK

Calculations were made using the computer programme PROLIS20 developed at Delft University of Technology. The complete track and bridge configuration was modeled in a discrete system consisting of 263 nodes and 416 elements assuming construction symmetry over both tracks. The study started with looking at the standard case, i.e. with full CWR track, in which both tracks are subjected to temperature loading. The results are shown in Fig. 2, which consists of three graphs respectively referring to (a) the track (rail) displacement, (b) the relative displacement between bridge and track, and (c) the compressive internal track force.

Graph (a) shows a practically free expansion of the 7 bridge spans, as was to be expected when regarding the huge difference in normal stiffness between bridge and track. The maximum track displacement is 18.4 mm. The maximum relative displacement (graph (b)), however, amounts to 28.6 mm at the location of the roller support of the main span, i.e. span 6. As the longitudinal restraint between sleeper and ballast is usually lower than between rail and sleeper and the elastic part of the displacement is limited, most of the relative displacements are due to shifting of the sleepers in the ballast. As depicted in graph (c), the maximum compressive internal track force amounts to -2300 kN (-1150 kN per rail). For comparison, in the undisturbed track, built on subgrade, it is -1550 kN (-775 kN per rail). These values remain within the limits set out in UIC leaflet 774/3. The maximum bridge force appears to be -4320 kN, which includes the friction force acting at the roller support.

3. MEASURES

In the following the effect of two constructional measures is assessed, i.e. the installation of a conventional expansion device at the location of the maximum relative displacement and, alternatively, the installation of a number of fastenings with sliding facilities, so-called zero longitudinal restraint (ZLR) fastenings. As shown in Fig. 3, this type of fastening - successfully applied at the 'Olifants River Bridge' in South Africa - consists of a special steel baseplate which is fastened to the sleeper with a Pandrol rail clip. Under normal circumstances there are small openings between the baseplate and the top side of the rail foot. In case of large lateral forces, the baseplate prevents turning-over of the rail. The rail pad under the rail, is made of a low friction material like Teflon, provides an almost zero friction movement between rail and sleeper when train loading is absent. When train loading is present, it offers some resistance to possible braking forces.

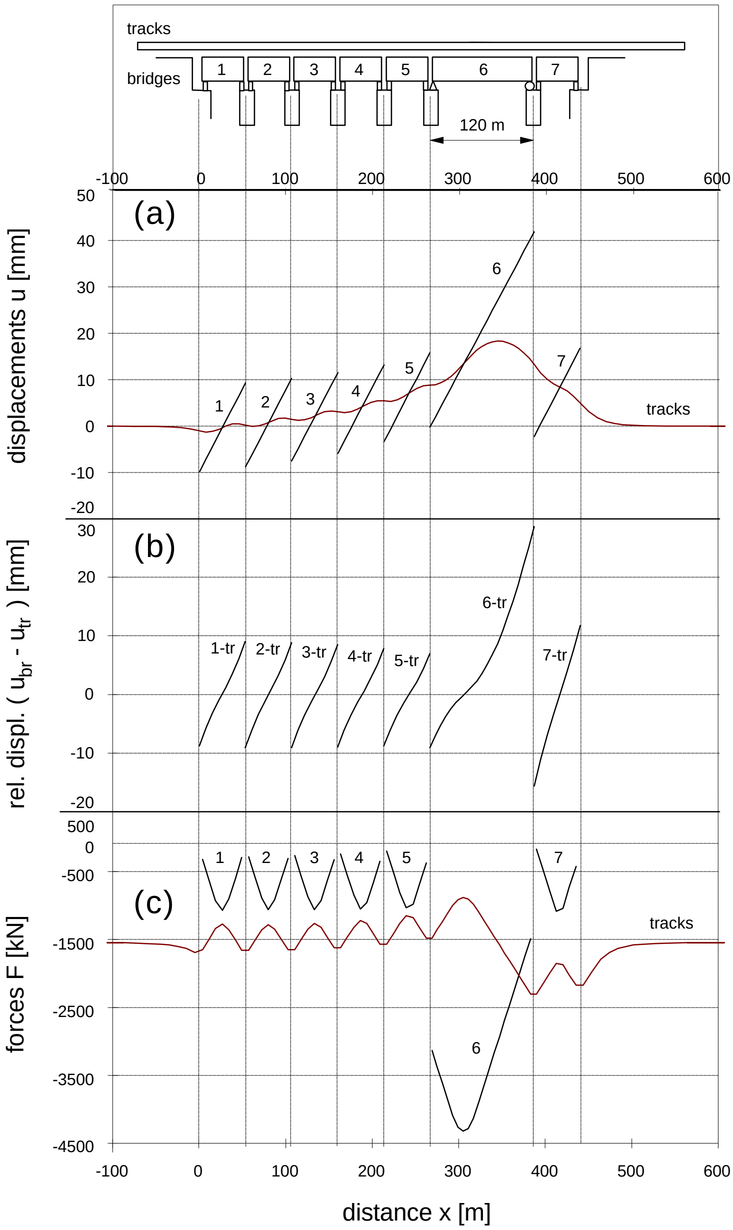

Figure 2 Longitudinal displacements and forces in CWR track on a bridge featuring a large

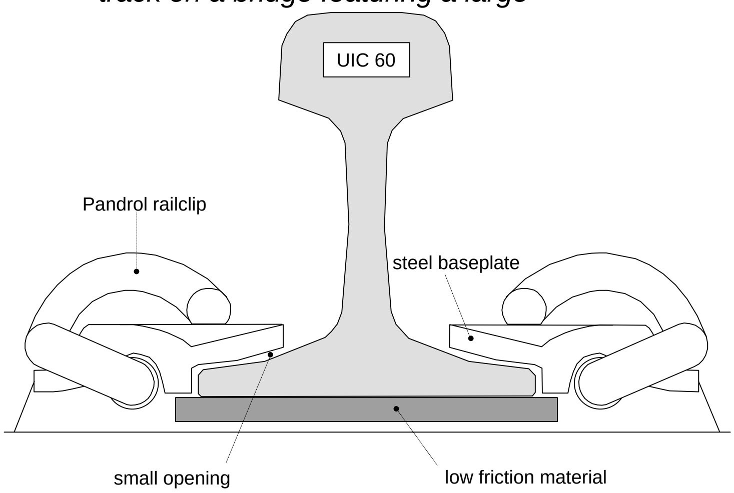

Figure 3 Principle of ZLR rail fastening

3.1 COMPARISON OF RESULTS

In order to facilitate comparison, the calculation results of four different cases, I-IV, are given in a single illustration, i.e. Fig. 4, which consists of three graphs (a), (b) and (c). The insensitive bridge displacements and bridge forces are not shown in graph (c).

Case I, the standard case with full CWR track, has already been described in great detail in Fig. 2. In Case II an expansion device is present, located above the roller support of span 6. As shown in graph (a), the rail displacement - i.e. between the two rails - at the location of the expansion device reaches 79.3 mm (special expansion devices can accommodate rail displacements of up to 220 mm). The maximum relative displacement between track and bridge, shown in graph (b), is rather small (10.5 mm absolute value). According to graph (c), the maximum track force has decreased to the undisturbed value and is, of course, zero at the location of the expansion device. The maximum force in span 6 is 1450 kN.

Cases III and IV illustrate the application of ZLR fastenings over 39 m and 75 m, respectively. The maximum track displacements, shown in graph (a), has decreased to 12.6 mm and 7.0 mm respectively. The relative displacement, graph (b), has increased to 37.0 mm and 41.7 mm, which seems to deteriorate the situation.

However, when omitting the relative displacements over the ZLR part of the track, i.e. the dotted lines, the maximum relative displacements in the non-ZLR part, where the frictional forces between track and bridge fully develop, is reduced to 17.6 mm in Case III and 9.3 mm in Case IV (respectively 63% and 33% of the value in Case I). Thus in case IV an even better reduction, with regard to ballast movement, has been achieved than in Case II. The maximum track compressive force and bridge compressive force have also decreased more or less proportionally.

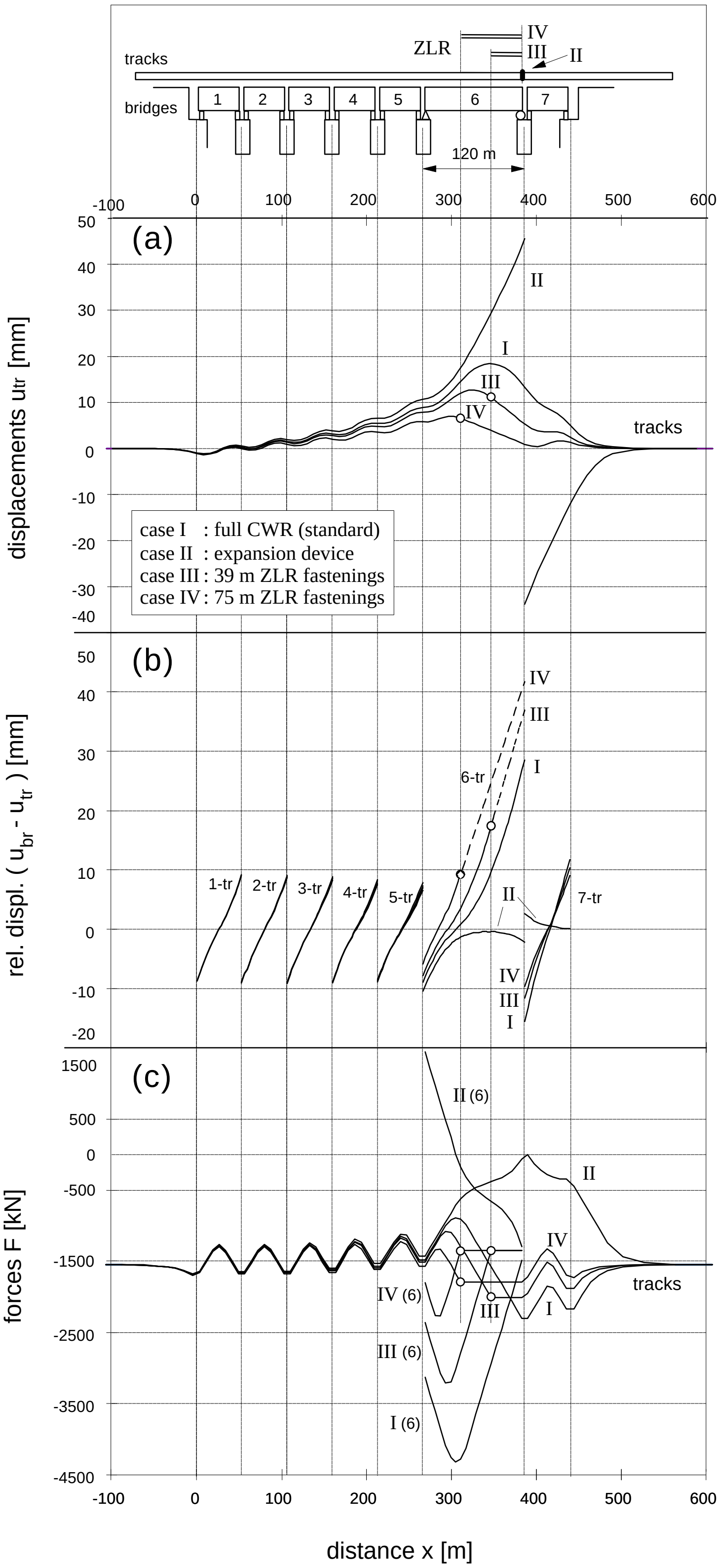

Figure 4 Comparison of possible solutions to alleviate excessive displacements and forces in CWR track on long bridges

3.2 BRAKING LOAD

An interesting situation arises when the track with 75 m ZLR fastenings, which is subjected to the temperature loading (Case IV), is also loaded by braking forces exerted by a TGV train. After applying the temperature load, a distributed braking force of 8 kN/m was exerted on track over a length of 400 m, i.e. the length of a TGV train A situation outline and respective results are given in Fig. 5, graphs (a), (b) and (c).

Graph (a) shows the maximum track displacement to be 11.4 mm, when braking is applied in the direction of the bridge expansion. The maximum relative displacement (graph (b)) of the non-ZLR part, obtained with braking in the direction contrary to the bridge expansion, has increased to 16.7 mm (80% higher compared to the situation without breaking forces). It is instructive to see what the result would be when, instead of ZLR fastenings, expansion devices are used (Case II). The result is also shown in Fig. 5 (b). Apparently the absolute value of the relative displacement (16.2 mm) is of the same order as the corresponding value of the ZLR case.

As mentioned before, some part of the relative displacement is elastic due to the longitudinal elasticity of the rail fastenings and ballast. The unfavourable assumption of zero longitudinal restraint is also not realistic in this case of a vertically loaded track. Based on these considerations it may be expected that the plastic part of the relative displacement, causing sleeper sliding in the ballast, will be less in practice.

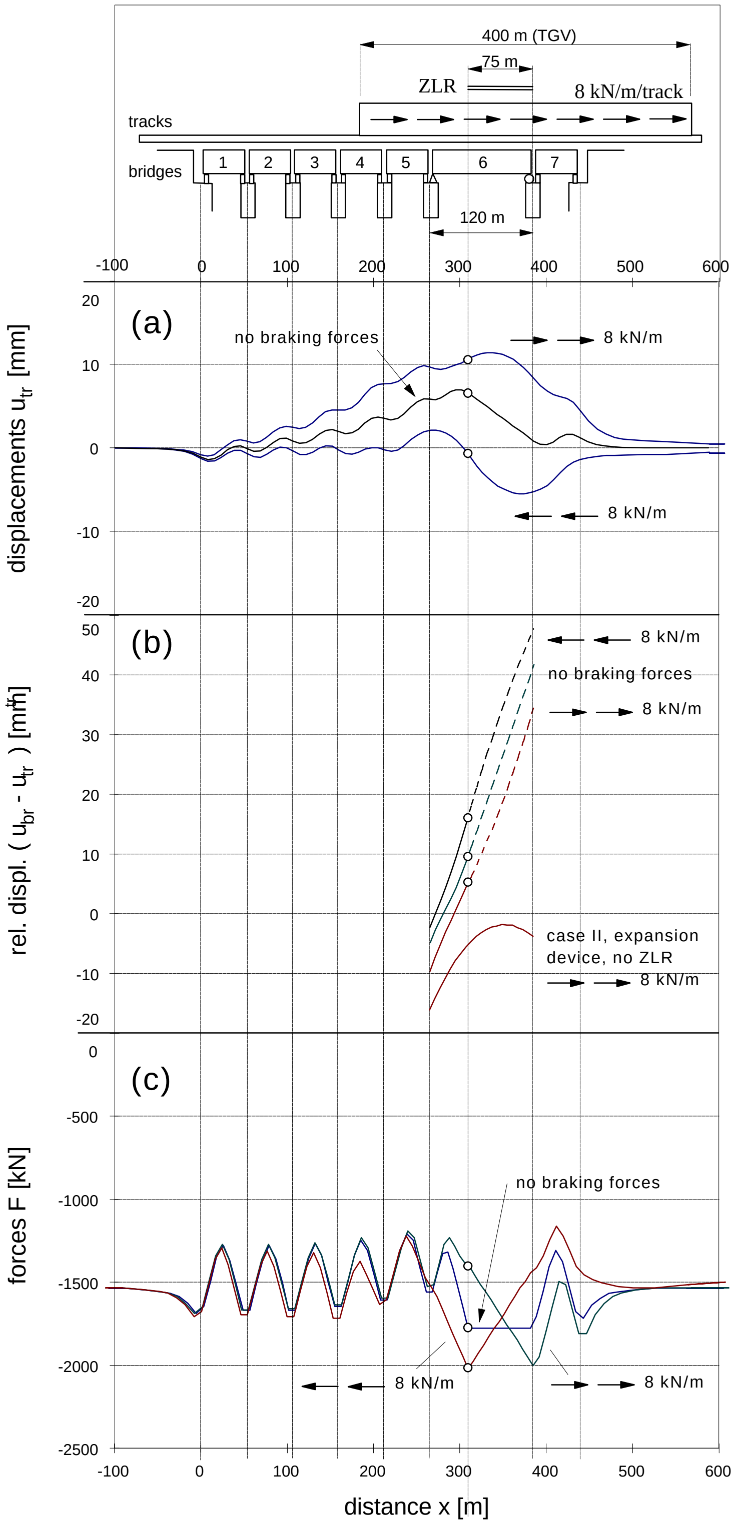

Figure 5 Effect of braking forces acting on one track of which 75 m is equipped with ZLR fastenings

4. FIELD MEASUREMENT RESULTS

For the computer modelling of the bridge assumptions were made with regard to temperature variations of the bridge spans and the rails, based on the available UIC-leaflets. These values are overall maxima for all types of bridges. For this particular application, i.e. a concrete bridge, these values were assumed to be severe. Therefore, it was decided to install measuring gauges at the bridge itself so that the actual values of the bridge temperature and expansion for span 6 could be recorded.
The measurement data presented in Fig. 6 was obtained at the end of July/-beginning of August 1995 during a period with extremely high temperatures. Despite this heat spell, the maximum temperature of the span did not exceed 28 °C. As an initial result it can be concluded that the assumptions made with regard to the temperature of the span were very conservative.

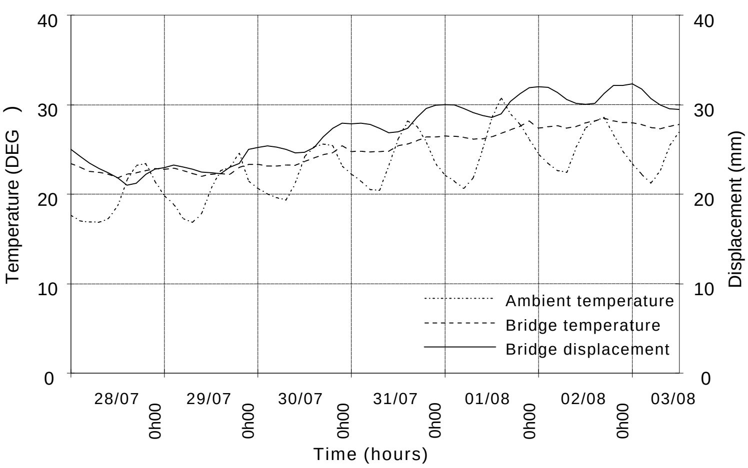

Figure 6 Measured temperature and displacement of span 6 as a function of time

It is also remarkable that these initial measurement results do not show the assumed linearity between temperature and expansion. Various reasons may be responsible for this behaviour, such as the influence of the arch temperature movement on expansion and the non-uniformity of the temperature over the cross-section of the bridge span.

5. CONCLUSIONS

The application of expansion devices in high-speed tracks on existing bridges, as a means to prevent excessive longitudinal displacements and forces, is not attractive due to comfort, safety and maintenance aspects. An alternative and very effective solution is possibly the use of so-called zero longitudinal restraint (ZLR) fastenings over some length of the track. The calculations, carried out in this respect, show a considerable reduction of track displacements, track forces, and the relative sleeper/ballast displacements. This reduction depends on the length over which these fastenings are installed.
The use of ZLR fastenings, though not widely accepted yet and the construction perhaps requiring some further development, should be given more attention considering the favourable theoretical results achieved.
In cases where the temperature limits, or the constructional parameters, are not known very well in advance it is advised to postpone the decision whether or not to install ZLR fastenings until sufficient measurement results are available.
As the measurements carried out to date have given very interesting results, they will be continued for at least another year. In the meantime, no rail expansion devices will be installed in the track mainly for two reasons:

- the calculations have shown that the supplementary rail stresses are acceptable according to the UIC-leaflet 774/3;
- referring to the initial measurement results, the assumptions made for the calculations seem to be safe.

Therefore, this is an appropriate decision, which at the same time represents a saving in investment costs.

6. REFERENCES

[1] Esveld, C., R.C.M. Delhez, P. Godart and J. Mijs: ‘Avoidance of expansion joints in high-speed CWR track on long bridges. Rail Engineering International, 1995, nr 3, p.7-9.