Test Methods

INTERSECTII
INTERSECTIONS
http://www.intersections.ro

Advantages and Disadvantages of the Counter Deflection Based on the Average of the Deflections Recorded in the Sections of the Superstructure of a Railway Bridge

Mircea Suciu[1], Gavril Kollo[1]
[1]*Civil engineering, Tehnical University, Cluj, 400027, Romania*

Summary

Objectives:
The paper analyses the vertical displacements of a railway bridge with a special shape of counter deflection, steel-concrete composition, 50m span, under the action of a high speed train.

Work method:
The running track of the bridge has a special structure, without ballast bed, with rails continuously fixed into the concrete slab using the Edilon material.
In order to determine the impact of the increased speed upon the vibrations and deflections of a mixed section railway bridge superstructure, this superstructure has been carried into the SAP2000 finite element calculation programme.
Two variants of superstructure have been analysed, one without counter deflection and one with counter deflection, based on the average of the deflections obtained in the bridge that had a straight running track.
Twelve non-linear dynamic analyses have been performed for each model, with the Thalys train that covers the analyzed models with speeds: 1, 10, 20...110m/s (3.6...396km/h). The maximal value of the counter deflection is 10.323mm.

Conclusions:
The paper presents comparatively the deformations and vibrations obtained under the action of the Thalys train running with the above-mentioned speeds for two analyzed superstructures.
The superstructure with counter deflection made up of the average deflections has a better behaviour (lower vibrations), for speeds higher than 90m/s.

KEYWORDS: high speed train, Thalys, railway superstructure, counter deflection.

INTERSECTII
INTERSECTIONS
http://www.intersections.ro

Mircea Suciu, Gavril Kollo

1. INTRODUCTION

The increase of the running speed on the railway determines the apparition of deformations and vibrations in the superstructures of the bridges, which can be amplified under certain conditions. The limitation of the deformations and vibrations can be made from the very stage of conception of the structure, by choosing and appropriate shape of the counter deflection.

In the case of high speed trains, the choice of the counter deflection is even more important because the superstructure is crossed over a shorter period of time than in the case of regular speeds. If the value of the counter deflection is too high or the shape that has been chosen is wrong, the shock created can be too difficult to be taken over by the damping systems of the rolling stock.

Based on the following observations, a shape of counter deflection can be suggested. For the crossing of a superstructure that has a horizontal running track, the vibrations and deformations around an average value will be recorded in each section of the superstructure. If, for that particular superstructure, the counter deflection of a section is the average of the deflections recorded in that section under the train running on that bridge with a horizontal running track, there is a possibility that the vibrations be brought close to a horizontal line.

In case the vibrations are close to a horizontal line the comfort of the passengers will grow because only the deviations from the straight line that unites the joints are felt by the passengers and the running stock.

2. OBJECTIVES

The determination of the vertical displacements for a superstructure that has the counter deflection of a section equal to an average of the deflections recorded in the superstructure with a straight running track.

Non-linear dynamic analyses will be performed using the Thalys train with speeds between 1...110m/s (3.6...396km/h) and the SAP2000 programme.

The values of the deformations obtained for the bridge with counter deflection will be compared to the ones resulted from the dynamic analyses performed for the bridge that has a horizontal running track.

The critical speed where the phenomenon of amplification of the vibrations and increase of the value of the vertical deformations appears will be determined.

3. WORK METHOD

The superstructure of a steel-concrete section railway bridge without ballast bed, with a 50m span has been carried into the SAP2000 finite element calculation programme. The 51-meters-long superstructure presented in Figure 1 has been divided taking into consideration 0.5-meters-long elements along the bridge, thus 103 characteristic sections have been obtained.

The box-section and sidewalks plates are considered as “shell” plane elements, the rails and the linear elements of the sidewalks have been inserted as “frame” elements, the concrete slab has been inserted as “solid” type elements. The analyzed model is presented in Figure 2.

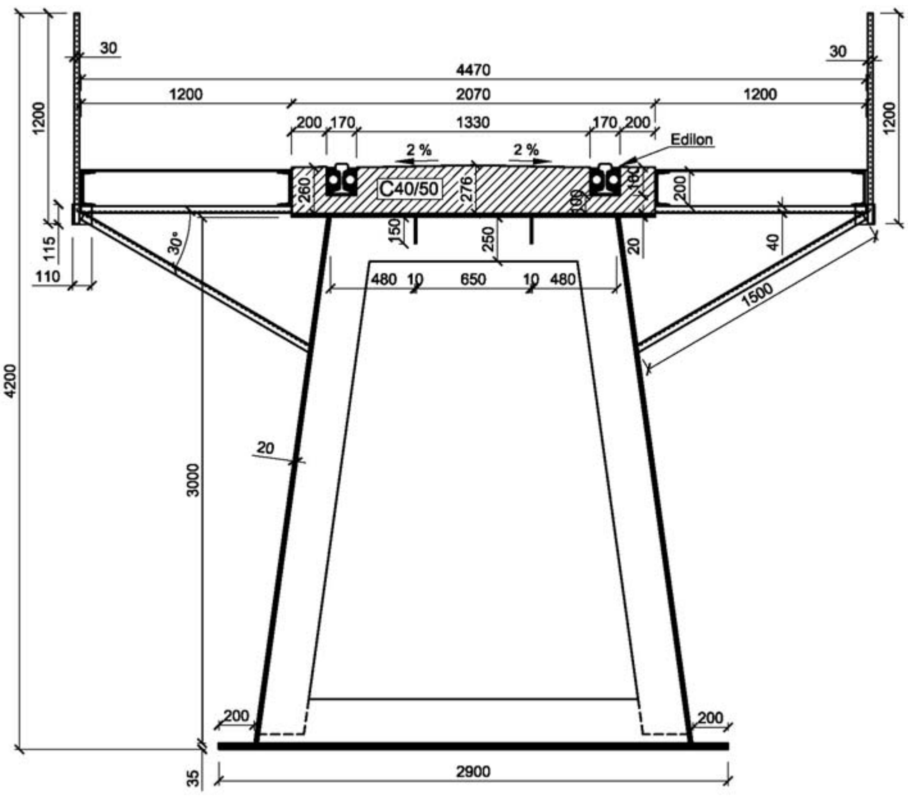


Figure 1. Cross section of the superstructure

Thalys is a high speed train made up of 2 engines and 8 intermediary cars, with axle loads between 7.25 and 8.5 tons, the distance between the car bogies of 18.7m. The total length of the train is Ltrain=193.14m.

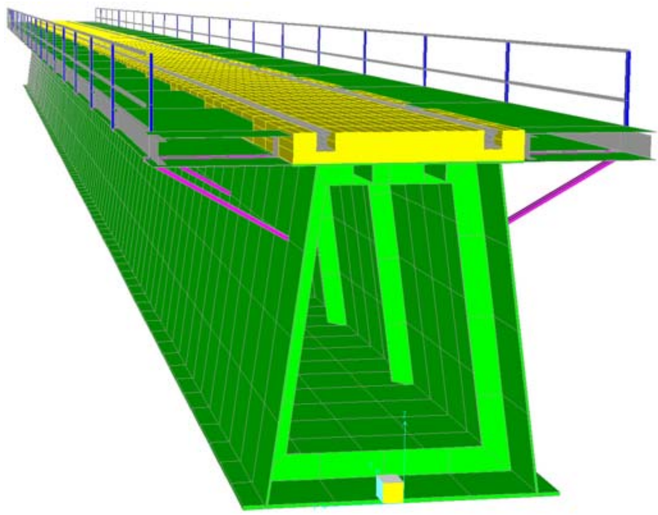
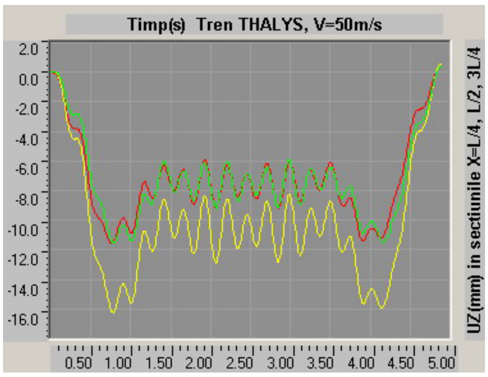


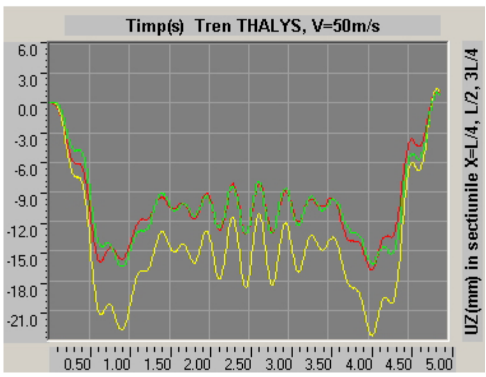
Figure 2. The structure analysed with the SAP2000 programme

From the moment the first axle enters the superstructure until the last axle leaves the superstructure, the train covers 102 elements 0.5m-long and has 490 successive loading steps. The vertical displacements of the superstructure have been recorded at the level of the rails, for all the 490 loading steps. The dynamic analyses are non-linear and they have been made using the direct integration method, with a 5% damping coefficient, directly proportional with the weight.

The vertical displacements obtained in 3 of the 103 characteristic sections, namely the ones situated at L/4 (red), L/2 (yellow), and 3L/4 (green), are represented in the graphics below (Figures 3, 4, 5, 6, 7). The deflections of the superstructure with a horizontal track appear on the left and the ones of the bridge with counter deflection appear on the right side of the figures.



-16.24mm for the straight track

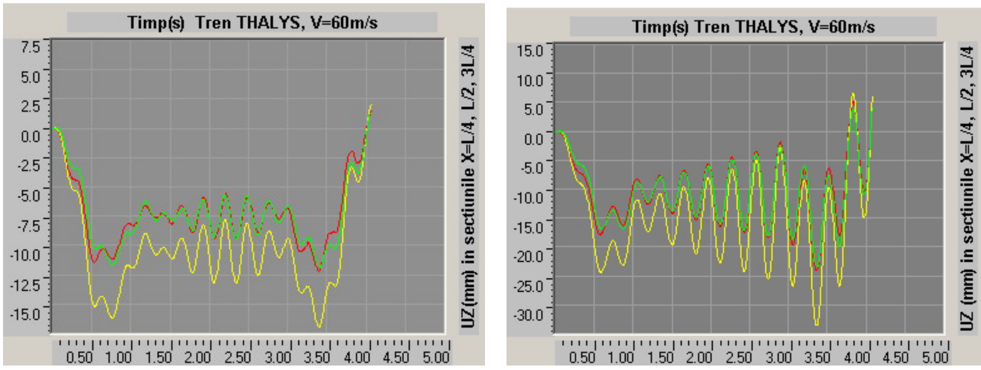


-23.55mm for the counter deflection track

ISSN 1582-3024

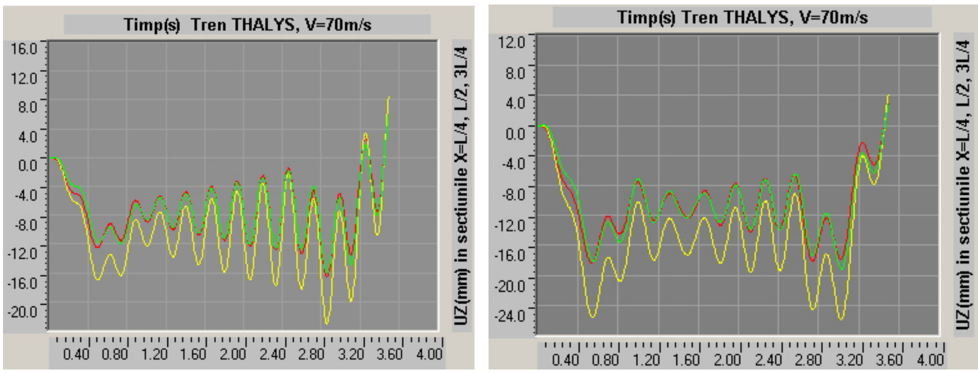
Advantages and Disadvantages of the Counter Deflection Based on the Average of the Deflections Recorded in the Sections of the Superstructure of a Railway Bridge

Figure 3. Vertical displacements UZ (mm), Thalys, V=50m/s (180km/h)



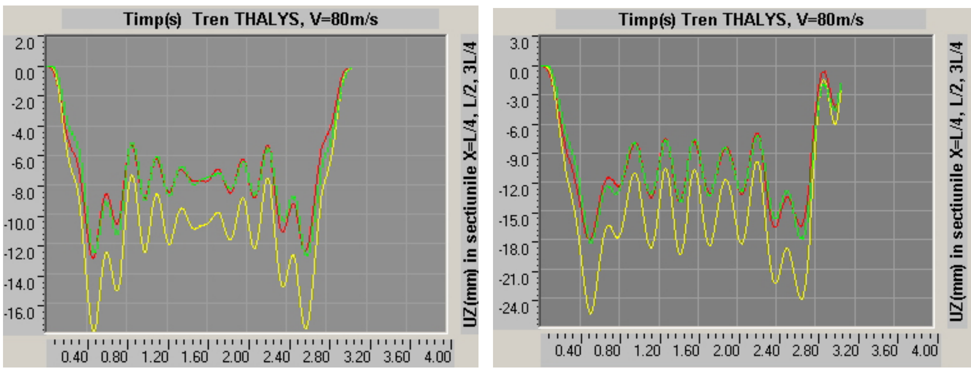
- 16.99mm for the straight track -33.59mm for the counter deflection track

Figure 4. Vertical displacements UZ (mm), Thalys, V=60m/s (216km/h)



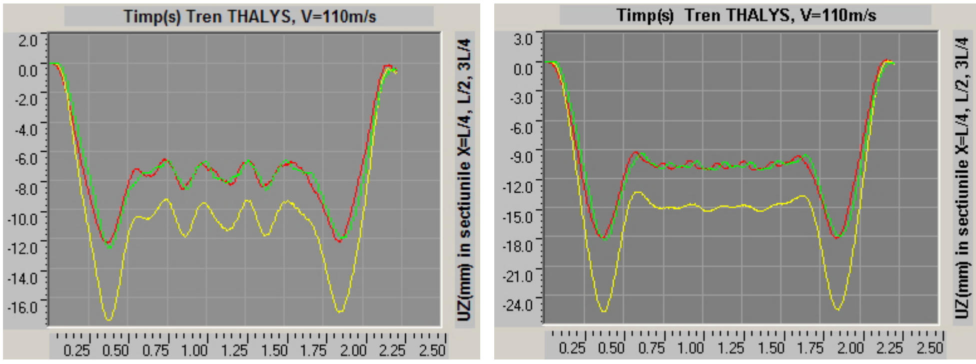
- 23.10mm for the straight track -25.89mm for the counter deflection track

Figure 5. Vertical displacements UZ (mm), Thalys, V=70m/s (252km/h)



- 17.94mm for the straight track -25.74mm for the counter deflection track

Figure 6. Vertical displacements UZ (mm), Thalys, V=80m/s (288km/h)



- 17.61mm for the straight track -25.74mm for the counter deflection track

Figure 7. Vertical displacements UZ (mm), Thalys, V=110m/s (396km/h)

Table 1 comprises the centralization of the results that have been obtained by the 24 dynamic analysis of the 51-meters-long superstructure with the Thalys train.

Table 1. Vertical displacements of the superstructure loaded with the Thalys train.

THALYS train speed	**Maximal and average deflections UZ (mm) measured at mid-span**					
	Horizontal bridge		**Bridge with counter deflection 10.323mm**			
V m/s (v km/h) (0)	Related to the horizontal line		Related to the non-deformed structure		Related to the horizontal line	
	UZ(-) max (1)	UZ(-) avg (2)	UZ(-) max (3)	UZ(-) avg (4)	UZ(-) max (5)	UZ(-) avg (6)
1m/s(3.6)	15.36	10.12	21.93	16.63	11.61	6.31
10 (36)	15.74	10.12	22.47	16.63	12.15	6.31
20 (72)	15.40	10.12	22.25	16.63	11.93	6.31
30 (108)	15.98	10.09	24.78	16.67	14.46	6.35
40 (144)	15.81	10.12	24.59	16.65	14.27	6.33
50 (180)	16.24	10.11	23.55	16.74	13.23	6.42
60 (216)	16.99	10.11	33.59	16.69	23.27	6.37
70 (252)	23.10	10.16	25.89	16.82	15.57	6.50
80 (288)	17.94	10.12	25.74	16.83	15.42	6.51
90 (324)	18.21	10.12	25.24	16.76	14.92	6.44
100 (360)	18.13	10.09	24.99	16.82	14.67	6.50
110 (396)	17.61	10.13	25.74	16.94	15.42	6.62

The significance of the values in the table:

- for a certain running speed, the SAP2000 programme records in all the 103 characteristic sections of the superstructure all the vertical deformations that occur in the 490 loading steps with the Thalys train;

- out of the 490 values recorded in the L/2 section we have selected only the maximal deformations, inserted in columns (1), and (3) in the table;

- we have made the arithmetical average of the 490 values of the deformations recorded in the 490 loading steps (all throughout the time when axles of the train are present on the superstructure) and we have inserted them in the table in columns (2), and (4);

- if the value of the counter deflection in a certain section is subtracted from the values related to the non-deformed structure, columns (3) and (4), the vertical deformations of the track related to the horizontal line are obtained; they appear in columns (5) and (6);

- the sign (-) that appears near Uz means that all the deflections in that column are below the horizontal line of the track in the absence of the train;

3. OBSERVATIONS AND CONCLUSIONS.

- The phenomenon of amplification of the vibrations is obtained at the speed of 70m/s (252km/h) for the straight superstructure and 60m/s (216km/h) for the counter deflection bridge.
- At the speed of 110m/s (396km/h) the vibrations decrease, the superstructure with counter deflection having the best behaviour (the superstructure practically does not vibrate at the passage of the cars).
- From the point of view of the maximal deformations, they are bigger at the counter deflection bridge than at the straight running track bridge (columns 1 and 3 compared);
- If the analyses are made from the point of view of the comfort of the passengers (who feel only the deviations from the straight line that unites the joints), we notice that the superstructure with counter deflection has a better behaviour, except for the speed of 60m/s (columns 1 and 5 compared);
- For the superstructure with a straight running track the most unfavourable speed is that of 70m/s (252km/h) with a maximal deflection of 23.10mm at L/2;
- For the counter deflection superstructure the most unfavourable speed is that of 60m/s (216km/h) with a maximal deformation of 33.59mm at L/2;
- For speeds higher than 90m/s (324km/h) the vibrations decrease significantly at the counter deflection bridge as compared to the ones recorded at the bridge without counter deflection (Figure 7);

Flaws of the analysed counter deflection shape:

The introduction of a counter deflection made up of the average of the deflections recorded under the train in the horizontal running track bridge leads to an increase of the strain and of the deformations in the superstructure (33.59mm as compared to 23.10mm in the bridge without counter deflection).

Advantages of the analysed counter deflection shape:

The vibrations are around an average value which is closer to the straight line (6.41mm instead of 10.12mm) which has as an effect the decrease of the strain in the rolling stock. The comfort will increase because the passengers will feel only the deviations from the straight line.

For speeds higher than 90m/s (324km/h), both the maximal value of the deviations from the horizontal line decreases and the amplitude of the vibrations of the counter deflection bridge decreases significantly. At these speeds, the behaviour of the counter deflection superstructure is much superior to the straight running track superstructure.

References

1. Bârsan, G.M.: *Dinamica şi stabilitatea construcţiilor*, Editura didactică şi pedagogică Bucureşti 1979. (in Romanian)
2. Esveld, C.: Modern Railway Track, MRT-Productions, ISBN 0-800324-1-7,1989
3. Esveld, C. and Kok, A. W. M.: Dynamic Behavior of Railway Track, Railway Engineering Course TU Delft, Department of Civil Engineering, November 1996
4. Esveld, C.: Modern Railway Track, Second Edition, Delft University of Technology 2001.
5. Goicolea, J.M., Domínguez, J., Navarro, J.A., Gabaldón, F.: New dynamic analysis methods for railway bridges in codes IAPF and Eurocode 1, RALWAY BRIDGES Design, Construction and Maintenance, Spanish group of IABSE, Madrid, 12–14 june 2002
6. Jantea,C., Varlam,F.: Poduri metalice. Alcătuire şi calcul. (Metallic bridges.Elements and calculation) Casa editorială "Demiurg".Iaşi.1996. (in Romanian)
7. Kollo,G., Moga,P., Guțiu,I.- Şt., Moga,C: Bending resistance of composite steel-concrete beams in accordance with Eurocode 4, 10 th International conference of civil engineering and architecture, EPKO 2006, Sumuleu Ciuc, 14-16 June. (in Romanian)