CETRA[2018]

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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NO-CLEARANCE COMPOSITE SUPERSTRUCTURE AND STEEL BRIDGE CONJOINT BEHAVIOUR AS A RESULT OF SPRINGTIME TEMPERATURE CHANGE

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Abstract

If no rail dilatation device is installed in the superstructure, the continuous welded rail remains stationary, in theory, under the influence of temperature change and allows the bridge structure to dilate freely. In practice, structural elements work closely together because the superstructure is fixed to the bridge. Dilating bridge structure attempts to drag the superstructure along but this latter withstands that force to some extent. As a result, relative displacement occurs between the bridge structure and superstructure allowing normal forces to develop in structural elements.

Keywords: heat induced movement, steel bridge, no-clearance superstructure, dilatation, monitoring system

1 Introduction

When routing a no-clearance superstructure through an engineering structure, their conjoint work has to be taken into account. Stress changes and displacements occurring in structural elements are closely interrelated. If rail dilatation devices are installed in the connecting superstructure at both sides of the bridge, then we make, in essence, track section coming across the bridge independent from the ballast bed track. Dilating bridge structure makes anchored superstructure move, which movement is impeded only by the internal friction of rail dilatation device. If there is no rail dilatation device installed, then interrelated effects emerging in both the superstructure and engineering structure will affect stress changes and displacements.

2 Longitudinal displacements

The following factors can induce relative longitudinal displacements during conjoint work of no-clearance superstructures:
- Temperature changes
- Vertical load induced by own weight of crossing vehicles
- Vehicles braking and accelerating.

Out of these effects, the greatest displacements are induced by temperature changes [1, 2], this article will deal with this effect only in more detail:
- Movements caused by temperature changes
- Solids tend to expand by temperature increase and contract when cooled. Instead of volumetric heat expansion, we often use linear thermal expansion in engineering calculations.

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By doing this way, the length changes in the direction of interest are examined, in our case this direction is parallel to the longitudinal axis of the rails.

On bridges with no rail dilatation device installed, the length change in the bridge structure can be theoretically described by linear thermal expansion. The linear expansion coefficient (1) induced by a given temperature change can be described by the following general formula [3]:

$$\propto = \frac{1}{L}\left(\frac{\vartheta L}{\vartheta T}\right)_p \left[K^{-1}\right] \quad (1)$$

Using the above, the length change due to ΔT change in temperature in a known (L) length material can be determined by the equation (2):

$$\Delta L = \propto \cdot L \cdot \Delta T \quad (2)$$

2.1 Stress variations caused by temperature changes

Impeded displacement causes variation in stresses in the given structural element. Conjoint work of the dilating bridge and no-clearance superstructure causes the bridge structure to drag and move the superstructure which can withstand this force to some extent. Due to this, the normal stress value will change both in the rails and in the bridge structure, which can be calculated by using equation (3):

$$\Delta\sigma = \propto \cdot E \cdot \Delta T \quad (3)$$

3 Key technical properties of the bridge structure

The bridge being studied is located in Budapest downtown, over Kerepesi Street, between Rákosszentmihály and Kőbánya Felső railway station. The two-track railway line of the circular railway is crossed by two separate bridge constructions over the road. The bridges lie in a straight line in the plot plan, distance between supports is 36.08 m.
The bridge over the right track was rebuilt in 2013. The structure is a simply-supported, trough-bridge type, lattice main girder design steel bridge with orthotropic track plate. The railway superstructure is crossed by utilizing direct anchoring (SIKA), Csilléry-type rail dilatating device installed at both ends. The bridge over the left track, which is the subject of this study, has almost identical geometry, expect the railroad track which is connected without disruption and uses bridge steeper. The simplified drawing of the bridge structure is shown in Figure 1.

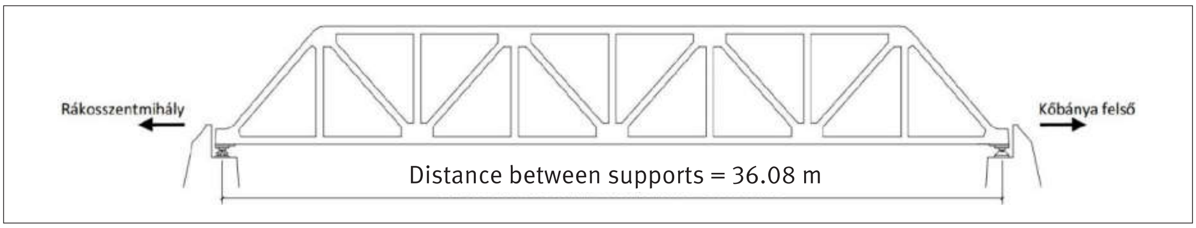

Figure 1 The simplified drawing of the bridge

There are welded on (reduced clamping force) GEO clamping plates for anchoring on the bridge structure, and traditional GEO clamping plates for anchoring on the connecting superstructure. There were visible sinking formed in the track in front of and behind the engineering structure.

4 Description of the monitoring system

Data collector in the measuring system installed on the bridge structure capable of saving measured values at user defined frequency. During the study period (April to June, 2017) this meant 1 hour and 2 hours intervals.
One thermometer mounted under the bridge measures the temperature of the air, one structural thermometer measures the temperature of the bridge, and two rail thermometers take rail temperature readings. In order to observe changes of normal forces occurring in the rail, four cross-sectional strain gauges have been fixed to the rail web. Measuring instruments fixed on the rail are always mounted on the left side rail.
Potentiometric proximity encoders are installed above the stationary and movable shoes to measure displacement of the rail and bridge structure relative to the bridgeheads. Allocation of instruments is shown in Figure 2.

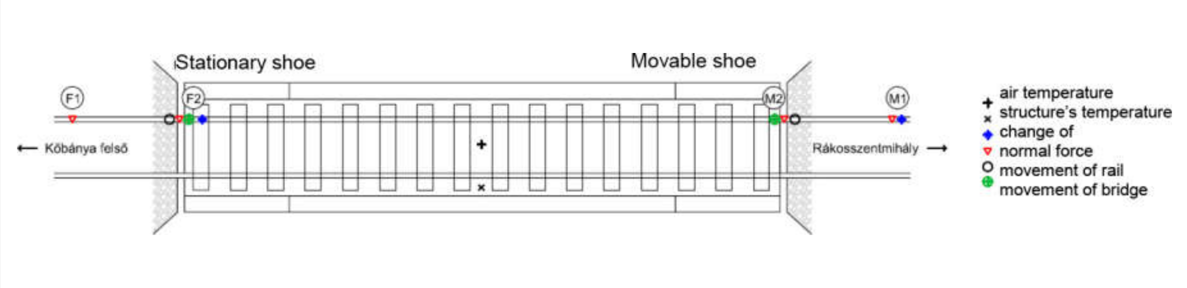

Figure 2 Positions of measuring instruments

5 Measurement results

Within the examined period (April 2017 – June 2017), the frequency of sampling varies between 1 and 2 hours. It was 2 hours between 1st April and 29th May and 1 hour following 29th May. The monthly temperature average calculated from daily average temperatures increased steadily, exceeding even 16.5 °C in June. Variation of daily average temperature is shown in Figure 3.

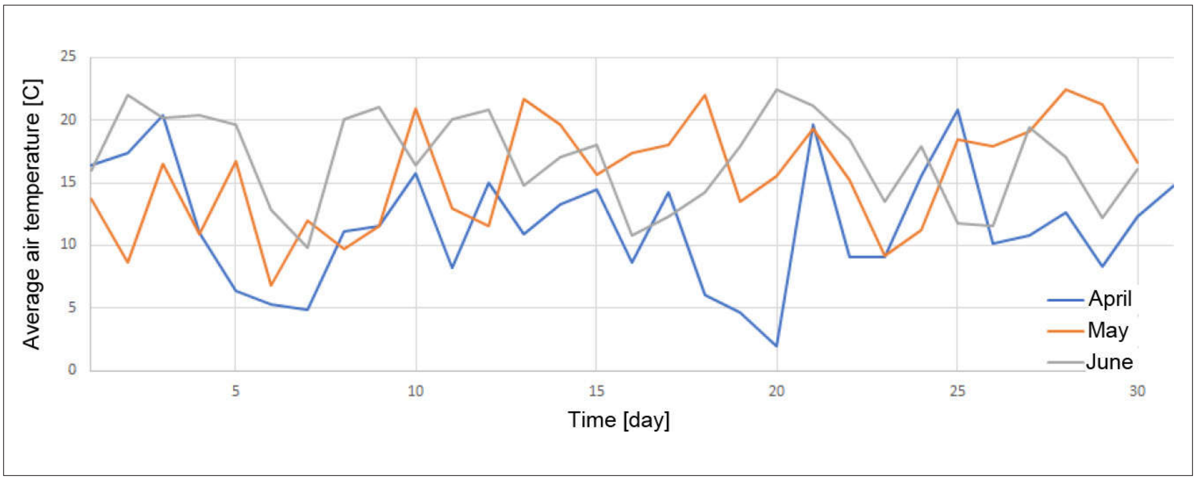

Figure 3 Daily average temperature

The biggest three temperature fluctuations can be seen on 28 May (22,4 °C), 2 June (22,0 °C), and 20 June (22,4 °C). Because lot more readings are obtained in June, we used the maximum value occurred on 20 of June.

5.1 Measured displacements

In order to evaluate displacements, we considered that the structure original position is the one characterized by readings taken on 26 September, 2017 / 19:00 pm, and we could choose it because either the rail and the bridge structure dwelt within neutral temperature zone that time. The shoe axis and the end of the bridge structure are 260 mm apart from each other horizontally, which should be taken into account when calculating thermal expansion, since displacements relative to the bridgeheads were measured at the two ends of the bridge structure. Dilating length of the engineering structure at the stationary shoes is therefore 260 mm meanwhile at the movable shoes it is 36340 mm. Due to the fact the temperature of the structure is taken only at one point (around the centre of the structure), this value can be considered for information only in order to calculate movements in the vicinity of shoes. We call it positive displacement when the bridge is moving away from the bridgehead, i.e. the bridge length decreases.

Table 1 Measured and calculated displacements of bridge-ends

Bridge temperature [°C]	Bridge temperature change [°C]	Bridge structure displacement at the stationary shoe			Bridge structure displacement at the stationary shoe		
		Measured vale [mm]	Calculated vale [mm]	Deviation [%]	Measured vale [mm]	Calculated vale [mm]	Deviation [%]
21.9	-1.7	-0.05	0.00	-90.3	-0.72	-0.69	-3.6
20.6	-3.0	-0.15	-0.01	-94.3	-1.15	-1.22	5.8
19.3	-4.3	-0.28	-0.01	-95.6	-1.51	-1.75	15.7
18.3	-5.3	-0.38	-0.02	-96.0	-1.85	-2.16	16.8
17.4	-6.2	-0.49	-0.02	-96.3	-2.10	-2.52	20.0
16.9	-6.7	-0.54	-0.02	-96.4	-2.36	-2.73	15.6
16.9	-6.7	-0.67	-0.02	-97.1	-2.31	-2.73	18.2
18.3	-5.3	-0.64	-0.02	-97.6	-1.82	-2.16	18.5
21.0	-2.6	-0.36	-0.01	-97.9	-0.90	-1.06	17.9
24.3	0.7	0.08	0.00	-97.3	0.25	0.28	14.0
26.6	3.0	0.41	0.01	-97.9	0.85	1.22	44.3
29.9	6.3	0.77	0.02	-97.6	1.90	2.56	35.1
32.8	9.2	1.00	0.03	-97.3	2.51	3.74	49.0
35.7	12.1	1.26	0.04	-97.2	3.54	4.92	39.2
35.4	11.8	1.33	0.03	-97.4	4.26	4.80	12.8
35.9	12.3	1.44	0.04	-97.5	4.95	5.01	1.2
36.1	12.5	1.49	0.04	-97.6	5.23	5.09	-2.7
35.5	11.9	1.44	0.03	-97.6	5.23	4.84	-7.4
34.8	11.2	1.33	0.03	-97.6	4.92	4.56	-7.4
33.3	9.7	1.28	0.03	-97.8	4.03	3.95	-1.9
31.8	8.2	0.97	0.02	-97.5	3.00	3.34	11.3
30.1	6.5	0.79	0.02	-97.6	2.05	2.65	29.0
28.4	4.8	0.62	0.01	-97.7	1.33	1.95	46.5
26.1	2.5	0.38	0.01	-98.1	0.62	1.02	65.4

The % of deviation at the stationary shoe seems to be significant from actual value but it is due to the extremely low displacement values seen here. Calculation yielded bigger displacement values at the movable shoe comparing to the actual values. Displacements occurred and calculated with equation (2) at the movable shoe are shown in Figure 4.

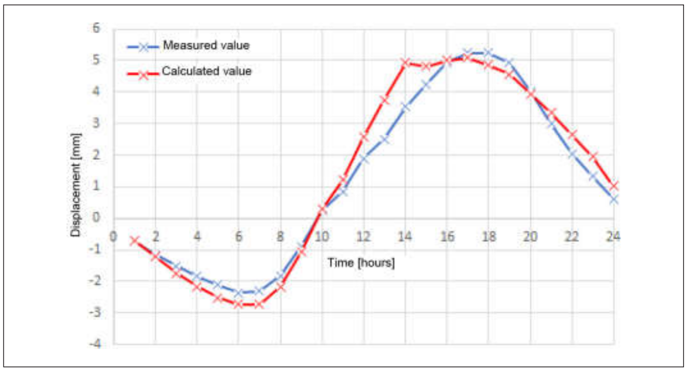

Figure 4 Bridge-end displacements on the movable shoe side

5.2 Measured stress changes

When examining conjoint work of the bridge and superstructure to show actual displacements, it is also necessary to investigate the changes in stress level which is caused by impeded movements. The high compression force developing in the rails can result in dislocation meanwhile the strong tensile force can cause rail break. In this study we measured stress variations in the rail at four different places, below data series show the readings provided by one of the four strain gauges, the one installed on the open rail section at the movable shoe.

Table 2 Measured and calculated change in stress value in M1 cross section

Rail temperature [°C]	Rail temperature change [°C]	Change in stress	
		Measured vale [MPa]	Calculated vale [MPa]
24.3	1.2	3.8	3.0
22.8	-0.3	0.0	-0.7
21.3	-1.8	-2.6	-4.5
20.2	-2.9	-5.0	-7.2
19.3	-3.8	-7.1	-9.4
18.5	-4.6	-7.8	-11.4
18.3	-4.8	-7.4	-11.9
23.7	0.6	1.4	1.5
32.3	9.2	9.5	22.7
39.4	16.3	23.0	40.3
44.8	21.7	34.5	53.7
46.7	23.6	46.4	58.4
46.8	23.7	52.2	58.6
47.4	24.3	56.4	30.1
48.2	25.1	59.9	62.1
49.1	26.0	62.1	64.3
49.1	26.0	65.3	64.3
49.0	25.9	63.3	64.0
46.7	23.6	56.4	58.4
40.5	17.4	45.0	43.0
36.6	13.5	33.5	33.4
33.4	10.3	24.6	25.5
30.8	7.7	18.9	19.0
28.4	5.3	13.1	13.1

Calculations performed with equation (3) result most of the time in overestimated values relative to actual ones. Stress variation within one day shown in Figure 5.

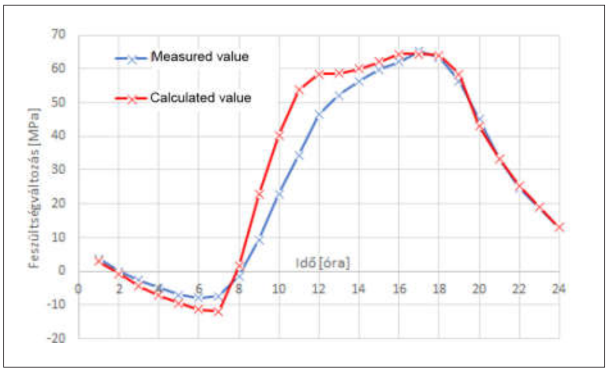

Figure 5 Stress variation in M1 cross section of the rail

6 Conclusion

We have presented in this paper how the movement and stresses are changing within a day featuring the largest temperature fluctuation by showing the actual and also the calculated values. The theory of linear thermal expansion represents pretty well the real displacements observed, meanwhile deviations may have come from certain extent of uneven temperature distribution or the properties of materials. Temperature distribution over the entire bridge structure will be subject of a future research. Deviations occurred beyond this consideration are due to the conjoint work of bridge and superstructure as well as the way these are influencing each other. The same factors apply on deviations of actual and calculated stresses. Values obtained from calculation allows actual values to remain on the safe side.

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