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INFLUENCE OF CLIMATE CONDITIONS ON STRESSES IN CWR ON THE BRIDGES IN SERBIA

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Abstract

Vehicle/track/bridge interaction causes additional stresses in CWR on the bridge, which include stress in rails due to temperature changes in the bridge deck, vertical bending of bridge deck, and braking/acceleration of railway vehicles on the bridge deck. Critical analysis of additional tensile stresses in CWR on the bridge using Smith diagram was performed and presented in this paper. Furthermore, results of rail temperature measuring at several monitoring locations in Serbia were presented. The influence of the local climate conditions and neutral rail temperature on the temperature stress in CWR was analysed. The paper points out that the prescribed values of additional stresses in CWR have to include influence of real local climate conditions on track stability on the bridge.

Keywords

railway, bridge, CWR, temperature, stress

1 INTRODUCTION

The increase of critical temperature in the rail might lead to track buckling and derailment during summer. Furthermore, the decrease of critical temperature in the rail might lead to rail break, which jeopardize the safety of rail transport during winter.

The dangerous consequences of derailment could lead to a loss of human life, injuries, environmental and material damage. The possible consequences of derailment are more severe on the sections on the railway bridges.

In the design and maintenance phase, the consideration of the vehicle /track/bridge interaction has to take into account all the effects on the safety of rail transport.

The considerations in this paper are primarily focused on the temperature changes in rail and bridge structure and their influences on the stresses in continuous welded rail (CWR - Continuous Welded Rail) on the bridge.

Figure 1 shows the influence of the temperature changes in rail and bridge deck on the tensile stress in CWR on the bridge. Similarly, Figure 2 shows the influence of the temperature changes in rail and bridge deck on the pressure stress in CWR on the bridge.

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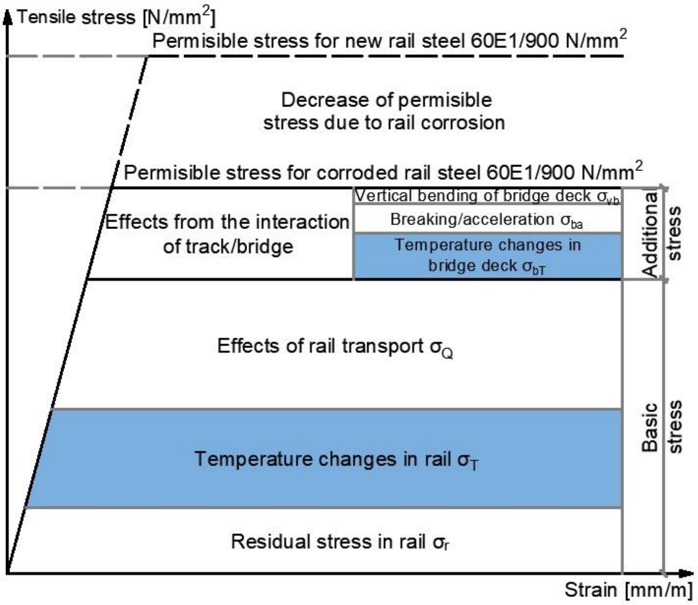
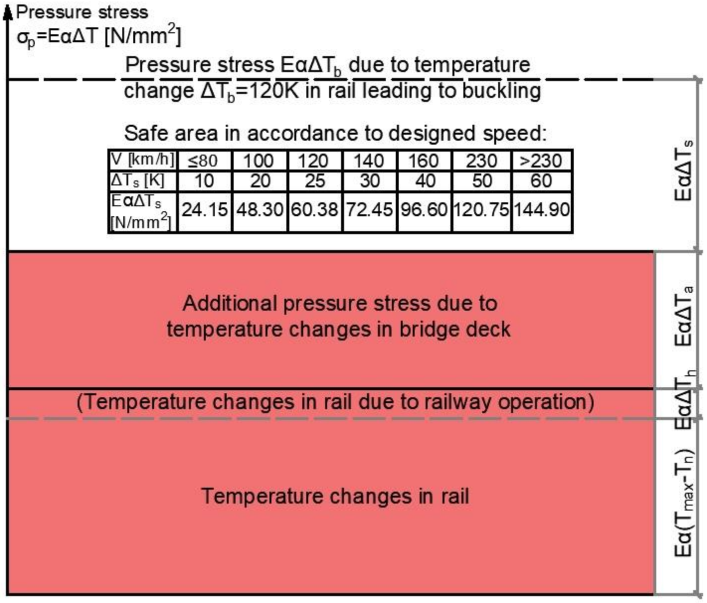


Fig. 1 The share of temperature changes in total tensile stress in the rails on the bridge



V [km/h]	≤80	100	120	140	160	230	>230
ΔT_s [K]	10	20	25	30	40	50	60
$E\alpha\Delta T_s$ [N/mm^2]	24.15	48.30	60.38	72.45	96.60	120.75	144.90

Fig. 2 The share of temperature changes in total pressure stress in the rails on the bridge

The influence of the local climate conditions in Serbia on the neutral rail temperature and the temperature stresses in CWR was analysed.

In accordance with design criteria for rails on the bridge and on the adjacent abutments defined in [1], the permissible additional rail stresses due to the combined response of the bridge structure and ballasted track to variable actions should be limited to 72 N/mm^2 for the pressure stress and 92 N/mm^2 for the tensile stress. The permissible additional rail stress for ballastless railway track on the bridge is 92 N/mm^2 for both the pressure and tensile stress. The detailed structure of the basic and additional stresses in CWR on the bridge was presented and analysed by the authors in [2]. In any case, calculation model for vehicle/track/bridge interaction should include vertical and longitudinal loads according to Figures 1 and 2. Figure 3 shows the example of calculation model.

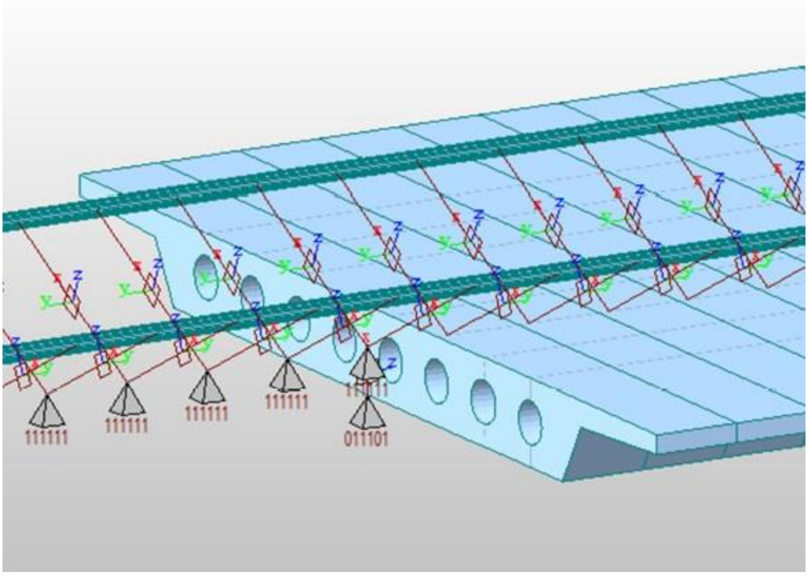


Fig. 3 Calculation model for vehicle/track/bridge interaction
(the bridge on Stalać - Đunis railway section, km 189 + 190.60, Corridor X through the Republic of Serbia)

This paper points out that the prescribed values of additional stresses in CWR have to include influence of real local climate conditions on track stability on the bridge.

2 INFLUENCE OF THE LOCAL CLIMATE CONDITIONS ON NEUTRAL RAIL TEMPERATURE

Neutral temperature in rails during track construction should be defined by Infrastructure Manager in such a way to ensure the safety of rail transport [3 - 7], as follows:

- the compressive stress in rail should prevent track buckling during summer and
- the tensile stress should prevent rail break or limit the gap in the event of rail break in tracks during winter.

Figure 4 shows the influence of the selected neutral temperature on the stresses in the rails during winter and summer. The absolute values of pressure and tensile stresses are equal when the neutral temperature is in accordance with (1).

$$T_n = \frac{\left(T_{\max} + T_{\min}\right)}{2} = T_s \, , \tag{1}$$

where T_n is neutral temperature, T_{max} is maximum temperature during summer, T_{min} is minimum temperature in rail during winter and T_s is mean temperature.

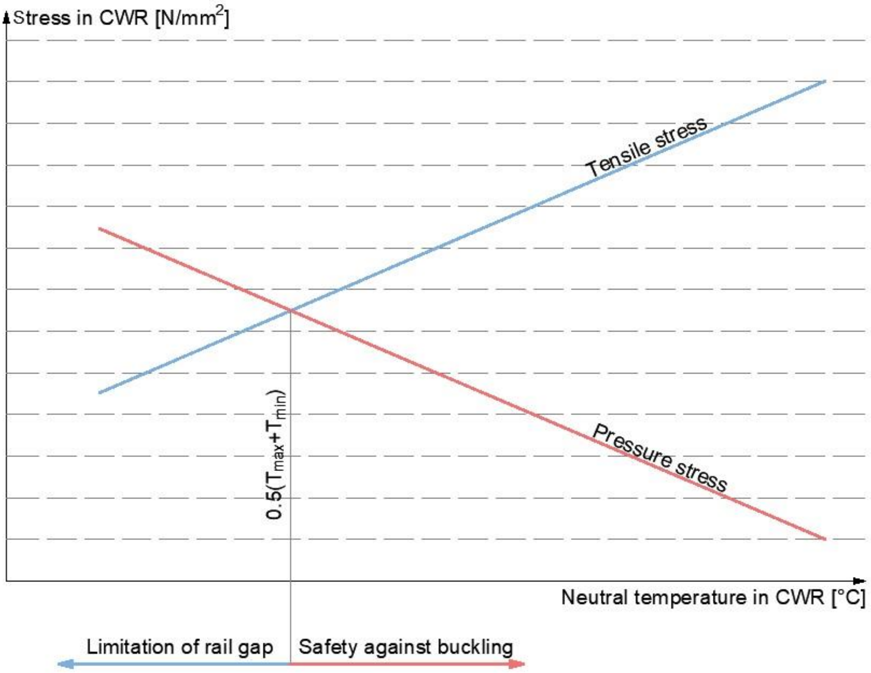


Fig. 4 Influence of neutral temperature on the rail stresses

Obviously, the neutral temperature depends strongly on the maximum and minimum temperature in the rails and influences the stresses in CWR. Table 1 shows the measured values of extreme winter and summer temperatures in the rails at three measurement locations for the last three years (2015 – 2017), which reflect the impact of climate change. These temperature measurement locations are shown in Figure 5.

Tab. 1 Extreme temperature in the rails at three measurements locations in the period 2015 - 2017

Year	**Measurement location 1**		**Measurement location 2**		**Measurement location 3**	
	$T_{min}[^0C]$	$T_{max}[^0C]$	$T_{min}[^0C]$	$T_{max}[^0C]$	$T_{min}[^0C]$	$T_{max}[^0C]$
2015	-5	53	-2	59	-20	55
2016	-8	50	-10	58	-12	58
2017	-10	59	-15	60	-22	60

Serbian Infrastructure Manager prescribed the unique temperature values as follows:

- T_{min} = -30°C,
- T_{max} = +65°C, and
- $T_n = T_s + 5 = 22.5$°C.

The extreme summer temperatures in rail showed in Table 1 are mostly uniform and do not exceed +60°C (the prescribed value T_{max} = +65°C is in the security area). The measurement locations Sremski Karlovci and Valjevo showed mostly uniform values of winter temperature in rail, which is about 50% of the prescribed minimum value (T_{min} = -30°C). On the other hand, the measurement location Priboj showed the minimum value -22°C, which is about 73% of the prescribed minimum value.

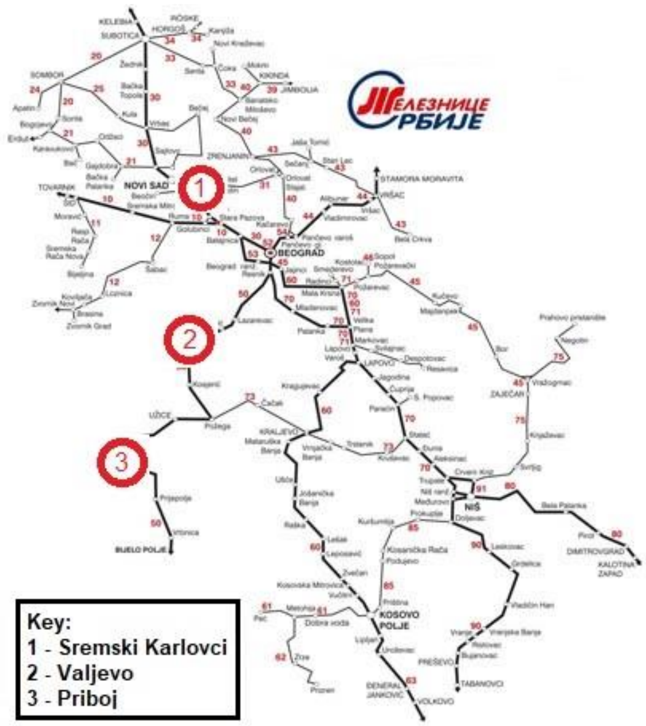


Fig. 5 Measurement locations on the Serbian railway network

Figure 6 shows the standard measurement of the temperature in the rails on the Serbian railway network. A qualified staff performs temperature measurement twice a day (at 7 o'clock a.m. and 2 o'clock p.m.) In Figure 6, the magnetic thermometer shows 40°C in 9 o'clock a.m. on 11 July 2017.

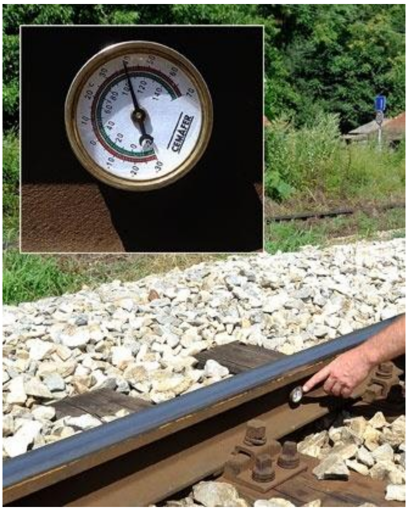


Fig. 6 Standard temperature measurement
(Topčider measurement location in the vicinity of Belgrade, July 2017)

The temperature measurement in rails and bridge decks is organized by the Infrastructure Manager. Temperature data for existing bridges are valuable for the reconstruction of existing and design of new railway bridges.

Figure 7 shows an interactive bridge model, which is linked to both the track and bridge database. Additionally, Figure 7 shows modern temperature measurement in rails, bridge deck and bearings using sensors. Among other representative data on the track, the database has to contain information about the measured minimum and maximum temperatures in the rails. Similarly, the base of representative bridge data has to include information about measured temperatures in the bridge deck and bearings.

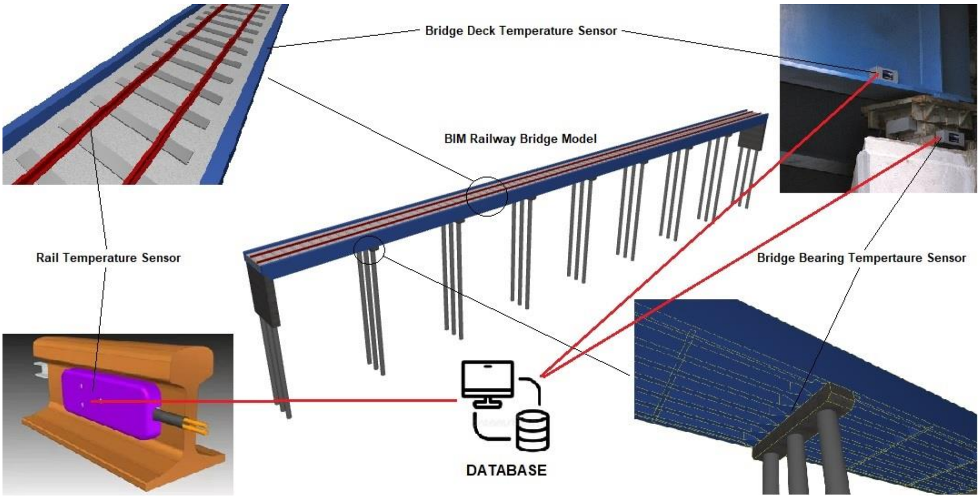


Fig. 7 An interactive bridge model linked to both track and bridge database

Furthermore, the neutral temperature T_n, which is higher than the mean temperature T_s, is favourable against track buckling during summer. Contrary to that, less neutral temperature than mean temperature T_s is favourable for the omitting or limiting the rail gap during winter (Figure 8).

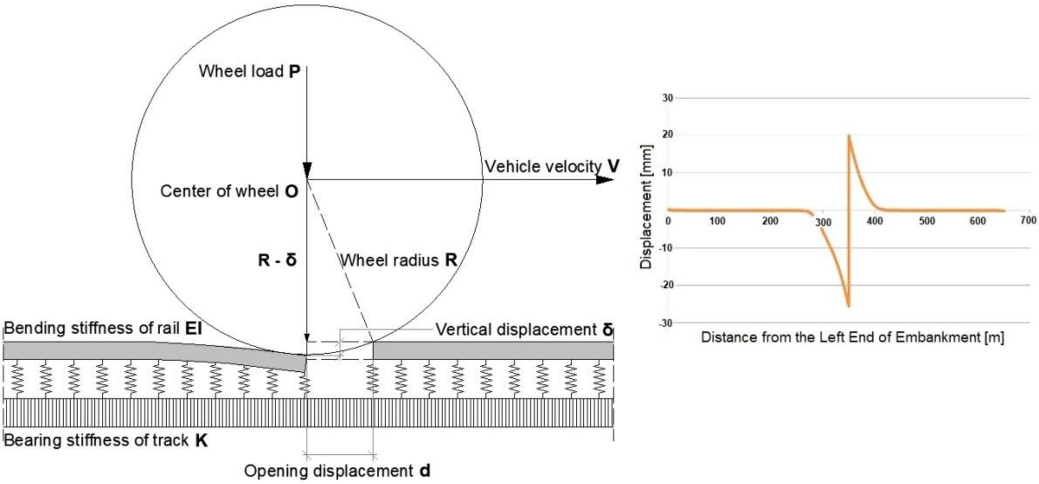


Fig. 8 Rail gap: calculation model (left) and the displacement diagram (right)

Obviously, neutral temperature defined by the Infrastructure Manager directly affects the safety of rail transport and maintenance costs.

Figure 9 shows permissible tensile bending strength in the rail foot centre according to Smith diagram for new and corroded rails with a tensile strength 900 N/m^2.

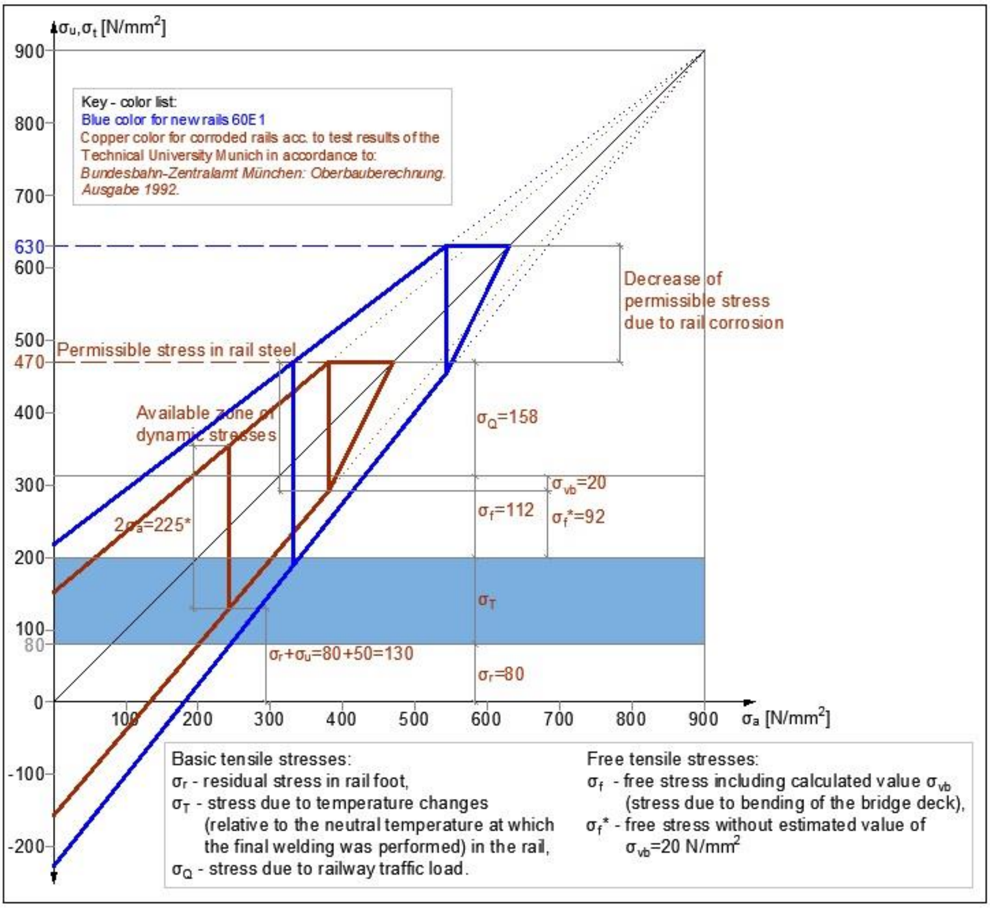


Fig. 9 Smith diagram for new and corroded rail 60E1/900

Stress σ_T (area highlighted in blue in Figure 9) due to temperature changes (relative temperature compared to the neutral temperature at which the final welding was performed) in rail falls into the basic tensile stress and affects the permitted value of the additional tensile stress (92 N/mm^2 according to [1]) in CWR on the bridge. The temperature stress in rail σ_T has to be in accordance with the measured temperature in the rail in the climatic zone in which the bridge is located. In this way, for specific climate conditions, the permitted value of the additional stresses in CWR on the bridge might be greater than, equal to or less than the prescribed value according to [1].

3 CONCLUSION

Considerations in this paper refer to the track with CWR on the bridge from the aspect of climate impacts to additional stresses in the rails. Interaction of vehicle/track/bridge plays a key role in design and maintenance of railway bridges in these considerations. Furthermore, general application of permissible values of pressure and tensile stresses prescribed in the current European standards was critically analysed.

Stresses induced by the vehicles (vertical load and longitudinal loads during acceleration/breaking of the vehicles), as well as temperature changes and bridge displacement, affect track superstructure, especially CWR. Management of the vehicle/track/bridge interaction requires appropriate calculations that correspond to the structure and expansion length of the bridge, vertical traffic loads, longitudinal loads due to acceleration/breaking of vehicles and temperature changes according to local climate conditions [2, 6, 7].

Neutral temperature for prevention of buckling unnecessarily increases due to the exceeded values of the maximum temperature (in relation to the real summer temperature in the rail). Furthermore, this results in an unrealistic increase of the calculated CWR gap during winter. On the other hand, the underestimated value of the maximum temperature decreases the neutral temperature, thus giving unrealistic safety against track buckling and unrealistic small gap. In any case, wrong estimate of minimum and/or maximum temperatures could lead to increased construction and maintenance costs. In the worst cases, it might jeopardize railway traffic safety.

Considering that measured air temperatures were above 42°C in some places in Serbia during last several years, it is necessary to reduce value of permissible pressure stress in rails in such climate zones.

Hot summers and cold winters in recent years imply the necessity for permanent monitoring of temperature in rails and bridge decks, in order to define the real values of permissible stresses. This paper presents the interactive model of the railway bridge, which includes information about measured temperatures in rails, bridge deck and bearings.

The technical regulation should harmonize the prescribed values of the permissible stresses in CWR with the climate zone in which the bridge is located, instead of strictly adhering to the prescribed values in European standard [1].

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Bibliography

[1] CEN/TC 250: EN 1991-2:2003, Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges, Brussel, 2003.

[2] MIRKOVIĆ, N et al. Management of Stresses in the Rails on Railway Bridges. *FME Transactions.* 46 (2018), s. 636-643.

[3] ZAKERI, J.A. et al.. New Definition of Neutral Temperature in Continuous Welded Railway Track Curves. *Periodica Polytechnica Civil Engineering*. 62 (2018), s.143-147.

[4] UIC: Code 774-3: Track/bridge Interaction - Recommendations for calculations, Paris, 2001.

[5] DIN: Fachtbericht 101, Einwirkungen auf Bruecken, Deutschland, 2003.

[6] FREYSTEIN, H. Interaktion Gleis/Brücke – Stand der Technik und Beispiele. *Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin Stahlbau 79*. 3 (2010), s. 220-231, DOI: 10.1002/stab.201001299

[7] WENNER, M. at al. Längskraftabtragung auf Eisenbahnbrücken Teil 2: Hintergründe des Nachweises. *Bautechnik*. 93 (2016),s. 470-481.,. DOI: 10.1002 / bate.201600034