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Nexus of the Load Bearing Capacity of Rails and the Stiffness of the Optimized Sleepers

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Abstract

In the railway track modernizations an important role is played by the connection between the sleepers and the rails.
In this article the authors are studying the effect of the sleepers on the rails in the ballasted railway superstructure, considering the ballast layer properties according to local conditions, but unchanged during the studies. The optimised dimensions of the sleepers are aimed in order to allow increased speed of the railway.
The role of the sleepers mainly consists in taking over the load on the rails and transmitting to the ballast, therefore technical capabilities are highly influenced also by the behaviour of the other elements of the rail track system.

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Keywords: bearing capacity; stiffness; optimal cross section; blocks length; flexibility of the ballast.

1. Calculation of the bearing capacity of the ballasted superstructures` rail tracks

Dimensioning and study of elements of railways` superstructures is already a very old process, it had begun simultaneously with the appearance of the railway.

Initially the engineers designed the railways structures by completely relying on previous experiences and practices but over time many other methods had been developed for the calculation of railways superstructures.

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There are two main calculation methods for designing the ballasted tracks system with sleepers laid transversely to the rails: the method of Winkler and the method of Zimmermann [3, 4]. These methods were developed for a longitudinally sleepered track, considered to be resting on a compressible foundation. Since track is now transversely sleepered, a transformation of this track type to an equivalent longitudinally sleepered track is required in the analysis. This can be achieved if the assumption is made that the effective rail support area provided by the sleeper remains constant for both types of track [1, 2].

The most important difference between these applications is that, while in the method of Winkler, the ballasted layer is considered rigid, the method of Zimmermann takes into account the elastic characteristics of the ballasted layer, assuming that the transverse sleepers - which support the rail tracks - under the conditions of traffic load do not only sink into the ballast near the wheel load but also farther away from the load area [5, 7, 11, 12].

Current practices in the world concerning the calculation of railway structure are mainly based on the method of Zimmermann, “beam on elastic foundation” [1, 6].

The basic idea in Zimmermann method is to transform the transversely sleepered track represented theoretical by a discrete supported beam to an equivalent longitudinally sleepered track represented by a fictive, continuously supported beam on an elastic foundation (Fig. 1) [9, 5].

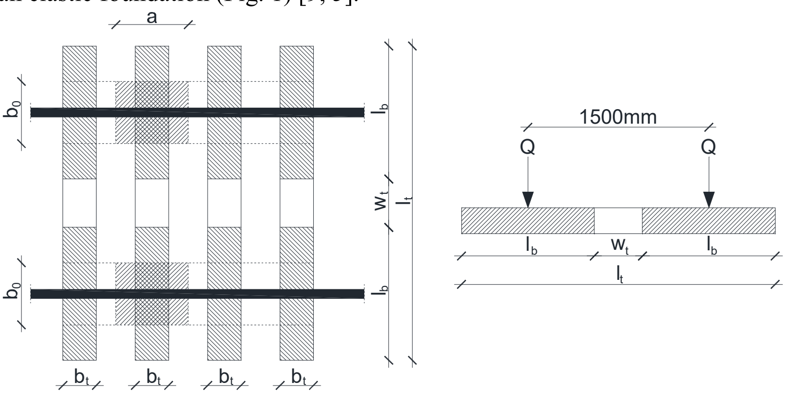

Fig. 1. Transformation of transversely sleepered track to an assumed longitudinally sleepered track using Zimmermann theory

2. Analysis of the load bearing capacity of the rails depending on the stiffness of the sleepers

Using the superstructures` calculation method relying on the model of Zimmermann, continuously supported beam on elastic foundation, the authors analysed the appearing bending moments in the rail beams depending on the variation of the length and the height of the sleepers under the rails (in the place of the rails bearing). For this calculation we used the following equation:

$$M_r = \frac{E_r I_r}{4(E_r I_r + E_t I_0)} \sqrt[4]{\frac{4(E_r I_r + E_t I_0)}{b_0 C}} Q \cdot (1 + t\delta\varphi) \tag{1}$$

M_r Maximum bending moment in the load rail;
E_r modulus of elasticity of the rail steel, N/mm^2;
I_r rail moment of inertia, mm^4;
E_t modulus of elastictiy of the sleeper concrete, N/mm^2;
I_t sleeper moment of inertia, mm^4;
I_0 moment of inertia of fictive, equivalent longitudinal sleeper, mm^4; $I_0 = \alpha \frac{l_t}{2a} I_t$;
b_0 breadth of fictive, equivalent longitudinal sleeper, mm; $b_0 = \alpha \frac{l_t}{2a} b_t$;
b_t breadth of sleepers, mm;
h_t height of sleepers, mm;