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Increasing Railway Stability with Support Elements. Special sleepers

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Abstract

Increasing traffic speed and loads on the railway system can be realized only with the support of a reliable infrastructure. The paper presents a new type of sleeper that offers a larger stability compared to the classical system, being able to support high speed and larger loads. The tests conducted on the frame sleeper were able to determine the lateral resistance of the ballast bed.

Rezumat

Creșterea vitezelor de circulație și a tonajelor remorcabile necesită o cale capabilă să preia în siguranță încărcările rezultate din trafic. Traversa tip cadru prezentată în această lucrare oferă o rezistență transversală sporită, o rigiditate mai mare a cadrului traverse - șine, reduce presiunea transmisă de convoi către prism și permite un tonaj mult mai mare față de sistemul clasic, asigurând o rezistență crescută la stabilitate. Testele efectuate pe traversa tip cadru au avut ca rezultat determinarea rezistenței laterale a prismei de piatră spartă.

Key words: concrete frame sleeper, railway track, ballast bed lateral resistance

1. Introduction

To keep the track stability, a railway track constructed from special rail sleepers, rails and ballast bed, the special sleepers embedded in the ballast and the ballast bed itself have a significant importance. Any rail structure must preserve as long as possible the designed rail position. In case of a welded structure, the rails are subjected to important stresses, both compression as tension depending on the temperature, this being the reason that the rail stability problem have a major importance to traffic safety.

Analysing the structure of the critical stability force, it can be observed that the ballast bed component has a significant percent of the total critical force value: 70-80%.

The paper presents a special frame rail sleeper and the experimental results for the lateral ballast bed resistance. A frame sleeper provides an increased railway track stability compared to the classical sleeper used in present in the majority of railway network.

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2. Frame sleeper - geometry and characteristics

The shape of the frame sleeper presented in this paper is the result of the research conducted by prof. Peter Veit from the Institute of Railway Engineering of Graz, Austria. It has an innovative design meant to achieve higher durability, easy integration on the existing structures and best cost - benefit relation. The advantages of this type of structure are: reduction of ballast pressure with 50%, increased lateral resistance, full frame stiffness, fit for curves with all radii and ramps, elastic sub surface, all mechanized methods for laying, tamping and maintenance existing applicable.

The results presented here were conducted on a 1:1 scale sleeper, fully manufactured in the Technical University of Cluj - Napoca testing lab. The geometry is presented in the drawing below:

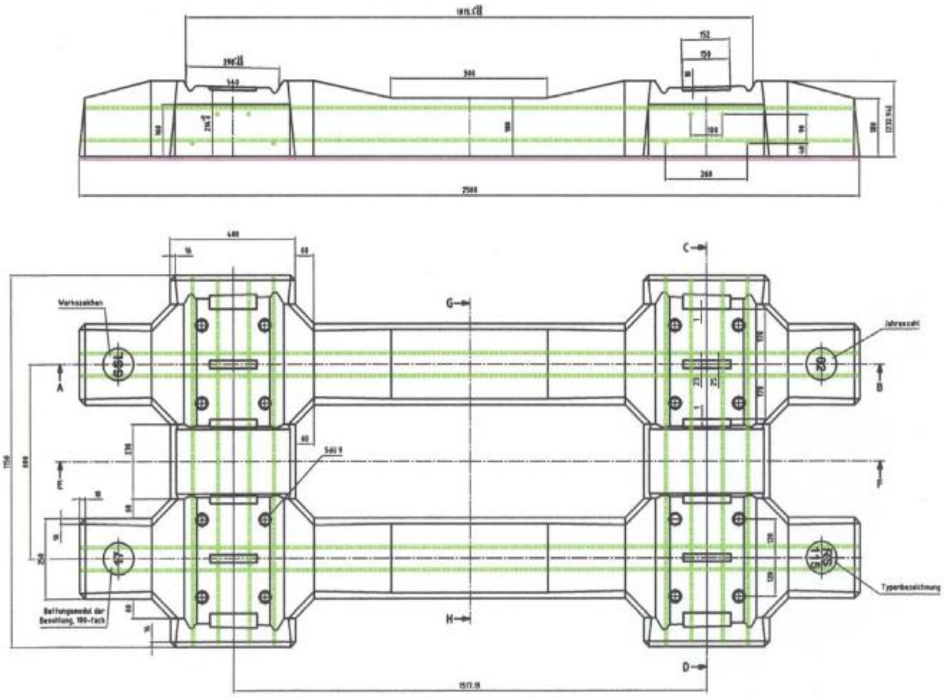

Fig. 1. Geometry of the frame sleeper [2]

Geometry and characteristics of the frame sleeper tested [1]:

- length = 2.50 m
- width = 1.15 m
- weight = 900 kg
- gauge of the track = 1437 mm ± 1
- concrete C50/60
- crossbred tension force 4x320 kN
- reinforcement: 16 x 9.4 Φ
- load per axle 250 kN
- speed 250 km/h
- rail fastening system: Vossloh W14

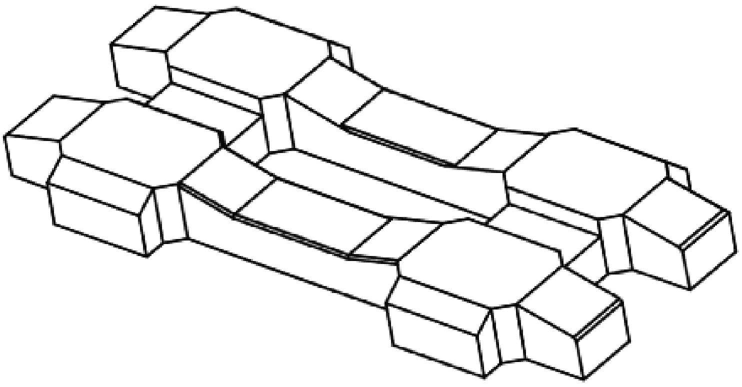

Fig 2. 3D view of the frame sleeper

Fig 3. RS 115 Frame Sleeper [1]

Phases of construction:

Fig 4. The sleeper after partial de-framing

Fig 5. The sleeper placed on the ballast bed

Fig 6. Manual tamping

3. Tested performed on the frame sleeper

To test the lateral resistance of the ballast bed, the frame sleeper vas subjected to an horizontal force with the help of a 20 tons hydraulic jack connected to an air compressor. The force was measured with a force transducer and the horizontal displacement with a displacement sensor, both connected to a data acquisition modem linked to a soft[3] on a computer.

The goal was to determine the lateral resistance of the ballast bed, with all its components:

a. the sleeper embedded in ballast on all 3 sides
b. the sleeper embedded in ballast only at the shoulder
c. the sleeper is not embedded in ballast, only the base ballast is present


Fig 7. The testing and measurements instruments

4. Results obtained

The paper presents the results obtained for a ballast shoulder of 35 cm and 60 cm, with the frame sleeper fully embedded in the ballast bed. 35 cm is the standard dimension for the shoulder on alignment track, as in curves it is necessary an increase of the shoulder due to the forces that are present in this situation. The frame sleeper has a higher stability, fact that recommends the use of this structure on small radius curves.

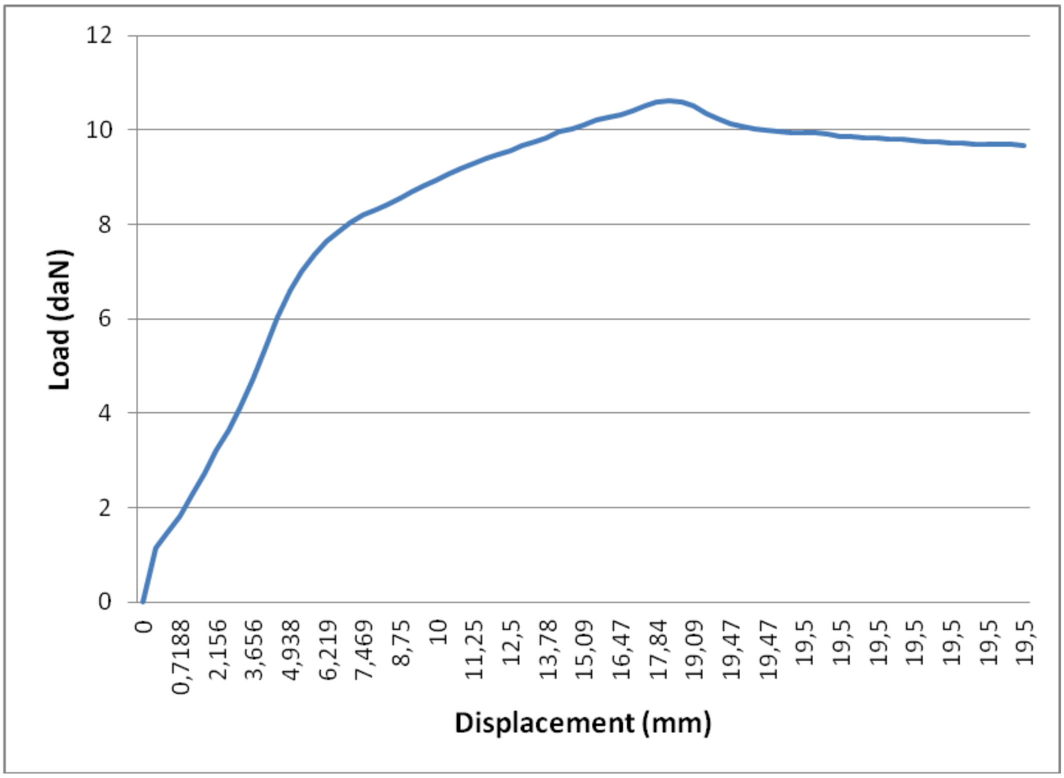

Fig. 8 Load - Displacement diagramme for a ballast shoulder of 35 cm

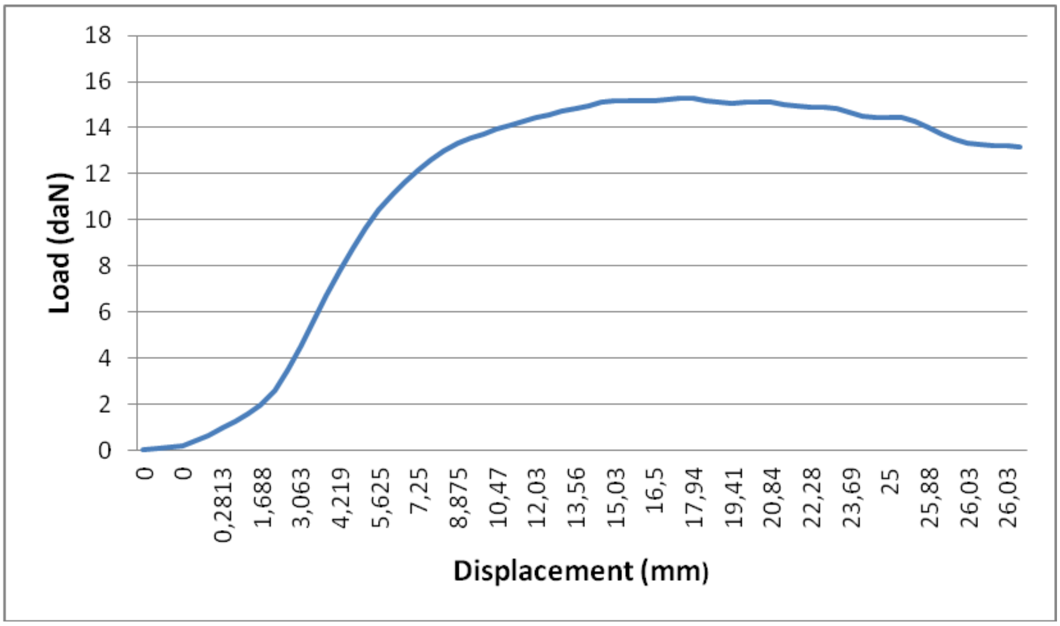

Fig. 9 Load - Displacement diagramme for a ballast shoulder of 60 cm

The jointless railway track is considered an horizontal frame embedded on a ballast bed, without being fixed, with a special geometry (alignments and space curves). The calculus elements for this structure must be determined in order to prevent the instability and to maintain the traffic safety.

Track buckling can be prevented by the railway stiffness, the rail-sleeper frame and the ballast longitudinal and lateral bed displacement resistance. Ballast bed influence was determined with:

$$q = q_0 + C \cdot y \tag{1}$$

if $y < y_o$, $q = q_0 + C \cdot y$ (linear variation)
if $y \geq y_o$, $q = q$ (constant lateral resistance)

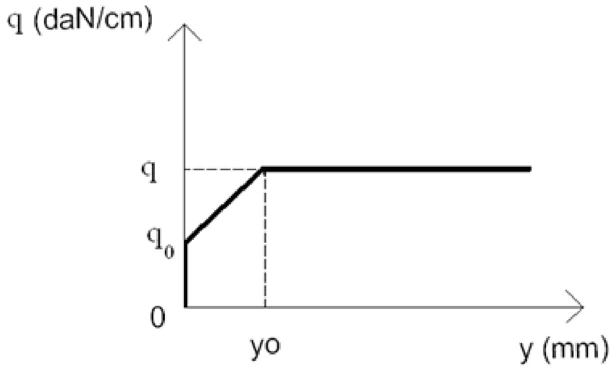

Fig. 10 Lateral resistence with the lateral displacement

5. Case study

The paper present the critical force for losing stability for two types of concrete rail sleepers: classical T17 sleeper and the RS 115 frame sleeper using two calculus methods: the approximate and the energetic method, for rail geometrical imperfection E type, rail type 60.

The approximate method:

$$P_{cr} = \alpha \frac{EI}{l^2} + \frac{2r}{a} + \beta \frac{l^2}{f} q \qquad (2)$$

where:
α, β - geometrical imperfection constants

For the studied case, imperfection type E:
$\alpha = 10$
$\beta = \frac{1}{8}$

E – elasticity rail module $2{,}1 \cdot 10^6$ [daN/cm^2];
I – inertial rail moment (rail type 60) 512,9 [cm^4];
a – distance between sleeper axes 60 [cm];
r – fastening coefficient $0{,}3 \cdot 10^6$ [daNcm]
q – lateral resistance of the ballast bed [daN/cm]
l - length of the geometrical imperfection l = 1200 [cm]
f - deflection of the geometrical imperfection f = 1,5 [cm]

Table 1.
Results obtained with the approximate method

	T17 Sleeper	Frame sleeper
P_{cr} ballast shoulder 35 cm [daN/cm^2]	696.959 $(q = 5{,}6\ [daN/cm])$	1.224.960 $(q = 10\ [daN/cm])$
P_{cr} ballast shoulder 60 cm [daN/cm^2]	-	1.704.960 $(q = 14\ [daN/cm])$

The energetic method:

$$Pcr = K_1 \cdot \frac{EI}{l^2} + K_2 \cdot q_0 \frac{l^2}{f} + K_3 C l^2 + \frac{2r}{a} \qquad (3)$$

where:
K1, K2, K3 - geometrical imperfection constants
For the studied case, imperfection type E:
K_1 = 9,867
K_2 = 0,129
K_3 = 0,101
C - ballast bed coefficient [daN/cm^2]

Table 2.
Elements used in the critical force calculus, from the real diagram

	T17 Sleeper	Frame sleeper	
	ballast shoulder 35 [cm]	ballast shoulder 35 [cm]	ballast shoulder 60 [cm]
q_o [daN/cm]	3,00	1,80	2,00
q [daN/cm]	5,60	10,00	14,00
C [daN/cm^2]	2,60	5,54	18,46

Table 3.
Results obtained with the energetic method

	T17 Sleeper	Frame sleeper
P_{cr} ballast shoulder 35 cm [daN/cm^2]	774.424	1.054.033
P_{cr} ballast shoulder 60 cm [daN/cm^2]	-	2.957.486

5. Conclusions

Using the frame sleeper presented in the paper, the lateral displacement is with 57% higher than the classic T17 sleeper in the same conditions, considering the lateral resistance of the ballast bed constant. In the situation when the real diagram of the resistance ballast bed components is used, the critical force is with 73% higher than the T17 classic rail sleeper, in the same conditions.

6. References

[1] http://www.ssl-linz.at/sleeper/rs115.pdf
[2] *K. Riessberger,. Field experience with frame - tie - constructions. Technical University Graz, Austria, 2004, PPT presentation.*
[3] Soft: *HBM: Catman*