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THE IMPACT OF BALLAST DEPTH ON VERTICAL TRACK STABILITY

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Abstract

The main elements of the superstructure of the classical rail track constructions are the rails, sleepers and the ballast bed. The connection of the rails and the sleepers is achieved by an appropriate method of fastening. If the rail track ballast is observed, its main purpose is to elastically and equally transfer the loads caused by the rail vehicles to the plane of the lower structure, to secure the direction and height of the rail track and to dampen the vibrations in the rail track. For the ballast to fulfil the mentioned requirements, it must have sufficient dimensions (width and thickness) and must be made out of good quality material. This paper considers impact of the ballast thickness on the vertical stability of the rail track. The measurements of track displacement were performed on the Croatian Railways network (location: Skrljevo – Meja – Pecine). This section is in a cut with longitudinal slope of 22 ‰ and thickness of the ballast is 15 to 20cm. During the year 2005 the wooden sleepers were replaced with the concrete sleepers. Two years after the replacement, new sleepers sunk due to further crushing of the ballast. Due to subsequent crushing, the crushed stones lost their sharp edged form, which in turn led to reduction of mutual wedging of the granules, which finally led to settlement of the sleepers.

1 Introduction

The main elements of the superstructure of the classical rail track constructions are the rails, sleepers and the ballast bed. The connection of the rails and the sleepers is achieved by an appropriate method of fastening. Fig. 1 shows the longitudinal cross-section of the classical rail track construction, [1]. If the rail track ballast is observed, its main purpose is to elastically and equally transfer the loads caused by the rail vehicles to the plane of the lower structure, to secure the direction and height of the rail track and to dampen the vibrations in the rail track. For the ballast to fulfil the said requirements, it must have sufficient dimensions (width and thickness) and must be made out of good quality material. Best material for the ballast is crushed stone produced out of eruptive rock. The optimal thickness of the ballast is 25 to 30cm measured from the lower part of the sleeper (Fig. 1).

This paper considers impact of the thickness of the ballast on the vertical stability of the rail track. The measurements were performed on the rail network of the Croatian Railways (location: Skrljevo – Meja– Pecine). Mentioned section is in a cut and has longitudinal slope of 22 ‰, thickness of the ballast is between 15 and 20cm. During the year 2005 the wooden sleepers were replaced by the concrete ones. But, after two years from the replacement, the new sleepers sunk due to further crushing of the ballast (Figure 2). Due to subsequent crushing, the crushed stones lost their sharp edged form, which in turn led to reduction of mutual wedging of the granules, which finally led to settlement of the sleepers.

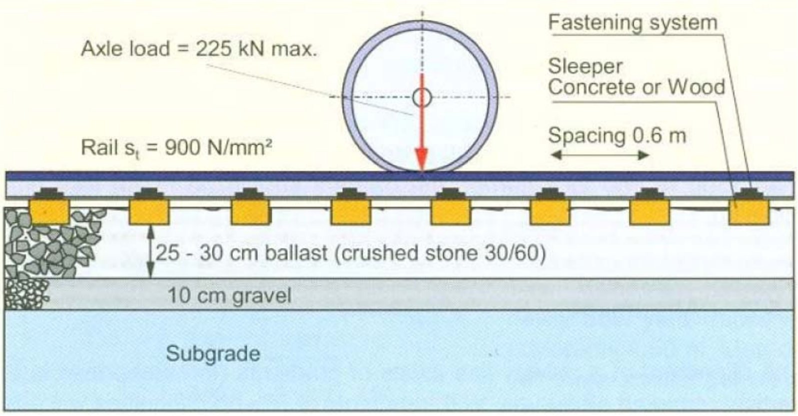

Figure 1 Principle of track structure, longitudinal cross-section

Figure 2 Settlement of the concrete sleepers

2 Experimental Testing and Results

The equipment used to determine the dynamic parameters for this research represents a significant factor upon which depend the basic approach for data collection and their processing. This is one of the basic prerequisites for analysis of the experimental research, to ensure recording and transmission of the data, as an analogue or a digital recording, to the computer “free” of the noise and errors. During the experimental research a lot of effort was made to customise the standard instruments to meet the set requirements. Quite often, original solutions were used both for the data collection phase and for the data processing phase (e.g. the code for transformation of the analogue signals into digital ones, for filtering the data, for the FFT analysis etc.).
In this research, measuring equipment produced by the Finnish company NOPTEL was used as follows. Laser measuring of the dynamic displacements – NOPTEL PSM90. The PSM90 is a device for measuring small dynamic transversal displacements or vibrations of the structures simultaneously in two orthogonal directions. Device is intended to be used for short

distance measurements (up to 100m) and represents an ideal solution for measuring small displacements with great precision. Device is based on a laser transmitter and optic-electronic receiver (Figure 3) that are mounted on the object where the measurements are being made.

Figure 3 Laser transmitter and optic-electronic receiver

The operator directs the laser beam towards the optic-electronic receiver, previously mounted to a certain measuring spot. After transmitting the laser beam to the optic-electronic receiver, the receiver detects the laser beam on the optical screen and measures the optical centre of gravity of the laser beam thus measuring transversal displacements with great precision up to five hundred times in a second. Measuring data is then transmitted to the controller where the calculations of the measuring results and the transfer of analog or digital signal to the computer are being processed [2].

Optic-electronic receiver and laser transmitter are waterproof units, stable and operable between -20 °C and +50 °C. Great environmental resistance, resistance to solar radiation, temperature, fog, rain, snow, can be prescribed to the proper modulation of the laser beam and detection of the laser beam position on the optic-electronic receiver built into the receiver controller. Schematic representation of the installed measuring device NOPTEL PSM90 is described in the figure 4. Figure 5 describes the preparation of the measuring spot on the concrete sleeper prior to installing the optic-electronic receiver PSM90 while the figure 6 describes the measuring equipment mounted to the railway track.

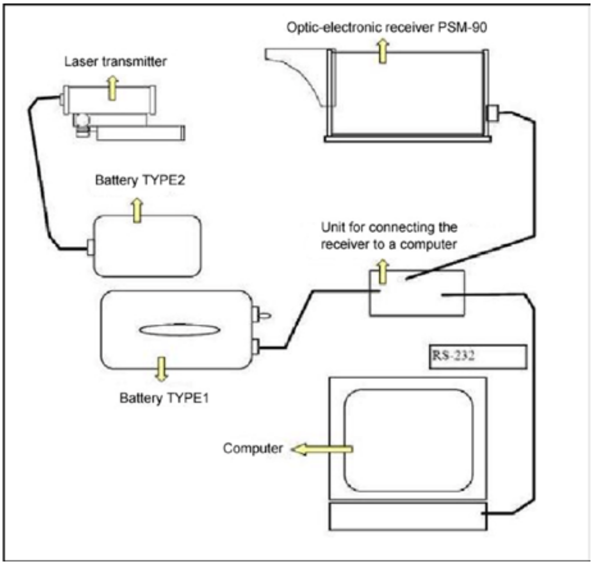

Figure 4 Schematic representation of the measuring equipment

Figure 5 Preparation of the measuring spot

Figure 6 Measuring equipment mounted on the railway track

The measurements data collected in the field require detailed analysis before they can be correctly interpreted and finally compared to the numerical analysis. Further processing of the measurement data is performed using the program packages for post-process analysis of the measured data. For this research our own program has been used, [2], [3], [4] which allows you to:

- load the collected signals and represent them graphically in the time domain
- windowing the signal
- extract noise from the signal
- extract static components from the dynamic record
- acquire clean dynamic data
- execute "fast Fourier's transformations" (FFT)
- display the energy spectre
- define the dynamic coefficient
- define relative damping of the construction

The results of the experimental testing of deformations of the concrete sleepers are shown as a function of deflection over time. Three measurements were made, depending on the track loads: maintenance train (figure 7), freight train (figure 8) and passenger train (figure 9).

Figure 7 Maintenance train (first live load)

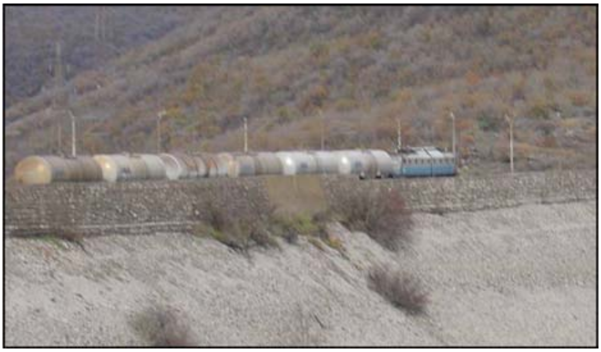

Figure 8 Freight train (second live load)

Figure 9 Passenger train (third live load)

Representation of the results of measured deflections for above listed loads is shown in the Figure 10 to 12. The deflection diagrams show that the range of deformations of the concrete sleepers is from 4.07mm up to 5.94mm, observing the total deflection (sagging) and rising of the sleepers. The mentioned phenomenon reflects very unfavourably on the ride comfort and safety, and for that reason the driving speed along that railway section had to be reduced.

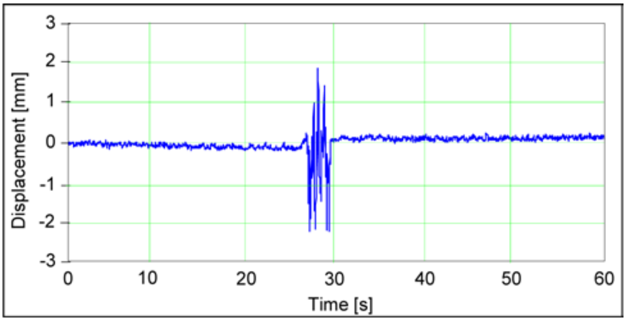

Figure 10 Deflection of the sleeper (maintenance train)

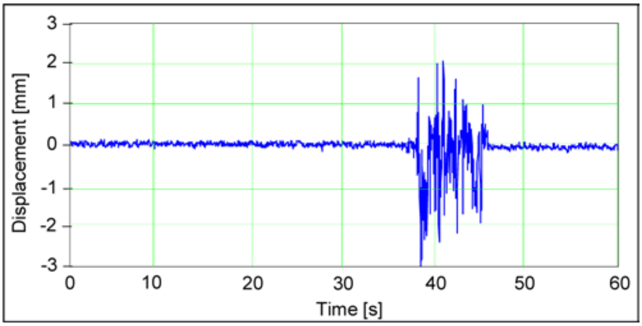

Figure 11 Deflection of the sleeper (freight train)

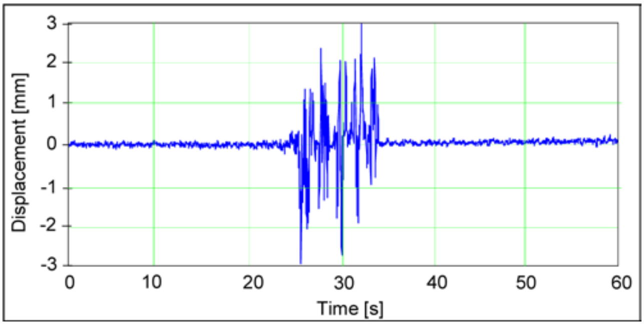

Figure 12 Deflection of the sleeper (passenger train)

The selected testing point can be characterised as a point of a “median” level of degradation, in the sense of the quantity of additionally crushed stone ballast and the surface of the covered ballast, figure 13. On certain sections of the track more severely degraded ballast bed has been spotted, where larger deformations of the railway track are to be expected, figure 14.

Figure 13 “Median” level of ballast degradation

Figure 14 “Severe” ballast degradation

3 Conclusion

Fitting the concrete sleepers to the ballast of small thickness, resulted in additional crushing of the material. If the concrete sleepers were to be kept on the rail track and crushing of the material avoided, the solution might be rising the level of the track for approximately 10cm or fitting the concrete sleepers with an elastomeric pad. The Croatian Railways (Skrljevo – Meja – Pecine) decided to replace the concrete sleepers with the wooden ones on the mentioned section, without enlarging the height of the ballast. The solution with the wooden sleepers proved to be the correct one since the wood is softer material that does not act as the “upper jaw” of a crusher on the thin (shallow) ballast, laying on the solid rock bed.

References

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