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# Acoustical properties of alternative sleepers: experimental testing

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**ABSTRACT**

*ProRail, the Dutch infrastructure manager , started a project to test alternative, sustainable, sleepers. A test setup was achieved along the line from Zwolle to Heino in the Netherlands, where six test sections were constructed. Two reference sections with standard concrete sleepers and four sections with alternative sleepers. For one day we performed simultaneous sound pass-by measurements at the six test sections. In addition, we measured the rail roughness and the track decay rate of each test section. The results clearly show that an alternative sleeper influences the track decay rate of the track. This difference in track decay rate leads to different pass-by sound levels. This paper shows the results of the experiments.*

## 1. INTRODUCTION

ProRail, the Dutch infrastructure manager, started a project to test, alternative, sustainable sleepers. Therefore, a test set up was achieved with six test sections next to each other. The goal of the research is to gain insight in the performance of the alternative sleepers in comparison with the standard concrete sleepers with respect to $CO_2$-emission, vibrations and sound emission.

The goal of the current research is to determine the effect of the sleeper on the rolling noise. Therefore, pass-by measurements are performed simultaneously at all test sections. In addition, we measured the rail roughness and the track decay rate at each test section.

## 3. TEST LOCATION

The test location is situated in the northeastern part of the Netherlands. The location has a single track, with trains running in both directions. The location consists of six test sections: two reference sections and four sections with the alternative sleepers. The reference sections consist of the standard concrete sleepers. The four other sections consist of alternative sleepers with different materials and/or different geometry. Each test section has a length of 100 meters. Pictures of the alternative sleepers are shown in figure 1.

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Figure 1: The alternative sleepers under testing

# 4 TRACK PROPERTIES

## 4.1. Rail roughness

At each section the rail roughness was measured according to the method in EN 15610 [1]. The resulting rail roughness spectra are shown in the figure below. As a reference, also the Dutch average rail roughness [4] is depicted. The results reveal small differences in rail roughness levels between the various sections.

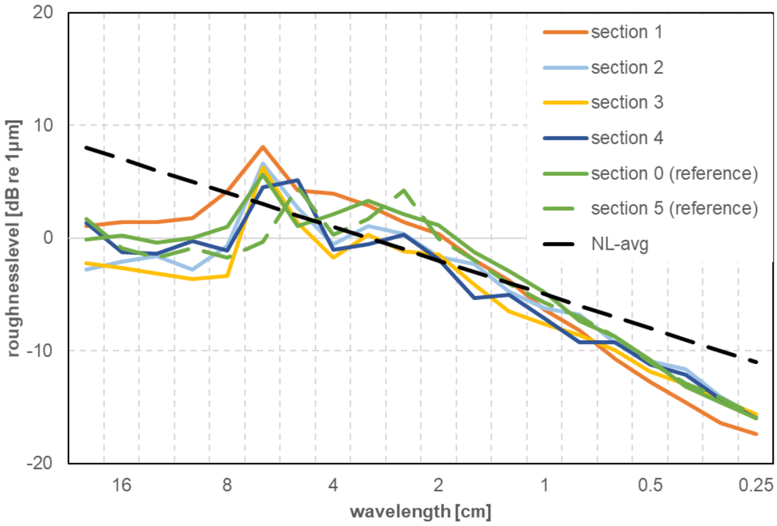


Figure 2: Rail roughness levels of the six sections. As a reference also the Dutch average rail roughness ('NL-avg') is depicted

The results of the sound measurements will be corrected for the difference in roughness levels between the section according to the procedure in the Dutch calculation scheme. There is a direct spectral relationship between the combined wheel and rail roughness on one hand and the change in noise emission on the other hand.

$$\Delta L_{p,i} = (L_{r,\text{track},i} \oplus L_{r,\text{vehicle},i}) - (L_{r,\text{track,average},i} \oplus L_{r,\text{vehicle},i}), \tag{1}$$

with $\Delta L_p$ as the noise emission change between test track and average track, $L_{r,\text{vehicle}}$ as the wheel roughness level, $L_{r,\text{track}}$ as the rail roughness level, $\oplus$ denoting energetic summation, and $i$ denoting a certain frequency band. Since roughness is usually known as a function of wavelength $\lambda$ and noise level difference is expressed as a function of frequency $f$ , a spectral transformation $f_i = v/\lambda$ is made, which depends on vehicle speed v . In this case the $L_{r,\text{track,average}}$ is the Dutch average roughness. The assumed wheel roughness is taken from the national noise impact calculation method.

### 4.2. Track decay rate

For each test section we determined the track decay rate in vertical and transversal direction according to EN 15461+A1:2011 [2]. The track decay rate was measured on both rails and the results were averaged arithmetically. The figures below depict the track decay rate in vertical and lateral direction for each section. The results for section 0 and section 5 are averaged, labelled as reference. Also depicted is the limit curve from the ISO 3095 standard [3].

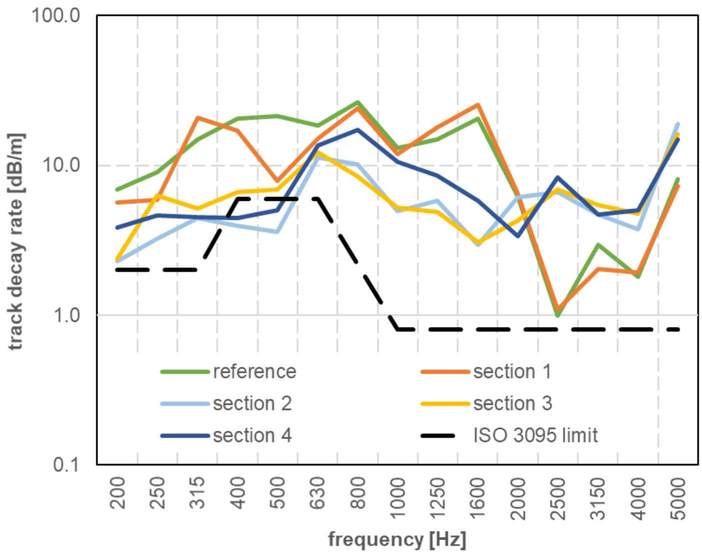


Figure 3: Track decay rate in vertical direction for the alternative sleepers

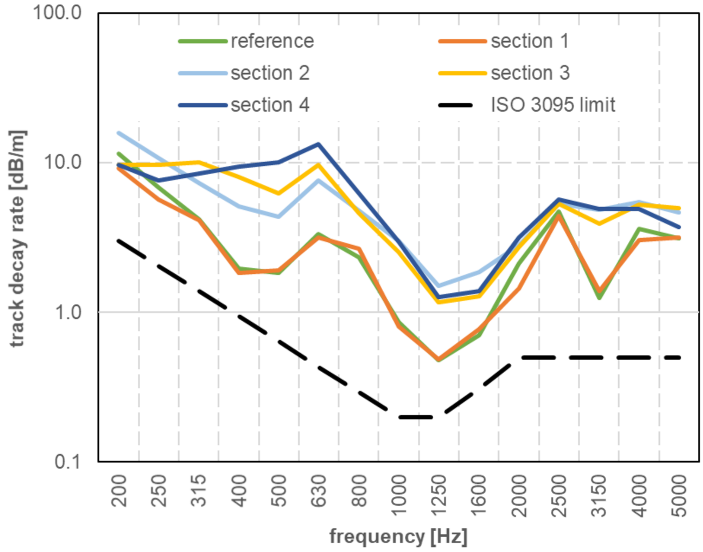


Figure 4: Track decay rate in lateral direction for the alternative sleepers

In general, we can conclude that all sections are well damped as the track decay rate is above the ISO limit values for almost all sections. Only sections 2 and 4 have a track decay rate below the limit value in vertical direction for 400 and 500 Hz.

However, the results also show clear differences in track decay rates for the various sleeper types in both directions. The track decay rate for section 1 is almost equal to the track decay rate of the reference. For sections 2 to 4 the track decay rate in vertical direction is lower than the track decay rate of the reference except for the higher frequencies. On the other hand, in lateral direction, we observe that the track decay rate of section 2 to 4 is higher than the track decay rate of the reference for the whole frequency range.

## 5. SOUND MEASUREMENTS

### 5.1. Test setup

We performed pass-by measurements to determine the noise reduction of the alternative sleepers. Microphones were placed at 5m from the center of the track at a height of 1.2m. During each pass-by we recorded the A-weighted sound level in third octave bands, the vehicle speed, the vehicle type and the number of cars. A total of eleven pass-bys of passenger trains were recorded. The trains drove in both directions with measured speeds between 123 and 135 km/h. Information about the pass bys is given in table 1. An example of the sound level during the pass-by at all six sections is shown in figure 5.

Table 1: Number of train types during the measurements

| | **direction north** | **direction south** |
|---|---|---|
| FLIRT 3 | 2 | 3 |
| FLIRT 4 | 3 | 3 |
| total | 5 | 6 |

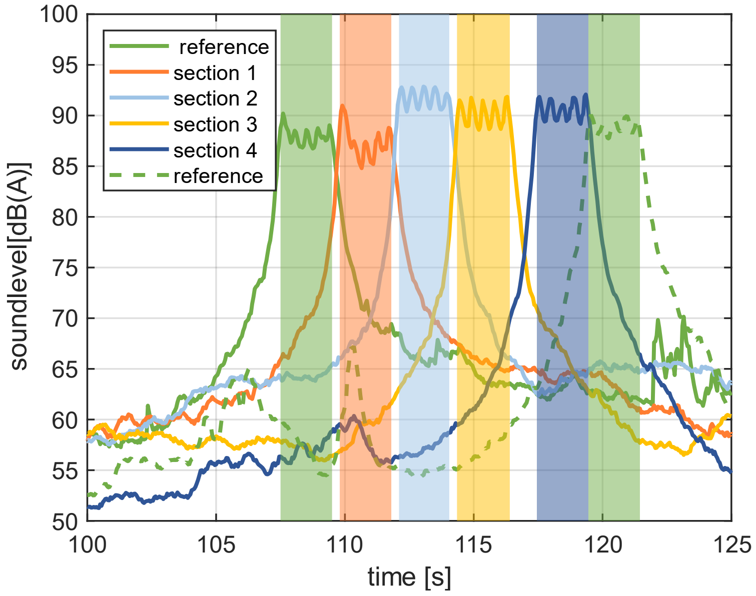


Figure 5: Sound level during a pass-by at the sections. The areas indicate the time that the train was in front of the microphone.

### 5.2 Analysis

We calculate the equivalent sound level over the time that the train is in front of the microphone. Per train pass-by, this results in an equivalent sound level, both in third octave levels and total sound level, together with the vehicle speed for each test section. The results are corrected for the differences in rail roughness between the sections. The measurement results reveal that section 0 and section 5, the reference sections, yield very similar results. Therefore, these results are averaged. The average results are used as the reference throughout the rest of the analysis.

### 5.3 Results

A typical result is given in the figure below. It shows the resulting sound level and sound spectra during one pass-by. We distinguish clear differences between the sound levels of the various sections, both in overall level as in third octave band levels.

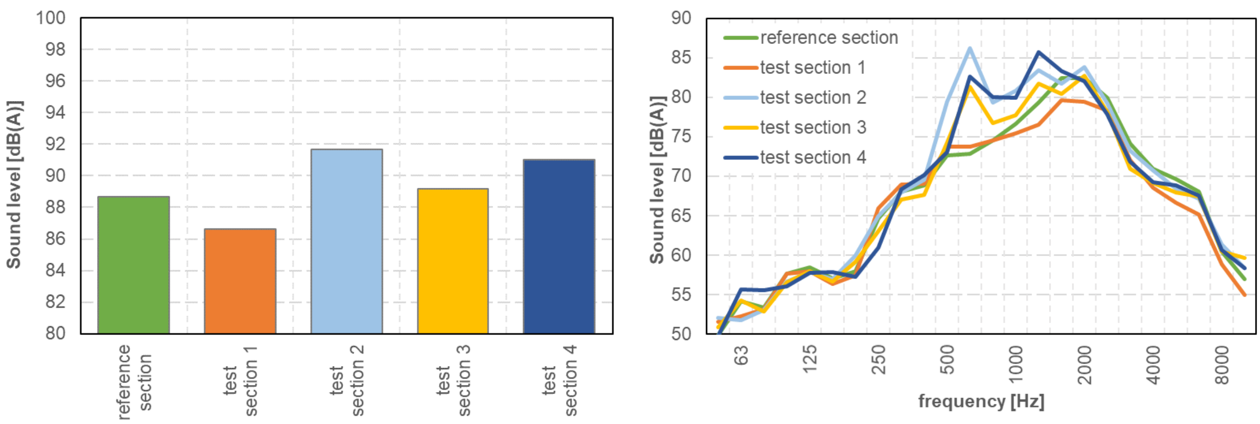


Figure 6: Equivalent sound level during a pass-by at the various sections. The reference section is the average over test section 0 and section 5. Left: overall level. Right: third octave band levels.

Next, the difference in sound level between section 1 to 4 and the reference section for each pass-by is calculated. These differences are then averaged, resulting in the average difference in sound level for section 1 to section 4. These differences are both in overall levels as in third octave band levels. Figure 7 depicts these resulting differences.

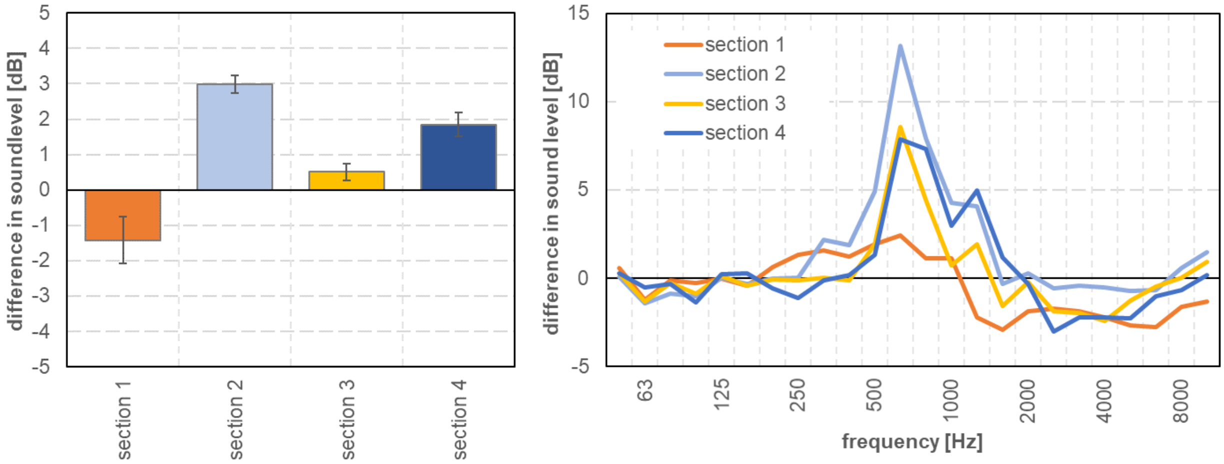


Figure 7: Average difference in sound level for each section. A positive value means an increase of the noise level at the section compared to the reference section. Left: overall level. Right: third octave band levels

The results reveal significant differences in sound level compared to the reference section. The sound level for the sleepers in section 1 is about 1 dB lower than the sound level at the reference section. The difference in sound level between the reference section and section 3 is just above 0 dB. The differences between the sound levels at section 2 and section 4 is clearly higher than the sound level at the reference section, 3 and 2 dB respectively. In third octave band levels, the main differences between the test sections occur between 500 to 1600 Hz. We observe differences up to 13 dB for section 2.

## 6. EVALUATION OF RESULTS

The results of the sound measurements clearly show differences in measured sound levels for the various test sections. These results roughly occur in the frequency range of 500 to 1600 Hz. This is in line with the difference between concrete and wooden sleepers as used in the Dutch noise calculation scheme. In the Dutch noise calculation scheme the main differences in sound level are in the 500 and 1000 Hz octave band.

We observe clear differences for the track decay rates of section 2 to 4 in comparison with the reference section: the track decay rate in vertical direction is lower than the reference section for the alternative sleepers and the track decay rate in lateral direction is higher than the reference section for the alternative sleepers. The sound level for all three sections is higher than the sound level at the reference section. This implies that the track decay rate in vertical direction is of more interest for the rolling noise than the track decay rate in lateral direction.

## 7. CONCLUSIONS

This paper has given an overview of the results of the pass-by testing of four sections with alternative sleepers. The results show that the sleepers have a clear influence on the sound levels and on the track decay rate. On overall level we measure differences up to 5 dB between the various test sections. On section 1 the average sound level is 1 to 2 dB lower than the sound level on the reference. For the other test sections the average sound level is 0 to 3 dB higher than the sound level on the reference. The main differences in third octave bands are found in the frequency range from 500 to 1600 Hz with a maximum difference of around 13 dB for one particular sleeper type.

The results of the track decay rate reveal that for three of the four alternative sleepers, the track decay rate in vertical direction is lower than the track decay rate of the reference. On the other hand, the track decay rate in lateral direction is higher than the track decay rate in lateral direction of the reference. This implies that the track decay rate in vertical direction is more significant than the track decay rate in lateral direction.

## 8. REFERENCES


1. EN 15160: Railway applications - Acoustics - Rail and wheel roughness measurement related to noise generation, 2019.
2. EN 15461:Railway applications - Noise emission - Characterisation of the dynamic properties of track sections for pass by noise measurements, 2010.
3. ISO 3095: Acoustics - Railway applications - Measurement of noise emitted by railbound vehicles, 2013.
4. Bijlage IV behorende bij hoofdstuk 4 van het Reken- en Meetvoorschrift geluid 2012.