Acoustic energy propagation around railways

Petra Cizkova

1CTU in Prague, Faculty of Civil Engineering, Thakurova 7, Praha 6, 166 29, Czech Republic

E-mail: petra.cizkova@fsv.cvut.cz

Abstract. The article deals with the issues of acoustic energy propagation around railways. The research subject was noise emission spreading into the surroundings during the passage of trains over a directly travelled steel bridge construction. Noise emissions were measured using direct measurements in the field. The measurements were performed in two measurement profiles. The noise exposures $A_{LAE}$ measured near the steel bridge construction were compared against the noise exposures $A_{LAE}$ captured on an open track. From the difference of these data, the noise level of the steel bridge structure was determined. Part of the research was to evaluate the effect of the reconstruction of the railway track superstructure on the acoustic situation in the given section of the railway track. The article describes the methodology of measurements, including the processing and evaluation of measured data. The article points out the noise levels of the steel bridge construction and assesses changes in the acoustic situation after the reconstruction.

1. Introduction

This article addresses the propagation of acoustic energy in the surroundings of an open railway track compared to an area around a steel bridge construction. It is generally assumed that noise emissions arising on a trafficked bridge construction will reach higher values than on a classic track section. This, in particular, refers to steel railway bridges, which represent a relatively frequently designed structural type.

Foreign literature sources state that the increment in the sound pressure level $A$ on steel bridge constructions with directly trafficked bridge decks with bridge sleepers ranges from $+3$ to $+16$ dB [1]. Thus, in acoustic terms, bridge constructions represent a major local source of noise on the railway track. There are two main causes of the growth in noise emissions. The first cause are vibrations of the bridge construction, which successively emits noise, caused by the passage of a train unit. The second cause is the noise emitted by the rail itself. Its intensity relies, among others, on the rail fastening method used on the bridge. [2, 3, 4] In this study, the investigated subjects are a railway bridge and its adjoining straight track section. The whole studied section is 468 m in length. The difference in elevation is 1 m (a gradient of 2 ‰).

2. Solved territory

The solved territory is situated near the settlement of Sány in the Nymburk District. The territory is crossed by a single-rail railway track No. 505A Chocen – Týniště n. O. – Velký Osek. The track incorporates a steel railway bridge structure across the Cidlina River. The load-bearing part of the bridge is a welded steel truss construction with a trough bridge deck. The trough bridge deck consists
of cross girders, longitudinal girders and a steel plate. The cross girders and longitudinal girders are welded plate girders. Rigid rocker bearings are mounted on concrete support O01 in the direction of Velký Osek, while expansion roller bearings are used on support O02 in the direction of Chlumec nad Cidlinou (Figure 1). The project included the measurement of sound pressure levels before and after the railway track reconstruction. Figure 2 shows the passage of a freight train unit across the steel bridge construction. [5]

![Application of bearings on the bridge.](image1)

Figure 1. Application of bearings on the bridge.

![Track section.](image2)

Figure 2. Track section.

3. State before and after reconstruction
In spring 2015, the reconstruction of the railway track superstructure was carried out. Within the reconstruction, the ballast graded 32/63 was completely cleaned, the R 65 jointed flat-bottom rail with visible corrugation (Figure 3) was replaced with a new jointless flat-bottom rail 60E2 (Figure 4) along the whole length of the solved territory.
SB6 concrete sleepers with ribbed baseplates and ŽS4 rigid clips were replaced with B91S concrete sleepers with W14 elastic baseplateless fastening on the straight track section. Before the reconstruction, the rail was jointed, and after the reconstruction, it was fitted as jointless.

A transition section, 17.5 m in length, is inserted between the adjoining track section and the closing wall of the bridge construction. The track skeleton construction before the reconstruction consisted of two wooden sleepers with the K type rail fastening and the R 65 flat-bottom rail (Figure 5). During the reconstruction, the rail was replaced and the Skl 24 elastic clip on a ribbed baseplate was newly used (Figure 6).

The load-bearing part of the railway bridge, 48 m in length, is composed of a welded steel truss construction with a trough bridge deck. During the reconstruction, the R 65 jointed rail was replaced with the 60E2 jointless flat-bottom rail on a ribbed baseplate using the Skl 24 elastic clips instead of the original Skl 12. The flooring of channelled plate was completely replaced (Figures 7 and 9). Part of the superstructure are L-shaped bridge guards (Figure 8).
4. Measurement methodology
After the reconstruction, the railway track No. 505A was put back into service on 1.6.2015. Technical measurement pursuant to ČSN EN ISO 3095 Railway Applications – Acoustics – Measurement of Noise Emitted by Wheeled Vehicles [6] was carried out on the railway track before and after its reconstruction. The measurement was aimed at finding out the effect of the reconstruction on the sound situation in the surroundings of the bridge construction and, at the same time, identifying the value of the noise emission increase due to the steel bridge construction. The measurement was performed simultaneously at two measurement points. The position of the points before the reconstruction corresponded by their location to the position after the reconstruction (Figure 10). The measurement point No. 1 (MP1) was situated in the straight track section on the embankment (stationing of km 3.984). The measuring microphone of the first noise meter was placed 7.5 m from the rail axis, at a height of 1.2 m above the running plane (Figure 11). The measurement point No. 2 (MP2) was situated in the stationing direction, at a level of ¾ of the bridge construction length (km 4.452). The measuring microphone of the second noise meter was placed outside the bridge construction, at a distance of 7.5 m from the rail axis, at a height of 1.2 m above the running plane, i.e. 3.55 m above the terrain level (Figure 12). The measured variables were time-related developments of the equivalent continuous sound pressure level $A_{L_{eq(t)}}$ with reading steps of 1 s.
5. Direct field measurement before reconstruction
The measurement before the reconstruction was performed simultaneously at both measurement points on 11. 6. 2014. A total of 20 passages of train units in both traffic directions were measured. The speed of train passage during the crossing was measured. The climatic conditions at the time of measurement complied with the requirements of the ČSN EN ISO 3095 standard [6]. The expanded combined measurement uncertainty was identified according to the procedure described in the document METHODOLOGICAL INSTRUCTION for the measurement and evaluation of noise in non-working environments [7]. For this type of measurement, the expanded combined measurement uncertainty according to the above document reaches a value of ± 2dB [7].

6. Direct field measurement after reconstruction
On 23.10.2015, a total of 15 passages of train units in both traffic directions was measured. The speed of train passage during the crossing was measured. The climatic conditions at the time of measurement complied with the requirements of the ČSN EN ISO 3095 standard. The expanded combined measurement uncertainty was identified according to the procedure described in the document METHODOLOGICAL INSTRUCTION for the measurement and evaluation of noise in non-working environments [7]. For this type of measurement, the expanded combined measurement uncertainty according to the above document reaches a value of ± 2dB [7].

7. Processing of measured data
The measured data were processed using the B&K Type 7820 Evaluator programme. Individual passages of train units were evaluated by selecting the time development sections in which the equivalent continuous sound pressure level of the noise (emitted by the monitored train unit) had exceeded the value \( L_{Aeq(t)} \geq 60 \) dB. This criterion was chosen based on a sufficient distance from the residual sound recorded during the measurement. To compare the noise emissions arising by the passage of a train unit along the straight track section on the embankment (MP1) and across the bridge construction (MP2) noise exposures \( A L_{AE} \) were generated in the Evaluator programme.

8. Evaluation of results
To gain a more accurate informative value the noise exposures \( A L_{AE} \) of individual passages were standardized according to velocity and the number of rail cars. The reference values for velocities and the number of rail cars were identified separately for each type of train. The units were divided into fast trains, freight trains and expresses.

Table 1 below displays the increments in the sound pressure levels on the bridge construction against the adjoining section for the situation before and after the reconstruction.
Table 1. Comparison of $L_{AE,\text{norm}}$ at measurement points MP1 and MP2 before and after reconstruction.

|                  | $L_{AE,\text{norm}}$ [dB] before reconstruction | $L_{AE,\text{norm}}$ [dB] after reconstruction |
|------------------|-----------------------------------------------|-----------------------------------------------|
|                  | MP1               | MP2               | MP2 - MP1 | MP1               | MP2               | MP2 - MP1 |
| All trains       | 109.9         | 116.9           | 7.0       | 98.0             | 112.1           | 14.1     |
| Fast trains      | 110.5         | 116.5           | 6.0       | 96.4             | 110.6           | 14.2     |
| Freight trains   | 113.7         | 121.8           | 8.1       | 103.7            | 117.8           | 14.1     |
| Expresses        | 101.2         | 108.3           | 7.1       | 93.0             | 105.3           | 12.3     |

The growth in the level LAE, norm in the bridge construction area is in a range of 6 - 8 dB before the reconstruction and 12 – 14 dB after the reconstruction. At measurement point MP1 – on an open track, the reconstruction resulted in a significantly higher sound pressure level attenuation than at measurement point MP2 – around the bridge construction (Table 2). The higher sound pressure level increment on the bridge construction after the reconstruction could have been due to e.g. the replacement of a jointed rail with a jointless one. The bridge construction was fitted with a jointless rail before the reconstruction as well.

Table 2. Reduced sound pressure levels at measurement points MB1 and MB2 due to reconstruction.

|                  | $L_{AE,\text{norm}}$ [dB] |
|------------------|---------------------------|
|                  | MP1 | MP2 |
| All trains       | 11.9 | 4.8 |
| Fast trains      | 14.1 | 5.9 |
| Freight trains   | 10.0 | 4.0 |
| Expresses        | 8.2  | 3.0 |

9. Conclusion
Foreign literature states that the increment in the sound pressure level A on steel bridge constructions with directly trafficked bridge decks with bridge sleepers ranges from +3 to +16 dB [1]. The carried out sound measurement revealed a growth in noise emissions on the bridge construction against a track section ranging between 6 - 8 dB before the reconstruction and 12 – 14 dB after the reconstruction. The above reconstruction reduced the sound pressure levels at MP1 – on a straight track section by 8 – 14 dB against MP2 – around the bridge construction where the attenuation only accounted for 3 to 6 dB. The completed reconstruction had a positive effect particularly on the straight track section where a significant sound pressure level attenuation was recorded. The attenuation at MP1 after the reconstruction could be caused by the replacement of a corrugated flat-bottom rail with a new rail. A steel bridge construction is an element on the railway track very noisy on its own, for this reason, the rail replacement was not manifested by such a significant reduction in the sound pressure levels as on a straight track. The conclusion drawn from the obtained data is the need to focus on potential applications of noise attenuating elements directly in the steel bridge construction.

Acknowledgements
Research reported in this paper was supported by Competence Centres program of Technology Agency of the Czech Republic (TA CR), project Centre for Effective and Sustainable Transport Infrastructure (no. TE01020168).
References
[1] Thompson D 2009 *Railway Noise and Vibration* (Oxford: Elsevier)
[2] Poisson F and Margiocchi F 2006 The use of dynamic dampers on the rail to reduce the noise of steel railway bridges *Journal of Sound and Vibration* **293** pp 944-52
[3] Alten K and Flesch R 2012 Finite element simulation prior to reconstruction of a steel railway bridge to reduce structure-borne noise *Engineering Structures* **35** pp 83-88
[4] Bonnett C F 2005 *Practical railway engineering* (London: Imperial College Press)
[5] Pliková E 2014 *Measurement of sound pressure levels in the surroundings of a bridge structure* (Czech Technical University in Prague, Faculty of Civil Engineering)
[6] Úřad pro normalizaci, metrologii a státní zkušebnictví 2014 *Akustika - Železniční aplikace - Měření hluku vyzařovaného kolejovými vozidly* / Acoustics - Railway applications - Measurement of noise emitted by railbound vehicles/ (ČSN EN ISO 3095)
[7] Ministry of Health and Main Health Officer of The Czech Republic 2005 *Metodický návod pro měření a hodnocení hluku v mimopracovním prostředí* /Methodological instruction for the Measurement and Evaluation of Noise in Non-Working Environments/ (HEM-300-11.12.01-34065)