Railway Plate Girder Bridges as a Source of Noise: Examples Selected

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Abstract. This paper presents the results of research of noise in the surrounding of three plate girder railway bridges of different type of deck structure. One of the objects has a track fixed directly to steel plate of the deck, next object has a deck in form of an open grid. The last of the objects is a bridge, where the track was laid on ballast. Sources of noise in these bridges were identified. Reasons for an increase of noise when a train crosses the bridges can be generally divided into two groups: a) vibrations coming from wheels transmitted through rails to a bridge structure, make its components vibrate; structure elements with large surface may act as membranes of a loudspeaker and emit unwanted sounds; b) in bridges with an open deck the lack of insulation makes the sounds at point-to-point contact of wheels with rails disseminate. The biggest threat to the environment from the noise emission point of view is caused by steel bridges with an open deck and with a steel deck with no ballast. The noise next to the track beyond the bridge depends mostly on the type of train, its speed and wheels condition. The noise under the bridge was almost 15 dB higher than the noise nearby the track beyond the bridge. The level of noise next to the bridge was higher 3.3 to 10 dB. Nowadays, the analysis of railway bridges for the emission of sounds should be the standard element in the process of preparation and design of investment projects.

1. Introduction

Railway bridges may affect the environment to much greater extent than railway lines on sections between bridges. This impact may be manifested as the excessive emission of noise which significantly important within agglomeration areas.

The problem of noise generated by railway bridges is referred in EN 1993-2, Euro-code 3 Design of steel structures, Part 2: Steel Bridges [1]. This norm, in a chapter relating to serviceability limit states, recommends limiting the natural frequencies, among others to limit the fatigue damages and to limit the excessive noise emission. In point 7.7 of this norm, relating to railway bridge use criteria, it was written: ‘Any requirements regarding the noise emission should be specified in design objectives’. The problem of noise generated by railway bridges was also mentioned in a document: UIC 717 Recommendations for the design of bridges to satisfy track requirements and reduce noise emissions [2], in which recommendation for the design of structures characterized by small noise emission were given.

The increase in noise level depends on the type of bridge structure and reaches as much as 15 dB. The biggest threat for the environment is posed by objects with no ballast and those without vibroisolation [3]. Objects with ballast may also affect worsening of acoustic climate around the bridge, in particular the objects with orthotropic platform [4, 5]. Also known are examples of contemporary
composite and concrete bridges that emit the excessive noise [6]. Some examples also refer to objects along high-speed line [7].

This paper presents the results of own research of noise in the surrounding of three rail-way bridges of different type of platform structure. One of the objects has a track affixed directly to steel plate of the platform, next object has a platform in form of open grid. The last of objects is a bridge, where the track was laid on ballast. Two of objects discussed pose a threat to environment.

2. Method of research
In order to establish an impact of bridge objects on noise, simultaneous measurements from a distance of 7.5 m from the axis of track at the bridge were conducted, and at the same distance from the track on a track section beyond the bridge (usually 50 to 75 meters before or after the bridge). In both cases, microphones were placed 1.5 m above the head of rail. At the same time, noise was measured additionally under the bridge, 1.5 m above the ground.

The acoustic phenomenon was registered during the passage of passenger trains, including long-distance trains, regional trains and railbuses (light suburban), as well as cargo trains. Measurements were conducted at a temperature of 15 – 25 °C and relative humidity of 50 - 70 % and wind speed not exceeding 5 m/sec. Microphones were covered with anti-wind covers. Prior to tests, the test tracks were checked using the reference sound source.

3. Type of bridge structure versus sound level
3.1. A viaduct with a platform in the form of steel plate without ballast
One of the objects analysed was 4-span steel viaduct of 84.4 m and static scheme of continuous beam. Main girders of the viaduct were two plates girder with a web height of 1.38 m. The viaduct deck was made of steel sheet reinforced with stringers and traverses (figure 1). Rails were affixed directly to steel structure. Outside the girders were designed service pathways, also made of steel plates. The object was situated within horizontal arch of small radius equalling 250 m. The truck within the object and outside was jointless. Inspection of the object shown its unsatisfactory condition. The main problem was the lack of vibroisolation between rails and platform (it was completely damaged) and improper track curvature. Next to the viaduct, at a distance of approx. 25 m there was a multi-family residential building, residents of which have claimed the excessive noise.

![Figure 1. A plate girder viaduct with a steel platform and without ballast](image)

The object was designed exclusively for a traffic of cargo trains and unwanted sounds were generated in spite of small speed of passage i.e. 30 km/h. Levels of sound recorded during three passages were presented in Table 1. The noise beside the viaduct reached 89 dB (A) and was higher by over 15dB than the noise nearby the track beyond the viaduct. The noise under the viaduct was even higher by approx. 18 dB than the noise beside the track.
Table 1. Results of measurements of sound level in the surrounding of a viaduct with steel platform and with no ballast

| No. | Type of train | Speed [km/h] | A sound level in [dB]: | Sound level difference in [dB]: |
|-----|---------------|--------------|------------------------|-----------------------------|
|     |               |              | beside the track (1)   | beside the viaduct (2)       | under the viaduct (3)       | (2) – (1) | (3) – (1) |
| 1   | cargo train   | 30           | 69.1                   | 84.7                        | 85.7                        | 15.6      | 16.6      |
| 2   | cargo train   | 20           | 72.7                   | 88.4                        | 88.9                        | 15.7      | 16.2      |
| 3   | cargo train   | 20           | 65.5                   | 82.2                        | 83.6                        | 16.7      | 18.1      |

The reason of noise increase beside the viaduct was the excessive vibrations of steel plates of the structure (plates of platform, pathways, girders) resulting in emission of sounds mainly within the range of low frequencies - this problem is discussed in details in the study [4]. The level of sound beside the track was greatly affected by sounds generated at point-to-point contact of wheels with a rails and loud operation of railway cars’ connectors.

3.2. A plate girder bridge with open platform
The object under analysis was one-span plate girder bridge, with free-supported beam and stringer-traverse grid, i.e. the so-called open deck (figure 2). The span length is 24.15 m. Rails were affixed to wooden bridge sleepers using PM-60 pads and PKW-type spacers. Bridge sleepers were supported on stringers. The object technical condition during the test was good.

![Figure 2. A plate girder viaduct with an open platform.](image)

The acoustic phenomenon was registered during passages of cargo and passenger trains - selected results of measurements are presented in table 2.

The noise beside the bridge was higher by 3.3 to 10.1 dB than the noise beside the track beyond the bridge. The noise under the bridge was even higher by approx. 20 dB than the noise beside the track. In few instances the noise under the bridge exceeded 100 dB. The main reason of such big noise was the type of structure. The open platform is not a barrier for sounds generated at point-to-point contact of wheels with rails. In addition, vibrations of plate girder’s web emit sounds within the range of low and medium frequencies. These matters were discussed in details in [8].
Table 2. Results of measurements of sound level in the surrounding of plate girder bridge with an open platform

| No. | Type of train          | Speed [km/h] | A sound level in [dB]: | Sound level difference in [dB]: |
|-----|------------------------|--------------|------------------------|--------------------------------|
|     |                        |              | beside the track (1)   | beside the bridge (2)          | under the bridge (3) | (2) – (1) | (3) – (1) |
| 1   | passenger train (traction unit) | 50           | 80.3                   | 83.8                           | 96.2               | 3.5       | 15.9      |
| 2   | passenger train (long-distance) | 60           | 83.8                   | 87.4                           | 99.9               | 3.6       | 16.1      |
| 3   | passenger train (light suburban) | 50           | 74.8                   | 78.1                           | 90.5               | 3.3       | 15.7      |
| 4   | passenger train (long-distance) | 70           | 84.7                   | 89.2                           | 102.0              | 4.5       | 17.3      |
| 5   | passenger train (long-distance) | 50           | 77.3                   | 87.4                           | 100.5              | 10.1      | 23.2      |
| 6   | cargo train            | 50           | 84.3                   | 88.9                           | 100.7              | 4.6       | 16.4      |
| 7   | cargo train            | 40           | 79.6                   | 88.6                           | 101.3              | 9.0       | 21.7      |

Due to modernisation works conducted on the railway line along which the object was located, it was not possible to record the acoustic emission during passages at higher speeds then 70 km/h. It is expected that this type of structures at higher speeds will adversely impact the environment to higher extent.

3.3. A plate girder bridge with a track laid on ballast

The example of currently designed objects is a plate girder bridge with steel orthotropic platform and a track laid on ballast (figure 3). The length of span of the bridge under tests is 31.68 m, height of girders 2.47 m. The track was laid on ballast which was situated on ribbed metal plate. The object was in very good technical condition, was open to operation just few months before the test.

![Figure 3. A plate girder bridge with a steel platform and a track laid on ballast](image)

The table 3 presents the results of measurements of sound level made during the passage of passenger and cargo trains. The noise beside the bridge does not differ significantly from the noise beside the track beyond the bridge. In some instances it is even smaller, which results from the fact that sounds generated at point-to-point contact of wheels with rails are damped by plate girders.
Table 3. Results of measurements of sound level in the surrounding of plate girder bridge with a track laid on ballast

| No. | Type of train          | Speed of passage [km/h] | A sound level in [dB] | Sound level difference in [dB]: |
|-----|------------------------|-------------------------|-----------------------|--------------------------------|
|     |                        |                         | beside the track (1)  | besides the bridge (2)         | under the bridge (3) (2) – (1) (3) – (1) |
| 1   | passenger train (regional) | 80                      | 76.9                  | 75.9                           | 84.7                           | -1.0 7.8 |
| 2   | passenger train (regional) | 60                      | 80.8                  | 76.7                           | 85.6                           | -4.1 4.8 |
| 3   | passenger train (suburban) | 80                      | 76.8                  | 75.5                           | 80.8                           | -1.3 4.0 |
| 4   | cargo train            | 35                      | 74.1                  | 73.0                           | 79.8                           | -1.1 5.7 |
| 5   | cargo train            | 50                      | 81.7                  | 81.3                           | 87.4                           | -0.4 5.7 |
| 6   | cargo train            | 40                      | 73.6                  | 74.3                           | 80.9                           | 0.7 7.3 |

The noise under the bridge was higher from 4.0 to 7.8 dB than the noise beside the track - the reason of noise increase under the bridge were excessive vibrations of steel plate of the platform. Since the object analysed was low over the ground, sounds were damped by the ground and did not disseminate. However, it must be noted that this type of structure used on populated areas on high supports may be inconvenient for the environment.

4. Summary and conclusions

Steel bridges constructed many years ago and those designed and constructed at present times may pose a threat to environment. They may contribute to the dissemination of noise generated at point-to-point contact of wheels with rails or independently emit the unwanted sounds.

If one wishes to design the silent bridges, a track should be laid on ballast, whereas it is worth noting that this type of structures may emit noise. If the frequency of excitation of vibrations matches the frequency of own vibrations of large-surface elements of bridge structures, then the emission of air sounds may occur. Since these sounds will occur most often under the structure, objects with a track laid on ballast may present a nuisance if they are situated high above the ground on urbanized areas. Acoustic properties may be improved by using pads or vibroisolation mats.

Objects with open platforms belong to type of structures in which noise is mainly due to free dissemination of sounds generated at point-to-point contact of wheels with rails and as a result of vibrations of large-surface elements e.g. plate web. This type of objects should not be used on urbanized areas. If they are present there, they should be replaced if possible with others, with better acoustic properties. The partial reduction of noise around this type of bridges may be obtained by separating the track from the bridge structure using vibroisolation and application of horizontal sound barriers.

If it is necessary to use a track directly affixed to platform, the emission of noise may be reduced by properly designed vibroisolation. It is also possible to consider the introduction of additional stiffeners to change the frequency of own vibrations of large-surface elements. In some instances, one may consider the possibility of increasing the platform weight or coating of noise emitting elements with material providing additional noise damping properties.

The analysis of railway bridges for the emission of noise should be the element in the process of preparation of investment projects. This recommendation applies not only to newly constructed objects but also to reconstructed and modernised objects. Requirements regarding the emission of noise should be specified by the investor. If the investor fails to define such requirements, the reconstruction or modernisation of railway line will not improve the acoustic climate and may even increase its environmental burden.
References

[1] EN 1993-2: Eurocode 3: Design of steel structures - Part 2: Steel Bridges

[2] UIC 717R. Recommendations for the design of bridges to satisfy track requirements and reduce noise emissions. 2nd edition, 2010.

[3] L. Janas, “The acoustic specificity of steel railway bridges”, Przegląd komunikacyjny, vol. 9, pp. 22–25, 2017 (in Polish).

[4] L. Janas L., W. Łakota, Analysis of the possibilities of noise reduction in the vicinity of the viaduct and the railway line. Drogi i Mosty, nr 2/2005, s. 71-90 (in Polish)

[5] X. Li, D. Yang, G. Chen, Y. Li, X. Zhang: Review of recent progress in studies on noise emanating from rail transit bridges. Journal of Modern Transportation, 2016, Volume 24, Issue 4, pp. 237–250.

[6] Z. G. Li, T. X. Wu: Estimation of vibration power flow to and sound radiation from railway concrete viaduct due to vehicle/track interaction. Noise and Vibration Mitigation for Transport Systems. NNFM 118, 2012, pp. 175-183.

[7] Q. Liu, X. Li, X. Zhang, Z. Zhang: Structure-born noise study of composite steel bridge on high-speed railway. Proceedings of the 9th International Conference on Structural Dynamic, Eurodyn, Porto, Portugal, 2014, pp. 1189-1194.

[8] L. Janas, Vibroacoustic tests of the plate girder bridge. Zeszyty Naukowo-Techniczne Stowarzyszenia Inżynierów i Techników Komunikacji w Krakowie. Seria: Materiały Konferencyjne, 2015, nr 2(106), s. 47-60, (in Polish).