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THE INFLUENCE OF THE BRIDGE STRUCTURAL ARRANGEMENT ON THE DISTRIBUTION OF THE NOISE IMPACT INDUCED BY TRAFFIC

M. Foglar*, J. Göringer**

Abstract: *Many articles and papers about mitigating the impacts of the transport infrastructure on the environment have pointed out that one of the factors influencing the usage of underbridges for mammal migration is the noise induced by traffic. However, this phenomenon has not yet been properly investigated and verified. This paper describes the influence of the structural arrangement of bridges on the noise induced by traffic. The findings come from noise measurements on several structures on the D1 motorway and the R35 expressway in the Czech Republic.*

Keywords: ***bridge, expansion joint, traffic noise, noise measurement***

1. Introduction

Many articles and papers about mitigating the impacts of the transport infrastructure on the environment have pointed out that one of the factors influencing the usage of underbridges for mammal migration is the noise induced by traffic. However, this phenomenon has not yet been properly investigated and verified. To verify this assumption, a noise measurement program was designed and undertaken on highway bridges on selected sections of the D1 motorway and the R35 expressway in the Czech Republic. Simultaneous measurements were made of the noise level and of the use of the bridges for mammal migration. The noise measurements were carried out in summer 2010 and summer 2011. Special attention was paid to the influence of expansion joints and bearings on the noise impact caused by heavy traffic entering the bridge.

The experimental program described here was preceded by a review of the literature on mitigating the impacts of the transport infrastructure on the environment and on the migration of mammals over roads and motorways.

In the following text, a methodology for noise measurement evaluation is established. This is followed by a description of the set-up of the experimental program. Noise measurement results for the studied bridges are presented in the form of equivalent and peak values, and are illustrated by noise frequency distribution diagrams, which lead on to further discussion.

2. The measurements of the traffic noise

2.1 Layout of the noise measurement program

The motivation for the noise measurements can be summarized as follows: to quantify the effect of noise induced by traffic on capacity motorways or expressways on the use of under-bridges as migration profiles. Noise further away from the bridge can completely prevent the animal (mammal) using the underbridge for migration (when passing around the fenced highway), while the noise impulse below the bridge induced by heavy traffic crossing an expansion joint can shock a migrating animal and make it change its originally desired migration route.

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Noise further away from the bridge can be minimized by noise barriers. These are very expensive, and it is questionable what effect they have on the noise impulse below the bridge.

The noise from expansion joints and bearings can be mitigated: by the design of integral bridges (this can be used for total bridge lengths up to 120m), and/or by the design of proper landscaping below and around the bridge. The landscaping can involve e.g. noise-reducing ramparts, vegetation and mainly refraining from designing bridges with little clearance.

For the reasons suggested above, the measurements must be designed in such a way that they produce data both on the noise level in the vicinity of the underbridge and on the impact of the noise below and/or close to the bridge. The arrangement of the noise measurements is explained in Figure 1.

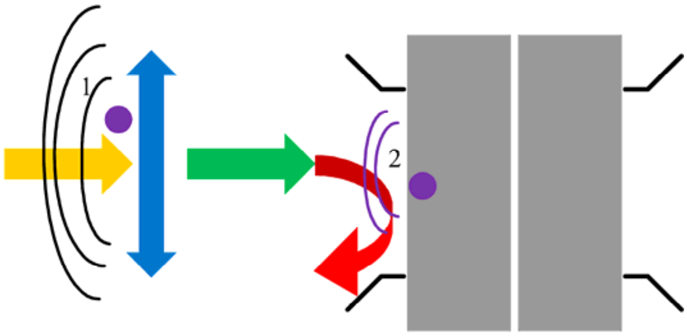

Fig. 1 – The measurement arrangement scheme

As noted in Figure 1, measurement point No. 1 (place of decision on migration) produces the noise level in the vicinity of the underbridge, while measurement point No. 2 (place of impulse noise shock) produces the noise impact below and/or close to the bridge. Two sound meters are used: No. 1 for measuring the equivalent noise level 30-50m from the bridge, where the animal decides whether or not to use the migration route, and No.2 for measuring the noise impact below and/or near the bridge.

The measurements were performed simultaneously at both measurement points, for a period of 30 minutes for each studied bridge.

At measurement point No. 1, only the equivalent noise level was studied, while at measurement point No. 2 both the equivalent noise level and the noise impact were studied.

The LAeq, LCeq and LCpeak values were evaluated at both measurement points. The equivalent continuous levels are indexed by “eq”, and they are evaluated as the mean energy values. The index labelling indicates the weighting filter used for the evaluation, where the values are determined according to Eq. 4. The peak acoustic pressure values were evaluated using the C-weighting filter, which corresponds more to the human perception of noise impulses.

The maximum, minimum and equivalent values were also evaluated for the frequency spectrum from 6.3 Hz to 20 kHz. These measurements were modified by the Z-weighting function for slow and fast time weighting.

2.2 The selection of the bridges for noise measurements

Because the measurements were logistically demanding and time demanding, the structures for the study were selected carefully, taking many considerations into account.

The noise measurements were limited to the newly opened part of the D1 motorway (sections D4704 and D4705) and the connecting expressway R35, so that the results would not be influenced by the effect of material deterioration of the bridges themselves and of their expansion joints, see Figure 2.

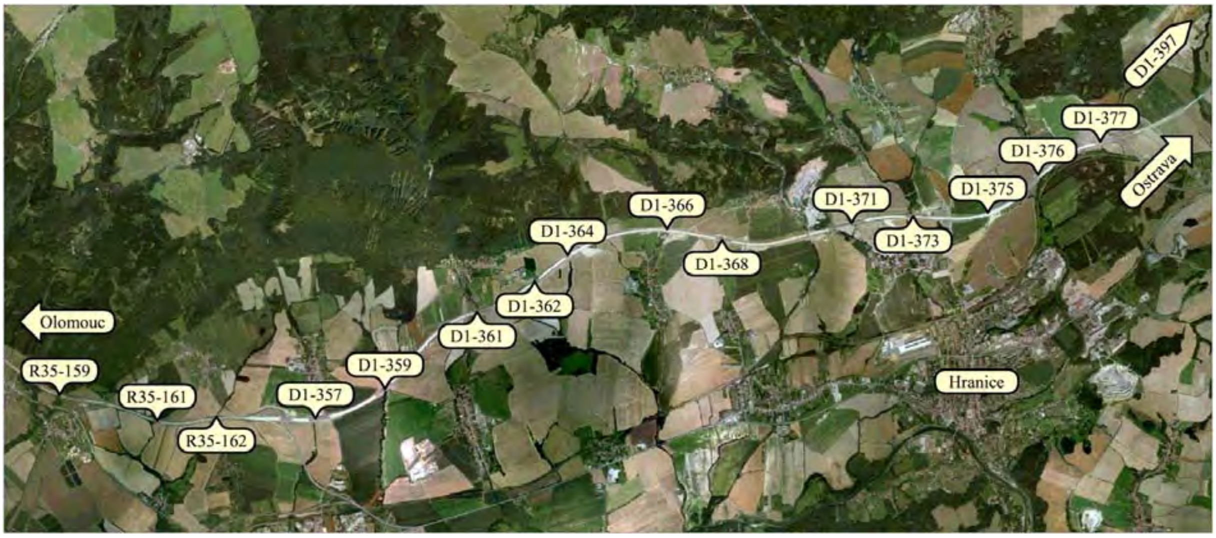

Fig. 2 – Location of the measurement sites

The bridges on the studied section of the motorway were divided into groups (families) according to the length and the number of spans, the position of the bridge (underbridge as a part of the motorway, overbridge crossing the motorway) and the structural arrangement:

• regular span underbridges with spans up to 30m and not more than 4 spans

• long span underbridges with spans longer than 30m and/or more than 4 spans

• buried underbridges

• buried overbridges (ecological tunnels)

All the bridges in all the "bridge families" on the selected motorway section were analyzed according to the following criteria:

• suitability for satisfying migration needs,

• structural system,

• landscaping around the bridge (type of landscape, proximity of other transport infrastructure and buildings, etc.),

• landscaping below the bridge (pavement of the embankments and the surface below the bridge, roads, railroads, watercourse, etc.),

• type of expansion joints,

• noise reduction measures on the bridge or in its vicinity.

As it was not possible to perform measurements on all the bridges in the selected motorway section, the noise measurements were performed on representative structures for the bridge families listed below:

• Regular span bridges

o D1 – 368 (2010)

o D1 – 361 (2010)

o D1 – 364 (2010)

o R35 – 161 (2011)

o R35 – 162 (2011)

o D1 – 357 (2011)

o D1 – 359 (2011)

o D1 – 373 (2011)

- Long span bridges
  - o D1 – 371 (2010)
  - o D1 – 376 (2010)
- Buried bridges
  - o D1 – 362 (2010)
  - o D1 – 366 (2011)
  - o D1 – 375 (2011)
  - o D1 – 377 (2011)
- Tunnels
  - o R35 – 159 (2010)
  - o D1 – 397 (2010)

The name of the bridge consists of the number of the road (D1 or R35) and the number of the bridge along the motorway. The year in which the noise measurement was made is added in brackets.

The following section provides a brief description of the bridges on which the measurements were performed.

2.3 A brief description of the bridges on which the measurements were performed

Ecological tunnel R35-159 is a two-span (14.2+14.2m) buried reinforced concrete structure made using a modular precast system. The structure is located in a 15m-deep cut corresponding to the surrounding landscape. The depth of the backfill enables the growth of trees.

Bridge R35-161 at Bohuslavky is a single span (23.5m) prestressed concrete composite girder, free height 5.2m, elastomeric bearings, asphaltic plug joint and subsurface joint, unpaved surface.

Bridge R35-162 at Bohuslavky is a single-span (26.5m) prestressed concrete composite girder, free height 6.5m, elastomeric bearings, asphaltic plug joint and subsurface joint, unpaved rural road and paved creek.

Bridge D1-357 at Loucka is a two-span (20+22m) prestressed concrete girder, free height 5/7.6m, pot bearings, strip-seal expansion joints, gravel surfacing.

Bridge D1-359 at Loucka is a three-span (27+42+27m) composite steel-concrete two-beam girder, free height 4/8.5m, pot bearings, strip-seal expansion joints, local road, paved creek.

Bridge D1-361 at Podhori is a three-span (15.7+22+17.2m) prestressed concrete girder, free height 7.9m, pot bearings, strip-seal expansion joints, paved surface.

Bridge D1-362 at Podhori is a narrow (8m*5m), quite long (35m) buried steel structure (Tubosider), unpaved rural road.

Bridge D1-364 “Zabnik” at Milenov is a two-span (11+11m) prestressed concrete girder, free height 3.4/1.75m, elastomeric bearings at the abutments, strip-seal expansion joint and subsurface joint, paved surface.

Bridge D1-366 at Milenov is a two-span (10.4+10.4m) buried reinforced concrete structure, free height 4.2m, unpaved surface.

Bridge D1-368 at Hrabuvka is a four-span (28+35+35+28m) prestressed concrete girder, free height 3.5/9m, pot bearings, modular expansion joints, paved surface, gravel surfacing.

Bridge D1-371 at Velka is a twelve-span (30+10*42+30m) prestressed concrete girder, average free height 14.4m, pot bearings, modular expansion joints, unpaved surface.

Bridge D1-373 at Velka is a single-span (34m) prestressed concrete composite girder, free height 3/7.3m, pot bearings, strip-seal expansion joint and subsurface joint, unpaved rural road and paved creek.

Bridge D1-375 at Velka is a four-span (4*9.5m) buried reinforced concrete structure, free height 3.5m, unpaved surface.

Bridge D1-376 at Hranice is a ten-span (25+8*32+25m) prestressed concrete two-beam girder, free height 4.8/8.4m, pot bearings, modular expansion joints, unpaved surface.

Bridge D1-375 at Belotin is a single-span (12m) buried reinforced concrete structure, free height 6.1m, paved surface.

Ecological tunnel D1-397 is a two-span (20+20m) buried reinforced concrete structure. The structure is located in a 9m deep cut corresponding to the surrounding landscape. The depth of the backfill enables growth of bushes.

2.4 Evaluation of the experimental results for the defined families of bridges

Average noise spectrum curves were evaluated from the unmodified maximum equivalent acoustic pressure levels $L_{ZFmax,eq}$, and were compared with a common traffic noise spectrum. These curves may be used for evaluating the noise levels for each bridge family and the effectiveness of the noise reduction measures that are used.

In the case of bridges with a missing expansion gap, or bridges with asphaltic plug joints or buried expansion joints, the traffic noise spectrum is similar to the common traffic noise spectrum, see Figure 3. The gap at the expansion joint causes an increase in noise in frequencies around 400Hz. The effect of noise barriers can be observed at low and medium frequencies.

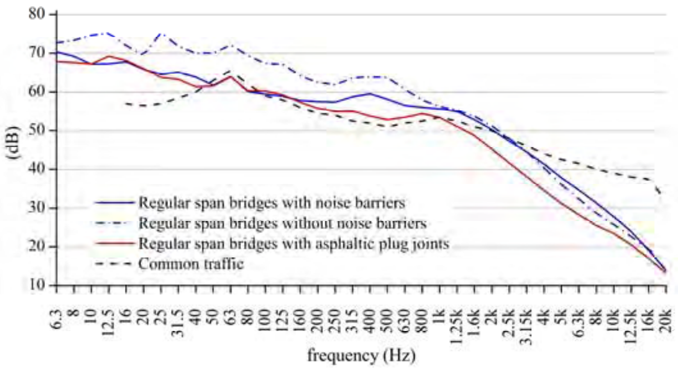

Fig. 3 – Traffic noise frequency distribution for regular span bridges

Long span bridges experience a more favourable noise distribution due to traffic than regular span bridges, see Fig. 4. This can be attributed mainly to the greater distance between the noise source and the ground.

The gap at the expansion joint causes an increase in noise in frequencies around 400Hz, similarly to regular span bridges but with a smaller increase due to the greater height of the bridges.

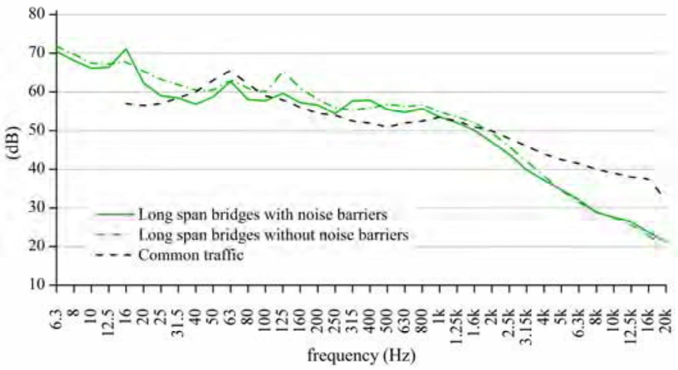

Fig. 4 – Traffic noise frequency distribution for long span bridges

In the case of buried bridges, the traffic noise spectrum is similar to the common traffic noise spectrum, see Figure 5. The decrease in the measured values can also be attributed to the location of measurement point No. 2 at the bottom of the embankment, where the earth dam acts as a noise absorber.

Similarities can be found with bridges without expansion gaps, see regular span bridges.

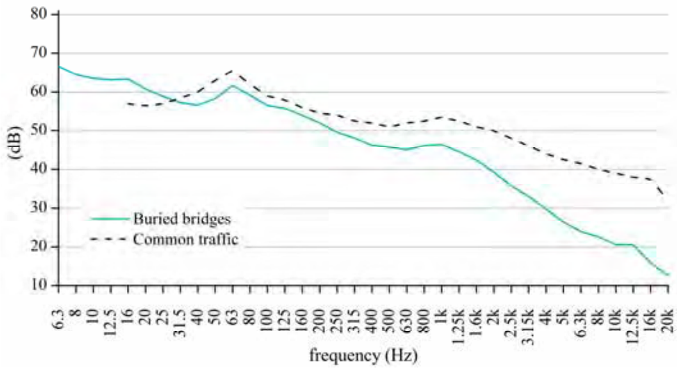

Fig. 5 – Traffic noise frequency distribution for buried bridges

The traffic noise spectrum of tunnels is similar to the common traffic noise spectrum, see Figure 6. The increased noise levels at the portals can be attributed to the interaction of the rebounded noise waves. The noise levels for the crossing mammals are influenced by the presence of noise barriers.

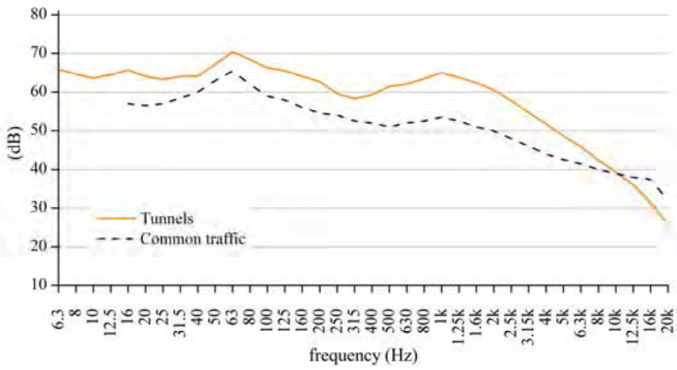

Fig. 6 – Traffic noise frequency distribution for tunnels

Fig. 7 presents the average traffic noise frequency distribution for the different families of bridges, together with the common traffic noise spectrum.

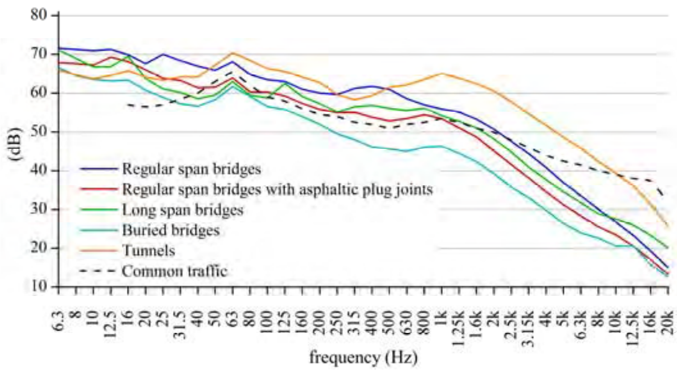

Fig. 7 – The average traffic noise frequency distribution for different families of bridges

2.5 Discussion of the results

The following conclusions can be drawn from the measurement results:

• The noise barriers reduce noise levels further from the bridge, but do not influence the noise levels below the bridge caused by the impact of wheels on the expansion joint and the noise coming from the gap between the two parallel dual carriageway structures.

• The noise levels for bridges with no expansion gap (buried structures, structures with a subsurface of asphaltic plug joints) are lower than for structures with an expansion gap (modular expansion joints, strip seal expansion joints).

• Structures with less free height above the terrain experience higher noise levels than structures with more free height (e.g. bridge R35-162 with free height of 6.5m with asphaltic plug joints experienced lower noise levels than bridge D1-368 with similar free height (6.0 m) but equipped with strip seal expansion joints). This effect is multiplied for structures with an expansion gap.

• Structures with less free height above the terrain and an expansion gap experience greater noise impact than structures with more free height.

• Structures with little free height have a higher traffic noise frequency distribution than bridges with more free height. The bridges with little free height exhibit a sudden increase in noise level at specific frequencies within the low and mid range. Conversely, bridges with free height more than 5m experience a gradual increase at those frequencies. In addition, bridges with little height exhibit greater noise impact in wheel-expansion joint contact frequencies.

• The traffic noise spectrum of buried structures is similar to the common traffic noise spectrum, and differs from the traffic noise frequency distribution of regular and long span bridges.

• Buried bridges of small width experience higher noise levels than buried bridges of greater width. Narrower structures exhibit an increase in maximum acoustic levels up to 10 dB and equivalent acoustic pressure levels up to 5 dB.

• The type of landscaping (pavement, grass, gravel) below the bridge affects the noise levels, e.g. D1-364 (paved) versus D1-373 (unpaved creek bed and unpaved road) with a similar structural arrangement and similar expansion joints. The measured values of LAeq for paved structures are up to 3dB higher, and the peak values are up to 15dB higher.

• The influences listed above combine and influence each other

3. Conclusions

This paper has described noise measurements carried out at bridges on the D1 motorway and the R35 expressway in the Czech Republic. The goals of the measurements were as follows: to quantify the influence of the type of expansion joints that are used and the structural arrangement of the bridges on the noise levels, and to quantify the effect of the structural arrangement on the usage of underbridges for mammal migration.

The lowest noise levels were observed for buried structures.

Long span bridges experienced smaller noise levels than regular span bridges. Structures with less free height above the terrain and an expansion gap experience higher noise impact than structures with more free height.

The noise levels for bridges with no expansion gap (buried structures, structures with a subsurface of asphaltic plug joints) are lower than for structures with an expansion gap (modular expansion joints, strip seal expansion joints). The presence of an expansion gap increases the noise level by up to 12dB.

The measurements show that the most favourable structural arrangement of underbridges for mammal migration are buried bridges and structures without surface expansion joints.

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