Pilot study on noise from expansion joints on highway bridges

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Expansion joints on highways can cause a considerable local noise problem. Therefore expansion joints have to be “low-noise” according to the Austrian guideline for road construction RVS 15.45. Unfortunately, no methodology is available to assess and classify joint constructions with regards to their noise emission. One of the main objectives of the pilot study presented here was the development of a draft measurement methodology. The second objective was to compare 2 different joint types. The study was sponsored by the Austrian motorway and high-speed road company (ÖSAG/Asfinag). As a baseline the methodology of the draft French Standard XP P 98-095 was used and statistical pass-by noise measurements at one site with 2 different constructions (before and after modification) had been carried out. Additionally to the French proposal 5 further microphone positions have been used to get a good feeling on the sound propagation effects in the vicinity of the expansion joint. Finding the right noise criterion was the second task comparing results of A-weighted maximum and sound exposure level. The main conclusion was that it is highly recommended to use a reference microphone and a Microphone under the bridge to be able to evaluate all different effects caused by the expansion joint.

1 Introduction

Main objective of the pilot study [1] presented here was the development of a draft measurement methodology. As a baseline the methodology of the draft French Standard XP P 98-095 [2] was used and statistical pass-by noise measurements at one site with 2 different constructions (before and after modification) had been carried out using 6 microphone positions. More than that 2 different noise criteria have been used namely A-weighted maximum pass-by level as well as A-weighted sound exposure level of the pass-by. The outcome of this pilot study is a proposal for the acoustical assessment of expansion joints on highway bridges which fulfils the following requirements:

- **Simple application:** the measurement methodology has to be as simple as possible, which means a reproducible result must be achieved by few microphone positions.
- **Quantification of all relevant acoustic effects:** the draft French Standard only takes noise into account that is emitted by tyre and joint. In reality we often have to deal with noise radiation from underneath the bridge as well.
- **Data input for RVS 3.02:** the results of the pass-by noise measurements and the assessment of the expansion joints should be used for prediction schemes of environmental noise. Therefore, the overall methodology used for the assessment has to be compatible to the methodology of the Austrian road traffic noise prediction scheme of RVS 3.02 [3].

2 Work programme

Pass-by noise has been measured on the bridge over the river Mur in Sankt Michael in Styria before and after replacement of the expansion joint. This bridge is part of the alpine A9 highway linking the city of Graz in south of Austria with the city of Linz in the north. According to the requirements of the draft French Standard a minimum of 100 pass-bys of ass-bys was recorded digitally. In parallel with the noise recordings pass-by speed was measured as well.

The draft French Standard demands only one microphone position at the cross section of the expansion joint in 3 m distance from the centreline of the first traffic lane and 1,3 m height above road surface. Additionally to these needs a reference microphone was placed about 30 m after the expansion joint at same distance and height. This reference microphone is used to determine the “normal” rolling noise on a road surface without expansion joint. Another 3 microphones have been put at the cross section of the expansion joint in 7 m distance from the traffic lane’s centreline in 3 different heights: one microphone in 2 m above road surface, one at road surface height and the third 2 m below road surface. Finally a sixth microphone has been put underneath bridge to evaluate the noise radiated from the gap under the expansion joint (figure 1).

The sound signal was triggered by two light barrier one at the cross sections of the expansion joint and one at the reference microphone. This configuration helped us to find the correct position of the vehicles in the level time history.
3 Data analysis

Analysis of the pass-by data recorded was made afterwards in the office. In a first step the time history of the acoustic and the trigger signals have been produced. From this diagrams several noise criteria were derived namely the A-weighted maximum pass-by level $L_{A,max}$ as compulsory for the draft French Standard as well as the A-weighted sound exposure level $L_{A,E}$.

Using a reference microphone helps to correct the influence of the road surface on the pass-by level. By referencing the signal the pure effect and level increase due to the expansion joint can be found.

The additional microphones 7 m aside the bridge are used to determine the sound radiation from both the expansion joint and the bridge construction. Finally the microphone under the bridge illustrates the noise radiation from the gap between the bridge and the abutment as well as form the bridge construction.

3.1 Vehicle categories

The draft French Standard includes 2 vehicle categories only namely passenger cars (PC) and heavy-duty vehicles (HDV). The pilot study presented here used 3 vehicle categories in accordance with the Austrian noise calculation scheme RVS 3.02 as well as the proposal in Harmonoise [4]. The category of heavy-duty vehicles is split into 2 categories of light HDVs with 2 axles only and heavy HDVs with 3 axles and more including also trailers.

3.2 Noise criterion

Generally speaking there are several ways to assess impulsive noise created by the tire rolling over the expansion joint. The draft French Standard uses the A-weighted maximum pass-by level $L_{A,max}$. The maximum level is able to describe the effects of noise peaks. However, the $L_{A,max}$ is sensitive to any peaks, so also to sound pressure peaks, which have a different origin than the expansion joint. This means random effects may influence the maximum pass-by level quite strongly and thus affect the results.

The main disadvantage of $L_{A,max}$ is related to the overall methodology used for noise prediction. Any modern noise prediction scheme in Europe is based on an energetic approach and uses equivalent levels. It is difficult to incorporate results, which are based on maximum levels in such a scheme. That was the reason to include the A-weighted sound exposure level $L_{A,E}$ in the pilot study as well and to weigh them against $L_{A,max}$.

The A-weighted sound exposure level $L_{A,E}$ includes the total sound energy of the pass-by both on the reference surface as well as on the expansion joint. Therefore, the exposure level is supposed to include and demonstrate all the acoustic effects when passing over an (noisy) expansion joint. In parallel results from the assessment of expansion joints can be used directly in the noise prediction scheme to include the additional effect of bridges and the expansion joints.

3.3 Microphone positions

According to the draft French Standard one single microphone is used directly at the cross section of the expansion joint. It has to be in 3 m distance from the centreline of the nearest traffic lane and in 1.3 m height above road surface. It appears essential to include a second such microphone position about 30 m before or after the cross section of the expansion joint to get a reference for the general amount of pass-by noise level on this specific road surface (figure 2). We know that texture of road surface has a great influence on the pass-by noise level of road traffic. A single microphone at the expansion joint only cannot illustrate both effects of impulsive noise from the expansion joint and rolling noise from the road surface texture.
The 3 microphone positions in 7 m distance from the centreline of the nearest traffic lane were introduced to demonstrate if these positions were able to assess both effects direct sound radiation from the road surface and the expansion joint as well as indirect noise radiation from the gap between the bridge and the abutment and from the bridge construction itself (figure 3).

4 Results

4.1 Measurement procedure

The microphone position proposed by the draft French Standard is appropriate for the assessment of noise radiated from expansion joints. In most cases of highway bridges the short distance of 3 m between the microphone and the centreline of the nearest traffic lane allows to put the microphone on the service lane.

- Data gained show that it is very appropriate to use the reference microphone position at about 30 m before or after the cross section of the expansion joint. The reference microphone displays the effects of the road surface and its influence on the height of the pass-by level. Results from the reference microphone only can show the pass-by level increase due to the expansion joint construction.

- Results from the microphone positions in 7 m distance from the centreline of the nearest traffic lane will correlate very well with the 3 m point. That means these microphone positions also mainly include the directly radiated noise and thus do not add extra information.

- An additional microphone position beneath the bridge is able to quantify all the secondary effects due to the bridge design. Data show that the secondary noise radiation strongly correlates with primary noise. However, there is second main factor influencing the noise level under the bridge namely the overall bridge design. The bridge design is independent from the expansion joint design and thus cannot be assessed by the microphone on the bridge.

4.2 Comparison of the two designs

The old design was a modular expansion joint (figure 4) and it was replaced by a cantilever finger joint (figure 6). Here are the changes in noise emission.

- The A-weighted maximum level decreased 6 dB due to the change of the expansion joint construction.

- In parallel the maximum pass-by level increased 2 to 5 dB at the reference point. This level increase is caused by the new road surface that has been

- The same effect was observed with the A-weighted sound exposure level, which decreased 4 dB at the expansion joint and increased 2 to 4 dB at the reference point.

- That means the replacement of the expansion joint lead to nearly the same pass-by level at the joint and at the reference point.

- A-weighted sound exposure level decreased 6 to 8 dB under bridge.
5 Conclusions

A measurement methodology for the assessment of the (additional) noise from expansion joints on highway bridges should include 3 microphone positions:

- 1 microphone in 3 m distance from the nearest traffic lane in 1,3 m height above road surface at the cross section of the expansion joint.
- 1 reference microphone about 30 m before or after the expansion joint also in 3 m distance from the nearest traffic lane in 1,3 m height above road surface.
- 1 microphone under the bridge to quantify noise radiated form the gap between the bridge and the abutment as well as form the bridge construction.

Our experience shows that A-weighted maximum and A-weighted exposure levels match very well. With regards to the environmental noise calculation schemes we prefer to use the exposure level in future because results from the assessment of expansion joints can be used as input for these calculation schemes.

References