Making road traffic bridges silent

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Summary

The noise of road traffic bridges can be nuisance, especially nearby in the low frequency range. There are no noise regulations, but for new bridges and in case of renovation, the Dutch traffic authority wants to reduce the noise and construct a "Silent Bridge". As a start of this project noise and vibration measurements were performed on a traffic bridge before and after the renovation of the steel bridge took place. Also a FEM BEM model of this bridge before and after renovation was built, to calculate the expected noise emission and for engineering towards a silent bridge. By comparing the FEM BEM calculations with the noise and vibration measurements, the FEM BEM model was validated. The analyses also lead to adjustments in the force excitation model used in the FEM-BEM approach, to a better prediction of the sound radiation coefficient. As a result of this study, more design tools can be given now to come to a silent traffic bridge. Engineering protocols for design, calculation and measurements were formulated to help other parties to build a silent steel bridge.

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1. Introduction

The noise of road traffic bridges can be a nuisance, especially for residents living nearby due to the extra noise emission in the low frequency range. There are no noise regulations with respect to noise from road bridges. For new bridges and in case of renovation, the Dutch road authority wants to reduce the noise and construct a "Silent Bridge".

2. Noise of road traffic bridges

The extra noise of road traffic bridges can be described with a bridge correction factor, in the same way as the extra noise emission of railroads [1]. This correction factor describes the extra noise emission due to the bridge. In the case of traffic noise, correction factors are defined for noise emission from the upper part of a bridge (CW1) and for the noise from beneath the bridge (CW2). The bridge correction factor is measured in situ with two microphone positions at +3m and -3m above and beneath the bridge and at 7,5m distance from the centre of the nearby traffic lane. The measured noise values are compared to the noise at a reference position along the traffic lane of the regular road. See also Figure 1.

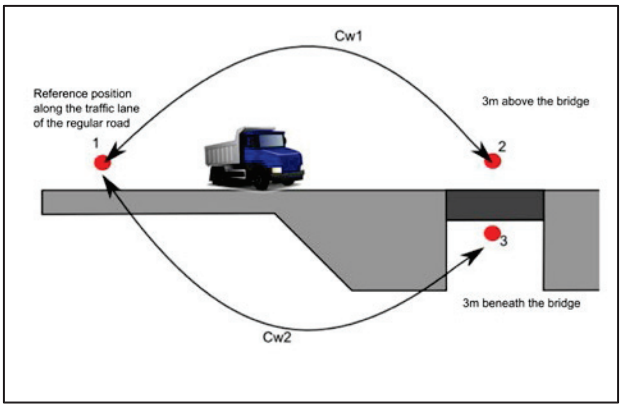

Figure 1: Measuring the bridge factors CW1 and CW2

In calculation models the extra noise emission of traffic bridges can be added by introducing an extra noise emission to the traffic lanes on the bridge and extra traffic lanes under the bridge for the emission of the underside. See also Figure 2.

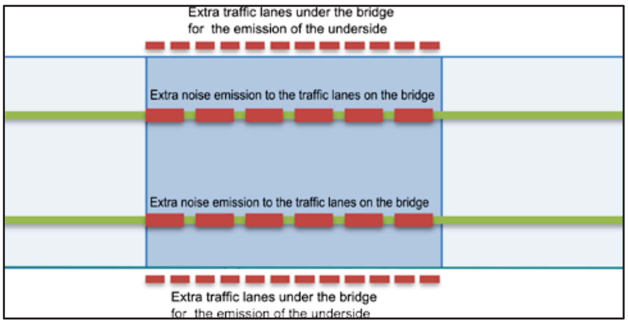

Figure 2. Calculation of bridge noise in acoustic models for sound propagation

3. Noise survey of traffic bridges

Using the described method to measure the extra noise of traffic bridges a noise survey of several existing bridges in highways in the Netherlands was held. A summary of the results for the values of CW1 and CW2 is published in figure 3 and 4.

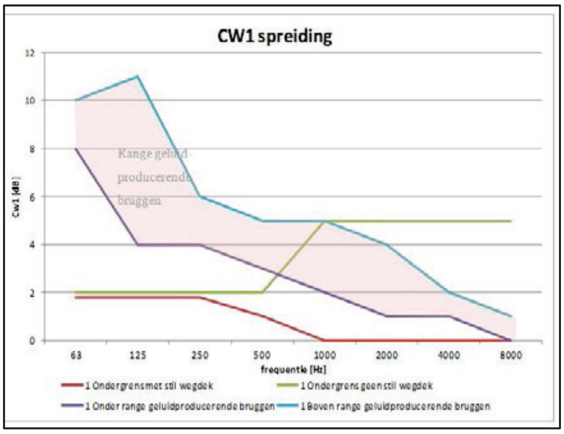

Figure 3. Spread in bridge correction factor CW1

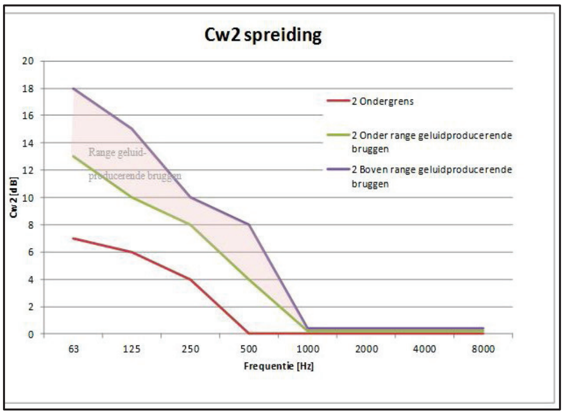

Figure 4: Spread in bridge correction factor CW2

The low frequency noise beneath 500 Hz is due to the extra noise radiation of construction parts. Extra noise emission at higher frequencies is merely related to the noise of the pavement.

The low frequency components of bridge noise may be 15 dB more than regular traffic noise and can provoke complaints in the near neighborhood about noise and low frequency noise in special.

To judge these complaints a comparison of the difference between the dB(C) and dB(A) noise levels is used as guideline [2].

Table I: Nuisance classification of bridge noise

dB(C)-dB(A)	Nuisance
≤10	None
11-15	Lightly annoyed
16-20	Mediate annoyed
>20	Seriously annoyed

4. Bridge renovation

In combination with the renovation of a traffic bridge, which provoked a lot of noise complaints, the Dutch traffic authority specified limits for the noise of the new bridge using target values for CW1 and CW2. This bridge renovation was the start of the project “Silent Bridge” to reduce the noise of bridges.

For the low frequencies a noise reduction of 10 dB in the 63Hz octave band and 7 dB in the 125 Hz octave band was the target value for the new bridge compared to the old one.

Before and after renovation, the noise and vibration levels of the bridge were measured and calculations were carried out using dynamic FEM/BEM models.

Comparing the FEM BEM calculations with the noise and vibration measurements lead to validation of the verification of the design process.

5. FEM/BEM calculations

For the FEM/BEM calculations a model of the old and the new bridge was built. An excitation force was simulated for the passage of a truck over the bridge with 6 paired excitation points at random positions selected on the slow lane. To get a more uniform power spectrum, the force was enlarged and the time of excitation was shortened.

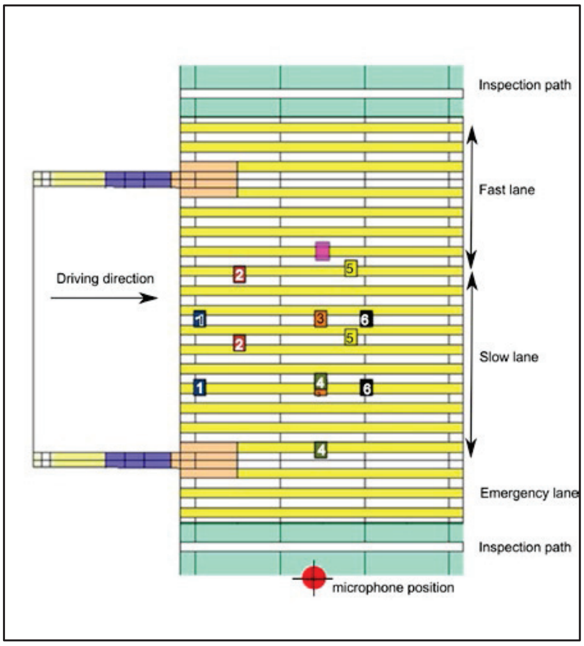

Figure 5: Excitation points randomly selected

To reach the target values for the noise reduction of 10 dB at 63Hz and 7 dB at 125 Hz, the new bridge was designed with a deck of 22 mm instead of 12mm thickness. The first calculations showed that an extra cross grider was also needed to comply the target. Also the inspection pad needed to be uncoupled from the deck.

6. Validation of the models

Noise measurements and calculations of the old bridge and the new bridge were compared to validate the FEM-BEM models and learn for future designs towards a silent Bridge.
Conclusions of this validation are:

For the low frequency radiation of the noise from below the bridge, force excitation of the bridge at a stiff point of the construction shows a better similarity with the measurements than averaging excitation points at random chosen positions.
For the radiation from the upper side of the bridge the randomly chosen positions are still useful.

The microphone position under the bridge has a relevant influence on the outcome of the calculations. Due to acoustic resonances the cavity under the bridge may have a significant effect in the 63 Hz range. The BEM calculations did not take this effect into account, see also figure 6.

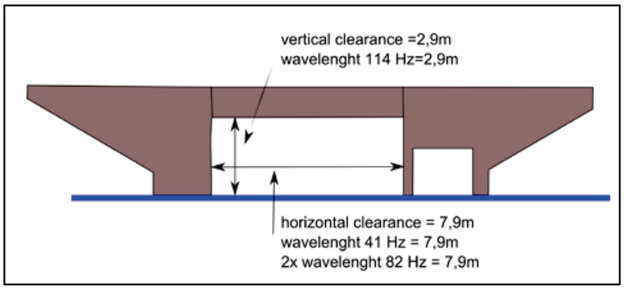

Figure 6: Cavity under the bridge influences the noise field.

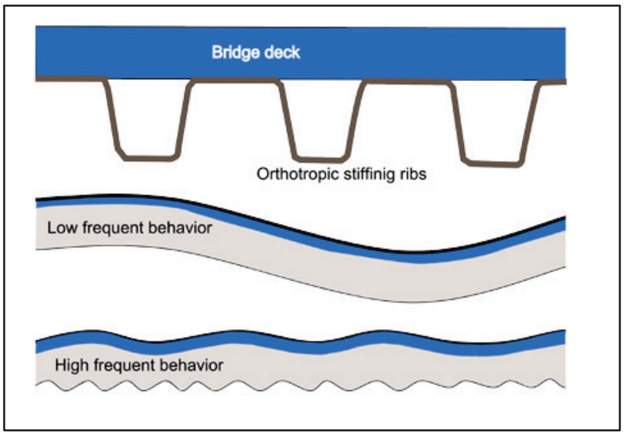

Figure 7. Different dynamic behavior of orthotropic bridge deck

The dynamic properties of an bridge deck with orthotropic stiffeners can be described as a coupled system for low frequencies up to 200-300 Hz and as an decoupled system for higher frequencies, see also figure 7.

For high frequencies around 1000 Hz, the tire-road noise is dominant for the noise emission. A rough bridge deck will then result in higher noise levels than an noise reducing pavement.

The comparison between the calculated and measured noise reduction of the bridge is shown in figures 8 and 9, both above and under the bridge. The FEM-BEM calculation results are based on averaging of 6 randomly chosen excitation positions.

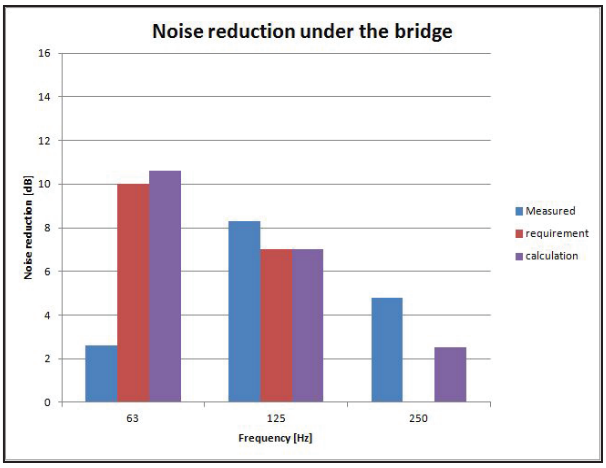

Figure 8: Noise reduction under the bridge

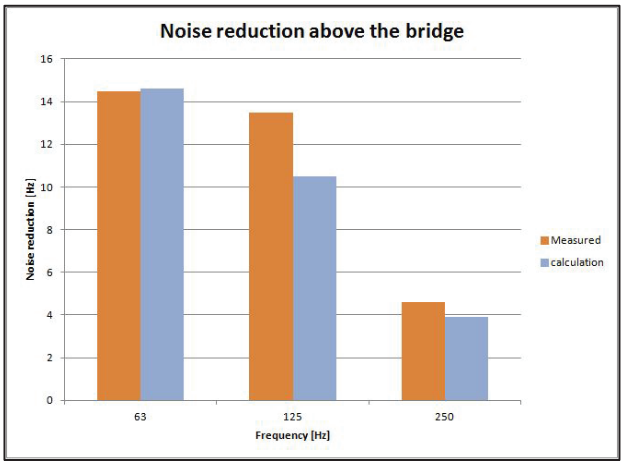

Figure 9: Noise reduction above the bridge

The results in figure 9 shows good conformity between measurements and calculations above the bridge. However, under the bridge this is only valid for 125 Hz and 250 Hz, but not for 63 Hz. The cause of this mismatch between measurements and calculations is subject for further investigation. The cavity response, see figure 6 is expected to be one of the possible causes.

7. Conclusions

The noise of traffic bridges can result in serious noise complaints in the vicinity of a bridge. Especially the low frequency components of the noise of the bridge are responsible for the perceived nuisance.
In combination with the renovation of a bridge, measures to reduce the noise can be dimensioned.

A measurement method is defined using pass-by measurements at a reference position along the traffic lane of the regular road and 2 positions above and beneath the bridge.

Evaluation of the low frequency nuisance using dB(C)-dB(A) seams valid to classify the noise complaints in the near neighborhood

Noise requirements can be realized in combination with the renovation of traffic bridges.

Verification techniques using FEM-BEM are useful to predict the noise reduction of new traffic bridges. Comparing calculation results with measurements showed for 125 Hz and 250 Hz that these methods are valid. For 63 Hz there was a mismatch between measurements and calculations is subject for further investigation.

A high impedance of a new traffic bridge in combination with silent expansion joints resulted in a noise reduction on the low frequency range of approximately 5 dB beneath the bridge and more than 10 dB above the bridge.

References

[1] Reken- en Meetvoorschrift Geluid 2012 (Dutch measurement and calculation regulation)

[2] DIN 45680:2011-08 “Messung und Beurteilung tieffrequenter Geräuschimmissionen”