In-situ measurement of road barriers made of natural stones

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Introduction

For high efficiency road barriers certain minimum acoustic properties are required [1]. The determination of these properties in laboratory often is difficult due to the constructions and mainly the weight of the barriers. Since 2003 there is the possibility to measure the acoustic properties of ready built-up barriers on site or in-situ. The quantities introduced in CEN/TS 1793-5 [2] are the so-called reflection index RI and the sound insulation index SI. RI is closely related to the sound absorption coefficient α, SI to the sound transmission loss measured in laboratory respectively.

In this contribution a description of the method applied is presented. Furthermore results of in-situ measurements from three different samples of gabions are presented. Gabions are more and more in use as road barriers because of non-acoustical properties such as visual impression, easy of application and cost. To fulfill the required acoustic specifications for absorption and transmission well-defined and proven constructions are required.

Finally a first mathematical approach towards the modeling of the the transmission loss of gabions is suggested. Applying this model will allow an optimization of the acoustic properties of the gabions investigated.

In-situ measurement methods applied for testing

The in-situ measurement procedure according to CEN/TS 1793-5 [2] summarizes many advantages compared to traditional measurement techniques such as the reverberation chamber method and sound transmission loss tests in specialized test facilities.

Firstly, the sound field used is closer to the real sound field emitted from traffic noise. It is impossible to get a diffuse sound field along highways and railways but it is the base of the traditional measurement techniques. Secondly, it is possible to measure the properties at the ready built-up road barrier. This allows proving measurements to determine quality of production as well as long-term performance [3]. Thirdly, the method is insensitive for noisy conditions. Measurements can be carried out along roads even with traffic. Finally the procedure is very easy and fast to apply.

CEN/TS 1793-5 [2] defines the measurement of the reflection index RI instead of sound absorption. Others have described the underlying technique in more detail [4, 5, 10, 11]. A survey of different measurement procedures is presented in [14]. The sound transmission measurement relies on the determination of relative changes of sound levels and yields a sound insulation index SI.

Both measurement approaches (reflection and insulation) CEN/TS 1793-5 [2] are based on MLS-measurement techniques. To determine the RI as well as the SI it is necessary to get a reference impulse response which is subtracted from the impulse response measured with the sample under test. The difference allows the computation of the wanted values. These are frequency depedent . Single number ratings for reflection and insulation are deduced from the frequency range from 200 to 5000 Hz.

The determination of the single number ratings DL_{RI} and DL_{SI} is based on a normalized traffic noise spectrum according to EN 1793-3 [6]. The comparison between modern in-situ measurement results with results from traditional procedures has been investigated by Garai/Guidorzi [4, 5].

The following figure 1 shows the two steps for the deduction of the sound reflection index RI. The method relies on a comparison of a pseudo free-field reference measurement (left) and a reflection measurement with the microphone close to the surface under investigation. Further details can be found in [2, 13].

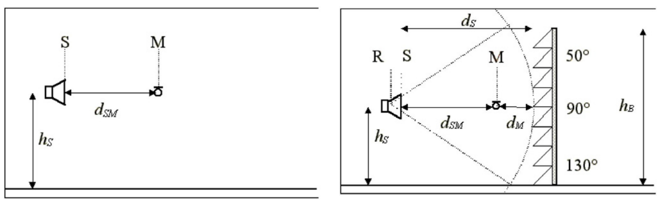

Figure 1: Set-up for measuring the reflexion index RI according to CEN/TS 1793-5 [2], measurement of impulse response without (left) and with sample (right).

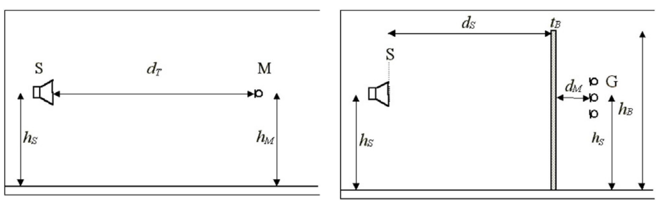

Figure 2: Set-up for measuring the sound insulation index SI according to CEN/TS 1793-5 [2], measurement of impulse response without (left) and with sample (right).

Figure 2 depicts the procedure applied for the measurement of the sound insulation index SI. The basic principle is the same: first a reference impulse response is taken and secondly the measurement is repeated with the same distance between sound source and microphone with the wall under investigation in between.

Samples and measurements

In the course of this research three different samples were investigated. All of them were gabions. Gabions are baskets of wire with a fill of natural stones. The first sample was a gabion with a thickness of 1 m filled with non-porous (dense) stones with a grain size from 6 to 9 cm. Each gabion has a dimension of $1 \times 1 \times 1m^3$. A picture of the sample and a sketch of the construction is shown in figure 3.

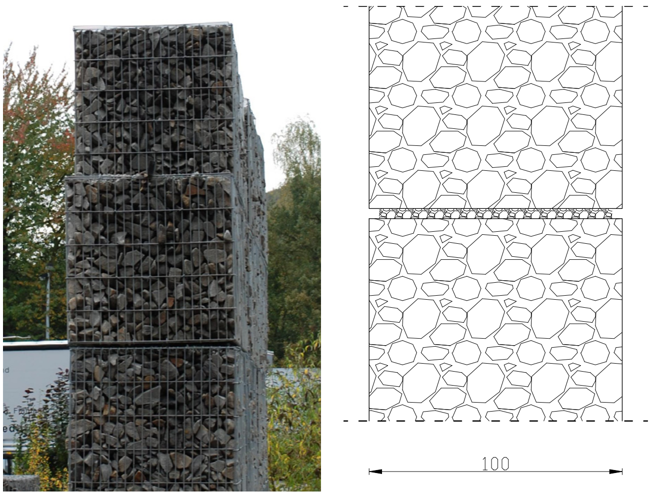

Figure 3: Picture and sketch of sample 1 (s1), gabion filled with dense stones without further elements.

Inside the second sample there was a core consisting of a mixture of sand and cement. The thickness of the core was 20 cm. Due to the construction process of the gabion on the site it was possible to create the core without any slits or leakages. The filling on both sides of the core were from non-porous stones with the grain size from 9 to 15 cm.

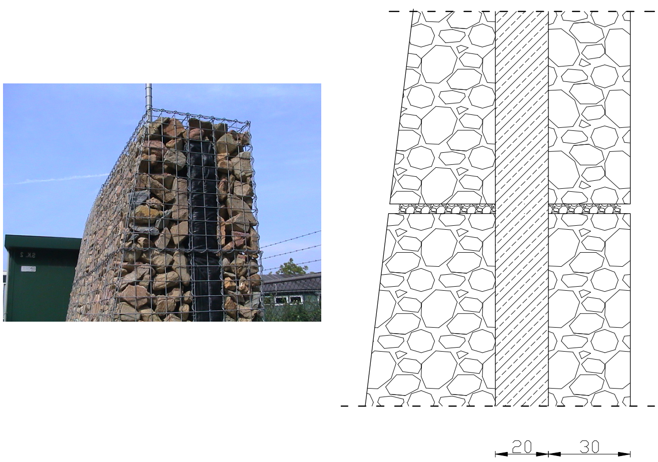

Figure 4: Picture and sketch of sample 2 (s2), gabion with a core of sand-cement mixture inside.

As can be seen from figure 4 the traffic facing side of the gabion was slightly tilted so that the layer thickness of the gabion varied from 80 cm at the bottom to 30 cm at the top at a height of 4 m.

The third sample was a barrier built of prefabricated elements with a core of concrete inside. Between each element joint tapes were used to seal the unavoidable slits. The gabion was filled with light, porous foam glass on one side to decrease the reflexion. A picture and a sketch of the construction of this sample is shown in figure 5.

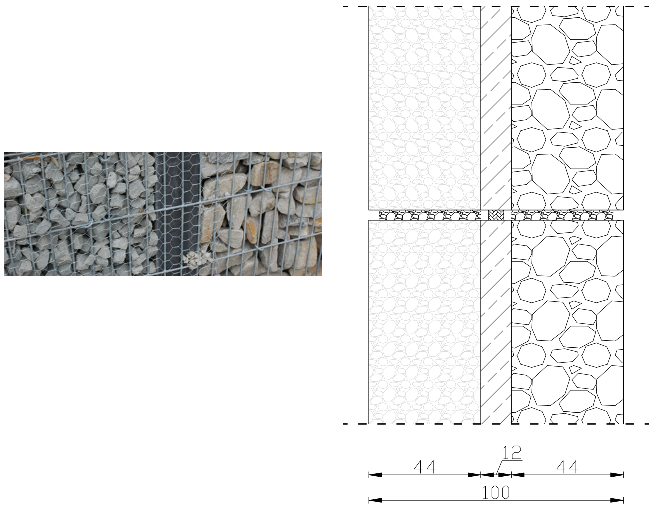

Figure 5: Picture and sketch of sample 3 (s3), gabion with a core of concrete inside, slits sealed with sealing tapes, traffic faced side with porous stones.

For each sample the reflection index and the sound insulation index were measured. The results of the reflection index are presented in figure 6. Sample 1 shows values of the reflection index down to 0.17 at 315 Hz and little reflection at low frequencies. This is not the result of a high absorption but of a high transmission through the construction. With a decreasing wavelength at higher frequencies the reflection index is increasing. Sample 2 has no clear tendency for the reflection index up to 1000 Hz. The reflection index varies from 0.6 to 0.3. Only at high frequencies the value stays nearly constant at a high level. The result for sample 3 is different. Especially at frequencies above 800 Hz the reflection index shows values down to 0.2 and is lower compared to samples 1 and 2. All samples do not comply with the requirements of ZTV-Lsw 06 [7] for highly sound absorptive surfaces. According to the formulas given by Garai/Guidorzi [4] it corresponds to $DL_\mathrm{a} = 14$ dB.

As expected the sound insulation index for sample 1 is low because of its large pore sizes. This documents the transmission through the construction. Particularly at low frequencies the sound insulation index is low. Barriers with high sound insulation should reach an DL_SI greater than 24 dB according to ZTV-Lsw 06 [7]. This is not reached by sample 1. Both other samples are categorized as high sound insulating according to [7]. The slits in sample 3 sealed with special joint tapes are the reason for lower values of sound insulation index.

Nevertheless, the sound insulation rating is sufficient for high sound insulation according to ZTV-Lsw 06 [7].

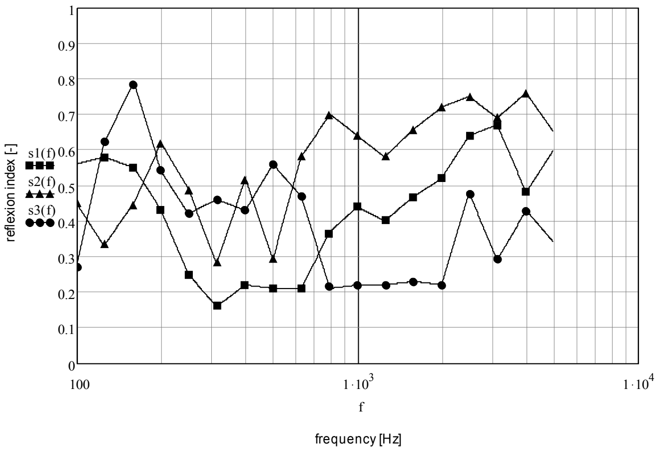

Figure 6: Measured results of the reflection index of the three different samples: normal gabion s1, core of sand-cement mixture s2, core of concrete with seals s3).

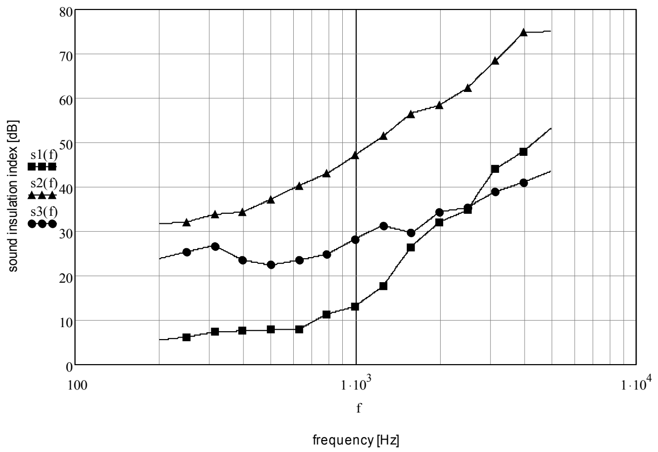

Figure 7: Measured results of the sound insulation index of the three different samples: normal gabion (s1), core of sand-cement mixture (s2), core of concrete with seals (s3).

These results are consistent with earlier research as shown in [8] which have also proven that gabions without any special elements inside can not be used as barriers. The reflection index of porous stones is quite high though the requirements are not met. Further research is necessary to fit the requirements of the standardized requirements.

Computation of transmission loss of barriers from several elements

Today it is not very common to apply gabions as road barriers but it is more and more in use. As mentioned before the transmission loss of these constructions is often a problem which makes it unsuitable for certain applications. Further special semi-rigid elements are necessary to be included into the construction. To improve the transmission loss a calculation with respect to the most important influencing factors can help. The following mathematical results include these important points:

- transmission loss of concrete core below the effect of coincidence (Berger's mass law)
- transmission loss of concrete core above the effect of coincidence
- transmission loss of the slits sealed with joint tapes (according to F.P. Mechel [9])
- transmission loss of leakages which probably occur where steel sticks cross the joint tapes (according to F.P. Mechel [9])

The filling of the gabion on both sides of the core has been ignored. Furthermore, curve progression at the frequency of coincidence has not been computed very accurate because it has nearly no influence on the computation of the single number rating DL_{SI}.

To get the most important parameters in each calculation one parameter was varied while all the others were kept constant. As seen from figure 8 it is impossible to improve the transmission loss by increasing the layer thickness of the concrete core. Even a 5 cm thick core leads to the same singular number rating DL_{SI} as a 20 cm thick concrete core. The transmission through the slits between the elements is most important factor. In conclusion it is possible to reduce the thickness of the concrete core used in the measured sample 3.

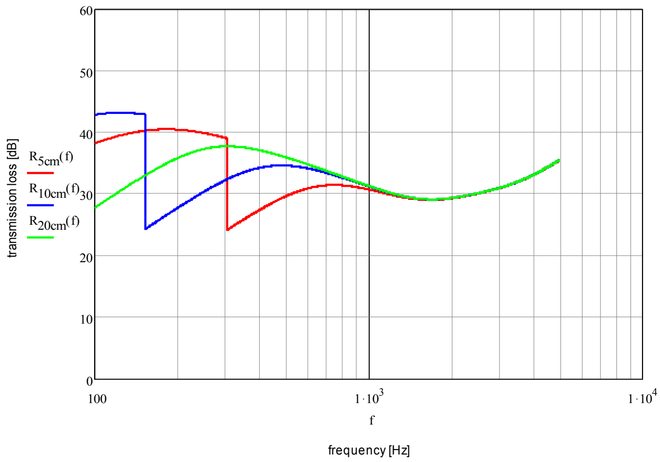

Figure 8: computation of transmission loss, variation of the layer thickness of the concrete core from 5 to 20 cm, flow resistance and layer thickness of joint tape is constant.

Figures 9 and 10 show the two possibilities to improve the transmission loss in the frequency range from 500 Hz to 2000 Hz which are the main frequencies emitted by traffic noise and therefore the most significant frequencies for the computation of the single number rating DL_{SI}. In these figures mean values for one-third octave bands are shown. Increasing the layer thickness of the joint tape has a similar effect on the transmission loss as the increase of the flow resistance of the joint tape by a higher compression.

Another relevant finding from both calculations shown in figure 9 and 10 is that the leakages through the slits can be neglected if the transmission loss is low. A local minimum of the transmission loss at about 3000

Hz appears only for high values of sound insulation corresponding to a single number rating of $DL_{SI} = 35$ dB. All the results are based on the assumption of 10 leakages per m^2 in every computation.

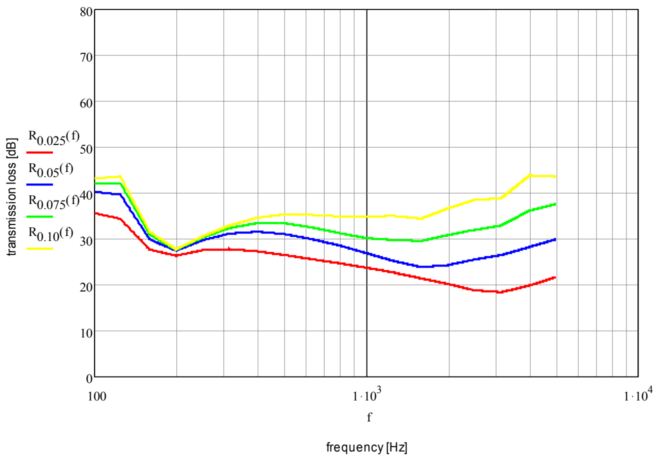

Figure 9: computation of transmission loss, variation of layer thickness of the joint tape, layer thickness of concrete core and flow resistance of joint tape is constant.

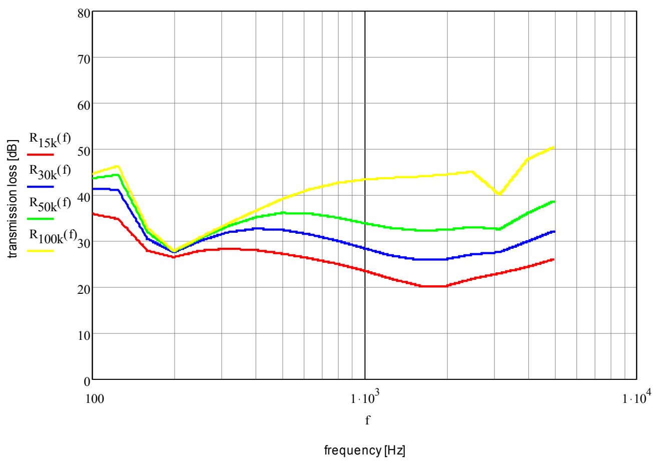

Figure 10: computation of transmission loss, variation of flow resistance of joint tape, layer thickness of core and joint tape is constant.

Conclusion

With the in-situ measurement procedures according to CEN/TS 1793-5 [2] a fast and easy-to-apply method to determine the acoustic properties of barriers is provided. Differences in the results compared to laboratory measurements can partly be physically explained. Standards for categorization should be adopted to the new methods of measurement.

Special constructions of gabions can meet the requirements set in regulations such as ZTV-lsw [7]. They are not only suitable for barriers because of their appearance but because of their acoustic properties. The presented computation of transmission loss allows predictions for optimization of the construction.

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