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Porous stones increase the noise shielding of a gabion

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ABSTRACT

Gabions – metal-wired cages filled up with stones – are increasingly becoming popular as decorative elements and land property boundaries. It has been shown before that such structures can be used as road traffic noise barriers as well. However, the types of stones used in gabions have not been experimentally studied so far. Exploratory measurements at full scale in a semi-anechoic room were performed to study the effect of both porous and rigid stones on their noise reducing potential. At the 1/3 octave bands below 1 kHz, low-height gabions (with depths of 20 cm and 30 cm) hardly provide any sound pressure level reduction. At higher sound frequencies, in contrast, the shielding rapidly increases. Porous lava stones were found to significantly increase the shielding compared to rigid stones. Reflections on such non-deep low-height barriers towards the source side were found to be of minor importance when considering a standardized A-weighted road traffic noise spectrum.

1. Introduction

Gabions are cages or boxes made of steel wire, filled with stones. Although such structures were traditionally used as foundations or to prevent erosion (e.g. river bank protection), they are becoming popular as a decorative element in gardens or to define land property boundaries. Advantages are their natural look and lack of maintenance. They are often used to replace vegetative hedges.

There has been some interest in the sound reducing potential of gabions. Koussa et al. [1] reported full scale in-situ measurements of the reflection index and transmission loss of a 3-m high and 1.1-m wide gabion made of crushed rigid stones. The single number ratings of the reflection and insulation indices were measured to be near 5 dB and 20 dB, respectively. Scale model studies [1] and numerical work [1] considering 1-m wide and 1-m high gabions showed that near 8 dBA road traffic noise insertion loss can be obtained at ear height, at 5 m distance from the gabion. Optimization by making the gabion a layered structure of stones with different sizes was numerically explored and seems possible [1]. Vegetative hedges, in contrast, were measured to only provide minor sound pressure level reduction [2], although the noise perception improvement is potentially strong [3].

A low-height barrier, in general, can be quite efficient for a low-height sound source at close distance from the barrier. Such conditions can be met in case of rail or road traffic. These low barriers, even when they can be overlooked (e.g. lower than 1 m high), were shown to be efficient to shield specific zones, also in an urban context [4,5,6,7,8,9,10].

So it can be concluded that low-height gabions can be effective in reducing noise. However, the type of stones used to fill the cage did not receive a lot of attention so far. Initial numerical simulations showed that the noise shielding of a gabion could be theoretically enhanced by using porous stones instead of rigid ones [11]. Since gabions can be categorized as “leaky” barriers, additional absorption during transmission could lead to better acoustic insulation. At the same time, the interaction with absorbing material during diffraction over a barrier could make such paths less intense as well [12,13]. Thirdly, absorption at the vertical barrier face at the source side could lead to a smaller amount of reflected sound energy.

In this work, exploratory full scale measurements were performed under well controlled conditions, comparing low-height gabions containing either porous or rigid stones. In contrast to the aforementioned 1-m wide gabions discussed in Ref. [1], the measurements in this study were restricted to barrier depths of maximum 30 cm. This is more related to the practical use of gabions positioned at plot borders near dwellings.

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2. Material and methods

2.1. Diffraction experiment in semi-anechoic chamber

The measurements were performed at full-scale in the semi-anechoic chamber at Ghent University with dimensions 5 m by 8 m. The cut-off frequency (99% absorption) of the 1.2-m long melamine pyramids is 63 Hz. The measured A-weighted background noise levels are below the noise floor of a type-1 measurement chain using a ½" microphone capsule (less than 15 dBA). Given the large weight of a filled gabion, these measurements cannot be performed in a full anechoic chamber. However, the fully rigid floor will give rise to pronounced interferences that will shift between the reference situation (i.e. unscreened ground) and the sound propagation case in presence of the gabion. Although this will make spectral insertion losses somewhat less clear, it is nevertheless more closely related to practice.

2.2. Gabion barriers

Three different gabion setups were tested, namely a 20-cm thick gabion filled with rigid stones (see Fig. 1, stone size distribution between 4 cm and 6 cm), a 20-cm thick gabion with porous lava stones (see Fig. 2, stone size distribution between 4 cm and 8 cm), and a 30-cm thick gabion with the same lava stones. To prevent excessive bending of the 2-m high metal structure (that could obviously not be screwed in the floor) and for safety reasons, the filling height has been limited to 1.6 m. In case of the 30-cm thick gabion setup, the height was limited to 1.4 m. The combined effect of the cage (consisting of 3–4 mm metal wires, forming a lattice of square openings of 5 cm by 5 cm), the metal U-profile at the bottom (with a height of 10 cm) and the supporting poles have been measured as well without stones (see Fig. 3).

2.3. Measurement equipment and signal processing

Four type-1 half-inch MK250 (Microtech Gefell) microphone capsules were used (with a fully flat response in the frequency range considered, see further), connected to SV12L (Svantek) preamplifiers. For the data acquisition, a National Instruments PXIe-1082 chassis with three NI-4498 data acquisition cards were used, steered by a Labview application to perform the processing to sound pressure levels. After each microphone manipulation (e.g. moving and reconnecting), the calibration was repeated with a SVAN30A (Svantek) type-1 pistonphone, producing a pure tone of 1 kHz at 94 dB. Throughout the full experiment the needed adjustments were 0.2 dB (root-mean-square value, considering all microphones channels).

The frequencies of interest were the 1/3 octave bands from 100 Hz to 8 kHz. Linear and logarithmic sweeps of 60 s covering this frequency range were emitted. These sound signals were sent by Labview to an external sound card type ESI U24XL (24 bits) and forwarded to a power amplifier A-607R (Pioneer) on "direct" mode, driving an OmniSource loudspeaker type 4295 (Bruel & Kjear). This loudspeaker directs sound through a conical coupler connected to a circular orifice, approaching a point source, yet with sufficient sound power.

Each sample was repeated 3 times and the one-minute equivalent sound pressure levels were linearly averaged afterwards. The variation on these repeatedly measured levels were very minor (much lower than 0.1 dB), pointing at highly consistent measurements as can be expected when experimenting in an anechoic room.

Insertion losses were calculated by subtracting the sound pressure levels in case of unscreened ground with the ones when the gabion was present. In a next step, the spectral insertion losses were summarized to total A-weighted white and pink noise insertion loss. In addition, the insertion losses were calculated using the (A-weighted) road traffic noise spectrum weighting according to EN 1793-3 [15]. Deviations from a flat spectral amplitude response by the loudspeaker were corrected for based on the product description by the vendor. Below 1 kHz, the sound source was measured (by the vendor) to be truly omnidirectional. At higher sound frequencies, the sound source becomes somewhat more directive and reported deviations (by the vendor, following ISO 3382) were at maximum 5 dB at 8 kHz. The loudspeaker exit was directed towards the gabion, and this orientation was maintained throughout the whole experiment. Therefore, the high frequency directionality is expected to have a minor influence only on the measured insertion losses.

2.4. Microphone and source positioning

Two microphone setups were considered. In a first one [see Fig. 4, (a) and (b)] the source was placed at close distance from the gabion (at 1 m), at half the screen height (0.8 m). Two

Fig. 1. Photograph of the rigid stones filling up the metal cage.