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Innovation Loam Noise Barrier

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Abstract
Cob (in German ”Wellerlehm”) and stamped loam are traditional earthen construction methods that have been used in Europe for hundreds of years. With a pilot project near Nebelin in the German federal state of Brandenburg, this forgotten construction technology, which can now be considered innovative, is to be applied to a noise barrier at a planned service area on the A14 motorway. The project is called the ”Alhambra of Brandenburg”. The aim is to determine the necessary boundary conditions for the realisation of noise protection walls in earthen construction, which meet both the technical requirements of the German ”ZTV-Lsw” (Additional Technical Contractual Conditions for noise barriers) as well as ecologically sensible criteria. Due to the wall thickness of a loam noise barrier of up to one metre and the density of the building material alone, achieving a sufficient airborne sound insulation does not represent a big problem. However, to improve the absorbing properties, the dense and sound-reflecting surface of the cob must be supplemented by a kind of facing shell. Promising results in this regard are shown by initial measurements in the impedance tube with Heraklith and hemplime, a composite material made of hemp, light wood and lime binder. In further test series, the material compositions of the sample bodies are varied in order to optimise the absorption spectrum to the road traffic spectrum.
It is hoped that the natural and locally occurring materials will contribute to a reduction in energy consumption and, due to the high content of renewable raw materials, a favourable CO_2 balance and a reduction in greenhouse gas emissions. Furthermore, the purely naturally occurring raw materials make the building completely recyclable.

Keywords: innovations, sustainable, noise barrier, new material

1 Introduction

Innovations in noise protection are usually understood to be new, artificially created materials or geometries that follow complex physical effects and require extensive calculations to function correctly. These can be, for example, so-called metamaterials or geometries which cause improvements in the near field due to diffraction, scattering or refraction effects, and thereby leading to level reductions in the far field.
The innovation of this study is a new but historically ancient building material for road noise protection, namely loam. Loam is an ancient building material used all over the world. There are still numerous buildings, some of them historical, which were built using loam. The loam construction method cob was particularly widespread in eastern Germany. The mixture of cob consists mainly of loam and straw, or other long-stemmed plant stalks. Partly due to environmental protection and sustainability considerations, this building material is experiencing a renaissance. Clay is again being used as a building material, not only in residential construction but also in larger industrial buildings. It is therefore not surprising that there are efforts to use it in road construction, too. This will be described in more detail here.

1.1 Sustainable loam construction

The expansion of the German A14 motorway [1] between Karstädt and Wittenberge runs in the immediate vicinity of and partly through the biosphere reserve "Elbe River Landscape". A rest area is to be built near Nebelin, which is to be embedded in the surroundings in a way that is as landscape- and people-friendly as possible [2]. A feasibility study is being conducted to determine whether various structures of the planned rest area can be built using earthen construction methods. For example, the acoustic and non-acoustic properties of loam construction could be investigated on the perimeter walls of the facility in order to assess its suitability for noise protection purposes. For official use, these walls must meet the requirements of the "Additional Technical Contractual Conditions and Guidelines for the Construction of Noise Barriers on Roads", in short ZTV-Lsw 06 [3].
One advantage of this construction method would be that the excavated soil produced on site can be used directly as building material and the erected noise barrier is thus fully recyclable. It can be returned to nature without any reprocessing - possibly directly on site. Loam construction is also reflected in several of the 17 Sustainable Development Goals (SDGs) to which the German government has committed itself [4].

1.2 Loam noise barrier

Depending on the type of loam and the construction method - both influencing the composition of the building material - the produced loam has a density between 1500 and 2200 kg/m³ and is thus in the range of concrete. To ensure stability and take into account initial weathering (i.e. the reduction of the wall thickness towards a balanced condition), loam noise barriers would be much thicker than conventional walls made of concrete, wood, glass or aluminium cassettes. Thus, depending on their height, they could have a thickness of 1 m at their base and still have a thickness of 0.5 m at their upper edge.

2 Acoustic condition of cob

Compliance with the minimum sound insulation of 25 dB required in Germany according to ZTV-Lsw 06 [3] is not a problem due to the density of the loam and the thickness of a loam noise barrier. With regard to its absorption properties, the surface of a wall in conventional stamped or cob construction represents a sound-hard surface, as initial measurements on the impedance measuring tube have shown, i.e. incident sound is largely reflected. In order to improve the sound absorption properties, the use of admixtures, incorporated absorption layers and facing shells is being investigated.

2.1 Improvement of the absorption capacity

The sound-reflecting surface of cob and stamped loam severely restricts its use as a noise barrier. Efforts have therefore been made to establish sound absorbing properties in a loam noise barrier. Initial attempts to improve the absorption properties by increasing the proportion of straw did not lead to any significant improvement. With the following three alternatives (see Figure 1), this goal seems to be achievable. Either an absorbent layer can be incorporated during the construction of the loam noise barrier (Figure 1 left and centre) or it can be attached to the loam noise barrier like a facing layer after its construction (Figure 1 right).

The three samples that instantly provided promising absorption curves in the impedance measuring tube are:

- Loam with reed stalks (see Figure 1, left)
- Cob with incorporated Heraklith (see Figure 1, centre)
- Hemp lime (see Figure 1, right)

The results of these investigations are shown and discussed below.

Figure 1: Test specimen, from left to right: loam with reed stalks, cob with inserted Heraklith slab, hemp lime.

2.2 Specimens for the impedance measuring tube

The samples examined were made directly to size (diameter 10 cm) or taken from larger blocks with a core drill. The height of the samples varied and can be taken from Table 1.

Table 1: Dimensions of the examined samples with a diameter of 10 cm

	Sample height /cm
Loam with reed stalks	10,5
Heraklith 2,5 cm x 5 cm	11
Hemp lime	11, 6.4 and 4

Loam with reed stalks

Pure loam is used here. It has a doughy consistency and, above all, no stones or other additives. Thus, reed stalks can be worked into this mass perpendicular to the surface without damage. As a result, the round openings of the reed stalks, which can vary in diameter, remain on the surface. Due to the open stalks, an open-pored structure of the surface is achieved. Absorption inside the stalks and interference effects due to phase-rotated reflection at the end of the channel can occur here and be responsible for a reduction in reflection.

Cob with Heraklith

Heraklith consists of wood wool and mineral binders. Heraklith is used in residential construction for thermal insulation and is available in panels. The Heraklith used in the sample is 2.5 cm thick and was worked into the cob in a 5 cm deep strip. Due to the open porosity of the material, sound can enter the structure and its energy can be absorbed.

Hemp lime

Hemp lime is made from hemp hurds (crushed soft wood from the inner core of the hemp stalk) and lime. The result is a very porous and open-pored product, which strongly reminds of the open-pored asphalt used in road construction. Sound can easily enter the structure, interfere and be absorbed. Hemp lime is very light and can be incorporated directly when building a loam noise barrier.

3 Absorption measurements in the impedance measuring tube

The measurements on the test specimens were carried out in an impedance measuring tube to accommodate specimens with a diameter of 10 cm and the heights listed in Table 1. In an impedance measuring tube, two

microphones are used to measure the sound absorption capacity of a test specimen, which is exposed to sound from a loudspeaker in the opposite direction to the specimen. The sound absorption capacity can be calculated from the difference between the incident sound energy on the sample and the sound energy reflected by it.
Figure 2 shows the absorption curves of the sample "loam with reed stalks" (blue) and the sample with incorporated Heraklith panels (red) in comparison to the initial absorption capacity of the pure cob sample (purple). Here, the clay with reed stalks shows an absorption maximum of 0.6 at about 800 Hz. The Heraklith plate incorporated into the reflecting cob shows a first low maximum of a bit more than 0.4 at about 350 Hz and a higher and very broad maximum of about 0.65, which extends from 1000 Hz to 1200 Hz and shows an absorption coefficient of at least 0.6 already from 900 Hz and up to 1300 Hz.

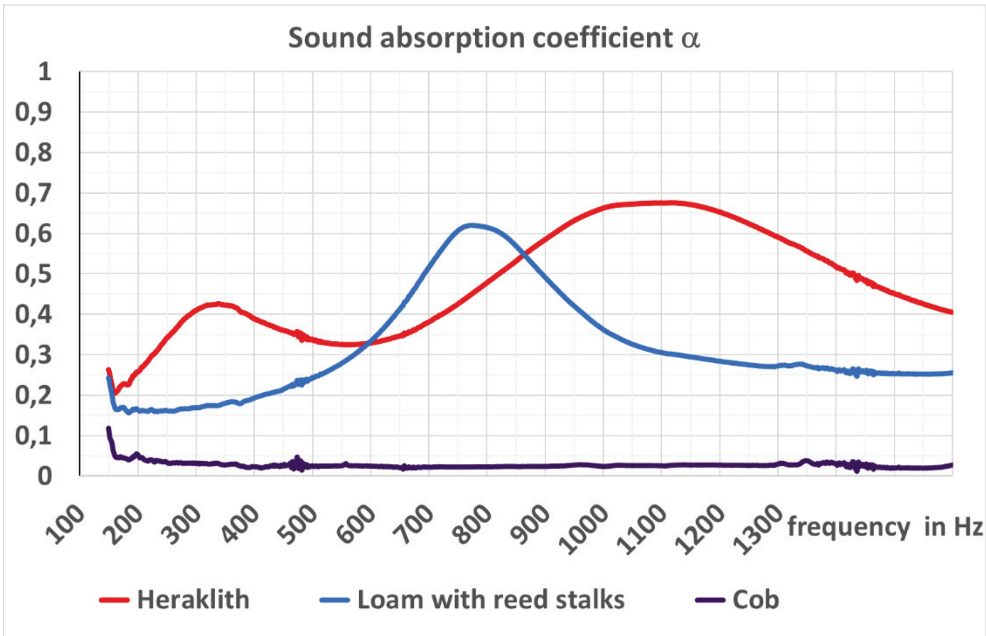

Figure 2: Sound absorption coefficients of cob, cob with Heraklith and loam with reed stalks measured in an impedance measuring tube.

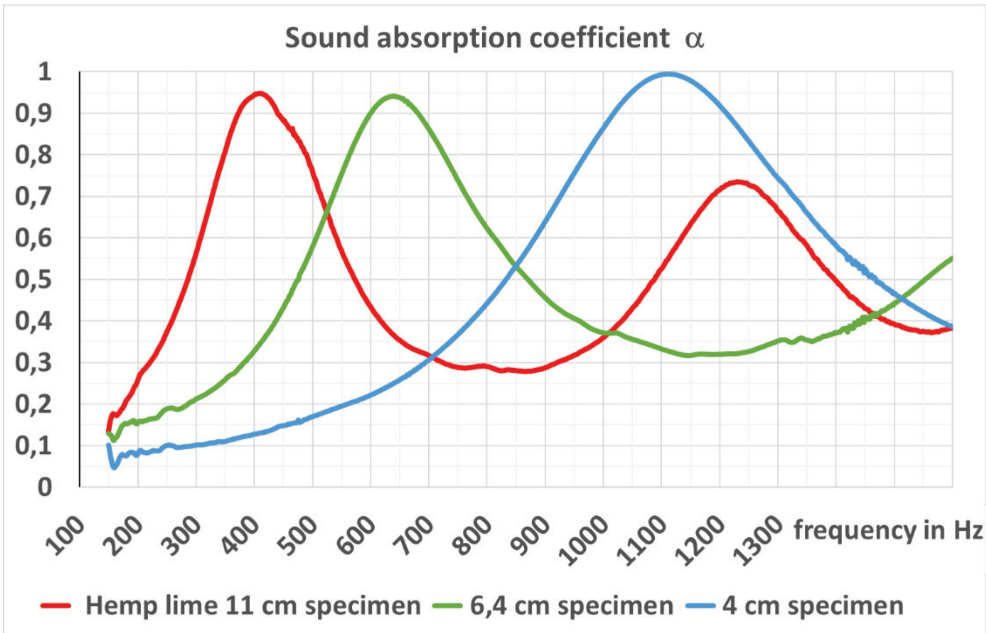

Figure 3: Sound absorption coefficient of hemp lime of different thickness (11 cm, 6.4 cm and 4 cm).

Figure 3 shows the absorption curves of hemp lime specimen. Starting with an 11 cm high sample (red), this was divided into a 6.4 cm (green) and a 4 cm (blue) sample to adjust the absorption maximum. The 11 cm specimen shows its absorption maximum of 0.95 at 300 Hz. For the lower samples, a clear shift of the absorption maximum of also 0.95 for the 6.4 cm sample to about 650 Hz and for the 4 cm sample to about 1100 Hz can be seen.

4 Conclusions

After the initial poor absorption values of samples made of cob or stamped loam, significant improvements could be achieved by incorporating reed stalks, integrating Heraklith and using hemp lime. The findings of the first series of measurements are now being used to produce new test specimens, which are to run through a further optimisation process.

Further improvements in the absorption behaviour are to be achieved through variations in the mixture composition and in the absorption layer thickness. Here, the phenomenological model according to Hamet [5] might be used for optimisation. According to Hamet, the shape factor, porosity, flow resistance and depth of a material determine the position and characteristics of the absorption maxima. The flow resistance, the form factor and the sample thickness have a main influence on the position of the maxima. Halving the sample thickness, for example, shifts a maximum to twice the frequency. The porosity in turn has an influence on the height and width of the maxima. These parameters can be used to optimise the adaptation to the traffic noise spectrum.

The aim is to achieve a highly absorbent surface structure in terms of acoustics and thus create the possibility of sustainable noise protection.

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