A NEW SOUND ABSORBING LIGHTWEIGHT CONCRETE MASONRY BLOCK

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ABSTRACT

The purpose of this paper is to present an innovative design approach for a sound absorbing lightweight concrete masonry unit made with expanded clay *LECA®*. This new type of block is presented and acoustically characterized.

This block is especially suited for sound control in critical listening or performance spaces as well for noise control in noisy environments like industrial areas, power transformers substations, sound barriers, etc.

The block measures 200x200x500 mm^3 and weights about 13.8 kg. Its design and weight allows easy placement. Two options were tested: with and without fiberglass inserts (installed at the block plant) in the unit's Helmholtz resonators chambers.

The sound absorption results obtained in the I.D.I.T.'s reverberant chamber using ISO 354 are presented. Sound absorption coefficients (α) above 0.65 for frequency bands between 200 and 400 Hz were found. Noise Reduction Coefficients (NRC) of 0.61 were calculated.
Keywords: Masonry Block, Acoustics, Helmholtz Resonator, Sound Absorption

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1 INTRODUCTION

Masonry is a common material with low cost, low maintenance, good durability and aesthetics and can be used as an interesting sound absorber.

The use of masonry units as sound absorbers is increasing on interior applications or as sound barriers along roads, to absorb and decrease traffic noise to neighbors [1].

One of the raw materials that can be used in masonry units is the lightweight concrete. Lightweight concrete blocks are a good masonry material because they are lighter and easier to lay than standard concrete blocks. Otherwise they can have good behavior under thermal and mechanical points of view. The suppression of renders or other finishes allows to obtain very interesting architectural solutions.

Under an acoustic point of view there are two different areas of analysis related to its acoustic behavior:

- sound isolation;
- sound absorption.

The sound isolation is fundamentally function of the known *wall mass*. Several studies in different countries allow to say that masonry made with lightweight concrete units, if conveniently plastered to be airtight, has a better behavior than the suggested by the *mass law* [2, 3].

Sound absorption is a different property and is related with the decreasing of sound reflection from a surface. Most lightweight concrete surfaces, if unplastered, have a quite good sound absorption.

Some of the advantages of using lightweight concrete compared with dense materials are the more open texture of the surface, the porosity of the usual lightweight aggregates and its sound absorption.

This paper presents a new sound absorbing lightweight concrete masonry block, made with expanded clay *LECA®* and developed for a lightweight concrete manufacture enterprise.

The adopted approach takes care of the following aspects:

- concrete as raw material;
- acoustic requirements;
- geometric and dimensional requirements;
- mechanical requirements;
- possibility of incorporation of complementary insulation materials;
- laying;
- production technology.

The results of sound absorption data obtained in a reverberant chamber are also presented.

2 PRODUCT CONCEPTION APPROACH

2.1 Concrete

The new absorbing lightweight concrete masonry unit has been developed for a Portuguese manufacture of lightweight concrete products – PAVILECA, S.A., that belongs to the *LECA®* Group. Their goal was to have a masonry absorption block that could be used not only in building walls but also as acoustic barrier in motorways.

The blocks ought to be done with one of the lightweight concrete composition used by the manufacture in their other products. The block ought also to respect some technical constraints in the fabrication process. The principles of mix design for normal and structural concrete are not valid for concrete to be used in blocks manufacturing process, and specially for lightweight concrete. The proportion of fine and very fine particles is important and the inclusion of normal sand is decisive to have enough resistance with low cement content.

It was decided to select the concrete used in current lightweight blocks with the following mix proportions:

- Portland cement - 155 kg/m^3
- Dense fine sand - 0.320 m^3/m^3
- Fine “Leca” aggregate (2/4 mm) - 0.320 m^3/ m^3
- Medium “Leca” aggregate (3/08 mm) - 0.64 m^3/ m^3
- Water - 0.070 m^3/ m^3

The characteristics of this concrete are presented in Table 1.

Table 1 – Characteristics of the lightweight concrete

Dry density (kg/m^3)	**Compressive strength at 28 days** (MPa)	**Modulus of elasticity** (MPa)	**Bending tensile strength at 28 days** (MPa)	**Thermal conductivity** (W/mºC)
1 150	6.0	8 200	1.7	0.43

2.2 Acoustical requirements

This block is thought to be especially suited for sound control in critical listening or performance spaces as well for noise control in noisy environments like industrial areas, power transformer substations, sound barriers, etc.

Two goals were desired for this type of block:

- A high sound absorption in low frequency bands;
- A reasonable sound absorption in medium-high frequency bands.

The first is handled by exploited the resonant sound absorbing principle of the *Helmholtz resonators* chambers. An *Helmholtz Resonator* consists of a connecting orifice and a backing volume in a structure so tuned to absorb sound especially in low frequencies [named after Hermann Ludwig Ferdinand who systematically characterized this system]. The blocks tested have resonant chambers with two different dimensions (see Figures 1 and 2). Two options were tested: with and without fiberglass inserts (installed at the block plant) in the unit's Helmholtz resonators chambers. The two independently tuned and overlapping low frequency resonator chambers have an efficiency of 100% at 200 Hz and a broad resonance bandwidth (125-400 Hz). The large absorption bandwidth is further broadened by inserts of fiberglass positioned behind the slots connecting with the backing volume.

The second goal is achieved by the surface absorption of the material used in the block (lightweight concrete made with expanded clay).

2.3 OTHER REQUIREMENTS

2.3.1 Dimensional requirements

The external dimensions of the units should respect modular co-ordination size principles. In Portugal the current co-ordinations sizes of blocks are:

- 500 mm (length) x 200 mm (height) x e (thickness);
- 400 mm (length) x 200 mm (height) x e (thickness).

Usually the current thickness - ***e*** - of blocks is multiple of 50 mm. The co-ordination size of 500 x 200 x 200 mm^3 has been selected.

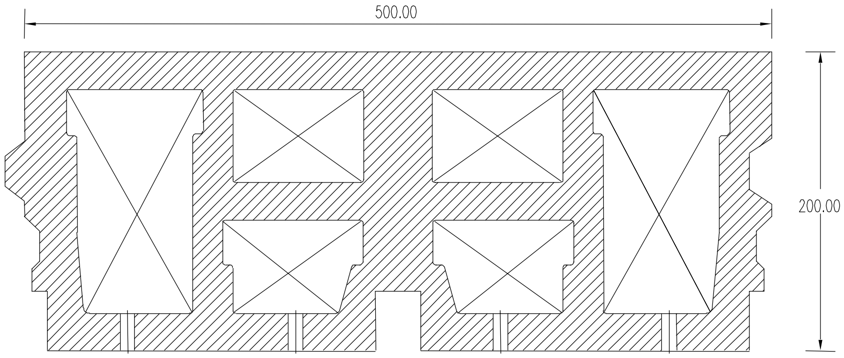
The work size, as the specified dimensions for the manufacture of the unit, is obtained for the co-ordination size reduced of the mortar joints thickness. In this case, as there are only mortar on the horizontal joint, the external dimensions of the blocks are:

- 500 mm (length) x 190 mm (height) x 200 mm (thickness)

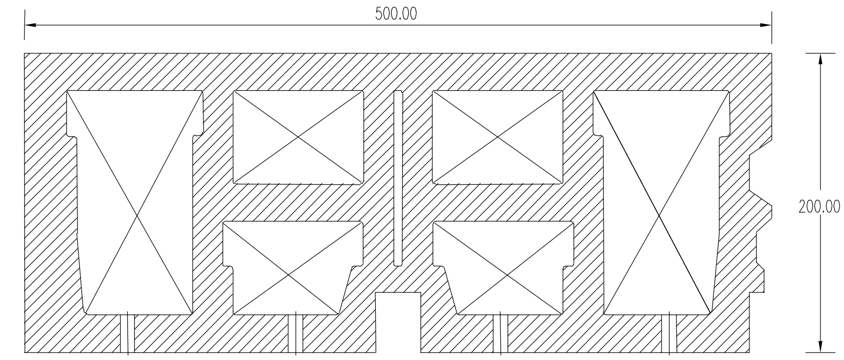
The specified permissible deviations for internal control are:

- 4 mm on length and thickness;
- 5 mm on height.

a) Current Block



b) Special Block



c) Front view

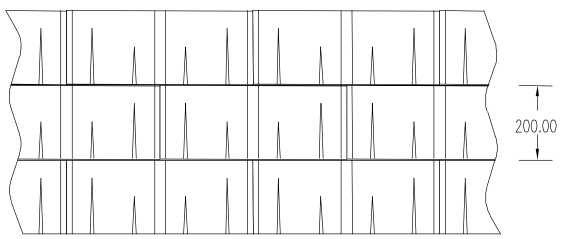


Fig. 1 - Block pattern

2.3.2 Geometric requirements

The standard development of the units regarding its shape considered first the acoustic requirements, but also some normal requirements in modern concrete masonry products.

The horizontal laying face of the block, that receives the mortar on the horizontal joint, is closed, as usual in south European countries.

The vertical ends of current blocks have been designed to be provided of interlocking features to allow a better and quicker laying process. In the production the mold is prepared to make a special block in each five blocks. These blocks have in their central area a long and thin hole that allows to obtain easily half blocks, and have a flat vertical end to realize openings, ends of walls and so on, Figure 2.

Fig. 2 – Photograph of a special block with fiberglass inserts and flat end

The blocks have two different shells. One is normal and equal to normal masonry blocks. The other one has several interruptions related with acoustic resonators and sound absorption. The position of this interruption in the block's face allows that, in running bond laying, all the interruptions that realize the orifices of the *Helmholtz resonators* are vertically aligned.

All the shells and webs have 25 mm thickness to guarantee that, even with the interruption in the acoustic shell, the blocks have yet enough resistance.

In two of the interior chambers recesses have been previewed to locate acoustic fiberglass inserts, with 30 mm, next to the back shell and web, Figure 2.

2.3.3 Mechanical requirements

The lightweight concrete used in the production of these blocks has a low compressive strength. This low value is related with the density of the concrete, the Portland cement content and, fundamentally, with the low resistance of the expanded clay aggregates when compared with another productions of the same aggregate.

Although this kind of blocks is not suited to resistant walls, they must be stable to several actions and have adequate mechanical resistance.

The requirement of the CEN standards concerning mechanical resistance of concrete masonry units has been choosed [4]. The minimum individual value of the compressive strength of the units shall be not less than 1,8 MPa. The compressive strength is expressed as the maximum crushing load of the specimen divided by the apparent external area, corrected by a shape factor that converts the compressive strength to a normalized value.

Another requirement is the need to limit the relative high drying shrinkage of the lightweight masonry blocks. The practical result of shrinkage is the development of dimensional constraints that allows to tensile stresses with cracking results. Is important that drying shrinkage magnitude not exceeds a reasonable value, and to store blocks enough time before laying to ensure that they are almost dry when used. In stock they must be keep out of rain.

The limit of the French standard NF P14-304 [5] concerning to drying shrinkage in conventional situation, 450×10^{-6} m/m, has been established to internal control.

2.3.4 Production technologies requirements

The production of concrete blocks, and particularly lightweight concrete blocks, differ from current structural concrete. The block production is compacted in a different way and requires a "green" strength to be demolded after forming and being handled and transported immediately. The controls of the grading and the quantity of water mix are of vital importance, to the better vibration and compacting.

A high efficiency mixer with volumic control of aggregates and water and weight control of cement is supposed to be used in production. The blocks machine is a stationary one, fully automatic, with high-speed. The machine distributes the fresh concrete into a mould, compact it on a flat pallet ejects the molded block and repeats the cycle.

The fresh blocks on the pallets are automatically transported to curing chambers where they stay some hours air-curing or steam curing depending of the atmospheric temperature. After curing on the chambers the blocks are packed and stored for complementary curing.

2.4 PERFORMANCE

2.4.1 Acoustical performance

The sound absorption results obtained in the I.D.I.T.'s reverberant chamber (*Instituto de Desenvolvimento e Inovação Industrial* at Stª M. da Feira with a volume of 318 m^3) using ISO 354 (or EN 20354) are presented in Table 2 and Figure 3.

Sound absorption coefficients (α) above 0.65 for frequency bands between 200 and 400 Hz were found. Noise Reduction Coefficients (NRC) of 0.61 was calculated.

The blocks behave as Helmholtz resonators for the frequency bands between 160 and 400 Hz in reasonable agreement with the predicted by analytical models. The block type 1 – with fiber glass inserts - has a slight advantage compared with block type 0 – without fiberglass inserts - regarding the sound absorption coefficients in low frequency bands (between 100 Hz and 200 Hz) and in medium frequency bands (between 630 Hz and 1600 Hz). An excellent increase of α (about 0.22) was found for the frequency bands of 125 Hz and 160 Hz. However a slight decrease ($\Delta\alpha$=0.04) was found in the frequency band of 400 Hz.

Table 2 - Sound absorption coefficients

Frequency (Hz)	***100***	***125***	***160***	***200***	***250***	***315***	***400***	***500***	***630***
block type 0	0.19	0.23	0.45	1.04	0.94	0.85	0.73	0.55	0.43
block type 1	0.20	0.47	0.65	1.04	0.93	0.85	0.54	0.47	0.48
$\Delta\alpha$	0.01	0.24	0.20	0	-0.01	-0.04	-0.01	-0.01	0.04
Frequency (Hz)	***800***	***1000***	***1250***	***1600***	***2000***	***2500***	***3150***	***4000***	***5000***
block type 0	0.38	0.49	0.51	0.51	0.46	0.43	0.37	0.35	0.45
block type 1	0.48	0.51	0.53	0.52	0.46	0.43	0.36	0.36	0.44
$\Delta\alpha$	0.10	0.02	0.02	0.01	0	0	-0.01	0.01	-0.01

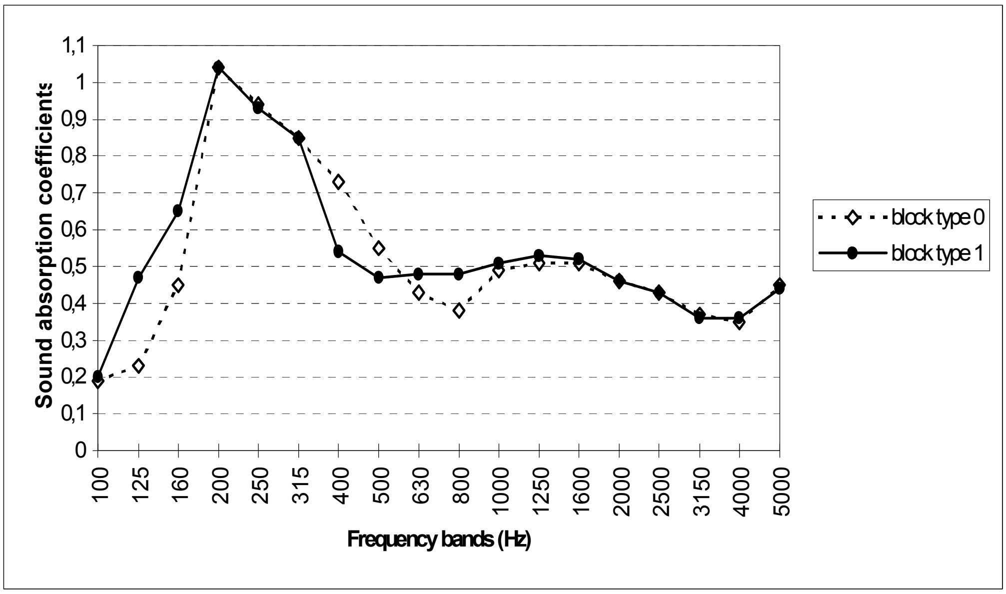


Fig. 3 – Spectral comparative data for the sound absorption coefficients for the two blocks

2.4.2 Production and product performance

Some experimental production of these blocks has been made with the referred lightweight concrete mix.

The weight of the blocks is almost 13,8 kg. Some problems arrived in the production; an important quantity of "green" blocks would break on the pallet when demolded. The production cycle has been enlarged from 26 s to 30 s and this problem almost disappeared.

The feasibility of the fiber inserts has also been tested. Small panels of fiberglass with the required dimensions have been cut and hand placed in the packing process, when the blocks come out from the curing chambers.

Some tests have been carried out with these experimental blocks. The dimensions of the blocks are within the expected deviations. The mean compressive strength of the blocks tested is about 2 MPa. Some experimental walls have been made with a general site mixed mortar used in masonry works – 1:4 cement: sand (by volume) mortar – and no difficulties have occurred.

3 REFERENCES

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