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ACOUSTIC TESTS ON ORIGINAL CONCRETE AND INERT MIXTURE MATERIALS

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Abstract

In this paper an innovative concrete and inert mixture is proposed to assemble building partition walls. Mixture is made for no-structural light concrete by aggregating concrete with natural and artificial inerts. Pumice, lapillus and rubber are employed as inerts.
A measurement campaign was carried out to evaluate the materials acoustic properties for different samples composition. Experimental tests were realized by an impedance tube: transmission loss was evaluated by a four microphone transfer function method, based on ISO 10534-2. Test results are here reported. Measurements results allows to determine the optimum mixture in term of acoustic properties.

1. INTRODUCTION

In the last years lightweight concrete have attracted a growing attention thanks to their applicative opportunities. These materials are employed both as filling or thermo-insulating concrete and to build bearing, reinforced and pre-compressed constructions. Two different typologies can be identified among these materials: lightweight aggregate structural concretes (LWAC) and lightweight aggregate no-structural concretes. Both typologies are particularly interesting for their properties. In this paper the attention is focused to no-structural lightweight aggregate, made by a mixture between concrete and inerts. Lapillus, pumice and rubber are employed as inerts. A new model is proposed to evaluate transmission loss due to the tested materials by density and air concentration.

2. MEASUREMENT CAMPAIGN

2.1 Normative

A measurement campaign has been carried out to determine transmission loss for different mixtures in order to find out the best composition.

Impedance tube methods were used to evaluate acoustic performances [1].

Acoustic insulation measurements were led by a methodology based on ISO 10534-2. A four microphone transfer function method is used to determine the Transmission Loss (TL) by a two-load method: two successive acquisitions are made for each sample by modifying the characteristics of a tube extremity. Channels phase displacement errors are avoided by a calibration procedure. Signal to noise ratio is kept over 10 dB for each measurement session.

2.2 Measurement method

Test equipment (see Fig. 1) is constituted by:

- Brüel & Kjær PULSE multichannel data acquisition system (model 3560-B-030);
- Brüel & Kjær Impedance tube model 4206;
- Brüel & Kjær amplifier model 7206;
- Brüel & Kjær ¼" microphones model 4187;
- Brüel & Kjær preamplifiers model 2670;
- Brüel & Kjær pistonophone model 4228 ;
- Brüel & Kjær PULSE LabShop (9.0.0.352 version) analysis software.

In figure 1 an arrangement of impedance tube and its measurement line are reported for transmission loss measurements. TL is determined by a two-load method: two successive acquisitions are made for each sample by modifying the characteristics of a tube extremity: a reflective and an absorbing material are installed on a tube terminal for the two acquisitions. This methodology is based on ISO 10534-2.

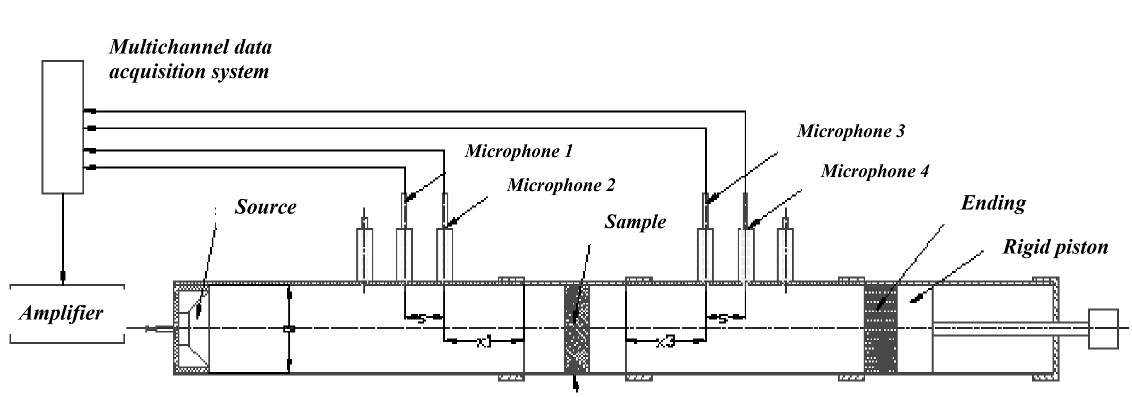

Figure 1. Standing wave tube arrangement and measurement tube line with 4 microphone, employed for transmission loss measurement.

Measurements were carried out on two diameters cylindrical shape samples: 100 mm and 29 mm, which are respectively related for [100, 1600] Hz and [1600, 6400] frequency ranges.

2.3 Samples description and tests execution

Aggregate lightweight concrete is due to low specific density and to high air percentage.

Concrete samples with light inerts are made by mixing concrete with natural and artificial inerts. The inerts show high porosity and low specific mass: pumice, lapillus and rubber are the inerts employed in samples preparation.

Pumice is a volcanic effusive rock formed by a complex natural silicate: pumice looks like a rock with a light color. Pumice is characterized by a cell-like structure with various size pores. Lapillus is originated from volcanic magma crystallization. Structure is tough and cell-like, hollows are very big and irregular. Rubber is obtained by recycling process and it is employed in a lot of applications: in building field rubber is employed as inert, mixing with cement mortar.

Samples mixtures tested in the first part of the study are made by aggregating concrete with a single type inert. Firstly, measurements were carried out on the following samples:

1) AL1: mixture is made by aggregating concrete with lapillus;
2) AP1: mixture is made by aggregating concrete with pumice;
3) AR1: mixture is made by aggregating concrete with rubber.

Four different mixtures samples have been prepared by aggregating concrete with two or three inerts type, in order to find the optimum mixture in term of insulation. Each sample is 10 mm thick and compositions are reported in table 1. The densities of employed concrete, lapillus, pumice and rubber were measured: they are respectively 2896 kg/m^3, 1304 kg/m^3, 851 kg/m^3 and 995 kg/m^3.

Table 1. Samples mixture composition

Sample	***Sample Mixture Composition***				***Mass (Kg/m^2)***
	Concrete	*Lapillus*	*Pumice*	*Rubber*	
AL1	30 %	70 %	-	-	16,40
AP1	30 %	-	70 %	-	13,63
AR1	30 %	-	-	70 %	14,27
ALP1	30 %	35 %	35 %	-	16,05
ALR1	30 %	35 %	-	35 %	15,75
APR1	30 %	-	35 %	35 %	14,65
ALPR1	30 %	23.3 %	23.3 %	23.3 %	15,21

2.4 Measurements results

By observing figs. 2 and 3, mixing percentages seem to strongly influence samples transmission loss.

ALP1 seems to be the best aggregate in term of overall TL although it shows a deep transmission loss dimming at 500 Hz for resonance phenomena.

Sample APR1 transmission loss is lower than ALP1's; anyway resonance frequency is about 400 Hz, which makes this aggregate suitable for low frequency application.

A very interesting consideration may be done comparing the measured TL behaviour to the one given by the theoretical mass law in figs. 2 and 3. For low frequencies, resonance phenomena due to sample composition and aggregation conditions make the experimental TL lower than the mass law TL. For frequencies higher than 1000 Hz, experimental TL is close to theoretical one only for sample ALP1. A TL bottom shifting is shown for the other samples.

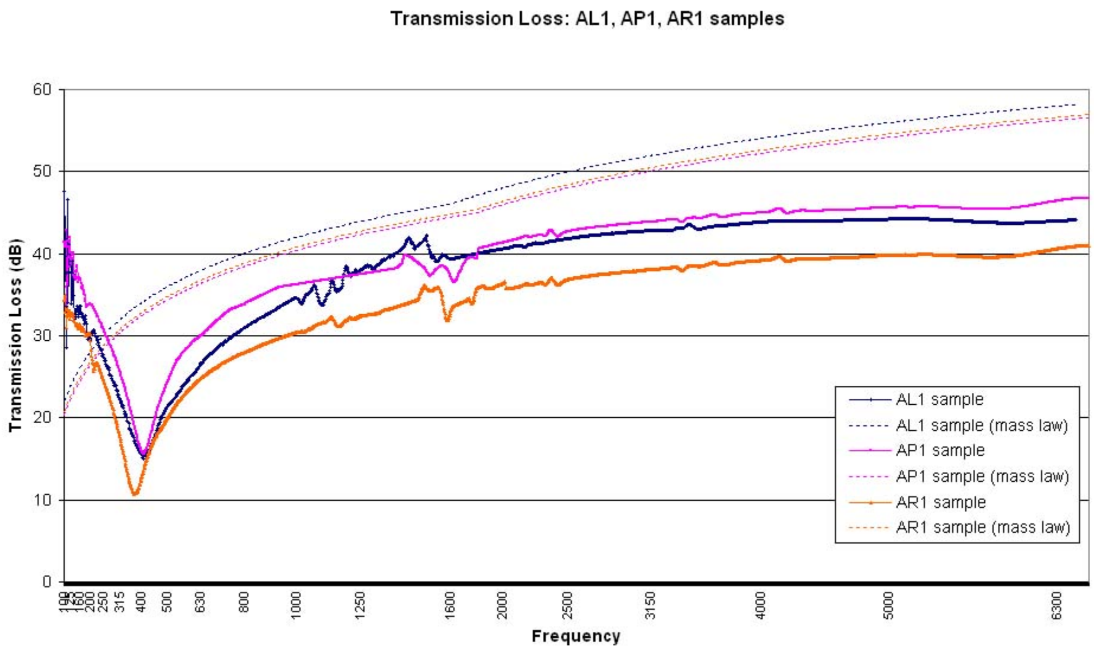

Figure 2. Transmission Loss experimental and theoretical results (mass law): samples AL1, AP1 and AR1.

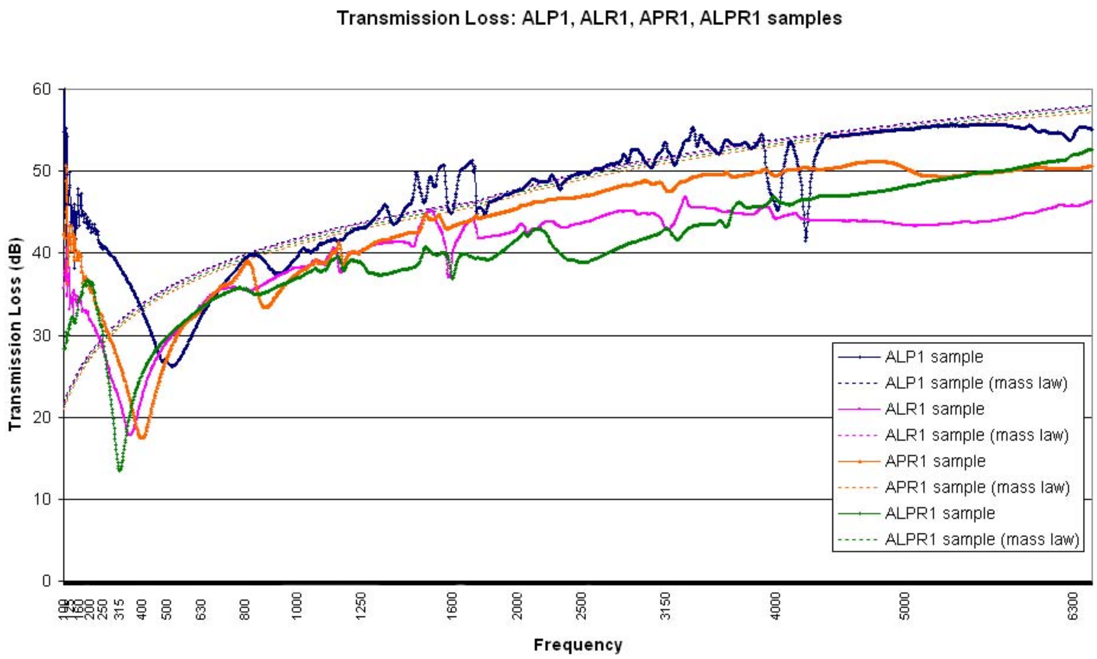

Figure 3. Transmission Loss experimental and theoretical results (mass law): samples ALP1, ALR1, APR1 and ALPR1.

This is due to the sample aggregation process. Air is included into the samples in different concentration; sound paths may be found and TL is lower than the theoretical one. This fact is verified by the samples densities. In Table 2, measured and theoretical densities of the tested samples are reported. The theoretical densities are calculated by Table 1 sample compositions. Theoretical densities are always higher than measured ones. This is due to the air included into the samples. Thus, air concentration was estimated by density data in Table 2. Estimated air concentration data were validated also by a morphologic analysis with a scanning electron microscope. The average difference (ΔTL) in the [1000,6400] Hz frequency range between experimental TL and mass law (ML) one is reported in Table 2. It is shown that ALP1 TL is the closest to the theoretical mass law because this sample is characterized by low air concentration (1.07%). This fact validates the hypothesized reason for which TL is often lower than the theoretical one.

Table 2. measured and theoretical densities, air concentration for the tested samples, measured ΔTL in the [1000,6400] Hz frequency range

Sample	***Measured Density (Kg/m^3)***	***Theoretical Density (Kg/m^3)***	***Air concentration (%)***	***Average measured ΔTL (dB)***
AL1	1640,0	1781,6	6,75	9,56
AP1	1363,1	1464,5	5,42	6,99
AR1	1426,8	1565,3	7,13	12,91
ALP1	1605,0	1623,1	1,07	0,63
ALR1	1575,0	1673,5	5,69	7,79
APR1	1465,0	1514,9	3,85	3,27
ALPR1	1521,0	1602,8	5,41	6,95

A modified mass law relation (MML) for the proposed materials is proposed to evaluate the average TL in the [1000,6400] Hz frequency range for normal incidence:

$$TL_{MML} = AVG_{[1000,\,6400]}(20\log_{10}(f \cdot M_s)) - 42.3 - \Delta TL \quad (dB) \tag{1}$$

where TL_{MML}, AVG, f, M_s and ΔTL are respectively TL given by MML relation in the [1000,6400] Hz frequency range, the average function in the [1000,6400] Hz frequency range, the frequency, the superficial mass and the corrective term introduced by taking into account the air concentration into the proposed materials. ΔTL is given by:

$$\Delta TL = K_1 \cdot x \cdot e^{K_2 \cdot x} \quad (dB) \tag{2}$$

where $K_1 = 35.0$, $K_2 = 22.5$, x is the air concentration.

A comparison among the measured TL, TL given by mass law (ML) and TL given by modified mass law (MML) is reported in Table 3. The comparison shows that the differences between experimental TL and MML TL is always much lower than the one between experimental TL and ML TL. ML and MML data are close only when air concentration is low (for ALP1 sample).

Table 3. comparison between measured and estimated average TL in the [1000,6400] Hz frequency range

Sample	*Average measured TL (dB)*	*Average Estimated TL by mass law (ML) (dB)*	*Average Estimated TL by modified mass law (MML) (dB)*	*Difference between average measured TL and ML TL (dB)*	*Difference between average measured TL and MML TL (dB)*
AL1	42,09	51,65	40,93	-9,56	1,16
AP1	42,96	49,96	43,53	-7	-0,57
AR1	37,45	50,35	37,98	-12,9	-0,53
ALP1	50,75	51,38	50,89	-0,63	-0,14
ALR1	43,42	51,21	43,97	-7,79	-0,55
APR1	47,32	50,28	47,53	-2,96	-0,21
ALPR1	43,96	50,91	44,40	-6,95	-0,44

3. CONCLUSIONS

In this paper acoustic transmission losses of light concrete natural aggregates have been evaluated and optimized. Experimentation was involved to acoustic properties evaluation of lightweight aggregate no-structural concretes. A measurement campaign was carried out to evaluate materials acoustic properties for seven different samples composition and optimum mixture.

Test results show that samples made by aggregating concrete with natural inerts (lapillus and pumice) are characterized by high acoustic properties in terms of transmission loss for all frequencies. Sample ALP1 combines and improves acoustic performances of AL1 and AP1 samples: the mixture made by aggregating concrete with lapillus and pumice is the optimum in term of acoustic properties and it shows a behaviour close to theoretical mass law. APR1 sample has an interesting course too. Samples shows a bottom shifting from theoretical mass law course. Only ALP1 TL is close to the mass law one. This is due to air concentration into the samples which is responsible of resonance phenomena for low frequency range and a bottom shifting with respect to mass law for frequencies higher than 1000 Hz. Thus, a modified mass law relation was proposed and validated to evaluate the average TL in the [1000,6400] Hz frequency range. The new relation takes into account the air concentration into the materials.

Measurements campaign results show that the proposed mixtures can be employed in special uses. The proposed materials may be a good solution also as acoustic insulation material for building applications. Experimentation results can be considered as guidelines for the following researches.

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