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INNOVATIVE AND SUSTAINABLE COATING SYSTEM: PRELIMINARY ACOUSTIC EVALUATION RESULTS

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The research and experimentation described in this study, aim to select an innovative material to be used in the refurbishment of buildings located in densely populated urban areas and / or in areas characterized by noise from transport infrastructures, in order to achieve both a substantial reduction of noise exposure and an improvement in energy efficiency. This applied research provides for the setting up of an analysis and testing laboratory situated in a full-scale building, located in the proximity of the Malpensa airport, where the thermal and acoustic properties of the innovative materials will be checked on site. A preliminary evaluation of acoustic properties of three different materials, selected in conjunction with Lombardy Region, which is the funding body of this research, was carried out in the laboratories of ITC - CNR (Construction Technologies Institute of the National Research Council of Italy) and of Brescia University, which include: airborne sound insulation improvement measured on the same wall as in the Malpensa’s real building; measurement of sound absorption in the reverberation room and in the impedance tube.
Keywords: coating system, sound absorption, sound insulation

1. Introduction

The Lombardy Region (which is the funding body of this research) and the Construction Technologies Institute of the National Research Council of Italy ITC - CNR, cooperate with the aim of jointly developing, by pooling their respective powers and structures, a research for an innovative and sustainable coating material, with high thermal and acoustic characteristics, aimed at the refurbishment of buildings in terms of reduction of the noise pollution from transport infrastructures (e.g. aircraft and road traffic) and reduction of energy consumption.

The material to be selected must meet requirements of modularity and easy application in order to be used on walls and ceilings in rooms of different intended uses.

Furthermore, it shall be possible to apply it in all those situations where it is not possible or not acceptable to use great thicknesses of insulating material on the outside and inside of the buildings; this would allow the refurbishment of the largest number of constructive peculiarities.

The first phase of the activities included the selection of the best materials among those proposed by Italian manufacturers of building materials participating in a specific call.

During the second phase, these materials were subjected to thermal and acoustic laboratory tests.

Finally, the third phase, which is still in progress, consists of the on-site experimentation of the selected products which will be applied to an experimental building located in an area characterized by a high noise pollution.

2. Tested systems

Three different systems were selected in conjunction with Lombardy Region.

Two of them are particular types of mortar with acoustics and thermal properties to be applied on both the internal and external surface of walls, while the third is a lining system with high ~~of~~ sound absorption properties to be applied only on the internal surfaces of rooms.

System A is a premixed cork plaster, composed of natural materials, such as cork, clay, diatomaceous earth and lime, therefore eco-friendly and fit for use in green building and in the restoration of the historical heritage. The product is also referenced in LEED.

System B is a nano-composite plaster based on cellular glass and nano-binders; it uses nano-structured compounds, pure and eco-friendly binders (low CO2 emission binders) and recycled raw materials (cellular glass, inerted fly-ashes). Its fields of application include: specific plaster for inner and outer walls (it can be used in historical buildings and buildings of artistic interest such as churches, historical palaces etc.) and suitable supports for solid, perforated, new and old brick masonries.

System C is a package composed by two linings:

a) material composed of elastomers and mineral fillers coupled with an expanded polyethylene physically reticulated; the elastomeric part is obtained by the partial recycling of the processing waste of the material itself.

b) polyethylene terephthalate (PET) panel coated with exposed fabric; the fiber is obtained by the recycling of common plastic PET bottles without the addition of chemical binders.

3. Airborne sound insulation

The verification of the airborne sound insulation properties of the different systems includes the measurement of the sound reduction index done at the ITC Acoustics Laboratory and the field measurement of the facade sound insulation done at the experimental building.

3.1 Sound reduction index

In order to evaluate the improvement of sound insulation due to the application of the selected systems in the particular case of existing buildings that need refurbishment, the same exact external wall incorporated in the experimental building was used instead of the construction specified in ISO 10140-5 [1] as basic element. This wall is a double wall, consisting of two identical walls separated by a 10 cm air gap. Each of the two walls consists of hollow bricks with vertical hollows and a void percentage less than 45%. To exactly know the brick typology, a core sampler was used to take samples of the cross-section of the building's façade. Fig. 1 shows the brick typology, the wall where the core sampler was used (showing the brick typology) and the installation of the wall in laboratory.

Systems A and B were tested in laboratory first added on the external side (6 cm in thickness), and then adding the material also on the internal side (2 cm in thickness). System C was tested only on the internal side. Before testing these systems, the sound reduction index (R) measurements of the basic wall have been repeated until there were no more changes in the trend of R versus the frequencies of the sample, following a previous study of the authors [2]; the curing time was about a month. For system A and B, the material was installed in laboratory first on the external side (emitting room side), in this case the curing time was about a month. On the internal side (receiving room side) the curing time was shorter, about 2-3 weeks, because the thickness was smaller. In the case of system C, installed only on the receiving room side, as it does not need a curing time, the test was performed after the installation.

Figure 1: From left to right: the brick typology, the wall where the core sampler was used (showing the brick typology) and the installation of the wall in laboratory.

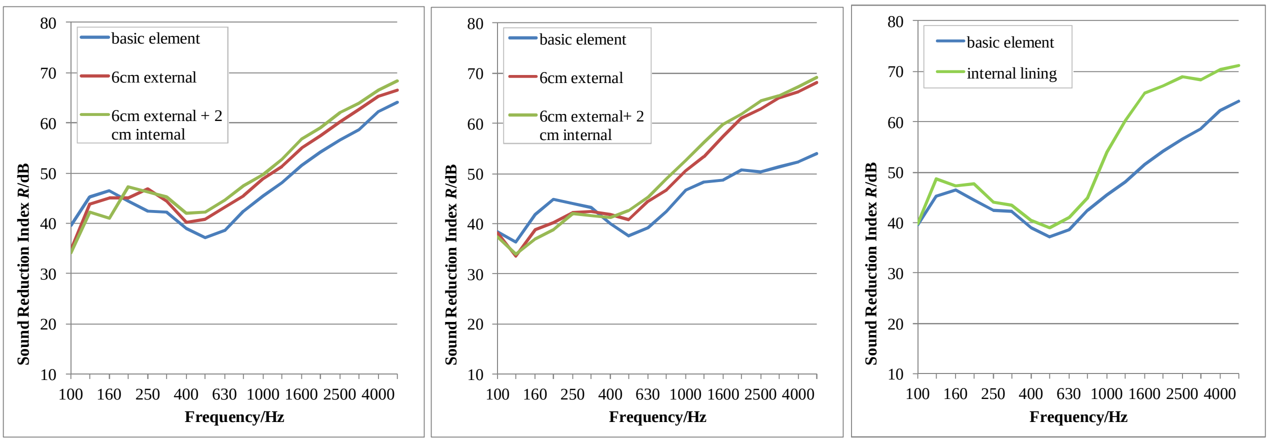

Figure 2:From the left to right: sound reduction index of the basic wall and of the additional linings for systems A, B and C.

Considering the single number quantity (SNQ), that is the weighted sound reduction index R_w, the following considerations can be done: the improvement of sound insulation of systems A and B, due to the installation of the material in the external side is equal to 3 dB in both cases; by adding the additional 2cm in the internal side, the improvement of sound insulation increases by one more dB. It can be observed that the curves of A and B systems are modified by the application of the finish. Since the sound reduction index depends on the bending stiffness of the structure [3] this behaviour may be related to the increase in the bending stiffness introduced by the additional layers. In the case of system C, the improvement due to the application of the system on the receiving room side, is equal to 3 dB. The SNQs are shown in table 1.

Table 1:Weighted sound reduction index, with spectrum adaptation terms of the measured systems.

	System A			System B			System C	
	Basic wall	6cm ext.	6cm ext. +2cm int.	Basic wall	6cm ext.	6cm ext. +2cm int.	Basic wall	int.
R_w	46	49	50	46	49	50	46	49
C	-1	-1	-1		-2	-2	-1	-1
C_{tr}	-1	-3	-4		-4	-5	-3	-3

3.2 Façade sound insulation

The experimental building is located near the Malpensa international airport. Fig. 1 shows the building and the runway.

The experimental building is a typical [4] Northern Italy building of the 60s, made of bricks, with single glazing wooden frame windows, without any particular kind of acoustic performances, that needs refurbishment.

Figure 3:Experimental building (red) and runway.

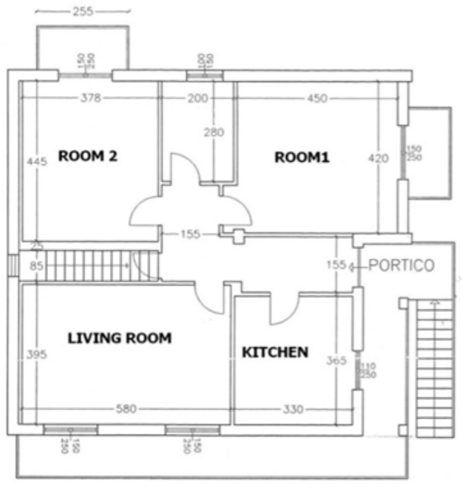

Figure 4:Plan of the experimental building.

The standardized level differences $D_{ls,2m,nT}$ of all the rooms of the experimental building (see fig. 2) are shown in Fig. 3, while the weighted standardized level differences $D_{ls,2m,nT,w}$ and the relative spectrum adaptation terms C and C_{tr} are given in Table 1.

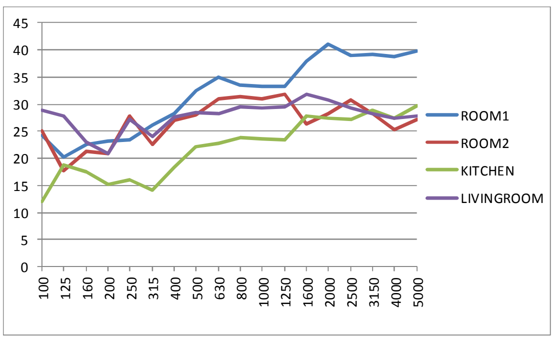

Figure 5:$D_{ls,2m,nT}$ of the rooms of the building.

Table 2:$D_{ls,2m,nT,w}$, C and $C_{tr}$of the rooms of the building

	Room1	Room2	Kitchen	Living room
$D_{ls,2m,nT,w}$	34	29	24	29
C	-1	-1	-1	0
C_{tr}	-4	-2	-3	-1

This is an initial evaluation of the experimental building before the application of the materials under test, aimed to evaluate the improvement due to the materials.

4. Sound absorption

The verification of the properties of the different systems was done in ITC (reverberant rooms) and Brescia University (impedance tube) laboratories.

4.1.1 Reverberant Room

Figure 6: From the left to right: laboratory measurements of sound absorption in reverberant room for systems A, B (with finish) and C.

System A and system B were measured in a reverberant room in two thicknesses: 6 cm, corresponding to the external cladding and 2 cm corresponding to the internal lining. Moreover the samples were also tested with finish on the absorbing side.

Results, in terms of sound absorption coefficient (α_p) and weighted sound absorption coefficient (α_w), are shown below.

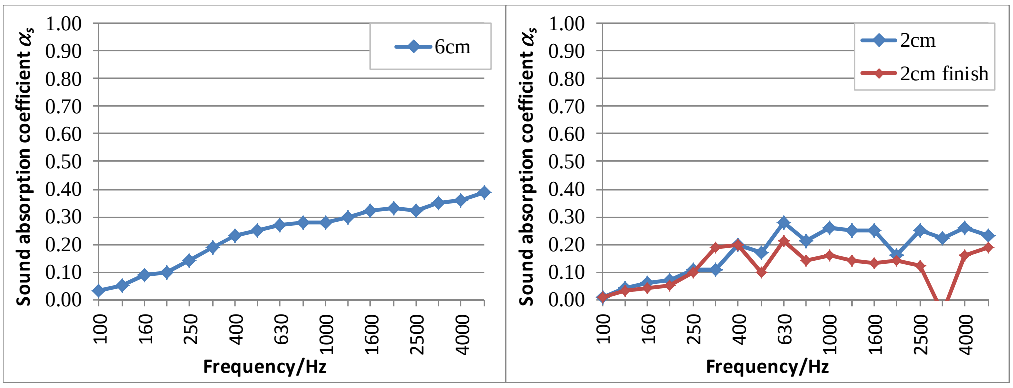

Figure 7:System A. Left: sound absorption coefficient of 6cm; right: sound absorption coefficient of 2cm with and without finish.

Table 3:System A α_w.

Sample	α_w
6cm	0.30
2cm	0.25
2cm finish	0.15

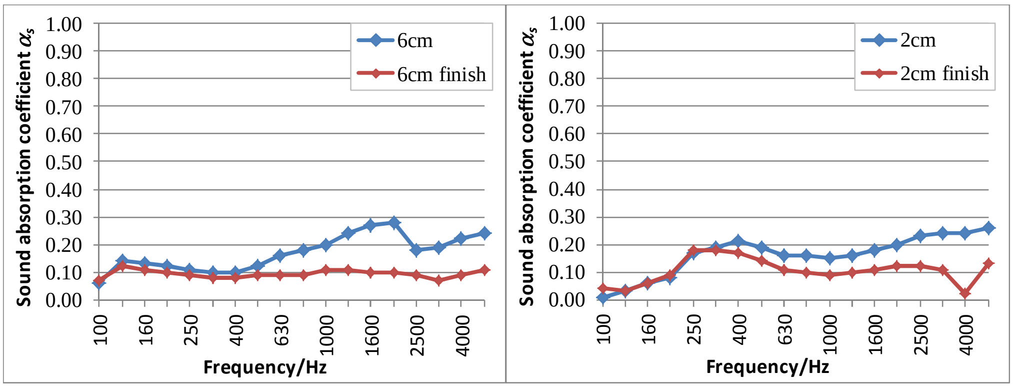

Table 4:System B α_w.

Sample	α_w
6cm	0.20
6cm finish	0.10
2cm	0.20
2cm finish	0.15

Figure 8:System B. Left: sound absorption coefficient of 6cm, 6cm with finish; right: sound absorption coefficient of 2cm with and without finish.

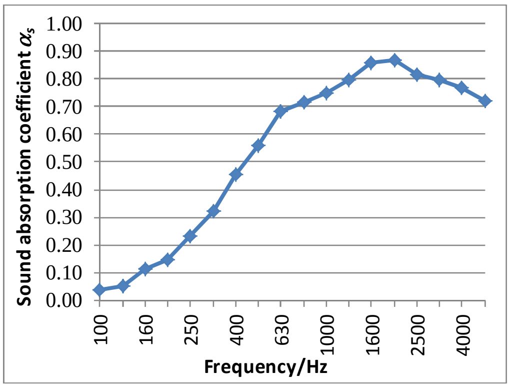

Table 5:System C α_w.

Sample	α_w
System C	0.55(H)

Figure 9:System C. sound absorption coefficient

4.1.2 Impedance tube

The same kind of materials tested in the reverberant room have been tested also by using a BSWA SW260 impedance tube. The specimens tested have a diameter of 60 mm. The thicknesses tested are the same used for the measurements in the reverberant room. The test signal used is a sine sweep from 30 Hz to 3300 Hz, with a duration of 30 s. The sweep has been recorded by using two BSWA 1/4’’ MPA416 microphones, which have excellent phase matches and are ideal for impedance applications, connected to an OROS OR36 analyser. The .wav files have been then post processed computing the impulse response after convolving them with the inverse filter, deriving the transfer functions and applying the procedure described in standard ISO 10534-2 [5]. The results of the measurements are reported in Figs. 10-12.

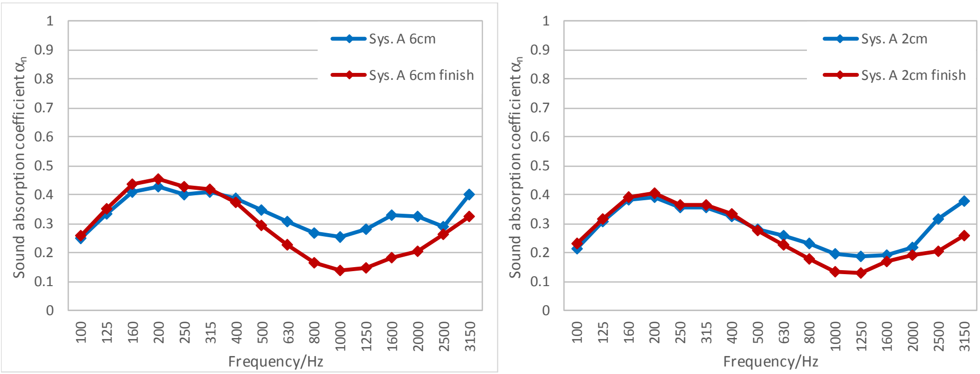

Figure 10:System A. Sound absorption coefficient for normal incidence with and without finish for 6cm (left) and 2cm (right).

Table 6:System A α_w.

Sample	α_w
6cm	0.34
6cm finish	0.23
2cm	0.27
2cm finish	0.22

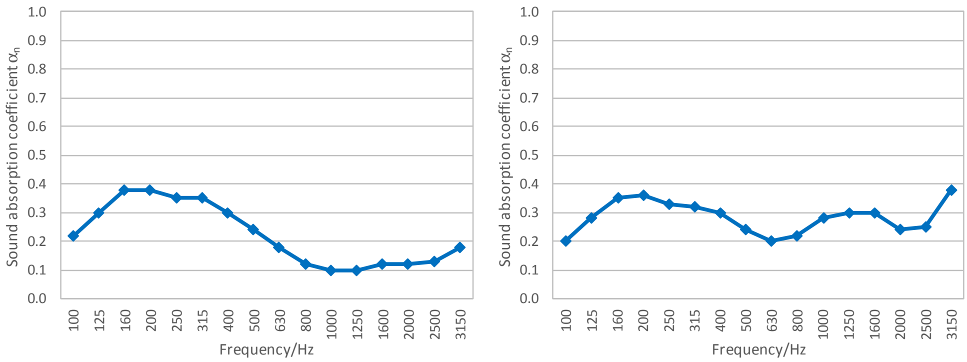

Figure 11:System B. Sound absorption coefficient for normal incidence for 6cm (left) and 2cm (right).

Table 7:System Bα_w.

Sample	α_w
6cm	0.18
2cm	0.29

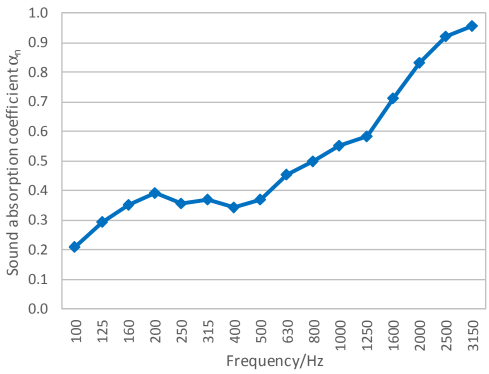

Figure 12:System C. Sound absorption coefficient.

Table 8:System C α_w.

Sample	α_w
System C	0.49

It can be noted that the sound absorption coefficient values obtained in the impedance tube differ from the results obtained in reverberation room for the same material. As pointed out in [6], the reasons may include the different incidence of the sound on the samples in the two cases, and the stiffness of the sample tested in the impedance tube causing extra losses and an overestimation of the material absorption properties.

5. Conclusions

The research and experimentation described in this study, was aimed to select an innovative material to be used in the refurbishment of buildings located in densely populated urban areas and / or in areas characterized by noise from transport infrastructures. Three systems were selected by Lombardy Region in conjunction with ITC/CNR. The sound reduction index of these systems was analysed and it was found that the improvement of sound insulation of systems A and B, is equal to 4 dB installed both on external and internal side of the basic wall; while the improvement of sound insulation of system C, installed only on the internal side, is equal to 3 dB. Moreover, it was found that the basic wall curves are modified by the application of both systems A and B. This behaviour may be related to the increase in the bending stiffness introduced by the additional layers.

Preliminary measurements of façade sound insulation of the experimental building, near the Malpensa airport, were performed in order to verify the sound insulation improvement in real conditions.

The sound absorption of the three systems was measured both in the reverberation room and with impedance tube and a preliminary analysis of the differences was carried out. It was found that the results of the two methods differ significantly, with the impedance tube tests overestimating the sound absorption coefficient for rigid samples (systems A and B) with respect to reverberant room measurements, though they both point out a decrease in the absorption coefficient after the application of the finishing.

These are early reported observations and further work will be carried out on this data, and on the scheduled measurements on the experimental building.

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