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# A more environmentally conscious design of passive solar buildings: the role of acoustical insulation with reference to traffic noise

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*Abstract*

In the past, passive solar buildings were specifically designed with respect to energy and thermal comfort requirements. Within this framework a façade able to collect sola energy and bring indoor suitable conditions for occupants was thought of as an optimal building device. On the contrary, little attention was paid to their acoustic behaviour.

In general, a high value of the overall thermal trasmittance is applied to a solar wall; if, particularly, this feature is combined with high values of surface density, with the aim of guaranteeing appreciable delays of heat transfe (like in storage walls), the wall generally assures a high level of noise insulation as well.

Nowadays technicians are becoming more and more interested in this feature in order to increase the spreading of the use of solar buildings in urban areas: a storage wall, in fact, besides capturing great amounts of solar energy, can also reduce the rising level of external noise (particularly due to the traffic of transportation systems) that enter dwellings causing annoyance to people.

Nevertheless, it should be noted that if storage walls are combined with large glazed surfaces, they reduce their acoustic properties g eatly.

Moreover, if the passive element is totally represented by a glazed surface, such as a greenhouse, the high value of its transmittance is combined with a low value of its surface density, obtaining fast heat transfer, but poor sound insulation.

This evidence makes it necessary to describe the physical behaviour of a passive element both from a thermal and an acoustic point of view.

Of course, such a description should be effected for every building module. In fact, due to the little attention paid to the comprehensive problem in the or ginal design, buildings greatly modified to overcome acoustic problems are becoming widespread in urban a eas.

In this paper some guidelines will be proposed for a method which is able to evaluate the above-cited characteristics in passive sola buildings, compared to conventional buildings, in order to maintain indoor comfort conditions. It would represent an effective procedure for a more environmentally conscious design of solar buildings within urban areas.

## INTRODUCTION

Most researches concerning indoor environments are generally focused on the impact that the specific aspects of comfort, such as thermal or acoustic, visual, etc. have on people.

At the beginning, in the design of private or commercial buildings, very much attention was paid to energy demand control through an analysis of their thermal behaviour, with special attention focused on free heat contributions, especially solar radiation.

Within this framework, nowadays passive solar systems are becoming particularly important, as they represent design elements able to capture great amounts of solar energy.

Lately, an increasing interest has been noticed in the evaluation of thermal comfort level for the occupants.

On the contrary, the sound insulation of buildings has not been properly taken care of, although the comfort sensations of the occupants are highly affected by indoor sound level.

But the rising level of external noise (particularly due to the traffic of transportation systems) that, especially in urban areas, enter dwellings causing annoyance to people, represents one of the most important problems affecting the quality of indoor environments.

In order to face the problem, at present, countries are issuing new rules aimed at reducing noise levels introduced in indoor environments from outside.

Actually, in indoor environments, people are simultaneously exposed to different environmental situations and, as a consequence, comfort conditions depend on combinations of different parameters.

Interventions aimed to reduce one cause of discomfort may increase other types of discomfort.

Table 1. Values of the overall thermal transmittance U and of the airborne insulation evaluation index Rw for different materials used in building.

| Material | Thickness (mm) | Surface mass ($kg/m^2$) | Transmittance ($W/m^2K$) | Airborne insulation evaluation index (dB) |
|---|---|---|---|---|
| Concrete | 160 | 250 | 2.704 | 51.5 |
| Concrete blocks | 100 | 160 | 3.089 | 32.0 |
| Concrete blocks with plaster | 15 + 120 + 15 | 180 | 2.026 | 48.0 |
| Hollowed bricks | 300 | 70 | 0.981 | 27.5 |
| Hollowed bricks with mortar and cement plaster | 15 + 300 + 15 | 110 | 0.945 | 40.5 |
| Plywood | 40 | 24 | 1.987 | 31.5 |
| Single glass | 3 | 7.5 | 5.785 | 28.0 |
| Single glass | 8 | 20 | 5.622 | 31.0 |
| Double glass with air interface | 6 + 12 + 6 | 30 | 2.763 | 30.0 |

This evidence suggests for close links in the design procedures for indoor and outdoor environments, in order to maintain people's quality of life within comfortable ranges.

## METHODOLOGY OF ANALYSIS

The façades of buildings act as a defence from heat/cold and sound from outdoors and allow, through their openable surfaces, suitable air changes and lighting indoors.

It is therefore of primary importance to describe the physical behaviour of a building element, particularly a solar passive one, with respect to the different environmental aspects that affect indoor comfort conditions.

In order to supply overall information on a building element, we propose to describe its behaviour by adopting at least two parameters, that is by adding to its widely-used overall thermal trasmittance U, a coefficient regarding sound transmission (i.e. the "airborne insulation evaluation index" Rw [1]). Such an index represents an average value of the airborne sound insulation, weighed on the whole range of involved frequencies.

Besides, as sound level entering dwellings, along with air flows and lighting, is particularly linked to the extension of glazed surfaces, further information can be obtained by analysing the characteristics of the whole compound wall, made up by both opaque and glazed surfaces, as a function of the ratio between the glazed wall and its total surface, that is when such ratio varies from 0 to 1.

Particularly, the acoustical behaviour of such compound wall can be defined in a quantitative way by evaluating the different levels of traffic noise transmitted as a function of the percentage of the glazed surface.

The analysis procedure here proposed has been applied to different building walls, both conventional and solar passive, in the hypothesis that their facing surfaces border with the external environment (say, a south-facing wall). Graphs allowing a comparative analysis of different design configurations for buildings are produced.

## ANALYSIS OF THE DATA

In Table 1 the values of U and Rw for different materials used in building, including different types of glass, are reported. It can be noticed that different combinations of materials and of their thicknesses can be used in different situations.

For instance, a hollowed brick wall, which can guarantee low heat transmission, whether plasterboarded or not, in the latter case shows poor sound insulation.

In general light materials, with low surface mass values, such as ply-wood, show poor sound insulation.

On the contrary, materials with high surface mass values, such as concrete, commonly used in particular types of passive solar elements (i.e. storage walls) show high thermal transmittance and high sound insulation.

This evidence should lead to a more wide-spread use of such building elements, which are not well known at the moment.

Glazed elements show a different behaviour: a large glazed surface allows for easy capture of solar energy, but also of sound. Therefore particular care of sound transmission should be taken when adopting passive glazed elements such as greenhouses.

In Table 2, a synthetic classification is reported of both thermal and acoustic performances of some types of walls among the most widespread used in building.

The role played by the percentage of glazed surface is important in determining the physical characteristics of a wall, whether solar passive or not, and it is of primary importance in determining the air changes and lighting characteristics.

Hence, referring to different types of walls (See Table 3), their thermal and acoustic performances are analysed. For each kind of element, the values of both the U transmittance and the Rw index have been calculated varying the percentage of glazed surface of the wall. The values referred to the direct gain wall have been evaluated as a particular case for both conventional and storage walls with a glazed percentage equal to 100% (See Figure 1).

As it can be easily seen, the behaviour of the values of U and Rw as a function of the percentage of glazed surface show opposite trends.

In addition, such a graph allows to obtain a direct, quantitative evaluation of the effects produced by different design solutions, characterized by the values of four parameters that mostly concur to determine the total comfort of an environment.

In details, the effects on thermal comfort can be evaluated by analysing the values of the overall thermal transmittance and solar heat gain entering windows (the latter is linked to the percentage of glazed surface), those on the acoustic indoor levels by analysing the values of the airborne insulation evaluation index, those on lighting and natural ventilation (affecting indoor air quality conditions) by analysing the percentage of glazed surfaces.

A suitable choice of the values of U, Rw and of the ratio between the glazed wall and its total surface should guarantee the best indoor environmental conditions.

Further information on the acoustic performances of the walls reported in Table 3 was obtained by analysing their behaviour with respect to traffic noise. The spectral diagram of such noise is reported in Figure 2; a percentage of heavy trucks equal to 15% of the total number of vehicles was chosen.

Table 2. Classification of the thermal and acoustic performances of different types of wall.

| | Conventional wall | Direct gain wall | Storage wall |
|---|---|---|---|
| Achieved energy saving | NOT[1] | YES | YES |
| Achieved acoustical performances | NOT[2] | NOT | YES |

[1] Only when thermally insulated
[2] Only when acoustical insulated

Table 3. Description of the different types of wall used in the analysis.

| Type of wall | Thickness (mm) |
|---|---|
| **Conventional wall:** hollowed bricks with mortar and cement plaster | 330 |
| **Direct gain wall:** Single glass | 3 |
| **Storage wall:** Concrete | 160 |

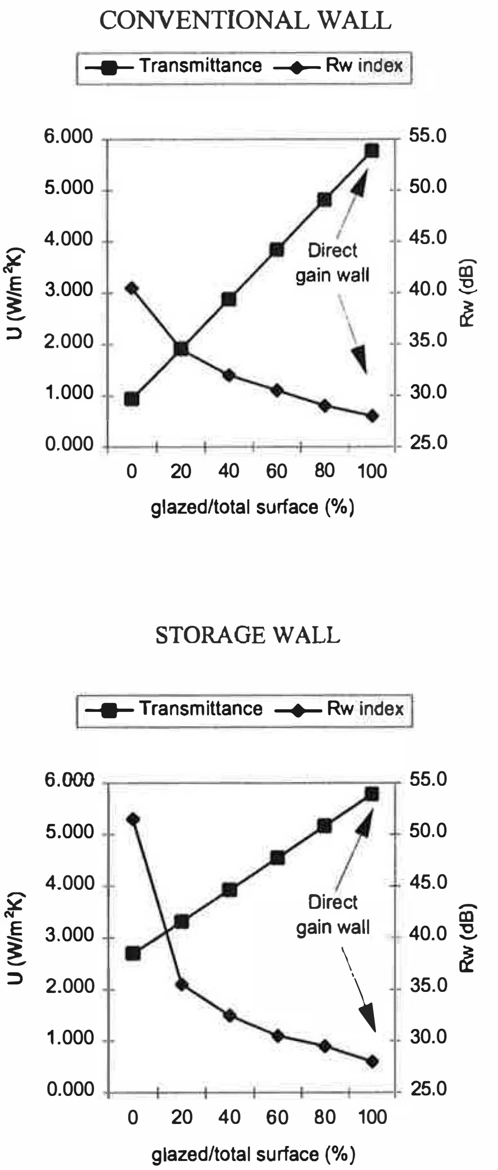


Figure 1. Values of the overall thermal transmittance and of the airborne insulation evaluation index of a wall as a function of the percentage of glazed surface.

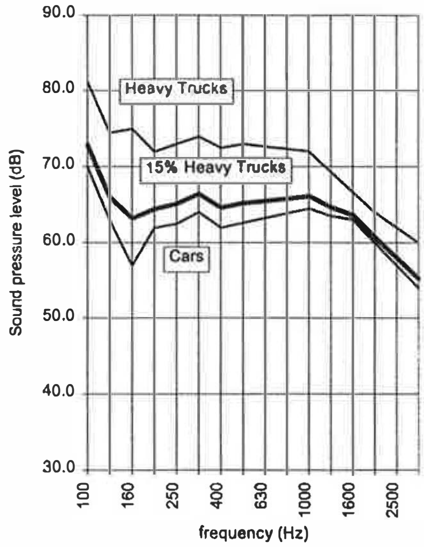


Figure 2. Typical spectrum of traffic noise due to transportation system.

The corresponding indoor noise levels, referred to the whole range of frequencies, have been assessed, as a function of the percentage of the glazed surface, by means of the following equation [2]:

$$L_{P,out} - L_{P,in} = R - 10 \log (S/A)$$

where R represents the value of the airborne sound insulation of the involved compound wall, S its surface and A the acoustic absorptance of the indoor environment, which has been supposed to measure 4m x 5m x 3m. In Figure 3 such levels have been reported as a function of the percentage of glazed surface.

Moreover, both the outdoor equivalent level and the corresponding indoor ones have been calculated as "A" weighed values over the whole range of frequencies and are reported in Figure 4.

As it can be easily seen, starting from an outdoor equivalent level of 74 dB(A), the difference between the levels transmitted by the most insulating wall (storage wall) and the most transmitting one (greenhouse) is 22 dB(A).

## CONCLUSIVE CONSIDERATIONS

The little attention paid to the acoustical features in the original design can require later modifications to buildings in order to overcome indoor acoustic problems.

With this aim in mind, some guidelines have been proposed throughout the paper for a method which is able to take into consideration both the thermal and acoustic aspects in the design of buildings, particularly referring to the passive solar ones. The method would lead to a more environmentally conscious design of solar buildings within urban areas.

The analysis procedure has been applied to the case of different building walls, both conventional and solar passive, with the hypothesis that their facing surfaces border with the external environment.

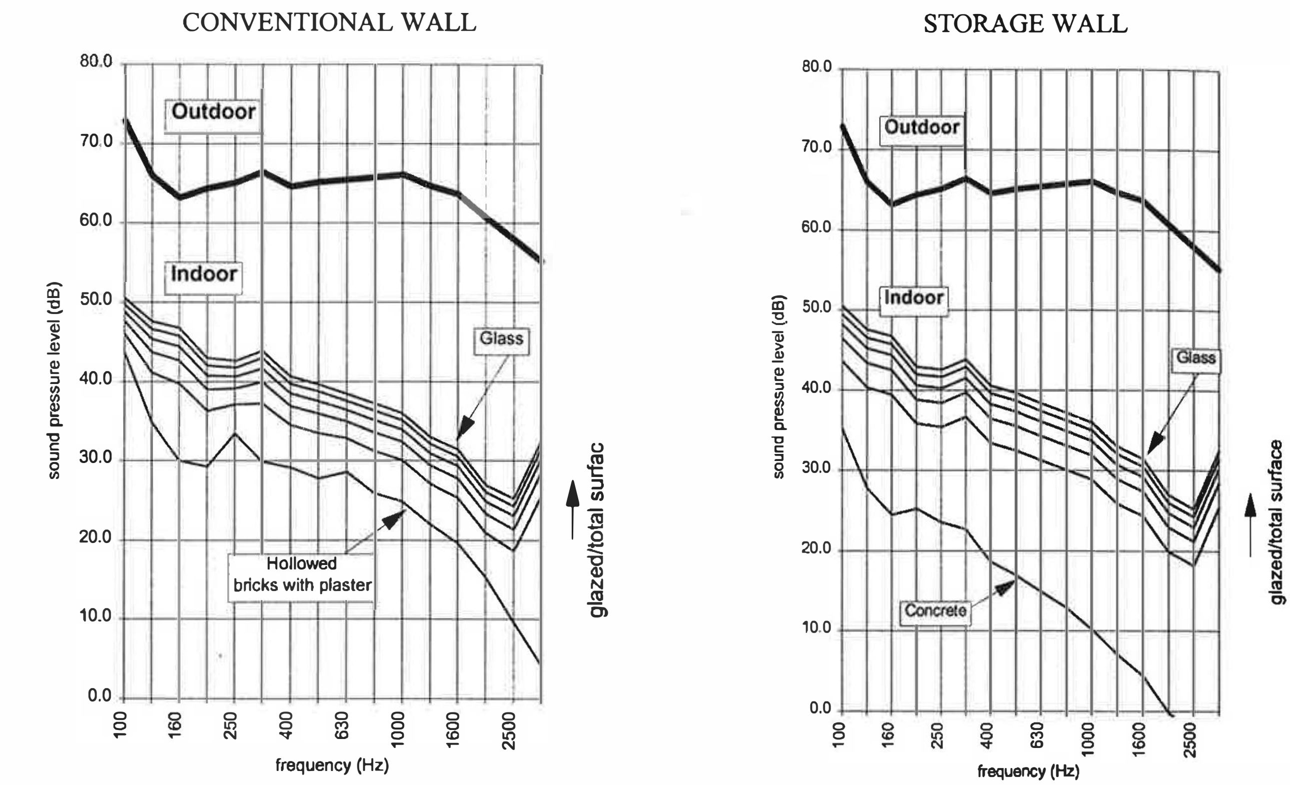


Figure 3. Spectral diagram of traffic noise and corresponding indoor spectra as a function of the percentage of glazed surface.

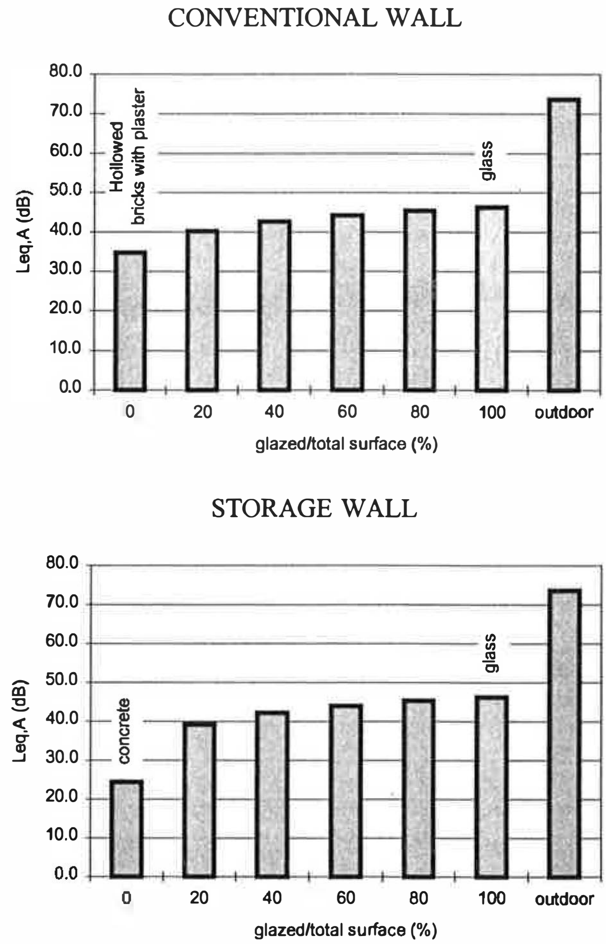


Figure 4. Outdoor equivalent levels and corresponding indoor ones as a function of the percentage of glazed surface.

In order to supply overall information on the building elements, we have described their behaviour by adopting two parameters, that is by adding to their widely-used overall thermal trasmittance U, a coefficient regarding sound transmission (i.e. the "airborne insulation evaluation index" Rw).

Besides, as the role played by the percentage of glazed surface is important in determining the physical characteristics of a wall, whether solar passive or not, and it is of primary importance in determining the air changes and lighting characteristics, we have analysed the characteristics of the compound walls, made up by both opaque and glazed surfaces, as a function of the ratios between the glazed wall and its total surface, obtaining further information.

In addition, the acoustic performances of the different types of walls have been assessed by analysing their behaviour with respect to traffic noise, evaluating the different levels transmitted as a function of the percentage of glazed surface. It can be observed that the difference between the levels transmitted by the most insulating wall (storage wall) and the most transmitting one (greenhouse) is 22 dB(A).

A special recommendation of this paper is that particular attention should be paid to the planning of the building in the early phase, so that thermophysical and acoustic requirements are taken into account at the same time in order to obtain general comfort conditions for occupants.

## REFERENCES

1. UNI 8270/7, 'Rating of sound insulation in buildings and of buildings elements' (UNI, 1987)
2. E. Cirillo, 'Acustica Applicata', ed. McGraw Hill, 1997.