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Sound insulation of gypsum board in practice

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Abstract The use of gypsum board is spread all over the world. In Brazil, its use in the building industry is quite recent and it has been used intensively for less than ten years. Manufactures highlight many of its positive aspects but users are still reticent and even have some complains, especially concerning its sound insulation ability. This is an important issue: despite the fact that gypsum board has low surface density, it may reach more than reasonable sound insulation performance. It can be even better than masonry walls, when used multi layers configurations together with fibre material infill. Unfortunately, in Brazil, practical limitations has been downsizing the insulation capacity of these light partitions and careless execution does not allow their full potential to be achieved. This paper presents a comparative analysis between theory and practice of the sound insulation of internal gypsum board partitions used in Brazil. Firstly, a theoretical modelling of the sound insulation performance of the element is presented. Secondly, possible reasons for their poor performance in this country are discussed and finally, the in situ conditions are investigated. Differences in theory and practice are discussed as well.

1. INTRODUCTION

Building engineering has been presenting significant development in recent years regarding materials, techniques and methods used. Nowadays, most companies are employing novel ways of production and there is a general concern regarding the quality of rooms [1]. Together with the latter, other matters have been considered as one of the most important, i.e. economical issues. Low implementation and maintenance costs, as well as the length of time spent in the whole process are important aspects considered.

On the other hand, buyers are concerned with the quality of the "product", that is to say, their apartment, house or commercial room. It has been common sense that the majority of buildings do not offer some of important requisites of performance and the consequence is the so-called "sick" building, where no one wants to live or work in it.

In response to such aspects, an alternative system for internal walls has started to be employed in Brazil, the dry wall system. Generally, in this country, usual internal walls are made out of brick masonry, therefore, configuring a hard wall, with low technology incorporated. Even being used for many years in several countries, gypsum board is starting to get popular as a construction material. Many properties of the system are considered to give good results, such as generating low amount of rubble, good sound insulation, good thermal properties and reducing weight upon the building structure.

Modern world produces high noise levels in urban areas, especially those coming from road traffic. Therefore, buildings need to protect people against noise, either coming from outside or from neighbours. Gueiros and Pinguelli Rosa [2] proposed the hypothesis that when the street itself is noisy, it will be a source of sickness for the surroundings. Also, people using noisier goods and appliances within their homes, such as stereos, washing machines, loud speakers, and so on, contribute to create a noisy environment. Privacy is needed in most habited spaces and, therefore, it is necessary to separated rooms acoustically [3].

As far as the use of gypsum boards is concerned, some questions remain: are the partitions offering enough sound insulation? Can gypsum board walls be considered as having a good insulation capacity? How can a slim and light component give the necessary insulation? These questions are discussed in this paper, taking into account special aspects found in Brazilian construction sites.

2. GYPSUM BOARD IN BRAZIL

The use of gypsum board partitions is recent in Brazil. Even being on the market since the seventies, only in the last couple of years the use of this component had become popular. Figure 1 shows the historical production of gypsum board in the country. Nevertheless, major worldwide manufactures have started to produce gypsum board in large scale, bringing the prices down and helping to make it known by architects, engineers and general consumers. But like any other novel technology, people still does not know all the possibilities of the system. Some special accessories and products to complete the system, such as waterproof sheets for bathrooms, special hangers for cabinets, pictures, and other accessories are not available outside the main cities.

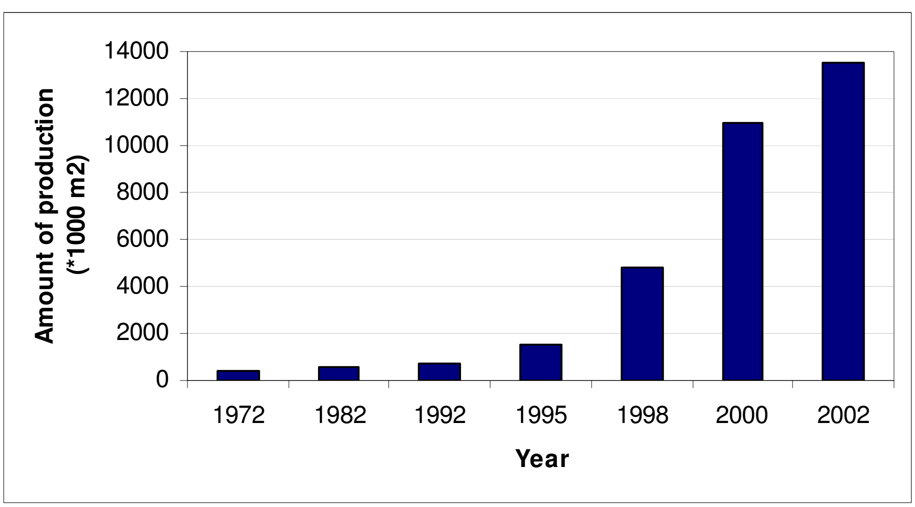

Figure 1: National production of gypsum board over the last years. [4]

Despite the efforts of manufactures, users are still reticent and have some complains yet, especially concerning sound insulation. This is an important issue: even if gypsum board has low surface density, it may reach more than reasonable sound insulation performance. Table 1 shows the properties of gypsum panels sold in Brazilian market.

It can be said that, in general, people do not know that gypsum board partitions may achieve good sound insulation performance. However, it is necessary to properly design the wall, with economical aspects taken into considerations, as well as cost/benefit issues.

Table 1 – Properties of gypsum panels sold in Brazilian market.

Manufactor	**Thickness (mm)**	**Width (m)**	**Length (m)**	**Surface density (kg/m^2)**
Knauf [5]	12.5	1.20	1.80 a 3.00	8.5 to 12.0
Lafarge [6]	12.5	1.20	1.80 a 3.00	8.0 to 12.0
Placo [7]	12.5	1.20	1.80 a 3.00	n/a

One advantage that producers emphasize is in the very early moment of production, because there is a high quality control of the panels, as a consequence of its industrial production, which sustains the material characteristic of each panel. In the construction site, there are many benefits. Firstly, there is less material transported, either in weight or volume. Secondly, it is easy to install water supply and electrical systems inside the wall and, finally, it is the cleanness of the construction site since it does not produce rubble. As far as the design of the buildings is concerned, the advantages are the low load walls, and consequently, the reduced need for more robust building structure, the fast mounting compared to a brick wall and the reduced necessity of workmanship. From the users viewpoint, the advantages are (i) the flexibility of the home or office layout, because it is not necessary to put partitions right over the structure beams, (ii) the possibility of having curved walls and (iii) the gain of about 4 % of area because gypsum board walls are thinner [8]. Also, gypsum walls have a good fire protection and thermal insulation [7].

3. SOUND INSULATION

In any kind of building, noise can be transmitted from one room to another in two ways: through airborne and/or structure borne. To quantify the amount of sound insulation offered by partitions, Transmission Loss (TL or R) and Sound Transmission Class (STC) are normally used [9]. TL is normally presented in octave band frequencies [10]. STC is a single number calculated from the 500 Hz of the TL curve [11].

3.1 Difference in Impedance

Solid construction materials usually found have a significant difference in impedance from the air. This makes harder for the sound energy to go through the building element and change from one medium to another many times. Table 2 shows density, sound speed and impedance for some construction materials, as well as for the air.

Table 2 – Some physical properties of many constructions materials and the air [12,13].

Solid material	Density (kg/m^3)	Sound speed (m/s)	Impedance (Rayls)
Lead	11300	1200	$1.36*10^7$
Steel	7700	5050	$3.90*10^7$
Aluminium	2700	5150	$1.39*10^7$
Concrete	2600	3100	$8.06*10^6$
Glass	2300	5200	$1.19*10^7$
Brick	1800	3700	$6.66*10^6$
Rubber	1100	1450	$1.54*10^6$
Gypsum	960	6800	$6.52*10^6$
Air at 20^{o}C	1.21	343	415

3.2 Mass Law

Basically, the capacity of insulation of any material depends on the frequency of the incident sound. Different frequencies may induce different behaviour.

The performance of any building element regarding their airborne sound insulation is related to the amount of their mass. When a sound energy impinges a wall, it set it up into vibration [10], transmitting great amount of energy to the adjacent ambient. Hence, the greater the mass, the greater the resistance to motion (inertia), and less energy is transmitted. Thus, a high density material has a better insulation property than a light density one. Every time either the density of the partition or the frequency of the incident sound is doubled the transmission loss is improved in about 5 dB.

Besides this relation, single walls need to have low stiffness to damp the vibrations that impinge on it. These combined solutions may be a good option for a wide variety of frequency range.

3.3 Double Leaf Partitions

Double leaf partitions (cavity constructions) can be an interesting strategy to increase sound insulation without increasing the total density of the wall. The air gap contributes to the insulation performance because the sound wave needs to pass through five different mediums, considering the two solid walls and three fluids (air). Because the solid walls have such a difference in impedance compared to the air, each time the sound wave changes the travelling medium the propagation is damped. Nevertheless, the cavity needs to have a minimum width and the existence of absorbent material will help to cancel possible standing waves building up in between partitions.

Gibbs [10] recommends minimum cavities depth of five centimetres in order to improve sound insulation at mid and high frequencies and fifteen centimetres or more to achieve significant low frequencies benefits. Regarding the thickness of the wall solid elements, the best choice is to have different thickness for each parallel wall, so it would require different frequencies to set the partitions into resonance.

3.4 Opened Areas

Small opened areas in solid partitions can significant reduce their sound insulation. Egan [11] states that sound leaking in a wall is similar to water leaking in a roof. It does not matter if a house has an excellent and expensive roofing system if there is small hole on it. Water will makes it way. The same applies to the sound. If there is a heavy stone or concrete partition the overall performance is going to be dictated by the weakest component, the opening areas of the cracks in a junction between the wall and the slab for example [14].

To avoid such leaks is necessary to take care of the sealing in between elements, such as walls, ceilings and floors and also of gaps around edges. Gerges [13] presents a graph that shows how low percentage of opened areas can strongly reduce the sound insulation capacity of elements. The graph is reproduced in Figure 2.

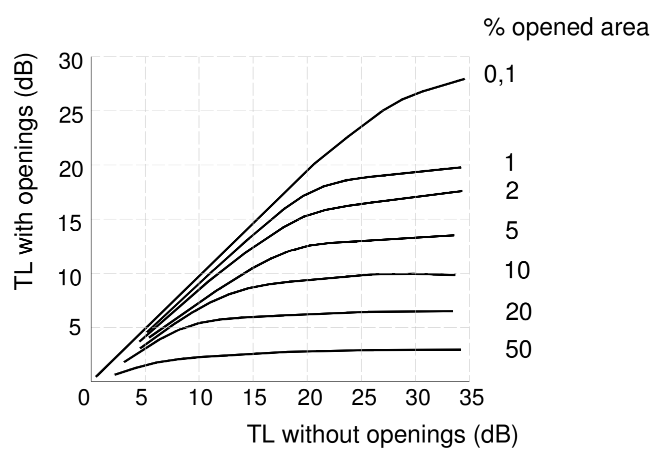

Figure 2: TL for different openings area [13].

3.5 Structural Borne Insulation

So far the discussion here concerned airborne transmission mainly. The structural borne transmission is also important and has to be treated with the same importance. Flanking paths along solid materials allows the sound waves to travel long distances and very fast. Any vibrating machine can cause annoyance to people many floors away within a building. The waves propagate along the structure and sets surfaces in the room into vibration radiating noise into other rooms.

Bistafa [15] relates important flanking transmissions that occur in buildings such as water pipes vibrations. The use of resilient mountings and resilient floor coverings are the correct solution, together with careful design of connections and adjacent framings [11].

4. DISCUSSION

4.1 Laboratory Performances

There are three main companies selling gypsum board in Brazil. These companies release the results of general insulation measurements considering different aspects, as presented in Table 3. The evaluations were carried out at the Technological Research Institute (IPT), which is a Brazilian laboratory for testing the performance of building components and materials. The sound insulation results are presented considering many arrangements of mounting, such as two or four panels, and with and without mineral glass wool within the internal cavity. The acoustical parameter considered was the weighted sound reduction index.

Table 3 – Acoustic properties of gypsum board. [5,6,7]

Manufactor/ wall pattern	Number of gypsum board layers	Weighted Sound Reduction Index (Rw)	
		Without glass wool	With glass wool
Knauf			
W111-73/48/600	2 x 12.5 – GKB-AK	34	44 (50 mm)
W115-195/70/600	4 x 12.5 – GKB-AK	51	61 (50 mm)
Lafarge			
D 100/75/600	2 BR 12.5	39	45 (75 mm)
D 125/75/600	4 BR 12.5	45	50 (50 mm)
Placo			
73/48/600	2 x 12.5	36	43 (50 mm)
98/48/600	2 x 12.5	42	49 (50mm)

IPT recommends a minimum value of 50 dB for Rw for the partition in between dwellings. There are no minimum performance recommendations for partitions in between internal rooms of same dwellings, but it is possible to assume that a smaller value would be acceptable. The data showed that the best result for single layers without glass wool is 39 dB. With the fibre infill is possible to achieve 50 dB. Only two layers arrangements can reach desirable results. Indeed, it is proved that only increasing the air cavity inside the wall significant best results are reached.

Considering the Sound Transmission Class (STC), Gerges [13] presents some recommended minimum values for different situations, as shown in Table 4. Table 5 presents results of STC for different wall configurations in measurements carried out by Baring [16].

The results show that a brick wall, 12.5 cm thick, has a STC of 41 dB and a single layer gypsum board with 10 cm glass wool has STC of 49 dB. Even being thinner than regular walls, gypsum board may achieve better STC results when corrected designed. However, this arrangement is still bellow the STC 47, where loud conversation can be weakly audible.

Table 4 – Recommended STC for different voice conditions. [13]

Privacy conditions	STC
Loud conversation not audible	52
Loud conversation weakly audible	47
Loud conversation audible when paying a lot of attention	45
Loud conversation audible	43
Loud conversation audible but not understandable	35
Loud conversation hardly audible	30
Normal conversation easily understandable	25

Table 5 – Acoustical properties of usual wall arrangements [16].

Configuration	Thickness (cm)	STC
Porous cement block with plasterboard on both sides	10.0	34
Single layer gypsum board on steel studs, empty internal space	7.3 (1.25 + 4.8 + 1.25)	37
Ceramic hollow block with plasterboard on both sides	12.5	41
Single layer gypsum board on steel studs, internal space with mineral wool of 16 kg/m^3	10.0 (1.25 + 7.5 + 1.25)	49
Double layer gypsum board, staggered steel studs, internal space with mineral wool of 16 kg/m^3	14.0 (2.5 + 9.0 + 2.5)	62

4.2 In-situ examples in Brazilian Constructions Sites

A relevant issue for the sound insulation performance of the gypsum partitions is the interface between walls and doors. It is usual in Brazil to use two ways to fix doors structures in dry walls. Firstly, small bits of wood are inserted into the steel stud and screws are used to fix the door to the wood pieces. A lot of air space is left around the boundary and will be only hidden by a wooden finishing.

An alternative means to fix doors is using flexible polyurethane expansible foam. In this way, foam is injected in six points around the door edges. This is enough to keep the door in place, but it also leaves many cavities connecting each side of the wall. These situations are shown in Figure 3. In an ordinary brick wall, this problem would not exist because it is common practice to use plasterboard to fix the door and seal the opened spaces.

Regarding the sealing around each gypsum panel, Ciocchi [8] reported that there is no standards for tapes, setting compounds and plasters, contributing to a worse performance in Brazil. Inflexible plasters have been used and result in crack appearing along the height of the panels, which let the sound go through.

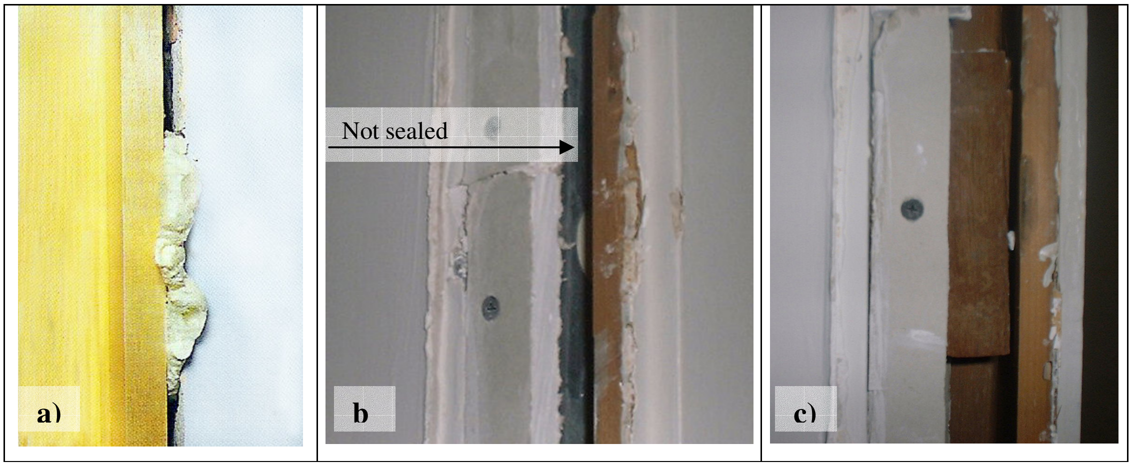

Figure 3– Example of the use of flexible foam and small pieces of wood to fix doors. Font: a) Manufactures catalogue b,c) photos by the author.

Flanking paths should also be avoided with proper design of the walls and the connection with other elements. In-situ inspections carried out by the author found water pipes connected to steel studs and even to the gypsum board, creating sound bridges, as it can be seen in Figure 4. Electrical back-to-back and side-to-side outlets were also found.

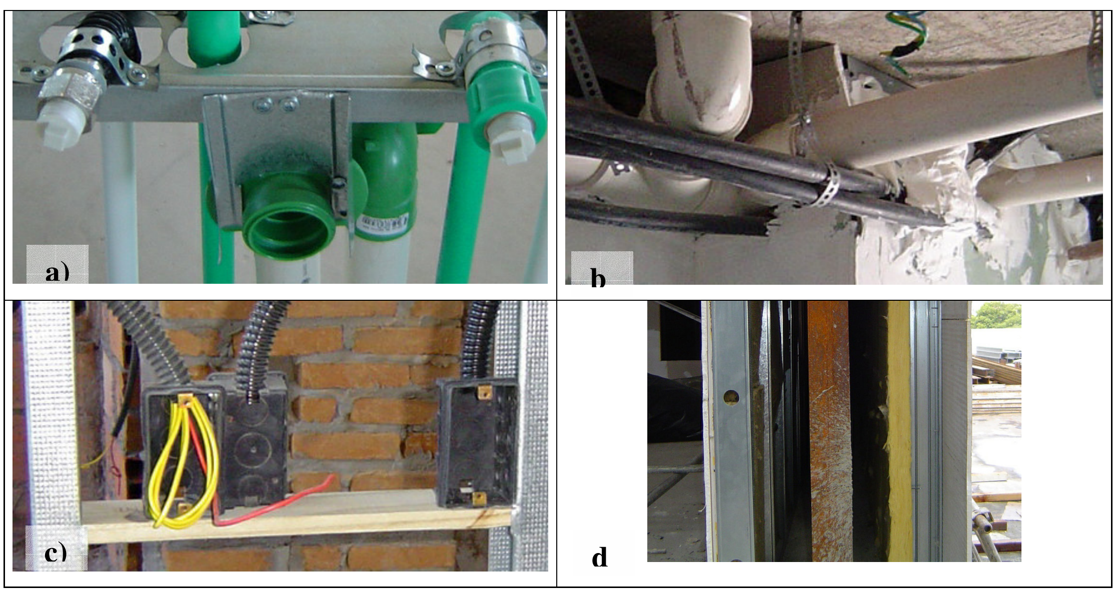

Figure 4 – Examples of sound transmission paths found: a) pipes with no resilient isolation; b) pipes glued to gypsum board walls; c) back-to-back electrical outlets in the same structure; d) better sound insulation performance of gypsum wall.

When the design of the partition is correctly done it is still necessary to take care with execution. A proper design is not guarantee that the workmanship will do it correctly. Taniguti and Barros [17] suggest that it should have a partition design besides the architectural design, to prevent inadequate setups. When there is no partition design, the responsibility of the setting up should be of the workers. Openings between gypsum panels with more than 1.5 cm were found by the author. After being asked why they were leaving this aperture, one working man answered: "*it is not a problem to leave this big opened space because the joint compound and the tape will cover it.*" Even in properly constructed partitions, a -5 dB difference in STC can be expected between field and laboratory measurements [12]. Therefore, when the execution is badly done, it will severely decrease the overall performance.

4.3 Theory and Practical Performances

Preliminary intuitive analysis may be enough to conclude that inadequate condition can be easily encountered due to in situ conditions. To provide a theoretical evaluation of the gypsum board partition, a field condition is schematically presented in Figure 5. It is a gypsum board single layer on steel studs partition, with 5 m width, 2.5 m high and 10 cm thick. The floor and the ceiling are concrete slabs. The perpendicular wall is made out of brick. There is also a door with solid wooden core (similar TL as the gypsum board) fixed on the partition by flexible polyurethane foam. There is no mineral wool inside the cavity as the usual situation in Brazil. According to IPT, this wall, similar to Knauf W111-73/48/600, is expected to have a Rw of 34 dB. Considering a gap area around the partition of about 1 cm around the edges of the partition, as recommended by manufactures, it could be reached a total opened area of 0.15 m^2. The wall area is 12.5 m^2 and, therefore, the opened area reaches 1.2% of the total area.

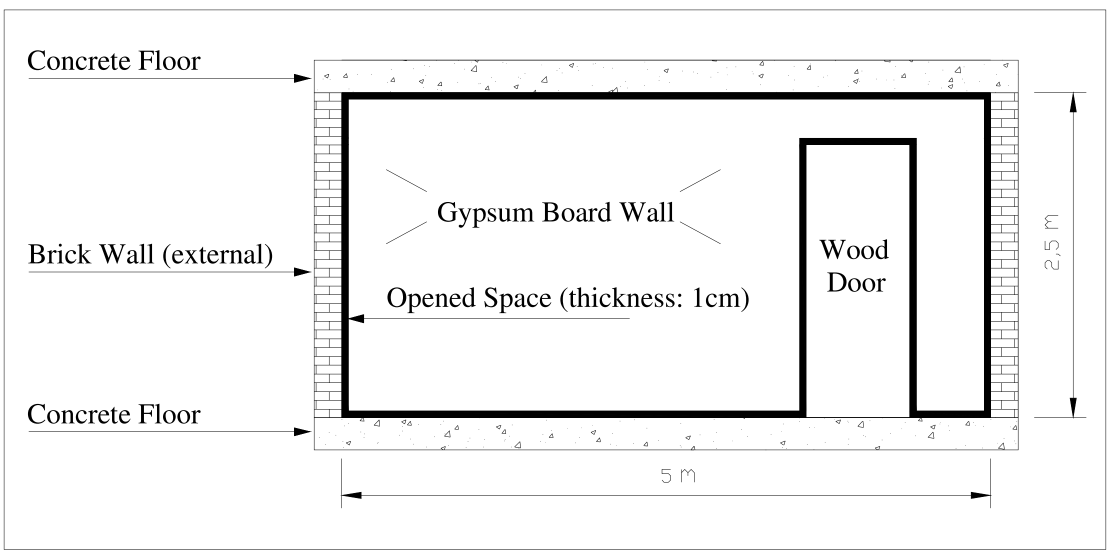

Figure 5: Schematic gypsum board partition with gaps represented in bold lines.

One may ask that the gap do not appear after the partition is ready because it is sealed with a tape and painted. But, unfortunately, the tape does not have enough thickness and its density is not significant. Thus, the tape can be disregarded. No resilient base is used to caulk bellow or over the partition.

Considering all the possible weak points that would leak sound and calculating their influence according to the chart shown in Figure 2, the expected transmission loss goes down from 34 dB to 20 dB. It is concluded that in such configuration, the partition does not satisfy the minimum requisites of sound insulation for dwellings.

Ciocchi [8] reports that the São Paulo State Construction Industry Syndicate (SINDUSCON-SP) performed a post-occupation evaluation in residential and commercial units. The aim was to assess the users satisfaction regarding the performance of gypsum board partitions. 52 units were evaluated in 16 buildings and it was concluded that noise levels were among the items that have more complains. The author also states that in 44% of the cases, partitions did not have mineral wool inside the cavity and, therefore, poor sound insulation performance is expected. The research also found that the problems encountered are originated in badly specification design and poor execution. These results reach the same conclusions as presented in this paper, since correct design and execution have a major importance on achieving final performance similar to the laboratory results.

5. CONCLUDING REMARKS

This paper presented an analysis of the sound insulation of gypsum board walls. The aim was to evaluate design and execution characteristics that influence final results.

It is concluded that gypsum board may have adequate performance when specifications are correct done. Examples of undesirably situations, where minimum performance is not reached, are presented.

In Brazil, the most common configuration is with one gypsum board on each side of the steel stud, giving a total of 10 cm thickness, without any infill in the air space such as mineral wool. According to the laboratory results, the setting is considered inappropriate.

Finally, the quality of the workmanship is decisive to get in situ performance similar to the laboratory. Execution and fixing can take from an appropriated design to an inappropriate condition.

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