Acoustic Evaluation of Some Non-Conventional Solutions in Construction

L. Bragança, M. Almeida, S. Silva and P. Mendonça

Department of Civil Engineering, University of Minho, Azurém 4800-058 Guimarães
braganca@civil.uminho.pt; malmeida@civil.uminho.pt; sms@civil.uminho.pt; pmend@civil.uminho.pt

ABSTRACT: Conservatism of construction industry and increasing comfort requirements had led to a certain depreciation of lightweight materials and the ancient construction techniques and materials. Construction has adopted more heavyweight and durable materials, such as stone and brick. But it could be questioned if this is the most environmental friendly attitude.
Reduction of the weight of construction systems can in fact have a significant influence on reducing environmental costs. One main problem is that lightweight buildings are usually characterised by a deficient acoustic insulation.
The use of non-conventional solutions such as sandwich walls with natural, light materials (cork, coconut fibre, plasterboard and wood cement board), and the ancient, but still actual, earth walls, improved with an acoustic absorbent material, are a way to increase the sustainability of the constructions.
The aim of this work is the evaluation of the acoustic potentialities of these technologies, because their acoustic behaviour is practically unknown.
During the study carried out at the Test Cells of non Conventional Solutions of the Laboratory of Building Physics and Technology of the University of Minho, the acoustic performance of non-conventional envelope technologies were experimentally studied and compared with a conventional principle. The paper describes such technologies and their acoustic characterisation.

1. INTRODUCTION

Nowadays there is an increasing interest in building solutions based on natural materials in order to reduce environmental impact of construction. This strategy can lead to the reduction of conventional materials, highly industrialized and with great production energy consumption, thus limiting the use of non-recyclable solutions.
The use of non-conventional solutions, such as sandwich walls with natural and lightweight materials (cork, coconut fibre, plasterboard and wood cement board), are a way to increase the constructions' sustainability. However, there is a lack of information about the behaviour of these solutions.
The research and development of new construction technologies, should lead to the improvement of the general quality of the buildings and especially of their comfort. Buildings' acoustic performance has an important role to play in these issues.
In this work, the acoustic performance of a non-conventional envelope technology (a test cell with a mixed earth and lightweight sandwich walls) has been experimentally studied and compared with a conventional solution, typical of Portuguese contemporary buildings (a test cell with traditional double hollow brick walls).

2. TEST CELLS CHARACTERIZATION

2.1 Geometry

The studied Test Cells have a rectangular shape and are south oriented as shown in Figure 1.

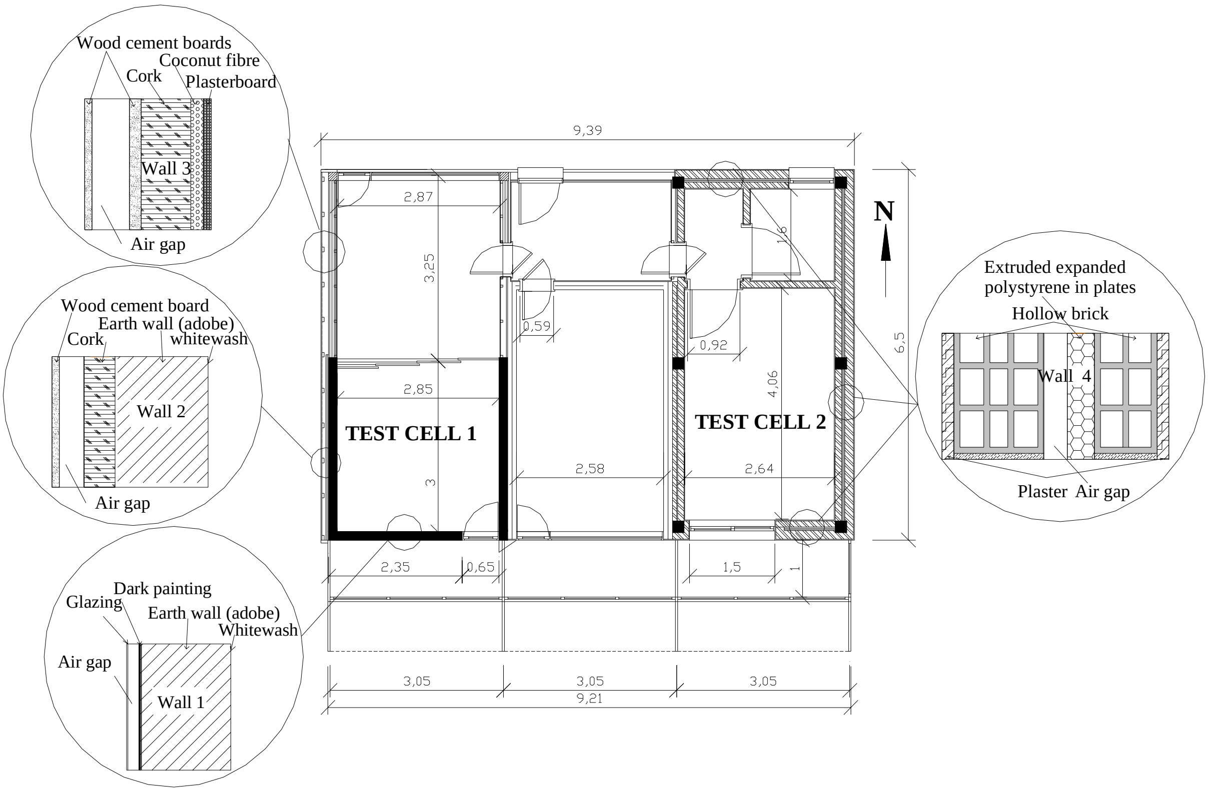

Figure 1 - *Schematic plan of the Test cells and schematic section of some envelope components (distances in metres)*

Test Cell 1 is the non conventional cell, where the acoustic behaviour of two heavy and one lightweight solutions were studied: two earth walls (one with insulation and other without insulation) on the South and West parts, and a sandwich wall with wood cement board on the West and North parts. This test cell is divided in two zones separated by a movable wood partition. For comparative analysis, a conventional cell, Test Cell 2, with the same dimensional characteristics, but with a traditional construction solution, was also studied.
Both test cells have a movable single glazed balcony on its' South part, which width can be changed between 0.10 m (close to the South wall) and 1.0 m, as Figures 2, 3 and 4 show.
In these figures are also represented the vertical schemes of the façades and a vertical section of each test cell, showing the shading devices.

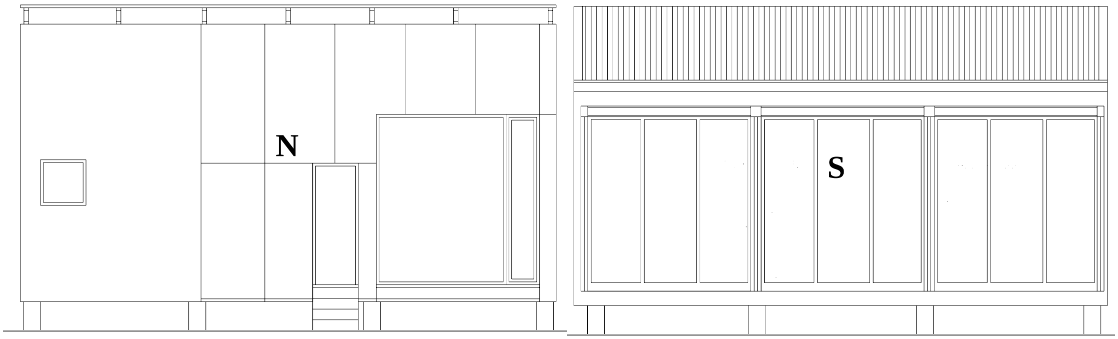

Figure 2 - V*ertical scheme of the Test cells* - *North and South façades*

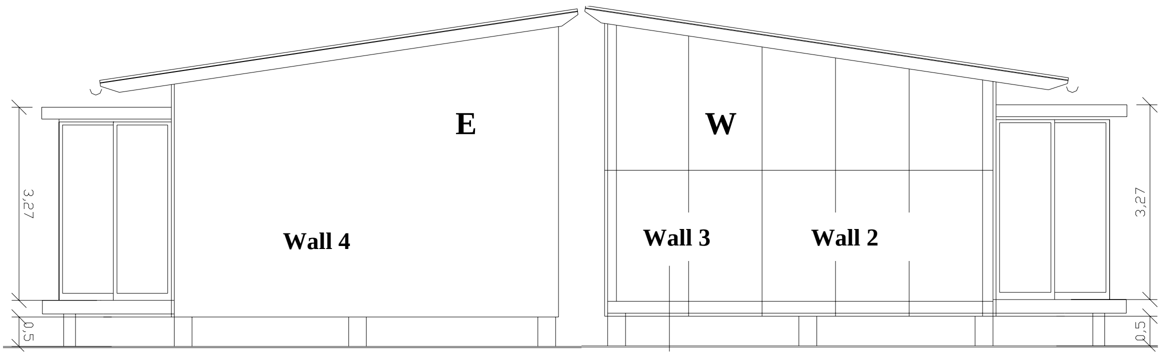

Figure 3 - V*ertical scheme of the Test cells* - *East and West façades (distances in metres)*

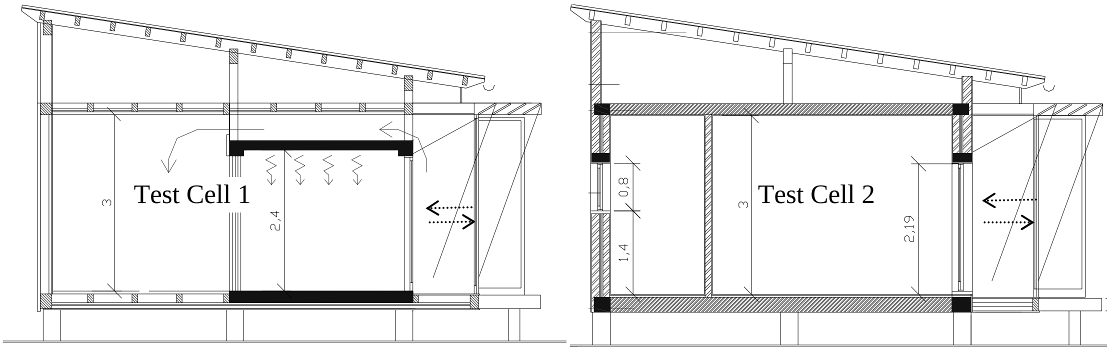

Figure 4 - *Vertical sections of Test cells 1 and 2 (distances in metres)*

Table 1 shows the geometric characteristics of the test cells.

Table 1 - *T*est cells area and volume

	Floor Area [m^2]	Volume [m^3]
Test Cell 1	9.3 + 8.6	28.0 + 20.5
Test Cell 2	10.7	32.2

2.2 Test Cells Envelope Components

Test Cell 1 has a 15 cm thick adobe masonry wall with an air gap and an exterior 0.6 cm thick glazing (wall 1 in Figure 1), a 15 cm thick adobe masonry wall with a 5 cm thick cork layer, a 4 cm air gap and a 1.2 cm wood cement board (wall 2) and a sandwich wall with a 1.3 cm

thick plasterboard layer, a 2 cm thick coconut fibre layer plus a 8 cm thick cork layer, a 1.9 cm wood cement board, a 4 cm thick air gap and a 1.2 cm thick wood cement board (wall 3).
The floor and the roof of Test Cell 1 are hollow core slabs with 30 cm and 20 cm of thickness respectively, on the South side (heavy zone).This cell has a lightweight roof (2 cm of coconut fibre, 8 cm of cork and a wood cement board with 1.9 cm of thickness on the bottom) and floor (1.9 cm wood cement board, 2 cm of coconut fibre supported by a wood structure, an air gap with 10 cm, 8 cm of cork and a 1.2 cm thick wood cement board layer) on the North zone, were this structure is placed 40 cm above the hollow core slab which allows the migration of the warm air from the South glazed balcony to the North zone of this Test Cell.
The area and the mass of each envelope component are presented in Table 2.

Table 2 – *Characteristics of the Test cells*

Element	**Area [m^2]**	**Mass [kg/m^2]**
Test Cell 1 - non-conventional solutions		
South Roof	10.5	404.8
South Floor	10.5	449.4
North Roof	10.9	37.0
North Floor	10.9	69.3
South façade – wall 1		
Adobe	5.7	289.5
Glazing	1.6	12.0
West façade – wall 2 and 3		
Adobe + insulation	9.0	318.7
Sandwich	9.8	79.1
North façade		
Glazing	8.6	12.0
Test Cell 2 - conventional solution		
Roof	19.8	356.0
Floor	19.8	418.0
South façade - wall 4		
Double leaf	5.9	452.0
Glazing	3.3	12.0
East façade - wall 4		
Double leaf	19.5	452.0
North façade - wall 4		
Double leaf	8.6	452.0
Glazing	0.6	12.0

Test Cell 2 (corresponding to a conventional solution in Portuguese construction) has a construction system of massive concrete structure, with pavement and ceiling on pre-stressed concrete “T” beams and hollow pots with 26 cm of thickness plus a 4 cm regularization layer and wood as surface finishing of the floor and plaster as interior surface finishing of the ceiling. The external walls are double leaf (15+11 cm) hollow brick walls with 4 cm of

extruded expanded polystyrene in plates placed in the air cavity and finished with plaster on both sides, as Figure 1 shows. It must be stressed that this type of wall is considered of high quality for common standards since the most usual insulation thickness used is only 2 cm.
The windows in both test cells are single glazed (6 mm) with a common metallic frame with a fixed blade as shading device.

3. ACOUSTIC PERFORMANCE EVALUATION

3.1 Acoustic evaluation method

The assessment of the acoustic performance of any building should be done through the evaluation of each building element noise insulation level normalized in accordance with the absorption equivalent area.
This evaluation has been carried out for the two test cells and for the four types of walls under analysis, where the non-conventional test cell results were compared with the acoustic insulation values obtained for the conventional solutions.
The acoustic measurements were done according to the EN ISO 140 Standards, part 5 [1], and EN ISO 717 Standards, part 1 [2].
According to the Portuguese Building Acoustics Requirements Regulation [3,4], the weighted normalized airborne sound insulation index of façades, measured at 2 m from them ($D_{2m,\,n,\,W}$), must be greater than 28 dB for sensitive zones (exposed to $L_{Aeq} \leq 55$ dB (A) between 7 h and 22 h and $L_{Aeq} \leq 45$ dB (A) between 22 h and 7 h) and greater than 33 dB for the other zones (usually named as mixed zones). For “in situ” measurements the Portuguese Building Acoustics Requirements defines an uncertainty index of 3 dB that must be added to the measured weighted normalized airborne sound insulation index [3].

3.2 Acoustic evaluation results and comments

The façades noise insulation ($D_{2m,\,n,\,W}$) has been determined through “in situ” experiments carried out in both Test Cells, for three situations. The first set of measurements was performed for the South wall without the glazed balcony and with the movable wood partition opened (Case 1). The second set of measurements took place for the East and West wall with the movable wood partition opened and closed (Case 2). The third set of measurements was carried out for the South walls with the glazing of the balcony at 0.1 m and at 1.0 m from the South wall and with the wood partition of Test Cell 1 opened and closed (Case 3). Figure 5 shows a view of the South façade of the two test cells.

Figure 5 - View of the Test cells’ without and with the glazed balcony

From the measurements performed, that can be seen in Table 3, it was possible to conclude that the conventional solution has a better overall acoustic performance in what concerns sound insulation due to its higher mass (54% higher than the other), that is essential for a good acoustic behaviour.

Table 3 - N*oise insulation of façades measured "in situ" ($D_{2m,\,n,W}$) (case 1 - without the glazed balcony and with the wood partition opened, case 2 - with the glazed balcony and with the wood partition opened and closed and Case 3 - with the glazed balcony at 0.1 m and at 1.0 m and with the Test Cell 1 wood partition opened and closed)*

Element Type		$D_{2m,\,n,W}$ **[dB]**		
		Case 1	*Case 2*	*Case 3*
non-conventional solutions				
South façade without glazed balcony		26	-	-
South façade	Glazing at 0.1 m (Opened / Closed)	-	-	28 / 36
	Glazing at 1.0 m (Opened / Closed)	-	-	32 / 39
West façade (south part + north part)		-	41	-
West façade	South part	-	45	-
	North part	-	41	-
conventional solution				
South façade without glazed balcony		23	-	-
South façade	Glazing at 0.1 m	-	-	35
	Glazing at 1.0 m	-	-	39
East façade		-	47	-
Reference value (sensitive zones / mixed zones)			28 / 33	

Additionally, in Figures 6, 7 and 8 some spectra results are presented for the constructive solutions studied and for the three situations analyzed. Again it is shown that the conventional East wall and the non-conventional West wall, both without fenestration, have the best acoustic performance. The conventional South wall, with the higher mass, but also with the higher glazing area, is the façade that has the lower acoustic insulation level.

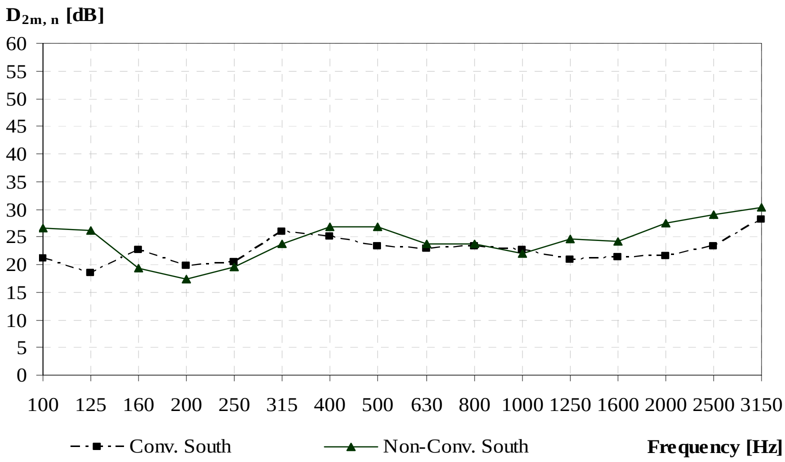

Figure 6 - *Test cells' South walls sound insulation – Case 1*

The measurements show also the great influence of the glazing area on the global acoustic performance of a wall: the conventional South wall, which has a glazing area 52% higher than the non-conventional South wall, has a noise insulation level 3 dB lower. When comparing the conventional South and East walls, which have the same mass per square meter, the difference on the insulation level is of 24 dB. Comparing the non-conventional South wall and the South part of the West wall, the acoustic insulation level difference is of 19 dB.
This shows that the glazing part of a wall has a strong influence on the acoustic insulation and its inclusion on a building element must be very well weighted. To improve the acoustic performance of heterogeneous elements it is necessary to use glazing and windows frames with very high quality.

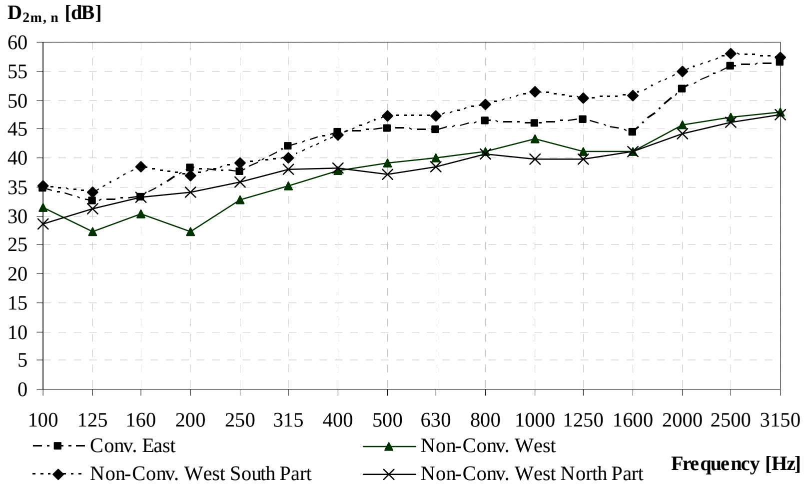

Figure 7 - *Test cells' East and West sound insulation – Case 2*

The non-conventional test cell South part of West wall and conventional test cell East wall, without windows and with the higher mass, are the walls that have the higher weighted normalized airborne sound insulation index, and a similar behaviour, as Figure 7 shows.

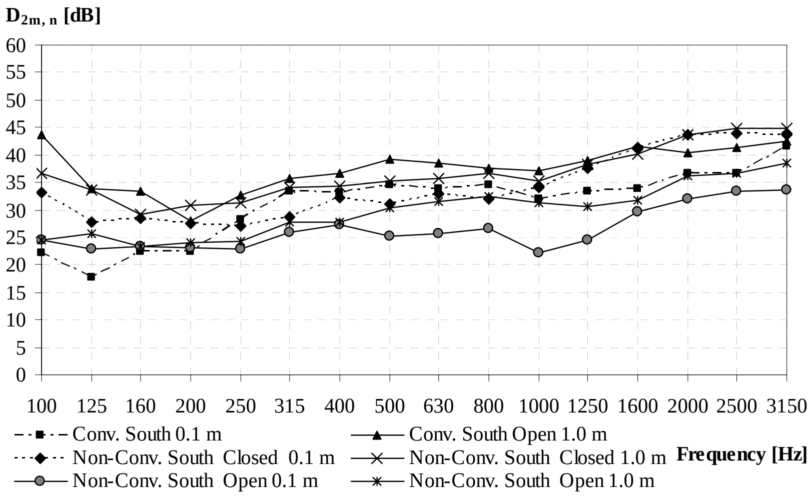

Figure 8 - *Test cells' sound insulation – Case 3*

Figure 8 shows the influence of the position of the balcony glazing, the location at 1 m of the façade is better for its acoustic behaviour; in this case the airborne insulation level is 3 to 4 dB higher.
It must be stressed that the weighted mass of the West wall (Test Cell 1), obtained in accordance with the area and mass of walls 2 and 3, is 59% lower than the mass of the East wall (Test Cell 2) and its insulation level is 6 dB lower than the conventional wall. According to the Mass Law, for a double layer element, the increase in sound transmission loss is 6 dB each time the mass or the frequency of the elements double. So, this study has shown that the conventional test cell, with its higher mass, has a better acoustic performance, but the non-conventional solutions tested, taking into account all the parameters involved, have a very similar behaviour.

4. CONCLUSION

From the analysis performed it was possible to verify that the studied walls, except the South conventional wall without balcony, respect the Portuguese Building Requirements for the weighted normalized airborne sound insulation index of façades, both for sensitive and mixed zones. The non-conventional South wall with the glazing at 0.1 m doesn't fulfil the Portuguese Building Acoustics Requirements for the weighted normalized airborne sound insulation index of façades, for mixed zones
From the measurements undertaken, it can be concluded that the conventional solutions have a better acoustic performance.
The lightweight solutions have also good behaviour, and are more sustainable, as they reduce the environmental impact of construction.
This highlights the need for further investigation of the acoustic behaviour of lightweight and other constructive solutions that include natural and recyclable materials.

5. ACKNOWLEDGEMENT

The authors wish to thanks Pedro Silva for his help performing the acoustic measurements.

6. REFERENCES

[1] EN ISO 140-5:1998. Acoustics - *Measurement of sound insulation in buildings and of building elements* - Part 5: Field measurements of airborne sound insulation of façade elements and façades.

[2] EN ISO 717/1:1996. Acoustics - *Rating of sound insulation in buildings and of building elements* - Part 1: Airborne sound insulation.

[3] PORTUGAL, Ministério do Ambiente e do Ordenamento do Território - *Portuguese Building Acoustics Requirements Regulation* - Decree-Law nº 129/2002, May 11th, Lisbon, 2002.

[4] PORTUGAL, Ministério do Ambiente e do Ordenamento do Território - *Portuguese General Noise Regulation* - Decree-Law nº 292/2000, November 14th, Lisbon, 2000.