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R+D for the Integration of High Acoustic-Thermal Performances in Spanish Building Products

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Many EU countries are introducing new national regulations aimed at complying with the European Directive 'Energy Performance of Buildings' (EPBD). Subsequently, in Spain a new normative has been recently approved (CTE-DB HE), compiling new requirements for energy saving in buildings. In this framework, energy efficiency considerations will have an increasing impact on the design of buildings and the choice of materials and products.

In the same way, the acoustical quality of dwellings in Spain is going to be guaranteed with the compliance of the new Spanish Building Regulation (CTE-DB HR). Searching a higher level of comfort in dwellings the CTE is increasing its requirements and is considering the building as a product itself.

These new developments involve efforts and resources for the upgrading of the constructive materials and systems, demanding investments for R&D activities. Therefore manufacturers of the constructive sector in Spain are launching many innovative research strategies for the development of better products, addressing key factors for the energy efficiency of buildings.

1 Introduction

Thermal Insulation and Protection against Noise are two of the main comfort demands of a building user. Concerned about this problem, governments introduce building regulations as the way to enforce minimum comfort levels. In Spain, the Building Regulations about acoustic and thermal insulation have changed recently.

This situation is going to involve changes in constructive elements and in the materialization of the building in Spain.

This paper shows some of research lines about thermal and acoustic characteristics of constructive elements carried out by different manufacturers for knowing and improving the acoustic and/or thermal characteristics of their products.

2 Construction elements in Spain

Dwellings in Spain are usually built with concrete pillars and beams structures, with no structural supporting walls. All the walls (façade, internal walls…) are built when the whole structure is lift.

Floors: Spanish dwellings are mainly built with 'beam and block' floors (see Fig.1). These blocks are: hollow concrete, hollow clay or EPS blocks, and their function is to lighten the floor's structure. The blocks are put in between the beams and then, the concrete is spilled over the set, reaching a level of ~5cm over the block top. This system is highly orthotropic. Floor's weight goes from 350 to 500 kg/m^2.

Fig. 1. Beam and block floor mounted in laboratory.

Walls: Many different kinds of walls are used, but all of them are based on hollow bricks. These bricks can both be 'perforated' (holes up to down) or 'hollowed' (holes left to right),. Always usually glued with mortar and covered with a gypsum layer on both sides. This brick's weight goes from 75 to 225 kg/m^2.

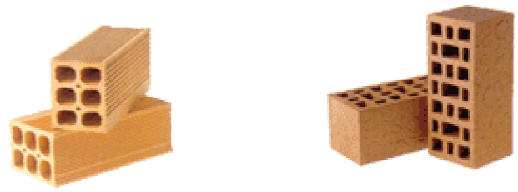


Fig. 2. 'Hollowed' and 'perforated' ceramic bricks.

Double walls with thermal insulation in between are also common when looking for high insulation levels

Fig. 3. Double ceramic brick wall.

3 Requirements

3.1 Thermal Requirements

The former requirements for thermal conditions in buildings were defined in NBE-CT-79 [1]. This Regulation established the fulfilling of a global thermal transmission coefficient for the building (K_G), with different limits depending mainly on the climatic zone.

The current Spanish regulation concerning the Energy efficiency in buildings is the CTE DB HE, Basic Document HE - Energy Saving in the Building Technical Code [2]. This regulation has been approved in September 2006. It has 5 parts:

HE 1 Limitation on the energy demands

HE 2 Efficiency of the thermal facilities

HE 3 Energy efficiency on lighting facilities

HE 4 Minimum solar contribution to hot water

HE 5 Minimum photovoltaic contribution to electric energy

The first part - limitation on the energy demands- refers to the envelope, to assure the limits of energy demands without lost of thermal comfort. The scope for applying is new buildings and rehabilitation of certain buildings.

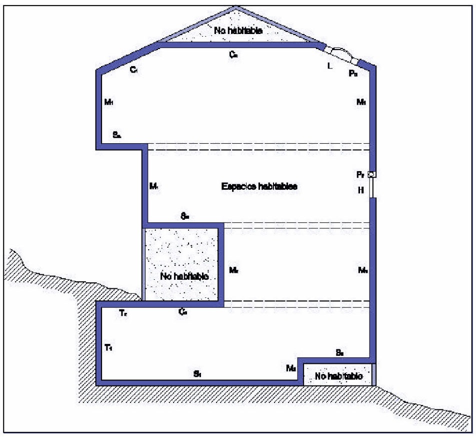


Fig. 4.Envelope of a building.

Table 1:Maximum Thermal Transmittance for building envelope (W/m^2K)

Partition	Climatic Zone				
	A	B	C	D	E
Walls	1,22	1,07	0,95	0,86	0,74
Floors	0,69	0,68	0,65	0,64	0,62
Roofs	0,65	0,59	0,53	0,49	0,46
Windows	5,70	5,70	4,40	3,50	3,10
Party wall	1,22	1,07	1,00	1,00	1,00

In addition to higher limit values than former requirements, other issues are taken into account: condensations, permeability to air of hollow spaces and isolation among different users.

The building code allows two different verification procedures: one simplified option (for buildings which fulfil certain requirements) and one general or more complex option.

The simplified option is based on the comparison of thermal features for enclosures and inner partitioning with certain limit values.

The method for verification involves:

- Determination of the climatic zone.
- Categorisation of building spaces: Non Habitable or Habitable.
- Definition of thermal envelope and closures.
- Requirements concerning air permeability for windows, etc.
- Calculation of the thermal parameters of the components of the closures and inner partitioning.
- Limitation of the energy demands:
  - Calculation of average values (thermal transmittance, solar factor…).
  - Comparison of obtained values with limit values.
- Control of interstitial condensations and surface condensations.

In the Fig. 5 there is an example of limit values (target values in the comparison) for one of the Spanish climatic zones.

ZONA CLIMÁTICA C3

Transmitancia límite de muros U_{Mlim}: 0,73 W/m^2k
Transmitancia límite de suelos U_{Slim}: 0,50 W/m^2k
Transmitancia límite de cubiertas U_{Clim}: 0,41 W/m^2k

	Transmitancia límite de huecos(1) U_{Hlim} W/m^2k				Factor solar modificado límite de h				
					Baja carga interna			Alta carg	
% Huecos	N	E/O	S	SE/SO	E/O	S	SE/SO	E/O	S
< 10	4,4	4,4	4,4	4,4	-	-	-	-	-
10 ≤ % < 20	3,4 (4,2)	3,9 (4,4)	4,4	4,4	-	-	-	-	-
20 ≤ % < 30	2,9 (3,3)	3,3 (3,8)	4,3 (4,4)	4,3 (4,4)	-	-	-	0,55	-
30 ≤ % < 40	2,6 (2,9)	3,0 (3,3)	3,9 (4,1)	3,9 (4,1)	-	-	-	0,43	-
40 ≤ % < 50	2,4 (2,6)	2,8 (3,0)	3,6 (3,8)	3,6 (3,8)	0,51	-	0,54	0,35	0,
50 ≤ % < 60	2,2 (2,4)	2,7 (2,8)	3,5 (3,6)	3,5 (3,6)	0,43	-	0,47	0,31	0,

Fig. 5. Limit values of the medium characteristic parameters.

3.2 Acoustical Requirements

Until October 2007, the acoustical quality of dwellings in Spain was guaranteed with the compliance of the building regulation NBE-CA88 [3]. Last version of this standard dates from 1988, though in practice it dates from 1981. According to this standard, buildings were acoustically characterized by means of the laboratory sound insulation required for each element composing the building. These requirements depended on the use of the construction element (floors, separating walls, internal walls...).

Next table summarizes the acoustical requirements for each element, as established by the NBE-CA88:

Table 2: Former acoustical requirements (NBE-CA88).

Construction element's use	Insulation	Laboratory Requirements
Partition walls (same use rooms)	Airborne	R ≥ 30dBA
Partition walls (different use rooms)		R ≥ 35dBA
Separating walls		R ≥ 45 dBA
Separating walls (with community spaces)		
Separating walls (with machinery rooms)		R ≥ 55dBA
Floors		R ≥ 45 dBA
	Impact	Ln ≤ 80 dBA
Floors (machinery rooms)	Airborne	R ≥ 55dBA
Façade	Airborne	R ≥ 30 dBA

Answering to the claim of higher insulation values, the new Spanish Building Regulation CTE DB HR [4] has increased its requirements, considering the whole building as a product itself (performance-based-regulation). In this way, the whole building is responsible for fulfilling the acoustical insulation requirements. In addition, these new requirements are higher, with sound insulation (measured on site) up to 50 dB what means laboratory requirements even higher for walls and floors.

As with former regulation, sound insulation requirements depend on the use of the rooms:

Table 3: Current acoustical requirements.

Analyzed Rooms		Insulation	On site Requirements
Living rooms and bedrooms	Any other room of different resident	Airborne	$D_{nT,A} \geq 50$ dBA
	Community spaces		
Living rooms and bedrooms	Machinery rooms		$D_{nT,A} \geq 55$ dBA
Kitchens and bathrooms	Community spaces		$D_{nT,A} \geq 45$ dBA
	Machinery rooms		
Living rooms and bedrooms	Any other room of different resident	Impact (vertical and horizontal)	$L'_{nT,w} \leq 65$ dB
	Community spaces		
	Under a roof		
	Machinery rooms		$L'_{nT,w} \leq 60$ dB
Façade insulation		Airborne	$D_{2m,nT,Atr} \geq$ (30-47) dBA * Depends on the Ld and the type of building

*For example, the insulation $D_{2m,nT,Atr}$ for dwellings, in bedrooms are:

L_d	$D_{2m,nT,Atr}$
Ld<=60	30
60<Ld<=65	32
65<Ld<=70	37
70<Ld<=75	42
Ld>75	47

Both, former and current requirements for sound levels from service equipment in buildings, only recommend limit values of L_{Aeq}=30 dBA in bedrooms.

4 R+D Activities for development of better products

These changes in Regulations involve efforts and resources for the upgrading of the constructive materials and systems, demanding investments for R&D activities. Therefore manufacturers of the constructive sector in Spain are launching many innovative research strategies for the development of better products, addressing key factors for the energy efficiency of buildings.

The main ways for changing the acoustical and thermal characteristics of constructive elements are modifying:

- Geometry
- Material and additives
- Glue between blocks
- Covering

Bellow, there are different experiences about it.

4.1 Lightened clay blocks

In this case the critical element is the thermal characteristic, and for improving it the manufacturer decided to change the glue between block: traditional glued with mortar and continuous joint, insulating mortar with continuous joint, insulating mortar with discontinuous joint (Fig. 6a) and adhesive bands (Fig. 6b).

(a) Discontinuous joint (b) Adhesive band

Fig. 6. Different types of joint between blocks.

The new glues versus the traditional one have improved the thermal transmittance of the wall from 1 to 0,7 W/m^2K.

However the wall with discontinuous joint presents worse sound insulation than the one with continuous joint (about 2 dB's difference).

4.2 Sandwich Blocks

A manufacturer has developed a sandwich construction element based on gypsum board, ceramic bricks and thermal insulation (expanded polystyrene, EPS): gypsum board/ceramic brick/EPS/ceramic brick/mortar layer. The thermal transmittance of this element is 0,4-0,6 W/m2K, and the sound insulation R_A is more than 52 dBA. Although the assembly between blocks is a bit complex (glued with adhesive bands and sealed with silicone) and it is supposed that this characteristic has influenced on the acoustics behaviour of the element.

4.3 Volcanic Concrete Blocks

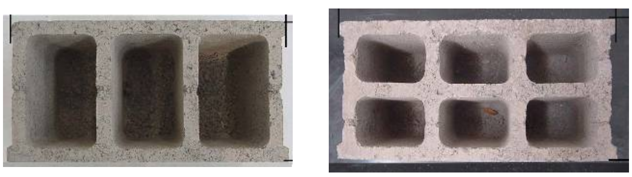
In Canary Islands, the material for construction elements is concrete with lapilli (pyroclastic particles, called 'picón' in the islands, see Fig. 7). Several Canary manufactures have characterized their products for knowing their strength and weakness against the new Regulations.

The results of thermal and acoustics characteristics are very similar to non volcanic concrete blocks, although the thermal transmittance is a bit better due to the porosity of the volcanic material.

Fig. 7. Lapilli ('picón' in Spanish).

Fig. 8. Building of volcanic concrete blocks.

From the acoustical point of view, the research shows that in this type of blocks the geometry is quite influential factor. For the same block thickness, high mass alterations means sound insulations (R_A) very similar. But if there are three row of hollows in the block (even being a heavier block), the sound insulation is worse than the blocks with one or two rows of hollows (Fig. 9). Whereas in thermal characteristics the geometry causes the opposite effect: with more rows of hollows the thermal transmittance is better.



one row of hollows two rows of hollows

Fig. 9. 'Picón' blocks with different geometry.

4.4 Thermal covering

Another way for improving the thermal characteristics is covering the wall with a special mortar based on lime and pearlite. This covering provide a very good thermal characteristic since its thermal conductivity is 0,09 W/m K.

Fig. 10. Wall of concrete blocks with thermal mortar layer.

An element of concrete blocks covered with this special mortar (15 mm) has a thermal transmittance of 1,7 W/m^2K, versus the values of 2,5-3 W/m^2K obtained using traditional mortar or gypsum layer.

The density of the thermal mortar (500-600 Kg/m^3) is less enough than the one of plaster (900-1200 Kg/m^3), so the acoustic behaviour of this wall with thermal mortar layer is expected to be worse than the one with gypsum layer.

4.5 Researches and work lines in progress

Other manufactures are studying material combinations, for example a traditional hollowed ceramic brick, with the hollow filled with EPS. This option is in process of researching.

And some rapprochements between manufactures of different kinds of construction elements are happening. Several manufacturers are considering forming an alliance between them. For example, thermal covering with sandwich blocks, or thermal covering with volcanic concrete blocks.

5 Conclusions

The new Regulations, in addition to achieve more comfortable and sustainable dwellings, will develop new construction products and systems which will change the present building scene in Spain.

It will be necessary to improve constructive elements and to combine between them.

Sometimes, thermal improvements involve acoustical declines and vice versa. Therefore the ideal thing is achieving a balance between thermal and acoustic parameters, which is a difficult task in some cases.

Due to the possibility of modifying several factors for changing the acoustical and thermal characteristics of constructive elements, there will be numerous options for improving the products or designing new ones: we only have to combine the various alternatives of changes.

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