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Trends in building and ductwork airtightness in Spain

Timo Hoek, airtest, Spain
Irene Poza-Casado, UVA, Spain
Sergio Melgosa, eBuilding, Spain

1 General Introduction

The Spanish residential stock is, on average, 45 years old and is in the lower part of the energy efficiency ranking, with an average valuation of 'E'. The market is recovering so vigorously from the Covid-19 hit that some voices in the sector warn that we are already facing the beginning of a new real estate "boom" that will continue until 2023. According to several projections, the number of dwellings in Spain could increase by 1,103,761 (5.9%) between 2020 and 2035, reaching 19,796,040.

As is the case at the European level, the non-residential market is the one with the most uncertain outlook: it has suffered a particularly negative year 2020 (-14.2%). The forecast for the following years includes growth (around 2.5% per annum) but it seems insufficient to recover the lost market volume. In a strict sense, it cannot be concluded that the global market is in a fragile situation, but niches with real momentum (logistics and offices) are coexisting with others where the demand raises questions. Although the Recovery Plan includes specific items for education, health and tourism, it is not expected that they will end up having a significant impact on construction [1].

2 Building airtightness

2.1 *Introduction*

Building airtightness has not traditionally been a major priority in the Spanish construction industry. Because most dwellings did not have any controlled ventilation systems, air infiltration has been a supplemental source of air renewal together with window airing, that contributed to indoor space air renewal [2]. From the point of view of research, knowledge on building airtightness is still scarce, owing to a lack of awareness about the subject. Whereas the topic has been widely addressed in the literature at an international level since the 1970s, little attention was paid on airtightness in Spain until a decade ago.

However, Spain is now on the change. Spanish building airtightness has only been present for windows and doors as an air permeability classification since 1975 [3], and, since 2006, according to UNE EN 12207 [4], when the Basic Document for the Energy Saving in Buildings (DB HE1) of the Spanish Technical Building Code (CTE) came into force [5]. The relative recent publication of the Royal Decree 732/2019, on 20th December 2019, modified the Technical Building Code. These modifications affected DB HE1 [6] and made the first statement limiting the whole air permeability of the building envelope.

So far, the main drivers have been certifications like Passivhaus, BREEAM or LEED. These certifications have given way to a broader knowledge on the airtightness tests.

2.2 Airtightness Indicator

The current DB HE1 limits whole building airtightness [6] referring to the air change rate at a reference pressure difference of 50 Pa, n_{50} [h^{-1}] as the airtightness performance indicator. Airtightness testing is performed according to UNE-EN ISO 9972:2019 [7] Therefore, to the authors' knowledge, the reference volume should be calculated according to the mentioned standard.

2.3 Requirements and drivers

2.3.1 Building airtightness requirements in the regulation

Whole envelope airtightness requirements were introduced for the first time at a national level in December 2019 [6]. This regulation established limitation of the air permeability of the thermal envelope for new buildings for private residential use with a total net area greater than 120 m^2, for which controlled mechanical or hybrid ventilation system is mandatory [8]. The air exchange ratio with a differential pressure of 50 Pa (n_{50}) shall not exceed the limit value established in DB HE1 (Table 1**Error! Reference source not found.**).

Table 1: Permeability limit values in relation to specific V/A ratio

Specific V/A_{ET} ratio $[m^3/m^2]$	n_{50} $[h^{-1}]$
$V/A_{ET} \leq 2$	6
$V/A_{ET} \geq 4$	3

where: n_{50} is the air change rate at 50 Pa $[h^{-1}]$; V is the internal volume of a building or part of a building $[m^3]$; A_{ET} is the sum of areas of the thermal building envelope with heat exchange with the outdoor air. Therefore, internal partitions and the envelope area in contact with other adjacent spaces or buildings are excluded $[m^2]$. Note: the limit permeability values for intermediate V/A values can be obtained by interpolation.

Furthermore, minimum airtightness requirements for windows and doors for new and retrofitted buildings, are given regarding the winter climate zone where the building is located according to Table 2.

Table 2: Permeability limit values for doors and windows of the thermal building envelope

	Climate zone for winter conditions					
	α	A	B	C	D	E
q_{100}	≤ 27	≤ 27	≤ 27	≤ 9	≤ 9	≤ 9

where: q_{100} is the reference air permeability at a pressure difference of 100 Pa $[m^3/h\,m^2]$. *Note*: according to UNE-EN 12207 [4], the permeability limit values correspond to Class 2 ($\leq 27\, m^3/h\,m^2$) and Class 3 ($\leq 9\, m^3/h\,m^2$). If a window has a rolling shutter, its permeability value should also include it. Climate zones A, B, C, D and E refer to Continental Spain. Zone α refers to the Canary Islands.

Apart from this regulation, there are no other incentives for building airtightness in Spain at a national level.

2.3.2 Building airtightness justifications

There are two options to prove compliance with the above airtightness requirements. On the one hand, a pressurisation test can be performed according to Method 2 described in UNE-EN ISO 9972 [7], with no further guidelines added.

On the other hand, an estimation of n_{50} can be done using building dimensions and reference values provided by the regulations (Equation (1)):

$$n_{50} = 0.629 \cdot \frac{C_0 \cdot A_0 + C_h \cdot A_h}{V} \quad (1)$$

where: n_{50} is the calculated air change rate at $50\,Pa$ $[h^{-1}]$; V is the internal volume within the thermal building envelope $[m^3]$; C_0 is the airflow coefficient of the opaque part of the thermal envelope at a reference pressure of 100 Pa $[m^3/h\,m^2]$. Reference values are assigned depending on the assumed airtightness of the building. For new or existing buildings with improved airtightness, C_0 is 16 $m^3/h\,m^2$, whereas for existing buildings a value of 29 $m^3/h\,m^2$ is assumed; A_0 is the sum of areas of the opaque thermal building envelope $[m^2]$; C_h is the permeability of doors and windows in the thermal building envelope at a reference pressure of 100 Pa $[m^3/h\,m^2]$, according to laboratory testing results provided by the manufacturer; A_h is the sum of the area of the doors and windows of the thermal building envelope $[m^2]$. The thermal building envelope consists of the building parts with heat exchange with the outdoor air. Therefore, internal partitions in contact with adjacent indoor spaces or buildings are excluded.

2.3.3 Sanctions

An energy performance calculation has to be performed, which verifies compliance. If the airtightness performance does not meet the requirements, the project will not be approved. Sanctions are considered if the information provided is proven to be untrue [9].

2.4 *Building airtightness in the energy performance calculation*

2.4.1 Calculation

Whole building and windows airtightness are input values of the energy performance calculation. The official unified tool LIDER/CALENER (HULC), or other accepted tools which use the same calculation method, is used to verify the requirements established by regulations (DB HE0 and HE1) and to certify the energy performance of buildings [10]. In this tool, the airtightness of the envelope can be either introduced by means of a default value obtained from Equation (1), or the air change rate at 50 Pa (n_{50}) if a pressurisation test has been performed according to Method 2 of UNE-EN ISO 9972 [7].

2.5 *Building airtightness test protocol*

Airtightness tests are performed according to the international standard UNE-EN ISO 9972:2019 [7] with a Blower Door. There are no further national guidelines.

There is no qualification scheme for testers on a national level but manufacturers of airtightness tests equipment provide several courses and levels. The number of testers is unknown.

2.6 *Building airtightness tests performed*

2.6.1 Tested buildings

The actual percentage of buildings tested in Spain is unknown. In general terms, airtightness testing has not driven awareness until recently, when some companies found a little niche in the market and started promoting its importance. From 2010 to 2015 not many tests were carried out on a national scale. País Vasco and Catalunya were somewhat ahead of other communities, where tests were carried out in public housing, schools or libraries and of course some assets of large foreign multinationals. During this time, a large percentage of tests were curiously carried out in existing buildings, where the aim was to improve its overall energy label and where airtightness started playing a role. The years 2015-2019 saw an interesting increase in testing mainly promoted by the Passivhaus institute and certifications like BREEAM or LEED. With the help of the new specifications set in the national Technical Building Code (CTE) at the end of 2019, the Blower Door movement has made a small step forward but still it is far behind to what is happening in other European countries.

2.6.2 Database

So far there is no official airtightness database promoted by the government or any dependent energy agency. As a result, field data is only available internally by private companies or measurements carried out for research purposes.

From a research point of view, several studies have been carried out since 2011 from limited samples of residential buildings [11–16]. Research has intensified for the past few years, and a growing interest in the topic is undeniable [17–23]. These databases focused on specific building stocks with particular characteristics and typologies.

To fill this knowledge gap, a database was built under the INFILES Project (BIA2015-64321-R) coordinated by Universidad de Valladolid in collaboration with 8 other universities in the country [24–27]. Airtightness data was gathered by trained agents following a qualification scheme and testing procedure that met the requirements of the project. This airtightness database can be considered the first representative sample of the Spanish residential building stock [28]. The tested cases were selected with the rationale of reproducing the existing building stock on a smaller scale on the basis of a considered sample size. A non-probabilistic quota sampling scheme was considered in order to ensure the heterogeneity and proportionality of the selected cases. Cases were selected according to a series of control variables, namely, the period of construction, typology (single-family or multi-family housing) and the climate zone. It was however only a one-time effort that contains 400 cases, which represents a minor share of the measured data.

2.6.3 Evolution of the airtightness level

The mentioned INFILES database verified the evolution of the airtightness level over time from the sample tested. Contrary to what one might expect, no statistically significant relation between airtightness and the period of construction of the dwellings was found [29]. Just a slight trend of improvement of the mean and median values of the air change rate over the years was observed. This could be explained considering the evolution of construction systems and practice, and the implementation of energy-related building regulations in the country in 1979 [30] and 2006 [5].

As an example, the mean air change rate at 50 Pa for dwellings built before 1979 (period 1960-1979) was 7.93 h^{-1}, whereas 7.19 h^{-1} was obtained in the case of dwellings built after 1979 (period 1980-2006), and dwellings built after 2007 had a mean value of n_{50}= 6.85 h^{-1}. Even though airtightness was not considered in neither of the regulations mentioned, the fact that the energy performance had to meet certain requirements might have led to an indirect improvement on the airtightness performance. The relationship between airtightness performance and the most significant changes in regulations was also studied in specific climate zones [25,26].

Overall, the steady airtightness values over the years might be due to the lack of airtightness limitation and because, traditionally, it has not really been a concern. In addition, construction technology in Spain still relies often on traditional systems with inadequate and careless execution.

The recent update of DB HE1 [6] in 2019, which implemented whole building airtightness limits, might be a reason to believe that the current airtightness trend could change, although testing is not mandatory to prove compliance.

2.7 *Guidelines to build airtight*

The Basic Document for the Energy Saving in Buildings (DB HE1) [6] encourages construction solutions and workmanship of the building envelope that guarantee adequate airtightness performance. Special attention should be paid to joints and discontinuities on the thermal envelope, whose correct execution is addressed in UNE 8529:2016.

2.8 *Conclusion*

The past few years have been key regarding building airtightness in Spain. For the first time, the recent incorporation of whole minimum building airtightness requirements on the last update of DB HE1 [6], although not too stringent, can be seen as a way to raise awareness on this parameter and familiarize with the existing tools and techniques to handle it, which encourages positive progress towards energy-efficient buildings.

The authors believe that regarding building airtightness improvement, regulation would be the best promoter, with a sincere objective and sanctions if results are not attained.

There is no official date for an update of regulations regarding airtightness. The national translation of the common framework for the calculation of EPB indicated that it is expected that future regulation will increase this requirement for all types of buildings [31].

For the next years, a rise of awareness regarding airtightness in the building sector and regulations is expected. A trend towards more demanding limits and mandatory compliance for buildings of any kind and size, at least for the most extreme climate zones, are believed as the next steps. In this regard, pressurisation tests should be encouraged as a diagnosis tool and to obtain real performance values, following the example of other countries.

3 Ductwork airtightness

3.1 *Introduction*

Ductwork airtightness is still an issue that does not entail much concern in the construction sector. According to technicians, ductwork is usually executed without concern and, thus, it is leaky. Ductwork testing used to be very rare, and usually the installing companies also performed these tests with rather archaic equipment. As a consequence, there are hardly any companies specialized on this market. However, for the past few years, the context seems to be changing, and concern has been raised.

3.2 *Airtightness indicator*

The airtightness indicator for ducts is the airtightness class according to UNE-EN 12237 [32], UNE-EN 1507 [33], and UNE-EN 13403 [34].

3.3 *Requirements and drivers*

3.3.1 Ductwork airtightness requirements in the regulation

Currently, ductwork airtightness is required by "Reglamento de instalaciones térmicas de los edificios" (RITE) [35] section IT 1.2.4.2.3 provides airtightness requirements, which specifies that the ductwork must comply at least with Class B values. This is in force since 2007 and the requirement makes reference to new buildings and retrofitted ones.

3.3.2 Ductwork airtightness justifications

On Section 2.2.5. of (RITE) [35], airtightness tests are required while the system is still accessible for its testing according to UNE-EN 12599:01 [36]. However, this requirement is somehow recent and still there is not much concern among construction agents. Therefore, in practice, ductwork is still not always tested. There are no sanctions if a ductwork does not comply with the requirement.

3.4 *Ductwork airtightness in the energy performance calculation*

To the authors' knowledge, the ductwork airtightness is not an input of the energy performance calculation. The lack of concern seems to be the reason.

3.5 *Ductwork airtightness test protocol*

There are no national guidelines on ductwork airtightness test, it is done according to UNE-EN standards.

There is also currently no specific qualification program. Usually, the technicians who install the system also test the airtightness.

3.6 *Ductwork airtightness tests performed*

There is no official data on the number of ductwork systems tested, but the percentage is rather low.

3.7 *Conclusion*

Overall, even though there are requirements for ductwork airtightness, the observed lack of concern and inspection seem to be the reasons why in practice there is no control over this issue. However, this might be changing lately and raised awareness has been identified.

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