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Characterization of the Airtightness Level in School Classrooms in Mediterranean Climate

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***Abstract*—**An analysis of the air tightness level is performed on a representative sample of school classrooms in Southern Spain, which allows knowing the infiltration level of these classrooms, mainly through its envelope, which can affect both energy demand and occupant's thermal comfort.

By using a pressurization/depressurization equipment (Blower-Door test), a characterization of 45 multipurpose classrooms have been performed in nine non-university educational institutions of the main climate zones of Southern Spain. In spite of having two doors and a high ratio between glass surface and outer surface, it is possible to see in these classrooms that there is an adequate level of airtightness, since all the n50 values obtained are lower than 9.0 ACH, with an average value around 7.0 ACH.

***Keywords*—**Air infiltration, energy efficiency, school buildings, thermal comfort, indoor air quality, ventilation.

I. Introduction

When the environmental performance of the architectonic enclosures is analysed, the ventilation appears as one of the main variables that affect the energy demand, the degree of environmental comfort [1], [2] and rate accumulation of CO2, suspended particles and pollutants [3].
In non-residential buildings, European ventilation standards [4] establish the need to guarantee a minimum outdoor airflow for an adequate IAQ control. Thus, it is necessary to resort to mechanical ventilation with stages of filtration. However, in Mediterranean climates, ventilation is usually relied both on uncontrolled infiltrations through the envelope and windows opening, except the most modern buildings.

An enclosure pressurization/depressurization equipment or Blower Door, widely recognized by the scientific community [5], [6], can quantify the infiltrations in this type of educational facilities. By its use, it is possible to perform a series of in situ pressurization/depressurization tests in a room, in order to determine the airtightness level of its envelope. This also allows assessing its associated impact on the inner thermal comfort level, due to uncontrolled air inlets with inadequate conditions of temperature [7].

The methodology presented in this airtightness study has been applied in non-university classrooms of Southern Spain. Educational facilities represent a geographically widespread typology, having a high constant use by highly sensitive occupants and being usually ventilated by uncontrolled infiltrations and windows opening [8], so the envelope permeability becomes a high relevant factor for their final indoor environmental quality [9]-[12].

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TABLE I
Educational Institutions per Climate Zone

Climate zone		Location		Educational institution (EI)	Classrooms under study
TBC*	Koppen	Province	Municipality		
A4	BSk	Almería	Almería	EI 1	4
	BSk	Almería	Almería	EI 2	4
	Csa	Huelva	Aljaraque	EI 3	3
B4	Csa	Seville	Dos Hermanas	EI 4	6
	Csa	Seville	Dos Hermanas	EI 5	3
C3	Csa	Granada	Churriana	EI 6	10
	Csa	Granada	Cullar Vega	EI 7	4
	Csa	Granada	Guadix	EI 8	5
C4	Csa	Jaén	Jaén	EI 9	6
			TOTAL		45

[a]Spanish Technical Building Code [13].

II. School Classrooms Case Study

For this work, it has been selected 45 multipurpose classrooms of nine primary and secondary educational institutions, which are located in Southern Spain (Table I). All of them are exempt building, with a lineal or comb-shaped distribution.

The multipurpose classroom typology under study, designed under the regional no-university educational institutions standard [14], accommodate up to 30 students with their teacher. Dimensions are about 50 square metres and at least 3.00 metres high, with the window to the left. Rooms are usually defined by horizontal and vertical partitions in contact with other classrooms of similar size and use, and the common access corridor, with which normally communicates through two doors (Fig. 1).

There is no false ceiling in any of the measured classrooms, as well as perforations in the inner partitions with adjacent classrooms.

The external vertical wall is usually performed by a half-brick wall (with or without rendering), air chamber, thermal insulation (projected polyurethane) and a simple hollow brick wall with setting plaster. The inner partitions are in general composed by a half-brick wall with setting plaster on both sides.

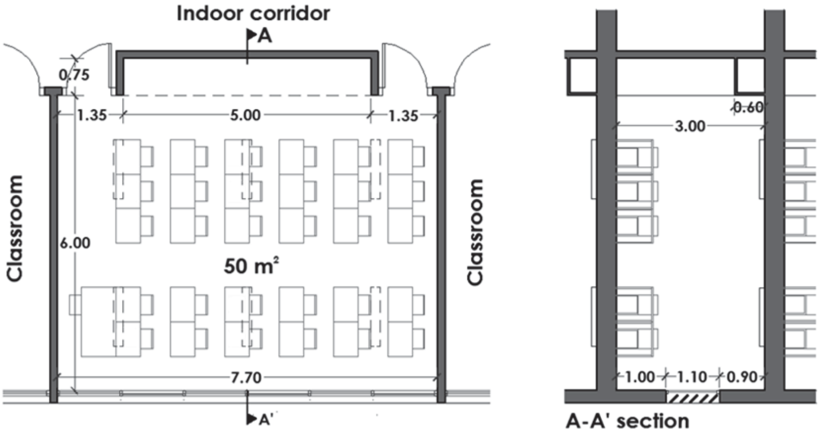

Fig. 1 Multipurpose classroom according to design standards for regional educational institutions

III. Methodology

The assessment of the infiltration level of the classrooms under study was performed by a series of airtightness tests (doors and windows closed); in order to obtain their expected average infiltrations rates (Fig. 2). These tests consist of decreasing the room pressure by using a fan, which extracts air till the indoor-outdoor differential pressure is stabilized. It is achieved by balancing the extracted airflow with the entering airflow through the envelope cracks. Then, the depressurization is decreased in steps by lowering the fan speed, in order to obtain the regression curve of the pressure/extracted airflow relation, which shows the entering airflow when the indoor pressure is equals to the atmospheric one. These tests were performed by using an enclosure pressurization-depressurization equipment or "Blower door", as specified in the ISO standard 9972: 2015 [6], considering each classroom as a single zone to be analyzed. The specific model used is the *Minneapolis Blower Door Model 4/230 V System*, which is controlled by the *TECTITE Express* software.

The higher-pressure difference used to create this regression curve must be at least ± 50 Pa; in this study, it has been reached until a ± 70 Pa differential pressures.

Fig. 2 Airtightness measurement of a classroom

When the classroom has a single access point, the pressurization-depressurization test characterizes the airflow that can pass through the envelope by sealing the corresponding door. However, in most of the studied classrooms there are two access points, so it is necessary to perform three measurements in each classroom, changing the location of the blower door and sealing, or not, the door in which the blower door is disposed. In this way, it is possible to determine the real airflow that enters into the classroom during its normal operation (Fig. 3):

- Measurement 1 (m1): The equipment is installed in the door B. Door A is not sealed (free air pass through its gaps).
- Measurement 2 (m2): The equipment is installed in the door A. Door B is not sealed (free air pass through its gaps)
- Measurement 3 (m3): The equipment is installed in the door A. Door B sealed.

Infiltrations values measured in each of these three ± 50 Pa depressurization test hypotheses, developed in each classroom, are obtained by the following expressions of the British Standard 5925 standard (1)-(4), obtained from a simplification of the "crack flow equation" [15]:

$$n_{50,1} = \left(V_{50,Da} + V_{50,e}\right)/V \quad (1)$$

$$n_{50,2} = \left(V_{50,Db} + V_{50,e}\right)/V \quad (2)$$

$$n_{50,3} = V_{50,Dc}/V \quad (3)$$

$$n_{50} = \left(V_{50,Da} + V_{50,Db} + V_{50,e}\right)/V = n_{50,1} + n_{50,2} - n_{50,3} \quad (4)$$

All the equation parameters are defined in Table II.

TABLE II
Units for Depressurization Test Equations

Symbol	Quantity	Unit
$V_{50,Da}$	air leakage rate at 50 Pa which circulates through the door A	m^3/h
$V_{50,Db}$	air leakage rate at 50 Pa which circulates through the door B	m^3/h
$V_{50,e}$	air leakage rate at 50 Pa which circulates through the envelope	m^3/h
V	infiltration rate at 50 Pa for the three measurements	m^3
$n_{50,1}$	infiltration rate at 50 Pa of the measurement 1	ACH
$n_{50,2}$	infiltration rate at 50 Pa of the measurement 2	ACH
$n_{50,3}$	infiltration rate at 50 Pa of the measurement 3	ACH

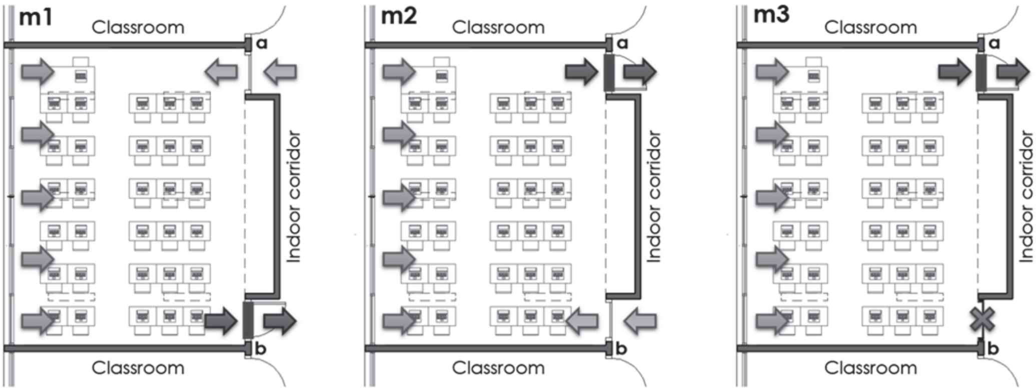

Fig. 3 Hypotheses of depressurization tests in classroom under study according to equipment location and door sealing

IV. Discussion and Results

As an example of this methodology, the average results obtained from Churriana's analysed educational institution (IE 6) are presented, since its classrooms are the most representative, both for their average values and the number of measurements performed. In this way, the depressurization test graph performed in one of its classroom is shown in Fig. 4.

The obtained results of the EI 6 measurement campaign are shown in Table III, for both V_{50} and n_{50}. It is possible to see that the average infiltration rate in EI 6 measured classrooms is 7.80 ACH for ± 50 Pa, with a standard deviation of 0.63 ACH.

TABLE III
EI 6 Classrooms' Average Infiltration Rates

Koppen climate zone	Classrooms under study	Air Leakage rate at 50 Pa (V_{50}) (m^3/h)		Infiltration rate at 50 Pa (n_{50}) (ACH)	
		Average	Standard deviation	Average	Standard deviation
Csa	10	1170	94	7.80	0.63

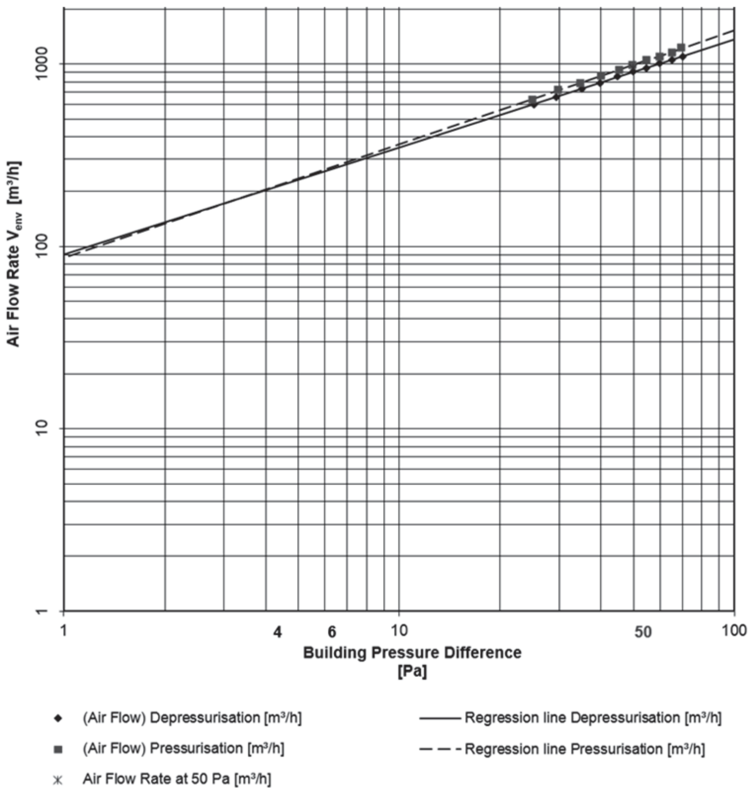

Fig. 4 Depressurization test graph of one of the EI 6 classrooms

When permeability of the all measured classrooms envelopes is analysed, it can be seen that is low. Despite having two access doors instead of one, and a glazed surface of more than 30% of the façade that contains it, n_{50} infiltration values in all these measured classrooms is 7 ACH with a standard deviation of 1.7 ACH. Which is less than 9 ACH, the average value for multipurpose classrooms (with a single access door) according to BS 5925:1991 [15] (Fig. 5).

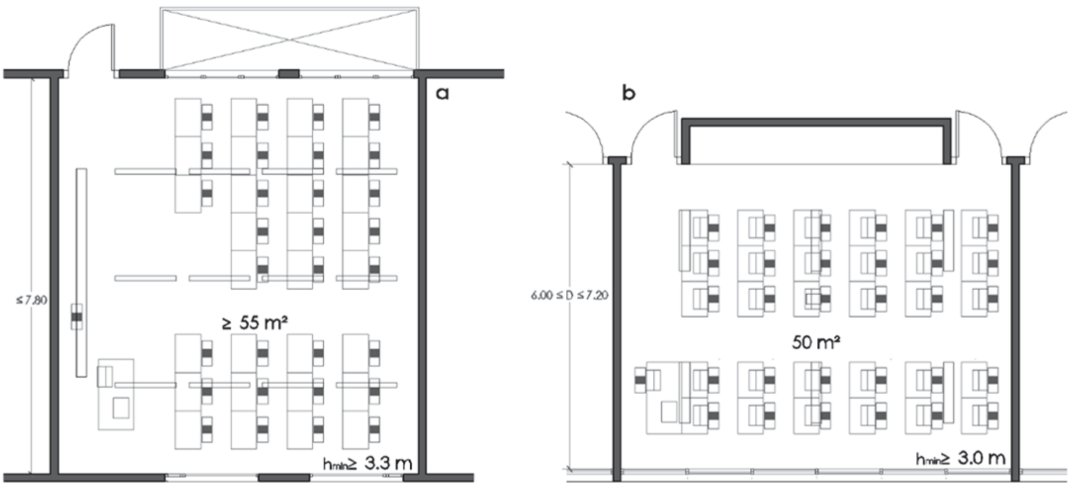

Fig. 5 Multipurpose classrooms in United Kingdom (a) and Southern Spain (b)

V. Conclusions

The envelope permeability of the non-university classrooms of Southern Spain (Mediterranean climate zone) can be considered as low. Since despite having two access doors and a glazed surface of more than 30% of the façade that contains it, the average infiltration of the measured classrooms is less than 9 ACH for ± 50 Pa (n_{50}), with an average value around 7 ACH and a standard deviation of 1.7 ACH. Further studies are required for establishing a relationship between classrooms airtightness and their environmental quality.

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