ADVANTAGES AND CONDITIONING FACTORS OF VENTILATED FAÇADES WITH RESPECT TO THE BASIC BUILDING REQUIREMENTS (TBC)

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ABSTRACT

Ceramics have been used since ancient times as materials for enveloping and cladding buildings due to their mechanical strength, durability, and surface or mass impermeability.

The traditional use of ceramics adhered to the façade has recently been complemented with installation using mechanical anchorings, which have allowed larger formats to be installed and the cladding to be separated from the closure, leaving an air chamber that can form a ventilated façade, a solution already used with other materials like stone, wood, metals, etc.

On the other hand, the increasing and ever-stricter building regulations attach more importance to building performance, and particularly to the building envelope. In the case of Spain, this regulation is synthesized in the basic building requirements defined in the Technical Building Code (TBC) and specified in this code's Basic Documents.

In other countries of the European Union, we can find similar regulations, for they all must comply with the EU Directive on the free circulation of building products and, therefore, similar requirements are the result.

This paper analyses these basic Safety (structural, fire and use) and Habitability

(Energy and Health) requirements of ventilated façade solutions, and sets out the advantages and conditioning factors that these requirements impose on façade design.

By way of advance conclusions of the work, it may be noted that there are significant advantages, mainly in energy saving; however, in order to save energy, some conditioning factors must be met in the use of the materials and in façade design.

1. THE VENTILATED FAÇADE COMPARED WITH TRADITIONAL ENVELOPES

The ventilated façade is an exterior face of a building made up of an external leaf, the weight of which is transmitted to a conventional closure or to the very structure of the building. The system allows continuous thermal insulation to be placed on the interior leaf, which functions as an envelope, leaving a continuous air chamber between this and the external leaf, providing the building with its aesthetic finish and protection, figure 1.

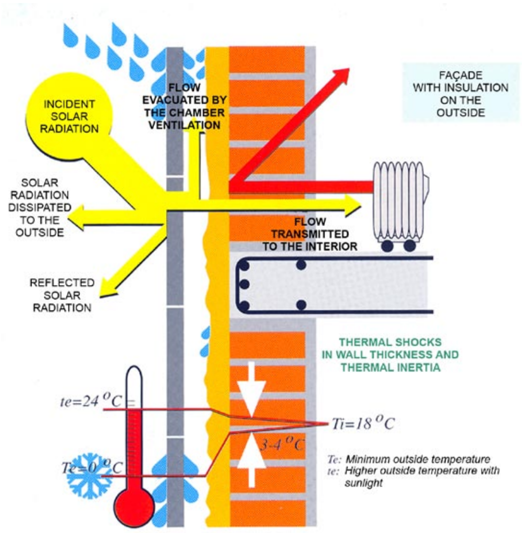


Figure 1. Schematic illustration of a ventilated façade [1].

In comparison with conventional façade systems, the ventilated façade is considered more efficient for resolving building insulation, since the continuous layout of the insulation protecting the inside leaf and protecting the deck edges minimizes undesirable thermal bridges, thereby reducing condensation problems and improving building thermal and moisture performance.

The heating of the air in the chamber due to the incident radiation on the outside leaf encourages continuous ventilation through the well-known *"chimney effect"*. The incidence of the sun on the outside skin of the building causes the air in the chamber to heat through radiation when its density decreases, which creates a current of rising air that is renewed by fresh air. In the warm months, this phenomenon prevents heat from accumulating on the facing and, along with the thermal insulation, it allows energy to be saved. In the cold months, with proper dimensioning of the air input and output, this ventilation allows the water vapour coming from both the inside and the outside of the building to be evacuated, while keeping the insulation dry and obtaining a better performance of it. This, along with the reduction in thermal bridges, results in larger savings in energy consumption.

As well as the beneficial chimney effect, the existence of an outside skin separated from the building by a ventilated chamber eliminates direct radiations and protects the inside leaf and the structure from the weather, which helps to reduce the pathologies that affect buildings built with traditional systems. Also, if façade system design is appropriate, it will allow both the outside leaf to move freely with respect to the inside one, as well as the components that make up the outside leaf, and this reduces the possible stresses created by the restriction of differential movements among different materials.

It should also be pointed out that certain systems allow entire pieces to be replaced, so the ventilated chamber can be inspected and, therefore, making it accessible for possible installations. Likewise, the pieces could be reused, allowing the envelope's aesthetic appearance to be readily modified.

Finally, in the specific case of the ceramic façade, the detachment of adhered pieces caused the material to be greatly distrusted. This drove the manufacturers to develop new systems for installing the pieces based on mechanical fastenings, with higher guarantees with respect to the risk of detachment.

Nevertheless, the ventilated façade also has certain drawbacks. Thus, it should be pointed out that, at present, these systems are more expensive in comparison with traditional systems like face brick façades, as a result of ventilated façades being less standardized.

On the other hand, although a proper design can reduce the risk of detachment, the system has to be analysed beforehand and the installation must be controlled, with a guarantee that the piece will remain in place in adverse weather conditions or against possible breakage. In the same way, easily changing pieces depends on the design of the system, so it can sometimes be complicated.

Although the ventilated façade generally has low impact resistance in the area where it starts, this drawback can be largely mitigated by interspersing intermediate profiles, increasing the thickness of the pieces in this area or using an arlite mortar filler, although in this last option we would have to leave slots without filler to allow ventilation [2].

Certain characteristics would also be required of the thermal insulation, since it will need to be waterproof and not hygroscopic since it is placed on the outside. On the other hand, when it is flammable, the risk of fire being spread among floors must be restricted.

2. THE CERAMIC VENTILATED FAÇADE IN COMPARISON WITH OTHER MATERIALS AND SYSTEMS

The functional specialization of each one of the materials that make up the ventilated façade has made it possible for a large number of materials to work as exterior cladding [1]. As a result, such different materials as aluminium, fibre-reinforced concretes, and natural and artificial stones, as well as ceramics, can make up the building exterior skin.

In this sense, table 1 compares some of the most important characteristics for use on a ventilated façade.

Sample	Mass/ Sufarce area g/cm^2	MPa modulus of rupture	Moisture expansion mm/m	Coeff. of thermal exp., $^oC^{-1}·10^{-6}$	Facing water absorption g/cm^2
Porcelain tile	1.85	45-57	<0.1	6.0	<0.001
Marble	5.32	10-11	<0.1	4.1-4.6	0.006
Limestone	5.20	9-12	<0.1	4.4-4.6	0.013
Granite	5.43	11-16	<0.1	7.1-7.9	0.013
HPL	1.39	107	0.6/1.5	9.4-19.4	0.008
Phenolic	1.38	108	0.6/1.5	9.4-19.7	0.007
Aluminium	0.54	Deformable	< 0.1	23.1	0.001

Table 1. Comparison of façade cladding materials [2].

As it may be observed, the high-pressure laminates (HPL) and the phenolic boards have the highest strength, which allows them to be thinner. However, their problem mainly lies in the high level of expansion due to humidity and temperature, so they require systems that allow them to expand freely without bulging. Likewise, although the aluminium-based systems do not change in dimension due to humidity, they have the maximum level expansion due to the temperature. On the other hand, their main drawback lies in their great deformability, so it is not advisable to use them in the lower areas of the building.

It should be pointed out how the little porosity of porcelain tile causes both small water absorption and high strength. Along with the homogeneity inherent in an industrial product, this allows the thickness of the slabs used to be reduced, which will have an influence on both the calculation of the required anchorages and on the weight of the final envelope. In contrast, the lower strength of natural stone and its greater heterogeneity make the minimum recommended thickness 3 cm [2], which conditions both slab weight and dimensions, since these must allow them to be handled.

All in all, the characteristics of the material determine both its performance and the design of the fixing system, which has led to the appearance of a wide range of systems. Figure 2 shows a diagram of the fixing system types commonly used on ventilated stone and ceramic façades.

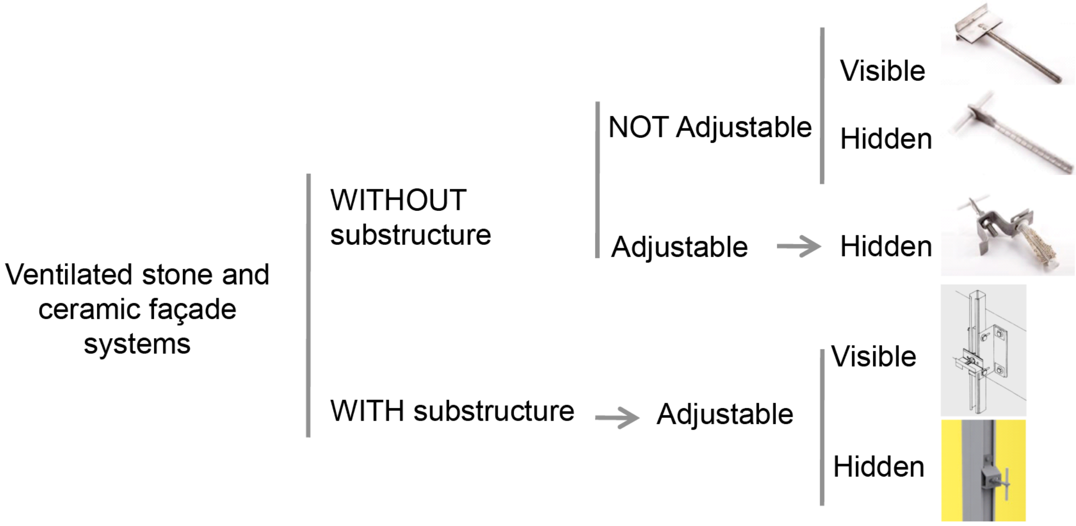


Figure 2. Ventilated façade systems used with stone and ceramic.

Ceramics characteristics have led these materials mainly to be set on systems with a substructure, which is basically due to the easier adjustment and better performance in the installation, for they allow the substructure to be assembled independently of the tile installation. In these types of systems, the manufacturers have developed many ways of fastening the ceramic piece to the substructure (table 2). Although it depends on the specific design, most of them are safe and they allow a piece to easily be changed in the event of breakage, although, since the shade of colour depends on parameters inherent to the manufacturing process, it is advisable to keep pieces in reserve once the façade cladding has finished in order to have a similar colour if a piece needs to be replaced.

Type of ceramic	Possible installation systems
Extruded terracotta	
Extruded stoneware	
Pressed tile (Porcelain tile)	
Extruded or pressed tile	

Table 2. Systems for fastening the ceramic to the substructure.

The table shows that the type of ceramic also conditions anchoring system design. Thus, in pressed ceramic, porcelain tile is the most widely used material since, as observed, its low porosity makes it highly resistant, which allows its thickness to be reduced and, therefore, the weight of the cladding and of the substructure required for placing it. Also, its acid nature and reduced absorption make it easy to clean and to maintain properties through time. Although extruded ceramics have more porosity, they allow the manufacturing process to be used for making the ribs that allow the pieces subsequently to be hung on the façade.

3. PERFORMANCE IN THE FACE OF THE REGULATORY REQUIREMENTS ESTABLISHED BY THE TBC

In this section, a comparative study will be made of the performance of a conventional envelope and a ventilated façade in the face of the current requirements established by the TBC. A conventional envelope is understood as the one made up of two-wythe masonry walls with thermal insulation and a non-ventilated chamber.

3.1. DB HE1: Restriction of energy demand.

In accordance with TBC DB-HE1, *"The energy demand of buildings is limited depending on the climate of the place where they are located, according to the climate zone and the internal load in their spaces"*. For this, 12 climate zones are established, which are identified by a letter (winter) and a number (summer). As well as the tabulated values established in appendix D, the climate zone can be determined using contrasted records.

To justify the envelope transmittance, the spaces are considered habitable or non-habitable, and the former can have a high or low internal load depending on the heat that is dissipated in their interior. Likewise, for calculating condensations, these are classified depending on the humidity created inside them and they may have a hygrometry of 3, 4 or 5.

Once the starting conditions have been established, the envelope is required to comply with certain limit (U_{LIM}) and maximum (U_{MAX}) transmittances. The U_{LIM} is determined as the average of the different construction solutions that make up the façade, including the integrated thermal bridges, such as the borders of spaces, pillars on the façade, blind casings or others. On the other hand, the U_{MAX} is established separately for each element and it is meant to prevent imbalances between the thermal qualities of different spaces. Surface condensations must also be prevented and the interstitial condensations restricted so that they do not cause a loss of thermal performance or a risk of degradation.

The compliance of these conditions can be checked through the General Option using the "LIDER" software or the Simplified Option on which we shall focus in this study. U_{MAX} (W/m^2K) is determined as the inverse of the envelope's total thermal resistance (RT), which is calculated as the sum of each layer's contribution (figure 3). The difference between a conventional and a ventilated façade[1] lies in the chamber. So, when this is non-ventilated, in its DB HE1, the TBC provides a table with the values to be adopted depending on the chamber thickness (figure 3a). On the other hand, *"for highly ventilated air chambers, the total thermal resistance of the envelope is obtained by disregarding the thermal resistance of the air chamber and that of the other layers between the air chamber and the exterior atmosphere, including an outside surface resistance equal to the interior surface resistance of the same element"* [3] (figure 3b). Therefore, according to the Simplified Option, ventilated façade transmittance will be higher, since the simplification does not consider the chimney effect or the protection of the direct radiation, and it disregards the contribution of the outside wall in the calculation.

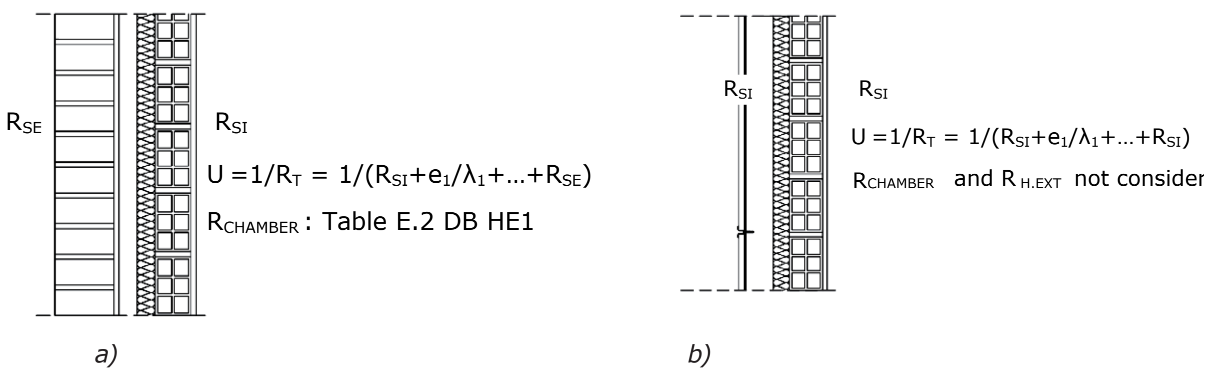


Figure 3. Transmittance calculation of an envelope according to the DB HE1 simplified option.

However, since the thermal insulator gives the maximum contribution to thermal resistance, the simplification that is normally carried out by the TBC for the calculation does not involve an increase in insulator thickness. Also, this effect is mitigated when the U_{LIM} (more restrictive than U_{MAX}) is calculated because, although it does not consider thermal bridges at joins (like deck fronts, etc.), it does take integrated bridges into account.

Therefore, the improved performance resulting from the installation of continuous thermal insulation on the outside and the existence of a ventilated chamber was only reflected in the calculation of the U_{LIM}, but not of the U_{MAX} or at the condensation level. Even so, it is obvious that protecting the interior leaf from radiation and from the direct action of the elements reduces the energy demand of the building, just as the ventilation of the chamber and the reduction of thermal bridges reduce the risk of condensations.

3.2. DB HS1. Protection from humidity.

In its DB HS1, the TBC demands a minimum degree of impermeability (DI) on the façades which depends on the pluviometric zone and on the degree of

1. DBE HE1: An air chamber is considered to be highly ventilated when the values of the openings exceed 1500 mm² per m length counted horizontally.

exposure to the wind. Five degrees of impermeability are thus established, such that degree 1 is associated with buildings with a low height, which are not exposed and are located in an area with little rain, while degree 5 would correspond to maximum exposure. For each degree of impermeability, the TBC requires that the construction solutions comply with certain conditions, listed in table 3 [4].

Degree of impermeability	*With external cladding*	*Without external cladding*
≤1	R1+C1(1)	C1(1)+J1+N1
≤2		B1+C1+J1+N1 · C2+H1+J1+N1 · C2+J2+N2 · C1(1)+H1+J2+N2
≤3	R1+B1+C1 · R1+C2	B2+C1+J1+N1 · B1+C2+H1+J1+N1 · B1+C2+J2+N2 · B1+C1+H1+J2+N2
≤4	R1+B2+C1 · R1+B1+C2 · R2+C1(1)	B2+C2+H1+J1+N1 · B2+C2+J2+N2 · B2+C1+H1+J2+N2
≤5	R3+C1 · B3+C1 · R1+B2+C2 · R2+B1+C1	B3+C1

(1) When the façade has only one leaf, C2 must be used

Table 3. TBC DB HS1. Conditions of façade solutions [4].

Where the R index refers to the resistance to filtration of the outside cladding; B to the resistance to filtration of the barrier against water penetration; and the C, H, J and N coefficients refer to the main wall, with reference to its **C**omposition; **H**ygroscopicity; resistance to the filtration of **J**oints, and resistance to the filtration of the i**N**termediate cladding on the internal side of the leaf. Since a higher GI means higher requirements, a higher block number means better performance, so the construction solution can be used on all the previous ones (e.g. R3 could also be used in R2 and R1).

In this way, the ventilated façade external cladding, made up of non-hydrophilic thermal insulation[2], an outer leaf and a ventilated chamber on the outside of the insulation, is considered R3 *"outside cladding with extremely high resistance to filtration"* and B3, *"a barrier with a very high resistance to filtration"*, which means that they satisfy any degree of impermeability. Obviously, with the adoption of a ventilated façade solution (R3 + B3), it is no longer necessary to establish special conditions in relation to the hygroscopicity of the material that makes up the main leaf (H), the resistance to filtration of the joints or of the inside cladding of the main leaf (J and N respectively). On the other hand, the previously described performance of the ventilated façade envelope allows the thickness of the main leaf to be medium (C1) instead of high (C2).

It should be pointed out that, for the chamber to be considered ventilated, there must be ventilation openings of at least 120 cm^2 every 10 m^2 of the façade length. For this, open joints with a minimum width of 5 mm or another similar solution can be used.

2. NON-ASORBENT: water absorption < 1 kg/m^2 in partial immersion for 24 hours. WS classification on the EC market of glass wool products.

3.3. DB HR. Protection against airborne noise.

The airborne noise soundproofing ($D_{2m,nT,Atr}$) required of a façade envelope ranges between 30 and 47 dBA, depending on the area's day noise index (L_d), on the use of the building and of the room it delimits (table 2.1 of the DB HR [7]). Although the L_d can be taken from noise maps or from data offered by administrations, when there are no data, a day noise index of 60 dBA shall be taken for residential use. On less exposed façades (closed block or interior patios, peaceful areas, etc.), the Ld can be reduced by 10 dBA, while if the prevailing outside noise comes from aircrafts, the dBA value shall be increased by 4 dBA.

The compliance with the airborne noise soundproofing required can be checked through the General Option, using the corresponding calculation tool [5], or the Simplified Option on which we shall focus in this study. According to this option, the insulation that the blind part of the envelope must have depends on the percentage of openings that exist in the façade and on their soundproofing. As an **example**, a façade envelope located in an area with an L_d of 67 dBA and which delimits an outside bedroom requires a $D_{2m,nT,Atr}$ of at least 37 dBA (table 2.1 TBC DB HR [7]). For this, as seen in table 4 (adapted from [7]), if there are no windows, the insulation on the blind part shall be 39 dBA, whereas when there are openings, this insulation depends on both the surface area occupied by these and on the characteristics of the window and the airer (table 4). Therefore, if the insulation of the windows is high, the blind part will have to have a RA soundproofing of 40 dBA, so normal solutions like those included in table 5 will be obeyed (42 dBA) [6].

Maximum level requiered (Table 2.1) $D_{2m,nT,Atr}$ dBA	**Blind part 100 % RA, dBA**	**Blind part ≠ 100 % RA, dBA**	**Openings, Percentage of openings $R_{A,tr}$ of the window and the blind casing and $D_{n,e,Atr}$ of the airer, dBA**				
			<15%	From 16 to 30%	From 31 to 60%	From 61 to 80%	From 81 to 100%
$D_{2m,nT,Atr}$=37	39	40	35	37	39	39	39
		45	32	35	37	38	
		50	31	34	37	38	

Table 4. Minimum soundproofing of a façade envelope according to the percentage of openings [Adapted from Ref. 7].

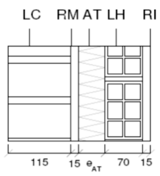
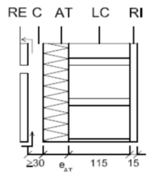
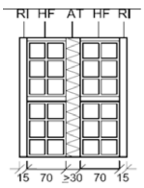
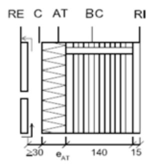
Cross-section, mm	HR[4]		Cross-section, mm	HR[4]	
	R_A, dBA	m, Kg/m^2		R_A, dBA	m, Kg/m^2
	49	240		43	168
	LH: 45 LGF: 44	LH: 170 LGF: 130		44	167

Table 5. Soundproofing of normally used construction solutions[3] [Adapted from Ref. 6].

However, in contrast to the previous basic regulation (NBE CA-88), the TBC DB HR attaches great importance to indirect transmissions, so the characteristics of the façade envelope are strongly determined by the type of **separation element between houses**. Thus, in two-leaf façades[5] , the separation element between dwellings is required to reach the external leaf of the façade envelope, thereby interrupting the inside leaf. According to this basic document, ventilated façades can be considered of one or two leaves, depending on whether they have a wall lining on the inside. With a view to limiting the indirect transmissions by flanks, the façade envelope must conform to certain conditions as a function of the fitted separation element, table 6.

3. LC: Ceramic brickwork, RM: Intermediate cladding, AT: Non-hydrophilic insulation, LH: Hollow brickwork, LGF: Large-format brick, BC: Ceramic blockwork, HF: Masonry work, RI: Internal cladding, RE: Discontinuous external cladding, C: Ventilated air chamber.
4. Average values.
5. TBC DB HR, Section 3.1.2.3.1. Types of façades:
- Of a SINGLE LEAF of masonry construction or concrete.
- Of TWO LEAVES: ventilated and non-ventilated. With a heavy external leaf (masonry construction or concrete) or lightweight external leaf (sandwich panel or GRC); and an inner leaf of self-bearing framework, masonry construction, concrete or heavy prefabricated panels.

<table>
<tr><th rowspan="3">SEPARATION ELEMENT</th><th colspan="4">FAÇADE TO WHICH IT IS FITTED</th></tr>
<tr><th colspan="3">TWO LEAF</th><th rowspan="2">SINGLE LEAF</th></tr>
<tr><th colspan="2">NON-VENTILATED</th><th>VENTILATED</th></tr>
<tr><td rowspan="2">TYPE 1</td><td colspan="2">External leaf m>130 Kg/m²</td><td>- Int. leaf. Brickwork or concrete:
R_A Int. leaf > 42 dBA
m Int. leaf >135 Kg/m²
Unsuitable for premises installations

- Ext. leaf. Framework:
R_A Int. leaf > 43 dBA
m Int. leaf >26 Kg/m²</td><td>R_A Int. leaf > 42 dBA

m > 135 Kg/m²

Unsuitable premises installations</td></tr>
<tr><td colspan="4">DOES NOT CONSIDER:
- Two-leaf façades with internal leaf of brickwork and concrete with framework partition walls.
- Two-leaf façades with internal leaf with frame and brickwork or concrete partition walls</td></tr>
<tr><td rowspan="3">TYPE 2</td><td>m<170 Kg/m²</td><td rowspan="2">NO RESTRICTION ON HEAVY EXTERIOR WALL</td><td>- Int. leaf. Brickwork or concrete:
CANNOT be fitted</td><td>CANNOT be fitted</td></tr>
<tr><td>m>170 Kg/m²</td><td>- Int. leaf. Brickwork or concrete:

R_A Façade > 50 dBA
m Façade>225 Kg/m²</td><td>R_A Façade > 50 dBA

m Façade > 225 Kg/m²</td></tr>
<tr><td colspan="4">DOES NOT CONSIDER:
- Two-leaf ventilated façade with internal leaf with framework.</td></tr>
<tr><td rowspan="2">TYPE 3</td><td colspan="2">- Int. leaf Framework:
R_A Ext. leaf. >45 dBA
m Ext. leaf. >145 Kg/m²</td><td>- Int. leaf Framework:
R_A Int. leaf. > 43 dBA
m Int. leaf. > 26 Kg/m²</td><td>NOT CONSIDERED</td></tr>
<tr><td colspan="4">DOES NOT CONSIDER:
- Single-leaf façades.
- Single-leaf or two-leaf façades with heavy internal leaf.</td></tr>
</table>

Table 6. Requirable characteristics for a façade envelope as a function of the separation element between dwellings.

The DB HR considers *type 1* elements to be those consisting of one base element of one or two leaves of brick masonry, concrete or heavy prefabricated panels, with no wall-lining or wall-lining on both sides; *type 2* differ from the former by the arrangement of elastic bands where at least one of the leaves meet with decks, floors, façades, etc., and *type 3* are elements with two leaves of self-supporting framework.

As observed in Table 6, single-leaf façade envelopes can only be fitted with type 1 or type 2 separation elements with a mass above 170 kg/m². For that reason, in most cases it is necessary to apply to a wall lining with a view to limiting flank transmissions, then being considered a two-leaf envelope. According to the Simplified Option, in this case the maximum restrictions occur for type 2 separation elements, while the type 3 elements could only be used when the wall lining is made with a self-bearing frame.

The consideration of a ventilated façade envelope from the acoustic viewpoint has improved substantially compared with the first version of the DB HR, in which construction solutions conventionally adopted for the installation of the inner leaf of a ventilated façade, table 7, were only sufficient for soundproofing against outside airborne sound, but were insufficient as soundproofing between dwellings when type 2 separation elements (with elastic bands at their borders) or type 3 separation elements (self-bearing frame) were used. The fact of considering single-leaf ventilated façades limited, according to the previous DB HR, the benefit provided by having a ventilated chamber on the outside of the thermal insulation, according to which DB HS1 allows inner leaves of medium thickness to be used (see section 3.2). This consideration also contradicted certain inherent advantages of ventilated façades, such as reduce the weight on the structure.

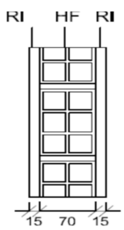
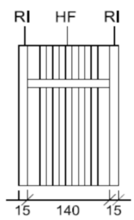
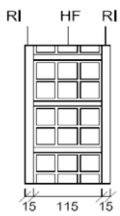
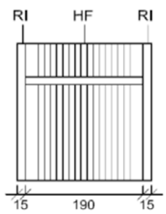
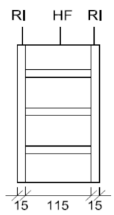
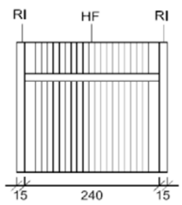
Cross-section, mm	m, Kg/m²	Cross-section, mm	m, Kg/m²
	LH: 97 LGF: 80		160
	LH: 160		198
	161		276

Table 7. Masonry masses normally used as substrates in ventilated façades [Taken from Ref. 6].

Therefore, it may be concluded that the change made in DB HR, in which ventilated façades can be considered to consist of two leaves, largely reduces the previously established restrictions for limiting the indirect transmission of the sound between different units of use. However, with a view to reducing indirect transmissions when separation elements with elastic bands or self-bearing frames are used, the wall lining shall conform to certain characteristics. Similarly, it is only advisable to use single-leaf envelopes (without a wall lining) in type 1 separation elements.

3.4. DB SI. Safety in the event of fire.

In accordance with the conditions established by the TBC in its DB SI, *"buildings must be compartmentalized in fire sections according to the conditions established in table 1.1"* [8], according to which a residential house must be sectorized every 2500 m^2, and the elements that separate houses from each other or those in the building common areas shall be at least EI 60 (E= Stability; I = Thermal insulation). Also, some premises and areas with a special risk are established, including junk rooms in residential housing.

In relation to this sectorization, it is established that *"in order to limit the **risk of fire spreading vertically through the façade between** two **sectors of fire or** between a **specially high-risk area** and other **higher areas** of the building, this façade must be at least EI 60 in a 1-m-high stretch, at least, measured on the plan view of the façade"*. Therefore, it can be interpreted that this resistance to fire must be provided by the internal leaf. However, in the case of the thermal insulation being flammable, the existence of a continuous chamber on the outside could lead to a strong risk with regard to both fire transmission and to the loss of resistance of the anchorages, with the consequent risk of detachment of the parts that make up the envelope outer leaf.

In this sense, in its DB SI, the TBC establishes that on façades that can be pulled off by the public, either from the outside ground level or from a roof, and on all façades with a height of over 18 m, the type of reaction to fire of the materials that cover more than 10% of the surface of the external finish or of the internal surface of the ventilated chamber shall have a classification of B-s3 d2 or better.

In accordance with standard UNE EN 13501-1 [9], the first letter refers to the Euroclass (A1, A2, B, C, D, or E) and the "s" refers to smoke production (s1, s2, s3), while the "d" refers to the drop of ignited drops or particles (d0, d1, d2). Lower or equal indices meet the conditions of the next class. For example, a main index "B" means a very limited contribution to fire, so it would meet class "C" and subsequent classes, but not class "A". Likewise, a d0 classification will meet the subsequent ones, d1 and d2.

In a practical way, it can be said that class B-s3 d2 is the equivalent to the M1 established by standard UNE EN 23727 [10]: that is, when the conditions described occur, the thermal insulation could be combustible, but not flammable.

The thermal insulations most commonly used on a ventilated façade are in *situ* polyurethane, with a market share of 95%, and waterproof rock wool, which makes up the rest [2]. On the other hand, the polyurethane foam with no covering could not be used on façades of over 18 metres that have not been compartmentalized or on façades that can be pull off by the public, because it belongs to Euroclass

E, with a higher reaction to fire than required. Although it could be used after rendering or plastering, the economic advantages caused by its great performance in installation would be lost. On the other hand, though rock wool costs more, it performs better with regard to fire. Other fibre-based insulations (glass or rock wool) perform better in relation to fire, but they need protection against moisture in order to avoid losing their effectiveness as thermal insulation.

All things considered, although the DB SI allows thermal insulation like polyurethane foam without covering to be used in certain situations, it is more advisable to use materials that do not help the fire to spread through the chamber, thereby minimizing both fire transmission and the risk of anchorages detaching through loss of mechanical strength.

4. CONCLUSIONS

In this work, the ventilated façade has been compared with other conventional envelopes and the advantages and disadvantages both at a qualitative level and with regard to compliance with the requirements established by the TBC have been analysed. The performance of the ceramic ventilated façade in comparison to other types of material and the most commonly used installation systems have also been analysed.

With regard to the level of limitation of the energy demand, the most important differences lie in the minimization of thermal bridges, which affects the calculation of maximum transmittance. On the other hand, ventilated façade performance is reflected in the DB HS1, because it allows the ventilated façade to be used for any degree of impermeability, and with an internal leaf with medium thickness. In relation to acoustic behaviour, the current DB HR establishes certain conditions that shall be met by the façade envelope as a function of the fitted separation element. However, the consideration of the ventilated façade as a two-leaf envelope considerably reduces the restrictions established in the first version of this document, because the existence of an internal wall lining limits the indirect transmissions.

Finally, although the DB SI limits the use of materials that help fire to spread through the outside, fireproof or non-flammable thermal insulations should always be used, which would reduce the risk of both the fire spreading and the weakening of the anchorages.

REFERENCES

[1] L. Reig, Estudio Técnico-Económico de materiales y sistemas de fachada, IX Congreso Mundial de la calidad del azulejo y del pavimento cerámico, Qualicer 2006.

[2] E. Montero, J. Pérez, A. Álvarez, Manual básico fachadas ventiladas y aplacados. Requisitos constructivos y estanqueidad, Ed. Consejería de Obras Públicas, Vivienda y Transporte de C. Murcia, 2007.

[3] CTE DB HE: Ahorro de energía. HE1 Limitación de demanda energética.

[4] CTE DB HS: Salubridad. HS1 Protección frente a la humedad.

[5] www.codigotecnico.org

[6] Catálogo de elementos constructivos del CTE.

[7] CTE DB HR: Protección frente al ruido.

[8] CTE DB SI: Seguridad en caso de incendio. SI1 Propagación Interior.

[9] UNE EN 13501-1 Clasificación en función del comportamiento frente al fuego de los productos de construcción y elementos para la edificación.

[10] UNE EN 23727 Ensayos de reacción al fuego de los materiales de construcción. Clasificación de los materiales utilizados en la construcción.