WATER PENETRATION INTO VENTILATED FAÇADE JOINTS

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ABSTRACT

In ventilated and cross-ventilated façades, the dimensioning of the joint has often been an issue in relation to ventilation and water penetration.

In this work, the façades are classified according to the different types of horizontal, and vertical, open or closed joints, in order to be able to analyse their performance with regard to direct, indirect, or run-off water.

Similarly, the recommendations from the different manuals, catalogues and Technical Suitability Documents in the offer of ventilated façades have been compiled, and the widths of real joints on some façades have been measured.

With all this information, knowledge is acquired on which joints in current façades have mechanical anchorages, and on the conditioning factors imposed by these joints.

On the other hand, to monitor water penetration, a prototype façade has been made that allows the width of the joint to be easily modified, which has been subjected to run-off and water protection tests in the façade surface to monitor water penetration as a function of joint width, as well as its end path.

The conclusions of the work indicate that water enters through almost all open joints, and it runs along the back of the outside leaf in some cases, while in others it reaches the thermal insulation, in which case we shall have to ensure that this absorbs little or no water.

1. JOINTS IN VENTILATED FAÇADES

Although from a ventilation point of view only two openings are required, one as an air inlet and the other as an outlet, for construction purposes, to allow the compatibility of movements of the elements that make up the façade, a series of joints are necessary in the ceramic claddings.

According to the classification of joints established by Lopez.G-Mesones (2001), four different types of joints can be defined in a façade:

- **Structural joints**, which coincide with the joints of the building structure.
- **Compression joints**, in a horizontal direction, dividing the façade facing according to the floors of the building.
- **Expansion joints**, in a vertical direction, dividing the length into smaller sections to prevent stresses caused by thermal expansion.
- **Connection** or installation joints, between slabs.

In the case of ventilated façades, almost all these joints are marked by the system itself and, in many cases, they are all disguised as installation joints.

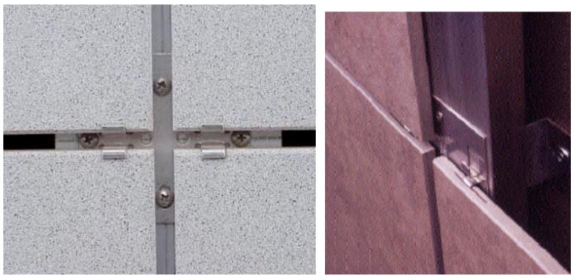
Thus, we can establish a classification of ventilated façade anchorage systems and of the type of joint that each anchorage uses:

With sub-structure	Visible anchorage		
	Hidden anchorage		
Without sub-structure	Visible anchorage	At points	
		Continuous	Horizontal or vertical
	Hidden anchorage	At points	
		Continuous	Unshared profile
			Chared profile
			Whith chemical anchorage

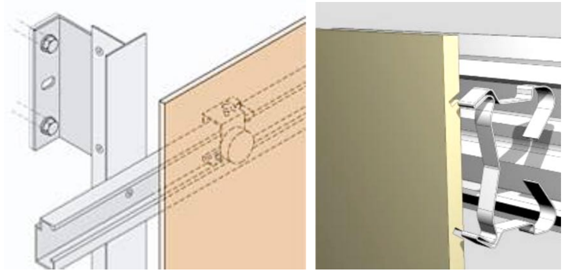
All these systems can give rise to all the possible combinations of joints: horizontal and vertical, open or closed:

Examples of joints as a function of the façade system:

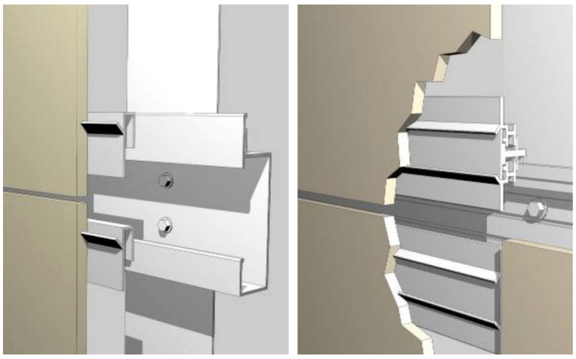
Open horizontal and vertical joints.



Open horizontal joints and closed (or not) vertical joints.



Horizontal joints with shared profile



Vertical joints closed by the profiles

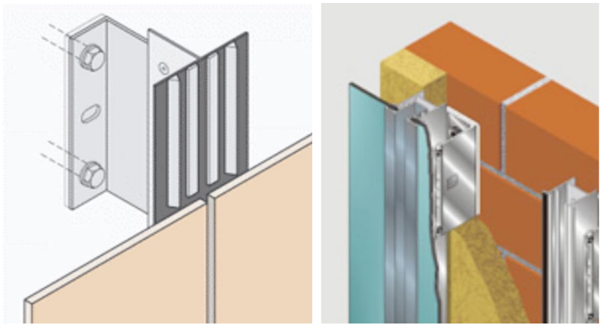


Figure 1.

This work has mainly focused on the study of the open horizontal connection joints between slabs to analyse the relation between the slab sizes and water penetration into the ventilated façade chamber.

2. ENTRANCE OF WATER AT THE JOINTS

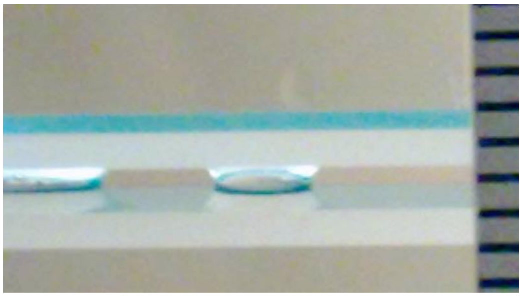
As defined by Avellaneda and Paricio (1999), stone slabs act as a semi-waterproof barrier against water, since, in contrast to the United States, in Europe the tendency is to not seal the joints, so that they allow a certain amount of water to pass through and only act as a first barrier against water.

According to Fernandez Madrid, water can enter through the joints for different reasons: "Through gravity (if the joint has a gradient into the interior); through surface stress; through kinetic energy; through capillary suction (this case explains water penetration when the joints are very small) and/or through air currents caused by the difference in pressure between the outside and the inside".

As a result, we can distinguish three water entrance mechanisms in our façades:

Surface stress: trickling along the back of the slab until it reaches the joint where it seeps inside either by gravity or even through capillarity. This phenomenon occurs especially with horizontal joints.

Effect of capillary stress in thin joints (Scale in mm)



Difference in pressure: the ventilation itself in the chamber causes a depression that makes it easy for air and water to enter through the joints of the slabs. This phenomenon occurs both with the vertical and horizontal joints.

Suction effect by depression in the chamber. (3mm joint)

Direct entry due to wind: the kinetic energy of the wind if there is rain causes the rain to fall with a certain slope that can enter the joints of the slabs. This phenomenon is even more pronounced in vertical joints.

Joint with possibility of direct entry of water due to the action of the wind (thickness/width>1)

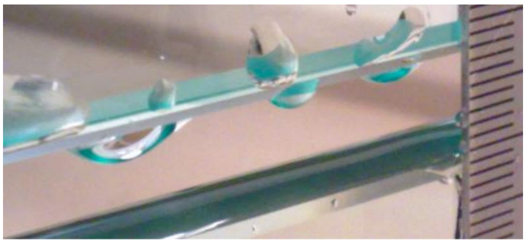


Figure 2.

Of these entrances, both the penetration caused by surface stress and by the difference in pressure, and in some cases, the water penetration due to the wind, are produced indirectly and, consequently, it will be difficult for them to dampen the chamber insulation; instead, the water will trickle along the internal face of the cladding.

3. RECOMMENDATIONS FROM MANUALS, GUIDE BOOKS AND SUITABILITY DOCUMENTS

By doing a literature search, we can find different publications and manuals on ventilated façades in which reference is made to joints.

On the other hand, the commercial manuals and the Technical Suitability Documents also define the ideal joint widths for each façade system.

3.1. Publications and regulations.

First, the regulations and recommendations from different manuals on the thickness of the joints were compiled.

According to the Technical Building Code (TBC), in the Basic Health Document TBC DB-HS 1, section 2.3.2 indicates that "...ventilation openings shall be arranged, the total effective area of which is at least equal to 120 cm^2 every 10 m^2. Open joints with a larger width than 5 mm, or another solution that produces the same effect, can be used in discontinuous claddings."

According to Avellaneda and Paricio (1999), in the "5 mm joints, water penetration is insignificant, whereas in the 10 mm joints, there can be an abundant water penetration. In general, the joint width is usually 6 to 8 mm, so that a certain amount of water should be expected to penetrate into the chamber..."

According to Lpez.G-Mesones (2001):

- Structural joints coincide with those of the building.
- Compression joints are used at the level of each floor and shall have a minimum width of 15 mm.
- Expansion joints shall be installed every 5 m and at a distance of 2 m from the corners of the building. Their width shall be at least 10 mm.
- The connection joints refer to the connection between slabs and they must have a minimum width of 2 mm. The larger the dimensions of the slabs, the larger these joints will be, and they can reach values of 6 -7 mm.

According to Montero et al. (2007), a thickness is recommended according to the type of joint:

- The structural joints must coincide with those of the building.

- The compression joints must be used at every floor and must have a width of about 15 mm.

- The expansion joints with a width of about 10 mm must be placed every 6 m and at 5 m from the corners.

- The connection joints must have a width ranging from 2 mm to 10 mm.

3.2. Technical Suitability Documents and commercial catalogues.

For non-traditional construction systems, there is the possibility of obtaining Technical Suitability Documents or European Technical Suitability Documents, issued by authorized organizations that accredit compliance of the basic building requirements.

In the second place, a follow-up of some technical suitability documents, as well as of commercial catalogues, has been done regarding the type and width of the installation joints and the width of the chamber. The following results were obtained:

TSD	TYPE OF JOINT	VERTICAL JOINT	HORIZONTAL JOINT	CHAMBER WIDTH
FAVEMANC XB	OPEN	4-6mm	≥ 4-6 mm	≥ 3cm
MECANOFAS KARRAT S-7	OPEN	Not specified		
TRESPA METEON FR	OPEN	≥ 10mm	≥ 10mm	≥ 4cm
TERREAL	OPEN	≥ 10mm	≥ 10mm	Not specified

Table 1.

CATALOGUES	TYPE OF JOINT	VERTICAL JOINT	HORIZONTAL JOINT	CHAMBER WIDTH
BUTECH	OPEN	≥ 4mm	4-8 mm	Not specified
PRODEMA	OPEN	6-8 mm	6-8 mm	≥ 20 mm
FAVETON	OPEN	≥ 10mm	≥ 10mm	Not specified
TERREAL	OPEN	5-7 mm	1,5 mm	Not specified
SUPERBOARD	OPEN	≥ 2,5mm	≥ 2,5mm	Not specified
CERACASA*	OPEN	Not specified	Not specified	Not specified
URSA	OPEN	Not specified	Not specified	Not specified
HUNTER D.	OPEN	Not specified	Not specified	Not specified
ITALGRES *	OPEN	Not specified	Not specified	Not specified

** The manufacturers have been consulted directly and an open joint with a width of about 7 mm is always recommended.*
Table 2.

3.3. Measurements on ventilated façades in Castellón.

In the third place, field work has been carried out and the actual thickness of the connection joints in the ventilated façades of some finished buildings was measured.

Figure 3. Domech Building. C/ Hermanos Bou no. 44.

Joint size	Both the vertical and horizontal joint, 6.6 mm.
Chamber tihickness	Minimum value: 50.7 mm Maximum value: 100.35 mm
Fastening system	At points with a hidden clip up to the first floor and visible above the first floor.
Remarks	The joints and the chamber thickness of this building were quite irregular. Depending on the stretch we were measuring, we got one result. The result shown in the joint size is more or less the most repeated one.

Table 3.

Figure 4. "La Salera" shopping centre.

Joint size	Vertical: 9 mm Horizontal: 6 mm
Chamber thickness	90.2 mm
Fastening system	At points, visible clip

Table 4.

Figura 5. Postgraduate Centre and Social Council. Universitat Jaume I

Joint size	2.5mm
Chamber thickness	100 -120mm
Fastening system	At points, hidden clip

Table 5.

Figure 6. Faculty of human and social sciences and Faculty of legal and economic sciences. Universitat Jaume I.

Joint size	Vertical: 2 -5 mm Horizontal: 5.6-7 mm
Chamber thickness	87 -98mm 58.5 mm
Fastening system	Hidden with a longitudinal profile and a shared sub-structure for two labs.

Tabla 6.

With the information analysed and the field work carried out, it can be concluded that most horizontal joints are thicker than 6 mm, whereas the vertical joints can be thinner.

4. EXPERIMENTAL STUDY

In order to monitor water penetration into ventilated façades, three prototypes were developed, one of ceramics and two of natural stone.

The first of the façade prototypes consisted of a vertical aluminium structure with two anchorages, one fixed at the bottom and the other moveable at the top, to which two ceramic tiles were adhered.

The moveable anchorage, which could be adjusted using a wheel, allowed the upper tile to be moved which easily modified the joint width.

This prototype was subjected to different tests with direct, indirect and run-off water, and the behaviour of the water was monitored for joint widths of 1mm, 3mm and 6mm.

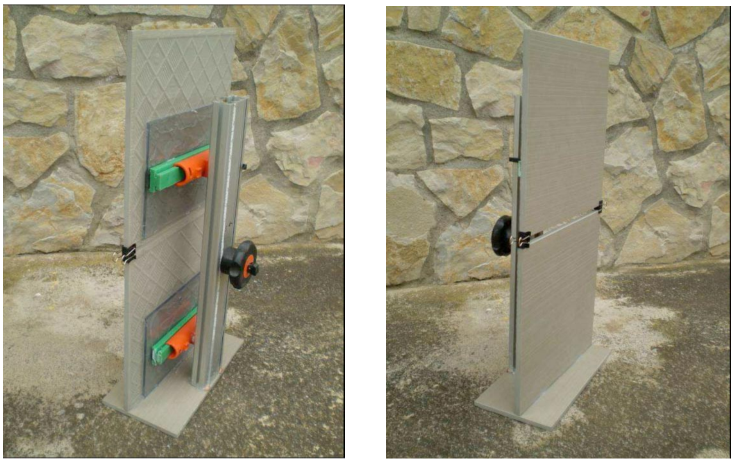


Figure 7.

To be able to determine the water penetration into façades with slabs with a larger thickness, two other prototypes were made, one of which had marble slabs with a thickness of 20 mm and the other with 38 mm granite slabs with different joint widths and water dispersion modes.

To simulate rainwater, elements that dispensed water in different intensities were used:

- **Watering can**, heavy rain, with run-off along the façade and sloping path.
- **Shower head**, moderate rain, with run-off and sloping path.
- **Hose with sprinkler**, rain with weak intensity, with run-off along the façade.
- **Spray**, dispersed drops with a vertical component.

4.1. Results.

	1mm joint	3mm joint	6mm joint
Spray	 Little water enters	 Water enters	 Water enters

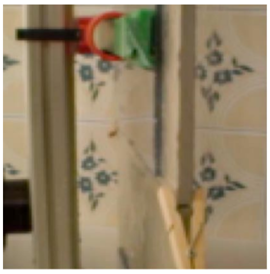
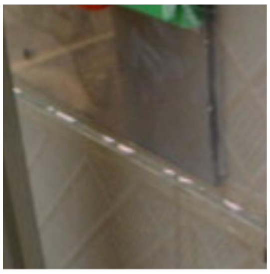
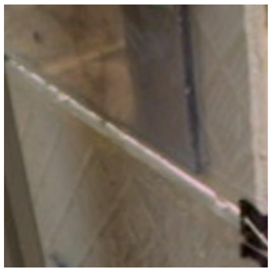
Shower head	 Little water enteres	 Water enters	 Water enters
Watering can with disperser	 Water enters	 A lot of water enters	 A lot of water enters
Hose	 Water enters	 Water enters	 Water enters

Table 7. 8mm porcelain tile.

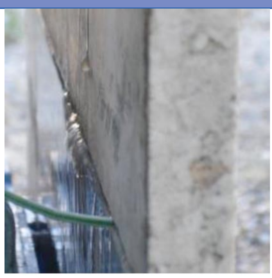
3mm joint	
Direct hose	**Hose with disperser**
 Entrance of water, splashing the chamber	 Entrance of water along the back of the slab

Table 8. 20mm marble.

	3mm joint	6mm joint	9mm joint
Spray	 Little water enters	 Little water enters	 Little water enters
Direct hose	A lot of water enters splashing	 A lot of water enters splashing	 A lot of water enters splashing
Hose with sprinkler	Water enters	Water enters	Water enters

Table 9. 38mm granite.

5. CONCLUSIONS

The study allows the conclusion to be drawn that there are some systems in which the very design of the joints or the shared profiles between slabs make it very difficult for water to penetrate.

However, even in these systems a minimum amount of water will always enter either through the vertical joints or due to the lack of a drainage system of the profiles, which prevents water from entering through the joints.

On the other hand, these systems with a closed or blocked joint due to the profiles are the ones that can provide more problems of dimensional compatibility, because of the difficulties they have in absorbing the expansions of the cladding due to thermal changes.

The different tests conducted show that, although the thickness of the joint does have an influence on the amount of water that can penetrate into the ventilated façade, for joints with a width of 3 mm and 5 mm, the water penetration can be significant. Also, under no circumstances is waterproofing assured, not even by reducing the joint to 1 mm. Slightly modifying Avellaneda and Paricio's contributions (1999), it may be stated that in 5 mm joints, water penetration can be insignificant, but this is produced in stone façades with slab thicknesses that are sure to exceed 2 cm.

This is due to the different water penetration mechanisms defined both by Avellaneda and Paricio (1999) and by Fernandez Madrid, which explain water penetration with different joint thicknesses.

The influence of the different pressures between the chamber and the outside has not been analysed, but it may be deduced *a prior* that even though they have an influence, they will not fully guarantee the prevention of water penetration, but rather the contrary.

The joints with a gradient towards the outside that provide water penetration have not been analysed either, but it may be deduced that a significant thickness, depth and gradient will be necessary to prevent water from entering.

Water penetration through the open joints can be worrying in very rainy climates or in very exposed orientations for, in the other cases, the problem is solved by guaranteeing the correct ventilation of the chamber which allows rapid drying and the use of non-hydrophilic insulation, as well as a correct sealing of the metalwork joins with the façade.

However, in areas where excessive rainfall does not allow the chamber to dry quickly, or where high exposure to wind worsens waterproofing conditions, solutions must be turned to that guarantee that an equalization of pressures between the outside and the inside of the chamber, to reduce water penetration.

In the "Basic Manual on Ventilated Façades and Claddings. Construction requirements and waterproofing" (Montero et al, 2007), it is indicated that "to eliminate any of the effects caused by the forces that drive the water, the chamber equalized with the outside pressure can be used as a resource". As Fernandez Madrid also points out, this is achieved "by confining and sectorizing the chamber".

Thus, it will be advisable in all cases to use non-hydrophilic insulation or closed joint systems, as long as they solve the problems of thermal expansion of the materials. In the case of façades with open joints, it will be advisable to sectorize the chamber to improve the waterproofing of the system and to guarantee the behaviour on exposure to water in any climatic situation.

ACKNOWLEDGMENTS

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REFERENCES

[1] ROYAL DECREE 314/2006, of 17 March, approving the **"Código Técnico de la Edificación" (Technical Building Code)** Ministry of Housing, Spain 2006.

[2] Montero Fernández de Bobadilla, Eduardo; Pérez Navarro, J. y Álvarez Sandoval, A. **"Manual básico. Fachadas ventiladas y aplacados. Requisitos constructivos y estanqueidad."** Consejería de Obras Públicas Vivienda y Transportes. Región de Murcia, 2007.

[3] López González-Mesones, Fernando. **"Manual para el uso de la piedra en la Arquitectura"** Informstone Tecnhic and Business, S.L. 2001.

[4] Avellaneda, J. y Aparicio, I. **"Los revestimientos de Piedra"** Ed. Bisagra, 1999.

[5] Carlos Sanchís **"Conferencia fachadas ventiladas".** UJI. Year 2008.

[6] Joaquín Fernández Madrid. **"Plan de formación CTE-CSCAE – Envolventes"**, Castellón, March 2007.

[7] AAVV. **"Manual fachadas ventiladas"** TAU-cerámica.

[8] Documentos de Idoneidad Técnica (DIT) Keraben, Favemanc , Mecanofas,Trespa, Meteon, Terreal. Instituto Eduardo Torroja de la Construcción y el Cemento.

[9] AAVV. Manual Técnico Comercial. **"Sistema de fachadas ventiladas. Mecanofas."**

[10] Catálogos Comerciales: Butech, Prodema, Faveton, Terreal, Superboard, Ceracasa, Ursa, Hunter, Italgres.

[11] www.wandegar2001.com

[12] www.mecanofas.com

[13] www.fachadasventiladas.com

[14] www.sotecniccol.com

[15] www.strow.es

[16] www.gutterkel.com

[17] www.grapamar.com

[18] www.tauceramic.net

[19] www.mecanotubo.es

[20] www.Saloni.com

[21] www.porcelanosa.com

[22] www.butech.es