ARCHITECTURAL ENGINEERING OF VENTILATED CERAMIC FAÇADES: DESIGN, PERFORMANCE AND MARKET IN BRAZIL

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1. ABSTRACT

As ventilated façade systems have become widely disseminated, it is possible to verify a considerable number of suppliers commercializing ceramic panel systems in the Brazilian market. Since the completion of the first project using this system in 2009, more than 80 projects have been concluded[1], these results presenting an upward growth curve regarding the amount of projects and built area. This paper presents an overview of the national context and discusses the difficulties and advances in the system implementation process. The project structure and development process are also mentioned, in addition to considerations regarding the system performance and technical information.

[1] Data obtained via websites of suppliers or directly with representatives: Eliane, Faveton, Gail, Portobello, Terreal.

2. VENTILATED FAÇADE SYSTEM

The ventilated façade is a non-adhered cladding system, which consists of fixed panels secured by a metal substructure with an air cavity between the cladding system and the building face.

The ventilated façade system must allow the air in the cavity to be refreshed and thus avoid heat transfer by convection to the sealing element, and consequently into the building interior.

Aspects to be considered in design, such as the width of the air cavity and specification of the materials as well as questions related to the environment, such as building orientation, air speed and pressure, must be taken into account to guarantee the performance of the system.

In Brazil, a country with a predominantly warm climate, natural ventilation is one of the principal strategies for building cooling. In the same way the ventilated cladding system aims to contribute to good thermal performance and energy efficiency of buildings.

The higher cost of execution and longer time necessary to develop a ventilated façade design, when compared to those of conventional cladding systems, are two important aspects to be considered at the concept stage of the architectural design. In contrast, the implementation of such systems in the national market has brought out aspects such as reduced construction time, with an indirect impact on overall building cost, as well as improved results in terms of performance[2].

There has been an increase in the use of this technology in Brazil since the completion of the first project in 2009. A recent study by *Inovatec Consultores Associados*, in which information was gathered from active suppliers in the building sector, has shown this tendency.

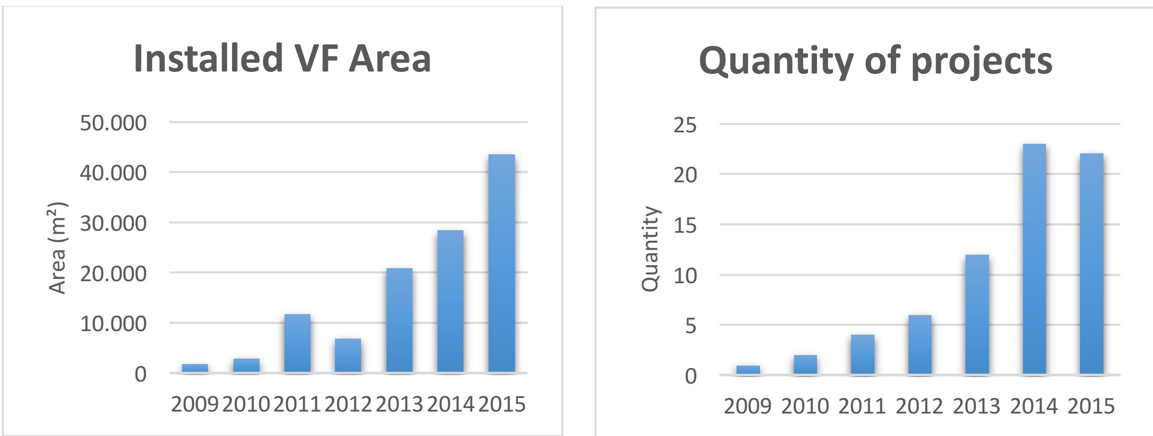

Figure 1. *Total area of ventilated façades installed and quantity of projects in Brazil.*
Source: Chart generated by Inovatec Consultores Associados, 2015 [3]

[2] Considering requirements as stated in ABNT NBR 15.575:2013

[3] Data obtained via websites of suppliers or directly with representatives: Eliane, Faveton, Gail, Portobello, Terreal.

With a strong focus on sustainability, the use of the system has been evidenced in the case of retrofits, where the fact of being an industrialized, no-grout system tends to significantly reduce the creation of construction debris. Even though the ventilated façade system can be used in a wide range of building projects, in Brazil it has been mostly used in commercial and institutional buildings.

This paper aims to contribute to the understanding of the implementation of ventilated façade system projects in Brazil, as well as detailed information on the design development process from a technical and conceptual perspective.

3. ARCHITECTURAL ENGINEERING OF VENTILATED CERAMIC FAÇADES

3.1. PROFESSIONAL PRACTICE AND SUPPLIERS IN THE BRAZILIAN MARKET

The ideal situation is that in which the ventilated façade is already integrated into the original architectural proposal. In this situation, from the inception of the architectural design, basic information on the constructive system, such as offsets, finishings and dimensions of the ceramic panels, can be considered, which allows a better result and interface with other building elements.

However, it is quite common to have building design with conventional cladding specifications and afterwards, while already in an advanced project stage or even with the construction underway, for its cladding system to be changed to a ventilated façade. In this case, the design process tends to become more difficult.

The architectural solution in many ways defines the performance of the building. However, when dealing with unconventional building technologies in Brazil, the vast majority of architects are unfamiliar with the technology of the ventilated façade.

When using glass or stone cladding, an independent consultant is usually part of the building design team. In contrast to those cladding systems, there are only a few consultants specialized in ventilated façade systems. For this purpose, technical knowledge of all different suppliers systems, as well as knowledge of conventional systems, is needed so that each alternative can be compared technically and by cost.

In Brazil, the specification process of ventilated façades has also been determined by the way in which suppliers have introduced their systems to the market. There are some suppliers who commercialize the system including product, design and execution, thereby taking responsibility for the whole process. On the other hand, there are also suppliers who share the responsibility with partner companies who supply the metal framework, design and execution of the whole system. This situation is considered less favourable, especially during the implementation phase of the technology, as in Brazil. It creates a more complex process in terms of liability in the case of problems during execution.

When consulted directly by architects and clients, suppliers usually offer some technical information, without developing a design before being contracted. On the other hand, where the system is part of the architectural proposal, there is a strong tendency to close a contract in time to develop respective projects and ensure compatibility with other building details.

This can mean a longer design development process; however, it makes understanding easier for the execution team by having all information and details necessary, promoting agility and minimizing improvisation on site.

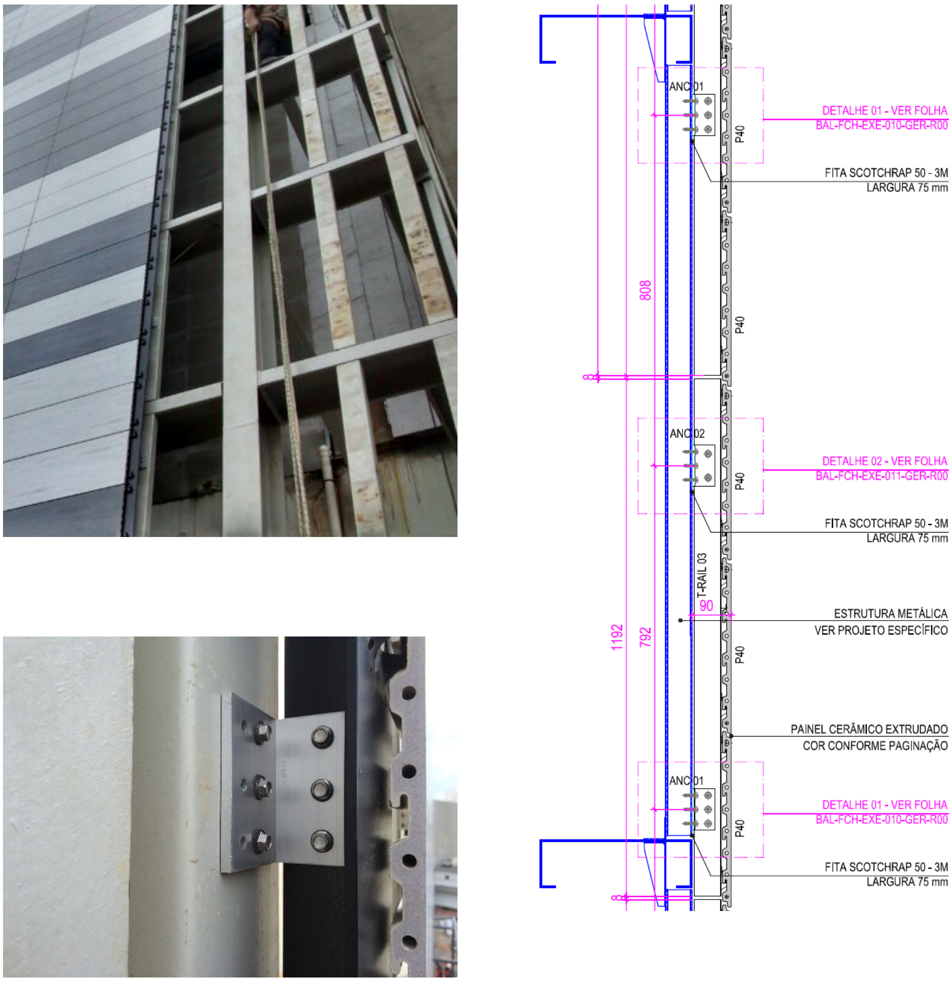

Figure 2. *Ceramic frame in design and construction detail*
Source: Archives Inovatec Consultores Associados

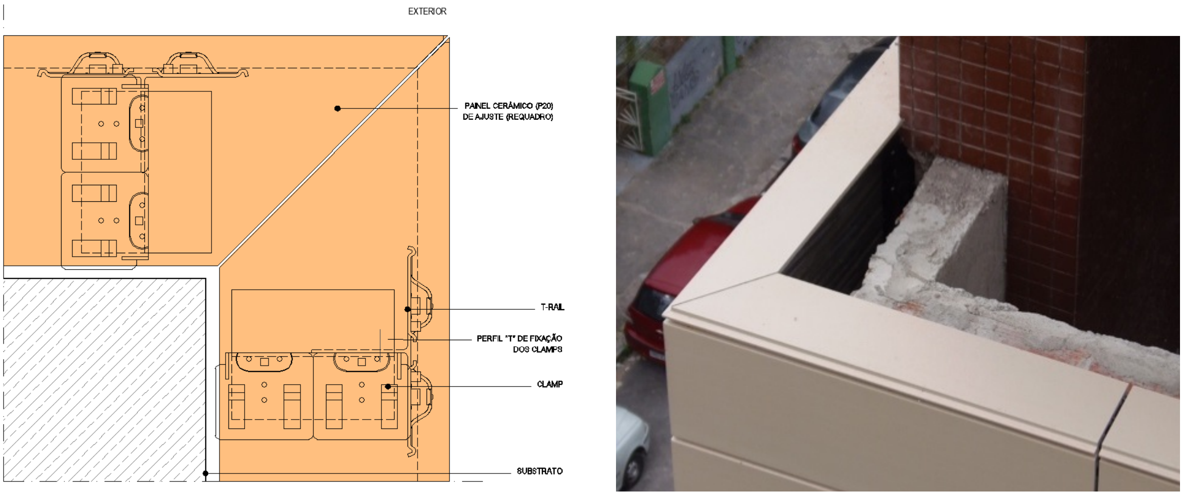

Figure 3. *Ceramic frame detail in project and construction detail*

Source: Archives Inovatec Consultores Associados

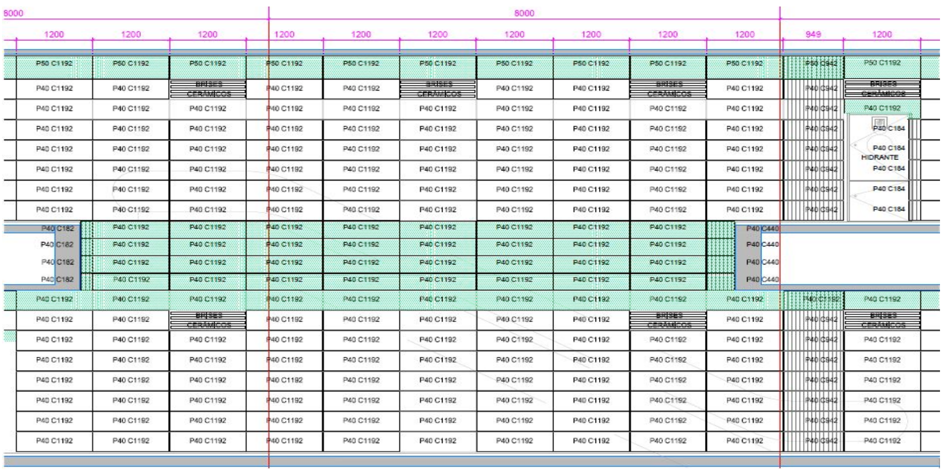

Figure 4. *Example of cladding panel alignments with large area of cut panels (highlighted in green)*

Source: Archives Inovatec Consultores Associados

3.2. STRUCTURE OF THE VENTILATED FAÇADE DESIGN PROCESS

Developing a ventilated façade project, strategic work steps should be considered in order to guarantee the best result in terms of design quality as well as the construction stage. Figure 5, below, illustrates this process.

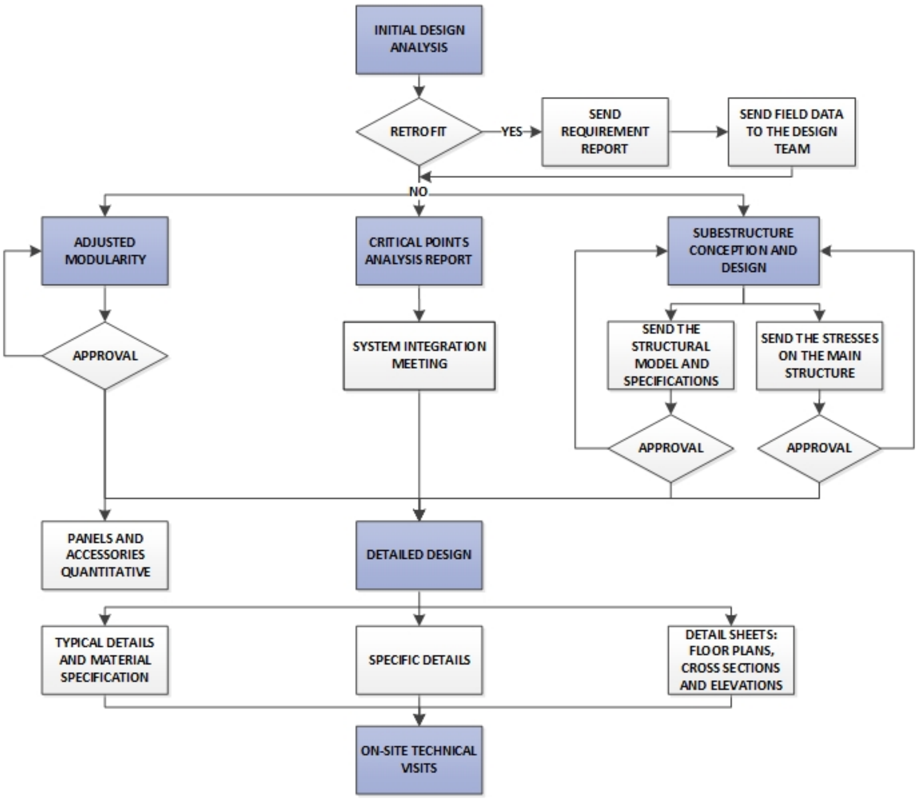

Figure 5. *Design process flowchart (Adapted from the archives of Inovatec Consultores Associados)*

An initial analysis by the ventilated façade designer should address all of the points of intersection, necessary adjustments and clarification concerning the limitations of the system. In the case of retrofits, an analysis of the existing substrate (infilling walls, structure and finishing) is also essential, by a technical inspection, tests and a topographical survey.

A revision of the modulation is important to identify essential points, such as how to propose alternative adjustments needed for the architectural design, while seeking the best solution for the efficient use of ceramic panels as well as framework arrangements.

In the conceptual and structural design phase, the framework elements and materials are defined. Another important point in this phase is the approval of the system loads acting on the main structure and infilling wall of the building.

The final design should contemplate the detailing of all the encounters between the ventilated façade and the other building systems as well as the typical situations.

The structure of a design presentation can be summarized in working drawing sheets that concentrate all the information needed for execution in order to optimize the construction process.

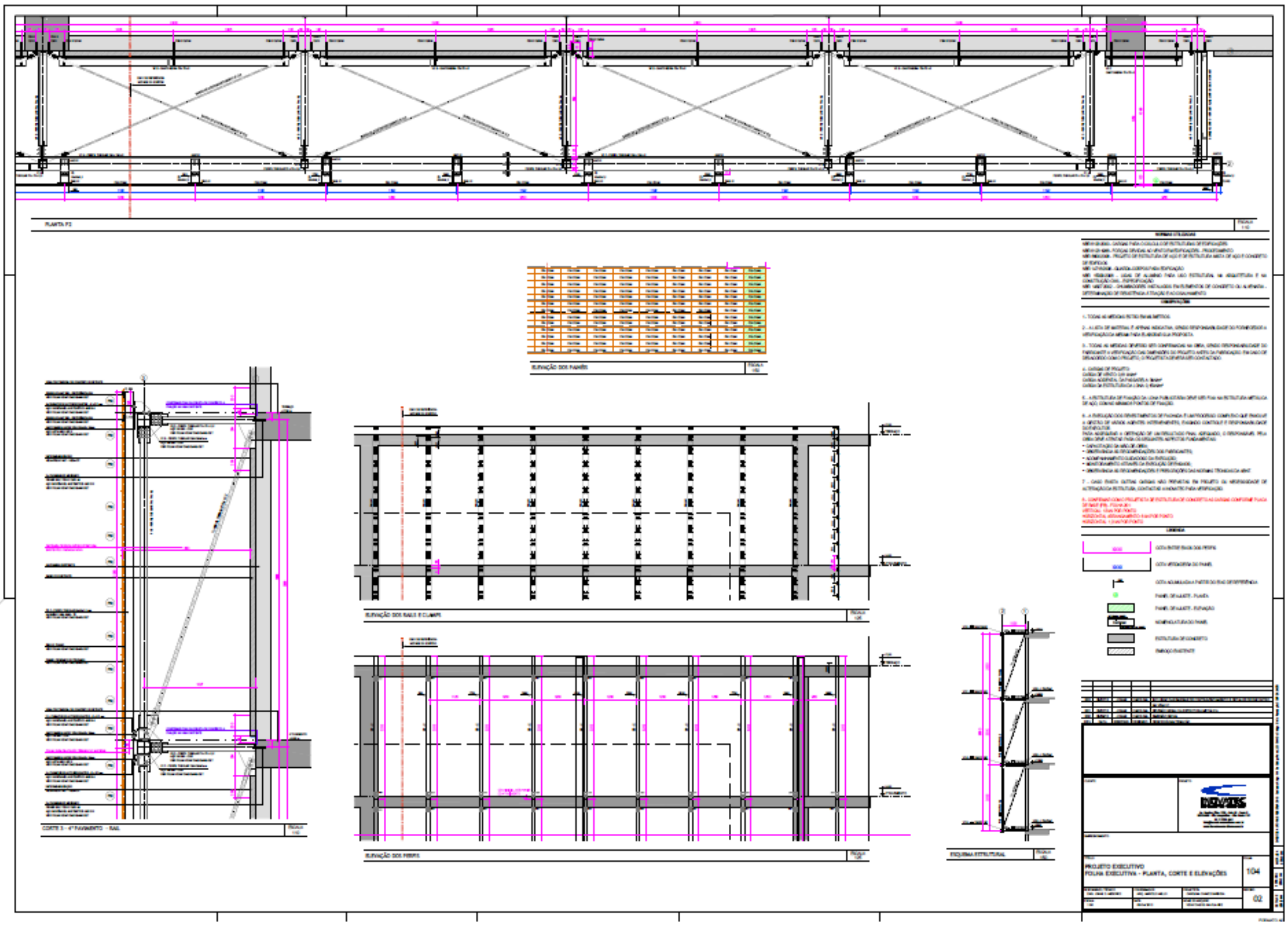

Figure 6. *Example of executive working drawings of a ventilated façade*
Source: Archives Inovatec Consultores Associados

Presenting and discussing the working drawings with the construction team ensures the complete understanding and correct execution of the system. Overseeing the project is fundamental at all crucial construction stages (tests, execution of fixings, assembly of understructure and panels), clarifying doubts and offering solutions when necessary.

3.3. CONCEPTION AND STRUCTURAL DESIGN OF METAL FRAMEWORK

The proposal of a structural concept within the limits of the project must consist of a structural solution placing the framework (aluminium profile understructure) of the ventilated façade system on the building main structure. At this stage, fixings and profiles (vertical and/or horizontal) are positioned on the façade in such a manner that they suit the character of the building and overall project.

Normally aluminium T or box section profiles are used (Alloy 6063-T6) to bridge spacing's between fixing. Fixings are usually composed of angles and fasteners for fixing the metal understructure to the building face. Usually mechanical anchors are used to fix the framework in concrete structures such as pillars and beams, and chemical anchors in infilling masonry walls. Stainless steel screws are used in the connections between metal components to ensure the desired durability.

The most common structural model is the beam simply supported at ends, where one of the supports is called pinned and the other roller. In the case of high ceilings, it may be necessary to introduce an intermediate roller support limiting the overall spacing so that the profile meets the design necessities.

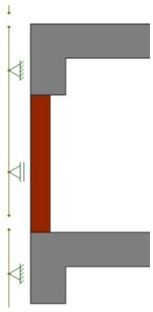

Figure 7. *Model of beam with two supports*

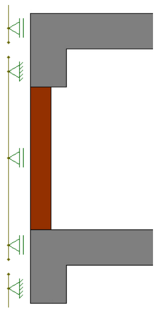

Figure 8. *Model of beam with three supports*

Pinned supports limit horizontal and vertical movements as they are executed with round holes in the junctions of profiles. Roller supports restrict movement only in one direction as they are executed with oblong bore holes in the direction in which movement is desired, e.g. to allow vertical movement due to thermal variations.

Figure 9. *Pinned support with round holes*

Figure 10. *Roller support with oblong holes*

Once a structural model has been defined, the profiles, fixings and screws should be checked to verify that they match the structural design. The structural design is composed by a comparison between the requirements caused by the wind pressure, self-weight of the system and possible dead or live loads with the element strength.

The resistance of each element varies depending on the solution used, the cross sections of the profile and the type of material, and it may be calculated by using structural engineering software such as SAP and STRAP. The design checks that need to be performed are outlined in the respective national standards. In general, the following are calculated: tension, compression, shear, bending, torsion strengths and maximum deflection of profiles. In case of the profiles undergoing compression, shear, bending or torsion stress, it is important to pay attention to overall and local buckling design.

Special attention must be paid to the checking of connections both of the profiles with the fixings and of the fixings with the main structure. As each connection has its unique characteristics, it is unlikely that a given software will meet all design variations and it should therefore be done individually in accordance with the checks described in the reference standards.

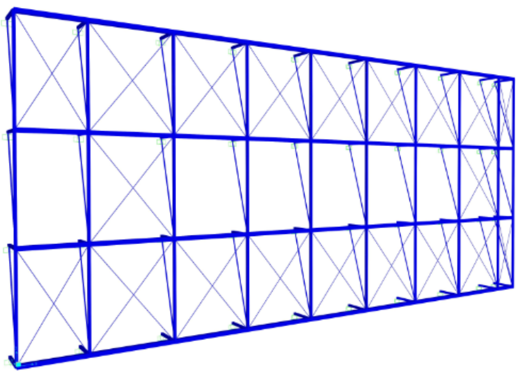

Figure 11. *Structural model*

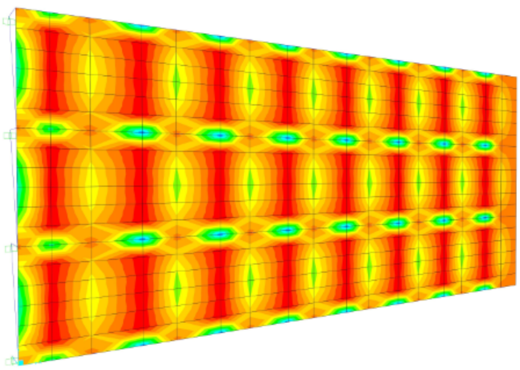

Figure 12. *Beam stress model*

4. PERFORMANCE

Compared to conventional fixed cladding systems, ventilated façades present advantages especially in constructability, maintainability, thermal performance and water-tightness.

Although the open joints between panels permit some water passage, the pressure from the cavity ensures drainage of this water before it can act on the building face. According to Marazzi (1997), based on tests of open joint cladding, less than 0.5% of rainwater reaches the building surface. In general, non-adhered cladding systems eliminate the risks presented in typical fixed cladding systems such as efflorescence, detachment, cracking and leaks from thermal and structural movements.

If maintenance is necessary, the replacement of one or more panels can be undertaken individually where needed without interfering with the rest of the façade.

According to Medeiros (2012), a building façade reflects not only aesthetic issues but also its overall performance. Through the building envelope, one defines the dynamics of heat and moisture exchange with the exterior, access to natural light, as well as the levels of natural ventilation.

4.1. STANDARDIZATION

In Brazil, specific standards for curtain wall or ventilated façades do not exist. For the design of metal structures, international standards[4] must be used as a reference.

NBR 15.575, the national non-prescriptive standard which deals with the performance of residential buildings is a conceptual reference irrespective of the particular building use. This standard indicates the performance of water-tightness testing, wind pressure, impact testing, and others that must be made by suppliers to guide the builders and users on the performance of each system. These tests enable a fair comparison between different coating systems and can serve as an incentive for the use of innovative technologies without published prescriptive standards.

4.2. THERMAL PERFORMANCE

The dimensions and overall size of the air cavity define its classification as less or more ventilated, while considering the variable reality according to conditions of wind speed and pressure, and orientation.

The specification of the panelling material is directly related to the heat exchange from the outside to the air cavity. Ceramic panels show a thermal transmission of the order of 1.00 W/(m.K), much more favourable if compared to

[4] Aluminum Design Manual (The Aluminum Association. 2000), EUROCODE 9: 2007 - Design of aluminium structures, ETAG 001: 2010 - Metal anchors for use in concrete - Technical Report 029: 2010 - Design of Bonded Anchors, ETAG 029: 2010 - Metal injection anchors for use in masonry

commonly used stone with a thermal transmission of the order of 3.00 W/(m.K)[5]. Extruded ceramic panels tend to have a better thermal performance when compared to monolithic ceramic panels as they contain air pockets.

Seeking a real contribution to thermal performance, the orientation of the façade leads to correct system specification, taking into account the rate of direct solar radiation incidence. Furthermore, in many urban centres in Brazil the environment is also a determining factor with regard to the shading pattern of other buildings.

4.3. SPECIFYING MATERIALS

As previously mentioned, the fixing of the cladding panels is done by a metal understructure. Proper specification of the components take into account their application in terms of forces and exposure to the weather elements. Overall, aluminium is suitable for the production of fixings and profiles, with alloy and temper characteristics varying according to strength demands and durability. Fasteners should essentially be of stainless steel. Proper specification of the understructure material gives the larger system a guarantee in terms of durability and safety.

As an example of nanotechnology applied to building materials in the Brazilian market most suppliers sell ceramic panels for ventilated façade treated with titanium dioxide (TiO_2), giving the system a self-cleaning feature. The incidence of sunlight triggers a superhydrophilic effect that allows surface cleaning by any stream of water, such as ordinary rainfall (FUJISHIMA *et al.*, 2000).

In addition, in the Brazilian context, the most widely applied solution does not usually have a thermal insulation layer, since the main issue is to reduce the internal temperature on hot days. Researches show greater contribution of ventilated façades to reduce cooling demand of buildings in warm climates (MULLER *et al.*, 2004; Silva *et al.*, 2010; Bannier *et al.*, 2012; Escrig *et al.*, 2014).

In Brazil, the ventilated façade can play a very important role since warm weather prevails throughout the country. For this climate situation, it is not necessary to install insulation material as we usually see in Europe, since heating systems are not very often used in the country (MEDEIROS, 2012).

From a safety point of view, the risk of falling panels of a ventilated cladding system is less than with an adhered façade covering, where other factors such as materials, weather, and labour quality can compromise the coating performance. Accordingly, the application of reinforcing mesh behind the ceramic panels has been a feature commonly used to give greater security to the ventilated façade system, preventing falling of the panels in the event of breakage.

[5] According to ABNT NBR 15220:2005

5. CONCLUSION

The advantages and quality of the ventilated façade system have been widely reported by suppliers and institutions in the field of construction since its early implementation in Brazil. The market has shown great interest in using the system, which is confirmed by the increasing number of investments in terms of amount of projects undertaken as well as built area.

As an industrialized system, it requires considerable design time, which varies depending on the particularities of each project. A good design tends to promote productivity and agility in the execution of the work. This contrasts with what is traditionally practiced in Brazil, where the design development time is usually reduced and often undertaken in parallel with the building construction.

As mentioned before, the delayed definition of the façade system in Brazil made difficult its incorporation into architectural design and the resolution of the compatibility of all design interfaces.

It is believed that a permanent effort in terms of disclosure and dissemination of technical knowledge, along with the experience gained with all the work that has been carried out, tend to contribute to a project development process that becomes more adequate to the reality of Brazil.

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