

# TECHNICAL CONDITIONINGS TO CONSIDER IN THE PROCESS OF DESIGNING CONSTRUCTIVE SYSTEMS OF INNOVATIVE FAÇADES

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## ABSTRACT

Previously to the study, the analysis or the design of new constructive systems of façade it is fundamental having a relation of those aspects that may condition or influence in their life cycle. The aspects should be considered at the beginning of the elaboration process of constructive systems and in a later stage to assess the obtained results.

The aim of this communication is to develop a complete relation of conditionings that ensures that those aspects, which can affect notably the life cycle of the constructive systems, are taken into consideration from the beginning of the process.

## 1.- INTRODUCTION

The Building Department of the School of Architecture of the University of Navarra is developing for some time a research line related to the development of constructive systems of innovative façades.

One of the developed tools in this research line refers to those factors that could determine or influence the final constructive solution. It is also important to take into account the whole life cycle of the new system, its relation to other constructive systems of the building and its influence in the global building process.

A thorough relation of the diverse types of conditionings, which should be considered in the design of façades, has been developed as a guide to identify those that explicitly or implicitly will be necessary to take into account in each case study.

In the communication presented by Joaquín Torres Ramo (General and specific conditionings to consider in the process of designing constructive systems of innovative façades) it is showed the general relation of conditionings that are set out in this research line. Among those, in this communication the technical conditionings are emphasized.

Every technical conditioning that is proposed should be consider separately although in a later stage, an estimation of its global repercussion should be made considering its characteristics and the simultaneousness with other type of conditionings.

This complete relation of technical conditionings ensures that those aspects, which can affect notably the life cycle of the constructive systems, are taken into consideration from the beginning of the process.

## **2.- TECHNICAL CONDITIONINGS**

### **2.1.- Conditionings related to the geometry and modular order of the façades and its components**

In this section every aspect related to the geometrical characteristics of the façades and its components has to be assessed. Among these characteristics we can highlight: the straightness of the edges, the flatness of the surfaces, the accuracy of the dimension and shape of the surfaces, the joints treatment, special points, etc.

It is very interesting to consider the necessity to take a specific system of dimensional and geometrical modular coordination and asses its consequences: industrial production, application to other projects, etc.

### **2.2.- Conditionings related to manufacture tolerances, assembly plays and adjustment of the façade components**

It is necessary to asses the admissible geometrical tolerances and the needed precision level of both, the components and their assembly, taking into account that the higher the precision is, the more specialized labour is needed.

The systems that permit a better three-dimensional adjustment of their elements will provide a better solution to the zones that are in contact between the building and the façade.

### **2.3.- Conditionings related to assembly procedures**

It is important to take into account the possibilities of planning the assembly process of the façade: how, in what order, interferences with other activities of the construction process.

The assembly process has to be well designed, including singular points, to avoid improvisations during building work. Likewise the process design must have considered other aspects, such as: avoiding easements with the rest of the constructive process, reducing the waste materials of the assembly process, giving the possibilities of adopting solutions with different features, allowing the immediate coming into service, the ease of use of each one of the components, etc.

### **2.4.- Conditionings related to the modification possibilities of façades before, during and after their building**

Facilitating the design of the façade to allow modifications during the project phase, the execution, or when it is in use, provides greater value to the design of the façade.

It is important to take into account: the ease of assembly or disassembly of the components of the façade irrespective of the rest; the capacity to allow the placing of different components of the façade both for external finishing as well as for internal, etc.

## **2.5.- Conditionings related to safety at mechanical actions suffered by façades**

It is necessary to consider the aspects related to the mechanical behaviour and stability. It is important to study each of the actions that affect the façade both directly (gravitational, wind, snow, etc.) and indirectly (constraints or imposition of movements due to geometric variations of other components) as well as to study their origin and the magnitude of the generated tensions.

Likewise, the aspects related to the repercussion of the effects of these actions in the service capability of the façades are equally important (inadmissible deformations, damages and functional anomalies, etc.).

## **2.6.- Conditionings related to water and air tightness of façades**

In order to value adequately water and wind tightness of façades and to perform their design, it is necessary to know their exposure conditions, the different kind of joints among their components, the position of the windows in the façade (exterior, interior or intermediate), the position of every façade in the building, the existence of protection elements, the needs of conservation of the different parts of the façade and their accessibility to carry out these operations, etc.

## **2.7.- Conditionings related to the thermal behaviour of façades**

The thermal behaviour of façades is one of the most important aspects during the design stage. For that purpose it will be suitable to define correctly each of the following aspects:

- Aspects related to the compulsory regulations.
- Aspects related to the thermal well-being of the users.

The effects produced in the physical interior environment by the physical exterior environment, and their repercussion in the well-being conditions (temperature variations, relative humidity, etc.); depend on the behaviour of the façade and on the characteristics of the HVAC systems.

- Aspects related to the actions that can produce variations of calorific energy in the façades.

There are actions that it is necessary to consider because they affect both façades themselves (solar radiation received, forced superficial convection, etc.), and interior spaces (across opaque or semitransparent zones). It is necessary to analyze them depending on their duration, intensity, etc.

- Aspects related to transference of calorific energy by conduction across the façades

It is necessary to consider each of the aspects on which the thermal resistance to the conduction heat flow across the components and layers of the façades depends. The composition of the façade (air spaces, isolations, mass, dimensions, etc.) influences enormously its behaviour.

- Aspects related to the transference of calorific energy by radiation

It is necessary to take into account the factors on which the transferences of calorific energy due to solar radiation depend (generally gains), and also other radiation transferences of energy, as losses during the night, gains as consequence of fires, etc.

The factors that influence the design depend both on the characteristics of the used materials (different degrees of absorption and reflection), and on the configuration of the building (solar protections, influence of the semitransparent parts, etc.).

- Aspects related to the transference of calorific energy by convection

This aspect is related to the actions and solicitations that influence the façades, and among them, principally the wind.

The aspects to consider depend on the transfers of calorific energy due to forced superficial convection produced by the wind on the outer layer of the façade, and due to natural and forced convection into the air spaces.

- Aspects related to the thermal inertia of the façades

It is necessary to know the aspects on which the thermal inertia depends (mass, specific heat, diffusivity, isotropy of the products), the influence of the thermal gradient on each one of the layers, the influence in the lag and damping of the temperature wave, etc.

It is a very important aspect to consider because it affects the energetic consumption of the building, the well-being of the users, the dimensional variations of the structure, etc. to a great extent.

- Aspects related to the degree of thermal isolation of the façades

The degree of thermal isolation depends to a great extent on the resistance that offers each of the layers of the opaque and semitransparent zones, on the heat flow by means of conduction, convection and radiation, on the behaviour of the singular points, etc.

It is convenient to know what degree of isolation it is necessary to obtain and to value its repercussion on the HVAC systems and on the use of energy needed to support the well-being conditions.

- Aspects related to the need to provide joints in the façades

It is necessary to absorb the geometric variations due to the movements and deformations of thermal origin, that take place in the façades and in their components providing joints.

The design of these joints will depend on the characteristics of these movements (magnitude of the expansions and contractions, etc.), and they will serve to prevent them from producing restrictions or impositions of movements that could be the origin of pathologies in the façades.

## **2.8.- Conditionings related to hygrothermal state and behaviour of façades**

In this family of conditionings the aspects related to the behaviour of the façade due to the combined effect of the temperature variations and of the humidity content are considered. For that purpose it is necessary to know the predictably hygrothermal condition, that depends on the exterior and interior physical air environment, and on the internal physical environment, as well as the repercussion that they have in the mentioned façade.

This repercussion will depend on the composition of the façade, on its resistance to the flow of the water vapour, on the influence of the air layers, on the homogeneity degree, on the different encounters between the components, on the resolution of the joints, on the shape of the façade, etc.

It is necessary to value the possibility that condensations could arise, by studying their magnitude and duration, situation (interstitial, superficial, etc.), and their consequences in the well-being of the users, in the behaviour of the whole façade and if they can produce damages in its components.

It must not be forgotten that in the design of the façades it is possible to act in a very positive way, reducing the possibilities that the mentioned condensations take place.

## **2.9.- Conditionings related to the fire behaviour of façades**

The principal requirements and demands to fulfill, come from the compulsory regulations, where the categories of protection and the safety measures that every building must have are defined.

For that purpose we will have to take into account not only the fire resistance of the façade, guaranteeing its stability, integrity and thermal isolation, but we will have to know its predictable behaviour, analyzing separately the zones with and without hollows, the behaviour of the seals, the influence of the joints, of the air spaces (draughts of convection) and of the flames, the influence of the shape and dimensions of the rooms, etc.

What is more, we must not forget that many materials exude and volatilize inflammable substances that can help to spread the fire, and that these substances are often toxic.

## **2.10.- Conditionings related to the acoustic behaviour of façades**

The principal aspects on which this family of conditionings depends are related to the nature and characteristics of the sound sources, to their propagation and to the vibrations that they produce.

It is necessary to consider that when the faults of its behaviour owe to faults of execution, that conceptually are raised well, they are solved better than if they owe to erroneous conceptions of the constructive solutions that have been adopted because, frequently, its solution is difficult or non-existent.

The principal constructive solutions are based on increasing the aptitude to damping the generated or received vibrations, so that they absorb or reduce the effects of the reverberation and the transmission of the sonorous air waves, as well as on preventing the components of the façade from having low or similar vibration frequencies and avoiding resonance effects.

### **2.11.- Conditionings related to the ventilation of buildings internal spaces and of their façade's air spaces**

It is necessary to take into account the requirements and demands of the compulsory regulations, evaluating the needs of renovation and purity of the internal air of the buildings.

Moreover, it is necessary to consider that the ventilation hollows of the façades are also crossing routes of particles in suspension, of animals (insects, rodents, birds, etc.), of water, smells, sounds, light, fire, etc.

In the design of the façades there can be included systems of energetic improvement by means of passive systems of accumulation or of dissipation of accumulated heat, using the ventilation of the air spaces.

### **2.12.- Conditionings related to natural lighting of buildings internal spaces**

Besides the compulsory regulations, it is necessary to consider the influence of the natural direct lighting, dependent on the orientation, and on the natural indirect (reflected or diffuse) lighting.

As for the façades, it is necessary to value the percentage, size and distribution of the windows; the nature, properties and characteristics of their materials; the texture and the color of the illuminated surfaces; the possibility of placing solar protection systems, etc.

It must not be forgotten that the use of the natural lighting can suppose an important saving in the energy consume and influences the conditions of well-being of the users.

### **2.13.- Conditionings related to visual control of the façade voids**

It is necessary to value for every building the need to obtain different degrees of privacy in the interior spaces, for reason of intimacy or view protection, during the day or the night, without forgetting that the activity that is done in the building can be promoted by means of this control (image of the building, advertising, etc.).

The design of the façade influences enormously on these aspects, because of its configuration or because it has elements of regulation of the solar radiation or views (lattices, blinds, etc.). All these decisions in the design will have to be compatible with the conditionings related to natural and artificial lighting of the building, and will have to consider the need to do the maintenance operations.

#### **2.14.- Conditionings related to intrusion resistance of façades**

It is necessary to analyze the existing possibilities of intrusion attempts into the building across the façades (urban, industrial zones, etc.), as well as their unprotected parts (windows, low parts, terraces, etc.).

The systems used for these threats can be active, by means of electronic safety systems that can be integrated in the façade, or passive, by means of the design of the façade (grilles, reinforcement of metalwork, etc.). These systems must not constitute a barrier to perform a rapid evacuation of the building, for example in case of fire.

#### **2.15.- Conditionings related to vandalism actions resistance of façades**

As in previous conditionings, it is necessary to value the possibilities that this type of acts can take place (isolated buildings or meeting zones, etc.).

The most unprotected zones of the façades have to be identified, as well as the predictable actions (impacts, crashes, graffitis, cartels, etc.).

In very visible or representative buildings like institutions, embassies, etc., it is very important to consider this type of conditionings.

#### **2.16.- Conditionings related to mechanical, chemical and functional compatibility of façades**

The chemical and mechanical compatibility of the different components, that conform the façade, with the rest of the building (vertical elements, partitions, pavements, facilities, etc.) is a very important aspect to consider because it is closely related to the functional compatibility of the mentioned façade.

Anyway, it is necessary to consider the need to use sustentation systems with several degrees of freedom (movement), joints and systems of union among the elements that form the façades, in order to allow the movement of components both during their construction and when they are in service.

#### **2.17.- Conditionings related to building products features of façades**

To have knowledge of the features of our façade facilitates us information about its limits of use. It is necessary to know the characteristics and properties of the natural, artificial or synthetic construction products that form part of the façades.

This knowledge will be a great help to value the rational, technical and economic viability of the constructive adopted solution.

## **2.18.- Conditionings related to the durability of façades**

Firstly it is necessary to value the characteristics of the physical exterior and interior environment and of the physical internal environment of the façades, as well as the different degrees of exposure of their diverse parts.

The durability of the façade depends on the durability of each of its components due to the different solicitations they may receive. For that purpose it is necessary to value its behaviour due to the different destructive actions of physical, mechanical, chemical and biological origin.

Another very important aspect to take into account is the compatibility among the components that form the façade to prevent alterations. It must not be forgotten that any failures of durability can be irreversible and that if they are not considered adequately, they will need a later repair before they affect other elements.

## **2.19.- Conditionings related to use safety of façades**

The safety degree of the façade must be reached both in the phase of execution, and in the phase of service. For that purpose it is necessary to fulfill the requirements and demands of the compulsory regulations, as well as the local regulations, etc.

During the design of the façades it is necessary to consider the measures to prevent accidents. This gives a safety degree adapted to the activities and type of users of the buildings. The reliability of the sustentation conditions of the façade components (handrails, anchorages of maintenance systems, etc.) will be essential to increase this safety.

The mobile elements of the façades (windows, grids of ventilation, etc.) driven manually or motorized have to be considered adequately, especially their dimensions, weight, opening systems, type of users, etc.

During extraordinary situations (fires, explosions, etc.), it is necessary to consider the probable behaviour of the façades, for the safety both of the users and of the fire brigade, because sometimes they can constitute an architectonic barrier.

## **3.- CONCLUSIONS**

The principal conclusion of the development of these technical conditionings is that it is a tool of great utility both for the design of façades and for the analysis of existing façades.