Pathology of light facades

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ABSTRACT It is necessary to point out that the statistics that are exposed here and the data contributed refer, exclusively, to building works designed and directed, in which at least one architect has taken part. The pathologies in the light facades (building external cladding that, by itself and together with the interior layer, contributes all the functions requirable to an external envelope regarding stability, security, sealing, insulation and solar control) present different symptoms that rarely have a unique cause and generally are produced by the concurrence of several of them. At the same time, one same cause can provoke different defects, and therefore, different symptoms. The origin of the pathologies is found in any of the phases of its creation, from the project to the end of the useful life of the facade: Architectural and Technical Project, Manufacture, Transport and Storage, Assembly and Use and Maintenance. It is in this process where the different processed judicial reports are studied, regarding the systems and materials that are involved: Structural Elements, Connectors, Anchorages, Glazing and Plates and Panels. The ones that affect those we called light, slightly more than 7.50 per cent, from which we should remark that a great part of their surfaces (affected) have glass as the main component.

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INTRODUCTION

During the organization and direction of the 'Master of Architecture in Light Facades' which has been taught since 2007–2008 in the Higher Technical School of Architecture of San Sebastián in the University of the Basque Country, taking advantage of the participation of almost 60 specialists in the subject and the personal experience of teaching during more than 30 years of 'Pathology of Construction' at said school, the study of the reported defects and the causes that provoke them in facades considered as 'light' was initiated.

From the start, it is necessary to notice that, given that these type of systems are relatively new and, as we will see later, the high technology with which they developed,

along with the extended space of time involved in the judicial resolution of any legal process of this type, trustworthy mathematical statistical results cannot be deduced because the parameters, variables and time range would not be sufficiently trustworthy.

Likewise, it is necessary to point out that the statistics that are exposed here and the data contributed refer, exclusively, to building works already designed and directed, in which at least one architect has taken part (and therefore, in almost the totality of the cases, foremen builders or architects), since it is practically impossible to obtain relevant information on the subject from the rest of the participant professions, either because they do not really have it, or because the receivers of the same do not want to give it for reasons declared as protection of data but, it being in short, probably a simple economic matter.

In any case, and taking into account what has been investigated, we do not think that the possible variations, considering all the official mathematical rates, can mean a remarkable modification in the conclusions.

Almost the totality of the systems used to formalize a light facade, are designed by multidisciplinary teams composed of specialist architects, engineers and physicists. Previously made prototypes are tested under the environmental, structural and comfort conditions for which they are intended to be effective. They are made in the workshop under optimal conditions and with the industry methods such as mechanical, naval and so on, resulting in a final product controlled from the design to its packaging. The transport is also appropriate and fit to its characteristics, and the assembly of prefabricated elements is made mainly with mechanical means (Asefave, 2006).

In short, except for the unavoidable mistakes in all industrial processes and the hidden vices of the used materials, the defects attributable to the process, let us call it the industrial process, are practically non-existent, and therefore, there are very few complaints about this part of the construction.

The last phase of the constructive process, Use and Maintenance of the element, can, by itself, originate pathologies if the limitations of use and the conditions of maintenance have not been previously detailed or if there has not been a correct intervention in any of the conditions.

Considering the complaints already seen through judicial channels, Figure 1 (and therefore, eliminating those that have already been solved by means of a transaction), those referring to defects observed in facades (including among others, in addition to the light ones, the ones with paint finish, with ceramic and other claddings) represent something more than 17 per cent of the total and, from this percentage, the ones that affect those we called light are just a little more than 7.50 per cent (see Figure 2) from which we should remark that great part of the surfaces (affected) have glass as the main component (Lozano and Lozano, 2006).

As there have not been enough court decisions to be able to compile them homogeneously, the most affected elements, the responsibility of the participants, the costs and so on cannot be deduced, and therefore, everything that is here exposed is based on the experience of those who had been consulted for this work (Escribano Villán, 1994).

THE PROBLEMS

The basic characteristic of the light facade is its constructive formation, using elements joined to each other and those to the framework of the building, there being, therefore, three primitive systems: anchorage from the substructure to the building, fixations between the substructure and the facade and the materials of formation and finish of the facade (Bobadilla, 2007).

Figure 1: Complaints already transacted through judicial channels.

Figure 2: The light facades are just a little more than 7.50 per cent.

Although, logically, the complaints are limited to the detected symptoms, and therefore to all which is visible without a deep investigation (Díaz Gómez and Casado i Martínez, 2002), the majority of them refers to the outer layer or finished system. However, a great part of these is a direct consequence of defects on the anchorage, substructure and/or fixations that are mostly hidden by the final cover (see Table 1).

Anchorage

The most repeated defects and the causes that produce them, are due to the following circumstances:

- The scarce size of the base material where the anchorage is inserted can cause its breakage (see Figure 3).

Table 1: Estadistics of defects

<i>Per cent defects of</i>		
Anchorages Substructure		24.50
	Profiles	1.50
	Loads	2
	Fixations	6
	Total	9.50
Finishes	Stone	5.50
	Wood	5
	Metallic	0.50
	Concrete	3.50
	Synthetic	1
	Glass	50.50
	Total	66
Total		100

Figure 3: Scarce size of the base material.

Figure 4: A short distance between anchorage and the edge of the base material.

- An excessive intensity of the loads and or the torque value can cause the failure of the base material.
- The turn of the plug inside the base material reduces its resistant capacity and the rotational fixation.
- If the legs of the anchorage are too short its detachment may not be avoided.
- A scarce depth of the anchorage causes its failure in case of a traction effort.
- An anchorage failure is produced when there is a short distance between this and the edge of the base material (see Figure 4).
- If the anchorage collides with a hard material, its trajectory diverts reducing its mechanical characteristics.

- If the size of the legs of the anchorage is not enough, the fixation can collapse due to the tear out of the base material.
- If the efforts of one plate on another one accumulate, they can cause the failure of the anchorage.

Substructure

The finish cover and support of the structure retaining system can be affected in three fields:

- *Profiles:*
 - If the inertia is lower than necessary.
 - If the expansion joints have not been considered.
 - If the expansion is impeded.
- *Loads:*
 - By the application of non-predicted loads or pushes.
 - By the action of earthquakes or extreme climatologic conditions.
 - By differential establishment among spots distant from the construction site.
 - By movements of the lifting structure outside tolerances.
- *Fixations:*
 - Non-existence or reduction of the mechanical fixations.
 - An excessive distance between the mechanical fixations.
 - By badly calculated anchorages and/or structural profiles.
 - By badly executed anchorages and/or structural profiles.
 - The lack of foresight of compatible expansion joints with the fixations.

Finishes

The finish elements of light facades are made up of almost all the traditional and high-technology materials, and so the defects that can appear are those already happening in these materials in other constructive systems of the building (Monjo Carrio, 2004).

Next, those that have had any complaint as a component element of the facade are indicated, leaving for the end those corresponding to the glass that, as already explained, are the ones which have generated a greater number of proceedings in this system:

- *Plates of stone:*
 - Anchorage oxidation.
 - Plate breakage (see Figure 5).
 - Sharp breakage in the edge of the plate.
 - Flexion breakage at the edge of the plate.
 - Detachment of the anchorage from the plate.
- *Wood panels* (Rodríguez Liñan and Rubio, 2000):
 - Ageing of the wood:
 - Atmospheric agents: photo degradation, wind and rain.
 - Mechanical agents: knocks, scratches and deformations due to efforts.
 - Chemical agents: strong acids or alkaline lies.
 - Absorption of water: hygroscopic and humidity variation.
 - Fungi:
 - Chromogen (modifying exclusively the colour of the wood): blue (in the coniferous) that does not affect its resistance, green (on the leafy vegetation) that reduces very little its resistant characteristics and red (affecting the beech) giving off a bad smell.

Figure 5: Plate breakage.

- Putrefaction (modifying its physical and mechanical properties: those with white putrefaction destroy the lignin; those with brown putrefaction attack the cellulose; it inflates and gets darker; and those with soft putrefaction, with a lot of humidity, soften the wood.
- Biotic: moths, woodworms and termites.
- *Metallic plates:*
 - Oxidation of the panel.
 - Oxidation of the attachments.
 - Distortion of the plate due to lack of thickness.
- *Concrete plates:*
 - Degradation of concrete due to pollution.
 - Decomposition of concrete due to chemical attack.
 - Oxidation of the frames due to the lack of protection.
 - Breakage due to non-foreseen efforts.
- *Synthetic plates:*
 - Bending of the plate due to external efforts.
 - Breakage of the plate in the area of the anchorages.
 - Lack of flatness as a whole.
- *Glass:*
 - Material:
 - Failure due to thermal stresses.
 - Failure due to inlays of nickel sulphide.
 - Defect of the planimetry due to dimensional mistake.
 - Distortion in the reflection due to abrasion.
 - Distortion due to the cleaning with abrasive products.
 - Breakages:
 - Because of glazing without wedges.
 - Because of internal–external thermal clash.
 - Because of temper and mechanizing (Figure 6a).
 - Because of inadequate manipulation.
 - Because of the movements of the elements it supports.
 - Because of accidental knocks and impacts (Figure 6b).
 - Sealing:
 - Lack of cleanliness of the support.
 - Lack of application of adhesive.
 - Bad choice of the silicones.
 - Porosity or bad application of the silicones.

Figure 6: (a) Breakages due to temper and mechanizing or (b) due to accidental knocks and impacts.

- Watertightness:
 - Non-existence/scarcity of mechanical fixations.
 - Profiles and/or mouldings without expansion joints.
 - By a different subsidence in different parts of the building.
 - Scarce size of drainage drill holes.
- Permeability:
 - Lack of expansion joints.
 - Not vulcanized or discontinuous joints.
 - Sealing incompatible with the waterproofing agents.
- Insulation:
 - Acoustic: reduction of its sound characteristics due to the placing of joints that have not been prescribed by the manufacturer, use of a sealing, which is not compatible with the waterproofing agents and/or manipulation of the elements by non-qualified staff.
 - Thermic: loss of the insulating capacity due to the use of not vulcanized or discontinuous external joints in the external sealings.

DISCUSSION

As it has been explained above, light facades are characterized by the use and application of a higher technology in almost all of the phases of its development.

On the one hand, the developer of the building corresponds to a holding (usually linked to banks), whose objective, in addition to the economic profitability, is to give a different and innovative corporate image that can be recognized all around the world. On the other hand, he assumes the need of hiring a multidisciplinary teamwork for the study and research of the singularity of, at least, the external envelope of the building.

This technical teamwork that must solve various technical conditions on the one hand, and an original image on the other hand, is formed by specialists in different fields that converge (although in some cases just tangentially) in the facade element and by project managers that solve the contradictions and/or incompatibilities between technique and aesthetics, see Figure 7 (Díaz-Grande, 1996).

The used materials, except for very specific cases, are practically the same as those of a traditional construction, although with more appropriate treatments for their new function and inserted in systems that have adopted the Technology of auxiliary industry and aeronautic, automobile, naval industry and so on thus achieving semiprefabricated elements for their direct placing in the building work.

Figure 7: Curtain wall.

Figure 8: Facade of synthetic plates.

All of this could not be possible if the construction had not been technified, and in particular, if the industrialists involved had not become real specialists developing systems, trying out different typologies and certifying valid models with the most appropriate methods and under a validated control (see Figure 8).

The combination of all these participants (developer, technicians and industrialists) to achieve the definitive system to be installed in the building work, would not have any sense, if the executant of this system, the builder, did not have the technical capacity and the adequate auxiliary means to put it into practice. Putting it into practice means the use of mechanical means of elevation and positioning developed almost exclusively for these cases, and therefore, with a minimum labour intervention (see Figure 9).

Like that, the weak point of all the process, the ‘sealing’ of the system in itself and with the civil building works, is reduced to its minimum by introducing precision anchorage methods, almost millimetrical means of adjustment positioning and sealing using trapping or expansion of the elements in contact with synthetic materials that have a debatable guarantee (Freitas, 1992).

Of course, the quality control of all the process, from its design to its placing is fundamental to assure the suitability of all the system. That is why different technical control offices are hired (by imposition of the insurance or the developer), and they follow the process and validate the phases of its development (see Figure 10).

Figure 9: Facade of metallic plates.

Figure 10: Facade of plates of stone and semiprefabricated modules.

Therefore, the insurance policies underwritten for this type of building work, besides the ones that are most appropriate for the implementation of the same, are not limited only to the Ley de Ordenación de la Edificación (Town Planning and Development Act), but in the majority of the cases, they surpass the coverages (economic and of responsible participants) because of the greater costs of the possible repairs and the greater number of people involved in all the process. If it was not this way, the processing and judicial resolution of a defect in the system could be almost endless.

And finally, the user. As the majority of the buildings where this light facades technology is applied are of public use, offices, administrative, of institutional representation, exhibition, hotels and so on, the end user, apart from not having invested money (directly) in its construction, uses it for the work, leisure, culture and so on, but, in fact, only from time to time. Therefore, the end user does not detect if there are defects, he does not feel involved in the result of the building and, above all, it does not affect him economically.

Figure 11: Prefabricated modules.

In short, the reports of the users are, until now, non-existent, which are perhaps the parameters for the sinister (the claims) in buildings with a light facade so that they have a very low percentage?

Obviously, an important part of the set exist that is practically repeated in all works of construction and that takes part, in principle, with the same conditioners and responsibilities: developer, architect, specialist engineer, office of engineering control, foreman builder, builder, control of quality and insurance agency.

Therefore, we would only have left the deeper research of the system to execute, the previous tryouts and its manufacture under ideal human and mechanical conditions, its transport and its set with adequate and highly technified means; in short, the formation of the facade using semiprefabricated modules that are inserted directly in the building work (see Figure 11).

That is, almost finished elements manufactured by industrialists, directly put in the building work and with a minimum intervention in their manipulation, with no specialized labour.

And without forgetting the part with greater incidence as far as claims are concerned, the user/owner, who in these situations, as previously explained, does not report since he does not feel implied.

CONCLUSION

The defects observed in facades (including among others, in addition to the light ones, the ones with a paint finish or with ceramic or plate cladding), mean something more than the 17 per cent of the total and from this percentage, the ones that affect those we called light, are just a little more than 7.50 per cent, from which we should remark that a great part of the surfaces (affected) have glass as their main component (Paricio and Pardal, 2006).

The percentage of defects due to the anchorages is 24.50 per cent, to the substructure 9.50 per cent and the finished ones 66.50 per cent.

The developer of the building assumes the need of hiring a multidisciplinary teamwork for the study and research of the singularity of, at least, the external envelope of the building.

This technical teamwork is formed by specialists in different fields that converge in the facade element and by project managers that solve the contradictions and/or incompatibilities between technique and aesthetics.

The used materials are inserted in systems that have adopted the technology of the auxiliary industry, the aeronautic, automobile, naval industry and so on, thus achieving with more appropriate treatments for its new function motor, and naval industry achieving semiprefabricated elements for their direct placing in the building work.

All this would not be possible if the construction had not been technified and, in particular, the industrialists involved had not become real specialists.

The parameters for the sinister (the claims) in buildings with a light facade to have a very low percentage are almost finished elements manufactured by industrialists, directly put in the building work and with a minimum intervention in their manipulation, with non-specialized labour.

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