38. Implantation of the BIM system to the Open Industrialization under Criteria of Sustainability

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Abstract: Uninteresting in buildings that have been carried out in the last years due to housing demand and speculation leads to the necessity of a change in the current outlook towards a sustainable construction. The main concern of this investigation is the construction with industrialization criteria, flexibility and sustainability that leads to the necessary change of the sector. The open industrialization or construction by compatible components is considered here as the base to reach these objectives. Furthermore, the use of new technologies available nowadays, such as the BIM tools, are essential for a sustainable change. Therefore, it is necessary to know the current situation of the system in this sense and the issues and necessities that could be contemplated, not only for the agents that take part in the process but also for the introduction of BIM in the industrialized systems. This will allow establishing a fixed criteria and conclusions in order to propose a new way of real intervention, sustainable and common, which are the catalogues by components or file cards. It could be affirmed first that the catalogue is the most adequate way of optimizing the tool and to take advantage of its potential; second that it solves all the current necessities and deficiencies; third that it connects the main agents and fourth that it favours the trend towards a sustainable industrialization. The study has been focused in the constructive system of heavy and light ventilated facade but in any case the procedure is comparable to any component.

Keywords: Architectural Technologies, open industrialization, compatible components, prefabrication, BIM methodology.

1. Introduction and Justification

The construction has to adapt itself to the new social and economic changes that we are going through. The main concern of this investigation is the construction under a new model based on the industrialized, adaptable and sustainable construction that leads to the necessary change in the sector.

Furthermore, the open industrialization or construction by compatible components (CCC) makes possible the technological innovation capable of generating big advantages for the productive model. In the last years, the BIM tools are having a relevant place in the construction and little by little in the industrialization as well. There will be a moment in which an industrialized architecture of quality has behind it the use of this kind of software, therefore, the bet could be a reality and generates a new outlook. Although this affirmation could seem presumptuous, it can be already seen evidences that this fact is happening.

"CIB W104. Open Building Implementation"(International Council for Research and Innovation in Building and Construction) is an international group of investigation founded in 1996 with important researchers and professionals working in areas included in a general frame of a new concept of sustainable, industrialized and adaptable construction.

2. Methodology and Objective

The main goal here is to determinate which one should be the procedure of implantation of the BIM system to the construction by compatible components (CCC) to follow. Throughout the analysis of the current implantation for a component and the analysis of the necessities/ responsibilities of the agents which take part in the process that leads to propose a plan of intervention that guide the actual situation.

3. Evaluation of the Techniques of Implantation of Industrialization's Systems to BIM Tools.

3.1 Current Theoretical State

3.1.1Present Situation of the Industrialization in the Construction

From the year 2000 there is a phase of consolidation in the construction by components (Salas, J. 2008) because it is in that moment in which is verified that:

-The technologies of component's production resisted the crisis well and they adapted better than the closed systems to new trends.

-The components were introduced in the growing market favorably.

-The drastic reduction of works of a great volume criminalized the concrete technologies and impulse the use of components of other materials.

- The elasticity of the constructive solutions based on components made possible the compliance of the new rules of energetic saving and the answer to other kind of architecture from the demand side.

By this way, it starts a period with a new constructive philosophy.

Currently, the tendency is the use of constructive elements of different business origins that are assembled in work thanks to its dimensional compatibility, tolerance, joints, resulting in different architectural relations in project edited with mentality and industrial discipline.

Table 1 Objectives of the open industrialization (Domínguez J.M. 2016)

OBJETIVES OF THE OPEN INDUSTRIALIZATION		
1. Satisfaction requirements of the building		
2. Instrument with will of universality		
3. Ordering and reactivating of the construction of industries		
4. Conectar la tecnología con la arquitectura		
5. Search for sustainability:		
Environmental Sustainability	Social Sustainability	Economic Sustainability
Dry assembly Reusability Recyclability Waste management Low energy used in transport and manufacturing Reduction of water consumption Minimum CO2 emissions	Improvement of the workers' conditions Improve working conditions Specialization of labor Fixed positions Incorporating new agents to the construction Industrial control and responsibility	Minimising the cost over the life cycle Materials and regional components Minimized maintenance costs System or component durability Serialization of products
6. Flexibility:		
Adaptability of the system to any measures Using universal connections and anchors Replacement of the systems and components Mobile system or shiftable	Recycling system and components Transport systems or components Modulation	
7. Industrialization:		
Volume de production Computerized systems	Automation level Specialized machinery	

This way of understanding the construction is called method of elements, that is, the industrialization by compatible components or open industrialization. However, this concept is not new. As Oliveri already reminds "Gropius had attended

the problem by its root proposing with a prominent intuition the industrialization of the construction throughout its components".

Therefore, it is determined as objectives (Del Águila, Alfonso, 2006) of the open industrialization the one reflected in the Table 1 whose research towards the sustainability in the urbanity process is an essential objective which is giving results.

3.1.2 Construction by Compatible Components

The current kinds of components make reference to the habitual decomposition of the building: facades, closing, forged, structures, installations. The different functions of the building fulfill traditionally throughout the parts of the construction properly defined (Bernard, 1982).

In the open industrialization is not enough if we just speak about the component. It is also necessary to add the term open as the criterion of opening involves numerous advantages and possibilities as it respond to economic and technical criteria at the same time, available in catalogue and that can be part of buildings.

The opening criteria are the following: independence between production and use, availability in catalogue, quick availability, put in work throughout simple and fast assembly, in relation to the conditions of compatibility, manufacture in series, transport and manipulation, respect to the compatibility conditions, in series production, transport and manipulation, technology in its production.

It is usually denied by utopian the universal compatibility between components, however, the facts show the enclosed compatibility, delimited and possible. According to (Bernard, 1982), it is important to bear in mind not only the aspects of compatibility between components but also among the agents would be possible.

3.1.3 Industrialization Put into Practice

The catalogue is an informative element that works as a connection between the products of components or constructive systems and the users (architects, promoters, constructors, etc) joining by families the totality of the products existing in the market. It should contain at least: technical synthesis, relation of manufacturers and brands, and technical adapted pieces for each product.

According to the kind of product will exist two principle groups of catalogues (Del Águila, Alfonso, 2006):

1. Catalogue of constructive systems that:

- It will contain the logic of the system, indicating the way in which is developed and how it has to employ in project as well as in execution.
- It will indicate that the components of the system are interchangeable with components of different origin.
- It will mark which ones are the specific components and, therefore, inseparable of the system. At the beginning, this point could enter in conflict with the same definition of the constructive system, but it will have to be accepted when many of them are proceeding of the primitive close methods.

2. Catalogue of components, whose main characteristics will be:
- Just one catalogue for each kind of component.
- Follow the totality of the general characteristics specified for the catalogues.

The number of catalogues is variable, depending of the degree of development in the open industrialization. In France, for instance, there are very developed ones and it exists around thirty dedicated to: structures, heavy and light facades, partition walls, heating, doors, forged, stairs, insulating element, protections against the fire, sanitary installations, etc.

3.2 Current Incorporations of National and International Manufacturers to the BIM System

BIM (Building Information Modeling) could be translated as Modeling Integrated of Information for the Construction. The philosophy of the CAD programs with this technology such as Allplan, Archicad or RevitArchitecture, is to integrate all its information to carry out a project in its initial phases in such a way that other applications that solve others phases have access to this information.

The flow of information towards other applications is done throughout the files of exchange in the IFC (Industry Foundation Classes) format. It has been developed by the IAI (International Alliance Interoperability) with the aim of becoming in a standard that facilitates the interoperability between programs of the sector. By doing that, the process of introduction of information is simplified and each of the informatics application that take part in the project does not need a complete introduction of information but it uses the information introduced in the program.

The software of study used in the present investigation will be Archicad of Graphisoft, one of the BIM software more important of the industry. Nowadays the way of acting and procedure is through the incorporation of objects to the work environment or making your own object. Therefore, the categories of objects that can be found in those days can be classified in four basic types:

Table 1 Category of objects BIM tools (Domínguez J.M. 2016)

CATEGORÍAS DE OBJETOS	
1. Generic solutions	stairs/ doors/ windows /wall / pillar / beam /forged / roof / structure / skylight.
2. Furniture Objects	storage / chimney / kitchen / details / drainage system/electricity / electrical appliances/ sanitary equipment.
3. Construction components	tiling / blacksmithing / air conditioning / stairs/ plumbing / soundproofing / sheathing
4. Objects Constructive System	walls / curtain walls / roofs / ceilings.
5. Solutions designed by the user	

After the classification done in here, it is necessary to put all the attention in the two categories that are going to influence more on the construction by components: **objects constructive system and the generic solutions**.

Therefore, it will be analyzed more in detail three files IFC elaborated by the manufacturer Pladur (Spain) y Metawall (Germany), Norgips (Sweden). In addition, it will be also analyzed the generic solution of the program for a facade wall. By doing that it will be also possible to compare and evaluate both ways of working. By doing the analysis of the background we can find favorable and unfavorable points that are going to influence the construction by components (CC):

Favorable aspects of the incorporation of BIM to the CC:

1. - Beginning of the incorporation of the components to the BIM tool.
2. - Generic solutions:
   - -It allows parameterize, dimensions, layers, thicknesses and materials.
   - -It provides infinite possibilities in terms of 3D modeling.
   - -It gives guidance values for the component concerning to measurements and budgets, stakeout, material properties, etc.
3. –Objects constructive system:
   - - It adapts to architectural design of the designer
   - - It includes actual and accurate information.
   - - It allows for real industrial solutions for components.
   - - Product's parameters adapted to the characteristics of the element
   - - Flexibility's parameters can be modified

Unfavorable aspects of the incorporation of BIM to the CC:

1. There is no current classification of the BIM objects.
2. The furniture objects with no relevance for the construction.
3. Incorporation of constructive components with not too much relevance.
4. The constructive objects systems:
   - -It does not incorporate real information of the manufacturer.
   - -It is not allowed to industrialized component solutions.
   - - The BIM tool does not take advantage of these solutions.
5. Objects constructive systems:
   - -Closed systems not compatible with other manufacturers or components.
   - -Lack between constructive reality and the software.
   - -Meetings not fixed or supported.
   - -The product and the needs of the designer go in different directions.

4 Analysis. Criteria of Implementation to BIM of the Facade System.

4.1 Criteria of BIM Implantation to the Construction by Compatible Components for Ventilated Facades.

It is analyzed a constructive system of generic ventilated walls and another one of specific ventilated wall (panel ΩZ, with certificate DAU).

The objective is to compare which one should be the procedure for the implantation to BIM throughout the analysis of the possibilities that it offers us in one or other way and which of them cover the necessities and responsibilities of the agents.

In order to do this, the variables taken are those aspects related to: expected uses, components of the system, the production, control of the production, storage, transport, reception in construction, criteria of project, execution of the system, assays and calculations for the adaptation to the use.

On the other hand, these conditions have been grouped into four. Therefore, it is perfectly defined for any component and can be also perfectly compared both ways of constructing, see Table 2. Firstly, the determinants or variables for any component in general; secondly, for the family of facades (as this investigation is dealing with a constructive system of facade); thirdly, for the family of ventilated facades and lastly the determinants for the specific facade of study.

Table 2 The determinants and criteria in the construction of components (Domínguez J.M. 2016)

DETERMINANTS FOR THE CONSTRUCTION BY COMPONENTS											
Project's criteria	Zeta profile	Omega piece	Prefabricated panel	Internal fin.	Ext. covering	Support structure	Components	Soporte estructural	Geometr. charact.	Value	Use	Variables
									The ones of the components	The one of the component	The expected by the component	General determinants for any component

General determinants for facades	General determinants for ventilated facades	General determinants for specific ventilated facades
The expected by the component	The expected by the component	As external covering in ventilated facade
The one of the component	The one of the component	The one of the component
The ones of the components	The ones of the components	The ones of the components
Basic structure in which the component is put	Basic structure in which the component is put	Basic structure in which the component is put
Of the system	Of the system	Prefabricated panel of prestressed mortar with soaked sleeve, pieces of the fixed panel, Omega piece, horizontal profiles of support of the panel, Zeta Profile
	Substructure in which the system is colocated	Substructure in which the system is colocated
	Formal characteristics and material	Formal characteristics and material
	Two typologies in relation to the support: ventilated facade with heavy and light basis	Two typologies in relation to the support: ventilated facade with heavy and light basis
		The standar dimensions of the panels are: lenght = 3000mm, nominal width= 2200mm, nominal thickness = 30mm. The minimum dimension will be 580x415mm, keeping always aminimum of four points of moorings. The steel sleeves of biggest diameter = 25mm, smallest diameter = 16mm, lenght = 24mm
		It exists two typologies of basis plaque. The way and dimensions of the basis plaques are 65x65x5mm and 61x65x5mm.
		The main characteristics of the Zeta profile are: estándar lenght= 3m. The way and dimensions of the profile section are: height = 60mm, width = 28mm, thickness = 2mm.
		A premeasuring effect should be considered for both the horizontal joint to a vertical dimension of 7mm board and the distance between holes or between hollow and corner should be 65cm or higher. When defining the total thickness of the facade, you should consider the overall thickness of the solution varies between 70 and 82.5 mm, wherein the thickness of the chamber between 40 and 52,5mm. The prefabricated panels can be placed both horizontally and vertically. It should be considered that the maximum distance between the fixing points Profile Zeta on the support structure must be 600mm . It should be considered that the same profile Zeta should not be attached to both sides of a movement joint or structural joint of the building. Elements supporting materials should have a dilation and contraction due to moisture and temperature.

4.4 Necessities of the Participant Agents

It is already known the importance that these agents have in the process of edification in the implementation to BIM in order the process to be completely efficient. The study and analysis of its properties and necessities (see fig. 1) will give the keys to propose a sustainable and common action to the three agents.

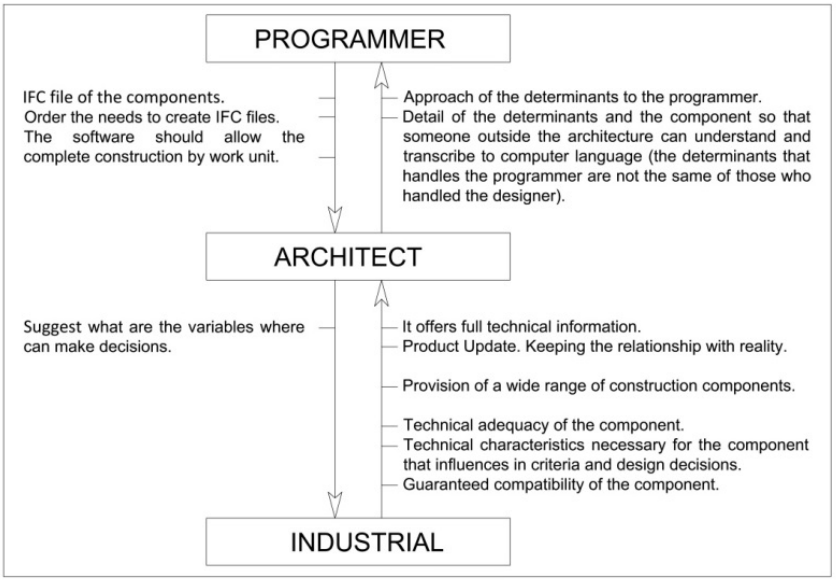

Fig. 1 Necessities and responsibilities of the agents. Figure elaborated by the author

5. Discussion of the results

The most important points will be compared in order to evaluate what is the most optimal procedure when designing and building with BIM tools.

1. **Quantity of information.** Regarding the user; the information that can be found in a specific solution is similar to the generic one when speaking about quantity, but much more accurate and realistic in terms of content. Regarding the programmer; the specific solution contains much more specific component information, but it is precise and concise information, it is also quick to communicate to the programmer and that this take it out. The singular points are widely studied and generally solve by the company, are pretty easy to carry out incorporating a higher quality to the final product that with a generic solution will be very difficult to get.
2. **Approach to the solution's price.** Regarding the user; the approximation to the real price of the specific solution is similar to the design request by the designer. This has numerous advantages compared to the generic solution when deciding between several options, designs, manufacturers, etc.
3. **Necessities of the Project.** The necessities could be different in one from the others: finishing material, singular points, place of origin of the product, geographical location and building supply company, etc. Regarding the programmer; from a generic solution we cannot take into consideration all those variables no less important whereas from a specific solutions yes. Regarding the user; they are

more specific solutions which come from a determinate company, they are easy to solve with the technical help of the manufacturer.

4. Determinants/parameters. The advantage in a specific solution for the seven constructive parameters taken into account (geometry, inner sheet and support, beginning of façade and pillar encounter with hollow joints and corner are higher). Regarding the user; he can determine its position and basic dimensions. It is accurate and gives the security to be fulfilling technical requirements of quality; the manufacturer provides the most adequate solution. Regarding the programmer; with no difficulty to in determining the chances that each parameter as are concrete, it has a very specific way of acting in terms of dimensions and materials, highly controlled solutions, etc.

5. Agents. For a general solution; the industrial, the designer and the programmer do not come into play with the same intensity driven by different interests. For a specific solution; industrial enter in continuous contact and update the product, i.e. continuous updating and revision of its technical, prices, news, regulations, certification, etc.

Evaluating the results obtained, the most successful solution when working with BIM tools and industrialized components is the one of projecting with work units (or constructive systems) of a particular manufacturer or specific company. This is the main necessity of the designer and the one which optimize the BIM tool and the whole constructive process.

6. Action Plan

It is pretended to tackle the issue through catalogues or constructive pieces systems or work units. It may be an opened or closed catalogue, in other words, that admit components from other manufacturers or on the contrary, it would be closed and only admits and supports the components of the building system itself. This component will always be compatible with other components or work units. In spite of being more interesting a catalogue/ piece by subcomponents because it allows a much more open industrialized system, with many constructive possibilities, it is an unrealistic and impractical catalogue because it complicates many other aspects of the construction.

Therefore, two different types of pieces are contemplated depending on the agent it is addressed to:

1. For the programmer: they are given a series of file cards which contain information about the progress of the IFC file for the type of component.
2. For the designer: they are given a series of file cards which contain information about the way of proceeding to Project the product.

The suggestion is focused in the family of ventilated facades. Inside this type of component it can be differentiated between heavy and lights. Therefore, there will

be at the end two different types of specific ventilated facade either for the programmer as for the designer.

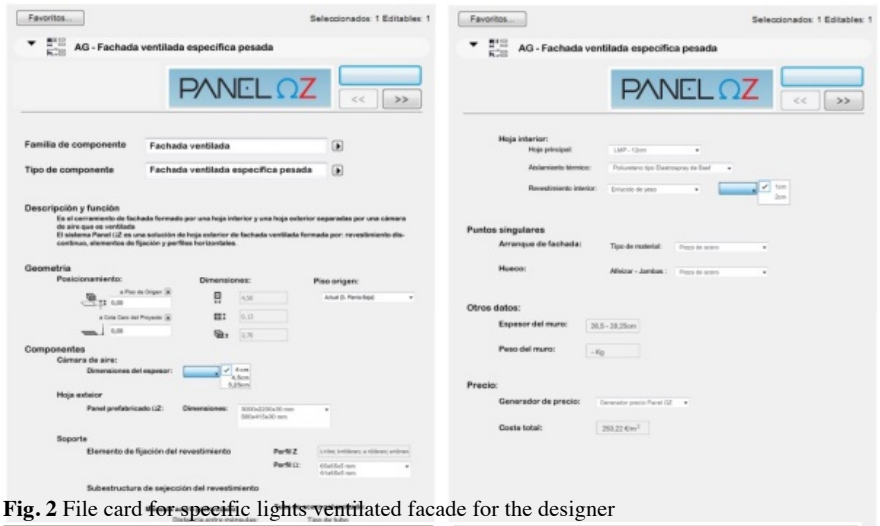

Fig. 2 File card for specific lights ventilated facade for the designer

Familia de componente	FACHADA VENTILADA
Tipo de componente	FACHADA VENTILADA ESPECÍFICA ΩZ LIGERA

Geometría

- El componente debe adaptarse a la forma recta o cueva que el proyectista diseñe.
- La altura del componente queda limitada en todo caso entre forjados.
- La **subestructura** queda por delante del forjado (queda fijada a la hoja interior de fábrica). Por lo tanto la hoja interior queda embebida y enrasada entre forjados, y la hoja exterior cubre totalmente el frente de forjado junto con el aislante.

Componentes

Cámara de aire ventilada

Descripción: capa de aire que hay entre el substrato o aislante térmico y el elemento de revestimiento que está en contacto con el ambiente exterior
- Dimensiones: El espesor de la cámara de aire entre **40 y 52,5 mm**.

Hoja exterior de revestimiento

Descripción: elemento de revestimiento discontinuo o piel exterior.
Panel prefabricado ΩZ:
- **Dimensiones**: longitud=3000mm; anchura nominal=2200mm; espesor nominal= 30mm; dimensión mínima= 580x415mm
- Se mantienen siempre como mínimo **cuatro puntos de anclaje**.
- Distancia mínima entre borde del panel y ejes de las primeras filas de casquillos ≥ 70mm.
- Distancia entre bordes del panel y ejes de las primeras columnas de casquillos ≥ 40mm.
- Distancia entre columnas de casquillos= 500mm, y entre filas= 275mm.
- Los **casquillos de fijación de acero** de diámetro mayor de 25mm, menor de 16mm. Longitud= 24mm.

Soporte

- **Elementos de fijación del revestimiento**: principalmente elementos metálicos para una fijación mecánica:
  - **Perfil Z**: Fijado mecánicamente a los montantes verticales
    Longitud estándar= 3m; forma y dimensión del perfil: h= 60mm, ancho= 28mm, e=2mm.
  - **Perfil Ω**: Apoyado simplemente sobre los perfiles Z
    Dos tipologías de placas: 65x65x5mm y 61x65x5mm

- **Subestructura de fijación a la estructura** soporte (hoja interior principal de fábrica de ladrillo):
  - **Ménsulas de acero galvanizado**: en forma de U, colocado sobre frente de forjado para fijar los montantes verticales. Cada **600mm**.
  - **Tubo de acero galvanizado**: dispuesto cada 600mm en el interior de las ménsulas. Espesor= **80x80x2**mm

Hoja interior

Descripción: se trata de un muro industrializado con los siguientes componentes. Componentes de la hoja interior desde el interior al exterior:
- Capa de pintura. Tipo: pintura plástica.
- Placa de yeso laminado. e=10-25mm, longitud=2,5-3m.
- Perfil de acero galvanizado (montantes, canales, perfiles de techo). Distancia entre perfiles=40-60cm.
- Aislamiento térmico proyectado de poliuretano tipo Elastospray de Basf, e= 5cm.
- Placa de yeso laminado. e=10-25mm, longitud=2,5-3m.

Puntos singulares

Cuando presenta la fachada algunas de los siguientes puntos singulares proceder de la siguiente manera:

Arranque de fachada

1. En el arranque de fachada colocar remate metálico, dejando en todo caso el hueco pertinente para la ventilación del sistema.
2. El remate irá fijado al tubo de acero galvanizado.

Huecos

1. Los montantes verticales y horizontales metálicos limitando las dimensiones del hueco. Espesor=**5cm**.
2. Aparecen montantes verticales fijando las cuatro esquinas del marco y los forjados.
3. Las distintas capas del componente se verán interrumpidas en este punto
4. El acristalamiento de la ventana o puerta se coloca:
   - Enrasado con el interior: aplicar aislante en la parte inferior del dintel que queda al exterior.
   - Enrasado al exterior: no necesita aplicar aislamiento
5. El alfeizar y las jambas se adaptarán a las dimensiones del hueco, ajustándose mediante fijación mecánica entre el acristalamiento y el revestimiento exterior. Será metálico principalmente.

Juntas

1. La distancia entre juntas dependerá del panel prefabricado instalado. Cada **3m** y cada **2,2m** generalmente.
2. Las fijaciones extremas de la pieza de revestimiento se sitúan a **7cm** de la junta desde la primera fila de casquillos.
3. Quedará sellado para evitar infiltraciones con **silicona**.

Esquinas

1. Los montantes (tubos de acero galvanizado) se sitúan en ambas direcciones del quiebro a la misma distancia de la esquina.
2. Terminación con pieza metálica en el encuentro entre los paneles

Encuentro con pilar

1. Queda interrumpida únicamente los componentes de la hoja interior industrializada.

Otros datos (en función del cerramiento elegido por el proyectista)

Espesor del muro (cm)

Descripción: el espesor total del muro es la suma de los espesores (cm) de todos los componentes.
Espesor de la fachada ventilada específica pesada= **7 -8,25cm** (dependiendo de la cámara y del panel) + **8cm** (tubo de acero galvanizado) + **9cm** (hoja interior industrializada) = **24-25,5cm**

Peso de fachada (kg/m²)

Descripción: el peso de la fachada es la suma del peso (Kg) de todos los componentes que lo conforman

Precio

Descripción: es el precio total de la fachada ventilada pesada específica definida. Suma del coste (€/m²) de los componentes que conforman la fachada.
Factores a tener en cuenta: €/m² componentes de la fachada específica (400 €/m² panel ΩZ), Hoja interior (23,22€/m² LMP), localización geográfica del fabricante y del destino, actualización del producto, número de encuentros y detalles singulares.

Fig. 3 File card for specific lights ventilated façade for the programmer file IFC

7. Conclusions

1. **About the Construction by Components**: a model of production based on the compatible components would solve some of the currently needs and demands of the sector, the requests of the industrialization and all that it entails when speaking about social , economic and environmental advantages and, therefore, in terms of building sustainability. It begins to rise in the market the number of solutions based on components although the implementation is slow. However, it gradually it is understood as an ideal model.

2. About the BIM Tool: firstly, the available objects in general are furniture-objects and construction components that do not have a great relevance in construction. Secondly, the generic solutions of each BIM program would be interesting if they incorporate real information from manufacturers as if they allow just one traditional solution it does not exist any company that would give this service in concrete, this leads to a solution of a low quality if we compared them to the industrialized. Lastly, there are some exceptions that have tried to implement the course of action studies in this research but it is still quite far and with many possible improvements.

In spite of these first steps, but no less important as they gives us they key to understand the process of implementation has the possibility of being a real fact, the current proposal is far from becoming a coherent, since it lacks a common guide, of a common classification of components and of a method or way of acting under specific criteria.

3. About the files by components: the two files studied, the one destined to both the programmer and the user or architect fulfill the objectives as they serve as a link between the constructive reality of the component (designer files) and the technical programming of the component through the software (programmer files). Although this investigation has focused on one unique family and kind of component, light and heavy ventilated façade, the conclusions, taken criteria and way of acting, are extrapolated to any component.

4. About the agents of the process: the criteria taken to propose these files are the necessaries for the computer programmer performs the component for the BIM tools. They are necessary to the industry to progress until this type of constructive solutions and it is nearer of the necessities of the designer. Finally, they are criteria according to the need of the designer, who will use his training and knowledge; he will be the essential agent to continue this process.

Final Conclusion: the implementation of the BIM methodology to the open industrialization by compatible components is almost a reality but it requires nowadays of a procedure towards the same goal, in order to do that the collaboration between the different agents present the greatest challenge as the technical possibilities are in our own range. The sustainability of a system of construction is more than tested nowadays and with the addition of the current technology, the

advantages and possibilities that allow in this sense are even bigger, as it would be the use of energetic control, the reuse of materials, dry assembly, times, etc.

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