CAD-BIM REQUERIMENTS FOR MASONRY DESIGN PROCESS OF CONCRETE BLOCKS

Scheer, Sérgio
Associate Professor of the Construction Engineering Department at the Federal University of Paraná – UFPR.
Civil Engineering Research Centre, CEP 81.531-980, Cx. Postal 19.011, Curitiba, Paraná State, BRASIL
scheer@ufpr.br

Ayres Filho, Cervantes[1]
ceayres@gmail.com

Azuma, Fabíola[2]
fabiolaazuma@yahoo.com.br

Beber, Michelle[3]
mi_arq@yahoo.com.br

[1,2,3] MSc candidate of the Civil Construction Postgraduate Program at the Federal University of Paraná - UFPR.

ABSTRACT

The masonry constructive technique of concrete blocks is a practice that contributes for a high level of industrialization in construction in addition to achieve the rationalization in this sector. The achievement of these benefits demands some design features such as modular coordination, blocks rows details and well documented and precise specifications. One solution to meet these design features without causing agility reduction during the process is the use of CAD-BIM (Building Information Modeling), which applies modeling and visualization techniques already consolidated in other industry branches. Although the CAD-BIM brings improvements in the design process, it does not provide tools aimed directly to blocks masonry design, what can cause difficulties. The goal of this work is to identify these problems through a case study in a builder office sited in Curitiba, Parana state, Brazil, which is specialized in building design of concrete blocks masonry. Based on the results of data collected in the case study and in the literature available was possible to develop a list of CAD-BIM requirements more suitable for this kind of design.

KEYWORDS

CAD, BIM, concrete blocks masonry.

1. INTRODUCTION: THE USE OF INFORMATION TECHNOLOGY IN THE PROCESS DESIGN

The use of communications and information technologies in the building industry is creating new opportunities for collaboration, coordination, and information exchange among organizations that work on a construction project (Caldas e Soibeman, 2003). These aspects contribute for the design accuracy and consequently result on a proper building execution. Moreover, there are also technologies such as presented by Ganah *et al*. (2005), developed to assist design teams in communicating design details that may be problematic for construction teams. In the design phase, the CAD technology represents one of the most influential information technology innovations of the last four decades and offer resources for drafts and design automation, communication and design and data base exchange (Kale e Arditi, 2005). The new generation of CAD systems is recognized by "Building Information Modeling – BIM", which can be described as the process of creating and managing building information in an interoperable and reusable way. Thus, BIM is a system that enables users to integrate and reuse building information and domain knowledge through the building lifecycle. Therefore, through a BIM model it is possible to encapsulate building knowledge in such a way that each object represented is able to hold an intelligent behavior in accordance with the context of their application (Lee *et al*. 2006).

Given these characteristics, the BIM approach is considered a proper solution for the development of specialized objects, which is able to represent the relevant characteristics of a masonry design. Thus, the design documentation could be automated in order to facilitate the representation of constructive details and as a consequence, contribute for the adequate construction in the site build. The objective of article is to take requirements stock for software based on the concept BIM appropriate for a masonry building of concrete blocks.

2. METHOD

The method adopted for this research was the literature research on the peculiarities of masonry process of concrete blocks and on the possibilities of implementing an object BIM for automatic extraction of design documentation. For this article, was chosen the way of implementation through an associated application. Thus, through this approach, and considering the possibilities offered by BIM model, was drawn up a list of proposed requirements. There this list of requirements, has proposed a model of processing data for representation of instances of BIM model.

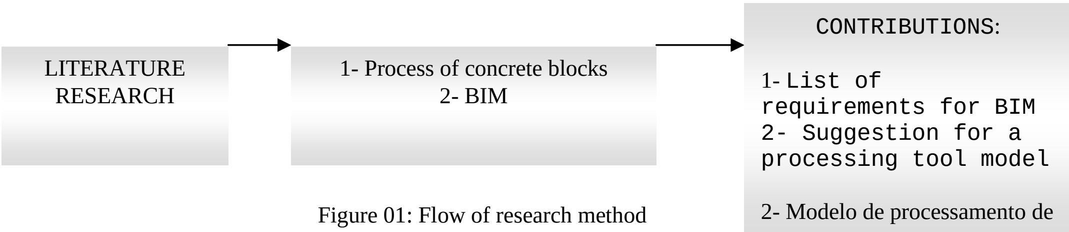

Figure 01: Flow of research method

3. APPROACHES FOR THE DESIGN DOCUMENTATION AUTOMATION

The development of a tool to automate the design documentation could basically follow two directions: an independent application or an associate application, which could be a plug-in to a BIM CAD. The advantages and disadvantages of each approach are described below:

Independent application: this approach would demand the development of a tool completely independent of others BIM CADs, although it could be used together. The key element of this approach is the reading of a file which holds the virtual model, preferable in IFC (Industry Foundation Classes) format. In such a way, the building model can be read by the main BIM CAD. The major advantage of this approach is the flexibility offered by the independency of proprietary formats that interact in the BIM process. Among the disadvantages is the enormous effort required to develop function and interfaces already available in BIM CADs: even applications specifically developed to defined process design stages, such as Tekla (Tekla, 2008) or the Ecotect (Square One, 2008) demand basic functions of object creation. Other disadvantage is the instability of IFC model, which still present some conversion problems between different applications.

Associate application: in this case, it would be developed a tool which could act from the main interface of the BIM CAD available in the market. This approach uses the basic functions already available in BIM CADs and focus in the automation of the masonry design documentation. The main disadvantage is in lack of flexibility, which would demand a new programming for each BIM CAD and also for each version of BIM CAD.

This article focuses on the second approach and demonstrates the key situations to be faced by a tool regarding to the automation of design documentation for masonry construction. This choice was due to the fact that a complete implementation (first approach) would only demand solutions to interfaces and basic functions, which are already described by the guides of major BIM CADs (Graphisoft, 2008; Autodesk, 2008; Nemetsheck, 2008; Bentley, 2008).

One of the BIM CADs principles, regardless of the manufacture, is the automated extraction of information from a model composed of objects that represent constructive elements of the designed building. Therefore, among the functions there are routines responsible for automating much of design documentation such as sections views, elevations, perspectives, layouts and quantities take-off (Ibrahim *et al*., 2004; Tse *et al*., 2005; Moum, 2006; Mao *et al*., 2007; Campbell, 2007). These routines are important agents for improving de design process, but usually they only correspond to generic situations. In such a way, the specifics characteristics of the constructive system are designed by the project team without the BIM CAD support. This aspect is in part result of the business strategy adopted by the BIM CADs manufactures, which invest primarily in the improvement of basic interfaces and in the more generic features to make the product adaptable to the largest number of consumers in the worldwide. To compensate this lack of detail about the constructive systems or specific regions, the manufactures advice the possibility of improving the basic functions of their applications. Below are described the main ways to do it with the focus in a tool to automate the design documentation for masonry construction.

Configuration of native parametric objects: the objects called "wall" in BIM CADs can be modified to behave as compositions of blocks or bricks. It only demands the configuration of the filling material, to represent blocks or bricks in sections views, and the external textures to represent their faces in the views and perspectives. This configuration is the easiest way to automate the masonry design documentation, and if it were implemented in a suitable way, can support the level of information required for this constructive system. However, this approach demands the management of all designers involved in order to verify the correct representation of the filling material in sections and the block faces textures in views. Moreover, the use of generic textures in the wall faces, although represent visually the course, do not embody intelligence in the object. It is not possible to; for instance, indicate the insertion of special blocks for modular adjustment or for facilities.

Templates: packages containing standards of graphic representation and rules for the creation of parametric objects which will represent the constructive elements. These patterns are consistent with the local regulations or with the standard guides of architectural offices and their use may prevent the designer to create elements that were not pre-defined. The templates assume great importance for the masonry design documentation because they hold options for blocks, course and coatings.

Special parametric objects: they are more detailed and flexible representation of constructive element created separately from the building model and later inserted. In previous experiences of this research group, parametric objects to represent concrete brick walls shown to be very useful for automation of design documentation.

Scripts and macros: tools that automate processes through algorithms composed of sequence of commands which trigger BIM CAD functions. Like the special parametric objects, they shown great useful in previous experiences, where scripts were created to automate the objects replication of concrete blocks in order to compose a complete wall. The limitation of their functionality is directly related with the scope limitation of the programming language used to generate the algorithms. In the ArchiCAD, for example, the programming language used in the scripts is not able to access all data of the building model, and the contextual intelligence of the object can be compromised.

Association with auxiliary data bases: function that allows associating the specific parameters of each parametric object (e. g. wall area) with generic data, inserted in auxiliary data bases (e. g. number of blocks per square meter). The data bases can be created from the BIM CAD or external to it. This is a very flexible approach to the data extraction from the building model because it eliminates the need to create new parameters in the objects each time that new information is required. Although it is a excellent alternative for quantities take-off, this approach do not solve the graphical representation of the composition of masonry wall: it is possible to know the number of blocks based on the area consuming index, but it is not possible to know the position of these blocks in the wall.

API (Application programming interface): are packages of functions and access rules to be inserted in new applications, which allow the communication with the application core of BIM CAD and their data structure. The main BIM CADs offer this alternative for software developers to permit the creation of new application that is able to improve the basic processes. The applications developed with the APIs holds unrestricted access to the building model data, which make this approach the most powerful among all presented.

4. FEATURES TO BE CONSIDERED IN THE AUTOMATION OF MASONRY DOCUMENTATION DESIGN

The following topics are related to the main features to be offered by a tool specialized in the automation of masonry design documentation through a BIM CAD.

Top-down modeling: During the early stages of a building design there is a great number of indeterminations related to the architectural spaces, constructive systems and materials to be used. In theses phases, parametric objects should behave in a generic and abstract way, in order to permit the agile handle and successive updates. As the design process continues, the parametric objects must be able to store more detailed information and to behave in a more specific way (Lee *et al.*, 2006). One disadvantage of using excessively determinants and complex parametric objects in the early stages of building modeling is overloading the designer with information that will be determinate only in the later stages. Cheng (2006) advice for the fact that very complex parametric objects can damage the experimentation process that is inherent in the architectural conception.

Behavior of objects: parametric objects are the essential of BIM CADs. They associate the description of constructive elements to behaviors that define, among others possibilities, the way the object must be graphically represented in each design view (floor plan view, elevation, section and perspective). The tool must, therefore, generate behaviors to the parametric objects in order to automate the masonry wall representation in any view selected by the user. This ability would allow the automatic extraction of masonry course plan, sections views, wall elevation, including the blocks indication, and perspectives that support the understanding of assembling elements.

Blocks and Bricks: they are the masonry basic units and vary considerable in accordance with the geographic region. Therefore, the tool must support various unit types and should also be possible to create new ones from the descriptions provided by the user. Different types of block or brick can be used in the same building (e. g. external or internal walls). Hence, this feature should be a parameter of an object that represents the wall.

Course: they refer to the basic unit laying and vary considerable in accordance with the local (as the blocks and bricks) and also in accordance with the basic unit selected. Thus it should also be possible to create new course types through the description of its basic rules. Another critical aspect is the correct interpretation of the basic unit, regardless the laying position (e.g. header, stretcher, brick-on-edge or soldier courses).

Modular coordination and neutral zones support: based on the block and on the course selected, dimension updates in the object would be limited by multiple modules of the basic units. Dimensions that are not suitable for the modulation would be clearly shown to the designer (e.g. through hatches). In such a case, there should be at least two possibilities: insert automatically units or materials for the adjustment, in accordance with the bound rules; or advice the user about the constructive interferences in order to give the option for the user to do the modular adjustment or resize the problematic objects.

Wall openings: the tool should make the automatic shifting of the wall openings (or at least suggested it) which is not in accordance with the basic unit modulation. Furthermore, based on user definition, should be included automatically frames, window sill elements and lintels, etc.

Wall interfaces: the joint toothed intersection masonry demand elements which extend beyond the geometric limits of the objects. An example is the joints with intercalated courses (in which the blocks of odd and even courses are interposed in a way to transfer strengths between different plans); wire meshes and reinforced steel bar (Pfeifer *et al.*, 2001). The resolution of this situation depends on the object ability to recognize properly the context where it is inserted, adapting itself.

Interfaces with other constructive elements: the tool must automatically adjust the parametric object in situations where it meets other elements such as slabs, columns, beams, foundations etc., in a way to insert the necessary components. A typical example would be the automatic insertion of special blocks as channels blocks in the last wall course, if there is a parametric object above them to represent a slab.

Gable walls: wall plans sectioned diagonally present a special challenge. Their graphical representation must consider a wall as an irregular polygon (at least one trapeze), and there may be several different angles resulting from the section operations executed in the object. One very useful function would be the recommendation for user about the better section angle which would result in the fewer block waste, considering the setting of the courses selected.

Facilities: an essential function for the tool is the indication of the facilities position (electrical, hydraulic, logic, etc.) in a way to permit, from the rules settled by the user, the automatic identification of special blocks for the passage of tubes.

Structural function: defining a wall with structural function opens a new range of situations to be considered by the tool. Therefore, a tool should represent the horizontal reinforcement and columns, conformed by the masonry hollow blocks, and also the steel anchor of these elements. This situation should be addressed by an approach similar to the item “facilities”: through the identification of elements position by the user. A more advanced tool version should even insert the structural elements automatically, based on the gaps and loads defined by the user.

Coatings: in addition to represent the basic units which make up the masonry, a tool should be able to associate multiple layers of coatings, and also to quantify the components used in these layers. The tool should also be able to interpret the design context (design stage, scale, and view) to decide whether the coating should be represented or not. In the architectural design, for instance, visualize the masonry units is unfavorable to the correct data interpretation (unless it refers to a facing brickwork). In the masonry design execution, the visualization of coatings is unfavorable to the information understanding.

Quantities take-off: the object created by the tool should include information regarding the components consumption to permit the automatic material quantification, based on their coverage or volume. The tool should offer functions for automatic report extraction, based on the features presented in the major BIM CADs. A more advanced tool version, regarding this function, should also consider the model section (e.g. by stories) and the place for the material delivery.

Standard guides: in addition to automate the graphical representation of masonry elements, a tool should also automate the requirement description for construction. From the data insertion in the auxiliary data bases, the BIM CAD is able to automatically associate the descriptions and indications in the drawings and in schedules separately, when a specific object fit in particular criterion previous established. For example, to insert a tag with the text “Follow NBR 8798:1985” in all drawings that contain wall composed of hollow blocks structural masonry.

5. SUGGESTION FOR A PROCESSING TOOL MODEL

From the associate application approach of a BIM CAD and also from the features to be considered by the tool, a suggestion for a processing model was developed, which should be adopted by a tool addressed to automate the design documentation of masonry construction. Briefly, the processing executed by the tool would implement a set of basic objects to generate specific objects, which would contain necessary representations in order to automate the design documentation.

One possible solution to represent constructive detail of masonry wall would be the three-dimensional representation of each block that constitutes them. Although it is possible to automate this task, previous experiences of this research group showed that it would demand high processing capacity, besides to generate files which contain dozens of megabytes, even considering simple construction. To create three-dimensional objects to represent facing bricks may be a good option, but in many cases (perhaps most of them), the masonry will be coated and the view of position of each block is used only in the execution documentation.

Alternatively, the presented suggestion would be useful if a tool generated temporary two-dimensional representation, which could result in a more fast processing and suitable to the view required by the user. The main steps of the use of the tool are described below.

Reference object creation: the constructive representation of masonry wall detail would be executed automatically by specialized parametric objects, which are created from references extracted from native parametric objects (in this case, the "wall" object of BIM CAD). Using native objects as a reference, rather than modify them directly, has the advantage of maintaining the speed and facility of handle provided by the simplified characteristics of them. Changes in objects of reference would spread these modifications to the others specialized objects automatically, such as examples of existing tools, like a Wall Framing Tool, which converts native objects of walls in wood frame components (Cadimage, 2008).

Facilities and structures definition: from special interfaces, the user could launch information about complementary facilities and structures, as occurs in applications like Constructor (Vico Software, 2008). This information would result in auxiliary objects to represent the facilities.

Selection of reference objects: the user would select the native parametric objects which would like to obtain detailed representations, leaving all other walls in charge of the standard representation of BIM CAD.

Masonry characteristics selection: Among several options available, the user would choice the brick or block type, the bound rules for laying and the coating types on the walls. These options would be stored in relational data bases of the building model, which would be managed from specific interfaces. Keeping independent data base of the model would result in availability of the settings created for a specific design for all the others.

Specialized parametric objects creation: for each native object selected would be made a sweeping, seeking the spatial-geometric characteristics of the wall and the interferences between it and the objects that represent the complementary facilities. For each issue found, the tool would select the suitable block (for example, a special block for electrical box if it meets an outlet point) and would record their characteristics and their position in a data matrix. A specialized parametric object copy is created, containing the data matrix and the set of behaviors necessary to generate the graphical representations.

Creation of the specialized parametric objects representation: the processing in charge for the generation of graphical representation of specialized objects would be separated from the processing in charge for the object creation. It would occur because in a BIM CAD the different geometric representations are only objects instances and they are not new objects. For each new visualization required by the user (floor plans, sections, elevations and perspectives), the processing would be in charge to generate a new "object view", composed of geometric elements which correspond to the new context. The geometric elements used (e.g. drawing of the block in section, indicative texts, textures) are stored in auxiliary data bases, allowing the automatic updates of the drawings.

Quantitatives take-off and schedules: from the same process of associate data bases, specific functions could generate notes of material list to be used in all derivative objects (obtained from the object data matrix reading). Besides, guidelines for construction carry out and instructions could also be generated automatically, based on the simple criterion association to descriptions inserted in the data bases.

The processing tool model data flow can be seen in figure 01 and the graphical instances of specialized objects can be seen in figure 02:

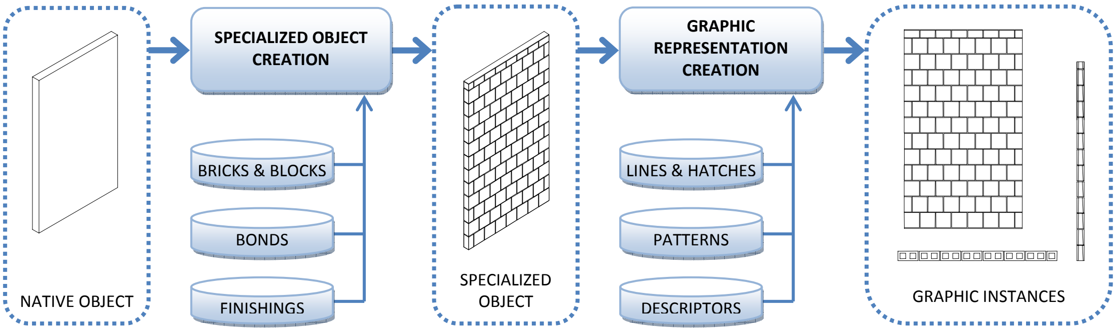

Figure 02: Processing tool model data flow

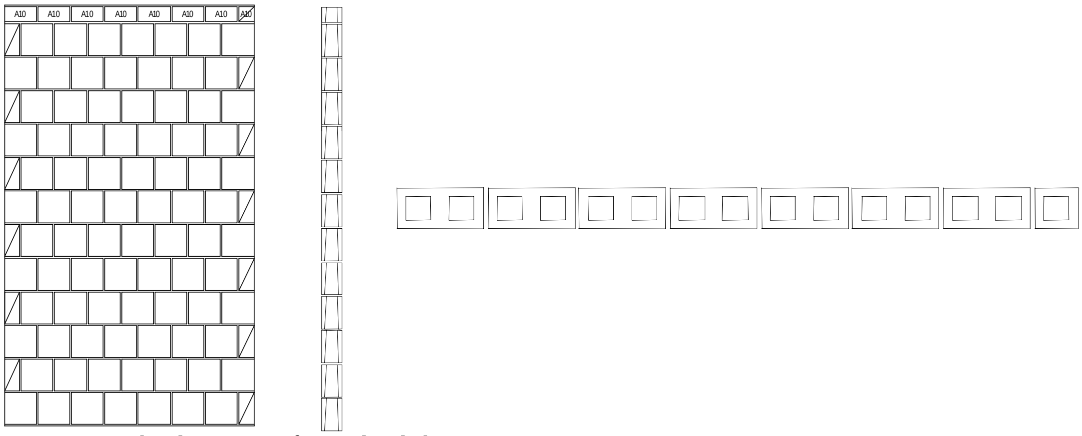
Figure 03: Graphical instances of specialized objects

6. CONCLUSION

In previous work conducted by this research group and also in experiences reported by the literature of the area demonstrated that through the parametric modeling capacity, provided by architectural BIM CAD, the automatic extraction of much of design documentation is feasible to be done. The features in charge for this task are those that distinguish this new CAD generation from the previous one: the use of parametric objects, the semantic interpretation of objects relationships which constitute the building model and the storage of this model in a data base format, from which information can be extracted automatically.

These experiments showed that is possible to automate the design documentation required to guide masonry construction, with high level of construction detail. A tool addressed to assist this task will demand several routines to analyze the context and to define the suitable behavior for the parametric objects, but much of the programming effort can be eliminated when basic features and interfaces available in BIM CADs are used. The proposed model aims to assist the source code generation necessary to develop such a tool, based on the assumptions which guide the BIM.

The automation of design documentation provide great potential for improvements in the quality design, adding value to it, besides to improve the communications among stakeholders. All these aspects contribute for the better quality of final products.

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