Introduction of BIM methodology in education: Concept and application

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Abstract

Teaching Civil Engineering and Architecture requires a permanent updating of knowledge concerning procedures and technologies used in Construction industry. In this sense, the school should seek to adapt its curriculum to include innovative issues to support a better construction. The methodology Building Information Modelling (BIM), involving the concept of information centralized in a unique geometric model and of collaboration of all participants in a project, is strongly supported in advanced technology. An important role of teaching is to organize actions to promote the insertion of new issues in school. The text presents several examples of BIM applications developed by students in the context of MSc researches. The objective is to add competitive skills in the training of future architects and civil engineers.

Keywords: BIM training; Constuction; 3D BIM model; 4D BIM model.

1. Introduction

The Building Information Modelling (BIM) methodology covers various sectors of the Construction industry. A BIM project constitutes a complete and full database, considering not only the digital geometric model, the most visible part of the process, but also the type of materials projected to be applied in the building and its mechanical properties and physical characteristics (Tardif & Smith, 2009). BIM interferes with all aspects involved in a building project: the initial stage concerning the generation of a form (architecture); the different phases of the structural study (structural solution design, analysis and production of technical drawings); the quantification of materials and budgets; the construction planning process (definition of geometric model for each construction phase); the usage of the building (management and maintenance), in a later stage (Singh *et al*. 2011).

In a more traditional process of developing a project, each player uses a different and non-integrated work methodology, as there is not a commun base of complete and updated information for the overall project. This lack of process integration is one of the main drivers for the loss of information and, causing a loss of valued through each stage. Information is a key factor in management in the internal context, as well as the relationship with the exterior. The BIM methodology, which combines the parametric design, three dimensional (3D) models, element level information, coordination, communication and visualization within the whole building lifecycle, is changing deeply the way how information is managed within the construction sector (Eastman *et al*. 2011). This new approach is based essentially in the integration of processes, supported by an information rich 3D model which allows to seamlessly tracking the whole lifecycle of the enterprise. As such, it is also expected that the whole process becomes more accessible to the multiple entities that collaborate in the enterprise either while developing the design and later in the management of the building.

In the context of the education activity in a Civil Engineering and Architectural school some topics of BIM application were developed by students within MSc researches. The main issue concerns the construction activity (Figure 1): Construction planning based on 4D/BIM models; Coordination and preparation of construction project using 3D/BIM models; Analysis of conflicts over an architectural, structural and MEP model.
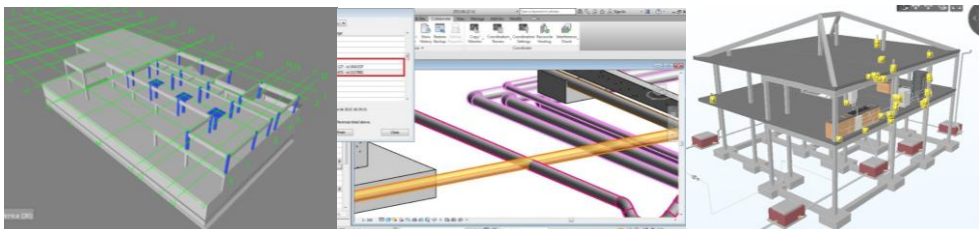

Figure 1: BIM uses – construction planning and coordination and conflict analyses.

2. Conflict analysis based in an 3D/BIM model

The BIM methodology and the associated tools present themselves as a n usefull asset to support the process of conflict analysis, as they make it possible to merge all disciplines in an integrated virtual environment, the 3D/BIM model. The high level of detail and visualization provided by a BIM model leads to a better collaboration between those involved throughout the design. The aim of the first study was to evaluate the practical capabilities of the BIM concept in the conflict analysis between building services, namely, the water supply and drainage systems design, and the architectural and structural design (Berdeja, 2014). As such, it was developed a 3D/BIM model containing the components: architecture, structures and building services. The model was analysed oriented to the clash detection between elements from all disciplines. The student learned to handle a BIM tool and how to use it in the development of a specific task within the construction activity.

2.1 Generating the 3D/BIM model

The selected case study consists of a building of two floors, comprising the garage and entrance hall, in the ground flor, and, the living room, kitchen, three bedrooms, two bathrooms, one utility room and hallways, in the upper floor. In the generation process of the BIM model's architectural and structural components, all elements, such as walls, windows, doors, floors, columns, roofs and footings, were created by adapting the 3D parametric objects existing in the Revit library, in order to resemble closely the real case (Figure 2). When modelling, the student has the first contact with a BIM tool improving its skills.
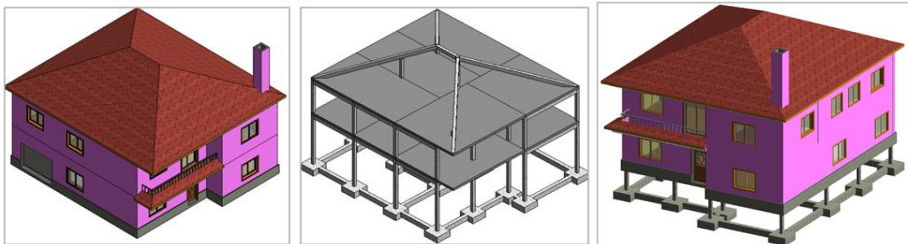

Figure 2: Architectural and structural components of the 3D/BIM model

Next, the MEP (mechanical, electrical and plumbing) component of the BIM model was generated, namely, the domestic hot and cold water supply system, the domestic wastewater system and the rain water drainage system (Figure 3). The modelling process requires the selection of appropriate parametric object and demanding for specific equipment connerning the MEP component within internet networks, made available by software houses. This way of working researching in internet networks became normal when new technologies are used.

The modeling was initially performed solely based on the architectural component of the house, with no visual guidance from the structural component. The architectural model was then supplemented with the plumbing fixtures. The piping diameters used in this work are approximate values of those present in the real design, for it was decided that the predefined nominal diameters from Revit were to be used.
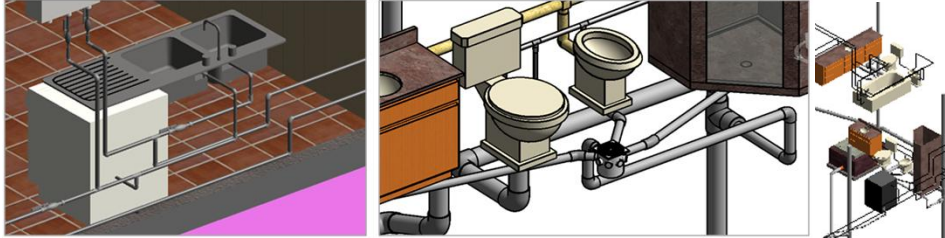

Figure 3: The water supply and the wastewater drainage systems of the BIM model.

2.2 Clash detection

The BIM modelling process requires overlapping multiple disciplines that coexist in an integrated manner, forming a complete model of the design. After each discipline is modelled forming a unique BIM model, the collision detection can be performed. Conflict analysis is an integral and very important part in the development process of a 3D BIM model. This process consists in searching objects belonging to different disciplines that are using the same physical space. The analysis of these inconsistencies is a critical task, since they could eventually severely impact the construction process, causing delays, design changes and increased expenses in materials and surpluses in the budget. The clash detection analyses is another issue, very helpful in BIM methodology, that the students, after developing the MSc study, is allowed to resolve in real and more complete project, after in its activity as a professional.

As a first step, the modelling of the MEP component was carried out using only the architectural component as guidance. That is, the structural component was not visible during the MEP modelling. After through the handling of the components structures and MEP, some of clashes were detect. Overlapping all the disciplines it is possible to change some of the elements of the MEP services, in order to obtain a correct model with no conflicts. Figure 4 presents some the realized changes needed to improve the complete 3D/BIM model of the house. The existing Clash Detective function in Revit is of great help in conflict analysis and project coordination. This work contributes to demonstrate the advantages of BIM in the conciliation and coordination between different specialties, as well as the benefits of its application in conflict analysis in an engineering design.

With this exercise the student learns: to model 3D BIM disciplines, forming a complete 3D digital BIM model; to export the model to specific tools in order to performe conflict analysis between BIM componnets; to judge the correction of information handled in the process; the point out the main limitations found in the work; to use BIM tools as a support on the development of a project.
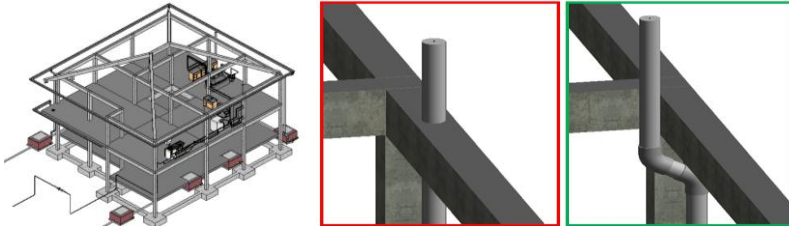

Figure 4: Coordination of structural and MEP disciplines.

3. 4D/BIM model for construction planning

Another example of modelling and work developed over the 3D/BIM concerns the creation of a 4D/BIM model addressing the construction project. The planning of the construction activity is a crucial stage in the conception of a design, and involves the selection of technologies, definition of work activities, estimation and resource management, logistics and duration of each individual task, as well as all the dependencies amongst the different tasks. Planning and scheduling in construction, involves the sequence of activities both in space and in time, taking into account the allocation and resource acquisition, quantities and space constraints amongst others (Pitake & Patil, 2013). The estimation for the duration of the activities is a decisive stage for a good project and building planning, as the control of the schedule, depends on the proper effort and duration estimation (Mukherjee & Clarke, 2012). Planning construction work is another discipline that can be supported in BIM viewers and BIM modelling tools. The student is able to develop similar projects after in its activity as an engineer.

3.1 Generation of a 4D/BIM model

In order to explore the BIM tools, as a support to construction planning, a 3D model of a second study case was first created. Using the Revit software only the architectural and infrastructure models of the project were generated. To create a 4D model the time factor must be linked to the 3D/BIM model elements. After, by running the defined 4D model, it allows the visualizations and analysis of the activity sequence for the construction. So, to generate the 4D model for the present case, the Navisworks software was used (Mota, 2015). This software allows the interconnections amongst sets of 3D elements of the BIM

model, with the planned tasks stablished in MS Project software. Briefly, the steps for the preparation of the 4D/BIM model are: Export the Revit 3D model, saved in the NWC format, to the Naviswork software as well as the MS Project planning file to the Naviswork timeliner; In the Naviswork, the 3D elements of the models were grouped according to the tasks defined in the planning. For this purpose, adequate "sets" were created. These "sets" can be created by selecting the elements directly over the model, by executing "tree selection" or by searching for its properties; Next the created "sets" were associated to the planning and schedule of tasks and set for each task its category, that is, whether it is construction, demolition, temporary activity or another.

3.2 Using the 4D/BIM model

By running the 4D/BIM model it is possible to visualize the planning simulation. Figure 5 shows a couple of frames, extracted from the simulation of this project. The practical part of this work fell mainly in study of the 3D modelling using Revit, and applying a model for 4D construction planning. The simulation will probably never match the reality, with its unforeseen, but this motivates the development of visualization technologies, trying to reduce the gap amongst the digital world as the reality. The aim is to minimize the number of execution errors, at least those believed to be predictable.
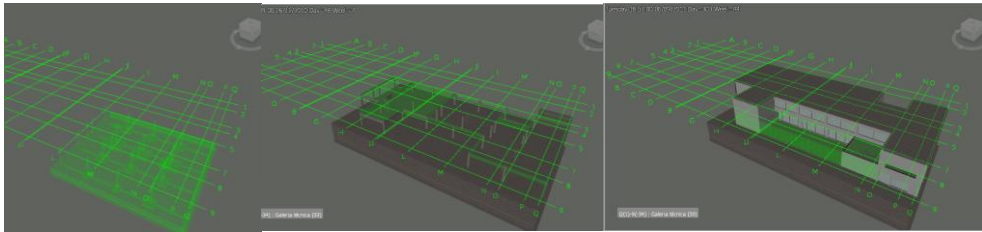

Figure 5: Construction simulation visualized in a 4D/BIM model.

In the process of modelling and application of the BIM model, the student had the opportunity to learn how to handle a new tool, to judge what is the most appropriate methodology of shaping the structure, to learn what are the requirements when using a BIM Viewer (Navisworks), how to associate tasks to groups of elements in order to achieve the simulation of the construction sequence. With this exercice the student learn several aspects concerning planning the construction of a building, that will be usefull in its future activity as an engineer.

4. Coordination of construction project supported on a BIM model

In a BIM process, the execution of a building project network would be superimposed to the structure of buildings. Because the elements are delivered to the construction company,

with the elements of the network components modelled with a high level of detail, during the project development. In addition, in the BIM collaboration environment, the construction company could be an integral part of those projects, according to the Integrated Project Development methodology (IPD). In this 3rd study case a 3D/BIM model was created. The model allow to support the coordination of phases of construction, the extraction of maps of quantities, the input and deleting elements of the model, to change slopes and coupling pipes, among other situations. The networks considered in the case study were: sewage, water supply network and power grid. As part of the design review of this another case, it was necessary to start the process by developing the 3D/BIM model of the project (Silva, 2015). This item describes the various situations that occurred in the workplace and conducts analysis of its resolution on a BIM methodology base, using the capabilities of the BIM software used.

4.1 Building networks and analyses of conflicts

The software used checks and alert for the occurrence of transgressions between objects, therefore, any errors that may appear in the construction are previously identified during the design phase, reducing the number of errors and additional costs. The preparation work of building networks on the basis of structure is a fundamental process that is performed on site, because changing the path of the tubing is constrained due to the presence of the structure elements. The analysis of the situation on the BIM model is done automatically. Figure 6 presents one of the conflicts identified during the development of the model, in this case, a conflict resulting from the interference between the pipe and a bunker foundation.
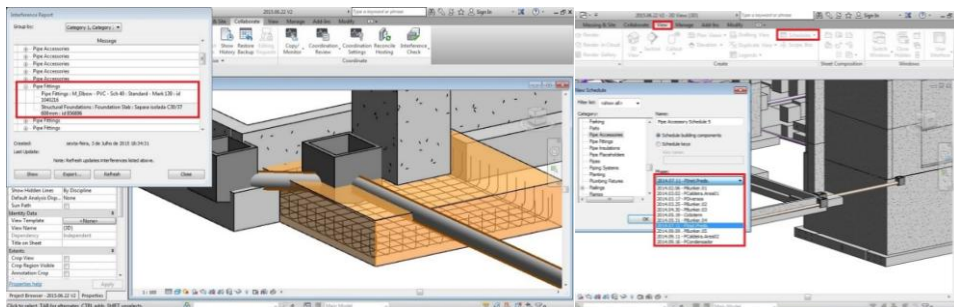

Figure 6: Conflicts between a piping and a bunker structural element

4.2 Coupling elements

Changing elements, because they fulfill the same space in the same instant, it is a recurring situation in Design-Build project delivery, because while the work is in progress some projects are still being created. This led to one of the already implemented elements that

had to be chopped in a certain area to allocate a coming slab foundation. Figure 7 (left) presents the chipping area of concrete represented in a AutoCAD drawing and Figure 7 (right) shows the modelling of these foundations, in the BIM model created.
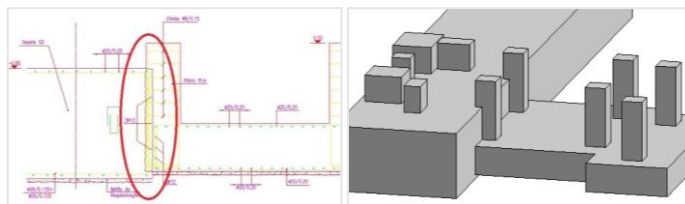

Figure 7: Docking area of the two foundations, in a CAD drawing and in a 3D/BIM model

5. Conclusions

The work enabled the knowledge of the subject BIM within a education context but oriented to the real activity. Research on the subject has exposed several objects of study covering BIM, from its origin to its application in the Construction sector, seeking to know the reasons for his development and how this methodology has been developed. The use of this methodology for the development of construction management emerged several situations that expose the benefits of using BIM. All students have learned to handle a new tool and how to use it for various purposes. In each case a 3D/BIM model is created and applied oriented to different points of view, contributing to improve student's skills. These research papers are MSc thesis and they are made available on school website. This kind of works contributes to the spread of BIM applied in several dimensions.

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