A methodological approach to BIM design

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ABSTRACT

More and more often the clients and the decision makers, require that the designers provide charts with realistic representations of the buildings from the earliest stages of design. Some of the requirements demanded to the specialists involved in the construction industry are the increase of the representative quality – intrinsic of the designed work – and the time and price reduction. However, those requirements are hardly combinable: before taking any choice it needs the right times of meditation in order to not neglect basic aspects that affect the time and the cost of implementation, and the quality of the work. Therefore, the designers face with the problem of delivering projects full of information, as quickly as possible. Furthermore, we do not have to forget that the involved areas concern in the same way the structural, the architectural and the MEP aspect. The three-dimensional models, conceptual and photo-realistic rendering, videos, etc., are just some of the possible infographics representations available and required by the market. Pursuant to the sectorialization of the specific professional skills, the Building Information Modeling is considered as a possible panacea that is able to face the interdisciplinary inefficiencies in building projects [1] and to reduce the planning times without affecting its quality. It must pay attention to the evolution of the information and data's exchange and management techniques that constitute a complex project. With this contribution we want to analyze the level of interoperability between three BIM software ArchiCAD 16 by Graphisoft®, Revit Architecture 2013 and Robot Structural Analysis both by Autodesk® confirming the compatibility of data exchange and, if necessary, how to proceed in the case of loss of information in the transition from one software to another. In particular the Graphisoft® program will be used for the architectural modeling of a residential building, Revit Architecture as control software of the BIM management project and finally Robot Structural Analysis for the structural analysis of the reinforced concrete frames in the same building.

Keywords

Rendering, image based rendering, CAD, .ifc object data model, Building Information Modeling, interoperability.

1. INTRODUCTION

In a time of economic crisis like the present, the companies are required to face the challenges of the global market with innovative technologies, but also with new engineers, architects and designers that know how to make the best use of them, in a world increasingly interconnected, multidisciplinary, international and fast. We clash ourselves, however, with the request of the clients who demand, on the one hand better projects on a quality level and on the other hand cheapness of the works and the implementation speed of the planned works [2].

To the requests of the private sector are added more and more pressing normative dispositions that, in addition to the traditional bi-dimensional graphic projects, require representations that could simplify the comprehension of the project, through a clear reading of the materials, of the rooms and the spatial organization where the project is situated. Although in the professional field there is still a certain reluctance [3] towards a new way of understanding the design, the Italian technicians are slowly approaching themselves to methodologies that have been realities in the international sphere for years. The concept of integral design is based on the mutual interconnection, that inevitably exists among the different figures that participate during the design and management phase of the entire life cycle of a building. The most remarkable design studios have already adapted themselves - and if they did not do it, they are going to - to the high quality standards required in the international sphere that are associated with reduced time and budget. This phenomenon pushes the various stakeholders of this area to increase their own level of specialization diversifying the specific skills. However the 'need' to improve the quality of technical, not verbal, communication is increasing: professionals, thousands of miles apart from each others, should be able to interact without communicational limits, reducing, as a consequence, the risks of errors due to misinterpretations. Therefore, this protocol must be clear and it must be based on a process previously agreed [4]. Maximizing the productivity, minimizing the costs and the interferences and at the same time maintaining the high quality of the project are the main goals and the motor of the new planning revolution. The Building Information Modeling (BIM), if used accurately, can reduce the interdisciplinary inefficiencies in the construction projects providing a high graphic and representative quality of the architectural projects. It is a further step of the unstoppable evolution of the technique to communicate the necessary information to the building process. Everything makes sense only when it is related to everything else involved in a process. The strength of this methodology is represented by the possibility to exchange data - and therefore information - among the different stakeholders in the construction industry. However, particular attention should be paid into the phase of files exchange and management, that are the heart of an architectural project. The BIM provides us with an important evolution of the common platform in which all the *supply* chain' protagonists operate and engage, opening inevitably to an even closer comparison among clients, designers and builders. In fact, in order to a collaborative design the stakeholders are supervisors and creators of the adopted solutions, they can supplement each other the different planning hypothesis and combine their work with the others. [5]. Although in many cases the adoption of the BIM has many potential benefits, it also poses interesting challenges regarding how they can integrate the construction process of individual files. In order that this method will be effective, it is essential that the software of different software houses will be able to communicate with each others, interchanging the models generated by the different stakeholders of the building sector without the loss of information.

2. THE ARCHITECTURAL MODELING

In order to analyze the operational feasibility of the implementation critically, the BIM collaborative design hypotheses are developed on a building project of new realization. Even if it was possible to model the artifact, both from the architectural and structural point of view with just one of the two above-mentioned software, it was better to verify the compatibility and the ability to interchange data and, possibly, the procedural steps in case of loss of information. For this reason, the architectural modeling of the building aim of the study was realized with the BIM software Graphisoft® ArchiCAD 16. Recognized as the first 'vertical software', it was commercialized for the first time in 1982 by the Graphisoft® software house [6]. Today it has about 150,000 users worldwide thanks to the introduction of parametric objects that make it easy to use. ArchiCAD integrates the .dwg format perfectly so that, starting from the classic elaborates of the bi-dimensional design, it is possible to implement the three-dimensional infographics model and subsequently its textured or 'colored' views, which provide a clear reading of the materials, the rooms, the spatial organization and the possible interferences. In addition to the modeling of the non-structural elements - first the wall plug, then the openings and the windows and finally all the ancillary parts that integrate the work from an architectural-formal point of view - and working in order to a collaborative design, it is essential to provide also the definition of the load bearing elements, so, in the specific case, beams, columns and floors, defining their *structural function* (Figure 1). The selection of one of the three possible functions (*load-bearing, non-load bearing, or not defined*) is going to permit the recognition of the behavior that each imported item is going to have during the data interchanging. In fact, exporting the file in .ifc format, the *structural function*, previously established, is going to add automatically to the same elements the *load-bearing* property making it easier to identify. In this way, the generated infographic model will be complete in each part: it will be easy to read the type of the materials used, their different use according to the performances required and also the untrained eye will have the ability to interpret that play of empty and filled spaces that distinguishes any building project.

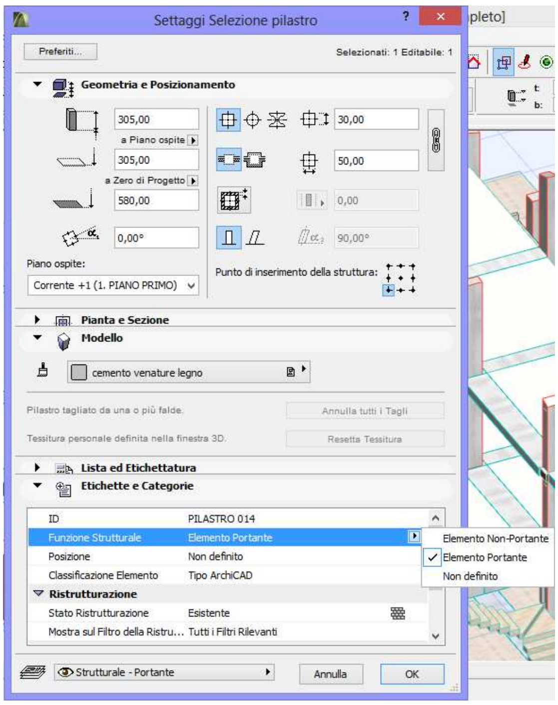

Figure 1. Input of the load - bearing function of the structural element.

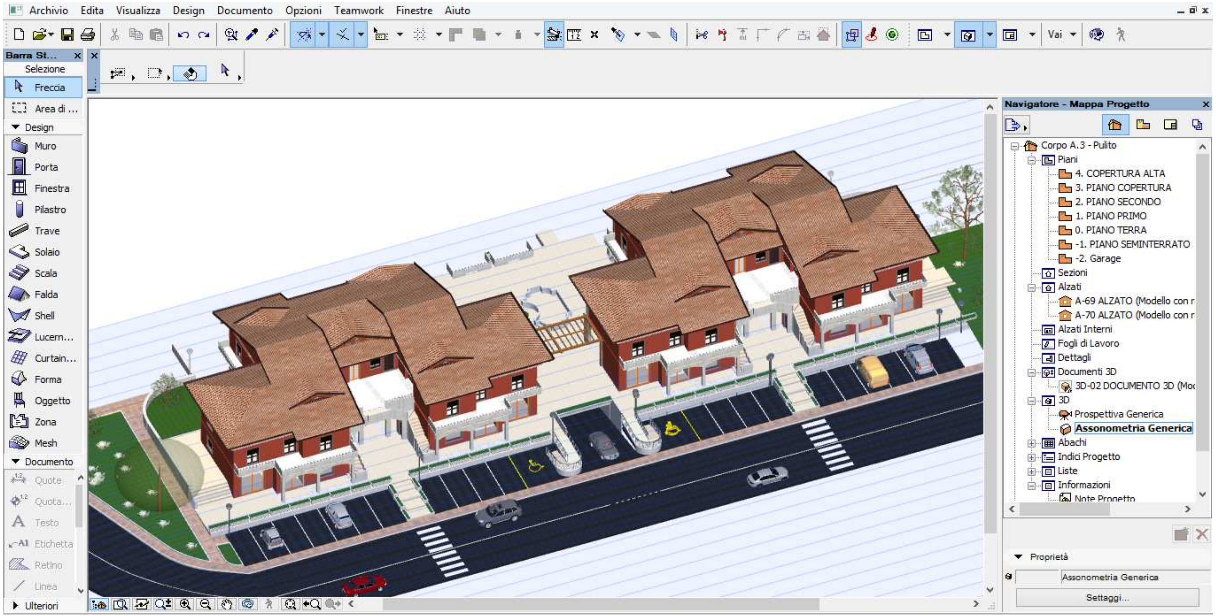

Figure 2. Visualization of the infographic model.

Figure 3. Rendering of the implemented model.

Figure 4. Rendering of the axonometric aereal view.

Figure 5. Rendering of an axonometric view.

To the aesthetic functionality, it should be added, on the other hand, the designer's critical reading, who is going to work and possibly to change the structural system assumed by the architect during the design phase. By applying *filters*, it is possible to select and then to view the different *disciplines* that characterize the realized project, as well as all the bi-dimensional graphic arts that distinguish a final project.

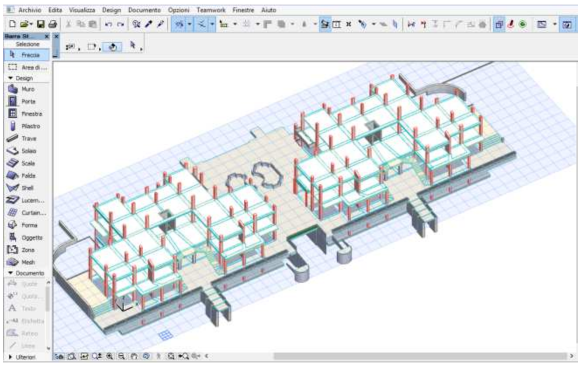

Figure 6. ArchiCAD visualization of the load - bearing structures.

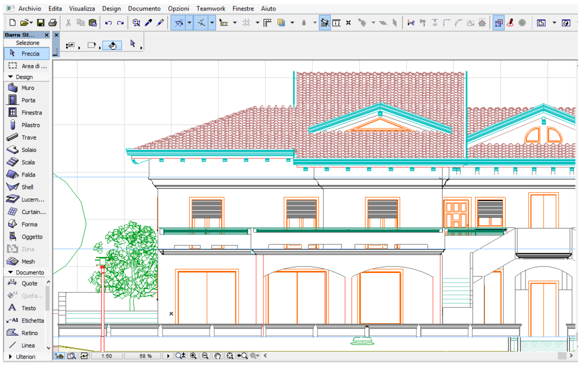

Figure 7. Example of the bi-dimensional planning graphic art.

3. INTEROPERABILITY WITH AUTODESK® REVIT

To guarantee the interoperability between the two programs in question is essential to follow a design 'protocol' to ensure, on the one hand, the speed of data input and, on the other hand, probably the most important aspect, a reduction of redundant elements. The workflow analyzed in this contribution is based on the operational guide ArchiCAD 16.

The interoperability between the two software is the basis of any data exchange protocol, it is achieved through the common language .ifc (2x3 version). Although it is possible to let interact the file created in ArchiCAD directly with the finite element software appointed for the structural analysis - in this case Autodesk® Robot Structural Analysis - we preferred to assume an additional 'transfer of file', for an input data check-in, before proceeding with the subsequent analysis of the finite elements.

The software used as 'cornerstone' of the BIM process is the Autodesk® Revit Architecture 2013: this is a program of intelligent computer modeling of the buildings, capable of integrating a physical model with an editable analytic one independently for the structural analysis, the design (both architectural and MEP), and the documentation.

Being interested in the export of the load - bearing structures, ArchiCAD provides the ability to upload to Revit only those elements that fulfill this task: the recognition is automatic having previously differentiated the elements with a structural function from those having no structural function, so the input data are translated into the .ifc file and managed directly into Revit Structure. ArchiCAD offers a built-in translator whose settings are optimized for the exportation of the models in Revit Structure by the .ifc format (the name of the translator is interchange data with Autodesk® Revit Structure Figure 8).

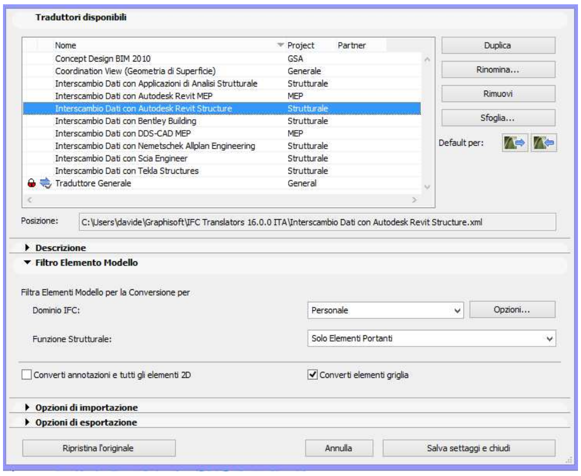

Figure 8. Window interface of the translators.

Of course it is possible to define own customized translators, according to the specific needs. This means that if *the filter model element* is set up on *only load - bearing elements*, only the elements classified as *load - bearing* by ArchiCAD will be exported, this represents a great advantage, avoiding to the structural engineer the cleaning of all the architectural elements that have no interest in the structural analysis.

The .ifc exported file is ready to be uploaded to Revit. In this regard, it was created a specific add-in connection that improves the bi-directional exchange of the data, based on .ifc format between Graphisoft® ArchiCAD and the Autodesk® Revit applications [7] (Figure 9). This, on the one hand, simplifies the architectural model reducing all the accessory parts and, on the other hand, it optimizes the input data and therefore those of the implemented model.

Figure 9. Module of the ArchiCAD – Revit bidirectional connection.

Import problems

Following the import phase, whose duration changes according to the geometrical complexity of the model to regenerate, the infographic model previously created in ArchiCAD, is uploaded to Revit: in the transfer from one software to another the floors height, the size of the constructive elements, the name of the individual views are recognized. After a more careful analysis, however, we immediately realize that in the import of the structural elements some imprecision occurs: although the geometry has been properly implemented, the mechanical properties, and especially the *structural function*, is not recognized by Revit.

Therefore, beams and columns, maintain the same geometry - section and dimensions – that has been attributed during the architectural design, but they do not have the information required for the subsequent structural analysis. Furthermore the columns placed on the top floor are transformed into masses because of the cut made with the roof.

In detail the problems to be overcome are three: the first one relating to the recognition of the *structural function* of the columns*;* the second one relating to the columns of the deck cover and the last one for the redefinition of the horizontal load - bearing elements. For the first two aspects, it was considered appropriate to proceed in this way: in Revit two columns families were modeled, their section was equal to those in the architectural model and having the mechanical properties required by the structural engineer (*concrete class C25/30*). So with the tool *copies the properties of the type*, the properties of the columns modeled by Revit have been uploaded on those imported by ArchiCAD: in this way the columns that initially were simple three-dimensional geometric elements became structural elements so, with load -bearing function.

Special reference also needs to be made regarding the beams, in fact, proceeding in a similar manner as described above, we have not arrived to a satisfactory result for which it was necessary the ex novo modeling of the same structural elements directly in Revit. Made every necessary corrections to the re-definition of the analytical model, automatically the intersection between the beams and the columns generates the analytical model: within any calculation program of the finite elements, the nodes represent the connection points of the beams, at the same time represent the elements at the base of the matrix analysis**.** (Figure 10).

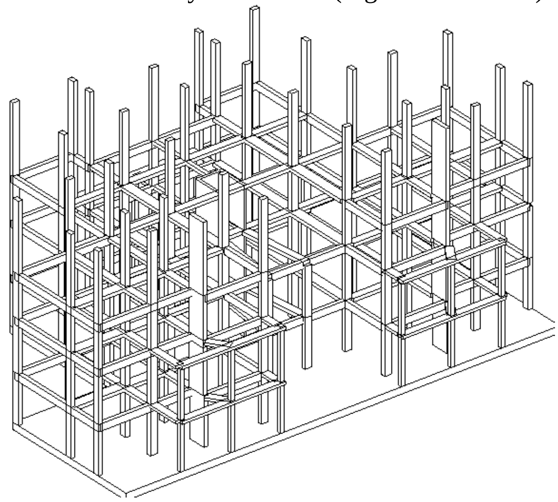

Figure 10. Revit visualization of the load – bearing structures.

4. INTEGRATION OF A MODEL FOR STRUCTURAL ANALYSIS

After the check-in phase of the model, we proceed with the export of essential structural geometry to the software in charge of structural analysis: Autodesk® Robot Structural Analysis 2013.

The file upload is done through a plug-in that allows you to improve the exportation of the structural models from Revit to Robot. In this case, as both programs are produced by the same software house, during the data exchange there is no loss of data: the structural model composed by beams and columns is imported in the working environment of Robot including all geometric characteristics - length, the Cartesian coordinates of the nodes - and mechanical ones- inertia, modulus of elasticity, etc.(Figure 11).

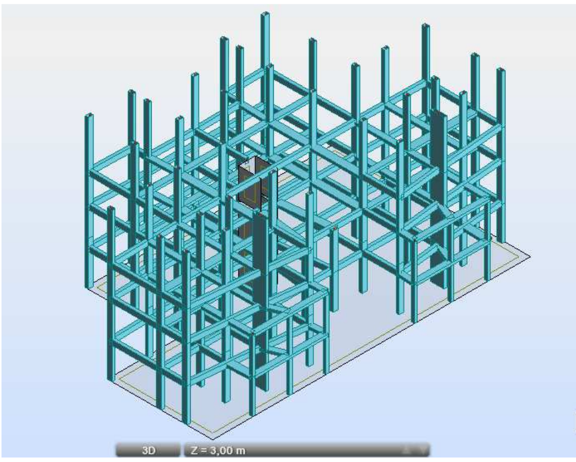

Figure 11. Import of the analytical model for the structural analysis.

To this point, verified the precision of the hypotheses conducted during the architectural design, the structural designer will proceed, where necessary, to the possible changes to the model used: the inclusion of the loads and their combinations, special conditions of constraint and boundary are just some of the routine tasks that precede the structural calculation itself.

5. CONCLUSION

This study highlights the limitations and the advantages that the designers can spot during the use of the suggested BIM methodology. At the present this is still closely tied to the software that we use, also due to the absence of protocols and guidelines that can guide the technical towards the 'methodological design revolution' resulting from BIM. At the same time, however, the software houses should tend to a greater interoperability that is guaranteed among the programs of the same had office, but in other cases it forces to tricks or manipulations to achieve the desired result.

In spite of everything, all the benefits are remarkable, compared to the traditional design methods based on CAD: the 2D/3D CAD describes a building representing it in a static way almost out of context, the graphics arts, that we will get such plans, sections and front, seem somehow unrelated to each others: a simple modification of one of these views would require the updating of all the other views, an operation that would involve greater risks, errors and extended delivery times. In addition, the elements of these projects are simple graphical entities such as lines, arcs, and circles, in contrast with the contextual intelligent semantic of the BIM models. Elements and systems such as spaces, walls, beams and floors etc. contain information that go beyond their own geometry. The single disciplines (architecture, structure and MEP) are contained in a single file so when we make some changes even only in one of the three, the visualization of any interference is immediate, in this way we have a considerable saving of resources both in terms of time, energy and costs.

The aim of this contribution is to highlight how, starting from a three-dimensional infographic representation of the own project, it is possible to save a large amount of data within the model of the building by reducing, as a consequence, considerably the times and the designs errors.

The procedural proposed process is clearly bidirectional: the changes or the modifications we made even to one of the disciplines (architecture, structure, MEP), are automatically invoked by updating the planning graphic arts and the computational and interference analysis. This requires the training of a specialized designers class who are able to manage consciously the tools that are on the market: if properly implemented by an infographic model - and with the right manipulations - it is possible to create charming views and high-impact three-dimensional visualizations and, at the same time, the input of data and the information that are necessary to the further design stages.

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