

Introducción de la metodología BIM en la educación de Ingeniería Civil: análisis de la interoperabilidad ArchiCAD-Revit-ETABS

Introduction of BIM methodology in Civil Engineering education: analysis of the interoperability ArchiCAD-Revit-ETABS

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RESUMEN

Building Information Modelling (BIM) es una metodología soportada en un proceso virtual basado en modelos 3D, que permite el modelado y la gestión de todas las actividades inherentes a la construcción. Se requiere el aprendizaje del BIM con respecto al concepto, las aplicaciones y las herramientas disponibles. Las herramientas BIM, de modelado y análisis, se aplicaron a un caso real. El análisis abarca el diseño, el modelado y la transposición de la información, con el fin de evaluar la interoperabilidad entre plataformas BIM (ArchiCAD/Graphisoft, Revit/AutoDesk y ETABS/CSI). Este estudio tiene como objetivo analizar el nivel de confianza de la información que se transfiere.

ABSTRACT

Building Information Modelling (BIM) is a methodology supported in a virtual 3D model-based process, allowing modelling and the management of all activities inherent to Construction. The BIM learning regarding the concept, range of application and tools available is required. For this purpose, BIM tools, for modelling and structural analysis, were applied to a real case study. The analysis covers the design, modelling and information transposition, in order to evaluate the interoperability between BIM platforms (ArchiCAD/Graphisoft, Revit/AutoDesk and ETABS/CSI). This study aims to analyse the level of trust inherent in the information that is transferred in the process.

PALABRAS CLAVE: BIM, estructuras, herramientas BIM, interoperabilidad, proyecto académico, educación.

KEYWORDS: BIM, structures, BIM tools, interoperability, academic project, education.

Introduction

The Construction industry has been admitting recently relevant changes and challenges, both at a technological and business level, in order to improve productivity, reaching higher levels of economic and environmental efficiency [1]. In

order, to improve the communication between teams and to enable the re-use of information, generated and manipulated in the different stages of a project [2], the Building Information

Modelling (BIM) methodology responds to these challenges [3].

The main objective of the study, an MSc research, is to analyze the process of transposition of information between structural models in BIM environment using a real case study, involving the selection and use of software, the identification and preparation of the information used in the modelling and analysis process, and finally, the identification of the difficulties found [4].

2. Case study and structural solution

The case study is the Jupiter Marina Hotel, in Algarve, Portugal (Figure 1). The structural solution outcomes from the compromise between the architect's solution and a hotel use: fungiform slabs (without beams) in a large part of the building, so that hydraulic networks (water, sewage, etc.) and HVAC is suspended, without the constraints imposed by the existence of beams; beams are established for some specific situations and only to solve local structural situations; floors with consoles and organic forms that do not advise lightening slab solutions were considered.



Figure 1. Jupiter Marina Hotel.

3. Structural modelling

In BIM methodology, experts operate on the same platform, where a 3D virtual model is generated, accessed and updated (Figure 2). The centralization of the information allows better management of design activities [5], and facilitates the use, reuse and exchange of

information in the conception stage, as needed in the particular case study. The modelling process is carried out using specific software: ArchiCAD 21 [6], Revit 2017 [7] and ETABS [8].

For the structural modeling and analysis of the case study the main steps are: reception of the architectural model; conception of the structural model through a reference model (architecture); pre-dimensioning and design of structural elements; transposition of information between ArchiCAD/Revit and the structural analysis program, ETABS; in ETABS, addition of structural attributes (actions and combinations), definition of support condition and carried out the structural analysis; transposition of the final structural model to BIM environment, Revit/ArchiCAD). Three ways for exchanging information between applications were studied:

- ArchiCAD-Revit-ETABS information flow using manufacturers' "add-ins" to improve the exchange of information and to transfer information between applications with the minimum of errors and failures (Fig.2);
- ArchiCAD-Revit-ETABS information flow using IFC open format;
- ArchiCAD-ETABS information flow using IFC open format (the use of "add-ins" is not studied, as it is not available by manufacturers).

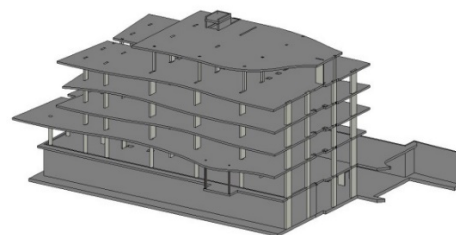
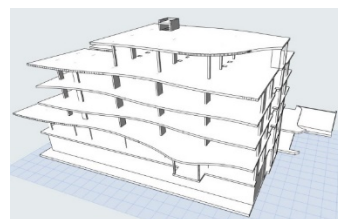


Figure 2. Perspective of the structural model created in ArchiCAD and in Revit (transposed).

In following, the information transfer process between the architectural model, the structural model and the structural analytical model, obtained in ETABS, is presented for each of the three information exchange ways.

3.1 *ArchiCAD-Revit-ETABS flow ("add-in")*

The connection of ArchiCAD model, with Revit, is made through the "add-in": "ArchiCAD Connection Add-in for Autodesk Revit" provided by Graphisoft. After the file has been save, in Revit, the "add-in" provides the possibility of "Improved IFC Import", and in the present work, two hypotheses were tested: import without any of the options selected and import with the three options selected.

In the first process, there are 110 warnings, namely, "Line in sketch is slightly off axis and may cause inaccuracies"; "Wall is slightly off axis and may cause inaccuracies"; "There are identical instances in the same place, and this will result in double counting in schedules".

In the second process, there are 32 warnings, all of the same type, "Line in sketch is slightly off axis and may cause inaccuracies", which shows the great reduction of warnings when using the assumptions made available by the "add-in" to facilitate the communication between applications. As so using the "add-in" could add errors to the model that later need to be corrected.

The next step is exporting information through an "add-in" called CSIXRevit2017 to pass information between Revit and ETABS. This process starts in Revit through the "add-in" menu where the "add-in" itself checks the elements to pass and the number of them, after that an .exr file is created to be imported by ETABS. After rectifying the warnings, the structural model obtained in ETABS is very similar with Revit model (Figure 3). A detailed

analysis of the model allows identifying some errors whose correction was done.

3.2 *ArchiCAD-Revit-ETABS flow (in IFC)*

This process starts by saving the ArchiCAD structural model in IFC format and opening it in Revit, selecting IFC option. An analysis of the structural model in Revit, concluded that there is no correction of the slab elements for the structural element, as happened when using the "add-in". All the irregularities found in the analysis of the model were corrected, as well as, the addition of the physical properties to the materials. Then Revit analytical model is verified.

The process errors are similar to the ones found in the previous process. Some errors are: columns without continuity on the lower floor (when not aligned by having different section); columns, inserted in structural walls, without connection. After correcting the identified errors, the final analytical model in Revit is reached (Figure 3) and it is equivalent to the previously analytical model.

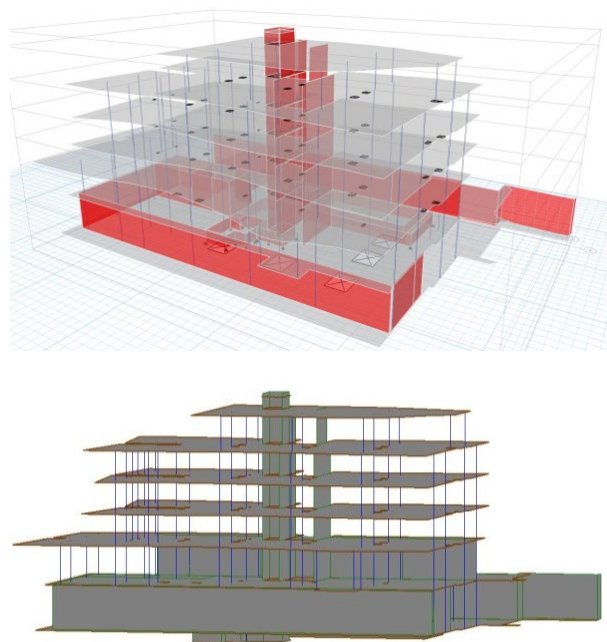


Figure 3. Structural model in ETABS ("add-ins") and analytical model in Revit (IFC)

3.3 ArchiCAD-ETABS flow (in IFC)

In this case, the interoperability between ArchiCAD and ETABS is analyzed through the IFC format. In ETABS, through the "Import" menu, "Ifc file" option and IFC file were selected. Using the import menu, the elements "IfcColumns", "IfcWalls" and "IfcSlabs" were identified in the imported model. This direct process, ArchiCAD/ETABS, without the corrections made in Revit, leads to an analytical model with several errors and disconformities.

So, a detailed analysis of the model allows identifying a series of elements lacking connections. It is, therefore, an analytical model with many errors and disconformities, requiring a deep editing work in ETABS (namely, because of lack of intermediate corrections step done in Revit).

After testing the above distinct directions of work flow it is more appropriate doing the sequence: ArchiCAD, if the architect is more familiarized with this modeling BIM-tool, and after transpose the model to Revit, in order to define the structural solution; transpose the Revit structural model to the ETABS (with flow in IFC).

4. Structural analysis

The determination of the efforts in the building's structure is done using a 3D model with six degrees of freedom per node, representing the flooring slab, floor slabs, beams, walls and columns. The mechanical characteristics of the structural elements are those that result from their physical dimensions (Figure 4).

4.1 Design of elements

Slabs' design is carried in ETABS in accordance with Eurocode 2. ETABS determines and graphically presents plants of

stresses, deformations and the reinforcement necessary to be added to a defined base reinforcement (Figure 5). ETABS positions the reinforcement at critical point (these were added to a base reinforcement of 12 mm rods, away from 0.20 meters in square mesh on the lower and upper faces of the slab).

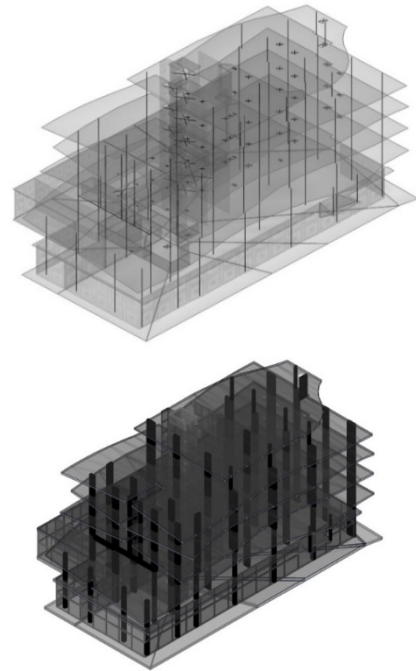


Figure 4. "Mesh of wires" model and "Volumetric" model.

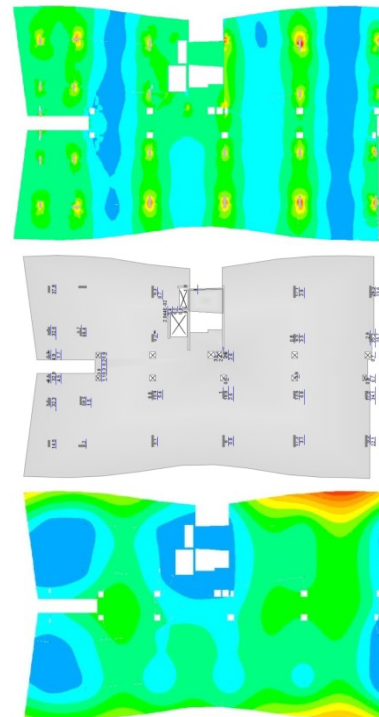


Figure 5. Slab moments (larger dimension), reinforcement and deformation (Floor 1)

Columns' design is carried in ETABS, following Eurocode 2. A set of predefined sections (concrete section and detailed reinforcement) is pre-defined. ETABS indicates which changes are required for all sections to be sufficient.

Figure 6 illustrates a volumetric perspective of columns, sections of columns (for example, section P802520 corresponds to a section of 80cm x 25cm armed with 8 rods of 20 mm) and a perspective where it is possible to visualize for each column the ratio between the required resistances and the solutions' resistances.

Beams' design is also done in an integrated way by ETABS, following Eurocode 2. The reinforcement is calculated by bending. ETABS graphically provides reinforcement in critical sections.

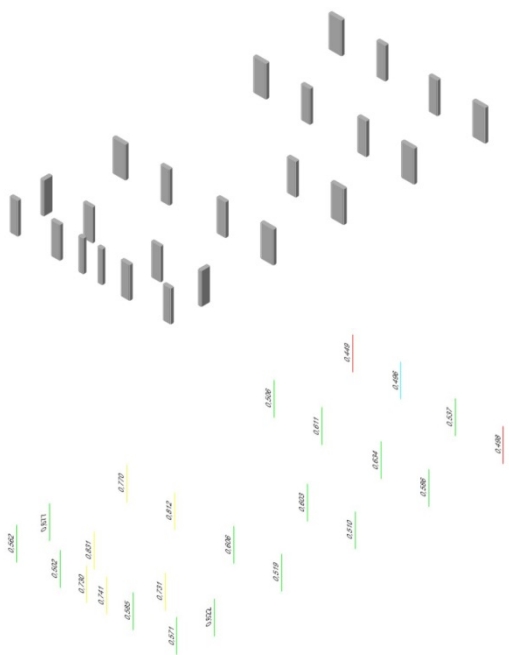


Figure 6. Ratio between the required resistances and the solutions' resistances

4.2 Modelling exportation

Once the structural design of the building is done in ETABS, the structural model must be transposed to Revit and ArchiCAD in order to concentrate the information created, in a single

model, the BIM model, according to BIM methodology.

An inverse interoperability process is carried out. Three processes of updating the BIM model are analyzed: ETABS-Revit-ArchiCAD flow (through "add-in"); ETABS-Revit-ArchiCAD flow (in IFC); ETABS-ArchiCAD flow (in IFC).

4.2.1 ETABS-Revit-ArchiCAD flow ("add")

The process starts using ETABS export menu, where there is the possibility to "Revit Structure .exr File" and an .exr file is created compatible with "Revit CSIXRevit2017 addin". In Revit, and using "add-in" there is the possibility of "Import to Update Existing Revit Project from ETABS SAFE or SAP2000".

Once the .exr file is chosen, an import menu is opened. Then it is possible to identify how many elements exist in the imported ETABS file, as well as, to identify how many corresponding elements exist in the source Revit model. It is noted that there are a much larger number of elements imported from the ETABS.

In the import process, there is also the option of matching the sections of the ETABS elements with the corresponding Revit families [9]. In this process, only one warning occurred because a Revit family corresponding to the section of steel profiles is not found, a warning that also occurred in the reverse process (Revit-ETABS). After correcting this warning, the model updates process starts and several warnings and errors were identified: "Element is slightly off axis and may cause inaccuracies"; "Line in sketch is slightly off axis and may cause inaccuracies"; "Wall is slightly off axis and may cause inaccuracies"; "Highlighted walls overlap"; "Cannot keep elements joined".

In this process of updating the structural model in Revit, the two models, the initial one existing in Revit [10], and the one imported from the ETABS, are overlapped, which explains the large number of warnings that

arise. Using "error detection options", a careful analysis of each error is performed. A partial analysis, for example, by floor, facilitates the identification of all situations. For this purpose, Revit's "Unjoin Elements" option is required to view the updated model (Figure 7).

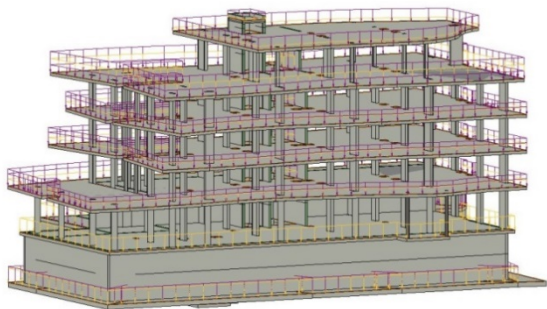


Figure 7. Revit model updated ("add-in")

4.2.2 ETABS–Revit–ArchiCAD flow (in IFC)

The process starts using ETABS export menu, where "IFC File" option creates an IFC file. In ETABS, it is possible to choose what type of IFC file to create, whether the file creation is for architectural upgrade or for structural analysis update, and confirm the number of elements that are included in the file to create. Once the export is complete, some differences are detected, between the number of exported elements and the number of elements detected in Revit when importing the .exr file, using the "add-in" CSIXRevit2017.

For example, the number of beams exported is 686, which corresponds to 16 beams and 670 "null lines". When the "add-in" is used only 16 beams are detected. "Null lines" are elements used in ETABS to improve the analyses without having neither geometric nor mechanical characteristics. Thus, cannot be considered as beams. However, when the export file is created in IFC format, the "null lines" are exported as beams.

After exporting the file in IFC the process of updating the structural model in Revit is carried out. For this purpose, the IFC

file is imported into the file with the original structural model in Revit. This process is tried several times, always leading to the shutdown of Revit. It is also analyzed the process of importing the IFC file into an empty Revit file but again 671 "Unrecoverable Error" and Revit's collapse. It is possible to conclude that the process of information transfer ETABS–Revit–ArchiCAD (in IFC) is not possible.

4.2.3 ETABS–ArchiCAD flow (in IFC)

The update of the model is made choosing "Detect IFC Model Change" in ArchiCAD. Two IFC files are selected: the one corresponding to the existing structural model in ArchiCAD and the exported file from ETABS. After that, and during the model update, an error message occurs reporting inconsistencies in reading the IFC file.

Continuing the model updated process, the number of new, modified and eliminated elements is identified and although expecting the creation of two new layers called "New" and "Old", what happen is the creation of only the "Old" layer and all elements of the existing ArchiCAD model were marked in red, corresponding to "deleted" elements.

The "New" layer is not created and no information is updated based on the IFC file imported from ETABS. The results obtained allow concluding that the transposition process ETABS–ArchiCAD using IFC format is not possible, and, the desired interoperability capacity does not exist.

Several workflow options were described and tested, mentioning the benefits and limitations of each sequence. The structural designer can choose the best way of modeling and doing the calculation activity, that are more familiarized with, but knowing the limitations that appears in each step, and what to do instead.

5. Conclusions

The main objective of this work was to analyze the process of transposition of information between structural models in BIM environment. For this purpose, a real case study, a hotel building, was used. The work involves different stages: design, structural modeling, information transposition (interoperability), dimensioning, updating the initial model and verifying the compatibility of the structural design with the existing architecture in order to evaluate interoperability between BIM platforms (ArchiCAD 21, Revit 2017 and ETABS 2016).

The main conclusions from the work done are: In the direct flow ArchiCAD-ETABS, although the transposition process occurs without great problems, the model obtained is very inconsistent; by using IFC format, the transposition process ArchiCAD-Revit-ETABS, occurs without major problems. It is a more time-consuming and labour intensive process in Revit and in ETABS than using “add-ins”; in the transposition process ArchiCAD-Revit-ETABS using “add-ins”, the process is reliable and is processed without significant loss of information, allowing a secure interaction between the architectural model and the structural model.

With regard to the reverse transposition process - to update ArchiCAD model - the use of IFC format is discouraged, leading to the collapse of the structural model in Revit, during ETABS-Revit process. In the case of ETABS-ArchiCAD transposition process, using IFC, the updating of ArchiCAD do not occur, which is also discouraged. ETABS-Revit-ArchiCAD transposition process using “add-ins”, by way of ArchiCAD import option "Detect IFC Model Changes", it is intuitive to check the elements that undergone geometric or parametrization changes and also to verify which elements are still compatible with the architecture.

In summary, it is possible to conclude that an adequate interoperability is fundamental when using available “add-ins” that enables the process of transposition of structural models to structural programs and to modelling platforms. The update is easy and intuitive enabling error detection and improved production compared to traditional processes.

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