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CHALLENGES OF EXPORTING AN IFC FILE TO INTEGRATE THE ENERGY SIMULATION ANALYSIS WORKFLOW

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ABSTRACT

The energy evaluation process of a building is usually made through computer simulation. Most software used in this application operate in an isolated manner, being common the need of rework on modeling the building with basic geometries in such a way that the computer application can generate the energy analysis report. To avoid this time-consuming and error-prone process, there has been a steady progress through the Industry Foundation Classes (IFC) to reduce rework and improve interoperability issues. This research had the primary objective of studying the process of exporting a virtual building information model to run an energy analysis in a different platform software, confronting with the traditional method which is based in remodeling the building in basic geometric forms. The research also aimed at studying issues occurred during this process and proposes actions to mitigate them. In order to do so, a popular home building project was used to simulate and run the analysis comparing conventional with innovative method. After going through the steps of exporting a virtual building information model and run an energy analysis in a different platform software, many issues were observed highlighting the need of improvement. These problems occurred in different steps within the workflow, from failing to export the data in IFC to extracting all needed data that were in the IFC file, leaving no doubts regarding opportunities of research and development in this area.

Keywords: IFC, BIM, Computational Simulation.

1. INTRODUCTION

The technological development contributed for the evolution of evaluation techniques and study of building energy performance. As stated by Lamberts, Dutra and Pereira (1997) this evaluation is important as a building is more energy efficient than another when it provides the same indoor environmental conditions with lower energy consumption.

Usually this evaluation is made through computer simulation. There are many software for simulation and energy analysis, but most of them operate in an isolated manner, being common rework on modeling the building with basic geometries in such a way that the software can generate the report on energy analysis, which can easily be a time-consuming and error-prone process (Santos and Couto, 2015). There is, however, a steady progress in reducing rework, the continued development of the Industry Foundation Classes (IFC) to improve software interoperability as studied by Bazjanac (2004). Such language for information exchange has since been more developed and matured for process optimization.

The use of IFC occurs mainly when building modeling is being performed in programs of different interface, for example when the architecture is in Revit® and the energy analysis is being done in EnergyPlus. In such cases interoperability is not simple and the process becomes more complex. In the scenarios studied by Aljundi, Pinto and Rodrigues (2017), the exchange of information between programs on the same platform (in the case Autodesk®) occurred in a simplified way, making smooth and efficient the energy analysis based on BIM modeling. Kim, Kim and Seo (2012) developed a tool that simplifies exporting IFC to EnergyPlus Input Data Files (IDF), in which they identified points that still needed to be improved, such as modeling guidelines; space boundary and integrated library of materials. Over time, SBTool software was developed aiming at being an IFC translator for IDF. The present study focused on a interoperability workflow based on virtual model in Revit, exportation in IFC, conversion to IDF and energy analysis in EnergyPlus. In this scenario, some limitations were observed. For instance, the creation of windows, doors and exports of parameters added to the model in Revit. Although the BIM software, Revit, offered the option to attribute parameters to materials, spaces and even add schedules to spaces, the program failed to correctly export all data, meaning that there was still a need of re-entering data into the program.

2. OBJECTIVE

The primary objective of this paper is to study the process of exporting a virtual building information model to run an energy analysis in a different software platform, confronting with the traditional method which is based on remodeling the building into basic geometric forms. The research also aims at studying the issues occurred during this process and proposes actions to mitigate them.

3. METHOD

In order to evaluate the steps of energy simulation considering a BIM model, it was selected a popular home project of the type "Minha Casa, Minha Vida" (a Brazilian housing government program). The same project was used in the classes of "Computational Simulation of Buildings Energy Performance" taught in the Professional Masters course of the Polytechnic School of the University of São Paulo. Therefore, the results and energy reports generated through the conventional simulation were known. To better understand the two types of simulation discussed in this paper, they were separated as follows:

Conventional simulation: usual process in which a virtual model of the building is made exclusively for use in energy analysis. Although this method implies in remodeling and heavy rework, it is highly used due to its popularity.

IFC to IDF Simulation: a process in which a virtual model loaded with parameters is exported to IFC and then later converted into IDF so Energyplus can run the simulation. Less used than the conventional, due to its difficulty and issues that appear when handling different files format.

3.1. Conventional Simulation

The conventional simulation method adopted in this paper follows the workflow shown in the Figure 1. This process requires a special virtual modeling of the building, it must be made from basic geometries and spaces delimitation. By using OpenStudio plug-in tools associated with SketchUp, the geometric model is made (Figure 2). The final model presents information of spaces delimitations, openings and shading. The OpenStudio plug-in provides an easy-to-understand user interface and allows other parameters to be added to the model, such as schedules, constituent material characteristics of building components, and user equipment that interfere with thermal comfort. The program then exports a file in .idf extension, supported by the EnergyPlus analysis software, if some adjustments are needed, they are made; afterwards, the extraction of energy analysis report is performed. As seen in Figure 3, the IDF file, read by EnergyPlus, is no more than an organized text file. Each element separated by a comma represents a parameter that the software will use to simulate. In order to keep the focus of this paper in the IFC export method, the conventional method will not be over explained. To further information on the conventional method, it is recommended the OpenStudio (2019) and EnergyPlus (2019) documentation homepage.

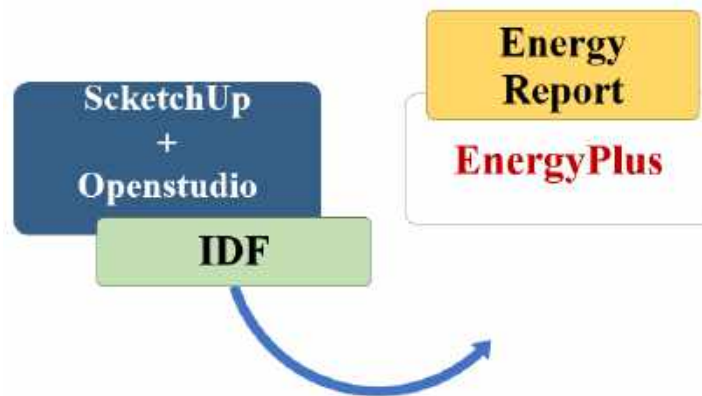


Figure 1 – Conventional Simulation workflow.

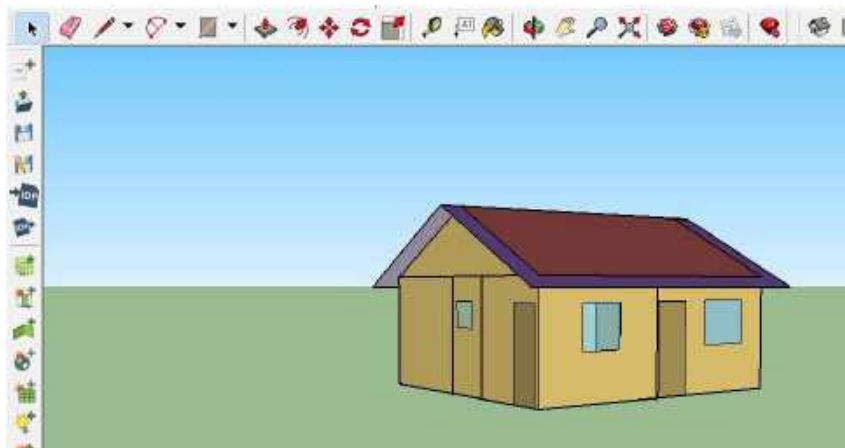


Figure 2 – Virtual model made in Scketchup by using OpenStudio tool.

```

BuildingSurface:Detailed,
  Surface 17,           !- Name
  Wall,                !- Surface Type
  Parede interna2 Reversed, !- Construction Name
  Thermal Zone banho, !- Zone Name
  Surface,             !- Outside Boundary Condition
  Surface 23,         !- Outside Boundary Condition Object
  NoSun,              !- Sun Exposure
  NoWind,             !- Wind Exposure
  ,                   !- View Factor to Ground
  ,                   !- Number of Vertices
  2.2,                !- Vertex 1 X-coordinate {m}
  -1.2,               !- Vertex 1 Y-coordinate {m}
  2.65,              !- Vertex 1 Z-coordinate {m}
  2.2,                !- Vertex 2 X-coordinate {m}
  -1.2,              !- Vertex 2 Y-coordinate {m}
  0,                 !- Vertex 2 Z-coordinate {m}
  2.2,                !- Vertex 3 X-coordinate {m}
  -7.21911419532262e-016, !- Vertex 3 Y-coordinate {m}
  0,                 !- Vertex 3 Z-coordinate {m}
  2.2,                !- Vertex 4 X-coordinate {m}
  -7.21911419532262e-016, !- Vertex 4 Y-coordinate {m}
  2.65;              !- Vertex 4 Z-coordinate {m}

```

Figure 3 - IDF file opened in a text reader.

3.2. IFC to IDF Simulation

Although the workflow for energy analysis using a BIM modeling software (Figure 4) has more steps than the conventional method, this flow is supposed to have a great time-saving advantage by not requiring the remodeling of the virtual model to a basic geometry. Assuming the exportation of architecture model to IFC and convert the file to IDF, there would no longer be necessary to remodel the building in SketchUp or similar. Although Revit already has some tools for energy analysis, many professionals prefer the report generated by EnergyPlus which motivated the research to incorporate an IFC model into the analysis flow. Initially, the method designed in this research was to model the building in Revit 2018; feed the model with parameters and data from material, schedule and spaces; export the Revit model to IFC, then, convert the IFC file into IDF by using the Space Boundary Tool (SBTool), open the IDF file in EnergyPlus and, finally, run the simulation to generate the report. As it will be explained in the next chapter, the researchers found opportunities of development in exportation and importation of the IFC file which didn't allow the report to be generated in the current horizon of this paper.

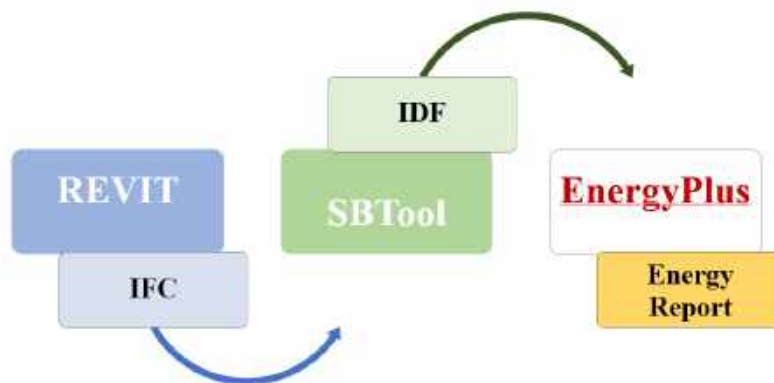


Figure 4 – Workflow of energy analysis using IFC file as primary input.

4. RESULTS

The complexity inside a virtual model and the non-interoperability between software made it difficult to understand some limitations and failures, and how to avoid them. On the other hand, it offered challenges that served as the basis for finding a way to understand and solve those questions. Following, the results generated in each step of the IFC to IDF workflow are presented.

4.1. Virtual Modeling

The virtual modeling of the building was done in Revit (Figure 5). In the model, spaces were defined, and material layers were added to the walls, floors and roofs. It was opted to add new materials into the model, such as “Textura acrílica” (Acrylic Texture) and its thermal characteristics, as shown in Figure 6 (the name

given to the material had special characters, e.g. “f”, to evaluate if this feature would affect the exportation process). Through the "Schedules Settings" tool, information about the building usage were added to the respective spaces (Figure 7). Having fed the model with these data, the IFC 2x3 was then extracted, doing so by using the Revit build-in tool (Figure 8).



Figure 5 – Virtual model in Revit (left); identification of spaces (right).

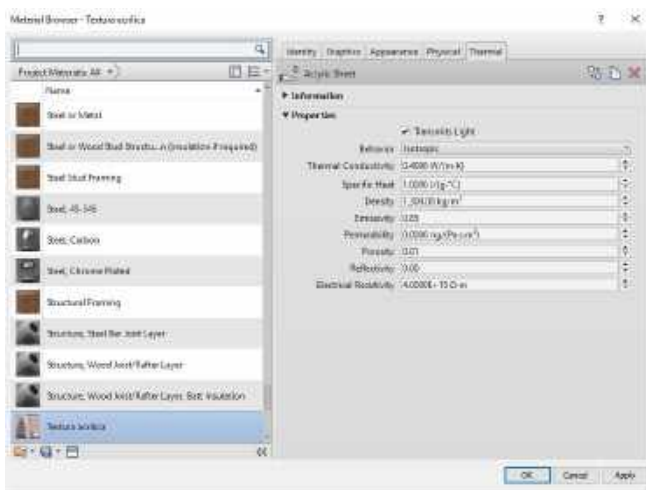


Figure 6 – Creation of new material to add into the model.

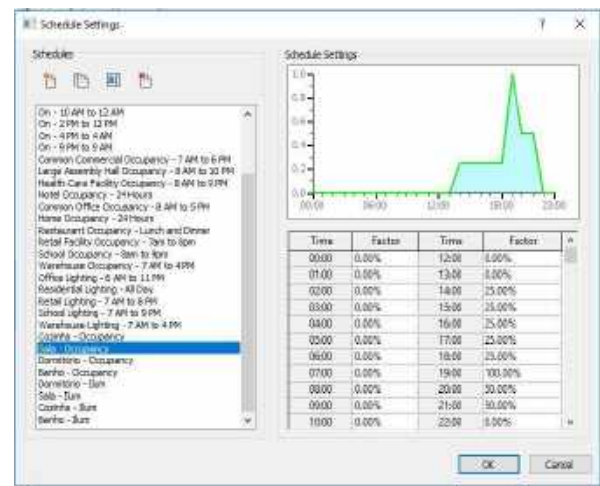


Figure 7 - Schedule de ocupação da sala.

(a)

(b)



Figure 8 - (a) Revit tool to export to IFC; (b) Property sets chosen to export.

4.2.From IFC to IDF

In order to convert the IFC file into IDF, the SBTool program was applied. As presented in Figure 8, the first step in the software is to delimit spaces of the model because it does not recognize the already existing spaces previously added in Revit. The result of this step is better observed after generating the IDF file and opening it into the OpenStudio program. It can be noticed that most spaces were created; however, openings (doors and windows) are not represented, and the roof was also not imported (Figure 9). The displacement between walls doesn't seem to be an issue since in the BuildingSurface Class List, in the IDF Editor, internal walls were not exposed to the sun and boundary condition was set as adiabatic, which probably solved the displacement issue.

The second step was to map the existing materials in the IFC model. At this stage a limitation of SBTool was observed: the software has a material data library that is loaded into its system and then a mapping is done between the loaded library materials and the materials inside the IFC model (Figure 10). Thus, if materials have the same name, both in the SBTool library and in the IFC model, the program automatically identifies the material and uses its library to feed the thermal data. In case names differ, the user must match the material from the loaded library in SBTool with the materials extracted from the IFC file. In other words, the thermal characteristics that were previously attributed to materials in Revit were not considered in this step, being whipped out and replaced by the data from SBTool library. This probably occurs to guarantee standardization of the necessary data for analysis, in case the user fails to feed the virtual model with the needed information. However, it would be more efficient if this step could be skipped or automated, in case the information is already in the model.

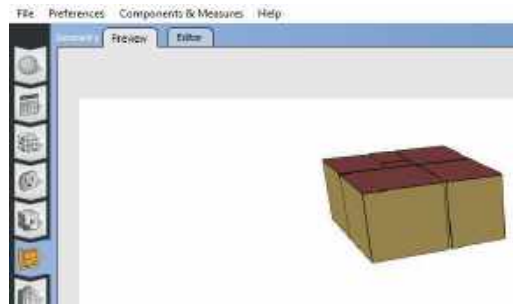


Figure 9 - IDF model exported from IFC through SBTool.

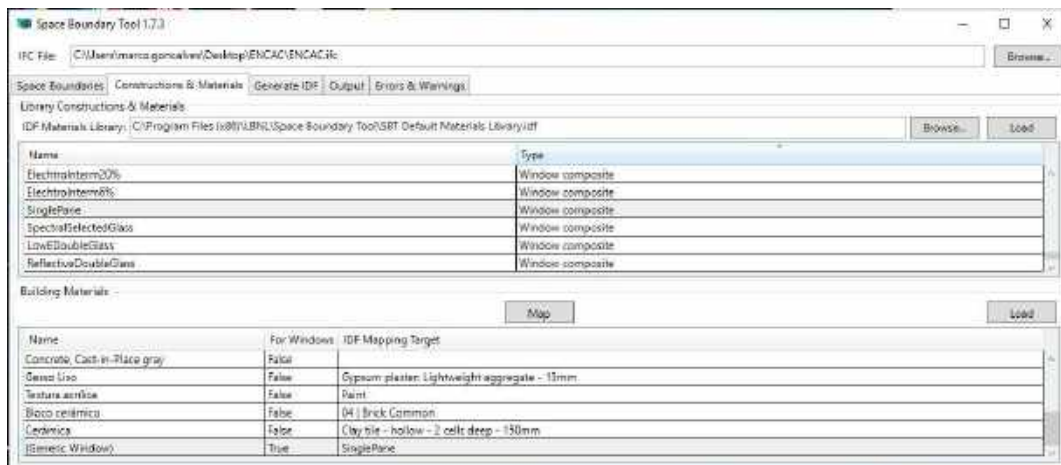


Figure 10 – Material mapping in SBTool.

4.3. Running in EnergyPlus

Lastly, once the IDF file was opened in EnergyPlus, it was necessary to upgrade the version of the file. The process was done inside EnergyPlus program in the "Utilities" tab. With the updated file the data was evaluated by using the IDF editor. It was noticed that some important parameters weren't imported, such as schedules (Figure 11), equipment usage and occupancy. After going through the IFC file, it was found that these data weren't exported from Revit to IFC. Subsequently, when trying to run the simulation, a fatal error occurred, and no energy report was given.

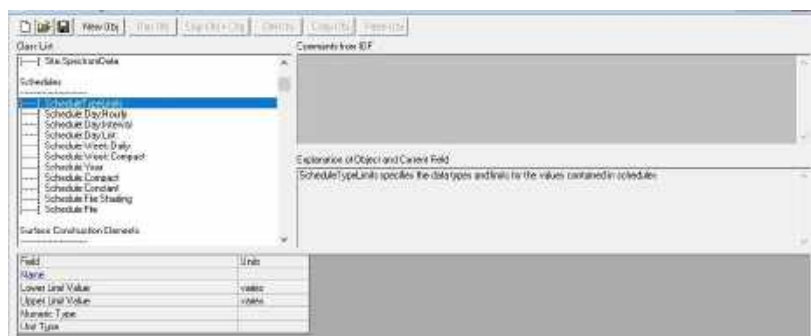


Figure 11 – IDF file after conversion with no schedules found.

4.4. Where have all data gone?

One possible way to solve the issues found during the conversion process might include writing a script in Python to get the information from inside the IFC file, and export to a text file which can then be converted to the IDF file. However, after looking at the IFC data, the only attributes regarding material was their names and thickness. No thermal attribute for each material was found. Leading the research back to the first step of the proposed workflow – the exportation from Revit to IFC must be mastered in order to make sure all data for energy analysis is being exported.

In order to explore the extraction of data from Revit, the authors opened a Dynamo script in Revit (Dynamo is an add-in that allows users to manipulate data inside Revit by using function boxes). The script, provided by Professor Ari Monteiro (2019), extracted thermal data from all construction elements (Figure 12) to an excel file (Figure 13). Although for energy simulation only 8 material thermal data are needed, the script exported all material thermal data, about 28 items. A Visual Basics Analytics (VBA) script (Figure 14) was used to filter the data and export to a text file organized and saved in an IDF compatible format (Figure 15).

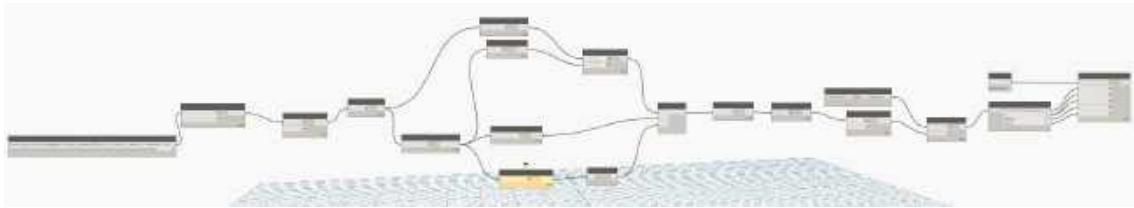


Figure 12 - General Panorama of the Script in Dynamo.

Material	Name	Value
1	Paint Thermal C	0.251
2	Paint Density	1300
3	Paint Shading	0
4	Paint Thermal C	0.251
5	Paint Source Autodesk	
6	Paint Family Name null	
7	Paint Transmits	1
8	Paint Category null	
9	Paint Type Name null	
10	Paint Reflective	0
11	Paint Porosity	0.001
12	Paint Property Acrylic Sheet	
13	Paint Category null	
14	Paint Design Op	-1
15	Paint Behavior	0
16	Paint Emissivity	0.85
17	Paint Thermal C	0.251
18	Paint Permeabil	0
19	Paint Class	3
20	Paint Source URL	
21	Paint Specific H	1
22	Paint Electrical	6E+15
23	Paint Descriptive Acrylic sheet - PMMA	
24	Paint Keywords Acrylic;Plastic;Glazing;Transparent;PMMA;thermal;solid	
25	Paint Unit weight	12.7486
26	Paint Subclass Plastic	
27	Paint Asset Idri AD111259-C03E-4A1D-92D6-59A12B4807AD	
28	Paint Thermal C	0.4
29	Gypsum o Source URL	

Figure 13 - Thermal data exported from Revit to an Excel file.

```

Sub MacroExport()
    'Declaring the variables
    Dim FileNames, sLine, Delimitator As String
    Dim LastCol, LastRow, FileNumber As Integer

    'Basic Location and File Name
    FileNames = "C:\Users\marco-gomes\OneDrive\Desktop\IDF\IDF"

    'Field Delimitator
    Delimitator = ";" & Chr(10) & Space(8)

    'Identifying the last Cell
    LastCol = ActiveSheet.Cells.SpecialCells(xlCellTypeLastCell).Column
    LastRow = ActiveSheet.Cells.SpecialCells(xlCellTypeLastCell).Row
    FileNumber = FileNames

    'Creating an Overwriting a text file
    Open FileNames For Output As FileNumber

    'Writing the data from excel using For Loop
    For i = 1 To LastRow
        For j = 1 To LastCol
            'Removing Delimitator if it is at the beginning the last column
            If i = LastCol Then
                sLine = sLine & Cells(i, j).Value & "*"
            Else
                sLine = sLine & Cells(i, j).Value & Delimitator
            End If
        Next j
    Next i

    'Highlighting data into text file
    Print #FileNumber, sLine
    sLine = ""
    Next i

    'Closing the text file
    Close #FileNumber

    'Generating message to display
    MsgBox "Text file has been generated"
End Sub

```

Figure 14 - VBA script to export in IDF.

```

Material,
04 | Belck Common, 0.001, 0, 0.4, 1500, 0.92;
Material,
09 | Plaster, 0.001, 0, 1.75, 2300, 1;
Material,
Aluminum, 0.001, 0, 230, 2700, 0.897;
Material,
Clay tile - hollow - 1 cell deep - 75mm, 0.001, 0, 0.9, 1500, 0.92;
Material,
Clay tile - hollow - 2 cells deep - 250mm, 0.001, 0, 0.9, 1500, 0.92;
Material,
Concrete - Cast-In-Place Concrete, 0.001, 0, 1.75, 2300, 1;
Material,
Gypsum or plaster board - 2.7mm, 0.001, 0, 0.5, 1200, 0.84;
Material,
Texture, 0.001, 0, 0.4, 1300, 1;
Material,
Tile (4), 0.001, 0, 0.9, 1500, 0.92;
Material,
Wood - Cherry, 0.001, 0, 0.18, 630, 2.385;

```

Figure 15 - Text file compatible with IDF.

To test the exportation, the generated file was opened in EnergyPlus and the materials were correctly identified as well as their thickness and some thermal characteristics, failing only in two items as shown in Figure 2. The first item "Roughness" refers to texture of the material, such information is present in the virtual model, however with numerical classification, while in EnergyPlus such classification is textual, ranging from "Very Rough" to "Very Smooth". The second item "Specific Heat" refers to the specific heat of

the material, this data was exported, however with different unit and thus the value was below the minimum limit of the program (100 J / Kg-K).

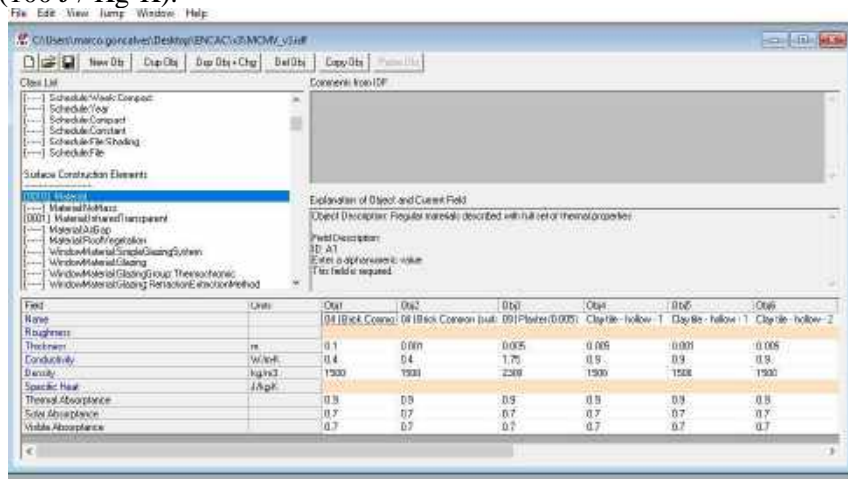


Figura 16 – Materials and their properties.

5. CONCLUSIONS

To sum up, after going through the steps of exporting a virtual building information model and running an energy analysis in a different software platform, several issues were revealed; thus, many are the opportunities of research and development to improve the interoperability within BIM software.

As seen in this paper, some information of the model was successfully exported. When using an add-in tool to extract the specific needed data; the result was compatible and reliable with only minor issues easily solved.

As suggestion for future research on integrating a BIM model into the energy simulation in the EnergyPlus software, there are some important aspects to be studied:

- Properly set exportation of all needed data from Revit to a text file organized in an IDF format, doing so by programing scripts
- Explore the use of mass model to export the geometry and spaces in an IDF file and combine with the thermal data exported from the architecture model

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