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STRUCTURAL STEEL DESIGN WITH BIM TECHNOLOGY - INTERVENTIONS ON A THREE BUILDINGS BLOCK IN DERUTA (PG)

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Index

ABSTRACT

The aim of this thesis is to use the developments, advantages and applications of "Building Information Modelling" (BIM) with emphasis on the discipline of structural design for steel building located in Perugia.

BIM was mainly considered as a new way of planning, constructing and operating buildings or infrastructures. It has been found to offer greater opportunities for increased efficiency, optimization of resources and generally better management throughout the life cycle of a facility. BIM increases the digitalization of processes and offers integrated and collaborative technologies for design, construction and operation.

To understand BIM and its benefits, one must consider all phases of a project. Higher initial design costs often lead to lower construction and operation costs. Creating data-rich digital models helps to better predict and coordinate the construction phases and operation of a building. One of the main limitations identified in the implementation of BIM is the lack of knowledge and qualified professionals. Certain disciplines such as structural and mechanical design depend on whether the main contractor, owner, general contractor or architect need to use or apply BIM to their projects. The existence of a supporting or mandatory BIM guideline may then eventually lead to its adoption.

To test the potential of the BIM adoption in the steel design process, some models were developed taking advantage of a largely diffuse authoring software (Autodesk Revit), to produce construction drawings and also material schedule that were needed in order to estimate quantities and features of a real steel building.

Once the model has been built the whole process has been analyzed and then compared with the traditional design process of steel structure. Many relevant aspect in term of clearness and also in time spent were shown and lead to final conclusions about the benefits from BIM methodology.

INTRODUCTION

Lack of communication between teams and software, costly for procedures for producing paper sheets, lack of clearness and correctness of drawings are just few examples related to steel traditional design problems.

The aim of this thesis is to use the developments, advantages and applications of "Building Information Modelling" (BIM) with emphasis on the discipline of structural design for steel building located in Perugia.

BIM was mainly considered as a new way of planning, constructing and operating buildings or infrastructures. It has been found to offer greater opportunities for increased efficiency, optimization of resources and generally better management throughout the life cycle of a facility. BIM increases the digitalization of processes and offers integrated and collaborative technologies for design, construction and operation.

To understand BIM and its benefits, one must consider all phases of a project. Higher initial design costs often lead to lower construction and operation costs. Creating data-rich digital models helps to better predict and coordinate the construction phases and operation of a building. One of the main limitations identified in the implementation of BIM is the lack of knowledge and qualified professionals. Certain disciplines such as structural and mechanical design depend on whether the main contractor, owner, general contractor or architect need to use or apply BIM to their projects. The existence of a supporting or mandatory BIM guideline may then eventually lead to its adoption.

In recent decades, many findings have been successfully identified in BIM application to projects. Civil engineers are very positive about the adoption of BIM compared to the other disciplines. The more you use BIM, the more likely you are to value its application in future projects. It is found that the introduction of in all phases of a project brings benefits. Higher quality, lower costs, reliable designs, accurate quantities, automated processes and drawing

management, virtual 3D visualization and better site coordination are just some of the benefits (https://revizto.com/en/top-benefits-of-bim/).

To test the potential of the BIM adoption in the steel design process, some models were developed taking advantage of a largely diffuse authoring software (Autodesk Revit), to produce construction drawings and also material schedule that were needed in order to estimate quantities and features of a real design case study, located in Italy.

1 BIM

1.1 WHAT IS BIM?

BIM is the acronym for "Building Information Modelling" or Information Model of a Building and is defined by the National Institutes of Building Science as the "digital representation of physical and functional characteristics of an object." Therefore, BIM cannot be considered a product, tool or even software but must be understood as an operational methodology for plaining, programming, designing, implementing, and maintaining a building that uses an information model, i.e., a model that contains all the information covering its entire life cycle, from design to construction, up to its demolition and disposal.

BIM was created to respond to the need for greater collaboration between designers, effective interoperability at the software level, easier integration between processes, and, last but not least, effective sustainability.

BIM is, in fact, a collaborative design method as it allows to integrate into a single model of the information useful in each phase of the design, from the architectural to the structural one, from the plant engineering one to the energy one to get to understand that of the management matrix.

The peculiarity of Building Information Modelling is, therefore, that of being able to recreate a virtual model of a building that is not a simple three-dimensional representation but an information model - dynamic, interdisciplinary, shared, and constantly evolving that contains a series of information that can be translated into a package of data that travels safely to other IT platforms that contribute to the

realization of the project. The working methodology on which BIM is based cannot be separated from the use of software capable of generating specific virtual models for each individual discipline and, at the same time, capable of communicating with all the participants in the process. The ability of designers to produce interoperable data is therefore guaranteed by compatibility with the IFC (Industry Foundation Class) format. These IFC files are classified as 3D image files, which also contain other technical information.

1.2 WHAT IS NOT BIM?

BIM is a popular term that software developers use to describe what their products can do. Because of this, there is some disagreement and confusion about what BIM technology is. To clear up this confusion, it's helpful to talk about modelling solutions that don't use BIM design technology. In this category are tools for making the following types of models:

- **Models that only have 3D data and no (or very few) attributes for objects**. These are models which can only be used for visualizing data and don't have any intelligence at the level of the object. They are fine for visualizing data, but they don't help much or at all with integrating data and analysing design. One example is Google's SketchUp app, which is great for quickly making building schematic designs but not so good for other types of analysis because it doesn't know anything about the objects in the design other than their shape and how they look.
- **Models that do not support behavior**. These are models that describe objects but don't have parametric intelligence, so you can't change their position or size. This makes it very hard to make changes and doesn't stop people from getting confused or wrong ideas about the model.
- **Models that are made up of several 2D CAD reference files that need to be put together to make the building**. It is impossible to know for sure that the 3D model that is made will be possible, consistent, countable, and smart about the objects it contains.
- **Models in which changing the size of some components in one view doesn't automatically change them in other views**. This makes it possible for errors in the model that are hard to find, like when you override a formula in a spreadsheet with a manual entry.

1.3 BIM USE IN DESIGN PROCESSES

The two technological bases of building information modelling (parametric design tools and interoperability), together with the growing diversity of BIM tools for specialized functions, enable various process improvements and information upgrades within traditional design procedures. These benefits cover all aspects of design. Here, we briefly analyze the role and process of design from three of those approaches, which apply in variable degrees to different projects, depending on their amount of information development.

1.3.1 BIM for conceptual design

The first point of view concerns conceptual design as it is commonly understood. The MacLeamy curves in Figure 3 illustrate the importance of concept design and the need for a refocus on it. In terms of massing, structure, general spatial layout, approach to environmental conditioning, and response to site and other local conditions, concept design establishes the basic design framework that will be developed in later stages. It is the most imaginative aspect of the design process. It takes into account all aspects of the project, including its function, costs, construction methods and materials, environmental impacts, construction practices, cultural and aesthetic considerations, and so on. It anticipates and considers the design team's entire range of expertise.
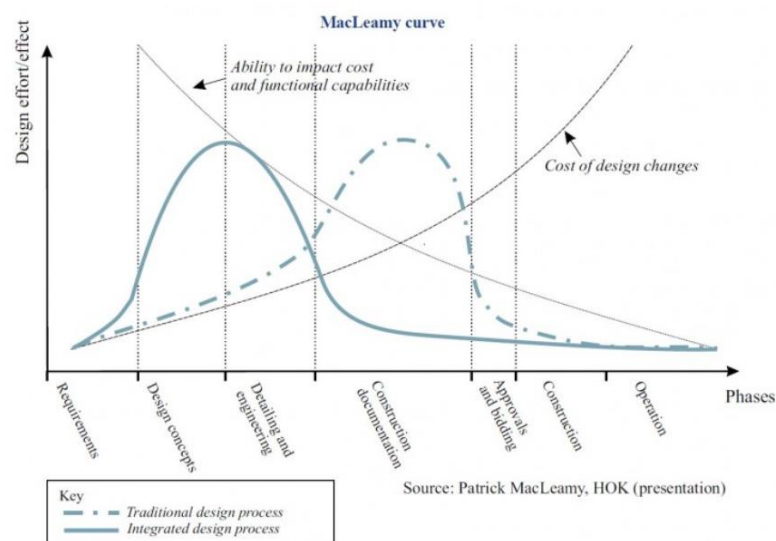

Figure 1 - MacLeamy diagram

1.3.2 BIM for design and analysis

The second point of view looks at how BIM can be used to design and analyze building systems. In this context, analysis can be considered as a process that measures the variations in physical parameters that can be predicted in real construction. Many functional aspects of a building's performance are examined, including structural integrity, temperature control, ventilation and airflow, illumination, pedestrian circulation, acoustic performance, energy distribution and consumption, water supply, and waste disposal, all of which are subjected to varying loads. The design team's specialists do these simulations and assessments, which are based on extensive analytical models with technical input requirements. This point of view is based on collaboration among the numerous professions involved, as well as integration of the analysis software used by those professions. They, in turn, create design layouts for planning and coordinating the numerous systems. From early concept design to construction-level modelling, the collaborations are extensive. The early design process can include experimental analyses of structure, environmental controls, construction methods, use of new materials or systems, detailed analyses of user processes, or other technical aspects of a building project in exceptional cases involving high-level information development. Problems are defined as the design of freshly conceived system components responding to a new or more stated set of performance requirements in these circumstances rather than a design needing analysis.

1.3.3 BIM use in developing construction-level information

The third viewpoint is the typical BIM viewpoint used in creating construction-level information. Building modelling software offers placement and composition rules that help speed the preparation of standard or predetermined building paperwork. This provides the possibility of both speeding up the procedure and boosting quality. Construction modelling is a an essential competency of modern BIM authoring tools. Today, the principal product of this phase is building documentation. But this is changing. In the future, the building model itself will serve as the legal basis for construction documents. This last viewpoint involves design and construction integration. At the most visible level, this concept applies to well-integrated design-build processes in conventional construction, permitting speedy, efficient construction of the building following design, or possibly in

simultaneously with it. This step also covers generating input for fabrication-level models. In its more ambitious component, this concept requires working out nonstandard fabrication techniques, working from carefully established comprehensive design models supporting what mechanical designers call "design for fabrication."

1.4 BIM FOR ARCHITECTS AND ENGINEERS

1.4.1 Architectural design

In the architectural field, designers are more efficient than those who do not use BIM because they can create a 3D virtual model and control every aspect of the designing phase without disregarding anything. They can also automatically generate plans, elevations, sections, and axonometric views from the simple design of parametric architectural objects (beams, pillars, walls, windows, and so on).

Each change made to the virtual model causes an automatic and dynamic variation of all project papers and the information contained within, resulting in increased productivity and lowering the risk of making mistakes or misalignments between the numerous design documents.

BIM software is quicker in transferring the project without sacrificing quality, allowing individuals working in the BIM model to supply all the information contained in the project. Some BIM software also includes "Real-Time Rendering" technology, allowing users to create photorealistic architectural renderings in real-time while designing, without wasting time waiting to evaluate design choices and experiment with new forms, materials, objects, lights, and so on, and instantly verify every hypothesis.

As a result, the benefit of this design approach is straightforward.

Figure 2 – Rendering in an Architectural model (Amir CG source)

1.4.2 Structural design

BIM is an intelligent, 3D model-based process that helps structural professionals to design, detail, document, and fabricate structural systems. It enables project teams to work more collaboratively–helping to optimize designs, improve accuracy, and connect design to fabrication to deliver projects faster and more efficiently

Using BIM, structural engineers can make more informed design decisions, automate construction documentation, and produce more accurate, constructible designs.

BIM helps structural engineers optimise and automate designs, reduce errors and risk, and improve accuracy and constructability, while improving overall project delivery.

1.4.3 MEP Systems design

Building Information Modeling (BIM) is an intelligent, 3D model-based process that helps MEP (Mechanical Electrical Plumbing) professionals design, detail, document, and fabricate building systems more efficiently. With BIM, project teams improve collaboration, share data, and speed up project delivery from design to construction.

Working in a BIM process gives MEP project teams insight into design and constructability, to improve accuracy, reduce and resolve clashes, and optimize building systems design.

Using BIM, MEP engineers can make better design decisions earlier to optimize designs, reduce risk, and improve accuracy and constructability.

Figure 3 – Rendering in a MEP model (cdes source)

1.4.4 Infrastructures Design

Infrastructure projects today have become more complex. Implementing BIM facilitates project team collaboration; reducing errors, increasing cost predictability, and improving understanding.

BIM for civil projects improves outcomes with its ability to investigate multiple scenarios, providing data-driven assurance that projects can be delivered on schedule and on budget. BIM offers shared information throughout the project life cycle, driving compelling results.

Building Information Modeling (BIM) is an intelligent, 3D model-based process that is the foundation of digital transformation. Civil engineers can create and manage all the information surrounding design assets ensuring improved collaboration, shared data, and project delivery that is on time and on budget.
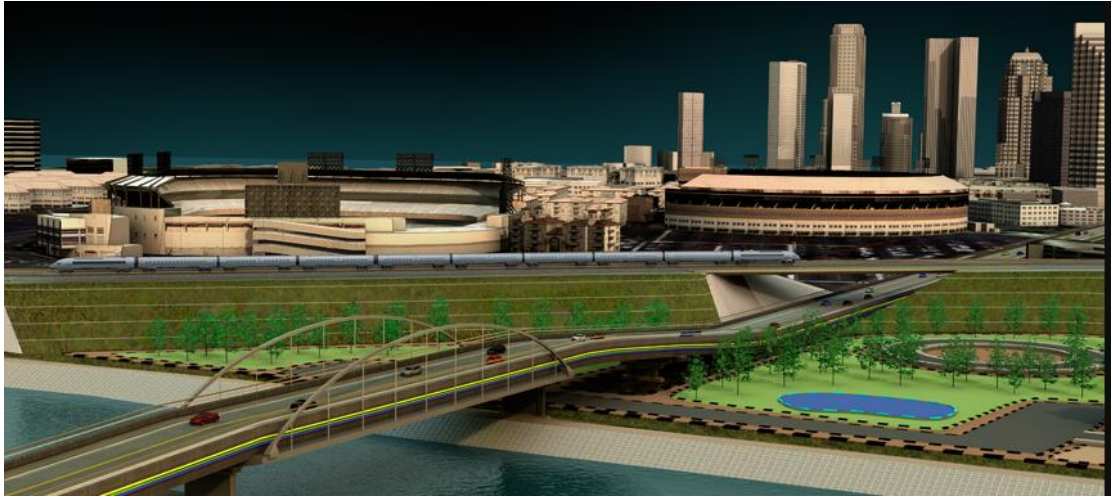
Figure 4 - Rendering of an infrastructure model (Autodesk source)

1.5   WHAT ARE BENEFITS AND PROBLEMS OF BIM ?

Many business operations can benefit from BIM technology. Although BIM adoption in the AEC/FM (facility management) business is still in its infancy, significant gains have already been made (as compared to traditional 2D CAD or paper-based procedures). Though it's unlikely that all of the benefits listed below are now in use, we've included them to demonstrate the breadth of changes that can be expected as BIM technology advances.

BIM technology and associated processes are at the heart of how the building design and construction process can respond to the increasing pressures of greater complexity, faster development, and improved sustainability while lowering the cost of the building and its subsequent use, as shown in Figure below.
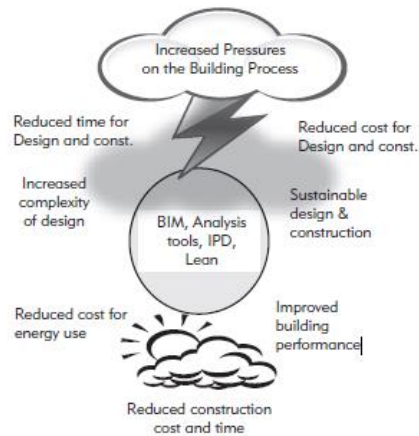
Figure 5 - BIM technology Benefis (BIM handbook)

These demands are beyond traditional practice's ability to respond. The sections that follow provide a quick overview of how this improved performance can be accomplished. The purpose of this dissertation is to equip readers with the information they need to comprehend both the technology and the business processes that underpin BIM.

1.5.1 Owner Benefits from Pre-Construction Concept, Feasibility, and Design

Before hiring an architect, owners must decide if a building of a certain size, quality level, and required program requirements can be built within a certain budget and time frame. In other words, can a certain building meet the financial needs of its owner? If these questions can be answered with a good amount of certainty, owners can move forward knowing that their goals will be met. It's a waste of time and work to spend a lot of time and work on a design only to find out that it's way over budget. A rough (or "macro") building model that is linked to a cost database can be very helpful to a building owner.

- **Improved Building Quality and Performance**

Creating a schematic model before creating a complete building model allows for a more thorough assessment of the proposed scheme to see if it fits the functional and sustainability needs of the project. The overall quality of the building is improved through early evaluation of design alternatives utilising analysis/simulation technologies.

- **Integrated project delivery**

When the owner uses Integrated Project Delivery (IPD) to buy a project, the project team can use BIM from the start of the design to better understand the project's needs and get cost estimates as the design progresses. This makes it easier to understand the design and cost, and it also gets rid of the need for paper exchange and the delays that come with it.

1.5.2 Design Benefits

- **Early and more accurate pictures of how a design will look**

The BIM software doesn't make the 3D model from a bunch of 2D views. Instead, the 3D model is designed directly. It can be used at any point in the design process to see how the design will look, with the expectation that it will look the same in every view.

- **When changes are made to the design, low-level changes are made automatically.**

If the objects used in the design are controlled by parametric rules that make sure they are aligned correctly, then the 3D model will be free of geometry, alignment, and spatial coordination errors. This means that the user doesn't have to deal with design changes as much.

- **At any point in the design process, accurate and consistent 2D drawings can be made.**

These drawings can be made for any set of objects or view of the project. This makes it much faster and less likely that mistakes will happen when making construction drawings for all design disciplines. When changes need to be made to the design, drawings that are consistent with the changes can be made as soon as the design changes are entered.

- **Earlier Collaboration of Multiple Design Disciplines**

BIM technology makes it easier for different types of designers to work on projects at the same time.

Collaboration is also possible with drawings, but it is harder and takes more time than working with one or more coordinated 3D models where changes can be well managed. This cuts down on the time it takes to design and makes it much less likely that mistakes will be made. It also lets you know about design problems earlier and gives you chances to make a design better and better over time. This saves a lot more money than waiting

until the design is almost done and then using value engineering after the big design decisions have been made.

- **Easy Verification of Consistency to the Design Intent**

BIM lets you see things in 3D earlier and measure the size of rooms and the amount of other materials, so you can get more accurate cost estimates. For technical buildings like labs, hospitals, and the like, the design goal is often stated in numbers. This makes it possible to use a building model to make sure the building meets these needs. The 3D model can also help with automatic evaluations for qualitative requirements, such as "this space should be close to another."

- **Extraction of Cost Estimates during the Design Stage**

At any point in the design process, BIM technology can be used to get an accurate bill of quantities and spaces that can be used to estimate how much something will cost. Early on in the design process, cost estimates are made using either formulas that are tied to important project quantities, such as the number of parking spaces or square feet of different types of office space, or unit costs per square foot. As the design moves forward, more accurate and detailed cost estimates can be made with the help of more detailed quantities. Before a design gets to the level of detail needed for construction bids, it is possible to make sure that everyone is aware of how much it will cost. At the end of the design process, an estimate can be made based on how many of each object is in the model. This gives a more accurate estimate of the final cost. So, if you use BIM instead of a paper-based system, you can make better-informed decisions about design costs. When using BIM to estimate costs, it makes sense to include the general contractor and, if possible, some of the key trade contractors who will be building the structure. During the design process, their knowledge is needed to get accurate cost estimates and insights into how something can be built.

- **Improvement of Energy Efficiency and Sustainability**

At any point in the design process, BIM technology can be used to get an accurate bill of quantities and spaces that can be used to estimate how much something will cost. Early on in the design process, cost estimates are made using either formulas that are tied to important project quantities, such as the number of parking spaces or square feet of different types of office space, or unit costs per square foot. As the design moves forward,

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1.5.3 Construction and Fabrication Benefits

- **Using the design model as a guide for making parts.**

If the design model is moved to a BIM fabrication tool and detailed to the level of fabrication objects (called a "shop model"), it will show the building objects for fabrication and construction in a way that is accurate. Since 3D models of the parts already exist, numerical control machinery can be used to make them more easily. In steel fabrication and some sheet metal work, this kind of automation is now the norm. It has been used successfully to make precast parts, window frames, and glass. This lets vendors all over the world add to the model, develop the details needed for making it, and keep the links that show how the design was meant to be used. This makes it easier to build things off-site, which cuts costs and construction time. Because BIM is so accurate, larger parts of the design can be made off-site than would normally be possible with 2D drawings. This is because onsite changes (rework) are likely and exact dimensions can't be known until other things are built in the field. It also lets installation crews be smaller, installation time to be shorter, and on-site storage space to be smaller.

- **Changes to the design can be made quickly.**

The effect of a suggested design change can be put into the building model, and the other parts of the design will automatically change to reflect the new information. Some updates will happen automatically based on the parameters that have already been set. More cross-system updates can be checked and changed visually or with the help of a program that finds conflicts. The model and all views of it after it can accurately show how a change affects things. Also, design changes can be fixed faster in a BIM system because changes

can be shared, visualized, estimated, and fixed without having to go through time-consuming paper transactions. In paper-based systems, updating in this way is very likely to cause mistakes.

- **Errors and omissions in the design that are found before construction**

All 2D and 3D drawings are based on the virtual 3D model of the building. This means that design errors caused by inconsistent 2D drawings are eliminated. Also, because models from all fields can be brought together and compared, it's easy to check both systematically (for hard and clearance clashes) and visually if the interfaces between systems work well (for other kinds of errors). Conflicts and problems with building are found before they are found in the field. It's easier for designers and contractors to work together, and mistakes are much less likely to happen. This speeds up the building process, cuts costs, reduces the chance of legal disputes, and makes things easier for the whole project team.

- **Synchronization of Design and Construction Planning**

In order to use 4D CAD for construction planning, you have to link a construction plan to the 3D objects in a design. This lets you simulate the building process and see what the building and site would look like at any time. This graphic simulation gives a lot of information about how the building will be built day by day. It also shows where problems could arise and how they could be fixed (site, crew and equipment, space conflicts, safety problems, and so forth). You can't get this kind of analysis from paper bid documents. It does, however, help more if the model includes temporary construction objects like shoring, scaffolding, cranes, and other large pieces of equipment, so that these objects can be linked to schedule activities and reflected in the desired construction plan.

- **Better Implementation of Lean Construction Techniques**

For lean construction techniques to work, the general contractor and all subcontractors must work together to make sure that work can be done when the right tools and materials are on-site. This cuts down on wasted work and the need to keep an inventory of materials on-site. Because BIM creates an accurate model of the design and the materials needed for each part of the work, it helps subcontractors plan and schedule their work better and makes sure that people, equipment, and materials arrive just in time. This saves money and makes it easier for people to work together on the job site. The model can also be

used with wireless hand-held computers to make it easier to keep track of materials, see how far along an installation is, and automatically place people in the field.

- **Synchronization of Procurement with Design and Construction.**

All (or most, depending on how good the 3D modelling is) of the materials and objects used in a design are accurately measured in the building model as a whole. With these quantities, specifications, and qualities, materials can be bought from product suppliers and subcontractors (such as precast concrete subs). Object definitions for a lot of manufactured goods haven't been set yet, so this isn't a sure thing right now (2010). When the models were made available (steel members, precast concrete members, some mechanical parts, and some windows and doors), the results were very helpful.

1.5.4 Post Construction Benefits

- **Better information on facility commissioning and handover**

During the building process, the general contractor and the MEP contractors collect information about the materials installed and how to take care of the building's systems. This information can be linked to the object in the building model and then given to the owner to use in their facility management systems. It can also be used to make sure that all of the building's systems work as planned before the building is given to the owner.

- **Better running and management of buildings**

The building model is a source of information about all of a building's systems, including diagrams and specifications. The owner can get access to the analyses that were used to decide what mechanical equipment, control systems, and other purchases to make. This way, the design decisions can be checked once the building is in use. After the building is done, this information can be used to make sure that all of the systems work well.

- **Integration with Facility Operation and Management Systems**

A building model that has been updated to include all of the changes that were made during construction is a reliable source of information about the spaces and systems as they are now, as well as a good place to start when managing and running the building. A building information model allows for real-time monitoring of control systems, a natural interface for sensors, and facility management that can be done from afar.

1.6   WHAT CHALLENGES CAN BE EXPECTED?

The number and severity of problems caused by traditional methods will go down as each step of design and construction is made better. Smart use of BIM, on the other hand, will also cause big changes in how project participants work together and what their contracts say. (Traditional contract terms are made for things that are done on paper.) Also, the architect, contractor, and other design disciplines will need to work together earlier, since the knowledge of specialists is most useful during the design phase. Buildings and other types of structures are using IPD project delivery more and more. This shows the strong benefits of integrated teams that use BIM and lean construction techniques to manage the design and building process.

1.6.1   Challenges with Collaboration and Teaming

BIM gives people new ways to work together, but it also makes it harder to build teams that work well together. A big issue is figuring out how members of the project team will be able to share information about the model in a useful way. If the architect uses traditional paper drawings, the contractor (or a third party) will have to build the model so it can be used for planning, estimating, and coordinating the construction. If the architect does use BIM to make their design, the model might not have enough detail to be used for construction, or the object definitions might not be good enough to get the numbers needed for construction. This might mean making a new model for use in construction. If the architectural model is provided, cost and time may be added to the project. However, the cost of a model is usually justified by the benefits of using it for construction planning and detailed design by mechanical, plumbing, and other subs and fabricators, design change resolution, procurement, and so on. If different people on the project team use different modeling tools, tools are needed to move models from one environment to another or to combine models from different environments. This can make the project harder, make it more likely that mistakes will be made, and take more time. Using IFC standards to exchange data could make these kinds of problems less likely. You could also use a model server that talks to all BIM programs through IFC or proprietary standards.

1.6.2   Legal Changes to Documentation Ownership and Production

Legal issues are making it hard to figure out who owns the different datasets for design, fabrication, analysis, and construction, who pays for them, and who is responsible for

making sure they are correct. Practitioners are working to solve these problems by using BIM on projects. As owners learn more about the benefits of BIM, they will probably need a building model to help with operations, maintenance, and any renovations that come after. Professional groups like the AIA and AGC are coming up with rules for how contracts should be written to cover issues that come up when BIM technology is used.

1.6.3 Changes in Practice and Use of information

Using BIM will also make it easier to incorporate construction knowledge into the design process earlier on. Integrated design-build firms that can coordinate all phases of the design and incorporate construction knowledge from the start will benefit the most. When BIM is used, IPD contracts that require and make it easy for good collaboration will give owners more benefits. When companies use BIM technology, the biggest change is that they have to use a shared building model heavily during the design phase and a coordinated set of building models during construction and fabrication as the basis for all work processes and to work together. This change will take time and education, just like any other big change in technology or how work is done.

1.6.4 Implementation issue

Getting rid of a 2D or 3D CAD environment and replacing it with a building model system requires a lot more than just getting new software, training, and new hardware.

For BIM to work well, almost every part of a company's business needs to be changed (not just doing the same things in a new way). Before the conversion can start, you need to know something about BIM technology and related processes and have a plan for how to use them. A consultant can help plan, keep track of, and help with this process.

2 BIM IN STEEL STRUCTURES

2.1 CAD AND BIM

Computer aided design and drafting (CADD) is a subfield of engineering which deals with the design and drafting of objects and materials through the use of specialized software that visualizes designs as modular 3D computer models.

BIM is a set of coordinated, reliable pieces of information about a project's design, construction, and operation that work together as a whole.

CAD is the acronym for Computer Aided Design. CAD is nothing more than using computers to help with design. Technically, BIM tools like Revit are CAD programs, but the term "CAD" is more often used for drafting programs. When it comes to building design, CAD is basically using a drafting tool like AutoCAD to make lines and curves that show how a building is supposed to look.

Look at figure below to see how the two are different (this figure is taken from REVIT software). In a plan view layout on the right, which says "CAD," is the same as the layout on the left, which says "BIM." When you click on one of the CAD walls on the right, you can see that it is just a line. A wall is shown by drawing two lines next to each other. When you look at the Properties palette, the Line Style is the only option (right side of the figure). When you click on a BIM wall on the left, though, you can see that it is a real wall element. There are several parameters that can be used to define the wall in the Properties palette (left side of the figure).
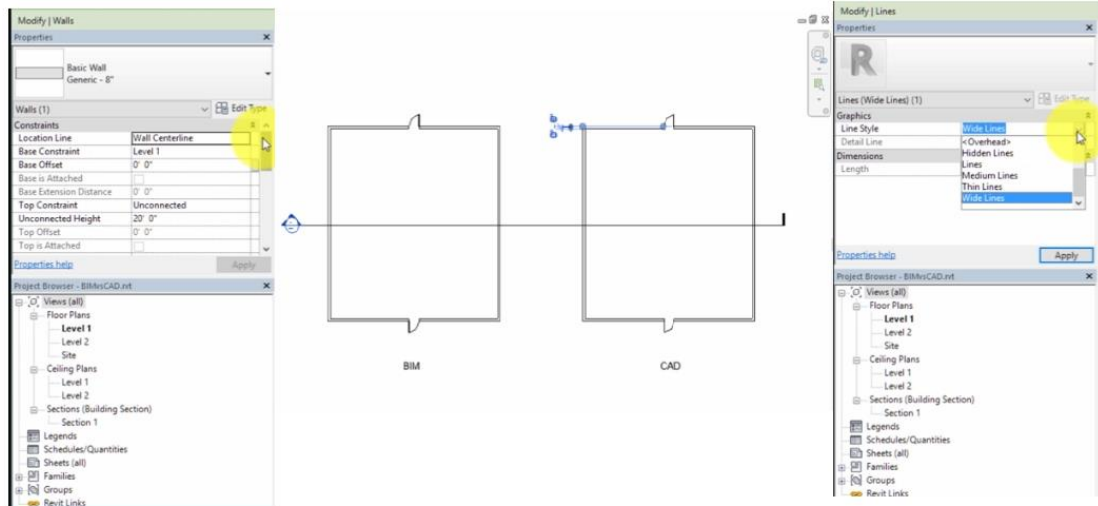
Also, when you click Edit Type, the Type Properties dialog box pops up. This is where you can change all the parameters that make up this wall type. Schedules and tags can use all of these parameters. The BIM method uses real elements to stand in for real-world parts. Not only are they made up of three-dimensional pieces, but they are also set up with parameters.
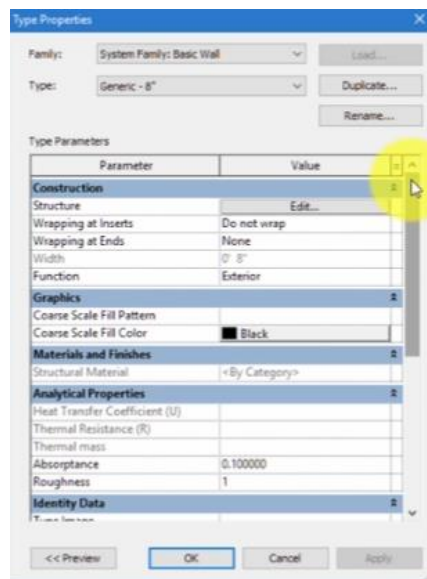
Moving the cursor over the wall and dragging it down while the wall is still selected. When you do this, the door moves with the wall, and the length of the walls that are connected shortens to keep them together.
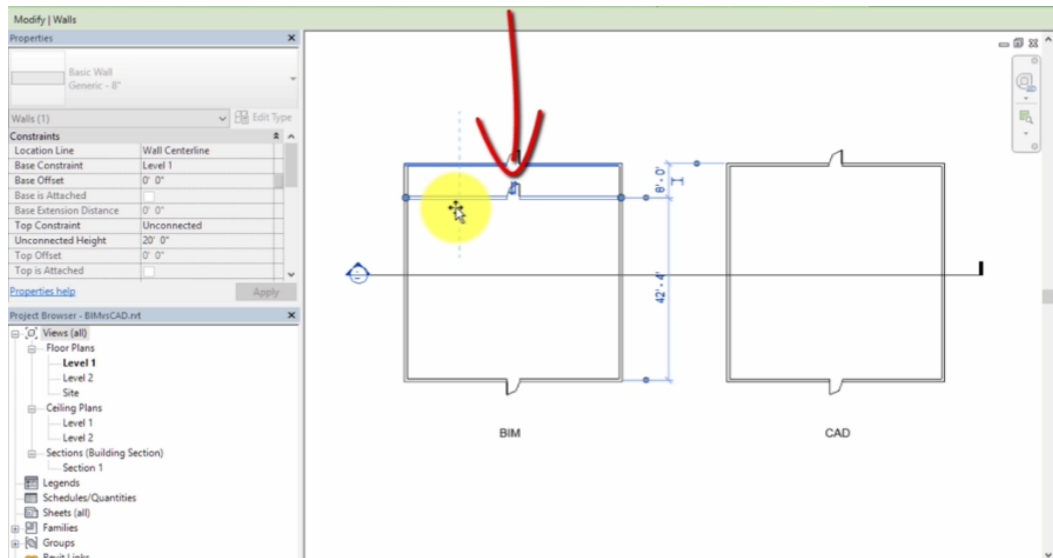
Figure 8 – Parametric wall (Autodesk source)

Now, looking at the CAD example again and choose one of the lines. When you pull it down, the lines that connect them stay connected, but the line next to it doesn't stay the same distance away, and the lines that make up the door don't move either. If you were actually working in CAD, all you would have to do to move the lines is select them all. But the point is that elements in Revit, which is made for BIM, are set up to connect in a certain way. For example, the corners of the walls are cleaned up, and when the door is put in place, the wall cuts a hole for it.
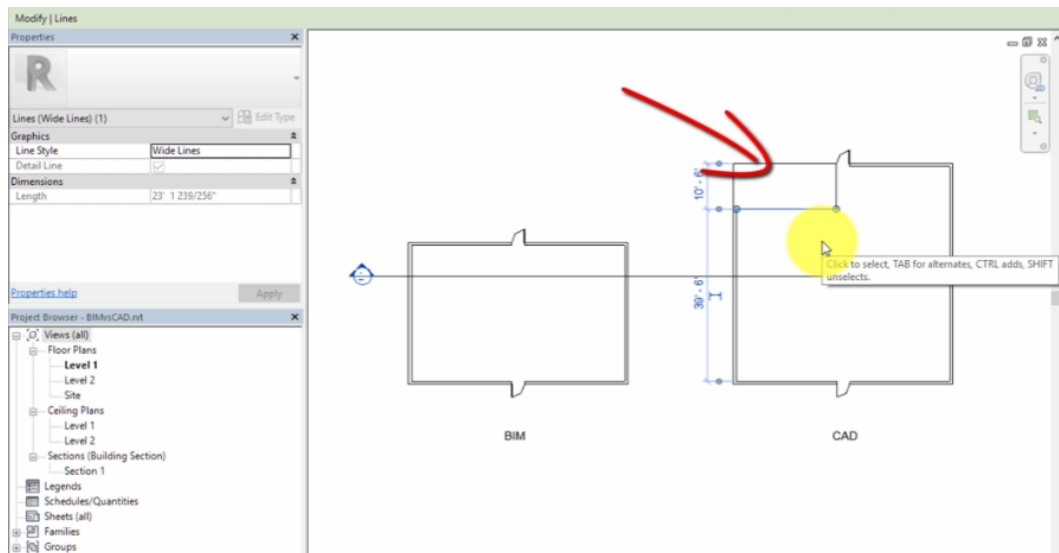

Figure 9 - Not parametric wall (Autodesk source)

Then, double-clicking the blue section head to open the section view. The only layout that shows up is the one on the left (BIM one).
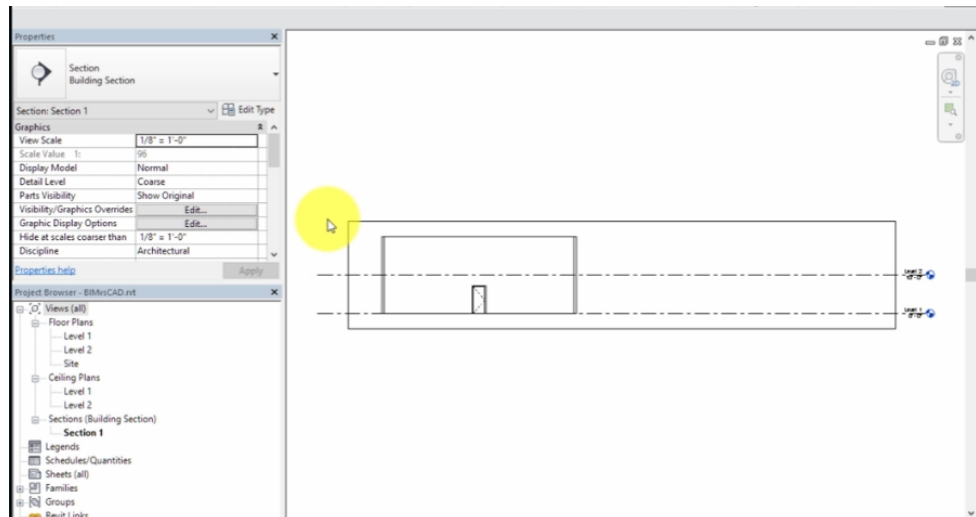
Figure 10 - Section view (Autodesk source)

Switching to the 3D view. There's a new view, and the walls and doors are already there. Again, this is because they are real parts of the building and not just lines.
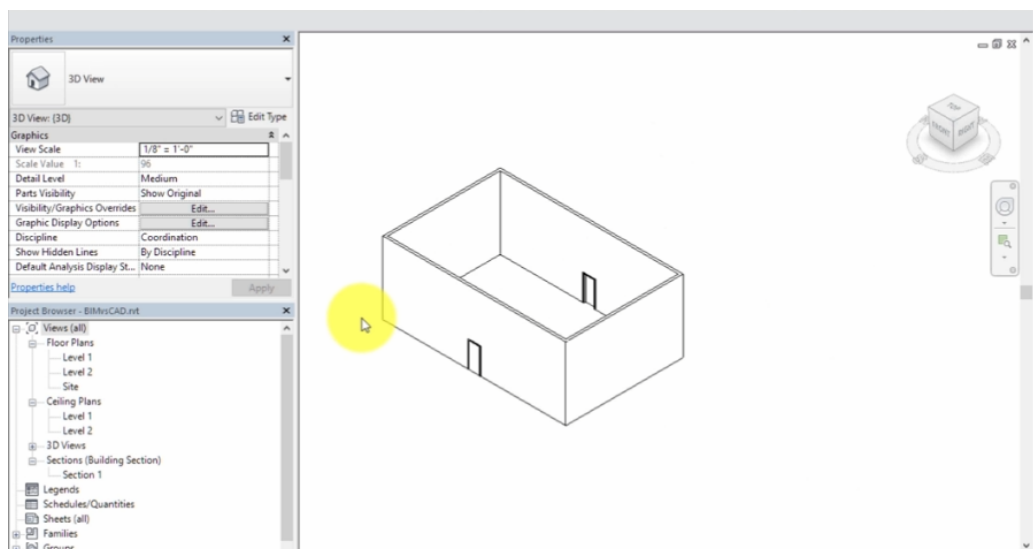

Figure 11 - 3D View (Autodesk source)

When you use CAD to design a building, you mostly focus on making drawings. When you use BIM, you focus on making a model of the building, which can then be used to make the drawings. This saves time because you don't need to draw the same thing twice. Most of the time, you draw floor plans and then sections with CAD. But with BIM, you make the elements in one view, and they show up in all other views where they are visible.

Also, it's easy to use the parameters that are built into the elements when you want to record your design with tags and schedules. This saves time when updating building

25

components and reduces mistakes because a component won't be labelled differently in two views.

Last, Revit is not the same as BIM. Revit was made for BIM, but it doesn't do everything that BIM does. But if you use Revit to make a model of a building, you can easily export it to other programs to make better renderings, do analyses, work with other disciplines, make parts, and so on. When you use CAD, you can't do many of these things. So, there is a lot more interoperability with BIM.

2.2 BIM ADOPTION FOR STEEL STRUCTURAL DESIGN

In the steel business, 3D modeling began to change in the 1990s. In those early days of manufacturing, software had already been made that could automatically make drawings and reports, pull CNC data, and process individual parts. In the 2000s, fabricators started using BIM to solve even bigger problems, like the expensive and time-consuming assembly phase. They let fitters draw information directly on parts by giving them their own interfaces that could use the power of CNC machines. Automatic layout marking technology became common in 2004 and made this great idea even better. From then on, the industry started to see how BIM could be used to boost productivity in a big way

Innovation was driven by the need to be more productive. The market wanted an automated assembly phase because it wasn't happy with traditional CNC equipment. Their dreams came true. Automation has made it easier to move and store things. Robotic welding has become common, even though it isn't always cheap or good for research. More and more software is being made for fabrication. This software uses BIM data to streamline processes and make schedules work better.

But as new ideas change the business, the tools must also change. For example, robotic welding is more complicated than simple duplication, so the ways in which information needs to be shared have changed. To meet new needs, tools like proprietary interfaces have been made better so that information can be sent from the model to the workshop.

After these problems were fixed, models were used to solve problems with logistics and scheduling. Schedules were added, and these became the basis for planning the production schedule. Before sending information to actual production planning, production offices used models to plan how things would work.

Models made it possible to store more information, which made it easier to talk about changes. Even while working on-site, it was possible to understand possible changes better and faster

Because these innovations worked so well, the need for more modelled information went through the roof. As a result, vendors made their own applications with a two-way interface (SW or CNC) to solve the problem. One problem remained, though: these technological advances didn't work well with tools that were already in use.

It was time to make a change. In 2009, the top vendors worked together to improve how the steel fabrication industry worked as a whole. Their goal was to improve the IFC file format so that it better fits the needs of the industry and makes the model a more important part of project workflow. IFC is now the standard neutral file format for exchanging BIMs between different fields.

2.3 MAJOR STRUCTURAL BIM ADVANTAGES

BIM makes things easier, and users will get a lot out of it. One of the best things about BIM is that it can help you do less work twice, like retyping information into models or making changes in the field.

- Better Collaboration and Communication
- Model-Based Cost Estimation
- Structural analysis
- Structural design
- 3D modeling construction
- Increased Productivity and Prefabrication
- Design structural steel
- Steel structure detailing
- Creation of 3D, 4D and 5D BIM services
- Extraction of structural components
- High-quality construction documents
- Clash detection and risk mitigation
- Creation of intelligent parametric libraries
- Accurate quantity take-offs and Cost estimates
- Improved Scheduling/Sequencing

- Stronger Facility Management and Structure Handover

On the following are reported some advantages from some applications in literature for BIM in Steel Structures

Tekla solid interface

One example of a case study is the Tekla solid interface, which has helped Ficep, an Italian company that makes equipment for structural steelwork, create a scribing interface through the Steel Projects WinSteel application. Using a special milling head on their latest CNC-controlled saw and drill machines, this interface marks the fitting positions and reference information (mark, angle of inclination, amount of weld, etc.) on the actual structural steelwork member. This saves time that would have been spent "marking out" the workshop, which is similar to how the outline of a stamp is put on an envelope to show where it should go. Welders can then just weld the fittings in the right place because all the reference information and weld requirements are on the member. They don't have to look at the fabrication drawings, which is another place where mistakes can happen. All of the 3D geometry is sent to their software systems, so all of the information about holes, copes, member bevels, and weld preparation can be sent. This is because all of this information can be very complicated and is not fully supported by the current industry manufacturing format, DSTV4 (Deutscher Stahlbau-Verband). In the precast concrete industry, this kind of technology will soon be used to control robots that weld and place reinforcements.

Lujiazui Finance and Trade Zone

It is in Shanghai's Lujiazui Finance and Trade Zone, which is the biggest international finance and trade center in Asia. The Shanghai World Financial Centre has a planned height of 492 m above ground level. It has 101 floors and three basement levels with office space, a 15-floor five-star luxury hotel, a six-floor observatory tower, conference facilities, shopping, and 1100 m2 of car parking. It has 31 elevators and 33 escalators and a total floor space of 381 600 m2.

This building was planned to be built in 1997, when the foundation stone was laid. It was designed by US architects Kohn Pedersen Fox. The project was then put on hold because of a lack of money brought on by the Asian financial crisis. The project has gone through a lot of changes. For example, the "moon gate" at the top of the tower was changed from

a circle to a trapezoid because some people thought the original shape looked too much like the Japanese flag. The tower height has also been cut from the original plan's 510 m to 492 m. China State Construction Engineering Corporation (the general contractor), Leslie Robertson Associates RLLP (the structural engineer), Shanghai Grandtower, Jinggong, scksteel, and Yokomori steel structure (the structural steelwork contractors) made up the development team for this $1 billion project. It was up to the steelwork contractors to make the 60,000 tonnes of structural steelwork. Shanghai Tongqing Technology Co., Ltd. and Shanghai Rightfly Building Technology Co., Ltd. made the BIM model, which was built and used by steelwork contractors for design coordination, drawing creation, and making fabrication information and NC data. This may be an older way to think about how BIM is used. But it's important to remember that this plan has been in the works for a long time and that a number of steelwork contractors have worked on it. Then, this could be seen as a common way to work on projects made in the last 10 years, using only modern technology.

3 CASE STUDY

3.1 INTRODUCTION

The case study chosen to test the methodology developed in this thesis is the project of a steel building in Deruta (Perugia). The choice was done because there is a need from the author to discover BIM Modeling benefits for steel structures design. Another reason is to compare the BIM methodology against traditional design in terms of time cost and clearness of paper sheets.

In parallel with this test field necessity, the application on a real context as favoured by the Studio Lenzi & Associati in Bologna (Italy) offered the chance also to evaluate how BIM methodology is effective in transforming a traditional engineering practice into a more competitive firm in AEC (Architectural Engineering and Construction).

3.2 DESCRIPTION OF THE BUILDING

The intervention area is located on the outskirts of Deruta (Province of Perugia), specifically in Via Circonvallazione Nord in an area that is mainly agricultural and industrial. The area is located in the north city of Deruta.

Figure 12 - Aerial photo of the lot (google maps source)

There are three buildings on which work has been done, as shown in the photo below:

Figure 13 - building labels (google maps source)

The project includes:

- in building 1, an internal metal structure is being built to respond to the seismic action. The reconstruction of the intermediate floors will be set back from the external wall to maintain the continuity of the external windows;
- building number 2 is completely demolished and replaced by a external staircase with metal structure, as well as services and technical rooms;
- Building 3 will be also demolished and reconstructed with steel frames. The spaces will remain the same and fire proof walls will be layered to separate the different owners of the warehouse;

In Building 1, the construction of an internal staircase and the installation of a panoramic lift are planned. In building 3, in correspondence with the other property, it is joined with such distances that it does not beat in the event of a seismic action. Close to the perimeter wall of the new building, about 60 cm, a 10 cm Ytong fire protection wall with EI-REI 180 was inserted.

It is also stated that some existing walls were preserved for their historical value. The latter were not assumed to be earthquake-resistant structures, but were

considered to be the seismic mass of the building, fully absorbed by the proposed metal structures.

As regards the foundation, as first step jet grouting was poured then a deck slab has been built.

The graphical drawings, for ease of reading and understanding, have been structured in three parts and named with A, B, C as in the following diagram:
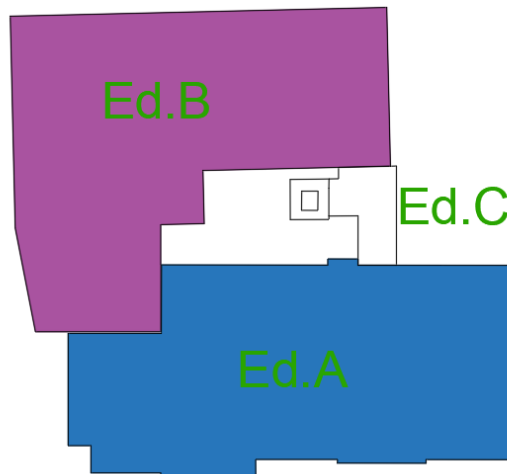
3.3 THE SOFTWARE AUTODESK REVIT

When you use CAD for building design, you concentrate on drawing. When using BIM (building information modelling), you concentrate on creating a building model, from which drawings can be generated.

Autodesk Revit is a type of BIM (building information modelling) design software that is commonly used in the architecture, engineering, and construction (AEC) industries. Revit, one of the most popular BIM solutions, goes beyond simple 2D drawings to provide 3D modelling and documentation of architectural, structural, and MEP (mechanical electrical plumbing) systems for a project's entire lifecycle, from design to construction. It also permits to professionals in AEC field to work together developing a master model. This master model is combining architectural, structural and MEP models in order to create a unique project. This master model helps to find interferences between different projects to anticipate on-site issues that can lead to delayed delivery of the building.

According to the UK-based NBS's annual BIM Report, only 13% of respondents used BIM tools in 2011. Currently, 73 percent of respondents use BIM software

such as Revit. In fact, 50 percent of those polled use Revit software (whether they are architects, MEP engineers, or structural engineers) for their daily 3D modelling workflows, with other 2D drafting software like AutoCAD trailing far behind.

3.3.1 Why use REVIT software

The benefits of using Revit are numerous, and this dissertation will highlight just some of them and its key capabilities as one of the leading tools for creating and managing building models.

Parametric Modeling

The term "parametric modelling" refers to the process of creating 3D models based on a set of rules. Revit employs parametric modelling through "families." Everything in Revit, from title blocks to 3D views to building components like walls or floors, is part of a "family"; some are built into the software, others are accessible through libraries, and still others are created from scratch. A family can be created by assigning dimensions and properties to 2D or 3D information, which can then be changed by a Revit user (for example, height, width, or thickness of a door family). Revit models now have more control over building design.

Automation

All data used to create a Revit model is stored in a single database. This means that whenever you modify the model, the database is updated. The changes are carried throughout the model, allowing for automation and making the building design process more efficient (as well as eliminating some of the rework associated with chasing changes around our various project files).

Collaboration

One of the key differences between Revit and AutoCAD is the ability for multiple users to work in the same Revit model at the same time, as opposed to AutoCAD, which only allows one user to make changes to a dwg file at a time. Using Revit's 'Sync with Central' tool, users can push their model changes to a 'Central' model while also pulling any changes made by colleagues from that same 'Central' model into their 'Local' copy of the model. This process provides the project team with full collaborative functionality.

The interoperability of Revit with other Autodesk software, such as AutoCAD or FormIt, as well as the extensive plug-ins developed by other software companies and applications, aids in collaboration between multiple teams and disciplines.

Scheduling

In the same way that a Revit model serves as a single database for all information in a model, scheduling in Revit saves time that traditional workflows require. As changes are made to the Revit model, previously created schedules will instantly update to reflect those changes, streamlining one of the more time-consuming processes in the architectural design process. Schedules can also be exported from Revit, modified, and then imported back in with the changes to aid in project management.

Energy Analysis

These days, sustainable design is critical in the design and construction process, and Revit includes several analytical tools that can assist in measuring the environmental impacts of your building design. Specifically, by combining the 'Energy Optimization' tools built into Revit (as well as additional plug-ins available) with "Insight 360" in the cloud, designers can visualize the impact their design could have at any stage of the design process, without the need to create a new model or use other software.

Rendering Presentation

In the design industry, using multiple pieces of software for rendering and presentation materials is a time-honored practice. Nonetheless, Revit provides tools for creating these materials in a single platform. While 3D modeling programs like 3ds Max are certainly useful for some industries, such as animation, the ability to create 3D drawings and renderings directly in Revit, rather than importing your model into another piece of software, saves a significant amount of time. Revit's extensive material libraries and rendering plug-ins are used to create tools for 2D presentations and 3D visualization deliverables. Other applications and plug-ins can be used in conjunction with Revit models to review and present your model in VR (virtual reality) settings, allowing your team to collaborate in real-time from anywhere.

Construction Documentation

Users can quickly review clash detection and identify other coordination issues by utilizing Revit's 3D modeling capabilities and the coordination tools at their disposal. Users can generate high-quality, coordinated, and error-free construction documents quickly with these changes, and in conjunction with the dynamic nature of how changes are populated throughout an entire model.

Furthermore, creating and using Revit project templates internally will ensure consistency across your team's construction documentation, ensuring consistent project delivery across all projects in your office.

Drawing Sheet Set-Up

Because all information in Revit is intelligently connected, changes made in one view are carried over to another. For example, if I move a wall in a floor plan, it will be updated in other plans, sections, perspectives, and so on. When views are dropped onto a sheet, users can rest assured that they will no longer have to chase changes around an entire drawing set housed in multiple files. Instead, the user makes a change in one view and can confidently print the drawing set immediately, knowing that the waterfall of changes associated with that single edit will be carried through the entire drawing set.

Cloud-Based Access

Remote work is now the norm, if not the requirement, for many offices. Keeping a Revit model in the cloud allows you to access it at any time and from any location. A variety of cloud-based platforms are compatible with Revit. Still, the most visible is Autodesk's BIM 360 platform, which functions as a "server in the cloud" where users can save their models, push changes to said models, mark up models and sheets, communicate with team members, and even assist with facility management after construction completion handoff – all through a web browser. This cloud connection expands Revit's power and collaborative capabilities.

3.4 STRUCTURAL MODELLING

3.4.1 Preliminary study

Before to start my travel through BIM methodology I have started analysing all documents related to the case study (i.e dwg files describing the building, technical reports etc.) and I have also spoken with the designers (Architect and Structural Engineer)

of this project in order to be aware with their expectations to achieve the best result possible.

All this preliminary study has been done to avoid the lack of communication that can bring to a increase of time of modelling and lower model information.

3.4.2 Goal-settings

When I started asking myself what I want to achieve from this project it comes naturally to my mind the idea of creating a 3D model that is not only a compound of objects but a model that when you navigate through it, gives you information related to the elements and suggestions on how the construction of these elements may be done in the best way.

The other expected objectives are:

- Creating quotable elements
- Obtain schedules from the model
- Finding interferences between the existing structure and the new constructed
- Obtain plan views, section and elevation views similar to the Autocad dwg files
- Obtain details for the steel connections and 3D views
- BIM information communication must be clear and readable

3.4.3 Methodology implementation

In order to start modelling I need to collect the material necessary to develop the project in a 3D shape.

At first dwg plan views from architectural project were checked and cleaned from not useful information (i.e furniture, quotes etc). Dwg plan views were also transformed in a unique layer. The final result is a simple drawing clear, readable and with low memory request on Revit.

As second step I was searching for parametric families for steel beams and steel pillars. This was a hard task because in Revit Italian contents library were not present, as consequence I could've generate them by myself or try to search an international content. The second option was the preferred one; families from UK content library was downloaded and installed because they were rich of useful information (weight of beams, cross section, moment of inertia etc). All this data are time costing if modelled by ourselves.

Third step is to open Autodesk Revit 2021 and link the dwg plan views. The important task to do in this stage is to make the software aware in which units these drawings were done otherwise putting the option auto-detect can sometimes lead to errors and strange behaviour from the software.
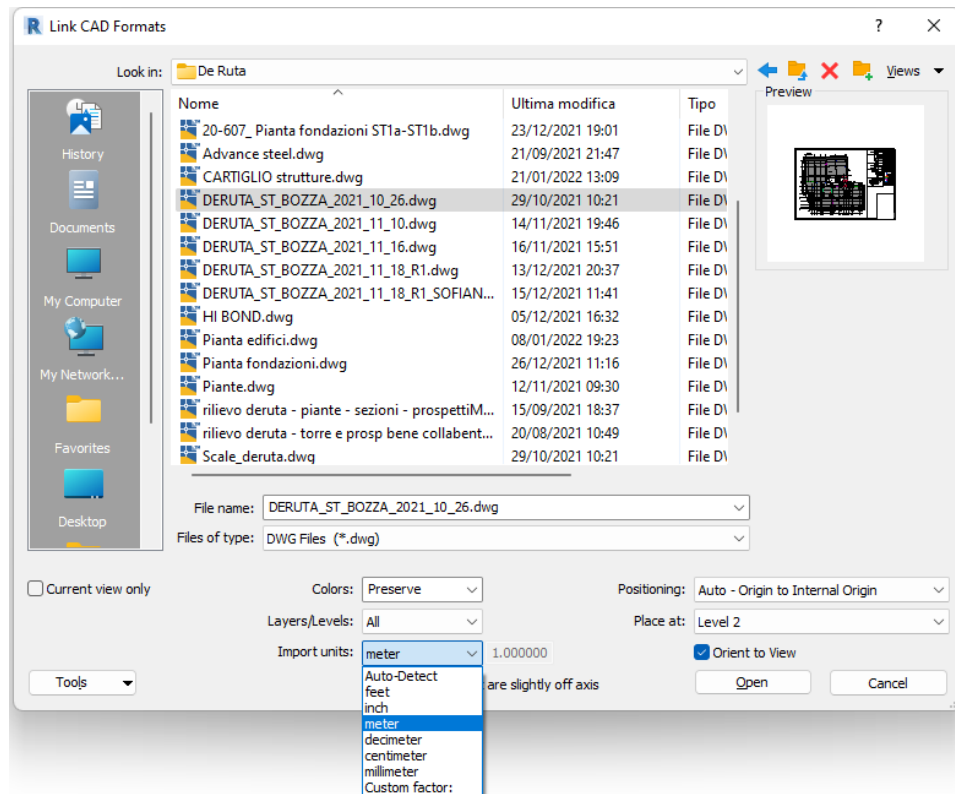

Figure 14 - Linking CAD Formats

Grids and levels

After gathering all of the necessary information, I began by defining the grid's position in order to be precise in putting the pillars in place and easily manage their future changes in position. Another fundamental task to do when starting modelling in Revit is to set up the levels that are finite horizontal planes that serve as a reference for elements that are level-hosted, such as roofs, floors, and ceilings. By setting the levels as we are doing our 3D model automatically plan views will be generated as consequence when you delete a level, Revit also deletes the model elements and views that the level hosts (for example: doors, furniture, and rooms).
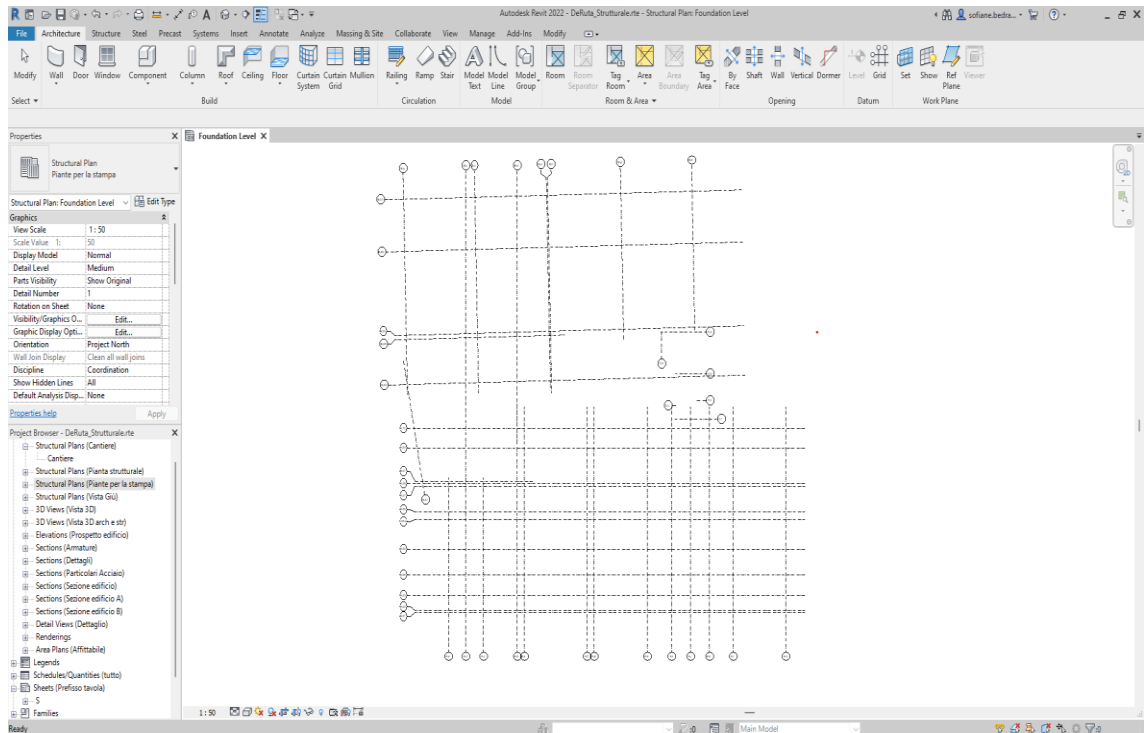
Figure 15 – Grids

3.4.3.1 *Slab foundations*

After located grids and levels now is time to model the structural foundations. For the three buildings the slab foundation with a 40 cm depth was used. For structural purpose there was necessity in buildings number 1 and 2 to create an isolated area underneath the pillars with a slab foundation deeper (60 cm).

To create the slab foundation, you can either select walls or by sketching. For this case it was done by sketching the surrounding perimetral area in the dwg drawings leaving empty the space necessary for the deeper foundations by doing so there were no overlapping between the two basements. Foundation slabs are added below the level in which they are drawn. Therefore, if you add a foundation slab in Level 1, it is added below Level 1 and will not be visible in the Level 1 plan view. To see the foundation slab in a plan view, create a new level below Level 1, for example, Foundation Level. When you create a new level below Level 1, you will also be able to see the foundation slab as an underlay (displayed in halftone) in Level 1.

3.4.3.2 *Ground floor*
Steel pillars

38

Once the substructure, grids and levels are set up now I have to put the steel columns in place. To do so I must seek in the Autodesk families that I have downloaded and look for the one I need. For the building blocks number one and two the choice was HEB 240 and HEB 200 respectively, but for the last component I have used HEB 200 and HEB 160.

In REVIT toolbar ones I have chosen which column to use I must specify the height of this pillars. The best choice I can do is to constrain for every level his set of columns (i.e. for the first floor I have chosen to constrain the pillars to the foundation level as bottom one and to the level 1 as highest one) and not one that goes from bottom to the top of the building. By doing so when I have do changes in my structure it will be easier and efficient.

Constraints	
Base Level	LEVEL 1
Base Offset	0.0
Top Level	LEVEL 2
Top Offset	-300.0

Figure 16 - Level 1 pillar constraints

To put the columns REVIT gives us two options: placing them manually by clicking on the position desired or automatically by selecting the intersection of the grids. As expected and for time saving I used the second one. Ones the columns are placed I had to rotate them one by one just pressing the space bar of my keyboard.

Steel beams

Now is time to join the steel pillars with steel beams. Therefore, as I have done for the steel columns, I need to seek for the designed metal beams in the Autodesk library content that I have installed. For the floors of the components, I have used HEB 260 / 240/ 200 and for the roof HEB 200/180 as primary beams. As secondary beams HEB 200/180 and IPE 220 were used.

To place them, I went to the plan view in the project browser of the desired level. I have used the command on grids but before this I had to check the level where I want to place them otherwise, they can be placed in a wrong level.

Now is time to set the secondary beams. For this operation REVIT comes in our help because there is a command called beam system that is a method to frame a desired area automatically by setting some inputs (i.e. beams type, spacing etc.). But before placing

this beam systems I had to set the reference plane. In some cases where needed just to set some instances like spacing and beam type in another cases I had to sketch. When sketching a beam system boundary, you can specify the beam direction within the structural beam system. All beams within the beam system will be parallel to a boundary line you select. To draw the secondary beams, I have preferred the 3D view.

Bracing

Always from UK content library I have uploaded my bracings in my project. For design purpose UPN 100 / 140 / 180 / 200 and 240 were used. To model them I had multiple choices and I preferred to create a section of the building then draw the bracings.
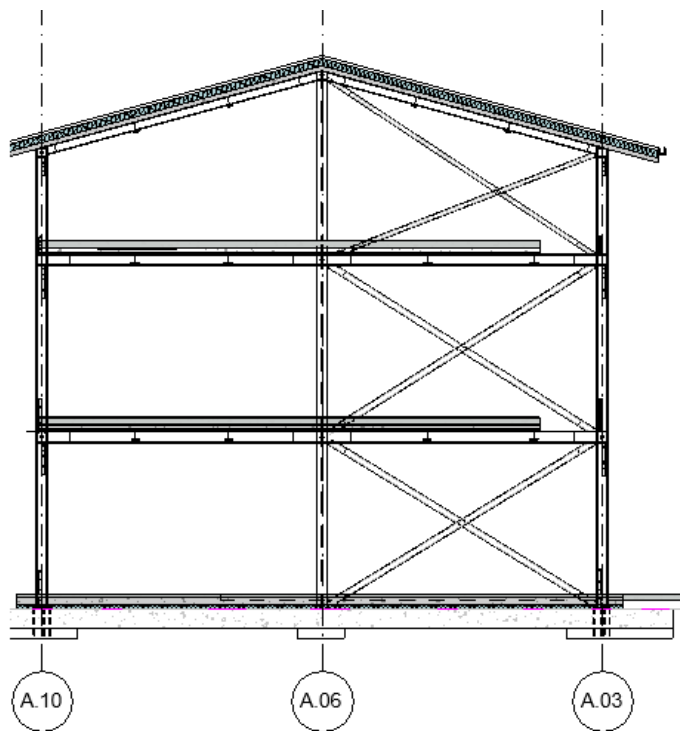
Figure 17 - Section view

Structural Floor

To create the floor for the ground level I have used an architectural floor and a structural floor from basic Autodesk Revit library. I have duplicated them and changed their properties to fulfil the design requirements (height and material). To align the floor with existing structure, I sketched the floor boundaries by drawing lines in the model. As we are in a structural model the floor is offset downward from the level on which it is created (this is a feature for structural project).

3.4.3.3 *First floor and second floor*

Once I have created the ground floor, I decided to not proceed in modelling every single structural element as I done for the ground floor but I just selected all the instances (pillars, beams and beam systems) and copied them simply by typing ctrl+c. After that I have exploited the command "paste" that allows users to paste elements copied and align them to selected levels.

The difference from the ground floor and upper floors is that we need for the latter floors where we can locate steel reinforcement and also a custom metal deck. To model this one I had to go on the project browser and look for a standard one similar to our custom profile and edit it with the desired dimensions.
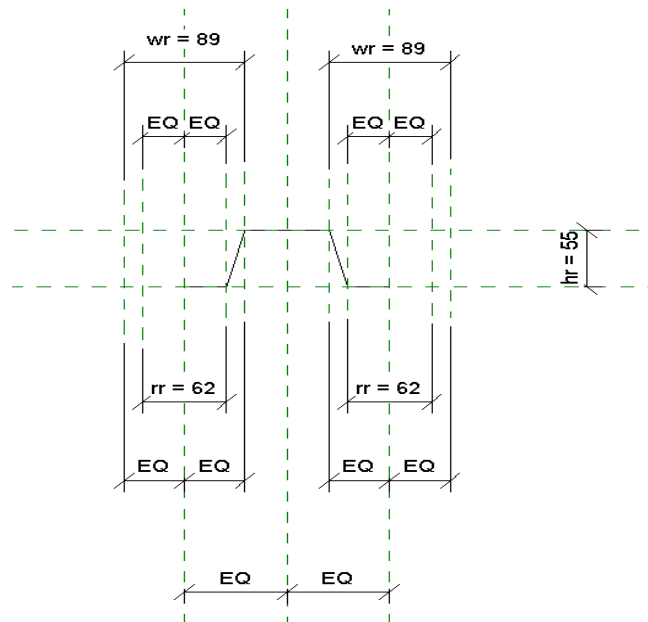
Figure 18 - Custom metal deck

When I have uploaded this metal deck on my project I just have to set it on the type properties section of the floor family. Ones this operation is done I sketched my floor boundaries and I have used the command shaft to do some opening in the structural element for plumbing and electrical.

I had also to draw manually bracings for upper floors because there were some inaccuracies if I wanted to copy/paste. I followed the same procedure described in bracing section.

3.4.3.4 Roof

To model the roof, I have imposed a level for the maximum height of the boundary pillars and a second one for the pillars in the roof ridge. This was helpful to have an easy snapping in the 3D view to join the pillars with primary beams. To model the secondary beams, I have used the command beam system and defining a spacing and the reference level because the roof has different slope pitch.

For the third building there was a need to create a vertical shaft in the roof. This was done by exploiting the command Vertical Shaft.

3.4.3.5 Stairs

After modelled the entire structure now I must connect the different floors by stairs. In this project I had to model two type of stairs one with reinforced concrete structure and the other one has a metal structure.

Reinforced concrete stair

To model the stair in building number 1. I have used the dwg architectural as base but before to start drawing I had to choose in the architectural tab the cast-in-place stair and editing it type properties (i.e. risers, structural depth etc).
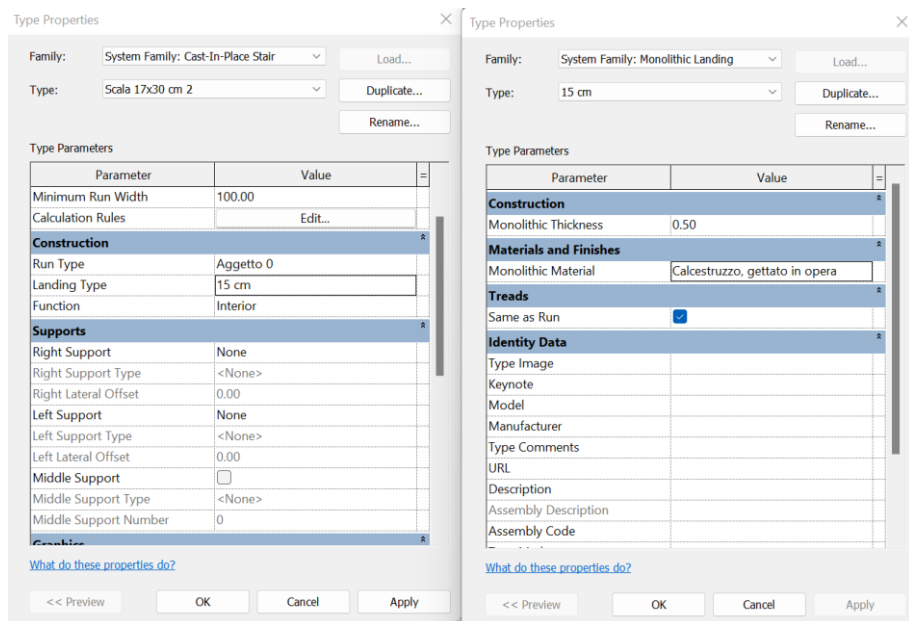

Figure 19 - Concrete stair type properties

Once I have set the type properties of the stairs, I defined the two levels that I want to connect (ground floor and first floor) and the width of my run. Furthermore, I have started

drawing the first run and the second run by sketching the boundaries. The landing is automatically created.

The stair is not yet finished because there was the need to connect the ground floor structure to the structural stair deck. For this purpose, I have chosen to model in place the structural part of the stair as consequence my steel reinforcement reached the base foundation.
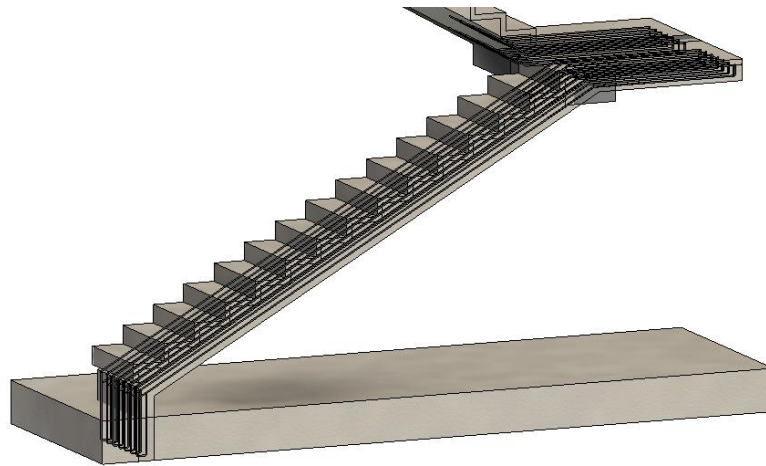

Figure 20 - Stair connection with the foundation

The stairs for the upper floors was modelled in the same way as described above.

Metal stair structure

This stair is connecting the different floors of building number 2. It is located outside of the structure. To model this type of stair I have followed the same procedure described for the concrete stair with the difference that I had two IPE160 at the two side of the run supporting the reinforced structure with the collaborating metal sheet.
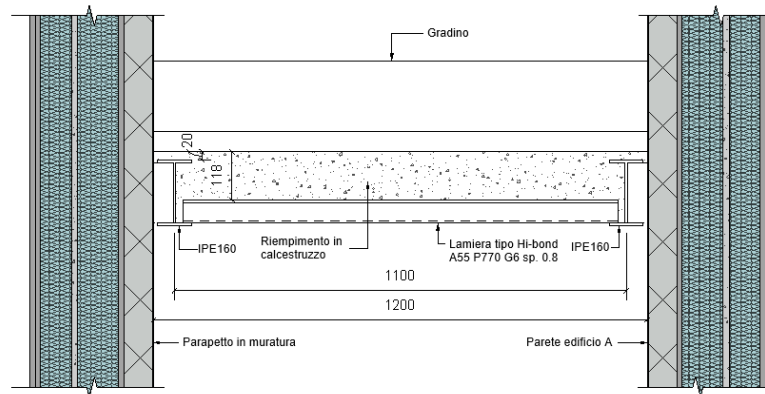
Figure 21 - Section of the exterior stair

The two beams supporting this stair has been modelled as last step in a section view in order to follow precisely the shape of the stair. The figure below shows a view for the final model.
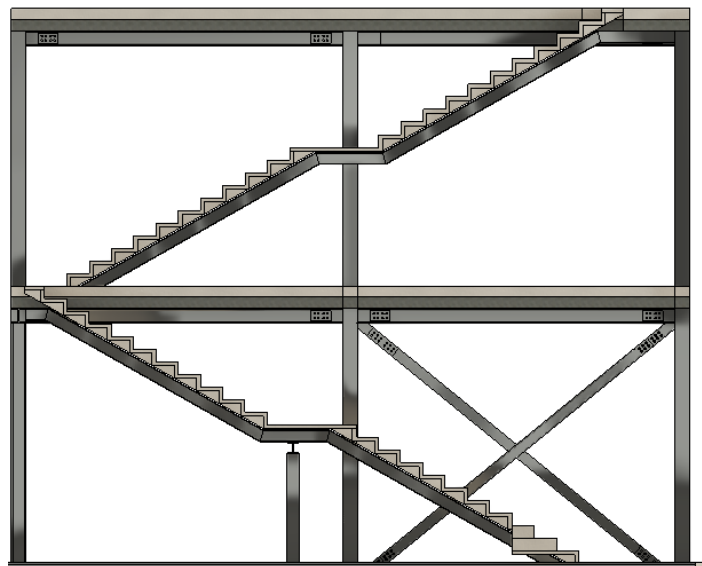

Figure 22 - view of the exterior stair

3.4.3.6   Steel Reinforcements

The first thing I did before I placed a single rebar in the project (given that I have some families at hand) is add and assign some Rebar Covers. This is done from the Structure Tab and Reinforcement menu. Expanding the fly-out and click on Rebar Cover Settings.
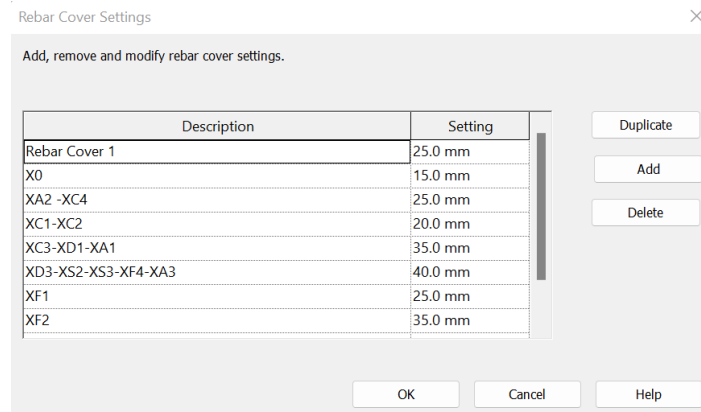
Figure 23 - Rebar cover settings

The Rebar Cover Settings is a simple dialogue box where you can add all the different covers you need for the project. There is always one cover setting that is used by default. If you plan to use one cover value more than the others in your project, you should replace the default cover with that value and then add the other value. So, the most-used setting for your cover will be the default for all elements you model. Getting the cover setting right is important because all (or almost all) of the modelled reinforcement will be slaves to the cover.

Structural rebar

The original and most important tool for detailing reinforcement in Revit is the Structural Rebar category. It can be reached from Revit's Structure Tab or the Modify Tab after an object has been chosen.
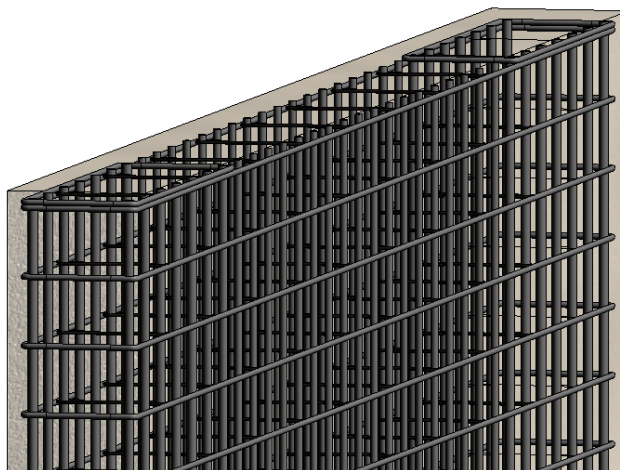

Figure 24 - Structural rebar for a structural wall

There are many ways to add a Rebar to an element, but my favourite is to draw a Reinforcement Section perpendicular to the object, by clicking on the element, and

45

choosing "Rebar" from the Modify Tab. Then I choose the size (diameter) of my rebar bar, its shape, and how it will be placed.

If you are looking at a section that is perpendicular to the element, Parallel to Cover will draw a bar that is perpendicular to your view, and Parallel to Work Plane will draw a bar that is parallel to the section view (even though the view has no valid Work Plane).
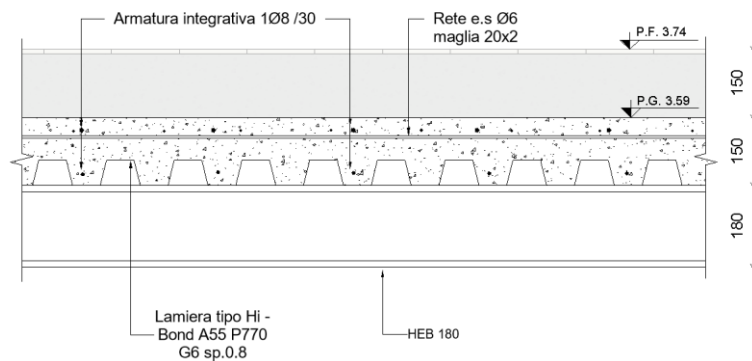

Figure 25 - Rebar floor section view

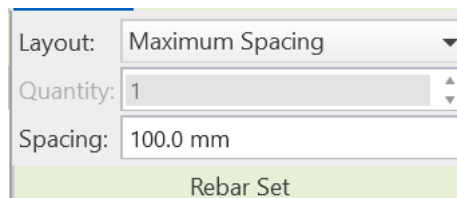You can also choose to lay out the Rebar Set before you actually place the rebar(s):

Figure 26 - Rebar set

With these settings, the Rebar Set will be spread out in a way that is parallel to the plane of the rebar shape.

Another way is to use the Sketch Rebar command under Placement Orientation.

As was said above, the Structural Rebar is made up of three families: the Rebar Bar, the Rebar Hook, and the Rebar Shape.

Rebar bar

Looking at the Rebar Bar Type Properties, there is one parameter that

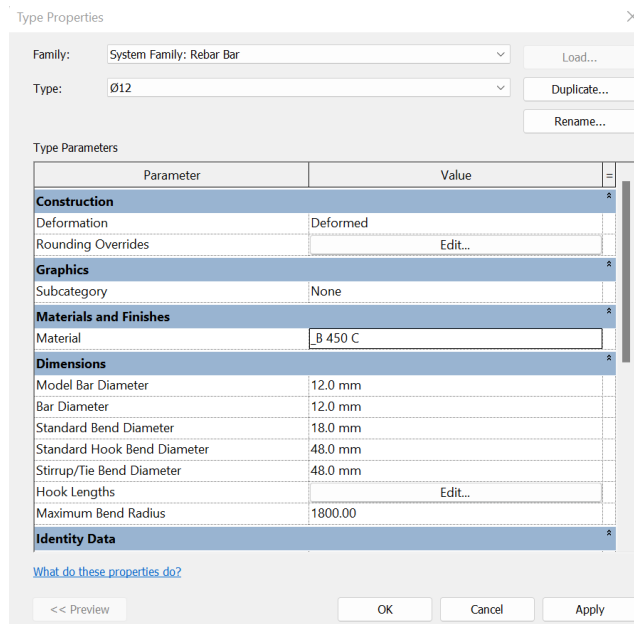stands out as more important than the others.

Figure 27 - Rebar bar Type properties

Like with a wall thickness, it's equally important to let the Bar Diameter parameter of a Rebar Bar family reflect the Type Name. In this project, I only used the Bar Diameter parameter for naming and in the parameter properties I have created a new material (B450C) because here in Italy the steel for reinforcement has different properties with comparison to the one uploaded in the software.

In this project I did not place all the reinforcement needed otherwise it would take a lot of memory making impossible to do even the simplest changes in the project. Therefore, I have used the technique for drawing steel in classical design (by just drawing some lines).

3.4.3.7 *Connections*

Connection in Revit will always show in Generic form in detail levels Medium and Coarse. Realistic connections are displayed in Fine. The Steel Connections for Revit offers 130 parametric steel connections available in 8 groups. Connections are loading into projects using the Structural Connection Settings.
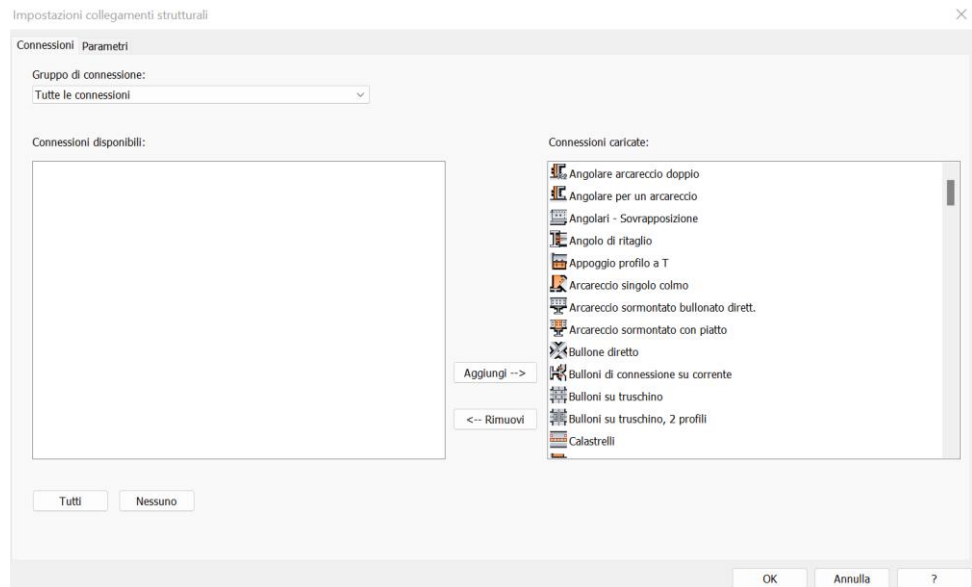
Figure 28 – Connections

This standard connections on Revit were not used for this project.

Bracings and beams

As first step done before implementing the connections is to create three pieces of the elements that I want to join and then start modelling the connections. The command "cut" in the steel tab was useful in cutting precisely the three pieces.

To create custom steel connections, I went in a 3D view by zooming where it was needed then I have used the command "plate" from the steel tab. On the modify/create steel plates tab, I have defined a suitable working plan and drawn my plate profile using the sketching tools. Ones the plate is ready I added the suitable bolts always from the steel tab. Ones I have finished modelling the connection I have created a generic connection between the two pieces of the beam / bracing and I have modified it into a custom one.

The procedure described previously for this type of connection had some issues so to solve this problem I have created a new structural steel connection family that is editable in spacing width height, number of bolts and diameter of bolts.
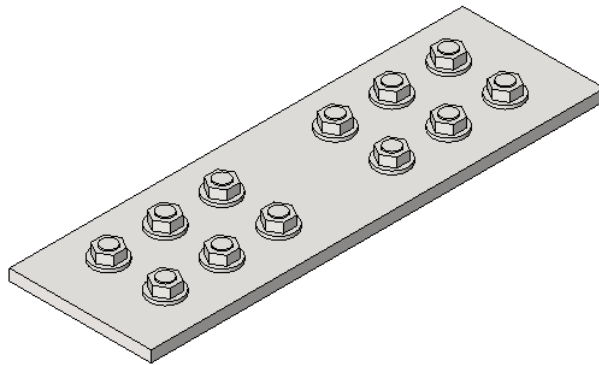
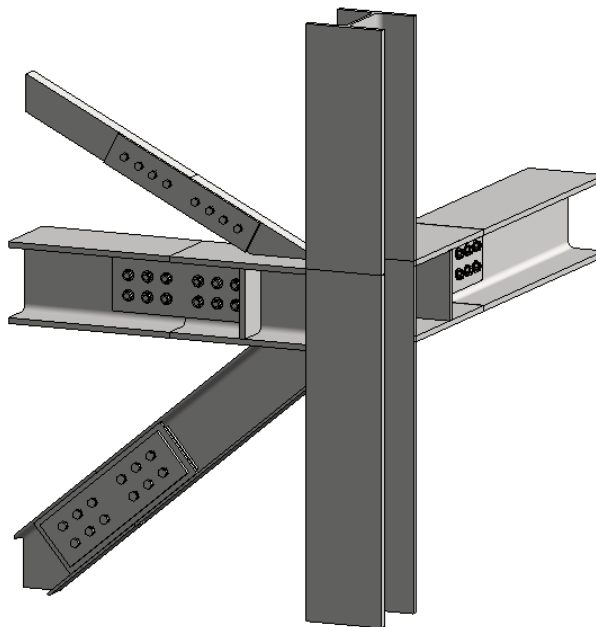*Figure 29 - Custom plate connection for beams/bracings*

Figure 30 - Bracings and beams connctions

Pillars – slab foundation connection

To connect pillars with the base structural element; firstly, I have tried to use Autodesk Revit connection but this was not possible due to the fact that Revit do not have the bolts required in design purpose. Therefore I created again a custom plate for this type of connection and I have download the required bolts from bimobject.com.
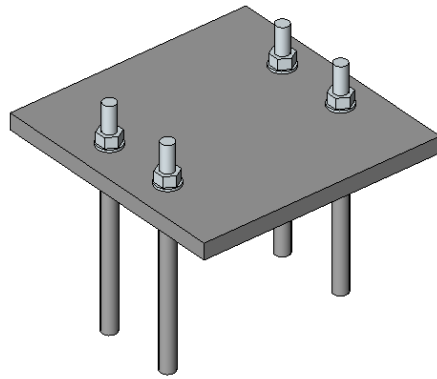
49

Figure 31 - base plate connection

Stiffeners

Stiffeners are an important component of structural steel design; they are used to strengthen a steel beam or a column. To create this stiffeners I went to steel tab, connection, I have chosen stiffeners and then selected the my beam.
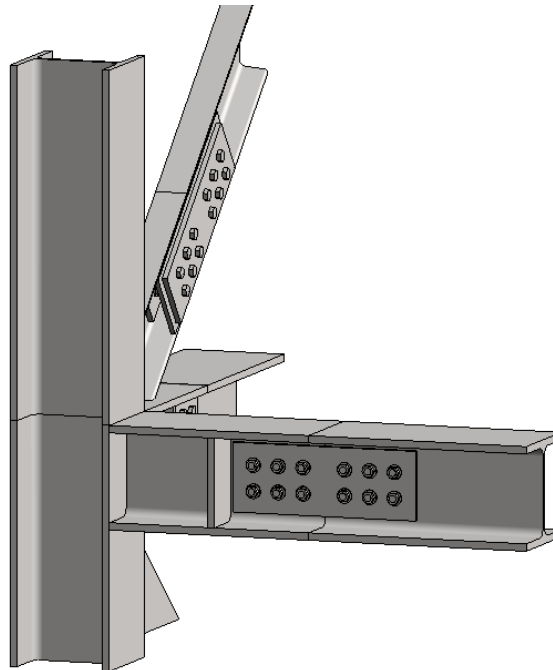

Figure 32 – Stiffeners

Shear connections

For shear connections between primaries and secondary beams I have created custom connections. As first step I have created a plate by drawing a section perpendicular to my primary beam by doing this I could've generate a plate with a custom geometry. As second step I have created a nested family containing a steel plate with bolts then everything was assembled to form the unique connection.
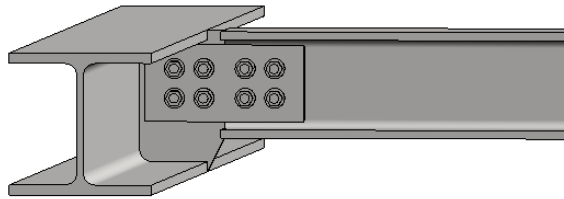

Figure 33 - Connection between primaries and secondary beams

3.4.4 Materials and Parameters

For each element in Revit we can assign a material and parameters. These features can also be scheduled.

3.4.4.1 Materials

A material library is a group of materials and other assets that go with them. Some libraries come from Autodesk, while others are made by Autodesk users. You can organize your things by making libraries.

The libraries that Autodesk gives you are locked, which is shown by a lock icon. The books in a locked library can't be changed or thrown away. You can copy items from a locked library to a user-created library that is not locked, where the items can be deleted or changed.

Libraries can be broken up into smaller parts by adding categories and moving items into them. A library from Autodesk has many different kinds of materials organized by type, like Concrete, Metal, and Glass. Libraries and categories made by users can be organized in different ways, such as by project name or by how they are used.

For this project there was a need for the roof of building number 3 to use a galvanized steel because is more resistant to corrosion as it is facing the weather changes. For this purpose I have used the Autodesk material library to create the new material by duplicating the one already present and changed the name into galvanized steel.

In the figure below is in a shaded view and I want to highlight what I have explained previously. For the building 3 we notice that beams, columns and connections are in red this is helpful when you want to check if you have the material in all the elements of your interest.
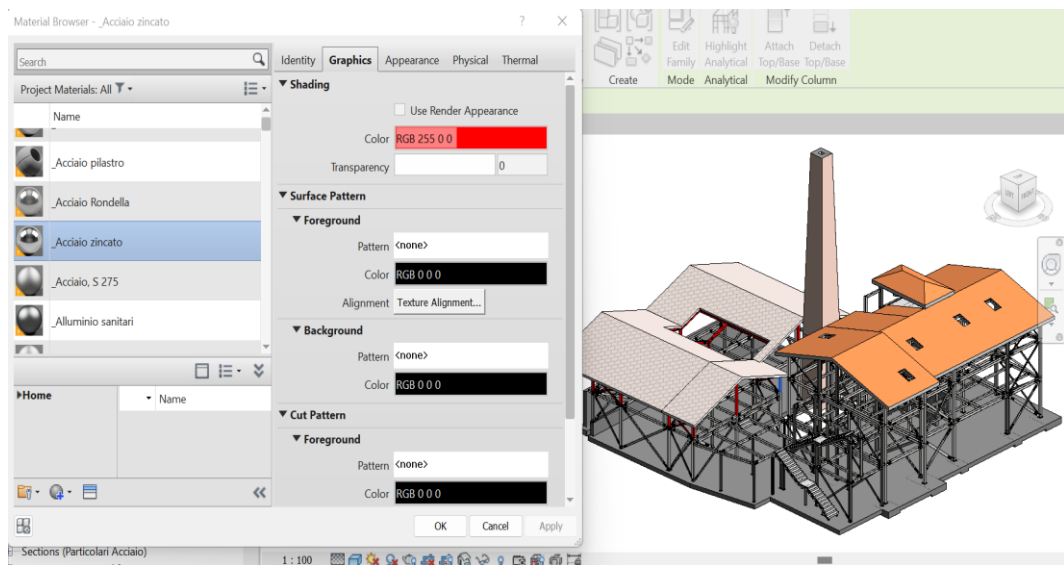

Figure 34 - Material browser, galvanized steel

3.4.4.2 Parameters

Parameters are used to show and control an element's information and properties. You can create custom parameters for each category/element in the projects and sort schedules based on the parameter data. Within Revit, there are three types of parameters: project, global and shared.

For this building I have used project parameter to estimate the weight of the steel elements. Project parameters are specific to each individual project created and added to multiple elements based on their categories in the project. They can be added to more than one category (such as furniture, specialty equipment, and/or generic models, etc.).

What I have done as first step is to create the new parameter from the Parameter dialog, set the discipline to common and set the type to number. I have set the Discipline to Common because the Weight Type Parameter already stored in the steel profiles is set to

the Number type. In order to use the weight in the Parameter formula, the parameters need to be the same type.

Ones I have created in the project the new project parameter, I went to the steel family profiles and I added this new parameter as a Type Parameter with a formula then I have loaded everything in the project.

3.4.5 BIM model information communications

In this section, I will discuss the methods I utilised in this project to communicate information within the 3D model.

Plan views, Elevations views, Section views 3D views and material schedules were used to communicate with all the parts interested in this project (contractors, subcontractors, manufacturers, owners etc).

In this project I have created for each type of information communication a view template in order to simplify the visibility of this ones

3.4.5.1 *Plan views*

Plan views are typically built automatically in Revit and BIM software as you build your 3D model. In Revit ones you set up your levels, plan views are automatically generated. As I have done this procedure in the begging of my project, I had all plan views done what was missing is the labelling of the steel elements. For this purpose, there are some plug-ins that does labelling automatically or to use the command "beam annotation" that labels all the beams in the current view.

Sometimes the default "view range" in the software is not the satisfactory one. So, there is a need to change it and choose another one remembering that in the structural plan view, you look at it from the bottom direction. Therefore, if there are present stairs you will not see them, but you will have to draw them manually by creating the tread depth by over drawing them. Another option I have used to show the stairs in my plan views is to overlap two plan views in the sheets one with stairs (by setting the look from up to bottom in the structural plan family) and one without.
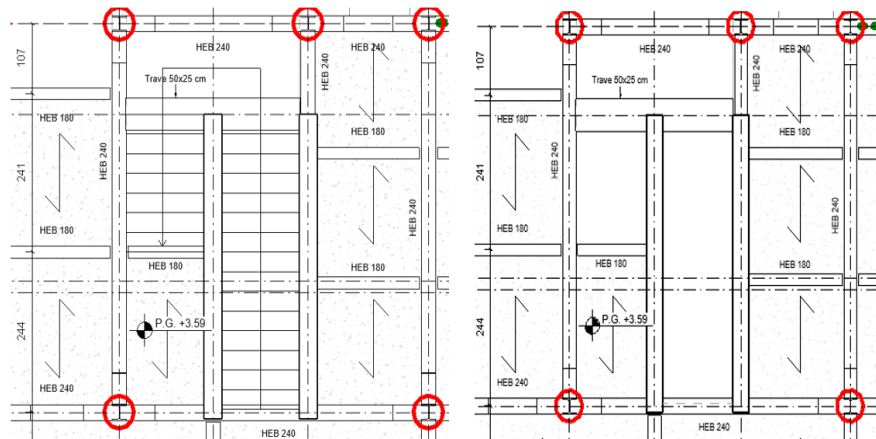
Figure 35 - Plan view stairs

In the upper left figure is depicted a stair with tread and in the right one is without even thought is the same stair but with a different view direction. As explained previously to view the treads we must set the view direction from top to bottom.

In the project browser I have created another type of structural plan naming it structural plan (for printing). The reason I have done this is to sort the plan views for printing and keep them clear as possible.

Figure 36 - Browser project - structural plan views

In the plan views I was asked also to draw some 2D lines to identify the different pillars in the project. This was done by creating for each column a different line with different colour.

Figure 37 - Line Styles

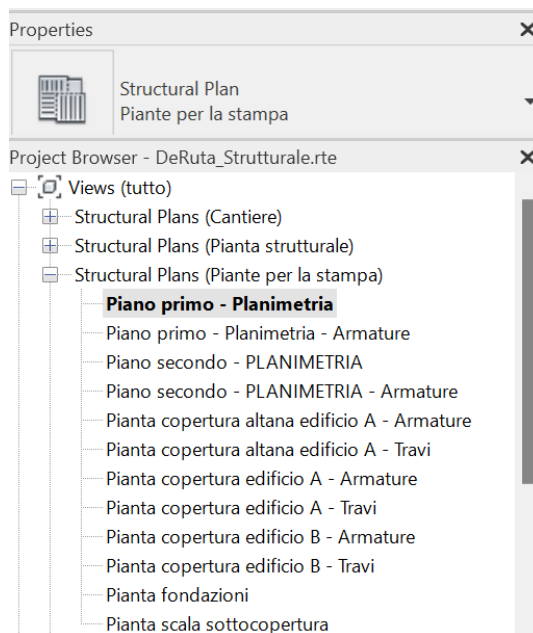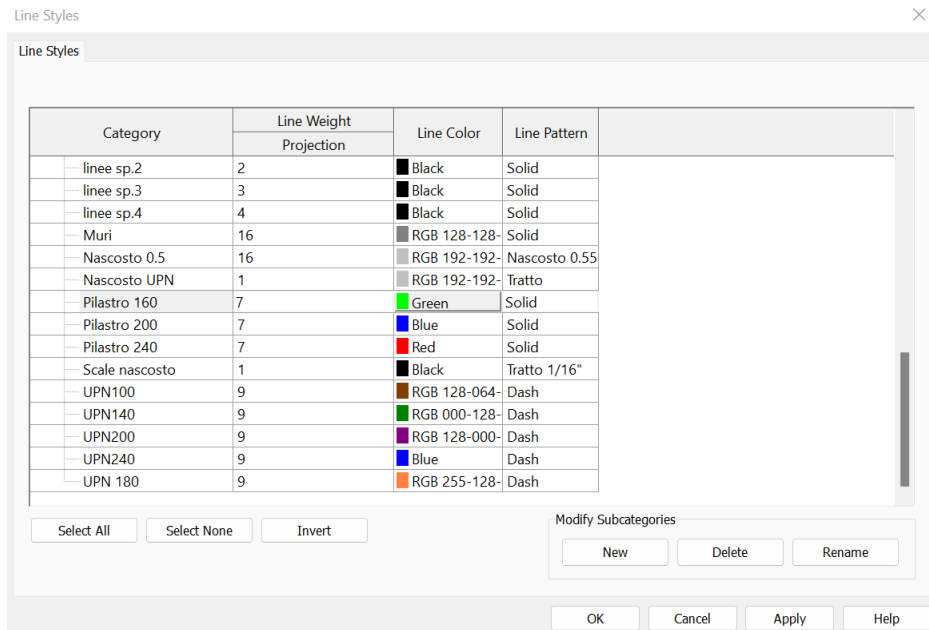When I completed all the adjustments in the plan views, I have checked the thickness by disabling the command "thin lines" and checked that primary, secondary beams had varied line widths. Also, for columns this step has been done.

3.4.5.2 Elevation views

Elevation views are part of the default template in Revit Structure. When you create a project with the default template, four elevation views are included: north, south, east, and west. Usually the elevation views are important to demonstrate how the exterior and interior shape of the building is made.

In Revit you can create additional elevation views by going in view tab and choose elevation. Once the elevation view is sketched by double clicking the symbol you go inside the generated view. Inside my elevation view I had to fix some overlapping elements with "detail line", add some spot elevation symbols because the program does not add them automatically. I have labelled the columns, beams and braces. I have also annotated the elevation view with some useful quotes.

After I completed the elevation view with the missing elements there was the necessity to define the braces with different colours. For this purpose I have created in visibility graphics some filters for displaying the braces with the colours needed.

55
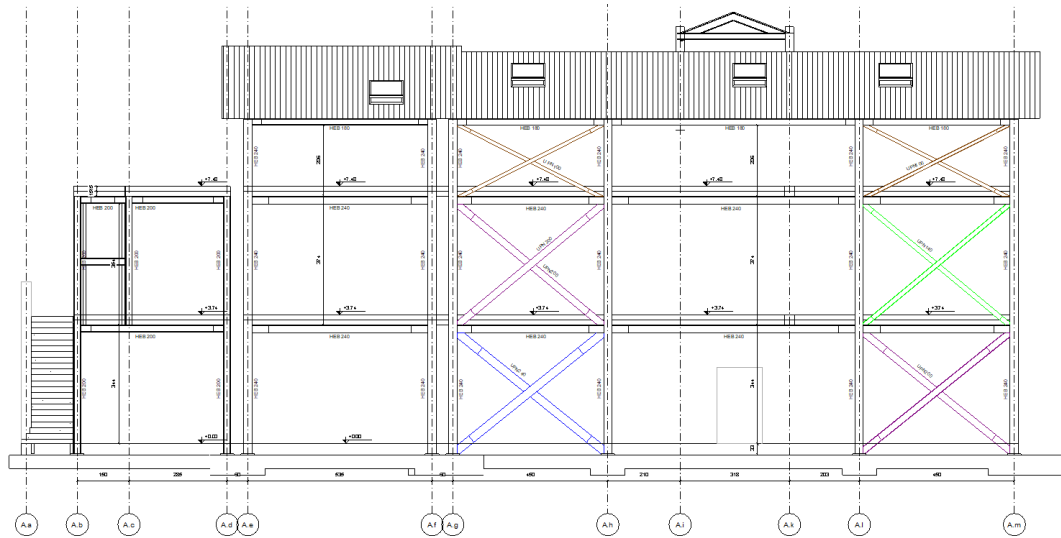
Figure 38 - North Elevation View

3.4.5.3 *Section views*

A section is a cross-section in a building model that you place by drawing a line. The view associated with this section is known as a section view. A section cuts through a model so that the interiors of model components along the section line are visible and from the section you can get the interrelationship between the elements in the building.

In Revit by simply using the section tool you can select the location, orientation and extents of a section view. Revit will automatically process all objects that are cut through and all objects that may be seen within the view, ensuring nothing is missed.

Once I have created my section I have used a view template and fixed overlapping elements as I did for elevation views. Also here I had to add quotes and all the necessary annotation.

Given that I had already created the filters for bracings visibility in the elevation views there was no need to create them again but I had just to activate this later.
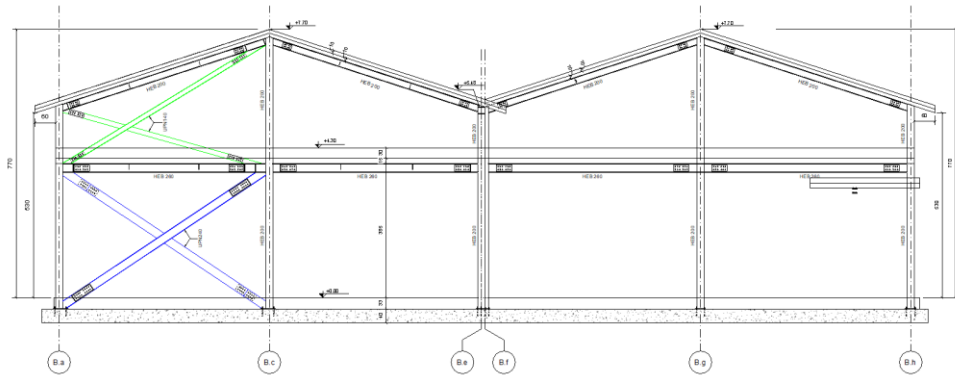
Figure 39 - Section view

3.4.5.4 *Callouts details*

Callout views are used to create an enlarged version of a section of an existing view. A plan, section, elevation, or detail view can have callouts added to it. Revit generates a callout view when you create a callout bubble with a callout tag. You have the option of creating a view callout, a detail callout, or a reference callout.

I want to provide more or different information about a section of the parent view, so I use a view callout. When I wanted to provide information about a specific part of the building model, I used a detail callout. To refer to a single callout view, I used multiple callout tags in different views.

Figure 40 - Section view with callouts
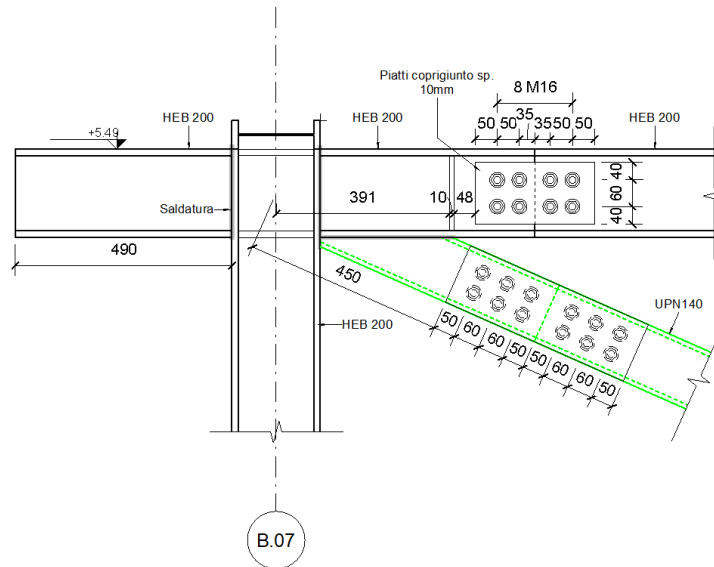
Figure 41 - Callout View from previous section

3.4.5.5 *3D views*

Although the three-dimensional views may seem superfluous in the engineering field, three-dimensional relationships between elements helps all the parts interested on the project during the design process and during the construction site phases.

3.4.5.6 *Schedules*

A schedule is a tabular display of information, extracted from the properties of the elements in a project. A schedule can list every instance of th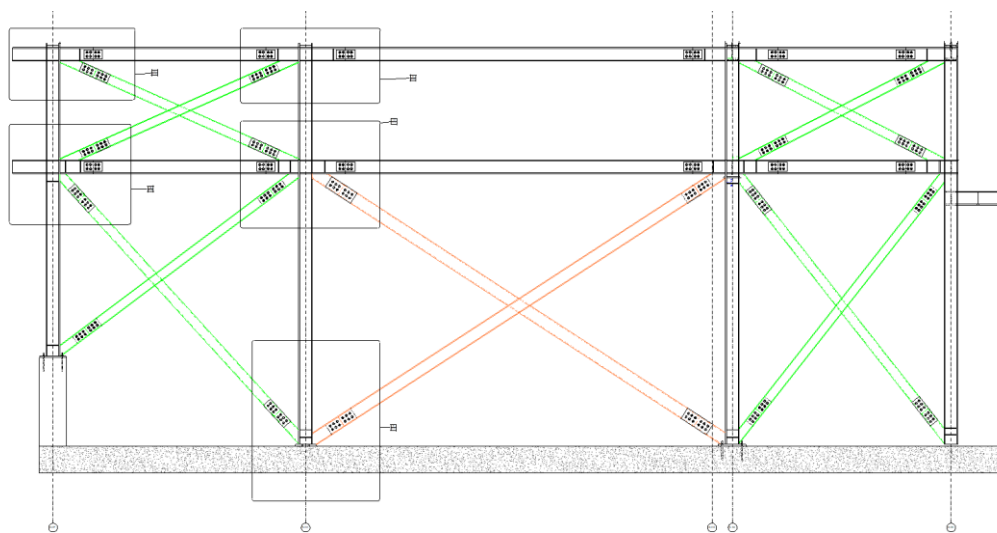e type of element you are scheduling, or it can collapse multiple instances onto a single row, based on the schedule's grouping criteria.

You can create a schedule at any point in the design process. As you make changes to the model that affect the schedule, it automatically updates to reflect those changes. You can add a schedule to a drawing sheet.

There are different types of schedules in BIM software for this project I had to do a takeoff of the steel material necessary to build the three-building block. For this purpose I went to schedule type and I have created my own structural parameter in order to build the final take off. Moreover I had to sort this schedule by material and building name (A,B,C) because there was a need to have a rough evaluation of steel mass.

In the following I have reported the two schedules done in Revit software.

	A	B	C	D
	Type	**Building Block**	**Structural Material**	**Massa**

<Structural Framing Material Takeoff>

Edificio A
_Acciaio

Type	Building Block	Structural Material	Massa
HE200B	Edificio A	_Acciaio	3.07 kg
HE240B	Edificio A	_Acciaio	454.01 kg
HEB 160	Edificio A	_Acciaio	50.62 kg
HEB 180	Edificio A	_Acciaio	17141.74 kg
HEB 200	Edificio A	_Acciaio	7052.20 kg
HEB 240	Edificio A	_Acciaio	23655.60 kg
IPE160	Edificio A	_Acciaio	627.85 kg
IPE220	Edificio A	_Acciaio	2419.54 kg
UPN100	Edificio A	_Acciaio	843.40 kg
UPN140	Edificio A	_Acciaio	2272.51 kg
UPN200	Edificio A	_Acciaio	1746.28 kg
UPN240	Edificio A	_Acciaio	355.91 kg

Edificio B
_Acciaio

Type	Building Block	Structural Material	Massa
HEB 200	Edificio B	_Acciaio	9907.25 kg
HEB 220	Edificio B	_Acciaio	1691.31 kg
HEB 260	Edificio B	_Acciaio	4349.24 kg
UPN140	Edificio B	_Acciaio	459.20 kg
UPN180	Edificio B	_Acciaio	605.21 kg
UPN200	Edificio B	_Acciaio	1451.37 kg
UPN240	Edificio B	_Acciaio	455.02 kg

_Acciaio zincato

Type	Building Block	Structural Material	Massa
HEB 200	Edificio B	_Acciaio zincato	9614.60 kg
IPE220	Edificio B	_Acciaio zincato	1588.67 kg
UPN140	Edificio B	_Acciaio zincato	1005.49 kg

_Acciaio zincato

Type	Building Block	Structural Material	Massa
HEB 200	Edificio B	_Acciaio zincato	9614.60 kg
IPE220	Edificio B	_Acciaio zincato	1588.67 kg
UPN140	Edificio B	_Acciaio zincato	1005.49 kg

Edificio C
_Acciaio

Type	Building Block	Structural Material	Massa
HEB 140	Edificio C	_Acciaio	719.73 kg
Grand total: 973			88469.83 kg

Figure 42 - Structural framing take-off

<Structural Columns Takeoff>			
A	**B**	**C**	**D**
Type	Building Block	Structural Material	Mass
Edificio A			
_Acciaio			
HEB 160	Edificio A	_Acciaio	1131.18 kg
HEB 200	Edificio A	_Acciaio	2992.37 kg
HEB 240	Edificio A	_Acciaio	20090.54 kg
IPE160	Edificio A	_Acciaio	8.03 kg
Edificio B			
_Acciaio			
HEB 200	Edificio B	_Acciaio	4291.12 kg
_Acciaio zincato			
HEB 200	Edificio B	_Acciaio zincato	2682.72 kg
Edificio C			
_Acciaio			
HEB 140	Edificio C	_Acciaio	677.97 kg
Gran total: 142			31873.93 kg

Figure 43 - Structural Columns Takeoff

CONCLUSIONS

3.5 WORK DONE

The casy study as I described in paragraph 3.2 is an existing structure composed from three blocks. In the first block the surrounding walls will not be demolished and we will just build the steel structure inside where as in the second and third blocks the entire structures had been demolished and reconstructed as new preserving the same geometry.

In this case study I had to reach the following goals:

- 3D model
- Creating quotable elements
- Obtain schedules from the model
- Finding interferences between the existing structure and the new constructed
- Obtain plan views, section and elevation views similar to the Autocad dwg files
- Obtain details for the steel connections and 3D views
- BIM information communication must be clear and readable

On the following I will analyse from my point of view for each objective the limits or maybe my limits on the BIM methodology.

The 3D model of the steel structure without connections between the elements it has been accomplished quickly with respect to traditional drawing design. This was favoured by the BIM software because when you are modelling the structure, the 3D steel elements are already prepared for you. You just have to download them and understand their behaviour on your model. Moreover if I was in CAD environment and I have the necessity to draw a beam in a plan, I would do at least 5 operations to draw this beam and it will be visible just in plan view. In the opposite in a BIM environment the plan views are drawn automatically once you are creating the 3D model.

Plan views, section and elevation views where so easy to draw because as I said before once your 3D model is built you obtain whatever views or sections you want. The problem I have encountered is the clearness of this views. For instance in an elevation view (referring to steel structures) in order to create an understandable drawing you must

61

increase your range of view and by doing this you will get so many overlapping lines and stuffs that you do not need. The operations to make the drawing clear are time requiring but still lower than by drawing them in CAD environment. Another problem I have encountered in this objective is that for plan views stairs are not showing and it is quite impossible to show all useful information in a in single sheet containing the plan view.

Another objective that was established is to find interferences between the existing walls in building n.1 and steel elements. This objective is the one that I appreciated mostly in achieving because it demonstrated me how even a novice in BIM methodology can appreciate the use of this later. I have found three fundamental interferences between the architectural model and the structural one that in CAD environment no one has noticed.

For what concerns the steel connections, it was a hard task to achieve because I could not exploit totally the BIM methodology in order to be quicker in modelling them. This task was time costly but in the end I achieved the expected result even thought there was some limits in the software for what concerns visibility for steel small elements. This is why I think that maybe another BIM software can give better results for steel connections and is not the about the methodology used.

I have also succeed in creating quotable elements even if there were some issues related to quotes in BIM environment (for i.e. some irregular geometries may generates difficulties in quoting them). To solve this issues you must "cheat" in order to keep working with BIM methodology because everything is automated.

In this project I had to obtain some takeoffs of the steel beams and columns in order to have an amount of the mass of steel necessary for the buildings. This has been successfully done even if I have encountered some issues related to computation. As it was not necessary a precise quantity of the steel used I can say that the objective has been accomplished quickly.

As new user of BIM software, it was not easy for me to accomplish all this objectives. The main problem that I have found is working alone on this project. I had to do everything by myself although the help of my supervisor. This was not a limit for me but I think I could have achieved all this objective in a lower time than I did and maybe with a better result. Another thing that I experimented is to be cleaver in finding different paths

to achieve the expected results. Because there is always a way, it is up to users to find the best or maybe the functional one.

As this work has been developed in-parallel with the Structural Engineer that had produced the CAD drawings I had the opportunity to compare the time necessary to get the final sheets. I can say that the time spent by me and the Structural Engineer is more or less the same (around 4 months). Although I am a new user of the BIM software I have noticed that using BIM methodology can effectively reduce the time necessary to produce drawings and can give you also some indicative costs of the project.

3.6 WHAT CHALLENGES CAN BE EXPECTED

The opportunity to know and work according to BIM methodology has allowed me to personally experience the potential of these tools. The study developed in my thesis focused only on part of the process. On the basis of the results achieved and the advantages found, I think that this working method can bring benefits in many other aspects of design.

It would also be very interesting to be able to check the progress of the work in the site once it has begun, in order to effectively ascertain how the BIM methodology helps the construction sector.

Throughout this experience I was able to broaden my knowledge about a subject that is not yet widespread in Italy particularly in small firms, and towards which in some cases there is some scepticism with respect to traditional practices. The hope is that my contribution, and that of many other researchers, will be of support for development, innovation and change, and that it will push the most doubtful to become curious.

ACKNOWLEDGEMENTS

BIBLIOGRAPHY

EASTMAN, C., et al., 2008. BIM Handbook. A guide to building information modeling for owners, managers, designers, engineers and contractors. John Wiley & Sons, Inc;

https://bimmda.com/en/what-is-bim-and-what-is-not-bim

https://www.autodesk.com/industry/aec/bim/structural-engineering#:~:text=What%20is%20BIM%20for%20structures,document%2C%20and%20fabricate%20structural%20systems.

https://www.autodesk.com/industry/aec/bim/mep

https://www.autodesk.com/industry/aec/bim/civil-engineering

https://constructionreviewonline.com/products/acca-software-architectural-bim-software/

https://civilfrance.typepad.com/.a/6a0120a619192b970b0168e9e46b20970c-pi

https://www.aimircg.com/10-best-architectural-rendering-software-for-architects-in-2019/

https://www.sotham.co.uk/advantages-and-disadvantages-of-bim/

https://knowledge.autodesk.com/support/revit/learn-explore/caas/video/youtube/lesson/143344-courseId-100332.html

https://blog.bimsmith.com/Whats-the-Big-Deal-About-Revit-Understanding-the-Role-of-Autodesk-Revit-in-Architecture-Engineering-and-Construction

https://microsolresources.com/tech-resources/article/10-benefits-of-revit/

https://knowledge.autodesk.com/support/revit/learn-explore/caas/CloudHelp/cloudhelp/2021/ENU/Revit-StructEng/files/GUID-8573C22F-191B-4954-9C29-00A245D39EC4-htm.html

https://knowledge.autodesk.com/support/revit/learn-explore/caas/CloudHelp/cloudhelp/2021/ENU/Revit-Customize/files/GUID-26E4614F-6BAF-4F63-A285-99F1B3BE02F5-htm.html

https://hvasshaug.files.wordpress.com/2014/12/session-7-rebar-handout.pdf

https://knowledge.autodesk.com/support/revit/learn-explore/caas/CloudHelp/cloudhelp/2021/ENU/Revit-DocumentPresent/files/GUID-73090B70-8A13-4E12-909C-F25D724D5BA7-htm.html

https://www.constrofacilitator.com/bim-in-steel-structures-value-and-case-studies