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Structural BIM Modelling Using Tekla Structures

Focus on a Modelling Process of an Office building

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The main objective of this thesis was to explore the utilization and benefits of BIM with a focus on the structural modelling process and clash detection. Structural BIM tools Tekla Structures (2016) and Solibri Model Checker v9.7 were used for developing a structural model and clash detection, respectively, of an office building.

The purpose was to find various underlying benefits of BIM in generating a structural model. Systematic use of different structural tools for the BIM application which focused on modelling and documentation phases were emphasized. BIM was studied from various perspectives. To test the various tools, an office building was modelled, and an IFC (Industry Foundation Class) file made of it for Tekla Structures. For clash checking, Solibri model checker was used.

A step by step guideline for modelling an office building and checking clashes was presented. This thesis can be used for educational purposes and for new Tekla Structures users as a guideline. In addition, engineers working with the Solibri model checker can use this thesis as a reference document.

Keywords	BIM, structural modelling, Tekla Structures, Solibri Model Checker, COBIM

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Aman Oli
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Contents

Abbreviations

BIM	Building Information Modelling
AEC	Architecture, Engineering, and Construction
CAD	Computer Aided Design
IFC	Industry Foundation Classes
MEP	Mechanical, Electrical and Plumbing
HVAC	Heating, Ventilation and Air Conditioning
VDC	Virtual Construction and Design
JUST	Järvenpäänn Uusi Sosiaali ja Terveyskeskus
CAVE	Computer Assisted Virtual Environment
GA	General Drawings
SMC	Solibri Model Checker
COBIM	Common BIM

1 Introduction

Building Information Modelling (BIM) in engineering industry is considered as a paradigm change and a periodic transition for new ways of handling engineering projects. BIM implementation in engineering projects saves time, reduces costs and provides better results. BIM is widely known as a digital representation of physical and functional characteristics of a facility. BIM places more emphasis on a conceptual design with a guarantee of consistency across all the reports and drawings with automatic space interference checking. BIM also provides a strong base for simulation and cost tools. Although different disciplines use specific tools and features in order to make their work processes smooth and easy, BIM helps them all to communicate at all phases of the project. [1.]

BIM is not a software program or a product nor just a 3D module, but a platform and tool for collaboration with reliable information exchange, product data information visualization, and analysis all through a project's life cycle. BIM principles and the underlying information continuously helps engineers to predict the project performance and enable them to extract valuable information from a model for better decision making. Furthermore, BIM applications also help to make projects economically and environmentally sustainable. [2.]

Figure 1. Information exchange through BIM [3.]

A 3D model is often misconceptualized as a building information model. However, a 3D model is one of the reliable ways of sharing project visual information which can make a significant change in the workflow and project delivery. The 3D model thus helps project stakeholders to visually perceive project information. BIM processes and tools, on the other hand, provide aid to simulate the whole project prior to the construction phase so that different engineering disciplines can identify the problems and find possible solutions before the construction begins. BIM helps project participants to communicate and exchange information during the life cycle of a project in a systematic way as shown in figure 1. BIM can be utilized from a very early phase of a project to the operation and maintenance phase of a building. BIM helps to optimize the construction process so that it is possible to deliver project on time with reduced costs and better quality. BIM technologies and processes have methods and tools to increase the productivity of construction industry. [3.]

1.1 Development history of BIM

Today, BIM is seen as an innovative solution towards increasing the productivity in engineering. The AEC (Architecture, Engineering, and Construction) industry has gone through various stages of technological evolution from various computer aided design (CAD) applications to the current state of BIM tools and processes. In 1970, the concept of Building Information Model was introduced theoretically by academia for the first time. Afterwards, the major CAD vendors such as Autodesk, Bentley Systems, Trimble and Graphisoft began to use the concept of BIM. [3.]

1.1.1 Evolution of BIM

Technology has the AEC industry. It has changed the way of managing engineering projects. The traditional approach of using pen and paper for representation of engineering elements was replaced by Computer Aided Design (CAD) systems as shown in figure 2. Along with the technological development, CAD systems introduced the possibilities of three-dimensional (3D) modelling approaches with basic primitive shapes like boxes and spheres. However, the 3D models lacked information. Object oriented CAD (OOCAD) was introduced so that information related with the products in the drawing was included to some extent. Today, BIM is a developed form of OOCAD systems, which uses information architectural element and includes the information model required for a smooth flow of projects. [3,4.]

Figure 2. Evolution of BIM [4.]

Along with the benefits of visualization, BIM tools provide various possibilities for a project, like quantity take off, cost calculation and optimization, resource calculation and optimization, linked automated documentation, structural analysis, clash detection, report generation and energy simulation. BIM implementation allows the projects to be viewed in different dimensions from simple 2D information to 3D to 4D (3D plus time) and even 5D (4D+ cost). BIM tools use information rich 3D objects and geometry that help users to control the significant amount of data. [4.]

1.1.2 BIM data exchange/ collaboration

BIM has benefits at all the phases of construction, from planning through construction and use to demolition. In an early CAD drawing, the majority of information was presented through graphics only. IFC (Industry Foundation Class) was developed by BuildingSMART (International Alliance for Interoperability), a neutral data model file format for sharing information between project stakeholders and BIM tools. An IFC file format allows the exchange of model and non-graphical data between many BIM tools. The main advantage of the IFC file format is that it saves time because an object only needs to be modelled once. This standard file format results in better designs and an increased efficiency and productivity of projects. For instance, the IFC file can be used as a reference document by a structural engineer for the structural analysis of the project. Everyone working on a single project from different locations can access the information and share it whenever required. They can update necessary information, coordinate between disciplines, and maintain data more consistently. [5.]

1.2 BIM on Project Life Cycle Phase

The lifecycle of a building has mainly four phases which are planning, design, construction and operation. BIM is equally important in all phases.

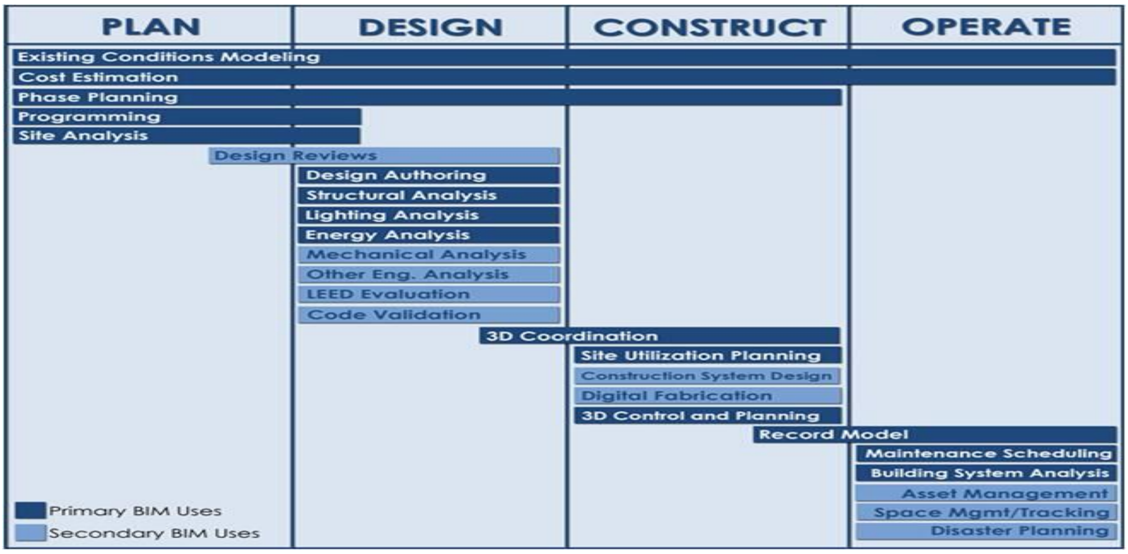

Figure 3. Uses of BIM throughout a building lifecycle [6.]

The uses of BIM throughout a building lifecycle are shown in figure 3 which explains that the site analysis was done during planning phase. Design work starts from the planning phase and continues to the design phase. 3D coordination is available from the final stages of the design phase and it is mostly used during the construction phase.

Table 1. Project phase and their benefits of using BIM [6.]

Project Phase	Benefits
Planning	Project scheduling, collaboration, goals setting, preliminary cost estimation
Design	Easy communication & coordination, accurate visualization, fast decision & modification, cost & design control, energy calculation
Construction	Site planning & logistics management, improved clash detection, understandable 2D & 3D models
Operation	Energy performance, automatic error reporting

Table 1 shows the most important benefits that can be found in the utilization of BIM tools during a project life cycle. BIM helps in numerous ways during the life cycle of the project from the initial phase to the operation phase. In many projects, BIM helps even in the demolition phase.

1.3 Research Methods and Objective

The aim of this research is to understand the structural modelling processes of BIM from the perspective of a structural engineer. The BIM application used in this thesis is by Tekla Structures. The thesis is based on various literary sources.

The thesis studies the importance of BIM processes and technologies for the construction industry and will mainly focus on the structural modelling process. The thesis explains the structural workflow of an office building. The most important objective of the research is to establish how a structural BIM application should be used to make the work easier, more reliable and faster. The major questions are

What are the benefits of BIM and why is it important?
How does BIM assist structural modelling work flow?
What are the key factors in the structural modelling process?
How to validate a structural model?

1.4 Structure and Limitations

The thesis answers the questions in eleven chapters. The background is explained in the introduction. Chapter 2 introduces the findings of the literary review into the topic. Chapter 3 gives a brief explanation about the benefits of using Tekla Structures in different projects. JUST, a case study project is presented in chapter 4, which shows the utilization of various BIM tools utilization in a single project. Chapter 5 gives details of an office building and chapter 6 shows every necessary step for modelling of an office building using Tekla Structures. The connection design and reinforcement is shown in chapters 7 and 8. Chapter 9 presents the way of creating drawing from Tekla Model and chapter 10 discusses BIM validation briefly, and finally, chapter 11 provides a conclusion and discussion.

BIM tools have a wide range of facilities and they can be implemented at any stage of construction. This thesis concentrates on structural modelling without the design calculation details. Architectural viewpoints are also outside the scope of the study. Suitable connection and assumed reinforcement data is used due to a lack of information details based on the authors' knowledge and experience.

2 Structural BIM

Structural engineering is the backbone for the design and construction of any project. Today, the constructability and stability of structures can largely be analysed through virtual construction and design (VDC) technologies such as BIM. Among various other benefits, like automated clash detections, information modelling and utilization, one of the best features of a 3D model using BIM tools is linked documentation. If any element in the model is revised or changed, the linked view and details in the model are automatically updated. This virtually eliminates the possible errors caused by uncoordinated drawings. Furthermore, BIM based design helps the designer in making smarter decisions which gives impacts positively on the overall efficiency and quality of the project. [7.]

Structural BIM is known for its design, analysis and documentation capabilities allowing all engineering disciplines to share the input information to make an informed decision towards constructability of the structures. Structural building information modelling includes all aspects related to the structure of the specific project. The development of BIM provides numerous benefits and possibilities. For examples, the manufacture of steel and precast concrete elements of a structure can be done easily, which improves the delivery, instillation and handling of the elements. Structural BIM contains many materials for structural modelling, such as steel, concrete, timber and masonry, along with information that aids in design and analysis. Structural BIM tools provides all information in a single click, all drawings and report can be easily prepared and generated. [8.]

Along with the development of the technologies, engineers and designers adopted new techniques through various means of drafting and designing application. As BIM is a new digital methodology in the AEC sectors. There are several BIM applications on the market provided by many companies. The features of two major BIM application are given in table 2.

Table 2. Companies and Software [9.]

Manufacturer	Product name	BIM uses	Primary Function
Autodesk	Revit Structure	Creating and reviewing 3D models	3D Structural Modelling
Trimble	Tekla Structures	3D Structural Model	3D Structural Modelling, Detailing, Fabrication and Construction Management

Revit Structure is developed by Autodesk and widely used for architectural and structural modelling. Revit Structure is also a 4D BIM (3D plus schedule) which can be used form the concept to construction and later maintenance and demolition phases in the building lifecycle. Moreover, Tekla Structure is a 3D modelling software used for steel and concrete detailing.

3 Tekla Structures as Structural BIM

Tekla is a software engineering corporation founded in 1966 in Espoo, Finland. The American company Trimble bought Tekla software in 2011. Tekla Structures is a 3D Building Information Modelling software is used for both steel and concrete modelling and construction purposes. The software is used for structural engineering design, documentation and modelling of structures such as, steel detailing, precast concrete detailing and reinforced concrete detailing. It can automatically produce the drawings and reports according to the requirements of a project. [10.] Tekla Structures is widely used in the construction industry. It allows efficient and accurate work. It can also be used to detect clashes in structures with the ‘clash detection’ tool. Tekla helps in construction coordination, quality, logistic scheduling and cost estimation. In concrete construction, Tekla calculates the quantity of concrete, as well as the amount of rebar needed for a project. [11.]

Benefits of Tekla Structures as a Structural BIM authoring tool have been identified in numerous projects. An example from Finland shows how Tekla Structures enhanced the collaboration and coordination in a project. A project in Britain benefitted from the possibility to model several materials offered by Tekla, and in China, the project Birds Nest would have been more difficult without the easy access to documentation without the easy access to documentation provided by Tekla Structures.

The Porin Puuvilla shopping center project in Finland had 13 project parties involved. Tekla Structures was utilized throughout the project for design and modelling purposes. A-Insinöörit and Narmaplan, two contracting companies successfully collaborated from different locations to create a Tekla model with zero dimensional mistakes. [12.]

Figure 4. Visualization of model and construction [12.]

Parma, a precast concrete provider, used the 3D Tekla model information directly without any paper drawings due to a very tight schedule. The geometry, location and building section information of the precast slabs were directly transferred from the Tekla Model to the factory ERP (Enterprise Resource Planning) system. This saved time and cost, and completed the project on the scheduled time. Figure 4 shows the visualization of model in comparison to the construction on site. [12.]

Exeter University Forum in the United Kingdom, was a challenging project in design and construction because of the several materials used on it. The project was successful only due to the use of Tekla Structures. It was possible to design timber and steel in the same software. This project has a very complex structure that has no standard parts. It also used a unique connection method. The glulam timber members were connected with steel nodes as shows in figure 5. [13.]

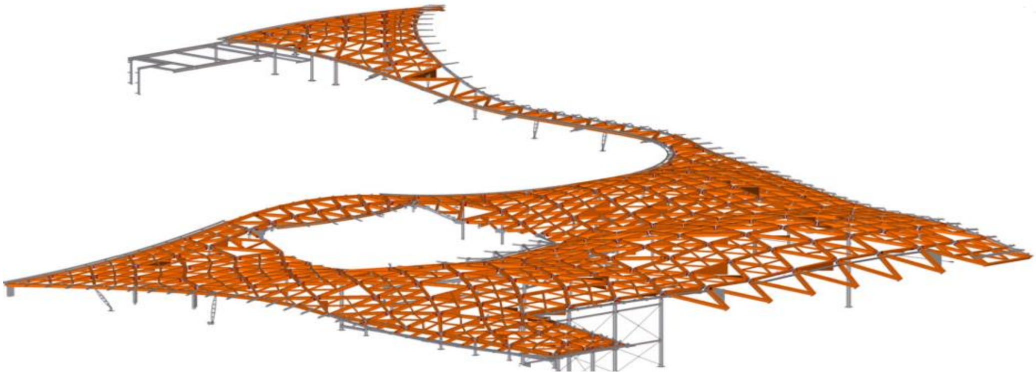

Figure 5. Steel and timber modelling [13.]

There were 162 different nodes carrying 6 primary timber connections. A total of 14,724 drawings produced and 7600 man hours were spent in modelling and detailing the structures. This would not have been possible without a solid model. [13.]

The Beijing National Stadium is called ‘Bird’s Nest’ due to its shape. The steel modelling and detailing was carried out with the help of Tekla Structures. The outer surface of the façade was inclined with an angle of 13 degrees to the vertical as shown in figure 6. The steel structures were complex and heavy. In order to reduce the weight, designers removed the roof and enlarged the roof opening which helped to decrease the weight of the steel from 45,000 to 42,000 tonnes. [14.]

Figure 6. Bird's Nest [14.]

The materials list, assembly list, and bolt list were very easy to produce and understand. This was possible by modelling of the structures with Tekla Structures. Furthermore, it was done quickly and at minimal costs. [14.]

4 Case Study: JUST

JUST stands for 'Järvenpäänn Uusi Sosiaali ja Terveyskus', and the building can be seen in figure 7, which is a social welfare and health care center located in Järvenpää, Finland. JUST won the BIM award for the design competition of 2016. The center covers a total area of 13,664 square meters with a volume of 60,600 cubic meters. The construction began in November 2014 and the estimated construction time is 22 months. It is estimated that the cost of the project is 49.2 million euros. A-Insinöörit Suunnittelu Oy was the structural designer of the project. [15.]

Figure 7. Model of JUST [15.]

BIM was used in various ways in the JUST project. The architectural model was done with SketchUP, the structural model with Tekla Structures, structural validation with Solibri Model Checker, scheduling and cost estimation with VicoOffice. Furthermore, the virtual reality environment CAVE was used to observe the virtual design and construction.

SketchUP is a programme mainly used for the visualization of a structure. The architectural modelling and site planning for the JUST project were done with SketchU. The model for JUST can be seen in figure 8. It is a visualization of the construction made before the design. JUST also utilizes it for the construction site management. [16.]

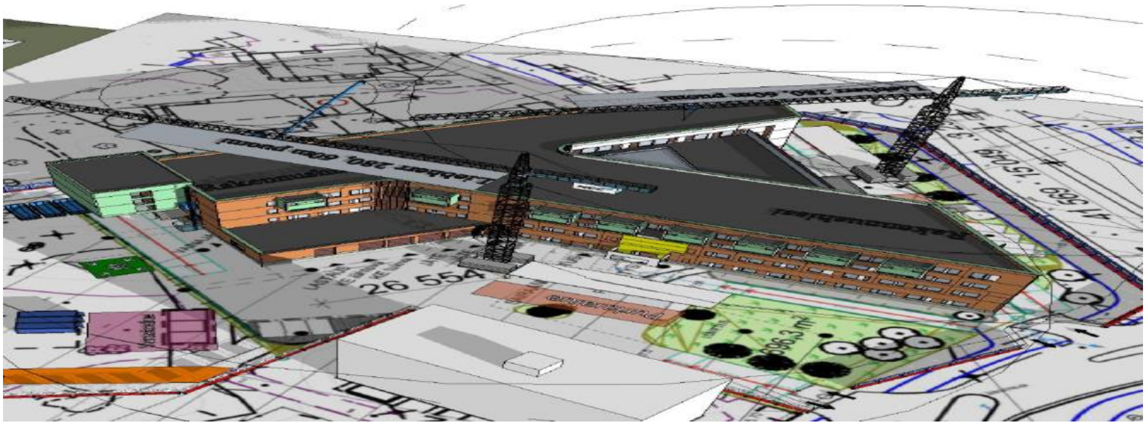

Figure 8. SketchUP model [16.]

Tekla Structure is used in JUST for detailed modelling design of steel and concrete structures. The manufacturing drawing for work shop and erection drawing for construction site were produced.

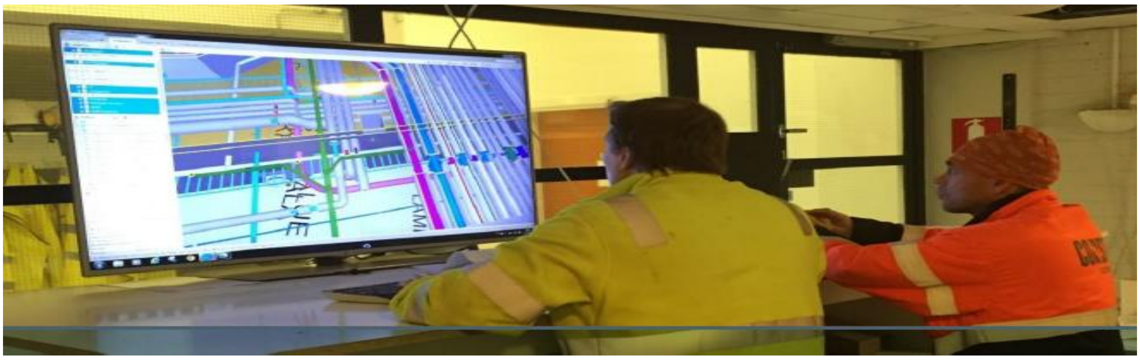

Figure 9. Solibri Model Checker [16.]

Solibri is a model checker develop by Solibri, Inc. located in Helsinki, Finland. Solibri automatically checks and controls the models of a building or structure. Figure 9 shows an example of clash detection between HVAC and structural components. Solibri is used in BIM projects to ensure the quality of the projects with various rulesets. Solibri offers structural BIM validation, clash detection, collaboration, information take offs between different design disciplines based on classification systems, and quality assurance. The JUST project uses Solibri for clash detection and management. [17.]

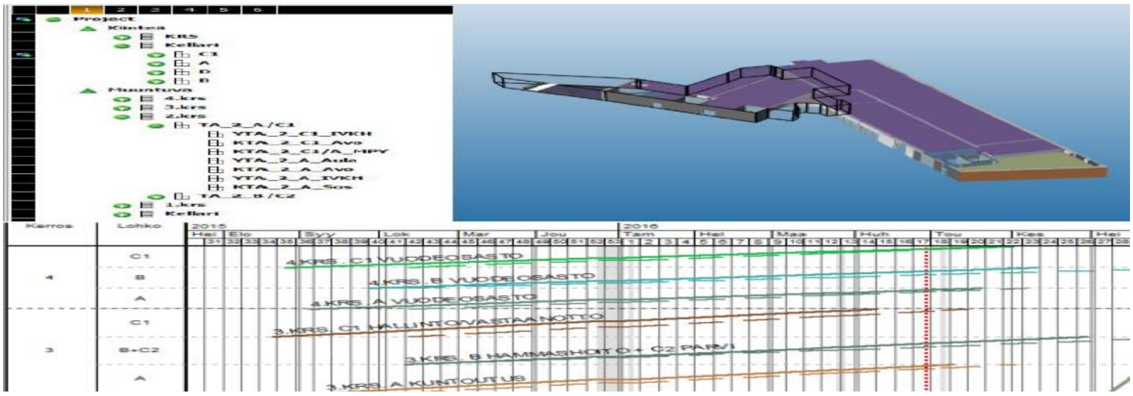

Figure 10. Scheduling using Vico Office [16.]

Vico office is an integrating construction software of Trimble used for the scheduling and cost management. Vico Office can be used by building owners and contractors to reduce the project risk, enhance collaboration between disciplines, estimate and improve the predictability of the project. The JUST project used Vico Office for scheduling and cost estimation. The scheduling of the construction work between the floors is shown in figure 10. [18.]

Collaboratation between the end user and the diverse applications of the information models is done by utilizing one of the principles of BIM, Virtual Design and Construction (VDC). In the JUST project, VDC was used by NCC. [16.]

Figure 11. 3D Model experience in CAVE [16.]

A virtual reality cave is an effective tool where realistic and detailed models can be studied when going to the general planning phase. It is one of the most efficient ways to evaluate the utility of plans in the early stages of development. CAVE is a space where the users and the client can visualize the model of the property as shown in figure 11. [16.]

5 Project Description

The project discussed in the thesis is an office building at Visamäentie 35, Hämeenlinna, Finland. It is a two-storey building which connects the buildings B and C of Häme University of Applied Sciences. The total area of the building is approximately 480 square meters**.** The first floor of the building is planned for a library and the second floor for some classes and offices. The building is designed according to RakMK (The Finnish Building Regulations). The designer of the building was Arcadia Oy. [19.]

A sub-structure is the lower portion of a building which is usually located below the ground level. It transmits all the load of the super structure to the supporting soil. The details of the sub-structure of the connection building are shown in table 3.

Table 3. Sub-structures details [19.]

Building Component	Details
Footings	Concrete Pad Footing-Precast-Size: 1900*1900 Strip Footing: Size: 700*1000 Height: 1780 mm
Foundation Column	Concrete Circular Column-Precast-Diameter: 400 Height: 1080 mm

A superstructure is the part of a building which is above the ground level. The superstructure of the connecting building has a total of two floors. The total gross area of the building is 438 m^2.

Table 4. Super-structures details [19.]

Foundation wall (US7)	Concrete Structure: 100 mm Thermal Layer Insulation: 180 mm Concrete Structure: 160 mm Total thickness: 440 mm
First/second floor wall	Concrete Structure: 45 mm Thermal Layer Insulation: 200 mm Concrete Structure: 190 mm Total thickness: 435 mm
Column	Concrete Column-Precast-Diameter: 400 mm
Beam	Steel Deltabeam-Precast-Profile: D32-400 mm
Foundation Slab	Concrete Slab: 100 mm Sealing Product: 30 mm Hollow core: 320 mm Insulation: 220 mm Total thickness: 670 mm
Intermediate Slab	Concrete Slab: 100 mm Sealing Product: 30 mm Hollow Core: 320 mm Total thickness: 450 mm
Roof	Concrete Slab: 10 mm Layer 1 Insulation: 30 mm Layer 2 Insulation: 150 mm Layer 3 Insulation: 150 mm Layer 4 Insulation: 150 mm Hollow core: 210 mm Sealing Product: 320 mm Total Thickness: 960 mm
Window opening	Opening sizes: 400x1500 mm^2, 400x2100 mm^2, 800x1500 mm^2, 800x2100 mm^2, 1200x1500 mm^2, 1200x200 mm^2

The properties of the building components used in the superstructure are shown in table 4. The total thickness of the first and second floor wall is 870 mm. Precast column with a diameter 400 mm and steel deltabeam of profile D32-400 mm is used. There are different dimensions for window opening.

6 Modelling of the Project

The modelling of the project was done with the setup of Finnish Environment which can be installed in the Tekla Structures programme by downloading it from Trimble Tekla home page. After the installation of Finnish Environment, the following steps should be selected.

Environment: Finland

Role: FIN Betonirakennesuunnittelija (concrete structural engineer)

Configuration: Educational

First, the detail modelling was carried out for the foundation, then the first floor, and a similar process is continued during the modelling all the way to the roof. Structural modelling is done according to the floor plan and elevation drawing as shown in the appendices. The steps in the modelling process are presented below

The starting point for the structural modelling is an IFC file with the architectural model. A reference model helps in establishing the unit systems, utilizing project location as well as detecting alignment of building structures. The reference model was added by selecting the ‘Add model’ option in the upper right-hand corner. For this, the ‘Browse’ option was clicked and the reference file as .ifc was selected. The floor plan of the architectural model is shown in appendix 3.

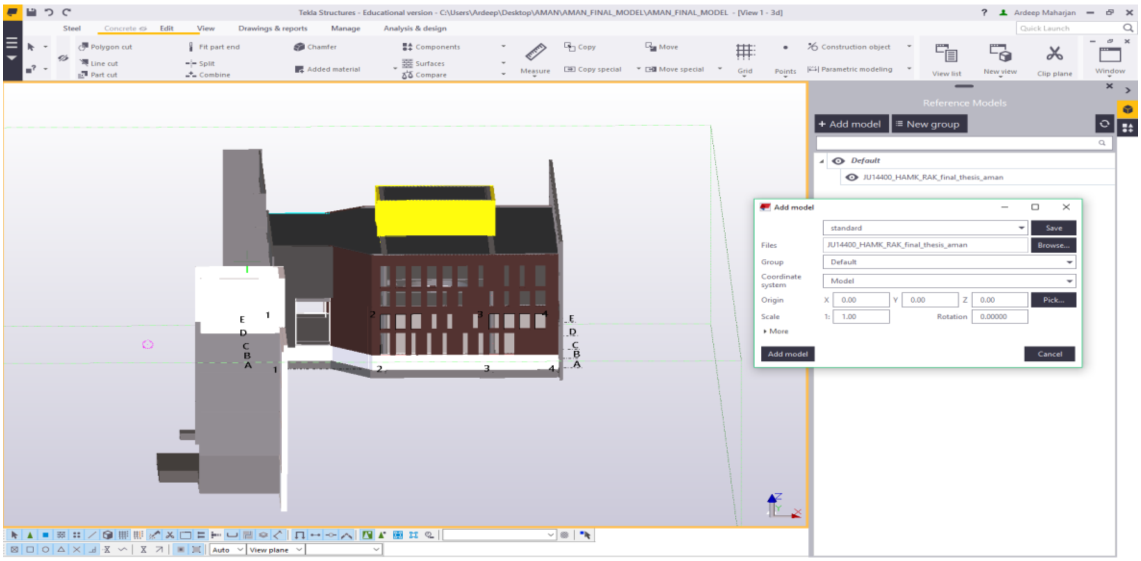

Figure 12. Tekla interface with reference model

After inserting the reference model, the distance between the footings and elevation was measured by selecting ‘Measure’ icon from the toolbar, then the grid was modified accordingly. It was double clicked on the grid and the measured values were inserted on the x, y and z coordinates and labels

Next, the reference model was turned off by clicking the eye symbol under ‘Add Reference’ and a concrete pad footing was placed on the grids. The path, Concrete >Footing >Pad Footing was followed. The breadth of pad footing was 1900 mm and the width was also 1900 mm which was defined and placed on the required position on the grid.

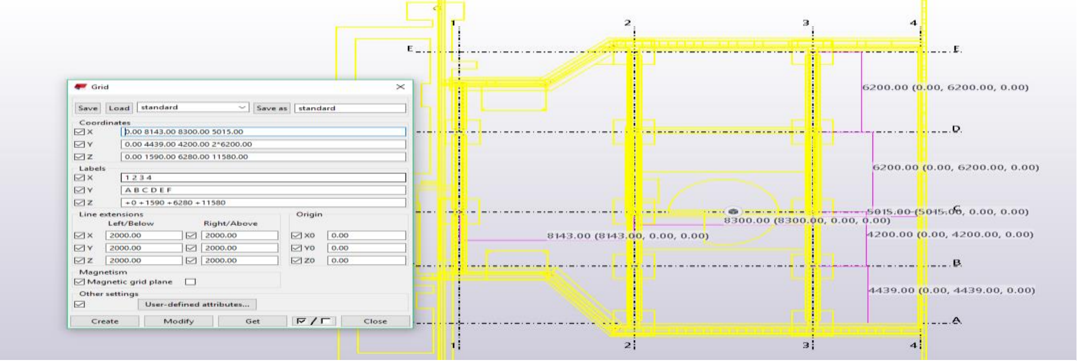

Figure 13. Grid modified as per measurement of reference model

These details can be added through a profile section in the properties panel of the elements as shown in figure 14. Moreover, material section and the class for the elements can be modified and updated if needed.

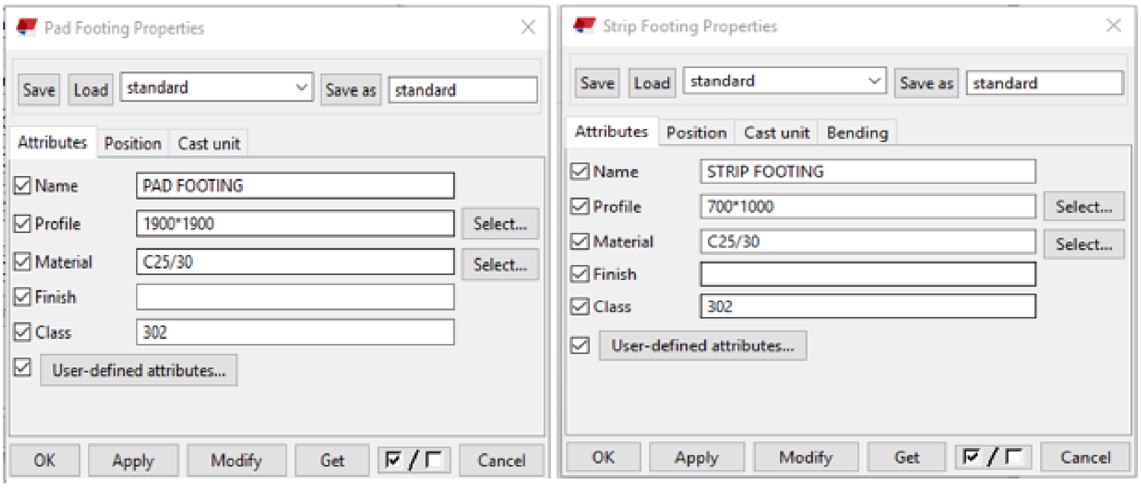

Figure 14. Pad footing dialogue box (Left) and strip footing dialogue box (Right)

The name, profile, materials, class was modified by double clicking the pad footing. The precast option was selected from ‘Cast Unit’ from the properties dialogue box. Similarly, strip footing was used for load bearing walls and this can be continuously placed according to requirement and middle mouse click to end the command. The height of strip footing was 700 mm and width was 1000 mm.

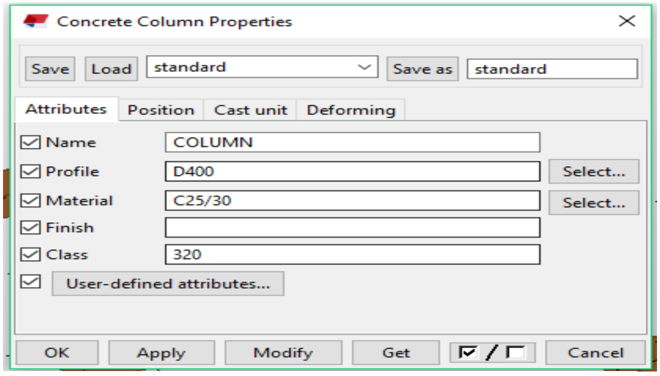

Figure 15. Concrete column dialogue box

A column with a diameter 400 mm was placed in the middle of the pad footing. The column can be found in the ‘Column’ toolbar. The properties of the column were changed as shown in figure 15. It was a precast element type that was adjusted from ‘Cast Unit’.

Figure 16. Peikko deltabeam [20.]

In this project a Peikko component called Deltabeam was used. It is a precast steel beam. The deltabeam is not available in the default library and was installed from Tekla Warehouse. To install the deltabeam, first the Tekla Warehouse website was opened and logged into. With the key word deltabeam it was searched from the search box. There were 3 results of deltabeam and for the project the ‘Peikko Profiles’ as shown in figure 16 was chosen. It was then downloaded and installed.

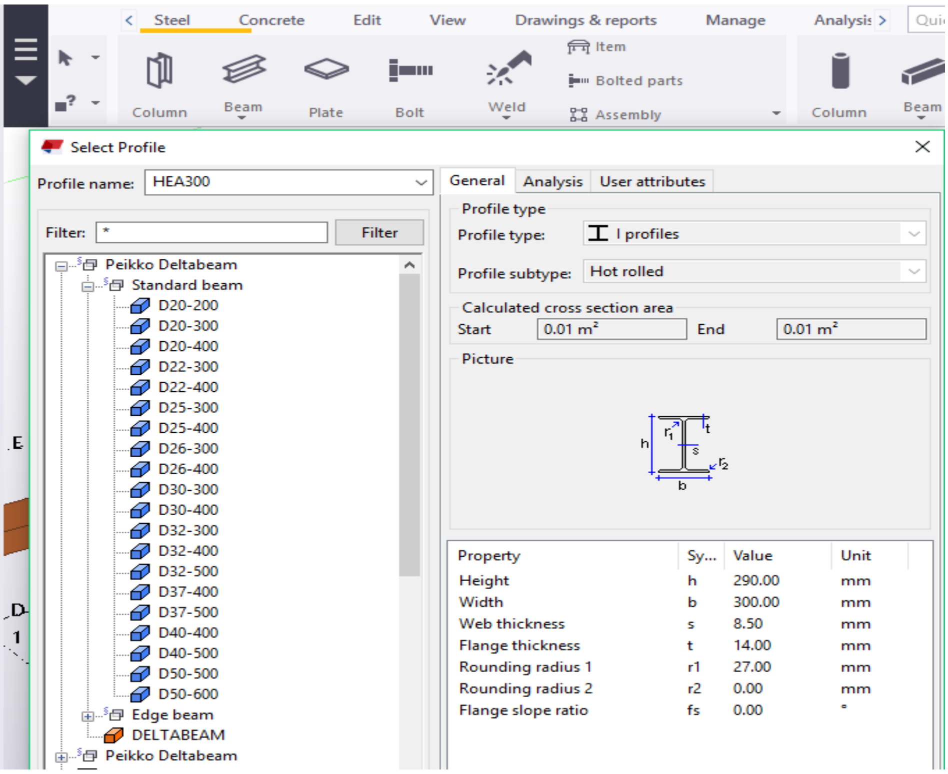

Figure 17. After installing deltabeam in Tekla Structures

The Tekla Structures program was closed once and reopened again to load the installed deltabeam component. Now the deltabeam which was installed can be found under the 'Steel' toolbar by selecting 'Beam' icon as shown in figure 17. The profile of deltabeam for this project was D32-400 which can be selected from the icon in the properties dialogue box.

A bearing sandwich was used as a wall element in this project. This component can be found in 'Application and Components'. It is double clicked on to edit its properties to match the sandwich components in the model. The thickness of the outer portion of concrete was 45 mm, the insulation in the middle was 200 mm, and the inner portion of concrete was 190 mm. The total thickness of the foundation wall was 440 mm; the height of the inner concrete layer height of the wall was reduced to 340 mm for the placement of a hollow core slab as shown in figure 18. Modify >Apply >Ok path, was used to update the modification. The slab was placed by clicking the first position and the last position of the wall. A similar process was carried out for the basic wall of the building.

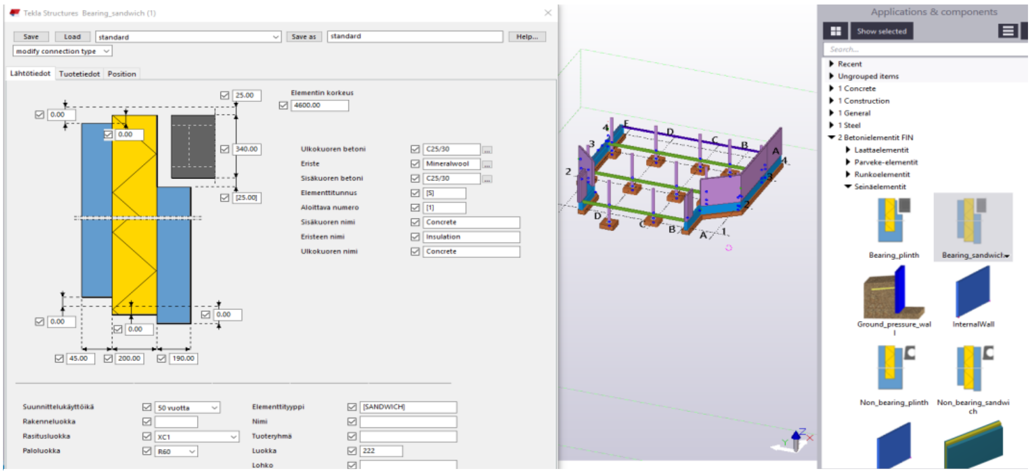

Figure 18. Bearing sandwich wall

Figure 18 show the details about the input values with each layer. Here, according to the requirements of the building wall, the name of the layers can be edited and the thickness can be changed.

In this project, 'Floor Layout' was used for modelling the slab. It has a feature that allows the adding of layers like insulation, hollow core and sealing product. It also has the features of adjusting the materials and thickness. As a finishing layer, cast-in-situ concrete was used on top of a hollow core slab. The total thickness of the foundation slab was 670 mm, where 100 mm was the concrete slab, 30 mm a sealing product, 320 mm the hollow core slab and an insulation 220 mm.

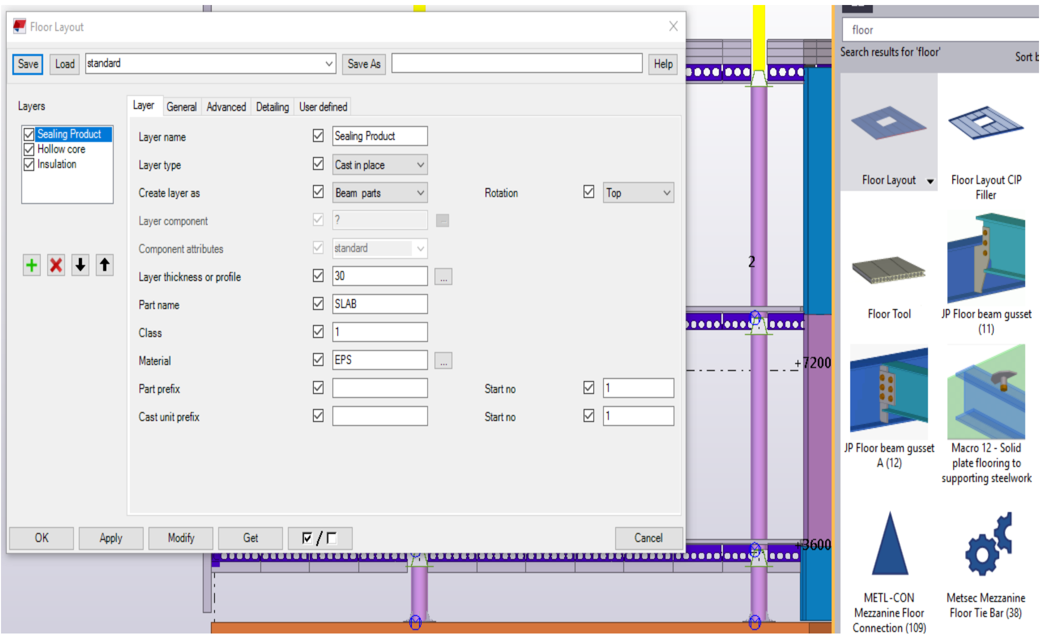

Figure 19. Floor layout tool

The thickness of the intermediate slab was 450 mm. On the top of that, a concrete slab of 100 mm was placed as cast-in-situ and a 30 mm sealing product, a 320 mm hollow core slab and a 220 mm insulation layer were adjusted, respectively, as precast elements.

A similar process was carried for the basic roof. The total thickness was 960 mm, where 10 mm was a cast-in-situ concrete finishing slab. The four layers of insulation were adjusted with 30 mm in first layer, 150 mm in each of the other three layers, 210 mm hollow core slab and a sealing product of 320 mm as shown in figure 19.

To create an opening for windows and doors, the 'Hole Generator' which can be found in 'Application & component' was used. The required height, width and position can be adjusted by double clicking the component. The hole was created by selecting and picking the corner of the wall. The dimension and the position of the opening were created according to the reference model.

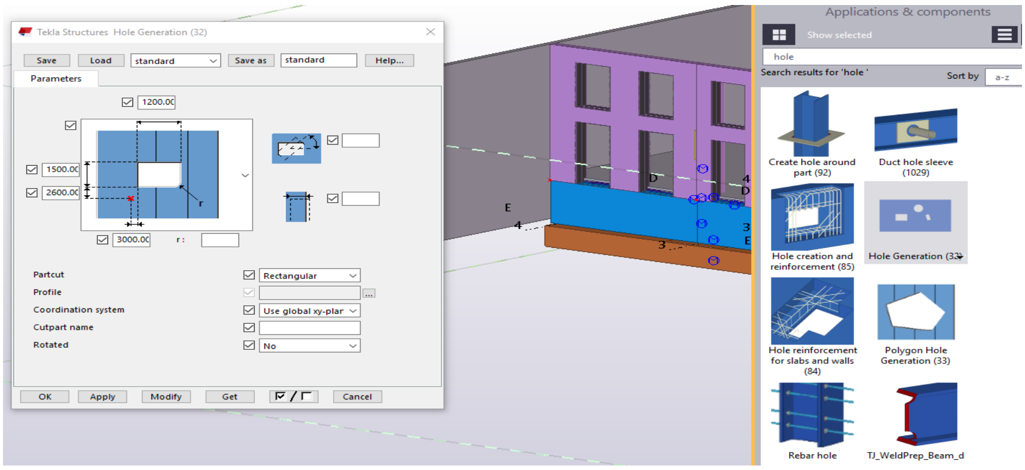

Figure 20. Hole generation tool

Figure 20 shows the required dimension for creating the hole of windows opening. In this dialogue box of hole generator, the height and the width of the opening was defined 1500 mm and 1200 mm respectively. The sill height was 2600 mm and the location of the opening was 3000 mm from the corner of the wall.

7 Connection Design

During the design of this project, various connection components were placed between the structural component in the model to make the structure stable. The connections used in this project are chosen from Tekla's 'Applications and components' feature. Connection types and their details were modified and used in the project.

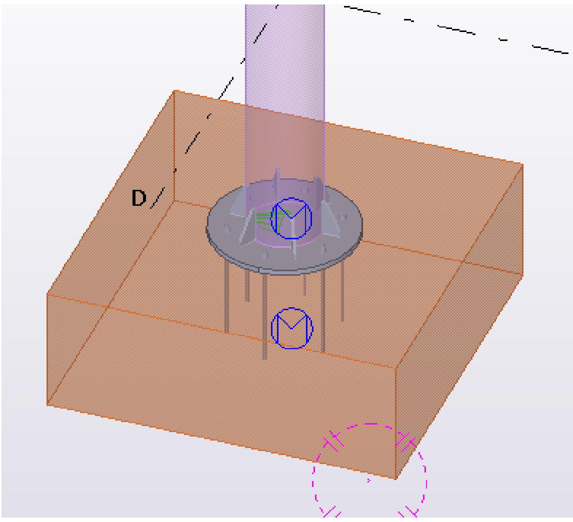

Figure 21. Base plate connection

The Circular base plates (1052) were used to connect the footing and column to the foundation. A representation of the connection used in the project is shown in the figure 21. The thickness of the plate was 30 mm with bolt size of 20, and bolt standard 799. The anchor rods of 700 mm were modified from the dialogue box property of the circular base plate.

There are two types of connections used in the wall. The selection of the wall connections was done according to the adjustment of the wall. In the connection menu, 'Select Object in Component' icon should be on and the position of the layer, i.e. 1, 2, 3, 4, 5, 6, of the wall should be selected as shown in figure 22. The types of connections available in Tekla model and used in this project are

PC_EW_WE_GR_20 (Corner facing Inward Connection)

PC_EW_EW_GR_18 (Corner facing Outward Connection)

PC_EW_EW_GR_13 (Horizontal Connection)

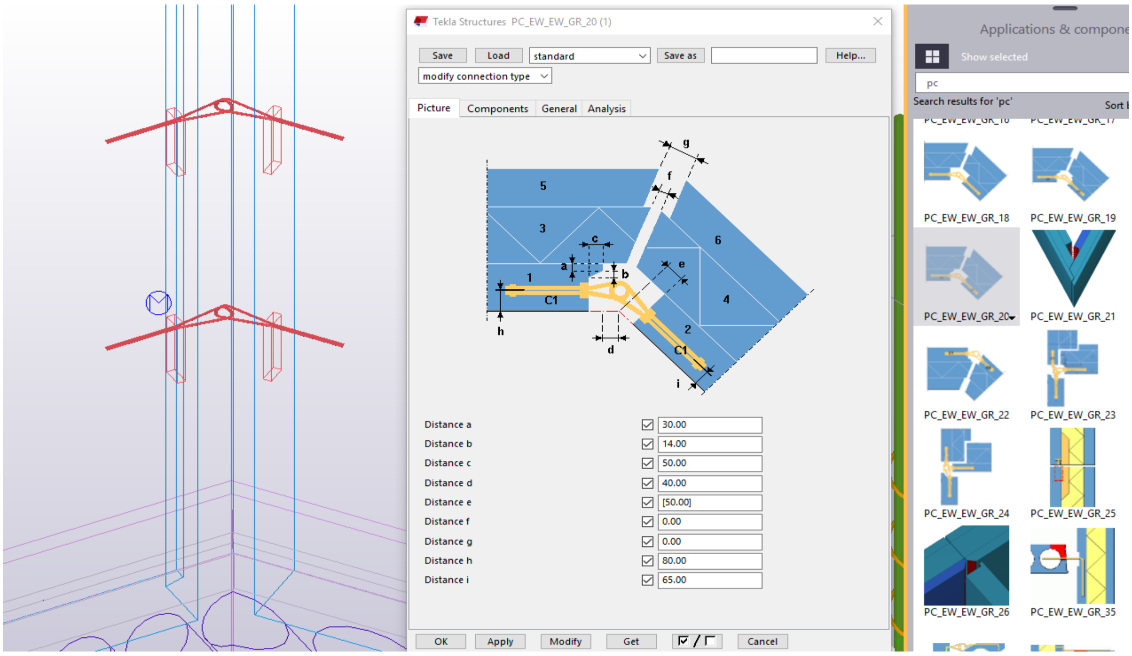

Figure 22. Wall connection component

In connection PC_EW_EW_GR_20, the distance was defined. The defined distance can be differed from one connection to another connection type.

8 Reinforcement Details

There are two types of footing were used in this project. ‘Pad footing reinforcement (77)’ was used for pad footings and ‘Strip footing reinforcement (75)’ was used for strip footings. An example of a pad footing reinforcement is shown in figure 23.

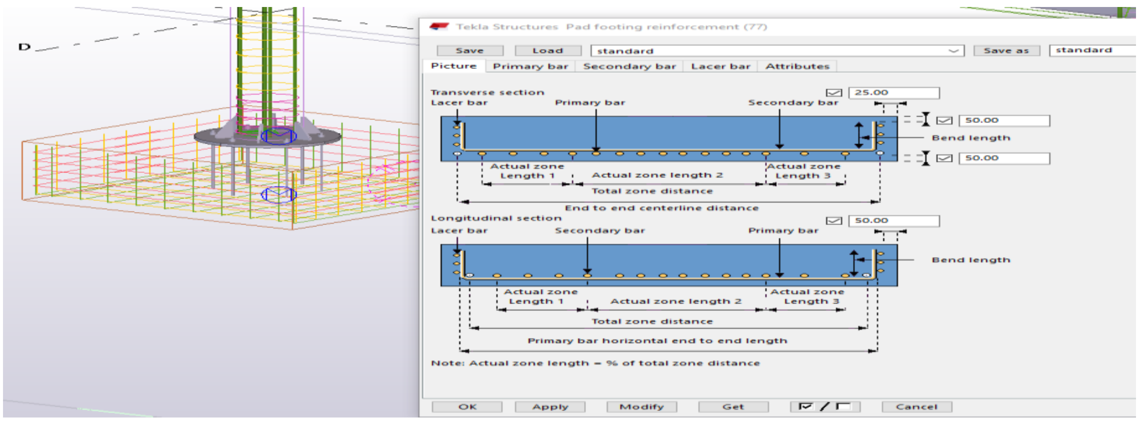

Figure 23. Footing reinforcement

For using this, each reinforcement was searched in ‘Application & components’. With a double click one can edit the Bend length, secondary bars, end to end centreline distance and son on. The grade of the steel and size was also defined. The path Modify >Apply >Ok allowed the selection of the footing by clicking it to apply the reinforcement.

‘Round column reinforcement (82)’ was used for column reinforcement. Different parameters such as numbers of grades, size, rotation and spacing between the rebars were changed and defined in the dialogue box. It was double clicked ‘Round column reinforcement (82)’ to change its parameters and the path Modify >Apply >Ok selects the column to the use the reinforcement by clicking on it.

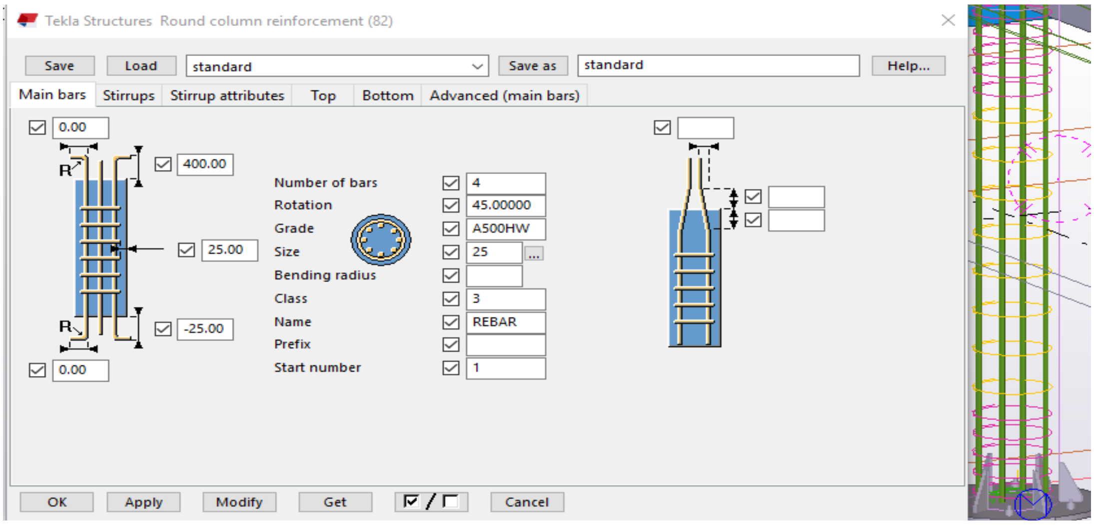

Figure 24. Column reinforcement

There are 4 number of bars used in this column reinforcement. The concrete cover was defined 25 mm as shown in figure 24. The steel grade for all the reinforcement bar was A500HW.

‘Wall Panel Reinforcement’ was used for selecting the reinforcement of wall reinforcement. Due to a lack of the reinforcement details, exact data was not used. The assumption data used for the horizontal and vertical diameter of the reinforcing bars was 8 mm the bending radius was 96 mm and the spacing is 200 mm. The splice length in the horizontal and vertical reinforcing bar was 200 mm with grade B500K. A concrete cover of 35 mm was used.

The minimal height defined for the wall was 2100 mm. The reinforcement type can be changed and defined as shown in figure 25. From the 'Reinforcement' option of wall panel reinforcement the size of the bar, grade, radius and splice length was defined. If the wall consists a diagonal shape, from the 'Diagonals' option the dimensions of the diagonal can also be defined.

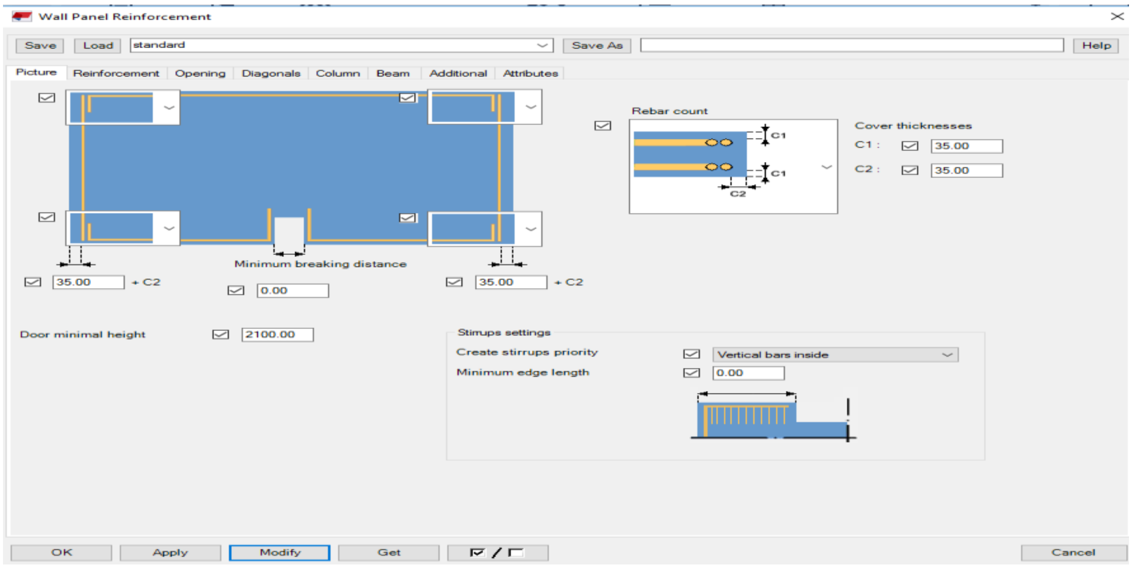

Figure 25. Wall panel reinforcement

The 'Slab Reinforcement Tool' was used to create reinforcement for the slab. A reinforcement Mesh of 8 mm diameter rebar with a spacing of 200 mm was placed on top of a hollow core slab as shown in figure 26.

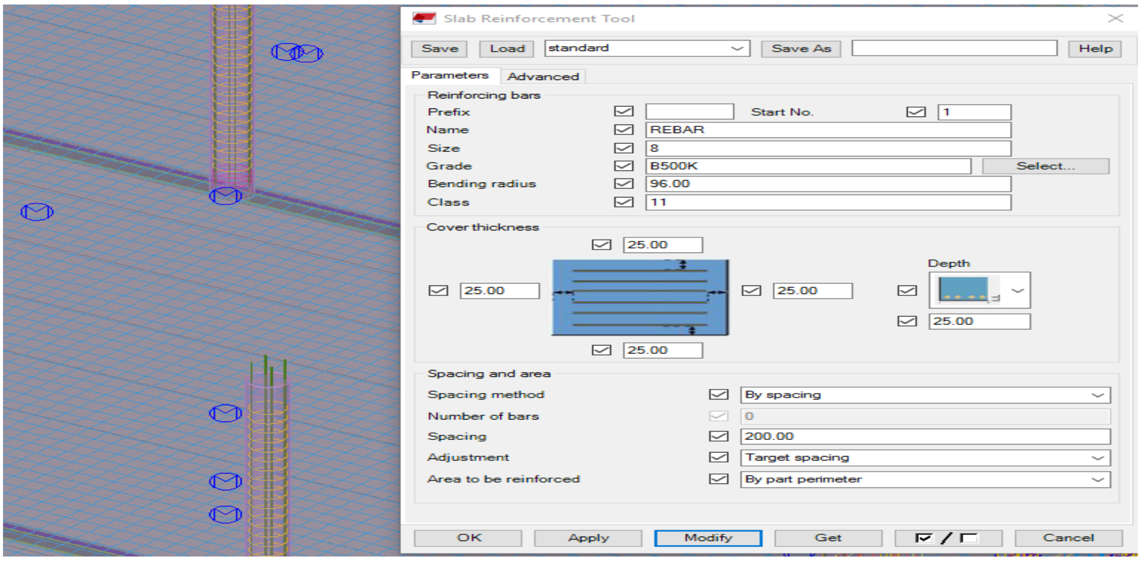

Figure 26. Slab reinforcement tool

The concrete cover defined in slab reinforcement was 25 mm. The steel grade defined was B500K. The depth of the bars, spacing and bending radius can be defined according to the structure of the component.

9 Creating Drawing

Once the modelling is finalized, communication for various purposes is done in several formats. As explained in chapter 1, IFC is the standard BIM data exchange format. However various supporting design documents are still a requirement. Tekla supports several types of automated drawing generation to support these. In order to send documents to a construction site and product manufacturing company, drawings are very important. It is always recommended to give the details of all information in the drawing. The types of drawings that can be created using Tekla Structures are listed below

1. General Arrangement Drawing

General arrangement drawings are usually known as GA drawings. They include the several views in one drawing. A GA drawing normally includes at least a plan drawing, 3D drawing, and elevation drawing. A GA drawing are usually done paper size A1 or A0.

2. Single Part Drawing

Workshop drawings are known as Single Part Drawings. They are used for extracting information of a single part on a single paper. Single part drawings are usually for steel parts, and in paper size A4.

3. Assembly Drawing

Assembly drawings are also workshop drawings. They are prepared to show the fabrication information: where the main part and the secondary parts are connected by welding or bolts and made ready for assembly at the construction site. The size of these drawings depends on the model, but usually they are on paper size A3.

4. Cast Unit Drawing

Cast unit drawings are basically prepared for concrete design and construction. They contain the information of dimensions, reinforcements, edge chamfers, insulation etc. The volume and weight information can also be checked from the cast unit drawings. The paper size depends upon the structural elements of the facility.

To create a drawing first, the path to follow is Drawing and Reports >Create Drawing >GA Drawing. A dialogue box with various views appears such as 3D, Grids and Plan. A separate drawing of each grid and plan can be created directly by choosing the desired grid and plan. Another way of creating a drawing is to create an empty drawing first.

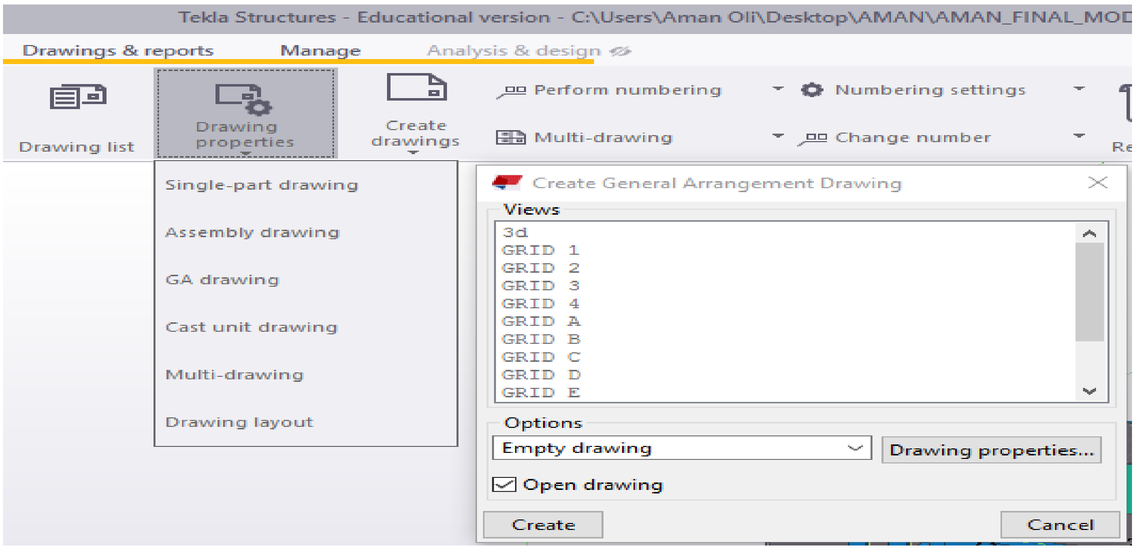

Figure 27. Preparing a GA drawing

For this thesis, an empty drawing was created to prepare a GA drawing. ‘Drawing & report >Create drawing >GA drawing’ was clicked first so that the dialogue box appeared. The alternative chosen was from the dialogue box ‘Create General Arrangement Drawing’ as shown in figure 27. The option ‘Empty Drawing’ was selected. A tick mark was inserted by clicking on the box in order to create an automatic empty drawing a final click was done on ‘Create’. And an empty drawing was created. From the ‘window’ in the right top corner in Tekla structures, ‘Tile Vertically’ was chosen so that the model and the empty drawing were seen vertically. To put the model in the empty drawing, ‘View->Entire model view’ was clicked from the drawing interface and with a final click the model was done. The model was thus created as a drawing.

Similarly, a 3D view and other necessary views can be added here with the same process as shown in figure 28.

A details of general arrangement drawing is shown in appendix 1. The cast unit drawing is another important document for manufacturing company and site. An example of cast unit drawing is also shown in appendix 2.

After completing the model, the file was converted into ifc file format. First of the, file option in the left-hand corner of Tekla Model was clicked. In the 'Export' option, IFC was then clicked and location to save the file was chosen.

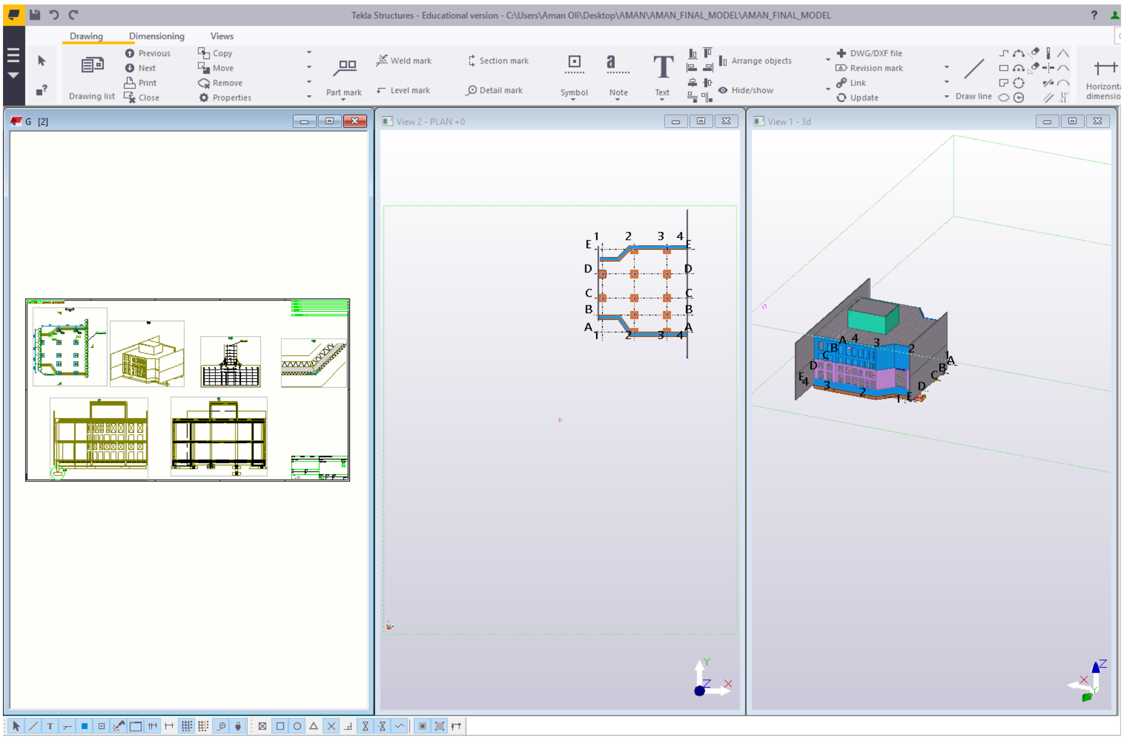

Figure 28. Adding model to drawing

10 Structural BIM validation

In the final year project, Solibri model checker (SMC) v9.7 was used to validate the structural model of the connecting building of Häme UAS in Hämeenlinna. The validation was carried out with the “COBIM 2012 - Checklist for structural building element BIM”. COBIM 2012 (Common BIM requirements; Yleiset tietomallivaatimukset in Finnish) is a commonly accepted ruleset of BIM requirements primarily used in Finland. [21.]

Figure 29. COBIM 2012 (left) and Solibri Model Checker (right)

Figure 29 on left shows COBIM 2012 series 5 and Solibri Model Checker on right. COBIM 2012 series 5 is based on the structural design determined by modelling scope, precision and data richness. Solibri Model Checker gives its result on the basis of COBIM 2012 rulesets.

10.1 Clash Detection

The COBIM2012 ruleset is available through Solibri’s solution centre as YTV2012 extension. After the installation of the extension, an IFC file exported from Tekla was opened in SMC. A structural disciple for the model was assigned. Solibri provides automated checking for any inconsistencies in a BIM model. Based on the rules, Solibri classifies the clashes with varying severity as Critical (red), Moderate (orange) and Low Severity (yellow) respectively. [22.]

As mentioned above, COBIM 2012 - Checklist for structural building element BIM was used to check the office model IFC for validating the model. The COBIM 2012 ruleset includes the checklist that is based on the COBIM guidelines. The rulesets include several rule groups. The primary checking results and the rule-groups are shown in figure 30. [21, 22.]

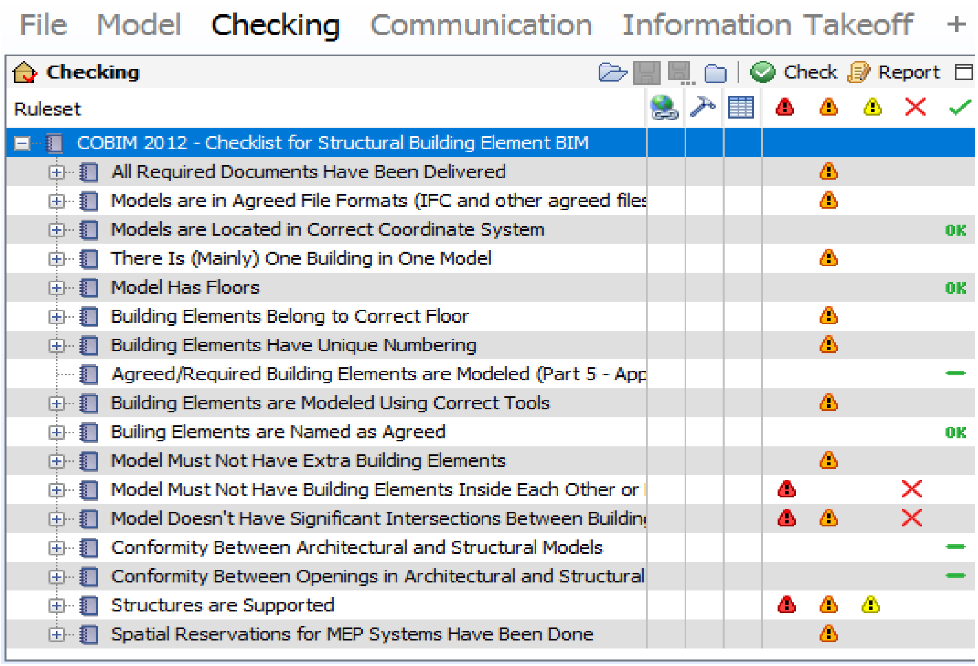

Figure 30. Rule-groups and error results

The error found were then gone through one by one. The critical error indicated by red sign were studied and according to the ruleset of COBIM 2012, the error were solved by going back to Tekla Strucutre model.

Figure 30 shows the error on column support. The error reported in the rulset and Structures are supported – Components Below and Above Columns and ruleset ‘Beam - Beam intersection’ are discussed below

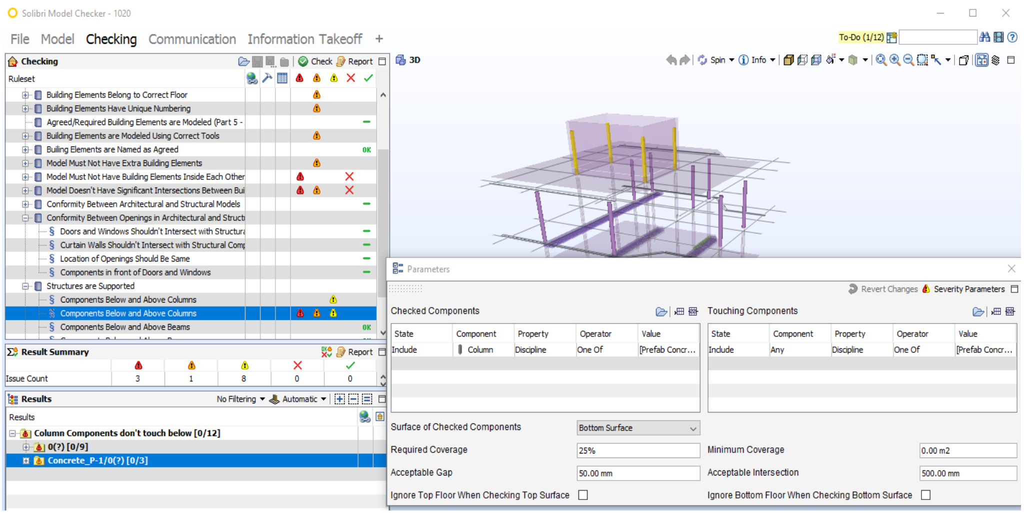

Figure 31. Column above the structure

Ruleset of COBIM 2012 defines that the acceptable gap between columns is 50 mm as shown in figure 31. In this case, Solibri reports error which means the gap was more than the defined parameters.

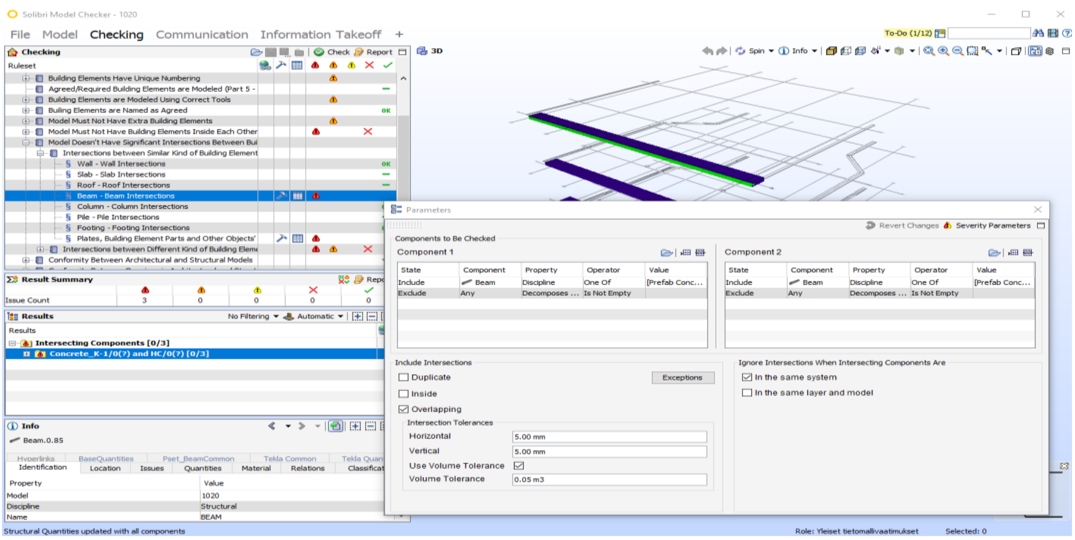

Figure 32. Beam intersections

Similarly, the intersection tolerance was 5 mm for beam as defined by COBIM 2012 as shown in figure 32. After this error reported, it was realised that the intersection was more the 5 mm between beam component. These types of check allow designers to validate a model even before sending it to the project participant. Thus, it helps in ensuring the product quality.

Issues that are detected during the modelling process not only assist the designers to deliver better quality but also improved the collaboration between project participants. Clashes that are detected can also be presented as a slide through ‘Communication’ tab in Solibri Model Checker.

Once the validation of clash free models is done, extracting information out of the model is important for various purposes, like cost calculation and resource calculation. All information such as identification, location, quantities and materials of the project can be included. The information can be filtered according to desired requirements as well as visualized with different color codes. It helps a project participant to quickly perceive the information visually, resulting in better communication and expression of information, like a quick visualization of the fire resistance of building elements, different window types, and different element types.

11 Conclusion and Discussion

Building Information Modelling (BIM) is one of the most convenient ways to gather and share information. It helps each discipline of engineering to reduce construction errors and lowers construction costs. BIM has made it possible to exchange design and modelling information between the participants of a project. BIM can be utilized from the pre-construction phase to the post construction phase of a project. All data can be extracted whenever it is needed for maintenance and inspection. BIM tools present advantages which help in a better visualization of a project before construction. This builds up customer relationships, improves profitability and reduces future errors.

The goal of this thesis was to explore the utilization of BIM which was verified through the case study JUST. The advantages of Tekla Model were shown with three different example from Finland, United Kingdom and China. Moreover, these examples suggest how to reduce construction costs and minimize construction errors and shows that a 3D visualized model helps in site management and predicts future consequences. The modelling steps of an office building act as a manual for new Tekla users. It is also of a great importance to check the clashes of building components. If the clashes are known before the actual construction, it helps to reduce the construction time.

In past, most of construction started without a 3D model. More time was spent in drafting and it was very difficult to communicate with project participants. BIM tools have provided better visualization during design. 3D modelling and clash detection tools reduce clashes between various elements. Building components in BIM tools consist of enriched information that can be modified according to the project demands. BIM helps in better outcomes through collaboration, optimizes solutions and enhances performance.

In brief, BIM is a very important process for every engineering department. It preserves information even after construction. From an early phase of design and modelling, BIM helps to predict future consequences. The IFC file format is a great achievement in BIM collaboration. The upcoming risks can be minimized through the BIM process. As a result, everyone involved in the project can benefit although BIM tools are expensive and special training is required to use them. Nonetheless, a further research can be performed for the role of BIM in design and structural analysis of building.

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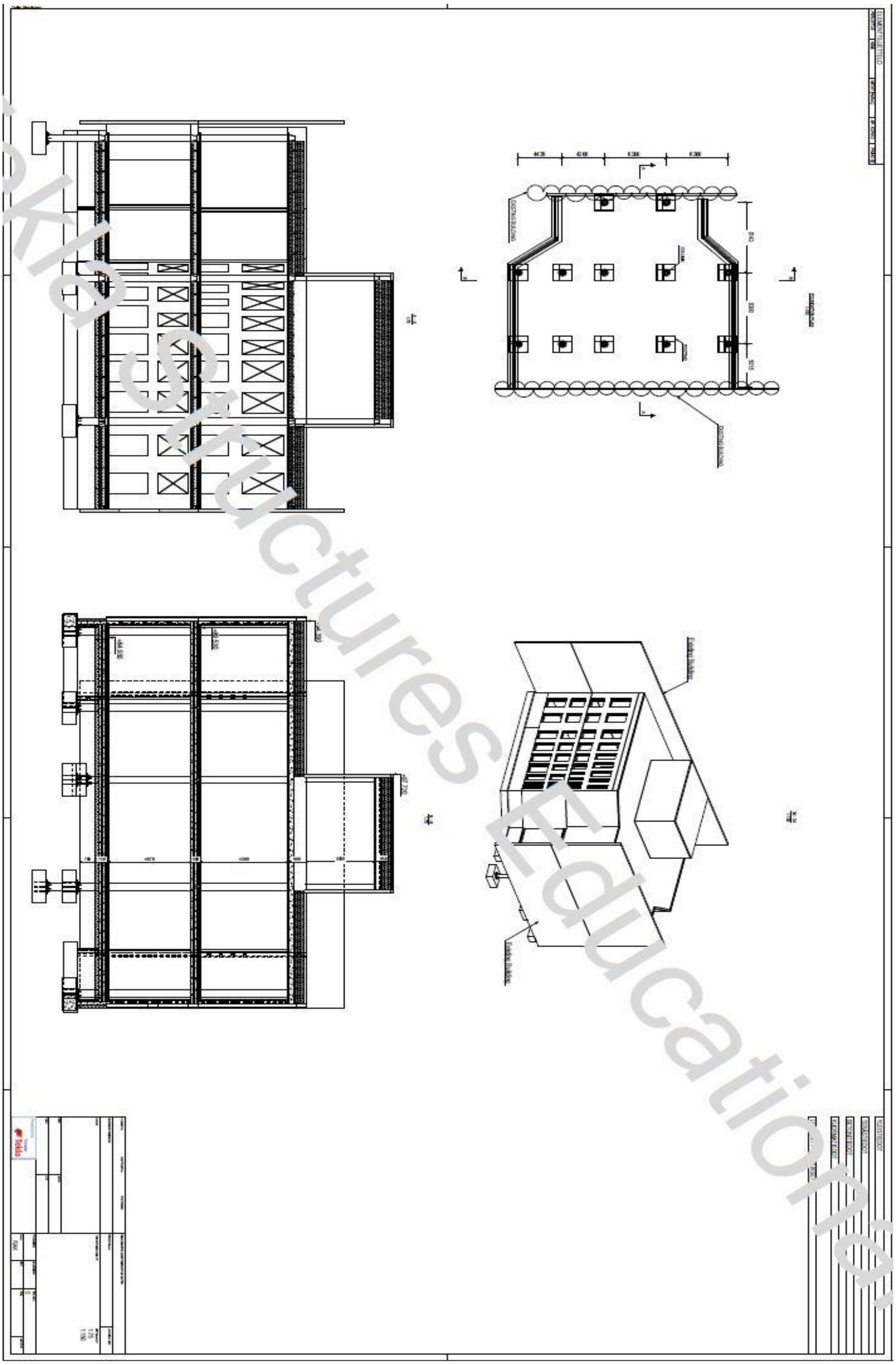
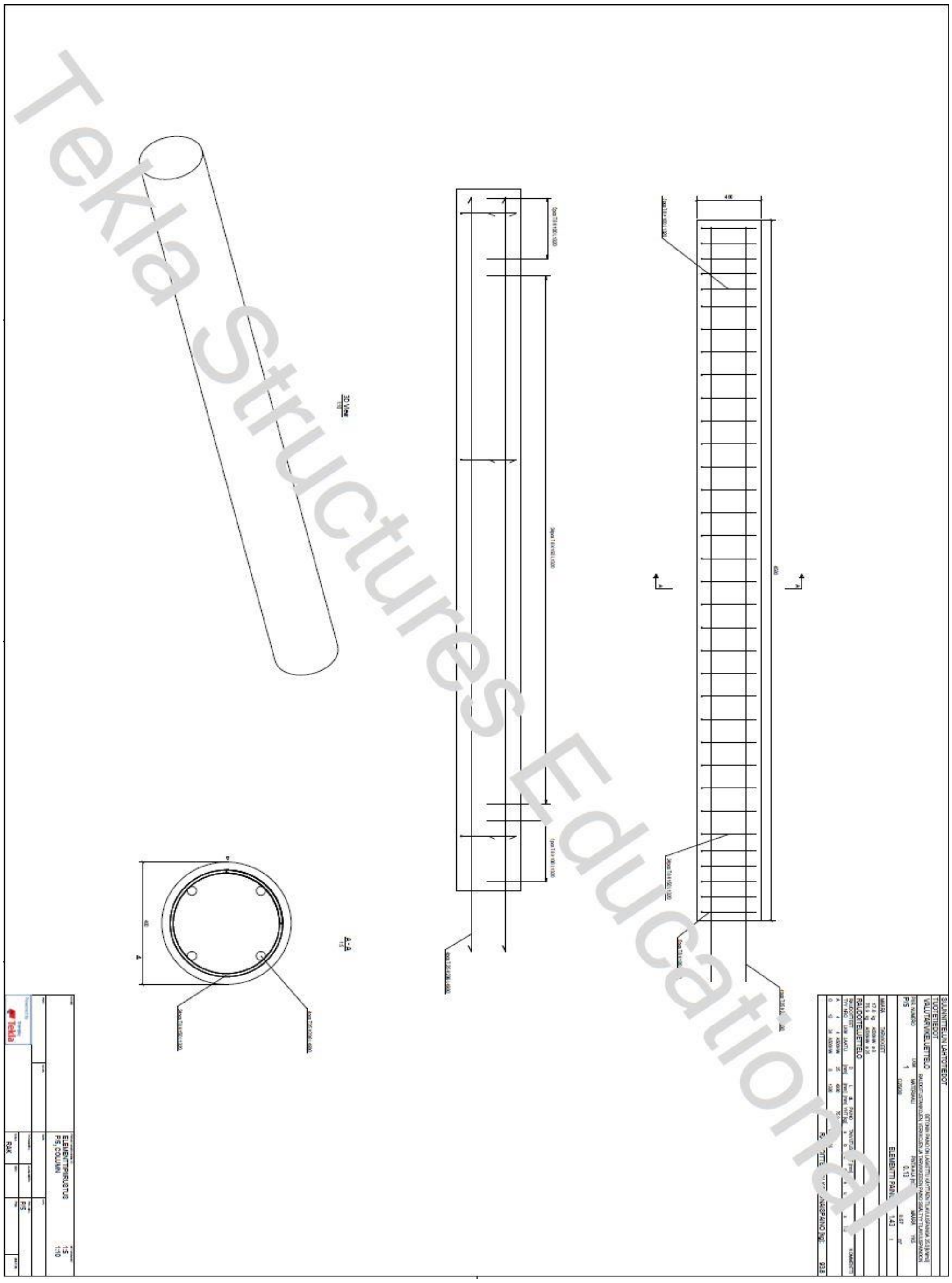
Appendix 1
An example of General Arrangement Drawing

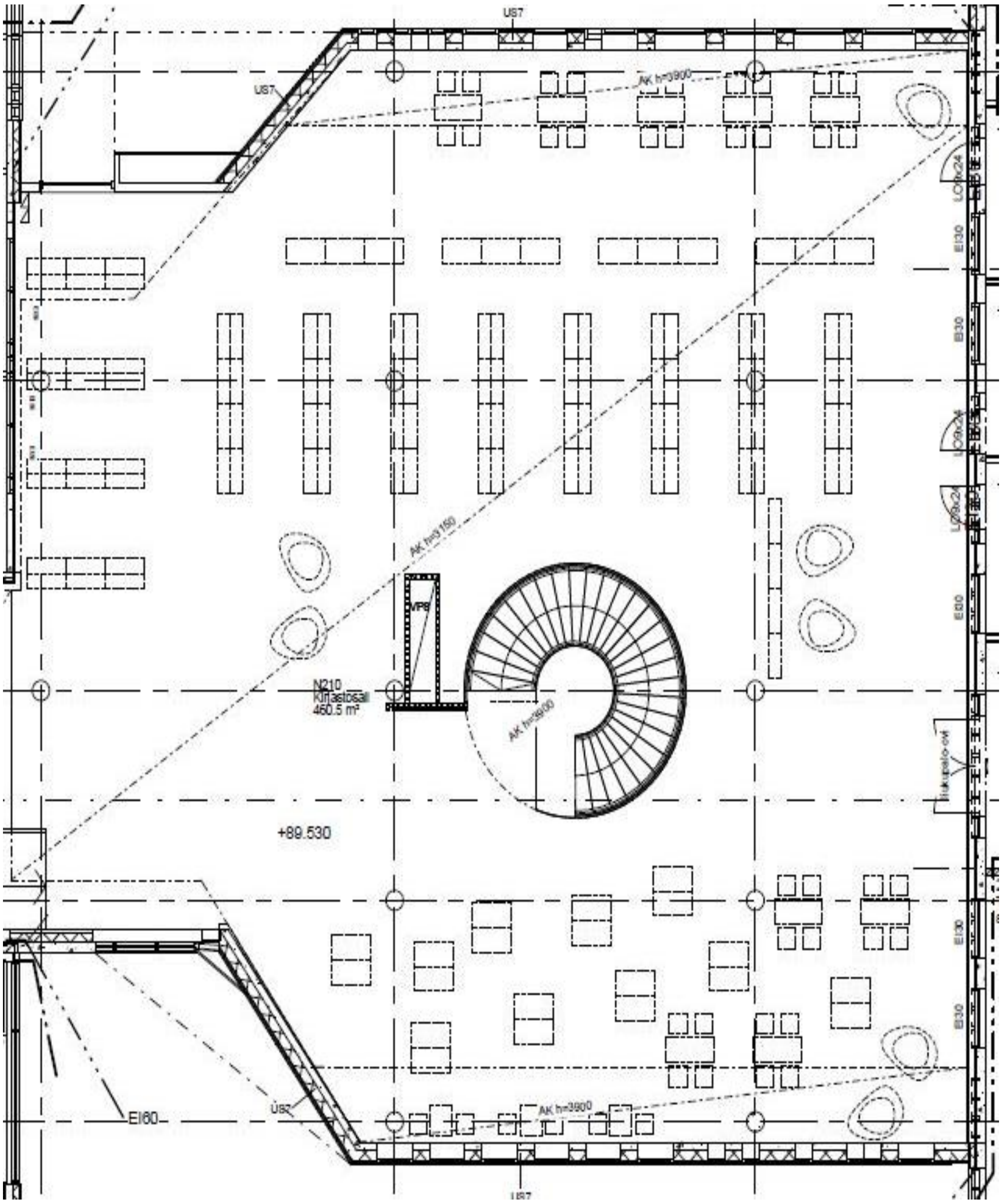


Appendix 2
An example of Cast Unit drawing



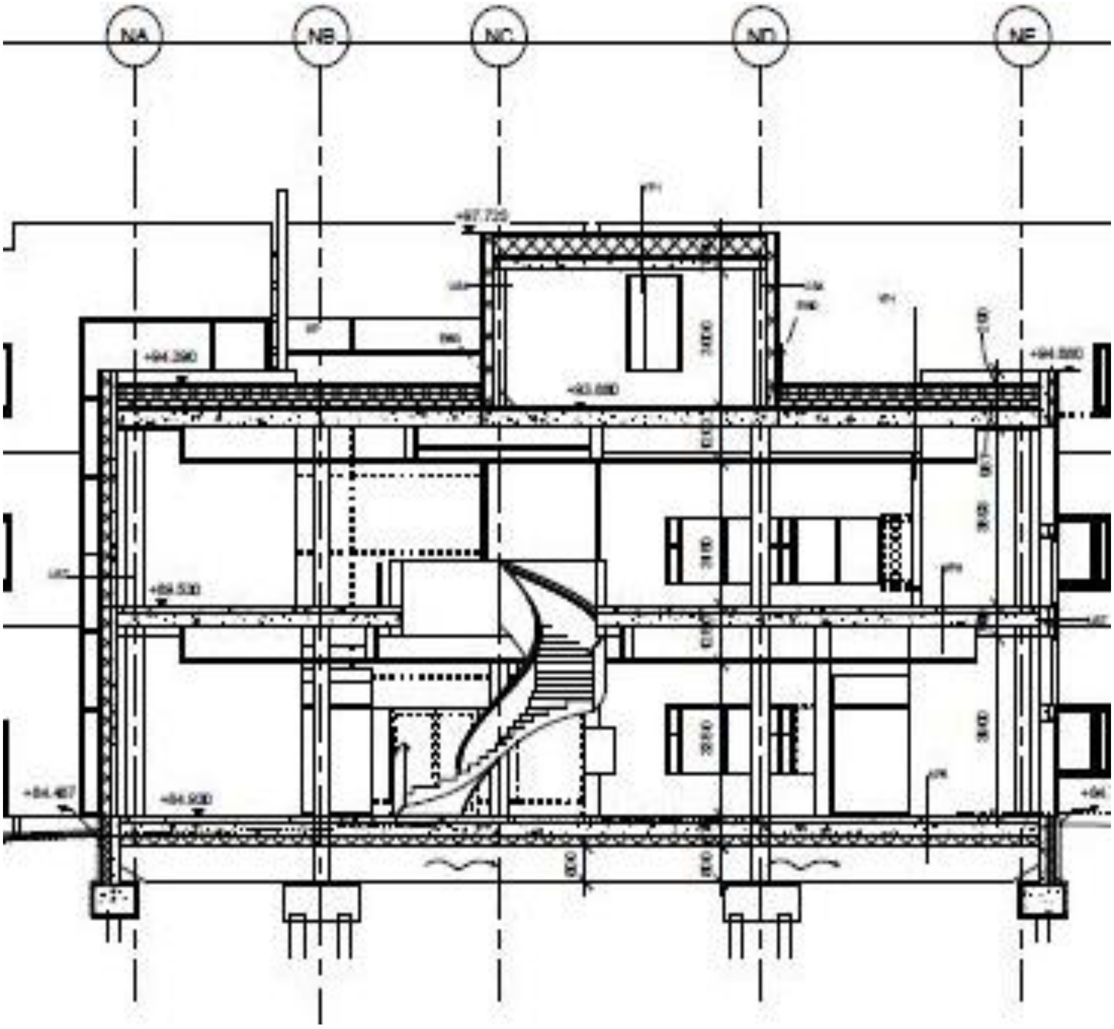
Appendix 3

Floor Plan



Appendix 4

Elevation Drawing



Appendix 5

Elevation Drawing