Scheduling and Visualization of Erection in Tekla

Construction of Sheet Metal Centre

HAMK
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ABSTRACT

The main purpose of this thesis was to find the possible ways of visualizing the construction of Sheet Metal Centre according to the working schedule, erection plan and final design in Tekla. The aim was to find effective solutions to the existing problems in relation to presenting the real-built construction situation in software. The thesis explains the methodologies of 4D design of the construction site in software, as well as the time schedule of the work required for all the phases of construction. In order to meet the requirements of the Construction phase, COBIM standard 2012: Series 13 was implemented in the visualization.

A well-managed construction plan is vital for any kind of project. To meet this requirement, the planner needs a comprehensive model of simulated design before the project begins. This thesis acts both as a manual and a technical report of the Tekla design. Therefore, a planner is able to simulate the construction site according to the available resources, and is also able to calculate the amount of time required for the completion of respective phases.

The thesis simulated the construction details of structural members of HAMK Sheet Metal Centre. The construction of the centre began on 25th June 2014 and ended on 13th March 2015. Therefore, the centre acts as a case study of the actual real-life situations of a construction site, and its successful pre-construction design in Tekla. Even though some other similar software could be used for the same task, Tekla was used in this thesis. Tekla BIM Tools of the Tekla Software was selected to perform all the designs. For this reason, this thesis serves well to anyone who needs a manual to perform the necessary designs, calculations, visualization and scheduling of a construction project. The Tekla model of the construction phase has been animated in Google SketchUp and the necessary components have been derived from it to make the visualization more effective and closer to the actual site. All in all, the thesis hopes to be a manual for the latest 4D concept and its visualization in Tekla.

Keywords Tekla BIM, 4D, Animation, Google SketchUp, Scheduling, Visualization

Pages 38p. +appendices 13p

FOREWORD

This Bachelor´s thesis "Scheduling and Visualization of Erection in Tekla" was written to assist construction planners to compare the real site with a model so that the different phases of the construction are clear and understandable to all the parties involved; even before the project begins.

I would like to thank Olli Ilveskoski, senior lecturer of HAMK for presenting me with such a thesis topic, which is practically important for companies and students involved in construction planning. His advice and suggestions have been very useful during my writing.

A great thanks goes to my teacher Tomi Karppinen, senior lecturer of HAMK for giving his valuable time for discussion of Tekla use as well as to Jarmo Havula, Director of Sheet Metal Centre for supplying me materials needed for animation. I must thank Tuomas Salonen, Real Estate Manager of HAMK Oy for providing me with the construction details of the Sheet Metal Centre.

I would like to thank my colleague Prabesh K.C and Tran Dinh Cu for their support and help during my thesis. Their encouragement and assistance have been very important for me. I also extend my gratitude to all the HAMK staff who have helped me throughout the thesis.

Finally, a big thanks to HAMK for a 4-year experience of a lifetime and memories.

Bhupendra Basnet
1.2.2016

CONTENTS

1 INTRODUCTION

The thesis aims to act as a bridge between a designer and the actual construction site in such a way that a site manager can successfully implement the model created by a designer. The construction of HAMK Sheet Metal Centre is the case of study.

HAMK Sheet Metal Centre was constructed on 25th June 2014 and it ended on 13th March 2015. The details of the construction can be modelled or simulated in Tekla. Therefore, the thesis presents the structural members of HAMK SMC such as concrete, steel piles, a column, crane beam, truss, foundation wall and exterior sandwich panel according to the work schedule. The above structural members have been visualized in Tekla. So, the valuable information such as the amount of work done/to be done in each time period, amount of manpower required and the amount of materials required in the site can be obtained. This is very important for any planner to design and finish a project in time. The objectives of the thesis can be summarised as:

- To get the necessary information needed in pre-tendering and planning phase.
- To make a weekly time schedule of construction using Tekla software.
- To find ways to link the working time schedule with a given model.
- To estimate the production rate required in construction.
- To find a proper way of visualizing the construction phase according to the time schedule.
- To find the way to exchange the erection date between the manufacturing company and contractor.
- To find necessary site materials which make the working schedule clearer and understandable.
- To find the possible ways to animate different phases of construction according to the schedule.

Tekla model is useful in comparing the actual construction site with the design model in Tekla. Therefore, it is very helpful to calculate the amount of labour needed to accomplish the project in time. This helps the manufacturing company to fabricate the essential elements so that all the required materials arrive in time during construction. This means that a considerable amount of confusion is prevented between the planner and the manufacturing company. In a way, this is important for the planner to save money and time.

After the successful visualisation, the pre-tender, pre-contract and construction phase can be carried out smoothly. Therefore, the thesis presents the model of HAMK SMC during each step of its construction; namely, from the beginning of its foundation to the complete erection of the structural members in Tekla. From this case study, anyone can easily understand the processes involved in the construction.

2 BIM

BIM stands for Building Information Modelling. BIM is the combination of different models giving complete information of building which helps in construction of the project. Simply, BIM is an organized group of building data easy to query both in a "visual" and a "numerical" way.

According to National BIM Standard United States "*Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition."* (Nationalbimstandard, 2004.)

The coordination of different models and planning helps in saving costs and time. BIM helps in the project with the function of detail information and coordination of model. A true BIM consists of virtual coordination between different parts and pieces used in the building. The BIM helps in simulating the different elements of building like columns, beams, walls, windows etc. with time factor and shows the behaviour in a virtual computer environment before the actual construction starts. CAD Stands for Computer Aided Design. CAD drawings are the two dimensional drawings which give limited information. BIM is the advanced form of CAD that imitates a real drawing. The developing technology helps in the development of BIM towards more advanced and intelligent technology. (Nationalbimstandard, 2004.)

2.1 3D, 4D, 5D Modelling

With the change in modern technology in the field of construction, there have been many developments in it. 2D CAD drawing is an improvement of 3D model drawing which helps to understand the construction work better. In simple language 3D modelling represents three dimensions of any surface. Tekla, ArchiCAD, Revit, Google SketchUp etc. are the famous software in structural modelling. Figure 1 below shows the concept of different dimensions in BIM. (Vico Service, 2014.)

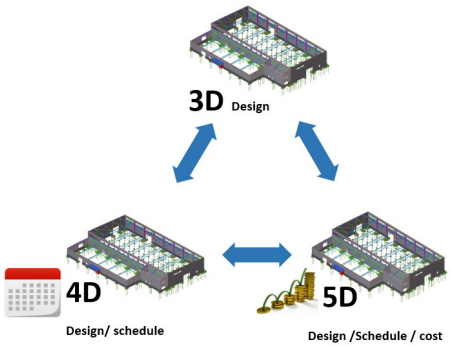


Figure 1 Concept of different dimensions in BIM (Rib U.S cost, 2014)

The combination of a 3D structural model with the construction time schedule refers to 4D modelling. 3D modelling is not enough to give com-

plete information on building since there is no date connected in it. 4D model shows how different levels of construction can be done according to the time schedule. 4D BIM model gives detailed information on the construction time, erection time and assembly delivery time.5D BIM modelling includes the 3D structural model with the construction time schedule and cost estimation. With the simulation of a 5D model, we can generate a bill of quantity, cost estimation with the time schedule and labour costs. (Vico Service, 2014.)

2.2 BIM Standard

In Finland, Building Smart Finland provides the Common BIM Requirement and necessary standards. Building Smart Finland is collaboration forum founded by the Finnish Property Owners, A/E Consultants, Software Vendors and Construction Companies with the aim of providing the necessary information on BIM and implementing the BIM based processes within the member group. The BIM Standards are as follows: (Common Bim Requirement, 2012)

Common BIM Requirement 2012, COBIM, provide the entire BIM requirements from the Series 1-13.

Series 13: Use of models in construction, provides the requirements for BIM utilization in the construction phase.

Heading 4.2 and 4.3: Construction Schedule in BIM and Presenting Construction Status Information in BIM give the necessary requirements in a construction visualization of any project. (Common Bim Requirement, 2012.)

2.3 Construction Planning

The systematic organizing of all the resources and tasks, which is needed to complete the project, is called construction planning. In practical terms, it is the process of monitoring and controlling all the elements, plant, labour, equipment, and service to undertake a project. From the contractor`s point of view, the main objective of construction planning is to meet the client requirements from the project output with limited resources and time. Construction planning can be divided into two different parts i.e. programming the tasks and monitoring and controlling the tasks which will be discussed below. (Griffith & Watson 2004, 86.)

2.3.1 Programming the tasks

The division of project tasks into different work according to time and necessary resources falls under programming the tasks. Pre-tender, pre-contract and contract are the major parts required in the planning phase of the project. (Griffith & Watson 2004, 90-94.)

a) Pre-tender: The main target of this phase is to get the information requirements to get a tender of the project. The construction planner prepares all the necessary documents required in estimating the tendering price of a project including the overall construction period, approximate labour requirements, approximate material and plant requirements. There are different kind of documents assembled in this phase, which are the following:

   - Condition of Contract
   - Bill of Quantity
   - Specification and Drawings
   - Project Correspondence
   - Site Visit Report

b) Pre-contract: The main part of this phase includes the contract of construction and detailed information on the site work. All the documents in the pre-tendering phase with a deep analysis with detailed information are the required documents in the Pre-contract. The master programme with detailed information on the carried site work is the main part of Pre-contract. The data presented in this phase should include accurate information on work like the exact volume, exact time, and exact labour and so on.

c) Contract: The main part of this phase includes the subdivision of site work into different subcontracts for short periods. The Master document with detailed information on subdivision work is the main required document. The Master document shows the construction sequence and division of site work into subcontracts accurately.

2.3.2 Monitoring and controlling the tasks

The other main aspect of construction planning is to plan how to control the work onsite or offsite. Different companies use different software to analyse and control the project. It is necessary to track the project work in its execution phase so that it is easier to supply all the resources needed in coming further to complete the project. The co-ordination of different software in managing and controlling the construction task helps to run the project smoothly. An effective control mechanism will bring momentum to the work. Early risk analysing and work safety are the advantages of a good controlling system. In Construction Management, using different software for controlling does not give the exact information. There are various challenges coming up in the execution phase of a project, which might turn down the project. The development of logical construction sequence represented by an accurate method is therefore a crucial step in planning and control processes. (Griffith & Watson 2004, 87.)

3 CONSTRUCTION OF SHEET METAL CENTRE

3.1 Project information

The structural model of HAMK SMC was designed by Tasoplan Oy and Ruukki Oy. The project started on 25th June 2014 and ended on 13th March 2015. SMC was built for R &D and teaching use for HAMK and Ruukki construction Oy. The SMC hall is the first near-zero energy building in Finland, and it has successfully shown that it is economically viable to build such a building even in Nordic climates. Figure 2 below shows the Structural model of SMC.

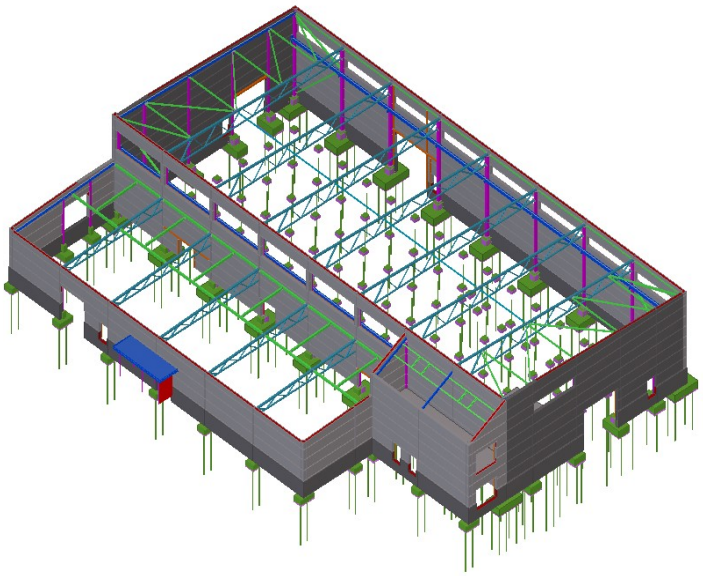


Figure 2 Structural model SMC

The structural members of the steel frame are beams, columns, truss, bracing of cold-formed steel (CFS) profiles of different dimensions. The erection of steel work began on 18th August 2014 and it ended on 27th October 2014. Ruukki Oy was the subcontractor for the erection of steel work and supply of the necessary steel elements. The organisation shown below in Figure 3 shows different parties involved in the construction of SMC.

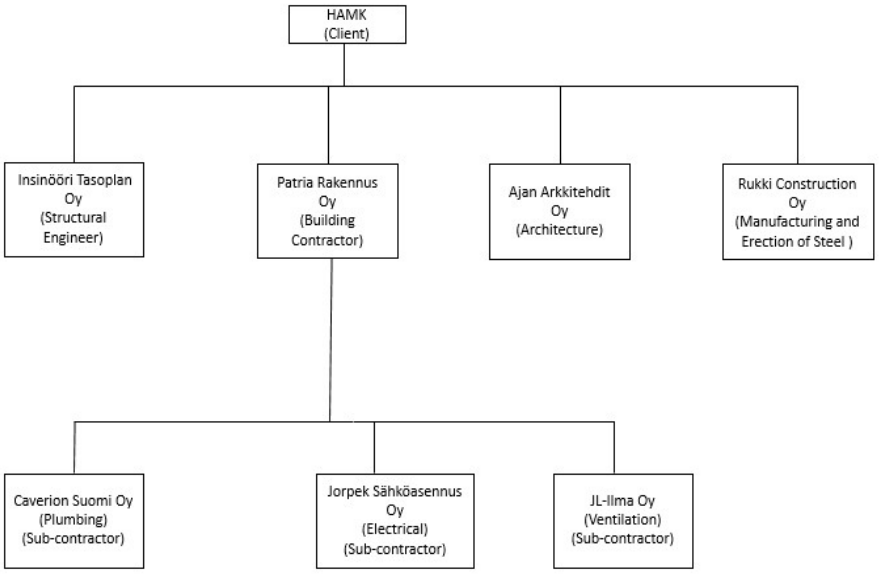


Figure 3 Organisation of SMC project

As shown, HAMK was the client and it appointed Insinööri Tasoplan Oy, Patria Rakennus Oy, Ajan Arkkitehdit Oy and Ruukki Construction Oy for structural engineering, building contracting, architecture and steel erection respectively. Caverion Suomi Oy (plumbing), Jorpek Sähköasenus Oy (Electrical) and JL-Ilma Oy (Ventillation) were the subcontractors of Petria Rakennus Oy. (RakennusFakta, 2014.)

3.1.1 Project schedule

There are different photos and videos that have been taken during the construction of SMC. Different phases of construction are analysed and new weekly schedule is generated as shown in Table 1. The weekly schedule is not as accurate as actual construction. According to Table 1, the concrete pouring date for footing was planned at end of the week so that it will dry during the weekend. The average working rate is calculated as per week. The project is divided into two parts: construction below the ground and construction above the ground to make the scheduling work clearer.

Table 1 Weekly working plan of SMC construction

	Task	Average Production rate	Erection Starting date	Erection ending date	Concrete pouring date
Construction Below Ground	1. Foundation				
	a. Pile	84 Pile /week	28.7.2014	12.8.2014	
	b. Footing	20.3m^3/ week	29.07.2014	10.10.2014	
	i. Main Footing		29.7.2014	04.08.2014	01.08.2014
			05.08.2014	11.08.2014	08.08.2014
			12.08.2014	18.08.2014	15.08.2014
			19.08.2014	25.08.2014	22.08.2014

	ii. Secondary footing		22.9.2014	26.09.2014	26.09.2014
			29.9.2014	3.10.2014	3.10.2014
	c. Concrete footing connection	20.3m^3/week	15.08.2014	29.08.2014	
			15.08.2014	21.08.2014	22.08.2014
			22.08.2014	29.08.2014	29.08.2014
Construction Above Ground	2. Erection of Main Building				
	a. Column/ wall bracing / Crane beam/Truss bracing / Truss		1.9.2014	5.9.2014	
	b. Door Bracing		8.9.2014	12.9.2014	
	c. Roof panel		15.9.2014	19.9.2014	
			22.9.2014	26.9.2014	
			29.9.2014	3.10.2014	
	d. Solace wall		8.9.2014	12.9.2014	
			15.9.2014	19.9.2014	
			29.9.2014	3.10.2014	
			6.9.2014	10.10.2014	
	e. Window bracing		15.9.2014	19.9.2014	
	f. Wall Panel		22.9.2014	26.9.2014	
			29.9.2014	3.10.2014	
			6.10.2014	10.10.2014	
	3. Erection of office Building and Ware house				
	i. Column		8.9.2014	12.9.2014	
	Wall Bracing / Truss bracing / Beam/ Truss		20.10.2014	24.10.2014	
	ii. Solace wall		8.9.2014	12.9.2014	
			3.11.2014	7.11.2014	
	iii. Roof panel		27.10.2014	31.10.2014	
			3.11.2014	7.11.2014	
	iv. Door bracing		27.10.2014	31.10.2014	
			3.11.2014	7.11.2014	
	v. Window bracing		27.10.2014	31.10.2014	
			3.11.2014	7.11.2014	
	vi. Wall panel		10.11.2014	14.11.2014	
			17.11.2014	21.11.2014	

4 4D TEKLA MODEL (SHEET METAL CENTRE)

The main part of 4D modelling is to link the working schedule to the 3D model and visualize the construction work according to the schedule. All the necessary information can be obtained from the model if the visualization is done according to the working date. It is possible to link the different model in Tekla and show that model according to

the working dates. Tekla BIM tools such as Tekla model organizer, Task manager, Project status visualization, Phase manager and so on are necessary tools used in visualizing the construction work.

4.1 Organizing the Model

Tekla Model organizer is one of the most effective tools that helps in planning and organizing the model. Figure 4 below shows the Model organizer tool with SMC model. The tool helps to group same type of objects in an organized way so that required object is obtained in a short period. It is a helpful tool for making labour calculation and useful in the calculation of production rate. The below chapter 4.1.1 demonstrate the use of the Model organizer tool in calculating the production rate of the concrete footing.

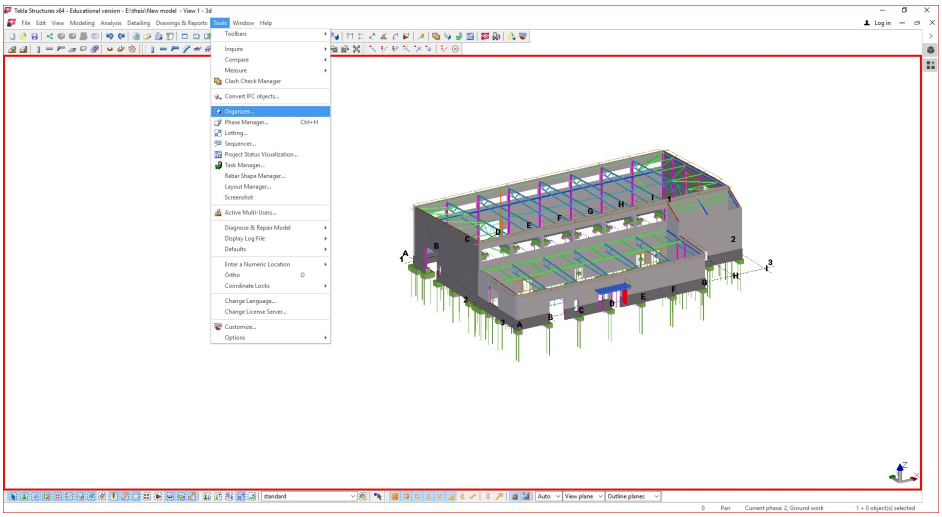


Figure 4 Model organizer tool with SMC model.

The Tekla Model organizer tool is opened from the heading called Tools in Tekla. Every time when the Model organizer is opened, a synchronizing option is selected where Tekla automatically picks the entire data from the model to organized group. The SMC model is divided into different parts called the main building, office building, store, foundation of main building, foundation of office building, foundation of store, roof of office building, roof of main building and roof of the store. The division of the building is done in order to pick the necessary parts and get the exact information. The following steps show the division of SMC into different parts using model organizer:

1. A new site is created named as Sheet Metal Centre. A new building called SMC is named and the boundary box is filled with different values as shown in Figure 5.

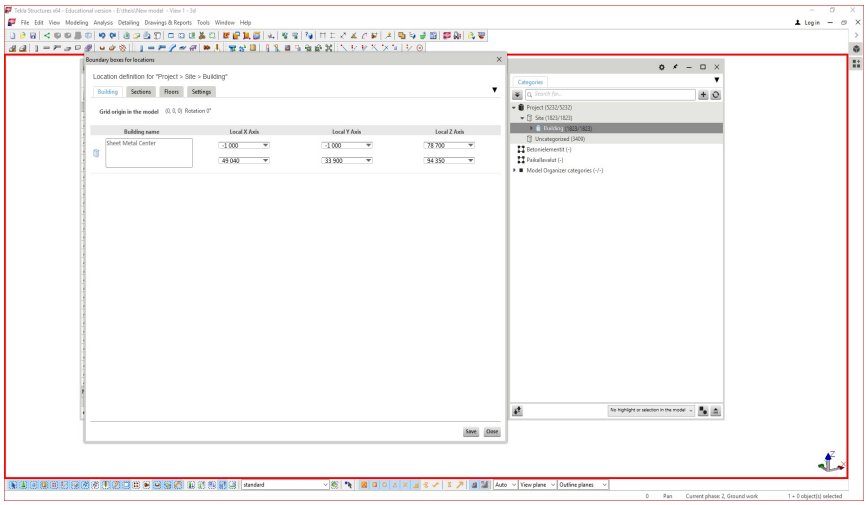


Figure 5 SMC model in boundary box of Tekla model organizer.

2. The SMC model is sub divided into different sections and floor parts. The different values for a boundary box is filled out in sections and floor box as shown in Figure 6.

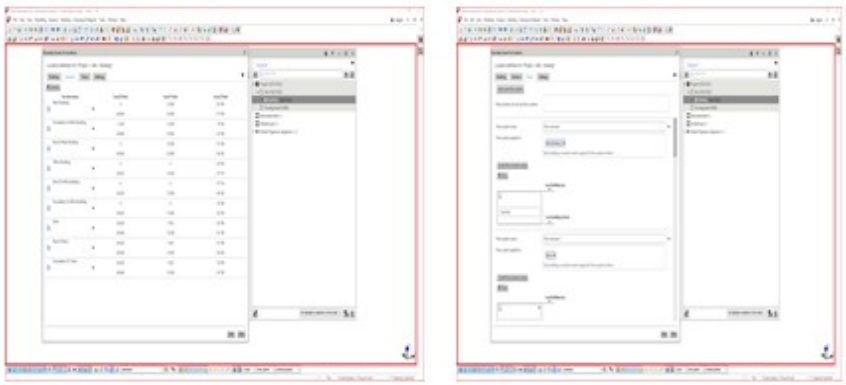


Figure 6 Different values for boundry box in Tekla model organizer

3. All the values filled out in the boundary SMC model are subdivided into different parts as shown in Figure 7. Tekla will automatically show all the material in the given boundary. The list of materials can be shown in an organizer browser according to the division of model. This will help BIM engineer to manage the material list of certain work. It is easier to pick the object and obtain the necessary data like the volume, area, length, material type and so on with the help of project division from the organizer tool. The objects under the boundary box can be easily selected and arranged in a different order like erection, cast unit, pour, rebar, column list etc. which give necessary information for project planning.

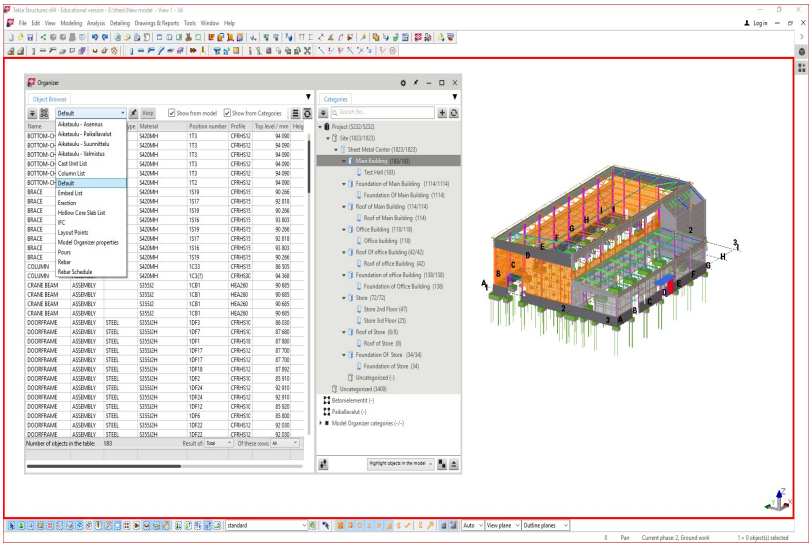


Figure 7 Division of SMC model in Tekla model organizer.

4.1.1 Production Rate Calculation of Concrete Work

Production rate is similar to the working rate. In general, the production rate means amount of work done in a certain period by a number of people. The contractor makes the plan for the number of workers needed in a project with the help of the production rate. The necessary data needed for the production rate calculation is obtained from the production card as presented in Figure 8. In Finland, the basic production rate data is obtain with the help of Rakenustöiden menekit as shown in Figure 8 (Wind, et al., 2014).The book gives a basic concept of labour required to finish different kind of construction work.

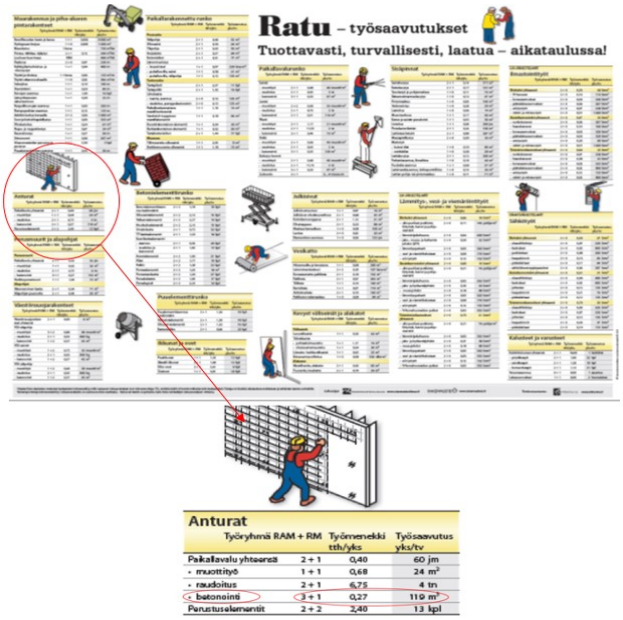


Figure 8 Sample of rakenustöiden menekit with required labour.(Wind, et al., 2014.)

According to Figure 8, three professional workers and one helper can complete 199m^3 volume of concrete work in 0.27 hour. In case of the construction of SMC, the footing work was completed between 29.7.2014 and 29.8.2014. The working hour is assumed as 6 hours a day. The working days are 5 days a week. In 24 working days, 144 working hour is calculated using a simple mathematical equation. In Figure 9, we can see that 97.5m^3 volume of concrete footing is obtained which is to be completed in 144 hours. By a simple arithmetic equation, 20.3m^3 volume of the concrete work should be completed in a week. It is calculated as shown below:

97.5 m^3 of concrete work is done in 144 hours.

20.3 m^3 of concrete work is done in 30 hours. (30 working hours in a week).

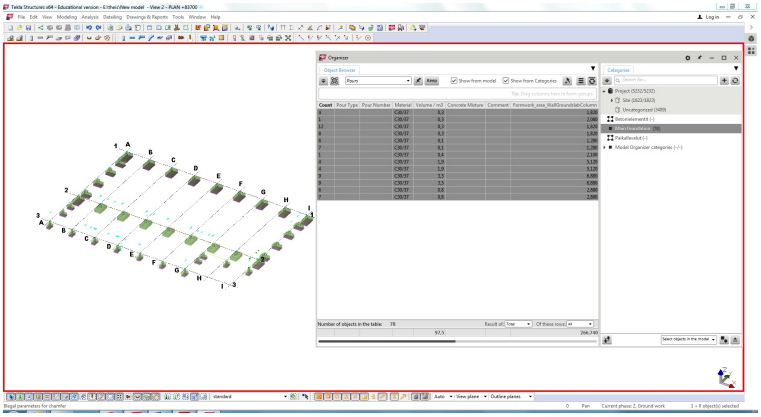


Figure 9 Tekla model organizer showing volume of concrete footing.

4.2 Simulation of time schedule in a project

The project is divided into different subtasks under Task manager tool in Tekla as shown in Figure 10. Tekla task manager is an effective tool for making project planning. It is easier to create a project plan and link the plan with model under task manager.

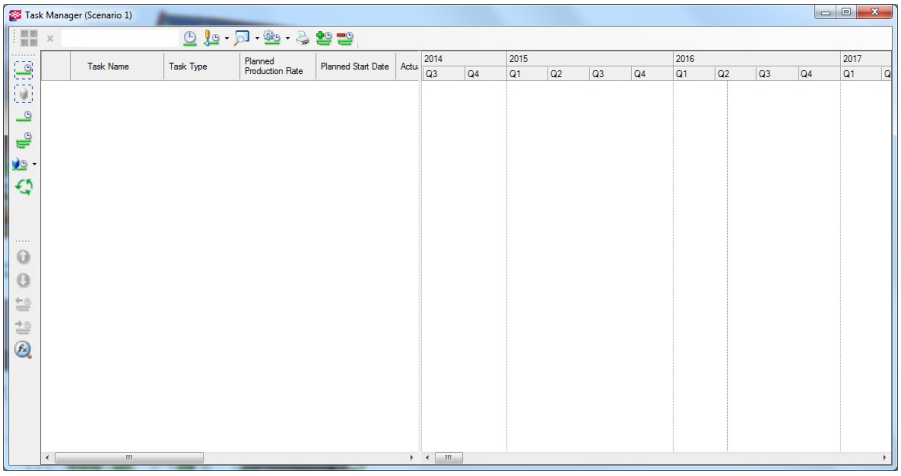


Figure 10 Task manager tool in Tekla

One can create a master plan, project erection plan, concrete task list, and many other necessary documents under the task manager. It is easier to input dates, change working hour, modify the task list, change the production rate of certain task and set the holidays under the Task manager. It is also possible to export the xml file from task manager or vice versa. One can create a project erection plan in Microsoft Excel, then import the file and link the task with the model with the help of the Task manager. (Tekla Corporation, 2016.)

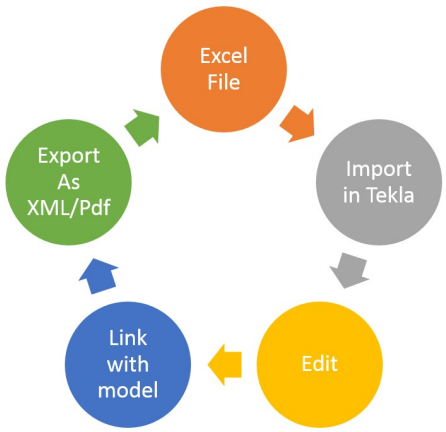


Figure 11 Workflow in Tekla task manager.

Figure 11 above demonstrates the basic workflow under the Tekla task manager. The other feature of the tool is that anyone can edit the production rate and get the dates according to input production rate. In the task manager, the production rate can be managed manually under task type. The Task type is opened under general setting and action as shown in Figure 12. This is done by clicking **General Setting -> Task setting**. The task setting window appears in the screen where the quantity and time of different work can be edited manually to get the required production rate.

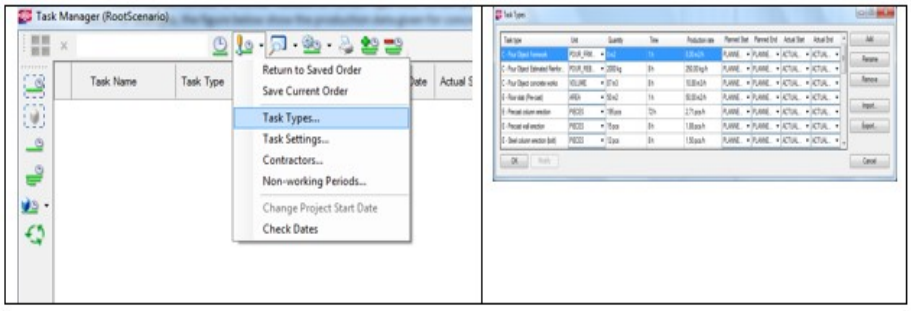


Figure 12 Task type in Tekla task manager.

The other feature of the tool is linking the plan date according to the production rate directly to an object in the model. The linked date is automatically be visible in the object user attribute at Erection box, Fabrication box and design box. The following flow chart below shows the steps to link the erection date and the production rate of piles with the model.

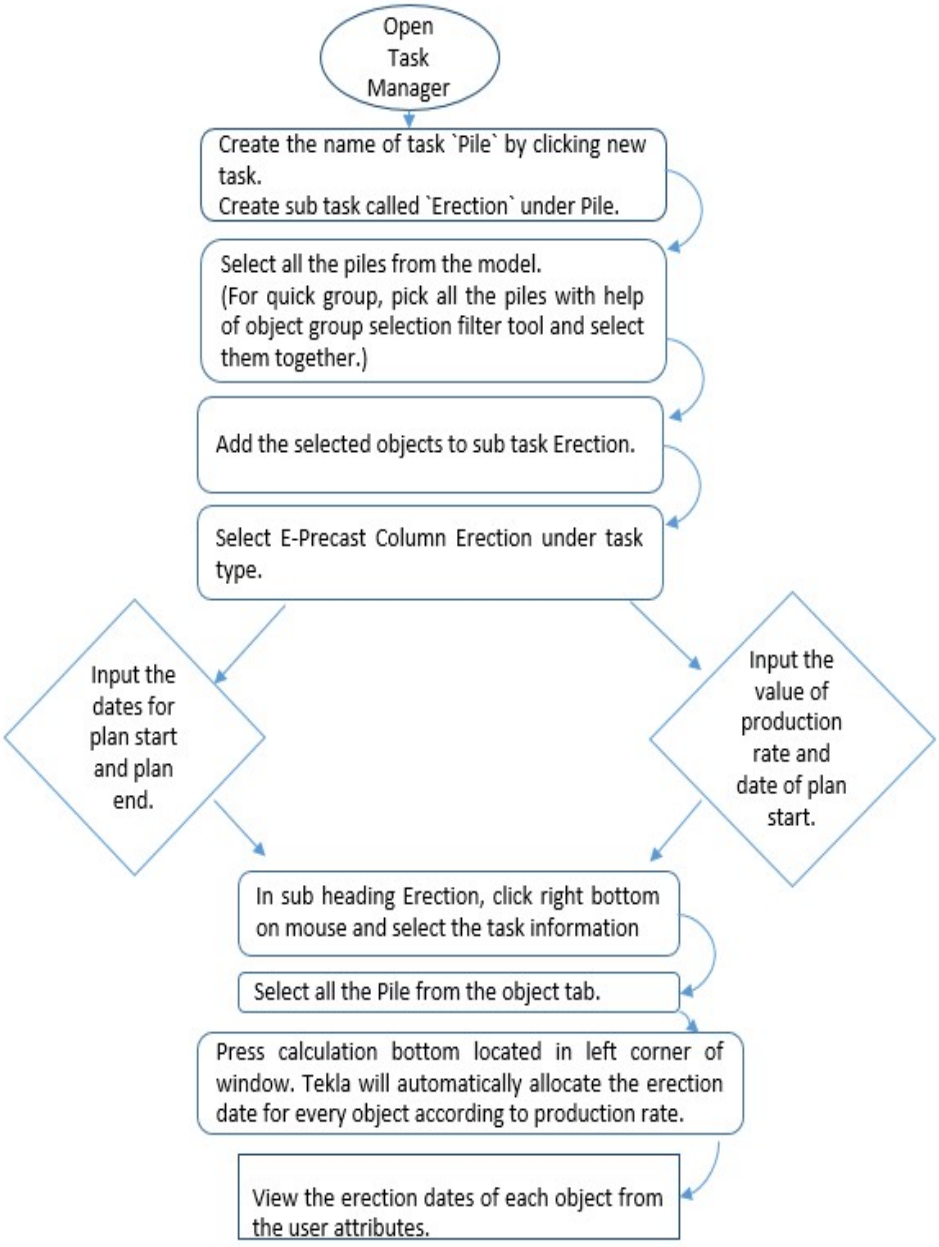


Figure 13 Flowchart to link the model with erection dates.

Based on the flowchart shown in Figure 13 above every object can be linked with its respective working time. In the case of concrete work, it is possible to link the concrete foundation with its pour date. In the case of steel work, it is possible to link the steel frame with detailed planning. For example, the Fabrication date and Erection date for steel frame can be linked with the construction plan, as shown in the following steps:

(Note: The blue colour in the Gantt chart shows that the objects are linked with the model and an empty box shows the objects are not linked in the model. The colour can be changed manually to visualize the chart effectively.)

Step 1.

All the parts needed to be linked in the model are selected as shown in below Figure 14.

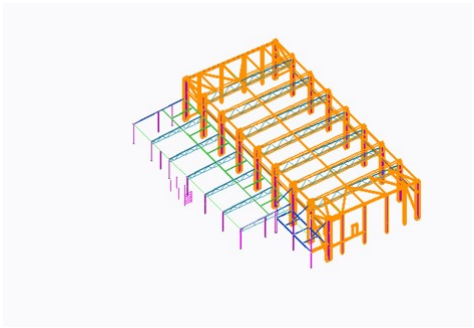


Figure 14 Steel frame selection in model.

Step 2.

Sub heading Erection and Fabrication is created under the heading steel frame and the selected parts are added to the sub heading as shown in Figure 15 below.

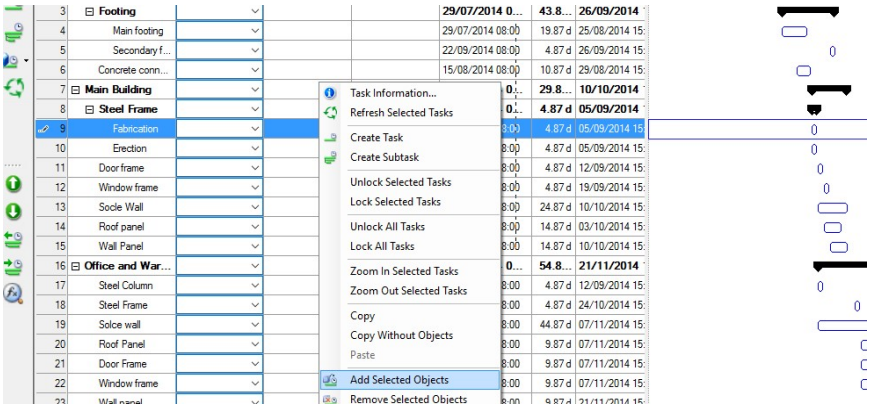


Figure 15 Fabrication and Erection in Tekla task manager.

Step 3.

Task type setting is opened and a new task type called F- Fabrication is added in the list. Since it is just an example to show how the scheduling for fabrication can be done in Tekla, the value given for unit quantity and time is not accurate. In real life, the manufacturing company has their own production rate and manufacturing date. The Planned Start Date is filled with Planned_Start_F and rest of the box is filled with the value ending letter “F” as shown in Figure 16.

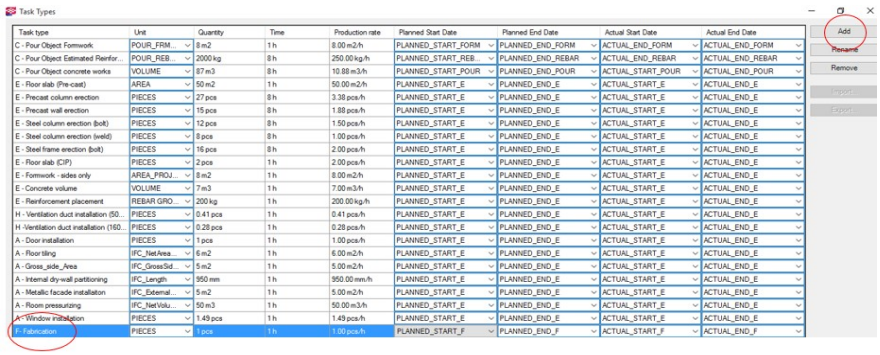


Figure 16 Fabrication task type in Tekla task manager.

Step 4.

F_Fabrication is chosen from subheading of Fabrication and E_ Steel column erection (bolt) is chosen from subheading of Erection task type as shown in Figure 17. Tekla will automatically calculate the production rate according to the Erection date or vice versa. The manufacturing rate of the steel assemblies is 2.70 pieces per hour and erection rate for steel frame construction is 2.40 pieces per hour as shown in Figure 17.

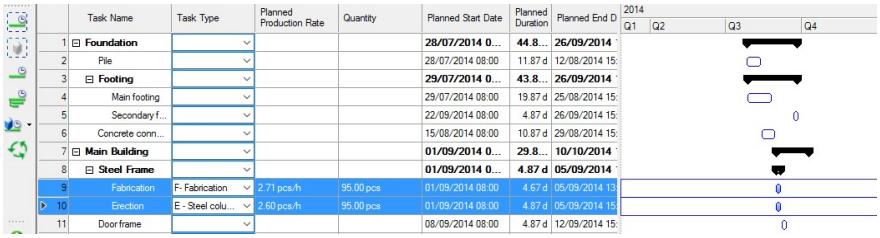


Figure 17 Erection task type in Tekla task manager

Step 5.

The fabrication date of steel work depends on the production rate of manufacturer. It is always necessary to plan the fabrication date early enough so that material can be deliver on the time. The fabrication date is filled in the table as shown in Figure 18.

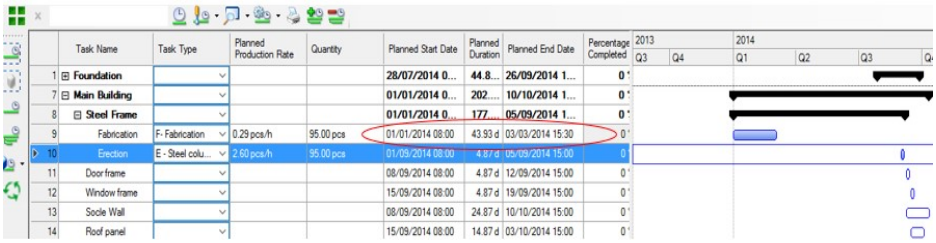


Figure 18 Fabrication date in Tekla task manager

Step 6.

It is possible to make the link between the fabrication date and erection date from the tool. The proper link between the fabrication date, transportation date and erection date show delay in the project if one of the condition is not met. The task information is opened under the heading Erection and the dependencies tab is selected. In the dependencies tab Fabrication

is chosen under the heading task name. Then, the Finish to Start (FS) is chosen from the heading type as shown in Figure 19.

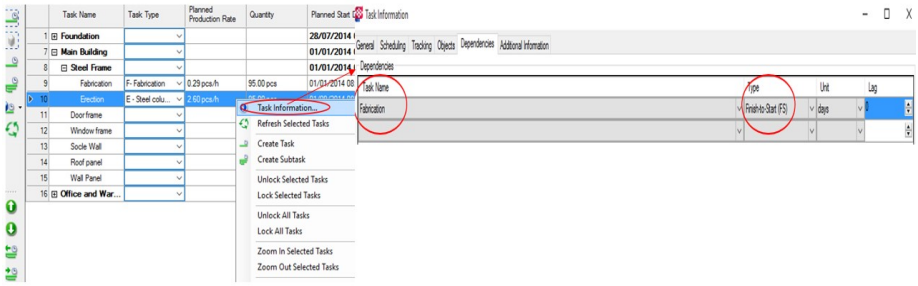


Figure 19 Erection date depending on fabrication date.

Step 7.

The arrow between the heading Fabrication and Erection in the Gantt chart shows the link between the dates respectively. If the date in the Fabrication and the Erection is changed, all schedule date for different task is changed in a project. The Figure 20 below shows the erection date dependence on the fabrication date.

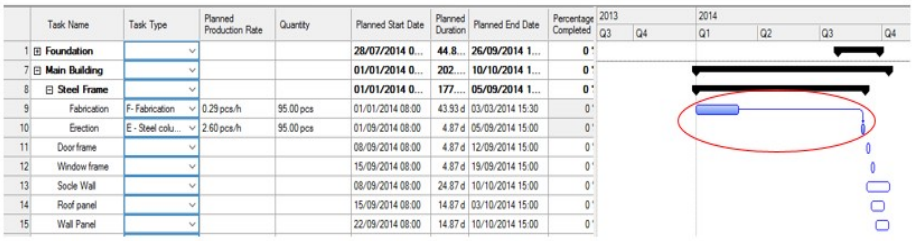


Figure 20 Chart showing erection date dependence on fabrication date.

Step 8.

The erection dates can be saved in the xml format or print as pdf format. (Go to scenario and click export as shown in Figure 21). The xml format file can be sent directly to the manufacturing company. The manufacturing company plan the manufacturing list according to the erection date of a project. In general transportation gap between the fabrication date and erection date is set as one week. In this way, the project material can be supply in time and project can run smoothly.

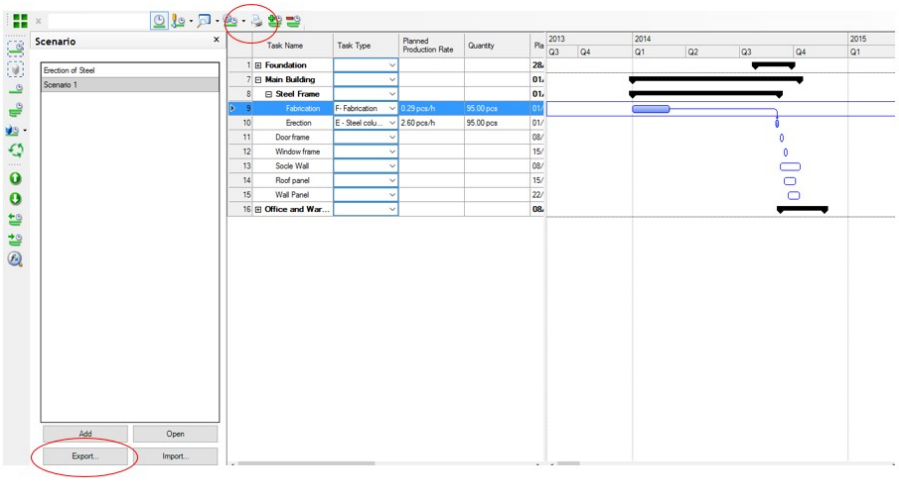


Figure 21 Types of file sharing in Task manager.

Step 9.

The task information on erection is opened and all the objects are selected under object tab. The calculate button is clicked as shown in Figure 22. Tekla automatically assign the erection date for each steel member and calculate the duration of the plan work. The same process is applied to assign the fabrication dates in the heading Fabrication.

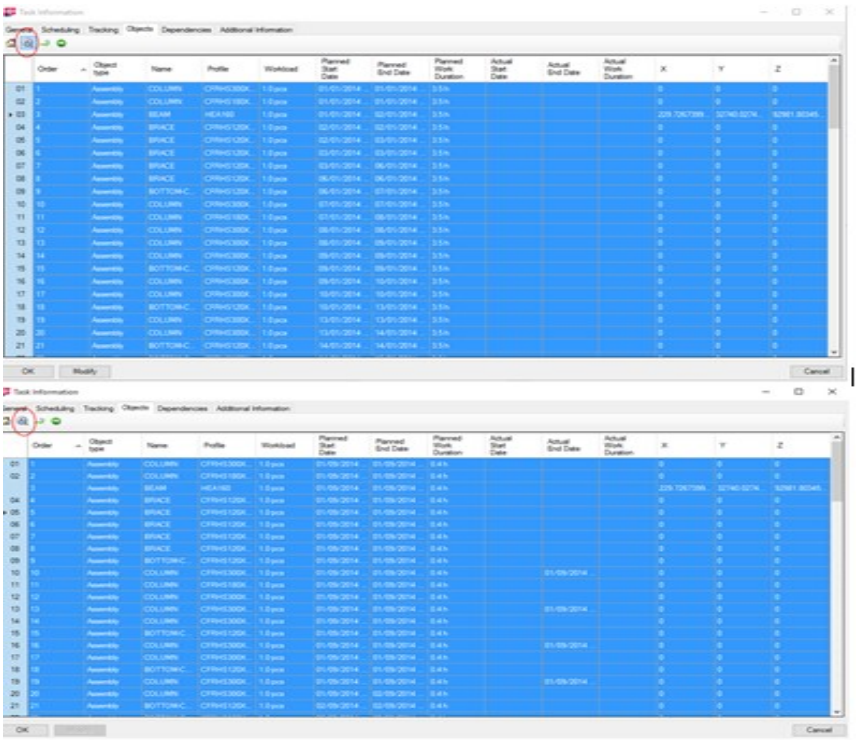


Figure 22 Calculation of working rate for each part in task manager.

Step 10.

The user attributes of a steel member opened in the model. The erection dates and fabrication dates for each steel member can be seen in respective box as shown in Figure 23.

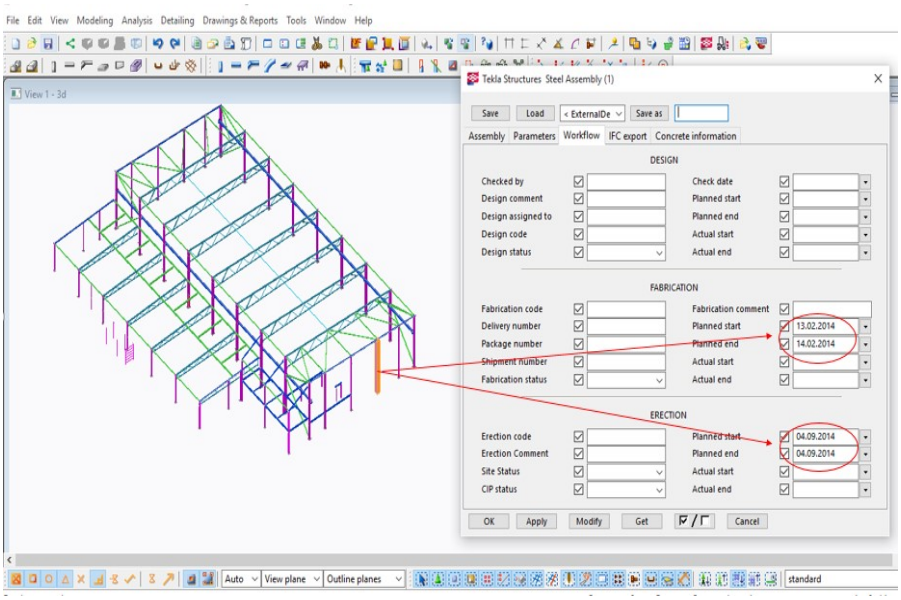


Figure 23 Erection and Fabrication dates in model.

The erection plan for construction of SMC is generated with the help of Task manager as shown in Figure 24 below. After analysing the photos and videos of construction of SMC, a general weekly erection plan is created in Microsoft Excel and imported to Tekla Task manager tool. However, the weekly erection plan is not accurate because of a lack of information. The erection and fabrication dates for piles and steel frames is linked in model with the help of Task manager. The fabrication date of steel frame is not as accurate as in the real SMC construction. The production rate and number of quantity data is not as accurate as in real SMC construction. However, it is possible to get a general production rate for each work with the help of a plan date. In Tekla, Tool Selection Filter is used to make a group of objects. After making the group, objects are selected and added with the related task. Figure 24 shows the erection plan for the construction of SMC in the task manager.

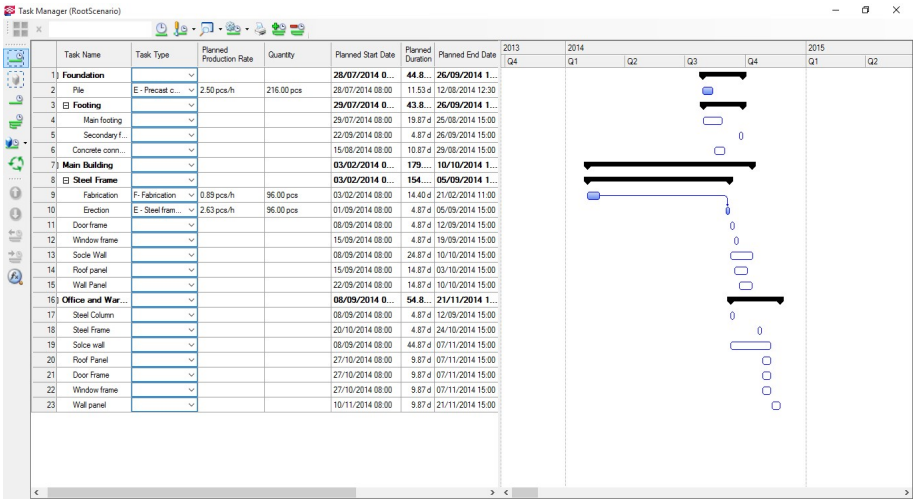


Figure 24 Erection Plan for construction of SMC.

4.3 Visualization of model

After creating the schedule for the model, the visualization of the model is carried out with the help of Project status visualization tool as shown below in Figure 25. Project Status Visualization is a handful tool for visualizing the 3D model according to the working date. It can be an effective tool since we can visualize the working date in the model and send it to the site work rather than the working date. Figure 25 below shows the Project status visualization tool in Tekla.(Tekla Corporation, 2014).

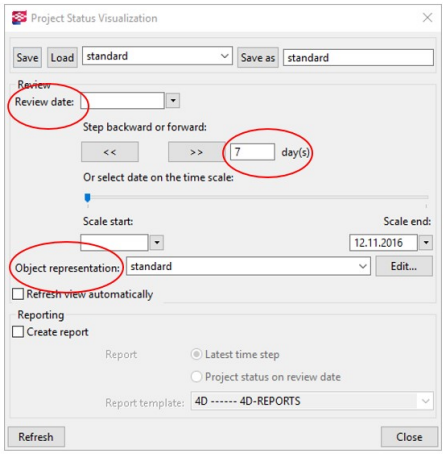


Figure 25 Project Status visualization tool in Tekla

Furthermore, it is possible to visualize the different phases of construction. The tool provides a different option and ways to visualize the project construction like 4D erection ongoing per day, 4D erection ongoing per week, 4D erection complete, and so on. The colour coding shows different stages of construction and the project can be visualized using different colours. COBIM 2012, Series 8 give standards of using different colours while visualizing the project.

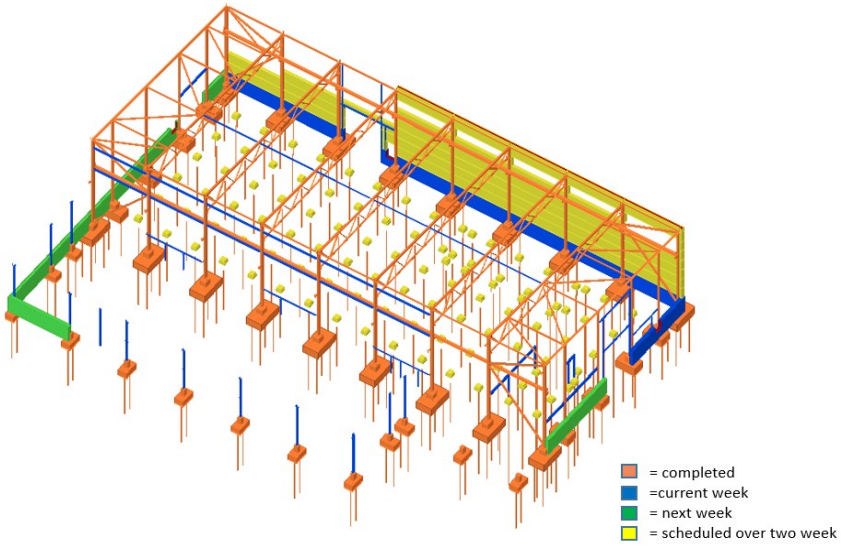


Figure 26 Colour coded model of SMC with construction plan.

Figure 26 above visualizes the construction phase of SMC on 10th of August 2014. The colour has been presented according to COBIM 2012 colour code. The orange colour represents that the tasks have been completed, blue colour represents the task for the current week, green colour represents tasks allocated for the following week and yellow colour shows the task schedule over a two-week period. It can be effective site material because:

d) Model coded with colours presenting different tasks can be sent to a real site instead of working dates.
e) Easy to explain to the workers their tasks and future plan using a colour coded model.
f) It avoids risk since a colourful model gives a clear idea of the work.
g) Easily printed and can be placed in various locations of the site.
h) It makes easy understanding between different sub-contractors to do their respective tasks.

The visual colour coded model can be used in different phases of construction. It is easier to understand the project construction phase over the time period. Therefore, it can be useful material before the project starts as well as during the project. The following steps show the process to obtain the colour coded SMC model according to its working dates:

Steps 1.
Object representation is opened in Tekla from the heading view as shown in Figure 27 below.

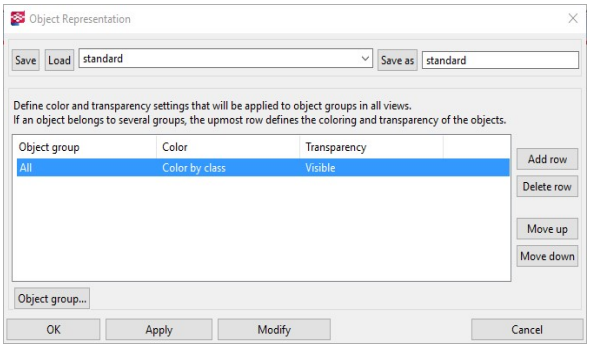


Figure 27 Tekla Object representation tool.

Step 2.

The colour representation helps to make a grouping of different colours. In order to make a group object group is opened. The box named as Object Group- Representation appears on the screen. Then, different headings of `Category´, `Property`, `Condition`, `Value` and `And` are edited as shown in Figure 28 below. The row can be added with the help of Add row bottom and it is saved as `completed` as shown in Figure 28 below.

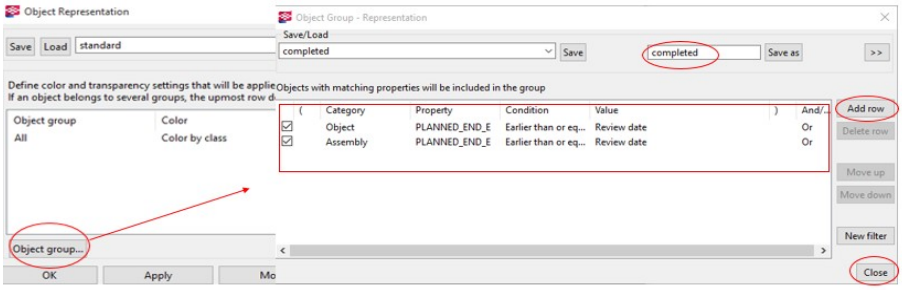


Figure 28 Setting for completed group in Object group representation.

Step 3.

After making an object group `completed` orange colour and visible is selected in the Object representation as shown in Figure 29.

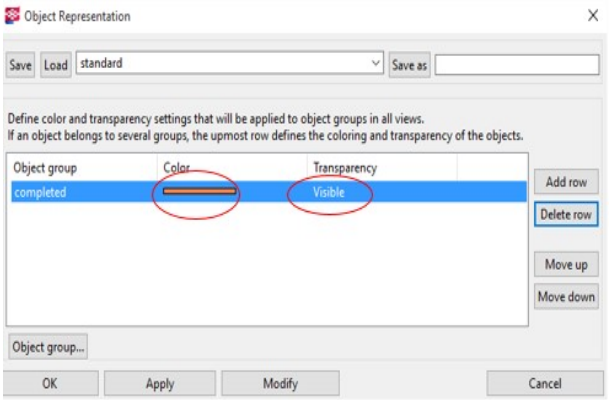


Figure 29 Colour setting for `completed` group in Object group representation.

Step 4.

A new row is added and Create a new group is selected in heading Object group. Step 2 and Step 3 is followed to achieve an object group called `this week´. All the necessary information is added in the group as shown in Figure 30. The blue colour is chosen and visible condition is selected in the group.

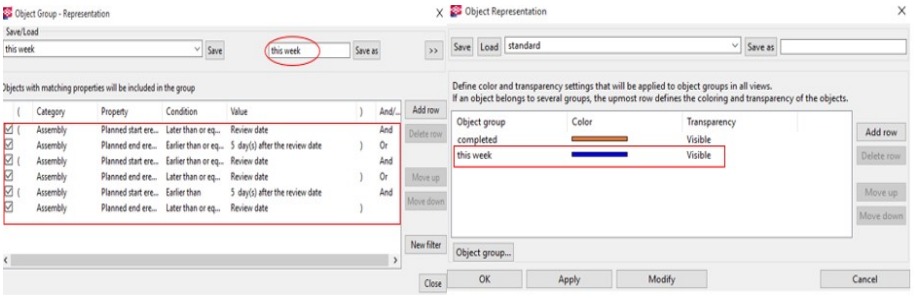


Figure 30 Setting for `this week` group in Object representation.

Step 5.

All the steps from 2 to 4 are followed to obtain the group called `next week` `two week` and `All`. The following Figure 31 shows the information filled in the respective group.

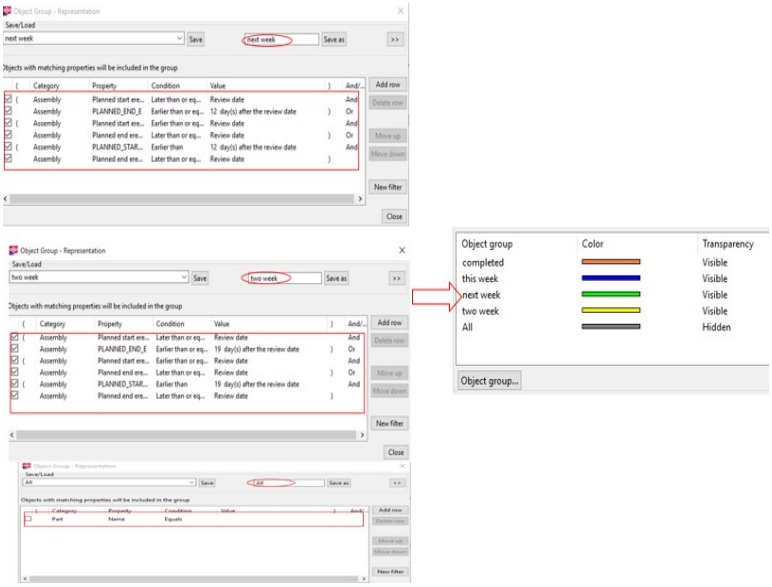


Figure 31 Setting for different group in Object representation.

Step 6.

The group is saved as `COBIM` in Object Representation as shown in Figure 32.

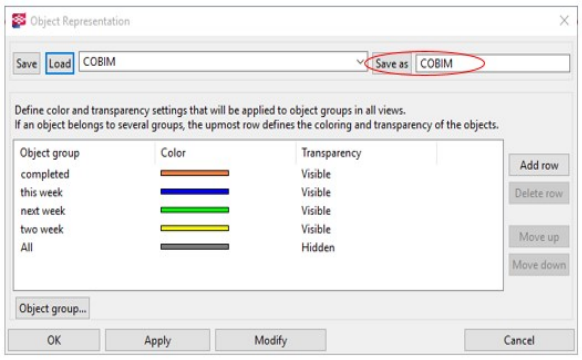


Figure 32 Colour setting for different group in Object representation.

Step 7.

After making the representation group it is necessary that all the objects in the model are scheduled according to its erection date. The erection date of objects can be manually filled in by picking the objects in the model or by automatic linking the dates using the task manager. The detailed process of automatic linking the objects with its erection date is being explained in the above subheading called simulation of time schedule in a project. The manual filling of erection dates is explained in the subheading called Erection Visualization with time. All the necessary erection dates of an object are filled in the model.

Step 8.

After filling in all the erection dates of an object in the model, Project Status Visualization is opened under heading Tools. Put in any construction date in Review date box to visualize the situation of construction. Scale start and Scale end is filled in with the construction starting date and ending date. Days is being set according to Figure 33 below. In the Object representation box ´COBIM` is selected as shown in Figure 33.

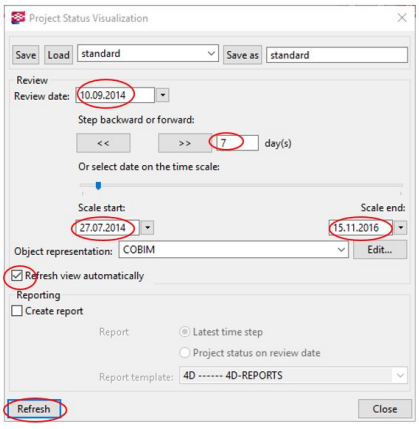


Figure 33 Visualizing setting in Project Status Visualization tool.

Step 9.

Tekla will automatically show the colour coded model as shown in below Figure 34 below.

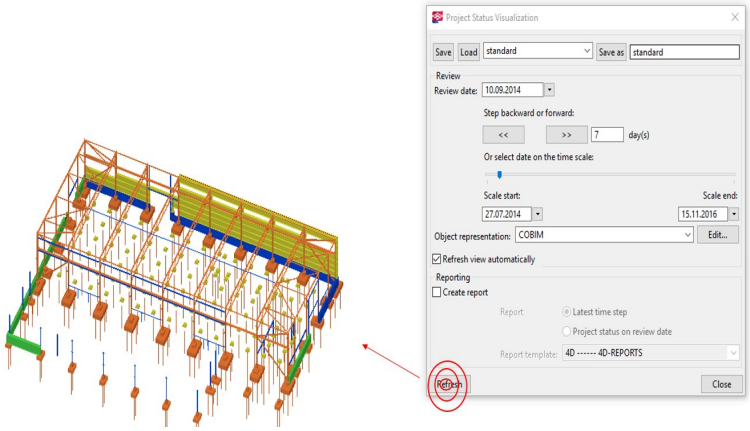
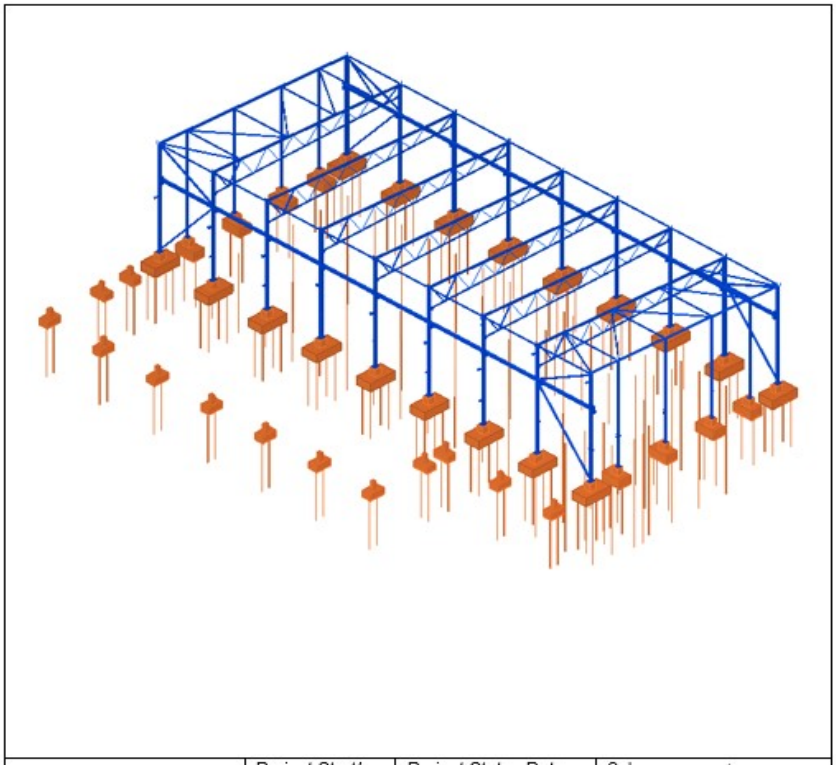


Figure 34 Colour coded model generated from Tekla tool.

Therefore, the colour coded building is obtained in Tekla. It is possible to change the colour and represent it as needed in the object representation. The complete colour coded model along with the working schedule can be used on site.

4.3.1 Sample of 4D site material



Construction HAMK Sheet Metal Centre	Project Start/ End	Project Status Date 1.9.2014	Colour represent: =completed =Current week
	Document	Site Material	
	Project Information		Material Needed
	Steel Member Erection Contractor: Rukki Construction Oy		Two specialist One helper Mobile crane Site tools Elevator

Figure 35 Sample of 4D site material.

Figure 35 above shows a sample drawing of the colour coded model that illustrates the task of Steel Erection in the specific week. The colour coded model is obtained as explained above method and edited in the word document. According to Figure 35, the erection of steel work is started on the first of September. The blue colour represents that the work needs to be completed within the same week. Therefore, the sample presented in Figure 35 above can be useful material to understand the status of the project and make a necessary plan. Furthermore, it is possible to represent the colour of specific over specific which makes the task clearer to different parties.

Thus, it is possible to create the site material as which erection date within the model with the colour representation. The sample shown in Figure 35 above is edited in the word after creating the colour coded building. The colour represents the actual construction schedule of SMC.

4.3.2 3D Sample of Site Layout

The Tekla model is exported to Google SketchUp. In the Google Sketch-Up general site layout in 3D and 2D prospective is designed as shown in Figure 36 and Figure 37.The obtained layout is designed as required in COBIM 2012. It is possible to locate and arrange the different material in the site before starting any project. Different components needed on site can be download with the help of Google SketchUp as shown in Figure 37. It is possible to get an online google map in the software and plan the site layout. The position of a crane and perimeter of the crane for the erection of steel frame is presented clearly. Thus, it makes it easier for the construction planner to plan the construction work.

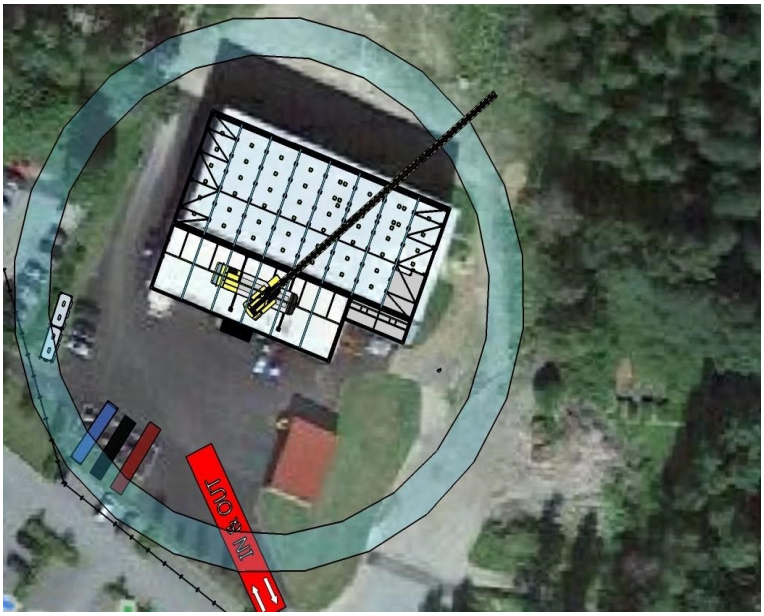


Figure 36 Sample of 2D prospective site layout.

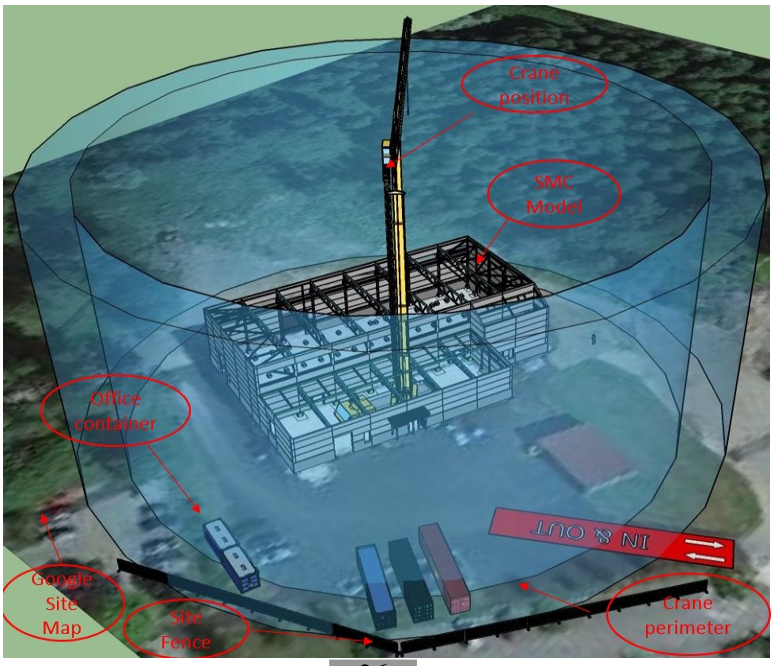


Figure 37 Sample of 3D prospective site layout.

4.3.3 Erection Visualization with time

Erection plan dates for each object are fill in Tekla under the erection dialogue box as shown in Figure 38. Erection date box of workflow tab can be opened by opening user attributes of each object. The objects are picked from the model and erection dates are filled in respectively. The process is called a manual filling of the erection dates. The erection date is picked from the Tekla Task manager accordingly.

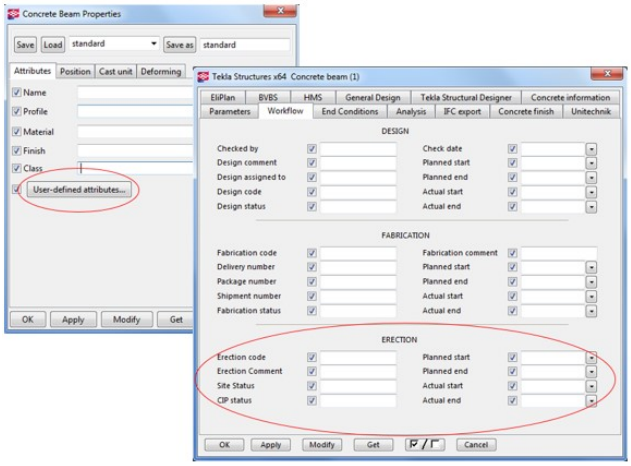


Figure 38 Erection date in workflow tab of object in user attribute.

In a big project the erection date is obtained from the contractor and other project planner before staring the project. The erection date of different parts and assemblies are sent to the manufacturing factory. The factory can only deliver the product on time if the erection date is sent early enough before running the project. The Tekla software can generate a report showing the erection date of all parts and assemblies in different document formats. The document showing the erection sequence and assemblies numbering will help in the erection. There are different Tekla animation tools under Tekla extension which can show a detailed animation of the erection process with time. The following points show how the erection date is filled in the different parts for the visualizing the construction of SMC.

a. The pile is grouped and a specific pile is selected from the model. The erection date of the pile is filled out in the erection box. Then, all the piles that need to be scheduled on the same date are selected and modified as shown in Figure 39 below.

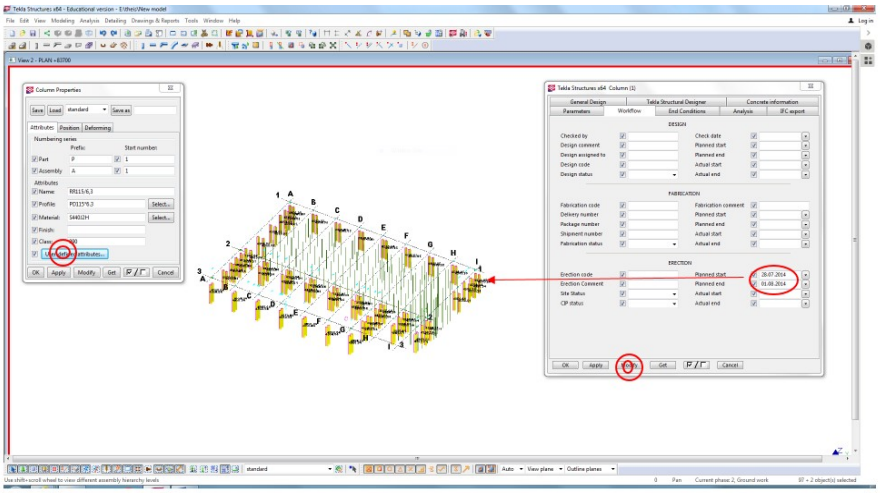
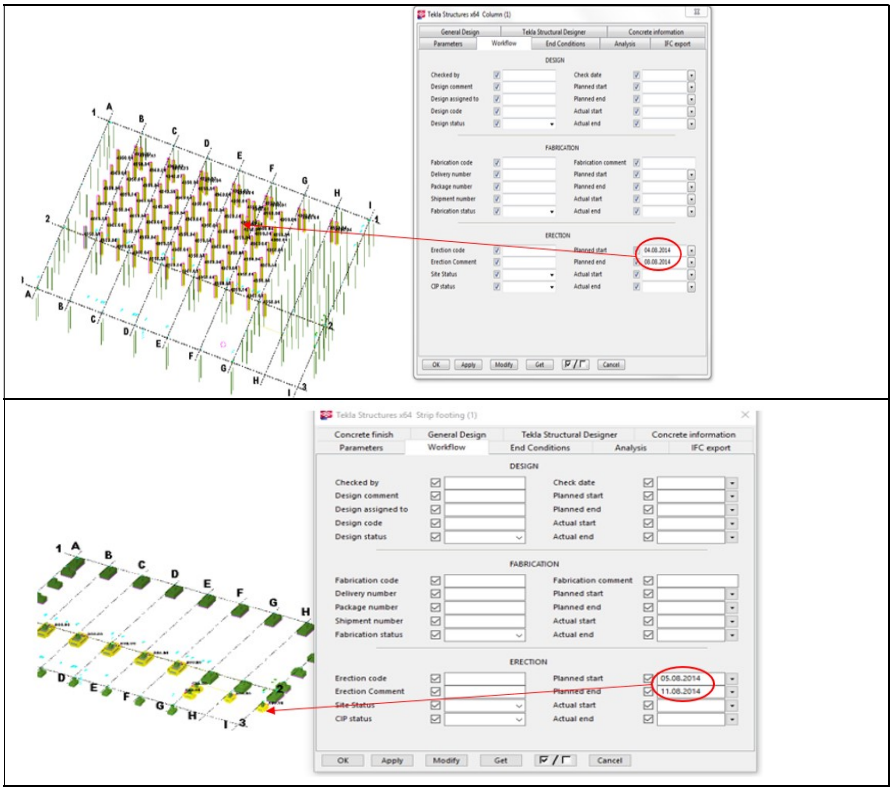


Figure 39 Erection date for pile work in Tekla.

b. Following the same process of Step 1, all the objects in the model are selected and erection dates are filled out accordingly. The following group of Figure 40 shows the selection of different objects in the model respectively with their erection dates.



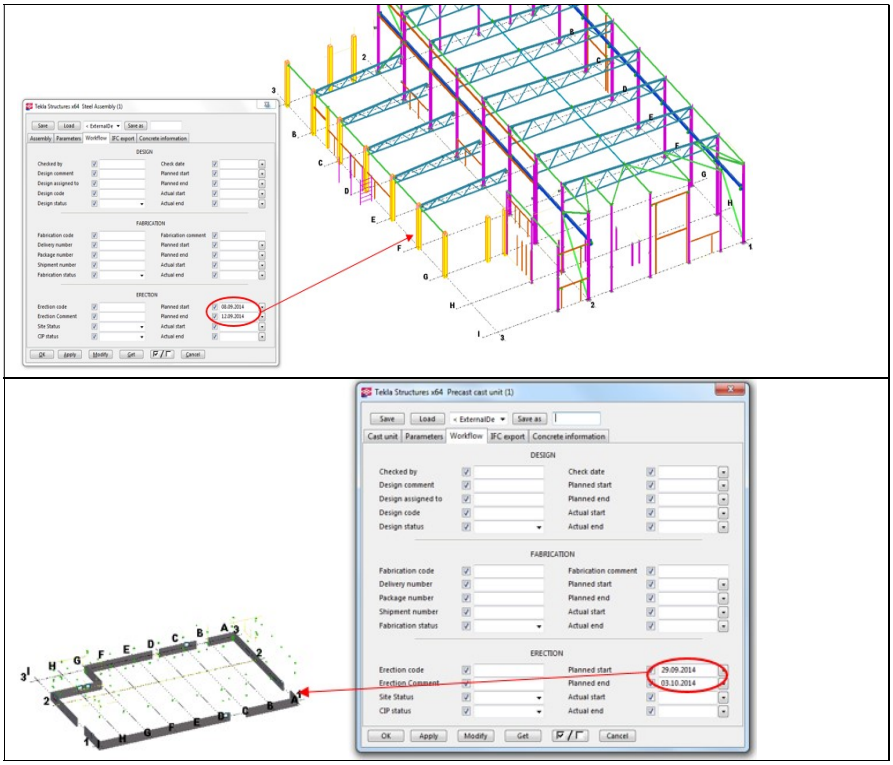


Figure 40 Erection date for different work in Tekla.

After filling out the erection dates of each object the project can be visualized accordingly in different colours. It easier to compare the different phase of construction with their erection date.

4.3.4 Visual comparison of project

The plan of erection starts and end dates of piling, concrete footing work, and steel frame are filled in for visualizing the construction of SMC to look like an actual construction. The visualization helps to know all construction work carried out in the same week. In order to make the construction work clear, the crane object is imported in Tekla. The crane object is imported from the Google SketchUp to SMC model as shown in Figure 41 below.

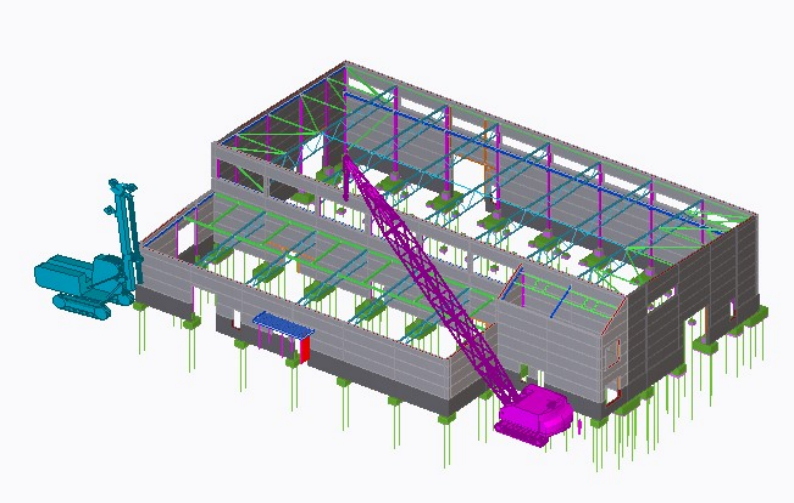


Figure 41 Crane console in SMC Tekla model.

It is possible to get different kind of site material like the crane, excavator, truck etc. form the Google SketchUp. In order to get the crane object to the Tekla, at first the necessary crane console is downloaded in Google SketchUp. Then the file is saved as skp format. The saved skp format file is imported in the Tekla model. The following steps 1 and 2 illustrate how the saves skp format file is imported in SMC model.

Step 1.
Item properties is opened by clicking twice in create item tool as shown in Figure 42.

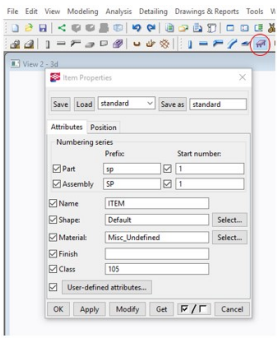


Figure 42 Item tool in Tekla.

Step 2.
Shape catalogue is opened by pressing Select as shown in Figure 43. The saved skp file of the crane is imported from the Import option of Shape Catalogue.

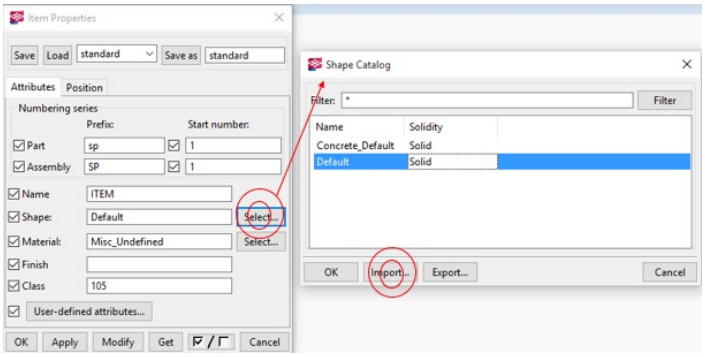


Figure 43 Shape catalogue in Tekla.

All the necessary components are imported in the model and the construction of SMC is visualized in the model. The model is colour coded according to the erection date. The Project Status visualization tool is used to show the weekly schedule of different construction work. The necessary information is filled out in the Project status Visualization Tool. Then next button is clicked to show the weekly schedule as presented in Figure 44 below.

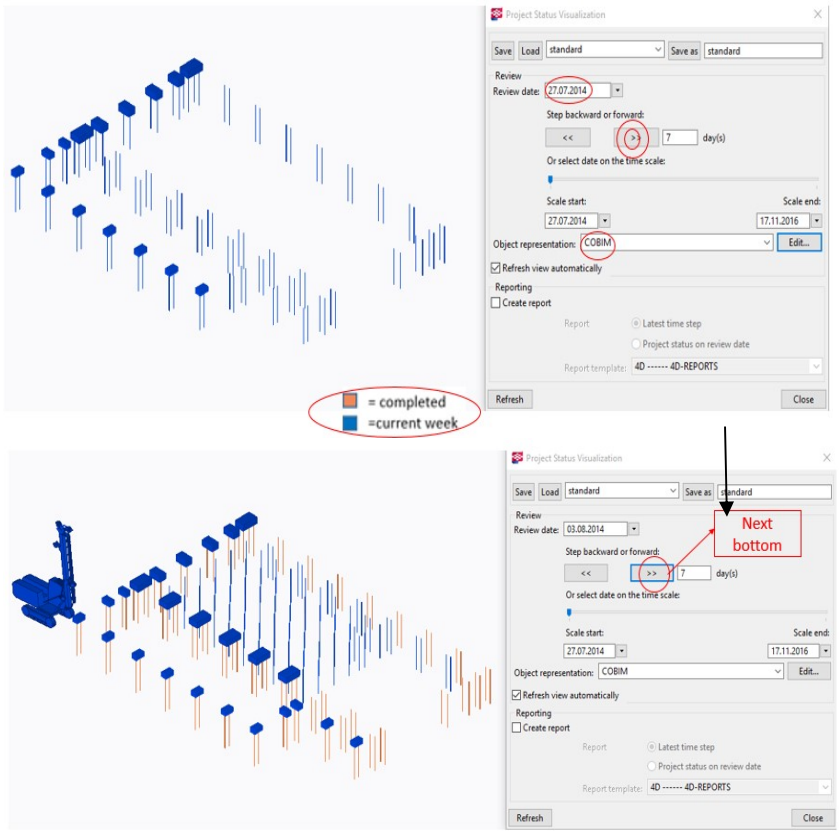
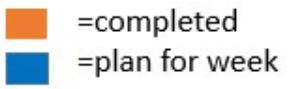


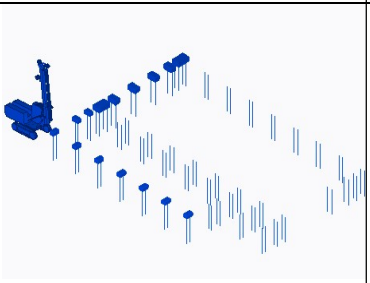
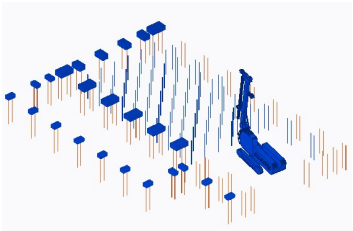
Figure 44 Visualization setting and command to show weekly plan.

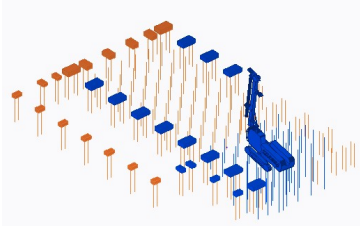
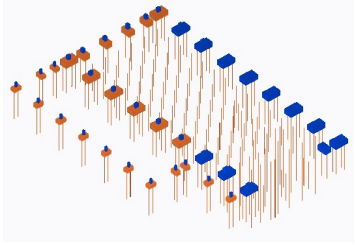
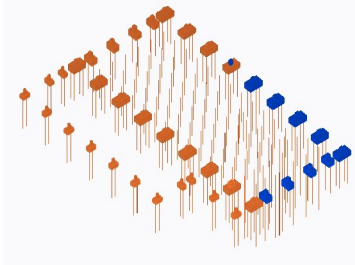
The blue colour represents the construction plan for the coming week and the orange colour represents the complete construcuion work of the previous week. Figure 44 shows the weekly plan of construction work of pile and foundation beginnig from the 27th August 2014. After pressing

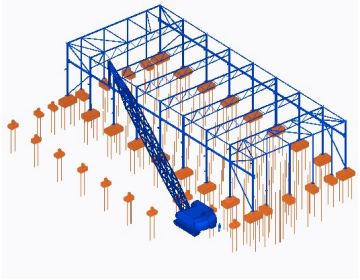
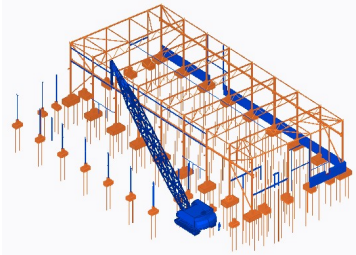
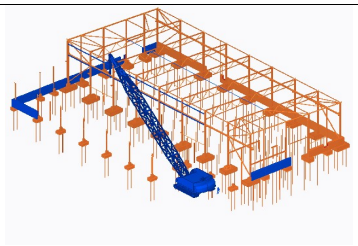
the next button,the construction phase of concrete footing and pile in the coming week is shown automatically.The date is changed automatically according to the schedule.The whole construction work is shown in the sequence using the same process.The different phases of the construction work of SMC is shown following the same procedure. It is possible to compare the model with photos of the actual construction. Table 2 below shows the visual comparison of different phases of the SMC construction created in Tekla model and the actual construction. The photos are taken in the same week of the construction period. The COBIM 2012 standard has beeen applied while comparing the construction model.

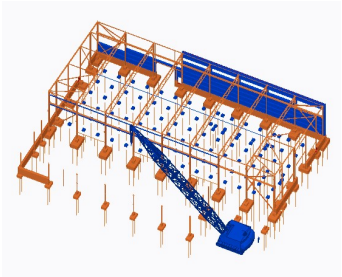
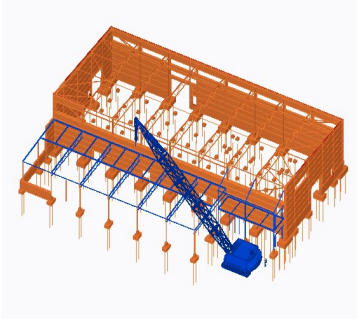
Table 2 Comparison of SMC model in Tekla with a Actual construction work.

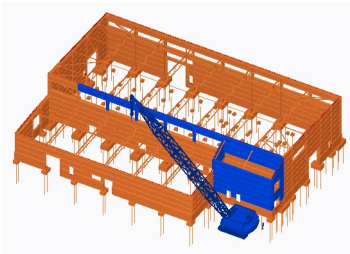
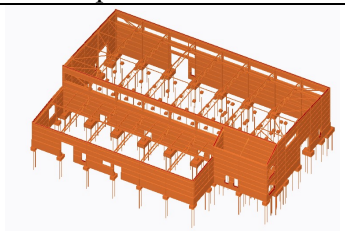


Time period	Tekla Model	Actual Construction
27.7.2014-3.8.2014		
	• Piling and construction of concrete footing work is the plan for the week	
3.8.2014-10.8.2014		
	• About 75 percent of piling is complted • 60 percent of concrete footing is planned for the week	

10.8.2014- 17.8.2014	 .	
	• About 90 percent of piling is completed • About 40 percent of concrete filling in the footing is completed • About 20 percent of concrete footing is planned for the week	
17.8.2014- 24.8.2014		
	• Pile work is completed • About 50 percent of concrete footing is completed • About 50 percent of concrete footing connection is planned for the week	
24.8.2014- 31.82014		
	• About 80 percent of footing is completed • About 40 percent of concrete footing and 20 percent of connection are planned for the week	

31.8.2014- 7.9.2014	 • Footing and connection are completed • Erection of Steel frame is planned for the week.	
7.9.2014- 14.92014	 • Erection of Steel frame in the main building is completed • About 40 percent of construction of foundation wall is planned for the week • Erection of column office builing and door frame in main building are planned for the week	
14.9.2014- 21.9.2014		

	• Erection of column in office builing and door frame in main builiding are completed • Erection of window frame and about 40 percent of construction of foundation wall is planned for the week	
21.9.2014-28.9.2014		
	• 60 percent of foundation wall is completed • Installation of sandwich panel in one side of builing is planned for the week • Secondary footing in the main building is planned for the week	
19.10.2014-26.10.2014		

	• About 90 percent of sandwich wall installed in the main building • Erection of steel frame in office building is planned for the week	
16.11.2014- 23.11.2014		
	• Erection of steel frame is completed • Installation of sandwich wall in office builing is completed • Installation of sandwich wall in store building is planned for the week	
23.11.2014- 30.11.2014		
	• Installation of sandwich wall is completed • Erection work is completed	

4.3.5 Extraction of Report

It is possible to generate a report showing the erection dates of different materials using the Tekla. A 4D-Erection report template is available in

Tekla. It is possible to create one´s own template in Tekla to show erection the date. The report is obtained as an Excel file showing the erection date for a specific part. The report in Appendix 1 contains the construction dates of pile from 27.7.2014 to the erection dates of steel frame 5.9.2014.

4.4 Animation Google SketchUp

The animation of different phases of construction is possible with the help of Google SketchUp. The SMC model is exported to Google SketchUp. In the Google SketchUp, the construction phase of SMC according to the plan is animated to look like the real construction. The animated video shows the location of the crane, movement of the crane and excavator, and other site materials used during the construction of SMC. The video only shows the construction sequence of the load bearing structure in the model. Figure 45 shows the construction phases of SMC in animation video. The Appendix 2 contains the list of photos taken from the animated video showing different phases of SMC construction.

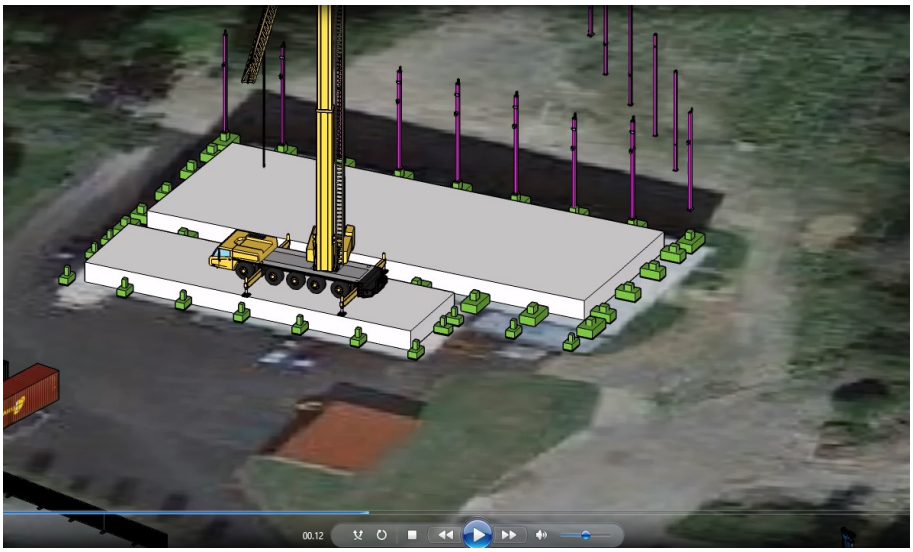


Figure 45 Animation video of SMC Construction (https://www.youtube.com/watch?v=qlUFkYS_nDg&feature=youtu.be)

5 CONCLUSION

The construction world is becoming more and more complex. With many contractors and sub-contractors involved in the process, there is a need to meet the growing challenges of effective scheduling and planning. This thesis has incorporated the ways in which such effectiveness can be achieved. For this reason, Tekla model can be used for a successful and well-managed construction plan.

Firstly, the thesis has included the main parts of scheduling. This means that we could easily see the effects of delay in the supply of materials in the overall project. This not only saves time, but a great deal of financial security is achieved. This thesis has shown the effective visualization of different phases of work in different time-periods as well as the representation of Gantt chart and timetable in a model.

Secondly, it is very important for a site manager to get the off-site prospective of the construction plan. The thesis shows how the 2D and 3D prospective site layout can be effective in positioning of cranes and perimeter covered by the crane. The 4D site material sample is much more effective than the traditional way of scheduling. This is helpful on the construction site so that everyone involved on the site gets a clear image of the overall project. It is the emphasis of this thesis that this way of using 4D site material increases coordination between the site workers, avoids any kind of confusion, and adds to the momentum of the project.

As a result of this thesis, a real construction visualization in an off-site model of the construction plan can be achieved before the project begins. This makes planning easier and helps in the comparison between the model and the actual construction.

The thesis has shown how the database of the required material during the construction can be presented through Tekla. Along with this, the animation of time scheduling using Google SketchUp has been successfully incorporated into this thesis so that a construction plan is understandable to all the parties involved.

Finally, the thesis has tried its best to act as a bridge between the on-site construction world and the off-site world of models and designs. A successful off-site model of the construction plan even before the project begins can be immensely helpful for any company or a manager to get a view of the project beforehand. It is a hope of this thesis that the models and designs of the site can be made easier and effective so that everyone on the site understands the project. All in all, the thesis will act as a manual of instructions for companies, students, schools and new Tekla users to compare the construction site with a model in 2D, 3D and 4D prospective.

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Appendix 1

Material List with erection dates

Name	Profile	Section	PLANNED START	PLANNED END
Pile	PD115*6.3	Foundation	28.7.2014 0:00	1.8.2014 0:00
Pile	PD115*6.3	Foundation	28.7.2014 0:00	1.8.2014 0:00
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Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Pile	PD115*6.3	Foundation	4.8.2014 0:00	8.8.2014 0:00
Strip footing	1600*2700	Foundation	5.8.2014 0:00	11.8.2014 0:00
Strip footing	1600*2700	Foundation	5.8.2014 0:00	11.8.2014 0:00
Strip footing	1600*2700	Foundation	5.8.2014 0:00	11.8.2014 0:00
Strip footing	1600*2700	Foundation	5.8.2014 0:00	11.8.2014 0:00
Strip footing	1600*2700	Foundation	5.8.2014 0:00	11.8.2014 0:00
Strip footing	900*1500	Foundation	5.8.2014 0:00	11.8.2014 0:00
Strip footing	900*1500	Foundation	5.8.2014 0:00	11.8.2014 0:00
Strip footing	900*1500	Foundation	5.8.2014 0:00	11.8.2014 0:00
Strip footing	900*1500	Foundation	5.8.2014 0:00	11.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00

Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Pile	PD115*6.3	Foundation	11.8.2014 0:00	12.8.2014 0:00
Strip footing	1600*2700	Foundation	12.8.2014 0:00	18.8.2014 0:00
Strip footing	1600*2700	Foundation	12.8.2014 0:00	18.8.2014 0:00
Strip footing	1600*2700	Foundation	12.8.2014 0:00	18.8.2014 0:00
Strip footing	1600*2700	Foundation	12.8.2014 0:00	18.8.2014 0:00
Strip footing	1600*2700	Foundation	12.8.2014 0:00	18.8.2014 0:00
Strip footing	1600*2700	Foundation	12.8.2014 0:00	18.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*900	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	600*700	Foundation	15.8.2014 0:00	21.8.2014 0:00

Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Footing connection	400*400	Foundation	15.8.2014 0:00	21.8.2014 0:00
Strip footing	1600*2700	Foundation	19.8.2014 0:00	25.8.2014 0:00
Strip footing	1600*2700	Foundation	19.8.2014 0:00	25.8.2014 0:00
Strip footing	1600*2700	Foundation	19.8.2014 0:00	25.8.2014 0:00
Strip footing	1600*2700	Foundation	19.8.2014 0:00	25.8.2014 0:00
Strip footing	1600*2700	Foundation	19.8.2014 0:00	25.8.2014 0:00
Strip footing	1200*2000	Foundation	19.8.2014 0:00	25.8.2014 0:00
Footing connection	600*700	Foundation	22.8.2014 0:00	29.8.2014 0:00
Footing connection	600*700	Foundation	22.8.2014 0:00	29.8.2014 0:00
Footing connection	600*700	Foundation	22.8.2014 0:00	29.8.2014 0:00
Footing connection	600*700	Foundation	22.8.2014 0:00	29.8.2014 0:00
Footing connection	600*700	Foundation	22.8.2014 0:00	29.8.2014 0:00
Footing connection	600*700	Foundation	22.8.2014 0:00	29.8.2014 0:00
Footing connection	600*700	Foundation	22.8.2014 0:00	29.8.2014 0:00
Strip footing	1200*2000	Foundation	26.8.2014 0:00	27.8.2014 0:00
Strip footing	1200*2000	Foundation	26.8.2014 0:00	27.8.2014 0:00
Strip footing	1200*2000	Foundation	26.8.2014 0:00	27.8.2014 0:00
Insulation	100*1200	Foundation	26.8.2014 0:00	27.8.2014 0:00
Insulation	100*1200	Foundation	26.8.2014 0:00	27.8.2014 0:00
Insulation	100*1200	Foundation	26.8.2014 0:00	27.8.2014 0:00
Footing connection	600*700	Foundation	28.8.2014 0:00	29.8.2014 0:00
Footing connection	600*700	Foundation	28.8.2014 0:00	29.8.2014 0:00
Footing connection	600*700	Foundation	28.8.2014 0:00	29.8.2014 0:00
BRACE	CFRHS120X12	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS150X15	Main Building	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS150X15	Main Building	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS150X15	Main Building	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS150X15	Main Building	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS150X15	Main Building	1.9.2014 0:00	5.9.2014 0:00
CRANE BEAM	HEA260	Main Building	1.9.2014 0:00	5.9.2014 0:00

CRANE BEAM	HEA260	Main Building	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS180X18C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS180X18C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS180X18C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS180X18C	Foundation	1.9.2014 0:00	5.9.2014 0:00
BEAM	HEA160	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BOTTOM-CHORD	CFRHS120X12C	Main Building	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
BOTTOM-CHORD	CFRHS120X12C	Main Building	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
BOTTOM-CHORD	CFRHS120X12C	Main Building	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
BOTTOM-CHORD	CFRHS120X12C	Main Building	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
BOTTOM-CHORD	CFRHS120X12C	Main Building	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Main Building	1.9.2014 0:00	5.9.2014 0:00
BOTTOM-CHORD	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X20C	Foundation	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS150X15C	Main Building	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS150X15C	Main Building	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS150X15C	Main Building	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
CRANE BEAM	HEA260	Main Building	1.9.2014 0:00	5.9.2014 0:00
CRANE BEAM	HEA260	Main Building	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X12C	Roof of Main	1.9.2014 0:00	5.9.2014 0:00

BRACE	CFRHS120X120	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X120	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X120	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X120	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X120	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X120	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
BRACE	CFRHS120X120	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS180X180	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS180X180	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS180X180	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS180X180	Foundation	1.9.2014 0:00	5.9.2014 0:00
BEAM	HEA160	Roof of Main	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X200	Foundation	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X200	Store	1.9.2014 0:00	5.9.2014 0:00
BOTTOM-CHORD	CFRHS120X120	Main Building	1.9.2014 0:00	5.9.2014 0:00
COLUMN	CFRHS300X200	Foundation	1.9.2014 0:00	5.9.2014 0:00

Animation photos of SMC construction