



CHALMERS
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BIM-uses

Concerning 3D-reinforcements in the construction process

Master's Thesis in the Master's Program Design and Construction Project Management

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Department of Architecture and Civil Engineering
Division of Construction Management
Research Group Name: Construction Management
CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover:

Here's how the construction site looks through the HoloLens glasses. The glasses provides the construction worker an opportunity to see the environment and the digital model at the same time.

Nohrstedt, Linda. "Masken styr armeringen på ESS-bygget". Nyteknik, Photo taken by Anders Hansson, BYGG, Date :4 April.2016,
<http://www.nyteknik.se/bygg/masken-styr-armeringen-pa-ess-bygget-6840540>.

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ABSTRACT

In recent decades, many industries have experienced how digitization has changed both ways of working and its results. The construction industry is now facing such development. The master thesis demonstrates how the current reinforcement process looks and how the future reinforcement process estimates to look. In addition, what upcoming projects should consider if they desire to implement/utilize digitalized reinforcement. The purpose of this master thesis were to find out the required management and technology for implementing digitalized reinforcement. At the same time figure out how the reinforcement process looks from the drawing desk to the construction site. The methodology performed in this master thesis has been interviews with the concerned project participants in the reinforcement processes and a 3D-modeling test in the project; Kvibergs-Ångar. The findings of this master thesis has been that there is a need of communication improvements between the structural engineers and the contractors. To reach an intact information flow must the contractor become clearer with their description of the casting stages they want and the reinforcement method they desire to the structural engineers, at the same time do the contractors need to procure the reinforcement supplier earlier in the process. In order to get the information right from the start do all the participants in the reinforcement process need to attend earlier in the process. Currently are there some good opportunities with visualizing and working with digitized reinforcement from the designer's drawing board to the construction worker's workplace on site. The current IT-tools allows the structural engineer create reinforcement specifications/schedules through two different alternatives. The first alternatives is creating it in the Revit structure and Teklas structure plugin app Q-reinforcement which has now developed to QR-cloud service. Alternatively, the second method is Solibri model checker where the contractor and supplier are allowed to view the color-coded reinforcement and follow up its order and delivery status. For visualization, purpose on the construction site do the contractor have two good option to utilize such as Glue BIM 360 or Tekla BIMsight/ Field on their IPads. Furthermore has few studies earlier addressed the use of digitalized reinforcement process among the site workers. Thus, the findings provide practitioners and researchers insight into how current practices maybe improved, as well as areas where more research is needed.

Key words: BIM, BIM-Uses, Digital Reinforcement, The Reinforcement Process.

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Preface

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Most of all, we would like to thank our respondents for this master thesis. For being helpful to enable this paper's interview questions and share a little of their valuable time and insight into their experiences in the reinforcement process.

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Notations

2D Drawing: An abbreviation for two-dimensional paper drawing, the space perspective is the length and width.

3D Design: An abbreviation for three-dimensional, is the space perspective where length, breadth and depth are perceived.

BIM: Building Information Model/Management

DWG: Drawings (CAD programs filename extension)

IFC: Industry Foundation Classes

IFD: INTERNATIONAL FRAMEWORKS for Dictionaries

ISO: International Organization for Standardization

RTV: (project) files for actual Revit® projects

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1 Introduction

The architectural-engineering-construction (AEC) industry creates complex and unique products, based on highly specialized processes. These processes utilize Building Information Modeling Tools (BIM-tools), which has improved construction projects in recent years. The 3D and 4D modelling (4D; 3D plus schedule time) tools offer the construction projects a significant possibility to facilitate its development process and give the project participant a good chance to follow how the project progresses (Fischer and Haymaker 2001, Staub-French and Fisher 2001, Kam et al., 2003).

Kensek & Noble (2014) continues with mentioning that BIM has developed from only being used by innovative software companies and universities to being widely used by the architecture, engineering and construction profession. Eastman, et al. (2008) explains that BIM dates back to the 1970s but has become more noticeable in recent years, and that the concept is not new. Bygginindustrin (2011) also mentions that the interest for Building Information Modelling (BIM) is increasing mostly, due to low efficiency and productivity in the Swedish construction industry. Lutz & Gabrielsson, (2002) argues that construction projects have at least 80% similar processes within all projects, which creates room for huge opportunities to make improvements within. These improvements can be achieved through BIM, which provides the professions a possibility to model advanced 3D reinforcement models, which creates complete, detailed and accurate reinforcement designs which offers scheduling tools for the reinforcement which is mounted and rolled out on the construction site. This BIM-use application within project management offers the opportunity to improve management of the project and the delivery of construction projects of any size and complexity (Vasshaug, 2014).

1.1 Background

Skanska located in Sweden is one of the world's leading construction companies. It is a huge provider of large house and infrastructure construction services and development of public-private partnership. That construct everything from small renovation projects to billion-dollar projects (Skanska a, 2015). The company operates in Gothenburg, where their technical house building department desire to develop their 3D BIM-work set through adding 3D-reinforcement to their Building information management list. The company has previous experience of working with 3D-modelled reinforcement and desires to develop their technical housing department through utilizing their own technology, which they have in their other technical departments in Sweden. Skanska housing production department purchases in the current situation their reinforcement specifications from hired consultants, which can be costly. Skanska believes that 3D-BIM reinforcement specifications can make the construction process cheaper through getting them better flow from their structural engineers. At the same time, can they be more effective in the purchasing process and give better quality of their work-set with the reinforcement on site with their construction workers.

1.2 Problem statement

The problem statement of the master thesis is to develop today's work set with reinforcement drawings. Mostly because most of the reinforcement drawings/specifications done today are in 2D-pdf drawings, which later are utilized to design the reinforcement specifications/schedule. Skanska wants to utilize their own main software for construction drawings in Autodesk program Revit instead of Skanska's current SSI supplier, which designs construction drawings in the software program Tekla.

1.3 Purpose

Skanska's technical housebuilding department in Gothenburg has a great desire to be capable of designing their own reinforcement specifications so they do not have to hire in consultants. The main purpose of this master thesis is to evaluate the optimal management of the entire chain, from drawing mode to purchasing- (call-off the purchase of armor) to production.

1.4 Limitations

The study will only conduct BIM-uses concerning 3D-reinforcements. The study will utilize the technical capacity of the technical department and the purchasing department. Suggestions from the production site will be evaluated and how the technical and the production site collaboration can be done more effectively. Only BIM-uses concerning reinforcement will be investigated.

1.5 Research Questionings

- How could 3D-BIM reinforcement be implemented and utilized in *Skanska's* technical housebuilding department?
- How could 3D-BIM reinforcement process function and be applied, from drawing desk and be quantified on the purchasing desk to the production management processes?

1.6 Disposition

The master thesis first chapter begins with a general instruction of BIM, the thesis purpose, limits and ends with research questions.

In the methodology chapter is it described how the master thesis is conducted and how the interview design was formed. In addition, also how the empirical data was collected. Further on the chapter includes a small description of the case study project performed in this thesis and introductions of the company Skanska way of working process with BIM.

The methodology chapter is followed by the theoretical background, which the master thesis is based on. This chapter gives the readers a general and more focused information about BIM, BIM-Uses, contractual laws, design regulations, software programs and the reinforcement process.

The result chapter presents the collected results of the performed interviews and the performed design test on the case study project; Kvibergs-Ångar. This part concludes with a summarizing analysis of the current state proposed to form the basis for further information process development.

The discussion chapter discusses the analysed results, which is evaluated based on the reports purpose, objectives and issues. Finally, some concluding remarks, main key points and a few recommendations for future studies is presented.

2 Theoretical background

The theoretical background chapter explains the different theories within the subject BIM, BIM-uses and the reinforcement process.

2.1 General information about BIM

In summary Building Information Management (BIM) is considered to be and described as a computer-tailored approach, which is utilized by members in the project team to effectively manage the information throughout the project lifecycle. Building information models contains parametric data which describes its attributes and object orientation of what they represent. The model continuously updates itself, when changes occur on one view in a coordinated way (Eastman et al. 2008). In the following Figure 1 below, is a brief picture of how the BIM process looks through the construction buildings life cycles are shown.

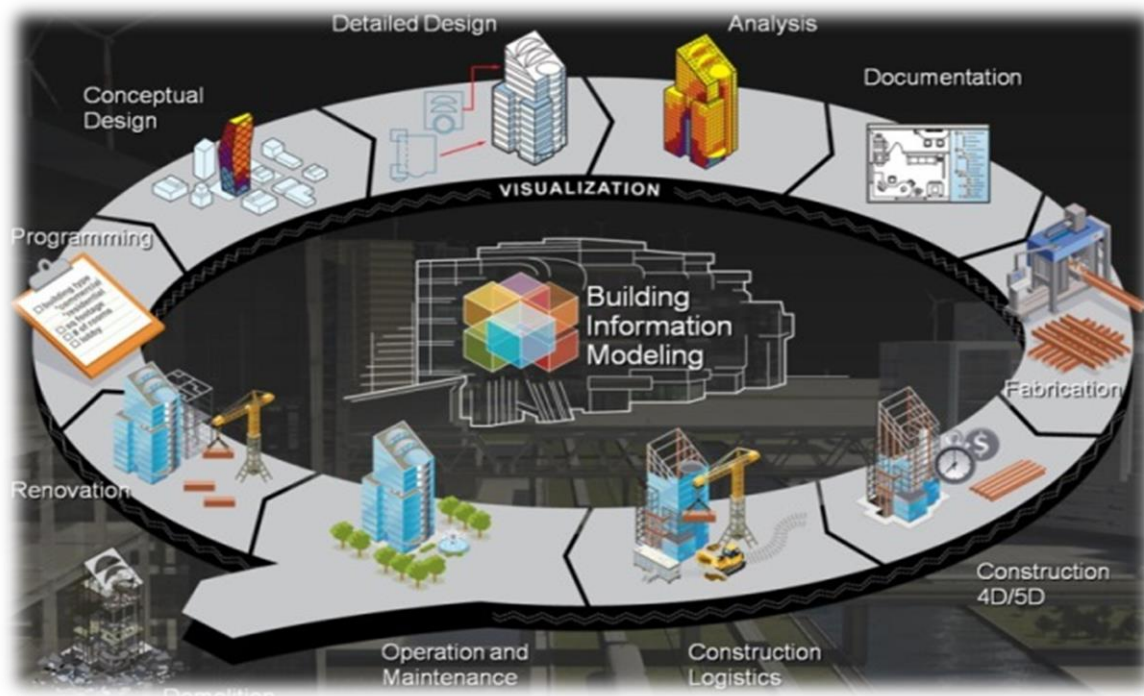


Figure 1 BIM lifecycle sharing information (Mistry,H. 2016)

2.1.1 Building Information Modelling lifecycle

Building information modeling is a process for creating and managing information on a construction project across the project lifecycle. One of the key outputs of this process is the Building Information Model, the digital description of every aspect of the built asset. This model draws on information assembled collaboratively and updated at key stages of a project. The lifecycle of the process requires a good collaborative environment, where the involved parties work together towards a common goal that benefits the construction project. The BIM collaboration projects are mostly between architects, engineers and contractors who operate within their firms and with other firm's participants. The high collaboration potentials with BIM provides its participants challenges, which need to be managed successfully or worked around if possible. The most common challenges that frequently occurs are often with Interoperability, Workflow, Firm culture etc. (Deutsch 2011).

American National Institute of Building Sciences (2007) further down describes a profound description about building information management:

" BIM is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update, or modify information in the BIM to support and reflect the roles of the stakeholder. BIM is a shared digital representation founded on open standards for interoperability"

BIM Levels – The Maturity Diagram

The Maturity Model Diagram (Figure 2), explains the different knowledge levels expected within these several levels. To get a greater understanding of the several levels, the categories are divided into the types of technical and collaborative work sets they have in their processes. Many constructions companies/clients use or have different experiences with their BIM approaches, e.g. between the level 0 to 3. The Maturity Model Diagram offers the construction company's customers an opportunity to understand what they are offered through a diagrams see (Figure 2) (Government Construction Client Group from the BIM Industry Working Group, 2011)

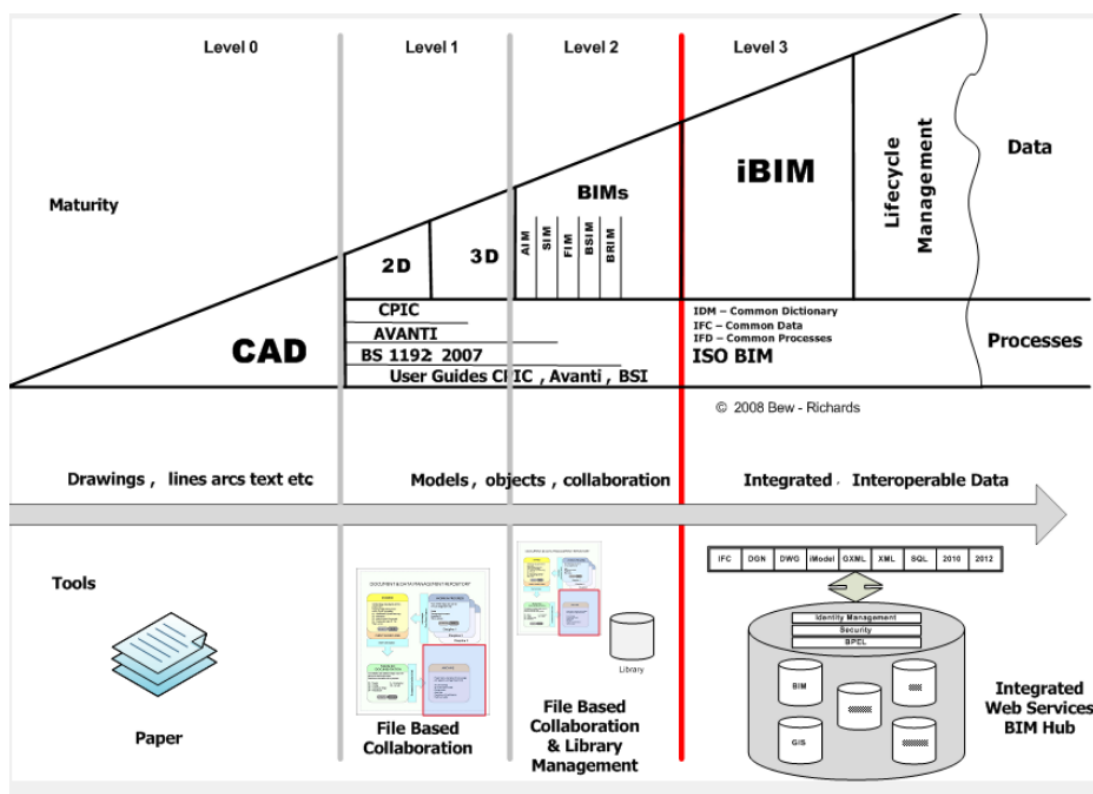


Figure 2 Illustration of the various Maturity levels in usage of BIM (Government Construction Client Group From the BIM Industry Working Group, 2011)

Description about the various levels.

The first level 0 in the Maturity Model Diagram is CAD, which usually are 2D electronic paper or ordinary paper form. The following level 1 contains 2D or 3D formats through utilizing a collaboration tool that provides a common data environment with standard data structures and formats. Level 2 offers the construction companies the opportunity to use other new approaches with 4D (3D, plus time) and 5D cost elements as well as feed operational systems. The third and last level the companies utilize open BIM-processes to the fullest. In addition, the File standards as IFC/IFD files are managed transparently by collaborative model servers, which later would be regarded as iBIM or integrated BIM that compiles all the technical processes (Government Construction Client Group From the BIM Industry Working Group, 2011).

Development of BIM

BIM Alliance (2016) states that contractual and commercial issues is something that has been overlooked by technical development. At the same time, the development of BIM develops at much higher speed then before estimated, but demands better contract conditions, organizational developments, software etc.

2.2 BIM-Use

Kraider, Messner & Dubler, (2010) defines building information modeling as “*the act of creating an electronic modeling of a facility for the purpose of visualization, engineering analysis, conflict analysis, code criteria checking, cost engineering, as-built product, budgeting and many other purposes.*”

A consistent digital language needs to be developed so better communication fosters within the digital world. BIM-uses are further described as “*a method of applying Building Information Modeling during a facility’s lifecycle to achieve one or more specific objectives.*” Further, on it is mentioned that a BIM use can only be classified with the intention of implementing BIM thought the life of the facility. Some other characteristics can be defined to properly identify and communicate a BIM Use. More information is described in figure 3 which explains the varying levels which depend upon the level of specificity required for different applications of the uses (Kraider, Messner & Dubler, 2010).

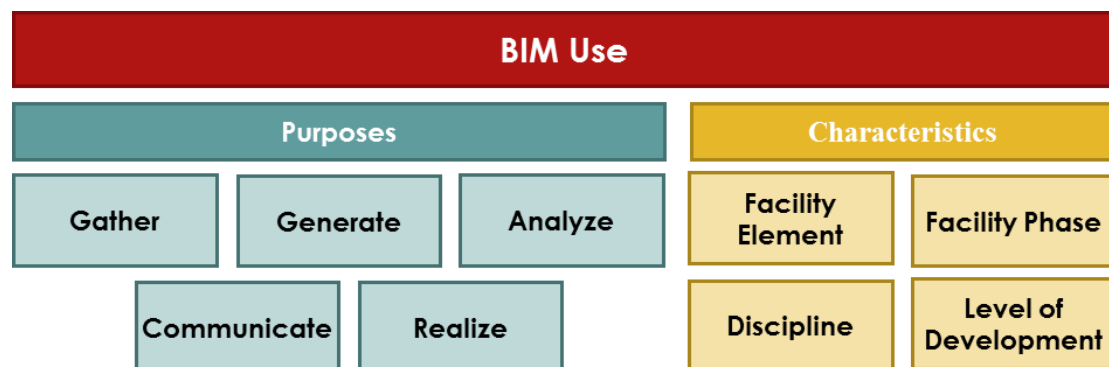


Figure 3 The Components of a BIM Use (Kraider, Messner & Dubler, 2010)

The uses of BIM documents was last released in 2013, with the purpose of communicating the BIM Use classification system and it’s purposes. The document presented that BIM classifications provides users a common language for the Uses of Building Information Modeling. A common language, which improves the purposes and methods for implementing BIM throughout the lifecycle of a facility (Kraider, Messner & Dubler, 2010).

BIM-uses fall into five primary different categories which contain more subcategories that further on specify the purpose of BIM. Furthermore description is described in Figure 4 with the five primary categories gathered, generated, analyzed, communicated, and realized (Kraider, Messner & Dubler, 2010).

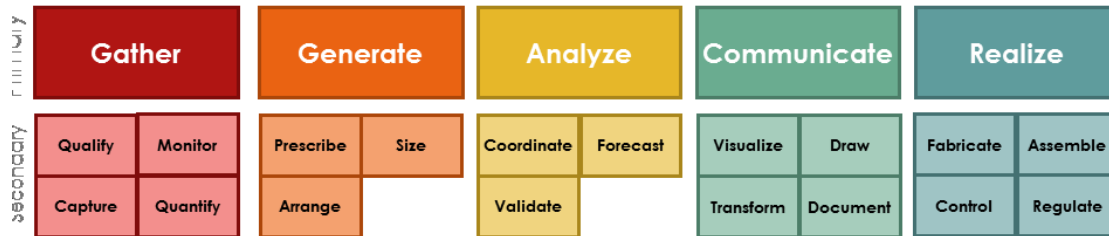


Figure 4 The BIM Use Purposes (Kraider, Messner & Dubler, 2010)

The relationship between the different BIM-uses has its logical motion from one BIM-use to another. The process often starts with the facility information being gathered then afterwards is its information generated which later is analyzed and finally communicated and realized. BIM-use is constructed upon a repeating process while its infrastructure is built upon information, which makes the BIM-use purposes linked and associated with each other (Kraider, Messner & Dubler, 2010).

2.2.1 Determine the purpose for implementing BIM

Before the design team begins to select and determine how their implementation of BIM will be on the project some consideration should be done on how their Gathering, Generating, Analyzing, Communicating and Realizing process will be performed. In addition, they should plan their implementation of BIM, how the information will be utilized and communicated during the project and how the project relates to how the potential-uses will be utilized (Kraider, Messner & Dubler, 2010).

Kraider, Messner & Dubler (2010) further on continues with the importance of having a Building Information Management implementation plan set out for the total life span of the construction building. The plan should include the facility owners, stakeholders interests with BIM and how the construction and design of the facility will be performed utilizing BIM overall.

Other terms, which should be determined, are the implementation of the BIM-use purposes. To carry out the project with BIM-use purposes it is required that the design team has the right competence, experience and resources. Resources in the form of computer software, hardware and IT support. Furthermore, to prevent obstacles through securing that the design team has earlier experience and skills of utilizing BIM in construction projects so they can elaborate the use of each BIM-purpose (Kraider, Messner & Dubler, 2010).

A short resume of the updated BIM Use Purposes with their objectives and synonyms is shown within the BIM Use Ontology in figure 5. The category, which this master thesis will immerse in, is the fifth BIM use purpose, Realize. Furthermore the fifth purpose contains four other sub categories that further specifies the aim of the BIM Use Purpose (Kraider, Messner & Dubler, 2010).

BIM Use Purpose		BIM Use Objective	Synonyms
01	Gather	to collect or organize facility information	administer, collect, manage, acquire
	01 Capture	to represent or preserve the current status of the facility and facility elements	collect
	02 Quantify	to express or measure the amount of a facility element	quantity takeoff
	03 Monitor	to collect information regarding the performance of facility elements and systems	observe, measure
	04 Qualify	to characterize or identify facility elements' status	follow, track, identify
02	Generate	to create or author information about the facility	create, author, model
	01 Prescribe	to determine the need for and select specific facility elements	program, specify
	02 Arrange	to determine location and placement of facility elements	configure, lay out, locate, place
	03 Size	to determine the magnitude and scale of facility elements	scale, engineer
03	Analyze	to examine elements of the facility to gain a better understanding of it	examine, evaluate
	01 Coordinate	to ensure the efficiency and harmony of the relationship of facility elements	detect, avoid
	02 Forecast	to predict the future performance of the facility and facility elements	simulate, predict
	03 Validate	to check or prove accuracy of facility information and that is logical and reasonable	check, confirm
04	Communicate	to present information about a facility in a method in which it can be shared or exchanged	exchange
	01 Visualize	to form a realistic representation of a facility or facility elements	review
	02 Transform	to modify information and translate it to be received by another process	translate
	03 Draw	to make a symbolic representation of the facility and facility elements	draft, annotate, detail
	04 Document	to create a record of facility information including the information necessary to precisely specify facility elements	specify, submit, schedule, report.
05	Realize	to make or control a physical element using facility information	implement, perform, execute,
	01 Fabricate	to use facility information to manufacture the elements of a facility	manufacture
	02 Assemble	to use facility information to bring together the separate elements of a facility	prefabricate
	03 Control	to use facility information to physically manipulate the operation of executing equipment	manipulate
	04 Regulate	to use facility information to inform the operation of a facility element	direct

Figure 5 The BIM Use Purpose and Objectives (Kraider, Messner & Dubler, 2010)

Realize

The objective of the BIM use; Realize's purpose is to construct or control the physical elements of the facility through utilizing the information and the (BIM data) the facility contains. Furthermore, it removes the direct input of needed human interaction in the construction industry through utilizing other construction methods such as fabricating, assembling, controlling and regulating elements of the facility. This in turn may lead to a more improved productivity of the construction and operation of the facilities (Kraider, Messner & Dubler, 2010)

The BIM-use purpose Realize has four other sub-purposes whose aim is to utilize facilities information in numerous other ways e.g. manufacturing its elements through fabrication, prefabricating and bringing together the separate elements while at the same time manipulating the executing equipment and directly using the information, the facility contains (Kraider, Messner & Dubler, 2010)

BIM-use elaboration characteristics

When the decision of which implementation form the design team decides to carry out, they need to determine which discipline, which phase, which facility elements, and to what level of development these BIM Use purposes will be implemented. Further description can be seen down on the BIM Use elaboration characteristics Figure 6 (Kraider, Messner & Dubler, 2010).

Characteristic	Description
Facility Element	The system of the facility on which the BIM Use will be implemented.
Facility Phase	The point in the facility's life at which the BIM Use will be implemented.
Discipline	The party by whom the BIM Use will be implemented.
Level of Development	The degree of granularity to which a model element is developed.

Figure 6 BIM Use Elaboration Characteristics (Kraider, Messner & Dubler, 2010)

2.3 Cooperating participant in a construction project

Building information management is about sharing information between various project participants who contribute to constructing the construction building. The participants have different roles in the project and utilize BIM to facilitate the project process. Building information models often provides the client the possibility to follow and monitor the projects development. The design allows the client in an early stage to virtually navigate in the model and see how the finished structure will be. While the building information model provides the design manager better communication between clients and the other parties involved in the project with a good overview of the project and coordination opportunities. The contractor mostly prefers the simulation of the model with integrated time scheduling, rough estimation of cost with simulating through the project. At the same time the suppliers have the opportunity to speed up the manufacturing process through utilizing the CNC files or manufacturing drawings, furthermore the facility owner has the ability also to use the BIM model in the facility management stage to manage the reparation , operation and maintenance of the building(Granroth, 2011).

2.3.1 Design programs

Some of the software programs that facilitates the usage of BIM are the following software programs.

Tekla Structures

Tekla is mostly used to design and model residential/office buildings, factories, offshore buildings etc. in 3D. The software program Tekla provides the designers the opportunity to design with enough information required for a building information model. The software program has the possibility to manage and handle complex detailed rich structures, with any sort of construction material (Tekla, 2012a).

Revit Structures

Revit is a software that gives the designer, the ability to weave together the different disciplines drawings in the construction industry. These disciplines are ventilation, electrical plumbing, construction, and architectural drawings. Revit is a program that is made up of items instead of lines; the software minimizes project management errors while improving the shared device, and cooperation (Autodesk 2015).

2.3.2 Coordination programs

Solibri Model Checker

Solibri Model Checker is a coordination program that analyzes models, collisions with a variety of parameters such as the building's geometries, spaces, and complete designs. A program which is suitable for implementing quality controls, visualization, navigation, intuitive walk-through functionality, escape routes etc. at the same time checking that the building meets its standards and regulations. Solibri model imports only the IFC files which are a file format that is suitable for numerous applications and programs. Further information about IFC can be found in the interoperability chapter (Solibri, 2016).

Autodesk Navisworks Manage 2016

Navisworks is a program that allows all the disciplines to coordinate and carry out collision checks. It also gives the coordinators the possibility to perform visualization, which are connected to the timeline and its various construction elements. These tools provides the BIM-coordinator a possibility to predict in advance the projects' different challenges. It offers the BIM-coordinator a variety of features that are well suited for visualization and presentations.

2.3.3 Construction Site Visualization Applications

Apricon C3

For coordination purpose the building information and files are stored in similar Webb-based cloud service portal named; Apricon C3. Through the cloud service the projects participants have access to the construction models, files and documentations, which concerns the project. Apricon C3 can also be used as a mobile application on the tablets in construction sites. The cloud service also provides reports and communication solutions and documents (Apricon, 2015).

Autodesk BIM 360 Glue

Glue BIM 360 is a cloud based coordination program that provides the project team the opportunity to collaborate between all project participants in the computer and tablet. Glue BIM 360 has the possibility to work with these following file formats e.g. - IFC-, RVT- and DWG. The program has also the possibility to handle collision controls, combines model coordination with project quantities and schedule to deliver simulation and quantification features, including analysis of time and cost. Entire project models can be published and freely viewed using Autodesk Navis Works Freedom software.

Tekla BIMsight

Tekla BIM-sight is a coordination program that improves communication between production site and the consultants by offering them the opportunity to provide the quality manager the possibility to become updated with notification functions. The program has the ability to handle collision detection (Tekla BIMsight, 2016).

2.4 Interoperability

Interoperability is interpreted as the capability of communicating between people and varying types of applications in the architecture, engineering and construction (AEC) industry. Interoperability is a significant barrier breaker when it concerns collaboration between different kinds of involved parties and their software and applications. The more we become reliant on building information modeling (BIM), we at the same time become more dependent on interoperability, which allows designers to share and work together with other participants on construction projects with different software and file formats (Green, 2016).

2.4.1 Utilizing IFC

To accomplish the best possible interoperability most BIM users are familiar with the industry foundation class (IFC) which is an ISO standard (ISO 16739:2013) and is known as partly being developed by the international alliance for Interoperability (IAI). Building smart and having a common data scheme (model) called IFC allows different applications to exchange relevant data. IFC is a data scheme that encodes the information, which is related to the entire lifecycle of a building. Offering all the participating participants, regardless of the software application they are using an open file format, which makes it possible to share information throughout the facilities lifecycle or any building environment, is highly valuable. IFC file format is neutral which means that it does not belong and is at the same time independent of any vendor software development plans (building SMART, 2011).

2.5 The Reinforcement process

The reinforcement process can become hugely improved through digitalization. In the case study project called “*Reinforcement within the construction process*” it has emerged that utilizing the new technology can save more time and create better information flow in the process (Engström et al ,2011). There has been a great need of improvements concerning the rebar specification/schedules within the reinforcement process. Currently technology that is used in the reinforcement process is more for calculations and designing (Engström et al ,2011).

Engström et al (2011) furthermore states that shortening the lead-time between the time of approval of the construction design and the delivery of the reinforcement on site would improve a lot. Engström et al (2011). In addition, they mention that there is a lack of staff that designs and works with the reinforcement specifications and the work mostly goes to few consultants that are specialized in that field. Furthermore some other improvements, which need to be made such as improving the adaptation of the reinforcement’s specifications to the construction’s delivery plan, difficulties with manually adjusting the rebar spec and the possibility to digitally transfer the rebar specification to the bending machine (Engström et al, 2011).

The participating participants in the reinforcement process are presented below.

- The Design Team (architect, structural and other consultants)
- The Construction Team (Entrepreneurs & contractors)
- Suppliers (Reinforcement suppliers)
- Construction workers

The report written by Engström et al (2011) mentions that several steps of manual information transmission of reinforcement mostly characterizes the current reinforcement process. At the same time repeated input of the same reinforcement information is often done before the reinforcement is delivered to the Construction site. However, this leads to increased risk of causing failure when relevant data is managed manually in several steps, which can in its turn result in waste in terms of time and money. However, simultaneously the digital development of the IT-tools offers a way of managing the reinforcement information digitally, with the complete freedom of manual input of the data between different systems. The use of these digital IT-tool improvements that covers several parts of the reinforcement process, will lead to a huge change of the current working methods and responsibilities.

The reinforcement process often starts with structural engineers who design a structural model, which is based on the architectural model. Further on the structural 3D-model is used to generate automatic reinforcement specifications by dividing them by casting stages. The reinforcement specification gets sent to the contractor digitally through xml-files, which are connected to the reinforcement specification program Q-reinforcement. The program Q- reinforcement now called QR is used to approve, complete and adjust to delivery plan and send it to the reinforcement supplier. Later on, the reinforcement is manufactured according to the reinforcement specification and delivered according to the delivery plan (Engström et al 2011).

2.5.1 Actors within the reinforcement process

The first stage of the reinforcement process always begins with the structural engineers calculating and designing the estimated reinforcement amount. Then later it is passed on to reinforcement specification consult.

The Structural Engineers

Designing reinforcement in 3D is becoming more and more usual in the construction market. Previously the structural engineers designed the reinforcement in 2D with software similar to Auto Cad etc. (Engström et al., 2011).

The structural engineer calculates the required reinforcement through calculations software, which specifies the right amount of rebar and dimension required in the concrete. The structural engineer designs the reinforcement drawing and sends them out for review (Cho, Y.S et al., 2014). After the reinforcement drawings are sent out for review in the design process, the communication between the structural engineers and the production staff is limited. This is mostly due to phase shifts, which occur between the designers and the production staff. These phase shifts, lead later to more time pressured revision work, which in its turn increases the risk of the occurrence of multiple errors. The errors can be, a result of the structural engineer maybe moving on to other projects or that the production staff have not previously had the time to take up the matter. This communication error creates a gap which reinforcement specification consultants fill and improves the communication between both parties. The consultant adapts the reinforcement specifications to the production site and performs an additional quality control of reinforcement (Engström et al., 2011).

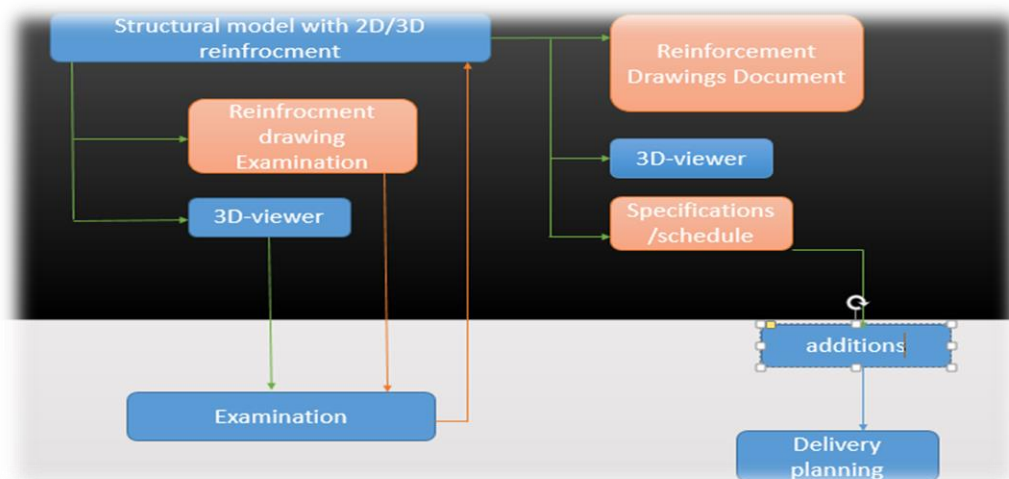


Figure 7 Structural engineers reinforcement processes (Engström et al., 2011).

Figure 7 explains that at each reinforcement drawing is delivered with a 3D-viewer from the structural model. This provides the viewer a chance to clarify how the reinforcement design looks. Simultaneously it is important that the updated information with the correct design documentation is sent out, the green arrow represents the digital transportations while the orange one represents the non digital transportations (Engström et al., 2011).

The second stage in the reinforcement process is when the structural design is handed over to the consultants, which creates the reinforcement specifications.

The Reinforcement Consultants

The consultants execute the reinforcement specifications practically by hand, after they received the reinforcement drawings from the structural engineers. They feed in the data into either Q or Q-spec, which now develops further to QR-data, which later is sent out in xml-format to the reinforcement suppliers (Engström et al., 2011). Further on BIM Alliance (2016) continues that all reinforcement information can be managed in the QR-data. There you also can check the quality of the reinforcement, color coding, delivery plan, the monitor status and create a report. The QR-data is integrated to other design software programs such as Tekla and Strusoft. The figure 8 bellow illustrets how a reinforcement schedule looks.

Klippt och bockad armering, ILF																												
TYP	NUMMER	STÅLSORT	ANTAL			Ø mm	KLIPP LÄNGD	DELMÅTT: mm, VINKLAR: grader																	R	BPP	KONSTRUKTIONSDEL ANMÄRKNINGAR	REV
			GRP	ST/GR	TOTALT			A	a	b	c	d	e	f	g	Ä	x	y	v	s	t	u						
S	101	K500C-T	2	20	40	10	3041	1500	1500									100									vägg 5, 6	
C	105	K500C-T	2	18	36	8	1107	500	140	500															16		vägg 5, 6	A
A	10-2600	K500C-T	2	52	104	10	2600	2600																			vägg 5, 6	
A	12-2600	K500C-T	2	2	4	12	2600	2600																			vägg 5, 6	
S	101	K500C-T	2	15	30	10	3041	1500	1500									100									vägg 6, 7	
C	105	K500C-T	2	18	36	8	1107	500	140	500														16			vägg 6, 7	A
A	10-2600	K500C-T	2	40	80	10	2600	2600																			vägg 6, 7	
A	12-2600	K500C-T	2	2	4	12	2600	2600																			vägg 6, 7	
S	101	K500C-T	2	11	22	10	2990	1500	1500									10									vägg 7, 8	
C	105	K500C-T	2	18	36	8	1107	500	140	500														16			vägg 7, 8	A
A	10-2600	K500C-T	2	30	60	10	2600	2600																			vägg 7, 8	
A	12-2600	K500C-T	2	2	4	12	2600	2600																			vägg 7, 8	
S	101	K500C-T	2	8	16	10	3041	1500	1500									100									vägg 8, 9	
C	105	K500C-T		36	36	8	1107	500	140	500														16			vägg 8, 9	A
A	10-2600	K500C-T	2	22	44	10	2600	2600																			vägg 8, 9	
A	12-2600	K500C-T	2	4	8	12	2600	2600																			vägg 8, 9	
S	101	K500C-T		72	72	10	3041	1500	1500									100									vägg 8	
C	105	K500C-T		46	46	8	1107	500	140	500														16			vägg 8	A
C	106	K500C-T		25	25	8	907	400	140	400														16			vägg 8	A
C	107	K500C-T	7	4	28	8	1723	L	700	160	700						L							16			vägg 8	
A	10-2600	K500C-T		160	160	10	2600	2600																			vägg 8	
A	12-2600	K500C-T		28	28	12	2600	2600																			vägg 8	

Figure 8 Reinforcement specifications/schedule (Engström et al., 2011).

Reinforcement specification dispatch form may vary depending on the method used. It can be sent in "dead" format, i.e. in plain paper form that requires manual transmission. It can also be sent in PDF-format or similar digital XML file formats or alternative cloud services. In addition, data can be carried out as reinforcement specification regardless of, whether it is in paper or digital BIM-form in the QR-reinforcement specification program. In order to adapt the reinforcement for production site, it further requires digital hand laying transformation within the QR-software. Then later the production staff can pick out the received XML files and forward them to the reinforcement suppliers who manufacture them. This approach creates an automated flow of armor production (Engström et al., 2011).

The third stage, the consultants have executed the reinforcement specifications from the reinforcement model design. Further on they send it to the entrepreneur, who later reviews the rebar's documentations for the concrete structure.

The Contractor

The contractor's engagement in the reinforcement process occurs in different stages of the project, much depending on the cooperation and the procurement form. The contractor provides the structural engineer with support and input on different reinforcement solutions and adjustments concerning the production stages (Engström et al., 2011).

Further Engström et al., (2011) describe that the production stages are one of the important parts of the reinforcement process, which explains and prepares the construction site with deliveries and mountings. To facilitate the production process, the reinforcement is divided into different casting stages e.g. concrete plate, walls, facility one, facility two etc. Further Celsa Steelservice, (2012) continues that, to reach an enhanced communication the casting stages are divided with different color codes and so on by the rebar specification consultants. Color-coded reinforcement design illustration can be seen on *figure 9*.

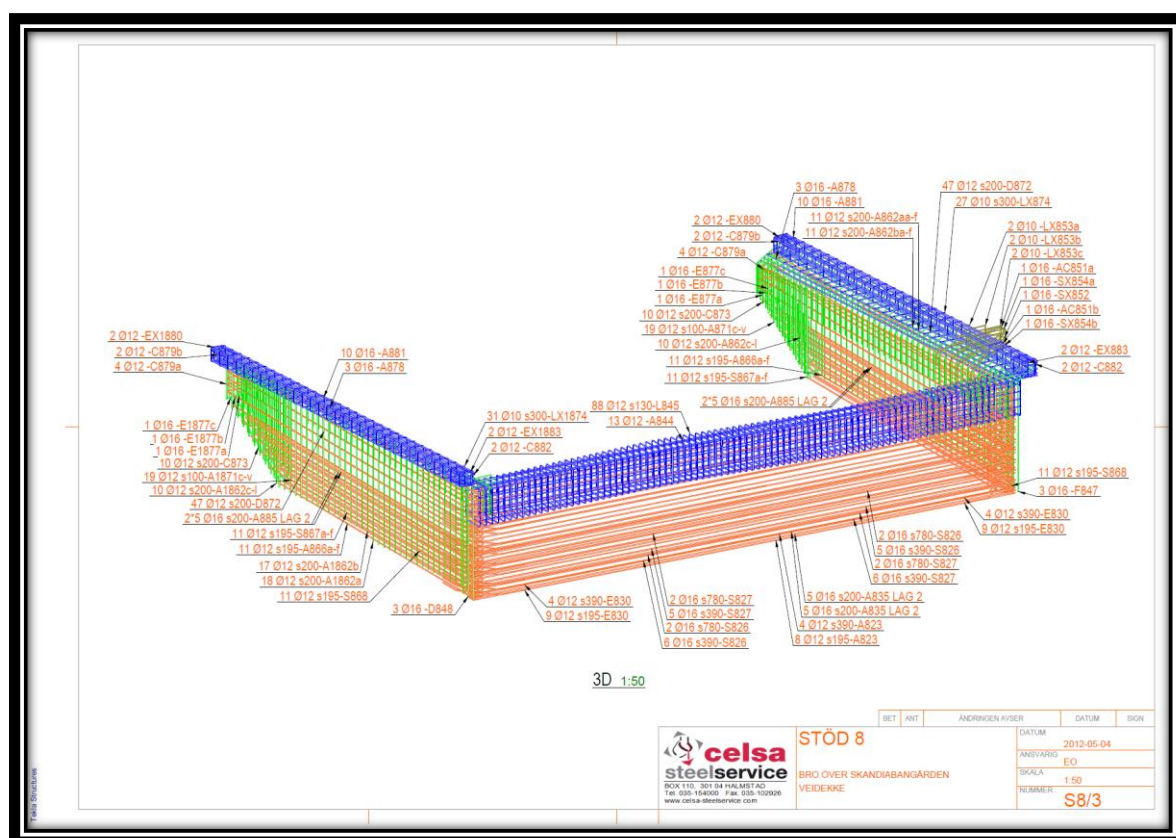


Figure 9 color-coded 3D - reinforcement drawings Celsa Steelservice, (2012)

Later the contractor receives the reinforcement specification deliveries grounded upon the specified casting stages with color-coding. The contractor currently only utilizes paper drawings or pdf: files. The contractors do not use any digital-tools to self-modify the rebar specifications; instead, the contractor communicates with the designer through the phone, the colored-coded rebar is delivered as shown in figure 10 below (Celsa Steelservice, 2012).



Figure 10 Reinforcement is delivered colure coded Celsa Steelservice, (2012).

Depending on the production conditions on the construction site, the contractor arranges start meetings with the reinforcement suppliers and discusses the production layup and the delivery plans. This is due to every reinforcement, specification being called-off separately while the production process progresses. The contractor often performs quick stick sampling on the delivered reinforcement by the suppliers; mostly due to the reception controls being time-consuming and so on. The consultant performs the contractor requests: clear reinforcement drawings with literate facility drawings and civil work drawings with stage classifications, color marking, end configuration of hooks, reinforcement method (the choice between separate reinforcement or mesh and roller rebar) (Celsa Steelservice, 2012).

Contract Forms

The procurement process includes various kinds of contract forms such as Design Bid Build contract and Design Build contract form. This has various impacts on the construction process concern of the opportunities of utilizing Building Information Management. Further description of the contract forms and their relations will follow down below.

Design Bid Build contract form

Design Bid Build contract provides the facility developer the responsibility of the design and development of the construction documents as building permits, descriptions and the Swedish Administrative regulations part (AF-part). It is often usual to hire in consultants that develop the construction documents for the client. Design Bid Build contract provides the contractor a good possibility to predict the build-up cost of the facility. The responsibility regulation in the traded contract form design bid build is governed by the Swedish contract regulation AB04, which stands for “*The general requirements for the construction industry and was published in 2004*”. The contract does have some form of requirement as input of added documentation, which later gives the contractor obligations if the documentation is not detailed correctly. The contractoforms structure is shown below on figure 11 (Nordstrand, 2000).

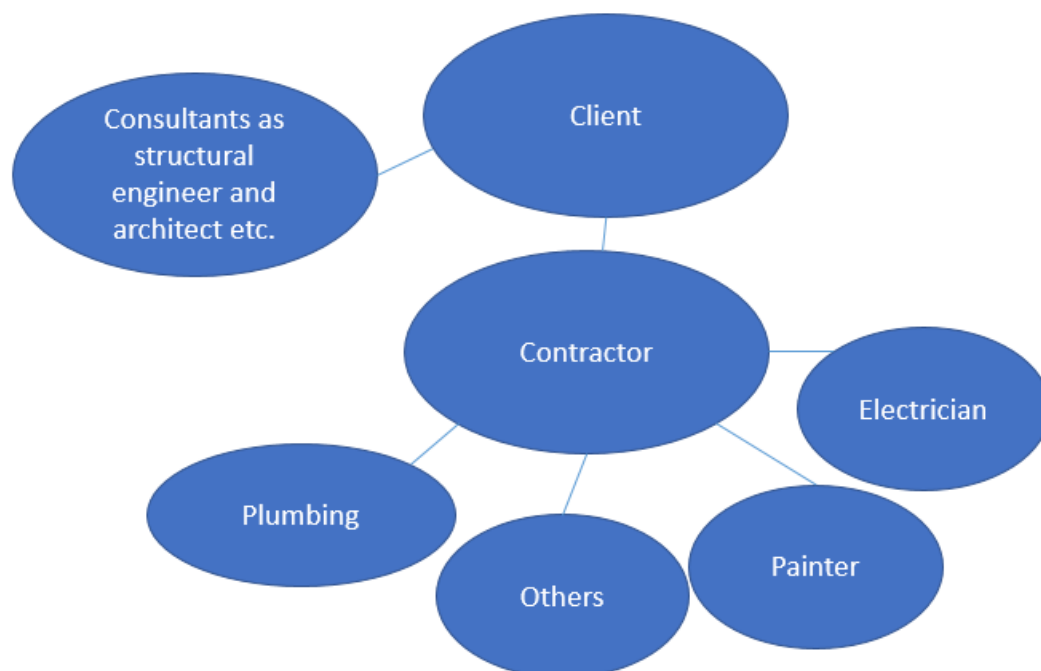


Figure 11 Design Bid Build Contract Form based on (Mittbygge, 2011)

Design Build contract form

Design Build contract offers the client the possibility to hand over contract agreements to one contractor, which performs the design according to the clients function requirements and develops the construction. The client usually purchases certain services by subcontractors in this simple contract forms, but there is only one contractor, which is responsible for carrying out the whole construction of the facility in a correct way. Design Build contract form AB06 has positive and some negative traits. The negative traits to start with are that the clients' input on the design varies while the positive trait is that the construction of the building can start before the design is finished (Nordstrand, 2000).

When the contractor procures the construction project in the design build contract form, the contractor at first has access to a small amount of information, only to the architectural drawings for the plan and the façade of the facility. This results in the structural engineer being involved in an earlier stage than usual and estimates the amount of reinforcement necessary for the construction project in kilogram/m². This provides the calculator a good material to estimate the cost of the construction project (Nordstrand, 2000).

The responsibilities within design build contract form is regulated by the Swedish responsibility regulation ABT06 which stands for "The General Regulations for Design Build contract form, published 2006". These responsibilities are shared by that client and the performing contractor. These contract documentations requires some proposals of the construction time, cost and technical descriptions (Nordstrand, 2000). Further structure of the contract form is shown on figure 12 bellow.

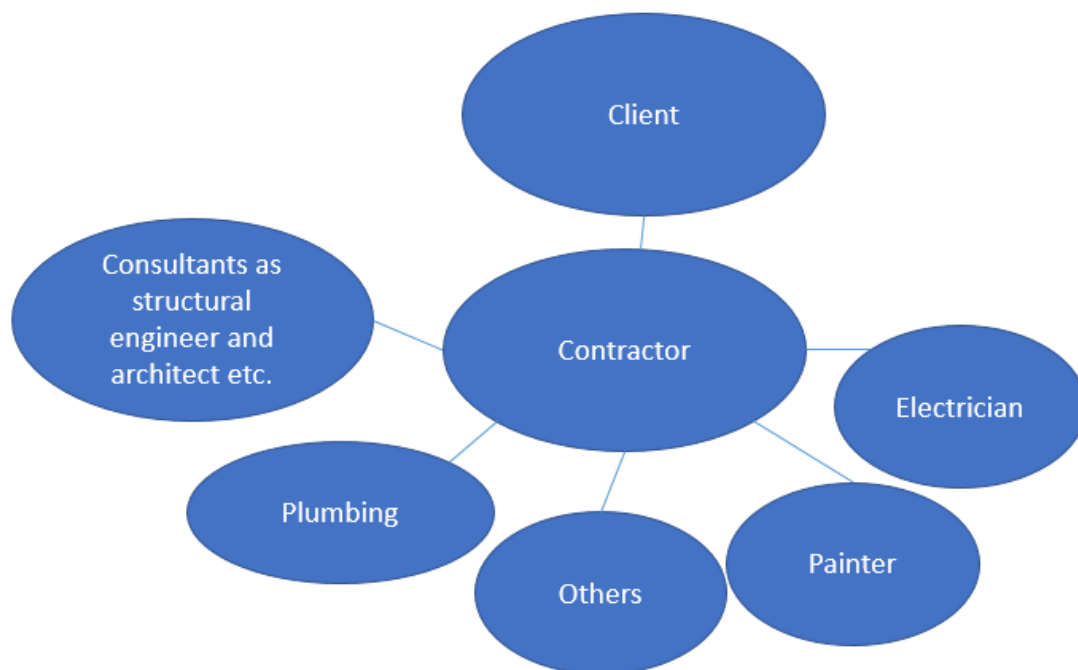


Figure 12 Design Build Contract Form based on (Mittbygge, 2011)

The Design build contract provides the construction projects the possibility of taking Strategic decisions concerning the projects work set. These decisions provide the project with systematical solutions, which the consultants can take into consideration.

Furthermore, the design build contract offers construction companies which do not have a standardized work set concerning reinforcement an opportunity to be able to come up with solutions that fits the projects condition. The production adaptation with the reinforcement often begins after the involved participants have agreed upon the contract documentation. Compared to Design bid build contract, this offers the contractor less chance to influence the construction project. The limited opportunity to make an influence on the project often comes from the contractor's procurement process, which starts after the design documentations is done. However, at the same time is it required that in design build contract that the contractor gets involved early in the project with defining the rebar production stages and the collaboration between the structural engineer and the contractor.

Juridical description

The Swedish non-profit sector-driven organization BIM Alliance, works with developing more efficient information management concerning building information management (BIM). BIM Alliance further on mentions that the Swedish juridical regulation concerning the BIM should have status as a current act. The BIM act is preferred to be at level nine, according to BIM Alliance in the Swedish standard agreements. They mentioning that the Swedish construction regulations AB04 and ABT06 should be updated so the possibility of working with the digital model is possible through the whole construction process BIM Alliance (2016). In the following figure 13, the regime of the Swedish regulation if contradictory information in the contract documents arises is shown. The following order applies, unless circumstances cause otherwise.



Figure 13 Juridical order if contradictory information arises in the contract documentation in Swedish standard agreements (BIM Alliance (2016))

The contractor sends their document further on to the reinforcement supplier, which handles the specification and produces reinforcement.

The Reinforcement Suppliers

Aretoulis, G. N et al., (2010) explains about an earlier observation, which describes that price or cost is not a widely adopted criteria compared with the evaluation of the quality performance the supplier delivers. Later on the quality criteria is followed by delivery, price or cost and so on. Anders (2016) explains that a reinforcement supplier is often an external supplier to the construction companies, but depending on the size of the construction company, they sometimes have an internal supplier within the company.

The reinforcement supplier receives the reinforcement specification from QR-data, which later automatically reads in its information in the factories production preparation system. To optimize the factories production system it is required that the contractor be ahead of their time with planning and ordering of reinforcement. Mostly because the later the order comes in to the reinforcement supplier the more of a possibility to reach an optimized manufacturing is hampered (Engström et al., 2011).

The reinforcement supplier often quality checks that the manufactured reinforcement suits the reinforcement specifications they have received from the consultants. Other quality checks are often done by the supplier only when they them self-have designed the reinforcement specification. (Engström et al., 2011)

Engström et al., (2011) mention that the reinforcement suppliers desire to e.g. become engaged earlier in projects so they can become committed to the project as soon as possible. Engström et al., (2011) believes that through early engagement they have the possibility to support the production staff with questions and solutions. What is equally important is that contractor has a good long-term planning attitude concerning the deliveries so the manufacturing of rebar in the factories becomes as optimal as possible. Further this will generate cost savings in the work place which is appreciated both by the contractors and the suppliers.

The produced reinforcement specification's by the suppliers is later constructed on put together by the construction workers in site.

Construction workers

The traditional labor within the construction process of site-casting concrete structures still has the same similarities construction methods as previous craft-based work on site. Furthermore do the work on the construction site contains several factors that can require a large-scale of work, which results in that the cost of labor being almost equivalent to material cost. At the same time has other studies shown that the labor cost of concrete buildings was about 40% of the total cost of the building in the year 2002 (Harryson, 2002) & (Löfgren, 2002).

The association between time and money is frequent, the most time consuming elements in the reinforcement work is the manually carried out work. The manually carried out work is currently an urgent workmanship that includes many heavy lifts, which are done in inappropriate work positions. This causes a poor work environment for the construction workers and becomes disadvantageous for the construction projects from an economic point of view (Sandberg & Hjort, 1998).

Sandberg & Hjort, (1998) continues that there is a need to industrialize the reinforcement design so the work environment becomes improved, the time consumption becomes shortened and the quality becomes improved. However, at the same time mentions Sandberg & Hjort, (1998) that the best production adaption of the reinforcement is achieved when it is adapted early at the design stage, which requires that the structural engineer is aware of which production methods are utilized on the construction site. In addition, some knowledge from both the architectural drawings and the structural engineers is required so the most efficient production adaptation is achieved (Sandberg & Hjort, 1998).

Engström et al., (2011) States that construction companies require at least some basic knowledge of BIM. The basic required knowledge gives the employees a good understanding of what can be achieved through BIM so the clipping from 2D to 3D is done as smoothly as possible.

BIM usage of site-workers (BIM-kiosks)

BIM-kiosks gives site workers the possibility of viewing updated design information of the planned construction building. According to Bråthen & Moum (2016) this concept contributes to good communication between the site office manager and the construction workers. Furthermore, it is mentioned that workers experienced great advantage from using digital iPad models compared to traditional drawings. The author also argued according to Bråthen & Moum (2016) that the building process productivity raises when BIM is introduced to the construction-site. Their findings also show that the workers experienced great advantages of using models compared to traditional drawings. This potentially leads to reduced risks of costly errors and delays on the construction site.

Furthermore, digital management of construction drawings leads to more mutual interdependence between the various parties involved in the project. This contributes also to a good project management, monitoring and updates on the build and planned building. The digital model can achieve simplification of the production purchasing process, with good material flow tracking, management and workplace disposal as well as support with material flow tracking. Many authors express that the good combination of mobile devices and BIM-kiosks, might open up interesting new working ways in the construction site Bråthen & Moum (2016).

3 Method description

Will describe the research method for this thesis.

Chapter 3 begins with literature and documentation to get an understanding the subject, later it goes through the implementation of the interviews.

3.1 Research methods

The report is conducted as a case study in Skanska's Technical Housing department in Gothenburg. According to Merriam (1994) a case study presents, an important component in anthropology, psychology, sociology, work science, social work and political science, which are utilized to systematically study events. The focus of the research has been to conduct information of how 3D-reinforcement can be implemented in Skanska technical housing department in Gothenburg, at the same time evaluate the optimal management of their reinforcement process. A study is done on how different disciplines in the construction process work with reinforcement; The following interviewed disciplines are structural engineers, project managers, production managers, supervisors, district procurers with reinforcement suppliers and construction workers.

The literature study gave a good description of how 3D-reinforcement should be utilize theoretically and the advantages of it. The interview process started with unstructured interviews and site visits on construction sites. As Merriam (1994) mentions, the goal of the unstructured interviews, is in fact, to learn enough about a subject, which makes one able to formulate questions for future interviews. Based on this knowledge, the important information that was needed for the interviews and surveys could be conducted.

3.2 Literature study

The literature research of the master thesis started at an early stage, through researching on information, which was mainly obtained through two databases; Summon at Chalmers Library and Google Scholar. Key words which gave a better overview understanding of 3D-reinforcement were these following; implementation of 3D-reinforcement, reinforcement schedule and the reinforcement process. Further, the keywords was narrowed down so more relevant articles within the topic was found e.g. BIM-uses/BIM-tools.

3.3 Skanska's internal network

The documentation of Skanska internal network were done through selection between relevant data for the research in their internal “Our Way Of Working (VSAA) website”, which is Skanska Sweden's management system site. It includes their decision and management approach, which Skanska considers leads to satisfied customers, satisfied and committed employees, predictable and efficient operations and increased profitability (One Skanska, 2017a)

The purpose of analyzing Skanska's internal network was to conduct information about how Skanska works with BIM today and how they follow up their work set with their own reinforcement processes. One of the documents that was reviewed was; Skanska Sweden's ID Guide to Project BIM Implementation. The use of appropriate data has been discussed between the author of this report and BIM coordinating officer, about what should be emphasized in the report. Further below is Skanska's process for their designing of house projects on figure 14(One Skanska, 2017b)

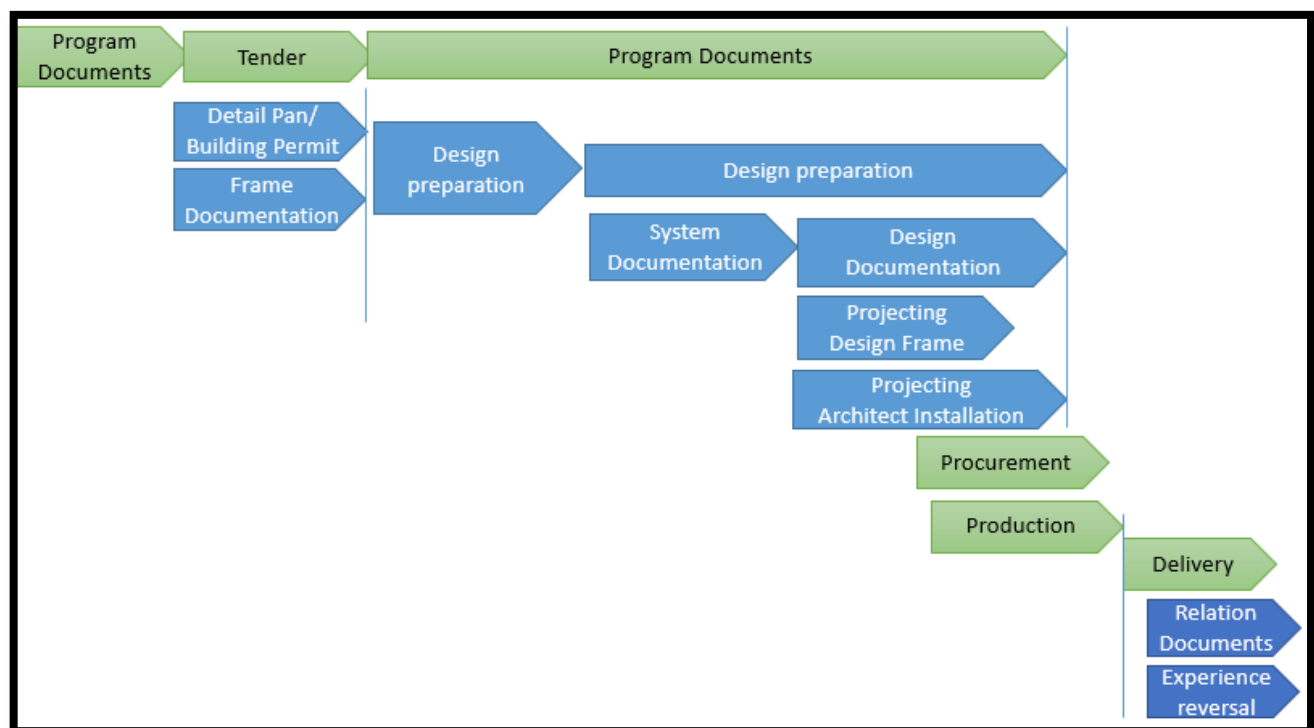


Figure 14 Skanska Process Map Design of House projects (One Skanska, 2017b)

3.4 Interview design

The interviews and construction site visits for this report were performed during two weeks' time in three different Skanska residential, office and hospital projects that were located in these following Swedish cities Kunsbacka, Kungälv and Gothenburg. The interview questions were designed to leave room for open answers which lead to interesting discussions. The interviewed respondents were selected based on a list of recommendations from the BIM coordinator of Skanska's technical housing department in Gothenburg. The list consists of the different interviewed respondent's disciplines, which is listed in Table 1.

Occupational category	Companies
Structural engineer	Skanska Sweden
Structural engineer	Skanska Sweden
Structural engineer	Skanska Norway
Reinforcement supplier	Celsa Steel
Reinforcement supplier	Celsa Steel
Reinforcement supplier	SSI Skanska Sweden
Supervisor purchaser on site	Skanska Sweden
Supervisor purchaser on site	Skanska Sweden
Production manager purchaser	Skanska Sweden
District purchaser manager	Skanska Sweden
Project manager	Skanska Sweden
Construction worker	Foreign subcontractor
Construction worker	Foreign subcontractor
Construction worker	Skanska Sweden
Construction worker	Skanska Sweden
Construction worker	Skanska Sweden

3.5 Collection of empirical data

The time expectations from the interviews were approximately calculated to take about 20-30 min with each respondent and the method that was used were the semi structured interview form which according to Berg (2009, p.107) lets the interviewed freely develop and elaborate their answers and explanations. Furthermore Berg (2009, p.105) explains that semi-structured interviews gives the interviewer the possibility to change the order of the questions and wordings. Silverman (2010, p.8-11), continues to explain that it's an advantage for the interviewer if they have in mind during the interview that how they ask the question is more important than how many questions they ask. The interviewed respondents were recorded for later transcription, which makes it easier for the interviewer to intercept the important information and facilitates the writing process. All respondents were informed that the interviews were anonymous and would be submitted based on the respondent's occupational category.

3.5.1 Transcription

The interviews were transcribed as quickly as possible to recall the appearance and feeling the interviewer had from the respondent's. The transcription of each interview took about one hour per interview. The author Wallen (1996) describes the importance of transcribing as soon as the interview was performed.

3.5.2 Selection of relevant data

The selection of relevant data has been done through selection through primary data which interprets all previous data collected in the form of information, which has been collected for the purpose of creating new sorts of data. The study consisted of 16 interviews. After the transcribing and selection of relevant data, the interviews were distributed into smaller summaries based on the occupational category.

3.5.3 3D-Modelling-Tools

In this master-thesis will a test model of 3D-reinforcement ground plate and elevator shaft be modeled. Skanska Gothenburg housebuilding project Kvibergs-Ångar will be the first project utilizing this technology in Gothenburg, Sweden. The aim is to model 3D-Reinforcement and create reinforcement specifications at the same time visualize the rebar will be created in the following design software programs represented on this list. Table 2

Program	version
Revit structure	2017
Naviate structure	2017
Glue- BIM360	2017
Solibri checker	v.9.7
Naviswork	2016
iConstruct	2017

3.5.4 Description of the case study project

The real life project studied in this thesis is the construction project called; *Kvibergs-Ängar* which is located in northeast of the city of Gothenburg. The project is a construction of 300 residential apartments. The project delivery method is based on design build. The construction phase will reach its finish in year 2019. Figure 15 illustrates how the finish design of the facility will look.



Figure 15 Facility & Neighborhood design of Kvibergs-Ängar (One Skanska, 2017b)

The master thesis focus on designing the bottom concrete plate reinforcement in 3D-model form and elevation shaft.

3.6 Skanska: Company presentation

The construction company Skanska's successful accomplishment up to now indicates that Skanska is one of the major construction companies, which works for building more sustainable societies. The construction company's history all started in 1887 with the former name "Skånska Cement foundry" there they manufactured and produced concrete products with great success. Later on the company had its major climb in the international market in the midst of 1950s and onwards. The continents Skanska has established itself in are Africa, Asia and South America where they built power stations, roads, schools and hospitals in developing countries. However, later in 1971, Skanska had the confidence to step into the US market to build their subway systems in New York and Washington D.C. These projects resulted in the United States becoming one of Skånska Cement foundry's largest markets. The company Skånska Cement foundry changed its name to Skanska in the year 1984 (One Skanska, 2017a).

3.6.1 Organizational view of Skanska

Organizationally Skanska did develop more in the 90s, which resulted in the doubling of sales in a short period. The organizational development was the acquisition that made Skanska AB one of the major global companies.

Skanska changed its strategy later in the 20th century; there they focused more on developing and constructing residential and commercial properties. Also constructing infrastructure projects in their home markets in Europe and the United States. At the same time as the home market, continued developing, the safety aspects and work environment criteria has become more important. To achieve these work environmental goals Skanska has put its weight on ethics, achieving zero occupational accidents and putting sustained social development into focus (One Skanska, 2017a).

3.6.2 Building Information Management (BIM) within Skanska

Skanska vision is that BIM (Building Information Management) will provide them a good opportunity to gather information and create a common information source (One Skanska, 2017a). Through digitalizing the design and administration process they believe that all unnecessary waste of paper for drawing would be avoided. Through saving, the natural materials by using digital equipment they believe this will contribute to creating a more sustainable society. As well as digitalization will create better flow in the production stage by reducing all the unnecessary interruptions in every project line. Globally Skanska has a constant development within BIM where colleagues gather with the purpose of sharing experiences. Furthermore, Skanska explains (One Skanska, 2017a) that BIM has its advantages such as utilizing it in work preparation and safety planning, quantity removal and improving communication between all project-involved participants.

4 Results

The results chapter aims to present the study's research section. The first results part is broken down by occupational categories and issues related to the reinforcement process. The second result part is divided according to the various digital processes that exist within the reinforcement process. The chosen heading aims to create a red thread between theory, results and analysis.

4.1 Interview results

The perspective of the actors within the reinforcement process is presented in the interview results chapter. The results themes are based on the thesis research questions. The presentation of the results describes how and in what way the current reinforcement process looks.

4.1.1 Skanska Sweden Structural engineers current work set

Collaboration between the various disciplines in the reinforcement process

Utilizing 3D-reinforcement in construction projects often depends on the construction projects design and the demands requested in the project. If the construction project requests utilizing the 3D-reinforcement, the structural engineers often design with traditional 2D-drawings. Later the traditional 2D drawing are handed over, to another structural engineer, who is responsible for designing the reinforcement specifications in 3D with casting stages. 3D-reinforcement is in the current situation designed mostly for visualization purposes in other technical departments within Skanska.

Then structural engineers start their design process by calculating the carrying load of the structure and estimate the basic loads before they utilize the reinforcement for the structure and design it in traditional 2D drawings. They often design the 3D-reinforcement, mostly depending on if the project wants to utilize 3D-reinforcement or not. Afterwards the 3D-model or designed drawings are sent to the construction site, there they order the reinforcement from their suppliers. Depending on how much support the construction site desires or its conditions, the engineers are always helpful with that support.

Construction Projects are often similar but rarely identical which makes the reinforcement process unique. However, the structural engineers mention that in the design phase, if they have the opportunity, they utilize some design parts or work sets from previous projects. Through adjusting some parameters the reinforcement design can become more general. The structural engineers mention also that they believe that utilizing more standardized work procedures would lead to an improved communication between them and the project managers on the construction site. This is partly due to, better visualization of the design requests from the project managers. The program software, which are utilized mostly for designing 3D-reinforcement, are Revit, Tekla and Solibri. Concerning quality controls of the reinforcement design, the models are checked 2-3 times before they hand them over to the construction site production staff.

Suggestions on improvements in the reinforcement process?

The structural engineers considers that the communication between all de different disciplines can hopefully become more improved through utilizing the same communication systems (cloud). If they design in program software Revit or Tekla they have the opportunity to upload it in the same shared cloud.

Advantages / disadvantages with 3D reinforcement in the reinforcement process

The conditions to use 3D reinforcement are beginning to look brighter than they did before. Previously, the round shaped elements were a challenge to design with 3D reinforcement but recently it has become more useful. While modeling with rectangular and square shapes has worked excellently. The structural engineers would like to find a way to simplify the 3D design of reinforcement so its design process becomes more optimal.

The advantages 3D-reinforcement has is that it gives the user the opportunity to find and visualize all the strange cuts and at the same time it gives another opportunity to get all quantities of it, so they are able to calculate the project cost of the reinforcement.

The disadvantage is that the knowledge with designing 3D-reinforcement is small and the design program Revit has become good but not enough for designing in 3D. The use of 3D reinforcement in construction projects is up to 30% while compared with traditional 2D reinforcement, which is used up to 70% of the designing process.

The structural engineers prefer to have better contact with the construction sites production staff. So the misunderstandings are prevented which usually take place. The structural engineers wish to have an earlier cooperation with the production staff so they get a better picture of the project and prevent extra work on the construction site. At the same time the structural engineers become better at designing the 3D-reinforcement so it becomes more adapted to the construction site.

Current Working Methods

Currently do the structural engineer perform overdraft calculation of the reinforcement cost in the software programs Solibri, which allows them to estimate how much cost they will put on the projects reinforcement procurement. Further on is their communication limited with the construction workers and often governed by the projects procurement form. Depending on the project design do the productions staff contact the structural engineers; otherwise do they handle the reinforcement process by their own. Current possibilities of visualizing reinforcement work are good but could be better.

Software Comparison between Revit and Tekla

All the structural engineers mention that the Autodesk design software program Revit is progressing and becoming more suitable to design 3D-reinforcement. The benefit with 3D visualization is that it gives the viewer a chance of easily obtaining c / c distances in a simple manner while knowing the number of reinforcing rebar iron that should be on the position with the right chap length and radius booking etc. Compared with the 2D-design where users need to run practical calculations for getting the information that 3D-design offers. If any changes occur 3D-design offers an update on the information and design modifications shared with the design. In addition, the amount of rebar has specific identification numbers, that gives information about which casting stage it belongs to. Revit is customized more for house construction buildings while Tekla is more unspecified and has larger design opportunities, where you can design bolts, bridges, steel buildings and foundations. Tekla has an open approach to BIM there you can run fabrication machinery. But what Tekla and Revit has in common is that both have access to the Scientific program Q-reinforcement or QR plugin which allows the designers to have the opportunity to organize their lists and project components and save them directly in QR. The scientific program supports export of-cut and bent rebar, special types of rebar and rebar welded baskets. The time difference with designing 2D or 3D differs, they mention that the project conditions and the design knowledge of the structural engineer sets up the time duration of the design. The structural engineers mention also that designing 3D-reinforcement has shorter time duration when it comes to designing smaller projects. Furthermore, in larger projects it may take less time with 2D-design compared to 3D-reinforcement.

4.1.2 Skanska Norway Structural engineers current work set

Skanska Norway has digitalized their way of carrying out their construction process and is currently performing their project without traditional paper drawings.

The digitalization of their reinforcement process often start with that their structural engineers creating 3D-model of their reinforcement work in DWG: file formats. For planning production adaptations and casting stages the structural engineer collaborates with the production staff on the construction site. Later on they receive feedback on their 3D- reinforcement model and produce the reinforcement schedule through collaborating with their supplier by using the software program Solibri Model checker.

To also have an opportunity to visualize the 3D-reinforcement work on the construction site the structural engineers use Glue-BIM 360, the cloud service that shows the reinforcement work to the production staff and the construction workers on the construction site. Through Glue-BIM 360 the construction workers communicate directly with the structural engineers, by just commenting edit on their iPad/tablets.

The conditions for using 3D-reinforcement are good and Skanska Norway has now used it for about a one year period in seven different projects. They have experienced that the digitalization of the reinforcement processes delivers a higher quality and goes faster than traditional paper work. In addition, it provides a better underlay for their design process, which saves time and money in every line of the projects.

The advantages with digitalization of the reinforcement work is that it gives all the project participants a better understanding and an opportunity to start earlier in the process. This is an especially useful for the production staff, who comes up with important tips on production adaptations. 3D-reinforcement saves the structural engineers up to 50-70 percent time on their reinforcement process.

The structural engineers use these following software programs to design and work with in the reinforcement process; Revit, Solibri, the plugin program Iconstruct for Navis Works and Glue BIM 360.

4.1.3 Skanska Sweden Procurement /Contractors

Collaboration between the various disciplines in the reinforcement process

In order to keep the production work fluent the purchasers who suborder reinforcement at Skanska Gothenburg Building department plan the reinforcement work along their working schedule. The supervisor or the production managers are often the ones that manage the procurement of reinforcement on site. However, dependent of the project design and conditions they have the opportunity to get support from their central purchaser in their company. Their central purchasers are often a central district purchaser that provides the site managers, with support of interpreting and estimating the projects framework agreements and cost managing the project. The reinforcement purchases made today are mostly roller rebar reinforcement, straight iron, reinforcement baskets, and IFL / cut, bent reinforcing, and even prefabricated rebar.

The reinforcement process is partly dependent on how the production processes are carried out on the construction site. While its procurement processes depend on which procurement form is utilized in the project, the various general procurement forms are Design Build and Design Bid Build contracts which set different project conditions. The contract form, Design Build gives the various disciplines involved in the project better communication opportunities through whole chain compared to Design bid build contract. The Design Build contract involves all the project participants in an early stage, which contributes to the project productivity. The participating disciplines involved in the reinforcement process are the structural engineer, carpenter, supervisor, production manager and the central district purchaser as well as the reinforcement supplier. Through support of the report called NPU, (Skanska Nordic procurement unit) the district purchaser estimates the reinforcement cost that they most regularly buy from their suppliers. Skanska has framework agreement with their own supplier SSI and their external supplier Celsa Steel AB. These following frameworks, give Skanska the great opportunities to geographically choose cost beneficial reinforcement suppliers for their projects. At the same time Skanska's house procurement department have a close collaboration with their own technical department, which provides them with good basis on how the reinforcement is planned and customized in the production.

All respective interviewees from the purchasing side states that they agree that the reinforcement is procured quite project specifically, but they mostly encounter similar processes with different degrees of difficulties on the construction site. However, the purchasers on the construction site expressed desire of simplifying the practical work in the workplace for the construction workers so the heavy workload of the reinforcement decreases.

But most quality checks on the reinforcement are performed by Skanska's reinforcement suppliers, but the most checks which are done by the purchasers are more to ensure that the delivery order sent matches the requested orders. The construction workers examine the rebar's length, dimensions and distance so they have access to the right reinforcement. The software program used mostly by the supervisors that the procurement on the construction site is Tekla's own iPad program BIM-sight.

Suggestions on improvements in the reinforcement process

Some improvements requested by all interviewed respondents are that the structural engineer draws more production fitted drawings, which suit more to how things are practically built and so the rebar is do not get crowded and end up in the wrong layers. In addition, the file export and import of models between the structural engineer and the reinforcement supplier could have be improved so they are co-coordinated. The purchasers on the construction site would also like to improve their communication with the structural engineer regarding revisions and changes that occur in the work place and with the drawings so they do not need to wait months before getting support. A request from all purchasers has been for more meetings between all the different disciplines involved and with more frequent follow ups so improvements in the reinforcement processes occurs.

Advantages / disadvantages with 3D reinforcement in the reinforcement process

The advantages mentioned by the following purchaser with 3D-reinforcement is that it gives the structural engineer the possibility to adjust rebar designs before handing them out to the production site. Another advantage, which is well appreciated, is that the supervisors need less time to manage the reinforcement work and the construction workers get the opportunity to bring out their iPads with them so they can understand their reinforcement work better. The 3D-reinforcement adds better visual holistic pictures of the complicated reinforcement areas in the construction e.g. reinforcement's clashes, casting splice etc. it also gives the unexperienced but more technically knowledgeable production staff and construction workers better understanding of the reinforcement drawings. The disadvantage the purchasers mentioned is that designer and reinforcement supplier poorly promote the 3D-reinforcement. Another well-appreciated function that the 3D-reinforcement offers the purchasers is the possibility to receive digital information about the reinforcement which they can cost-estimate the projects with.

The current conditions for 3D-reinforcement are good and the request of visualizing is high, but could have been better if we started utilizing it more on projects, so that their technique and the operation of it becomes improved and more time saving. However, the utilization of 3D-reinforcement has been limited partly due to software program complications and unexperienced production staff.

Current Working Methods

The supervisors and the production manager receives 2D drawings or 3D-models through their central project share centrals and often the deliveries come through distributed production stages. The district purchasers get involved with production adaption of the reinforcement work through supporting the production staff with procuring reinforcement from their suppliers. The production staff determines, depending on available workforce if they will perform the reinforcement work practically or order pre-manufactured reinforcement to the construction site. Later the cooperation with the structural engineers mainly depends on which contract form the project is procured or if they are internal or external structural engineers. If the project is utilizing their own structural engineers, then it will become much cheaper, in terms of the construction cost stays within their own company.

The work coordination with the construction workers can differ depending on the documents the production manager has access to. If 3D-reinforcement is utilized, then the coordination with the construction workers is done in the sheds with a flat screen that visualizes the project in 3D-models. Sometimes depending on the project complexity the construction workers have usage of iPads that they bring with them outside on the construction site. While traditional projects with 2D-drawings are held in similar ways but with, 2D drawing on paper form and which often remains in the sheds.

Contract form that promotes 3D-reinforcement.

The most appreciated contract form by all purchasers overall is Design Build contract. In this contract form they have the possibility to request better demands by the structural engineers and govern the reinforcement process in a more suitable way. The Design Build contract offers the purchasers lower risk with delays if changes should occur with the design. While in Design Bid Build contract the risk for delays is potentially higher, due to that structural engineers often might start working with other projects. The reinforcement is purchased through the Swedish general requirements for purchasing of material goods in commercial construction ABM07. Otherwise the purchaser considers the 3D-reinforcement more profitable in larger projects than smaller ones and also that the possibility to have the 3D-models sent with the reinforcement specification is more time saving then getting them separate paper forms

4.1.4 Internal & External Reinforcement Suppliers

Collaboration between the various disciplines in the reinforcement process?

Skanska's external reinforcement supplier Celsa Steel AB works in a similar way regardless of their geographical operation. Mostly they prefabricate, bend and order their steel abroad from their own Scandinavian steel workshops. Then later their technical sales men utilize their framework agreements or search for new different projects. When their sellers meet their clients they often start with having an overview over the 2D-drawing then later have short introduction there they leave suggestions on different methods they can work with the reinforcement. The discussion can be about everything from deciding if they will utilize roller rebar's on the base plate, welded elements in fundamentals or in the edge beams and specially designed nets so the production time gets more optimized. After the production staff has decided roughly which reinforcement products they need to utilize, the work is handed over to their own technical departments, which start designing the special products that they receive through Pdf (2D) drawings or (3D) models DWG: files formats. Through early formation, the rebar specification list shapes the projects reinforcement process. Their technical department has often a long dialog with the structural engineer so they can simplify the design and the construction process.

Skanska's internal technical reinforcement support/supplier SSI has similar process as Celsa Steel with their suppliers abroad in Poland. SSI supplies Skanska with significantly lower costs than their Nordic domestic ones. Since SSI Skanska is a technical support which is an intermediary between project and suppliers abroad, they focus more on invoices and placing orders with deliveries so they arrive on time.

Standard processes

Most of Celsa Steels reinforcement processes in their projects are unique, their projects can sometimes vary from e.g. a simple villa flats to more complex bridge constructions. It can also vary from a waterproof residential building with rebar in the floor slabs etc. They always assume from the unique project and try to find solutions that suit them through utilizing previous experiences from earlier projects. While SSI mentions the same as Celsa Steel, that their reinforcement projects also are unique and that they tries to utilize previous experiences. However, SSI mentions also that what always varies in projects are the design interpretations from the structural engineers and their work preparation.

Celsa steel have a standardized workflow where they have sellers, which are out as early as possible to discuss what the workplace desires. In addition, workplace meetings, designing and making templates so their clients are able to go through the standard questions, so their technicians do not need to call around. However, Celsa Steel mentions that they are able to standardize certain reinforcing products, usually on the welded projects basket if it is an edge beam. 3D reinforcement is used mostly in major projects. SSI utilizes a same call-off template so misunderstandings become reduced. Their template is an excel-sheet, which is printed out as a pdf; there is a box for desired delivery time and confirmed delivery time. For the moment, they utilize IFC-file format as export and import tool.

Cooperation

To improve the 3D-reinforcement cooperation, SSI and Celsa mentioned that the various disciplines to come together at an early stage and have a dialogue about how 3D reinforcement and its communication needs to be improved.

Celsa Steel wishes that the reinforcement call-offs are done more digitally instead of through the phone. At the same time they want to create a shared data network where all the designer revisions are easily visible, so the construction site as well as the reinforcement supplier easily can get an update on the design. A common database will lead to a better communication between the construction site, designers as well as suppliers.

Quality

The rebar suppliers admit that they perform quality checks of the reinforcement supplies before the reinforcement specifications are done. They also perform tests of steel, tensile strength and the digitized around the ridge area, re-bending sustainability, crack formations and so on. Controls done by the receiver are extremely rare because it is difficult to control several tons of rebar. The recipient of the reinforcement delivery, usually just sign the paper and then solve it on the spot if there are any difficulties or the supervisor contacts them again. Partly the construction workers carry out the visual assembly inspection with c / c distance. Celsa Steel also mentioned that they have ISO 14001-quality certification.

The reinforcement suppliers utilize Tekla BIM-sight visualization software where they have the opportunity, to locate themselves in their field easily and Tekla main modeling program which can handle IFC and DWGs files. Connected to Tekla we have QR Celsas Steels own developed program that acts as a cloud service to their reinforcement specifications. QR provides the reinforcement suppliers a planning and delivery program.

Suggestions on improvements in the reinforcement process?

SSI are trying to standardize their approach. In every project, they want to utilize more of Standards building models, so that the designer and the reinforcement supplier projects are more designed alike. This is mainly because in the current situation is all the designs drawings on the same way but not likewise. Celsa Steel mentions that they want to utilize an approach that can streamline the time element with reinforcement projects. This is primarily done by having meetings where all the disciplines involved in the early stages of the project and discuss what is important to utilize in the workplace. This sort of meetings gives the project the opportunity to earn money and time on communication on the most optimal possible way.

At the same time Celsa Steel wants more long-term partnerships between Skanska and them, which offers both an opportunity to design and work with more central discussions in the current situation about the design. Instead of just utilizing their current central price discussion with their purchasers.

Celsa steel mentions that they wish to have someone they can discuss delivery schedules and find a way where they can standardize the reinforcement process. Celsa Steel mentions that they have a similar collaboration with other contractors where there is discussion of how the reinforcement must be marked, how they should deliver reinforcement. In addition, where they usually get a description of how entrepreneurs wishing to get reinforcement delivered.

Utilizing, a central discussion may result to new approaches and concepts can which can be tried. Central discussions may leads to a more developmental cooperation. They also want more transparency in the projects in the case that they want more integrated digital timetable so they see how it is in the projects.

Celsa Steel also want a more advanced process tools with digitized communication networks where a lot of communication in the current situation is via phone and email. This gives Celsa Steel the opportunity to put their order in the workplace-digitized schedule so the supervisors can see more easily, what is in stock and so on. This will lead in is turn to the creation of a better policy which then Celsa feed on delivering good products, they deliver today without knowing about how Skanska wishes to have it. By having a shared network, can they have more joined supplies

Advantages / disadvantages with 3D reinforcement in the reinforcement process

3D-reinforcement offers much more quality controlled reinforcement it is easier to visualize the errors for those who perform the reinforcement specifications and those who builds it. The disadvantage that it takes more time to make 3D-modeled reinforcement compared to 2D-reinforcement.

A disadvantage with today's current work set with 3D-reinforcement is that they do not early utilize a product list that regulates the reinforcement work so double work is avoided by structural engineers and designers. Another downside is that the knowledge in BIM is small in Sweden and that we have not come that far with it so everyone knows how to work with it compared to our neighbor Norway.

Pre-conditions with 3D reinforcement can vary a bit, mostly depending on the opportunities that there are for projects and their work-set. The early directives play a major role, since three years ago. The supplier tried to push the construction site to utilize the new technology while today we notice that construction sites asking more about 3D models. However, the usability of the software program earlier had technical complications with Tekla and Revit. However in the course of the technology getting better, it becomes faster to work with 3D reinforcement then earlier work sets. The 3D reinforcement cost is higher than 2D when their price range is lower than usual because they want people to exploit technology to cost-effectively possible. It takes more time to draw in 3D than 2D while the cost is higher when counting it home. But if workplaces and suppliers had worked together better with 3D reinforcement to create better value to it so it would have gone better when all the conditions are there on the spot.

Current Working Methods

Celsa Steel wishes to get their reinforcement specifications by their self-developed web-based database called Q-R, which is utilized for different reinforcement products. Their self-developed database is and plugin software for Revit and Tekla. Otherwise, do they usually hunt for DWG: files on the drawings they receive in PDF forms by their clients. While SSI work as a technical support for Skanska and their reinforcement suppliers in Poland and the Baltic countries. SSI orders mostly with DHL shipping company and supports with reinforcement transport and technical issues.

Adapting the reinforcement deliveries with the construction sites conditions and requirements is done in the manufacturing stage so it prevents errors in the delivery phase. Celsa Steel uses its delivery data networks in their self-developed Q-R software where the delivery status is available. They also have access to an internal scanning system used for sortation of the reinforcement before it's placed in the trucks. They also conduct visual inspection of the reinforcement before they later allow the work place organizes the work on the construction site.

Usually does the reinforcement supplier adapt their work set after the available information they have access to from the construction site and their designers. Then after that, is the reinforcement sorted up and marked up in different colors depending on which building group they belong and casting stage. The reinforcement orders are checked in with the projects timetable, which usually is established in the beginning of the projects. Through early collaboration with the entrepreneur, do they believe that reinforcement supply can become more effective right away. SSI has the same price range on the reinforcement specifications costs, compared to Celsa Steel where it costs more to with reinforcement specifications through 3D reinforcement than 2D.

Celsa Steel mentions that they plan their concrete casting in different production stages, which they design through the software program Tekla, there they outsource reinforcement specification lists. When the delivery schedule and casting stages is determined do they send over all finished reinforcement lists and drawings, which show what order they assemble the elements or how they deploy the rolling armor, and where the reinforcement net will be set. After that requirement from the construction site is met and approved by them, do they only have delivery of the product left. They perform add ones on the reinforcement where they draw the rebar, welded elements and special nets.

The reinforcement suppliers usually receive 3D-concrete models without the reinforcement from the structural engineers. Most partly to that, the structural engineers often used to send concrete models in 3D and detail design the reinforcement in 2D. However, later in time has the structural engineers started including the reinforcement in the 3D-concrete models, which has added to us that we adjust or remove portion of the reinforcement because it is not always the structural engineer's designs on the right way. Often do their reinforcement design require ads in there welded elements and rebar nets. The reinforcement suppliers prefer mostly to receive the concrete model, without 3D-reinforcement included.

Because of the adjustments often takes long time and if the structural engineer utilizes Revit and export through IFC to Tekla do they often encounter compatibility issues with the 3D reinforcement. Celsa Steel mentions that it is easier for them to utilize the concrete model and design with software programs like Tekla's concrete units or receive the reinforcement specifications through their own developed database Q-R.

Design options with 3D-reinforcement?

All reinforcement suppliers admit that they usually adapts their work to their customer's requirements and uses software products, which suits them. Their clients appreciate the possibility to being able to visualize in 3D. All suppliers prefer to share in the IFC file format mostly because it offers them a smooth software transition, IFC is an open file format, which can be utilized by most software programs. They wish to gain better insight into workplace delivery schedules that govern and plans the reinforcement work. Mostly because they want to avoid that such info will come at the last minute.

4.1.5 Skanska Sweden Construction Workers

Collaboration between the various disciplines in the reinforcement process?

The construction workers way of working with reinforcement in the present situation is that they utilize 2D-designed reinforcement for cut and bent reinforcement, which their reinforcement suppliers deliver to them.

In the reinforcement process, has the construction workers mentions that it always depend on which time in the process they get included. If they are involved early in the process do they have the chance to be involved in the discussions with making the project as cost effective as possible e.g. the selection between using C-clamps instead of another kind of reinforcement bracket. In addition, which can be made differently and fastest or what they should prefabricate.

Further on do the workers tell that the reinforcement process are project unique with varying experiences on the construction workers on the construction site. Many workers usually come with new and old idea's that might work as well. Many of the older generation workers prefer 2D-drawings compared with the younger generation, which easier catches up the new technologies. They mentions that the older generation has a better overview of the whole project with 2D-design reinforcement instead of 3D-designed reinforcement. The file size, the design functions and the communication with the other involved in the process are crucial for the reinforcement process.

The construction workers desire more simplified drawing, since many of the new workers possess a minor 2D-reinforcement drawings knowledge compared with the older generation. Utilizing more of standardized reinforcement work set would favor, the construction time allot.

The construction workers collaboration with the other disciplines in the reinforcement process varies. Usually do they work with the sit manager, production manager and also the reinforcement suppliers and structural engineers in various different ways. Mostly do they plan their work with the site and the production manager but sometimes also the reinforcement suppliers. The communication varies depending on if; their supplier is from abroad or domestic. Some workers mentions that communication with the production manager is sufficient for them most of the times but that they appreciate if the structural engineer could be involved more so if errors occur, it could easily be solved.

The supplier often insures the quality check of the reinforcement so it holds its standards. There are also done a practical checking's by the construction site workers, which compares the amount of information written in the reinforcement specification with the delivered order. The visualization program the construction workers uses are Tekla's own site software BIM-Sight.

Suggestions on improvements in the reinforcement process?

The conditions for utilizing 3D-reinforcement are variable and often depend on the design of the project. So far has the 3D-reinforcement been used mostly in house-projects. The construction workers mention that it depends much on the pre-knowledge that the construction workers have but that it usually takes up to two or three weeks to learn working with 3D-reinforcement. They also mention that the 3D-visualization gives more information than the 2D-drawings and that this facilitates the language difficulties for foreign construction workers and does not require great knowledge of 2D-drawings for the newer construction workers.

The construction workers desire to have more experienced structural engineers, which are more able to support them with adjustments of complicated changes that might occur. They also desire that the structural engineers are able to be with them on the construction site, they believe that it would facilitate dialogue and give it a better chance to get a faster response if something comes up. In this way can they avoid managing and adjusting themselves in sheets into the changes. Otherwise, they bring their experience with them from previous projects with solving complicated adjustment.

Advantages / disadvantages with 3D reinforcement in the reinforcement process

The benefits that numerous construction workers mention is that they appreciate that at the early stage of the project being able to predict if it will occur any collision clashes or not. The disadvantages they mention is that there is too much detail of the reinforcements, so it becomes difficult to see, sectional and elevation views and fragility of the iPad used to visualize the construction site today. Professional workers wish that the visualization of information on the tablet could come up in text from on the side of the object, so you do not need to count bars and so on. Another goal is the iPad's digital programs toolbar becomes more optimal so that it complements and simplifies 2D drawing for the younger construction workers with less experience and knowledge.

The desire to visualize the reinforcement by the construction workers varies but they think it's fun and are gladly with keeping up with the progress of the digital developments. They also explained that it makes it easier for them to understand what is possible and impossible and creates a safer workplace for the workers.

Current Working Methods

The workers answers that the 2D drawing do not give them enough information so they need sometimes to utilize 3D designs on their iPads as a complement. Their production managers, suppliers and structural engineers usually predetermine their production plan with casting stages and color codes of the reinforcement. The reinforcement rolls are usually marked with specific numbers, which can be found on the 2D-drawings. In the current stage do the construction workers utilize the 3D-reinforcement as visualization guide only. The Most cooperation and contact they have with the structural engineers is usually through their production managers.

Design options with 3D-reinforcement?

The construction workers desires their simulation of 3D reinforcement on their iPad, becomes more improved graphically and that it contains more information e.g. reinforcements numbers and so on. The construction workers wishes also that the iPad became more resistant to conditions that are out there on the construction site.

4.2 3D-Modelling results

This chapter will visualize the achieved 3D-reinforcement design results. The project; *Kvibergs Ängar*, which earlier has been presented in the method part is the first project Skanska Gothenburg technical department will perform 3D-reinforcement design with. The results, which been from this master thesis, have been execution of two different kind method to produce reinforcement schedules, which can be utilized in the software program Revit 2017.

The first method is more of a traditional one; there the reinforcement schedule is executed in the software plugin program named Q-reinforcement (Q-armering). The other method is through exporting out the design in an IFC-export to the collaboration software program Solibri v9.7 and color code the rebar's ,divide them in different casting stages and visualize them etc. On the figures, 16 bellow do we have the opportunity to visualize and see how the process looks from the structural engineers design table to the construction site.

The Design Phase- part One, Overview of the project model.

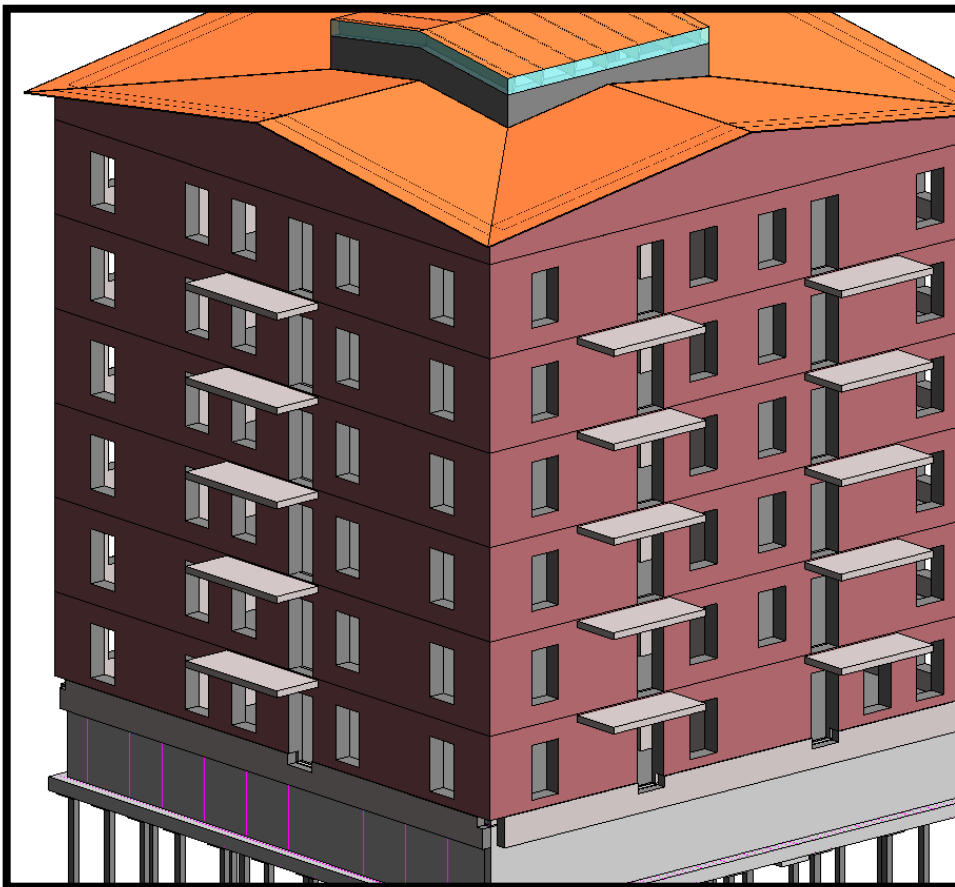


Figure 16 Kvibergs Ängar Revit 2017 Modell

All concrete elements, which are not prefabricated in this project contains 3D-reinforcement. The bottom plate and the elevator pit with the electrical pit are does which are designed with 3D-reinforcement. This master thesis will only focus on how the 3D-reinforcement design of the elevator pit is scheduled.

4.2.1 Revit.

The Structural Engineers design work

Overview of the 3D-reinforcement work of the elevator pit. Further down below is the design result of the 3D-reinforcement elevator pit visualized in the design software program Revit 2017 on figure 17 & 18.

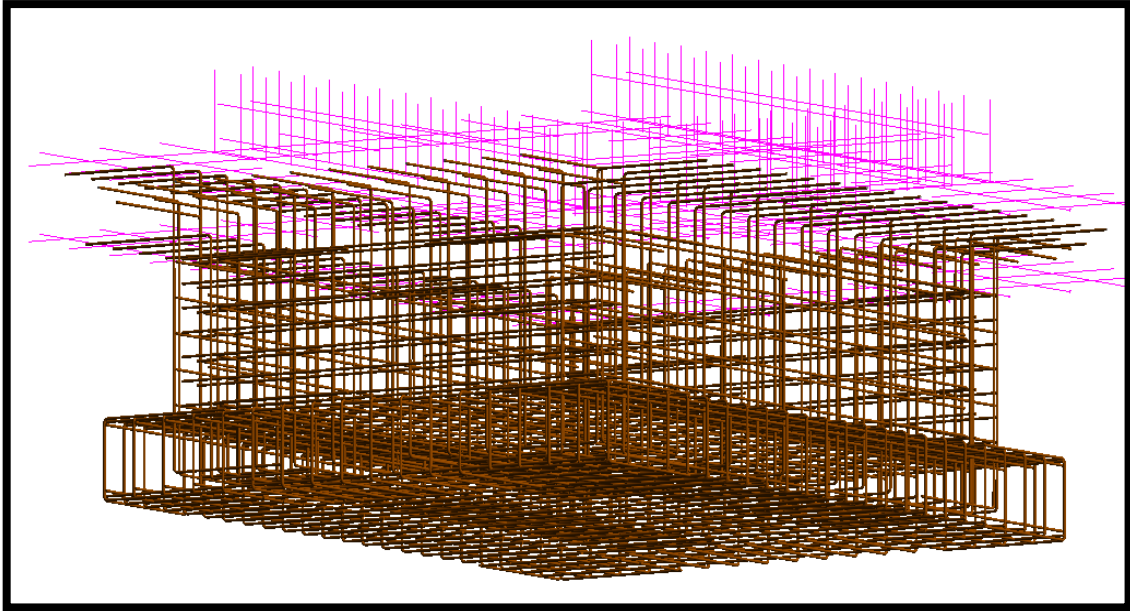


Figure 17 3D reinforcement elevator pit Kvibergs Ängar Revit 2017 Modell

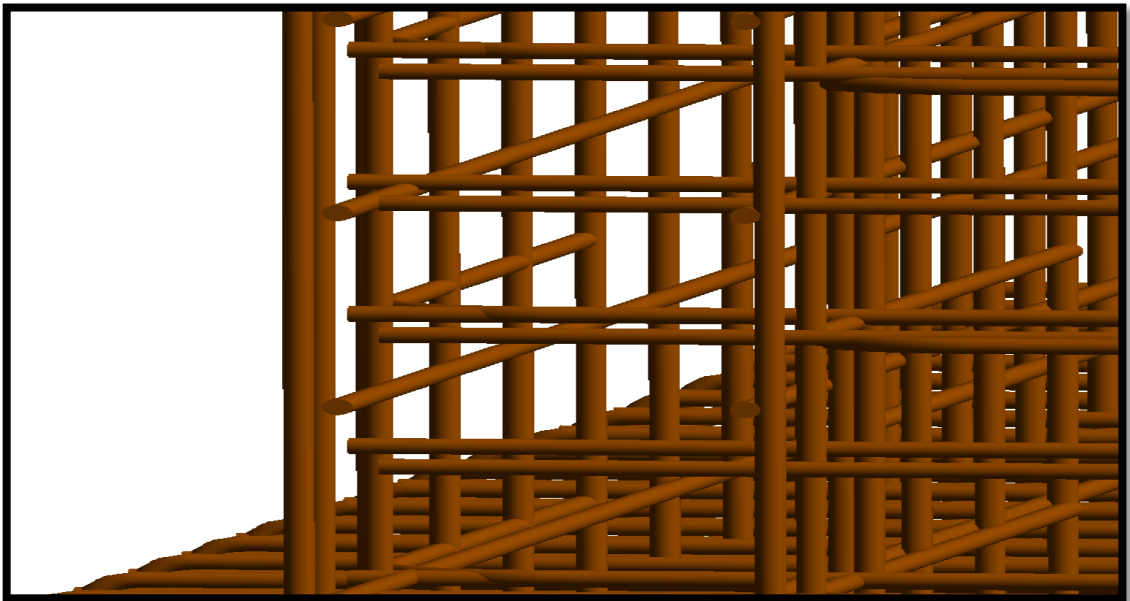


Figure 18 Elevator pit 3D reinforcement Kvibergs Ängar Revit 2017 Modell

4.2.2 Q-reinforcement.

Structural Engineers collaborate with Suppliers.

The first alternative, a view of the reinforcement schedule in the Q-reinforcement program.

Q-reinforcement follows Swedish Reinforcement and Building Documents 90. Q-reinforcement is a complete special program used to create dimensioned drawings on flat iron and typefaces for special figures. Own types can be specified and saved in "library" for recurring use. You can also create flat and bent rebar networks. Furthermore has the obstacle to the program been that there are too few steel varieties. This can be seen on the figure 19, 20 below, which has red marked texts, Mostly due Revit 2017 has several different steel varieties which is not included in the software program. In addition has the program now been updated to QR by the supplying company Celsa Steel, which is a Web-based application.

ArkivRedigeraBländraFönsterVerktygHjälp

Nytt

Öppna

Spara

Stäng

Spara urval till fil...

Innehåll/Utskrifter

Infoga från fil

Eoga in från klippbord

Nät

Bokningslista

Std-prod

Sparstöd

Element

Typ

Intervall

Eritext

Min-längdskontroll

Infoga Ny sida

Badera sida

Klipp ut

Kopiera

Klistra in

	Typ	Littera	Stålsort	Gr	SvGr	Totalt	Ø	Längd	Å	a	b	c	d	e	f	g	Å	x	y	v	s	t	u	R	Konstr del	r
1	A	1	B500C-T			20 12	2950																		HS04	
2	A	1	K600B-T			24 12	2490																		HS06	
3	A	1	K600B-T			24 12	2490																		HS07	
4	C	1	B500C-T			84 12	1500			600	340	600													12 HS02	
5	G	1	B500C-T			16 12	2090			610	1000	510						210		90					12 HS03	
6	REB	1	K600B-T			18 12	1380			760	670														64 HS05	
7	A	2	B500C-T			14 12	2100																		HS04	
8	A	2	K600B-T			18 12	3360																		HS06	
9	A	2	K600B-T			18 12	3360																		HS07	
10	B	2	K600B-T			4 12	1160			620	590														64 HS05	
11	G	2	B500C-T			16 12	2350			590	1260	530						210		90					12 HS03	
12	A	3	B500C-T			14 12	2060																		HS04	
13	G	3	B500C-T			40 12	2200			610	1110	510						210		90					12 HS03	
14	REB	3	K600B-T			8 12	1160			590	620														64 HS05	
15	G	4	B500C-T			28 12	2210			590	1120	530						210		90					12 HS03	
16	REB	4	K600B-T			4 12	1150			590	600														64 HS05	
17	G	5	B500C-T			12 12	2240			620	1120	530						210		90					12 HS03	
18	A	10	B500C-T			158 12	18670																			
19	A	11	B500C-T			12 12	3230																			
20	A	12	B500C-T			12 12	3230																			

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Rev

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Detaljdata

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Figure 19 3D-reinforcement Schedule Kvibergs-Ångar Q-armering

ArkivBedigeraBläddraFönsterVerktygHjälp

NyttÖppnaSparaStängSpara urval till...

Innehåll/UtskrifterInfoga från filEgga in från klippbord

NätBöckningslistaStöd-prodSparstödElementTyperIntervallEritextMin-längdskontroll

Infoga Ny sidaRadera sidaKlipp utKopieraKlistra in

	Typ	Littera	Stålsort	Gr	StGr	Totalt	Ø	Längd	Å	a	b	c	d	e	f	g	Å	x	y	v	s	t	u	R	Konstr del	r
1	A	23	B500C-T			18 12		8450																		
2	A	24	B500C-T			18 12		8500																		
3	A	26	K600B-T			108 12		2350																		
4	A	27	K600B-T			26 12		2660																		
5	A	28	K600B-T			26 12		2430																		
6	A	29	K600B-T			26 12		2410																		
7	A	30	K600B-T			26 12		1820																		
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Figure 20 3D-reinforcement Schedule Kvibergs-Ängar Q-armering

All data is saved in XML format, which makes it possible to exchange information with e.g. CAD programs and become inserted in a rebar manufacturing machine.

4.2.3 Solibri.

Collaboration between Structural engineers, Contractors and Suppliers.

The second alternative provides the opportunity to visualize the reinforcement at the same time execute a reinforcement design schedule where the structural engineer, suppliers and the contractors can have use of Solibri utilizes IFC which is an open file format. The colored-coded rebar with complete information is shown below on figure 21 & 22.

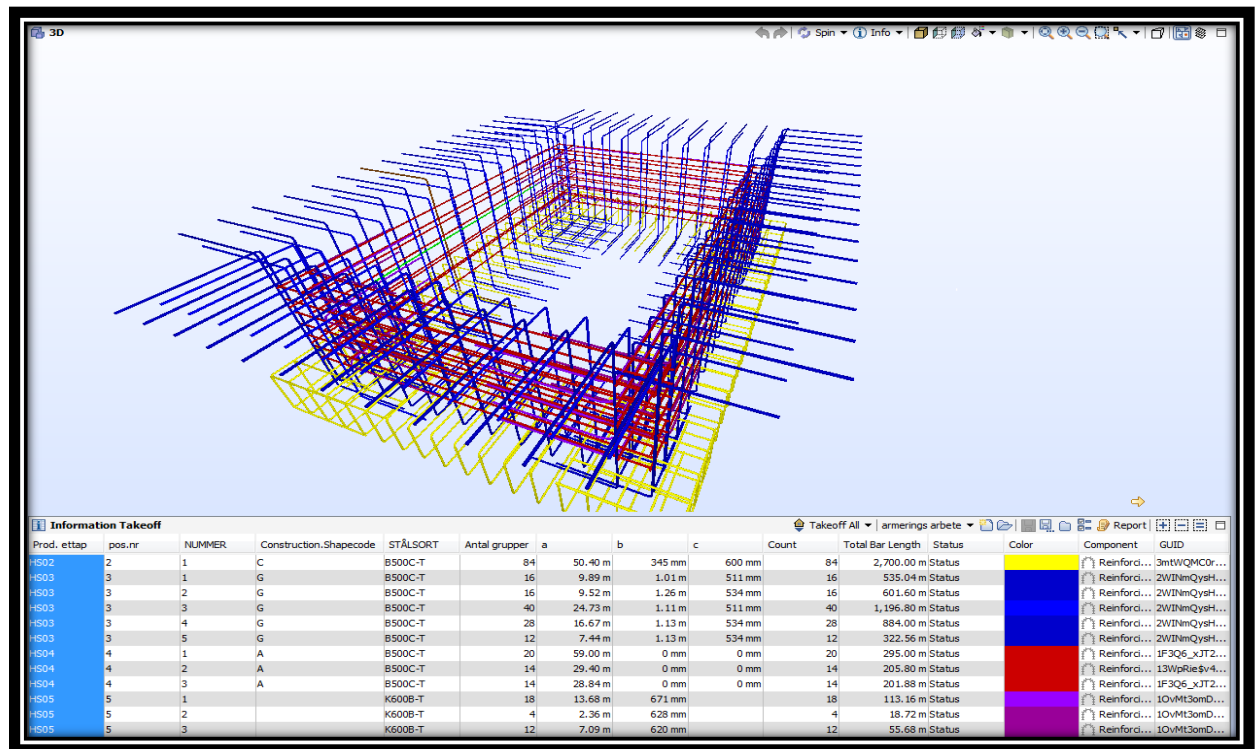


Figure 21 3D reinforcement schedule Kvibergs Ängar Solibri

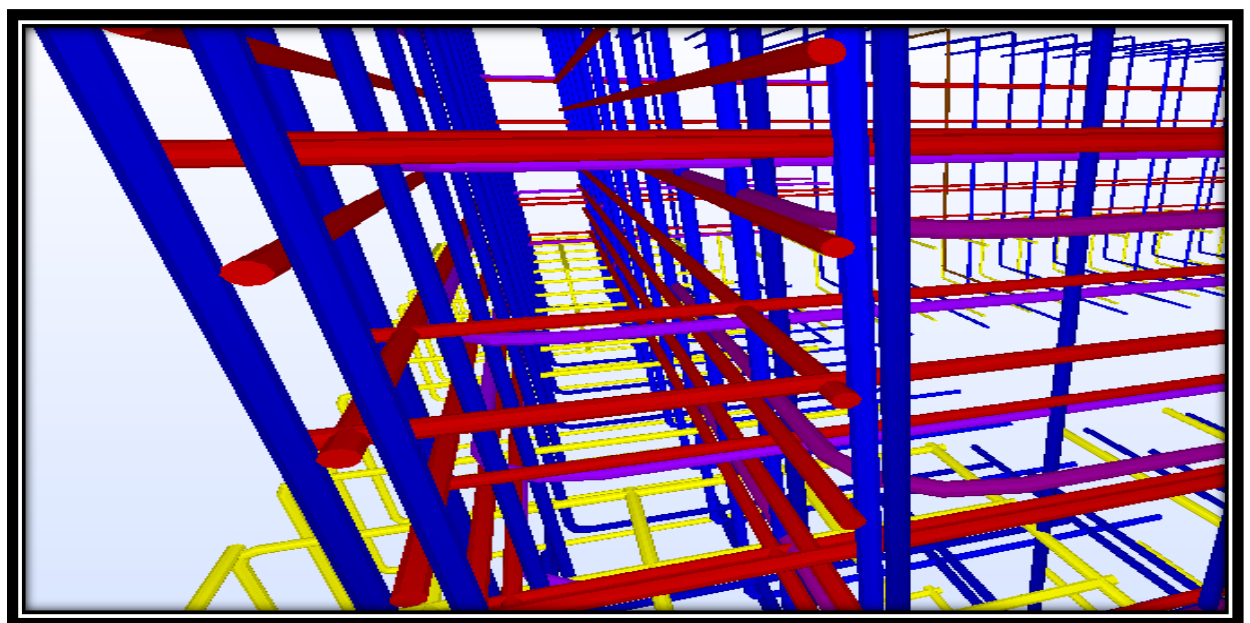


Figure 22 3D reinforcement Collision Kvibergs Ängar Solibri

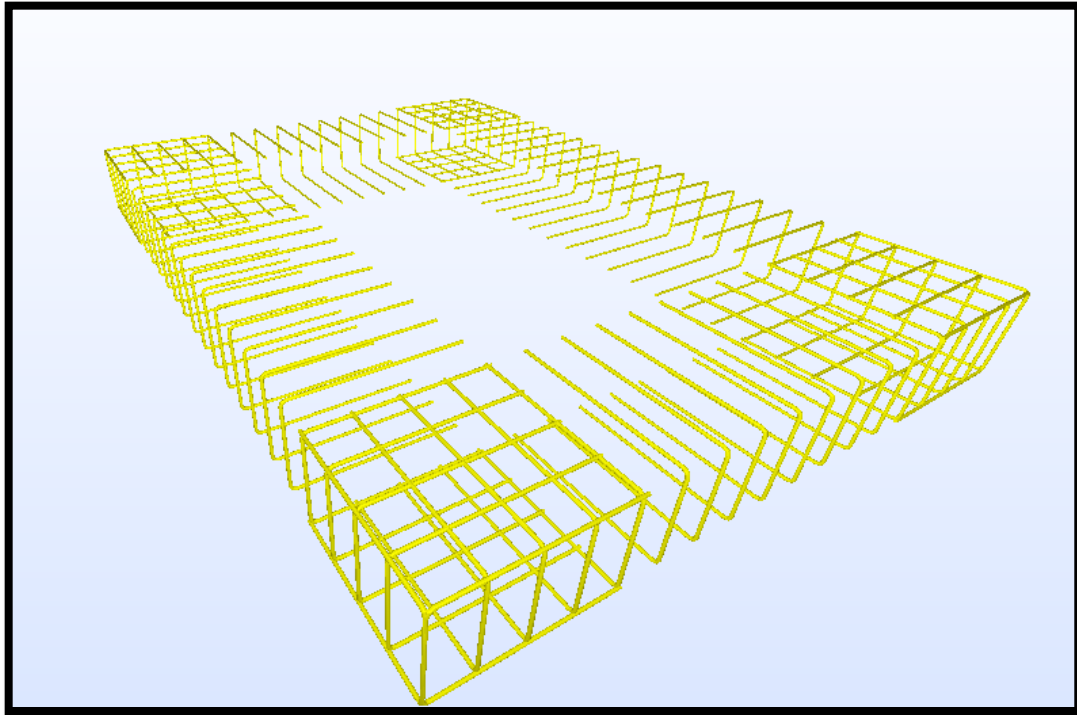


Figure 23 3D reinforcement Shape code C Kvibergs Ängar Solibri

The casting stage classification, visualizes in which order and which reinforcement parts they belong to it's other as above shown on figure 23.

The reinforcement work of the elevator pit could become schedule through on casting phase with one color. However, to show the possibilities the program has, is the reinforcement color-codes and sorted out in different casting stages. In the software, program Solibri. The reinforcement schedule is later exported out in an Excel file format to the supplier, which converts it to XML format to manufacture the desired reinforcement and deliveries it to the construction site.

4.2.4 Iconstruct Navis Works.

Collaboration between structural engineers, Contractors and construction Workers

Iconstructi Navis Works suits for planning the visualization contribution to the construction sites workers; this includes the contractors and the construction workers. There are several opportunities to visualize the reinforcement through e.g. with flat screen on BIM-kiosks or similar or iPad/tablets. The visualization work is planned through color-coding, dividing the reinforcement to different the casting stages etc. When the procedure is finished the plugin program iconstruct exports out the file to Glue BIM 360, which provides all participants an excellent collaboration program figure 24 views a picture of the colored-coded rebar's.

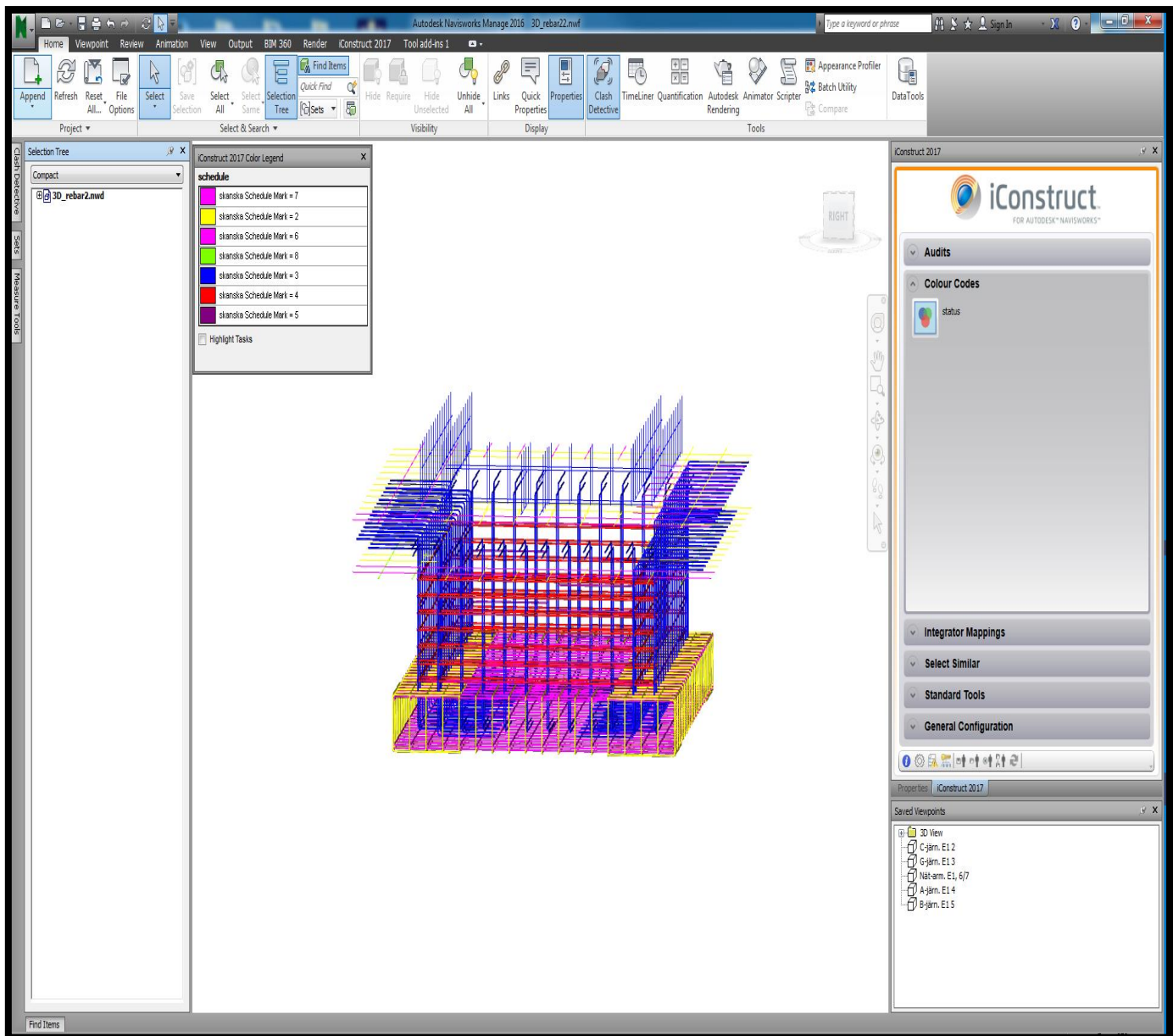


Figure 24 3D reinforcement color-coding Kvibergs Ångar (Iconstruct) NavisWorks

Through color-coding the casting stage in the parameters A, B type of iron reinforcement, will this work set facilitate the work preparation for the construction workers, see more on figure 25 & 26.

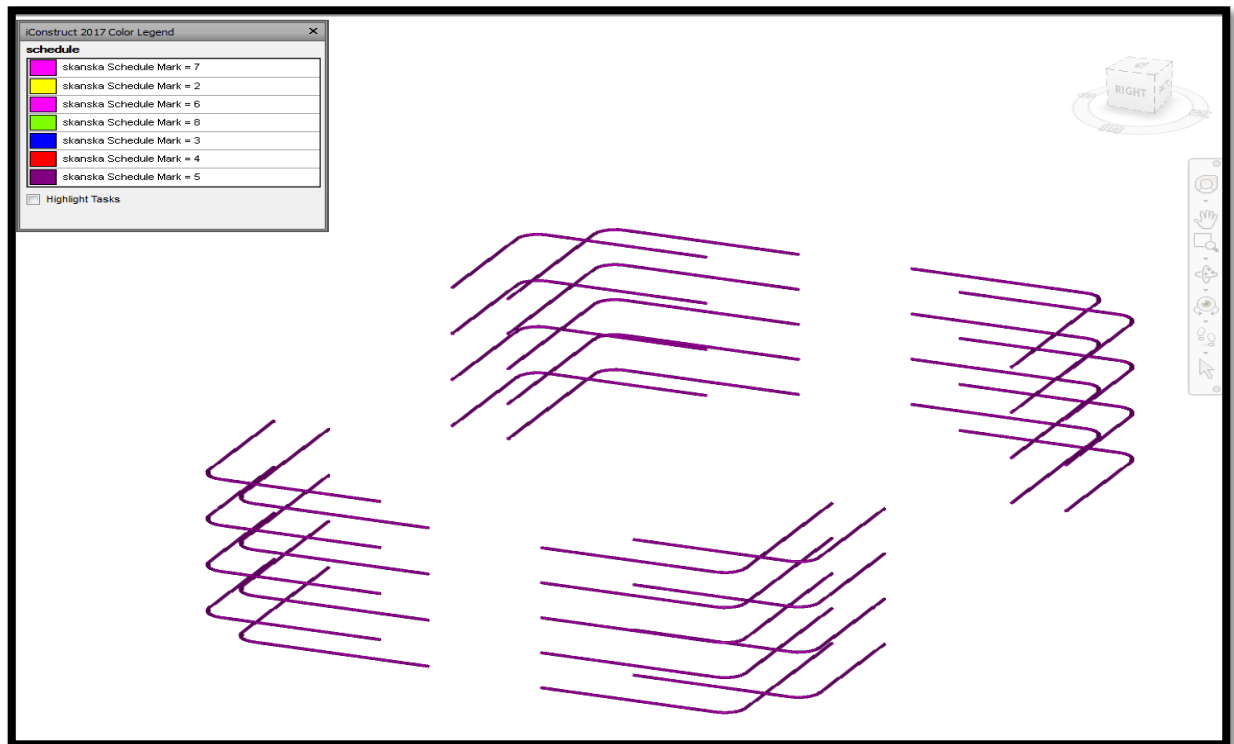


Figure 25 3D reinforcement color coding Shape code : B Kvibergs Ängar (Iconstruct) NavisWorks

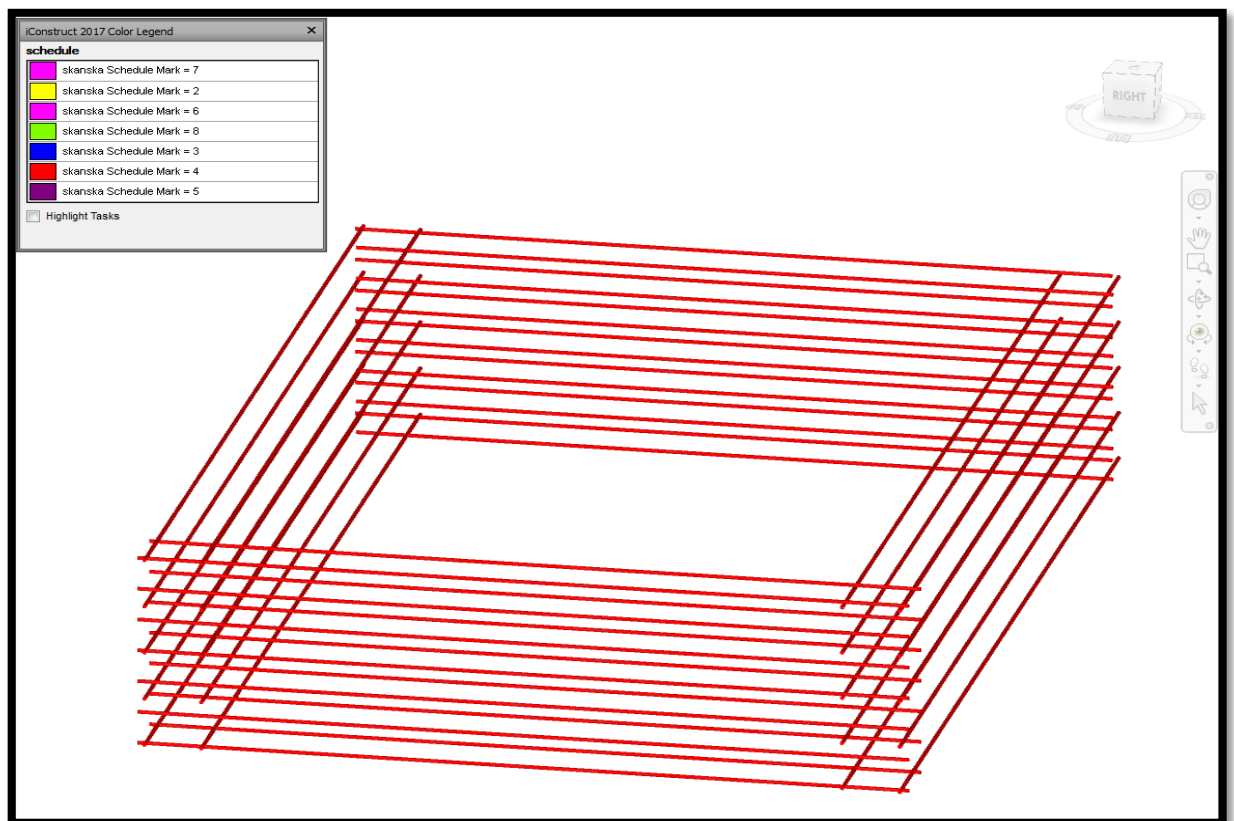


Figure 26 3D reinforcement color coding Shape code : A Kvibergs Ängar (Iconstruct) NavisWorks

4.2.5 BIM 360 Glue.

Collaboration between structural engineers, contractors and construction Workers

Later on is the 3D-reinforcement design visualized on the construction site, through the software plugin program for Revit; Glue BIM 360. This software program allows the construction workers to view and have direct connection with the structural engineers, through the edit, comment option that can be seen on the figures below 27 & 28.

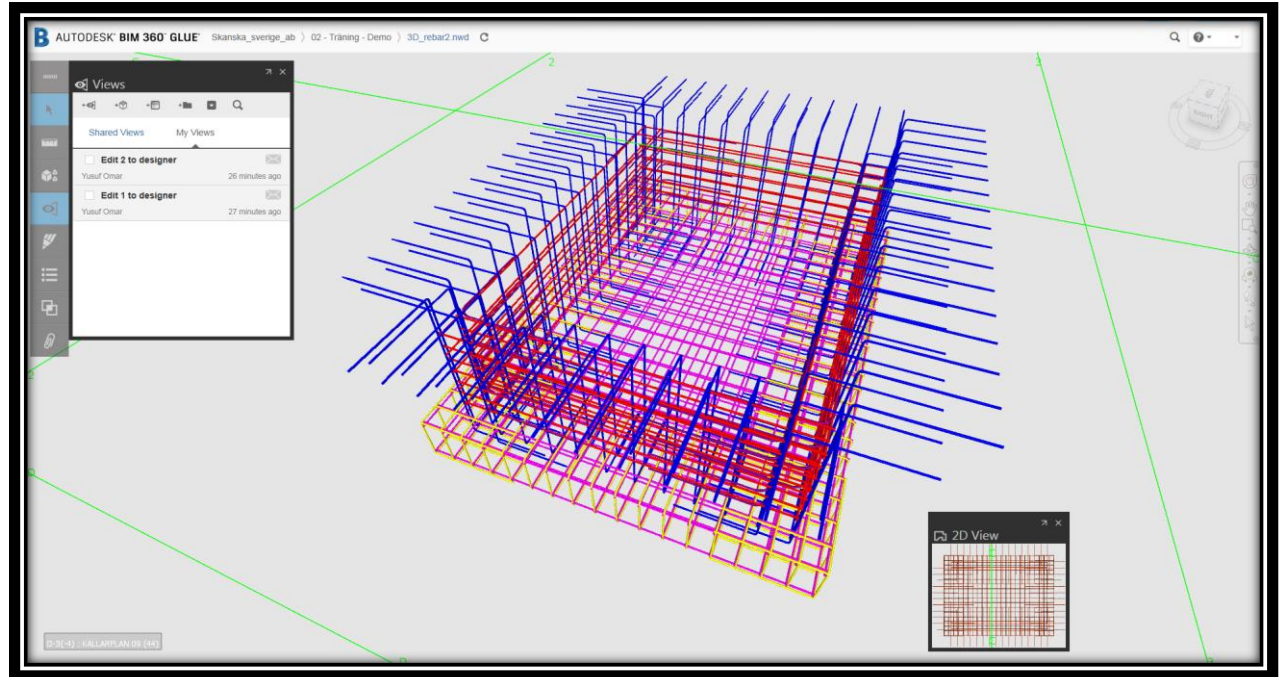


Figure 27 3D-reinforcement visualized in Glue BIM 360

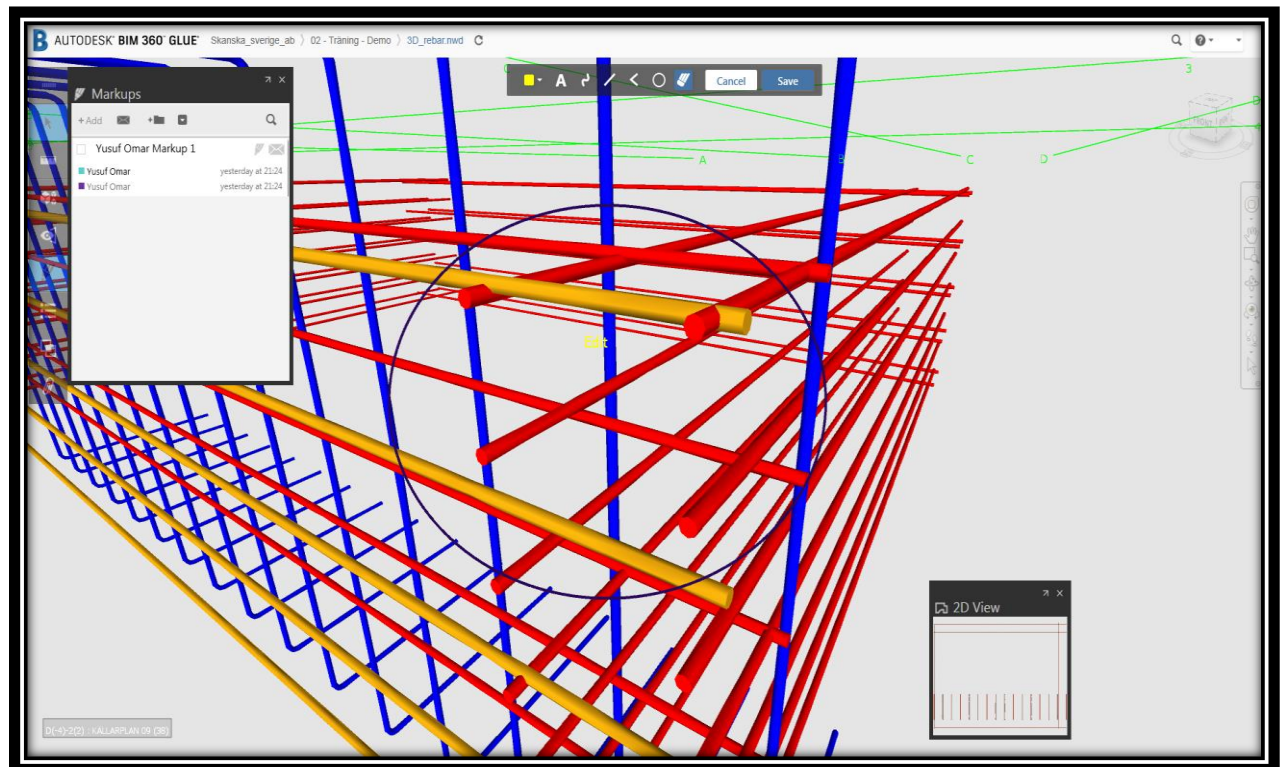


Figure 28 Edit reinforcement Glue BIM 360

5 Discussion & Conclusions

5.1 Communication and interoperability

Between different actors within the construction process

This section is subdivided into discussion related to the different actors within the construction process.

5.1.1 Structural engineer

The structural engineers mention that more standardized work set with the reinforcement would contribute to improved communication between the actors within the reinforcement process. Another factor that would improve the communication and prevent extra work would be an earlier cooperation between the structural engineer and the production staff.

“If a picture is worth a thousand words, a 3D-model of a rebar is worth a million!”

The structural engineers say that the advantages, which comes with 3D-model of the reinforcement, is that it gives the project participants a possibility to get a better project overview. In addition, a chance to visualize all the strange cuts, easily obtaining c/c distances, creates awareness of the number of reinforcing iron that should be in position with right chap length and radius booking. The process is good but not perfect yet, to reach a perfect one, requires that 3D-reinforcement are utilized more on projects then current traditional 2D-drawings. A software comparison that the structural engineers mention is that the software program Revit is more for designing construction of houses while the other program Tekla from a General structural engineer's point of view is more suited for designing steel building products. In addition, that project conditions are the most decisive of how long the designing takes with 3D reinforcement work design. The design process goes faster and easier with 3D-reinforcement then traditional 2D and another benefit with 3D reinforcement is that it provides the construction workers, productions staff with a quick update of the reinforcement work.

Skanska Norway have had a great experience of utilizing 3D-reinforcement on construction projects. The greatest benefits they have experienced has been that the communication between all project participants has become much better. Which in its turn has saved their projects time and money.

5.1.2 Contractors

The purchasing contractors desire better communication with the structural engineers so the reinforcement work designs becomes production fitted models/drawings. In addition, the contractors desire better collaboration between the designers and the suppliers. Some advantages the contractor mentions is that, 3d-modelled reinforcement provides better visual information of the reinforcements clashes etc. another advantage that is appreciated is the tablet/iPad that the site workers can bring with themselves. Also having the possibility to have direct contact with the structural engineers through the iPad BIM (BIM 360 glue).

Although the knowledge with working with 3D- visualized reinforcement is small, the demands of working with them are higher for the contractor on the construction site. The contractors mention that it gives them a much earlier opportunity to quality check the reinforcement than before. It is also a time and cost saving method, which is limited by software complications and unexperienced production staff. On the other hand, they believe by using the technology more and more on the construction site the contractor tells us that it will become more improved. In the current situation, they use it to plan the work on site with the construction worker.

5.1.3 Suppliers

Something, which is desired by the suppliers is the opportunity to improve their digital communication with their customers, so unnecessary phone calls are avoided. Receiving the reinforcement schedules through software programs as QR-reinforcement or DWG: files instead of ordinary PDF:s files formats. The suppliers want also to develop their coordination system with their customers so the digital call offs, planning and the cost is estimated more precisely. In addition, a common digital database between the participating participants where they can share and become aware of the projects time, logistic and cost development is preferred.

The suppliers believe that through having long-term agreement with their contractors and customers they will develop together a more suitable technical system. This system will simplify the reinforcement process and develop more standardized approach. This approach would insure the quality of the reinforcement and deliver the best possible product.

5.1.4 Construction workers

The construction workers on site mention that they do not mind working and visualizing the 3D-reinforcement on site, but that it requires an earlier involvement. Due to reinforcement process, unique characters in projects the construction workers would appreciate visualizing the project in advance, so the participating people can come up with cost effective advices and solutions. The workers appreciate having the opportunity to receive information through their iPads, but point out that there is a need for some technical and graphical improvement. In addition, enough education can facilitate the challenges with the technical devices on site. Something that all the construction workers appreciate is that the 3D-visualization simplifies language barrier between them and foreign construction workers and having the structural engineer with them on the construction site. Another mentioned aspect is that more industrialized reinforcement method creates better work environment, reduces the waste, they also mention that reinforcement methods usually based on available resources of staff.

5.1.5 New roles

Some disappear and some old roles will be strengthen within the reinforcement processes

As technology progresses, and as it advances, the advancement creates new structures and systems, which simplifies the current process development. These new structures lead to more responsibility being added on those involved in these new structures so the process works as smoothly as possible. The current manual waste of information flow become minimized as much as possible through utilization of new IT-tools. The reinforcement process will take part of this information technical development, which in the future will steer it to new working methods. The new structures provide the structural engineer with more responsibility then previous, through being capable of delivering reinforcement schedules. This means at the same time that the current consultant function of making reinforcement schedules disappears. The current reinforcement schedule consultants contribute with enormous knowledge concerning production adaption of the schedules, quality insurance so on. This means that other remaining actors must take more responsibility concerning production adaptations and quality insurance. Further on the structural engineer, who designs the reinforcement schedules must charge for payment for the service they provides. The payment agreement for the reinforcement schedules should be clarified in the procurement contract. The agreement should lead to more motivated structural engineers who shorten the lead-time and deliver higher quality. This means also that the contractor must get involved earlier in the process and assist with the production adaptations, casting stages and reinforcement methods. Further below figures show how the current reinforcement process looks and at the same time how the future process will look

5.1.6 Preferred Contract form.

The contract form, which facilitates the digital reinforcement process, is Design Build contract form. The contract form improves the involved actors' better communication within the process and provides them better-required early collaboration, which improves the process. Compared with Design Bid Build contract there information gap arises. This occurs mostly because the structural engineers often moves on to other projects when their design process are finished and the supplier are often procured later in the project. Another contract form that needs to be examined is Partnering contract form, its advantages also its disadvantages and how it effects the process. See further below in the appendix Contract Form Of Kungälv's Sjukhus.

5.1.7 The current & future reinforcement process

Current

Current reinforcement processes uses many of its transfers through “dead” format, which is documentation, transfer through non-digitalized processes e.g. pdf, email or paper documents. The orange arrow visualizes the dead transactions while the green arrow visualizes the digital transaction on figure 29. The figure where inspired by SBUF report *Armering i byggprocessen – effektivisering av informationshanteringen* Written by Engström et al (2011) but where re-designed to fit Skanska Sweden’s current reinforcement process.

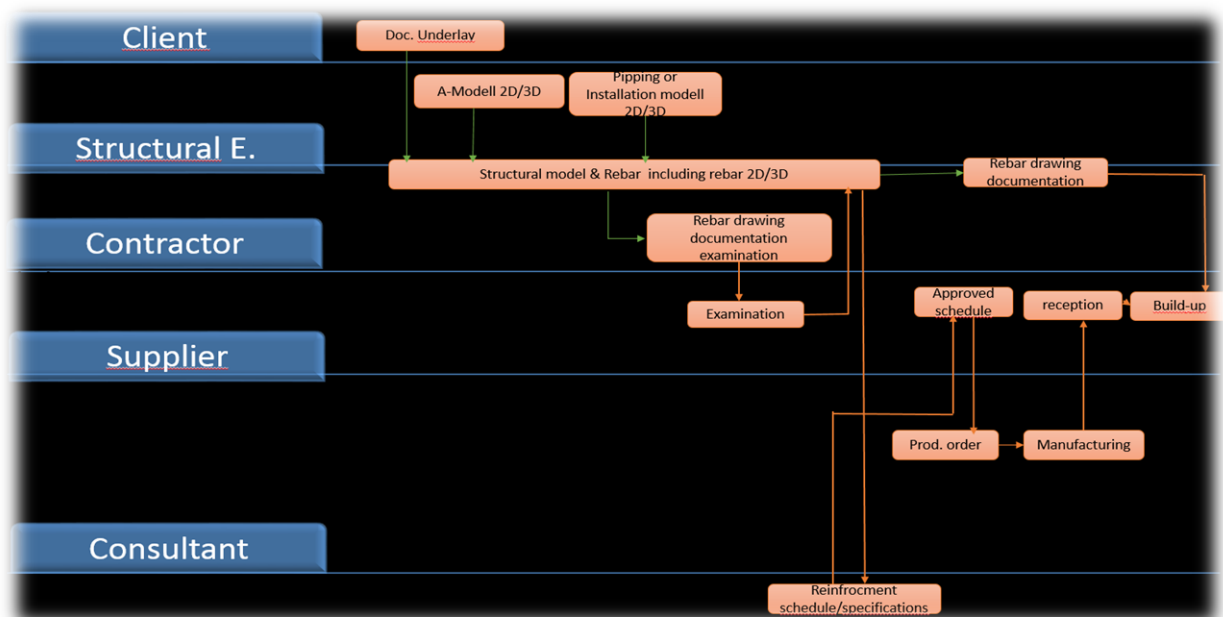


Figure 29 Current reinforcement process (Engström et al ,2011).

Future

The future reinforcement process will function with more digital transactions and work properly without a reinforcement schedule/specification consultant. The future reinforcement process participants will have better communication then before and possess more knowledge of adapting the reinforcement to the production casting stages/planning. The figure 30 bellow visualizes the more digital future reinforcement process.

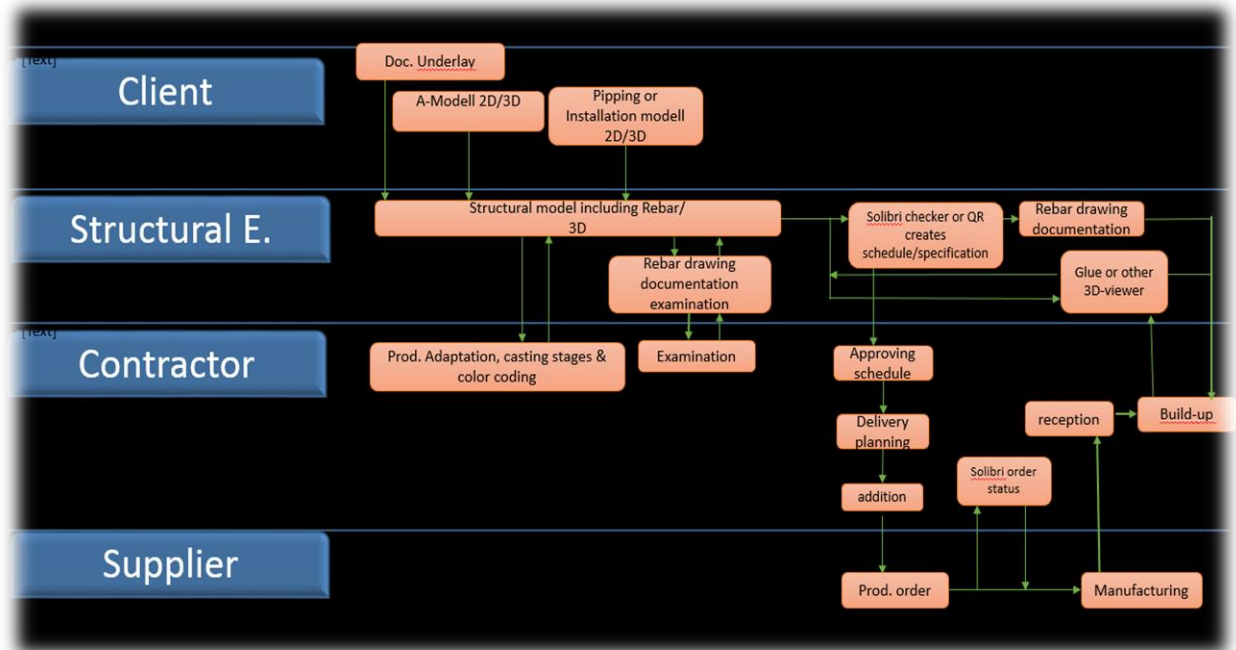


Figure 30 Future reinforcement process (Engström et al ,2011).

5.1.8 Realization through BIM-use reinforcement

Communication between the various BIM-based IT-tools are just as important as all other types of communication. That's why the word interoperability is such an important factor that facilitates the communication between people and varying types of software in the construction (AEC) industry. The goal with software interoperability is creating freely fluent information between different databases or information models based on one overall perception.

The previous problems with the interoperability have been for example that a file format had missing information when they were exported out between different software programs. This in turn has led to designers having to remake the reinforcement design so it became useful again. The aforementioned issues have emerged in terms of IFC export/import between the software programs Revit and Tekla, this happens mostly because Revit and Tekla are two competing software program companies.

To get around the problem, some different methods have been used. The first method is through directly creating the schedule in Q-reinforcement/QR (quality reinforcement) program. The second method, which has been the most effective, has been utilizing the IFC-export and exporting out the reinforcement design to Solibri, where the designer can visualize it and create Excel file formats, which later become converted to XML file formats. The XML file format that can later be used in the reinforcement schedule-manufacturing program Q-reinforcement or QR to manufacture the reinforcement. The reason the second method is most effective is that it allows the structural engineer, contractor and supplier to have an opportunity to visualize and color-code reinforcement. The second method simplifies both their IT-tools interoperability and their communication between the different actors involved in the reinforcement process.

The interoperability continues further on to the construction site where the IT-tool Glue BIM 360 provides the site workers the opportunity to communicate if something needs to be edited. The site workers can simply communicate through commenting edit on their tablets/IPads and upload it into the common shared glue BIM 360 cloud service.

Furthermore, need for improvement has been demonstrated by the software program users. These improvements can be achieved through using these software programs more and more on projects. The benefit with 3D-reinforcement are mainly in larger projects, because it facilitates the visual understanding of complicated projects which handles large amount of reinforcement, Furthermore are they some great potentials for smaller ones there the usefulness of the 3D-reinforcement can be tried out. Finally will this lead to more appreciated improved communication between the actors involved in the reinforcement process.

5.2 Conclusion

One reason for the construction industry's poor productivity is that it still relies on paper to manage its processes and deliverables such as traditional design drawings. The purpose of the master thesis has been to evaluate the optimal way of handling the entire reinforcement chain; from the drawing board to the construction site, where the actual building is built. Also to figure out the best and the productive working way to implement 3D-reinforcement in Skanska Gothenburg Sweden. The approach has been performing interviews on involved participants such as structural engineers, contractors, suppliers and construction workers. Even test modeling in a case study project, Kvibergs Ängar. The results of the master thesis has shown that Skanska Gothenburg Sweden has a functioning process for utilizing digitalized reinforcement, but that there still is room for improvements in terms of interoperability between participating project participants and their IT-software tools. The primary recommendations is to involve all the participants early and obtaining the process as simply and clearly as possible. The importance of having closer collaboration between the contractors and the structural engineers has clearly been stated in this master thesis. Even more important have been pointing out the benefits with having better collaboration within their own company Skanska through utilizing their own knowledge they have abroad and other regions in the country. Designing with 3D reinforcement results in longer design time but reduces the time of the entire reinforcement process. Further are there some suggestion of improving the IT-software coordination through utilizing IFC, which is an open file format. IFC allows the construction process participants to share data regardless of what software application they use. The thesis has shown through the interview results that working with digitalized reinforcement contributes to better collaboration in every line of the reinforcement process and saves time and money. The 3D-modeling chapter has proven that the possibilities with modeling and visualizing 3D-reinforcement are currently possible and good. The master thesis indicates that Skanska Gothenburg Sweden can safely address the digital challenge of working paperless.

6 Suggestions for further research

It is time for a new mind-set for the construction industry. Project owners often believe that their responsibility ends when they award contracts, forgetting that they pay the economic costs of delay. This master thesis has contributed to identifying some key improvements areas within the reinforcement process. The thesis has also proposed some suggestions on how to perform these improvements. Developing effective interoperability between the participating participants involved in the reinforcement process and their IT-tools is the biggest challenge with developing the process. This in its turn makes further research fundamental in order to create an understanding of how information can become transported between people and various IT-software in an effective way. The subject proposed has not been within the scope and purpose of this study and is therefore suggested as subjects for further research. The following bellow subjects are those, which require further investigation for example:

- How integrated 5D-BIM reinforcement will affect the construction projects processes, e.g. project delivery, quality and productivity?
- How organizational culture and projects procurement forms affects the ability to implement new ways of working?
- How much further on can organizations develop their interoperability concerning BIM-uses and how could they become sharper?
- How much does Virtual-Reality and HoloLens effect the projects productivity from the procurements board to the construction site?

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8 Appendices

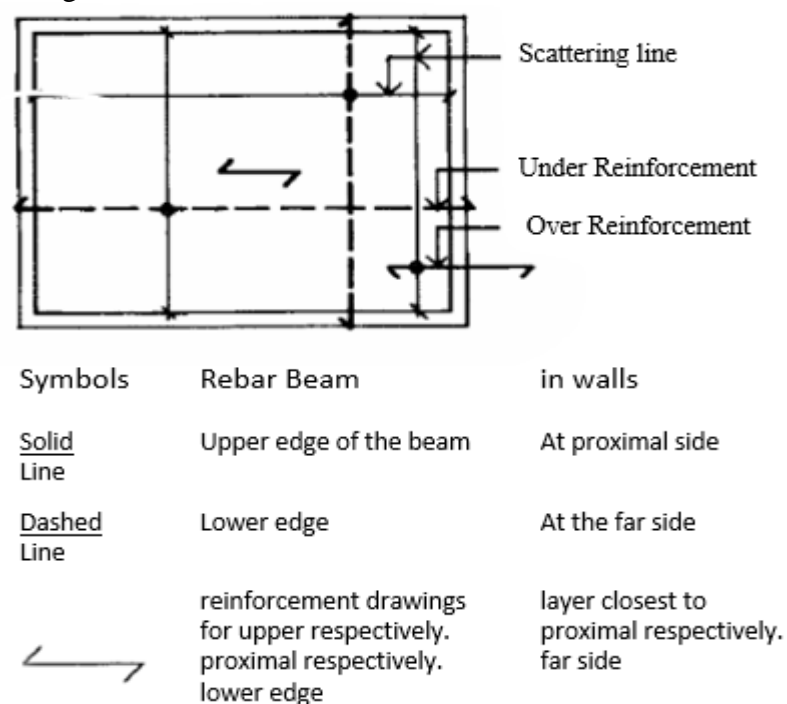
Content

- ❖ The Swedish design requirement
- ❖ Contractual form of the project: *Kungälv's Sjukhus*
- ❖ Contractual form of the project: *Kungälv's Sjukhus*
- ❖ Traditional Reinforcement Schedule
- ❖ Specification sheet 2A

8.1 The Swedish design requirement

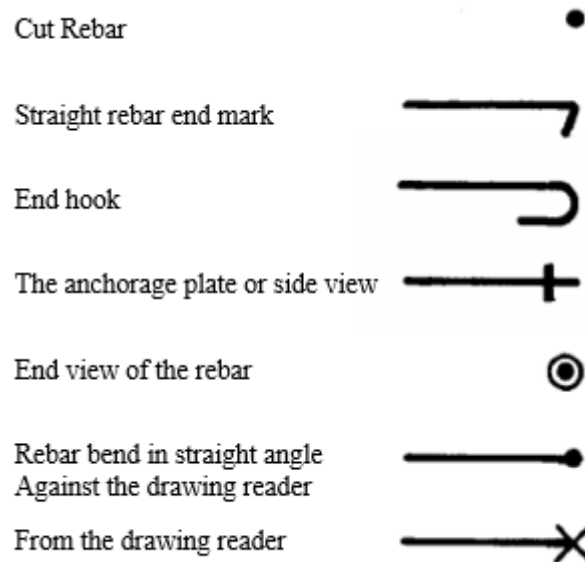
Currently is 3D modelling in the Swedish construction design requirements only seen as a helping aid tool while 2D designing is more included in the design regulations of AB04 while 3D- design modelling are not stamped as construction documents, but requires an constant flow of communication between the entrepreneur and designer so the 3D-modell stays updated (BIM Alliance, 2016).

The construction documents “Bygghandlingar 90” (BH90) are the fundamental documents, which are the underlying basis for the production site of the construction industry. BH90 documents contains two chapters, which presents how the reinforcement should be designed, these chapters are two and four. While chapter 8 describes how digital supplies for the construction and management is delivered, it replaces the earlier edition accounting CAD. BH90 contains also other basic requirements for designing construction documents (Hertzell T. Bergenudd, C. 2003). The design recommendation that BH90 recommends are that the designer should stick to the three different line combinations which called, symbol line, material lines and helplines. Mostly because in drawings, do they the lines illustrates different kind of meanings, with their various kind of characters and dimensions. Especially texts and numerus digits, which has standardized fonts with the standard high of 2.5mm. (Hertzell T. Bergenudd, C. 2003). Some illustrations of 2D plan and sectional views is presented on figure below.

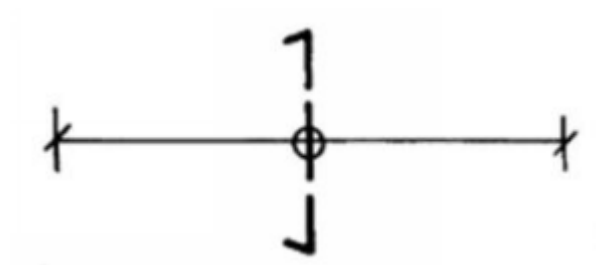


As seen above, is a brief presentation of the reinforcing rebar on a concrete beam. The presentation illustrates the end markers for each solid reinforcement is designed downwards while the vertical lines end marks is designed to the right. While it is the other way around for dashed lines i.e. up and to the left.

While in the sectional- and details, rebar is shown as bellow



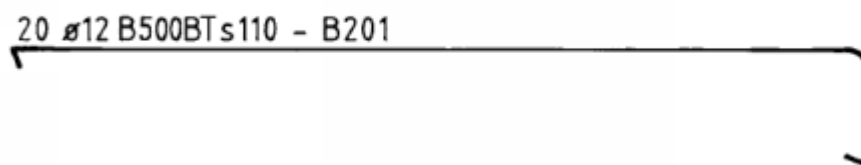
Following further down is distribution line presented which shows the reader that has the similar rebar's along, the on the structural plan view.



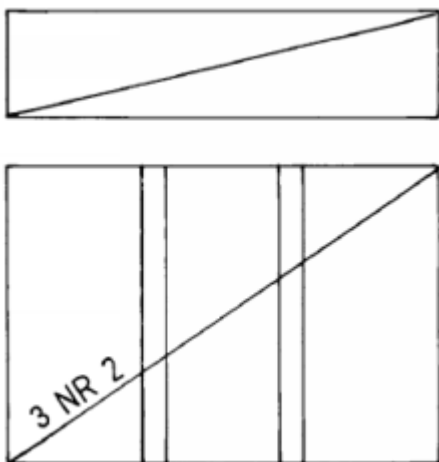
Design Categories

The rebar information and properties is written along its reference line. The rebar data is called design categories and is presented according to the following six criteria's which are the amount of bars/stacks of rebar, dimension, quality, the centre distance between bars, bending type and also the rebar number's that references reinforcement list.

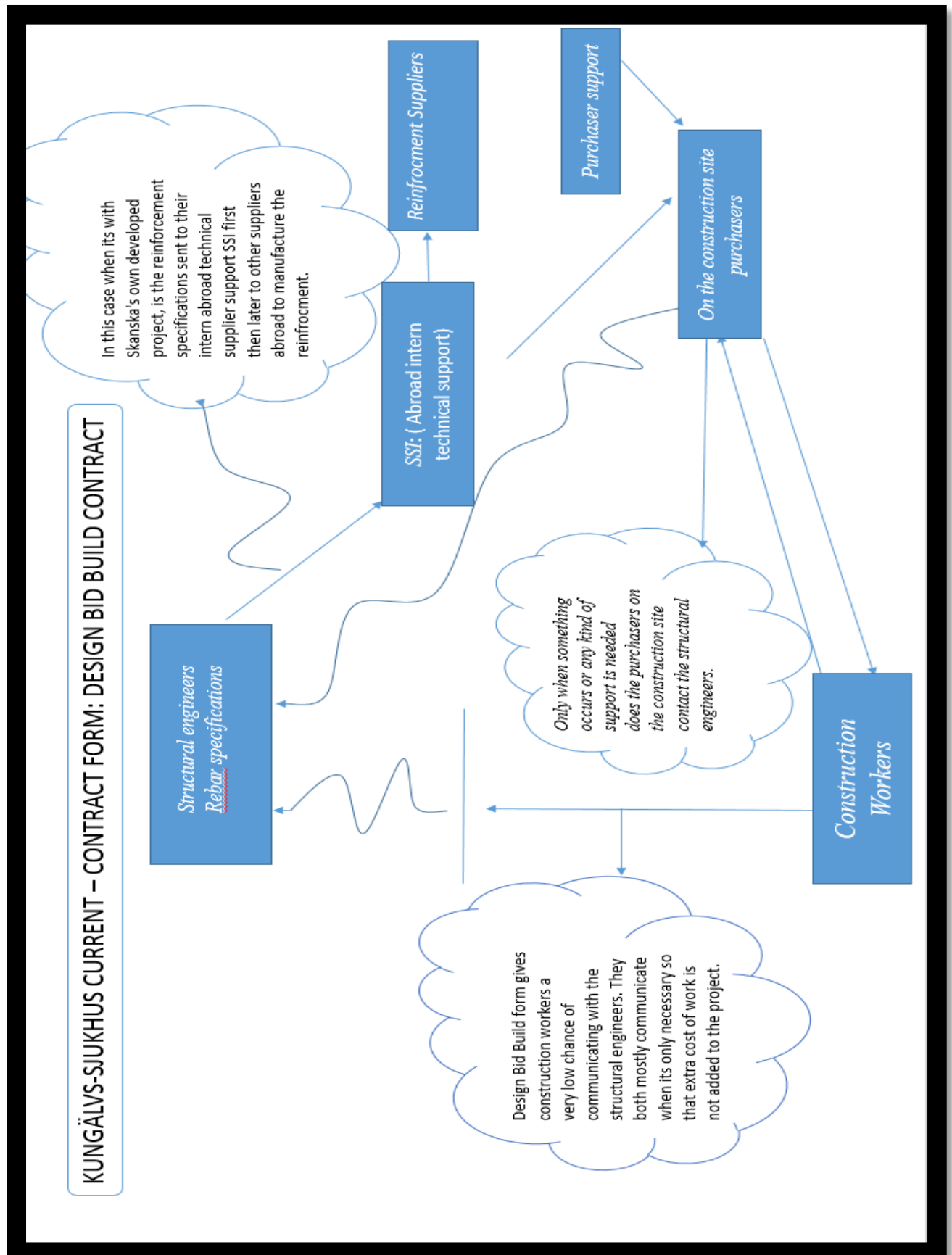
The design categorization of the rebar bellow indicates that it has bending type B, the unique rebar number 201, at the same time is it viewed that its twenty stocks rebar's with the diameter of twelve millimetres. The Steel quality of the rebar is B500BT and are laid with a distance of 110mm.

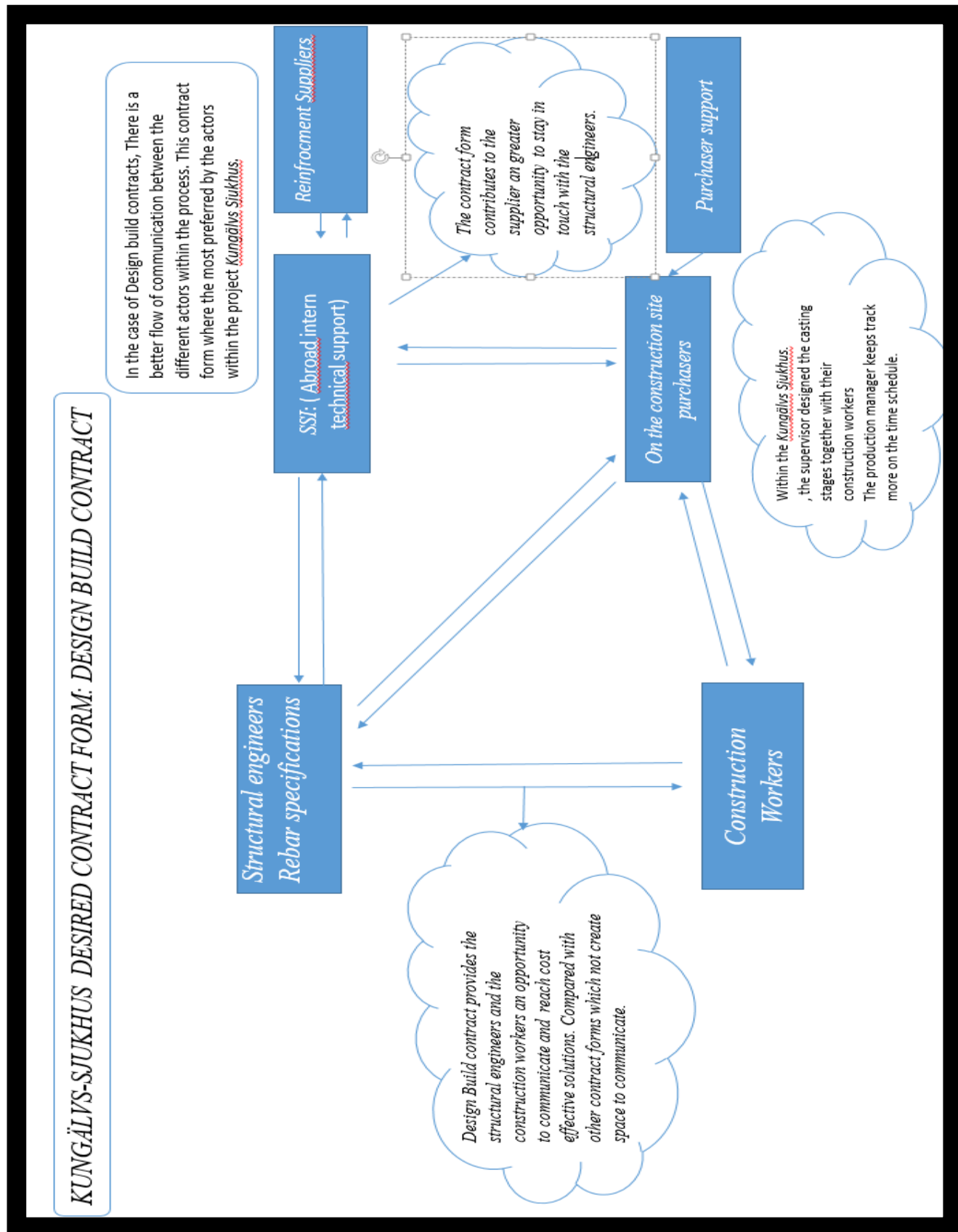


The rebar's mesh are designed with outer contour, which are in scale and follows the attached other reinforcing elements. The reinforcement mesh has diagonal lines, which are from the upper right to the lower left side of the corners. The rebar mesh is also names after its position depending if it's positioned on the top or on the lower edge of the structural concrete. The rebar's on the top position is named in Swedish terms (ÖK) while those on the lower edge is named (UK). Continuously according to BH90 should the designer primarily use the paper size 594x841 mm size when the original design is printed out, the Swedish term for the paper size is called A1 and belongs to A-series paper format (Hertzell, T. Bergenudd, and C. 2003).

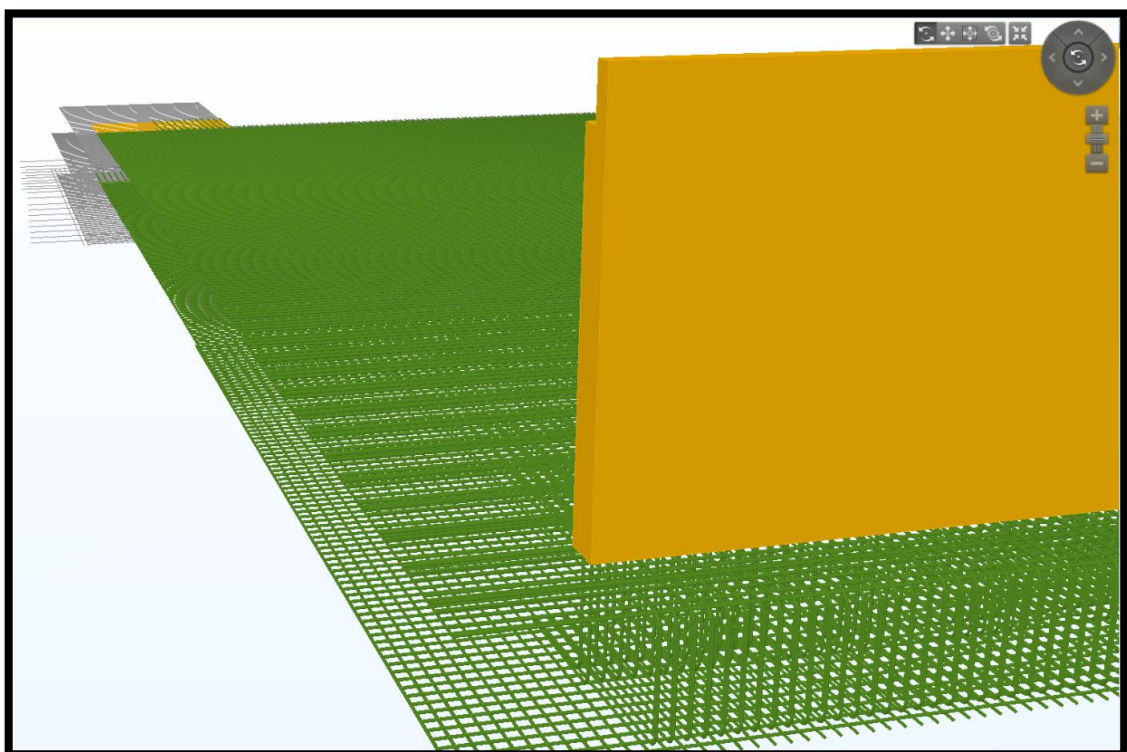
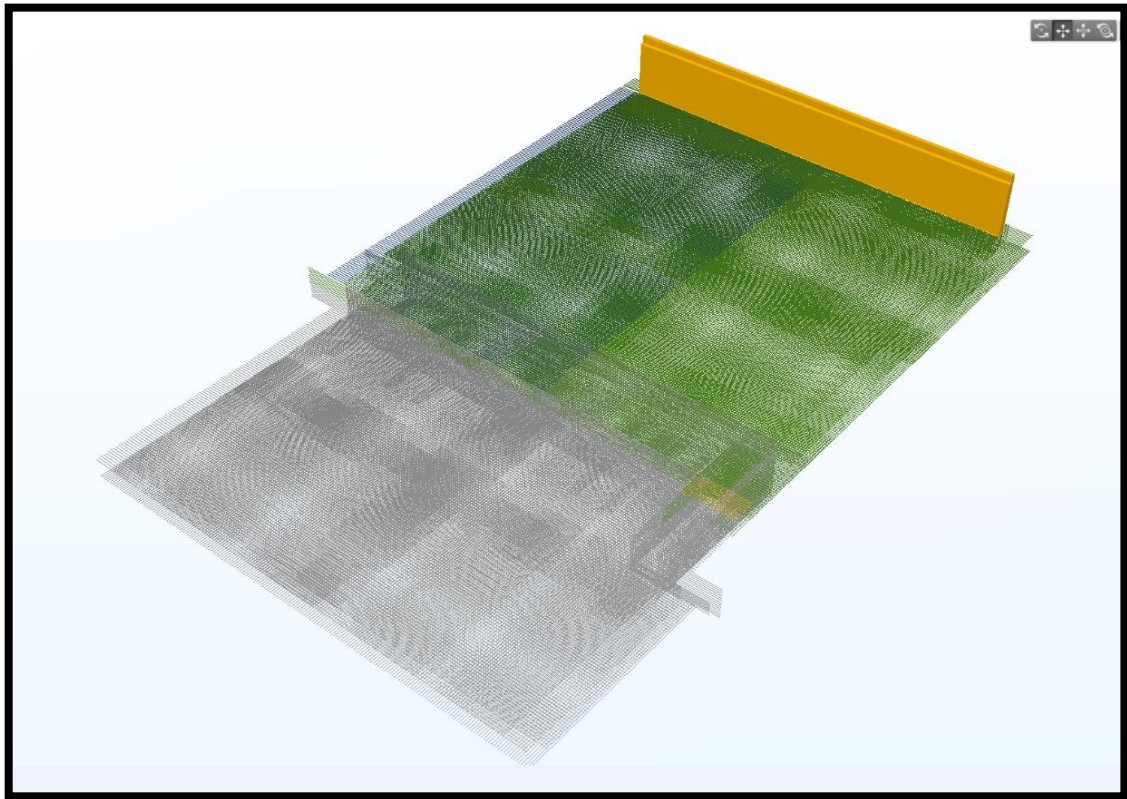


8.2 Contractual form of the project: *Kungälvvs Sjukhus*

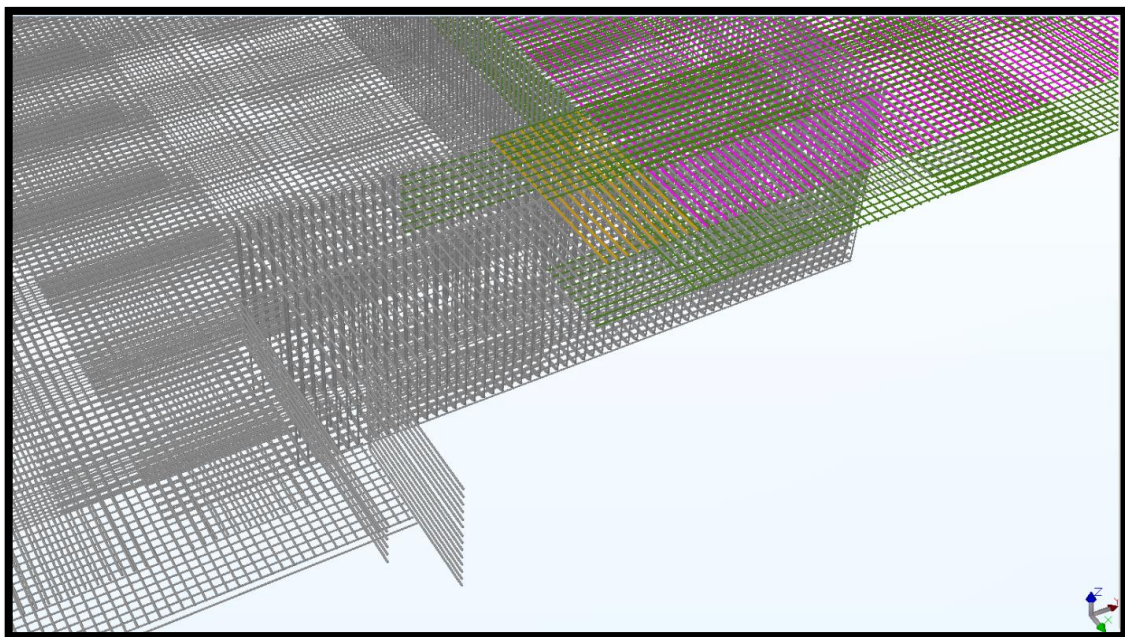
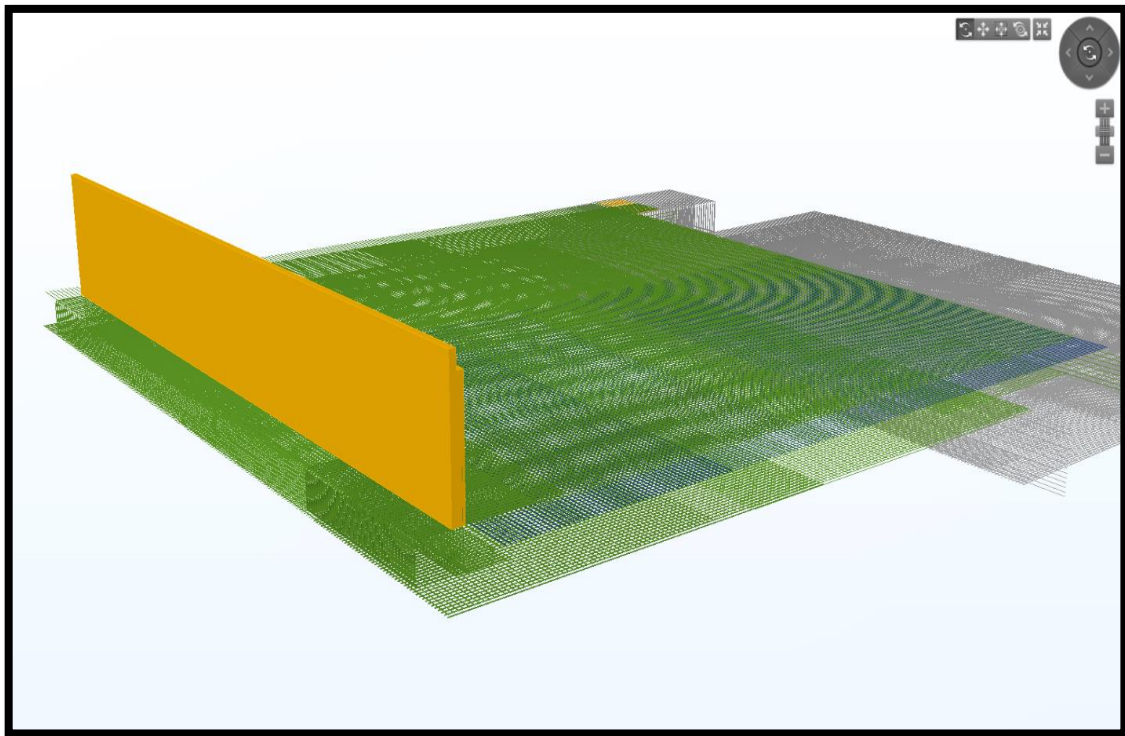




8.3 Project: Valand in Kungsbacka, *Tekla BIM Sight*



8.3.1 Project: Valand in Kungsbacka, *Tekla BIM Sight*



8.4 Traditional Reinforcement Schedule

[illegible]

8.5 Specification sheet 2A

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A 	B 	C 	D 	E 	EX
F 	G 	H 	J 	K 	L
LX 	M 	N 	NX 	O 	Q
R 	S 	SH 	SX 	T 	U
V 	W 	X 	XX 	Z 	Klipplängder Special: S: $a+b+0,5y$ SH: $a+b+c+d+0,5y$ SX: $a+b+c+d+0,5y-korr$
PRINCIP FÖR MÄTTSÄTTNING 		TYPBLAD 2A			
UTFÖRD AV		GRANSKAD AV		OBJEKT	
DATUM 2017-08-11		SENASTE REV DATUM		UPPDRAG NR	
SIDA (AV) 5 (5)		ÄNDRING			