INSTITUTO SUPERIOR DE ENGENHARIA DO PORTO

MESTRADO EM ENGENHARIA CIVIL

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Analysis and Comparison of different Structural Solution with regard to Construction Site Organization based on BIM 4D

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ANALYSIS AND COMPARISON OF DIFFERENT STRUCTURAL SOLUTIONS WITH REGARD TO CONSTRUCTION SITE ORGANISATION BASED ON BIM 4D

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RESUMO

O presente trabalho inserido na Unidade Curricular de DIPRE, do Mestrado em Engenharia Civil do Instituto Superior de Engenharia do Porto, foi desenvolvido na Universidade do Luxemburgo. O trabalho insere-se num projeto mais extenso denominado SiMCo, acrónimo para "Steel in Modern Construction", e é liderado pela empresa de aço multinacional ArcelorMittal. O projeto SiMCo tem como objetivo promover o aço de alto valor acrescentado (AVA) da marca ArcelorMittal e criar uma metodologia que permite a comparação de edifícios funcionalmente equivalentes, projetados em aço AVA e os construídos com materiais de construção mais convencionais e competitivos, como por exemplo betão pré-fabricado.

Neste trabalho foram estudadas 6 variantes construtivas diferentes de um mesmo edifício de escritórios tipo, nomeadamente no que diz respeito ao planeamento da construção e a organização do estaleiro, tendo como objetivo a otimização tanto do planeamento como da logística no estaleiro. Adicionalmente, a definição de detalhes construtivos, bem como a análise das etapas de produção necessárias à execução foram realizadas.

No planeamento da construção das várias variantes foi utilizada uma metodologia inovador, desenvolvida e maioritariamente aplicada no seio de grandes empresas de construção francesas. Nesta metodologia, a abordagem aplicada para o cálculo da duração da construção baseia-se na carga horária da grua ou das gruas presentes no estaleiro, com o objetivo de otimizar ao máximo a eficácia das gruas, de modo a obter uma organização de estaleiro rentável em que as gruas estejam sempre em movimento e a trabalhar com um alto desempenho durante toda execução das estruturas. A aplicação destas abordagens necessitou o uso e a atualização do um programa VBA denominado "ChaCAD", no qual os diferentes tempos de grua estão incorporados numa base de dados, permitido a análise do planeamento da estrutura baseado nas quantidades extraídas de um modelo 3D.

De seguida, as cadências e sequências de construção, os recursos humanos e matérias foram calculados e a logística de estaleiro foi desenvolvida. Um plano de estaleiro foi igualmente elaborado.

Por fim, o processo de construção das várias opções construtivas foi simulado em BIM 4D com o software Navisworks, o que não só permitiu visualizar eficazmente a execução das diversas variantes, como também apoiou a otimização do planeamento e possibilitou a comparação visual de todas as variantes estudadas.

Palavras-chave: gestão de projetos, planeamento, estaleiro, otimização ChaCAD, BIM 4D, Navisworks

ABSTRACT

This paper is integrated in the DIPRE curricular unit of the Master in Civil Engineering of the Instituto Superior de Engenharia do Porto, and was developed at the University of Luxembourg. It's embodied in an important research project called SiMCo, acronym for "Steel in Modern Construction", which is led by multinational steel manufacturing cooperation ArcelorMittal. The goal of the project SiMCo is to promote high added value (HAV) steel of ArcelorMittal's brand and to create a methodology that allows the comparison between functionally equivalent buildings, built with HAV products and those constructed with competitive products and materials, such as precast concrete.

In this work, six different constructive options were analysed on the basis of one study case office building, particularly with regard to construction planning and construction site organisation, having for a purpose the optimisation of the planning, as well as construction site's logistic and installations. Additionally, constructive details and necessary work steps in the production process were analysed and defined.

An innovating methodology was used for the construction planning of each studied variant, which was development and is widely applied by big French construction companies. In this methodology, the approaches used for calculations of the construction duration are based on the workload of the crane or cranes on the construction site, with the purpose to optimise to a maximum the effectiveness of those cranes. This means, for a profitable construction site organisation the cranes should always be in movement and working with a high effectivity. Therefore, the on Excel based VBA program "ChaCAD" was used and extended, in which different crane times are embedded for the analysis of structural work based on operational measurement issued from 3D model.

Based on the approaches stated above, work cadences, work flow, material and human resources were calculated and construction site logistics were developed. Furthermore, a construction installation plan for the most interesting variant was elaborated.

Finally, the construction progress of the various cases analysed was simulated in BIM 4D with the software Navisworks, which not only allows a better visualisation of the construction progress of each variant, but furthermore helped to optimise the work schedule, and validate and oppose the different structural options. At last, it also allows a better monitoring on building site for the later construction.

Keywords: project management, schedule, construction site, optimisation, ChaCAD, BIM 4D, Navisworks

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1 INTRODUCTION

1.1 MOTIVATION

The realisation of a construction project is often complex and linked to a series of technical challenges. It is not unusually to identify increases in costs and delays in the schedule delays only during the construction phase. It is therefore necessary to attach particular importance to a realistic construction planning. The more realistic the calculation of the construction progress is, the more reliable the construction schedule will be, which consequently results into a more accurate planning of material and personal resources, as well as a more precise construction site logistic planning and budget.

Analysing the various working steps in a construction site's production chain, is the basic prerequisites for a realistic calculation of a construction schedule. While some processes only rest on manpower deployment, the majority of the working steps of a construction's structure shows a strong dependence on the tower crane (production accessory). This means that the tower crane and his occupancy determinate the working speed on a construction site and consequently the construction duration. If for every construction element the production steps are standardised and the required crane time defined, the result would be the optimum construction schedule as a function of the crane efficiency. Based on that, the deployment of manpower and the use of material can be planned wisely and efficient. Also the number of tower crane needed on site and the construction site installation can be optimised, in order to realise a cost-optimised project within the time scheduled.

By dissemble a construction project into various individual components (objects), defining specific working step for each object and assign the appropriate crane time to every production step, the planning of the work schedule, the costs and the construction site can be done through computer-based algorithmic calculations.

1.2 OBJECTIVES

The systematically studying of a construction project's milestones, shown in Figure 1.1, will be carried on in this Master's thesis. The case study project is taken from a research project called SiMCo, which is led by the Luxembourg-based multinational manufacturing corporation ArcelorMittal. Using a BIM-model of the case study, the aim is to study the operative modus, followed by the elaboration of the work schedule (4D) as function of the crane efficiency and consequently planning the needed material and personal resources (5D).

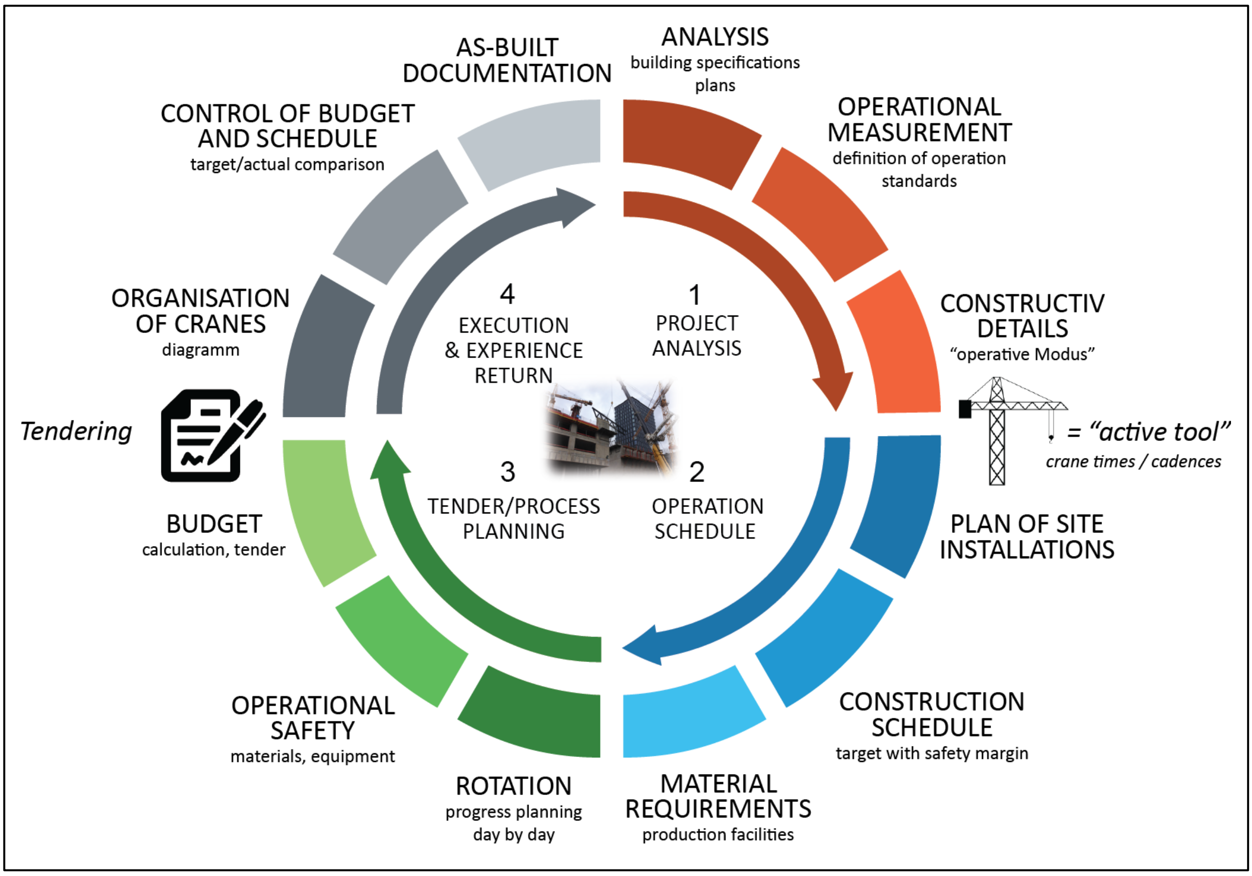


Figure 1.1 – Construction management system – Milestones of a construction project [M. Schäfer]

Different methods of construction for the case study building will be analysed and the end result will be the comparison of the different construction methods and also a construction site plan for one of the construction options studied.

The used procedure and algorithm for the analyse of construction site organisation and calculation of crane times is based on approaches developed in France (e.g. Orchestra Chantier / Vinci Construction) and it was further developed in last year by M. Schäfer.

1.3 OVERVIEW

This master's thesis is divided in five chapters. In this current chapter is given a brief introduction to the subject of this work.

In the next chapter the Building Information Modelling (BIM) in general, 4D-BIM, 5D-BIM and BIM in construction sites will be briefly explained. A quick explanation about construction site planning will proceed. Cause this work will be about crane efficiency in a construction project, a detailed explanation about the main types of cranes used in Luxembourg will also be given. At the end of the chapter, a detailed explanation about the methodology of planning works through crane efficiency.

In chapter 3 the case study building is depicted, as also a little historical background of ArcelorMittal's project SiMCo is given. Also the approaches and methods taken into account for this work to reach the final results are explained.

In chapter 4 the results are given and at the end of the chapter a comparison between all constructive methods and case studied is done.

The final chapter presents the main conclusion and gives ideas for future developments.

2 STATE OF THE ART

2.1 BUILDING INFORMATION MODEL(LING)

2.1.1 BIM – From 2D drawings to 3D object-based digital data models

"Building Information Modelling" is the name given to an innovative methodology of collaborative work in the architecture, engineering and construction (AEC) industry. The concept of BIM gives to the AEC industry a new approach to the design, construction and maintenance of buildings, and especially to information management in construction. The concept is based on the elaboration of a virtual information model of buildings and other civil engineering constructions. The digital model not only contains 3D geometrical information, but all sort of data related to the construction project. In the AEC industry, BIM is considered the most promising evolution in the area. BIM allows the digital construction of a building and all his components with great precision. It is the digitalisation of the AEC industry with an object-oriented approach. [1] [2] [3]

In the late 70's, theories about modelling data, that outcomes of construction product, were first developed by Professor Charles M. Eastman. The concept of "Building Product Model" was created. [4] With the recent development of information and communication technology (ICT), and the increasing complexity of projects, the theories developed gained importance. The term "Building Information Modelling" was used the first time by an Autodesk architect, Phillip Bernstein, and later popularized by Jerry Laiserin, who used BIM as a common name to describe the digital representation of construction processes. According to some authors, the first application of the BIM principles was achieved with the ArchiCAD software from Graphisoft. [5] Nowadays, it is clear that BIM will become a standard in the AEC industry. Some countries, like the UK, are putting enormous efforts into supporting BIM implementation and adoption, providing best practice guidance for BIM and funding researches in the area to promote the modernisation of the AEC industry. Other countries are beginning with the efforts, like Portugal, France or Germany. In Luxembourg, first steps in this direction are also being taken right know.

The BIM methodology brings a major change in the industry, because with BIM the AEC industry is moving from graphics to object carrying data, from 2D drawings to 3D models build of objects containing data. A BIM model is much more than just a graphical representation, because it allows to introduce data to the model, during the whole life cycle of the project and construction. The data in the model can be used across AEC disciplines through planning, designing, analysis, fabrication, construction and furthermore through facility maintenance and demolition BIM can be present in the whole lifecycle of a project, as Figure 2.1 illustrates.

Figure 2.1 – BIM in the lifecycle of a construction (adapted from https://goo.gl/HdXoks)

BIM can either be referring to the model (Building Information Model) or to the process (Building Information Modelling or Management). So beside the model, BIM is also a whole set of tools and processes to help create and maintain a collaborative data base which contains, beside the digital model of the project, all sorts of information about it, for example data about the geometry, materials, yields, etc. [6] It can be seen as a tool for production efficiency. Efficient communication between project parties, added to a fluent transfer of building information, creates an integrated workflow that allows for efficient and accurate project delivery. With the development of cloud computing, the information transfer between all the parties involved in a project has become much easier than ever before, allowing project parties to work on one digital cloud-based model. It is up to each individual project team to create and provide all the valuable visuals and information needed for project delivery. Furthermore, the data in the model can be read by manufacturing and fabrication machinery, allowing for more automation within construction. This BIM principle is also important because more and more manufacturing companies are producing smarter objects, which can be placed directly within the model.

Traditionally, BIM works in the following construction workflow: All the AEC discipline create their specific model of a given project and these models will later be fitted into a combined model, which contains then all the information of the project. This BIM model is the place where all the information at every stage of the project is stored, up-to-date and accessible. A highly detailed model allows the project team members to visualise what is to be built in a virtual environment. All the needed construction documentation can be generated automatically from the BIM model (2D drawings, Detail Drawings, etc.). The reports needed for quantity take-offs, schedules, assembly, etc. can also be automated. It is also possible to run clash detection to see if there is any collision, for example between pipes and beams, and if there is, the design can correct the clash and the model, with all the views and reports, will automatically be updated. BIM also allows to run through sequencing scenarios of the construction erection, planning site logistics and verify safety plans.

The traditional construction process does not give value to the information management between the different project members. As we can see in Figure 2.2, in the traditional construction process, there are a lot of communication channels. In fact, each project member communicates with the others parties, which results in a big mesh of communication channels, and, furthermore, in a big work disorganisation, a lack of information sharing, loss of information and as a consequence in project errors. [7] With the BIM methodology, there is the so called "Integrated Project Delivery" (IPD), where data is managed from a central model, which results in an extremely collaborative process, in which every stakeholder takes part in the building of the model during the whole project life cycle. In this way, the sharing of information is simpler, richer and up-to-date. With the recent emergence of cloud computing, the management of information between all the parties is increasingly becoming easier.

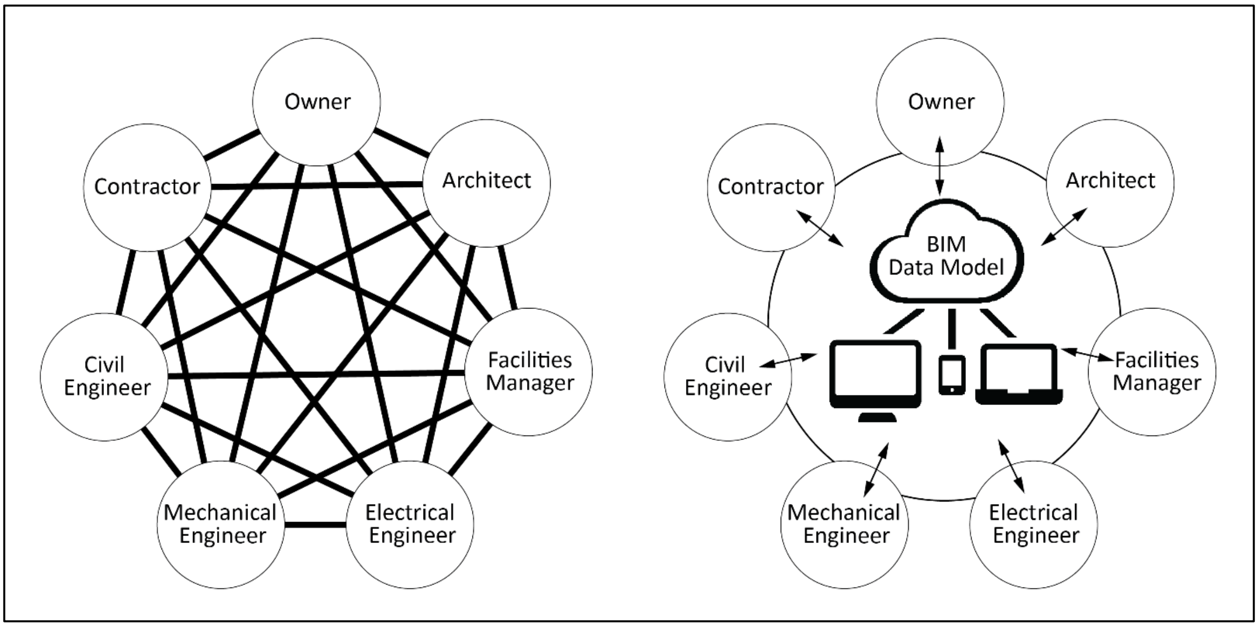


Figure 2.2 – Information management in the traditional construction process (left) and BIM (right)

2.1.2 4D BIM

For construction companies, one of the big interesting aspect of BIM is the BIM 4D. The 4th dimension of BIM introduces the notion of time into the models. In terms of construction process, this dimension brings with it the planning of the activities on site. Construction companies see this aspect not only as a big commercial valorisation of their tender's submission to a client, but also as a clear improvement of their work schedules. [8]

Traditional schedules are represented as Gantt charts, which allow temporal planning of activities and the possibility of adding material and human resources to each activity. However, Gantt chart schedules don't consider the spatial configuration of the activities, neither link these activities directly to the construction model. [7]

A 4D planning fills this technical gap, by given to each task a spatial configuration related to a 3D object-oriented model. In fact, by overlapping a 3D model with a Gantt chart, it is possible to entirely simulate construction process in 3D using an adequate BIM 4D software, such as Autodesk Navisworks. [7] [8] 4D-planning is a powerful tool because it allows to the parties involved in a project to visually communicate in a space-time dimension. It allows to evaluate and simulate a construction project, with virtual simulations of the construction schedule as output. 4D-simulation are also hugely beneficial in terms of work planning in a logical and safe way that maximises efficiency on site. Figure 2.3 is an example of a 4D simulation done in Autodesk's software Navisworks for this master's thesis.

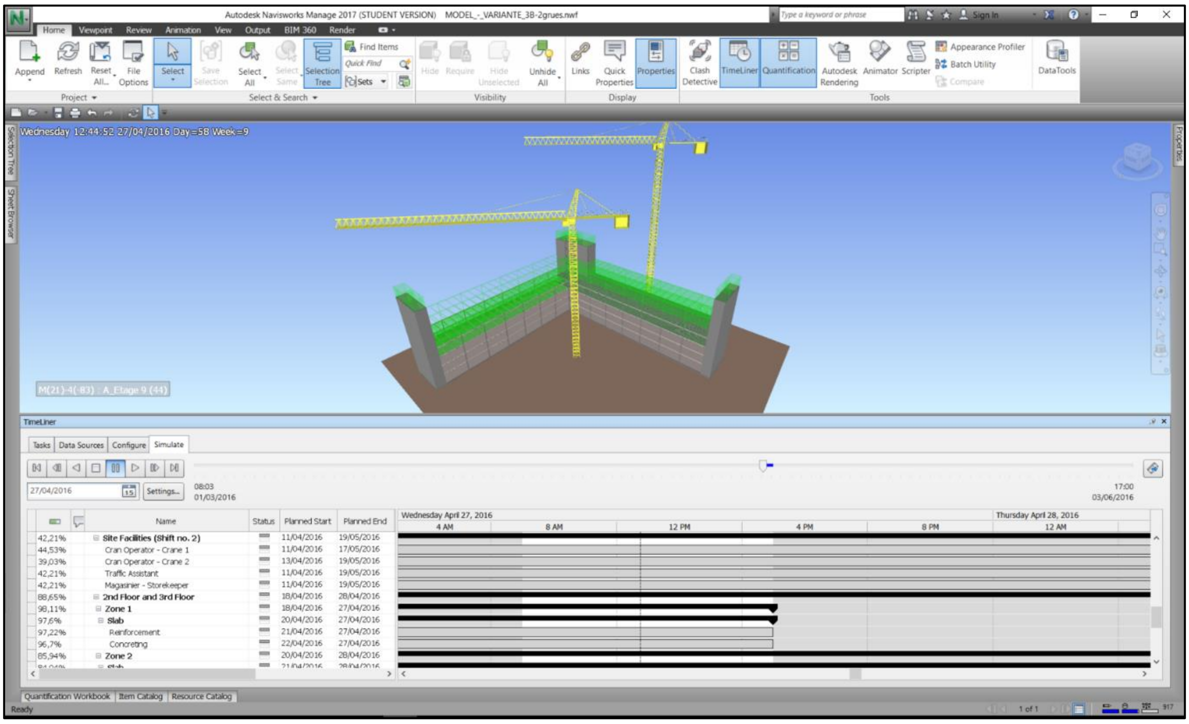


Figure 2.3 – Example of a 4D simulation in Autodesk's software Navisworks

The time related information included in a specific element or work area can be details on its lead time, construction and installation period, curing and drying allowances, sequences, or its interdependencies with other elements or areas.

4D-BIM simulation generally is used to communicate and collaborate with the others project involved parties. It is used by engineers and managers to analyse and visualise construction sequence and the site logistics, and to help as a decision support tool in feasibility studies and construction methods choices. [9] The 4th dimension in BIM contributes to a better understanding of the requirements for the construction sequence and the implication in 3D, which bring a lot of benefices into the project.

Communication, better visualisation of the works to be carried out, accurate and detailed construction programme, decision support and clash detection are the main advantages. Also the possibility of modelling alternative scenarios or different construction methods, and evaluating them quickly, is a big benefit of 4D BIM models.

Issues with 4D BIM are nowadays the interoperability of the software and the non-fully support of activities beyond the 3D models, such as building permits applications, external precast works, etc.

2.1.3 5D BIM

On the same principle as in 4D BIM, it is possible to add to the BIM model more dimensions beyond the 4th. The next step is also 5D BIM, which introduces cost-related information to the data model, making it possible to produce accurate cost estimations from the model components and also to cost control in all stages of a project. The cost estimations can also be based on the data and information associated and linked to the components (objects) of a model. [8]

Those estimations can consider the cost of purchasing a component, but also installing it. Furthermore, the running cost of the component after installation and the anticipated price of renewing it in the future can be considered. Due to the quickly determination of the quantities in a model and the cost data linked to the elements, engineers can easily and rapidly build an overall picture of a project's cost and so saving time in the counting process.

Estimations' accuracy is directly linked to the quality of the cost data introduces into the model by the project team. If something is wrong or inconsistent, errors can be carried throughout the costing, but can be fixed in real-time.

Also, cost estimations increase their accuracy as the project model develops over time. At the design stage, cost estimations are carried out on the available information, i.e. areas, volumes and space types. With further developed of the model by the project team, the realisation a parametric cost estimation in which costs are based on major building parameters such as number of floors and roof areas is possible. To get the best result, the project team has to properly define objects and components so that other parties involved in the project can extract estimation. Although, not everything is modelled in 3D, so nowadays a lot of 2D information is used, as for example temporary works, shoring, site facilities, etc. Unless the construction phases are fully modelled, the designers graphical model will indicate design quantities and not construction quantities.

2.1.4 BIM on construction sites

BIM is a recent technology on construction sites, although not yet really applied there. [10] This is due to the lack of mobile devices on construction sites, but essentially due to the deficiency of adapted formation.

In fact, on construction site biases about BIM are very common. For the workers on a construction site, BIM is a tool for coordination tasks which are done by engineers specializes in IT. [11] So it is necessary to show that a digital model is necessary for everyone involved in a construction site. On a construction site, there is BIM outside the site facilities and it brings with it a lot of big advantages, not only for the worker's safety but also for the optimisation of schedule and resources.

BIM is an upcoming technology based on visualisation, and the emergence of Virtual Reality based technology can bring to the AEC industry significant developments. Nowadays, this technology is already presented in our smartphones or tablets. For example, quick response codes (QR codes), which carry a lot of information, could be used to give to workers costume operational instruction adapted to their skills, and so increase the comprehension about particular operational steps of the project.

In a traditional construction site, information is normally available only in paper format, in drawings. This information is not always the most relevant for the workers on site, because it can be too vague or too technical. BIM enables one to access “invisible” information on a drawing, but which is crucial for the workers on site. In the Netherlands, construction sites with drawings “à la carte” are a reality right now. In fact, detailed prints from the digital model in A3 or A4 can be obtained in well-equipped site facilities and accessible to everybody. [12] The benefices are that the worker is better informed and less subjected to information non-relevant for him.

There are some on site technologies for the monitoring and management of construction sites available on the market, like BIM360 Field from Autodesk or BIMsight from Tekla. The access to these technologies should be democratised on construction sites, allowing the access not only for project managers and foremen but also to the workers on site. With a smartphone or a tablet, like in Figure 2.4, they could have access to the cloud-based digital model of the project and pick relevant information for their work. This would save time, time which can be use increase quality and safety of work.

Figure 2.4 – BIM use on construction site, using Tekla’s BIMsight app on a tablet (https://goo.gl/J0alPZ)

The inefficiency of BIM technology on construction sites is due to a lack of investment among construction companies, which brings with it that tools actually on market and which are available for free don't are sufficiently applied on field.

2.2 CONSTRUCTION SITE

2.2.1 Construction Site Installation

The organization and management of a construction site is a complex task. It goes beyond the physical arrangement of the space. This is the case because the construction industry presents a series of specific aspects, characterised by the subsector of building erecting, which affects the physical arrangement and exercise influence on the security at work.

The concept of site installations englobes the whole facilities needed in a construction, e.g. facilities for transportation, storage and production, which are needed for the construction or rehabilitation of a structure. It involves identifying, sizing and placing temporary facilities within the boundaries of a given construction site. In these site installations, main connections and the required technical equipment are also included.

The needed temporary facilities and their sizes depend of many factors, as project type, scale, design, location and organization of construction works, and need to be well planned in forward.

The planning of site installations englobes the spatial and temporal dimensioning and the layout planning of every facility on site. Site installations planning is a part of the construction preparation process.

The main aim of the planning is to determine the best arrangement of temporary facilities on a construction site, to minimize the transportation distance of site personnel and equipment, and so maximize efficiency of operations in order to promote worker productivity. These also leads to shorten project time and to have a secure and rentable construction process. The plan should promote a project with a good work environment, which is the basis to work quality and productivity.

Well planned site installations are not only important and essential for the parties involved in the construction project, but also give a good impression to the client and outside.

To achieve a reliable planning, many inputs must be considered in the process. These inputs are showed in Figure 2.5.

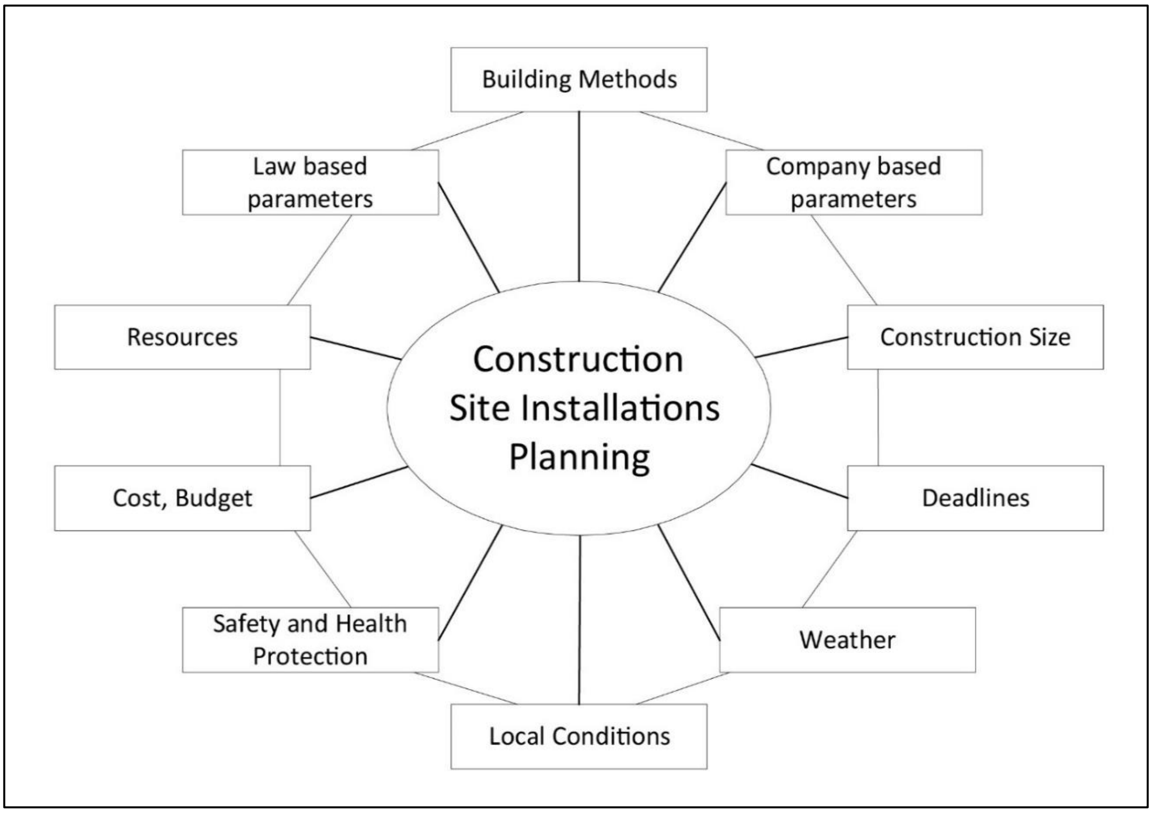


Figure 2.5 – Illustration of the complex linkage in the construction site installations planning (adapted from [13], Bild 1.1)

A construction site installations plan can be divided in several layers:

First of all, the background plan represents the actual terrain, the surroundings of the construction site and the building after being erected. The fence around the construction site is also represented, as to let the plan reader know the delimitation of it. The entry and exit of the construction site must be clearly identified on the plan. Another main representation, one of the most important, is the lifting devices. Mobile or fixed cranes must be on the plan due to their importance on a construction site. The crane characteristics must be figured, such as position on the site, jib length, crane height, crane type and lift capacity. The interface between the crane and his surroundings must be clearly depicted. Every obstacle must be represented on the top view and front view drawings, such as trees, buildings and other cranes.

Figure 2.6 represents a typical elevation drawing on an installation plan.

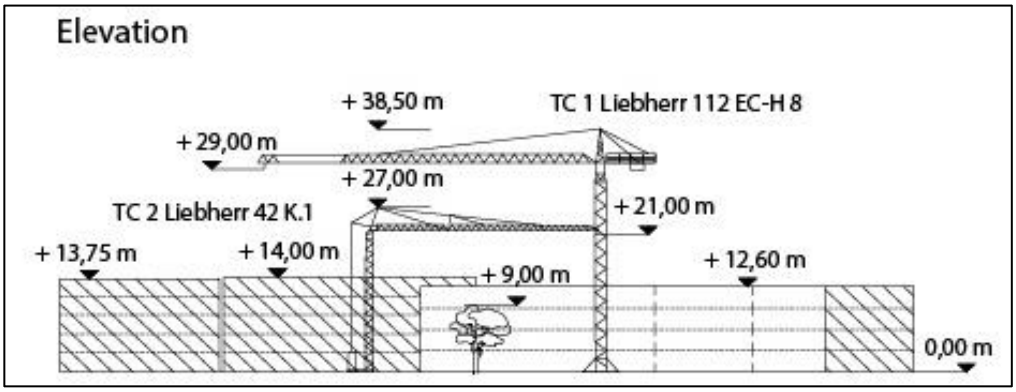


Figure 2.6 – Typical crane elevation drawing (adapted from [13], Bild 3.6)

Other representations on the plan are site accommodations like offices, sanitary facilities, locker rooms, refectories and parking spots.

The public's main connection, like water supply, electricity and so on, must be drawn on the plan to.

Another main aspect on the plan is the circulation flows. The construction site installations plan must embody the circulation flows for the workers, but also for the trucks and other vehicles that will be on the construction site. The workers' and trucks' flow must be separated and every single cross of these two flows must be taken seriously and be well signposted to ensure security for the workers.

Workshops, storage containers and storage areas for materials and equipment should be drawn on the plan too. These areas should be divided per type of material that they store, like formwork, mesh reinforcements, prefabrication elements, and so on. Workshops and storage containers must also be depicted. The environmental aspect on a construction site installation should not be forgotten during the planning. Therefore, it should be depicted on the plan areas for trash recycling, as well as areas for storage and treatment of pollutants.

Figure 2.7 gives an example of a site installations plan.

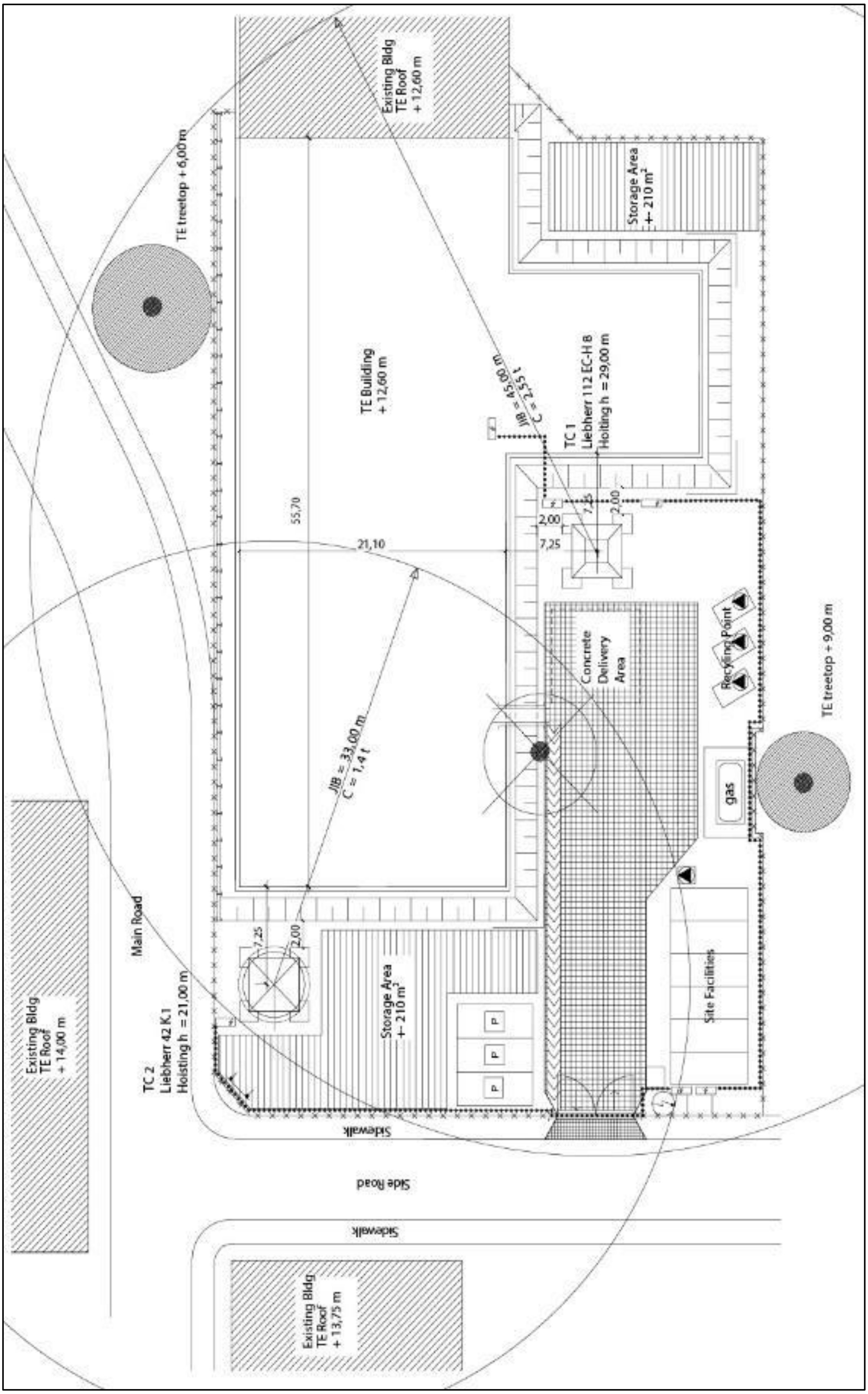


Figure 2.7 – Example of a site installation plan – (adapted from [13], Bild 3.2)

2.3 CRANES IN CONSTRUCTION

2.3.1 Initial considerations

A crane is a machine built to lift heavy loads efficiently and safely. Used for centuries, they are omnipresent on construction sites and without them it would be nearly impossible to build most of the constructions we are used to see every day. In a construction site, cranes are used to lift steel elements, concrete, large tools like generators, a wide variety of other building materials among other stuff. Two main types of cranes are used in the construction industry: tower cranes and mobile cranes, which can be subdivided in several categories: top-slewing tower crane, luffing jib tower crane, articulated jib tower crane and so one. In this chapter, only the most used tower cranes in Luxembourg will be presented.

2.3.2 Crane types used in construction

A multitude of crane types exists worldwide. They can have all sort of shape and usage. In the Luxembourgish construction industry mobile cranes, static tower cranes and self-erecting tower cranes are the most frequently used crane types.

Mobile cranes' (Figure 2.8) main characteristic is their mobility. In fact, these are cranes on wheels, which means they can be rapidly placed almost anywhere on the construction site. Due to the fact that in this master's thesis the focus will be put on tower cranes, these last ones will be descripted and explained more widely.

Figure 2.8 – A mobile crane on a construction site

Unlike mobile cranes, a tower crane is a fixed crane and has to be mounted on-site. A tower crane presents itself like a vertical metallic truss structure having a horizontal boom, called jib, that can turn over an angle up to 360°. Due to de fact that a tower crane is a fixed crane, it guarantees a greater stability than a mobile one, and can therefore carry greater loads and reach greater heights.

In the tower crane family there are two main types: the top-slewing crane and the self- (or fast-) erecting crane.

The top-slewing crane is the most common crane in big construction sites. It is usually fixed to the ground on a concrete slab and stabilised with big concrete blocks; it is called the base. In poorer soils or when there are heavy loads to be lifted that can make the crane tilt, pile foundations are used. The base connects to the mast or tower, which gives the tower crane its height. On top of the mast is attached the slewing unit; it houses the gear and the motor that allows the crane to rotate 360°. On top of this unit are three other parts, the jib, the machinery arm with the counter weights and the operator’s cabin. The long horizontal jib, also called working arm, is the part of the crane that carries the load. A trolley runs along the jib to move the load further or nearer from the crane’s mast. The load is attached to the hook. The machinery arm, also called counter jib, contains the crane’s motor that lifts the load and also the control electronics that drive it and the cable drum. At the edge of the machinery jib are concrete counter weights. Figure 2.9 shows the anatomy of a top-slewing crane.

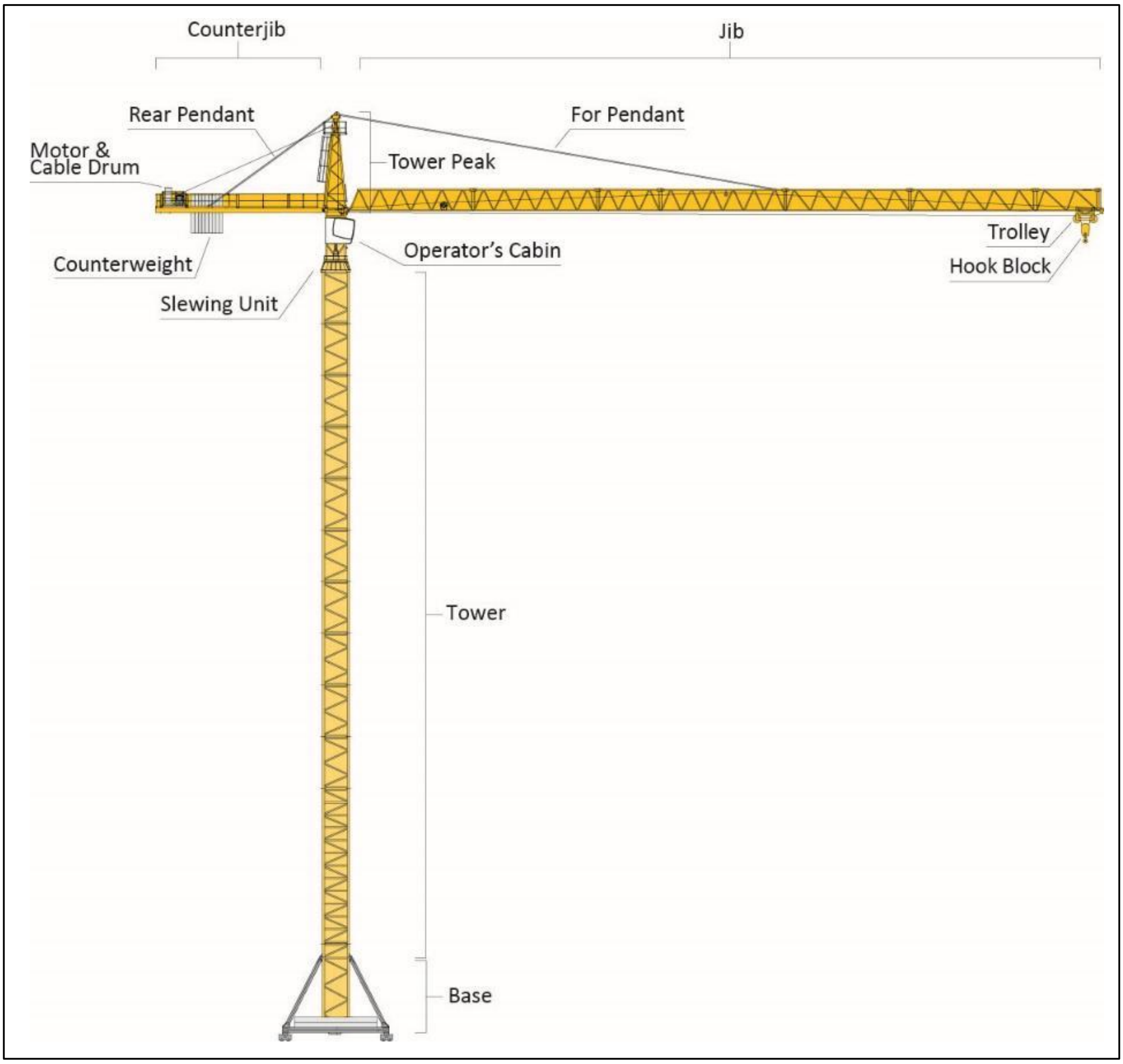


Figure 2.9 – Anatomy of a top-slewing tower crane

In the category of the top-slewing crane are two main subcategories, the high-top cranes and the flat-top cranes.

High-top cranes, also called A-frame or hammerhead cranes, have above the operator's cabin, the slewing unit and the jib, a so called tower peak, also called tower top or A-frame. The use of a tower top provides further stability to the crane by attaching pendant bars from the tower top to the jib and the counter-jib. This type of crane is represented in the figure above (Figure 2.9).

Flat-top cranes eliminate the need for pendant bars and a tower top by having larger and thus stronger jibs. In Figure 2.10 can be seen the two main subcategories of top slewing cranes.

Figure 2.10 – A high-top crane (front) and a flat-top crane (back) (Project Muse, Metz, France)

The self-erecting crane is another very common tower crane type, usually on smaller construction sites. It’s also called the fast-erecting crane. These cranes have the slewing unit between the tower and the base. This means when the crane rotates, not only the jib will rotate liker for the other tower cranes, but also the whole tower will rotate. Furthermore, this type of crane doesn’t have a machinery arm. Every motor, gear and the cable drum are located by the slewing unit above the base. They don’t have an operator’s cabin, but usually are radio remote controlled. The main advantage of this type of crane is the rapid erection of it, as stated by its name. They come to a construction site as a complete unit, already assembled but folded. On site, when connected to power, they erect themselves up in the skies, as it is shown in Figure 2.11.

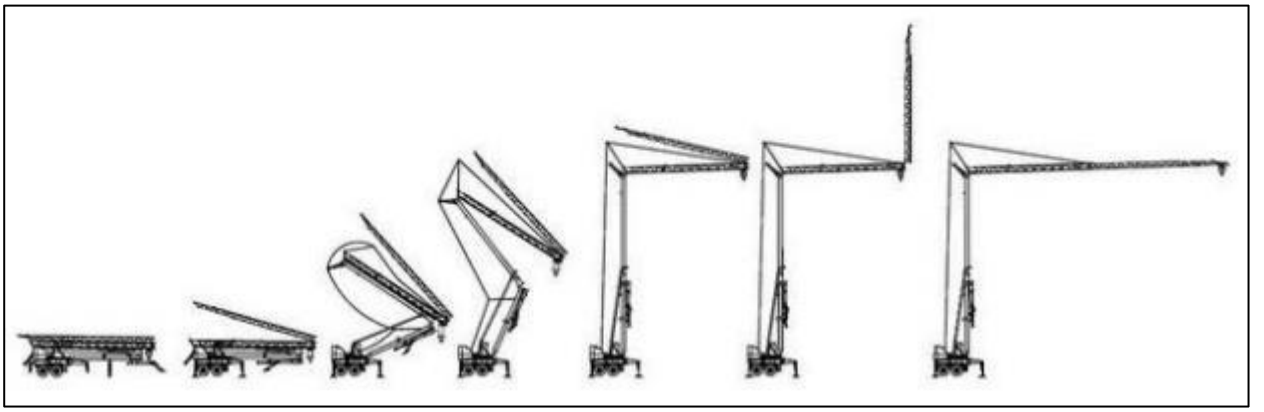


Figure 2.11 – Out folding of a self-erecting crane (https://goo.gl/mDeidh)

They are very versatile in use, but their load capacities and ranges are below those of top-slewing cranes. Figure 2.12 shows the anatomy of a fast-erecting crane.

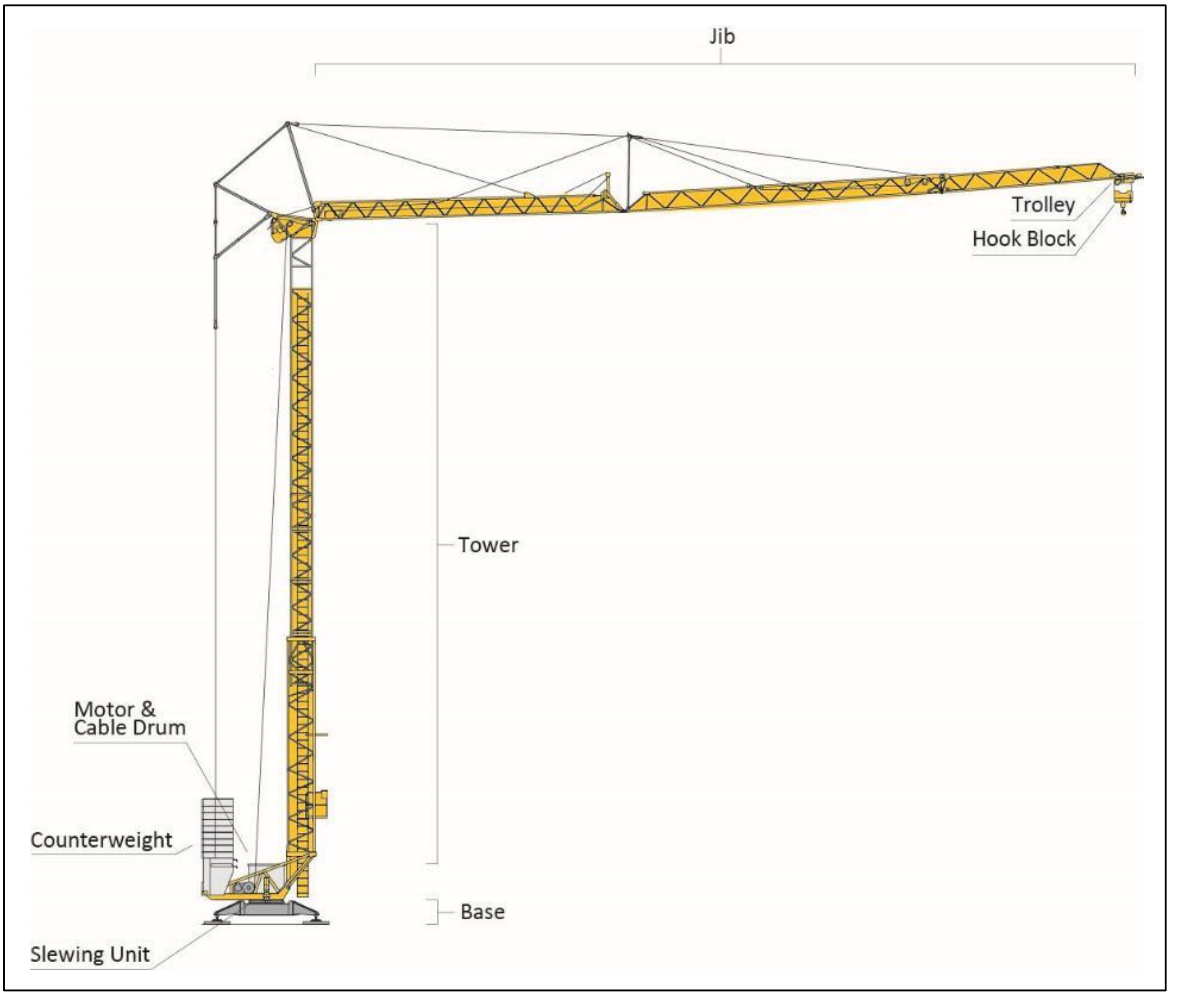


Figure 2.12 – Anatomy of a self-erecting crane

2.3.3 Tower crane foundations

Tower crane foundations are subjected to complex and varying loads. The applied loads originate from the masses of the crane, ballast, counter-weight, hook load and the effect of the wind. These loads are often aggregated into three components, a vertical load, a horizontal load and a moment that must be resisted by the foundation. These components will normally be given by the manufacture of the tower crane for the cast-in bases, as it is recommended in the EN14439 norm.

There are two main types of foundations, the anchored foundation and the static one. In the first one, the tower anchors directly to the base, in other words to a big concrete block, as Figure 2.13 illustrates. The stability is provided by the concrete block, which is therefore subjected to an overturning moment as well as vertical and horizontal forces. The tower is casted into the base using special anchor sections or holding-down bolts, normally designed by the crane manufacture. The base could be a pad base, also called gravity or piled base. The tower could also be casted into the permanent works' foundation. It's the most common used foundation for tower-cranes.

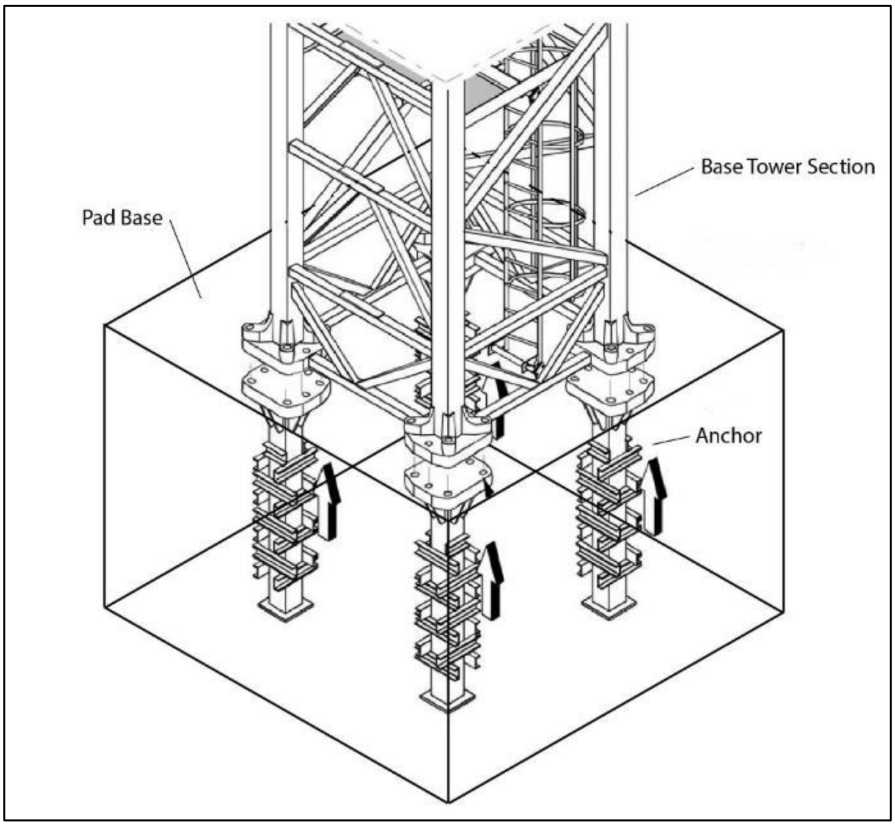


Figure 2.13 – Anchored foundation for tower-cranes (adapted from https://goo.gl/q9Uqxh)

The other main foundation type is the static one, also called undercarriage. The base of the tower relies on a cruciform frame, which is on anchor shoes as shown in Figure 2.5. These anchor shoes could be on a slab, pads, piles and piers. If the base is subjected to any uplifted force at the corners, the connections must be capable of transmitting it. Big concrete blocks, also called the central ballast are normally placed in the cruciform itself to guarantee the stability of the crane.

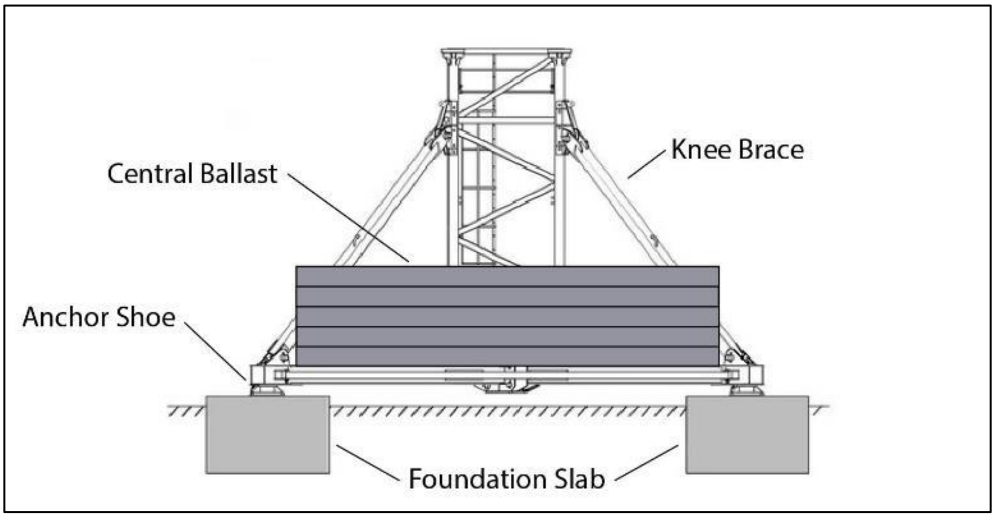


Figure 2.14 – Static Foundation / Undercarriage (adapted from https://goo.gl/eY2J0N)

Another type of foundation is the rail mounted undercarriage, illustrated in Figure 2.15. In this case, the anchor shoes of the undercarriage are not mounted on a foundation slab or pad, but on bogies. The electric driven bogies can travel on rails in one direction and so move the whole crane in one dimension. A rail-mounted tower crane can therefore cover a bigger area. This solution is not often seen on construction sites, because it is an expensive one due to the rails installation costs. (dictionary of construction terms).

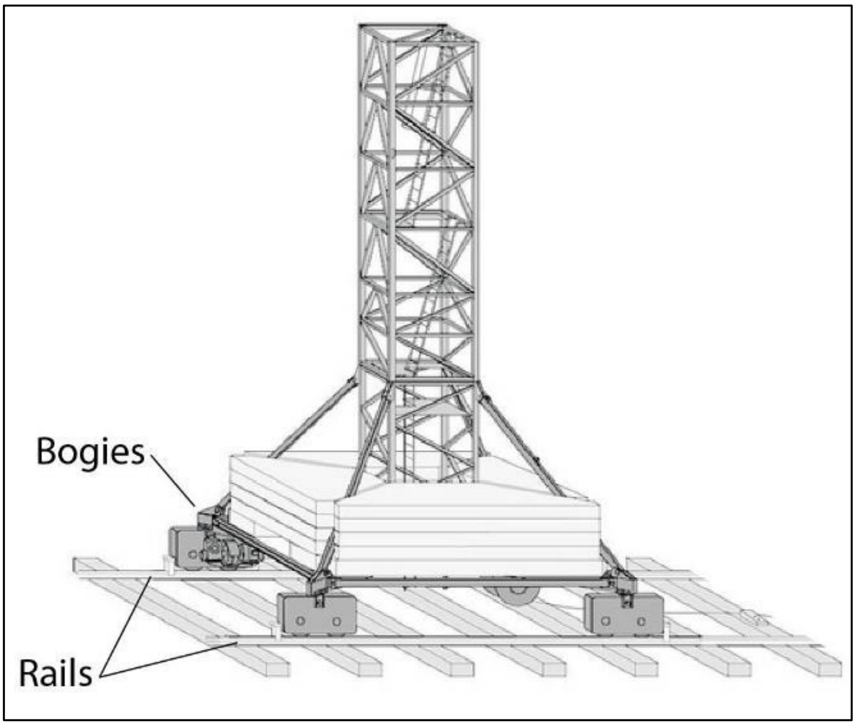


Figure 2.15 – Rail-mounted undercarriage (adapted from https://goo.gl/eY2J0N))

The selection of a type of foundation will be determined by a number of practical and geotechnical issues. It is generally all about the safety, economics and ground conditions.

2.4 PLANNING THROUGH CRANE EFFICIENCY

2.4.1 Initial considerations

Traditionally, calculations to determine the construction duration of a building are based on construction rates. Construction companies have determined these rates during years of experience and have collect them into their own database. But fact is, that many projects end up having delays. One of the problems leading to these delays, is that nowadays the construction rates are not linked to elements of the project, but to areas and nor they consider the production steps of the elements on a project. For example, it's usually that a construction company tenders by given the total construction duration based on the square meters of floor area, in which the only characteristics that can change the rates is the floor type.

The method that will be introduced in this chapter uses another approach to duration calculation. The aim of the method is to have the tower crane or cranes on the construction site fully occupied, this means fully efficient. By analysing the production step of each element, given crane times to each element and each production step, the total duration of a structure building can be determined.

2.4.2 Method

When analysing production steps of the various production chains on a construction site, the main factor that influences the quality and duration of production can be identified. While some processes are bases only on human resource, the majority of the work steps in the structural works shows a strong dependence on the construction site's tower crane (production accessory). This means that the tower crane and its effectivity determine the working speed on a construction site, which results in the daily work cadence and at least in the construction schedule. If for each construction element the work steps are standardised and the crane ratios are defined, the result would be the optimal construction time as function from the crane workflow. Based on it, the planning of the works and the economically management of human (workers) and material (e.g. formwork) resources are possible and more reliable. And not least, in order to complete the project on time, the results of this approach are an optimization of the construction site installations, as well as of the tower crane number on site.

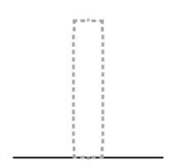
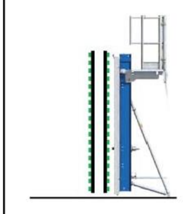
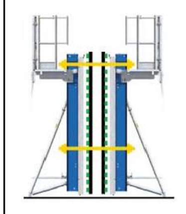
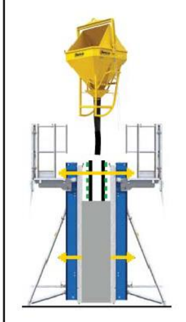
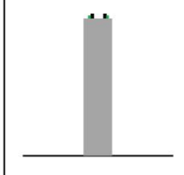
This method is based on approaches from stationary industries, such as manufactories. In the industrial production, the operating cycle is given normally by machine or robot. This means that on a production line, input resources need to be given in enough quantities to the machine in order to ensure the best efficiency without any production stop. The needed human resource (workers) will be added in the next production steps, so that the subsequent processing of the product is assured.

This approach applies also on the production processes in a construction site. A breakdown into single components of a building's complex structure must first be done, in order to use this method on a construction. The single components of a building's structure can so be grouped in different categories, i.e. walls, columns, beams, etc. Then, the needed resources (i.e. material) and production accessories (i.e. formwork, scaffold) need to be determined, depending on the chosen construction technology. Besides this, the operation tracking of each construction's component should be done; this means the method of how the components will be build should be defined.

As an example, the application of this approach on a concrete wall will be used. The material resources will be concrete, in this case ready-mixed concrete, reinforcement steel in form of steel bars and/or steel mats. In addition, further components could be added i.e. components for electric facilities. Before analysing each working step, the execution procedure must be specified. The erection of the wall could be done in in-situ concrete, with semi precast elements with subsequent in-situ concrete filling or the entire wall could be precast. This decision determines the layout of the construction site installations, but also the structural planning. The chosen construction method often depends on project-based boundary conditions, but also on the construction company's know-how. At this stage, the BIM technologies advantages come really into their own. Due to the cloud based networking capacities between specialised planners concerned by the project, the structural engineer can respond promptly to the needs of the other project-related parties and their requests. Necessary information could be instantaneously shared and the model updated with the required modifications.

The analysis of the production chains the key of this method and will be illustrated through the example of a concrete wall. The chosen construction method is in-situ concrete and the production steps are explained in Table 2.1.

Table 2.1 – Production steps of a wall section [M. Schäfer]

Step	1	2	3	4	5	6
Description	**Geometry setting, measuring**	**Placing and adjusting one formwork panel,**	**Placing reinforcement, recess, installations (i.e. electricity) and quality check (geometry + reinforcement)**	**Closing the formwork, formwork anchors, quality check (formwork)**	**Concreting**	**Stripping the formwork, curing of concrete**
						
Human Resource	foreman	form worker, concrete worker	steel fixer, electrician	form worker	concrete worker	concrete worker
Production Accessories	drawings	formwork	recesses	formwork, threader rods	internal vibrator	various
Material Resources	-	-	reinforcement steel bars / welded meshes	-	concrete	-
Crane Use	no	yes	partly	yes	yes	yes

The operation steps show that the successful production of the final product, in this case the concrete wall segment, depends on diverse resources:

- personnel deployment, their qualifications and the number of workers on the site
- production accessories, these include material and machines which are needed for the production process
- raw materials, essentially ready-mixed concrete and reinforcement steel.

It is also apparent that in almost every operation step the tower crane is needed. The construction tower crane is also the crucial machine on a construction site and has the key role in the construction progress. The tower crane has the same significance on a construction site as a robot in the industrial production, for example in the automotive industry. To achieve the optimum in construction progress, the tower crane must be used to the full capacity, this means the crane should turn and work the whole day. If the crane runs without noteworthy interruptions, it will let the workers in the area underneath the crane having their maximal working progress speed.

In the industry, the time a machine needs to produce one unit of production must be determined. For a tower crane on a construction site, every single operation step and their respective operating time must be identified. Figure 2.16 illustrates the needed operation steps of a tower crane to produce a reinforced concrete wall.

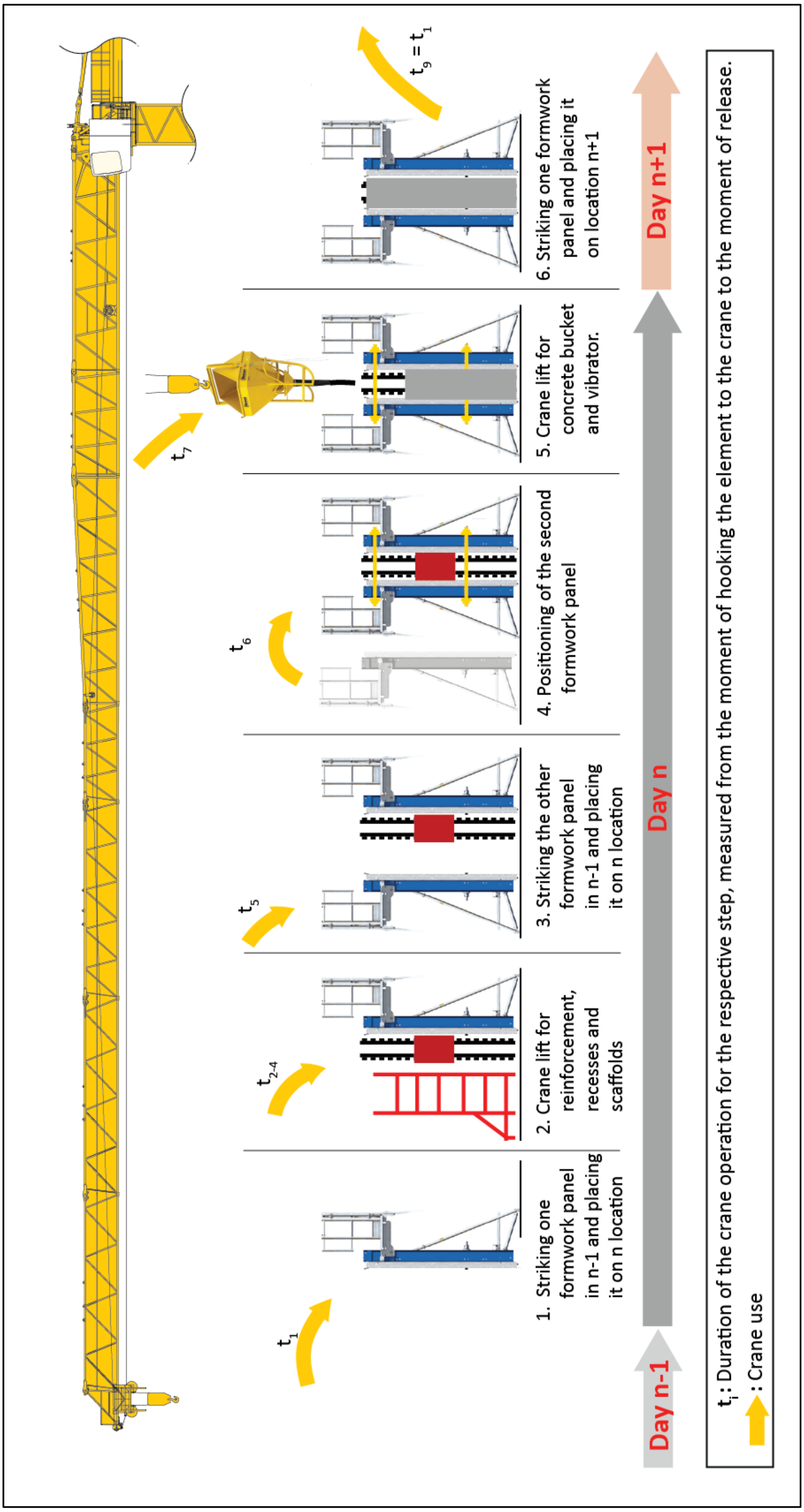


Figure 2.16 – Crane use in the production of a wall section [M. Schäfer]

Crane operating times (or cycles) can be determined for every single operation step, from attaching the chains to the hook to the detaching step. These times are obtained by empirical measurements or by means of methods-time measurements.

Afterwards, every single crane operating time of a floor or an area can be added. From the sum results the production time of, for example, a floor. The quantities (running meter concrete wall, square meter slab area, number of beams, number of columns, etc.) divided by the crane operating times results in the daily work rate.

In conclusion, the working steps' analysis delivers the needed tower crane's operation cycle to build the final element. This will allow to plan the construction site installation, to do the construction schedule and to estimate the needed human and material resources. This data can also carry the calculation of project costs and the planning of the work-preparation phase.

2.4.3 Crane time measurements

In order to give crane times to every operation steps, the data must be available. In France, where this methodology is to some extend known and partly applied, large construction companies have their own crane times' databases. As said before, the crane times are obtained by empirical measurements or by means of methods-time measurements. Usually, the companies using this methodology, send men on their construction sites to collect the data. Their task is to time the occupation of the crane by each single task.

Figure 2.17 is a picture of a table containing time measurements taken on a construction site during the preparation of this master's thesis. These times were taken on the construction site of the administrative buildings located in the new intermodal terminal in Bettembourg, Luxembourg. After analysed, this data was also used for this project.

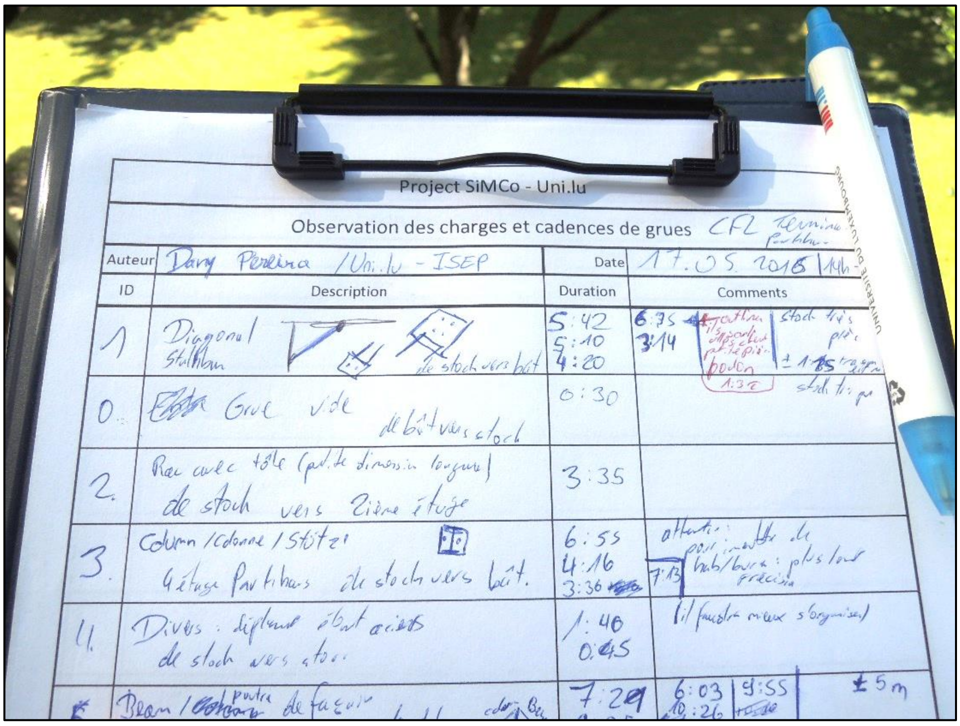


Figure 2.17 - Example of crane cycles timed on a construction site

The data is then collected and analysed. The final result is an average crane cycle for different types of elements. Table 2.2 illustrates a typical table with the crane cycles for producing one in-situ concrete column.

Table 2.2 – Crane Cycles for producing one in-situ concrete column

COLUMNS IN-SITU	
Rectangular columns; h < 6,0m	
Nature of the task	Duration of a crane cycle [min]
- Formwork mounting and unmounting	6,00
- Reinforcement Supply	5,50
- Setting up of the Reinforcement	5,00
- Various Handling	3,50
- Concreting of the columns	8,50

These databases are different from company to company, vary from region to region, took years to be completed, and need to be updated regularly.

Many of the data used in this master's thesis is from Dr.-Ing. M. Schäfer's database, which was collected on Luxembourgish construction sites, as well as from experiences and feed-backs of construction site managers.

3 CASE STUDY

3.1 INTRODUCTION

The case study for the thesis is an office building issued out of the ArcelorMittal's project SiMCo (see Figure 3.1). The task given to the University of Luxembourg, as well as the main aim of this thesis, was to study site methodologies for the given office building. This embeds the elaboration of the structural work's schedule, the calculation of the needed workers on site for the structural work, and the study of the site traffic. Six different constructive options should be studied and compared. At the end, a BIM 4D-model for each variant should also be created.

Figure 3.1 – Logo of ArcelorMittal and project SiMCo

3.2 GENERAL PRESENTATION OF THE SIMCO PROJECT

The Steel in Modern Construction (abr. SiMCo) project was started by Luxembourg-based multinational steel manufacturing cooperation ArcelorMittal in 2015. The aim of the project is to promote High Added Value (HAV) steel products from ArcelorMittal. The goal is to create a methodology that allows the comparison between functionally equivalent[1] buildings built with HAV products and those constructed with competitive products and materials like precast concrete.

In order to carry out the project, a case study office building was designed in different construction options to make possible the comparison between HAV products and other competitive ones.

At the end, the project's results will allow to highlight existing advantages and disadvantages of ArcelorMittal HAV products and solutions.

[1] EN 15978: Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method

3.3 THE CASE STUDY OFFICE BUILDING

In order to define the functional equivalent office building an external partner, TBC Innovations (France), was asked to survey office buildings from three to eight floors tall constructed across Europe.

The overall objectives of the survey were to define the typical office building configuration for each previous established European geographic zone (Western Europe, Southern Europe and Northern Europe), define the performances and technical solutions used for these typical office buildings, and evaluate the trends for future office buildings at horizon 2018-2020.

The 2020 office building was designed based on the results and conclusions of the report.

Based on the results and conclusions of the survey, the 2020 office building was designed and its characteristics and technical solutions defined in order to reach the required performances. The study based office building designed for the project is a building in L-shape. It has 9 upper floors and 2 underground floors and each wing of the building has a length of approximately 80 meter and a width of 13 meter. The geographical location selected is a high-density urban area in Luxembourg. Figure 3.2 shows a 3D-model of the office building.

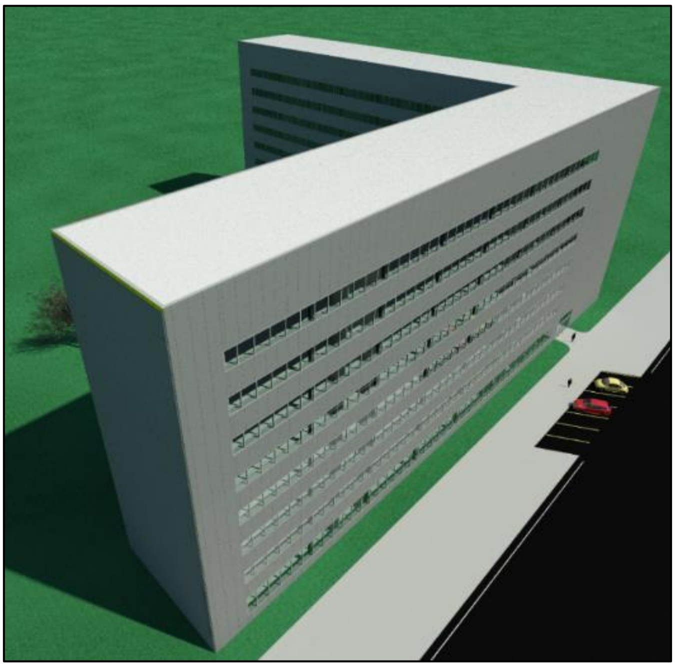


Figure 3.2 – 3D-model of the case study office building

The offices are spread along 8 floors on a total of 11000 m². In accordance with TBC recommendations, the number of users of the office building is defined as 1036. The last floor of the building houses the whole technical equipment and building services. A parking area can be found in the two floors under the ground-level.

For the case study building, construction options using different construction materials and different products have been defined and designed. The building is divided in following parts: earthworks, foundations, infrastructure, structure (including framing and flooring), roofing, facades, internal partitions and technical systems.

Two types of layout design for the office building were proposed, type A and type B (Figure 3.3 and Figure 2.5 resp.).

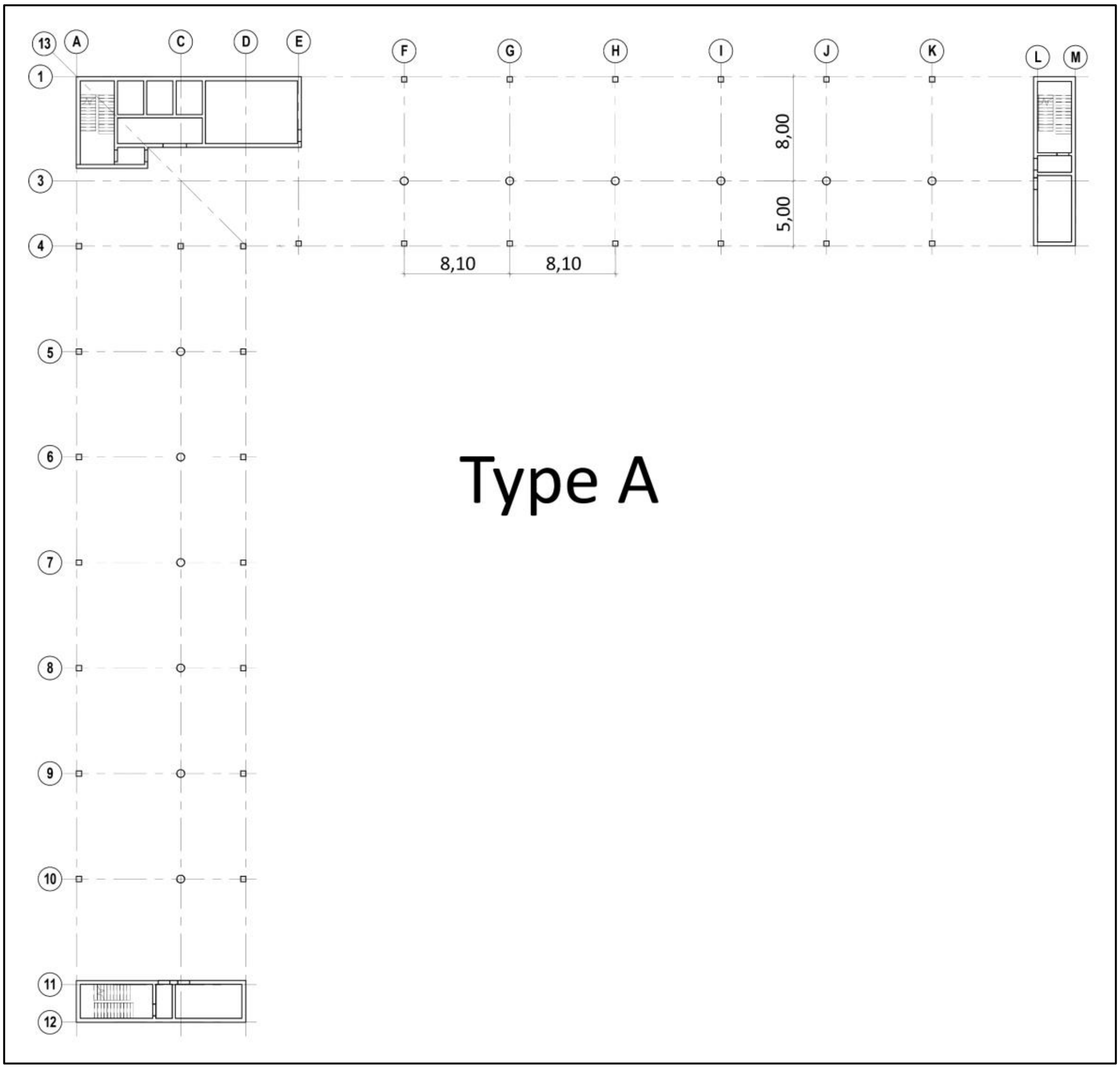


Figure 3.3 – Layout design type A

Type A design includes in the middle of the offices a column. The span lengths are 8 meters and 5 meters respectively. The columns are spaced of 8,10 m. This spacing is conditioned by the façade modules of 1,35 m. The rectangle of 8,10 m x (8+5) m will be called during the whole project as block.

Type B design doesn't foresee a column in the middle of the offices. The dimensions are the same than in the Type A design, but without the middle column, the span length is of approximately 13 m.

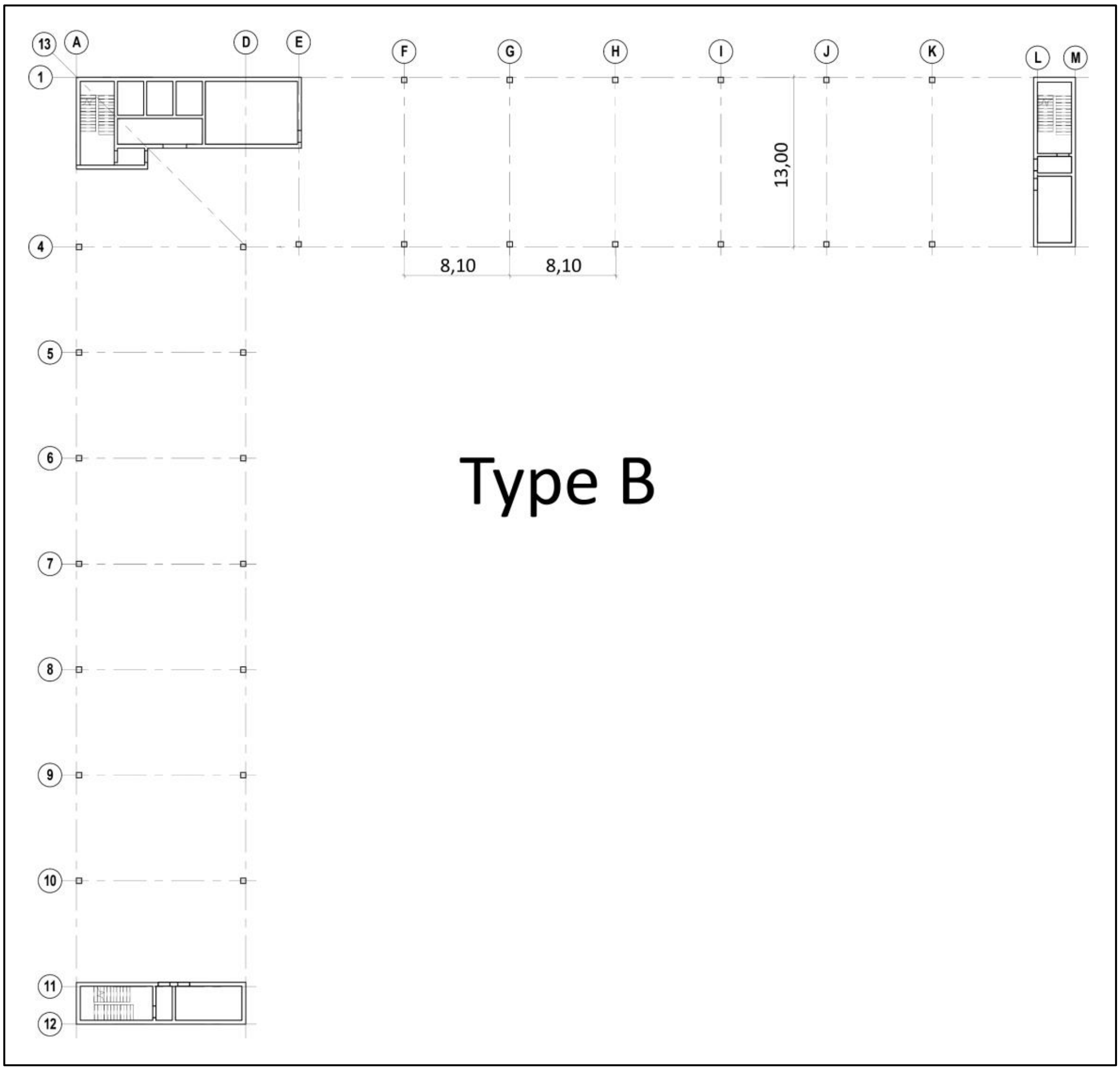


Figure 3.4 – Layout design type B

For each layout design type there are 3 different constructive options: concrete, steel and ArcelorMittal HAV solutions. The materials for the construction options were chosen among the 4 more used structural materials pointed out by the TBC report. In Table 3.1 and Table 3.2 these options are summarised and, the framing and flooring are briefly described.

Table 3.1 - Constructive options brief summary (1/2)

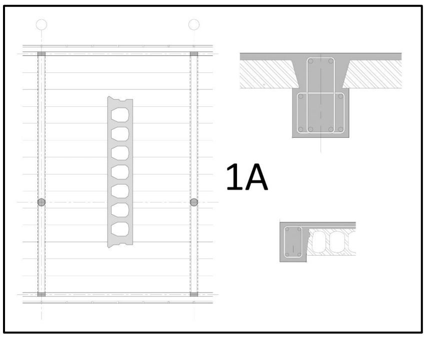
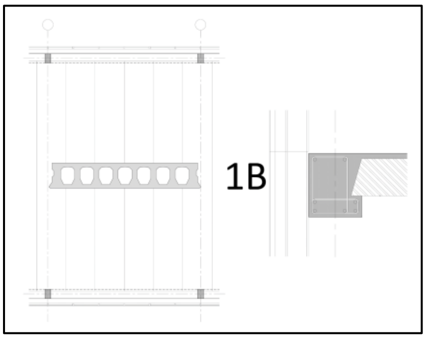
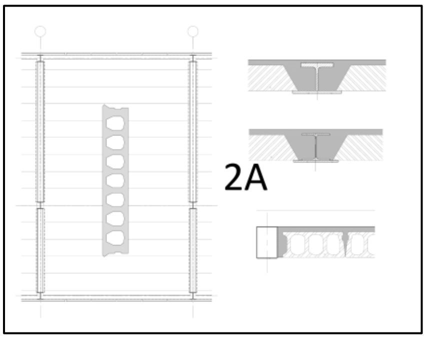
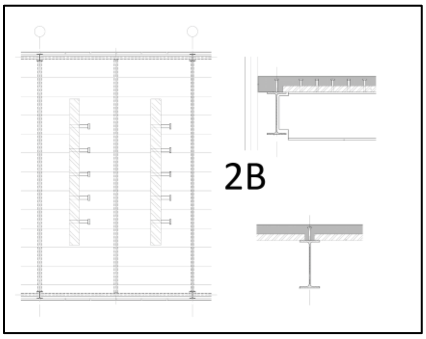
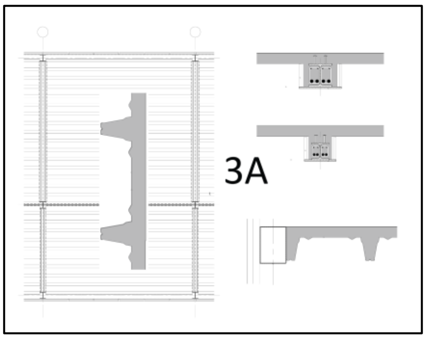
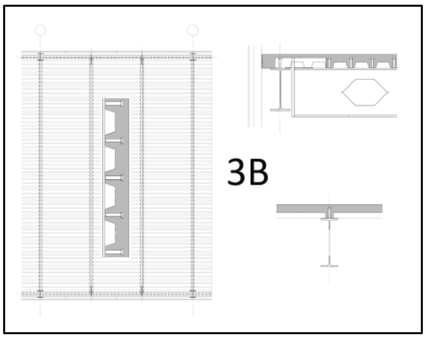
Number	Constructive Option	
Variant 1A		Precast Concrete Precast Columns Precast Beams Hollow-Core Slab
Variant 1B		Precast Concrete Precast Columns Precast Beams Hollow-Core Slab
Variant 2A		Steel Frame Steel Columns Steel Beams Hollow-Core Slab
Variant 2B		Steel Frame Steel Columns Steel Beams Semi-Precast Elements Slab

Table 3.2 - Constructive options brief summary (2/2)

Number	Constructive Option	
Variant 3A		Steel Frame Steel Columns Steel Beams CofraPlus 220 Composite Floor System
Variant 3B		Steel Frame Steel Columns Steel Beams CofraPlus 60 Composite Floor System

All the requirements for the design were in accordance with the Eurocodes and with legislations in Luxembourg. The complete detailed drawings of each variant can be found in Appendix I.

The cores of the building for each variant are made of reinforced in-situ concrete. For all options, the same concrete core geometry has been taken into account in order to allow fair comparison between all options. The drawings in Figure 3.5 show the geometry of the three concrete cores.

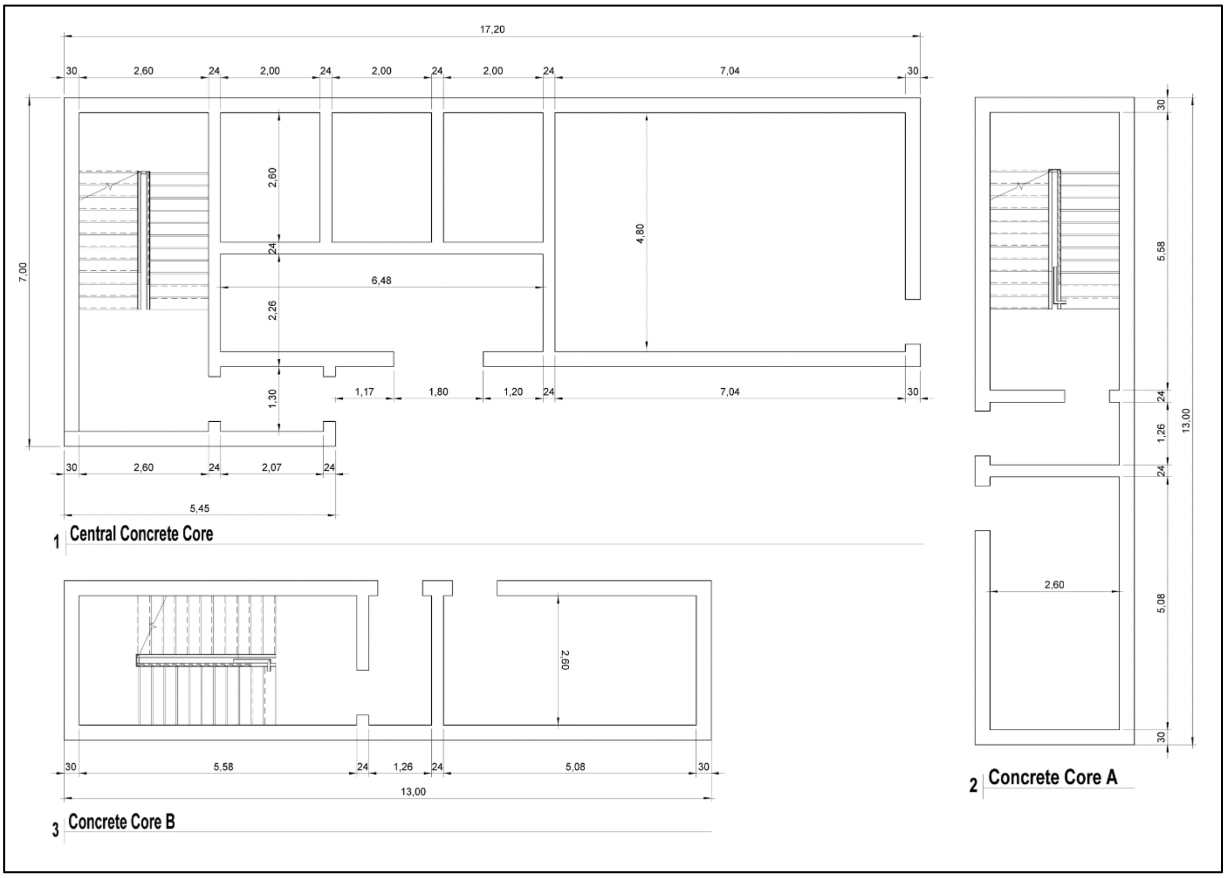


Figure 3.5 – Concrete cores designs of the case study office building

Each variant has its own 3D-BIM model in Autodesk Revit format. The models for the variants 1A, 1B, 3A and 3B were created by Arcadis Belgium SA. The review of these models and the creation of the models for variant 2A and 2B were carry out by Schroeder & Associés, Luxembourg.

3.4 CONSTRUCTION SCHEDULE

One of the tasks asked by ArcelorMittal was to calculate and optimise the schedule for the superstructure of each constructive option. The aim was to optimise to a maximum the planning. To achieve it, the traditional planning method base on unit prices was not used; instead the hypothesis taken was to plan the works for the superstructure through the crane maximum efficiency, the method explained in the previous chapter. Each party involved in the project agreed to use this methodology.

For the calculation of the crane's occupancy, an Excel VBA program called ChaCAD was used. This program was developed a few years ago by Dr.-Ing. Markus Schäfer. In his former job as technical director for an international general contractor, he was responsible for tender, methodologies and work site preparation as well as for the development of alternative and special structural solutions and was introduced and formed to this innovative planning method and gained practical experience by the application of it. The development of Excel program ChaCAD to calculate the needed crane operations and cycles is based on an included database of crane cycles and a predefined take-off of realized projects and the experience of Vinci and CFE group. Still in a beta version, the Excel VBA program was elected for the final innovation price at Vinci Construction in year 2010. For the project SiMCo, it was suggested to use the Excel VBA program ChaCAD in order to calculate the duration of the superstructure construction. The in 2009 developed Excel VBA program had to be updated for this project.

Before beginning the planning calculation, quantity take-offs must be done for each variant. With a 3D information model available, this task was done pretty fast. With only a few clicks in Revit, quantity take-offs sorted by element type and floor were done and then exported to Excel.

In order to ensure that the data exporter from Revit to Excel was correct, manually quantity take-offs were done for some variants and later compared with Revit's data. To perform the manually quantity take-offs, each element must be identified first. Figure 3.6 exemplifies the identification process for Variant 2B.

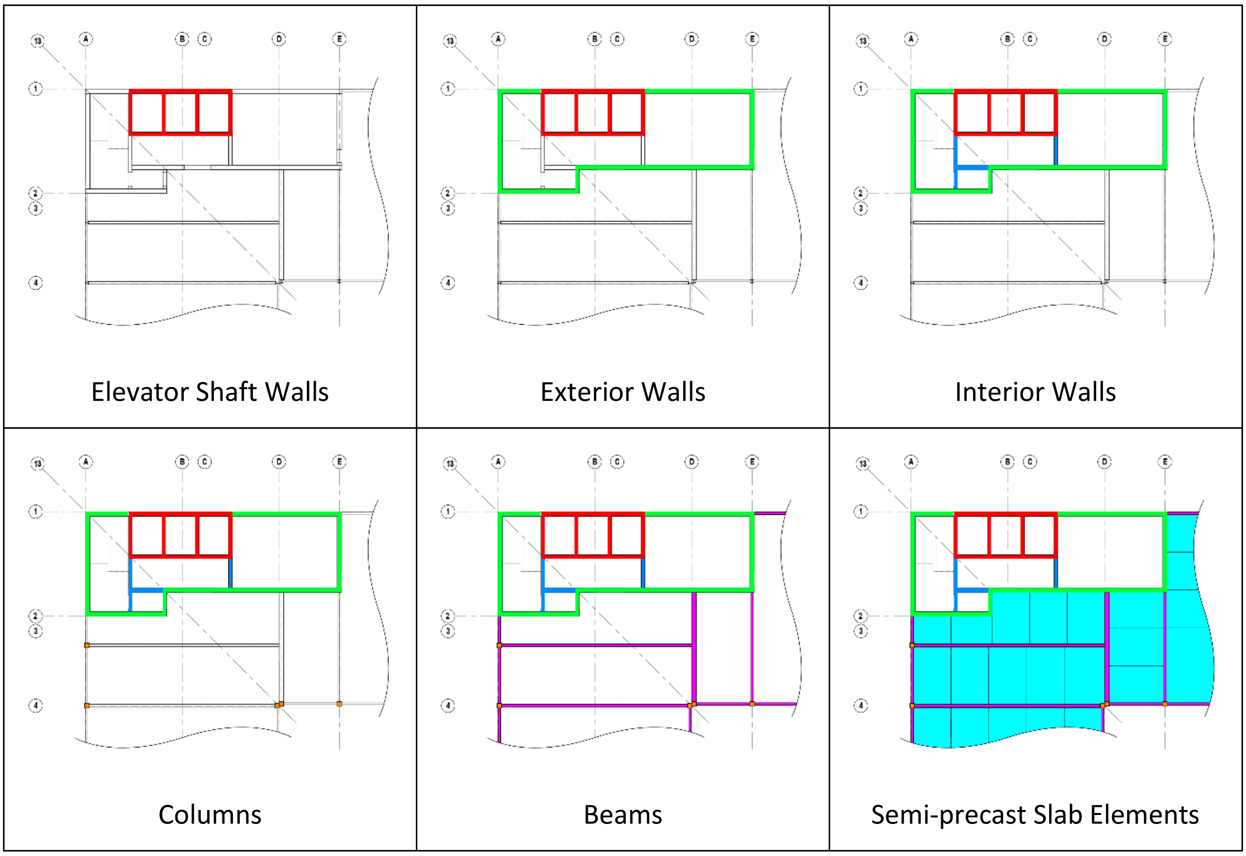


Figure 3.6 – Element identification (Variant 2B)

The characteristics of every wall types identified in the concrete cores can be found in Table 3.3 and Table 3.4.

Table 3.3 – Wall type and characteristics (1/2)

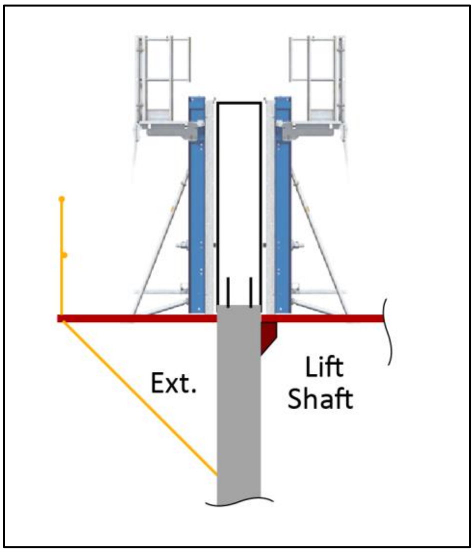
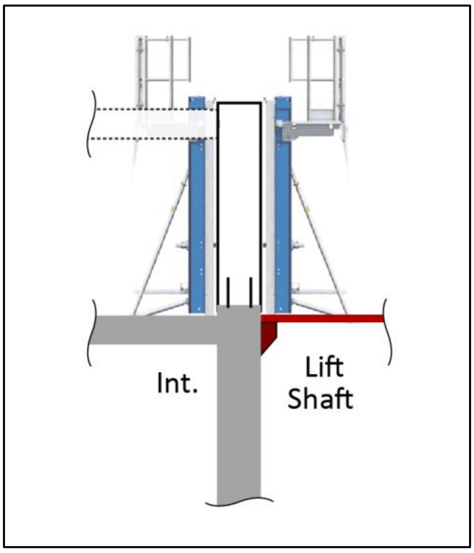
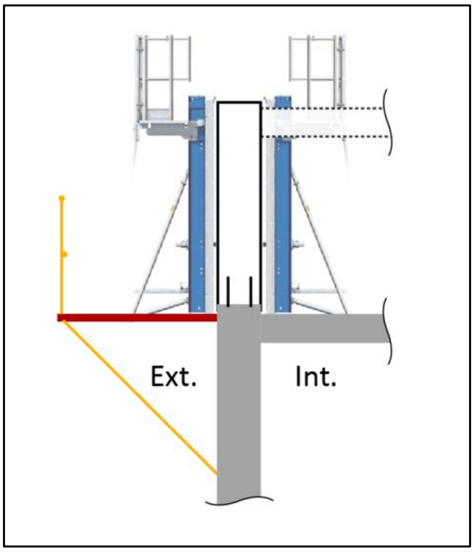
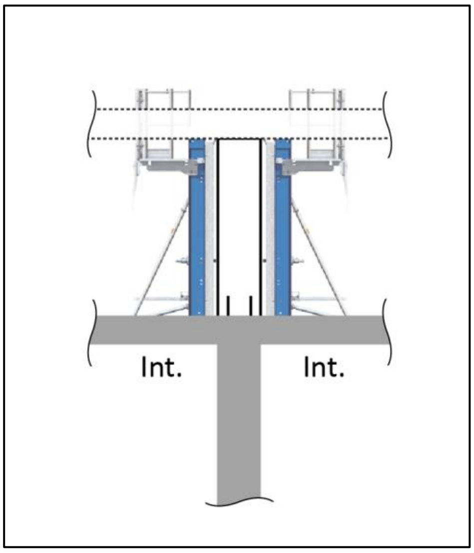
Wall Type	Characteristics	Illustration
Elevator shaft walls	Wall thickness: 30-24 cm Special Formwork Formwork height: Floor height + 5 cm above the upper floor slab level Use of a security platform inside the elevator's shaft Use of a security platform on the exterior walls	 
Exterior walls	Wall thickness: 30 cm Normal metallic formwork Formwork height: Floor height + 5 cm above the upper floor slab level Use of a security platform on the exterior walls Special recess for corbel concreting (see Figure 4.3)	

Table 3.4 – Wall type and characteristics (2/2)

Wall Type	**Characteristics**	**Illustration**
Interior walls	Wall thickness: 24 cm Normal metallic formwork Formwork height: height from the surface of the floor to the bottom of slab	

After identification of the elements, quantity take-offs sorted by the elements identified and by floor was done.

The comparison between the automatic quantity take-offs exported from Revit to Excel and the manual done quantity take-offs have not shown any significant deviation.

Henceforth, the example that will be presented to explain the calculation of the crane efficiency is the erection of the concrete cores. In fact, our hypothesis was that for all the variants (expected 1A with one crane and 1B with one crane) the concrete cores will be built apart from the rest of the structure. In the morning shift (8h) the cores will be erected, and in the afternoon shift (8h) the framing and flooring will be build. This means that the time needed to build the concrete cores is always the same for all the variants because the geometry is equal in every variant. The only factor that can change the duration is the number of cranes used to build the core.

The next step after the element identification process is to input the quantity take-offs of one floor into the developed Excel for crane efficiency calculation. Then, each item of the quantity take-off needs to be connected to the right crane cycle defined in the database which is presented in the Excel program. For that purpose, each item is given a “family” number. In the database, a family matches a type of element and contains the needed production steps on construction site and its related crane cycle for the erection of the respective element.

Table 3.5 exemplifies the family number 13 “exterior concrete wall” taken from the calculation of the 1st floor of the concrete cores.

Table 3.5 – Example of a family element, here: exterior concrete wall, family n° 13

13	Family Element							
	13 EXTERIOR CONCRETE WALL	u	LM	m²	m³	u (recess)	Operations	
	Wall: h<4,0m | thk = 0,24 - 0,35m	-	110,16	360,68	28,99	6,00	/	x
	Crane operation	Duration of cycle	Number of cycle	Total	Hypothesis			
	- Strip, shuttering 2 wall faces	8,50	62	527,00	Panels from 2,4 to 4,8 m		3,6	2,0
	- Supply reinforcement steel	6,50	3	19,50	110kg steel/m3, 1,5to/crane-cycle		1500	110,0
	- Divers handling	4,50	14	63,00	approx. 3 crane loads per cycle		1,0	3,0
	- Reinforcement positioning	6,50	32	208,00	every 3,50mL one crane cycle		3,5	1,0
	- Concrete pouring	8,00	29	232,00	Concrete buckets: 1m3		1,0	1,0
	- Lift safety platforms	7,50	32	240,00	platform from 3 to 4 m length		3,5	1,0
	- Close the formwork panels	4,00	31	124,00			3,6	1,0
	- Recesses handling	5,00	6	30,00			1,0	1,0
	Concrete pouring with crane = 0 Concrete pouring with pump = 1	0	**minutes**	1443,5	**min/mL**	13,10		

As we can see in Table 3.5, the example taken, family number 13, includes all exterior walls with a height under 4 meters and a wall thickness between 0,24 and 0,35 meter. For the 1st floor, we have in total 110,16 linear meter of concrete wall, which is equivalent to 360,68 m² wall and a volume of 28,99 m³. The red numbers in the second row correspond to these totals. These quantities correspond to the exterior walls of the concrete cores. The number of recess for, in this case doors, are a total of 6. In the column "crane operation" are summarily described all needed crane operations for the realisation of an exterior concrete wall. In the next column is given to each step the appropriate cycle duration in minutes. This means that for example the "recesses handling" step fully occupies a crane during 5 minutes. The next column gives the number of cycles needed for the construction of this family of elements. As example for recesses handling, 6 crane cycles will be needed. This is the case because 6 recess need to place. Depending on the hypothesis taken, the number of needed crane cycles can increase or decrease. The hypotheses used in this family example are shortly described under the column "Hypothesis". Depending on the employed hypothesis for the execution and based on the individual experience of the company, the variable factors influencing the number of cycles are added in the two last yellow columns. One column is for multiplication and the other for division. They are pre-given, but a manually manipulation of them is possible.

In the case of the steel reinforcement supply for example, the hypothesises are 110 kg steel is needed per 1 m³ and that the crane can lift maximum 1,5 tons. This means that the 28,99 m³ of concrete should be multiplied by 110 kg steel/m³ and divide by 1500 kg/crane cycle. At the end, the result is 2,12 crane cycles, which rounded up equals 3 crane cycles. Not all numbers of crane cycles in this example are calculated from the volume to be build, but also from the linear meter. For example, the number of cycles needed to lift the security platforms is calculated from the linear meter. The hypothesis is that each platform has a length between 3 and 4 meters, so the division factor chosen can be the average of the both extremes, in this case 3,5m. The 110,16 LM will also be divided by 3,5 which results into 32 roundup crane cycles. No multiplication factor is needed for this steps, also 1,0 is added to the corresponding cell.

For the working step of "strip, shuttering 2 wall faces", the 110,16 LM wall will be divided by 3,6 because the hypothesis taken here is that for the long exterior walls, two 2,4-meter-lenght formwork panels will be placed together with one crane cycles, which corresponds to a wall length of 4,8 meter. For the smaller inner walls, only the 2,4-meter panels will be placed. The average of formwork length moved by crane is also 3,6 meters. The 110,16 LM wall will be multiplied by 2 in this step because the wall ass two faces which need to be strip and shuttered.

The total time that one step occupies the crane is then calculated by multiply the cycle's duration with the number of cycle needed. The grand total is afterwards calculated adding the totals of every step. The step of concrete pouring can be added or not to the grand total depending on the chosen methods. In the bottom left of the table, the concreting method can be chosen by simply writing 1 or 0. "0" means pouring concrete with a crane bucket, this means the crane needs to be used for the pouring step and "1" means pouring concrete with a pump, in this case the crane will not be used. But it's important to point up that the crane can only work simultaneously with the concrete pumping, if the pump boom doesn't interfere with the working area of the crane. In the example given before, the method of pouring concrete with a concrete bucket was chosen, so the step of concrete pouring will be added to the grand total, which in this case is 1443,5 minutes. This means, to build all walls of the 1st floor with the characterises of the family number 13, the crane will be occupied 1443,5 minutes. The ratio can then be calculated by dividing the grand total with the total linear meters. In the given example. It will take 13,10 minutes' crane time in average to build 1 meter of wall.

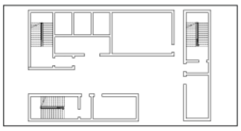
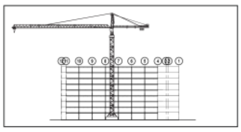
When the calculation of the total minutes for every family is done, the grand totals are added and the result is the time needed to build the 1st floor of the concrete cores of the 1st floor. This time is then converted and rounded up into days. In this case, and with a work day of 8 hours, 6 working days will be needed to build the concrete cores in one floor.

It must be emphasised that this values includes a safety factor. The application of a safety factor is necessary because the calculation based on crane times is based on the hypothesis that the crane turns and is actively working all the time, this means 60 minutes over one hour. Due to statistic variance of the crane times in the databases, the crane will not be active over all the time. Also workers underneath the crane cannot work effectively 60 minutes in 1 hour. The value of 15% was suggested by Dr.-Ing. Markus Schäfer, whose experience on the field confirms these circumstances and which imply a crane effectivity of 52,2 minutes over one hour. He also suggested to raise the factor to 20% if two or more tower cranes are placed on construction site, due to interferences between cranes.

At the end, every element presented in the quantity take-off can be divided by the amount of days needed to build the concrete cores. The results are ratios which give the daily quantities that should be build, in order to build the cores in 7 days.

Table 3.6 shows the final results for the construction of the 1st floor. It gives us the theoretical amount of work that should be done to successfully build the concrete cores of the 1st floor in 7 days. As example, for the concrete walls a daily rate of 20,677 linear meter per day should be achieved in order to succeed.

Table 3.6 – Crane efficiency calculation for the concrete cores – end results

uni.lu UNIVERSITÉ DU LUXEMBOURG – Markus Schäfer, Univ.-Doz. Dr.- Ing. – FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION		Project :	**Project SiMCo - Concrete Cores**				
		Work :	Concrete Cores				
		Floor :	1st Floor				
		Author :	Dany Pereira Figueiredo				
Crane Efficiency Calculation - RESULTS							
 							
Working day:		8	hrs/day	Security Applied :	15	%	
Crane on site:		1	**Expected construction duration :**		**7**	**days**	
ID	Description	Element Type	Work	Rate of Work			
		w, c, b, s, u, d	Days	u/d	LM/d	m²/d	m³/d
1	**Reinforced C. Walls**						
1.1	Ext. Walls	w	7	-	8,786	29,344	2,636
1.2	Interior Walls 0,24 cm	w	7	-	2,460	7,724	0,391
1.3	Int. Ext. Walls 0,30 cm	w	7	-	0,330	1,036	0,099
1.4	Lift Shaft Walls	w	7	-	2,480	8,283	0,330
1.5	Int. Wall with corbel	w	7	-	6,621	22,116	1,572
S	**TOTAL**		**7**	**-**	**20,677**	**68,504**	**5,028**
2	**Slabs**						
2.1	In-Situ Slab	s	7	-	-	15,918	3,184
S	**TOTAL**		**7**	**-**	**-**	**15,918**	**3,184**
3	**Stairs**						
3.1	Intermediate Landings	s	7	-	-	1,337	0,241
3.2	Precast Flights	u	7	0,857	-	-	-
S	**TOTAL**		**7**	**0,857**	**-**	**1,337**	**0,241**
4	**Various**						
4.1	Stabox	d					
4.2	Neopren Strips	d					
S	**TOTAL**						

Having this data, a daily production plan can be done. This plan shows the everyday production, in accordance to the results obtained through the crane efficiency calculation. Figure 3.7 illustrates the daily production plan of the concrete core walls with the usage of one tower crane.

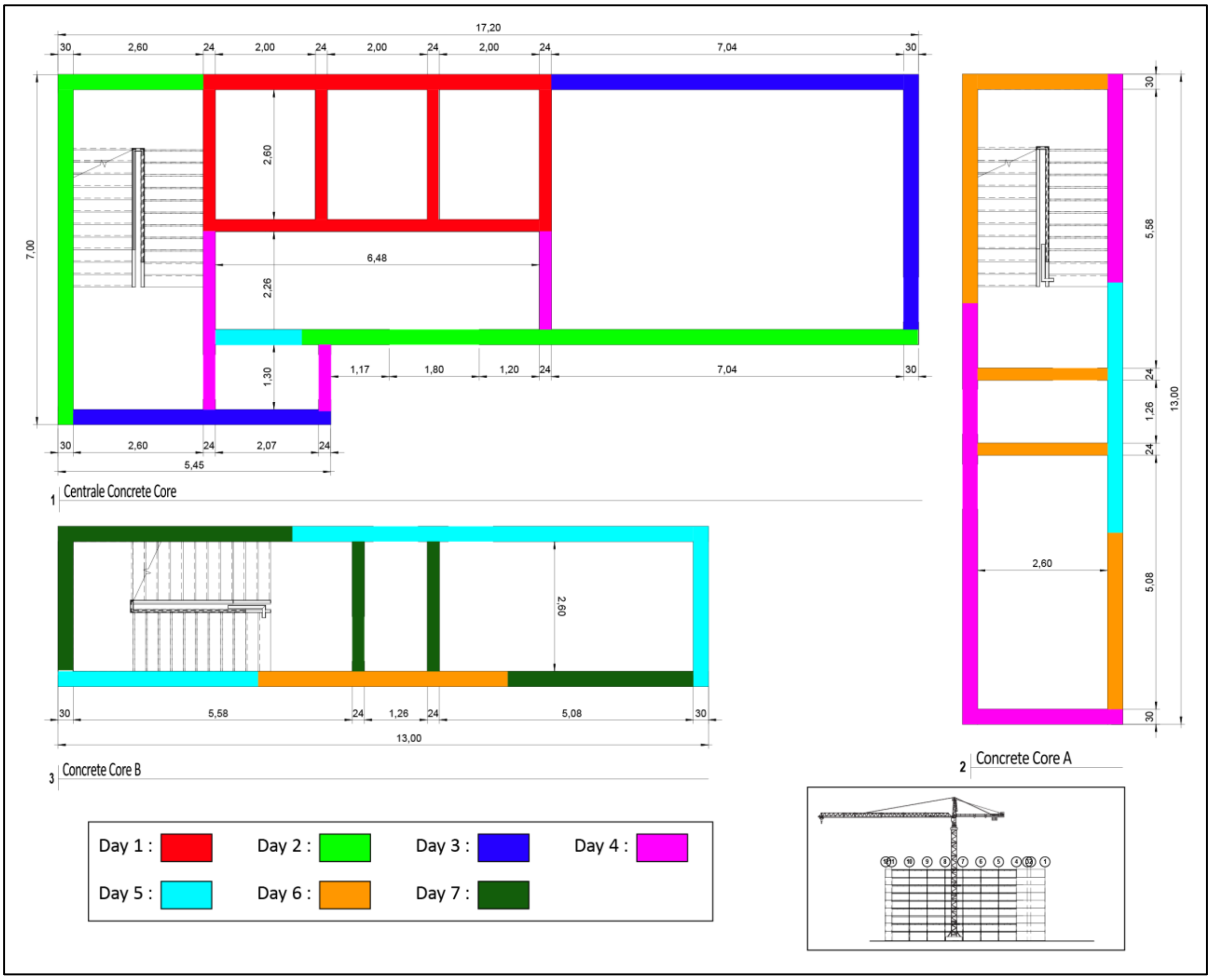


Figure 3.7 – Daily rotation plan of the concrete cores building, with the use of 1 crane

The aim of this planning is not only to ensure that the rate resulted of the crane efficiency calculation are respected, but also to optimise the process and use human and material resource, e.g. formwork panels. In the example shown on Figure 3.7, the hypothesis used is that the 3 lift shafts will be constructed in one day using special climbing formwork. It is also to notice that the building of concrete core A and B use the same formwork panels, in order to optimise the use of the panels. Also, during the whole construction process, only one corner framework panel is used. To achieve this optimum plan, a lot of tries were done.

If another crane is added to the construction site, the calculation of the crane efficiency results in 4 days to build the concrete cores. The quantity take-off taken into account for the calculation must be divided into two zones, one zone for crane number 1 and another for crane number 2. In the case of the concrete cores, there are various division possibilities and the hypothesis taken is that one crane only works for the main core and the other one for the two smaller cores. The resulting daily production plan is shown in Figure 3.8.

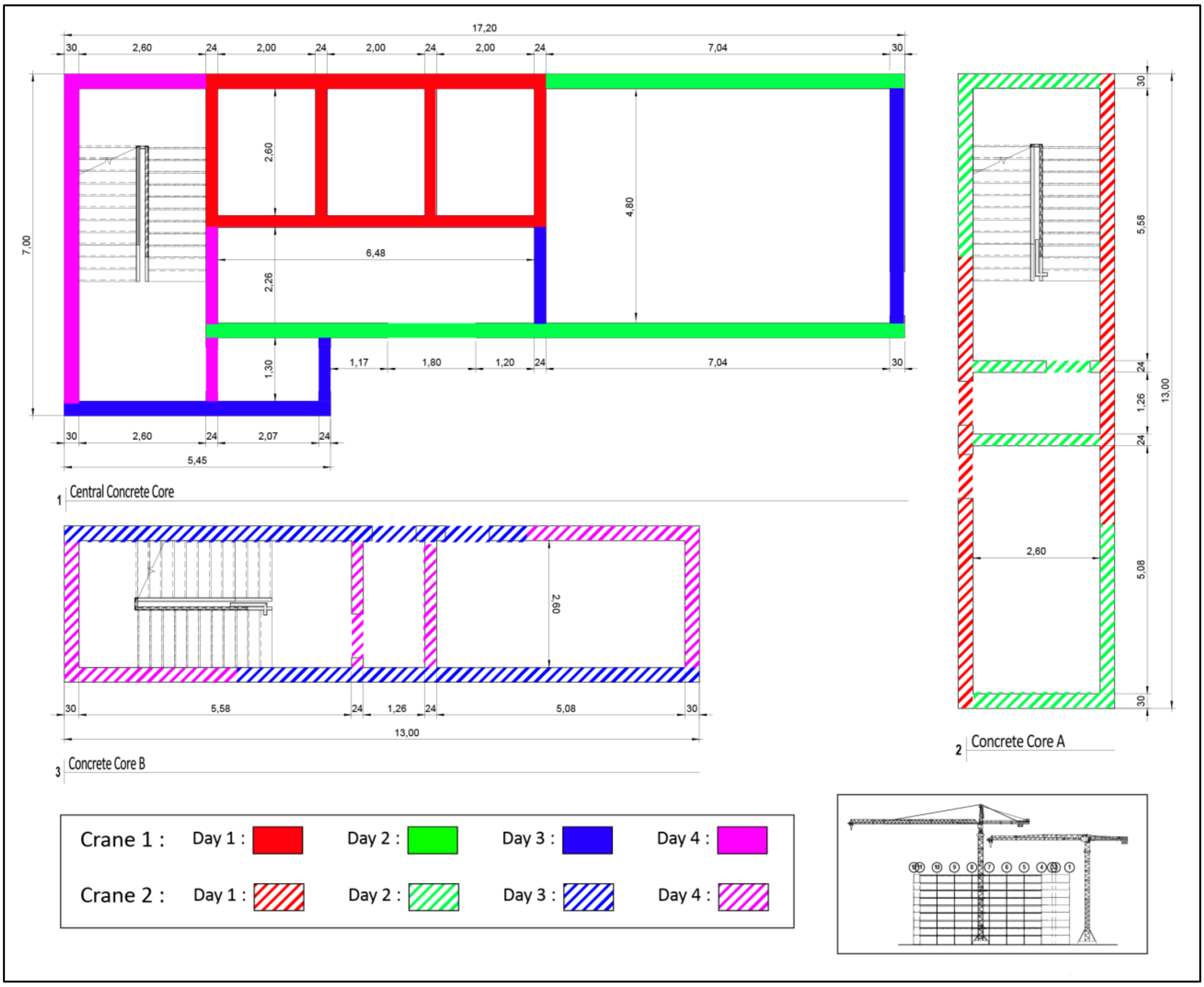


Figure 3.8 – Daily rotation plan of the concrete cores building, with the use of 2 cranes

As before, the aim was to optimise to a maximum the rotation of the formwork panels. The special formworks for the lift shafts were considered and the two smaller cores use the same formwork panels. The total time needed to build the entire concrete cores (Ground-floor to 8th floor) is 66 days using one crane and 47 using two cranes. In Appendix II a complete 2D-simulated floor construction progress, with one crane and with two cranes, of the concrete cores can be found, in which the construction progress of the slabs is also visible.

For every variant, the same procedure was done with the framing and flooring. As said before, the hypothesis taken is that the works will be done in 2 shifts of 8 hours. In the morning shift the concrete core are erected, and in the afternoon shift the framing and flooring are built. It’s important to mention that for variant 2A, 2B, 3A & 3B the framing and flooring is done simultaneously on 2 floors, because the columns in the steel framing are 2 levels height, except in the last floor were columns are only 1 floor height. So for these variants, the quantity take-offs for the crane efficiency calculation are always of 2 floors, expect for the last floor (Ground-floor + 1st floor; 2nd floor + 3rd floor; 4th floor + 5th floor; 6th floor + 7th floor; 8th floor). Moreover, all variants were analysed having 1 tower crane on site or 2 tower cranes, except variant 2A, 2B and 3A. The analyses of variant 1A and 1B with one crane were just done with one shift of 8 hours, this means the erection of the concrete core and the building of the framing and flooring are done simultaneously. Additionally, another hypothesis was studied for variant 3B, where in the morning shift 2 cranes are active for the core's erection and in the afternoon shift only one is active for framing and flooring. Table 3.7 summarises all the analysed cases.

Table 3.7 – Analysed cases

Variant	Cranes on Site	Construction Method		Shift	
		Concrete Cores	Floors	Morning (8h)	Afternoon (8h)
1a	1	In-Situ Concrete	Precast Structure + Hollow-Core Slab	Core + Floor simultaneously	
1a	2	In-Situ Concrete	Precast Structure + Hollow-Core Slab	Core	Frame + Floor
1b	1	In-Situ Concrete	Precast Structure + Hollow-Core Slab	Core + Floor simultaneously	
1b	2	In-Situ Concrete	Precast Structure + Hollow-Core Slab	Core	Frame + Floor
2a	1	In-Situ Concrete	Steel Structure + Hollow-Core Slab	Core	(Frame + Floor)*
2b	1	In-Situ Concrete	Steel Structure + Semi-Precast Elements Slab	Core	(Frame + Floor)*
3a	1	In-Situ Concrete	Steel Structure + CofraPlus 220 Composite Slab	Core	(Frame + Floor)*
3b	1	In-Situ Concrete	Steel Structure + CofraPlus 60 Composite Slab	Core	(Frame + Floor)*
3b	2	In-Situ Concrete	Steel Structure + CofraPlus 60 Composite Slab	Core	(Frame + Floor)*
3b	2+1**	In-Situ Concrete	Steel Structure + CofraPlus 60 Composite Slab	Core	(Frame + Floor)*

* erecting 2 floors simultaneously
** 2 cranes working on the concrete cores (morning shift) & 1 crane working on the steel frame and CofraPlus 60 composite slab (afternoon shift)

During the planning of the construction, a 4D-BIM simulation was also done to confirm the hypothesis employed for the planning. For example, the framing and flooring cannot be done simultaneously on the same levels as the erection of the cores. In fact, because of the security platforms for workers, the erection of the core must be minimum 2 levels higher than the framing/flooring building. On a daily work 2D-simulation like Figure 3.8, one cannot see clearly the link between core and framing/flooring, but using a 4D-BIM simulation one can see clearly the evolution of the building, and adapted the construction program to the boundaries condition imposed. Also, having a 4D-BIM simulation allows one to easily compare various variants and so chose the better one.

The 4D-BIM simulations were done in Autodesk software Navisworks, using therefore the Revit 3D-model and the planning in MS Project.

At the end and for each case studied, the results of the planning are represented in Gantt Charts. It is important to point out that a security factor for natural hazards caused by weather wasn't included in the tasks themselves. Instead, another approach was applied, where the safety factor for weather hazards is added as an own task at the end of the Gantt Chart. This safety factor is different from the one earlier stated in this chapter. Figure 3.9 represents a Gantt Chart that will help to understand this approach.

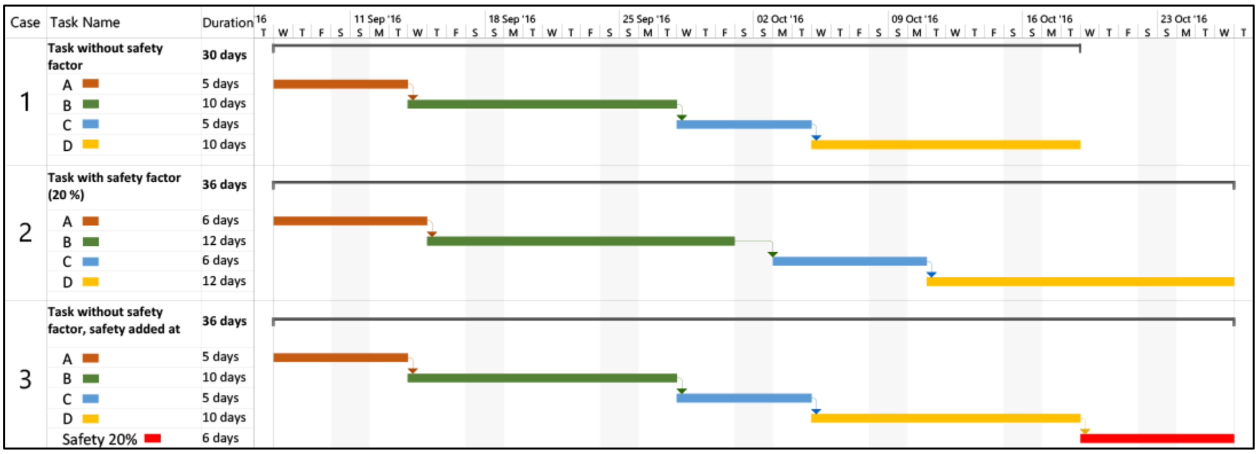


Figure 3.9 – Gantt chart for the explanation of the safety factor approach used

The safety factor for weather hazards varies from company to company and depend of the risk of the project and the season in which it will be built. For example, if the projects will be executed in winter, the safety factor will be higher than in summer. Normally, construction companies (in Luxembourg) give to their clients and subcontractors a construction schedule similar to the case 2 in Figure 3.9, where a safety factor is included in every tasks. This leads to the stretching of every task and if they are linked together, the start time of every task will be delayed. The problem with this approach is when no hazards delayed the project. If this is the case, the schedule given to clients and subcontractors will not correspond to the existing situation on the site, but it will probably resemble to the schedule without safety factor (case 1). This can lead to problems with the logistic on site and resource management. Example: The subcontractor who is in charge of delivering elements for task C has the schedule case 2; this means that according to the schedule he has, he needs to deliver the elements on Monday the 3rd of October; but on the construction site no hazard caused disruption to the good progression of the work, this means task C will begin Wednesday the 28th of September; the problem is that the subcontractor hasn't the elements ready for the date on which task C will begin, because according to his schedule the task will begin 3 workdays later. In conclusion, the approach used in case 2 can lead to unnecessary delays and leading to a standstill on the construction site.

Using the approach of case 3 is the best solution to prevent such problems on site. It gives the client and subcontractor the necessary information, and the safety task added at the end shows the possible final delay that the project can have. Also it leads to an open and visible relation to the client.

All the different analyses and subsequent results will be explained in chapter 4.

3.5 WORKERS ON SITE

After planning the whole structural works for each variant and analysed hypothesis, the number of workers needed on site was calculated. This process was done based on Dr.-Ing. Markus Schäfer's experience and using the resource function in MS Project. The result at the end are graphics representing the evolution of the workers during the works. Each variant and case analysed has its own graphic which can then be compared to one other. In the next chapter, they will be shown and explained.

In every work shift and beside the workers needed to construct the concrete cores and the remaining structure, a traffic assistant, a storekeeper and a crane operator for each crane active on the respective shift were also considered. Workers in the site facilities, e.g. foremen or engineers, were not taken into account.

3.6 TRUCK FLOW ON SITE

After planning the whole structural works for each variant and analysed hypothesis, the number of trucks needed to transport concrete and elements necessary for the building can be calculated. This calculation is based on the number of elements and volume of concrete needed each day, determined from the work schedule planning. The maximal capacity and the dimension of a standard truck in Luxembourg were also taken into account. For the concrete mixer trucks, a capacity of 9 cubic meters was considered.

The daily quantities of concrete and other elements, such as steel elements or precast elements, were calculated using the end results of the planning and 4D-simulation. An Excel was created for this calculation, were the inputs were the daily quantities and the outputs the needed trucks. Graphics showing the number and type of trucks each day on site can then be created. As stated in the previous subchapter, each variant and case analysed have their own graphics which then can be compared to one another. In the next chapter they will be shown and explained.

For all analysis, no temporary storage of the building elements, such as precast elements, steel elements or floor elements, was considered. This means that all elements brought by truck will be directly put in their right place, and that the elements will not be temporary stocks anywhere on the construction site.

3.7 SOFTWARE USE

Several software were used to carry this thesis to a successful conclusion. Revit was the start point of every variant analyse. With Revit, quantity take offs and 2D drawings of each variant were provided as inputs for ChaCAD program, respectively CoralDRAW software. In ChaCAD the construction rates were calculated as explained in Chapter 2.4.2, using therefore update crane cycles' databases. The construction rates were used as references for the creation of the 2D construction progress simulation in vector graphic editor CoralDRAW. This software was also used for the elaboration of several detailed illustrations. Based on the 2D construction progress simulations, Gantt Chart schedules were elaborated in MS Project. The human resource management was also done in MS Project. The 3D-model taken from Revit and the resulting Gantt Chart from MS Project were used as inputs in Navisworks for the creation of a 4D-model and the development of a 4D-visualsation. The visualisation of the construction progress in 3D provided a better understanding of the construction progress and the linking between concrete cores and the remaining structure. This perception was used to optimise, if needed, the Gantt Chart in MS Project. Due to the linkage between MS Project and Navisworks, the 4D model was automatically updated if the schedule in MS Project was subjected to modifications.

Unfortunately, it's not possible to extract from Navisworks the daily quantity of elements constructed. Therefore, to calculate the daily truck flow on construction site, Excel was used and the daily constructed elements based on the 4D-model were manually input into the spreadsheets. The calculation of the required daily number of trucks on site was based considering the approaches stated in Chapter 3.6. Excel was also used to elaborated workforces' graphics for each case analysed, because it is not possible to do it with MS Project.

Figure 3.10 gives an overview about the software used, their inputs and outputs and the link between software.

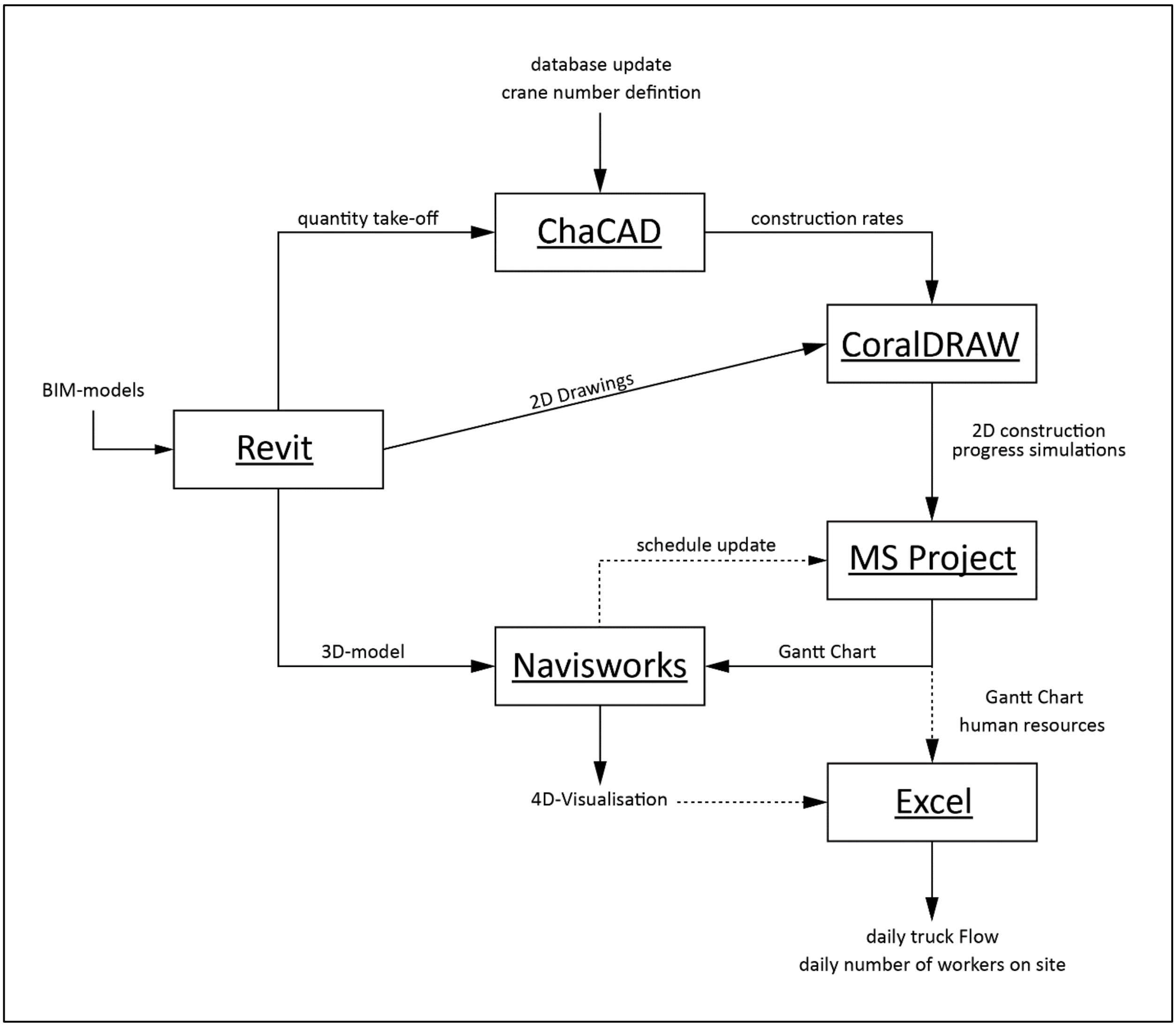


Figure 3.10 – Software use in this master's thesis, input and outputs and link between them

4 RESULTS

4.1 INTRODUCTION

In this chapter, the results of each variant and case studied will be shown and explained as far as possible. Due to the big Gantt chart resulting from the studies, these will be presented as appendices. Graphics showing the number of workers and of trucks during the construction time will also be shown. Each variant and case studies will then be compared to each other. Due to special requirement from ArcelorMittal, a better analysis between variant 1A and 3B, each with 2 tower cranes, will be done. At the end, a site installations plan of variant 3B will be shown and explained.

4.2 VARIANT 1A

Variant 1A (Figure 4.1) is, along with 1B, the constructive option which includes precast elements; precast columns and beams for the framing and precast hollow-core elements for the flooring. The task of planning the work schedule also includes the thinking about how the building will be erected, how the connections between framing/flooring and the cores will be made, etc.

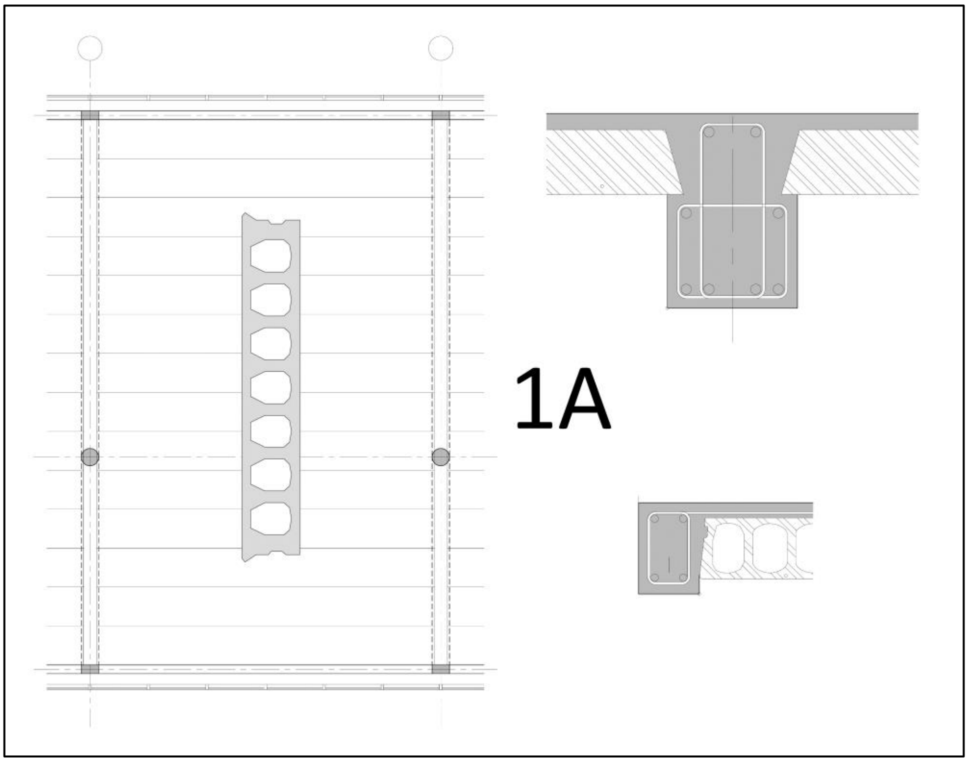


Figure 4.1 – Variant 1A

For the connection between the precast beams and the hollow-core elements with the concrete core, several suggestions were analysed. One was to simply put the elements directly on the walls; the other to use a corbel. The second was chosen, due to static issues with the concrete cores concerning the first suggestion How to erect the walls with a corbel was another question. One idea was to concrete the corbel after erecting the wall, using therefore a rebend connection system, i.e. Stabox® (see Figure 4.2), to ensure a strong anchorage of the corbel with the wall. Another option was to concrete the wall and the corbel in simultaneously, using therefore a special recess. The second option, being the fastest one, was therefore chosen. The special recess can be reemployed every time there is a corbel to be concrete. Figure 4.3 illustrates the building option chosen, where the grey shape represents the wall with a corbel and the yellow shape represents the special designed wooden recess.

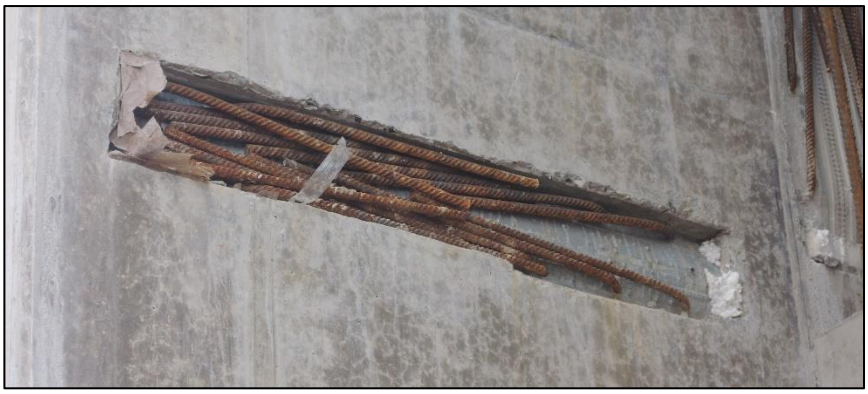


Figure 4.2 – Rebend Connection System Stabox® [CFL Multimodal Terminal construction site]

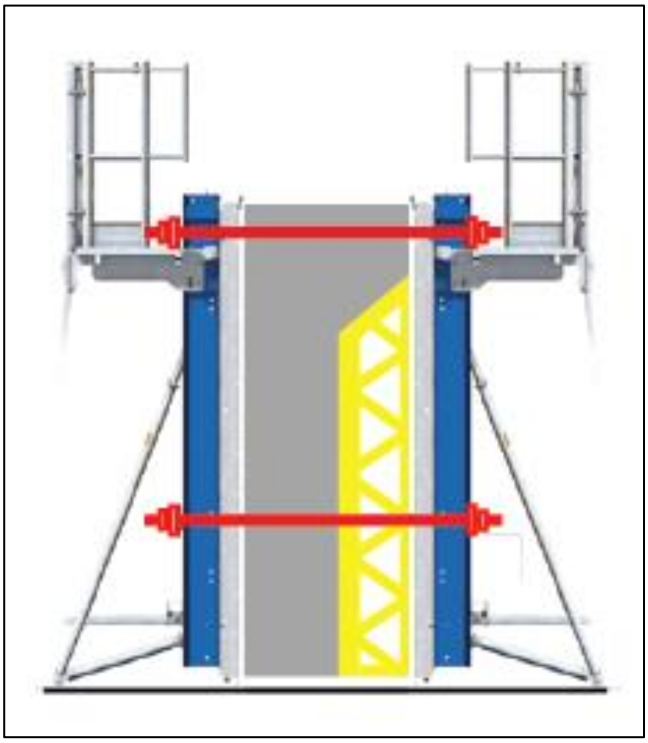


Figure 4.3 – Formwork and recess for building a concrete core wall with a corbel

Another discussion topic was about the 8-meter long façade beams, as they can be seen in detail drawings of variant 1A in Appendix I. These beams don't have any main static function, but are needed to fixed façade elements. An option to build these beams was to use precast beams. Another suggestion was to pour them in-situ. For the last option, a framework specialist suggested a special formwork that can be lifted by crane and which allows to pour one complete beam. Figure 4.4 is a proposed design for the special formwork, which include a security 1,5-meter width security platform.

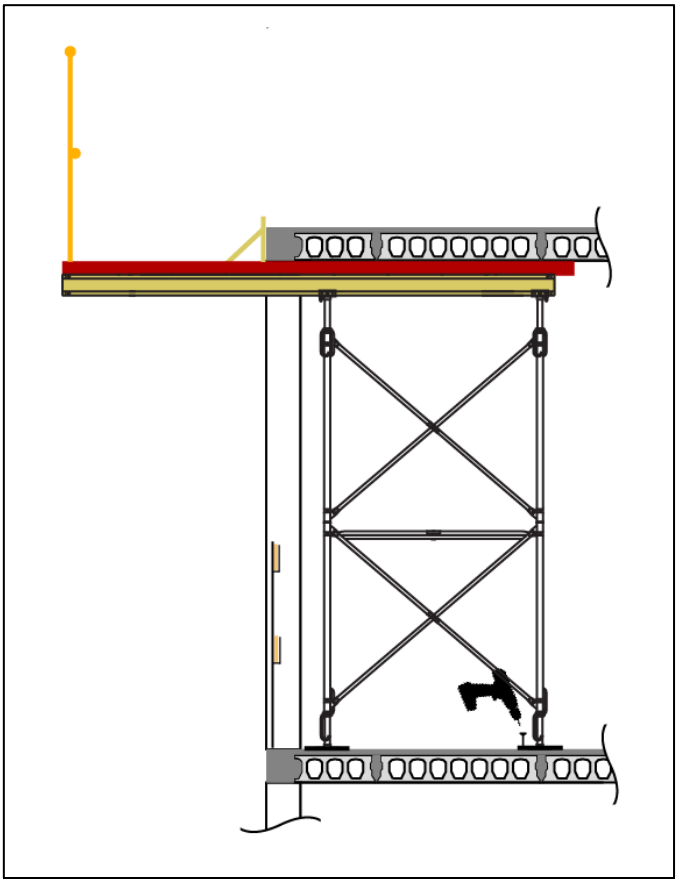


Figure 4.4 – Formwork and security platform for concreting the façade beams

This last solution was chosen because, it was the cheaper one and it reduces the number of trucks on site transporting precast elements. Furthermore, it fulfils the requirements for worker's safety.

Table 4.1 gives an overview of quantities of elements (objects) in variant 1A.

Table 4.1 – Quantity of elements - variant 1A

Quantity of Elements - Var 1A			
	[mL]	[m³]	[u]
Concrete for Walls	1330	1263	
Concrete for Slabs		1127	
Precast Columns			360
Precast Beams			252
Hollow-Core Elements			1530

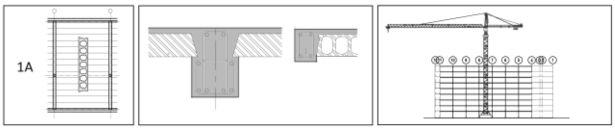
4.2.1 One tower crane on site

The analyses with one crane was done with the hypotheses that everything, this means concrete cores and structural frame/slab, is done simultaneously in two shift of 8 working hours each. The duration of constructing one floor resulting from the crane efficiency calculation was 7 days. The resulting work ratio for every task are shown in Table 4.2.

Table 4.2 – Results of the crane efficiency calculation for variant 1A / one crane

Markus Schäfer, Univ.-Doz. Dr.- Ing., Université du Luxembourg, Faculté des Sciences, de la Technologie et de la Communication	
Project :	Project SiMCo - Variant 1A
Work :	Concrete Cores - Frame - Floor
Floor :	1st Floor
Author :	Dany Pereira Figueiredo

Crane Efficiency Calculation - RESULTS



Working day:	15 hrs/day	Security Applied :	15 %
Crane on site:	1	**Expected construction duration :**	**7 days**

ID	Description	Element Type	Work	Rate of Work			
		w, c, b, s, u, d	Days	u/d	LM/d	m²/d	m³/d
1	**Reinforced C. Walls**						
1.1	Ext. Walls	w	7	-	8,786	29,344	2,636
1.2	Interior Walls 0,24 cm	w	7	-	2,460	7,724	0,391
1.3	Int. Ext. Walls 0,30 cm	w	7	-	0,330	1,036	0,099
1.4	Lift Shaft Walls	w	7	-	2,480	8,283	0,330
1.5	Int. Wall with corbel	w	7	-	6,621	22,116	1,572
S	**TOTAL**		**7**	**-**	**20,677**	**68,504**	**5,028**
2	**Precast Columns**						
2.1	Ext. Rect. Columns	c	7	3,857	-	-	-
2.2	Int. Round Columns	c	7	1,714	-	-	-
2.3	Int. Rect. Columns	c	7	0,143	-	-	-
S	**TOTAL**		**7**	**5,714**	**-**	**-**	**-**
3	**Precast Beams**						
3.1	Int. 8m Beams	b	7	2,000	-	-	-
3.2	Int. 5m Beams	b	7	1,857	-	-	-
3.3	Ext. D4-E4 Beam	b	7	0,143	-	-	-
S	**TOTAL**		**7**	**4,000**	**-**	**-**	**-**
4	**Slabs**						
4.1	In-Situ Slab	s	7	-	-	15,918	3,184
4.2	Hollow-Core Elements	s	7	24,286	-	114,881	-
4.3	Formwork Façade Beam	d	7	2,143	32,400	-	-
S	**TOTAL**		**7**	**26,429**	**32,400**	**130,799**	**3,184**
5	**Stairs**						
5.1	Intermediate Landings	s	7	-	-	1,337	0,241
5.2	Precast Flights	u	7	0,857	-	-	-
S	**TOTAL**		**7**	**0,857**	**-**	**1,337**	**0,241**
6	**Various**						
6.1	Stabox	d					
6.2	Neopren Strips	d					
S	**TOTAL**						

A working day of 15 hrs was chosen instead of 16 hrs, because it is intended to overlap 1 hour the 2 working shifts.

After simulating the building process in 2D (Appendix III), following the same steps as explained in chapter 3.4, the schedule was established and the result was a construction duration of 77 working days. With a security of 20% for hazards, the total duration increases 15 working days to a total of 92 working days. The resulting Gantt chart can be accessed in Appendix IV.

The resulting truck flow is illustrated in Figure 4.5 and the workforces' graphic is shown in Figure 4.6.

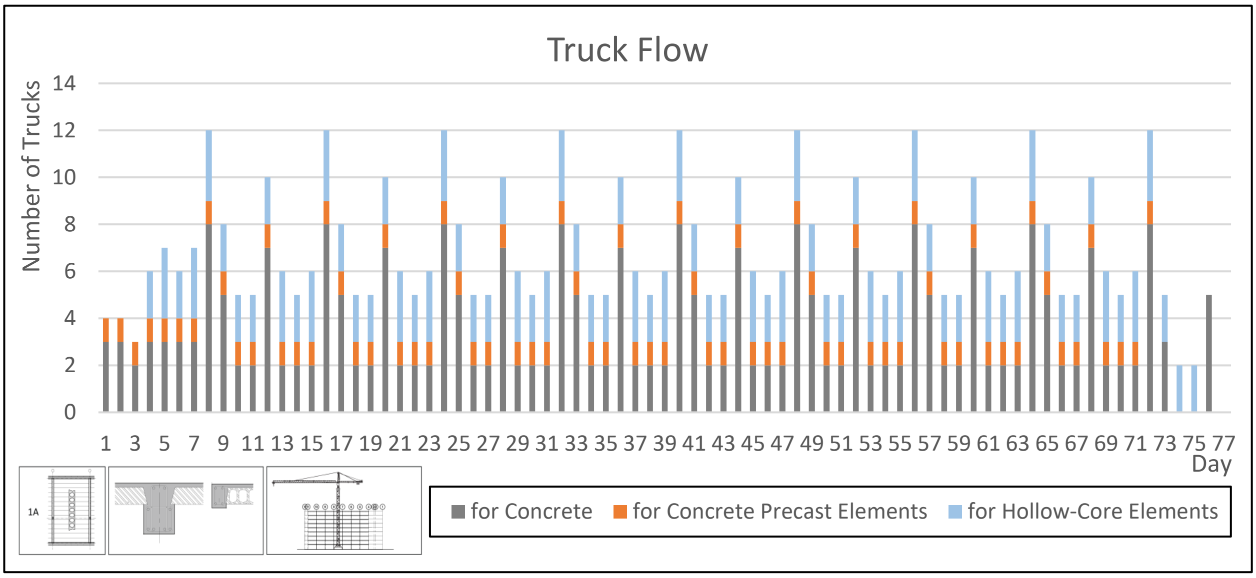


Figure 4.5 – Resulting ruck flow for variant 1A one crane

In average, 1 truck transporting precast element and 2 to 3 trucks transporting hollow-core elements are needed per day. In the case of concrete mixer trucks, an average 3 trucks are needed every day, with pics of 8 trucks. These pics correspond to the pouring of 5-centimeter thick concrete layer sealing together the hollow-core elements. In total, 276 concrete mixer trucks, 72 trucks transporting precast elements and 171 trucks transporting hollow-core elements will be needed. Table 4.3 gives an overview of the required trucks.

Table 4.3 – Required trucks (Variant 1A – one crane)

Required Trucks - Var 1A - one crane	
Trucks for	[u]
concrete	276
precast elements	72
hollow-core elements	171

Concerning personal resources, a maximum of 31 workers will be needed during 77 working days. On the bar chart above, one can see that the number of workers increase and decrease in the first, respectively last working days. This is because of the initial lag between the beginning of the works on the cores, on the structural frame and on the slab. The workers are equivalent allocated to the two shifts.

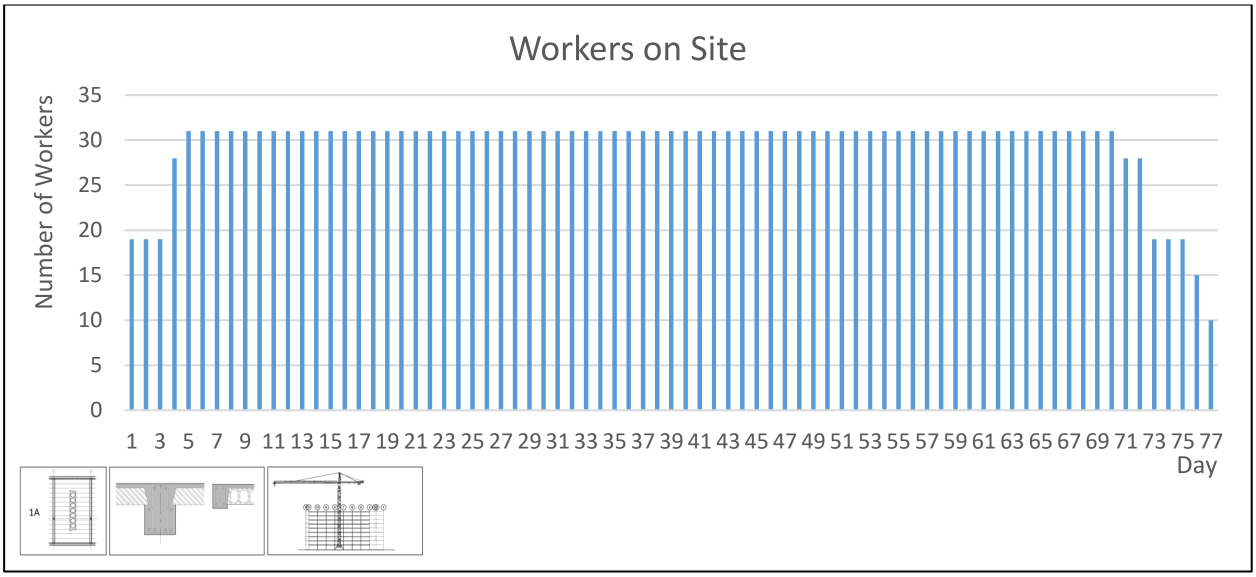


Figure 4.6 – Resulting workforce analysis graph for variant 1A one crane

4.2.2 Two tower cranes on site

With one more crane on site, the hypothesis taken was that in the morning shift, only the concrete cores would be erected, and in the afternoon shift the precast farming and hollow-core flor would be build. With two cranes on site, the building was divided into two zones. The chosen position for the cranes on the construction site is illustrated in Figure 4.7, as well the division of the building. The construction process for the concrete cores was previously explained in chapter 3.4 and is the same for every variant.

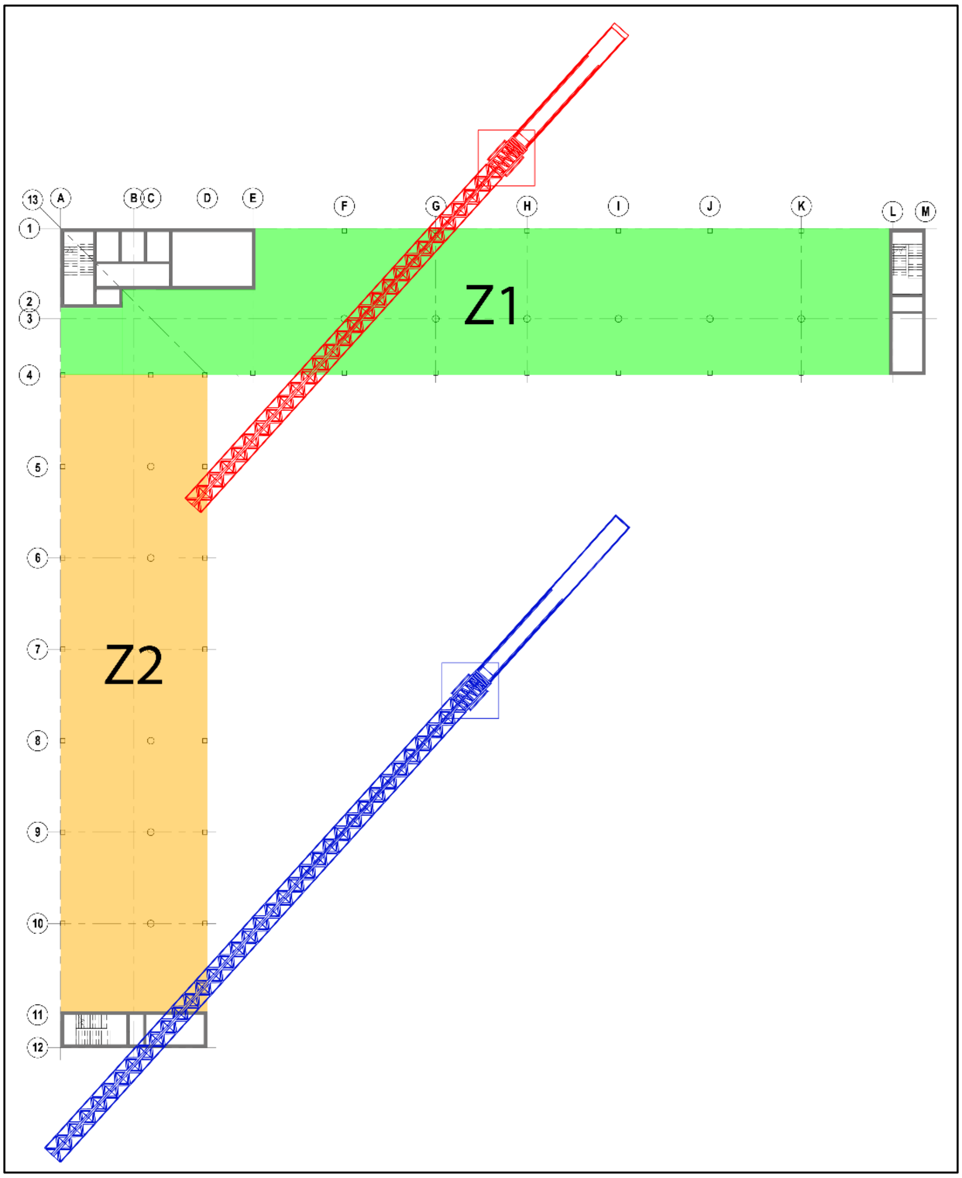


Figure 4.7 – Tower cranes positions in variant 1A

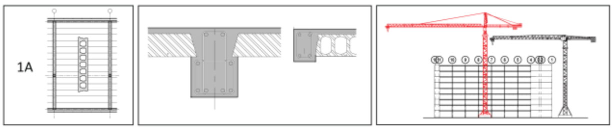
For each zone, a crane efficiency calculation was done. The resulting ration of the two calculation can be found in Table 4.4 and Table 4.5.

Table 4.4 –Crane efficiency calculation results for the framing/flooring under crane/zone 1 (Var. 1A)

Project :	Project SiMCo - Variant 1A
Work :	Structural Frame - Floor
Floor :	1st Floor - Zone 1
Author :	Dany Pereira Figueiredo

Markus Schäfer, Univ.-Doz. Dr.- Ing. — Université du Luxembourg, Faculté des Sciences, de la Technologie et de la Communication

Crane Efficiency Calculation - RESULTS



Working day:	8	hrs/day	Security Applied :	20	%
Crane on site:	2	**Expected construction duration :**		**5**	**days**

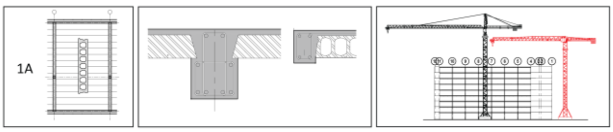
ID	Description	Element Type w, c, b, s, u, d	Work Days	Rate of Work u/d	LM/d	m²/d	m³/d
2	**Precast Columns**						
2.1	Ext. Rect. Columns	c	5	2,60	-	-	-
2.2	Int. Round Columns	c	5	1,40	-	-	-
S	**TOTAL**		**5**	**4,00**	**-**	**-**	**-**
3	**Precast Beams**						
3.1	Int. 8m Beams	b	5	1,20	-	-	-
3.2	Int. 5m Beams	b	5	1,40	-	-	-
3.3	Ext. D4-E4 Beam	b	5	0,40	-	-	-
S	**TOTAL**		**5**	**3,00**	**-**	**-**	**-**
4	**Slabs**						
4.1	Hollow-Core Elements	s	5	16,80	-	160,83	-
4.2	Formwork Façade Beam	d	5	-	22,68	-	-
S	**TOTAL**		**5**	**16,80**	**22,68**	**160,63**	**-**

Table 4.5 - Crane efficiency calculation results of the framing/flooring under crane/zone 2 (Var. 1A)

Project :	Project SiMCo - Variant 1A
Work :	Structural Frame - Floor
Floor :	1st Floor - Zone 2
Author :	Dany Pereira Figueiredo

Markus Schäfer, Univ.-Doz. Dr.- Ing. — Université du Luxembourg, Faculté des Sciences, de la Technologie et de la Communication

Crane Efficiency Calculation - RESULTS



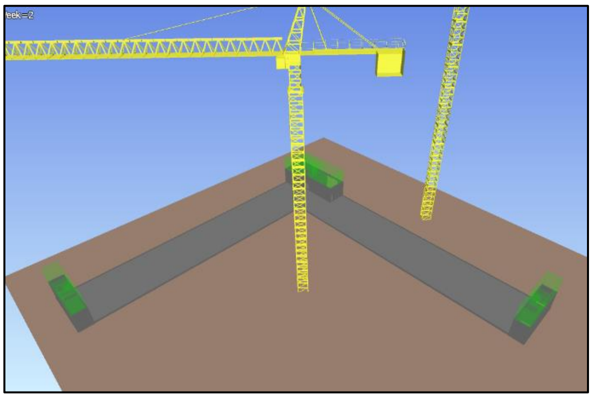
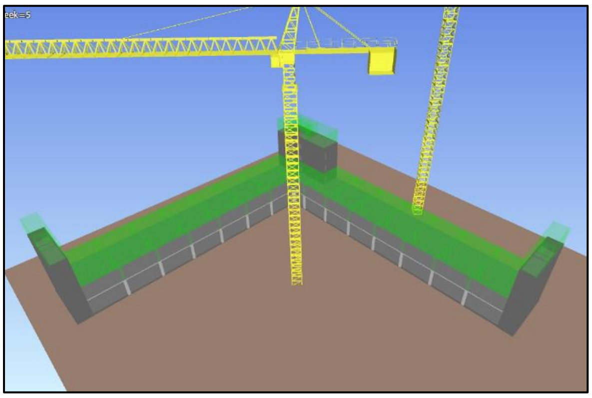
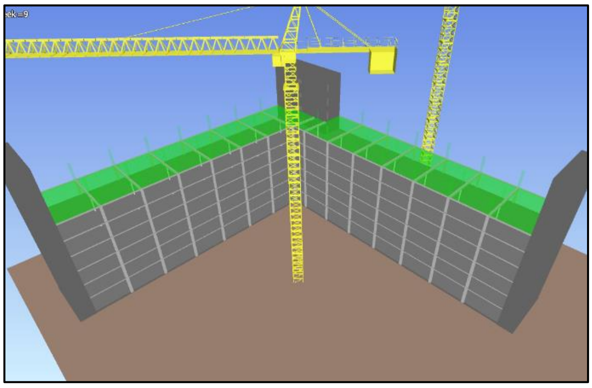
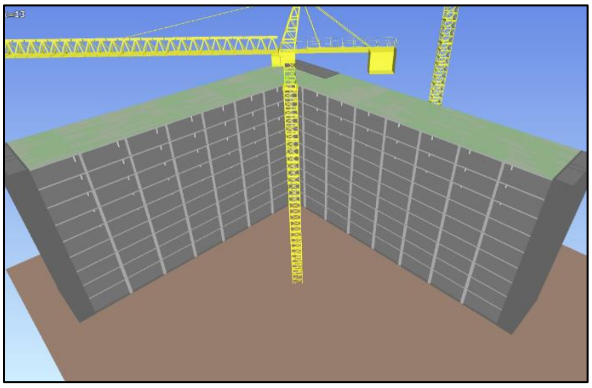
Working day:	8	hrs/day	Security Applied :	20	%
Crane on site:	2	**Expected construction duration :**		**5**	**days**

ID	Description	Element Type w, c, b, s, u, d	Work Days	Rate of Work u/d	LM/d	m²/d	m³/d
2	**Precast Columns**						
2.1	Ext. Rect. Columns	c	5	2,800	-	-	-
2.2	Int. Round Columns	c	5	1,400	-	-	-
S	**TOTAL**		**5**	**4,200**	**-**	**-**	**-**
3	**Precast Beams**						
3.1	Int. 8m Beams	b	5	1,600	-	-	-
3.2	Int. 5m Beams	b	5	1,400	-	-	-
S	**TOTAL**		**5**	**3,000**	**-**	**-**	**-**
4	**Slabs**						
4.1	Hollow-Core Elements	s	5	17,600	-	137,616	-
4.2	Formwork Façade Beam	d	5	3,000	24,300	-	-
S	**TOTAL**		**5**	**20,600**	**24,300**	**137,616**	**-**

With two cranes on site, the security factor applied in the calculation was increased by 10%. This is due to the possible interferences between both tower cranes. The end result is a duration for the construction of the frame and floor of 5 working days per floor and for each zone.

After simulating the floor by floor construction process in 2D (Appendix III) and the whole building in 3D (see Table 4.6), the end result for the construction's duration is 61 days without any hazards factor included, and 73 days with a security factor of 20% for hazards included. An offset between the constructions' beginning of the concrete cores and the frame/floor is taken into account, because of the security platform's constraint explained in the previous chapter. The resulting offset is in this case of 13 days. The corresponding Gantt chart of this variant can be found in Appendix IV.

Table 4.6 – Screenshots from the 4D simulation of studied case Variant 1A with 2 cranes

Day 9 	Day 22 
Day 38 	Day 61 

The resulting truck flow is illustrated in Figure 4.8 and the workforces' graphic is shown in Figure 4.9.

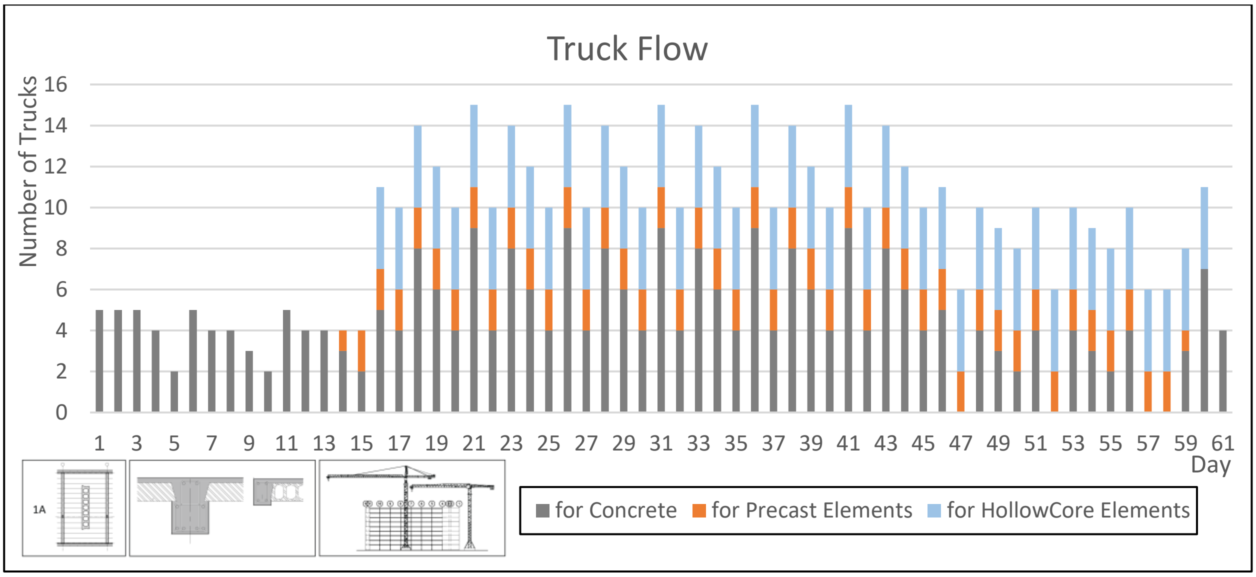


Figure 4.8 – Resulting truck flow for variant 1A two cranes

In Figure 4.8, we can see clearly when the construction of the frame and floor begins. In fact, for the first 13 days, only concrete is needed for the construction of the cores, so only concrete mixer trucks will be present on site. From day 45, the number of concrete mixer needed decreases. The only concrete needed at this stage of the project is for the pouring of the 5-centimeter thick concrete layer sealing together the hollow-core elements. In total, 284 concrete mixer trucks, 90 trucks transporting precast elements and 180 trucks transporting hollow-core slab elements will be needed. Table 4.7 gives an overview of the required trucks.

Table 4.7 - Required trucks (Variant 1A – two cranes)

Required Trucks - Var 1A - two cranes	
Trucks for	[u]
concrete	284
precast elements	90
hollow-core elements	180

As for the truck flow graphic, it can be deciphered from the workforces' graphic when the second shift starts (from day 14) and the concrete cores erection ends (day 47). The concrete core team is allocated to the morning shift and the other team to the afternoon one. The constant fluctuation of the number of workers is due to the subcontractor's workforces, as for example the steel fixers, who aren't needed in the same number every day. The maximum workers need on site are 58, 30 workers in the morning shift and 28 in the afternoon one.

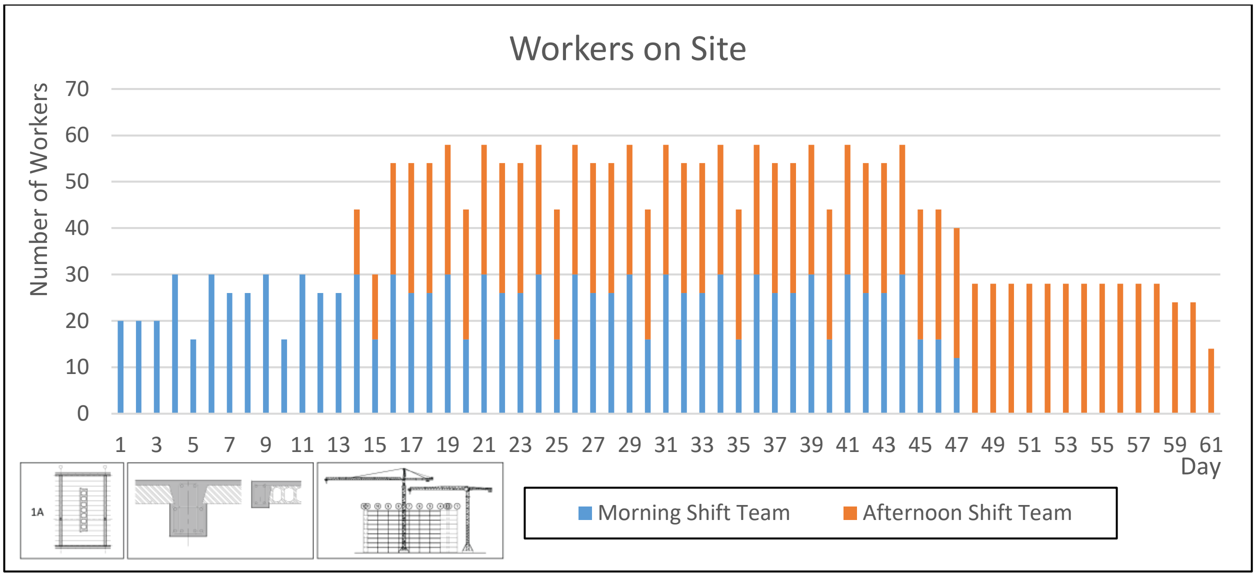


Figure 4.9 - Resulting workforce analysis graph for variant 1A two cranes

4.3 VARIANT 1B

Compared to variant 1A (Figure 4.10), variant1B only has one in-situ concreted beam. It's the façade beam A2-A4 located near the main core (see Figure 4.11). The other elements are precast and overall there are fewer elements in 1B then 1A, due to the non-existence of a middle column. Because hollow-core elements are bigger in this Variant than in 1A, the crane time needed for placing them was increased in relation to 1A. The walls with corbels are built the same way as in 1A, this means using the system illustrated in Figure 4.3.

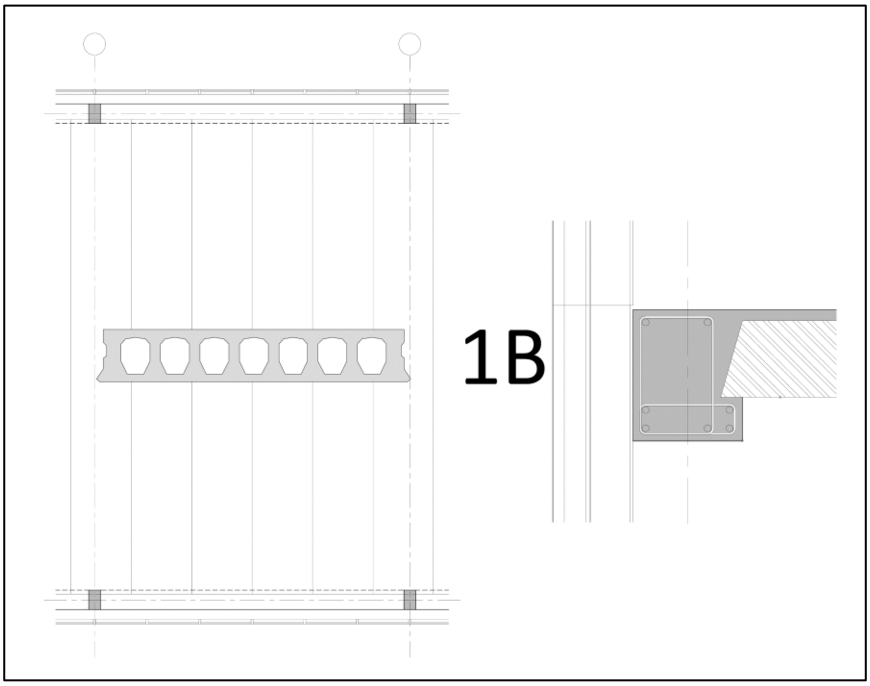


Figure 4.10 – Variant 1B

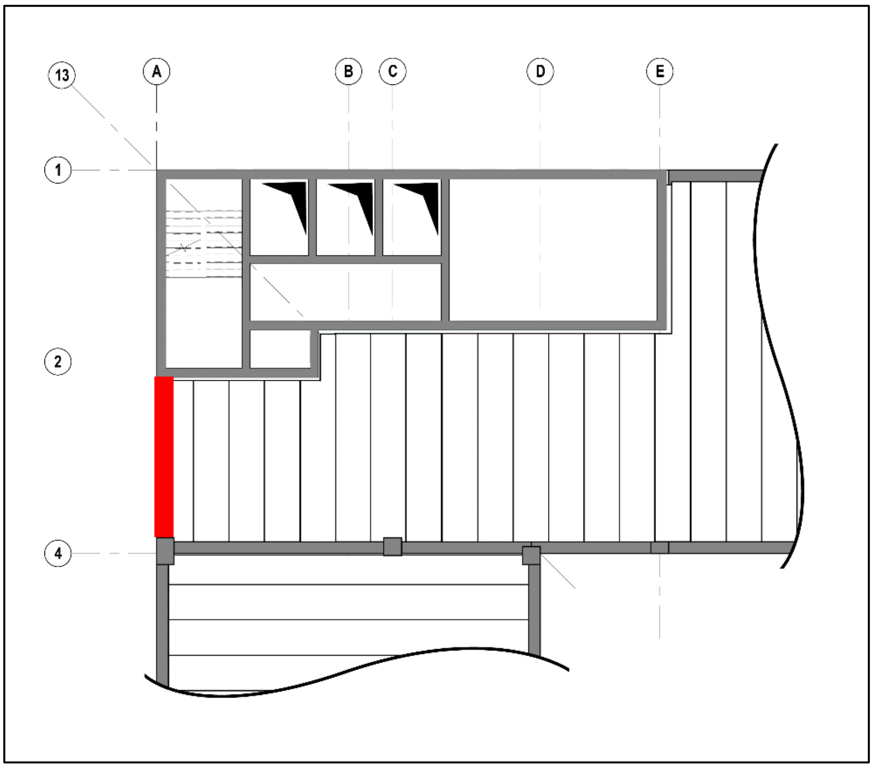


Figure 4.11 – Only in-situ beam of variant 1B (red beam)

The analyses with one crane was done with the hypotheses that concrete core, frame and floor are built simultaneously in 2 shifts. For the analyses with two cranes, the hypotheses taken was that the concrete cores are built first and only in the morning shift and that the frame and floor are built only in the afternoon shift.

Table 4.8 gives an overview of the elements' quantity in variant 1B.

Table 4.8 - Quantity of elements - variant 1B

Quantity of Elements - Var 1B			
	[mL]	[m³]	[u]
Concrete for Walls	1330	1263	
Concrete for Slabs		1185	
Precast Columns			261
Precast Beams			279
Hollow-Core Elements			954

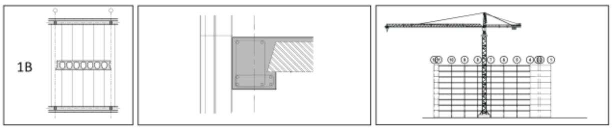
4.3.1 One tower crane on site

The results of the crane efficiency calculation for variant 1B with one tower crane on site can be found in Table 4.9.

Table 4.9 – Results of the crane efficiency calculation for variant 1B / one crane

uni.lu UNIVERSITÉ DU LUXEMBOURG – Markus Schäfer, Univ.-Doz. Dr.- Ing. – FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION	
Project :	**Project SiMCo - Variant 1B**
Work :	Concrete Cores - Frame - Floor
Floor :	1st Floor
Author :	Dany Pereira Figueiredo

Crane Efficiency Calculation - RESULTS



Working day:	15 hrs/day	Security Applied :	15 %
Crane on site:	1	**Expected construction duration :**	**7 days**

ID	Description	Element Type w, c, b, s, u, d	Work Days	Rate of Work u/d	LM/d	m²/d	m³/d
1	**Reinforced C. Walls**						
1.1	Ext. Walls	w	7	-	8,786	29,344	2,636
1.2	Interior Walls 0,24 cm	w	7	-	2,460	7,724	0,325
1.3	Int. Ext. Walls 0,30 cm	w	7	-	4,559	14,314	0,870
1.4	Lift Shaft Walls	w	7	-	2,480	8,283	0,330
1.5	Int. Wall with corbel	w	7	-	2,393	7,992	0,552
S	**TOTAL**		**7**	**-**	**20,677**	**67,658**	**4,713**
2	**Precast Columns**						
2.1	Ext. Main Columns	c	7	3,714	-	-	-
2.2	Ext. Type 2 Columns	c	7	0,143	-	-	-
2.3	Interior Columns	c	7	0,143	-	-	-
S	**TOTAL**		**7**	**4,000**	**-**	**-**	**-**
3	**Precast Beams**						
3.1	Exterior Main Beams	b	7	4,000	-	-	-
3.2	Beam A4-C4	b	7	0,143	-	-	-
3.3	Beam C4-E4	b	7	0,286	-	-	-
S	**TOTAL**		**7**	**4,429**	**-**	**-**	**-**
4	**Slabs**						
4.1	In-Situ Slab	s	7	-	-	15,961	3,990
4.2	Hollow-Core Elements	s	7	15,429	-	213,179	-
4.3	Formwork Façade Beam	d	7	0,167	0,857	-	-
S	**TOTAL**		**7**	**15,595**	**0,857**	**229,139**	**3,990**
5	**Stairs**						
5.1	Intermediate Landings	s	7	-	-	1,337	0,241
5.2	Precast Flights	u	7	0,857	-	-	-
S	**TOTAL**		**7**	**0,857**	**-**	**1,337**	**0,241**
6	**Various**						
6.1	Stabox	d					
6.2	Neopren Strips	d					
S	**TOTAL**						

With a security factor of 15%, a working day of 15 hrs (2 shifts of 8 hours with one overlapping hour) and one crane one site, the time needed to build a whole floor (concrete cores + frame and floor) is of 7 days, according to the crane efficiency calculation. The relevant construction ratios are 20,677 LM per day of concrete wall, 4 columns per day, 4 to 5 beams per day and 15 to 16 hollow-core elements per day.

After simulating the construction progress in 2D (Appendix III), following the same steps as explained in chapter 3.4, the construction schedule was elaborated. The end result was a construction duration of 68 working days without any security for hazards and an increasing of 14 working days to a total of 82 days with a security of 20% for hazards. The resulting Gantt Chart can be found in Appendix IV.

The consequential daily truck flow and needed workforces are represented in Figure 4.12 and Figure 4.13.

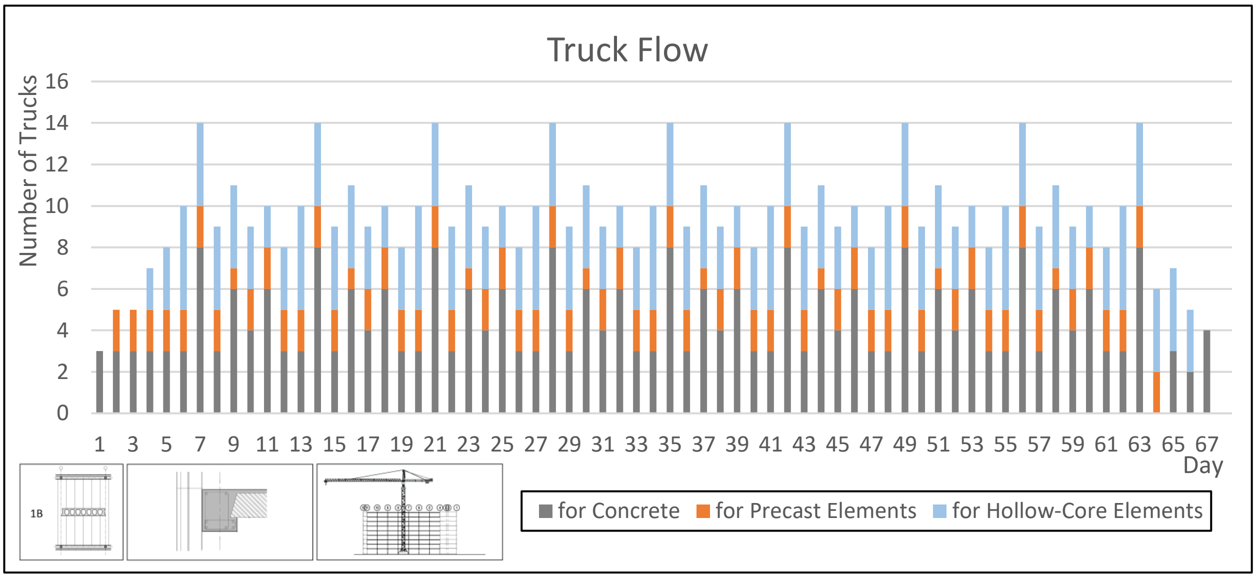


Figure 4.12 – Resulting truck flow for variant 1B one crane

For this variant, 299 concrete mixer trucks, 118 trucks transporting precast elements and 225 trucks transporting hollow-core slab elements will be needed. The number of trucks needed for the transporting of precast and hollow-core elements is higher than for the same configuration in variant 1A, because the precast elements and hollow-core slab elements are heavier due to their greater thickness. The 9 peaks seen in the graphic represent the days in which big area of floor will be poured with the concrete screed. In the graphic it is also recognisable that the mounting of the precast elements starts the second day, and the placing of the hollow-core slab elements on the fourth day. This deduction can be made because, as told in chapter 46, no element brought by the trucks will be temporarily stock anywhere on the construction site, but it will be directly placed in its foreseen position. Table 4.10 gives an overview of the required trucks.

Table 4.10 - Required trucks (Variant 1B – one crane)

Required Trucks - Var 1B - one crane	
Trucks for	[u]
concrete	299
precast elements	118
hollow-core elements	225

About personal resources, a maximum of 29 workers will be needed during 54 working days. The first and last working days, the number of workers will increase, respectively decrease, essentially due to the initial lag between the beginning of the works on the cores, on the structural frame and on the floor. The workers are equivalent allocated to the two shifts.

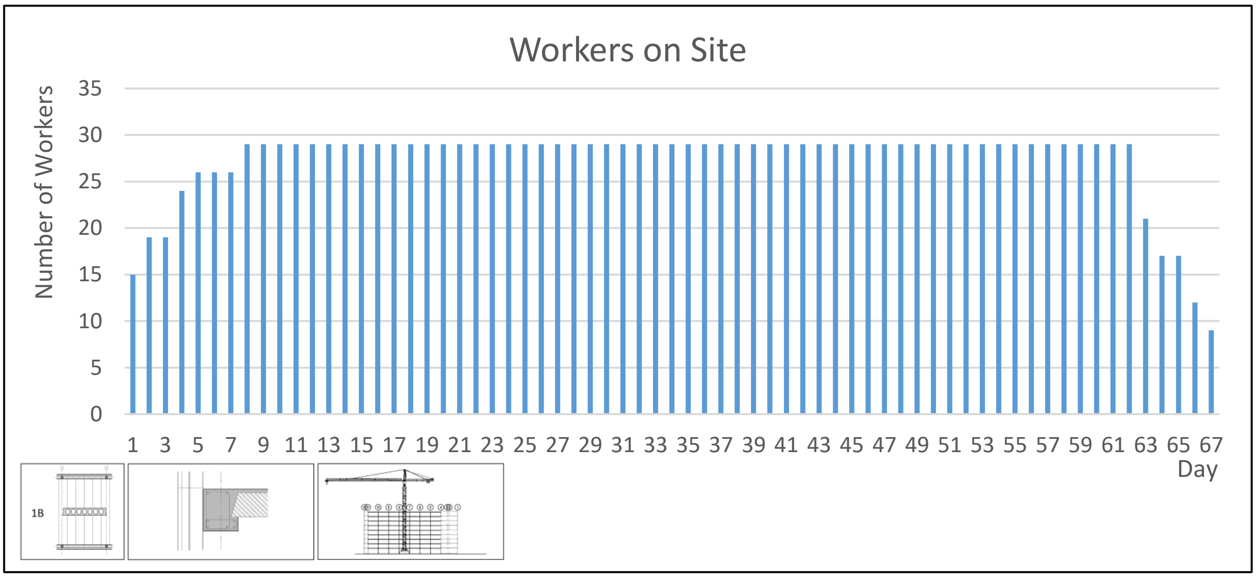


Figure 4.13 – Resulting workforce analysis graph for variant 1B one crane

4.3.2 Two tower cranes on site

As said in chapter 3.4, the hypotheses taken for this analysis was that the erection of the concrete cores will take place in the morning shift and the building of the frame and floor in the afternoon shift. Also, the erection cores start a few weeks earlier. The initial lag was calculated in function of the crane efficiency calculation results and is represented in the Gantt Chart in Appendix IV.

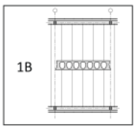
As for variant 1A and as it is explained in chapter 3.4, the duration of the concrete cores construction is 47 working days.

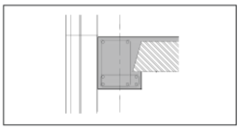
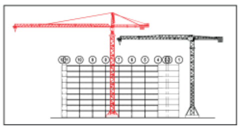
The same division of the project as it is illustrated in Figure 4.7 were taken into account for the crane zones. The results of the two crane efficiency calculation can be found in Table 4.11 and Table 4.12.

Table 4.11 – Crane efficiency calculation results for frame/floor building - crane/zone 1 (Var. 1B-2 cranes)

uni.lu UNIVERSITÉ DU LUXEMBOURG – FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION	Project :	**Project SiMCo - Variant 1B**
Markus Schäfer, Univ.-Doz. Dr.- Ing.	Work :	Structural Frame - Floor
	Floor :	1st Floor - **Zone 1**
	Author :	Dany Pereira Figueiredo

Crane Efficiency Calculation - RESULTS



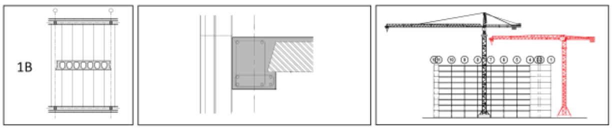
Working day:	8	hrs/day	Security Applied :	20	%
Crane on site:	2	**Expected construction duration :**		**4**	**days**

ID	Description	Element Type	Work	Rate of Work			
		w, c, b, s, u, d	Days	u/d	LM/d	m²/d	m³/d
2	**Precast Columns**						
2.1	Ext. Main Columns	c	4	3,500	-	-	-
2.2	Ext. Type 2 Columns	c	4	0,250	-	-	-
2.3	Interior Columns	c	4	0,250	-	-	-
S	**TOTAL**		**4**	**4,000**	**-**	**-**	**-**
3	**Precast Beams**						
3.1	Exterior Main Beams	b	4	3,500	-	-	-
3.2	Beam A4-C4	b	4	0,250	-	-	-
3.3	Beam C4-E4	b	4	0,500	-	-	-
S	**TOTAL**		**4**	**4,250**	**-**	**-**	**-**
4	**Slabs**						
4.1	Hollow-Core Elements	s	4	15,250	-	201,043	-
4.2	Formwork Façade Beam	d	4	0,250	1,500	-	-
s	**TOTAL**		**4**	**15,500**	**1,500**	**201,043**	**0,000**
6	**Various**						
6.1	Stabox	d					
6.2	Neopren Strips	d					
S	**TOTAL**						

Table 4.12 – Crane efficiency calculation results for frame/floor building - crane/zone 2 (Var. 1B-2 cranes)

uni.lu UNIVERSITÉ DU LUXEMBOURG – Markus Schäfer, Univ.-Doz. Dr.- Ing. – FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION	Project :	**Project SiMCo - Variant 1B**
	Work :	Structural Frame - Floor
	Floor :	1st Floor - **Zone 2**
	Author :	Dany Pereira Figueiredo

Crane Efficiency Calculation - RESULTS



Working day:	8	hrs/day	Security Applied :	20	%
Crane on site:	2	**Expected construction duration :**		**4**	**days**

ID	Description	Element Type	Work	Rate of Work			
		w, c, b, s, u, d	Days	u/d	LM/d	m²/d	m³/d
2	**Precast Columns**						
2.1	Ext. Main Columns	c	4	3,000	-	-	-
S	**TOTAL**		**4**	**3,000**	**-**	**-**	**-**
3	**Precast Beams**						
3.1	Exterior Main Beams	b	4	3,500	-	-	-
S	**TOTAL**		**4**	**3,500**	**-**	**-**	**-**
4	**Slabs**						
4.1	Hollow-Core Elements	s	4	11,750	-	172,020	-
S	**TOTAL**		**4**	**11,750**	**-**	**172,020**	**-**
6	**Various**						
6.1	Stabox	d					
6.2	Neopren Strips	d					
S	**TOTAL**						

The Gantt Chart for this analysis was elaborated after simulating the construction progress in 2D for one floor (Appendix III). The resulting total construction duration for this studied variant is of 60 working days without any hazard safety factor. The construction of the cores will last 47 working days and the building of the structural frame in precast elements and of the hollow-core floor will last 45 days. The lag between the construction start of the cores and the structural frame/floor is of 15 days. The resulting Gantt Chart can be found in Appendix IV.

The resulting need for trucks and workforces are shown in Figure 4.14 and Figure 4.15.

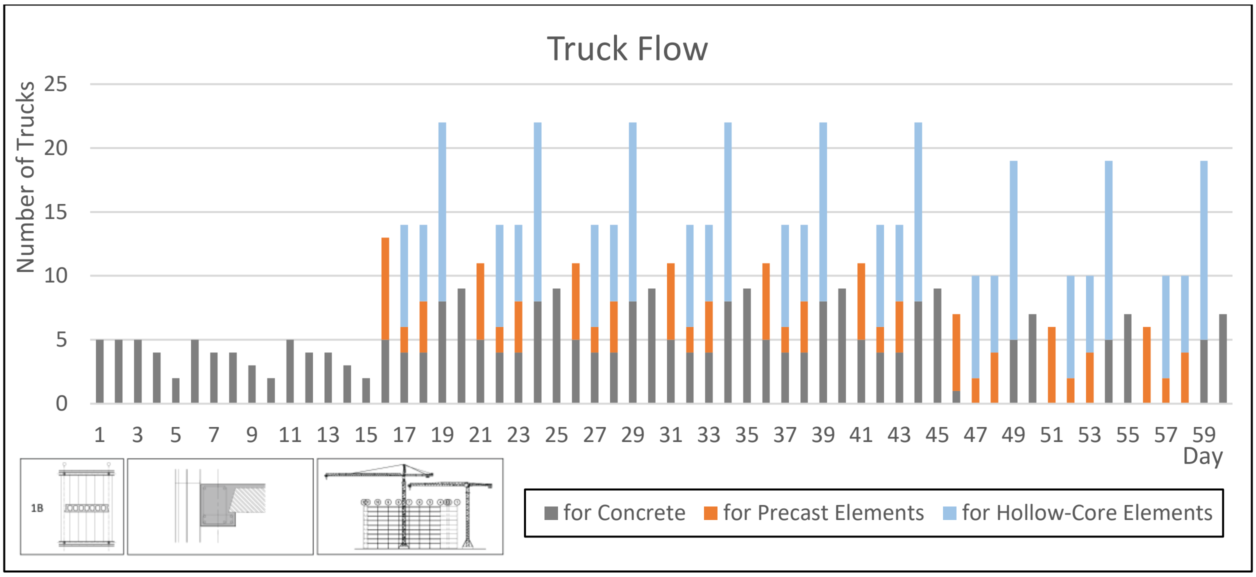


Figure 4.14 – Resulting truck flow for variant 1B two cranes

In the graphic above, the start of the structural fame construction is clearly recognisable in the 16 working day, with the construction of the floor starting one day later. The peaks of trucks transporting hollow-core elements, for example in day 19, is due to the fact that on these days only hollow-core elements will be placed. In day 16 for example, there won't be placings of hollow-core elements, but there will only be worked on the structural frame. In day 20, there won't be work done on the structural frame, neither will there be placing of hollow-core elements, but reinforcement and pouring of the slab will be executed.

In total 274 concrete mixer trucks, 110 trucks transporting precast elements and 252 trucks transporting hollow-core elements will be needed. Table 4.13 gives an overview of the required trucks.

Table 4.13 - Required trucks (Variant 1B – two cranes)

Required Trucks - Var 1B - two cranes	
Trucks for	[u]
concrete	274
precast elements	110
hollow-core elements	252

In the workforce analysis graph, it is clearly visible when the afternoon shift begins. With the start of the shift, the workers needed on site nearly duplicate. As for the analysis of the variant 1A with 2 cranes (see Chapter 4.2.2), the concrete core team corresponds to workers allocated to the morning shift and the precast/hollow-core slab team are the workers allocated to the afternoon shift. Also, the continual variation of the daily maximum needed workers is due to the subcontractor's workforces, as for example the steel fixers. The maximum number of workers on site is 52, 30 in the morning shift and 22 in the afternoon one.

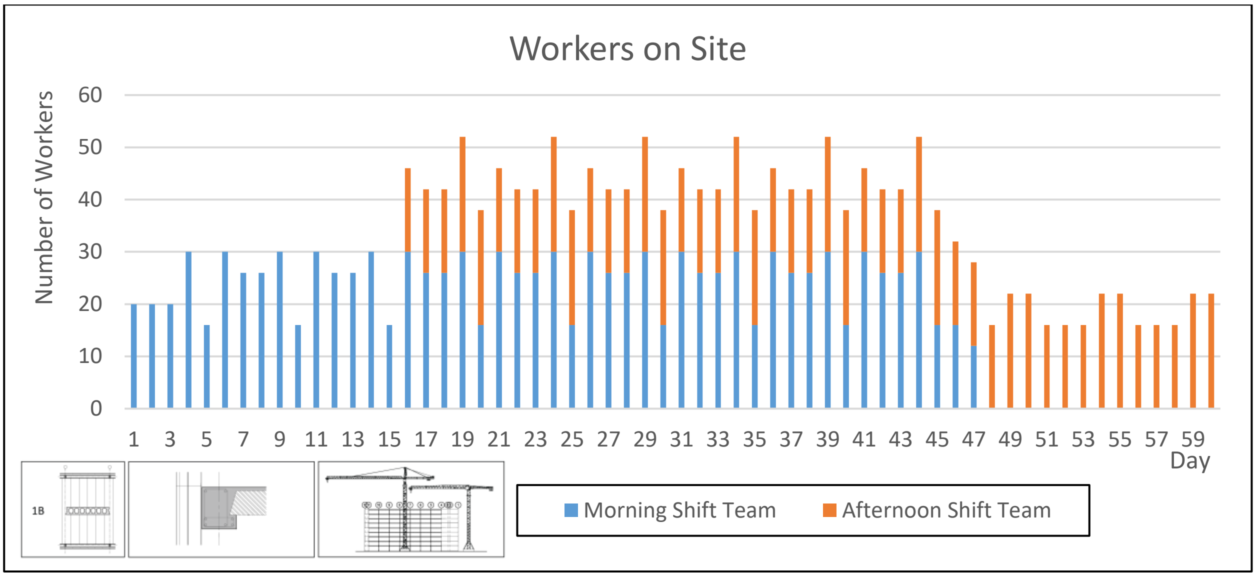


Figure 4.15 – Resulting workforce analysis graph for variant 1B two cranes

4.4 VARIANT 2A

Variant 2A (Figure 4.16) is a constructive option with one of the slim-floor solutions for this project. The structural frame is made of steel beams and columns, and the slab is designed with hollow-core elements. In opposition to the variant 1A, the façade beams are not concrete beams but steel beams in a tube shape. In this variant, the columns have the height of 2 floors (except the columns of the last floor), so the hypotheses taken for the construction progress was to erect the building not floor by floor, but 2 floors simultaneously.

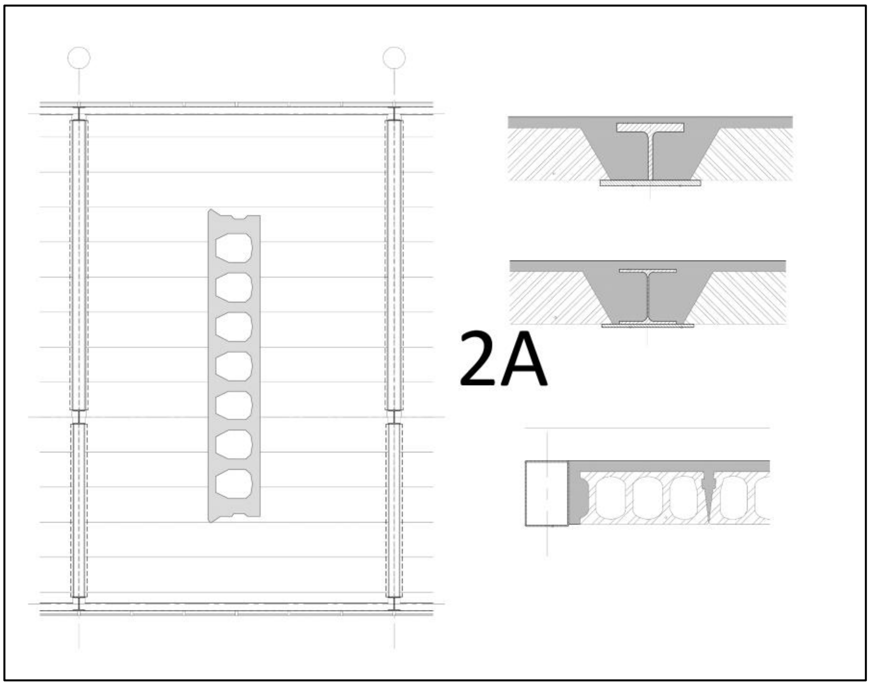


Figure 4.16 – Variant 2A

To install the steels beams and columns, aerial work platforms need to be considered in the planning of the project to facilitate the task for the workers and essentially to ensure workers' security by giving them a secure work platform. Planning the movement of the aerial work platform and the choice of the type of aerial platform is primordial, because it can impact the site installations plan, the cost and also the construction schedule.

The first thought was to use big truck-based aerial platforms, as shown on Figure 4.17.

Figure 4.17 – Truck-based aerial platform from the Boels Rental (seen in www.boels.nl)

But this solution was set aside due to the heights involved in. The decision was not taken because of technical characteristics (some truck-based aerial platforms can reach 100 meters and more), but due to workers' safety and comfort, which should always be the priority on a construction site. To make the workers feel safer and comfortable, and therefore more productive, they shouldn't work on an aerial platform on a height greater than 2 floor.

As for the height problem, the solution is to place aerial platforms directly on the slab inside the office buildings and build two floors simultaneously. After the two floors are completed, frame and slab, the process can start again, placing the aerial platforms on the new slab and building two new floors simultaneously. The aerial platforms should be of the type articulated telescopic boom lift to facilitate the task for the workers.

To guarantee the stability of the building, the boom lifts can be placed on a rail track system. This one is made out of steel beams, which are laying on wooden beams where the steel beams of the structural frame are, so that the loads can be directly distributed into the structural frame and not into the slab. The boom lifts can travel on this rail track system in one direction. The rail tracks are 8,10m long and can easily be moved by the tower crane. To reduce the loads, the boom lift should be the lightest possible. The concept is illustrated in Figure 4.18.

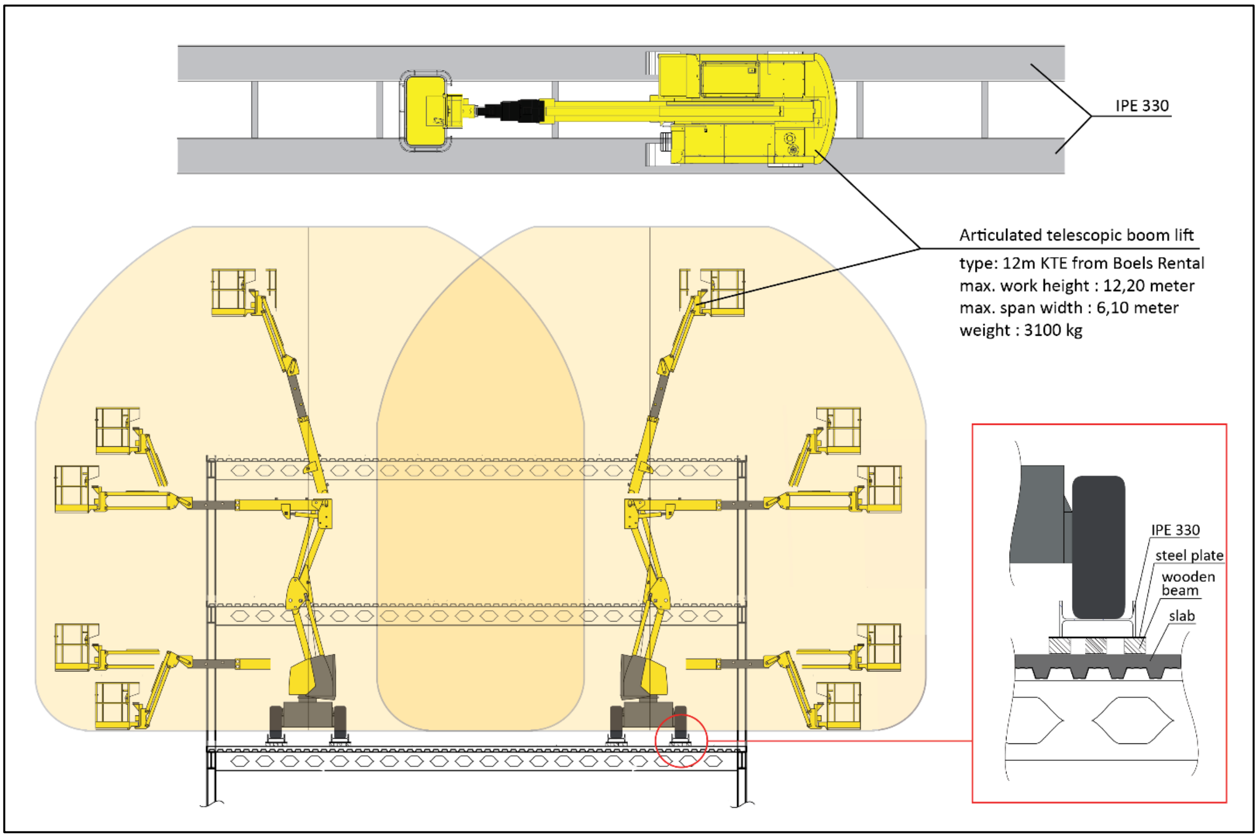


Figure 4.18 – Articulated telescopic boom lift on steel beam track

Table 4.14 gives an overview about the number of elements (objects) presented in variant 2A.

Table 4.14 - Quantity of elements - variant 2A

Quantity of Elements - Var 2A			
	[mL]	[m³]	[u]
Concrete for Walls	1330	1222	
Concrete for Slabs		979	
Steel Columns			210
Steel Beams			522
Hollow-Core Elements			1521

For this variant, only the analysis with one tower crane on site was done.

4.4.1 One tower crane on site

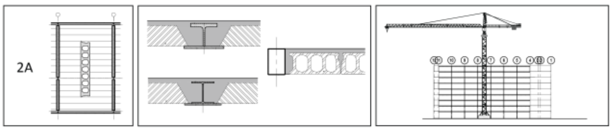
For this analysis, two shifts were considered. In the morning shift, as in the previous analysis, the concrete cores are erected, and in the afternoon the remaining structure is build. The hypothesis taken for the afternoon shift was that the steel frame would be built first, two floors at the same time, and then the hollow-core elements would be placed in the finished steel frame. This means that the steel structure and the slab would not be built simultaneously, but one after the other. Two separated crane efficiency calculation are also needed, one for the steel frame and one for the slab.

The choice to build the structural frame and slab not simultaneously was taken, because of the impact caused to the site facilities. The duration of the building is fairly the same if frame and slab would be built simultaneously, but the number of workers on site is significantly higher, which increases the need of site facilities accommodations. Only after the conclusion of the concrete cores (66 working days, see Chapter 3.4), the building of the steel frame and the slab could be done in parallel, the steel frame in the morning shift and the slab in the afternoon one. The hypothesises taken can be clearly identified in the final Gantt Chart of this analysis.

The results of the crane efficiency calculation for variant 2A with one tower crane on site can be found in Table 4.15 and Table 4.16. The time needed to moving the boom lifters and rail track was considered in the calculations. Two boom lifters will be necessary.

Table 4.15 – Crane efficiency calculation results for steel frame building (Var. 2A)

uni.lu UNIVERSITÉ DU LUXEMBOURG – FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION	Markus Schäfer Univ.-Doz. Dr.- Ing.	Project :	Project SiMCo - Variant 2A				
		Work :	Structural Steel Frame				
		Floor :	Ground-Floor + 1st Floor				
		Author :	Dany Pereira Figueiredo				
Crane Efficiency Calculation - RESULTS							
		Working day:	8	hrs/day	Security Applied :	15	%
		Crane on site:	1	**Expected construction duration :**		**6**	**days**
ID	Description	Element Type w, c, b, s, u, d	Work Days	Rate of Work u/d	LM/d	m²/d	m³/d
2	**Steel Columns**						
2.1	Exterior Columns Type 1	c	6	2,167	-	-	-
2.2	Exterior Columns Type 2	c	6	2,500	-	-	-
2.3	Interior Columns	c	6	2,333	-	-	-
S	**TOTAL**		**6**	**7,000**	**-**	**-**	**-**
3	**Steel Beams**						
3.1	Main Beams Type 1	b	6	4,333	-	-	-
3.2	Main Beams Type 2	b	6	4,333	-	-	-
3.3	Main Beams Type 3	b	6	0,333	-	-	-
3.4	Main Beams Type 4	b	6	0,333	-	-	-
3.5	Main Beams Type 5	b	6	0,333	-	-	-
3.6	Façade Beams Type 1	b	6	9,333	-	-	-
3.7	Façade Beams Type 2	b	6	0,333	-	-	-
S	**TOTAL**		**6**	**19,333**	**-**	**-**	**-**

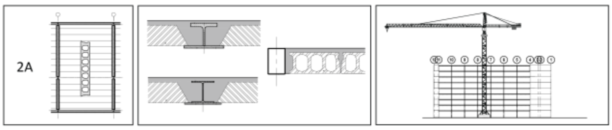


With a security factor of 15%, a working day of 8 hours (afternoon shift) and one tower crane on site, the needed time to build the structural steel frame of two floors is of 6 days, according to the calculation. The building rates are 7 steel columns and 19 to 20 steel beams per day.

Table 4.16 – Crane efficiency calculation results for floor building (Var. 2A)

uni.lu UNIVERSITÉ DU LUXEMBOURG – Markus Schäfer, Univ.-Doz. Dr.- Ing. – FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION	Project :	Project SiMCo - Variant 2A
	Work :	Floor
	Floor :	Ground-Floor + 1st Floor
	Author :	Dany Pereira Figueiredo

Crane Efficiency Calculation - RESULTS



Working day:	8	hrs/day	Security Applied :	15	%
Crane on site:	1	**Expected construction duration :**		**6**	**days**

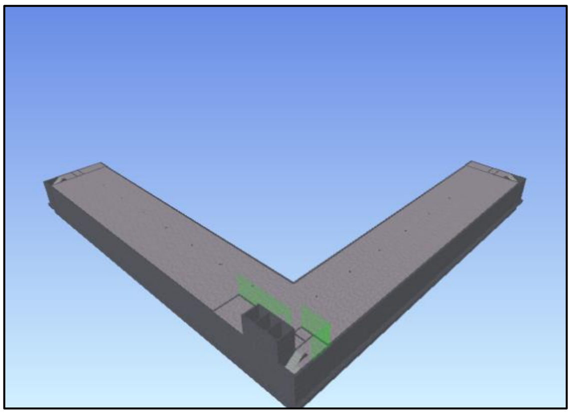
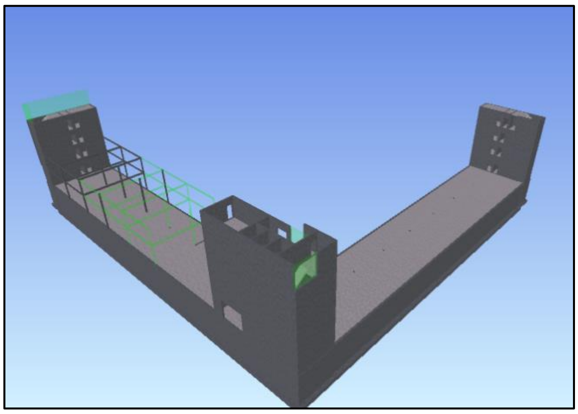
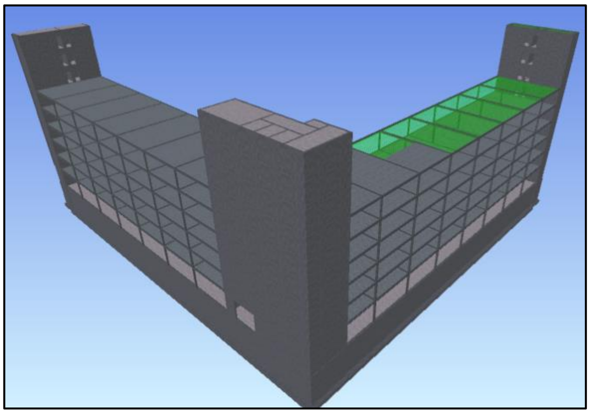
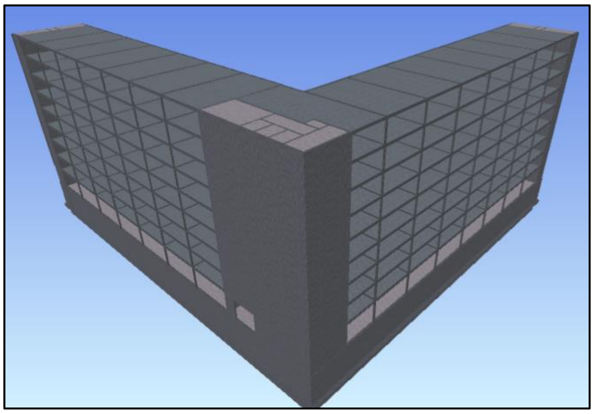
ID	Description	Element Type	Work	Rate of Work			
		w, c, b, s, u, d	Days	u/d	LM/d	m²/d	m³/d
4	**Slabs**						
4.1	Hollow-Core Elements	s	6	56,833	-	247,120	-
S	**TOTAL**		**6**	**56,833**	**-**	**247,120**	**-**
6	**Various**						
6.1	Neopren Strips	d					
S	**TOTAL**						

Considering the same conditions than previously, the time to build the hollow-core slabs of two floors is of 6 days too, with a placing rate of 56 to 57 hollow-core elements per day. The concrete pouring of the slab is not taken into account in the calculations because it will be done with concrete pumps and not with concrete crane buckets.

As analysed in Chapter 3.4, the time needed to build the concrete cores is 66 working days.

The construction schedule was created after simulating the construction progress in 2D (Appendix III) and 3D (see Table 4.17), following the same steps as explained in chapter 3.4. The final results were a total of the construction duration of 78 working days without security for hazard and 94 working days with a security of 20%. The initial lag between the beginning of the concrete cores' erection and the building of the structural frame was calculated and is of 30 working days. The resulting Gantt Chart can be found in Appendix IV.

Table 4.17 – Screenshots from the 4D simulation of Variant 2A studied case

Day 2	Day 32
	
Day 66	Day 78
	

The subsequent daily truck flow and needed workforces are represented in Figure 4.19 and Figure 4.20.

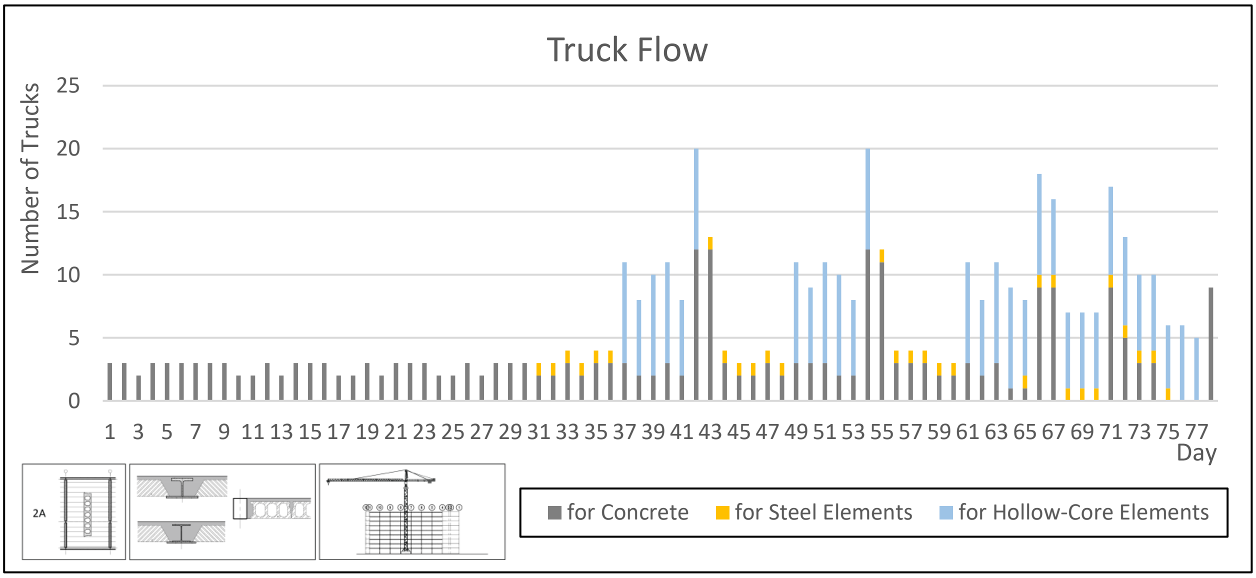


Figure 4.19 – Resulting truck flow for variant 2A one crane

In the graphic above, it is recognisable when the steel frame building starts (31st working day). Furthermore, the beginning of the hollow-core elements' placing (37th working day) and the swap between frame and slab works can be seen. From day 65, the structural frame and the slab are built in parallel as explained above, because the concrete cores are finished. The peaks of the number of trucks on site correspond to the days in which the office hollow-core slabs are poured with concrete.

In total 249 concrete mixer trucks, 29 trucks transporting steel elements and 198 trucks transporting hollow-core elements will be needed. Table 4.18 gives an overview of the required trucks.

Table 4.18 - Required trucks (Variant 2A – one crane)

Required Trucks - Var 2A - one crane	
Trucks for	[u]
concrete	249
steel elements	29
hollow-core elements	198

As in the truck flow graphic, it is visible in the workforce graphic when the building of the steel frame and slab begins, because of the rise of the number of workers needed on site. Workers in the concrete core team are allocated to the morning shift and workers in the other team are allocated to the afternoon shift. The continual variation of the daily maximum needed workers is due to subcontractors' workforces, as for example the steel fixers. The maximum number of workers is of 29, 15 in the morning shift and 14 in the afternoon one.

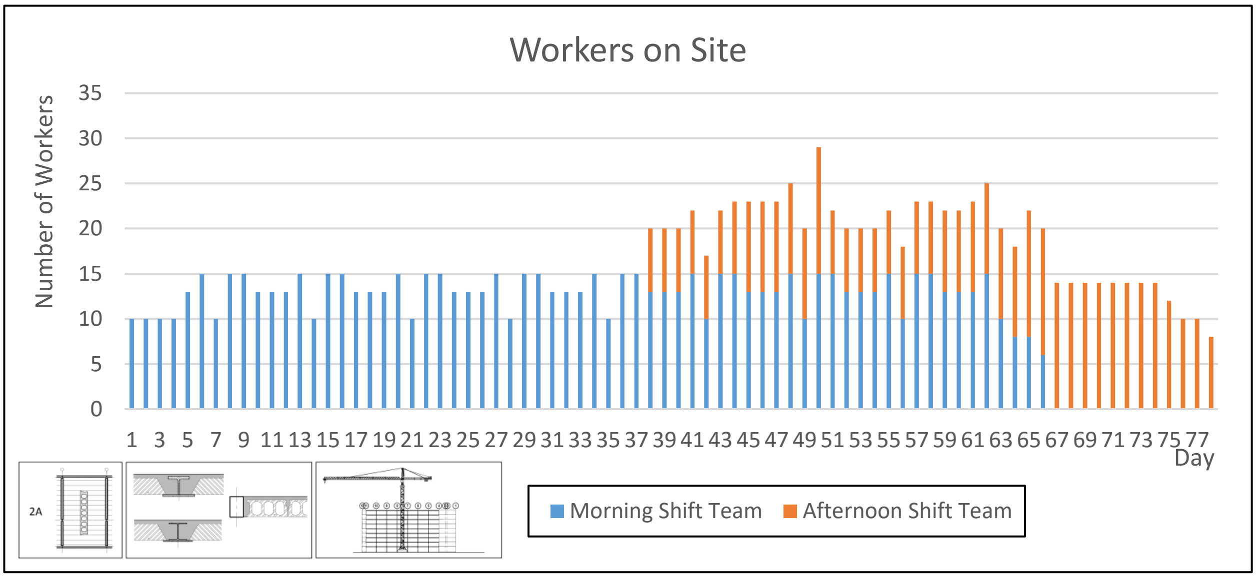


Figure 4.20 – Resulting workforce analysis graph for variant 2A one crane

As in the truck flow graphic, it is visible in the workforce graphic when the building of the steel frame and slab begins, because of the rise of the number of workers needed on site. Workers in the concrete core

team are allocated to the morning shift and workers in the other team are allocated to the afternoon shift. The continual variation of the daily maximum needed workers is due to subcontractors' workforces, as for example the steel fixers. The maximum number of workers is of 29, 15 in the morning shift and 14 in the afternoon one.

4.5 VARIANT 2B

Variant 2B (Figure 4.21) is the other slim-floor solution designed for this project, beside variant 2A. Otherwise than in variant 2A, in this variant there is no central column inside the offices. The slab is not made of hollow-core elements, but of semi-precast slab elements, which are lighter and smaller than hollow-core elements. Like in 2A, the columns have a height of 2 floors, except the columns of the last floor.

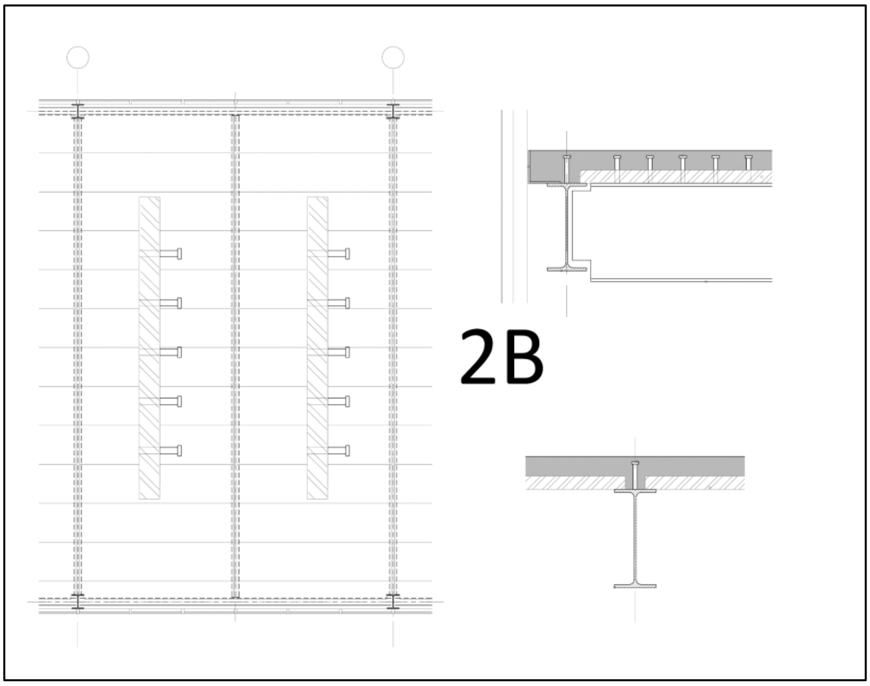


Figure 4.21 – Variant 2B

The hypothesises for the buildings construction progress are the same than for those taken in Variant 2A. Also the boom lift concept explained in the previous chapter (see Figure 4.18) is applied here.

Table 4.19 gives an overview about quantities of elements (objects) in variant 2B.

Table 4.19 - Quantity of elements - variant 2B

Quantity of Elements - Var 2B			
	[mL]	[m³]	[u]
Concrete for Walls	1330	1222	
Concrete for Slabs		1474	
Steel Columns			169
Steel Beams			538
Semi-Precast Elements			1377

For this variant, only the analysis with one tower crane on site was made.

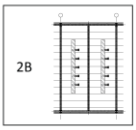
4.5.1 One tower crane on site

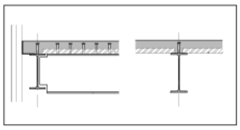
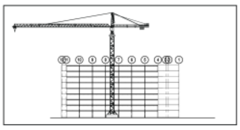
The same hypothesis taken in Variant 2A was considered for this analysis. In the morning shift, the concrete cores will be erected, and in the afternoon shift the structural frame and slab will be built, but not simultaneously. But as in variant 2A, after the conclusion of the concrete cores (66 working days, see Chapter 3.4), the building of the structural frame and slab are done in parallel, the frame in the morning shift and the slab in the afternoon.

The results of the crane efficiency for the structural steel frame and the slab can be found in the Table 4.20, respectively in Table 4.21. The crane cycles for the boom lifters and the rail track were also considered.

Table 4.20 – Crane efficiency calculations results for steel frame building (Var. 2B)

Markus Schäfer Univ.-Doz. Dr.- Ing.		Project :	Project SiMCo - Variant 2B					
		Work :	Structural Steel Frame					
		Floor :	Ground-Floor + 1st Floor					
		Author :	Dany Pereira Figueiredo					
Crane Efficiency Calculation - RESULTS								
Working day:		8	hrs/day	Security Applied :	15	%		
Crane on site:		1	Expected construction duration :		5	days		
ID	Description	Element Type	Work	Rate of Work				
		w, c, b, s, u, d	Days	u/d	LM/d	m²/d	m³/d	
2	**Steel Columns**							
2.1	Columns HEM 200	c	5	5,600	-	-	-	
S	**TOTAL**		**5**	**5,600**	**-**	**-**	**-**	
3	**Steel Beams**							
3.1	Comp. IPE 450 Type 1	b	5	10,800	-	-	-	
3.2	Comp. IPE 450 Type 2	b	5	0,400	-	-	-	
3.3	Comp. IPE 400	b	5	0,400	-	-	-	
3.4	Comp. HEA 450	b	5	0,400	-	-	-	
3.5	C. Faç. IPE 400 Type 1	b	5	11,200	-	-	-	
3.6	C. Faç. IPE 400 Type 2	b	5	0,400	-	-	-	
3.7	C. Faç. IPE 400 Type 3	b	5	0,400	-	-	-	
S	**TOTAL**		**5**	**24,000**	**-**	**-**	**-**	



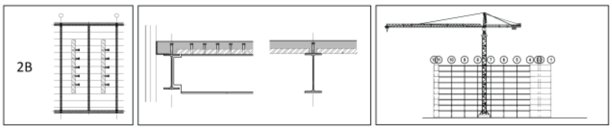



With a security factor of 15%, a working day of 8 hours, and one tower crane on site, the required time to build the structural steel frame of two floors is 5 working days according to the calculations. The building rates are 5 to 6 steel columns and 24 steel beams per day.

Table 4.21 – Crane efficiency calculation results for floor building (Var. 2B)

uni.lu UNIVERSITÉ DU LUXEMBOURG – Markus Schäfer, Univ.-Doz. Dr.- Ing. – FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION	Project :	**Project SiMCo - Variant 2B**
	Work :	Floor
	Floor :	Ground-Floor + 1st Floor
	Author :	Dany Pereira Figueiredo

Crane Efficiency Calculation - RESULTS



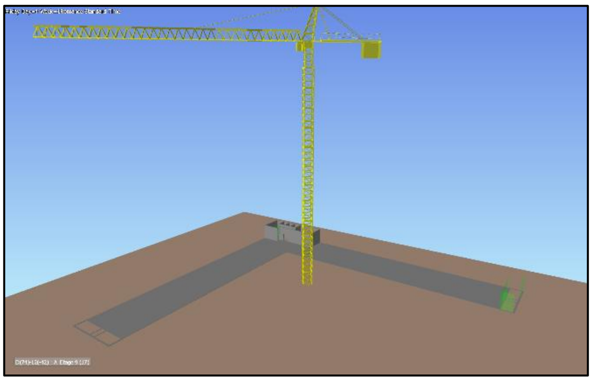
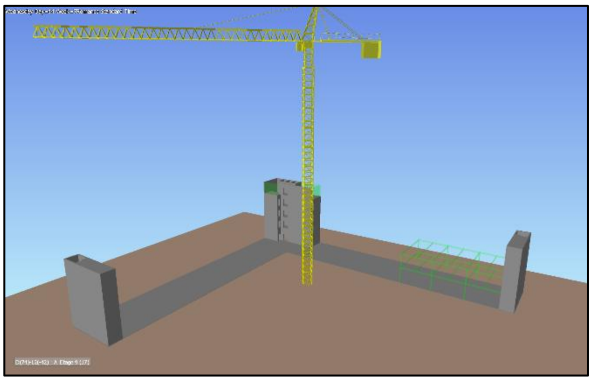
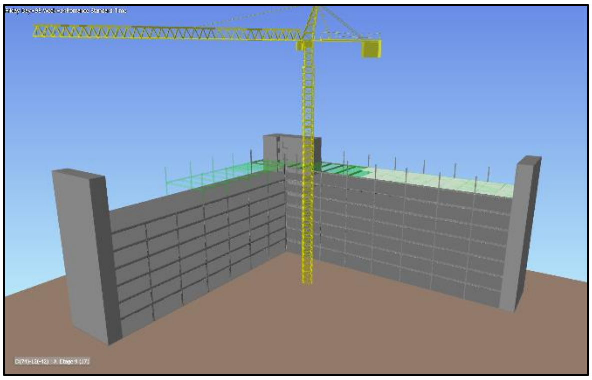
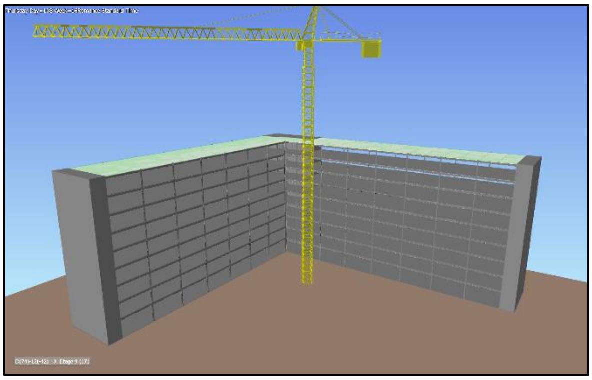
Working day:	8	hrs/day	Security Applied :	15	%
Crane on site:	1	**Expected construction duration :**		**6**	**days**

ID	Description	Element Type	Work	Rate of Work			
		w, c, b, s, u, d	Days	u/d	LM/d	m²/d	m³/d
4	**Slabs**						
4.1	Semi-Precast Element T1	s	6	49,000	-	488,828	-
4.2	Semi-Precast Element T2	s	6	0,333	-	3,546	-
4.3	Semi-Precast Element T3	s	6	1,000	-	9,115	-
4.4	Semi-Precast Element T4	s	6	0,333	-	1,825	-
4.5	Semi-Precast Element T5	s	6	0,333	-	1,688	-
S	**TOTAL**		**6**	**51,000**	**-**	**505,002**	**-**
6	**Various**						
6.1	Neopren Strips	d					
S	**TOTAL**						

Considering the same conditions then previously, the time needed to place all the semi-precast elements on 2 levels is 6 working days, with a rate of 51 elements places per day. The concrete pouring of the slabs is not taken into account here because it will be done with concrete pumps, and not with the concrete buckets attached to the tower crane.

After simulating and analysing the construction progress in 2D (Appendix III) and 3D (see Table 4.22), the construction schedule was created. The calculated duration for the construction of the structure is 75 working days without safety for hazards and 90 working days with a 20% safety for hazards. 66 working days will be needed for the completion of the concrete cores and 45 working days will be necessary for the building of the structural steel frame and slab. The lag between the works begin of the concrete cores and the structural frame is of 30 working days. The resulting Gantt Chart can be found in Appendix IV.

Table 4.22 – Screenshots from the 4D simulation of Variant 2B studied case

Day 4	Day 30
	
Day 67	Day 75
	

The consequent daily number of trucks and workers needed is shown in Figure 4.22 and Figure 4.23.

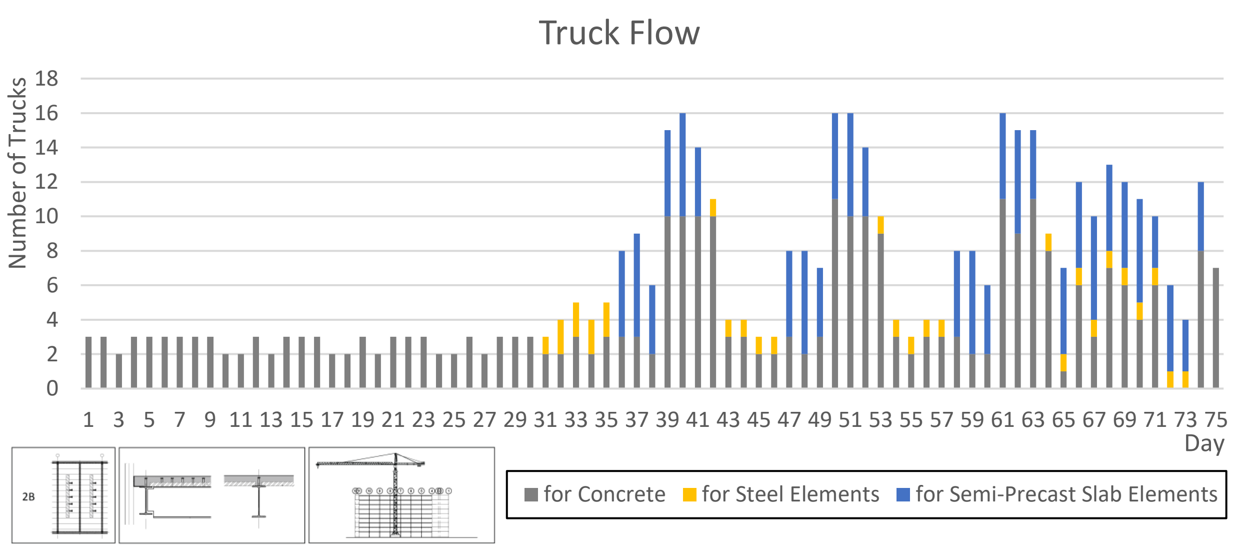


Figure 4.22 – Resulting truck flow for variant 2B one crane

As seen in the resulting daily truck of variant 2A, in the graphic above it is also recognisable when the steel frame building starts (31st working day), when the hollow-core elements' placing begins (36th working day) and when the concrete core works ends, and the building of the frame and slab starts to be done in parallel (65th working day).

In total 303 concrete mixer trucks, 29 trucks transporting steel elements and 137 trucks transporting semi-precast slab elements will be necessary. The peaks of the number of trucks on site corresponds to the days in which the office slab are poured with concrete. In contrary to variant 2A, in 2B there are more peaks and concrete mixer trucks needed because for the type of slab used in this variant more concrete is necessary. Table 4.23 gives an overview of the required trucks.

Table 4.23 - Required trucks (Variant 2B – one crane)

Required Trucks - Var 2B - one crane	
Trucks for	[u]
concrete	303
steel elements	29
semi-precast slab elements	137

As in the truck flow graphic, it is recognisable in the workforce graphic when the works on the frame and slab begin. Workers of the concrete core team are allocated to the morning shift and the other workers are allocated to the afternoon shift. The continual variation of the daily maximum needed workers is due to subcontractor's workforces, as for example the steel fixers. The maximum number of workers needed on site is of 31 men. In average, 15 men for the concrete works are going on, and 16 for the works on the structural frame and slab.

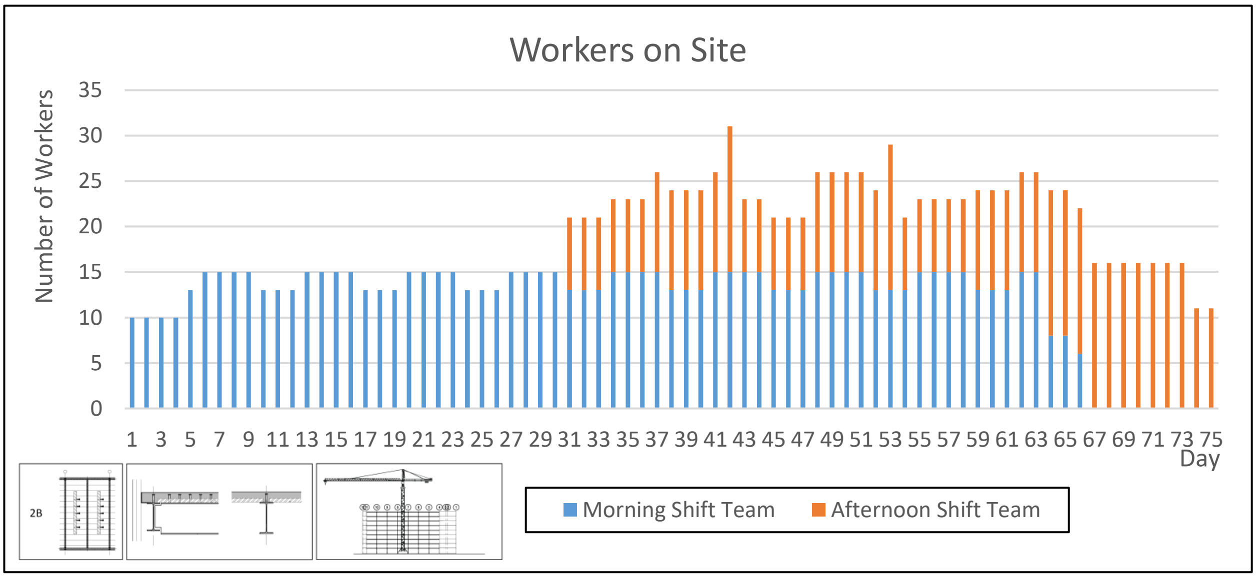


Figure 4.23 – Resulting workforce analysis graph for variant 2B one crane

4.6 VARIANT 3A

Variant 3A (Figure 4.24) is one of the constructive option using a structural steel frame and a composite floor system, using ArcelorMittal CofraPlus 220 steel sheets and concrete. The steel sheets have embossments, which make the steel deck and the concrete slab interdependent and working together to produce a composite resistance of the floor.

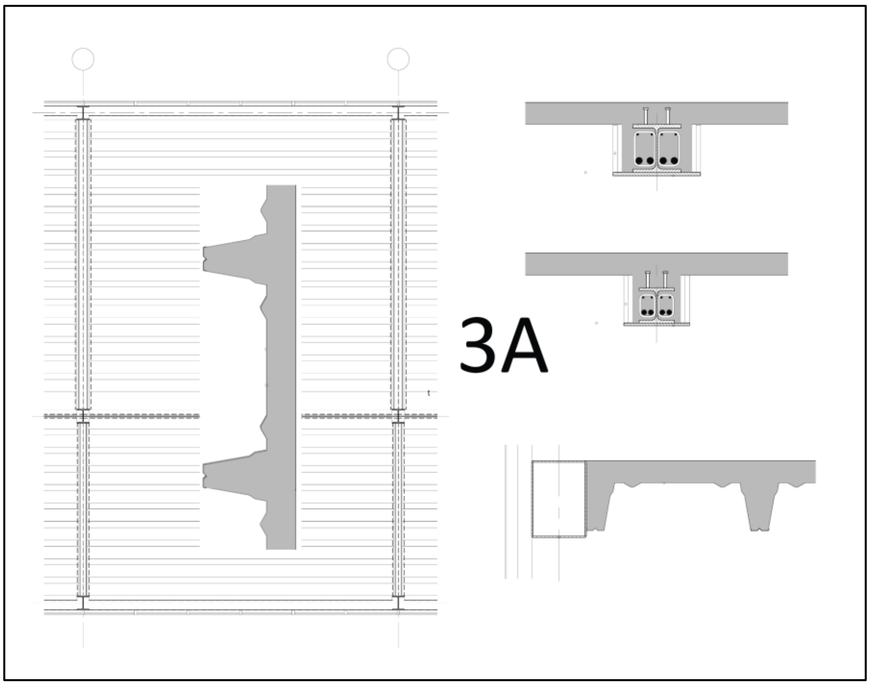


Figure 4.24 – Variant 3A

Composite girders are used in this variant. They will be concrete in a controlled environment in a factory, brought to the construction site and then placed with the crane on their locations. The steel deck assembly does not occupy the cranes on site a lot. Only the racks containing the steel sheets (normally 20 to 25 sheets per rack, depending on the sheet type) need to be moved by crane. Furthermore, in this variant and due to the span width that each sheet needs to overcome, a falsework needs to temporarily be placed underneath the deck to ensure the stability of the floor during concrete pouring. The elements needed for the falsework have to be placed on the floors by crane and in racks, therefore they were considered in the crane efficiency calculation. After calculations, the number of pours needed for a complete falsework is between 60 to 65 per floor. A rack can contain 25 pours.

As for the variants 2A and 2B, the columns in this variant have the height of 2 floors (except the columns of the last floor), which leads to the application of the same hypothesis for the construction progress used in 2A and 2B. This implies that the erection of the building is not done floor by floor, but two floors simultaneously.

Also, the same aerial work platform concept (see Figure 4.18) is considered in this variant, to ensure comfort and security to the workers mounting the steel frame. The movements of the boom lifters will be shown in the 2D construction simulation.

Table 4.24 gives an overview about quantities of elements (objects) in variant 3A

Table 4.24 - Quantity of elements - variant 3A

Quantity of Elements - Var 3A				
	[mL]	[m³]	[u]	[racks]
Concrete for Walls	1330	1222		
Concrete for Slabs		2385		
Steel Columns			210	
Steel Beams			676	
CofraPlus 220			2461	83

For this variant, only one analysis was done, the one with one tower crane on site.

4.6.1 One tower crane on site

As for the other variants, two shift were considered in this analysis. In the morning shift, the concrete cores will be erected, and in the afternoon, the remaining structure will be build. As explained in chapter 3.4, the building duration of the concrete cores will be 66 days.

In contrary to variants 2A and 2B, the steel frame and slab will be built simultaneously, but 2 levels will still be built at the same time. So for this analysis, beside the calculation of the crane efficiency for the concrete cores buildings, only one crane calculation will be needed for the remaining structure.

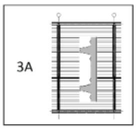
The results of the crane efficiency calculation for steel frame and composite slab of variant 3A with one crane can be found in Table 4.25.

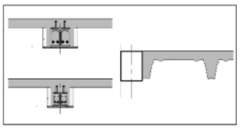
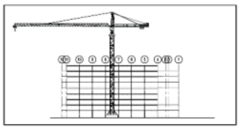
Table 4.25 – Crane efficiency calculation results for steel frame/floor building (Var. 3A – 1 crane)

Project :	Project SiMCo - Variant 3A
Work :	Steel Frame - Composite Floor
Floor :	Ground-Floor + 1st Floor
Author :	Dany Pereira Figueiredo

Markus Schäfer, Univ.-Doz. Dr.- Ing. – Université du Luxembourg, Faculté des Sciences, de la Technologie et de la Communication

Crane Efficiency Calculation - RESULTS



Working day:	8 hrs/day	Security Applied :	15 %
Crane on site:	1	**Expected construction duration :**	**9 days**

ID	Description	Element Type	Work	Rate of Work			
		w, c, b, s, u, d	Days	u/d	LM/d	m²/d	m³/d
2	**Steel Columns**						
2.1	Columns HEM 240	c	9	1,444	-	-	-
2.2	Columns HEM 280	c	9	1,556	-	-	-
2.3	Columns HEM 220	c	9	1,667	-	-	-
S	**TOTAL**		**9**	**4,667**	**-**	**-**	**-**
3	**Steel Beams**						
3.1	HEB 220 + Plat 400x15	b	9	3,111	-	-	-
3.2	HEB 160 + Plat 300x12	b	9	3,111	-	-	-
3.3	1/2 IPE 300	b	9	3,333	-	-	-
3.4	Tube Rect. 350x250x6	b	9	6,667	-	-	-
3.5	HEB 160 + Plat 300x12	b	9	0,222	-	-	-
3.6	Tube RO 101,6x5	b	9	0,444	-	-	-
S	**TOTAL**		**9**	**16,889**	**-**	**-**	**-**
4	**Slabs**						
4.1	CofraPlus 220	d	9	58,889	-	338,550	-
S	**TOTAL**		**9**	**58,889**	**-**	**338,550**	**-**

Considering a security factor of 15%, a working day of 8 hours (afternoon shift) and one tower crane on site, the expected construction duration of the structural frame and composite slab of two floors is 9 working days, according to calculations. The resulting building rates are 4 to 5 steel columns, 16 to 17 composite girders and 338 m² steel deck per day.

As for the previous analyses, a 2D construction progress simulation was done (Appendix III), following the same steps explained in chapter 3.4. Also, the movement of the boom lifters and rail tracks for the steel frame mounting were considered in the 2D construction progress simulation that can be found in Appendix III.

The resulting total construction duration for this analysis is 74 working days without any security for hazards, and 89 working days with a security of 20% for hazards. As stated before, 66 working days will be needed for the completion of the concrete cores. For the construction of the remaining structure, 45 working days will be necessary. The calculated lag between the beginning of the concrete cores' erection and the start of the structural frame and composite slab building is 29 working days.

The corresponding Gantt Chart for this analysis can be found in Appendix IV.

The resulting daily truck flow and needed workforces are represented in Figure 4.25 and Figure 4.26.

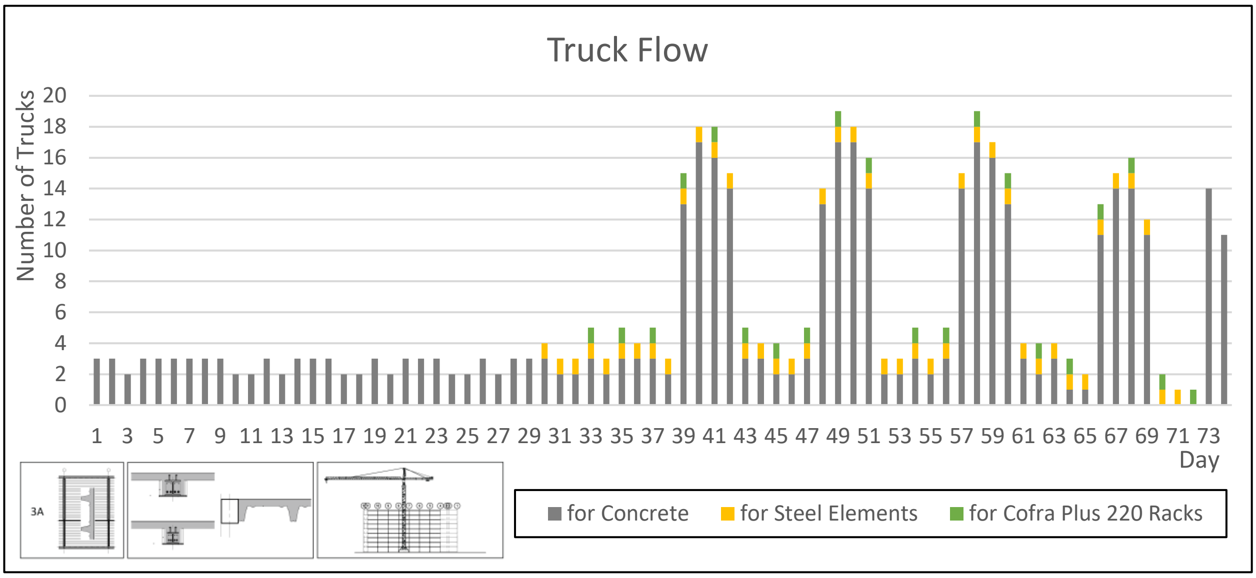


Figure 4.25 – Resulting truck flow for variant 3A one crane

In the graphic above, it is visible when the works on the structural frame begin (30th day). Also it's to notice that the supply of CofraPlus 220 sheets is done every second day. This is due to the huge number of sheets one truck can transport, so that not every day CofraPlus 220 sheets need to come in on site. In the site installations, a temporary storage location for the racks containing CofraPlus 220 needs to be considered. The peaks of the concrete mixer trucks match with the days in which the office slabs are poured with concrete.

In total, 391 concrete mixer trucks, 42 trucks transporting steel and composite elements, and 20 trucks transporting the steel sheets are necessary. Table 4.26 gives an overview of the required trucks.

Table 4.26 - Required trucks (Variant 3A – one crane)

Required Trucks - Var 3A - one crane	
Trucks for	[u]
concrete	391
steel elements	42
CofraPlus 220 steel sheets	20

In the workforce graphic, and as seen in the daily truck flow graphic, it is also visible when works on the structural frame and composite slab begin. The concrete cores team works only in the morning shift; the other team works in the afternoon shift. The continual variation of the daily needed workers is due to subcontractor's workforces, as for example the steel fixers. In average, 15 men are needed on site until the 30th working day, then the number duplicates to 30 men. The maximum number of workers on site is 32, 15 in the morning shift and 17 in the afternoon one.

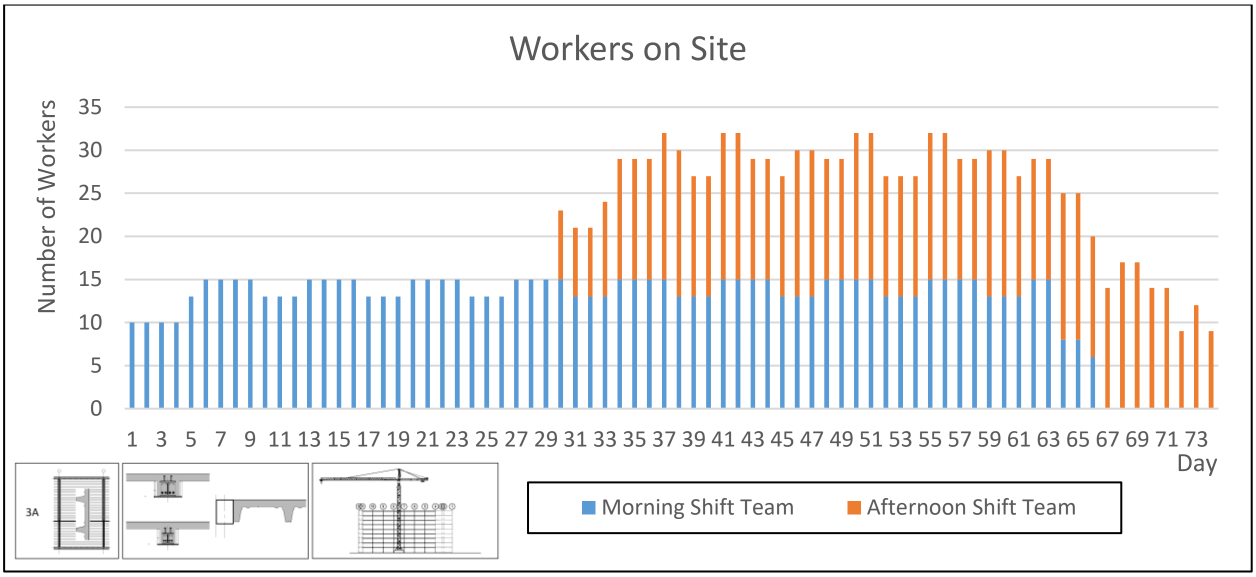


Figure 4.26 – Resulting workforce analysis graph for variant 3A one crane

4.7 VARIANT 3B

Along with variant 3A (Figure 4.27), variant 3B is a constructive option which includes a composite slab system. In this case there are no composite girders in the structural steel frame, but ArcelorMittal's cellular beams called Angelina™ beams (see Figure 4.28). The steel columns have a height of 2 floors (except the columns of the last floor), so the same construction progress hypothesis as in variant 3A was taken, namely a building erection done not floor by floor, but 2 floors simultaneously. In this variant, the steel deck of the composite slab is made of CofraPlus 60 steel sheets from ArcelorMittal.

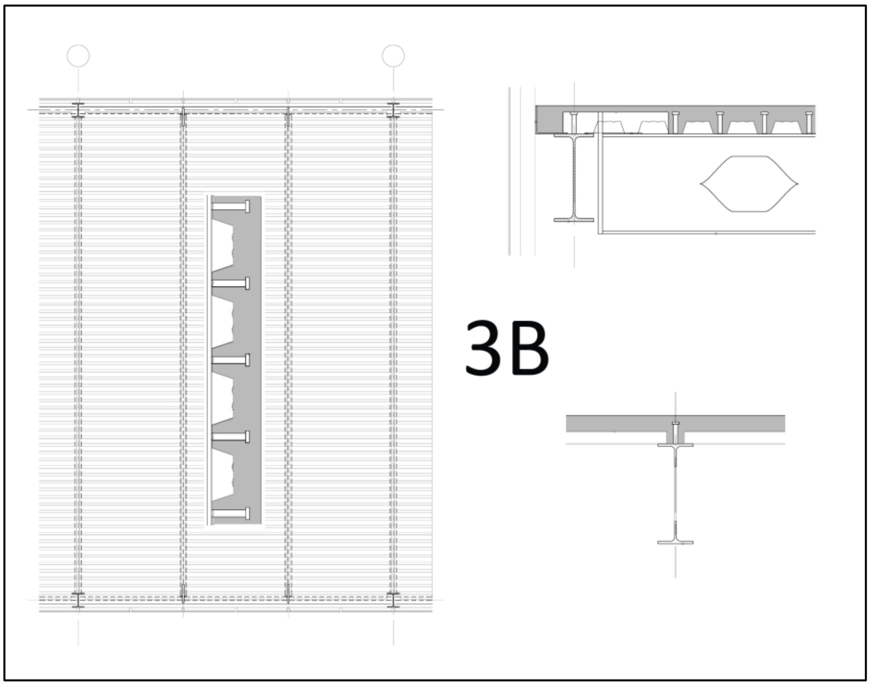


Figure 4.27 – Variant 3B

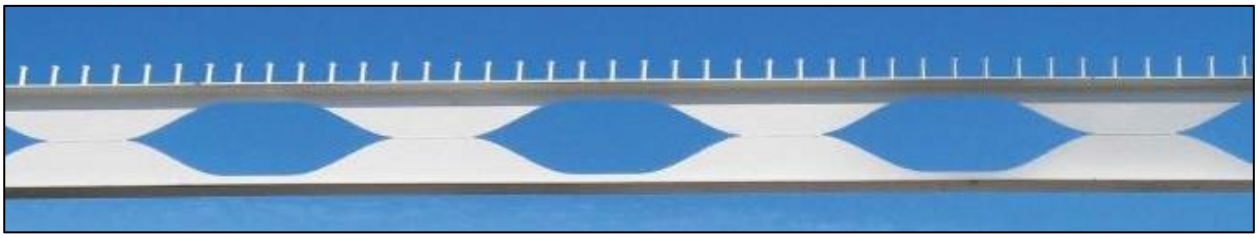


Figure 4.28 - Angelina™ beam (Credit: tectonia-online.com)

Furthermore, the same areal work platform concept (see Figure 4.18) was considered for the installation of the steel beams and steel columns. The movements of the boom lifters will be shown in the 2D construction simulations. In contrary to variant 3A, a temporarily falsework isn't necessary to ensure the stability of the floor during concrete pouring for this variant.

Table 4.27 gives an overview of the quantities of elements (objects) in variant 3B.

Table 4.27 - Quantity of elements - variant 3B

Quantity of Elements - Var 3B				
	[mL]	[m³]	[u]	[racks]
Concrete for Walls	1330	1222		
Concrete for Slabs		1533,574		
Steel Columns			140	
Steel Beams			684	
CofraPlus 60			2817	94

This variant was analysed with one tower crane and with two tower cranes on site. In addition, another analyse was carried in which the hypothesis employed was that in the morning shift, two cranes would be used for the concrete core erection, and in the afternoon shift only one crane would be used for the steel frame and composite slab installation. This means that during the afternoon shift, the second crane could stand still during, so no crane operator would be needed, or the second crane could be used for other work, i.e. façade or substructure works.

4.7.1 One tower crane on site

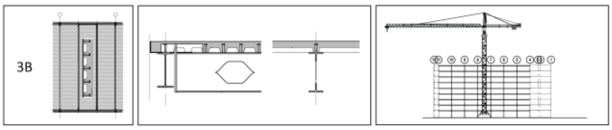
In this analyse, one tower crane was considered. The result of the crane efficiency calculation for the erection of the concrete cores can be found in Chapter 3.4. The resulting construction of the concrete cores duration is 66 working days.

For the remaining structure, only one crane efficiency calculation was necessary, due to the fact that the structural frame and slab are built simultaneously, as in the case of Variant 3A. In the crane efficiency calculation, the crane cycles of the movements of the special concept areal platform were considered. The results are shown in Table 4.28.

Table 4.28 – Crane efficiency calculation results for steel frame/floor building (Var. 3B – 1 crane)

UNIVERSITÉ DU LUXEMBOURG – Markus Schäfer, Univ.-Doz. Dr.- Ing. – FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION	Project :	Project SiMCo - Variant 3B
	Work :	Steel Frame - Composite Floor
	Floor :	Ground-Floor + 1st Floor
	Author :	Dany Pereira Figueiredo

Crane Efficiency Calculation - RESULTS



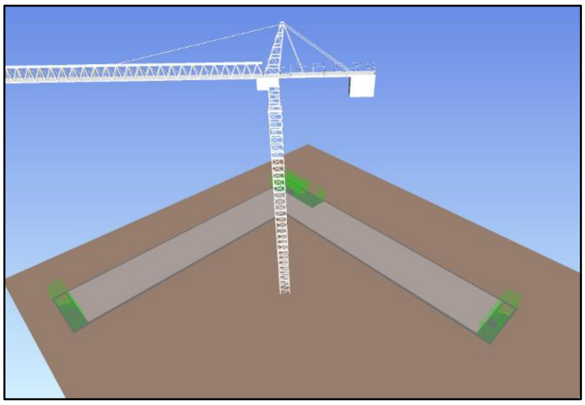
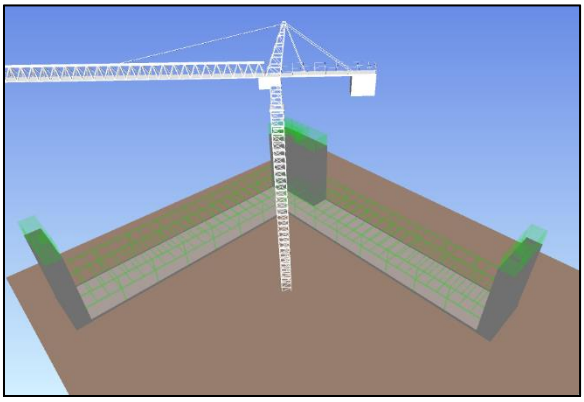
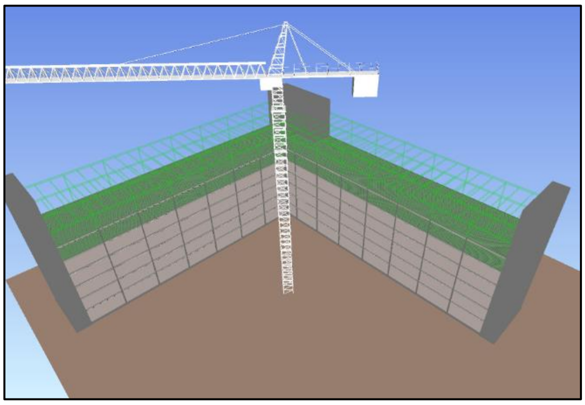
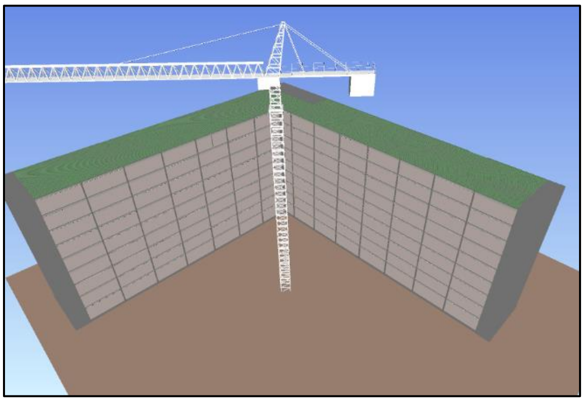
Working day:	8 hrs/day	Security Applied :	15 %
Crane on site:	1	**Expected construction duration :**	**8 days**

ID	Description	Element Type w, c, b, s, u, d	Work Days	Rate of Work u/d	LM/d	m²/d	m³/d
2	**Steel Columns**						
2.1	Columns HEM 240	c	8	3,500	-	-	-
S	**TOTAL**		**8**	**3,500**	**-**	**-**	**-**
3	**Steel Beams**						
3.1	Angelina IPE 330	b	8	11,500	-	-	-
3.2	Façade IPE 400	b	8	7,500	-	-	-
S	**TOTAL**		**8**	**19,000**	**-**	**-**	**-**
4	**Slabs**						
4.1	CofraPlus 60	d	8	76,750	-	428,956	-
S	**TOTAL**		**8**	**76,750**	**-**	**428,956**	**-**

With a security of 15%, a working day of 8 hours (afternoon shift) and one crane on site, the calculated construction duration for the frame and slab construction of two floors is 8 working days. The resulting building rates are 3 to 4 steel columns, 19 steel beams and 428 m² of steel deck per day.

The consequent 2D construction progress simulation elaborated from the given rates was done and can be found in Appendix III. From the progress simulation, a Gantt Chart was created and a 4D simulation was done, which helped to optimise and correct the schedule (see Table 4.29).

Table 4.29 – Screenshots from the 4D simulation of studied case Variant 3B with one crane

Day 1 	Day 39 
Day 67 	Day 78 

The resulting total construction duration for this analysis is 78 working days without any security for hazards and 90 working days with a security of 20% for hazards. As mentioned previously, the construction duration of the concrete cores is 66 working days. The time necessary for the building of the structural steel frame and composite slab is 39 working days. The lag between the construction’s beginning of the concrete cores and the structural frame is 39 working days. The resulting Gantt Chart can be found in Appendix IV.

The consequent daily truck flow and needed workforces on site are represented in Figure 4.29 and Figure 4.30.

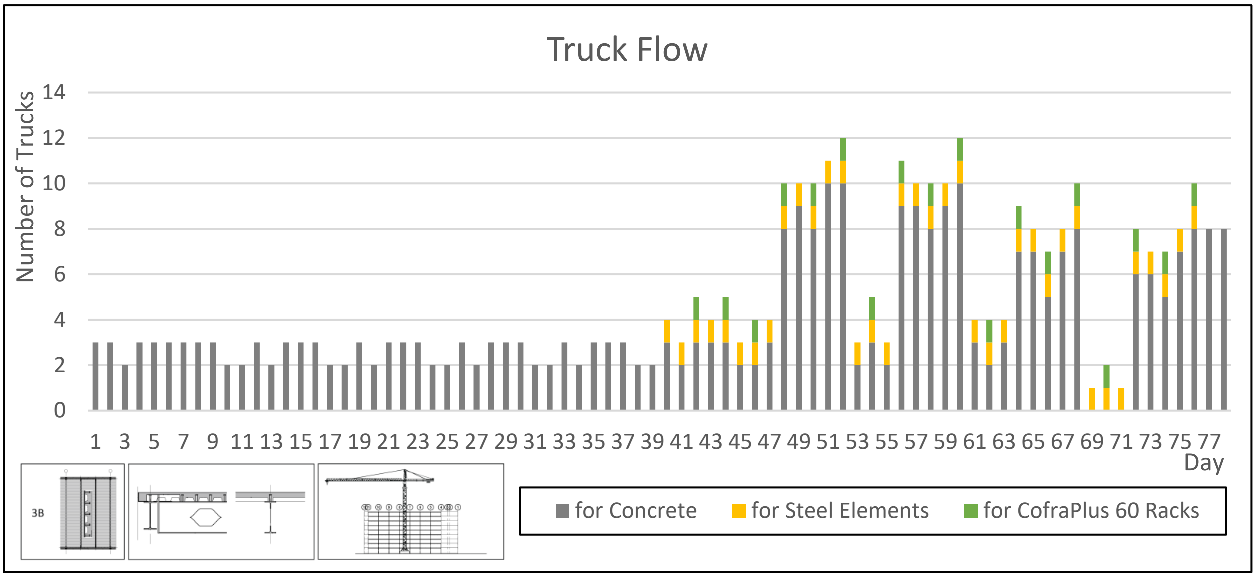


Figure 4.29 – Resulting truck flow for variant 3B one crane

In the truck flow graphic, it's recognisable when the beginning of the structural frame and slab work is (40th day). It is also to notice that the supply of CofraPlus 60 sheets is done every second day. As in the previous variant, this is due to the huge number of sheets one truck can transport. The peaks of the concrete mixer trucks on site match with the days in which the office slab is poured with concrete.

In total 310 concrete mixer trucks, 37 trucks transporting steel elements and 18 trucks transporting the racks with the CofraPlus 60 steel sheets are needed. Table 4.30 gives an overview of the required trucks.

Table 4.30 - Required trucks (Variant 3B – one crane)

Required Trucks - Var 3B - one crane	
Trucks for	[u]
concrete	310
steel elements	37
CofraPlus 60 steel sheets	18

In the workforce graphic below, it is also recognisable when the steel frame and slab construction begins. As for the other analysis, the constant variation of the needed workers on site is due to subcontractors' workforces, as for example the steel fixers. The maximum number of workers on site is 32 men, 15 men in the morning shift and 17 in the afternoon one.

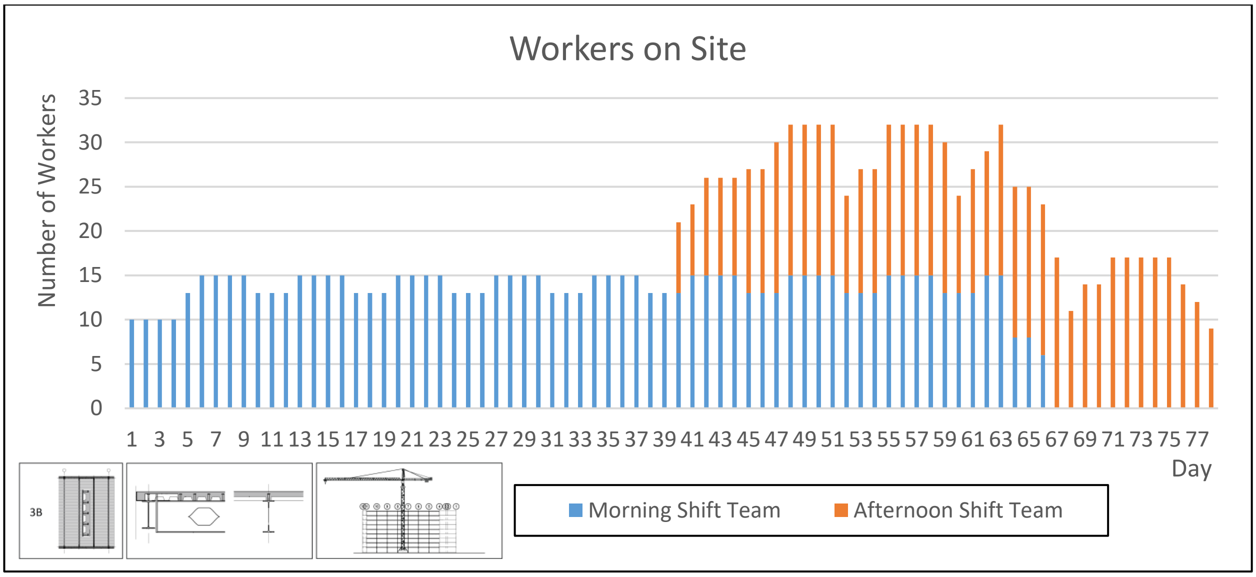


Figure 4.30 – Resulting workforce analysis graph for variant 3B one crane

4.7.2 Two tower cranes on site

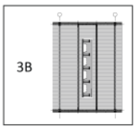
For the analysis with a second tower crane on site, the same building division and cranes' position considered in Chapter 4.2.2 (Variant 1A two tower cranes) were used (see Figure 4.7). Also, the hypothesis that in the morning shift the concrete cores works would take place, and in the afternoon the remaining structure would be build, was taken for this analysis.

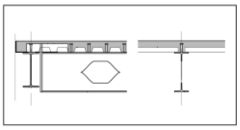
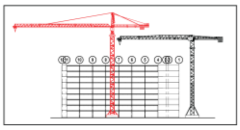
The construction duration for the concrete cores with two cranes is of 47 working days as seen in Chapter 3.4. For the remaining structure, two cranes efficiency calculation needed to be carried out, one for each crane. The results are shown in Table 4.31 for crane no. 1 and in Table 4.32 for crane no.2.

Table 4.31 – Crane efficiency calculation results for frame/floor building - crane/zone 1 (Var. 3B-2 cranes)

Markus Schäfer Univ.-Doz. Dr.- Ing.	
Project :	**Project SiMCo - Variant 3B**
Work :	Steel Frame - Composite Floor
Floor :	Ground-Floor + 1st Floor - **Zone 1**
Author :	Dany Pereira Figueiredo

Crane Efficiency Calculation - RESULTS



Working day:	8 hrs/day	Security Applied :	20 %
Crane on site:	2	**Expected construction duration :**	**5 days**

ID	Description	Element Type w, c, b, s, u, d	Work Days	Rate of Work u/d	LM/d	m²/d	m³/d
2	**Steel Columns**						
2.1	Columns HEM 240	c	5	2,800	-	-	-
S	**TOTAL**		**5**	**2,800**	**-**	**-**	**-**
3	**Steel Beams**						
3.1	Angelina IPE 330	b	5	9,200	-	-	-
3.2	Façade IPE 400	b	5	6,000	-	-	-
S	**TOTAL**		**5**	**15,200**	**-**	**-**	**-**
4	**Slabs**						
4.1	CofraPlus 60	d	5	70,800	-	395,701	-
S	**TOTAL**		**5**	**70,800**	**-**	**395,701**	**-**

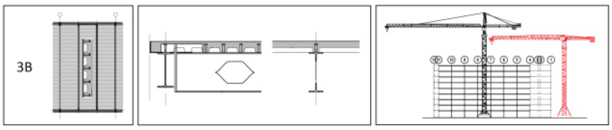
According to the results above, crane no.1 takes 5 working days to complete two floors in its zone. A 20% security factor is here applied because of the presence of two cranes on site. A working day of 8 hours was considered, which corresponds to the afternoon shift. The building rates are 2 to 3 columns, 15 to 16 beams and 395 m² steel deck per day.

Table 4.32 – Crane efficiency calculation results for frame/floor building - crane/zone 2 (Var. 3B-2 cranes)

uni.lu UNIVERSITÉ DU LUXEMBOURG – Markus Schäfer, Univ.-Doz. Dr.- Ing. – FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION

Project : **Project SiMCo - Variant 3B**
Work : Steel Frame - Composite Floor
Floor : Ground-Floor + 1st Floor - **Zone 2**
Author : Dany Pereira Figueiredo

Crane Efficiency Calculation - RESULTS



Working day: 8 hrs/day — Security Applied : 20 %

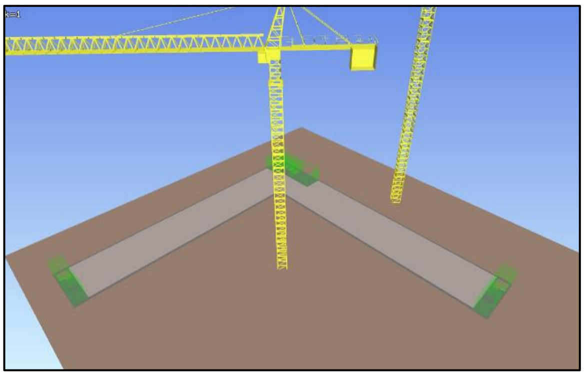
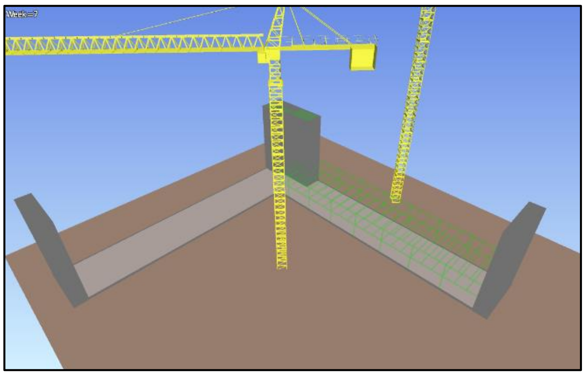
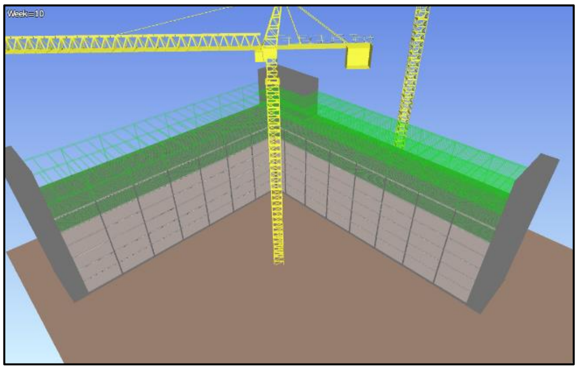
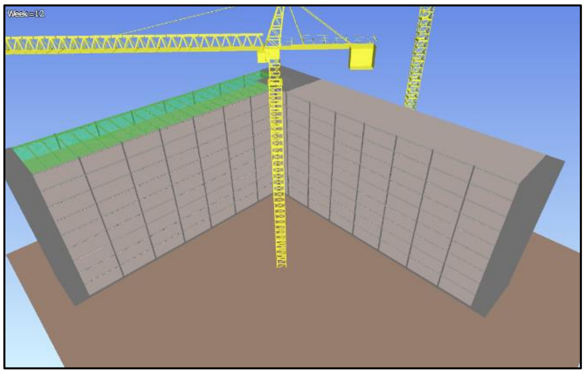
Crane on site: 2 — **Expected construction duration : 5 days**

ID	Description	Element Type (w, c, b, s, u, d)	Work Days	Rate of Work u/d	LM/d	m²/d	m³/d
2	**Steel Columns**						
2.1	Columns HEM 240	c	5	2,800	-	-	-
S	**TOTAL**		**5**	**2,800**	**-**	**-**	**-**
3	**Steel Beams**						
3.1	Angelina IPE 330	b	5	9,200	-	-	-
3.2	Façade IPE 400	b	5	6,000	-	-	-
S	**TOTAL**		**5**	**15,200**	**-**	**-**	**-**
4	**Slabs**						
4.1	CofraPlus 60	d	5	52,000	-	290,628	-
S	**TOTAL**		**5**	**52,000**	**-**	**290,628**	**-**

The same parameters were applied for crane no.2's efficiency calculation. The resulting construction duration for two floors in zone 2 is 5 working days. The building rates are 2 to 3 columns, 15 to 16 beams and 290 m² steel deck per day.

The elaborated 2D construction progress simulation from the resulting building rates can be found in Appendix III. According to the progress simulation, a Gantt Chart was made, and with a help of a 4D simulation, the Gantt Chart was optimised (see Table 4.33).

Table 4.33 – Screenshots from the 4D simulation of studied case Variant 3B with 2 cranes

Day 1	Day 28
	
Day 48	Day 54
	

The resulting total construction duration for this analysis is 55 working days without any security for hazard and 66 working days with a security of 20% for hazards. As seen formerly, the construction duration of the concrete cores is 47 working days. The time needed for the structural steel frame and the composite floor building is 27 working days. The lag between the start of concrete core and frame/slab works is 28 working days. The Gantt Chart resulting of this analysis can be found in Appendix IV.

The resultant daily truck flow and needed workforces on site are represented in Figure 4.31 and Figure 4.32.

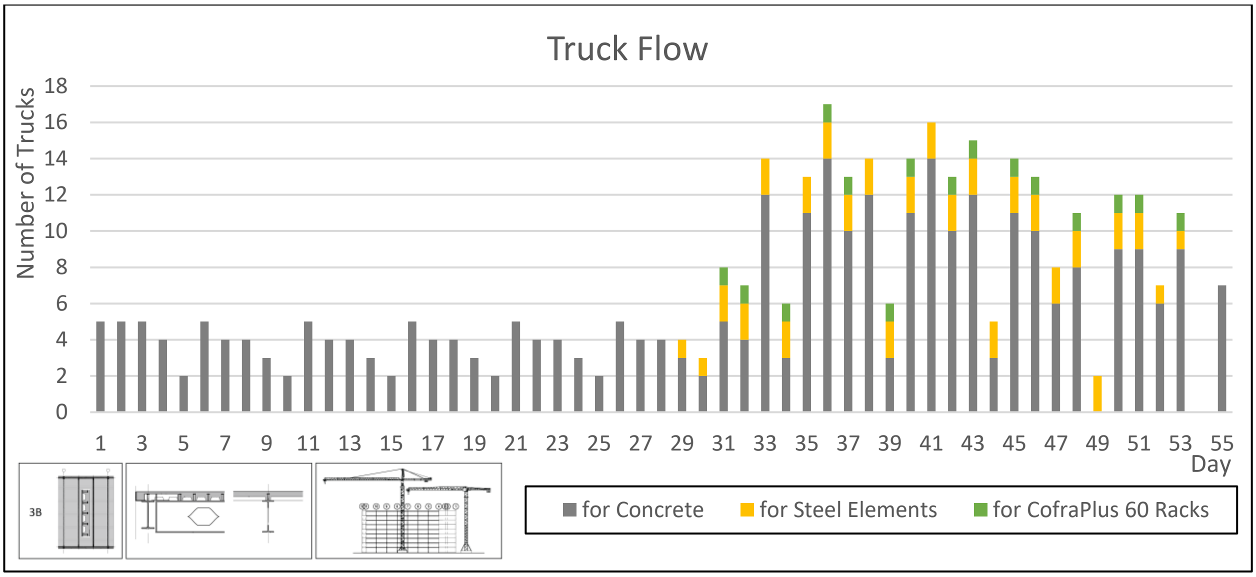


Figure 4.31 – Resulting truck flow for variant 3B two cranes

As for previous analyses, it is visible in the truck flow graphic when the second shift starts. In this case it's on the 29th work day. Overall, 310 concrete trucks, 46 trucks transporting steel elements and 15 trucks transporting racks with Cofraplus 60 steel sheet will be necessary to carry the works properly out. Table 4.34 gives an overview of the required trucks.

Table 4.34 - Required trucks (Variant 3B – two cranes)

Required Trucks - Var 3B - two cranes	
Trucks for	[u]
concrete	310
precast elements	46
CofraPlus 60 steel sheets	15

In the workforces' graphic, it is also to distinguish when the works on the structural frame and composite slab begin. The maximum needed workers on site is 54 men, 30 in the morning shift and 24 in the afternoon shift. The constant variation of the needed workers is due to the workforces of the subcontractors', as for example the steel fixer, who are not needed in the same number every day.

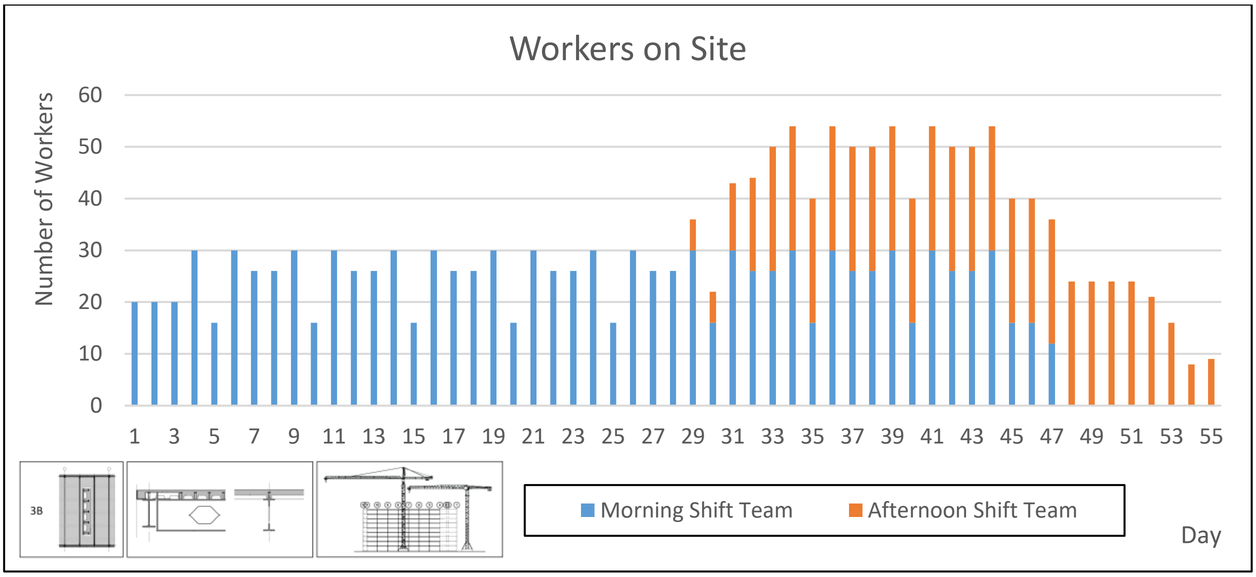


Figure 4.32 – Resulting workforce analysis graph for variant 3B two cranes

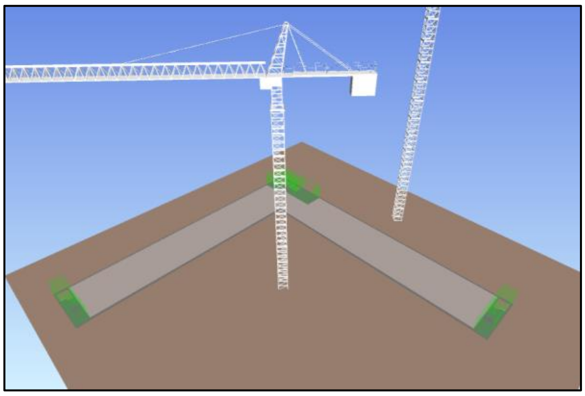
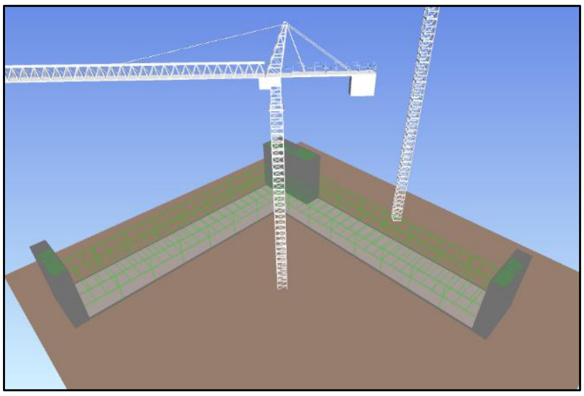
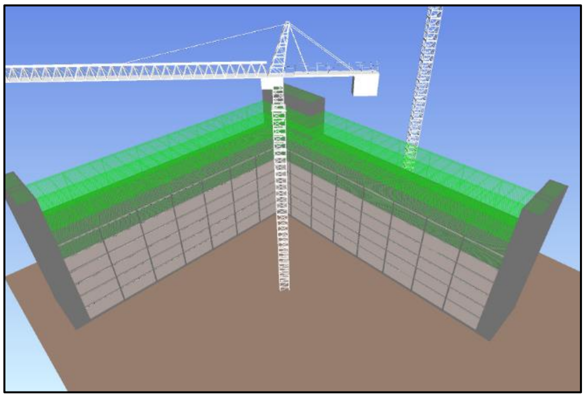
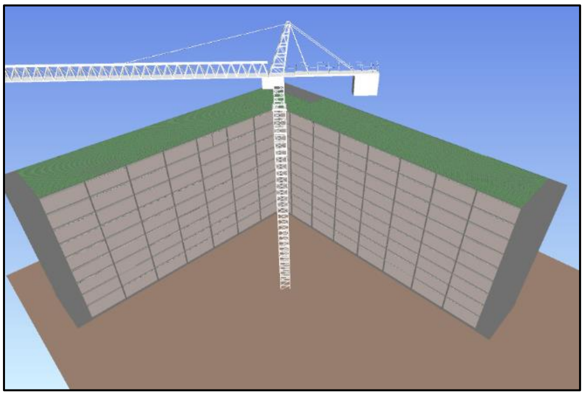
4.7.3 Two tower cranes on site, two active in the morning shift, one active in the afternoon shift

For this analysis, the idea was to have two tower cranes on site, which would fully work for the construction of the concrete cores in the morning shift, but have only one working on the construction of the structural frame and slab in the afternoon shift. The second crane would then stay still, so no cab operator and less workforces would be needed, or alternatively it could be used for works on the façade or substructure.

In this case, the same crane efficiency calculation as seen in Chapter 3.4 was used for the concrete cores building, in which the result is 47 working days needed for the construction, using two cranes. For the afternoon shift, the same crane efficiency calculation used in Chapter 4.7.1 (Variant 3B, one tower crane) was applied. The resulting building rates can be seen in Table 4.28.

As for the others analyses, a 2D construction progress simulation was done (Appendix III), which led to the elaboration of a Gantt Chart. With the use of a 4D simulation (see Table 4.35), the Gantt Chart was reviewed and optimised. The resulting construction duration is 58 working days without any security factor for hazards, and 70 working days with a 20% security factor for hazards. As said before, the concrete cores construction takes 47 working days to be completed. The construction of the remaining structure takes 39 working days. The lag between the beginning of concrete cores' construction and the remaining structure is of 20 working days.

Table 4.35 – Screenshots from the 4D simulation of studied case Variant 3B 2+1 cranes

Day 1	Day 20
	
Day 47	Day 70
	

The definitive construction programme for this analysis can be found in form of a Gantt Chart in Appendix IV. The resulting daily truck flow and needed workforces on site are represented in Figure 4.33 and Figure 4.34.

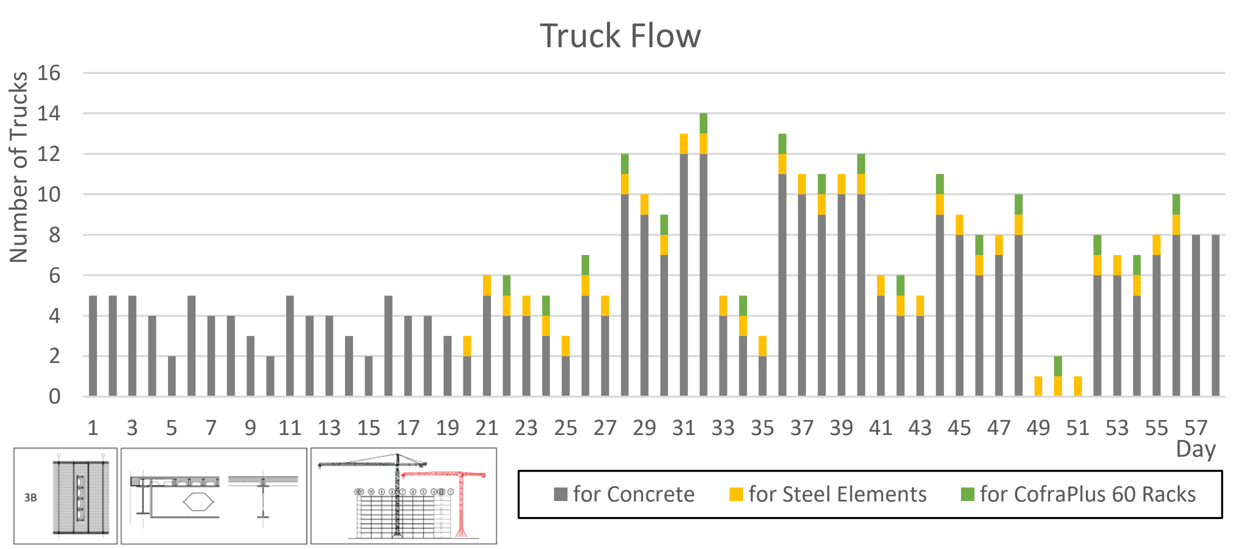


Figure 4.33 – Resulting truck flow for variant 3B two + one cranes

In the truck flow graphic above, the start of the works on the steel frame and slab is recognisable, as it is the case in the other analyses. In this case, it's on the 20th work day.

In total, 310 concrete mixer trucks, 37 trucks transporting steel elements and 18 trucks transporting racks with CofraPlus 60 steel sheet are necessary. Table 4.36 gives an overview of the required trucks.

Table 4.36 - Required trucks (Variant 3B – 2+1 cranes)

Required Trucks - Var 3B - 2+1 cranes	
Trucks for	[u]
concrete	310
precast elements	37
CofraPlus 60 steel sheets	18

In the workforces' graphic below, the daily number of needed workers is represented. The concrete core team is allocated to the morning shift and the other team is allocated to the afternoon shift. The maximum workers needed on site is of 47 men, 30 in the morning shift and 17 in the afternoon shift. As for the other analyses, the constant variation of the number of workers needed is due to subcontractors' workforces, as for example the steel fixers.

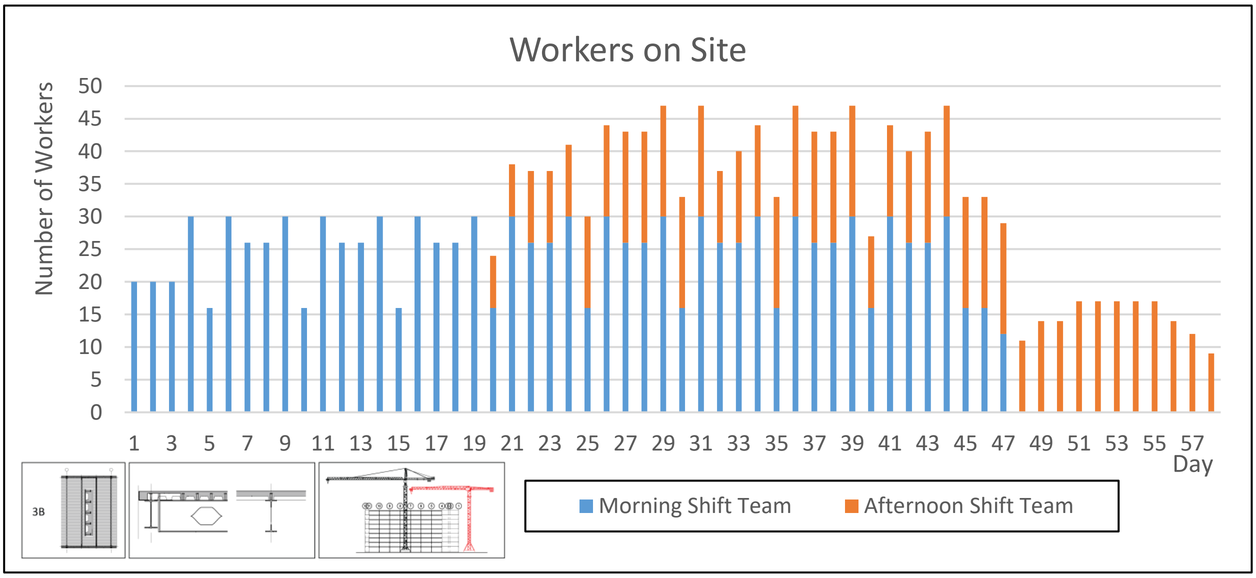


Figure 4.34 – Resulting workforce analysis graph for variant 3B two + one cranes

4.8 COMPARISON BETWEEN ALL THE ANALYSED CASES

After analysing each hypothesis taken for the different variants of the project, a comparison between them all is necessary to clarify which one has the shorter duration, the fewest trucks or workers on site.

The results of each case analysed are summaries in Table 4.37. To a better overview, a Gantt Chart representing the values in Table 4.37 is to be found in Figure 4.35.

Table 4.37 – Results of each analysed case (green row: shortest duration; red row: longest duration)

Variant	No. Cranes	Construction Method		Shift		Rotation [d]		Total Time [d]			Total Duration [d]	
		Concrete Cores	Floors	Cores	Floors	Cores	Floor	Cores	Floors	Lag Core - Floors	without hazards	with hazards
1a	1	In-Situ Concrete	Precast Structure + Hollow-Core Slab	-	-	-	8	-	-	-	**77**	**92**
1a	2	In-Situ Concrete	Precast Structure + Hollow-Core Slab	Morning (8h)	Afternoon (8h)	5	5	47	48	13	**61**	**73**
1b	1	In-Situ Concrete	Precast Structure + Hollow-Core Slab	-	-	-	7	-	-	-	**68**	**82**
1b	2	In-Situ Concrete	Precast Structure + Hollow-Core Slab	Morning (8h)	Afternoon (8h)	5	5	47	45	15	**60**	**72**
2a	1	In-Situ Concrete	Steel Structure + Hollow-Core Slab	Morning (8h)	Afternoon (8h)	7	12*	66	48	30	**78**	**94**
2b	1	In-Situ Concrete	Steel Structure + Semi-Precast Elements Slab	Morning (8h)	Afternoon (8h)	7	11*	66	45	30	**75**	**90**
3a	1	In-Situ Concrete	Steel Structure + CofraPlus 220 Composite Slab	Morning (8h)	Afternoon (8h)	7	9*	66	45	29	**74**	**89**
3b	1	In-Situ Concrete	Steel Structure + CofraPlus 60 Composite Slab	Morning (8h)	Afternoon (8h)	7	8*	66	39	39	**78**	**94**
3b	2	In-Situ Concrete	Steel Structure + CofraPlus 60 Composite Slab	Morning (8h)	Afternoon (8h)	5	5*	47	27	28	**55**	**66**
3b	2+1**	In-Situ Concrete	Steel Structure + CofraPlus 60 Composite Slab	Morning (8h)	Afternoon (8h)	5	8*	47	39	19	**58**	**70**

The case with the shortest overall construction duration is variant 3B with 2 cranes in the morning and afternoon shifts (see Chapter 4.7.2), with a duration of 66 working days, including safety for hazards. Also, this specific analysed case is the one where the building of the structural frame and slab is the fastest, with a duration of 27 working days.

Overall, it is recognisable that the building of the concrete cores is for every case the conditioning factor in the construction progress of the case study. When focusing on the remaining structure, the structural frame and slab, the construction duration is shorter for the all steel solution (Variants 3) than for the other variants. Furthermore, layouts from type B have a shorter construction duration than type A layouts. This is the case because type B layouts don't consider a column in the middle of the offices, so there are fewer elements in type B layouts. It's also plausible that the analysed cases with 2 tower cranes on construction site have also a shorter construction time than the ones with only 1 tower crane.

The lag between the construction's beginning of the concrete cores and the remaining structures depends on the construction progression speed of the structural frame and slab. The faster the construction of the frame and slab is, the greater the lag. This has to do with the fact that it was took into consideration to erect concrete cores in the morning shift, since the duration of the concrete core always is the same, and only the number of cranes on site would change. (one crane: 47 working days; two cranes: 66 working days).

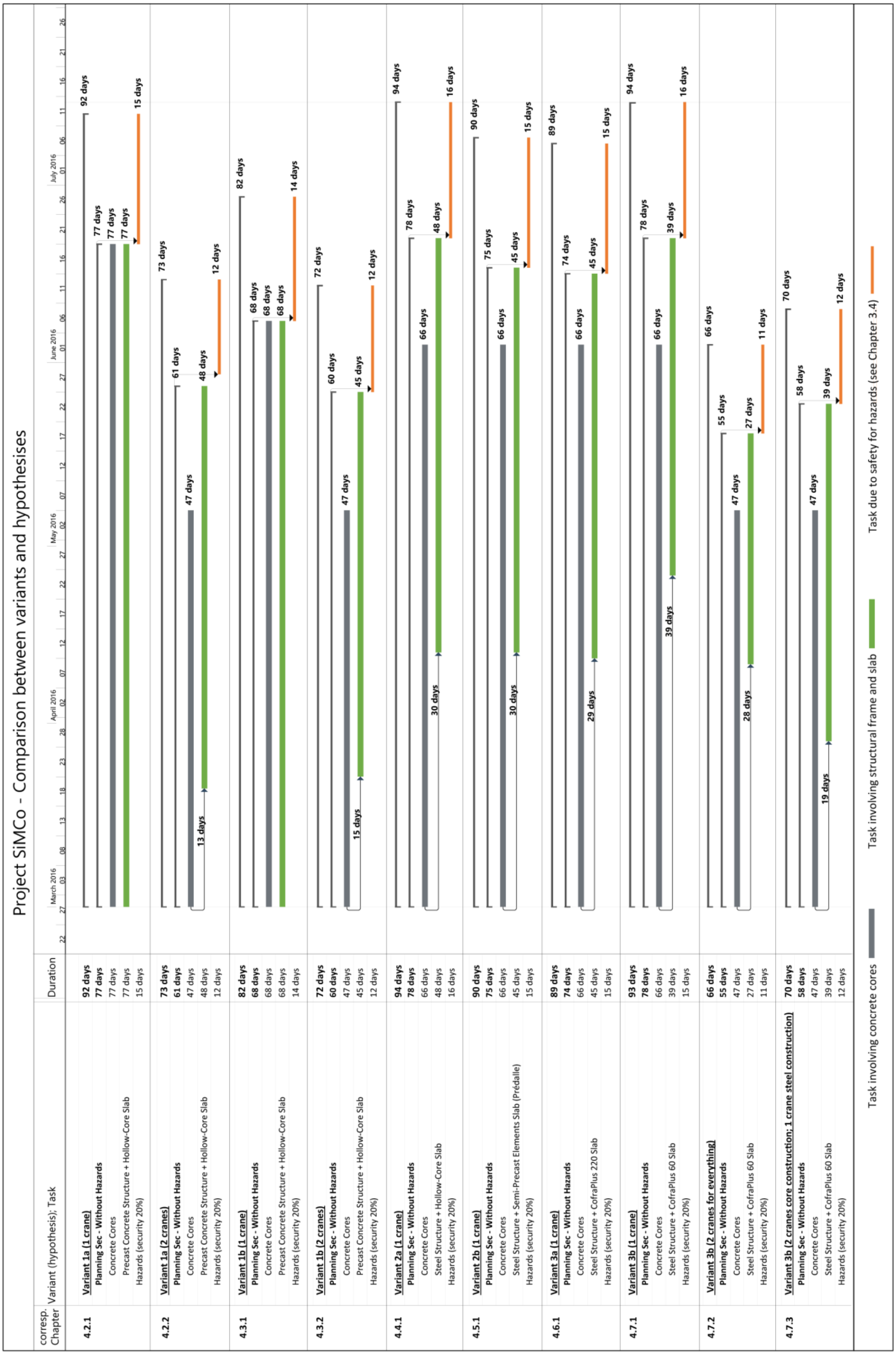


Figure 4.35 – Comparison of the construction schedule of each analysed case

Beside the comparison of the schedules, the comparison of the total trucks necessary on site was also made. The comparison can be found in Figure 4.36.

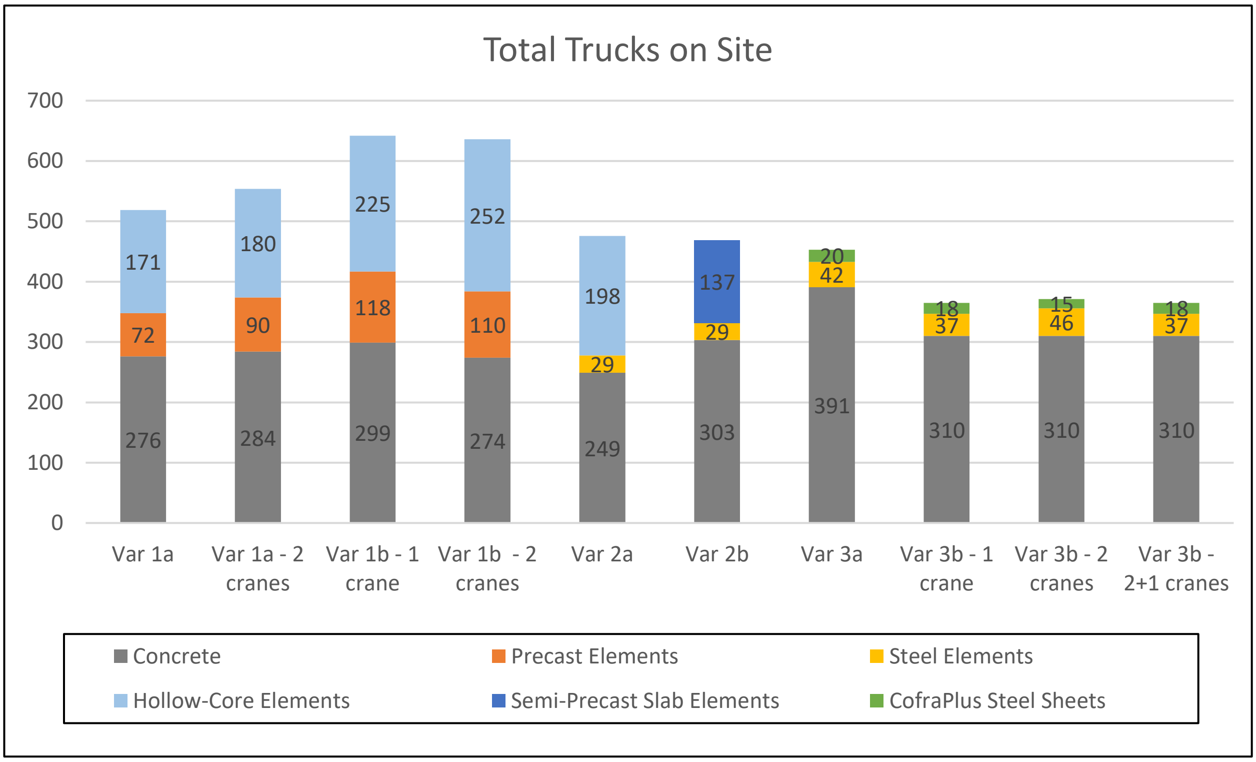


Figure 4.36 – Trucks' need comparison between each studied case

The bar chart above shows that for all studied cases, the variants 1 are, from all the variants, those which need the most trucks. This is due to the fact that precast elements are much heavier than the steel elements employed in the other variants. However, the number of concrete mixer trucks increases in the variants number 3, especially in variant 3A. This has to do with the composite floor used. In fact, for the construction of a composite floor, more cubic meter of in-situ concrete is required than for slabs composed of precast elements. The composite floor in Variant 3A using CofraPlus 220 steel sheets requires an in-situ concrete quantity of 0,159 m^3 per m^2, the composite floor in Variant 3B using CofraPlus 60 steel sheets requires a quantity of 0,093 m^3 per m^2, the hollow-core slab in Variant 1A requires a quantity of 0,057m^3 per m^2, the hollow-core slab in Variant 1B requires a quantity of 0,063 m^3 per m^2, the hollow-core slab in Variant 2A requires a quantity of 0,059 m^3 per m^2 and the slab in semi-precast elements of Variant 2B requires a quantity of 0.096 m^3 per m^2. In conclusion, the CofraPlus 220 slab is, out of all the types of slabs analysed, the one which consumes the most in-situ concrete, followed by the CofraPlus 60 composite slab and semi-precast slab.

The last comparison made was between the needed workforces on site. The comparison can be found in form of a bar chart in Figure 4.37.

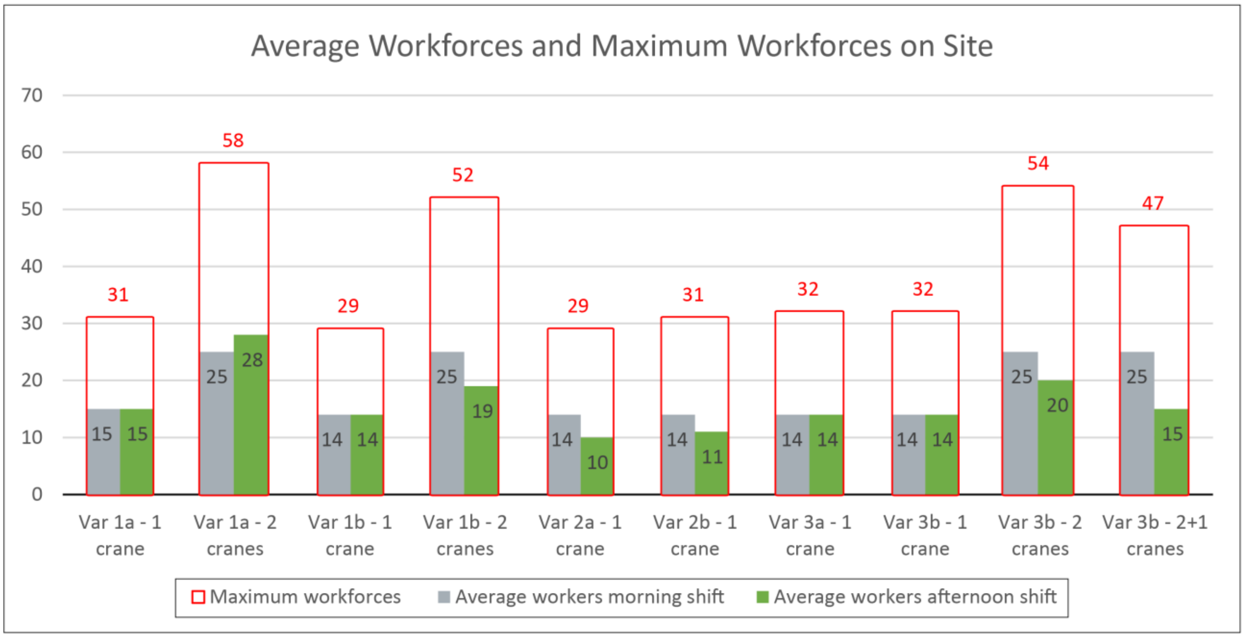


Figure 4.37 – Workforces comparison

In the bar chart above, the maximum number of workforces needed for each case analysed is represented, as well as the average workers on site during the morning and the afternoon shift. As predictable, the cases analysed with one more crane on site have the highest number of workforces. More cranes, more workers to complete the tasks. But no significant variation of the number of workforces can be observed when comparing to each other the analysed cases which consider the same number of cranes.

Beside the charts which made possible the comparison, 4D simulation are a much more powerful visualisation tool for the comparison of each case studied. They were used to present the results of the work to ArcelorMittal and other interested parties in the project. Unfortunately, they can't be shown on paper, but Figure 2.3 – Example of a 4D simulation in Autodesk's software Navisworks Figure 2.3 is an example of a 4D simulation done for this master's thesis. The illustration shown is of variant 3B analysed with 2 cranes.

4.9 CONSTRUCTION SITE INSTALLATION PLAN

After finishing the planning of the construction and resource management, the next step was the elaboration of a site installation plan following existing Luxembourgish standards. Beside the Luxembourgish standards, another reference considered for the elaboration of the site installation plan was also a site installation seen on construction site which was visited during the development of this master's thesis. The visited construction site was located in Metz (France) and belonged to company of the construction group Vinci, which have one of the best policy concerning the construction site installation layout. Figure 4.38 is a picture of the visit in which a red carpet indicating the pathway for the workers and a recycling point can be seen. Also one can observe how clean the construction site is. Unfortunately, such construction sites are still not standard today.

Figure 4.38 – Site visit in Metz; red carpet indicating workers' pathway; recycling point

For the project SiMCo, only the construction site installation of variant 3B with two cranes was done, because it is the variant with the shortest construction duration and because it was also required by ArcelorMittal. The site installation plan can be found in Appendix V. Beside the site installation plan, a detailed containers' layout of the site facilities realised regarding the Luxembourgish standards and the main characteristics of both cranes can also be found.

In the installation plan can be found: site facilities on two levels, parking, unloading areas for each crane, storage areas for each crane, recycling point, drum washing point concrete bucks washing point, storage container, workshop for steel reinforcement or formwork, tire wash equipment, security guard container, a chemical toilet near the security guard container and a chemical toilet in each floor.

The substructure layout was imagined, because no information to the underground levels was given.

The site facilities include on the ground level: A meeting room, an office for the project manager, an office for his secretary, a kitchenette, a toilet container for women and men, an office for the concrete engineer, an office for the steel engineer, an office for the site technician and an office for two general foremen. On the level above there is: a refectory, 5 locker rooms, a shower room and a toilet container for women and men.

On the plan the maximal crane loads with their respective radius are represented. Also the areas over which the cranes cannot travel with loads are indicated.

5 Final Considerations

5.1 Conclusions

The results of the comparison between all case studied, shows clearly that the steel variants and in particular the steel frame/composite steel slab variants have a considerable impact on construction site logistics, with a significant reduction of trucks on site in relation to variants without any steel solution. In terms of the construction duration, only a little decrement of the global construction duration is visible. But when looking only for the construction times of the frame and slab, without considering the construction duration of the concrete cores, it's is that construction of steel solutions is faster. Concerning the number of workers, it doesn't vary much from case to case, being the significant variations the ones seen between the use of one or two cranes.

Unfortunately, it was not possible to use construction site specific objects in the 4D simulation, as for example scaffoldings, frameworks, or even construction site facilities equipment, mainly because there was no time to model every element, but also because most elements specific the execution material, e.g. frameworks, are yet not available in online object libraries. The use of such elements in the simulation would clearly be beneficial for the visualisation and would probably increment the optimisation level of the schedule and construction site.

Due to lack of time, the cost aspect was not studied in this paper. But a study led by M. Schäfer [14], in which he compared different constructive options of one building and their respectively resulting construction site logistics and cost, concludes that a variant with a relatively cheap structure building, will be not necessarily the cheapest variant when considering a holistic approach to analyse the global costs of the building (e.g. including façade, interior finishing, building service technic). The cost aspect and the inclusion of façade works could be a further development of the present work.

5.2 Future developments

The AEC industry drastically needs BIM to bring it into the 21st connected and mobile world. BIM implementation and practice is showing that there is lots of room to grow and potential for even greater innovation and bigger savings. BIM helps to make construction of buildings and infrastructure less fragmented, breaking down silos and increasing communication and connection. Of course an implementation of a new technology and all the cultural change that it brings with it, doesn't come risk free.

By breaking down a project in its elementary elements (objects), defining for each object their production steps and given each production step the right crane time, the calculations of the construction duration and cost, as well as the planning of the construction site, could be done by computer-based algorithmic calculations. Because the main BIM feature is 3D-object data modelling, the implementation in BIM of the calculation method explained in this master's thesis is the next step. The collecting of relevant data should be component-specific and prepared for data exchange in BIM. Furthermore, the calculation method and data should be implement in BIM itself, for example in openBIM. A 5D visualisation of the construction progress related to all needed resource should be the aim, which lead to an effective resource and logistics management.

Through a detailed planning and visualisation of the construction progress, a simplified and a reliable monitoring of the cost and construction work, as well as a more accurate site logistic management could be realised. Subcontractors with an intensive shop and logistic activity, e.g. precast elements manufacturers or steel constructors, could profit from the cloud-based BIM by planning and monitoring their delivery on site based on the determined work sequence on site. The use of Radio-frequency identification (RFID) could be considered.

The effective implementation of BIM on construction sites, which must involve all workers and subcontractors on site, might be the next big challenge of the AEC industry.

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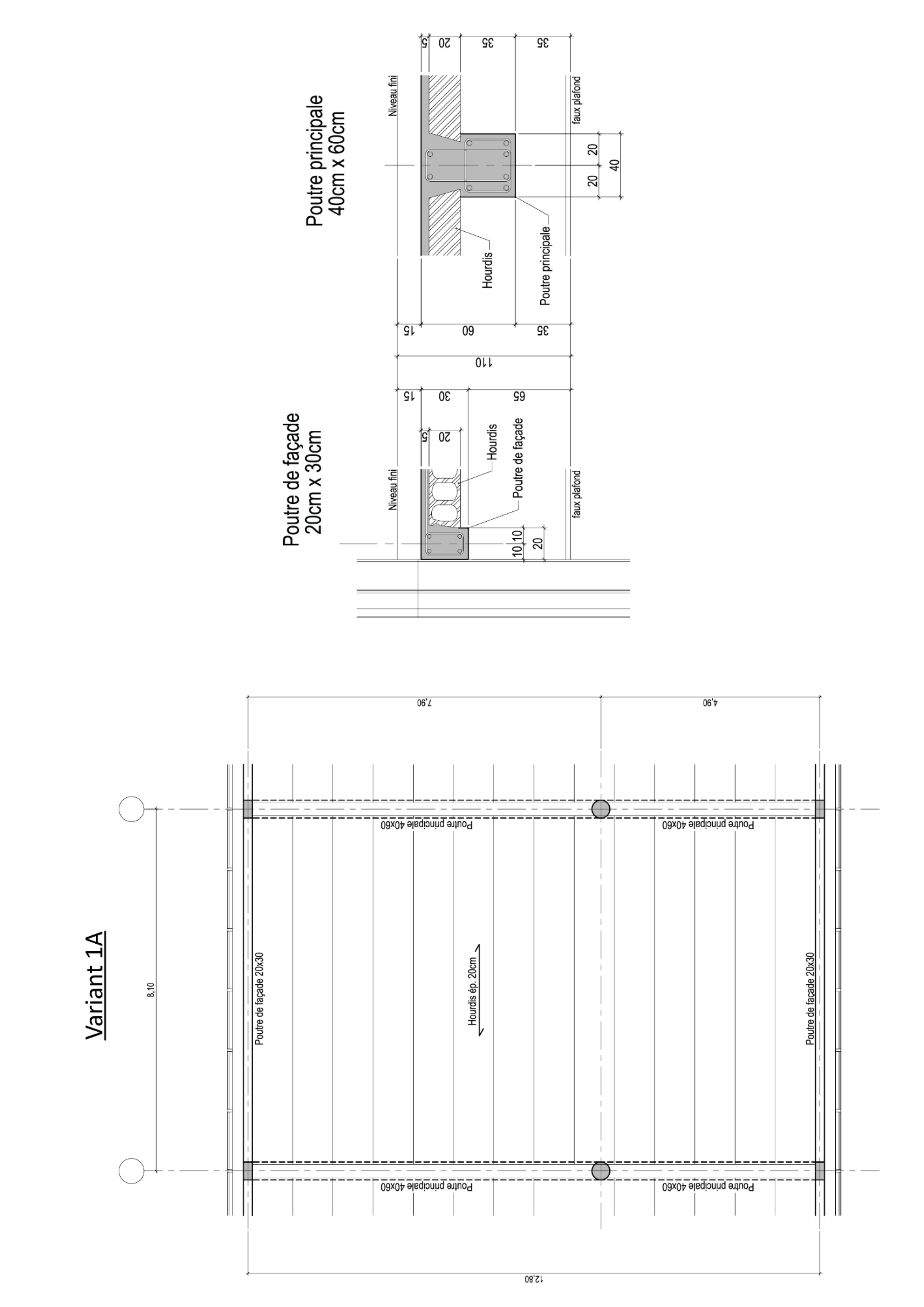
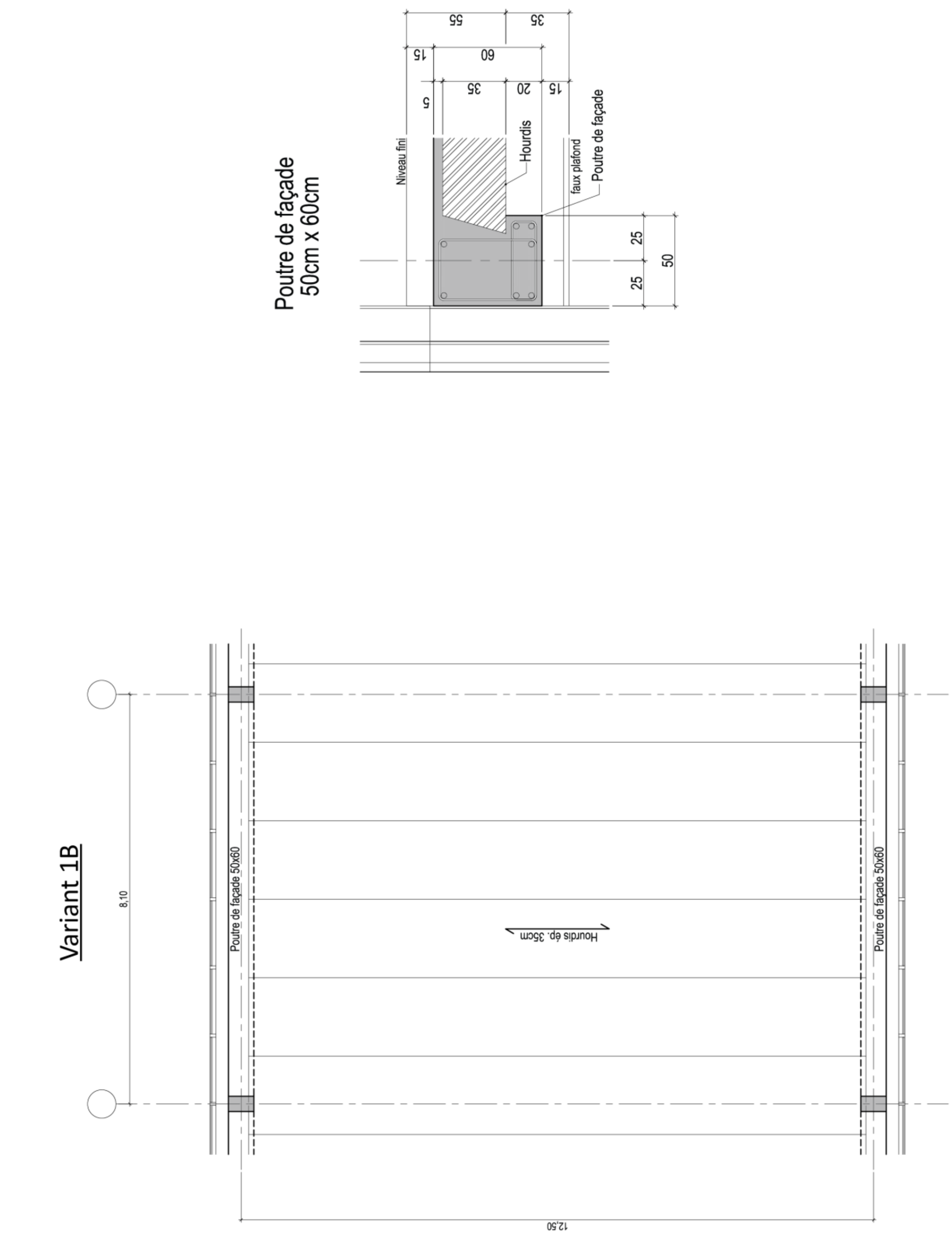
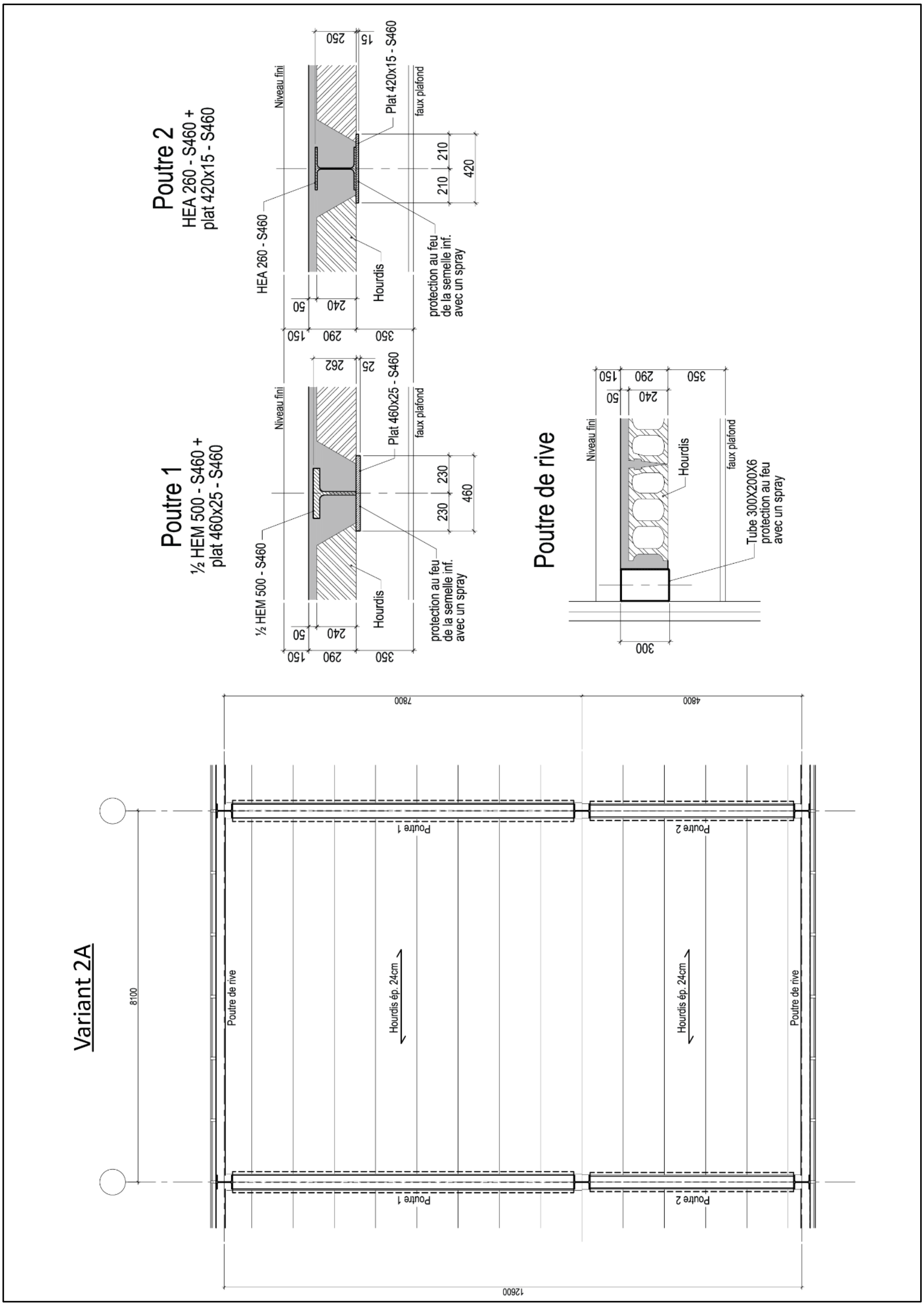
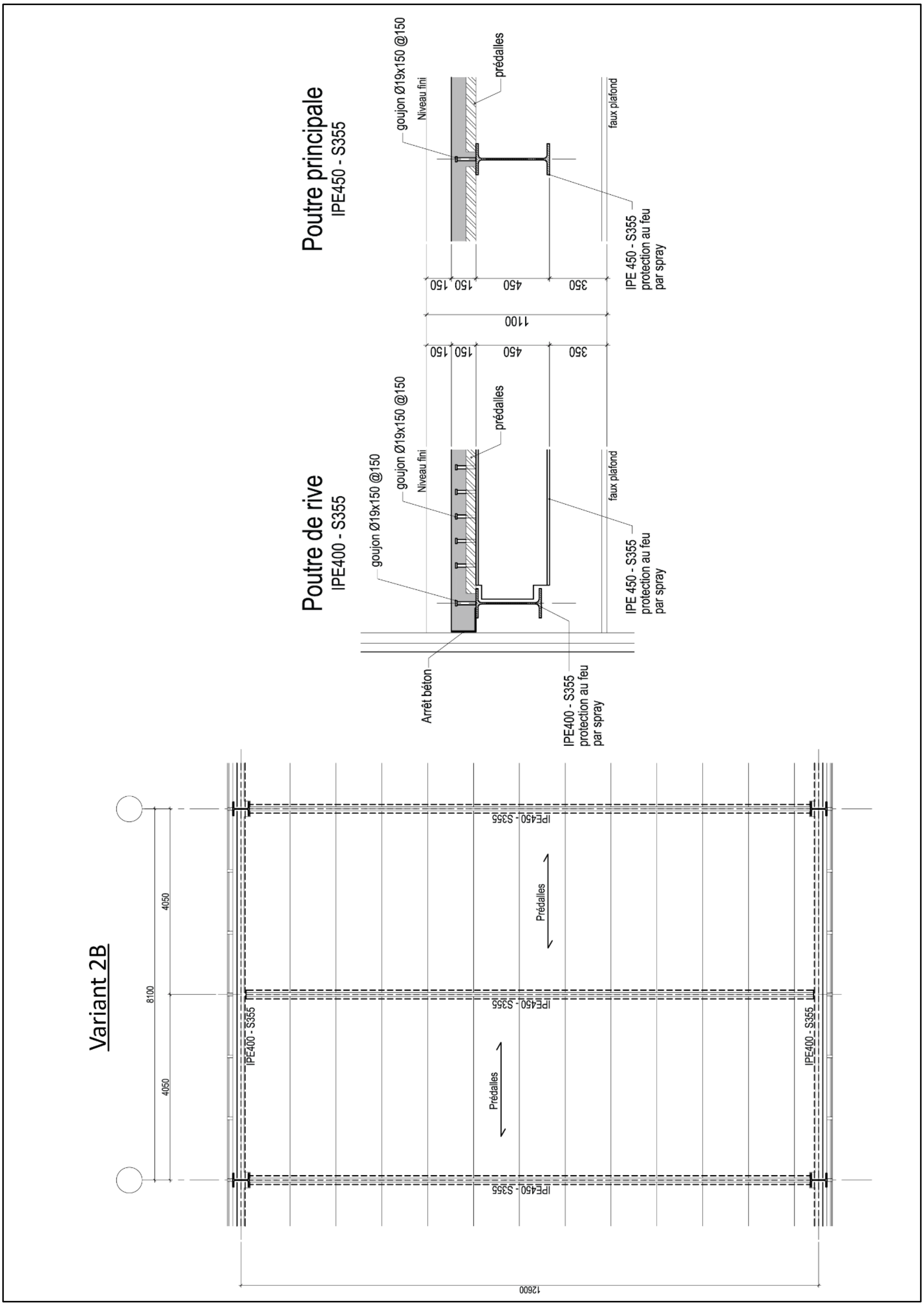
APPENDIX I – CONSTRUCTIVE OPTIONS


Variant 1A
Poutre principale
40cm x 60cm
Poutre de façade
20cm x 30cm
Niveau fini
faux plafond
Hourdis
Poutre principale
Poutre de façade
Poutre principale 40x60
Poutre de façade 20x30
Hourdis ép. 20cm
7,90
4,90
12,80
8,10
110


Poutre de façade
50cm x 60cm
Niveau fini
Hourdis
faux plafond
Poutre de façade
Variant 1B
8,10
Poutre de façade 50x60
Hourdis ép. 35cm
Poutre de façade 50x60
12,50


Variant 2A
Poutre 1
½ HEM 500 - S460 +
plat 460x25 - S460
Poutre 2
HEA 260 - S460 +
plat 420x15 - S460
Poutre de rive
½ HEM 500 - S460
HEA 260 - S460
Hourdis
protection au feu
de la semelle inf.
avec un spray
Plat 460x25 - S460
Plat 420x15 - S460
Niveau fini
faux plafond
Tube 300X200X6
protection au feu
avec un spray
Hourdis ép. 24cm
Poutre de rive
8100
7800
4800
12600
150
290
350
50
240
262
25
250
15
230
460
210
420
300


Variant 2B
Poutre principale
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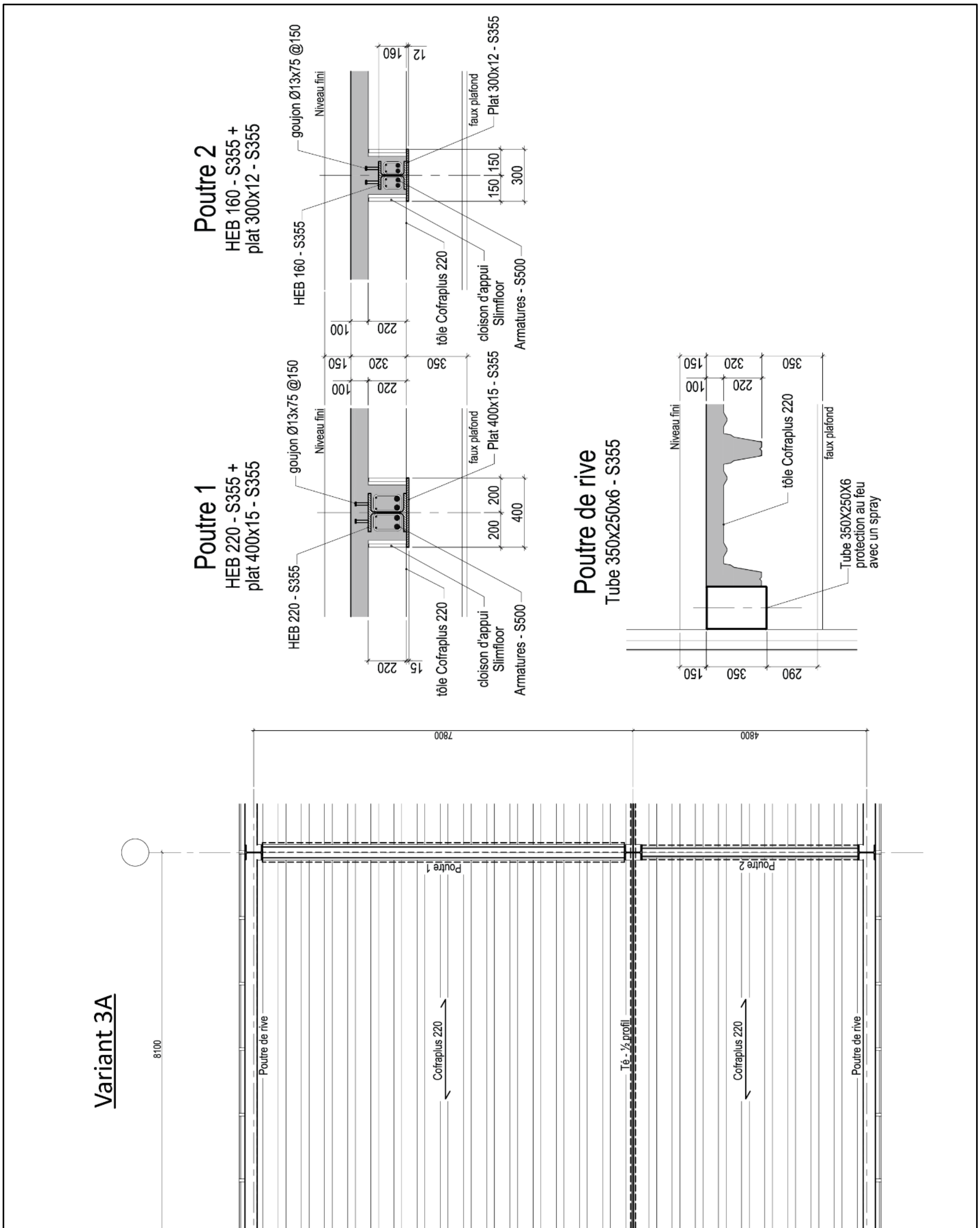
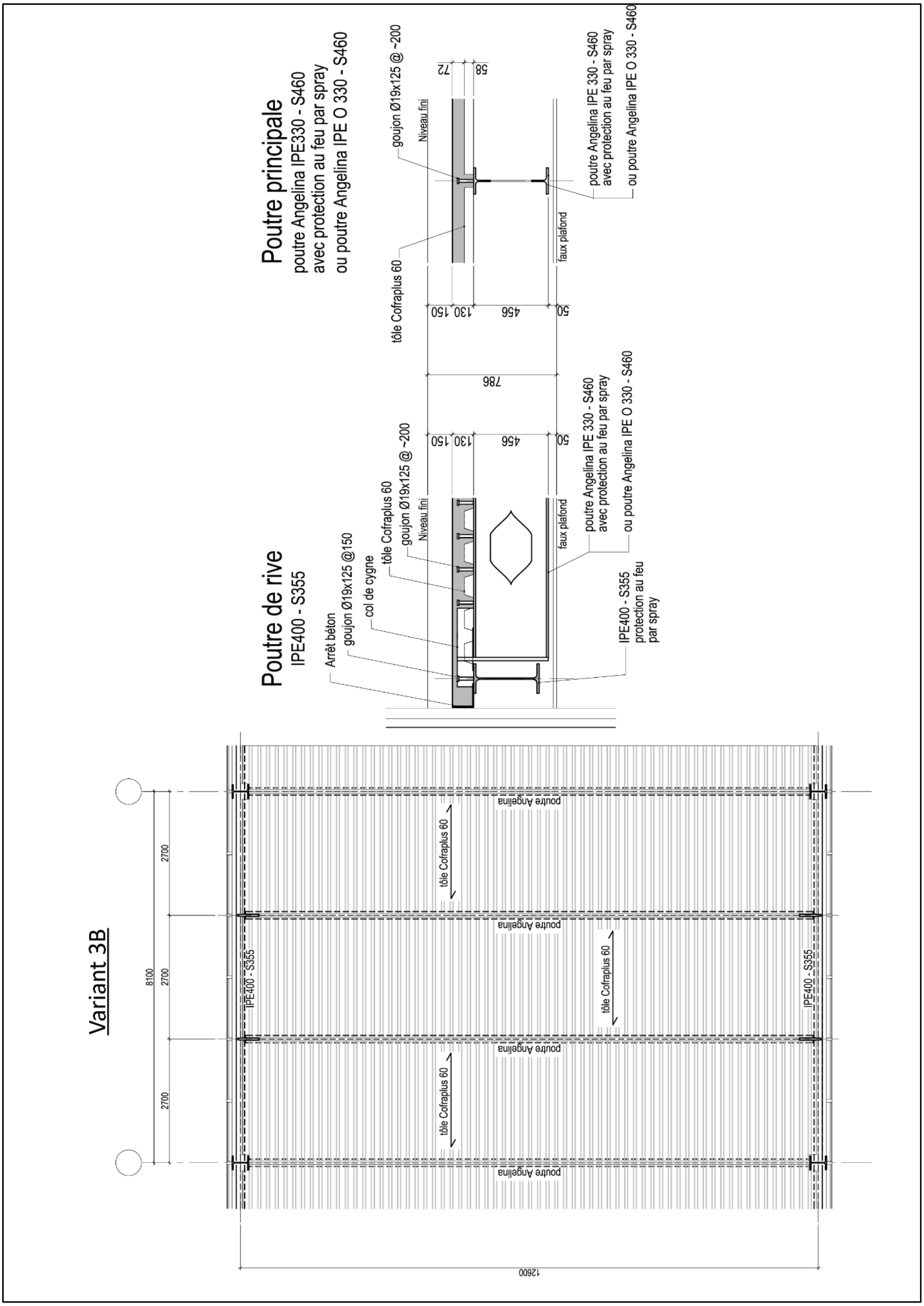
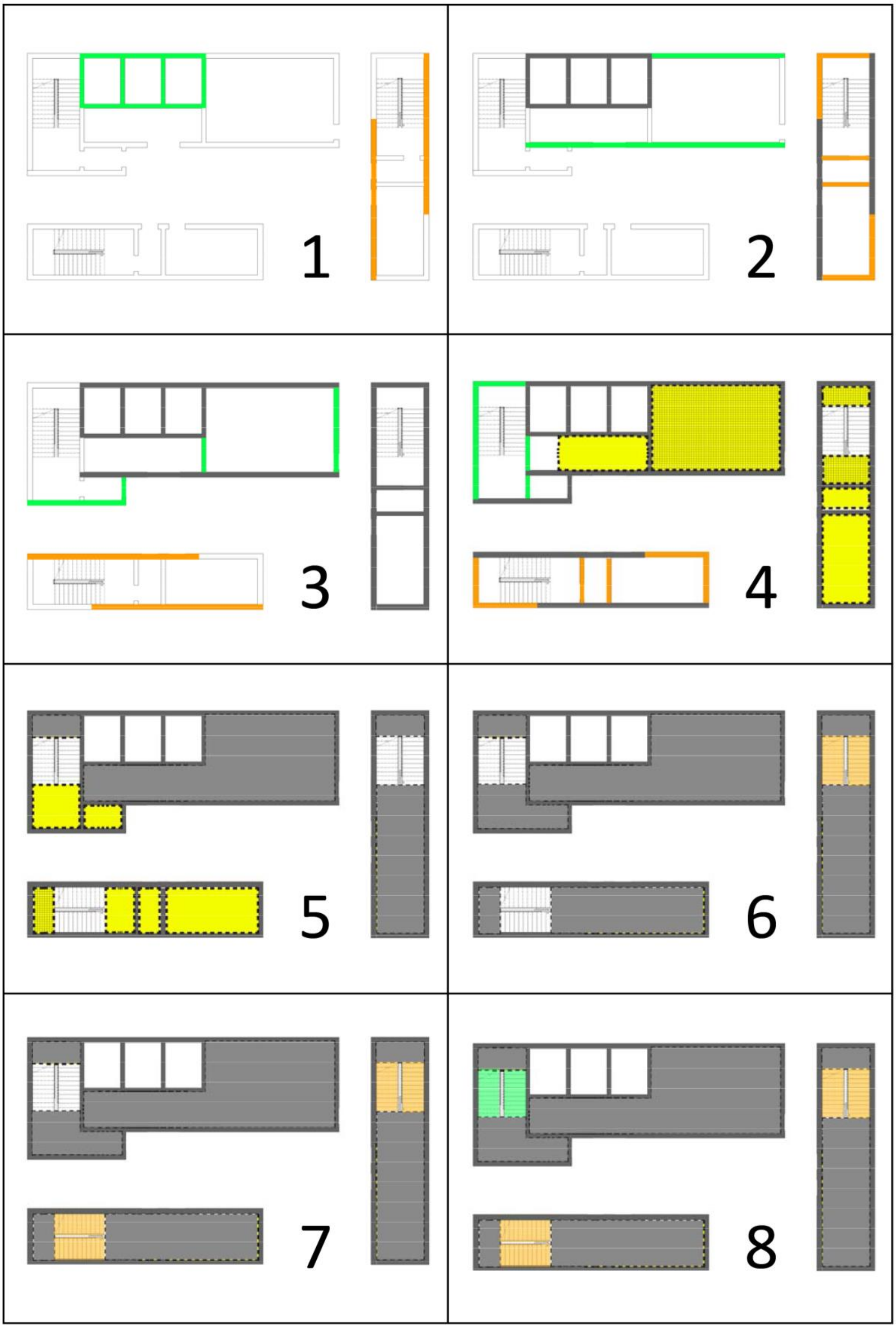
goujon Ø19x150 @150
Niveau fini
prédalles
faux plafond
IPE 450 - S355
protection au feu
par spray
Poutre de rive
IPE400 - S355
goujon Ø19x150 @150
Arrêt béton
IPE400 - S355
protection au feu
par spray
150
450
350
1100
IPE450 - S355
IPE400 - S355
Prédalles
4050
8100
12600


Variant 3A
8100
Poutre de rive
Cofraplus 220
Té - ½ profil
Cofraplus 220
Poutre de rive
Poutre 1
Poutre 1
Poutre 2
Poutre 2
7800
4800
12600
Poutre 1
HEB 220 - S355 +
plat 400x15 - S355
goujon Ø13x75 @150
Niveau fini
faux plafond
Plat 400x15 - S355
HEB 220 - S355
tôle Cofraplus 220
cloison d'appui
Slimfloor
Armatures - S500
Poutre 2
HEB 160 - S355 +
plat 300x12 - S355
goujon Ø13x75 @150
Niveau fini
faux plafond
Plat 300x12 - S355
HEB 160 - S355
tôle Cofraplus 220
cloison d'appui
Slimfloor
Armatures - S500
Poutre de rive
Tube 350x250x6 - S355
Niveau fini
faux plafond
tôle Cofraplus 220
Tube 350X250X6
protection au feu
avec un spray


Variant 3B
8100
2700
2700
2700
12600
IPE400 - S355
IPE400 - S355
poutre Angelina
tôle Cofraplus 60
Poutre de rive
IPE400 - S355
Arrêt béton
goujon Ø19x125 @150
col de cygne
tôle Cofraplus 60
goujon Ø19x125 @ ~200
Niveau fini
faux plafond
poutre Angelina IPE 330 - S460
avec protection au feu par spray
ou poutre Angelina IPE O 330 - S460
IPE400 - S355
protection au feu
par spray
150
130
456
50
786
Poutre principale
poutre Angelina IPE330 - S460
avec protection au feu par spray
ou poutre Angelina IPE O 330 - S460
goujon Ø19x125 @ ~200
tôle Cofraplus 60
72
58

APPENDIX II – CONCRETE CORES CONSTRUCTION PROGRESS 2D SIMULATIONS


2D Concrete Cores Construction Progress - with one crane
1
2
3
4
5
6
7
8
9

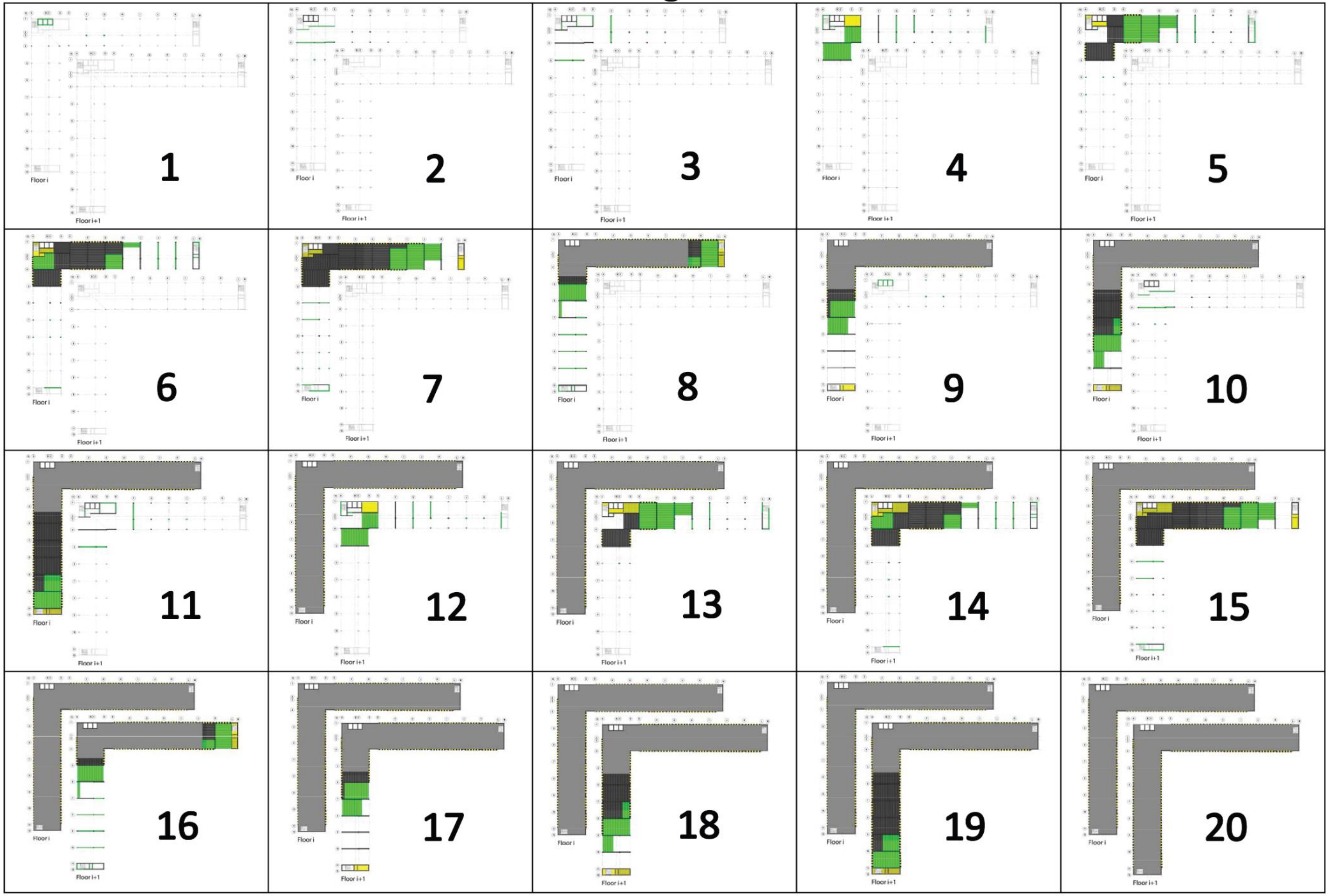


2D Concrete Cores Construction Progress - with two cranes (C1 : orange; C2 : green)

APPENDIX III – STRUCTURAL FRAME AND SLAB CONSTRUCTION PROGRESS

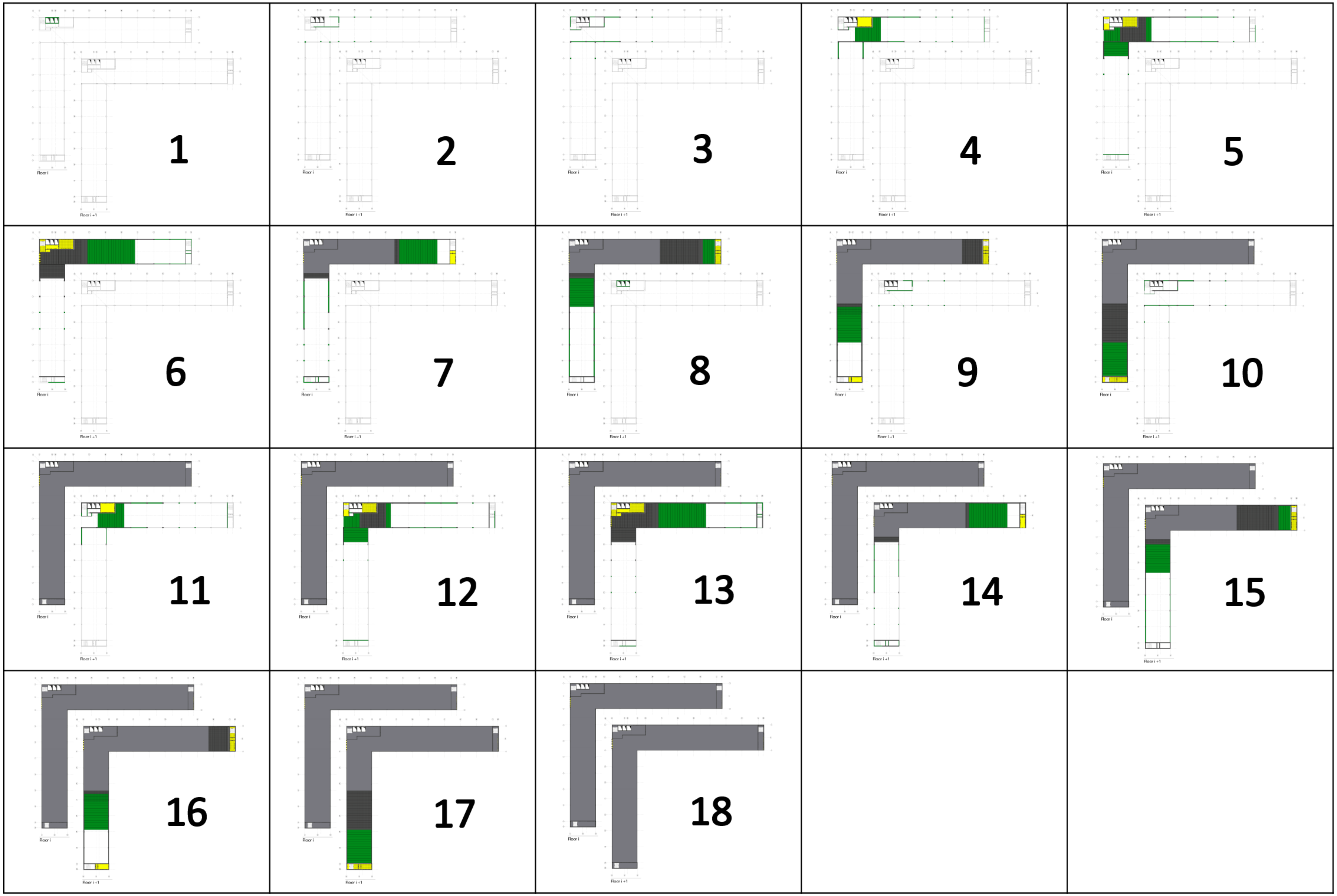
2D SIMULATIONS

2D Floor Construction Progress - Variant 1A one crane

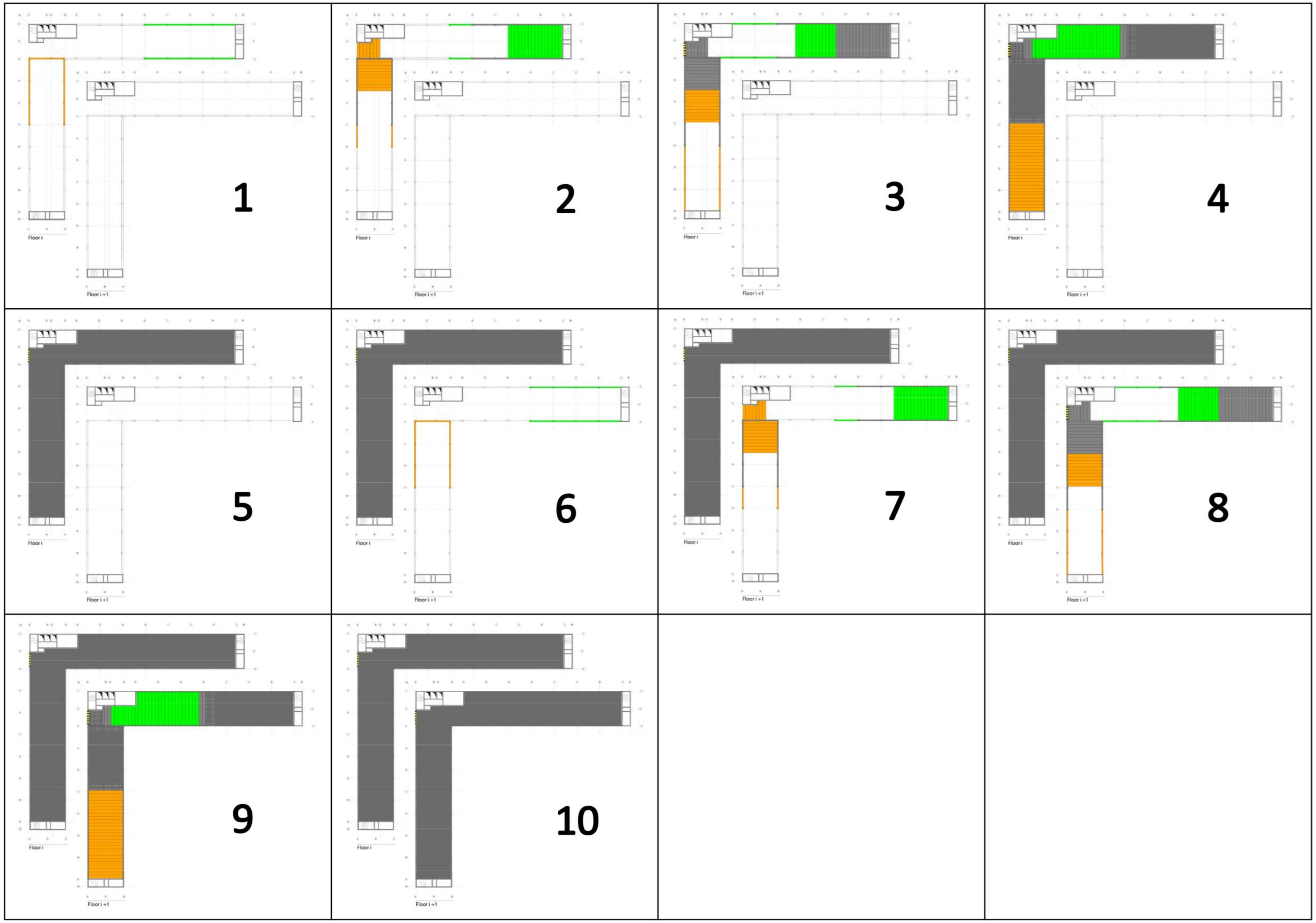


2D Floor Construction Progress - Variant 1A two crane (C1 : orange; C2 : green)

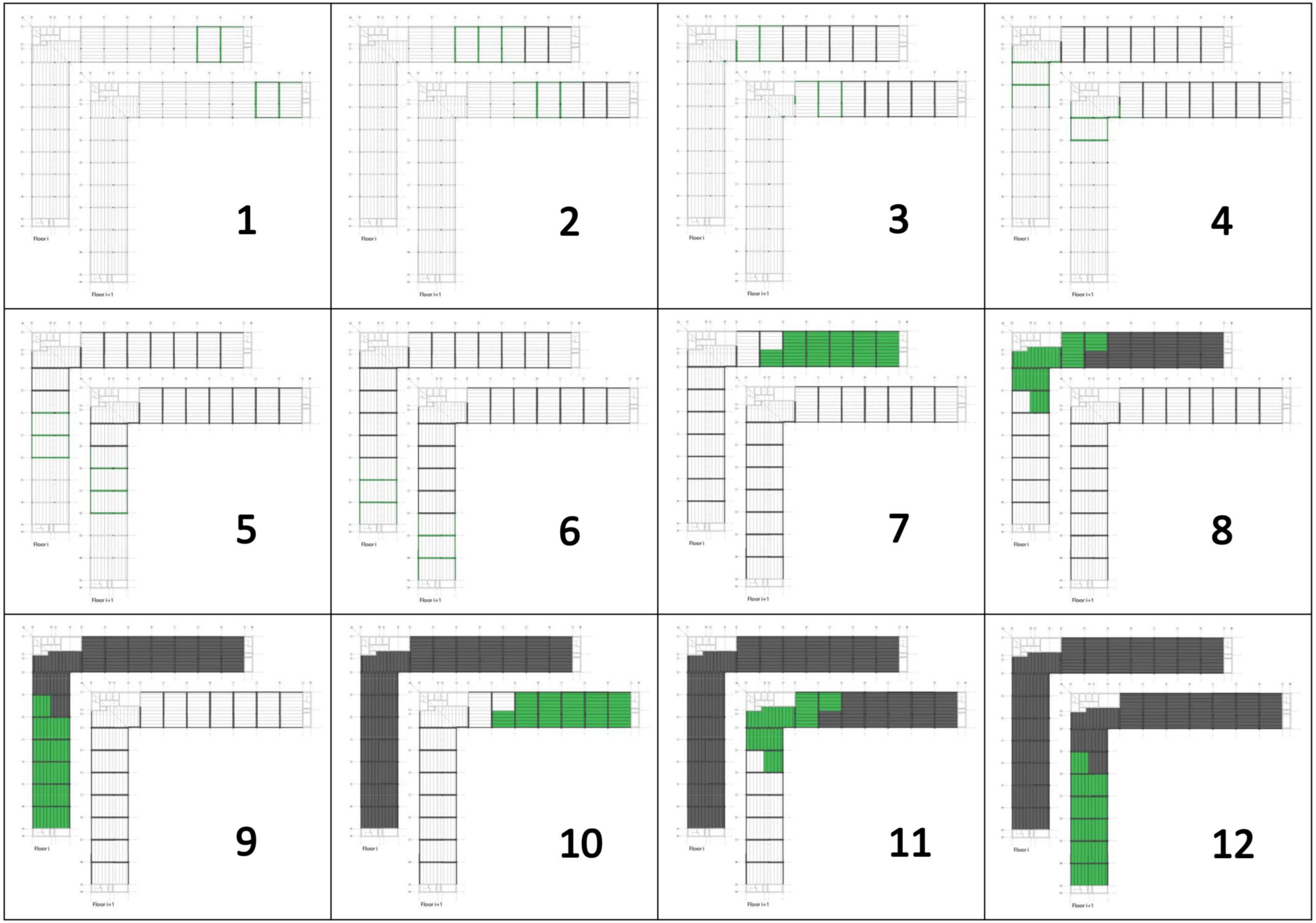
2D Floor Construction Progress - Variant 1B one crane



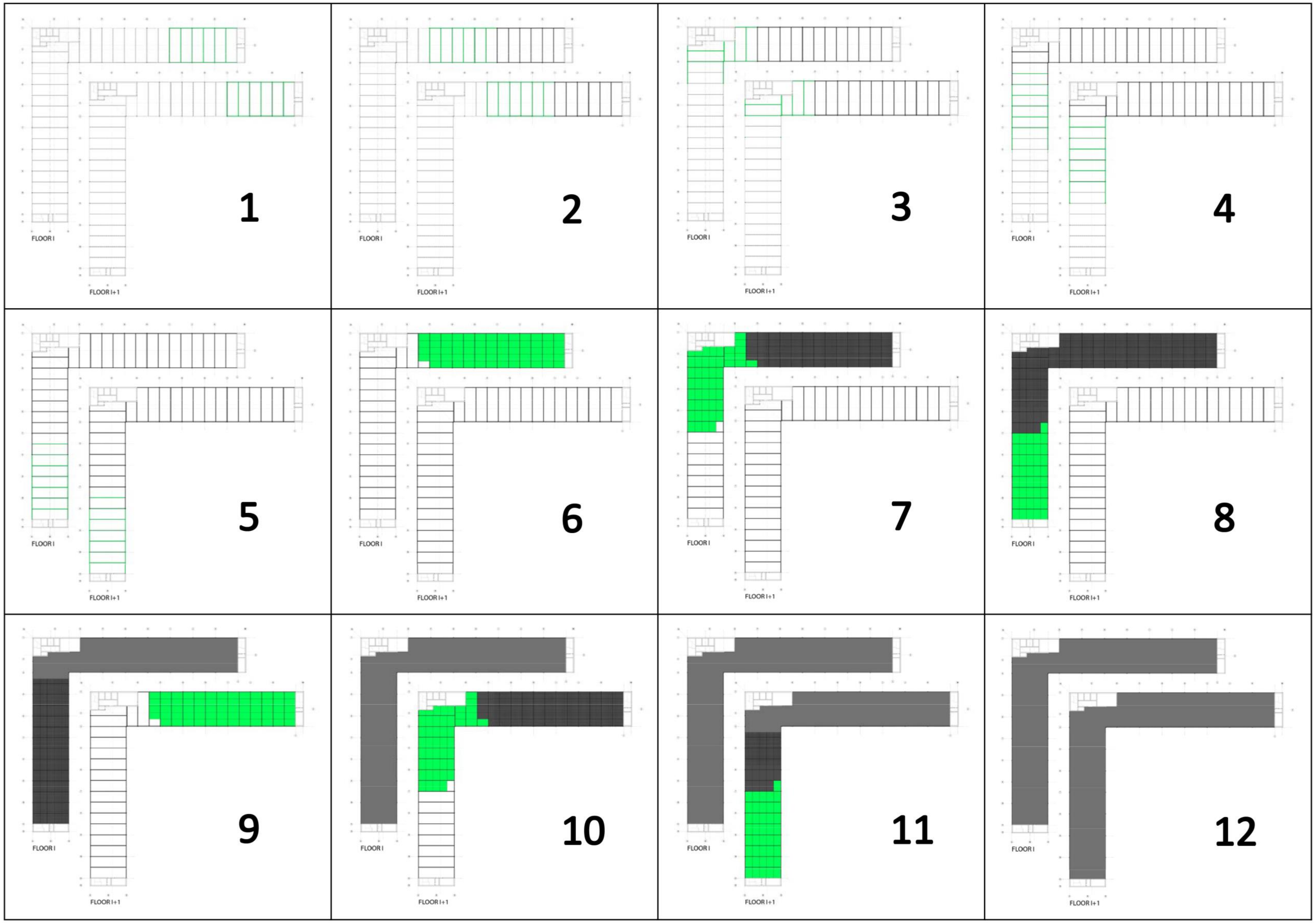
2D Floor Construction Progress - Variant 1B two crane (C1 : orange; C2 : green)



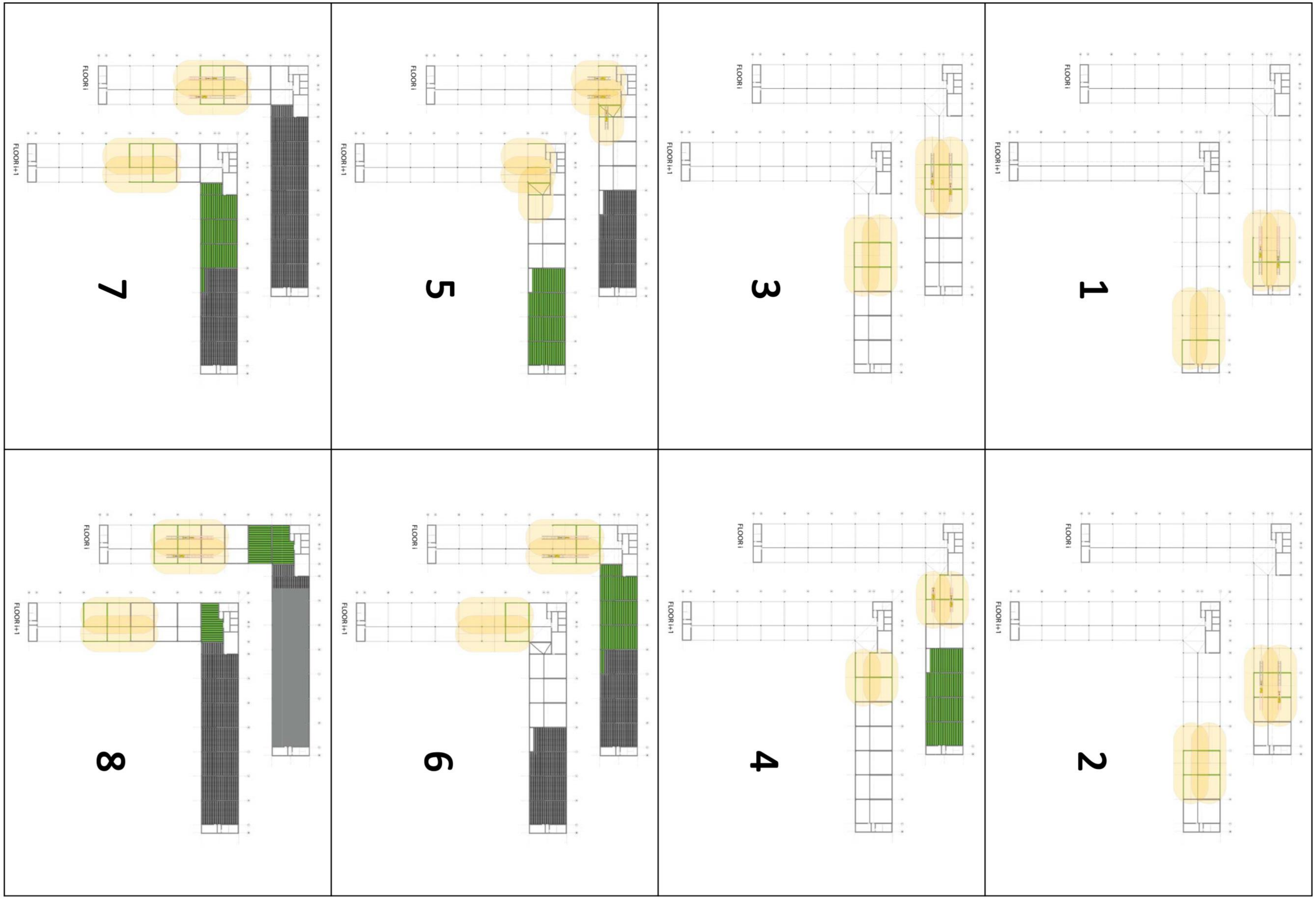
2D Floor Construction Progress - Variant 2A one crane



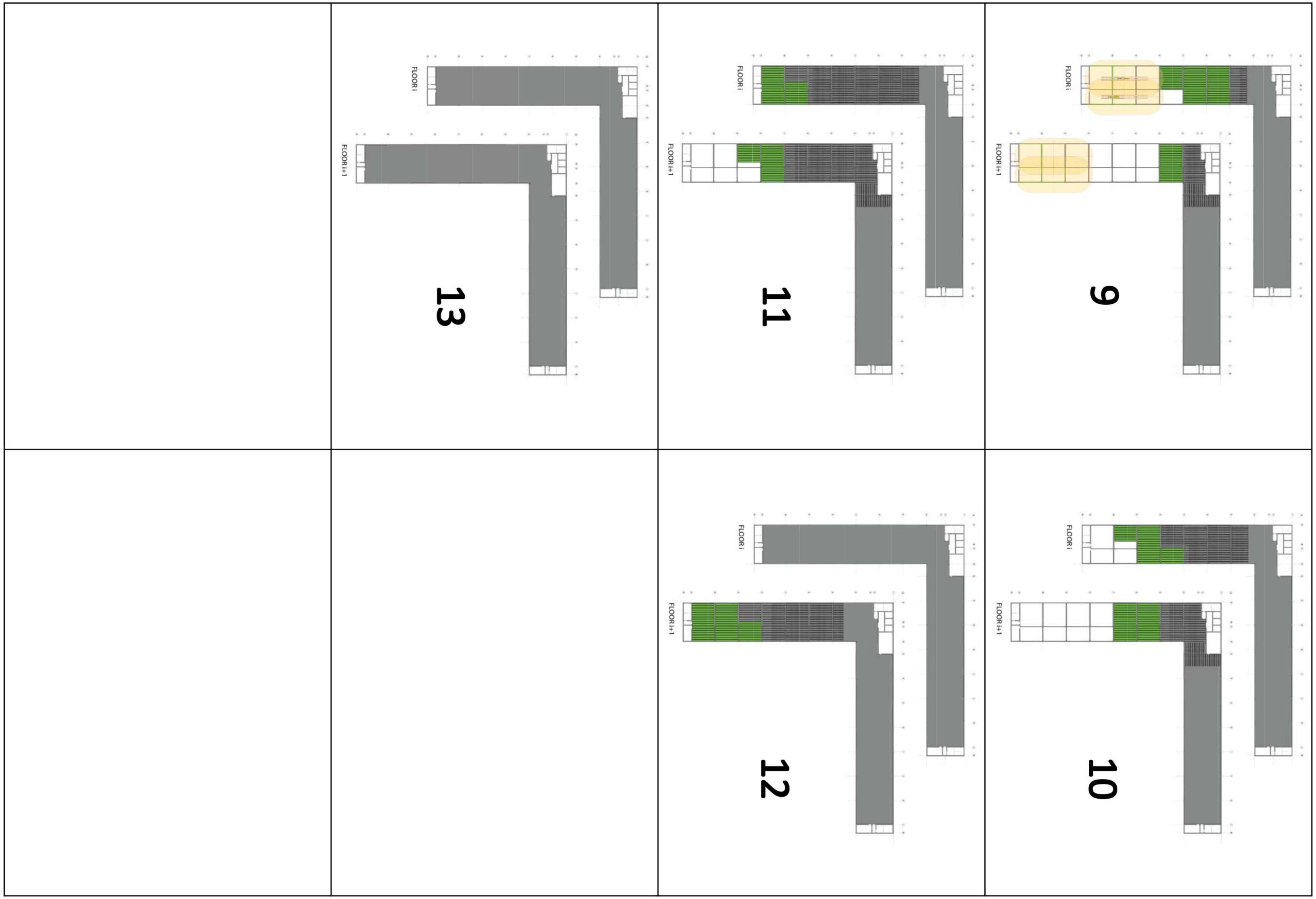
2D Floor Construction Progress - Variant 2B one crane



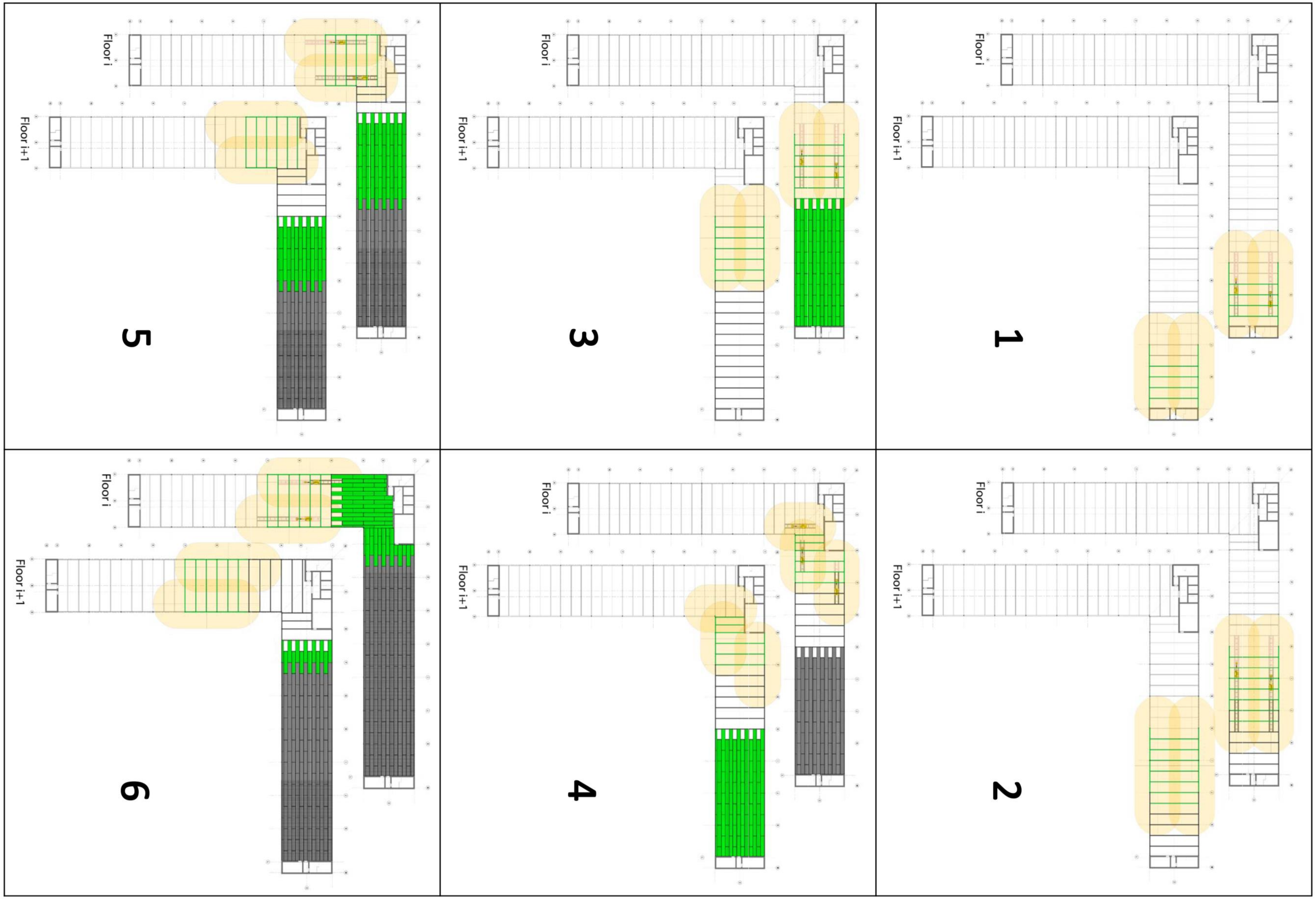
2D Floor Construction Progress - Variant 3A one crane (1/2)



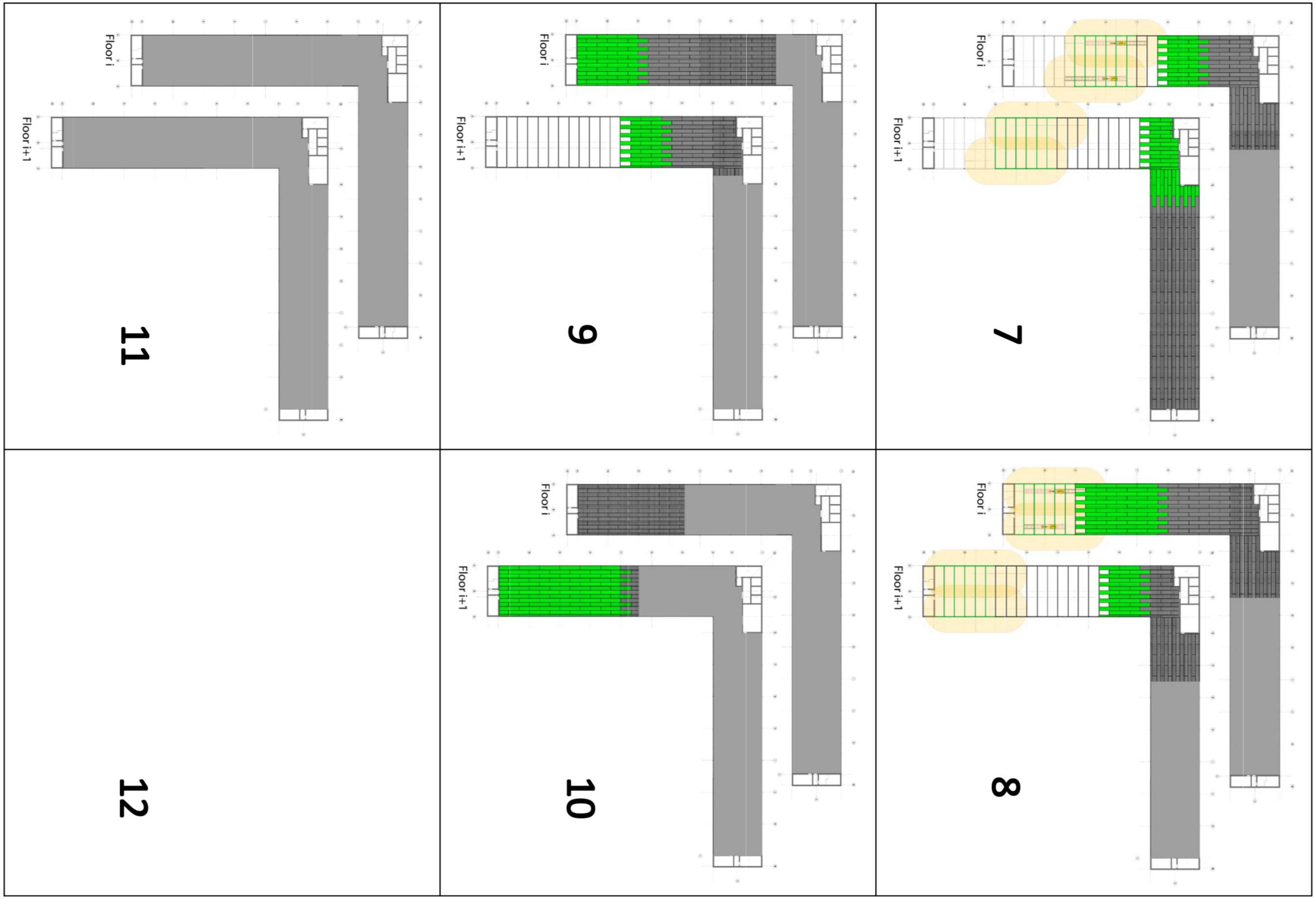
2D Floor Construction Progress - Variant 3A one crane (2/2)



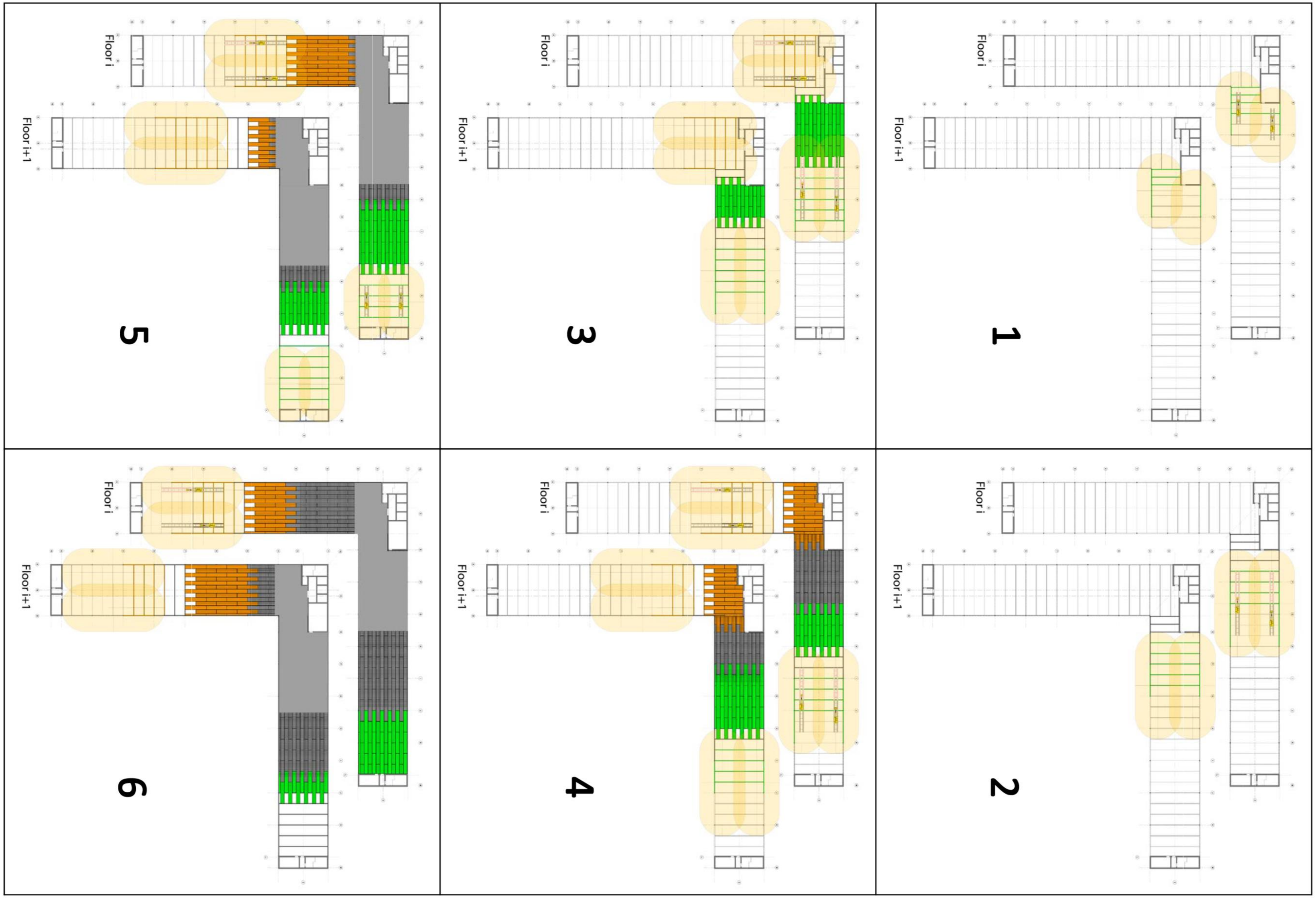
2D Floor Construction Progress - Variant 3B one crane (1/2)



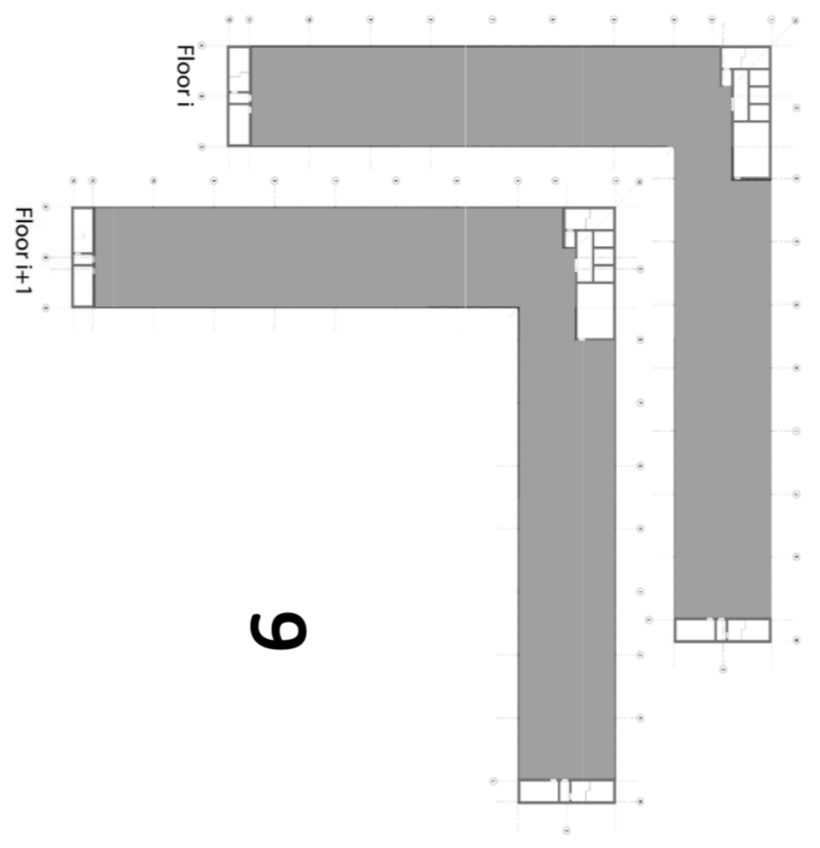
2D Floor Construction Progress - Variant 3B one crane (2/2)

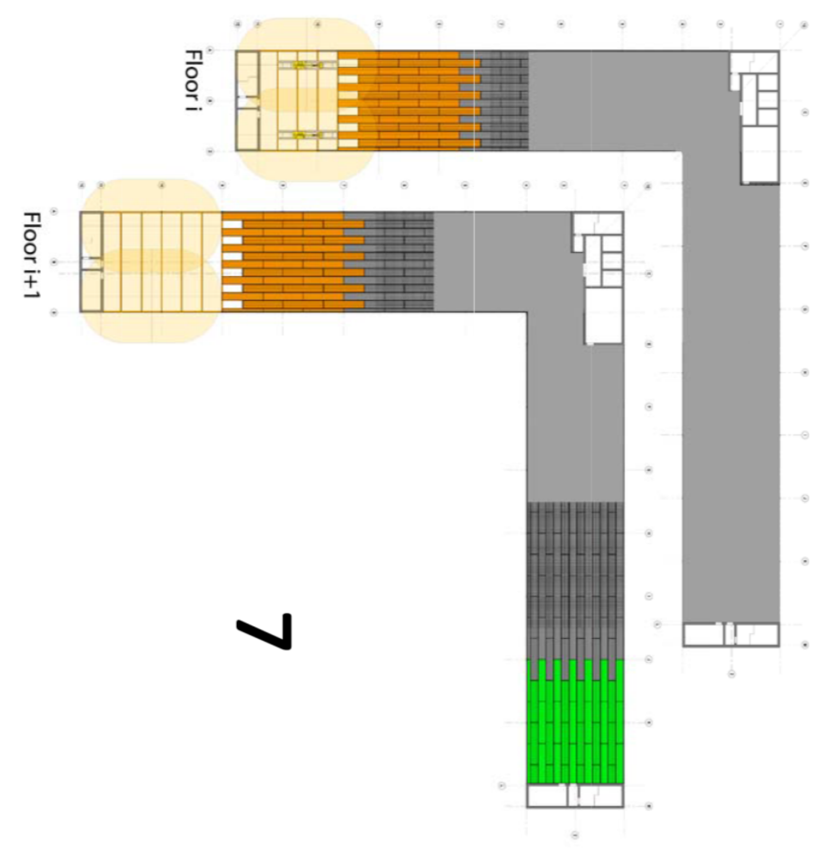


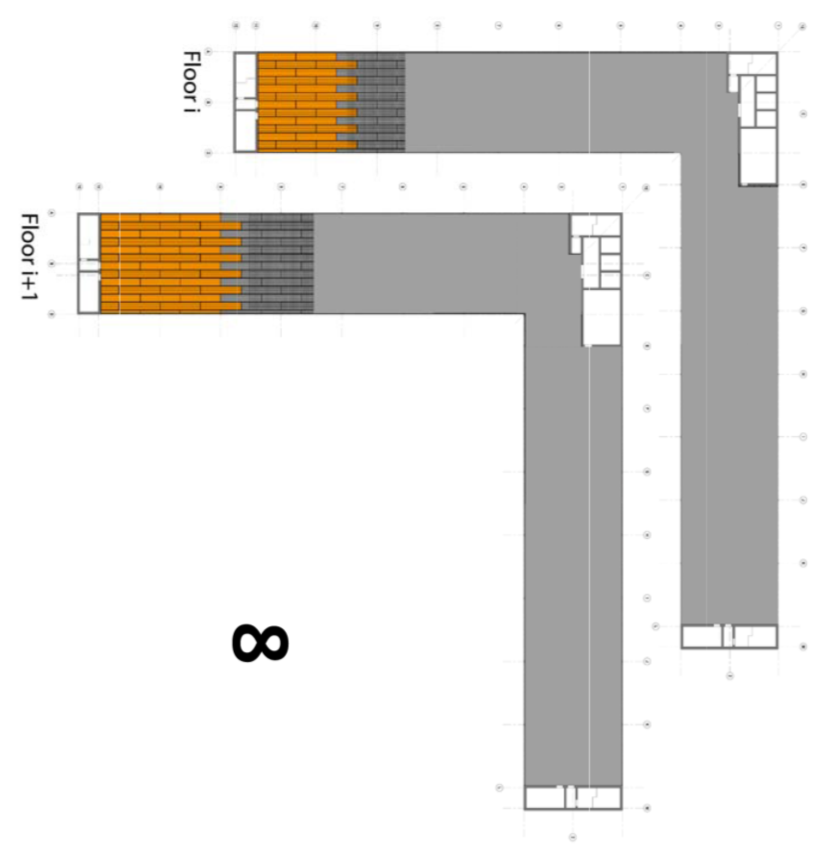
2D Floor Construction Progress - Var. 3B two crane (C1 : orange; C2 : green) [1/2]



2D Floor Construction Progress - Var. 3B two crane (C1 : orange; C2 : green) [2/2]





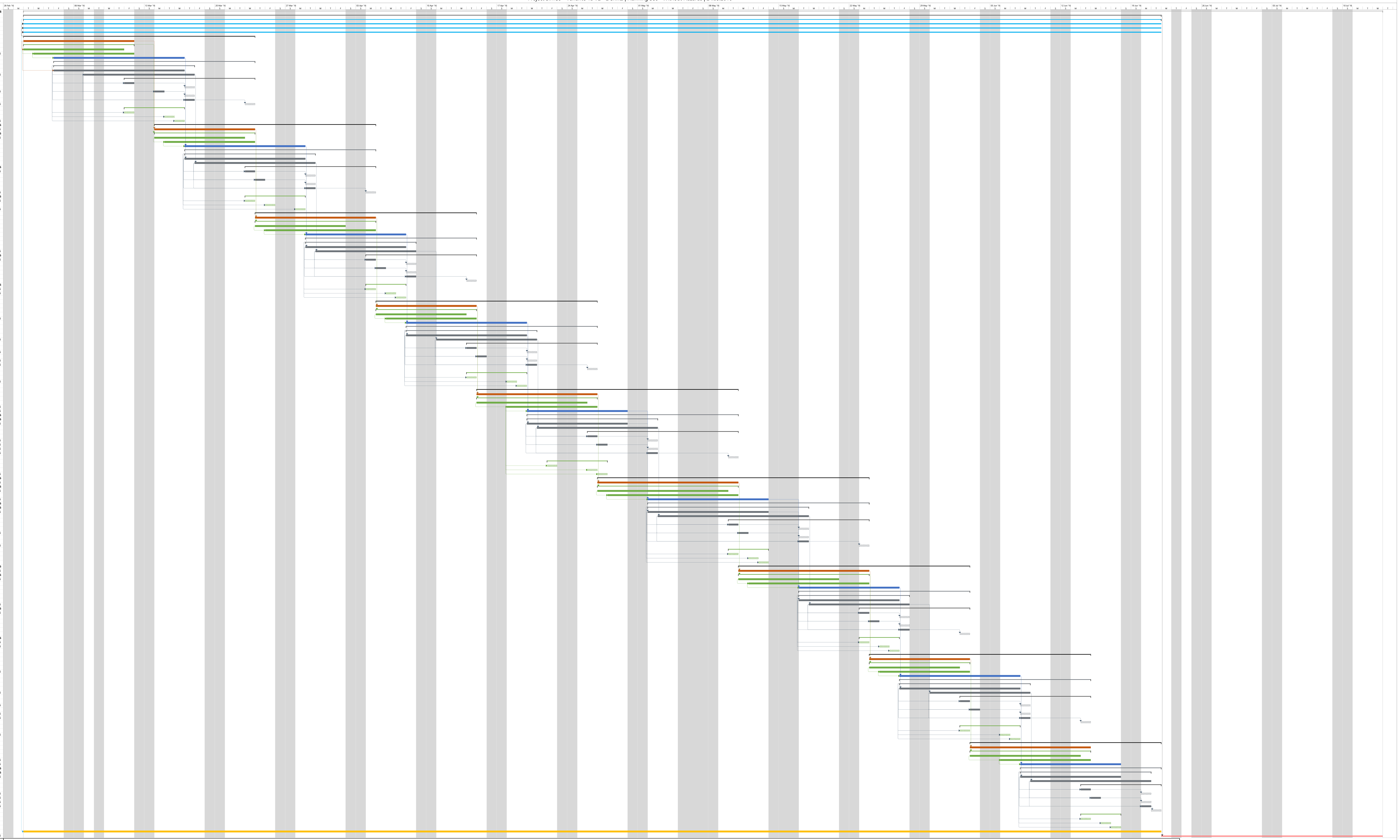


APPENDIX IV – GANTT CHARTS

(The Gantt Charts can be found in their original sizes (A0) on the digital format of this document.)

Project SiMCo - Variante 1a V2 - 2 Shifts | Planning Sec - Without Hazards | 24.05.2016

ID	Task Name	Duration	Start
0	**SiMCo - Variante 1a - V2 New Core - 2 Shifts**	**92 days**	**Tue 01/03/16**
1	**Planning Sec - Without Hazard**	**77 days**	**Tue 01/03/16**
2	**Instalation de Chantier - Site Facilities**	**77 days**	**Tue 01/03/16**
3	Cran Operator	77 days	Tue 01/03/16
4	Traffic Assistant	77 days	Tue 01/03/16
5	Magasinier - Storekeeper	77 days	Tue 01/03/16
6	**Rez-de-Chaussée**	**16 days**	**Tue 01/03/16**
7	**Voiles**	8 days	Tue 01/03/16
8	**Préfa**	**8 days**	**Tue 01/03/16**
9	Columns	7 days	Tue 01/03/16
10	Beams	7 days	Wed 02/03/16
11	**Hollow-core slab (Hourdis)**	8 days	Fri 04/03/16
12	**Concreting**	**13 days**	**Fri 04/03/16**
13	**Preparatory Work**	**9 days**	**Fri 04/03/16**
14	Formwork	8 days	Fri 04/03/16
15	Reinforcement	8 days	Mon 07/03/16
16	**Concreting (Dalle CSP + Chape de Compressio**	**9 days**	**Fri 11/03/16**
17	Core +2/3 Z1 +1/7 Z2	1 day	Fri 11/03/16
18	Formwork Removal	1 day	Thu 17/03/16
19	Z1 CORE + 1/3 Z1 + 1/7 Z1	1 day	Mon 14/03/16
20	Formwork Removal	1 day	Thu 17/03/16
21	Z2 CORE + 5/7 Z2	1 day	Thu 17/03/16
22	Formwork Removal	1 day	Wed 23/03/16
23	**Préfa - Stairs**	**4 days**	**Fri 11/03/16**
24	Stair Flights of Core Stairs	1 day	Fri 11/03/16
25	Stair Flights of Z1 Stairs	1 day	Tue 15/03/16
26	Stair Flights of Z2 Stairs	1 day	Wed 16/03/16
27	**Étage 1**	**16 days**	**Mon 14/03/16**
28	**Voiles**	8 days	Mon 14/03/16
29	**Préfa**	**8 days**	**Mon 14/03/16**
30	Columns	7 days	Mon 14/03/16
31	Beams	7 days	Tue 15/03/16
32	**Hollow-core slab (Hourdis)**	8 days	Thu 17/03/16
33	**Concreting**	**13 days**	**Thu 17/03/16**
34	**Preparatory Work**	**9 days**	**Thu 17/03/16**
35	Formwork	8 days	Thu 17/03/16
36	Reinforcement	8 days	Fri 18/03/16
37	**Concreting (Dalle CSP + Chape de Compressio**	**9 days**	**Wed 23/03/16**
38	Core +2/3 Z1 +1/7 Z2	1 day	Wed 23/03/16
39	Formwork Removal	1 day	Tue 29/03/16
40	Z1 CORE + 1/3 Z1 + 1/7 Z1	1 day	Thu 24/03/16
41	Formwork Removal	1 day	Tue 29/03/16
42	Z2 CORE + 5/7 Z2	1 day	Tue 29/03/16
43	Formwork Removal	1 day	Mon 04/04/16
44	**Préfa - Stairs**	**4 days**	**Wed 23/03/16**
45	Stair Flights of Core Stairs	1 day	Wed 23/03/16
46	Stair Flights of Z1 Stairs	1 day	Fri 25/03/16
47	Stair Flights of Z2 Stairs	1 day	Mon 28/03/16
48	**Étage 2**	**16 days**	**Thu 24/03/16**
49	**Voiles**	8 days	Thu 24/03/16
50	**Préfa**	**8 days**	**Thu 24/03/16**
51	Columns	7 days	Thu 24/03/16
52	Beams	7 days	Fri 25/03/16
53	**Hollow-core slab (Hourdis)**	8 days	Tue 29/03/16
54	**Concreting**	**13 days**	**Tue 29/03/16**
55	**Preparatory Work**	**9 days**	**Tue 29/03/16**
56	Formwork	8 days	Tue 29/03/16
57	Reinforcement	8 days	Wed 30/03/16
58	**Concreting (Dalle CSP + Chape de Compressio**	**9 days**	**Mon 04/04/16**
59	Core +2/3 Z1 +1/7 Z2	1 day	Mon 04/04/16
60	Formwork Removal	1 day	Fri 08/04/16
61	Z1 CORE + 1/3 Z1 + 1/7 Z1	1 day	Tue 05/04/16
62	Formwork Removal	1 day	Fri 08/04/16
63	Z2 CORE + 5/7 Z2	1 day	Fri 08/04/16
64	Formwork Removal	1 day	Thu 14/04/16
65	**Préfa - Stairs**	**4 days**	**Mon 04/04/16**
66	Stair Flights of Core Stairs	1 day	Mon 04/04/16
67	Stair Flights of Z1 Stairs	1 day	Wed 06/04/16
68	Stair Flights of Z2 Stairs	1 day	Thu 07/04/16
69	**Étage 3**	**16 days**	**Tue 05/04/16**
70	**Voiles**	8 days	Tue 05/04/16
71	**Préfa**	**8 days**	**Tue 05/04/16**
72	Columns	7 days	Tue 05/04/16
73	Beams	7 days	Wed 06/04/16
74	**Hollow-core slab (Hourdis)**	8 days	Fri 08/04/16
75	**Concreting**	**13 days**	**Fri 08/04/16**
76	**Preparatory Work**	**9 days**	**Fri 08/04/16**
77	Formwork	8 days	Fri 08/04/16
78	Reinforcement	8 days	Mon 11/04/16
79	**Concreting (Dalle CSP + Chape de Compressio**	**9 days**	**Thu 14/04/16**
80	Core +2/3 Z1 +1/7 Z2	1 day	Thu 14/04/16
81	Formwork Removal	1 day	Wed 20/04/16
82	Z1 CORE + 1/3 Z1 + 1/7 Z1	1 day	Fri 15/04/16
83	Formwork Removal	1 day	Wed 20/04/16
84	Z2 CORE + 5/7 Z2	1 day	Wed 20/04/16
85	Formwork Removal	1 day	Tue 26/04/16
86	**Préfa - Stairs**	**4 days**	**Thu 14/04/16**
87	Stair Flights of Core Stairs	1 day	Thu 14/04/16
88	Stair Flights of Z1 Stairs	1 day	Mon 18/04/16
89	Stair Flights of Z2 Stairs	1 day	Tue 19/04/16
90	**Étage 4**	**16 days**	**Fri 15/04/16**
91	**Voiles**	8 days	Fri 15/04/16
92	**Préfa**	**8 days**	**Fri 15/04/16**
93	Columns	7 days	Fri 15/04/16
94	Beams	7 days	Mon 18/04/16
95	**Hollow-core slab (Hourdis)**	8 days	Wed 20/04/16
96	**Concreting**	**13 days**	**Wed 20/04/16**
97	**Preparatory Work**	**9 days**	**Wed 20/04/16**
98	Formwork	8 days	Wed 20/04/16
99	Reinforcement	8 days	Thu 21/04/16
100	**Concreting (Dalle CSP + Chape de Compressio**	**9 days**	**Tue 26/04/16**
101	Core +2/3 Z1 +1/7 Z2	1 day	Tue 26/04/16
102	Formwork Removal	1 day	Mon 02/05/16
103	Z1 CORE + 1/3 Z1 + 1/7 Z1	1 day	Wed 27/04/16
104	Formwork Removal	1 day	Mon 02/05/16
105	Z2 CORE + 5/7 Z2	1 day	Mon 02/05/16
106	Formwork Removal	1 day	Tue 10/05/16
107	**Préfa - Stairs**	**4 days**	**Fri 22/04/16**
108	Stair Flights of Core Stairs	1 day	Fri 22/04/16
109	Stair Flights of Z1 Stairs	1 day	Tue 26/04/16
110	Stair Flights of Z2 Stairs	1 day	Wed 27/04/16
111	**Étage 5**	**16 days**	**Wed 27/04/16**
112	**Voiles**	8 days	Wed 27/04/16
113	**Préfa**	**8 days**	**Wed 27/04/16**
114	Columns	7 days	Wed 27/04/16
115	Beams	7 days	Thu 28/04/16
116	**Hollow-core slab (Hourdis)**	8 days	Mon 02/05/16
117	**Concreting**	**13 days**	**Mon 02/05/16**
118	**Preparatory Work**	**9 days**	**Mon 02/05/16**
119	Formwork	8 days	Mon 02/05/16
120	Reinforcement	8 days	Tue 03/05/16
121	**Concreting (Dalle CSP + Chape de Compressio**	**9 days**	**Tue 10/05/16**
122	Core +2/3 Z1 +1/7 Z2	1 day	Tue 10/05/16
123	Formwork Removal	1 day	Tue 17/05/16
124	Z1 CORE + 1/3 Z1 + 1/7 Z1	1 day	Wed 11/05/16
125	Formwork Removal	1 day	Tue 17/05/16
126	Z2 CORE + 5/7 Z2	1 day	Tue 17/05/16
127	Formwork Removal	1 day	Mon 23/05/16
128	**Préfa - Stairs**	**4 days**	**Tue 10/05/16**
129	Stair Flights of Core Stairs	1 day	Tue 10/05/16
130	Stair Flights of Z1 Stairs	1 day	Thu 12/05/16
131	Stair Flights of Z2 Stairs	1 day	Fri 13/05/16
132	**Étage 6**	**16 days**	**Wed 11/05/16**
133	**Voiles**	8 days	Wed 11/05/16
134	**Préfa**	**8 days**	**Wed 11/05/16**
135	Columns	7 days	Wed 11/05/16
136	Beams	7 days	Thu 12/05/16
137	**Hollow-core slab (Hourdis)**	8 days	Tue 17/05/16
138	**Concreting**	**13 days**	**Tue 17/05/16**
139	**Preparatory Work**	**9 days**	**Tue 17/05/16**
140	Formwork	8 days	Tue 17/05/16
141	Reinforcement	8 days	Wed 18/05/16
142	**Concreting (Dalle CSP + Chape de Compressio**	**9 days**	**Mon 23/05/16**
143	Core +2/3 Z1 +1/7 Z2	1 day	Mon 23/05/16
144	Formwork Removal	1 day	Fri 27/05/16
145	Z1 CORE + 1/3 Z1 + 1/7 Z1	1 day	Tue 24/05/16
146	Formwork Removal	1 day	Fri 27/05/16
147	Z2 CORE + 5/7 Z2	1 day	Fri 27/05/16
148	Formwork Removal	1 day	Thu 02/06/16
149	**Préfa - Stairs**	**4 days**	**Mon 23/05/16**
150	Stair Flights of Core Stairs	1 day	Mon 23/05/16
151	Stair Flights of Z1 Stairs	1 day	Wed 25/05/16
152	Stair Flights of Z2 Stairs	1 day	Thu 26/05/16
153	**Étage 7**	**16 days**	**Tue 24/05/16**
154	**Voiles**	8 days	Tue 24/05/16
155	**Préfa**	**8 days**	**Tue 24/05/16**
156	Columns	7 days	Tue 24/05/16
157	Beams	7 days	Wed 25/05/16
158	**Hollow-core slab (Hourdis)**	8 days	Fri 27/05/16
159	**Concreting**	**13 days**	**Fri 27/05/16**
160	**Preparatory Work**	**9 days**	**Fri 27/05/16**
161	Formwork	8 days	Fri 27/05/16
162	Reinforcement	8 days	Mon 30/05/16
163	**Concreting (Dalle CSP + Chape de Compressio**	**9 days**	**Thu 02/06/16**
164	Core +2/3 Z1 +1/7 Z2	1 day	Thu 02/06/16
165	Formwork Removal	1 day	Wed 08/06/16
166	Z1 CORE + 1/3 Z1 + 1/7 Z1	1 day	Fri 03/06/16
167	Formwork Removal	1 day	Wed 08/06/16
168	Z2 CORE + 5/7 Z2	1 day	Wed 08/06/16
169	Formwork Removal	1 day	Tue 14/06/16
170	**Préfa - Stairs**	**4 days**	**Thu 02/06/16**
171	Stair Flights of Core Stairs	1 day	Thu 02/06/16
172	Stair Flights of Z1 Stairs	1 day	Mon 06/06/16
173	Stair Flights of Z2 Stairs	1 day	Tue 07/06/16
174	**Étage 8**	**13 days**	**Fri 03/06/16**
175	**Voiles**	8 days	Fri 03/06/16
176	**Préfa**	**8 days**	**Fri 03/06/16**
177	Columns	7 days	Fri 03/06/16
178	Beams	7 days	Mon 06/06/16
179	**Hollow-core slab (Hourdis)**	8 days	Wed 08/06/16
180	**Concreting**	**10 days**	**Wed 08/06/16**
181	**Preparatory Work**	**9 days**	**Wed 08/06/16**
182	Formwork	8 days	Wed 08/06/16
183	Reinforcement	8 days	Thu 09/06/16
184	**Concreting (Dalle CSP + Chape de Compressio**	**6 days**	**Tue 14/06/16**
185	Core +2/3 Z1 +1/7 Z2	1 day	Tue 14/06/16
186	Formwork Removal	1 day	Mon 20/06/16
187	Z1 CORE + 1/3 Z1 + 1/7 Z1	1 day	Wed 15/06/16
188	Formwork Removal	1 day	Mon 20/06/16
189	Z2 CORE + 5/7 Z2	1 day	Mon 20/06/16
190	Formwork Removal	1 day	Tue 21/06/16
191	**Préfa - Stairs**	**4 days**	**Tue 14/06/16**
192	Stair Flights of Core Stairs	1 day	Tue 14/06/16
193	Stair Flights of Z1 Stairs	1 day	Thu 16/06/16
194	Stair Flights of Z2 Stairs	1 day	Fri 17/06/16
195	**Ragréage - Cleaning**	77 days	Tue 01/03/16
196	**Aléa - Hazard (20%)**	15 days	Wed 22/06/16



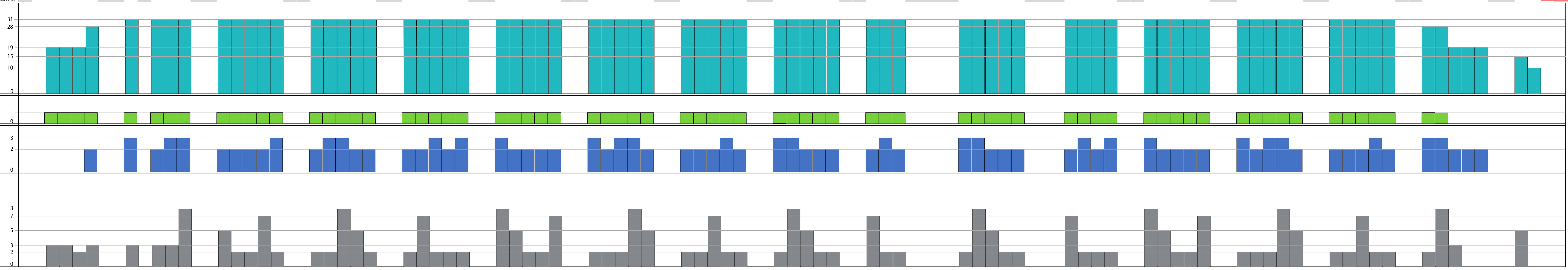
Workforces Graph

Note : 19 general workforces allocated over different tasks plus 2 crane operators, 2 storekeepers, 2 traffic assistants and 6 steel fixers.

Flow of Prefab Trucks per day

Flow of Hollow-Core Slab Trucks per day

Flow of Concrete Trucks per day



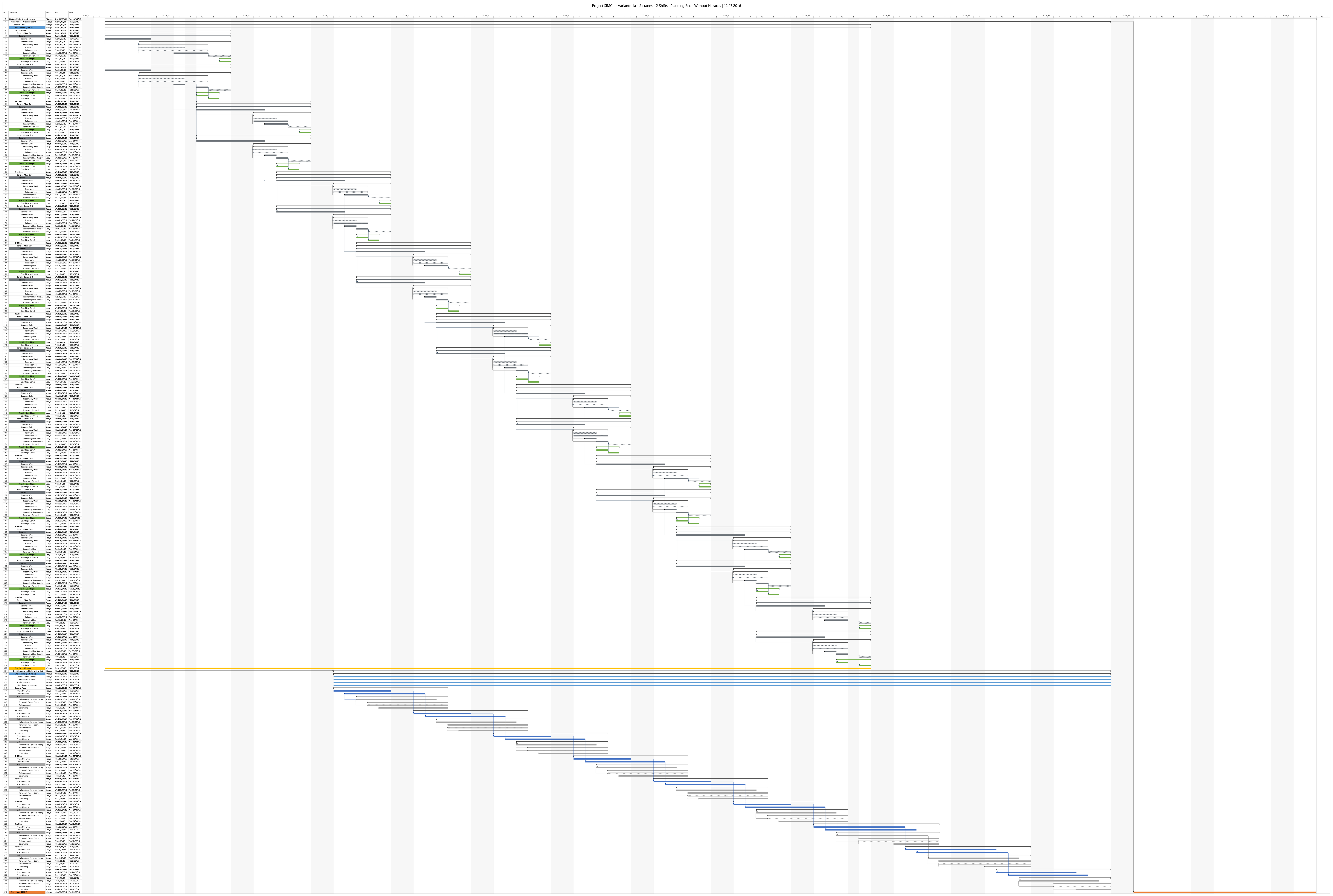
UNIVERSITÉ DU LUXEMBOURG

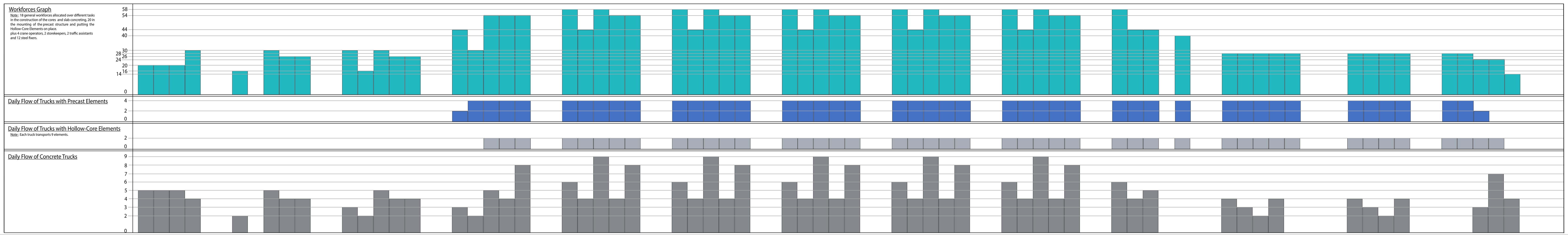
FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION

Univ.-Doz. Dr.-Ing. M. Schäfer

Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variante 1a - V2 New Cores - 2 shifts Planning of the main structure construction of the floors above the ground.
Author :	Dany Pereira
Version:	2.1
Date:	24/05/2016

Project SiMCo - Variante 1a - 2 cranes - 2 Shifts | Planning Sec - Without Hazards | 12.07.2016



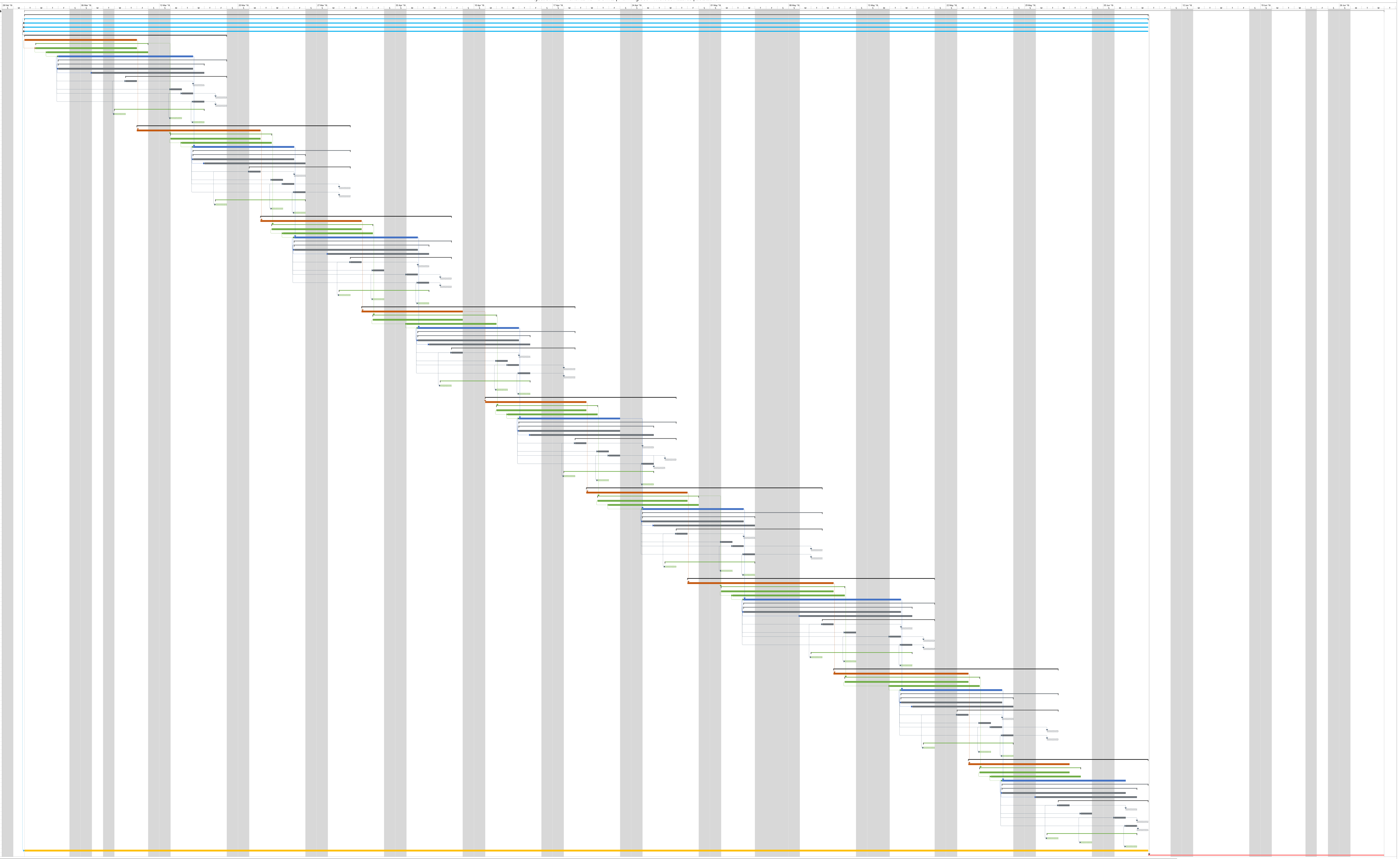


UNIVERSITÉ DU LUXEMBOURG
Univ.-Doz. Dr.- Ing. M. Schäfer
FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION

Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variant 1a 2 cranes- 2 shifts Planning of the main structure of the floors above the ground.
Author :	Dany Pereira
Version:	1.0
Date:	12/07/2016

Project SiMCo - Variante 1b - 2 Shifts | Planning Sec - Without Hazards | 26.5.2016

ID	Task Name	Duration	Start	Finish
0	SiMCo - Variant 1b - 2 Shifts	82 days	Tue 01/03/16	Wed 29/06/16
1	Planning Sec - Without Hazard	68 days	Tue 01/03/16	Wed 08/06/16
2	Installation de chantier - Site Facilities	68 days	Tue 01/03/16	Wed 08/06/16
3	Crane Operator	68 days	Tue 01/03/16	Wed 08/06/16
4	Traffic Assistant	68 days	Tue 01/03/16	Wed 08/06/16
5	Magasinier - Storekeeper	68 days	Tue 01/03/16	Wed 08/06/16
6	Ground Floor	13 days	Tue 01/03/16	Fri 18/03/16
7	Reinforced Concrete Walls	[illegible]	[illegible]	[illegible]
8	Prefab	[illegible]	[illegible]	[illegible]
9	Columns	[illegible]	[illegible]	[illegible]
10	Beams	[illegible]	[illegible]	[illegible]
11	Hollow-core slab (Hourdis)	[illegible]	[illegible]	[illegible]
12	Concreting	[illegible]	[illegible]	[illegible]
13	Preparatory Work	[illegible]	[illegible]	[illegible]
14	Formwork	[illegible]	[illegible]	[illegible]
15	Reinforcement	[illegible]	[illegible]	[illegible]
16	Concreting (Dalle CSP + Chape de Compressio	[illegible]	[illegible]	[illegible]
17	Core Staires + 3.5/7 Z1 + 0.5/7 Z2	[illegible]	[illegible]	[illegible]
18	Formwork Removal	[illegible]	[illegible]	[illegible]
19	2/7 Z1 + 2/7 Z2	[illegible]	[illegible]	[illegible]
20	Core Z1 + 1.5/7 Z1	[illegible]	[illegible]	[illegible]
21	Formwork Removal	[illegible]	[illegible]	[illegible]
22	Core Z2 + 4.5/7 Z2	[illegible]	[illegible]	[illegible]
23	Formwork Removal	[illegible]	[illegible]	[illegible]
24	Prefab - Stairs	[illegible]	[illegible]	[illegible]
25	Stair Flights Main Core	[illegible]	[illegible]	[illegible]
26	Stair Flights Z1 Core	[illegible]	[illegible]	[illegible]
27	Stair Flights Z2 Core	[illegible]	[illegible]	[illegible]
28	1st Floor	13 days	Fri 11/03/16	Tue 29/03/16
29	Reinforced Concrete Walls	[illegible]	[illegible]	[illegible]
30	Prefab	[illegible]	[illegible]	[illegible]
31	Columns	[illegible]	[illegible]	[illegible]
32	Beams	[illegible]	[illegible]	[illegible]
33	Hollow-core slab (Hourdis)	[illegible]	[illegible]	[illegible]
34	Concreting	[illegible]	[illegible]	[illegible]
35	Preparatory Work	[illegible]	[illegible]	[illegible]
36	Formwork	[illegible]	[illegible]	[illegible]
37	Reinforcement	[illegible]	[illegible]	[illegible]
38	Concreting (Dalle CSP + Chape de Compressio	[illegible]	[illegible]	[illegible]
39	Core Staires + 3.5/7 Z1 + 0.5/7 Z2	[illegible]	[illegible]	[illegible]
40	Formwork Removal	[illegible]	[illegible]	[illegible]
41	2/7 Z1 + 2/7 Z2	[illegible]	[illegible]	[illegible]
42	Core Z1 + 1.5/7 Z1	[illegible]	[illegible]	[illegible]
43	Formwork Removal	[illegible]	[illegible]	[illegible]
44	Core Z2 + 4.5/7 Z2	[illegible]	[illegible]	[illegible]
45	Formwork Removal	[illegible]	[illegible]	[illegible]
46	Prefab - Stairs	[illegible]	[illegible]	[illegible]
47	Stair Flights Main Core	[illegible]	[illegible]	[illegible]
48	Stair Flights Z1 Core	[illegible]	[illegible]	[illegible]
49	Stair Flights Z2 Core	[illegible]	[illegible]	[illegible]
50	2nd Floor	13 days	Tue 22/03/16	Thu 07/04/16
51	Reinforced Concrete Walls	[illegible]	[illegible]	[illegible]
52	Prefab	[illegible]	[illegible]	[illegible]
53	Columns	[illegible]	[illegible]	[illegible]
54	Beams	[illegible]	[illegible]	[illegible]
55	Hollow-core slab (Hourdis)	[illegible]	[illegible]	[illegible]
56	Concreting	[illegible]	[illegible]	[illegible]
57	Preparatory Work	[illegible]	[illegible]	[illegible]
58	Formwork	[illegible]	[illegible]	[illegible]
59	Reinforcement	[illegible]	[illegible]	[illegible]
60	Concreting (Dalle CSP + Chape de Compressio	[illegible]	[illegible]	[illegible]
61	Core Staires + 3.5/7 Z1 + 0.5/7 Z2	[illegible]	[illegible]	[illegible]
62	Formwork Removal	[illegible]	[illegible]	[illegible]
63	2/7 Z1 + 2/7 Z2	[illegible]	[illegible]	[illegible]
64	Core Z1 + 1.5/7 Z1	[illegible]	[illegible]	[illegible]
65	Formwork Removal	[illegible]	[illegible]	[illegible]
66	Core Z2 + 4.5/7 Z2	[illegible]	[illegible]	[illegible]
67	Formwork Removal	[illegible]	[illegible]	[illegible]
68	Prefab - Stairs	[illegible]	[illegible]	[illegible]
69	Stair Flights Main Core	[illegible]	[illegible]	[illegible]
70	Stair Flights Z1 Core	[illegible]	[illegible]	[illegible]
71	Stair Flights Z2 Core	[illegible]	[illegible]	[illegible]
72	3rd Floor	13 days	Thu 31/03/16	Mon 18/04/16
73	Reinforced Concrete Walls	[illegible]	[illegible]	[illegible]
74	Prefab	[illegible]	[illegible]	[illegible]
75	Columns	[illegible]	[illegible]	[illegible]
76	Beams	[illegible]	[illegible]	[illegible]
77	Hollow-core slab (Hourdis)	7 days	Tue 05/04/16	Wed 13/04/16
78	Concreting	10 days	Tue 05/04/16	Mon 18/04/16
79	Preparatory Work	8 days	Tue 05/04/16	Thu 14/04/16
80	Formwork	7 days	Tue 05/04/16	Wed 13/04/16
81	Reinforcement	7 days	Wed 06/04/16	Thu 14/04/16
82	Concreting (Dalle CSP + Chape de Compressio	7 days	Fri 08/04/16	Mon 18/04/16
83	Core Staires + 3.5/7 Z1 + 0.5/7 Z2	1 day	Fri 08/04/16	Fri 08/04/16
84	Formwork Removal	1 day	Thu 14/04/16	Thu 14/04/16
85	2/7 Z1 + 2/7 Z2	1 day	Tue 12/04/16	Tue 12/04/16
86	Core Z1 + 1.5/7 Z1	1 day	Wed 13/04/16	Wed 13/04/16
87	Formwork Removal	1 day	Mon 18/04/16	Mon 18/04/16
88	Core Z2 + 4.5/7 Z2	1 day	Thu 14/04/16	Thu 14/04/16
89	Formwork Removal	1 day	Mon 18/04/16	Mon 18/04/16
90	Prefab - Stairs	6 days	Thu 07/04/16	Thu 14/04/16
91	Stair Flights Main Core	1 day	Thu 07/04/16	Thu 07/04/16
92	Stair Flights Z1 Core	1 day	Tue 12/04/16	Tue 12/04/16
93	Stair Flights Z2 Core	1 day	Thu 14/04/16	Thu 14/04/16
94	4th Floor	13 days	Mon 11/04/16	Wed 27/04/16
95	Reinforced Concrete Walls	7 days	Mon 11/04/16	Tue 19/04/16
96	Prefab	7 days	Tue 12/04/16	Wed 20/04/16
97	Columns	6 days	Tue 12/04/16	Tue 19/04/16
98	Beams	6 days	Wed 13/04/16	Wed 20/04/16
99	Hollow-core slab (Hourdis)	7 days	Thu 14/04/16	Fri 22/04/16
100	Concreting	10 days	Thu 14/04/16	Wed 27/04/16
101	Preparatory Work	8 days	Thu 14/04/16	Mon 25/04/16
102	Formwork	7 days	Thu 14/04/16	Fri 22/04/16
103	Reinforcement	7 days	Fri 15/04/16	Mon 25/04/16
104	Concreting (Dalle CSP + Chape de Compressio	7 days	Tue 19/04/16	Wed 27/04/16
105	Core Staires + 3.5/7 Z1 + 0.5/7 Z2	1 day	Tue 19/04/16	Tue 19/04/16
106	Formwork Removal	1 day	Mon 25/04/16	Mon 25/04/16
107	2/7 Z1 + 2/7 Z2	1 day	Thu 21/04/16	Thu 21/04/16
108	Core Z1 + 1.5/7 Z1	1 day	Fri 22/04/16	Fri 22/04/16
109	Formwork Removal	1 day	Wed 27/04/16	Wed 27/04/16
110	Core Z2 + 4.5/7 Z2	1 day	Mon 25/04/16	Mon 25/04/16
111	Formwork Removal	1 day	Tue 26/04/16	Tue 26/04/16
112	Prefab - Stairs	6 days	Mon 18/04/16	Mon 25/04/16
113	Stair Flights Main Core	1 day	Mon 18/04/16	Mon 18/04/16
114	Stair Flights Z1 Core	1 day	Thu 21/04/16	Thu 21/04/16
115	Stair Flights Z2 Core	1 day	Mon 25/04/16	Mon 25/04/16
116	5th Floor	13 days	Wed 20/04/16	Tue 10/05/16
117	Reinforced Concrete Walls	7 days	Wed 20/04/16	Thu 28/04/16
118	Prefab	7 days	Thu 21/04/16	Fri 29/04/16
119	Columns	6 days	Thu 21/04/16	Thu 28/04/16
120	Beams	6 days	Fri 22/04/16	Fri 29/04/16
121	Hollow-core slab (Hourdis)	7 days	Mon 25/04/16	Tue 03/05/16
122	Concreting	10 days	Mon 25/04/16	Tue 10/05/16
123	Preparatory Work	8 days	Mon 25/04/16	Wed 04/05/16
124	Formwork	7 days	Mon 25/04/16	Tue 03/05/16
125	Reinforcement	7 days	Tue 26/04/16	Wed 04/05/16
126	Concreting (Dalle CSP + Chape de Compressio	7 days	Thu 28/04/16	Tue 10/05/16
127	Core Staires + 3.5/7 Z1 + 0.5/7 Z2	1 day	Thu 28/04/16	Thu 28/04/16
128	Formwork Removal	1 day	Wed 04/05/16	Wed 04/05/16
129	2/7 Z1 + 2/7 Z2	1 day	Mon 02/05/16	Mon 02/05/16
130	Core Z1 + 1.5/7 Z1	1 day	Tue 03/05/16	Tue 03/05/16
131	Formwork Removal	1 day	Tue 10/05/16	Tue 10/05/16
132	Core Z2 + 4.5/7 Z2	1 day	Wed 04/05/16	Wed 04/05/16
133	Formwork Removal	1 day	Tue 10/05/16	Tue 10/05/16
134	Prefab - Stairs	6 days	Wed 27/04/16	Wed 04/05/16
135	Stair Flights Main Core	1 day	Wed 27/04/16	Wed 27/04/16
136	Stair Flights Z1 Core	1 day	Mon 02/05/16	Mon 02/05/16
137	Stair Flights Z2 Core	1 day	Wed 04/05/16	Wed 04/05/16
138	6th Floor	13 days	Fri 29/04/16	Fri 20/05/16
139	Reinforced Concrete Walls	7 days	Fri 29/04/16	Wed 11/05/16
140	Prefab	7 days	Mon 02/05/16	Thu 12/05/16
141	Columns	6 days	Mon 02/05/16	Wed 11/05/16
142	Beams	6 days	Tue 03/05/16	Thu 12/05/16
143	Hollow-core slab (Hourdis)	7 days	Wed 04/05/16	Tue 17/05/16
144	Concreting	10 days	Wed 04/05/16	Fri 20/05/16
145	Preparatory Work	8 days	Wed 04/05/16	Wed 18/05/16
146	Formwork	7 days	Wed 04/05/16	Tue 17/05/16
147	Reinforcement	7 days	Mon 09/05/16	Wed 18/05/16
148	Concreting (Dalle CSP + Chape de Compressio	7 days	Wed 11/05/16	Fri 20/05/16
149	Core Staires + 3.5/7 Z1 + 0.5/7 Z2	1 day	Wed 11/05/16	Wed 11/05/16
150	Formwork Removal	1 day	Wed 18/05/16	Wed 18/05/16
151	2/7 Z1 + 2/7 Z2	1 day	Fri 13/05/16	Fri 13/05/16
152	Core Z1 + 1.5/7 Z1	1 day	Tue 17/05/16	Tue 17/05/16
153	Formwork Removal	1 day	Fri 20/05/16	Fri 20/05/16
154	Core Z2 + 4.5/7 Z2	1 day	Wed 18/05/16	Wed 18/05/16
155	Formwork Removal	1 day	Fri 20/05/16	Fri 20/05/16
156	Prefab - Stairs	6 days	Tue 10/05/16	Wed 18/05/16
157	Stair Flights Main Core	1 day	Tue 10/05/16	Tue 10/05/16
158	Stair Flights Z1 Core	1 day	Fri 13/05/16	Fri 13/05/16
159	Stair Flights Z2 Core	1 day	Wed 18/05/16	Wed 18/05/16
160	7th Floor	13 days	Thu 12/05/16	Tue 31/05/16
161	Reinforced Concrete Walls	7 days	Thu 12/05/16	Mon 23/05/16
162	Prefab	7 days	Fri 13/05/16	Tue 24/05/16
163	Columns	6 days	Fri 13/05/16	Mon 23/05/16
164	Beams	6 days	Tue 17/05/16	Tue 24/05/16
165	Hollow-core slab (Hourdis)	7 days	Wed 18/05/16	Thu 26/05/16
166	Concreting	10 days	Wed 18/05/16	Tue 31/05/16
167	Preparatory Work	8 days	Wed 18/05/16	Fri 27/05/16
168	Formwork	7 days	Wed 18/05/16	Thu 26/05/16
169	Reinforcement	7 days	Thu 19/05/16	Fri 27/05/16
170	Concreting (Dalle CSP + Chape de Compressio	7 days	Mon 23/05/16	Tue 31/05/16
171	Core Staires + 3.5/7 Z1 + 0.5/7 Z2	1 day	Mon 23/05/16	Mon 23/05/16
172	Formwork Removal	1 day	Fri 27/05/16	Fri 27/05/16
173	2/7 Z1 + 2/7 Z2	1 day	Wed 25/05/16	Wed 25/05/16
174	Core Z1 + 1.5/7 Z1	1 day	Thu 26/05/16	Thu 26/05/16
175	Formwork Removal	1 day	Tue 31/05/16	Tue 31/05/16
176	Core Z2 + 4.5/7 Z2	1 day	Fri 27/05/16	Fri 27/05/16
177	Formwork Removal	1 day	Tue 31/05/16	Tue 31/05/16
178	Prefab - Stairs	6 days	Fri 20/05/16	Fri 27/05/16
179	Stair Flights Main Core	1 day	Fri 20/05/16	Fri 20/05/16
180	Stair Flights Z1 Core	1 day	Wed 25/05/16	Wed 25/05/16
181	Stair Flights Z2 Core	1 day	Fri 27/05/16	Fri 27/05/16
182	8th Floor	12 days	Tue 24/05/16	Wed 08/06/16
183	Reinforced Concrete Walls	7 days	Tue 24/05/16	Wed 01/06/16
184	Prefab	7 days	Wed 25/05/16	Thu 02/06/16
185	Columns	6 days	Wed 25/05/16	Wed 01/06/16
186	Beams	6 days	Thu 26/05/16	Thu 02/06/16
187	Hollow-core slab (Hourdis)	7 days	Fri 27/05/16	Mon 06/06/16
188	Concreting	9 days	Fri 27/05/16	Wed 08/06/16
189	Preparatory Work	8 days	Fri 27/05/16	Tue 07/06/16
190	Formwork	7 days	Fri 27/05/16	Mon 06/06/16
191	Reinforcement	7 days	Mon 30/05/16	Tue 07/06/16
192	Concreting (Dalle CSP + Chape de Compressio	6 days	Wed 01/06/16	Wed 08/06/16
193	Core Staires + 3.5/7 Z1 + 0.5/7 Z2	1 day	Wed 01/06/16	Wed 01/06/16
194	Formwork Removal	1 day	Tue 07/06/16	Tue 07/06/16
195	2/7 Z1 + 2/7 Z2	1 day	Fri 03/06/16	Fri 03/06/16
196	Core Z1 + 1.5/7 Z1	1 day	Mon 06/06/16	Mon 06/06/16
197	Formwork Removal	1 day	Wed 08/06/16	Wed 08/06/16
198	Core Z2 + 4.5/7 Z2	1 day	Tue 07/06/16	Tue 07/06/16
199	Formwork Removal	1 day	Wed 08/06/16	Wed 08/06/16
200	Prefab - Stairs	6 days	Tue 31/05/16	Tue 07/06/16
201	Stair Flights Main Core	1 day	Tue 31/05/16	Tue 31/05/16
202	Stair Flights Z1 Core	1 day	Fri 03/06/16	Fri 03/06/16
203	Stair Flights Z2 Core	1 day	Tue 07/06/16	Tue 07/06/16
204	Ragréage - Cleaning	68 days	Tue 01/03/16	Wed 08/06/16
205	Aléa - Hazard (20%)	14 days	Thu 09/06/16	Wed 29/06/16



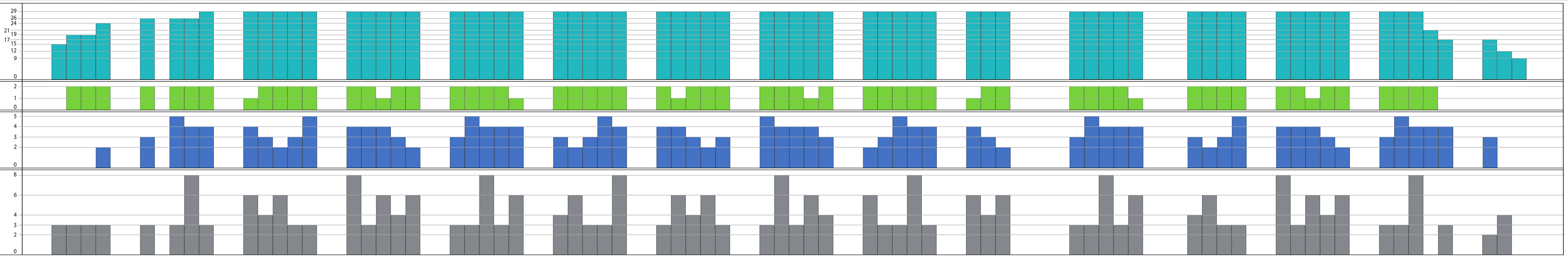
Workforces Graph

Note : 18 general workforces allocated over different tasks plus 2 crane operators, 2 storekeepers, 2 traffic assistants and 5 steel fixers.

Flow of Prefab Trucks per day

Flow of Hollow-Core Slab Trucks per day

Flow of Concrete Trucks per day



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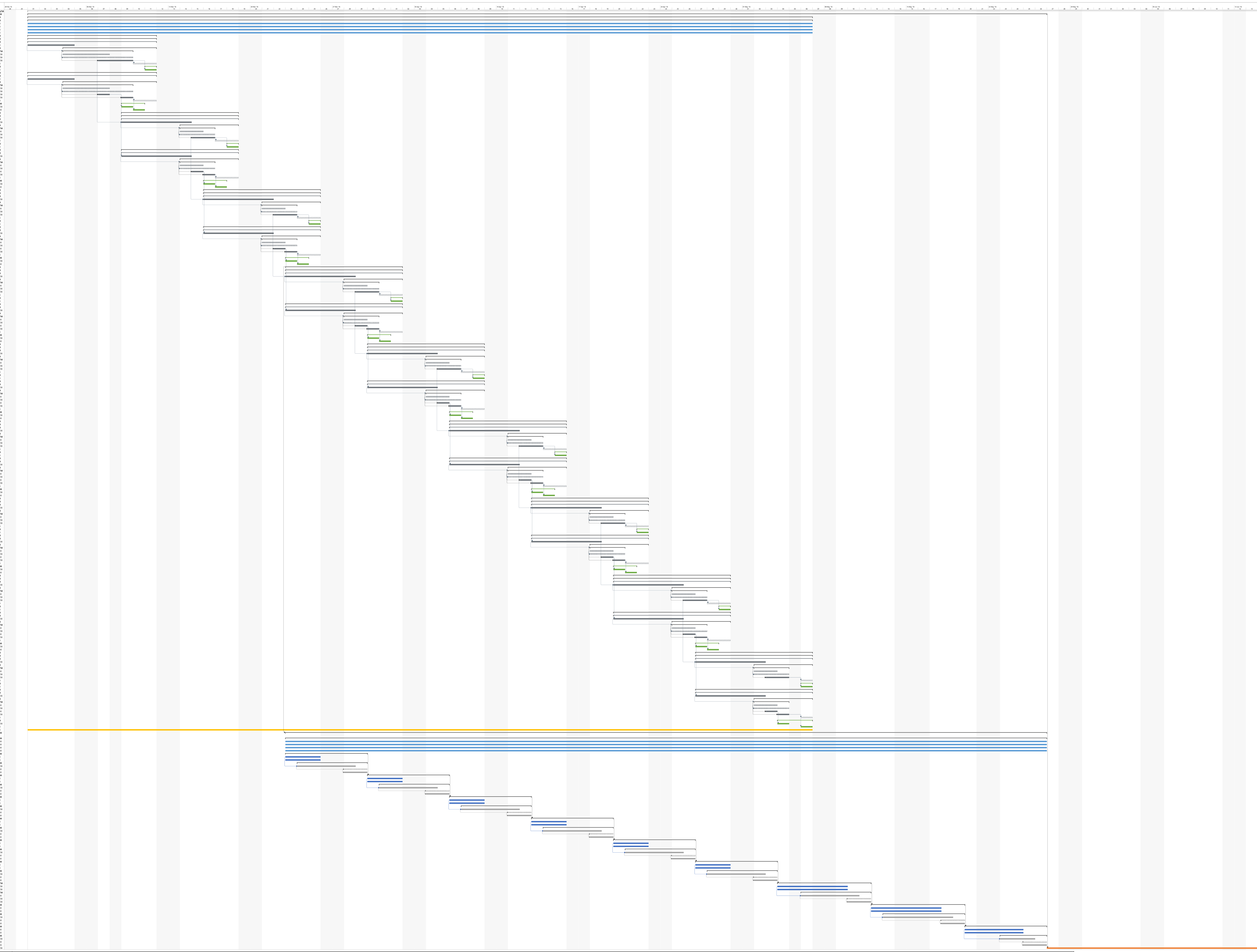
FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION
Univ.-Doz. Dr.- Ing. M. Schäfer

Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variant 1b - V2 New Cores - 2 shifts Planning of the main structure construction of the floors above the ground.
Author :	Dany Pereira
Version:	2
Date:	26/05/2016

Project SiMCo - Variante 1b - 2 cranes concrete cores - 2 Shifts | Planning Sec - Without Hazards | 08.07.2016

ID	Task Name	Duration	Start	Finish
0	**SiMCo - Variant 1b - 2 cranes**	**72 days**	**Tue 01/03/16**	**Mon 13/06/16**
1	**Planning Sec - Without Hazard**	**60 days**	**Tue 01/03/16**	**Thu 26/05/16**
2	**Concrete Cores**	**47 days**	**Tue 01/03/16**	**Fri 06/05/16**
3	**Site Facilities (Shift no.1)**	**47 days**	**Tue 01/03/16**	**Fri 06/05/16**
4	Cran Operator - Crane 1	47 days	Tue 01/03/16	Fri 06/05/16
5	Cran Operator - Crane 2	47 days	Tue 01/03/16	Fri 06/05/16
6	Traffic Assistant	47 days	Tue 01/03/16	Fri 06/05/16
7	Magasinier - Storekeeper	47 days	Tue 01/03/16	Fri 06/05/16
8	**Ground-Floor**	**8 days**	**Tue 01/03/16**	**Fri 11/03/16**
9	**Zone 1 - Main Core**	**8 days**	**Tue 01/03/16**	**Fri 11/03/16**
10	**Concrete**	**8 days**	**Tue 01/03/16**	**Fri 11/03/16**
11	Concrete Walls	4 days	Tue 01/03/16	Fri 04/03/16
12	**Concrete Slabs**	**5 days**	**Fri 04/03/16**	**Fri 11/03/16**
13	**Preparatory Work**	**3 days**	**Fri 04/03/16**	**Wed 09/03/16**
14	Formwork	2 days	Fri 04/03/16	Mon 07/03/16
15	Reinforcement	3 days	Fri 04/03/16	Wed 09/03/16
16	Concreting Slab	2 days	Mon 07/03/16	Wed 09/03/16
17	Formwork Removal	2 days	Thu 10/03/16	Fri 11/03/16
18	**Prefab - Stair flights**	**1 day**	**Fri 11/03/16**	**Fri 11/03/16**
19	Stair flight Main Core	1 day	Fri 11/03/16	Fri 11/03/16
20	**Zone 2 - Core A & B**	**8 days**	**Tue 01/03/16**	**Fri 11/03/16**
21	**Concrete**	**8 days**	**Tue 01/03/16**	**Fri 11/03/16**
22	Concrete Walls	4 days	Tue 01/03/16	Fri 04/03/16
23	**Concrete Slabs**	**5 days**	**Fri 04/03/16**	**Fri 11/03/16**
24	**Preparatory Work**	**3 days**	**Fri 04/03/16**	**Wed 09/03/16**
25	Formwork	2 days	Fri 04/03/16	Mon 07/03/16
26	Reinforcement	3 days	Fri 04/03/16	Wed 09/03/16
27	Concreting Slab - Core A	1 day	Mon 07/03/16	Mon 07/03/16
28	Concreting Slab - Core B	1 day	Wed 09/03/16	Wed 09/03/16
29	Formwork Removal	2 days	Thu 10/03/16	Fri 11/03/16
30	**Prefab - Stair flights**	**2 days**	**Wed 09/03/16**	**Thu 10/03/16**
31	Stair flight Core A	1 day	Wed 09/03/16	Wed 09/03/16
32	Stair flight Core B	1 day	Thu 10/03/16	Thu 10/03/16
33	**1st Floor**	**8 days**	**Wed 09/03/16**	**Fri 18/03/16**
34	**Zone 1 - Main Core**	**8 days**	**Wed 09/03/16**	**Fri 18/03/16**
35	**Concrete**	**8 days**	**Wed 09/03/16**	**Fri 18/03/16**
36	Concrete Walls	4 days	Wed 09/03/16	Mon 14/03/16
37	**Concrete Slabs**	**5 days**	**Mon 14/03/16**	**Fri 18/03/16**
38	**Preparatory Work**	**3 days**	**Mon 14/03/16**	**Wed 16/03/16**
39	Formwork	2 days	Mon 14/03/16	Tue 15/03/16
40	Reinforcement	3 days	Mon 14/03/16	Wed 16/03/16
41	Concreting Slab	2 days	Tue 15/03/16	Wed 16/03/16
42	Formwork Removal	2 days	Thu 17/03/16	Fri 18/03/16
43	**Prefab - Stair flights**	**1 day**	**Fri 18/03/16**	**Fri 18/03/16**
44	Stair flight Main Core	1 day	Fri 18/03/16	Fri 18/03/16
45	**Zone 2 - Core A & B**	**8 days**	**Wed 09/03/16**	**Fri 18/03/16**
46	**Concrete**	**8 days**	**Wed 09/03/16**	**Fri 18/03/16**
47	Concrete Walls	4 days	Wed 09/03/16	Mon 14/03/16
48	**Concrete Slabs**	**5 days**	**Mon 14/03/16**	**Fri 18/03/16**
49	**Preparatory Work**	**3 days**	**Mon 14/03/16**	**Wed 16/03/16**
50	Formwork	2 days	Mon 14/03/16	Tue 15/03/16
51	Reinforcement	3 days	Mon 14/03/16	Wed 16/03/16
52	Concreting Slab - Core A	1 day	Tue 15/03/16	Tue 15/03/16
53	Concreting Slab - Core B	1 day	Wed 16/03/16	Wed 16/03/16
54	Formwork Removal	2 days	Thu 17/03/16	Fri 18/03/16
55	**Prefab - Stair flights**	**2 days**	**Wed 16/03/16**	**Thu 17/03/16**
56	Stair flight Core A	[illegible]	Wed 16/03/16	Wed 16/03/16
57–177	[illegible]	[illegible]	[illegible]	[illegible]
178	Concreting Slab - Core B	1 day	Wed 20/04/16	Wed 20/04/16
179	Formwork Removal	2 days	Thu 21/04/16	Fri 22/04/16
180	**Prefab - Stair flights**	**2 days**	**Wed 20/04/16**	**Thu 21/04/16**
181	Stair flight Core A	1 day	Wed 20/04/16	Wed 20/04/16
182	Stair flight Core B	1 day	Thu 21/04/16	Thu 21/04/16
183	**7th Floor**	**8 days**	**Wed 20/04/16**	**Fri 29/04/16**
184	**Zone 1 - Main Core**	**8 days**	**Wed 20/04/16**	**Fri 29/04/16**
185	**Concrete**	**8 days**	**Wed 20/04/16**	**Fri 29/04/16**
186	Concrete Walls	4 days	Wed 20/04/16	Mon 25/04/16
187	**Concrete Slabs**	**5 days**	**Mon 25/04/16**	**Fri 29/04/16**
188	**Preparatory Work**	**3 days**	**Mon 25/04/16**	**Wed 27/04/16**
189	Formwork	2 days	Mon 25/04/16	Tue 26/04/16
190	Reinforcement	3 days	Mon 25/04/16	Wed 27/04/16
191	Concreting Slab	2 days	Tue 26/04/16	Wed 27/04/16
192	Formwork Removal	2 days	Thu 28/04/16	Fri 29/04/16
193	**Prefab - Stair flights**	**1 day**	**Fri 29/04/16**	**Fri 29/04/16**
194	Stair flight Main Core	1 day	Fri 29/04/16	Fri 29/04/16
195	**Zone 2 - Core A & B**	**8 days**	**Wed 20/04/16**	**Fri 29/04/16**
196	**Concrete**	**8 days**	**Wed 20/04/16**	**Fri 29/04/16**
197	Concrete Walls	4 days	Wed 20/04/16	Mon 25/04/16
198	**Concrete Slabs**	**5 days**	**Mon 25/04/16**	**Fri 29/04/16**
199	**Preparatory Work**	**3 days**	**Mon 25/04/16**	**Wed 27/04/16**
200	Formwork	2 days	Mon 25/04/16	Tue 26/04/16
201	Reinforcement	3 days	Mon 25/04/16	Wed 27/04/16
202	Concreting Slab - Core A	1 day	Tue 26/04/16	Tue 26/04/16
203	Concreting Slab - Core B	1 day	Wed 27/04/16	Wed 27/04/16
204	Formwork Removal	2 days	Thu 28/04/16	Fri 29/04/16
205	**Prefab - Stair flights**	**2 days**	**Wed 27/04/16**	**Thu 28/04/16**
206	Stair flight Core A	1 day	Wed 27/04/16	Wed 27/04/16
207	Stair flight Core B	1 day	Thu 28/04/16	Thu 28/04/16
208	**8th Floor**	**7 days**	**Wed 27/04/16**	**Fri 06/05/16**
209	**Zone 1 - Main Core**	**7 days**	**Wed 27/04/16**	**Fri 06/05/16**
210	**Concrete**	**7 days**	**Wed 27/04/16**	**Fri 06/05/16**
211	Concrete Walls	4 days	Wed 27/04/16	Mon 02/05/16
212	**Concrete Slabs**	**4 days**	**Mon 02/05/16**	**Fri 06/05/16**
213	**Preparatory Work**	**3 days**	**Mon 02/05/16**	**Wed 04/05/16**
214	Formwork	2 days	Mon 02/05/16	Tue 03/05/16
215	Reinforcement	3 days	Mon 02/05/16	Wed 04/05/16
216	Concreting Slab	2 days	Tue 03/05/16	Wed 04/05/16
217	Formwork Removal	1 day	Fri 06/05/16	Fri 06/05/16
218	**Prefab - Stair flights**	**1 day**	**Fri 06/05/16**	**Fri 06/05/16**
219	Stair flight Main Core	1 day	Fri 06/05/16	Fri 06/05/16
220	**Zone 2 - Core A & B**	**7 days**	**Wed 27/04/16**	**Fri 06/05/16**
221	**Concrete**	**7 days**	**Wed 27/04/16**	**Fri 06/05/16**
222	Concrete Walls	4 days	Wed 27/04/16	Mon 02/05/16
223	**Concrete Slabs**	**4 days**	**Mon 02/05/16**	**Fri 06/05/16**
224	**Preparatory Work**	**3 days**	**Mon 02/05/16**	**Wed 04/05/16**
225	Formwork	2 days	Mon 02/05/16	Tue 03/05/16
226	Reinforcement	3 days	Mon 02/05/16	Wed 04/05/16
227	Concreting Slab - Core A	1 day	Tue 03/05/16	Tue 03/05/16
228	Concreting Slab - Core B	1 day	Wed 04/05/16	Wed 04/05/16
229	Formwork Removal	1 day	Fri 06/05/16	Fri 06/05/16
230	**Prefab - Stair flights**	**2 days**	**Wed 04/05/16**	**Fri 06/05/16**
231	Stair flight Core A	1 day	Wed 04/05/16	Wed 04/05/16
232	Stair flight Core B	1 day	Fri 06/05/16	Fri 06/05/16
233	**Ragréage - Cleaning**	47 days	Tue 01/03/16	Fri 06/05/16
234	**Precast Concrete Structure and Hollow-Core Slab**	**45 days**	**Wed 23/03/16**	**Thu 26/05/16**
235	**Site Facilities (Shift no. 2)**	**45 days**	**Wed 23/03/16**	**Thu 26/05/16**
236	Cran Operator	45 days	Wed 23/03/16	Thu 26/05/16
237	Cran Operator	45 days	Wed 23/03/16	Thu 26/05/16
238	Traffic Assistant	45 days	Wed 23/03/16	Thu 26/05/16
239	Magasinier - Storekeeper	45 days	Wed 23/03/16	Thu 26/05/16
240	**Ground Floor**	**5 days**	**Wed 23/03/16**	**Tue 29/03/16**
241	**Precast Columns**	3 days	Wed 23/03/16	Fri 25/03/16
242	**Precast Beams**	3 days	Wed 23/03/16	Fri 25/03/16
243	**Slab**	**4 days**	**Thu 24/03/16**	**Tue 29/03/16**
244	Installation Hollow-Core Element	3 days	Thu 24/03/16	Mon 28/03/16
245	Reinforcement	2 days	Mon 28/03/16	Tue 29/03/16
246	Concreting	2 days	Mon 28/03/16	Tue 29/03/16
247	**1st Floor**	**5 days**	**Wed 30/03/16**	**Tue 05/04/16**
248	**Precast Columns**	3 days	Wed 30/03/16	Fri 01/04/16
249	**Precast Beams**	3 days	Wed 30/03/16	Fri 01/04/16
250	**Slab**	**4 days**	**Thu 31/03/16**	**Tue 05/04/16**
251	Installation Hollow-Core Element	3 days	Thu 31/03/16	Mon 04/04/16
252	Reinforcement	2 days	Mon 04/04/16	Tue 05/04/16
253	Concreting	2 days	Mon 04/04/16	Tue 05/04/16
254	**2nd Floor**	**5 days**	**Wed 06/04/16**	**Tue 12/04/16**
255	**Precast Columns**	3 days	Wed 06/04/16	Fri 08/04/16
256	**Precast Beams**	3 days	Wed 06/04/16	Fri 08/04/16
257	**Slab**	**4 days**	**Thu 07/04/16**	**Tue 12/04/16**
258	Installation Hollow-Core Element	3 days	Thu 07/04/16	Mon 11/04/16
259	Reinforcement	2 days	Mon 11/04/16	Tue 12/04/16
260	Concreting	2 days	Mon 11/04/16	Tue 12/04/16
261	**3rd Floor**	**5 days**	**Wed 13/04/16**	**Tue 19/04/16**
262	**Precast Columns**	3 days	Wed 13/04/16	Fri 15/04/16
263	**Precast Beams**	3 days	Wed 13/04/16	Fri 15/04/16
264	**Slab**	**4 days**	**Thu 14/04/16**	**Tue 19/04/16**
265	Installation Hollow-Core Element	3 days	Thu 14/04/16	Mon 18/04/16
266	Reinforcement	2 days	Mon 18/04/16	Tue 19/04/16
267	Concreting	2 days	Mon 18/04/16	Tue 19/04/16
268	**4th Floor**	**5 days**	**Wed 20/04/16**	**Tue 26/04/16**
269	**Precast Columns**	3 days	Wed 20/04/16	Fri 22/04/16
270	**Precast Beams**	3 days	Wed 20/04/16	Fri 22/04/16
271	**Slab**	**4 days**	**Thu 21/04/16**	**Tue 26/04/16**
272	Installation Hollow-Core Element	3 days	Thu 21/04/16	Mon 25/04/16
273	Reinforcement	2 days	Mon 25/04/16	Tue 26/04/16
274	Concreting	2 days	Mon 25/04/16	Tue 26/04/16
275	**5th Floor**	**5 days**	**Wed 27/04/16**	**Tue 03/05/16**
276	**Precast Columns**	3 days	Wed 27/04/16	Fri 29/04/16
277	**Precast Beams**	3 days	Wed 27/04/16	Fri 29/04/16
278	**Slab**	**4 days**	**Thu 28/04/16**	**Tue 03/05/16**
279	Installation Hollow-Core Element	3 days	Thu 28/04/16	Mon 02/05/16
280	Reinforcement	2 days	Mon 02/05/16	Tue 03/05/16
281	Concreting	2 days	Mon 02/05/16	Tue 03/05/16
282	**6th Floor**	**5 days**	**Wed 04/05/16**	**Wed 11/05/16**
283	**Precast Columns**	3 days	Wed 04/05/16	Mon 09/05/16
284	**Precast Beams**	3 days	Wed 04/05/16	Mon 09/05/16
285	**Slab**	**4 days**	**Fri 06/05/16**	**Wed 11/05/16**
286	Installation Hollow-Core Element	3 days	Fri 06/05/16	Tue 10/05/16
287	Reinforcement	2 days	Tue 10/05/16	Wed 11/05/16
288	Concreting	2 days	Tue 10/05/16	Wed 11/05/16
289	**7th Floor**	**5 days**	**Thu 12/05/16**	**Thu 19/05/16**
290	**Precast Columns**	3 days	Thu 12/05/16	Tue 17/05/16
291	**Precast Beams**	3 days	Thu 12/05/16	Tue 17/05/16
292	**Slab**	**4 days**	**Fri 13/05/16**	**Thu 19/05/16**
293	Installation Hollow-Core Element	3 days	Fri 13/05/16	Wed 18/05/16
294	Reinforcement	2 days	Wed 18/05/16	Thu 19/05/16
295	Concreting	2 days	Wed 18/05/16	Thu 19/05/16
296	**8th Floor**	**5 days**	**Fri 20/05/16**	**Thu 26/05/16**
297	**Precast Columns**	3 days	Fri 20/05/16	Tue 24/05/16
298	**Precast Beams**	3 days	Fri 20/05/16	Tue 24/05/16
299	**Slab**	**4 days**	**Mon 23/05/16**	**Thu 26/05/16**
300	Installation Hollow-Core Element	3 days	Mon 23/05/16	Wed 25/05/16
301	Reinforcement	2 days	Wed 25/05/16	Thu 26/05/16
302	Concreting	2 days	Wed 25/05/16	Thu 26/05/16
303	**Aléa - Hazard (20%)**	12 days	Fri 27/05/16	Mon 13/06/16



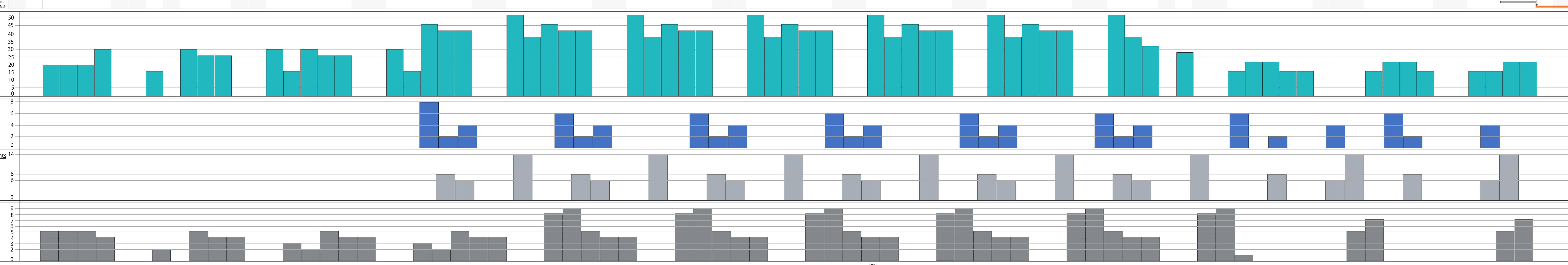
Workforces Graph

Note : 18 general workforces allocated over different tasks in the construction of the cores and slab concreting, 12 in the mounting of the steel structure and puting the Cofra-Plus Elements on place, and 4 concreting the floors. plus 4 crane operators, 2 storekeepers, 2 traffic assistants and 12 steel fixers.

Daily Flow of Trucks with Precast Elements

Daily Flow of Trucks with Hollow-Core Elements

Daily Flow of Concrete Trucks



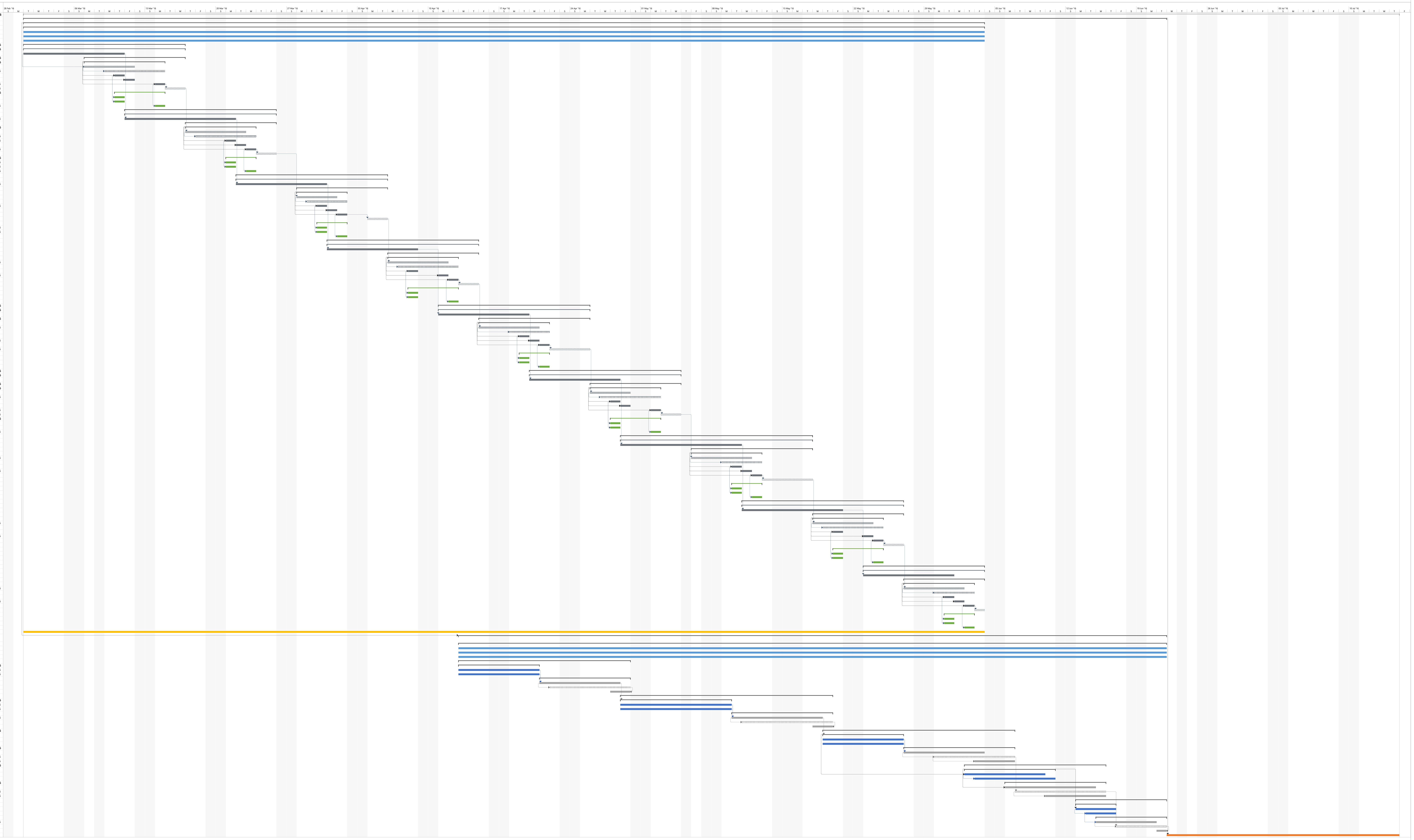
Univ.-Doz. Dr.- Ing. M. Schäfer

FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION

Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variant 1b 2 cranes- 2 shifts Planning of the main structure of the floors above the ground.
Author :	Dany Pereira
Version:	1.0
Date:	08/07/2016

Project SiMCo - Variante 2a - 2 Shifts | Planning Sec - Without Hazards | 02.06.2016

ID	Task Name	Duration	Start	Finish
0	**SiMCo - Variant 2a V3**	**94 days**	**Tue 01/03/16**	**Thu 14/07/16**
1	**Planning Sec - Without Hazard**	**78 days**	**Tue 01/03/16**	**Tue 21/06/16**
2	**Concrete Cores**	**66 days**	**Tue 01/03/16**	**Fri 03/06/16**
3	**Site Facilities (Shift 1)**	**66 days**	**Tue 01/03/16**	**Fri 03/06/16**
4	Cran Operator	66 days	Tue 01/03/16	Fri 03/06/16
5	Traffic Assistant	66 days	Tue 01/03/16	Fri 03/06/16
6	Magasinier - Storekeeper	66 days	Tue 01/03/16	Fri 03/06/16
7	**Ground-Floor**	**11 days**	**Tue 01/03/16**	**Wed 16/03/16**
8	**Concrete**	**11 days**	**Tue 01/03/16**	**Wed 16/03/16**
9	Concrete Walls	7 days	Tue 01/03/16	Thu 10/03/16
10	**Concrete Slabs**	**7 days**	**Mon 07/03/16**	**Wed 16/03/16**
11	**Preparatory Work**	**5 days**	**Mon 07/03/16**	**Mon 14/03/16**
12	Formwork	4 days	Mon 07/03/16	Fri 11/03/16
13	Reinforcement	4 days	Wed 09/03/16	Mon 14/03/16
14	Concreting Slab - Main Core	1 day	Thu 10/03/16	Thu 10/03/16
15	Concreting Slab - Core A	1 day	Fri 11/03/16	Fri 11/03/16
16	Concreting Slab - Core B	1 day	Mon 14/03/16	Mon 14/03/16
17	Formwork Removal	2 days	Tue 15/03/16	Wed 16/03/16
18	**Prefab - Stair flights**	**3 days**	**Thu 10/03/16**	**Mon 14/03/16**
19	Stair flight Main Core	1 day	Thu 10/03/16	Thu 10/03/16
20	Stair flight Core A	1 day	Thu 10/03/16	Thu 10/03/16
21	Stair flight Core B	1 day	Mon 14/03/16	Mon 14/03/16
22	**1st Floor**	**11 days**	**Fri 11/03/16**	**Fri 25/03/16**
23	**Concrete**	**11 days**	**Fri 11/03/16**	**Fri 25/03/16**
24	Concrete Walls	7 days	Fri 11/03/16	Mon 21/03/16
25	**Concrete Slabs**	**7 days**	**Thu 17/03/16**	**Fri 25/03/16**
26	**Preparatory Work**	**5 days**	**Thu 17/03/16**	**Wed 23/03/16**
27	Formwork	4 days	Thu 17/03/16	Tue 22/03/16
28	Reinforcement	4 days	Fri 18/03/16	Wed 23/03/16
29	Concreting Slab - Main Core	1 day	Mon 21/03/16	Mon 21/03/16
30	Concreting Slab - Core A	1 day	Tue 22/03/16	Tue 22/03/16
31	Concreting Slab - Core B	1 day	Wed 23/03/16	Wed 23/03/16
32	Formwork Removal	2 days	Thu 24/03/16	Fri 25/03/16
33	**Prefab - Stair flights**	**3 days**	**Mon 21/03/16**	**Wed 23/03/16**
34	Stair flight Main Core	1 day	Mon 21/03/16	Mon 21/03/16
35	Stair flight Core A	1 day	Mon 21/03/16	Mon 21/03/16
36	Stair flight Core B	1 day	Wed 23/03/16	Wed 23/03/16
37	**2nd Floor**	**11 days**	**Tue 22/03/16**	**Tue 05/04/16**
38	**Concrete**	**11 days**	**Tue 22/03/16**	**Tue 05/04/16**
39	Concrete Walls	7 days	Tue 22/03/16	Wed 30/03/16
40	**Concrete Slabs**	**7 days**	**Mon 28/03/16**	**Tue 05/04/16**
41	**Preparatory Work**	**5 days**	**Mon 28/03/16**	**Fri 01/04/16**
42	Formwork	4 days	Mon 28/03/16	Thu 31/03/16
43	Reinforcement	4 days	Tue 29/03/16	Fri 01/04/16
44	Concreting Slab - Main Core	1 day	Wed 30/03/16	Wed 30/03/16
45	Concreting Slab - Core A	1 day	Thu 31/03/16	Thu 31/03/16
46	Concreting Slab - Core B	1 day	Fri 01/04/16	Fri 01/04/16
47	Formwork Removal	2 days	Mon 04/04/16	Tue 05/04/16
48	**Prefab - Stair flights**	**3 days**	**Wed 30/03/16**	**Fri 01/04/16**
49	Stair flight Main Core	1 day	Wed 30/03/16	Wed 30/03/16
50	Stair flight Core A	1 day	Wed 30/03/16	Wed 30/03/16
51	Stair flight Core B	1 day	Fri 01/04/16	Fri 01/04/16
52	**3rd Floor**	**11 days**	**Thu 31/03/16**	**Thu 14/04/16**
53	**Concrete**	**11 days**	**Thu 31/03/16**	**Thu 14/04/16**
54	Concrete Walls	7 days	Thu 31/03/16	Fri 08/04/16
55	**Concrete Slabs**	**7 days**	**Wed 06/04/16**	**Thu 14/04/16**
56	**Preparatory Work**	**5 days**	**Wed 06/04/16**	**Tue 12/04/16**
57	Formwork	4 days	Wed 06/04/16	Mon 11/04/16
58	Reinforcement	4 days	Thu 07/04/16	Tue 12/04/16
59	Concreting Slab - Main Core	1 day	Fri 08/04/16	Fri 08/04/16
60	Concreting Slab - Core A	1 day	Mon 11/04/16	Mon 11/04/16
61	Concreting Slab - Core B	1 day	Tue 12/04/16	Tue 12/04/16
62	Formwork Removal	2 days	Wed 13/04/16	Thu 14/04/16
63	**Prefab - Stair flights**	**3 days**	**Fri 08/04/16**	**Tue 12/04/16**
64	Stair flight Main Core	1 day	Fri 08/04/16	Fri 08/04/16
65	Stair flight Core A	1 day	Fri 08/04/16	Fri 08/04/16
66	Stair flight Core B	1 day	Tue 12/04/16	Tue 12/04/16
67	**4th Floor**	**11 days**	**Mon 11/04/16**	**Mon 25/04/16**
68	**Concrete**	**11 days**	**Mon 11/04/16**	**Mon 25/04/16**
69	Concrete Walls	7 days	Mon 11/04/16	Tue 19/04/16
70	**Concrete Slabs**	**7 days**	**Fri 15/04/16**	**Mon 25/04/16**
71	**Preparatory Work**	**5 days**	**Fri 15/04/16**	**Thu 21/04/16**
72	Formwork	4 days	Fri 15/04/16	Wed 20/04/16
73	Reinforcement	4 days	Mon 18/04/16	Thu 21/04/16
74	Concreting Slab - Main Core	1 day	Tue 19/04/16	Tue 19/04/16
75	Concreting Slab - Core A	1 day	Wed 20/04/16	Wed 20/04/16
76	Concreting Slab - Core B	1 day	Thu 21/04/16	Thu 21/04/16
77	Formwork Removal	2 days	Fri 22/04/16	Mon 25/04/16
78	**Prefab - Stair flights**	**3 days**	**Tue 19/04/16**	**Thu 21/04/16**
79	Stair flight Main Core	1 day	Tue 19/04/16	Tue 19/04/16
80	Stair flight Core A	1 day	Tue 19/04/16	Tue 19/04/16
81	Stair flight Core B	1 day	Thu 21/04/16	Thu 21/04/16
82	**5th Floor**	**11 days**	**Wed 20/04/16**	**Wed 04/05/16**
83	**Concrete**	**11 days**	**Wed 20/04/16**	**Wed 04/05/16**
84	Concrete Walls	7 days	Wed 20/04/16	Thu 28/04/16
85	**Concrete Slabs**	**7 days**	**Tue 26/04/16**	**Wed 04/05/16**
86	**Preparatory Work**	**5 days**	**Tue 26/04/16**	**Mon 02/05/16**
87	Formwork	4 days	Tue 26/04/16	Fri 29/04/16
88	Reinforcement	4 days	Wed 27/04/16	Mon 02/05/16
89	Concreting Slab - Main Core	1 day	Thu 28/04/16	Thu 28/04/16
90	Concreting Slab - Core A	1 day	Fri 29/04/16	Fri 29/04/16
91	Concreting Slab - Core B	1 day	Mon 02/05/16	Mon 02/05/16
92	Formwork Removal	2 days	Tue 03/05/16	Wed 04/05/16
93	**Prefab - Stair flights**	**3 days**	**Thu 28/04/16**	**Mon 02/05/16**
94	Stair flight Main Core	1 day	Thu 28/04/16	Thu 28/04/16
95	Stair flight Core A	1 day	Thu 28/04/16	Thu 28/04/16
96	Stair flight Core B	1 day	Mon 02/05/16	Mon 02/05/16
97	**6th Floor**	**11 days**	**Fri 29/04/16**	**Tue 17/05/16**
98	**Concrete**	**11 days**	**Fri 29/04/16**	**Tue 17/05/16**
99	Concrete Walls	7 days	Fri 29/04/16	Tue 10/05/16
100	**Concrete Slabs**	**7 days**	**Fri 06/05/16**	**Tue 17/05/16**
101	**Preparatory Work**	**5 days**	**Fri 06/05/16**	**Thu 12/05/16**
102	Formwork	4 days	Fri 06/05/16	Wed 11/05/16
103	Reinforcement	4 days	Mon 09/05/16	Thu 12/05/16
104	Concreting Slab - Main Core	1 day	Tue 10/05/16	Tue 10/05/16
105	Concreting Slab - Core A	1 day	Wed 11/05/16	Wed 11/05/16
106	Concreting Slab - Core B	1 day	Thu 12/05/16	Thu 12/05/16
107	Formwork Removal	2 days	Fri 13/05/16	Tue 17/05/16
108	**Prefab - Stair flights**	**3 days**	**Tue 10/05/16**	**Thu 12/05/16**
109	Stair flight Main Core	1 day	Tue 10/05/16	Tue 10/05/16
110	Stair flight Core A	1 day	Tue 10/05/16	Tue 10/05/16
111	Stair flight Core B	1 day	Thu 12/05/16	Thu 12/05/16
112	**7th Floor**	**11 days**	**Wed 11/05/16**	**Thu 26/05/16**
113	**Concrete**	**11 days**	**Wed 11/05/16**	**Thu 26/05/16**
114	Concrete Walls	7 days	Wed 11/05/16	Fri 20/05/16
115	**Concrete Slabs**	**7 days**	**Wed 18/05/16**	**Thu 26/05/16**
116	**Preparatory Work**	**5 days**	**Wed 18/05/16**	**Tue 24/05/16**
117	Formwork	4 days	Wed 18/05/16	Mon 23/05/16
118	Reinforcement	4 days	Thu 19/05/16	Tue 24/05/16
119	Concreting Slab - Main Core	1 day	Fri 20/05/16	Fri 20/05/16
120	Concreting Slab - Core A	1 day	Mon 23/05/16	Mon 23/05/16
121	Concreting Slab - Core B	1 day	Tue 24/05/16	Tue 24/05/16
122	Formwork Removal	2 days	Wed 25/05/16	Thu 26/05/16
123	**Prefab - Stair flights**	**3 days**	**Fri 20/05/16**	**Tue 24/05/16**
124	Stair flight Main Core	1 day	Fri 20/05/16	Fri 20/05/16
125	Stair flight Core A	1 day	Fri 20/05/16	Fri 20/05/16
126	Stair flight Core B	1 day	Tue 24/05/16	Tue 24/05/16
127	**8th Floor**	**10 days**	**Mon 23/05/16**	**Fri 03/06/16**
128	**Concrete**	**10 days**	**Mon 23/05/16**	**Fri 03/06/16**
129	Concrete Walls	7 days	Mon 23/05/16	Tue 31/05/16
130	**Concrete Slabs**	**6 days**	**Fri 27/05/16**	**Fri 03/06/16**
131	**Preparatory Work**	**5 days**	**Fri 27/05/16**	**Thu 02/06/16**
132	Formwork	4 days	Fri 27/05/16	Wed 01/06/16
133	Reinforcement	4 days	Mon 30/05/16	Thu 02/06/16
134	Concreting Slab - Main Core	1 day	Tue 31/05/16	Tue 31/05/16
135	Concreting Slab - Core A	1 day	Wed 01/06/16	Wed 01/06/16
136	Concreting Slab - Core B	1 day	Thu 02/06/16	Thu 02/06/16
137	Formwork Removal	1 day	Fri 03/06/16	Fri 03/06/16
138	**Prefab - Stair flights**	**3 days**	**Tue 31/05/16**	**Thu 02/06/16**
139	Stair flight Main Core	1 day	Tue 31/05/16	Tue 31/05/16
140	Stair flight Core A	1 day	Tue 31/05/16	Tue 31/05/16
141	Stair flight Core B	1 day	Thu 02/06/16	Thu 02/06/16
142	**Ragréage - Cleaning**	66 days	Tue 01/03/16	Fri 03/06/16
143	**Steel Structure and Hollow Core Slab**	**48 days**	**Wed 13/04/16**	**Tue 21/06/16**
144	**Site Facilities (Shift 2)**	**48 days**	**Wed 13/04/16**	**Tue 21/06/16**
145	Cran Operator	48 days	Wed 13/04/16	Tue 21/06/16
146	Traffic Assistant	48 days	Wed 13/04/16	Tue 21/06/16
147	Magasinier - Storekeeper	48 days	Wed 13/04/16	Tue 21/06/16
148	**Ground and 1st Floor**	**13 days**	**Wed 13/04/16**	**Fri 29/04/16**
149	**Steel Structure**	**6 days**	**Wed 13/04/16**	**Wed 20/04/16**
150	Steel Columns	6 days	Wed 13/04/16	Wed 20/04/16
151	Steel Beams	6 days	Wed 13/04/16	Wed 20/04/16
152	**Hollow Core Slab**	**7 days**	**Thu 21/04/16**	**Fri 29/04/16**
153	HollowCore Elements Laying	6 days	Thu 21/04/16	Thu 28/04/16
154	Reinforcement	6 days	Fri 22/04/16	Fri 29/04/16
155	*Chape de Compression*	2 days	Thu 28/04/16	Fri 29/04/16
156	**2nd Floor and 3rd Floor**	**13 days**	**Fri 29/04/16**	**Thu 19/05/16**
157	**Steel Structure**	**6 days**	**Fri 29/04/16**	**Mon 09/05/16**
158	Steel Columns	6 days	Fri 29/04/16	Mon 09/05/16
159	Steel Beams	6 days	Fri 29/04/16	Mon 09/05/16
160	**Hollow Core Slab**	**7 days**	**Tue 10/05/16**	**Thu 19/05/16**
161	HollowCore Elements Laying	6 days	Tue 10/05/16	Wed 18/05/16
162	Reinforcement	6 days	Wed 11/05/16	Thu 19/05/16
163	*Chape de Compression*	2 days	Wed 18/05/16	Thu 19/05/16
164	**4th Floor and 5th Floor**	**13 days**	**Thu 19/05/16**	**Mon 06/06/16**
165	**Steel Structure**	**6 days**	**Thu 19/05/16**	**Thu 26/05/16**
166	Steel Columns	6 days	Thu 19/05/16	Thu 26/05/16
167	Steel Beams	6 days	Thu 19/05/16	Thu 26/05/16
168	**Hollow Core Slab**	**7 days**	**Fri 27/05/16**	**Mon 06/06/16**
169	HollowCore Elements Laying	6 days	Fri 27/05/16	Fri 03/06/16
170	Reinforcement	6 days	Mon 30/05/16	Mon 06/06/16
171	*Chape de Compression*	2 days	Fri 03/06/16	Mon 06/06/16
172	**6th Floor and 7th Floor**	**10 days**	**Thu 02/06/16**	**Wed 15/06/16**
173	**Steel Structure**	**7 days**	**Thu 02/06/16**	**Fri 10/06/16**
174	Steel Columns	6 days	Thu 02/06/16	Thu 09/06/16
175	Steel Beams	6 days	Fri 03/06/16	Fri 10/06/16
176	**Hollow Core Slab**	**8 days**	**Mon 06/06/16**	**Wed 15/06/16**
177	HollowCore Elements Laying	7 days	Mon 06/06/16	Tue 14/06/16
178	Reinforcement	7 days	Tue 07/06/16	Wed 15/06/16
179	*Chape de Compression*	4 days	Fri 10/06/16	Wed 15/06/16
180	**8th Floor**	**7 days**	**Mon 13/06/16**	**Tue 21/06/16**
181	**Steel Structure**	**4 days**	**Mon 13/06/16**	**Thu 16/06/16**
182	Steel Columns	4 days	Mon 13/06/16	Thu 16/06/16
183	Steel Beams	3 days	Tue 14/06/16	Thu 16/06/16
184	**Hollow Core Slab**	**5 days**	**Wed 15/06/16**	**Tue 21/06/16**
185	HollowCore Elements Laying	4 days	Wed 15/06/16	Mon 20/06/16
186	Reinforcement	3 days	Fri 17/06/16	Tue 21/06/16
187	*Chape de Compression*	1 day	Tue 21/06/16	Tue 21/06/16
188	**Aléa - Hazard (20%)**	16 days	Wed 22/06/16	Thu 14/07/16



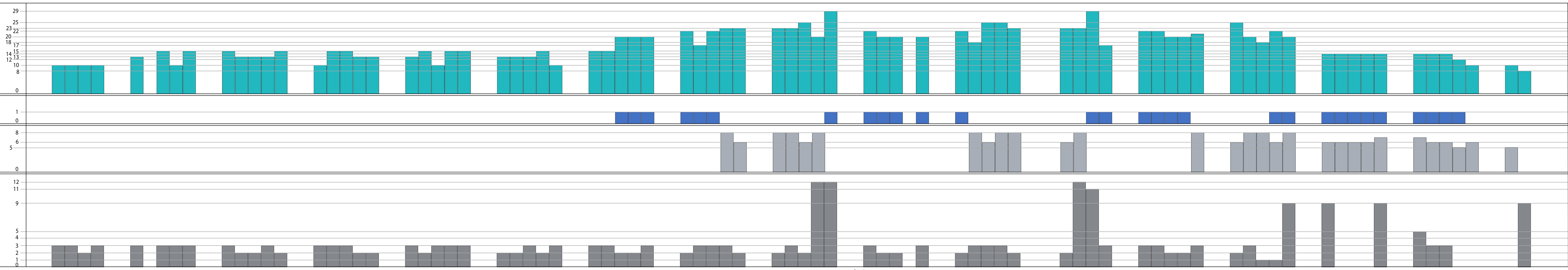
Workforces Graph

Note : 8 general workforces allocated over different tasks in the construction of the cores, 4 in the mounting of the steel structure, 5 in the construction of the hollow core slab, plus 2 crane operators, 2 storekeepers, 2 traffic assistants and 7 steel fixers.

Daily Flow of Trucks with Steel Elements

Daily Flow of Trucks with Hollow-Core Elements

Daily Flow of Concrete Trucks



UNIVERSITÉ DU LUXEMBOURG

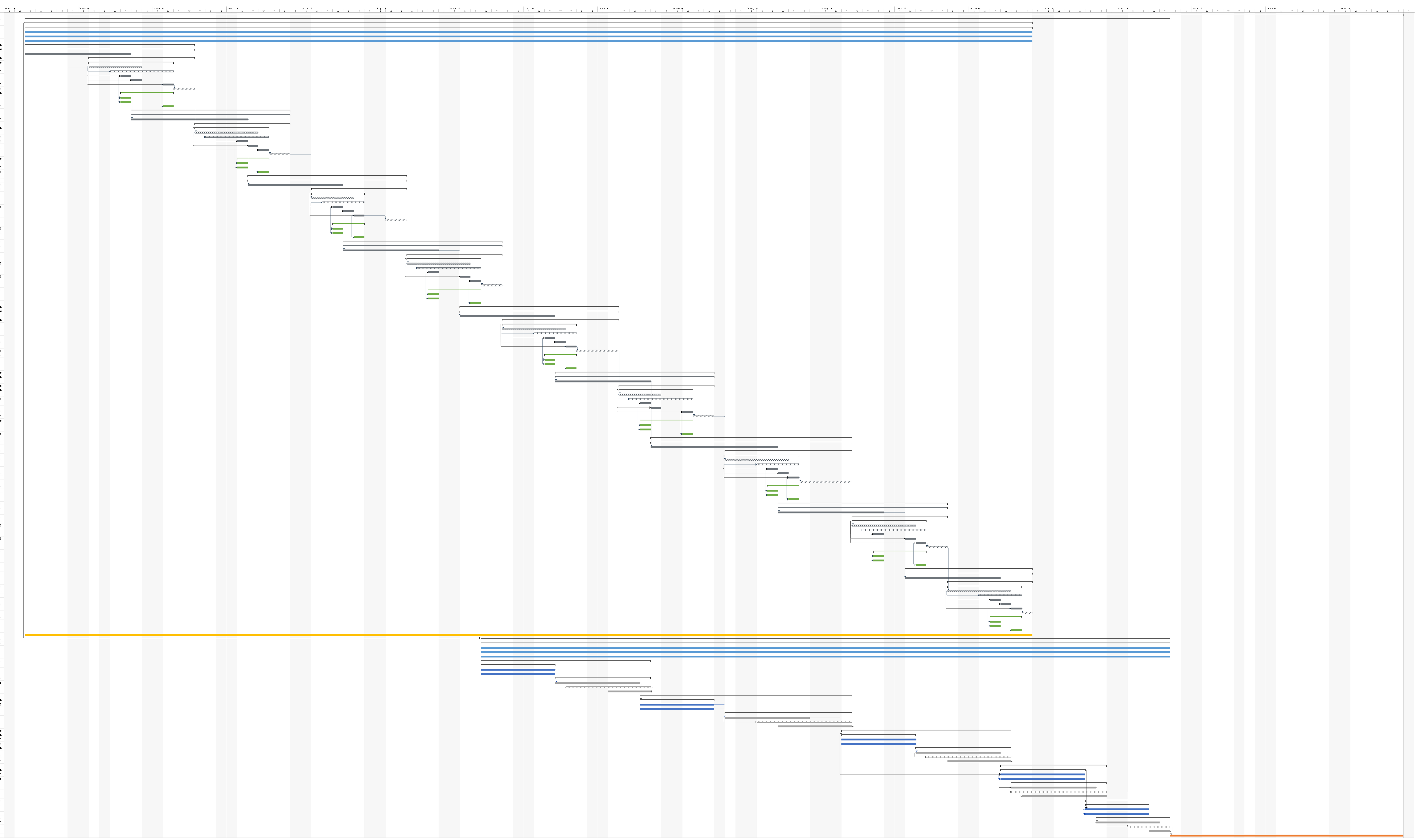
Univ.-Doz. Dr.- Ing. M. Schäfer

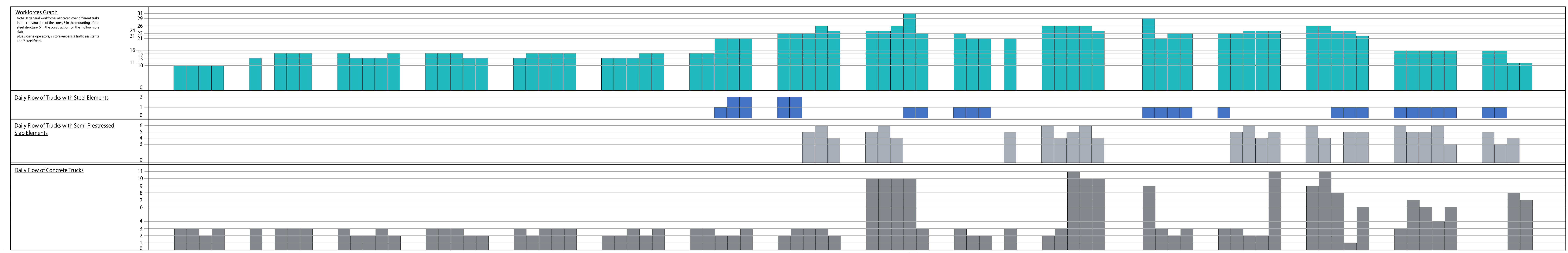
FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION

Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variant 2a - 2 shifts Planning of the main structure of the floors above the ground.
Author :	Dany Pereira
Version:	2.0
Date:	02/06/2016

Project SiMCo - Variante 2b - 2 Shifts | Planning Sec - Without Hazards | 09.06.2016

ID	Task Name	Duration	Start	Finish
0	**SiMCo - Variant 2b**	**90 days**	**Tue 01/03/16**	**Fri 08/07/16**
1	**Planning Sec - Without Hazard**	**75 days**	**Tue 01/03/16**	**Thu 16/06/16**
2	**Concrete Cores**	**66 days**	**Tue 01/03/16**	**Fri 03/06/16**
3	**Site Facilities (Shift 1)**	**66 days**	**Tue 01/03/16**	**Fri 03/06/16**
4	Cran Operator	66 days	Tue 01/03/16	Fri 03/06/16
5	Traffic Assistant	66 days	Tue 01/03/16	Fri 03/06/16
6	Magasinier - Storekeeper	66 days	Tue 01/03/16	Fri 03/06/16
7	**Ground-Floor**	**11 days**	**Tue 01/03/16**	**Wed 16/03/16**
8	**Concrete**	**11 days**	**Tue 01/03/16**	**Wed 16/03/16**
9	Concrete Walls	7 days	Tue 01/03/16	Thu 10/03/16
10	**Concrete Slabs**	**7 days**	**Mon 07/03/16**	**Wed 16/03/16**
11	**Preparatory Work**	**5 days**	**Mon 07/03/16**	**Mon 14/03/16**
12	Formwork	4 days	Mon 07/03/16	Fri 11/03/16
13	Reinforcement	4 days	Wed 09/03/16	Mon 14/03/16
14	Concreting Slab - Main Core	1 day	Thu 10/03/16	Thu 10/03/16
15	Concreting Slab - Core A	1 day	Fri 11/03/16	Fri 11/03/16
16	Concreting Slab - Core B	1 day	Mon 14/03/16	Mon 14/03/16
17	Formwork Removal	2 days	Tue 15/03/16	Wed 16/03/16
18	**Prefab - Stair flights**	**3 days**	**Thu 10/03/16**	**Mon 14/03/16**
19	Stair flight Main Core	1 day	Thu 10/03/16	Thu 10/03/16
20	Stair flight Core A	1 day	Thu 10/03/16	Thu 10/03/16
21	Stair flight Core B	1 day	Mon 14/03/16	Mon 14/03/16
22	**1st Floor**	**11 days**	**Fri 11/03/16**	**Fri 25/03/16**
23	**Concrete**	**11 days**	**Fri 11/03/16**	**Fri 25/03/16**
24	Concrete Walls	7 days	Fri 11/03/16	Mon 21/03/16
25	**Concrete Slabs**	**7 days**	**Thu 17/03/16**	**Fri 25/03/16**
26	**Preparatory Work**	**5 days**	**Thu 17/03/16**	**Wed 23/03/16**
27	Formwork	4 days	Thu 17/03/16	Tue 22/03/16
28	Reinforcement	4 days	Fri 18/03/16	Wed 23/03/16
29	Concreting Slab - Main Core	1 day	Mon 21/03/16	Mon 21/03/16
30	Concreting Slab - Core A	1 day	Tue 22/03/16	Tue 22/03/16
31	Concreting Slab - Core B	1 day	Wed 23/03/16	Wed 23/03/16
32	Formwork Removal	2 days	Thu 24/03/16	Fri 25/03/16
33	**Prefab - Stair flights**	**3 days**	**Mon 21/03/16**	**Wed 23/03/16**
34	Stair flight Main Core	1 day	Mon 21/03/16	Mon 21/03/16
35	Stair flight Core A	1 day	Mon 21/03/16	Mon 21/03/16
36	Stair flight Core B	1 day	Wed 23/03/16	Wed 23/03/16
37	**2nd Floor**	**11 days**	**Tue 22/03/16**	**Tue 05/04/16**
38	**Concrete**	**11 days**	**Tue 22/03/16**	**Tue 05/04/16**
39	Concrete Walls	7 days	Tue 22/03/16	Wed 30/03/16
40	**Concrete Slabs**	**7 days**	**Mon 28/03/16**	**Tue 05/04/16**
41	**Preparatory Work**	**5 days**	**Mon 28/03/16**	**Fri 01/04/16**
42	Formwork	4 days	Mon 28/03/16	Thu 31/03/16
43	Reinforcement	4 days	Tue 29/03/16	Fri 01/04/16
44	Concreting Slab - Main Core	1 day	Wed 30/03/16	Wed 30/03/16
45	Concreting Slab - Core A	1 day	Thu 31/03/16	Thu 31/03/16
46	Concreting Slab - Core B	1 day	Fri 01/04/16	Fri 01/04/16
47	Formwork Removal	2 days	Mon 04/04/16	Tue 05/04/16
48	**Prefab - Stair flights**	**3 days**	**Wed 30/03/16**	**Fri 01/04/16**
49	Stair flight Main Core	1 day	Wed 30/03/16	Wed 30/03/16
50	Stair flight Core A	1 day	Wed 30/03/16	Wed 30/03/16
51	Stair flight Core B	1 day	Fri 01/04/16	Fri 01/04/16
52	**3rd Floor**	**11 days**	**Thu 31/03/16**	**Thu 14/04/16**
53	**Concrete**	**11 days**	**Thu 31/03/16**	**Thu 14/04/16**
54	Concrete Walls	7 days	Thu 31/03/16	Fri 08/04/16
55	**Concrete Slabs**	**7 days**	**Wed 06/04/16**	**Thu 14/04/16**
56	**Preparatory Work**	**5 days**	**Wed 06/04/16**	**Tue 12/04/16**
57	Formwork	4 days	Wed 06/04/16	Mon 11/04/16
58	Reinforcement	4 days	Thu 07/04/16	Tue 12/04/16
59	Concreting Slab - Main Core	1 day	Fri 08/04/16	Fri 08/04/16
60	Concreting Slab - Core A	1 day	Mon 11/04/16	Mon 11/04/16
61	Concreting Slab - Core B	1 day	Tue 12/04/16	Tue 12/04/16
62	Formwork Removal	2 days	Wed 13/04/16	Thu 14/04/16
63	**Prefab - Stair flights**	**3 days**	**Fri 08/04/16**	**Tue 12/04/16**
64	Stair flight Main Core	1 day	Fri 08/04/16	Fri 08/04/16
65	Stair flight Core A	1 day	Fri 08/04/16	Fri 08/04/16
66	Stair flight Core B	1 day	Tue 12/04/16	Tue 12/04/16
67	**4th Floor**	**11 days**	**Mon 11/04/16**	**Mon 25/04/16**
68	**Concrete**	**11 days**	**Mon 11/04/16**	**Mon 25/04/16**
69	Concrete Walls	7 days	Mon 11/04/16	Tue 19/04/16
70	**Concrete Slabs**	**7 days**	**Fri 15/04/16**	**Mon 25/04/16**
71	**Preparatory Work**	**5 days**	**Fri 15/04/16**	**Thu 21/04/16**
72	Formwork	4 days	Fri 15/04/16	Wed 20/04/16
73	Reinforcement	4 days	Mon 18/04/16	Thu 21/04/16
74	Concreting Slab - Main Core	1 day	Tue 19/04/16	Tue 19/04/16
75	Concreting Slab - Core A	1 day	Wed 20/04/16	Wed 20/04/16
76	Concreting Slab - Core B	1 day	Thu 21/04/16	Thu 21/04/16
77	Formwork Removal	2 days	Fri 22/04/16	Mon 25/04/16
78	**Prefab - Stair flights**	**3 days**	**Tue 19/04/16**	**Thu 21/04/16**
79	Stair flight Main Core	1 day	Tue 19/04/16	Tue 19/04/16
80	Stair flight Core A	1 day	Tue 19/04/16	Tue 19/04/16
81	Stair flight Core B	1 day	Thu 21/04/16	Thu 21/04/16
82	**5th Floor**	**11 days**	**Wed 20/04/16**	**Wed 04/05/16**
83	**Concrete**	**11 days**	**Wed 20/04/16**	**Wed 04/05/16**
84	Concrete Walls	7 days	Wed 20/04/16	Thu 28/04/16
85	**Concrete Slabs**	**7 days**	**Tue 26/04/16**	**Wed 04/05/16**
86	**Preparatory Work**	**5 days**	**Tue 26/04/16**	**Mon 02/05/16**
87	Formwork	4 days	Tue 26/04/16	Fri 29/04/16
88	Reinforcement	4 days	Wed 27/04/16	Mon 02/05/16
89	Concreting Slab - Main Core	1 day	Thu 28/04/16	Thu 28/04/16
90	Concreting Slab - Core A	1 day	Fri 29/04/16	Fri 29/04/16
91	Concreting Slab - Core B	1 day	Mon 02/05/16	Mon 02/05/16
92	Formwork Removal	2 days	Tue 03/05/16	Wed 04/05/16
93	**Prefab - Stair flights**	**3 days**	**Thu 28/04/16**	**Mon 02/05/16**
94	Stair flight Main Core	1 day	Thu 28/04/16	Thu 28/04/16
95	Stair flight Core A	1 day	Thu 28/04/16	Thu 28/04/16
96	Stair flight Core B	1 day	Mon 02/05/16	Mon 02/05/16
97	**6th Floor**	**11 days**	**Fri 29/04/16**	**Tue 17/05/16**
98	**Concrete**	**11 days**	**Fri 29/04/16**	**Tue 17/05/16**
99	Concrete Walls	7 days	Fri 29/04/16	Tue 10/05/16
100	**Concrete Slabs**	**7 days**	**Fri 06/05/16**	**Tue 17/05/16**
101	**Preparatory Work**	**5 days**	**Fri 06/05/16**	**Thu 12/05/16**
102	Formwork	4 days	Fri 06/05/16	Wed 11/05/16
103	Reinforcement	4 days	Mon 09/05/16	Thu 12/05/16
104	Concreting Slab - Main Core	1 day	Tue 10/05/16	Tue 10/05/16
105	Concreting Slab - Core A	1 day	Wed 11/05/16	Wed 11/05/16
106	Concreting Slab - Core B	1 day	Thu 12/05/16	Thu 12/05/16
107	Formwork Removal	2 days	Fri 13/05/16	Tue 17/05/16
108	**Prefab - Stair flights**	**3 days**	**Tue 10/05/16**	**Thu 12/05/16**
109	Stair flight Main Core	1 day	Tue 10/05/16	Tue 10/05/16
110	Stair flight Core A	1 day	Tue 10/05/16	Tue 10/05/16
111	Stair flight Core B	1 day	Thu 12/05/16	Thu 12/05/16
112	**7th Floor**	**11 days**	**Wed 11/05/16**	**Thu 26/05/16**
113	**Concrete**	**11 days**	**Wed 11/05/16**	**Thu 26/05/16**
114	Concrete Walls	7 days	Wed 11/05/16	Fri 20/05/16
115	**Concrete Slabs**	**7 days**	**Wed 18/05/16**	**Thu 26/05/16**
116	**Preparatory Work**	**5 days**	**Wed 18/05/16**	**Tue 24/05/16**
117	Formwork	4 days	Wed 18/05/16	Mon 23/05/16
118	Reinforcement	4 days	Thu 19/05/16	Tue 24/05/16
119	Concreting Slab - Main Core	1 day	Fri 20/05/16	Fri 20/05/16
120	Concreting Slab - Core A	1 day	Mon 23/05/16	Mon 23/05/16
121	Concreting Slab - Core B	1 day	Tue 24/05/16	Tue 24/05/16
122	Formwork Removal	2 days	Wed 25/05/16	Thu 26/05/16
123	**Prefab - Stair flights**	**3 days**	**Fri 20/05/16**	**Tue 24/05/16**
124	Stair flight Main Core	1 day	Fri 20/05/16	Fri 20/05/16
125	Stair flight Core A	1 day	Fri 20/05/16	Fri 20/05/16
126	Stair flight Core B	1 day	Tue 24/05/16	Tue 24/05/16
127	**8th Floor**	**10 days**	**Mon 23/05/16**	**Fri 03/06/16**
128	**Concrete**	**10 days**	**Mon 23/05/16**	**Fri 03/06/16**
129	Concrete Walls	7 days	Mon 23/05/16	Tue 31/05/16
130	**Concrete Slabs**	**6 days**	**Fri 27/05/16**	**Fri 03/06/16**
131	**Preparatory Work**	**5 days**	**Fri 27/05/16**	**Thu 02/06/16**
132	Formwork	4 days	Fri 27/05/16	Wed 01/06/16
133	Reinforcement	4 days	Mon 30/05/16	Thu 02/06/16
134	Concreting Slab - Main Core	1 day	Tue 31/05/16	Tue 31/05/16
135	Concreting Slab - Core A	1 day	Wed 01/06/16	Wed 01/06/16
136	Concreting Slab - Core B	1 day	Thu 02/06/16	Thu 02/06/16
137	Formwork Removal	1 day	Fri 03/06/16	Fri 03/06/16
138	**Prefab - Stair flights**	**3 days**	**Tue 31/05/16**	**Thu 02/06/16**
139	Stair flight Main Core	1 day	Tue 31/05/16	Tue 31/05/16
140	Stair flight Core A	1 day	Tue 31/05/16	Tue 31/05/16
141	Stair flight Core B	1 day	Thu 02/06/16	Thu 02/06/16
142	**Ragréage - Cleaning**	66 days	Tue 01/03/16	Fri 03/06/16
143	**Steel Structure and Hollow Core Slab**	**45 days**	**Wed 13/04/16**	**Thu 16/06/16**
144	**Site Facilities (Shift 2)**	**45 days**	**Wed 13/04/16**	**Thu 16/06/16**
145	Cran Operator	45 days	Wed 13/04/16	Thu 16/06/16
146	Traffic Assistant	45 days	Wed 13/04/16	Thu 16/06/16
147	Magasinier - Storekeeper	45 days	Wed 13/04/16	Thu 16/06/16
148	**Ground and 1st Floor**	**12 days**	**Wed 13/04/16**	**Thu 28/04/16**
149	**Steel Structure**	**5 days**	**Wed 13/04/16**	**Tue 19/04/16**
150	Steel Columns	5 days	Wed 13/04/16	Tue 19/04/16
151	Steel Beams	5 days	Wed 13/04/16	Tue 19/04/16
152	**Hollow Core Slab**	**7 days**	**Wed 20/04/16**	**Thu 28/04/16**
153	Semi-Precast Slab Elements	6 days	Wed 20/04/16	Wed 27/04/16
154	Reinforcement	6 days	Thu 21/04/16	Thu 28/04/16
155	*Chape*	4 days	Mon 25/04/16	Thu 28/04/16
156	**2nd Floor and 3rd Floor**	**12 days**	**Thu 28/04/16**	**Tue 17/05/16**
157	**Steel Structure**	**5 days**	**Thu 28/04/16**	**Wed 04/05/16**
158	Steel Columns	5 days	Thu 28/04/16	Wed 04/05/16
159	Steel Beams	5 days	Thu 28/04/16	Wed 04/05/16
160	**Hollow Core Slab**	**7 days**	**Fri 06/05/16**	**Tue 17/05/16**
161	Semi-Precast Slab Elements	6 days	Fri 06/05/16	Fri 13/05/16
162	Reinforcement	6 days	Mon 09/05/16	Tue 17/05/16
163	*Chape*	4 days	Wed 11/05/16	Tue 17/05/16
164	**4th Floor and 5th Floor**	**12 days**	**Tue 17/05/16**	**Wed 01/06/16**
165	**Steel Structure**	**5 days**	**Tue 17/05/16**	**Mon 23/05/16**
166	Steel Columns	5 days	Tue 17/05/16	Mon 23/05/16
167	Steel Beams	5 days	Tue 17/05/16	Mon 23/05/16
168	**Hollow Core Slab**	**7 days**	**Tue 24/05/16**	**Wed 01/06/16**
169	Semi-Precast Slab Elements	6 days	Tue 24/05/16	Tue 31/05/16
170	Reinforcement	6 days	Wed 25/05/16	Wed 01/06/16
171	*Chape*	4 days	Fri 27/05/16	Wed 01/06/16
172	**6th Floor and 7th Floor**	**8 days**	**Wed 01/06/16**	**Fri 10/06/16**
173	**Steel Structure**	**6 days**	**Wed 01/06/16**	**Wed 08/06/16**
174	Steel Columns	6 days	Wed 01/06/16	Wed 08/06/16
175	Steel Beams	6 days	Wed 01/06/16	Wed 08/06/16
176	**Hollow Core Slab**	**7 days**	**Thu 02/06/16**	**Fri 10/06/16**
177	Semi-Precast Slab Elements	6 days	Thu 02/06/16	Thu 09/06/16
178	Reinforcement	7 days	Thu 02/06/16	Fri 10/06/16
179	*Chape*	6 days	Fri 03/06/16	Fri 10/06/16
180	**8th Floor**	**6 days**	**Thu 09/06/16**	**Thu 16/06/16**
181	**Steel Structure**	**4 days**	**Thu 09/06/16**	**Tue 14/06/16**
182	Steel Columns	4 days	Thu 09/06/16	Tue 14/06/16
183	Steel Beams	4 days	Thu 09/06/16	Tue 14/06/16
184	**Hollow Core Slab**	**5 days**	**Fri 10/06/16**	**Thu 16/06/16**
185	Semi-Precast Slab Elements	4 days	Fri 10/06/16	Wed 15/06/16
186	Reinforcement	4 days	Mon 13/06/16	Thu 16/06/16
187	*Chape*	2 days	Wed 15/06/16	Thu 16/06/16
188	**Aléa - Hazard (20%)**	15 days	Fri 17/06/16	Fri 08/07/16





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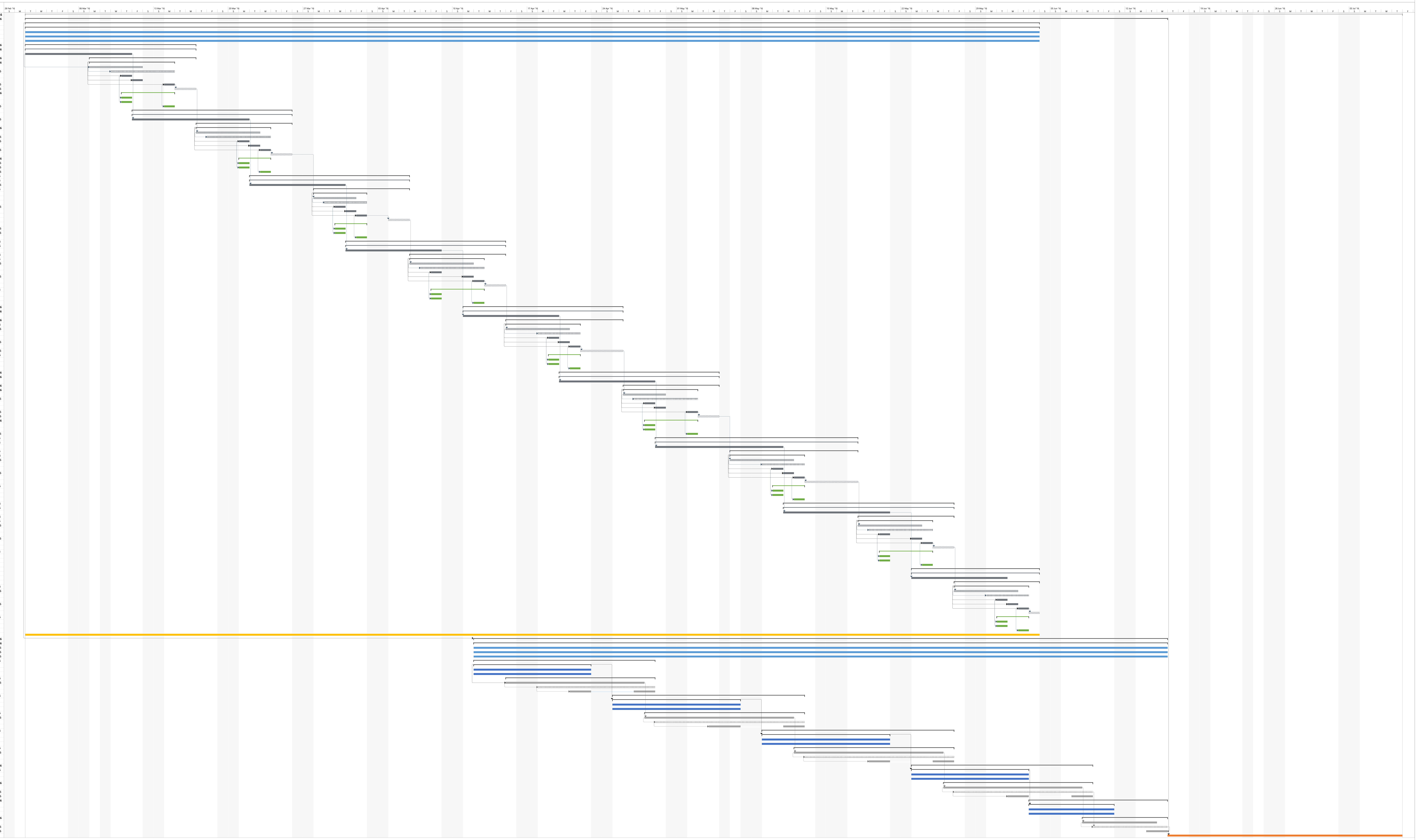
Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variant 2b - 2 shifts Planning of the main structure of the floors above the ground.
Author :	Dany Pereira
Version:	1.0
Date:	03/06/2016

Project SiMCo - Variante 3a - 2 Shifts | Planning Sec - Without Hazards | 22.06.2016

ID	Task Name	Duration	Start	Finish
0	**SiMCo - Variante 3a**	**89 days**	**Tue 01/03/16**	**Thu 07/07/16**
1	**Planning Sec - Without Hazard**	**74 days**	**Tue 01/03/16**	**Wed 15/06/16**
2	**Concrete Cores**	**66 days**	**Tue 01/03/16**	**Fri 03/06/16**
3	**Site Facilities (Shift no.1)**	**66 days**	**Tue 01/03/16**	**Fri 03/06/16**
4	Cran Operator	66 days	Tue 01/03/16	Fri 03/06/16
5	Traffic Assistant	66 days	Tue 01/03/16	Fri 03/06/16
6	Magasinier - Storekeeper	66 days	Tue 01/03/16	Fri 03/06/16
7	**Ground-Floor**	**11 days**	**Tue 01/03/16**	**Wed 16/03/16**
8	**Concrete**	**11 days**	**Tue 01/03/16**	**Wed 16/03/16**
9	Concrete Walls	7 days	Tue 01/03/16	Thu 10/03/16
10	**Concrete Slabs**	**7 days**	**Mon 07/03/16**	**Wed 16/03/16**
11	**Preparatory Work**	**5 days**	**Mon 07/03/16**	**Mon 14/03/16**
12	Formwork	4 days	Mon 07/03/16	Fri 11/03/16
13	Reinforcement	4 days	Wed 09/03/16	Mon 14/03/16
14	Concreting Slab - Main Core	1 day	Thu 10/03/16	Thu 10/03/16
15	Concreting Slab - Core A	1 day	Fri 11/03/16	Fri 11/03/16
16	Concreting Slab - Core B	1 day	Mon 14/03/16	Mon 14/03/16
17	Formwork Removal	2 days	Tue 15/03/16	Wed 16/03/16
18	**Prefab - Stair flights**	**3 days**	**Thu 10/03/16**	**Mon 14/03/16**
19	Stair flight Main Core	1 day	Thu 10/03/16	Thu 10/03/16
20	Stair flight Core A	1 day	Thu 10/03/16	Thu 10/03/16
21	Stair flight Core B	1 day	Mon 14/03/16	Mon 14/03/16
22	**1st Floor**	**11 days**	**Fri 11/03/16**	**Fri 25/03/16**
23	**Concrete**	**11 days**	**Fri 11/03/16**	**Fri 25/03/16**
24	Concrete Walls	7 days	Fri 11/03/16	Mon 21/03/16
25	**Concrete Slabs**	**7 days**	**Thu 17/03/16**	**Fri 25/03/16**
26	**Preparatory Work**	**5 days**	**Thu 17/03/16**	**Wed 23/03/16**
27	Formwork	4 days	Thu 17/03/16	Tue 22/03/16
28	Reinforcement	4 days	Fri 18/03/16	Wed 23/03/16
29	Concreting Slab - Main Core	1 day	Mon 21/03/16	Mon 21/03/16
30	Concreting Slab - Core A	1 day	Tue 22/03/16	Tue 22/03/16
31	Concreting Slab - Core B	1 day	Wed 23/03/16	Wed 23/03/16
32	Formwork Removal	2 days	Thu 24/03/16	Fri 25/03/16
33	**Prefab - Stair flights**	**3 days**	**Mon 21/03/16**	**Wed 23/03/16**
34	Stair flight Main Core	1 day	Mon 21/03/16	Mon 21/03/16
35	Stair flight Core A	1 day	Mon 21/03/16	Mon 21/03/16
36	Stair flight Core B	1 day	Wed 23/03/16	Wed 23/03/16
37	**2nd Floor**	**11 days**	**Tue 22/03/16**	**Tue 05/04/16**
38	**Concrete**	**11 days**	**Tue 22/03/16**	**Tue 05/04/16**
39	Concrete Walls	7 days	Tue 22/03/16	Wed 30/03/16
40	**Concrete Slabs**	**7 days**	**Mon 28/03/16**	**Tue 05/04/16**
41	**Preparatory Work**	**5 days**	**Mon 28/03/16**	**Fri 01/04/16**
42	Formwork	4 days	Mon 28/03/16	Thu 31/03/16
43	Reinforcement	4 days	Tue 29/03/16	Fri 01/04/16
44	Concreting Slab - Main Core	1 day	Wed 30/03/16	Wed 30/03/16
45	Concreting Slab - Core A	1 day	Thu 31/03/16	Thu 31/03/16
46	Concreting Slab - Core B	1 day	Fri 01/04/16	Fri 01/04/16
47	Formwork Removal	2 days	Mon 04/04/16	Tue 05/04/16
48	**Prefab - Stair flights**	**3 days**	**Wed 30/03/16**	**Fri 01/04/16**
49	Stair flight Main Core	1 day	Wed 30/03/16	Wed 30/03/16
50	Stair flight Core A	1 day	Wed 30/03/16	Wed 30/03/16
51	Stair flight Core B	1 day	Fri 01/04/16	Fri 01/04/16
52	**3rd Floor**	**11 days**	**Thu 31/03/16**	**Thu 14/04/16**
53	**Concrete**	**11 days**	**Thu 31/03/16**	**Thu 14/04/16**
54	Concrete Walls	7 days	Thu 31/03/16	Fri 08/04/16
55	**Concrete Slabs**	**7 days**	**Wed 06/04/16**	**Thu 14/04/16**
56	**Preparatory Work**	**5 days**	**Wed 06/04/16**	**Tue 12/04/16**
57	Formwork	4 days	Wed 06/04/16	Mon 11/04/16
58	Reinforcement	4 days	Thu 07/04/16	Tue 12/04/16
59	Concreting Slab - Main Core	1 day	Fri 08/04/16	Fri 08/04/16
60	Concreting Slab - Core A	1 day	Mon 11/04/16	Mon 11/04/16
61	Concreting Slab - Core B	1 day	Tue 12/04/16	Tue 12/04/16
62	Formwork Removal	2 days	Wed 13/04/16	Thu 14/04/16
63	**Prefab - Stair flights**	**3 days**	**Fri 08/04/16**	**Tue 12/04/16**
64	Stair flight Main Core	1 day	Fri 08/04/16	Fri 08/04/16
65	Stair flight Core A	1 day	Fri 08/04/16	Fri 08/04/16
66	Stair flight Core B	1 day	Tue 12/04/16	Tue 12/04/16
67	**4th Floor**	**11 days**	**Mon 11/04/16**	**Mon 25/04/16**
68	**Concrete**	**11 days**	**Mon 11/04/16**	**Mon 25/04/16**
69	Concrete Walls	7 days	Mon 11/04/16	Tue 19/04/16
70	**Concrete Slabs**	**7 days**	**Fri 15/04/16**	**Mon 25/04/16**
71	**Preparatory Work**	**5 days**	**Fri 15/04/16**	**Thu 21/04/16**
72	Formwork	4 days	Fri 15/04/16	Wed 20/04/16
73	Reinforcement	4 days	Mon 18/04/16	Thu 21/04/16
74	Concreting Slab - Main Core	1 day	Tue 19/04/16	Tue 19/04/16
75	Concreting Slab - Core A	1 day	Wed 20/04/16	Wed 20/04/16
76	Concreting Slab - Core B	1 day	Thu 21/04/16	Thu 21/04/16
77	Formwork Removal	2 days	Fri 22/04/16	Mon 25/04/16
78	**Prefab - Stair flights**	**3 days**	**Tue 19/04/16**	**Thu 21/04/16**
79	Stair flight Main Core	1 day	Tue 19/04/16	Tue 19/04/16
80	Stair flight Core A	1 day	Tue 19/04/16	Tue 19/04/16
81	Stair flight Core B	1 day	Thu 21/04/16	Thu 21/04/16
82	**5th Floor**	**11 days**	**Wed 20/04/16**	**Wed 04/05/16**
83	**Concrete**	**11 days**	**Wed 20/04/16**	**Wed 04/05/16**
84	Concrete Walls	7 days	Wed 20/04/16	Thu 28/04/16
85	**Concrete Slabs**	**7 days**	**Tue 26/04/16**	**Wed 04/05/16**
86	**Preparatory Work**	**5 days**	**Tue 26/04/16**	**Mon 02/05/16**
87	Formwork	4 days	Tue 26/04/16	Fri 29/04/16
88	Reinforcement	4 days	Wed 27/04/16	Mon 02/05/16
89	Concreting Slab - Main Core	1 day	Thu 28/04/16	Thu 28/04/16
90	Concreting Slab - Core A	1 day	Fri 29/04/16	Fri 29/04/16
91	Concreting Slab - Core B	1 day	Mon 02/05/16	Mon 02/05/16
92	Formwork Removal	2 days	Tue 03/05/16	Wed 04/05/16
93	**Prefab - Stair flights**	**3 days**	**Thu 28/04/16**	**Mon 02/05/16**
94	Stair flight Main Core	1 day	Thu 28/04/16	Thu 28/04/16
95	Stair flight Core A	1 day	Thu 28/04/16	Thu 28/04/16
96	Stair flight Core B	1 day	Mon 02/05/16	Mon 02/05/16
97	**6th Floor**	**11 days**	**Fri 29/04/16**	**Tue 17/05/16**
98	**Concrete**	**11 days**	**Fri 29/04/16**	**Tue 17/05/16**
99	Concrete Walls	7 days	Fri 29/04/16	Tue 10/05/16
100	**Concrete Slabs**	**7 days**	**Fri 06/05/16**	**Tue 17/05/16**
101	**Preparatory Work**	**5 days**	**Fri 06/05/16**	**Thu 12/05/16**
102	Formwork	4 days	Fri 06/05/16	Wed 11/05/16
103	Reinforcement	4 days	Mon 09/05/16	Thu 12/05/16
104	Concreting Slab - Main Core	1 day	Tue 10/05/16	Tue 10/05/16
105	Concreting Slab - Core A	1 day	Wed 11/05/16	Wed 11/05/16
106	Concreting Slab - Core B	1 day	Thu 12/05/16	Thu 12/05/16
107	Formwork Removal	2 days	Fri 13/05/16	Tue 17/05/16
108	**Prefab - Stair flights**	**3 days**	**Tue 10/05/16**	**Thu 12/05/16**
109	Stair flight Main Core	1 day	Tue 10/05/16	Tue 10/05/16
110	Stair flight Core A	1 day	Tue 10/05/16	Tue 10/05/16
111	Stair flight Core B	1 day	Thu 12/05/16	Thu 12/05/16
112	**7th Floor**	**11 days**	**Wed 11/05/16**	**Thu 26/05/16**
113	**Concrete**	**11 days**	**Wed 11/05/16**	**Thu 26/05/16**
114	Concrete Walls	7 days	Wed 11/05/16	Fri 20/05/16
115	**Concrete Slabs**	**7 days**	**Wed 18/05/16**	**Thu 26/05/16**
116	**Preparatory Work**	**5 days**	**Wed 18/05/16**	**Tue 24/05/16**
117	Formwork	4 days	Wed 18/05/16	Mon 23/05/16
118	Reinforcement	4 days	Thu 19/05/16	Tue 24/05/16
119	Concreting Slab - Main Core	1 day	Fri 20/05/16	Fri 20/05/16
120	Concreting Slab - Core A	1 day	Mon 23/05/16	Mon 23/05/16
121	Concreting Slab - Core B	1 day	Tue 24/05/16	Tue 24/05/16
122	Formwork Removal	2 days	Wed 25/05/16	Thu 26/05/16
123	**Prefab - Stair flights**	**3 days**	**Fri 20/05/16**	**Tue 24/05/16**
124	Stair flight Main Core	1 day	Fri 20/05/16	Fri 20/05/16
125	Stair flight Core A	1 day	Fri 20/05/16	Fri 20/05/16
126	Stair flight Core B	1 day	Tue 24/05/16	Tue 24/05/16
127	**8th Floor**	**10 days**	**Mon 23/05/16**	**Fri 03/06/16**
128	**Concrete**	**10 days**	**Mon 23/05/16**	**Fri 03/06/16**
129	Concrete Walls	7 days	Mon 23/05/16	Tue 31/05/16
130	**Concrete Slabs**	**6 days**	**Fri 27/05/16**	**Fri 03/06/16**
131	**Preparatory Work**	**5 days**	**Fri 27/05/16**	**Thu 02/06/16**
132	Formwork	4 days	Fri 27/05/16	Wed 01/06/16
133	Reinforcement	4 days	Mon 30/05/16	Thu 02/06/16
134	Concreting Slab - Main Core	1 day	Tue 31/05/16	Tue 31/05/16
135	Concreting Slab - Core A	1 day	Wed 01/06/16	Wed 01/06/16
136	Concreting Slab - Core B	1 day	Thu 02/06/16	Thu 02/06/16
137	Formwork Removal	1 day	Fri 03/06/16	Fri 03/06/16
138	**Prefab - Stair flights**	**3 days**	**Tue 31/05/16**	**Thu 02/06/16**
139	Stair flight Main Core	1 day	Tue 31/05/16	Tue 31/05/16
140	Stair flight Core A	1 day	Tue 31/05/16	Tue 31/05/16
141	Stair flight Core B	1 day	Thu 02/06/16	Thu 02/06/16
142	**Ragréage - Cleaning**	66 days	Tue 01/03/16	Fri 03/06/16
143	**Steel Structure and Hollow Core Slab**	**45 days**	**Tue 12/04/16**	**Wed 15/06/16**
144	**Site Facilities (Shift no. 2)**	**45 days**	**Tue 12/04/16**	**Wed 15/06/16**
145	Cran Operator	45 days	Tue 12/04/16	Wed 15/06/16
146	Traffic Assistant	45 days	Tue 12/04/16	Wed 15/06/16
147	Magasinier - Storekeeper	45 days	Tue 12/04/16	Wed 15/06/16
148	**Ground and 1st Floor**	**13 days**	**Tue 12/04/16**	**Thu 28/04/16**
149	**Steel Structure**	**9 days**	**Tue 12/04/16**	**Fri 22/04/16**
150	Steel Columns	9 days	Tue 12/04/16	Fri 22/04/16
151	Steel Beams	9 days	Tue 12/04/16	Fri 22/04/16
152	**Slab**	**10 days**	**Fri 15/04/16**	**Thu 28/04/16**
153	Installation Cofra Plus 220	9 days	Fri 15/04/16	Wed 27/04/16
154	Reinforcement	9 days	Mon 18/04/16	Thu 28/04/16
155	Concreting	4 days	Thu 21/04/16	Thu 28/04/16
156	**2nd Floor and 3rd Floor**	**13 days**	**Mon 25/04/16**	**Thu 12/05/16**
157	**Steel Structure**	**9 days**	**Mon 25/04/16**	**Fri 06/05/16**
158	Steel Columns	9 days	Mon 25/04/16	Fri 06/05/16
159	Steel Beams	9 days	Mon 25/04/16	Fri 06/05/16
160	**Slab**	**10 days**	**Thu 28/04/16**	**Thu 12/05/16**
161	Installation Cofra Plus 220	9 days	Thu 28/04/16	Wed 11/05/16
162	Reinforcement	9 days	Fri 29/04/16	Thu 12/05/16
163	Concreting	4 days	Wed 04/05/16	Thu 12/05/16
164	**4th Floor and 5th Floor**	**13 days**	**Mon 09/05/16**	**Thu 26/05/16**
165	**Steel Structure**	**9 days**	**Mon 09/05/16**	**Fri 20/05/16**
166	Steel Columns	9 days	Mon 09/05/16	Fri 20/05/16
167	Steel Beams	9 days	Mon 09/05/16	Fri 20/05/16
168	**Slab**	**10 days**	**Thu 12/05/16**	**Thu 26/05/16**
169	Installation Cofra Plus 220	9 days	Thu 12/05/16	Wed 25/05/16
170	Reinforcement	9 days	Fri 13/05/16	Thu 26/05/16
171	Concreting	4 days	Thu 19/05/16	Thu 26/05/16
172	**6th Floor and 7th Floor**	**13 days**	**Mon 23/05/16**	**Wed 08/06/16**
173	**Steel Structure**	**9 days**	**Mon 23/05/16**	**Thu 02/06/16**
174	Steel Columns	9 days	Mon 23/05/16	Thu 02/06/16
175	Steel Beams	9 days	Mon 23/05/16	Thu 02/06/16
176	**Slab**	**10 days**	**Thu 26/05/16**	**Wed 08/06/16**
177	Installation Cofra Plus 220	9 days	Thu 26/05/16	Tue 07/06/16
178	Reinforcement	9 days	Fri 27/05/16	Wed 08/06/16
179	Concreting	4 days	Wed 01/06/16	Wed 08/06/16
180	**8th Floor**	**9 days**	**Fri 03/06/16**	**Wed 15/06/16**
181	**Steel Structure**	**6 days**	**Fri 03/06/16**	**Fri 10/06/16**
182	Steel Columns	6 days	Fri 03/06/16	Fri 10/06/16
183	Steel Beams	6 days	Fri 03/06/16	Fri 10/06/16
184	**Slab**	**6 days**	**Wed 08/06/16**	**Wed 15/06/16**
185	Installation Cofra Plus 220	5 days	Wed 08/06/16	Tue 14/06/16
186	Reinforcement	5 days	Thu 09/06/16	Wed 15/06/16
187	Concreting	2 days	Tue 14/06/16	Wed 15/06/16
188	**Aléa - Hazard (20%)**	15 days	Thu 16/06/16	Thu 07/07/16



Workforces Graph

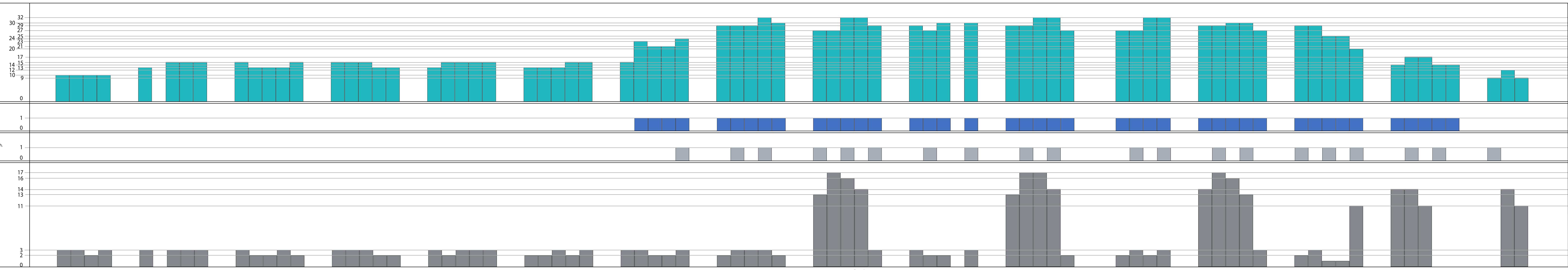
Note : 11 general workforces allocated over different tasks in the construction of the cores and slab concreting, 5 in the mounting of the steel structure, 3 puting the Cofra-Plus Elements on place, plus 2 crane operators, 2 storekeepers, 2 traffic assistants and 7 steel fixers.

Daily Flow of Trucks with Steel Elements

Daily Flow of Trucks with Cofra-Plus Elements

Note : Each truck transports 4 racks with a maximum of 30 elements each, enough for 2 days work

Daily Flow of Concrete Trucks



UNIVERSITÉ DU LUXEMBOURG
Univ.-Doz. Dr.-Ing. M. Schäfer
FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION

Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variant 3a - 2 shifts Planning of the main structure of the floors above the ground.
Author :	Dany Pereira
Version:	1.0
Date:	29/06/2016

Project SiMCo - Variante 3b - 2 Shifts | Planning Sec - Without Hazards | 22.06.2016

ID	Task Name	Duration	Start	Finish
0	**SiMCo - Variant 3b**	**93 days**	**Tue 01/03/16**	**Wed 13/07/16**
1	**Planning Sec - Without Hazard**	**78 days**	**Tue 01/03/16**	**Tue 21/06/16**
2	**Concrete Cores**	**66 days**	**Tue 01/03/16**	**Fri 03/06/16**
3	**Site Facilities (Shift no.1)**	**66 days**	**Tue 01/03/16**	**Fri 03/06/16**
4	Cran Operator	66 days	Tue 01/03/16	Fri 03/06/16
5	Traffic Assistant	66 days	Tue 01/03/16	Fri 03/06/16
6	Magasinier - Storekeeper	66 days	Tue 01/03/16	Fri 03/06/16
7	**Ground-Floor**	**11 days**	**Tue 01/03/16**	**Wed 16/03/16**
8	**Concrete**	**11 days**	**Tue 01/03/16**	**Wed 16/03/16**
9	Concrete Walls	7 days	Tue 01/03/16	Thu 10/03/16
10	**Concrete Slabs**	**7 days**	**Mon 07/03/16**	**Wed 16/03/16**
11	**Preparatory Work**	**5 days**	**Mon 07/03/16**	**Mon 14/03/16**
12	Formwork	4 days	Mon 07/03/16	Fri 11/03/16
13	Reinforcement	4 days	Wed 09/03/16	Mon 14/03/16
14	Concreting Slab - Main Core	1 day	Thu 10/03/16	Thu 10/03/16
15	Concreting Slab - Core A	1 day	Fri 11/03/16	Fri 11/03/16
16	Concreting Slab - Core B	1 day	Mon 14/03/16	Mon 14/03/16
17	Formwork Removal	2 days	Tue 15/03/16	Wed 16/03/16
18	**Prefab - Stair flights**	**3 days**	**Thu 10/03/16**	**Mon 14/03/16**
19	Stair flight Main Core	1 day	Thu 10/03/16	Thu 10/03/16
20	Stair flight Core A	1 day	Thu 10/03/16	Thu 10/03/16
21	Stair flight Core B	1 day	Mon 14/03/16	Mon 14/03/16
22	**1st Floor**	**11 days**	**Fri 11/03/16**	**Fri 25/03/16**
23	**Concrete**	**11 days**	**Fri 11/03/16**	**Fri 25/03/16**
24	Concrete Walls	7 days	Fri 11/03/16	Mon 21/03/16
25	**Concrete Slabs**	**7 days**	**Thu 17/03/16**	**Fri 25/03/16**
26	**Preparatory Work**	**5 days**	**Thu 17/03/16**	**Wed 23/03/16**
27	Formwork	4 days	Thu 17/03/16	Tue 22/03/16
28	Reinforcement	4 days	Fri 18/03/16	Wed 23/03/16
29	Concreting Slab - Main Core	1 day	Mon 21/03/16	Mon 21/03/16
30	Concreting Slab - Core A	1 day	Tue 22/03/16	Tue 22/03/16
31	Concreting Slab - Core B	1 day	Wed 23/03/16	Wed 23/03/16
32	Formwork Removal	2 days	Thu 24/03/16	Fri 25/03/16
33	**Prefab - Stair flights**	**3 days**	**Mon 21/03/16**	**Wed 23/03/16**
34	Stair flight Main Core	1 day	Mon 21/03/16	Mon 21/03/16
35	Stair flight Core A	1 day	Mon 21/03/16	Mon 21/03/16
36	Stair flight Core B	1 day	Wed 23/03/16	Wed 23/03/16
37	**2nd Floor**	**11 days**	**Tue 22/03/16**	**Tue 05/04/16**
38	**Concrete**	**11 days**	**Tue 22/03/16**	**Tue 05/04/16**
39	Concrete Walls	7 days	Tue 22/03/16	Wed 30/03/16
40	**Concrete Slabs**	**7 days**	**Mon 28/03/16**	**Tue 05/04/16**
41	**Preparatory Work**	**5 days**	**Mon 28/03/16**	**Fri 01/04/16**
42	Formwork	4 days	Mon 28/03/16	Thu 31/03/16
43	Reinforcement	4 days	Tue 29/03/16	Fri 01/04/16
44	Concreting Slab - Main Core	1 day	Wed 30/03/16	Wed 30/03/16
45	Concreting Slab - Core A	1 day	Thu 31/03/16	Thu 31/03/16
46	Concreting Slab - Core B	1 day	Fri 01/04/16	Fri 01/04/16
47	Formwork Removal	2 days	Mon 04/04/16	Tue 05/04/16
48	**Prefab - Stair flights**	**3 days**	**Wed 30/03/16**	**Fri 01/04/16**
49	Stair flight Main Core	1 day	Wed 30/03/16	Wed 30/03/16
50	Stair flight Core A	1 day	Wed 30/03/16	Wed 30/03/16
51	Stair flight Core B	1 day	Fri 01/04/16	Fri 01/04/16
52	**3rd Floor**	**11 days**	**Thu 31/03/16**	**Thu 14/04/16**
53	**Concrete**	**11 days**	**Thu 31/03/16**	**Thu 14/04/16**
54	Concrete Walls	7 days	Thu 31/03/16	Fri 08/04/16
55	**Concrete Slabs**	**7 days**	**Wed 06/04/16**	**Thu 14/04/16**
56	**Preparatory Work**	**5 days**	**Wed 06/04/16**	**Tue 12/04/16**
57	Formwork	4 days	Wed 06/04/16	Mon 11/04/16
58	Reinforcement	4 days	Thu 07/04/16	Tue 12/04/16
59	Concreting Slab - Main Core	1 day	Fri 08/04/16	Fri 08/04/16
60	Concreting Slab - Core A	1 day	Mon 11/04/16	Mon 11/04/16
61	Concreting Slab - Core B	1 day	Tue 12/04/16	Tue 12/04/16
62	Formwork Removal	2 days	Wed 13/04/16	Thu 14/04/16
63	**Prefab - Stair flights**	**3 days**	**Fri 08/04/16**	**Tue 12/04/16**
64	Stair flight Main Core	1 day	Fri 08/04/16	Fri 08/04/16
65	Stair flight Core A	1 day	Fri 08/04/16	Fri 08/04/16
66	Stair flight Core B	1 day	Tue 12/04/16	Tue 12/04/16
67	**4th Floor**	**11 days**	**Mon 11/04/16**	**Mon 25/04/16**
68	**Concrete**	**11 days**	**Mon 11/04/16**	**Mon 25/04/16**
69	Concrete Walls	7 days	Mon 11/04/16	Tue 19/04/16
70	**Concrete Slabs**	**7 days**	**Fri 15/04/16**	**Mon 25/04/16**
71	**Preparatory Work**	**5 days**	**Fri 15/04/16**	**Thu 21/04/16**
72	Formwork	4 days	Fri 15/04/16	Wed 20/04/16
73	Reinforcement	4 days	Mon 18/04/16	Thu 21/04/16
74	Concreting Slab - Main Core	1 day	Tue 19/04/16	Tue 19/04/16
75	Concreting Slab - Core A	1 day	Wed 20/04/16	Wed 20/04/16
76	Concreting Slab - Core B	1 day	Thu 21/04/16	Thu 21/04/16
77	Formwork Removal	2 days	Fri 22/04/16	Mon 25/04/16
78	**Prefab - Stair flights**	**3 days**	**Tue 19/04/16**	**Thu 21/04/16**
79	Stair flight Main Core	1 day	Tue 19/04/16	Tue 19/04/16
80	Stair flight Core A	1 day	Tue 19/04/16	Tue 19/04/16
81	Stair flight Core B	1 day	Thu 21/04/16	Thu 21/04/16
82	**5th Floor**	**11 days**	**Wed 20/04/16**	**Wed 04/05/16**
83	**Concrete**	**11 days**	**Wed 20/04/16**	**Wed 04/05/16**
84	Concrete Walls	7 days	Wed 20/04/16	Thu 28/04/16
85	**Concrete Slabs**	**7 days**	**Tue 26/04/16**	**Wed 04/05/16**
86	**Preparatory Work**	**5 days**	**Tue 26/04/16**	**Mon 02/05/16**
87	Formwork	4 days	Tue 26/04/16	Fri 29/04/16
88	Reinforcement	4 days	Wed 27/04/16	Mon 02/05/16
89	Concreting Slab - Main Core	1 day	Thu 28/04/16	Thu 28/04/16
90	Concreting Slab - Core A	1 day	Fri 29/04/16	Fri 29/04/16
91	Concreting Slab - Core B	1 day	Mon 02/05/16	Mon 02/05/16
92	Formwork Removal	2 days	Tue 03/05/16	Wed 04/05/16
93	**Prefab - Stair flights**	**3 days**	**Thu 28/04/16**	**Mon 02/05/16**
94	Stair flight Main Core	1 day	Thu 28/04/16	Thu 28/04/16
95	Stair flight Core A	1 day	Thu 28/04/16	Thu 28/04/16
96	Stair flight Core B	1 day	Mon 02/05/16	Mon 02/05/16
97	**6th Floor**	**11 days**	**Fri 29/04/16**	**Tue 17/05/16**
98	**Concrete**	**11 days**	**Fri 29/04/16**	**Tue 17/05/16**
99	Concrete Walls	7 days	Fri 29/04/16	Tue 10/05/16
100	**Concrete Slabs**	**7 days**	**Fri 06/05/16**	**Tue 17/05/16**
101	**Preparatory Work**	**5 days**	**Fri 06/05/16**	**Thu 12/05/16**
102	Formwork	4 days	Fri 06/05/16	Wed 11/05/16
103	Reinforcement	4 days	Mon 09/05/16	Thu 12/05/16
104	Concreting Slab - Main Core	1 day	Tue 10/05/16	Tue 10/05/16
105	Concreting Slab - Core A	1 day	Wed 11/05/16	Wed 11/05/16
106	Concreting Slab - Core B	1 day	Thu 12/05/16	Thu 12/05/16
107	Formwork Removal	2 days	Fri 13/05/16	Tue 17/05/16
108	**Prefab - Stair flights**	**3 days**	**Tue 10/05/16**	**Thu 12/05/16**
109	Stair flight Main Core	1 day	Tue 10/05/16	Tue 10/05/16
110	Stair flight Core A	1 day	Tue 10/05/16	Tue 10/05/16
111	Stair flight Core B	1 day	Thu 12/05/16	Thu 12/05/16
112	**7th Floor**	**11 days**	**Wed 11/05/16**	**Thu 26/05/16**
113	**Concrete**	**11 days**	**Wed 11/05/16**	**Thu 26/05/16**
114	Concrete Walls	7 days	Wed 11/05/16	Fri 20/05/16
115	**Concrete Slabs**	**7 days**	**Wed 18/05/16**	**Thu 26/05/16**
116	**Preparatory Work**	**5 days**	**Wed 18/05/16**	**Tue 24/05/16**
117	Formwork	4 days	Wed 18/05/16	Mon 23/05/16
118	Reinforcement	4 days	Thu 19/05/16	Tue 24/05/16
119	Concreting Slab - Main Core	1 day	Fri 20/05/16	Fri 20/05/16
120	Concreting Slab - Core A	1 day	Mon 23/05/16	Mon 23/05/16
121	Concreting Slab - Core B	1 day	Tue 24/05/16	Tue 24/05/16
122	Formwork Removal	2 days	Wed 25/05/16	Thu 26/05/16
123	**Prefab - Stair flights**	**3 days**	**Fri 20/05/16**	**Tue 24/05/16**
124	Stair flight Main Core	1 day	Fri 20/05/16	Fri 20/05/16
125	Stair flight Core A	1 day	Fri 20/05/16	Fri 20/05/16
126	Stair flight Core B	1 day	Tue 24/05/16	Tue 24/05/16
127	**8th Floor**	**10 days**	**Mon 23/05/16**	**Fri 03/06/16**
128	**Concrete**	**10 days**	**Mon 23/05/16**	**Fri 03/06/16**
129	Concrete Walls	7 days	Mon 23/05/16	Tue 31/05/16
130	**Concrete Slabs**	**6 days**	**Fri 27/05/16**	**Fri 03/06/16**
131	**Preparatory Work**	**5 days**	**Fri 27/05/16**	**Thu 02/06/16**
132	Formwork	4 days	Fri 27/05/16	Wed 01/06/16
133	Reinforcement	4 days	Mon 30/05/16	Thu 02/06/16
134	Concreting Slab - Main Core	1 day	Tue 31/05/16	Tue 31/05/16
135	Concreting Slab - Core A	1 day	Wed 01/06/16	Wed 01/06/16
136	Concreting Slab - Core B	1 day	Thu 02/06/16	Thu 02/06/16
137	Formwork Removal	1 day	Fri 03/06/16	Fri 03/06/16
138	**Prefab - Stair flights**	**3 days**	**Tue 31/05/16**	**Thu 02/06/16**
139	Stair flight Main Core	1 day	Tue 31/05/16	Tue 31/05/16
140	Stair flight Core A	1 day	Tue 31/05/16	Tue 31/05/16
141	Stair flight Core B	1 day	Thu 02/06/16	Thu 02/06/16
142	**Ragréage - Cleaning**	66 days	Tue 01/03/16	Fri 03/06/16
143	**Steel Structure and Hollow Core Slab**	**39 days**	**Tue 26/04/16**	**Tue 21/06/16**
144	**Site Facilities (Shift no. 2)**	**39 days**	**Tue 26/04/16**	**Tue 21/06/16**
145	Cran Operator	39 days	Tue 26/04/16	Tue 21/06/16
146	Traffic Assistant	39 days	Tue 26/04/16	Tue 21/06/16
147	Magasinier - Storekeeper	39 days	Tue 26/04/16	Tue 21/06/16
148	**Ground and 1st Floor**	**12 days**	**Tue 26/04/16**	**Thu 12/05/16**
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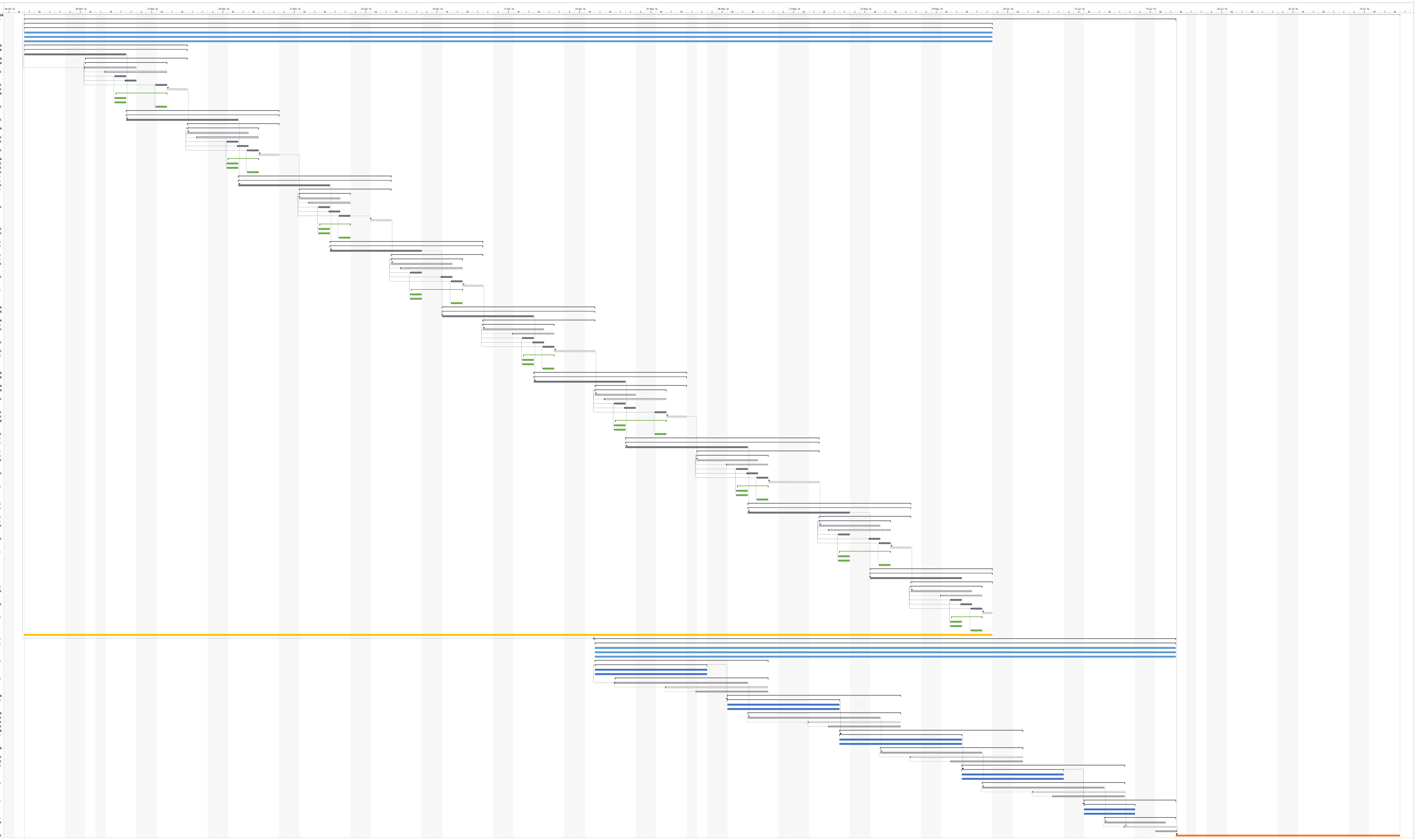
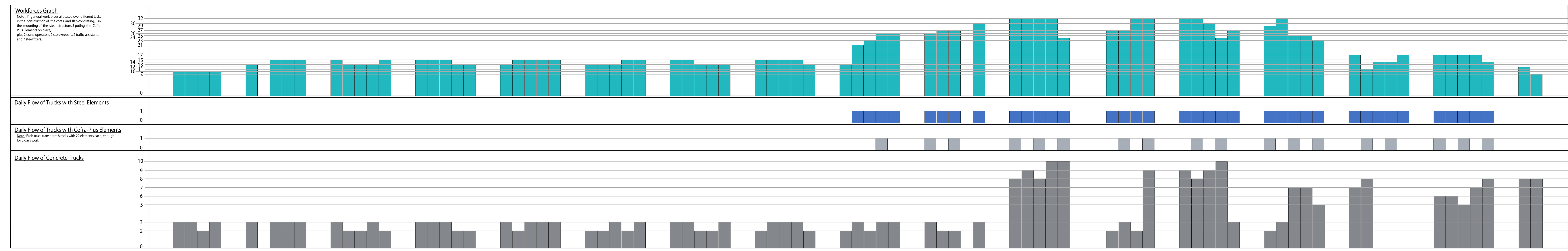




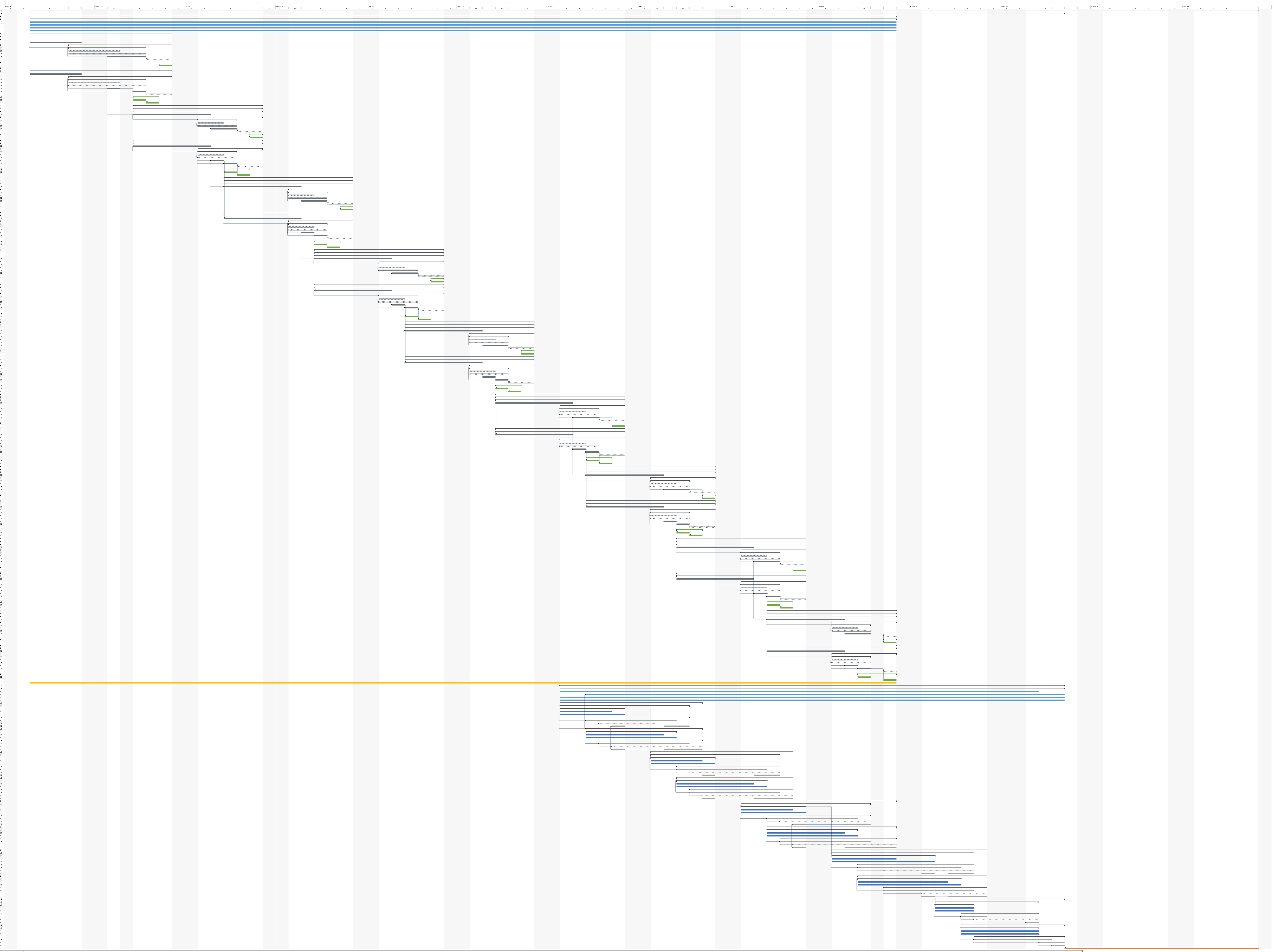
UNIVERSITÉ DU LUXEMBOURG
FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION
Univ.-Doz. Dr.-Ing. M. Schäfer

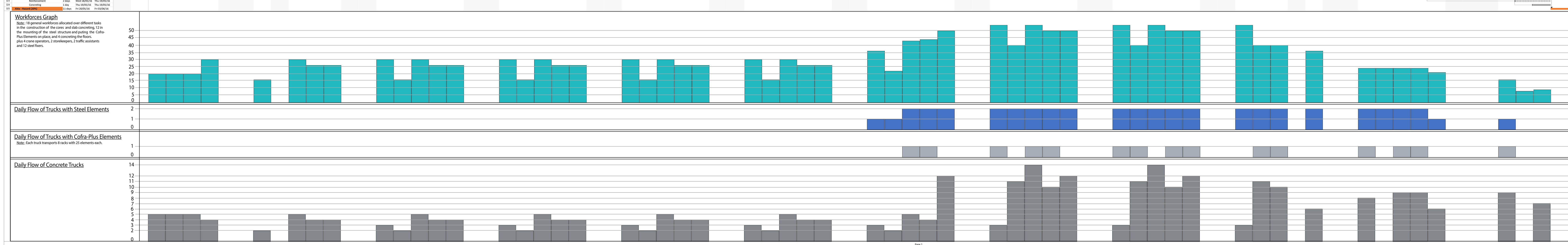
Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variante 3b - 2 shifts Planning of the main structure of the floors above the ground.
Author :	Dany Pereira
Version:	1.0
Date:	22/06/2016

Page 1

Project SiMCo - Variante 3b - 2 cranes - 2 Shifts | Planning Sec - Without Hazards | 01.07.2016

ID	Task Name	Duration	Start	Finish
0	SiMCo - Variant 3b - 2 cranes	66 days	Tue 01/03/16	Fri 03/06/16
1	Planning Sec - Without Hazard	55 days	Tue 01/03/16	Thu 19/05/16
2	Concrete Cores	47 days	Tue 01/03/16	Fri 06/05/16
3	Site Facilities (Shift no.1)	47 days	Tue 01/03/16	Fri 06/05/16
4	Cran Operator - Crane 1	47 days	Tue 01/03/16	Fri 06/05/16
5	Cran Operator - Crane 2	47 days	Tue 01/03/16	Fri 06/05/16
6	Traffic Assistant	47 days	Tue 01/03/16	Fri 06/05/16
7	Magasinier - Storekeeper	47 days	Tue 01/03/16	Fri 06/05/16
8	Ground-Floor	8 days	Tue 01/03/16	Fri 11/03/16
9	Zone 1 - Main Core	8 days	Tue 01/03/16	Fri 11/03/16
10	Concrete	8 days	Tue 01/03/16	Fri 11/03/16
11	Concrete Walls	4 days	Tue 01/03/16	Fri 04/03/16
12	Concrete Slabs	5 days	Fri 04/03/16	Fri 11/03/16
13	Preparatory Work	3 days	Fri 04/03/16	Wed 09/03/16
14	Formwork	2 days	Fri 04/03/16	Mon 07/03/16
15	Reinforcement	3 days	Fri 04/03/16	Wed 09/03/16
16	Concreting Slab	2 days	Mon 07/03/16	Wed 09/03/16
17	Formwork Removal	2 days	Thu 10/03/16	Fri 11/03/16
18	Prefab - Stair flights	1 day	Fri 11/03/16	Fri 11/03/16
19	Stair flight Main Core	1 day	Fri 11/03/16	Fri 11/03/16
20	Zone 2 - Core A & B	8 days	Tue 01/03/16	Fri 11/03/16
21	Concrete	8 days	Tue 01/03/16	Fri 11/03/16
22	Concrete Walls	4 days	Tue 01/03/16	Fri 04/03/16
23	Concrete Slabs	5 days	Fri 04/03/16	Fri 11/03/16
24	Preparatory Work	3 days	Fri 04/03/16	Wed 09/03/16
25	Formwork	2 days	Fri 04/03/16	Mon 07/03/16
26	Reinforcement	3 days	Fri 04/03/16	Wed 09/03/16
27	Concreting Slab - Core A	1 day	Mon 07/03/16	Mon 07/03/16
28	Concreting Slab - Core B	1 day	Wed 09/03/16	Wed 09/03/16
29	Formwork Removal	2 days	Thu 10/03/16	Fri 11/03/16
30	Prefab - Stair flights	2 days	Wed 09/03/16	Thu 10/03/16
31	Stair flight Core A	1 day	Wed 09/03/16	Wed 09/03/16
32	Stair flight Core B	1 day	Thu 10/03/16	Thu 10/03/16
33	1st Floor	8 days	Wed 09/03/16	Fri 18/03/16
34	Zone 1 - Main Core	8 days	Wed 09/03/16	Fri 18/03/16
35	Concrete	8 days	Wed 09/03/16	Fri 18/03/16
36	Concrete Walls	4 days	Wed 09/03/16	Mon 14/03/16
37	Concrete Slabs	5 days	Mon 14/03/16	Fri 18/03/16
38	Preparatory Work	3 days	Mon 14/03/16	Wed 16/03/16
39	Formwork	2 days	Mon 14/03/16	Tue 15/03/16
40	Reinforcement	3 days	Mon 14/03/16	Wed 16/03/16
41	Concreting Slab	2 days	Tue 15/03/16	Wed 16/03/16
42	Formwork Removal	2 days	Thu 17/03/16	Fri 18/03/16
43	Prefab - Stair flights	1 day	Fri 18/03/16	Fri 18/03/16
44	Stair flight Main Core	1 day	Fri 18/03/16	Fri 18/03/16
45	Zone 2 - Core A & B	8 days	Wed 09/03/16	Fri 18/03/16
46	Concrete	8 days	Wed 09/03/16	Fri 18/03/16
47	Concrete Walls	4 days	Wed 09/03/16	Mon 14/03/16
48	Concrete Slabs	5 days	Mon 14/03/16	Fri 18/03/16
49	Preparatory Work	3 days	Mon 14/03/16	Wed 16/03/16
50	Formwork	2 days	Mon 14/03/16	Tue 15/03/16
51	Reinforcement	3 days	Mon 14/03/16	Wed 16/03/16
52	Concreting Slab - Core A	1 day	Tue 15/03/16	Tue 15/03/16
53	Concreting Slab - Core B	1 day	Wed 16/03/16	Wed 16/03/16
54	Formwork Removal	2 days	Thu 17/03/16	Fri 18/03/16
55	Prefab - Stair flights	2 days	Wed 16/03/16	Thu 17/03/16
56	Stair flight Core A	1 day	Wed 16/03/16	Wed 16/03/16
57	Stair flight Core B	1 day	Thu 17/03/16	Thu 17/03/16
58	2nd Floor	8 days	Wed 16/03/16	Fri 25/03/16
59	Zone 1 - Main Core	8 days	Wed 16/03/16	Fri 25/03/16
60	Concrete	8 days	Wed 16/03/16	Fri 25/03/16
61	Concrete Walls	4 days	Wed 16/03/16	Mon 21/03/16
62	Concrete Slabs	5 days	Mon 21/03/16	Fri 25/03/16
63	Preparatory Work	3 days	Mon 21/03/16	Wed 23/03/16
64	Formwork	2 days	Mon 21/03/16	Tue 22/03/16
65	Reinforcement	3 days	Mon 21/03/16	Wed 23/03/16
66	Concreting Slab	2 days	Tue 22/03/16	Wed 23/03/16
67	Formwork Removal	2 days	Thu 24/03/16	Fri 25/03/16
68	Prefab - Stair flights	1 day	Fri 25/03/16	Fri 25/03/16
69	Stair flight Main Core	1 day	Fri 25/03/16	Fri 25/03/16
70	Zone 2 - Core A & B	8 days	Wed 16/03/16	Fri 25/03/16
71	Concrete	8 days	Wed 16/03/16	Fri 25/03/16
72	Concrete Walls	4 days	Wed 16/03/16	Mon 21/03/16
73	Concrete Slabs	5 days	Mon 21/03/16	Fri 25/03/16
74	Preparatory Work	3 days	Mon 21/03/16	Wed 23/03/16
75	Formwork	2 days	Mon 21/03/16	Tue 22/03/16
76	Reinforcement	3 days	Mon 21/03/16	Wed 23/03/16
77	Concreting Slab - Core A	1 day	Tue 22/03/16	Tue 22/03/16
78	Concreting Slab - Core B	1 day	Wed 23/03/16	Wed 23/03/16
79	Formwork Removal	2 days	Thu 24/03/16	Fri 25/03/16
80	Prefab - Stair flights	2 days	Wed 23/03/16	Thu 24/03/16
81	Stair flight Core A	1 day	Wed 23/03/16	Wed 23/03/16
82	Stair flight Core B	1 day	Thu 24/03/16	Thu 24/03/16
83	3rd Floor	8 days	Wed 23/03/16	Fri 01/04/16
84	Zone 1 - Main Core	8 days	Wed 23/03/16	Fri 01/04/16
85	Concrete	8 days	Wed 23/03/16	Fri 01/04/16
86	Concrete Walls	4 days	Wed 23/03/16	Mon 28/03/16
87	Concrete Slabs	5 days	Mon 28/03/16	Fri 01/04/16
88	Preparatory Work	3 days	Mon 28/03/16	Wed 30/03/16
89	Formwork	2 days	Mon 28/03/16	Tue 29/03/16
90	Reinforcement	3 days	Mon 28/03/16	Wed 30/03/16
91	Concreting Slab	2 days	Tue 29/03/16	Wed 30/03/16
92	Formwork Removal	2 days	Thu 31/03/16	Fri 01/04/16
93	Prefab - Stair flights	1 day	Fri 01/04/16	Fri 01/04/16
94	Stair flight Main Core	1 day	Fri 01/04/16	Fri 01/04/16
95	Zone 2 - Core A & B	8 days	Wed 23/03/16	Fri 01/04/16
96	Concrete	8 days	Wed 23/03/16	Fri 01/04/16
97	Concrete Walls	4 days	Wed 23/03/16	Mon 28/03/16
98	Concrete Slabs	5 days	Mon 28/03/16	Fri 01/04/16
99	Preparatory Work	3 days	Mon 28/03/16	Wed 30/03/16
100	Formwork	2 days	Mon 28/03/16	Tue 29/03/16
101	Reinforcement	3 days	Mon 28/03/16	Wed 30/03/16
102	Concreting Slab - Core A	1 day	Tue 29/03/16	Tue 29/03/16
103	Concreting Slab - Core B	1 day	Wed 30/03/16	Wed 30/03/16
104	Formwork Removal	2 days	Thu 31/03/16	Fri 01/04/16
105	Prefab - Stair flights	2 days	Wed 30/03/16	Thu 31/03/16
106	Stair flight Core A	1 day	Wed 30/03/16	Wed 30/03/16
107	Stair flight Core B	1 day	Thu 31/03/16	Thu 31/03/16
108	4th Floor	8 days	Wed 30/03/16	Fri 08/04/16
109	Zone 1 - Main Core	8 days	Wed 30/03/16	Fri 08/04/16
110	Concrete	8 days	Wed 30/03/16	Fri 08/04/16
111	Concrete Walls	4 days	Wed 30/03/16	Mon 04/04/16
112	Concrete Slabs	5 days	Mon 04/04/16	Fri 08/04/16
113	Preparatory Work	3 days	Mon 04/04/16	Wed 06/04/16
114	Formwork	2 days	Mon 04/04/16	Tue 05/04/16
115	Reinforcement	3 days	Mon 04/04/16	Wed 06/04/16
116	Concreting Slab	2 days	Tue 05/04/16	Wed 06/04/16
117	Formwork Removal	2 days	Thu 07/04/16	Fri 08/04/16
118	Prefab - Stair flights	1 day	Fri 08/04/16	Fri 08/04/16
119	Stair flight Main Core	1 day	Fri 08/04/16	Fri 08/04/16
120	Zone 2 - Core A & B	8 days	Wed 30/03/16	Fri 08/04/16
121	Concrete	8 days	Wed 30/03/16	Fri 08/04/16
122	Concrete Walls	4 days	Wed 30/03/16	Mon 04/04/16
123	Concrete Slabs	5 days	Mon 04/04/16	Fri 08/04/16
124	Preparatory Work	3 days	Mon 04/04/16	Wed 06/04/16
125	Formwork	2 days	Mon 04/04/16	Tue 05/04/16
126	Reinforcement	3 days	Mon 04/04/16	Wed 06/04/16
127	Concreting Slab - Core A	1 day	Tue 05/04/16	Tue 05/04/16
128	Concreting Slab - Core B	1 day	Wed 06/04/16	Wed 06/04/16
129	Formwork Removal	2 days	Thu 07/04/16	Fri 08/04/16
130	Prefab - Stair flights	2 days	Wed 06/04/16	Thu 07/04/16
131	Stair flight Core A	1 day	Wed 06/04/16	Wed 06/04/16
132	Stair flight Core B	1 day	Thu 07/04/16	Thu 07/04/16
133	5th Floor	8 days	Wed 06/04/16	Fri 15/04/16
134	Zone 1 - Main Core	8 days	Wed 06/04/16	Fri 15/04/16
135	Concrete	8 days	Wed 06/04/16	Fri 15/04/16
136–212	[illegible]	[illegible]	[illegible]	[illegible]
213	Preparatory Work	3 days	Mon 02/05/16	Wed 04/05/16
214	Formwork	2 days	Mon 02/05/16	Tue 03/05/16
215	Reinforcement	3 days	Mon 02/05/16	Wed 04/05/16
216	Concreting Slab	2 days	Tue 03/05/16	Wed 04/05/16
217	Formwork Removal	1 day	Fri 06/05/16	Fri 06/05/16
218	Prefab - Stair flights	1 day	Fri 06/05/16	Fri 06/05/16
219	Stair flight Main Core	1 day	Fri 06/05/16	Fri 06/05/16
220	Zone 2 - Core A & B	7 days	Wed 27/04/16	Fri 06/05/16
221	Concrete	7 days	Wed 27/04/16	Fri 06/05/16
222	Concrete Walls	4 days	Wed 27/04/16	Mon 02/05/16
223	Concrete Slabs	4 days	Mon 02/05/16	Fri 06/05/16
224	Preparatory Work	3 days	Mon 02/05/16	Wed 04/05/16
225	Formwork	2 days	Mon 02/05/16	Tue 03/05/16
226	Reinforcement	3 days	Mon 02/05/16	Wed 04/05/16
227	Concreting Slab - Core A	1 day	Tue 03/05/16	Tue 03/05/16
228	Concreting Slab - Core B	1 day	Wed 04/05/16	Wed 04/05/16
229	Formwork Removal	1 day	Fri 06/05/16	Fri 06/05/16
230	Prefab - Stair flights	2 days	Wed 04/05/16	Fri 06/05/16
231	Stair flight Core A	1 day	Wed 04/05/16	Wed 04/05/16
232	Stair flight Core B	1 day	Fri 06/05/16	Fri 06/05/16
233	Ragréage - Cleaning	47 days	Tue 01/03/16	Fri 06/05/16
234	Steel Structure and Hollow Core Slab	27 days	Mon 11/04/16	Thu 19/05/16
235	Site Facilities (Shift no. 2)	27 days	Mon 11/04/16	Thu 19/05/16
236	Cran Operator - Crane 1	25 days	Mon 11/04/16	Tue 17/05/16
237	Cran Operator - Crane 2	25 days	Wed 13/04/16	Thu 19/05/16
238	Traffic Assistant	27 days	Mon 11/04/16	Thu 19/05/16
239	Magasinier - Storekeeper	27 days	Mon 11/04/16	Thu 19/05/16
240	Ground and 1st Floor	9 days	Mon 11/04/16	Thu 21/04/16
241	Zone 1	8 days	Mon 11/04/16	Wed 20/04/16
242	Steel Structure	5 days	Mon 11/04/16	Fri 15/04/16
243	Steel Columns	4 days	Mon 11/04/16	Thu 14/04/16
244	Steel Beams	5 days	Mon 11/04/16	Fri 15/04/16
245	Slab	6 days	Wed 13/04/16	Wed 20/04/16
246	Installation Cofra Plus 60	5 days	Wed 13/04/16	Tue 19/04/16
247	Reinforcement	2,5 days	Thu 14/04/16	Mon 18/04/16
248	Concreting	3 days	Fri 15/04/16	Wed 20/04/16
249	Zone 2	7 days	Wed 13/04/16	Thu 21/04/16
250	Steel Structure	5 days	Wed 13/04/16	Tue 19/04/16
251	Steel Columns	4 days	Wed 13/04/16	Mon 18/04/16
252	Steel Beams	5 days	Wed 13/04/16	Tue 19/04/16
253	Slab	6 days	Thu 14/04/16	Thu 21/04/16
254	Installation Cofra Plus 60	5 days	Thu 14/04/16	Wed 20/04/16
255	Reinforcement	5 days	Fri 15/04/16	Thu 21/04/16
256	Concreting	4 days	Fri 15/04/16	Thu 21/04/16
257	2nd Floor and 3rd Floor	9 days	Mon 18/04/16	Thu 28/04/16
258	Zone 1	8 days	Mon 18/04/16	Wed 27/04/16
259	Steel Structure	5 days	Mon 18/04/16	Fri 22/04/16
260	Steel Columns	4 days	Mon 18/04/16	Thu 21/04/16
261	Steel Beams	5 days	Mon 18/04/16	Fri 22/04/16
262	Slab	6 days	Wed 20/04/16	Wed 27/04/16
263	Installation Cofra Plus 60	5 days	Wed 20/04/16	Tue 26/04/16
264	Reinforcement	5 days	Thu 21/04/16	Wed 27/04/16
265	Concreting	3 days	Fri 22/04/16	Wed 27/04/16
266	Zone 2	7 days	Wed 20/04/16	Thu 28/04/16
267	Steel Structure	5 days	Wed 20/04/16	Tue 26/04/16
268	Steel Columns	4 days	Wed 20/04/16	Mon 25/04/16
269	Steel Beams	5 days	Wed 20/04/16	Tue 26/04/16
270	Slab	6 days	Thu 21/04/16	Thu 28/04/16
271	Installation Cofra Plus 60	5 days	Thu 21/04/16	Wed 27/04/16
272	Reinforcement	5 days	Fri 22/04/16	Thu 28/04/16
273	Concreting	4 days	Fri 22/04/16	Thu 28/04/16
274	4th Floor and 5th Floor	9 days	Mon 25/04/16	Fri 06/05/16
275	Zone 1	8 days	Mon 25/04/16	Wed 04/05/16
276	Steel Structure	5 days	Mon 25/04/16	Fri 29/04/16
277	Steel Columns	4 days	Mon 25/04/16	Thu 28/04/16
278	Steel Beams	5 days	Mon 25/04/16	Fri 29/04/16
279	Slab	6 days	Wed 27/04/16	Wed 04/05/16
280	Installation Cofra Plus 60	5 days	Wed 27/04/16	Tue 03/05/16
281	Reinforcement	5 days	Thu 28/04/16	Wed 04/05/16
282	Concreting	3 days	Fri 29/04/16	Wed 04/05/16
283	Zone 2	7 days	Wed 27/04/16	Fri 06/05/16
284	Steel Structure	5 days	Wed 27/04/16	Tue 03/05/16
285	Steel Columns	4 days	Wed 27/04/16	Mon 02/05/16
286	Steel Beams	5 days	Wed 27/04/16	Tue 03/05/16
287	Slab	6 days	Thu 28/04/16	Fri 06/05/16
288	Installation Cofra Plus 60	5 days	Thu 28/04/16	Wed 04/05/16
289	Reinforcement	5 days	Fri 29/04/16	Fri 06/05/16
290	Concreting	4 days	Fri 29/04/16	Fri 06/05/16
291	6th Floor and 7th Floor	9 days	Mon 02/05/16	Fri 13/05/16
292	Zone 1	8 days	Mon 02/05/16	Thu 12/05/16
293	Steel Structure	5 days	Mon 02/05/16	Mon 09/05/16
294	Steel Columns	4 days	Mon 02/05/16	Fri 06/05/16
295	Steel Beams	5 days	Mon 02/05/16	Mon 09/05/16
296	Slab	6 days	Wed 04/05/16	Thu 12/05/16
297	Installation Cofra Plus 60	5 days	Wed 04/05/16	Wed 11/05/16
298	Reinforcement	5 days	Fri 06/05/16	Thu 12/05/16
299	Concreting	3 days	Mon 09/05/16	Thu 12/05/16
300	Zone 2	7 days	Wed 04/05/16	Fri 13/05/16
301	Steel Structure	5 days	Wed 04/05/16	Wed 11/05/16
302	Steel Columns	4 days	Wed 04/05/16	Tue 10/05/16
303	Steel Beams	5 days	Wed 04/05/16	Wed 11/05/16
304	Slab	6 days	Fri 06/05/16	Fri 13/05/16
305	Installation Cofra Plus 60	5 days	Fri 06/05/16	Thu 12/05/16
306	Reinforcement	5 days	Mon 09/05/16	Fri 13/05/16
307	Concreting	4 days	Mon 09/05/16	Fri 13/05/16
308	8th Floor	7 days	Tue 10/05/16	Thu 19/05/16
309	Zone 1	5 days	Tue 10/05/16	Tue 17/05/16
310	Steel Structure	3 days	Tue 10/05/16	Thu 12/05/16
311	Steel Columns	3 days	Tue 10/05/16	Thu 12/05/16
312	Steel Beams	3 days	Tue 10/05/16	Thu 12/05/16
313	Slab	3 days	Thu 12/05/16	Tue 17/05/16
314	Installation Cofra Plus 60	2 days	Thu 12/05/16	Fri 13/05/16
315	Reinforcement	2 days	Fri 13/05/16	Tue 17/05/16
316	Concreting	1 day	Tue 17/05/16	Tue 17/05/16
317	Zone 2	5 days	Thu 12/05/16	Thu 19/05/16
318	Steel Structure	3 days	Thu 12/05/16	Tue 17/05/16
319	Steel Columns	3 days	Thu 12/05/16	Tue 17/05/16
320	Steel Beams	3 days	Thu 12/05/16	Tue 17/05/16
321	Slab	4 days	Fri 13/05/16	Thu 19/05/16
322	Installation Cofra Plus 60	3 days	Fri 13/05/16	Wed 18/05/16
323	Reinforcement	2 days	Wed 18/05/16	Thu 19/05/16
324	Concreting	1 day	Thu 19/05/16	Thu 19/05/16
325	Aléa - Hazard (20%)	11 days	Fri 20/05/16	Fri 03/06/16





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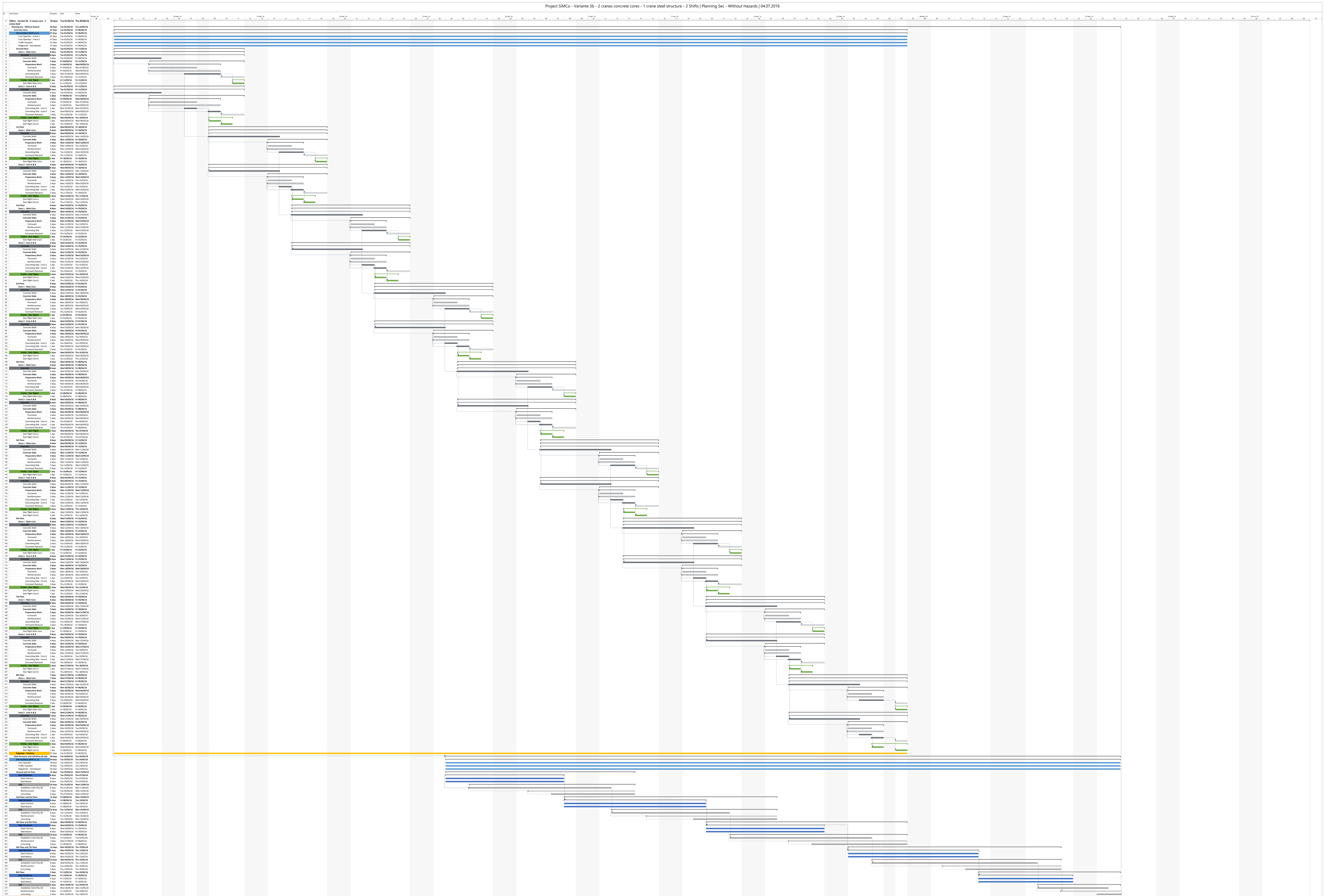
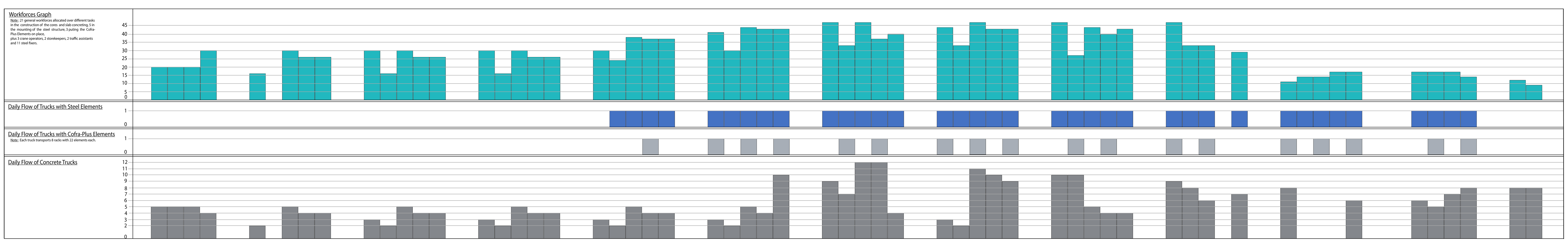
FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION

Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variant 3b 2 cranes- 2 shifts Planning of the main structure of the floors above the ground.
Author :	Dany Pereira
Version:	1.0
Date:	01/07/2016

Project SiMCo - Variante 3b - 2 cranes concrete cores - 1 crane steel structure - 2 Shifts | Planning Sec - Without Hazards | 04.07.2016





UNIVERSITÉ DU LUXEMBOURG

Univ.-Doz. Dr.- Ing. M. Schäfer

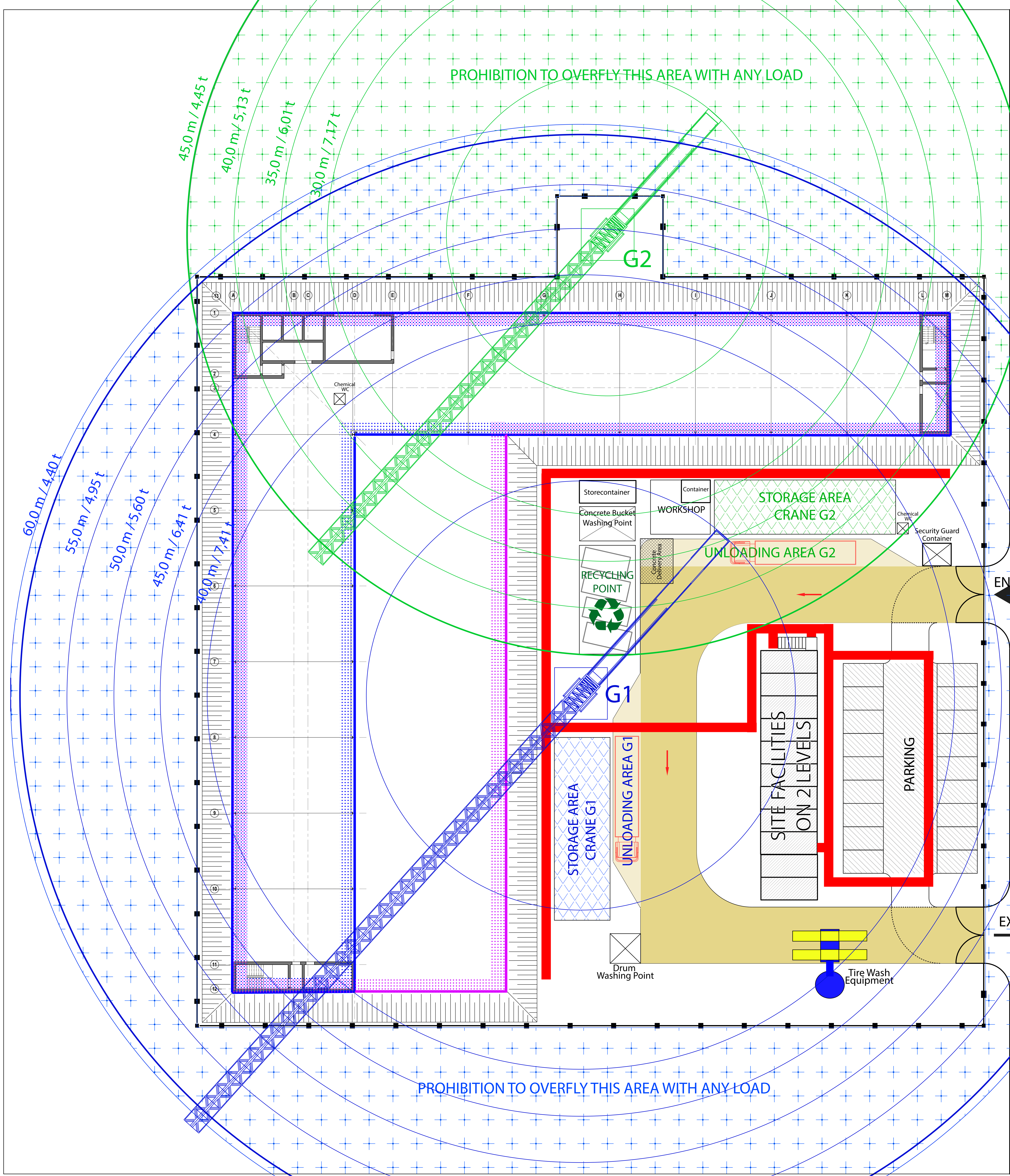
FACULTÉ DES SCIENCES, DE LA TECHNOLOGIE ET DE LA COMMUNICATION

Project :	SiMCo - ArcelorMittal - Uni.lu
Topic :	SiMCo - Variant 3b - 2 shifts 2 cranes core construction 1 crane steel structure Planning of the main structure of the floors above the ground.
Author :	Dany Pereira
Version:	1.0
Date:	04/07/2016

Appendix V – Construction Site Installation Plan of Variant 3B

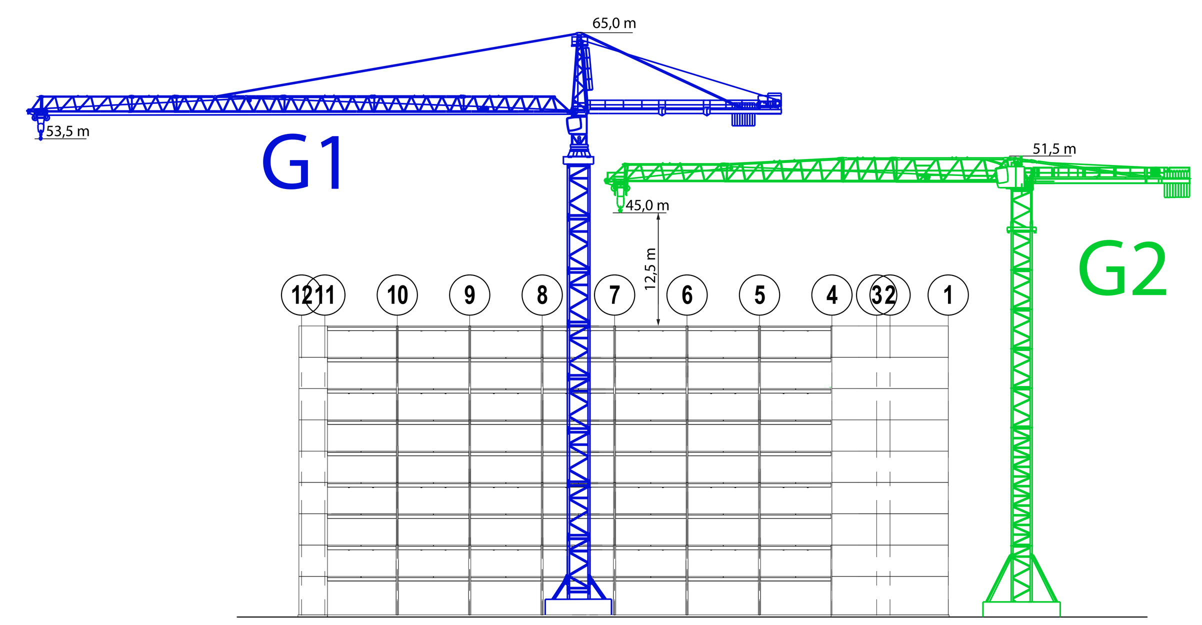
TWO CRANES

(The construction site installation plan can be found in its original size (A0) on the digital format of this document.)



ELEVATION

RATIO 1/500



CRANE G1 MAIN FEATURES

MODEL	HOISTING HEIGHT	JIB	C-JIB	BASE
Liebherr 280 EC-H16	53,5 m	60 m	22,7 m	Concrete Slab

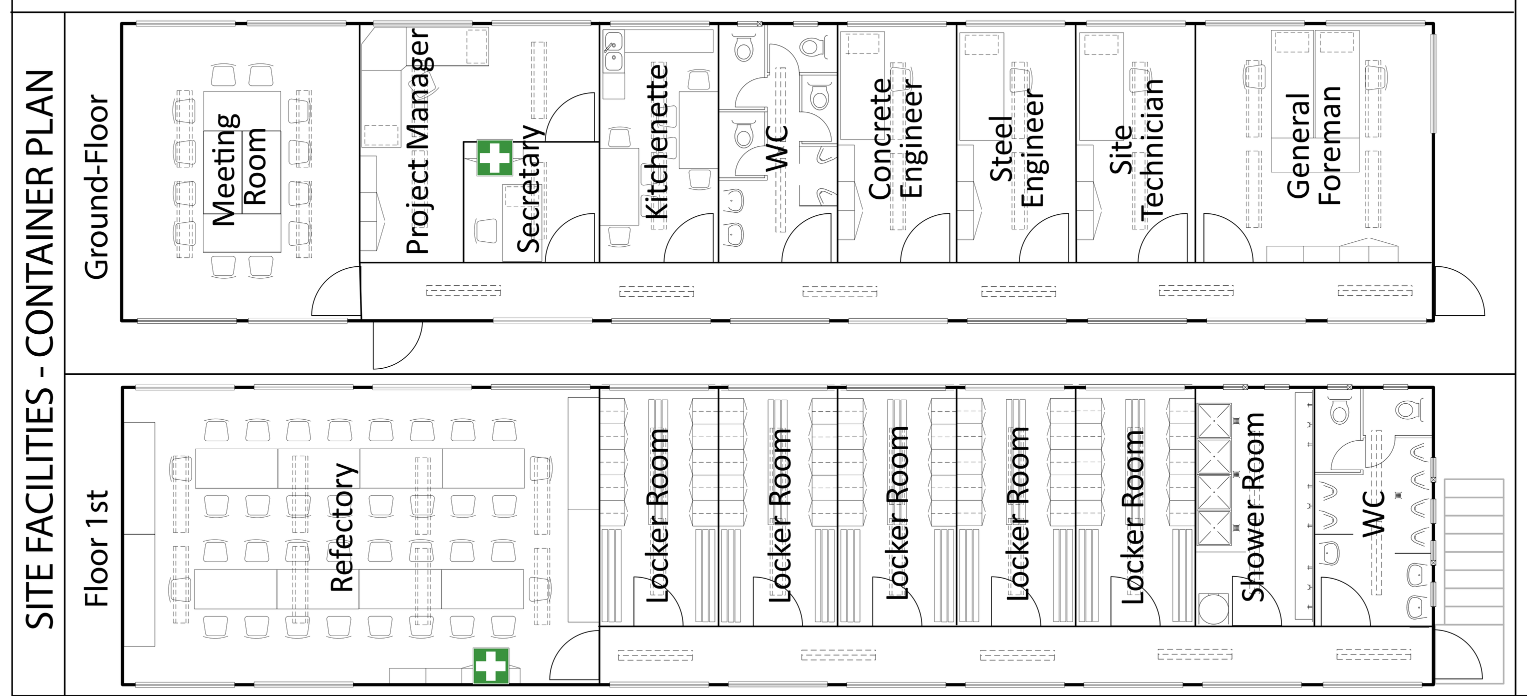
RADIUS [m]	20,0	25,0	30,0	35,0	40,0	45,0	50,0	55,0	60,0
CAPACITY [t]	16,0	12,9	10,5	8,7	7,4	6,4	5,6	4,9	4,4

CRANE G2 MAIN FEARTURES

MODEL	HOISTING HEIGHT	JIB	C-JIB	BASE
Liebherr 202 EC-B10	45 m	45 m	17,6 m	Concrete Slab

RADIUS [m]	19,0	22,0	25,0	30,0	35,0	40,0	45,0
CAPACITY [t]	10,0	10,0	8,8	7,2	6,0	5,1	4,6

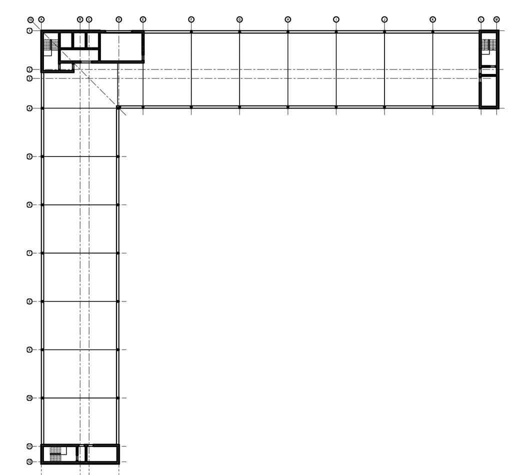
SITE FACILITIES - CONTAINER PLAN



LEGEND

- Substructure
- Superstructure
- Trucks Pathway
- Unloading Area
- Concrete Delivery Area
- Storage Area
- Site Facilities
- Parking
- Workers Pathway
- Site Fence

PROJECT SiMCo
Arcelor-Mittal



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SITE INSTALLATION PLAN
Variant 3b - 2 tower-cranes

Author : Dany Pereira	Date : 16/08/2016	Version: 1.0
	Ratio : 1/150	