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Study of the constriction schedulling of a car storage building in the port of Valencia

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STUDY OF THE CONSTRUCTION SCHEDULING OF A CAR STORAGE BUILDING IN PORT OF VALENCIA

ESTUDIO PARA LA PROGRAMACIÓN DE LAS OBRAS DE CONSTRUCCIÓN DE UN ALMACEN DE VEHÍCULOS EN EL PUERTO DE VALENCIA

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Preface

This thesis is made as a completion of the master education in Project Management and, having a bachelor degree in Geodesic Engineering, it was a way of learning and gaining theoretical knowledge in this field of master.

Firstly, I would like to thank to my supervisor, Mr. Professor Julian Alcala Gonzalez, from Department of Construction Engineering and Civil Engineering Projects, who have contributed academically to this master thesis, for his support and valuable advices.

Also, I would like to thank to Professor Juan Jose Clemente Tirado for his help.

This Erasmus journey has highlighted a learning opportunity and I am grateful for having the chance to elaborate my master thesis at Polytechnic University of Valencia (Universitat Politècnica de València, UPV), School of Civil Engineering (Escuela Técnica Superior de Ingenieria de Caminos, Canales y Puertos).

Madalina Augustin

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Abstract

The need for efficient project management is always continuous.

Managing a project involves planning, organizing, executing and monitoring that project. Planning often has been construed to mean scheduling, but a significant portion of a project manager's time is spent in planning. A project consists of many elements, all of which require careful planning: time, cost, material and organization.

This thesis is about the basic scheduling of a project. It does not consider the connections to budgeting, cost control or other many disciplines that require a schedule as a base. The project has a precast car storage building focus, a schedule of the principal elements erection, but the techniques mentioned can be applied to any other precast construction.

The techniques covered in this thesis are based on theoretical research and I believe that the principles of scheduling must be learned "by doing" together with the theoretical knowledge.

Resumen

La necesidad por gestionar del modo más eficiente es una constante en todos los proyectos.

Gestionar un Proyecto incluye planificar, organizar, ejecutar y monitorizar este Proyecto. A menudo se interpreta que la planificación es solo la programación, aunque una parte importante del tiempo invertido en la gestión del proyecto se dedica a la planificación. Un proyecto consta de muchos elementos, que denen ser cuidadosamente planificados: tiempo, coste, materiales y organización

Este trabajo trata de la programación básica de un proyecto. No se han considerado las cuestiones relacionadas con el presupuesto, control de costes u otros aspectos que necesitan la programación como dato de partida. El trabajo se ha centrado en un edificio prefabricado para almacenamiento de coches, y en la programación del montaje de sus principales elementos, pero las técnicas que se usan pueden ser aplicadas a cualquier otra construcción prefabricada.

En este trabajo se usa técnicas basadas en investigaciones teóricas y creo que los principios de la programación deben ser aprendidos "aplicandolos" conjuntamente con el conocimiento teórico.

Contents

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Scope of the Thesis

The construction of each structure is largely individual. However, in all construction projects the repetitive stages, the same elements of construction can be traced.

The construction of a car storage building can be divided into several major steps. These stages involve the execution of all works in a professional standard.

Each stage of the construction is largely independent but the completion of the stage is a significant event in the complex of works on a construction.

The sequence of works is linked with the main factors. The phased development of these factors will lead to the realization of the construction process in the end result.

The principal purpose of the thesis is to plan, describe, understand and assimilate the steps of car storage building erection as a project management process, learn what includes each stage during the construction, what works occur at the stage and what should be done at the end of each stage. In the thesis the stages of a particular car storage building in Port of Valencia will be considered, a property of Grimaldi Group.

1.2. The project Management Process

1.2.1. Project Management: A Process-Based Approach

A project can be defined as a set of complex, coordinated activities with a clearly defined objective that can be achieved through synergetic, coordinated efforts within a given time, and with a predetermined amount of human and financial resources.

What distinguishes a project (no matter its degree of innovation) from all other activities carried out in a firm is that it always has a beginning and an end. It is temporary and sooner or later will finish (either because the objective has been achieved, the scheduled time has passed, the financial resources have been used up, or the reorganization involved has closed down)

But what does managing a project mean? Managing means dealing with variables that can be more or less influenced: it is impossible to manage when no variation is allowed or, likewise, when the factors are beyond control, since managing means making decisions and acting accordingly (i.e. planning and executing interventions).

What can be managed are those variables that are typical of a project, since they are linked to its definition. The main variables are as follows:

1. Quality
2. Time
3. Costs
4. Resources

The first three variables are project performances, whereas the last represents the (human and technological) restraints limiting the activities needed to execute a project.

1.2.2. Operations Management and Project Management

Company management can be differentiated into specific management (with activities that are specific for the sector/compartment) and extraspecific management (with activities – usually of a financial nature – that are independent of the field/sector where the company operates).

Many departments require specific management: Production (including the delivery of services, if the company operates in this field), Procurement, Trade, Marketing, Distribution/Supply, Design, Process Engineering (Technology/ Machines or similar), Research & Development (R&D). For the sake of simplicity, without considering the supporting Functions/Boards (Administration & Control, Personnel – Human Resources, Information Systems, etc.), the functions listed previously can carry out two types of processes.

- Order execution (or production on forecast), characterized by more or less repetitive activities complying with standards
- Innovation, a process characterized by change and the absence of reference standards

Because of the repetitiveness of operations, the type of management required for the former process is also known as Operations Management and consists in managing the (logistic) flow of materials and information that starts from the upstream supplier/company interface (the Procurement Office) and flows through the various Production Departments, finally reaching the downstream interface with the customers (i.e. Marketing, Trade and Distribution).

All the activities of this process refer, in a more or less formalized manner, to the standards defined during the process of innovation/change. The management of the latter process is known either as Innovation Management, with reference to the result of the activity characterizing it, or Project Management, with reference to how these activities – the projects – are carried out.

The Project Management Institute – PMI (in PMBOK – A Guide to the Project Management Body of Knowledge, 3rd ed., 2004) explains how operations share various characteristics with projects (both are carried out by persons, exploit limited, available resources, and are planned, executed and controlled); however, "operations are ongoing and repetitive while projects are temporary and unique" … "A project can be defined in terms of its distinctive characteristics: it is a temporary endeavor undertaken to create a unique product or service. Temporary because each project has a definite start and finish. Unique because the product or service somehow differs from all other similar products and services".

1.3. General presentation of the area

1.3.1. Description of the area

The Port of Valencia, seaport located in Valencia, Spain. It is the fifth busiest seaport in Europe, being also the largest in Spain and in the Mediterranean Sea basin, with an annual traffic capacity of around 57 million tones of cargo (2009) and 4,210,000 TEU (2010).

The port is also an important employer in the area, with more than 15,000 employees who provide services to more than 7,500 ships every year.

The three ports controlled by the Port Authority of Valencia are in Valencia, Sagunto and Gandía. They are located on the shores of the Mediterranean Sea, along an 80 km stretch of Spain's eastern coastline.

The Port of Valencia is the center of economic activity in an area of influence encompassing a radius of 350 km, which generates 51 percent of Spain's GDP and includes half the entire working population of the country. The port has a quay length of 12 km and a total storage area of 300 acres (1.2 km2).

Valencia handles traffic of practically all types of goods from every sector of the economy. The main customers of the Port of Valencia include: the furniture and timber industries, textiles, footwear, agriculture and foodstuffs (grain and fodder, wine and beverages, tinned food, fruit, etc.), fuel products (diesel fuel, petrol, coal, etc.), chemical and motor vehicles (Ford, Fiat, Land Rover, Jaguar, etc.), the construction industry (cement and clinker, ceramic tiles, marble, etc.), machinery, etc.

The Port of Valencia also has regular passenger traffic to and from the Balearic Islands and Italy. In recent years the Port of Valencia has experienced a continued and solid growth in Mediterranean cruise traffic.

Figure 1.1 – Port of Valencia

1.3.2. History of Port of Valencia

The history of the Port of Valencia began in 1483, when King Ferdinand the Catholic granted Antoni Joan the privilege of building a wooden bridge on the beach of the Grao district, called the Pont de Fusta.

From 1483 until the 19th century, various construction projects were built in the port, but because of periodic flooding of the Turia River and the continual movements of sand on the beach the port was not notably successful. However, traffic did increase incrementally over time and the king eventually granted trading privileges with other kingdoms and sovereign states in 1679 and for the Americas in 1791, with Valencia becoming the sixth maritime province in Spain.

1.3.3. Grimaldi Group

Established in 1947, Grimaldi is a fully integrated multinational logistics Group specialising in maritime transport of cars, rolling cargo, containers and passengers.

Wholly owned by the Grimaldi family, the Group is led by Gianluca and Emanuele Grimaldi, sons of the founder Guido, and their brother-in-law Diego Pacella.

Family members are complemented by a highly skilled international management team, based both at the Group's headquarters in Naples (Italy) and at subsidiary companies and branches located in over 25 countries.

The Grimaldi Group has continued the strategy of expanding its maritime services as part of a plan to provide worldwide logistics with a strong maritime base. From 2000 to 2013 the fleet owned directly or through subsidiaries has nearly tripled in size from 36 to more than 100 vessels.

The Group's shoreside and shipboard staff currently total about 15,500. Every week, the Grimaldi Group's ships call at more than 120 ports in the Mediterranean and Baltic regions as well as in Northern Europe, West Africa, and North and South America, thus contributing to the economic development of many countries.

The Group has also launched a process to develop its logistics chain by investing hundreds of millions of euros in port terminals in the Mediterranean, Northern Europe and West Africa, as well as creating road transport companies for the distribution of vehicles in some European countries, while the subsidiary Atlantic Container Line operates a fleet of more than 2,700 trailers in North America.

Such a powerful fleet is the core of a vertically integrated logistics chain which numbers sixteen port terminals plus several road and rail shipping companies.

At the same time, while building its own international network of port terminals, since 2001 the Group has completed a number of strategic acquisitions and taken shareholdings in major shipping companies with the aim of strengthening its leading position in the Ro/Ro business while building an extensive network of Motorways of the Sea around Europe, both in the Mediterranean and in the Baltic Sea, in line with the European Union's effort to remove freight from the congested road network.

Most of these terminals are veritable logistics platforms, fitted with Pre-Delivery Inspection (PDI) facilities and workshops. Currently their aggregate operating surface is in excess of 5 million square metres, but the main terminals are all continuously expanding.

The Grimaldi Group operates its own regional hub terminals in Antwerp (Belgium), Civitavecchia (Italy), Salerno (Italy), Barcelona (Spain) and Lagos (Nigeria). Other terminals are located in Esbjerg (Denmark), Cork (Ireland), Valencia (Spain), Monfalcone (Italy), Palermo (Italy), and Alexandria (Egypt). The entire port of Wallhamn has been purchased and is the first wholly privatised Swedish port, while the Unikai Lagerei und Speditionsgesellschaft terminal in Hamburg (Germany) is owned in partnership with Hamburg Harbour and Logistic AG (HHLA), a state-owned company. As for the Baltic Region, Finnlines' subsidiary Finnsteve operates terminals in the Finnish ports of Helsinki and Turku.

With the vehicles' Pre-Delivery Inspection (PDI) and Fleet personalisation undertaken at the Group's terminals, the final leg of logistics consists mainly of the delivery of cars or containers to the dealers' or importers' depots. At the customer's request, the Group takes responsibility for the first leg of transport as well, from the factory to the port terminal where the vehicles or containers are embarked on the Group's vessels.

2. SOFTWARE AND SCHEDULING

2.1. Microsoft Project

Microsoft Project is a project management software product, developed and sold by Microsoft. It is designed to assist a project manager in developing a plan, assigning resources to tasks, tracking progress, managing the budget, and analyzing workloads.

Microsoft Project was the company's third Microsoft Windows-based application, and within a couple of years of its introduction it became the dominant PC-based project management software.

It is part of the Microsoft Office family but has never been included in any of the Office suites. It is available currently in two editions, Standard and Professional. Microsoft Project's proprietary file format is .mpp.

Microsoft Project and Microsoft Project Server are the cornerstones of the Microsoft Office enterprise project management (EPM) product.

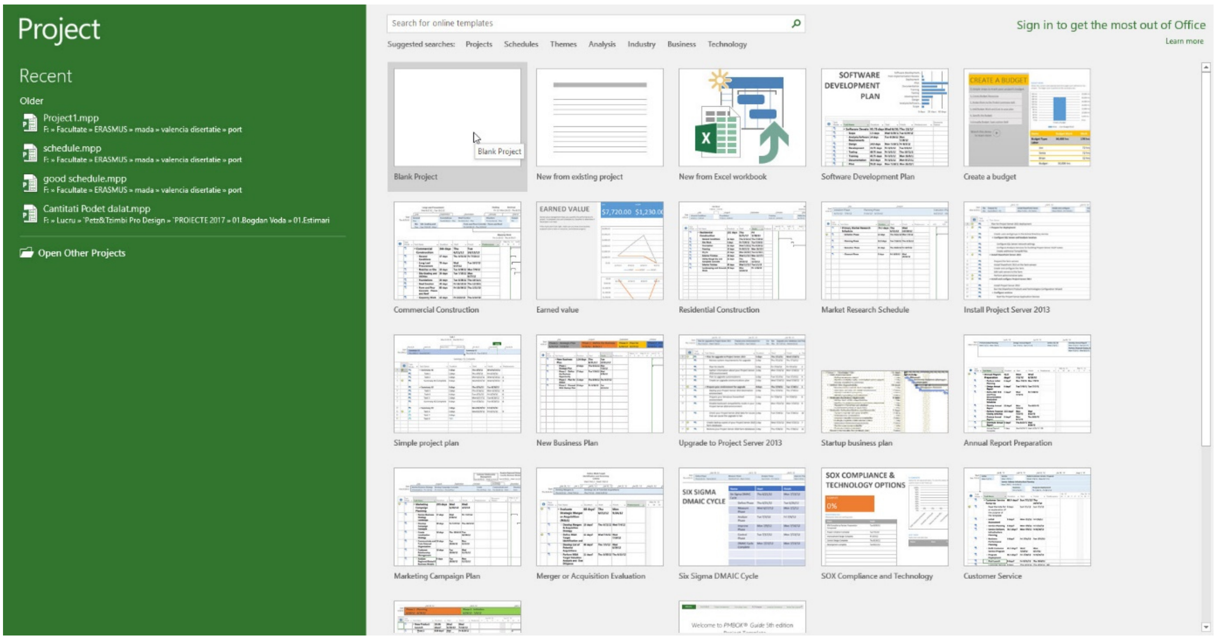

Figure 2.1 – Microsoft Project software

Project creates budgets based on assignment work and resource rates. As resources are assigned to tasks and assignment work estimated, the program calculates the cost, equal to the work times the rate, which rolls up to the task level and then to any summary tasks and finally to the project level. Resource definitions (people, equipment and materials) can be shared between projects using a shared resource pool. Each resource can have its own calendar, which defines what days and shifts a resource is available. Resource rates are used to calculate resource assignment costs which are rolled up and summarized at the resource level. Each resource can be assigned to multiple tasks in multiple plans and each task can be assigned multiple resources, and the application schedules task work based on the resource availability as defined in the resource calendars. All resources can be defined in label without limit. Therefore, it cannot determine how many finished products can be produced with a given amount of raw materials. This makes Microsoft Project unsuitable for solving problems of available materials constrained production. Additional software is necessary to manage a complex facility that produces physical goods.

The application creates critical path schedules, and critical chain and event chain methodology third-party add-ons also are available. Schedules can be resource leveled, and chains are visualized in a Gantt chart. Additionally, Microsoft Project can recognize different classes of users. These different classes of users can have differing access levels to projects, views, and other data. Custom objects such as calendars, views, tables, filters, and fields are stored in an enterprise global which is shared by all users.

The scheduling of the car storage building erection was made using Microsoft Project software. All the construction steps were introduced in the program and for every task were assigned resources.

2.2. Time Representation: Gantt Chart

Time was the first variable in Project Management to be supported in a coherent manner by specific techniques. Thanks to the great repercussions caused by variations in the costs and delivery times for the high-profile military and civil orders made after the war. But while costs could be ascribed to a number of causes that, although often impossible to predict or control (as in th case of cost fluctuations), could be managed through various techniques, in the case of delays, management seemed less complex, and problems easier to solve.

The first steps in improving project management date back to 1911, when Frederick W. Taylor experimented on scientific production management (coinciding with roday's times and methods) and Henry G. Gantt (1861-1919) was working for the US Army.

Gantt is the father of one of the two time representations still in use today: the activity bar on time axis or Gantt chart (the other being the network diagram).

2.3. Scheduling the construction

Using the Microsoft Project software and analyzing the drawings with the position of precast elements, a construction scheduling of the car storage has been done.

The working time was set at 10 hours/day (more or less given the fact it is an execution process)

For piles installation and pile caps construction, Annex A1 was consulted. One place (with 3 piles driven deep in the ground) is finalised in one hour, so the time for each section of the site was calculated considering one hour for each place, the number of places for piles and the delimitation of the sections. For pile caps time, one day was considered for building a row and 3 days for drying.

Time for columns installation was determined consulting Annex A2. The number of columns for each sections was determined and 15 minutes were allocated for installation of one element.

Annex A3 and Annex A4 illustrates the position of beams and slabs. Also, as in the case from above, the number of this two elements for each section was determined and 10 minutes were allocated for installation of one element.

As well, for each task, different resources were allocated:

Resource Name	Type	Material Label	Initials	Group	Max. Units
Hammer H6	Work		H		100%
Worker 1	Work		W		100%
Mobile crane 1	Work		M		100%
reinforced concrete	Material		r		
Worker 2	Work		W		100%
worker pile cap 3	Work		w		100%

worker pile cap1	Work		w		100%
worker pile cap2	Work		w		100%
worker1 cr1	Work		w		100%
worker2 cr1	Work		w		100%
worker1 cr2	Work		w		100%
worker2 cr2	Work		w		100%
Mobile crane 2	Work		M		100%
worker pile cap4	Work		w		100%
worker pile cap5	Work		w		100%
worker1 b&s cr1	Work		w		100%
worker2 b&s cr1	Work		w		100%
worker3 b&s cr1	Work		w		100%
worker4 b&s cr1	Work		w		100%
worker1 b&s cr2	Work		w		100%
worker2 b&s cr2	Work		w		100%
worker3 b&s cr2	Work		w		100%
worker4 b&s cr2	Work		w		100%

Table 2.1 - Task resources

Task Mode	Task Name	Duration	Start	Finish	Predecessors
Auto Scheduled	**Section 1**	**59 days**	**Mon 11.06.18**	**Thu 20.09.18**	
Auto Scheduled	Driving piles foundation	27.5 days	Mon 11.06.18	Fri 27.07.18	
Auto Scheduled	building pile caps and strap beams for foundation	11 days	Fri 27.07.18	Thu 16.08.18	2
Auto Scheduled	installation of columns	1.5 days	Thu 16.08.18	Fri 17.08.18	3
Auto Scheduled	installation of beams and slabs for levels 1, 2, 3 and 4	19 days	Mon 20.08.18	Thu 20.09.18	4
Auto Scheduled	**Section 2**	**51.5 days**	**Fri 27.07.18**	**Thu 25.10.18**	
Auto Scheduled	Driving pile foundation	22.5 days	Fri 27.07.18	Wed 05.09.18	2
Auto Scheduled	building pile caps and strap beams for foundation	11 days	Wed 05.09.18	Tue 25.09.18	7;3
Auto Scheduled	installation of columns	1.5 days	Tue 25.09.18	Thu 27.09.18	8;4;5
Auto Scheduled	installation of beams and slabs for levels 1, 2,3 and 4	16.5 days	Thu 27.09.18	Thu 25.10.18	9

Auto Scheduled	**Section 3**	**50.5 days**	**Wed 05.09.18**	**Mon 03.12.18**	
Auto Scheduled	Driving pile foundation	21.5 days	Wed 05.09.18	Fri 12.10.18	7
Auto Scheduled	building pile caps and strap beams for foundation	9 days	Fri 12.10.18	Mon 29.10.18	12;8
Auto Scheduled	installation of columns	1.5 days	Mon 29.10.18	Wed 31.10.18	13;9;10
Auto Scheduled	installation of beams and slabs for levels 1, 2, 3 and 4	18.5 days	Wed 31.10.18	Mon 03.12.18	14
Auto Scheduled	**Section 4**	**46.5 days**	**Fri 12.10.18**	**Wed 02.01.19**	
Auto Scheduled	Driving piles foundation	18 days	Fri 12.10.18	Tue 13.11.18	12
Auto Scheduled	building pile caps and strap beams for foundation	9 days	Tue 13.11.18	Thu 29.11.18	17;13
Auto Scheduled	installation of columns	1.5 days	Mon 03.12.18	Wed 05.12.18	18;14;15
Auto Scheduled	installation of beams and slabs for levels 1, 2, 3 and 4	16 days	Wed 05.12.18	Wed 02.01.19	19
Auto Scheduled	**Section 5**	**53.5 days**	**Tue 13.11.18**	**Thu 14.02.19**	
Auto Scheduled	Driving piles foundation	24 days	Tue 13.11.18	Tue 25.12.18	17
Auto Scheduled	building pile caps and strap beams for foundation	10 days	Tue 25.12.18	Fri 11.01.19	22;18
Auto Scheduled	installation of columns	1.5 days	Fri 11.01.19	Tue 15.01.19	23;19;20
Auto Scheduled	installation of beams and slabs for levels 1, 2, 3 and 4	18 days	Tue 15.01.19	Thu 14.02.19	24
Auto Scheduled	**Section 6**	**47 days**	**Tue 25.12.18**	**Mon 18.03.19**	
Auto Scheduled	Driving piles foundation	19.5 days	Tue 25.12.18	Tue 29.01.19	22
Auto Scheduled	building pile caps and strap beams for foundation	10 days	Tue 29.01.19	Thu 14.02.19	27;23
Auto Scheduled	installation of columns	1.5 days	Thu 14.02.19	Mon 18.02.19	28;24;25
Auto Scheduled	installation of beams and slabs for levels 1, 2, 3 and 4	16 days	Mon 18.02.19	Mon 18.03.19	29

Table 2.2 - Task and time scheduling for 6 sections

The Gantt Chart and the Critical Path of this scheduling can be seen in Annex A5. The critical path is marked with red colour.

2.4. Division of the plan into sections and order of erection

Because the construction site is in port of Valencia, the access is restricted and the space is limited. Therefore, site organization must be done very carefully. Also, the on-site staff structure is determined by the size, type and complexity of the project.

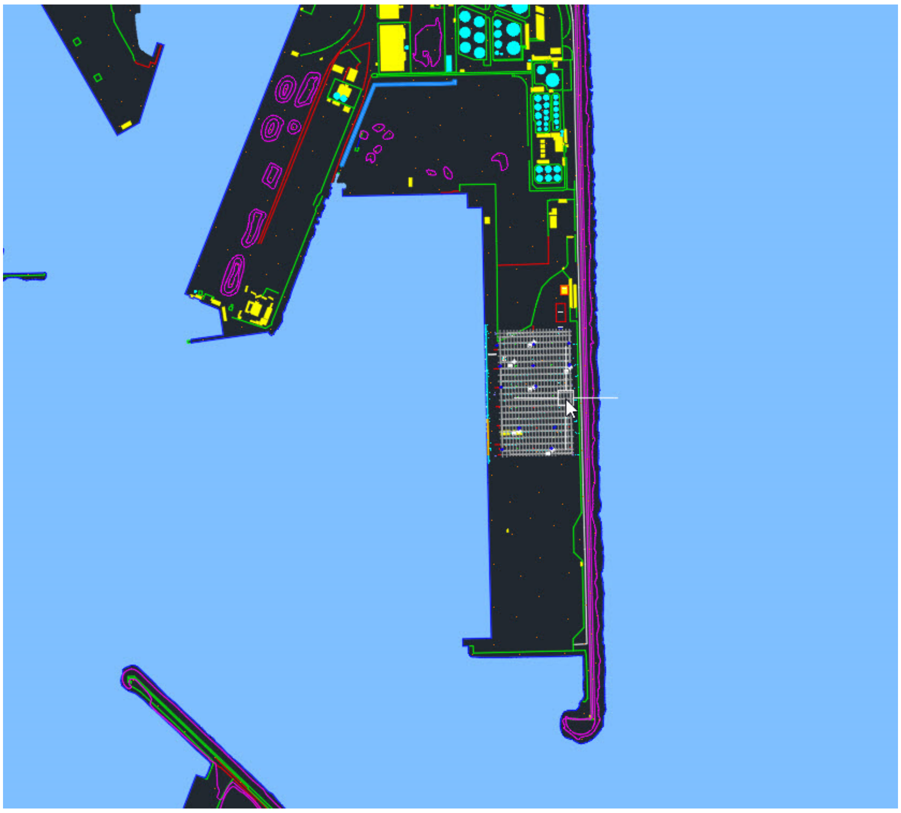

Figure 2.2 - Localization of the construction

Consulting the plan from real measured coordinates, the access for necessary machines will be done from the North part of the future construction, given the fact that there is a railway line along it on the East side and the location is surrounded by sea water. Also the access road is continued on the South and West side of the site so all the sections can be easily accessed. A temporary road is considered on the East side of the site, near the railway line. All this specifications can be seen in Annex A6 as a technological flow.

Figure 2.3 - Access to the site

Work on sections will be more useful due to the limited area. Thus, the erection of parking will be divided in 6 sections, following the joints position from the plan. The erection will start on section 1 (S1) with foundation process. When the work is done at S1, the workers can do it to the next section (S2) and, at the same time, the installation of columns and then the beams and slabs (respecting this order for each four levels) can start at S1. Every current section depends on the previous one and all the work will continue till the last section (S6) is done.

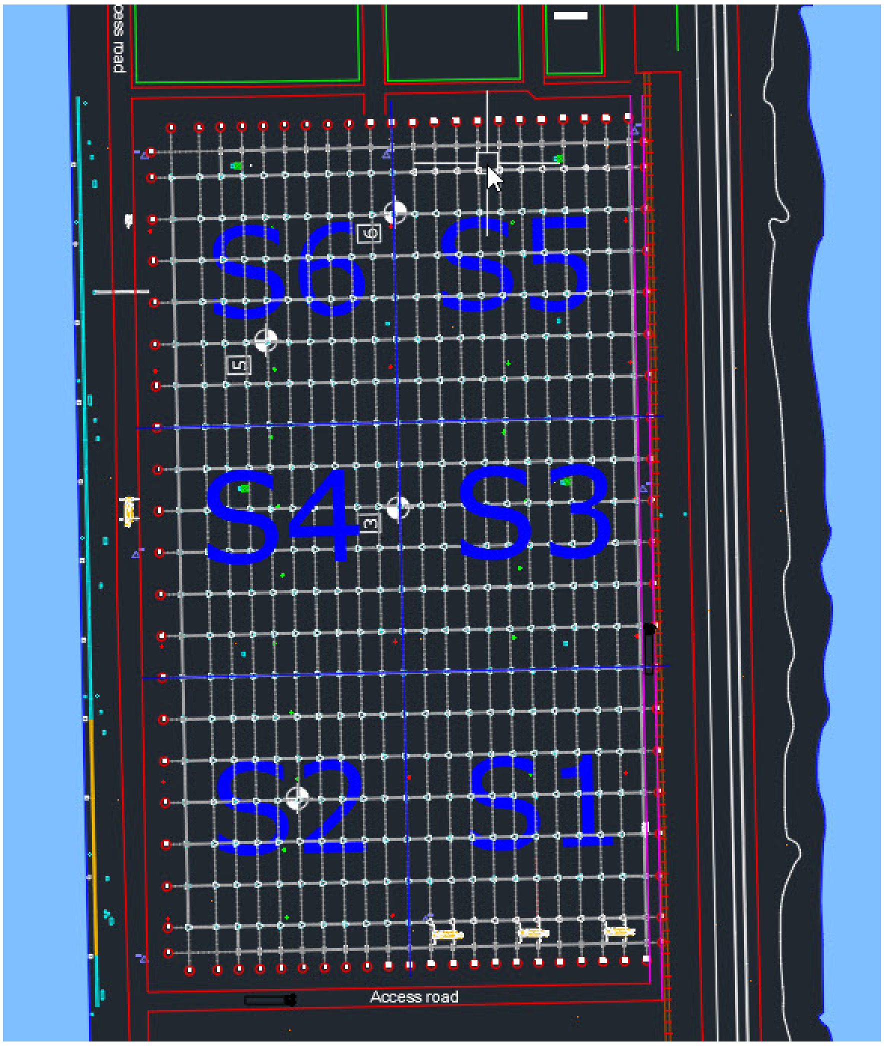

Figure 2.4 - Sections of the erection

Every section is defined and delimited by the axes from the plan as follows:

Section 1 - vertical axes from 11 to 22, horizontal axes from N to T

Section 2 – vertical axes from 1 to 11, horizontal axes from N to T

Section 3 – vertical axes from 11 to 22, horizontal axes from H to N

Section 4 – vertical axes from 1 to 11, horizontal axes from H to N

Section 5 – vertical axes from 11 to 22, horizontal axes from A to H

Section 6 – vertical axes from 1 to 11, horizontal axes from A to H

A plan with the axes of the construction can be seen in Annex A1.

First step of the erection is to make the foundation. The work will be done following the horizontal axes of the plan, starting from the South. After this, the building of pile caps and strap beams will be done next. To not damage the concrete drying with the process of driving piles, it is recommended to start the pouring for those elements when the machine is at a distance where the vibration does not affect them, in the same section, and then the processes can continue simultaneously, but, for this thesis, an analysis of wave propagation was not performed, so the pile caps construction was consider to start after all the piles for one section are finalized.

Columns, beams and slabs will come after all the foundation piles from the section are done and all the pile caps and strap beams from the same section will be ready.

For columns installation the best way is to start at each section from South and to do all the work on horizontal direction, following the horizontal axis, with two cranes working simultaneously and having a free row between them. Given the mobile crane dimensions, in Annex A7 are presented the positions of the machine on the site.

For beams and slabs installation, the horizontal direction will be kept but these will be installed alternatively. Also two cranes will be used simultaneously, as in column case. Beams will follow two axes and the slabs will come between them and all the four levels will be completed, operations presented in Annex A8. Every section must end with installation of beams on the end axis.

2.5. Comparison with 4 sections division of the plan

Given the fact that no surfacing layer will be poured above the slabs and all the joints of the structure and the ones between slabs, which are made from polystyrene, could be installed after a sufficient quantity of elements are erected, can be followed a different division of the erection plan which does not consider the one of the joints.

Therefore, a 4 sections division was made to be compared with the 6 sections division. This new plan has the same principle as the 6 sections one: the working hours/day, the number of resources, the time allocated to errect each element, etc, all are the same. Just the delimitation of work per each section is different, as follows:

Section 1 - vertical axes from 12 to 22, horizontal axes from L to T

Section 2 – vertical axes from 12 to 22, horizontal axes from A to K

Section 3 – vertical axes from 1 to 11, horizontal axes from L to T

Section 4 – vertical axes from 1 to 11, horizontal axes from A to K

Task Mode	Task Name	Duration	Start	Finish	Predecessors
Auto Scheduled	**Section 1**	**72 days**	**Mon 11.06.18**	**Fri 12.10.18**	
Auto Scheduled	Driving piles foundation	32 days	Mon 11.06.18	Fri 03.08.18	
Auto Scheduled	building pile caps and strap beams for foundation	14 days	Mon 06.08.18	Wed 29.08.18	2
Auto Scheduled	installation of columns	3 days	Wed 29.08.18	Tue 04.09.18	3
Auto Scheduled	installation of beams and slabs for levels 1, 2, 3 and 4	23 days	Tue 04.09.18	Fri 12.10.18	4
Auto Scheduled	**Section 2**	**80 days**	**Mon 06.08.18**	**Fri 21.12.18**	
Auto Scheduled	Driving pile foundation	35 days	Mon 06.08.18	Thu 04.10.18	2
Auto Scheduled	building pile caps and strap beams for foundation	14 days	Thu 04.10.18	Tue 30.10.18	7;3
Auto Scheduled	installation of columns	3 days	Tue 30.10.18	Fri 02.11.18	8;4;5
Auto Scheduled	installation of beams and slabs for levels 1, 2,3 and 4	28 days	Mon 05.11.18	Fri 21.12.18	9;5
Auto Scheduled	**Section 3**	**73.5 days**	**Thu 04.10.18**	**Mon 11.02.19**	
Auto Scheduled	Driving pile foundation	31.5 days	Thu 04.10.18	Thu 29.11.18	7
Auto Scheduled	building pile caps and strap beams for foundation	14 days	Thu 29.11.18	Mon 24.12.18	12;8
Auto Scheduled	installation of columns	3 days	Mon 24.12.18	Fri 28.12.18	13;9;10
Auto Scheduled	installation of beams and slabs for levels 1, 2, 3 and 4	25 days	Fri 28.12.18	Mon 11.02.19	14;10
Auto Scheduled	**Section 4**	**82 days**	**Thu 29.11.18**	**Mon 22.04.19**	
Auto Scheduled	Driving piles foundation	35 days	Thu 29.11.18	Tue 29.01.19	12
Auto Scheduled	building pile caps and strap beams for foundation	14 days	Tue 29.01.19	Fri 22.02.19	17;13
Auto Scheduled	installation of columns	3 days	Fri 22.02.19	Thu 28.02.19	18;14;15
Auto Scheduled	installation of beams and slabs for levels 1, 2, 3 and 4	30 days	Thu 28.02.19	Mon 22.04.19	19;15

Table 2.3 - Task and time scheduling for 4 sections

Also, the Gantt Chart and the Critical Path of this scheduling can be seen in Annex A9. The critical path is marked with red colour.

Comparing this two plans (4 sections and 6 sections), it can be seen that the time of erections is similar, even the one with 6 sections is with a month less. Consequently, there is no advantage to not consider the joints plan in the erection and it is favorable that the 6-section plan to be followed.

3. ERECTION CONSIDERATIONS

3.1. General procedures

The erection process must be considered during the design stage. Temporary connections to stabilize the partially completed structure must be studied carefully to determine their effect on the completed structure. Consideration should be given to define the temporary connection details that are acceptable and also how they are to be incorporated into the completed structure.

Erection considerations for precast concrete parking structures vary to some degree from erection considerations for other precast concrete structures. Some of the unique aspects of these structures include the high percentage of long, heavy members, the exposed nature of the structural frame; the relative instability of the structure during erection until the topping is poured or all connections are completed; and the special access conditions created by tight construction site.

Precast concrete parking structures tend to be multi-story and contain vertical-load supporting members, such as columns and wall panels. These usually are manufactured in the maximum length reasonable to cast, handle and transport. This minimizes field splices, joints and the number of pieces to erect.

Erection procedures vary in accordance with the size and shape of members, engineering design and the overall complexity of the structure. The sequence of erection should be established as early as possible.

It can be assumed that all necessary permits and insurances have been obtained and all preparatory planning and documentation are sufficiently advanced to enable the site management team to take possession of the site and start the construction phase of the contract.

Prior to beginning erection, a field check of the project must be performed by the precast concrete supplier or erector. Special conditions created by tight construction sites require early evaluation of access for erection equipment and trucks. A final check prior to the move-in of equipment should be also completed.

Probably the most important step of the preconstruction planning process is a review of the plans and details by the designer with the erector.

3.2. Stability of the construction

Evaluating how to stabilize the structure during construction is essential for properly planning the erection. As this is a common requirement for each of the three types of load-bearing members to be covered in detail, the following considerations for temporary bracing and guying apply to deck members, long columns. Stability during erection is paramount, since parking structures are typically multi-story.

During construction, the members are exposed to wind, possible seismic shock, temporary torsion due to applied loads and possible impact from construction equipment or adjacent members while being erected. Special requirements for stability during various stages of construction should be determined in advance of the erection process. A preplanning meeting between the erector and the design engineer should be held to identify special requirements for the installation and removal of bracing, the sequence of member placement and the percentage of completed connections necessary to tie the structure together.

3.3. Foundation processes

The installation process and methods of pile foundations are equally important factors of the design process. Pile foundation installation will be made by pile hammer.

To avoid damages to the piles, during design, installation methods and installation equipment are carefully selected.

Because the installation is to be carried out using pile-hammer, the following factors should be taken into consideration:

- Size and the weight of the pile
- Driving resistance which has to be overcome to achieve the design penetration
- Available space and headroom on the site
- Availability of cranes
- Noise restrictions which may be in force in the locality.

Foundation piles are made from precast concrete having a size of 12x0.4x0.4 m and a weight of 4.8 t. For car parking's foundation will be driven 3 piles, each with a height of 12 meters for transport considerations.

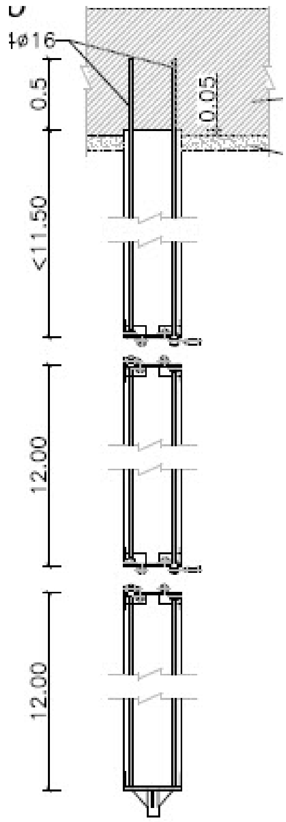

Figure 3.1 – Piles for foundation

3.4. Pile Driving Method

Precast Driven Piles are first cast at ground level and then hammered or driven into the ground using a pile driver. This is a machine that holds the pile perfectly vertical, and then hammers it into the ground blow by blow. Each blow is struck by lifting a heavy weight and dropping it on the top of the pile - the pile is temporarily covered with a wood cap to prevent it from disintegrating. The pile driver thus performs two functions - first, it acts as a crane, and lifts the pile from a horizontal position on the ground and rotates it into the correct vertical position, and second, it hammers the pile down into the ground.

3.4.1. Hammer H 6-Hydraulic hammer (H series)

The hydraulically driven free-fall hammer is ideally suited for impact driving of steel pipes, beams and sheet piles, as well as precast concrete and timber piles. Thanks to the modular weights, the hammer can be perfectly adapted to the respective piling requirements.

Technical data:

Max. ram weight 6,000 kg

Max. energy 72 kNm

Blow rate 0 - 120 bpm

Total weight 8,400 kg

Total height version C (compact) 4,110 mm

Figure 3.2 – Hydraulic hammer

The foundation consist of three piles driven into the ground one after the other in the same spot. The bottom end of the pile rests on a layer of strong soil. The load of the building is transferred through the pile onto the strong layer. The key principle is that the bottom end rests on the surface which is a strong layer. The load therefore bypasses the weak layer and is safely transferred to the strong layer. Three spots will be grouped together and then topped with pile cap, after those three piles for each spot are driven into the ground. The distances for the foundations are those in the annexed plan (see Annex A1).

3.5. Columns installation

Prior to erecting structural columns, all the details of the column are analyzed.

The designer's instructions must be followed closely in the unloading and turning of columns.

Being long columns of more than 12 meters usually will have to be turned using multiple lines and multiple pick points. Guying or bracing also is required for these long lengths. Long columns can be spliced when it is not practical to erect them in one piece.

Sufficient access is required to allow anchor bolts to be tightened. If the columns are to be loaded immediately, sufficient shims must be installed to transfer the load. If the columns are erected far enough ahead of placing the rest of the structure, dry packing or grouting of bases with non-shrink grout should follow directly behind erection.

Columns have to be plumbed by using two transits placed at 90 degrees. Column plumbness (verticality) should be rechecked after load is applied. Column plumbness should be checked periodically throughout the erection process. Spandrels frequently produce eccentric loads on the columns when they are used to support floor members. These eccentric loads make it difficult to keep the columns plumb. One solution is to erect the columns a measured amount out of plumb as load is applied. To maintain a plumb condition, the columns should be braced.

3.6. Fastening procedures for beams and hollow core slabs

Beams are fixed on columns. After the columns are erected in their correct locations, further layout for the beams should not be required other than to monitor their length prior to erection and to keep joint widths constant. Corbels are used as connections on the columns, to serve as a support for the beams.

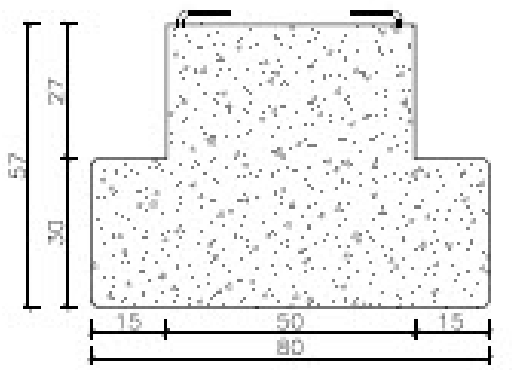

Figure 3.3 - The beam used for car storage erection

Unloading and hoisting of hollow core slabs shall be conducted using a special lifting device – a hoisting traverse, which consists of a lifting beam with two hoisting grippers.

Figure 3.4 - Hoisting of hollow core slabs

The position of the hoisting grippers on the lifting beam shall be adapted to the length of the slab. The free ends of the slab should not be protruded from the gripper by more than 0,5 m. When hooking the hoisting gripper to the slab, one should be extremely careful. Check whether the zone of slab hooking is not damaged and take care of gripping the slab in all width. During unloading and hoisting, it shall be necessary to use safety chains that are at the grippers to ensure safe hoisting of the item and its holding in the case of sudden release of the grippers. The chains will be put on after the slab has been lifted at the height not greater than 10 cm from the supporting members. They cannot be unhooked until the slab occurs directly above the planned bearing surface, at 10 cm from it.

After the banksman has commanded, the item shall be lowered into the planned position. Prior to unhooking the slab from the crane, its lateral position is verified and also the length of the bearing surface.

Five people are needed for slabs to be installed: one crane operator, two workers for guidance and two for installation.

Interim storage on the construction site is not established in one place, as production items are deposited next to the area of their erection.

3.7. Mobile crane used for hoisting

Crane size is determined by the weight of the heaviest component, maximum reach and site restriction.

All the heavy masses of the parking components were analyzed to choose the right mobile crane.

object	volume [mc]	mass [kg]	density of reinforced concrete	[tone]
slab	2.728	6820	2500	6.82
beam 3	3.3465	8366.25		8.36625
end beam 3	3.9944	9986		9.986
foundation pile	1.92	4800		4.8
column	3.592	8980		8.98

Table 3.1 - Heaviest components of the parking

To operate with this members for car parking erection, mobile cranes are versatile and economical.

The LTC 1050-3.1 compact mobile crane delivers the outstanding handling or classic all-terrain cranes and its compact design also makes it an ideal hoisting unit for use in very constricted areas, for example for crane work inside industrial buildings, ports, etc.

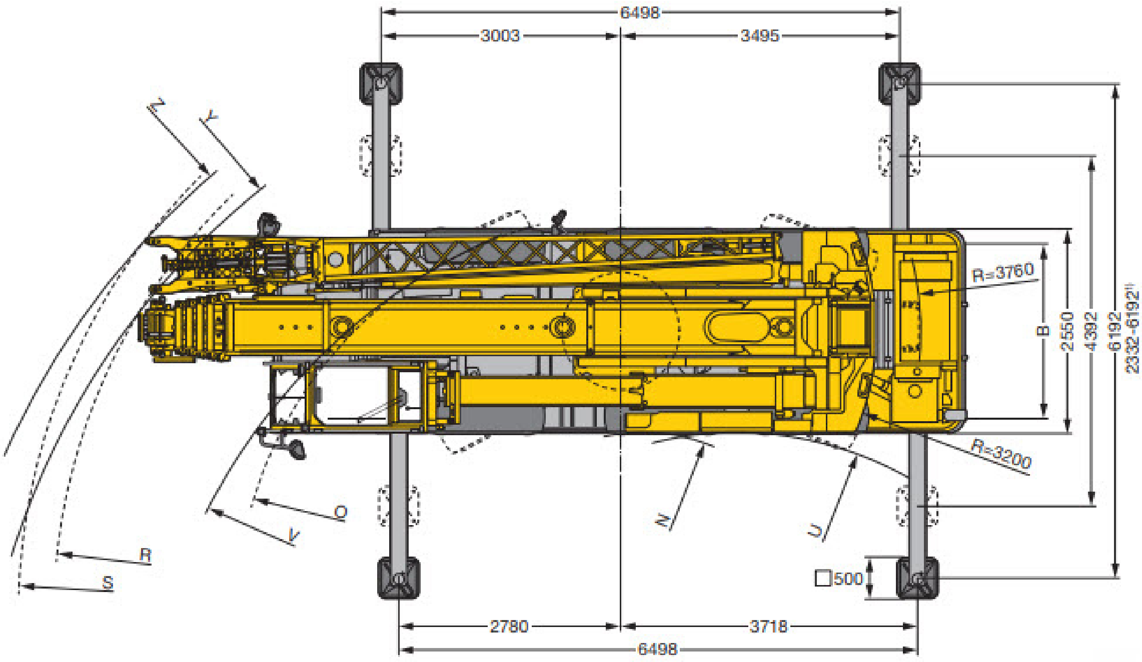

Figure 3.5 – Dimensions of the crane

Considering the characteristics of this mobile crane and the dimensions and weights of the parking members, this crane is suitable to lift, install or any other operations for the erection.

Figure 3.6 – Mobile crane

Max. load capacity	50 t	Max. radius	39 m
Telescopic boom	36 m	Number of axles	3
Max. hoist height	48 m		

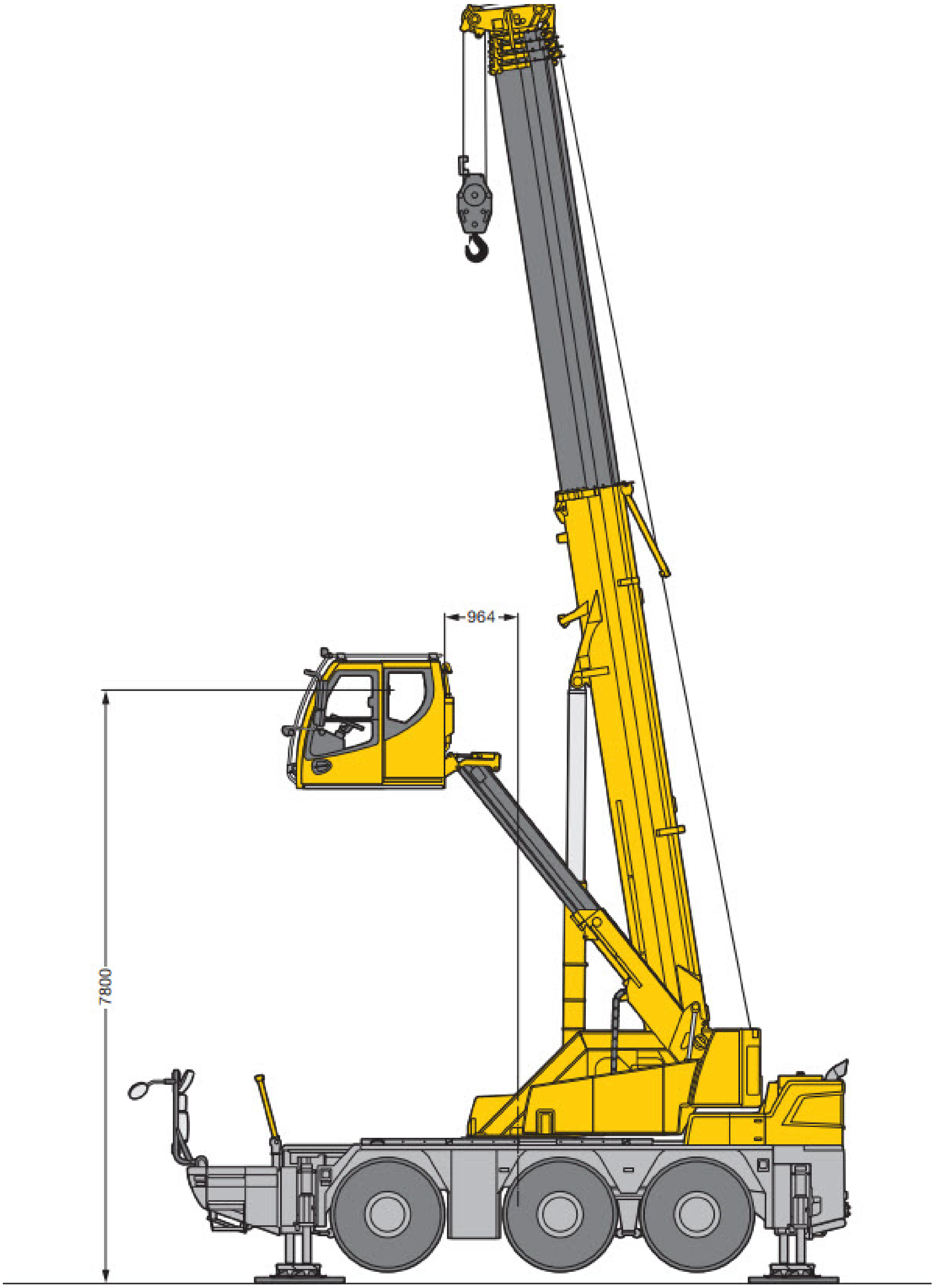

Figure 3.7 - Cab lifting and telescopic arm

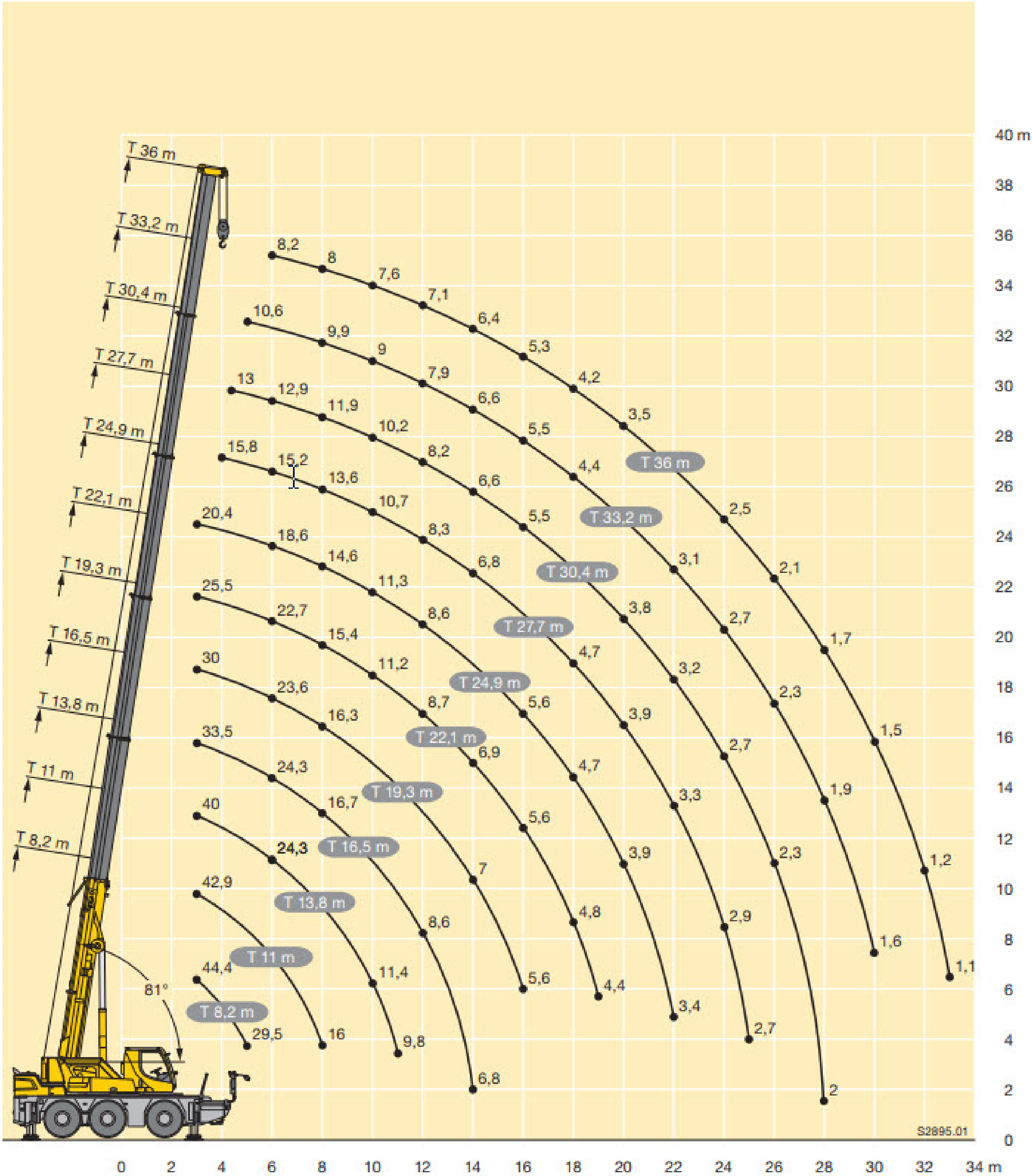

Figure 3.8 - Dimension specifications of the mobile crane

The specifications from the figure above and the weights of the elements from the table below were used to determine the exact position of the crane, on the site, to install the precast elements.

object	volume [mc]	mass [kg]	density of reinforced concrete	[tone]
slab	2.728	6820	2500	6.82
beam 1	2.5496	6374		6.374
beam 2	2.6835	6708.75		6.70875
beam 3	3.3465	8366.25		8.36625
end beam 1	3.0432	7608		7.608
end beam 2	3.203	8007.5		8.0075
end beam 3	3.9944	9986		9.986
foundation pile	1.92	4800		4.8
column	3.592	8980		8.98

Table 3.2 - Weight of precast elements

The powerful diesel engine on the LTC 1050-3.1 enables it to be driven at high speeds. The automatic powershift transmission delivers excellent manoeuvrability and comfort. A torque converter allows for sensitive manoeuvring and minimal crawling speeds.

The LTC 1050-3.1 is easy to manoeuvre with its five steering programs. Its handling is stable even at high speed. Its active rear axle steering significantly reduces tyre wear.

The optional telescoping crane cabin delivers excellent visibility during crane operations. It takes the crane driver to an eye level of up to 7.8 m. The lift cabin makes a valuable contribution to high safety levels.

Figure 3.9 – Possibility of crane movements

Supporting the crane: The supports are extended fully hydraulically. They are controlled using the BTT Bluetooth Terminal or from the crane cabin. Four integral lights provide excellent lighting of the support area. The extension system requires very little maintenance.

VarioBase allows each individual crane support to be extended to variable lengths. At the same time, the crane's work is secured by the LICCON controlled load moment limiter. The extension length and support force of each outrigger is measured and the maximum load capacities for exactly this situation are calculated by the crane controller.

Even with the maximum support base VarioBase delivers higher lifting capacities and a larger working area. The greatest advantages are made in the operating ranges directly above the supports. The variable supporting base also makes improvements for hoisting to the front rear.

The LTC 1050-3.1 compact crane features extremely small dimensions. The front storage box can be removed to make it even smaller. A whole host of storage compartments can be used for accessories such as attachment equipment and support timbers.

The automatic rapid action TELEMATIK telescoping system makes Liebherr cranes more powerful and more efficient. It operates using just one hydraulic cylinder and an internal locking system for the individual telescoping sections. It delivers excellent lifting capacity properties since the various telescopes can be extended in any order and completely independently of each other.

4. CONCLUSIONS

Overall project schedules need to be construction sensitive. It is necessary to establish a sequence of activities with realistic durations to prevent costly overtime, schedule acceleration, or counterproductive high levels of craft labor. Project success and failure is a subject of perception and the criteria could vary from project to project. A project that has been perceived to be a failure by one stakeholder may be perceived as a success by another. The knowledge and understanding of the project have a great importance for project management effectiveness.

Using Microsoft Project software for this thesis was a way to schedule all the erection steps more clearly and comparing different scenarios (for this case one with 4 sections and one with 6 sections) could be obtained the safer and preferable version of the execution. Also the Gantt chart still has a very important part to play as a management tool for both planning and controlling. Its visual clarity and ease of understanding make it a valuable medium for summarizing complex networks, displaying project scheduling information and affording an easy and convenient way to monitor progress.

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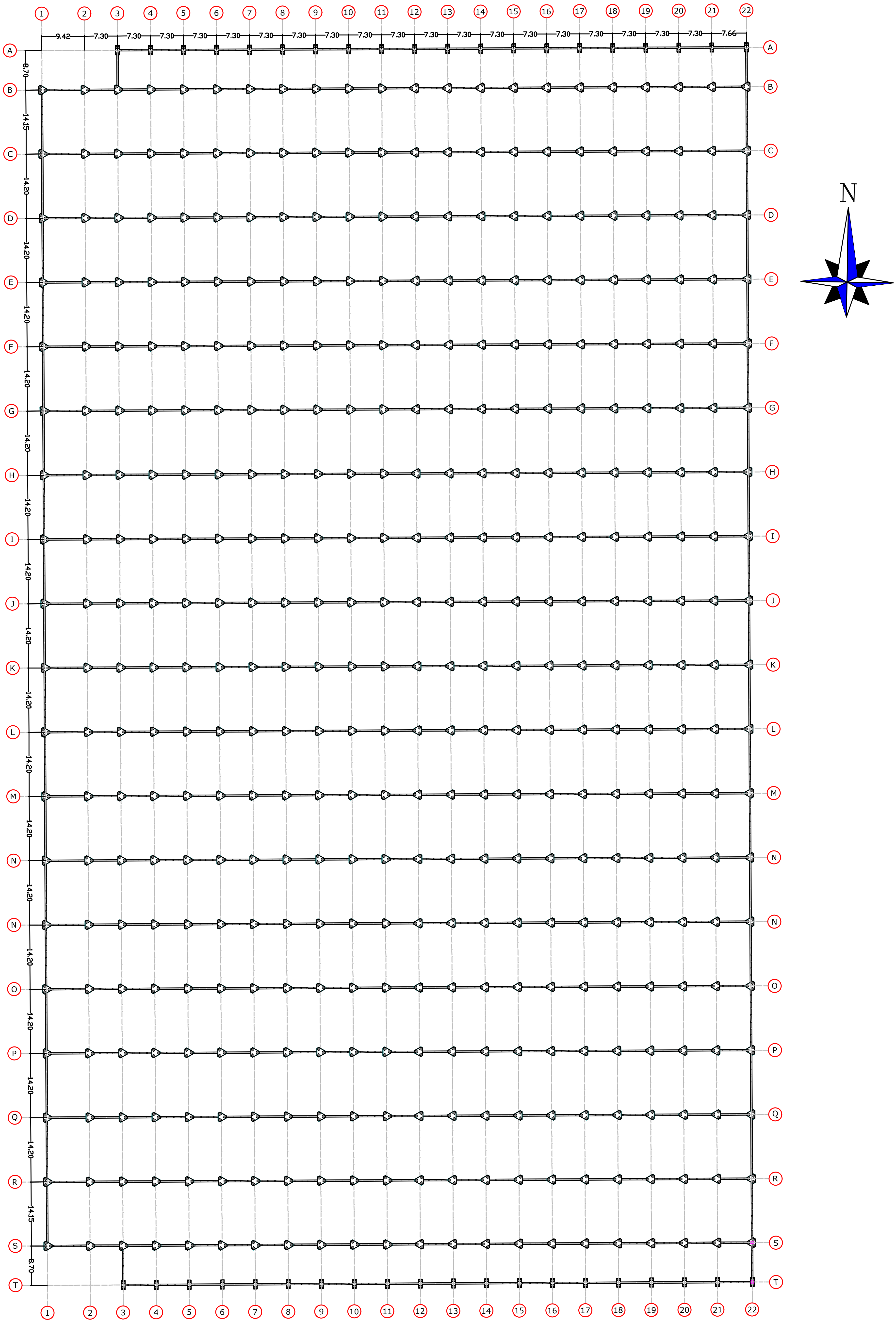
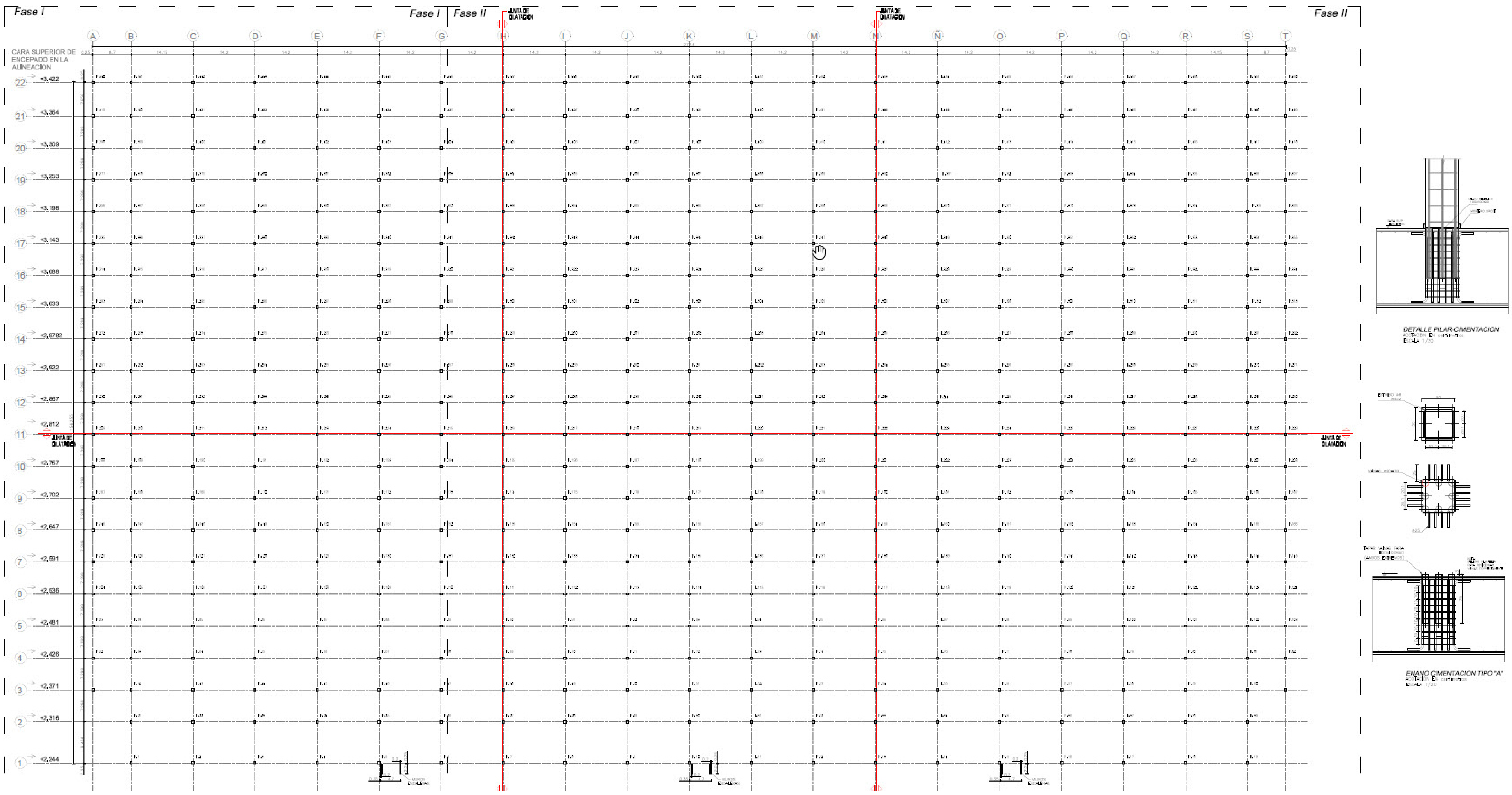
LIST OF ANNEXES

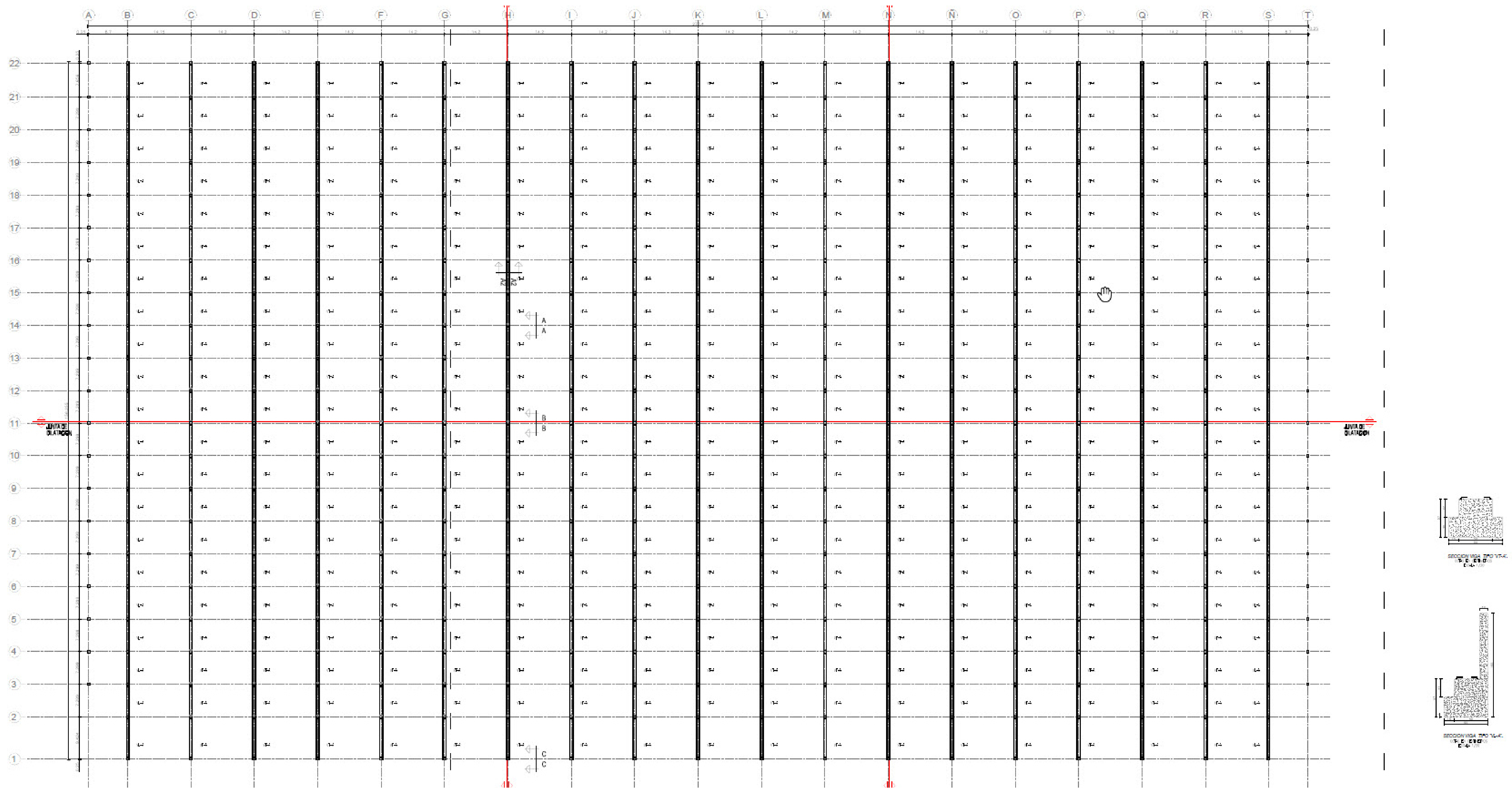
Annex A1 - Piles plan and axes of construction



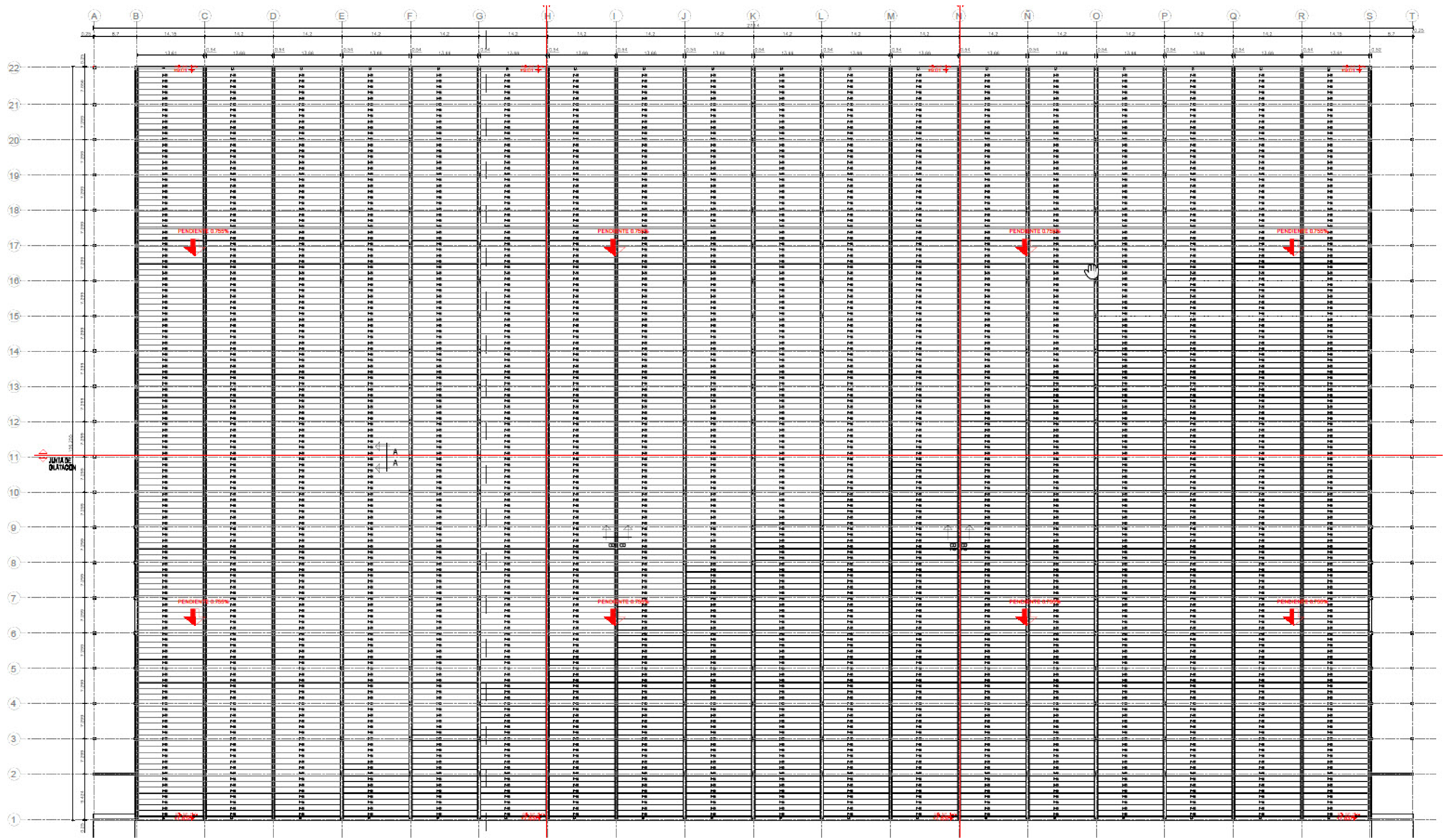
Annex A2 – Columns plan



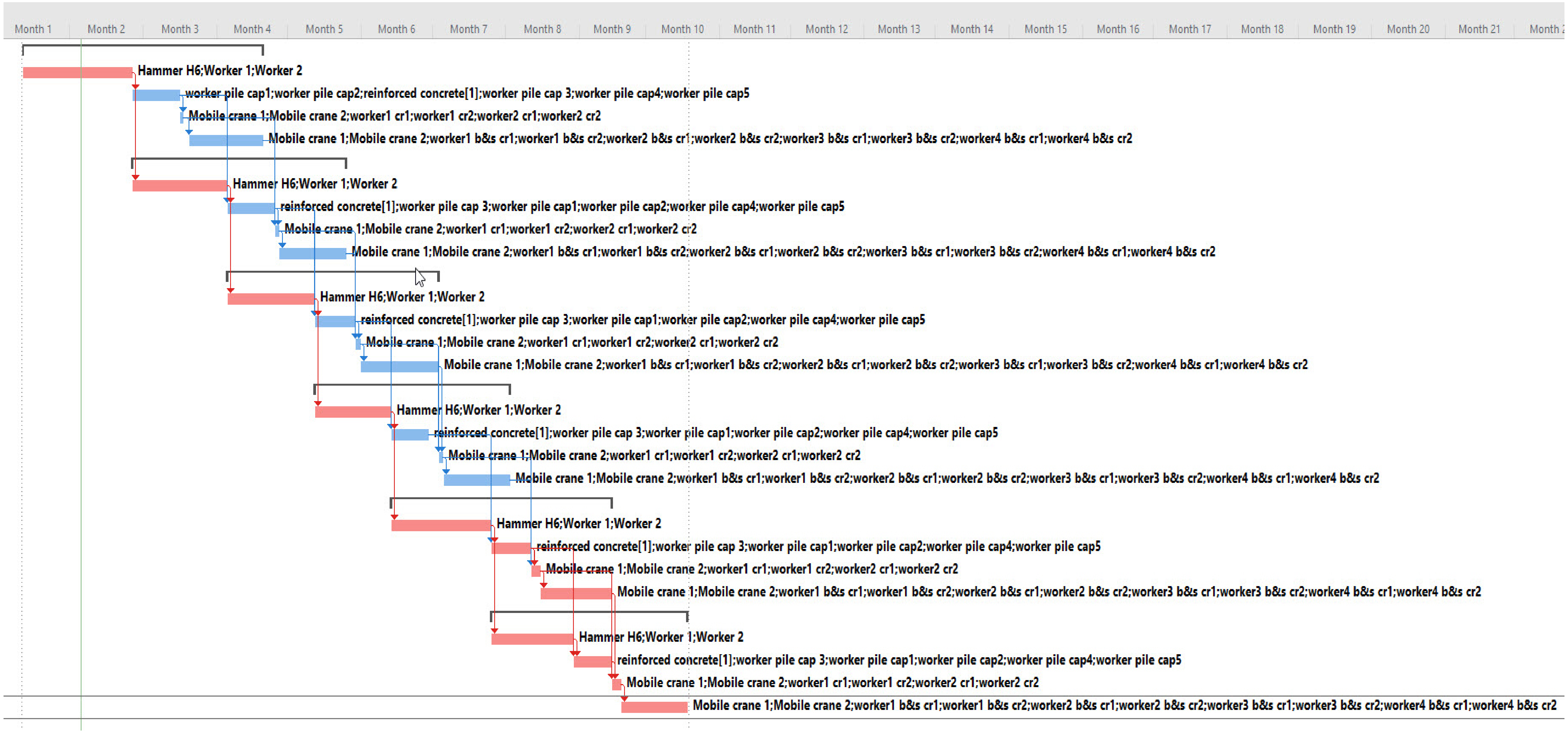
Annex A3 – Beams plan



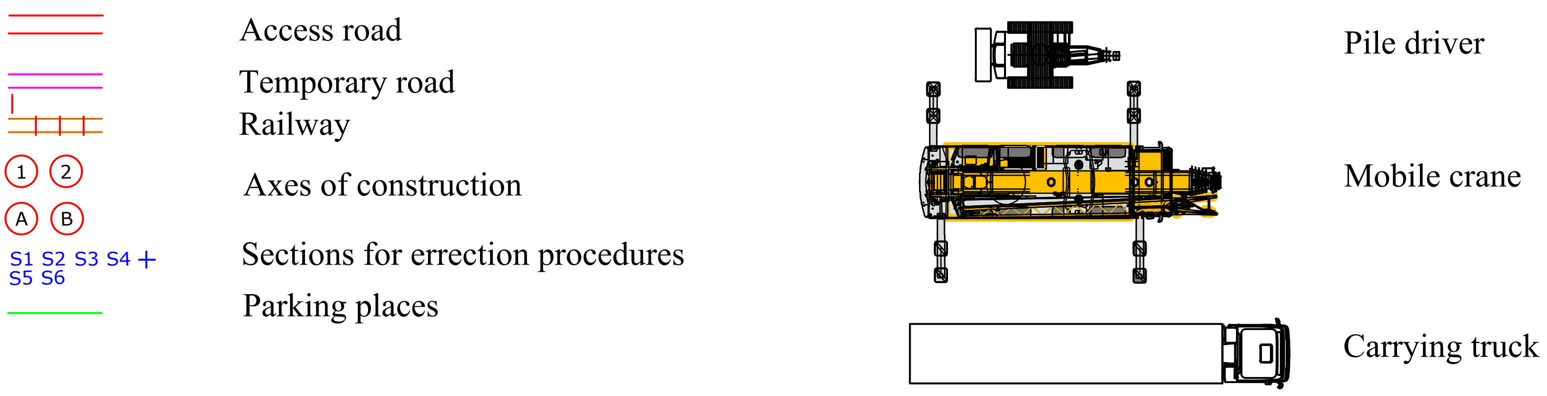
Annex A4 – Slabs plan



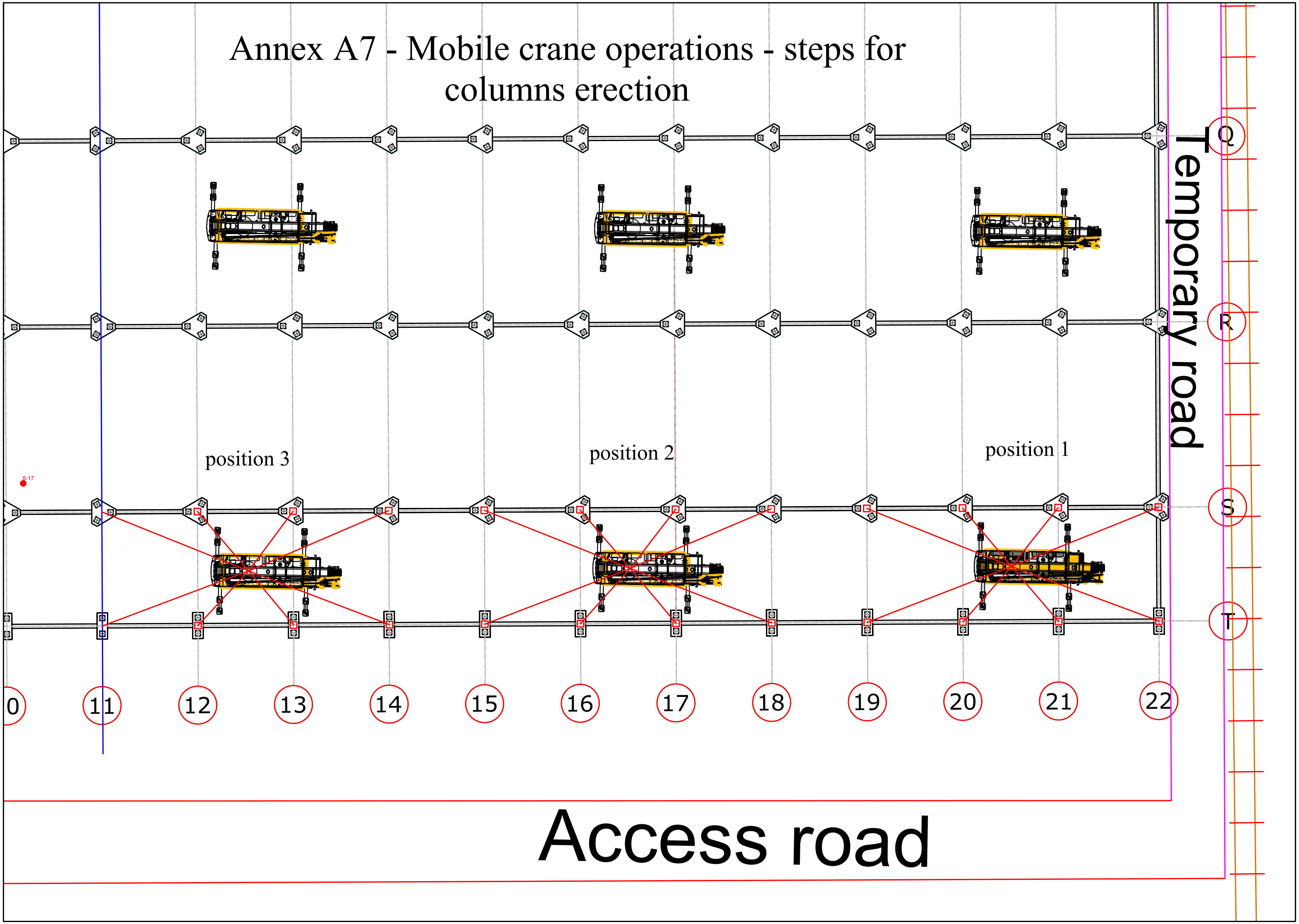
Annex A5 - Gantt Chart and the Critical Path for 6 sections division



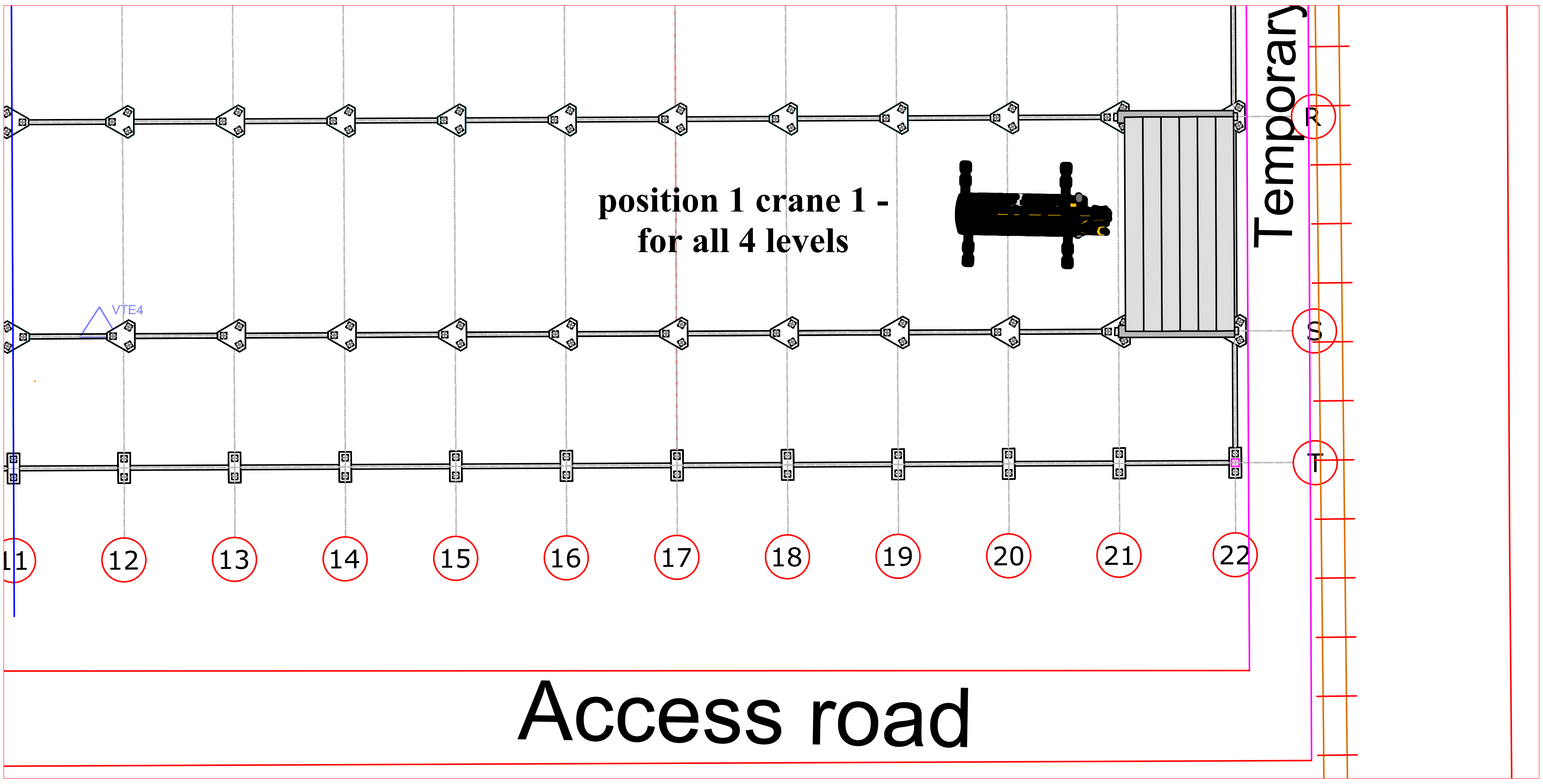
Annex A6 - Technological flow of the site

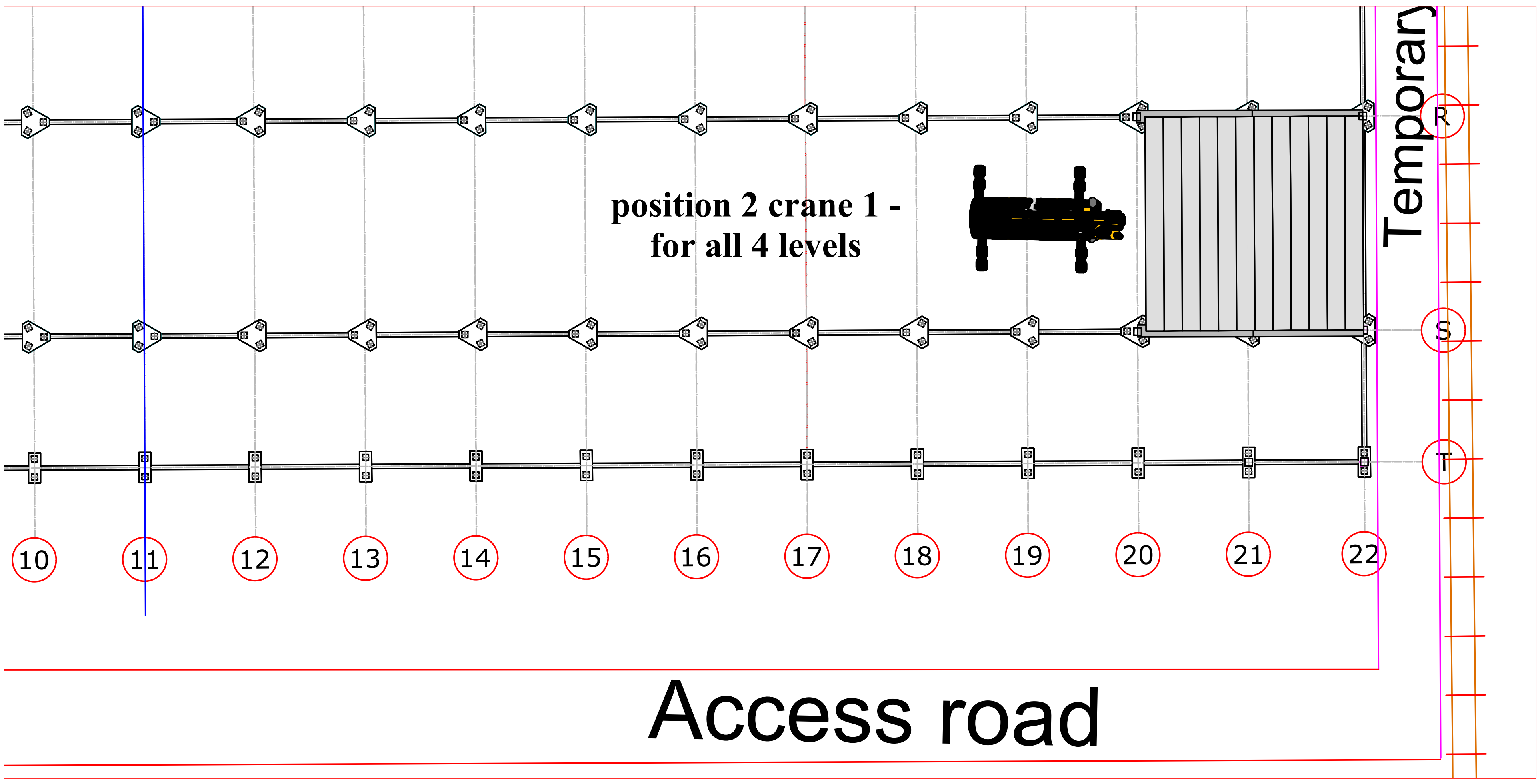


Annex A7 - Mobile crane operations - steps for columns erection



Annex A8 - Mobile crane operations - steps for beams and slabs erection





Annex A9 - Gantt Chart and the Critical Path for 4 sections division