FINAL PROJECT
BIM 4D MODELING FOR STRUCTURAL WORKS SCHEDULING: CASE STUDY OF GEDUNG PELAYANAN ARSIP UNIVERSITAS NEGERI YOGYAKARTA

Submitted To Universitas Islam Indonesia To Fulfill The Requirements For The Bachelor Degree Of Civil Engineering

AFIF RAMADHAN
21511238

CIVIL ENGINEERING
INTERNATIONAL UNDERGRADUATE PROGRAM
FACULTY OF CIVIL ENGINEERING AND PLANNING
UNIVERSITAS ISLAM INDONESIA
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Arranged by:

Afif Ramadhan
21511238

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to obtain a Bachelor's degree in civil engineering.

Has been examined and reviewed on July 15th, 2026
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PLAGIARISM-FREE STATEMENT

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

I declare in fact that the Final Project compiled as a requirement to meet one of the requirements in the Civil Engineering Study Program of Universitas Islam Indonesia is the result of my independent work. Certain parts of writing Final Project reports that quote from the work of others have been written in the source clearly, according to the rules for writing scientific papers. If later it becomes known that this work practice report, or part of it, is not my work or there is plagiarism in some parts. I am willing to accept sanctions, including the cancellation of my degree.

Yogyakarta, 15 July 2026

Author,

erai 10000)

Afif Ramadhan

(21511238)

DEDICATION

This Final Project is dedicated to:

Papa Mama,
Yonfi Zanefo and Yulfienti,
who have always trusted, supported, prayed, and
strengthened me to face every challenge.

My brothers,
bang Idil and bang Adal,
who have always guided and encouraged
me to reach my potential.

21st Batch of Civil Engineering,
especially in Internasional Program,
who shared wonderful experiences through
all the ups and downs.

My best friends,
Tedi, Agoy, Faqih, Bopi, and Yunda
who shared countless laughs and tears,
and made every second in Yogyakarta
memoriable.

My partner, Laisa Azka,
who has encouraged and accompanied me
to finish what I started.

And Mavis, who reminds me every day that I matter.

One of these lives, i'ma make things right.
- Kendrick Lamar -

PREFACE

Thank God Almighty because the Final Project entitled BIM 4D Modeling for Structural Works Scheduling: Case Study of Gedung Pelayanan Arsip Universitas Negeri Yogyakarta was able to completed. This Final Project is one of the academic requirements in completing undergraduate studies at the Faculty of Civil Engineering and Planning, Universitas Islam Indonesia.

In the preparation of this Final Project, there were many obstacles faced, but thanks to criticism, suggestions, and motivations from various parties, this Final Project was resolved. In regard, the Author would like to express his deepest gratitude to:

1. Dinia Anggraheni, S.T., M.Eng., as the Acting Head of the Civil Engineering Undergraduate Study Program,
2. Ir. Tri Nugroho Sulistyantoro, S.T., M.T., as the author's Supervisor of the Final Project,
3. Adityawan Sigit, S.T., M.T., Ph.D. as the Examiner Lecturer I,
4. Rizki Budiman, S.T., M.T as the Examiner Lecturer II,
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6. All parties who have helped in the process of implementing this Final Project and preparing the reports.

Finally, The author hopes this Final project can bring benefits to all parties who read it.

Yogyakarta, July 2026
Author,

Afif Ramadhan
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NOTATIONS AND ABBREVIATIONS

Mathematical Notations

A_f	=	formwork contact area of the element (m^2)
$A_{f,i}$	=	formwork area of element type i (m^2)
$A_{f,total}$	=	total formwork area of a pour phase (m^2)
b	=	section width (mm)
D	=	activity duration (working days)
D_{co}	=	concreting activity duration (working days)
D_{fw}	=	formwork activity duration (working days)
D_{phase}	=	total pour phase duration (working days)
h	=	section height / pile cap height (mm)
l	=	slab plan width (mm)
L	=	element length / pile cap plan length (mm)
n	=	number of workers assigned to an activity
n_i	=	number of identical elements of type i in a pour phase
p	=	slab plan length (mm)
P	=	single-worker daily productivity from AHSP CK 2023
Q	=	quantity of work (m^2 for formwork, kg for reinforcement, m^3 for concrete)
W	=	pile cap plan width (mm)

Abbreviations

4D	=	Fourth Dimension
AHSP	=	*Analisis Harga Satuan Pekerjaan* (Unit Price Analysis)
BBS	=	Bar Bending Schedule
BIM	=	Building Information Modeling
CK	=	*Cipta Karya*
CPM	=	Critical Path Method

DED	=	Detailed Engineering Design
FF	=	Finish-to-Finish (activity dependency type)
FS	=	Finish-to-Start (activity dependency type)
IFC	=	Industry Foundation Classes
LOD	=	Level of Development
OH	=	*Orang Hari* (person-day, unit of labour input)
PT	=	*Perseroan Terbatas* (Limited Liability Company)
QR	=	Quick Response
QTO	=	Quantity Take-Off
RC	=	Reinforced Concrete
SE	=	*Surat Edaran* (Circular Letter)
SNI	=	*Standar Nasional Indonesia* (Indonesian National Standard)
UII	=	Universitas Islam Indonesia
UNY	=	Universitas Negeri Yogyakarta
VDC	=	Virtual Design and Construction
WBS	=	Work Breakdown Structure

ABSTRACT

Conventional construction scheduling relies on S-curves representing progress through cumulative cost-weighted percentages, concealing activity dependencies and producing inaccurate duration estimates. BIM 4D addresses this by linking a three-dimensional structural model to an explicit, activity-based schedule, making sequencing constraints visible before construction begins. This study develops a BIM 4D schedule for Gedung Pelayanan Arsip Universitas Negeri Yogyakarta, comparing its duration against the conventional S-curve and measuring how far both schedules deviate from the actual duration recorded on site.

The research workflow integrates structural modeling and quantity take-off in Tekla Structures, activity duration calculation in Microsoft Excel using AHSP CK 2023 coefficients, the standard in force when the project was executed in 2024, scheduling in Microsoft Project, and four-dimensional simulation in Autodesk Navisworks through TimeLiner. The structural model comprises 541 cast units, a concrete volume of 1,148.50 m^3, reinforcement weight of 143.74 tons, and formwork area of 5,406.98 m^2, organized into 155 tasks across 37 pour phases and 14 zones.

The BIM 4D method produced a structural duration of 127 working days, against 102 days from the conventional S-curve. The actual duration derived from the site weekly reports was about 132 working days. The BIM 4D estimate deviated by five days out of 132, a 3.8 percent error, whereas the S-curve underestimated it by 30 days out of 132, a 22.7 percent error. Formwork was identified as the rate-limiting resource of the concrete structure, a constraint the S-curve cannot reveal. BIM 4D yields a longer but more transparent and accurate schedule.

Keywords: BIM 4D, structural scheduling, Tekla Structures, Autodesk Navisworks, AHSP CK 2023

CHAPTER I
INTRODUCTION

1.1 Background

In Indonesia, the construction industry is a crucial sector that has rapidly developed within national infrastructure demand. Simanjuntak (2023) stated that "digital technology (digitalization) has a significantly positive effect on the effectiveness of the project implementation team. Sig. Value = 0.000 < 5%". That statement shows that the technology implementation in the construction sector has started to show a positive progression in improving the efficiency and quality of project implementation. The industry continues to evolve, and the demand for technology in construction is increasing due to its numerous benefits, including improved collaboration, enhanced data management, and increased accuracy (Purwanto et al., 2024). The application of engineering software, digital management systems, and technology-supported construction methods is increasing within the industry.

Building Information Modelling (BIM) is a management revolution that improves the conventional construction process through digitalization by integrating various project information dimensions into a cohesive digital environment. BIM can provide visualization, simulation, and coordination in construction activities. It allows the stakeholder to identify some conflicts early, optimize planning, and improve decision-making during construction. Reddy Anireddy (2024) stated that BIM provides a digital platform that integrates various aspects of a project from design to facility management in one common model, enabling better collaboration, efficiency, and sustainability in construction for stakeholders. BIM's multidimensional approach includes 3D modelling, 4D scheduling, 5D cost estimation, 6D energy analysis, 7D facility management, 8D safety management, 9D lean management, and 10D manufacture management (PUPR, 2019). It offers an effective solution to many challenges faced in modern construction, such as coordination inefficiencies and time delays.

Structural works are one of the main components of the construction stages that determine the stability and continuity of the construction process. A time schedule is needed as it provides a detailed division of time for each activity or type of activity from the beginning until the end of implementation (Utami and Nugraheni, 2023). A precise and well-structured time schedule not only ensures that the construction process runs as planned but also supports resource efficiency, work safety, and final quality of the project. Therefore, the ability to visualize the workflow more clearly and accurately is essential, since this process is usually done conventionally. A conventional time schedule not only requires extra time to create but also provides inconsistent information, leading to delays in implementation and increasing the project cost. The implementation of Building Information Modelling (BIM) has been proposed as a technological solution since it offers work efficiency (Saputra & Abma, 2023).

Although several studies have discussed the implementation of BIM 4D in construction projects, research that specifically focuses on structural works scheduling in the Indonesian context is still limited. Most local projects still rely on conventional scheduling techniques such as bar charts and the Critical Path Method (CPM), which often do not adequately capture the complex interdependencies among structural elements like foundations, columns, beams, and slabs(Muzaffar et al., 2025). In practice, these methods frequently face coordination problems, such as delays in formwork installation that affect concrete casting, idle time for heavy equipment and workers due to sequencing conflicts, and misalignment between planned and actual durations. The lack of integrated visualization makes it difficult for project teams to anticipate clashes in the work sequence, which may result in higher costs, quality risks, and unsafe working conditions. Therefore, strengthening the use of BIM 4D specifically for structural scheduling can address these gaps by providing more accurate simulations and improved coordination compared to conventional approaches.

Hence, in this study, BIM 4D is implemented in stages, beginning with three-dimensional (3D) modeling using Tekla Structure software to simulate the structural component's detail of the building. This 3D model was then integrated into Autodesk Navisworks to develop the fourth dimension (4D), which is construction scheduling. The case study project used in this study is the *Gedung Pelayanan Arsip Universitas Negeri Yogyakarta* project. Through the implementation of these tools, BIM 4D facilitates a more accurate visualization of structural work progression over time, which is expected to support planning and supervising more efficiently than conventional methods. Furthermore, this study aims to analyze the differences in project duration between BIM 4D simulation compared to conventional scheduling. By comparing both approaches, the study can demonstrate how the implementation of BIM 4D is able to optimize construction timelines and reduce the risk of project delays. In addition, the durations produced by the two methods are measured against the actual structural duration recorded in the project weekly reports, so that the accuracy of each schedule can be evaluated against what the site delivered rather than judged only against each other.

1.2 Statement of Problem

Based on the background above, the problems statement in this study are formulated as follows.

1. How does the project duration of structural works differ between the conventional scheduling method and the BIM 4D simulation using Tekla Structures and Autodesk Navisworks?
2. How far do the durations produced by the conventional scheduling method and the BIM 4D simulation deviate from the actual duration of the structural works recorded on site?

1.3 Research Purposes

Based on the problem statement above, the purpose of this study are as follows.

1. Analyze the difference in project duration between the conventional scheduling method and BIM 4D simulation for structural works using Tekla Structures and Autodesk Navisworks.

2. Measure the deviation of the conventional scheduling duration and the BIM 4D simulation duration against the actual structural works duration recorded from the site weekly reports.

1.4 Research Benefit

The benefits expected to be obtained in this study are as follows:

1. As a source of knowledge and learning about the implementation of Building Information Modelling (BIM) in 3D structural modelling and 4D scheduling using Tekla Structures and Autodesk Navisworks.
2. To provide insight into how adding a time element (4D) to a 3D BIM model can produce a clear and structured visual simulation of construction sequences.
3. To demonstrate the application of structural modelling and scheduling integration systematically in supporting construction planning processes.
4. To show the importance of implementing Building Information Modelling (BIM) in structural works for better visualization and coordination in construction projects.
5. As a technical foundation for students in developing BIM 4D skills, which will be useful in entering the professional field of construction.

1.5 Research Limitation

To ensure the research objectives are achieved properly and stay within the scope of discussion, the following limitations are listed below.

1. This study uses the *Gedung Pelayanan Arsip Universitas Negeri Yogyakarta* as a case study.
2. The research focuses on the implementation of the 4D dimension of Building Information Modeling (BIM) for structural work.
3. The 3D modeling is developed using Tekla Structures software without any modification to the original model from the company.
4. The 4D scheduling process is carried out using Autodesk Navisworks and is intended only for visualization and time simulation purposes.
5. The actual structural duration used as the benchmark in this study is derived

from the contractor's weekly reports, which are internal project documents adopted as received, without independent third-party validation of their contents.

CHAPTER II
LITERATURE REVIEW

2.1 Overview

This chapter presents a literature review that serves as a reference for conducting research related to the implementation of Building Information Modeling (BIM) 4D in structural work on construction projects. The review includes general theories about BIM as well as relevant previous research used as supporting references and comparisons. Through this chapter, the research is expected to have a strong theoretical foundation and demonstrate clear distinctions from previous studies, in order to avoid redundancy in topics and methods.

2.2 Previous Research

2.2.1 The Efficient Generation of 4D BIM Construction Schedules: A Case Study of the Nanterre 2 CESI Building

Doukari et al. (2022) conducted a study entitled "The Efficient Generation of 4D BIM Construction Schedules: A Case Study of the Nanterre 2 CESI Project in France". This research aims to develop an efficient method for building 4D BIM-based construction project scheduling. The case study is the CESI education building construction project in France. This research divides the stages of BIM implementation into 4 main phases, namely project orientation, integration of schedule data with 3D models, data synchronization between teams, and visualization finalization. The research showed that the 4-phase approach reduced the integration time of the 3D model with the schedule by 40% and increased the team's involvement in developing the visual-based scheduling. The resulting 4D model contained more than 130 structural components linked to 56 construction activities in Microsoft Project.

2.2.2 Construction Site Design Planning Using 4D BIM Modeling

Caldart and Scheer (2022) conducted a study entitled "Construction Site Design Planning Using 4D BIM Modeling". This research aims to develop a dynamic project site layout planning method based on the 4D BIM approach. The case study was conducted on the construction of a 14-story hotel in São Paulo, Brazil. In this study, scheduling was modeled with Autodesk Navisworks and linked to site logistics simulation to show the development of work zones for each floor. The results showed that the 4D BIM approach enabled layout planning to be up to 25% more efficient than manual estimation and helped avoid three main types of conflicts: material stacking, overlapping logistics lines, and crane placement. Researchers also noted an increase in time efficiency in the site plan validation process of up to 35%.

2.2.3 The Integration of Virtual Design and Construction (VDC) With the Fourth Dimension of Building Information Modeling (4D BIM)

Salman and Hamadeh (2023) conducted a study entitled "The Integration of Virtual Design and Construction with the Fourth Dimension of Building Information Modeling". This research evaluates the integration of 4D BIM with the Virtual Design and Construction (VDC) approach for a pharmaceutical association building project in Tartous, Syria. The research involved 3D modeling with Autodesk Revit, clash detection and quantity take-off in Navisworks, and 4D scheduling using Bentley Synchro. The results of the study showed that the plan and actual conformity rate reached 90-100% after the 4D BIM integration was carried out. The model includes 43 activities with a detail level of LOD 200. The researcher concluded that the use of 4D BIM with VDC was able to improve time accuracy and accelerate planning validation by stakeholders by 80%.

2.2.4 Exploring BIM Based Automated Quantity Take Off for Contractors in Bridge Structural Models

Abma et al. (2026) conducted a study entitled "Exploring BIM Based Automated Quantity Take Off for Contractors in Bridge Structural Models." This study aims to explore the implementation of Building Information Modeling

(BIM)-based automated Quantity Take-Off (QTO) from the contractor's perspective during the construction phase of a bridge project. The bridge structure was remodeled into a 3D BIM model using Autodesk Revit with a Level of Development (LOD) 350 to ensure accurate geometric and information details before performing automated quantity extraction. The research methodology consisted of BIM execution planning, 3D modeling, model verification, and automated quantity take-off within the BIM environment. The extracted quantities were validated against project data to evaluate their reliability. The results showed that the BIM-based automated QTO successfully generated a total concrete volume of 2,075.30 m^3 and reinforcement quantity of 381,548.21 kg. The study concluded that BIM-based QTO significantly improves the accuracy and efficiency of quantity extraction, reduces dependence on manual calculations, supports material procurement and construction planning, and provides more reliable data for contractor decision-making.

2.2.5 *Analisis Kinerja Waktu dan Penerapan Building Information Modeling pada Proyek Pembangunan Jasmine Park Apartment Bogor*

Ulil Albab and Erizal (2021) conducted a study entitled "Time Performance Analysis and Application of Building Information Modeling in the Bogor Jasmine Park Apartment Construction Project". This study aims to apply 4D Building Information Modeling (BIM) using Tekla Structures 2019i software to the Jasmine Park Apartment project, Bogor, and analyze the performance of the implementation time by comparing the planned and realized S curves. 3D modeling was carried out on structural elements such as foundations, columns, beams, slabs, and roofs, which were then added to the time dimension to produce a 4D model. The results of the time performance analysis show that the project is experiencing delays, with the highest time deviation of -13.67% in June 2020. The main causes of the delay were delays in procuring MEP logistics and weather conditions. To catch up with the delay, additional working hours (overtime) and additional workers were carried out. The application of BIM 4D helps in visualizing the work and provides a clearer picture in field decision making.

2.3 Research Comparison

From the literature review above, a comparison can be seen in Table 2.1.

Table 2. 1 Research Comparison Table

No.	Author	Research Title	Method	Research Purpose	Research Result	Gap Analysis
1	Doukari, Seck, Greenwood (2022)	The Efficient Generation of 4D BIM Construction Schedules	3D modelling, Microsoft Project, CESI Method	Develop an efficient workflow for producing 4D BIM schedules.	3D-4D integration accelerated by 40%, 56 activities connected with 130 BIM model objects.	This research focuses on improving the efficiency of 4D BIM schedule generation workflows but does not develop visual simulations as project outputs. Further exploration is needed on how 4D BIM can be visualized as a tool to support stakeholder understanding.
2	Caldart & Scheer (2022)	Construction Site Design Planning Using 4D BIM Modeling	Autodesk Navisworks, Design Science Research	Plan dynamic site layouts via 4D BIM simulation.	Space-use efficiency is up 25 %, site-plan validation is 35 % faster, logistic conflicts are reduced.	This study is limited to logistics and site layout design, not addressing structural work planning. There is still a gap for developing 4D BIM-based structural sequencing simulations.
3	Nagham Salman & Muna Hamadeh (2023)	The Integration of VDC with the Fourth Dimension of Building Information Modeling	Revit, Navisworks, Synchro, VDC	Evaluate the integration of BIM 4D and VDC for pharmaceutical building planning and simulation.	Plan–actual match 90–100 %, planning validation time cut 80 %, 43 activities visualised.	The research emphasizes VDC integration without focusing deeply on construction scheduling details. Future studies can focus more on visualizing structural scheduling using 4D BIM alone.

Continuity of Table 2. 1 Research Comparison Table

No.	Author	Research Title	Method	Research Purpose	Research Result	Gap Analysis
4	Vendie Abma, Tri Nugroho Sulistyantoro, & Fitri Nugraheni (2026)	Exploring BIM Based Automated Quantity Take Off for Contractors in Bridge Structural Models	Autodesk Revit, BIM-based Automated QTO, LOD 350	Explore the implementation of BIM-based automated quantity take-off from the contractor's perspective during the construction phase.	Automated BIM QTO produced 2,075.30 m^3 of concrete and 381,548.21 kg of reinforcement with higher accuracy and efficiency than conventional quantity calculations, supporting material planning and contractor decision-making.	This research focuses on automated quantity take-off (QTO) and quantity accuracy rather than 4D scheduling and construction sequence visualization. Therefore, opportunities remain to develop BIM implementation by integrating structural scheduling and visual simulation using BIM 4D.
5	Ahmad Ulil Albab & Erizal (2021)	*Analisis Kinerja Waktu dan Penerapan* BIM *pada Proyek Jasmine Park Apartment Bogor*	Tekla Structures 2019i, S-curve	Apply 4D BIM and analyse time performance by comparing planned and actual progress	The project experienced the highest delay of -13.67% (June 2020). 4D BIM helped identify causes and solutions.	The focus is on delay analysis rather than development of structured visual simulations. Research opportunities exist in creating animated models for structural planning.

Based on previous studies that have been discussed previously, there are several categories that differentiate this research from previous studies, namely as follows:

1. The implementation of Building Information Modeling (BIM) in this study focuses specifically on the 4D dimension for

scheduling structural work only, without including 5D or cost analysis.

2. The software used consists of Tekla Structures for 3D structural modeling and Autodesk Navisworks for 4D time simulation and visualization.
3. The case study is taken from the Construction Project of the Archives Service Building at Universitas Negeri Yogyakarta, where the researcher was directly involved during the internship program.
4. The research includes a comparative analysis between conventional scheduling (based on S-curve) and BIM 4D simulation, supported by a visual animation output.

CHAPTER III
THEORETICAL BASIS

3.1 Construction Project

A project is a series of activities aimed at producing a unique product, service, or outcome to meet client needs. In achieving its objectives, a project is typically defined by the triple constraint specific targets for time, cost, and performance requirements (Utama, 2020). A construction project is a type of project that focuses on physical structure such as building, road, bridges, and other infrastructure with unique characteristic, complexity, and duration.

In general, construction project management consists of several vital steps. The first is the planning stage, which is developing a work plan that includes the design, budget, and project implementation schedule. Next is the organizing stage, where the project team is formed and the roles and responsibilities of each member are clearly defined. After that, the controlling stage is carried out by monitoring the progress of the project periodically to ensure that all activities are running according to the established plan. The completion stage, which aims to complete the project and ensure that the end result meets the previously agreed requirements (Ketut Utami Nilawati et al., 2025). Finally, the handover stage is conducted, where the completed project is officially delivered to the owner or client through formal procedures, including documentation review and final inspections to confirm that all contractual obligations have been fulfilled.

Construction projects frequently face various challenges that can prevent the accomplishment of time, cost, and quality targets, such as delays, schedule clashes, and design changes. Delays in construction projects in Indonesia are largely caused by poor time management and design changes that occur during the project (Susanti et al., n.d.). This condition requires project management to be more adaptive and responsive in handling any changes so that there is no problem that leads to delays in project completion (Rauzana & Dharma, 2022).

In dealing with the complexity of construction projects, information integration and coordination between all parties involved are the major keys to achieving successful project management (Harjono et al., 2021). In the current technological context, digital approaches such as Building Information Modeling (BIM) play a significant role in collaboratively integrating all project data in real-time. The application of BIM improves communication efficiency, accelerates decision-making, and reduces errors due to fragmented information. With good collaboration, the planning process up to project implementation can run more synchronized, transparent, and controllable (Akinradewo et al., 2023).

3.2 Project Management

Project management is defined as the application of knowledge, skills, tools, and techniques to project activities to meet project requirements (Jumaan & Swaidi, 2023). Project management includes five main process groups: initiation, planning, execution, monitoring and control, and closure. Project management is a systematic approach to directing and controlling a project to meet its objectives. Both standards emphasize the importance of process integration and coordination across functions to achieve expected project results (Hidayanto, 2024).

Triple constraint, also known as the project triangle, is a basic concept in project management that includes three main elements: time, cost, and quality (Talib and Kashkol, 2019). They are closely connected. Changes to one aspect will affect the other two. For example, if the project is accelerated to finish faster, then costs may increase, or quality may decrease. Therefore, maintaining a balance between these three elements is essential to keep the project on track and optimized.

Project manager role is crucial in the implementation of a construction project as it control the work to stay on track and overcome various challenges that may arise (Pramono et al., 2024). Project manager is responsible for coordinating all aspects of the project from planning to execution, as well as being the connection between the project owner, the implementation team, and other stakeholders (Daniel & Inim, 2020). Effective project management requires not only leadership, communication, and decision-making skills but also the ability to plan and control time-related aspects of the project. To accomplish this, project managers rely heavily on various scheduling tools and techniques that help them manage timelines, track progress, and anticipate potential delays. These tools are essential to ensure that all project activities are executed in a timely and organized manner.

To support time management in construction projects, project managers typically utilize a range of scheduling methods, from simple bar charts to network planning techniques, and these methods are reviewed in Section 3.3. While these methods are valuable, their limitations in integrating visual design and dynamic data have led to the growing adoption of Building Information Modeling (BIM) as a more comprehensive project management tool.

In recent years, Building Information Modeling (BIM) has played a significant role in supporting project management activities, especially in construction (Yue, 2023). BIM provides a centralized digital platform where all project information such as design, schedule, and cost can be accessed and coordinated in real time. This integration facilitates better communication between stakeholders, improves planning accuracy, and enables early detection of potential conflicts or delays (Kalajian et al., 2023). By using BIM, project managers can make more informed decisions, visualize project progress through simulations, and ensure better alignment between the design and actual implementation stages. As a result, BIM contributes not only to operational efficiency but also to achieving the project's time, cost, and quality objectives.

3.3 Project Scheduling Methods

Construction scheduling methods range from simple visual tools to formal network techniques. Traditional bar charts are widely used to illustrate the sequence and duration of project activities in a simple and visual format, but they express timing without recording the logic that connects one activity to another. More rigorous scheduling therefore relies on network planning techniques, of which three dominate construction practice, namely the Critical Path Method (CPM), the Precedence Diagram Method (PDM), and the Program Evaluation and Review Technique (PERT). In linear or repetitive projects the Linear Scheduling Method

(LSM) is also applied to align resources and workflows efficiently across similar tasks (Raffaini & Manfredi, 2022).

CPM operates on a network of activities with deterministic durations and computes, through a forward and a backward pass, the earliest and latest times at which each activity can start and finish. Activities whose earliest and latest times coincide carry zero float and together form the critical path, the chain of activities that determines the total project duration, so that any delay on the critical path delays the project as a whole. PDM is the modern formulation of network scheduling in which each activity is drawn as a node and the dependencies between activities are drawn as links, which may take the form of finish-to-start, start-to-start, finish-to-finish, or start-to-finish relationships. PDM is the representation implemented by contemporary scheduling software, including Microsoft Project, and the CPM calculation is carried out on the PDM network. PERT differs from both by treating activity durations as probabilistic, combining an optimistic, a most likely, and a pessimistic estimate for each activity, and it suits projects whose durations are genuinely uncertain rather than derived from established productivity standards.

This study uses PDM with finish-to-start relationships, analysed by the CPM calculation, as implemented in Microsoft Project. The choice follows from the character of the data and the requirements of the 4D integration. The activity durations in this research are deterministic, being calculated from the quantity take-off and the AHSP CK 2023 productivity coefficients, so the probabilistic treatment of PERT is unnecessary. The construction logic of the structural works, in which the formwork, reinforcement, and casting of each pour phase must finish before the dependent phase can begin, is expressed naturally as finish-to-start links between activities. Finally, the 4D simulation in Autodesk Navisworks requires every model element to be attached to a dated task, and dated tasks are exactly what the CPM calculation on the PDM network produces. The application of this method to the case study schedule is described in Subsection 5.3.8.

3.4 Building Information Modeling (BIM)

Building Information Modeling (BIM) is a digital approach to planning and managing construction projects through three-dimensional (3D) modeling integrated with non-geometric information. Unlike Computer-Aided Design (CAD), which only visually depicts 2D or 3D shapes without supporting data, BIM stores detailed information of each building element, such as volumes, materials, work schedules, and costs (Abma et al., 2026). BIM is parametric, meaning that if there is a change to one part of the model, the change will be automatically updated throughout the system. This makes BIM superior to CAD in terms of consistency and efficiency of project data management (Syazwani et al., 2023). With BIM, users not only see the shape of the building, but also understand how and when the components were built and how much they cost.

In one project, there is more than one BIM modeller. Hence, each modeller need a clear Level of Development (LOD) from the 3D model they made. LOD is the level of development of a 3D model in BIM that indicates the detail information of an element has been developed throughout the project lifecycle. LODs help clarify responsibilities between BIM modelers and support effective coordination, planning and decision-making. Starting from LOD 100 which is conceptual without specific details, LOD 200 adds general plan and size divisions. LOD 300 includes more accurate construction information for analysis and estimation. LOD 350 is used in construction execution by producing shop drawings. LOD 400 is ready for automated fabrication with specific component standards. Finally, LOD 500 is an as-built model for asset management and operations needs. The geometry level of LOD 500 is not necessarily more detailed than LOD 350, as the main difference is the information content of each object (PUPR, 2019).

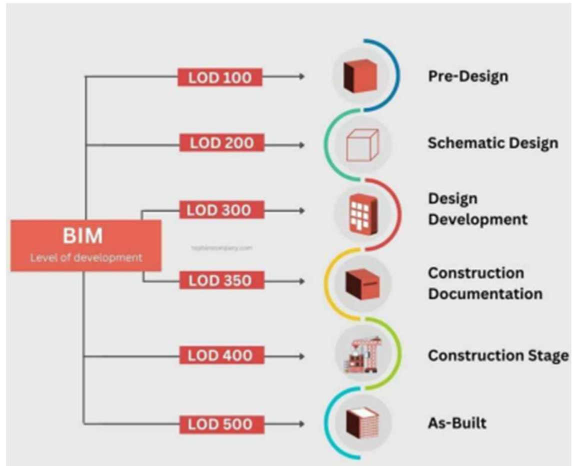


Figure 3. 1 Level of Development in Construction Phase
Source : PUPR (2019)

PUPR (2019) also explained that BIM has various dimensions that illustrate the integration of data in the project lifecycle. The basic dimension is 3D, which is a visual model of the building elements. Furthermore, 4D adds a time element (schedule) to the model, allowing visualization of the construction process from start to finish. 5D integrates the cost aspect, allowing real-time estimation and control of the project budget. In further development, there are also 6D (energy and sustainability), 7D (facility management), and even 8D (safety management), all of which support data driven decision-making throughout the building lifecycle.

Figure 3. 2 BIM Dimensions
Source : PUPR (2019)

The application of BIM in construction provides significant benefits. One of the main benefits is the ability to detect clashes or conflicts between design elements through the clash detection feature, for example between MEP ducts and beam structures (Abdalhameed & Naimi, 2023). In addition, BIM also improves time efficiency by reducing the need for design revisions and re-work on site. With more precise models, projects can be better planned and controlled (Kalajian et al., 2023). BIM also allows clearer visualization for non-technical parties such as project owners, so that all parties can understand the planning results easily.

BIM also acts as a collaborative system that brings together all parties involved in the project, such as architects, structural engineers, contractors and project owners. Through the BIM platform, all parties can work on the same model synchronously, reducing miscommunication and speeding up the coordination process (Sampaio et al., 2023). This collaboration is further supported by the adoption of open BIM, which promotes interoperability across different software through the use of standardized file formats such as Industry Foundation Classes (.IFC) (Farhana & Abma, 2022). The use of .IFC files enables seamless data exchange between various BIM tools, allowing each stakeholder to contribute without being limited by the software they use. Centralized information on one model avoids duplication of documents and conflicts between file versions. This collaboration is especially important in large projects involving multiple disciplines and subcontractors. With BIM, the decision-making process becomes faster and based on actual data.

3.5 4D Building Information Modeling

4D Building Information Modeling (4D BIM) is a development of the BIM concept that integrates a three-dimensional (3D) model with a time element or construction schedule (PUPR, 2019). By adding a time dimension, 4D BIM allows users to see how the project will be built over time, not just its final form. This integration makes it easier to plan site work as all structural elements can be linked to specific activities in the project schedule. Through this approach, information on the sequence of execution, duration of activities, and interrelationships between works can be clearly visualized. This makes 4D BIM a very useful tool in supporting strategic decision-making during the construction process.

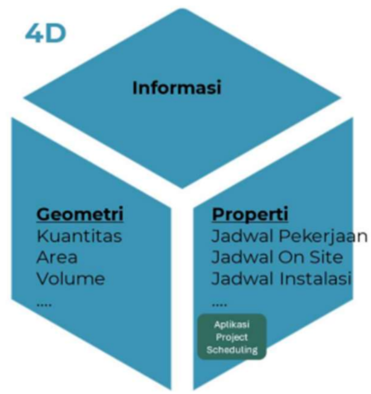


Figure 3. 3 Information Detail of BIM 4D
Source: PUPR (2019)

The main function of 4D BIM is to simulate the work execution sequence so that project stakeholders can understand the flow of activities visually and chronologically. This visualization is very helpful in identifying potential clashes of work, overlaps between activities, and more accurate time estimates (Nechyporchuk & Bašková, 2022). With 4D BIM, project planning can be digitally tested before being implemented in the field, thereby reducing the risk of failure or delay. In addition, 4D BIM can also be used to evaluate project progress on a weekly or monthly basis, which is very useful in reporting and supervision. These functions make 4D BIM an important tool in construction project time management.

In implementing 4D BIM, several stages need to be completed. The process begins with creating a detailed 3D model based on the building design drawings. It ensures that each element, such as foundations, columns, beams, and slabs, is carefully modelled. Once the model is complete, the next step is to export the model using an open BIM format such as Industry Foundation Classes (.IFC) so that it can be used on various BIM platforms. This standardized format enables cross-software collaboration, maintains data consistency, and reduces integration errors (Rubiu et al., 2022).

The next stage following 3D modelling is to perform Quantity Take Off (QTO), which aims to calculate the volume of each modelled structural element. These volume data are then processed to determine the sequence and duration of construction activities based on standard productivity rates or work norms. Once the activity sequence and durations are identified, they are compiled into a time schedule using scheduling software such as Microsoft Project. This schedule is then integrated with the 3D model in BIM software such as Autodesk Navisworks by linking each activity to its corresponding model element (Balakina et al., 2018). Through this integration, a complete 4D simulation of the construction process can be visualized chronologically and interactively.

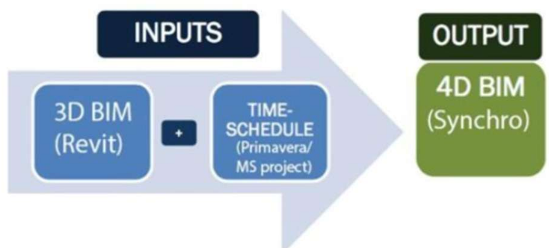


Figure 3. 4 BIM 4D Integration

Source: Balakina et al. (2018)

Mcquaid et al., (2022) described some popular software used in the application of 4D BIM include Autodesk Navisworks, Synchro Pro, and Bentley OpenBuildings Designer. Autodesk Navisworks is widely known for its TimeLiner feature that allows users to link model elements with schedules from Microsoft Project or Primavera. Meanwhile, Synchro Pro has very detailed visualization capabilities as well as more comprehensive scheduling and resource management features. Software selection is usually tailored to the complexity of the project, the level of detail of the model, and the collaboration capabilities of the team. All these tools support interoperability formats such as IFC and NWC that are compatible with various BIM platforms. The comparison of the commonly used 4D BIM software is summarised in Table 3.1 below.

Table 3. 1 Comparison Detail of 4D BIM Software

Software	Overview	Key Features	Best For
Autodesk Revit	Industry-standard BIM tool for design, MEP, structure & documentation	3D modeling, parametric design, collaboration, documentation	Architects, Engineers, Contractors
Navisworks	Coordination & clash detection tool	Clash detection, model aggregation, 4D simulation	Project Managers, BIM Coordinators
Autodesk BIM 360	Cloud-based construction management platform	Document control, issue tracking, and field collaboration	Owners, Contractors, PMs
Tekla Structures	BIM tool focused on structural engineering	Steel/concrete detailing, fabrication-ready models	Structural Engineers, Fabricators
Archicad	Architectural BIM design software	Intuitive design, real-time collaboration (BIMcloud), integrated documentation	Architects
Synchro 4D	4D scheduling and planning platform	Time-linked 3D models, visual scheduling, and progress tracking	Planners, Contractors
Trimble Connect	Cloud platform for BIM coordination and collaboration	Model sharing, task management, and version control	All project stakeholders
Dynamo	Visual scripting tool for Revit	Automation, parametric design, custom workflows	BIM Managers, Computational Designers
SketchUp	Lightweight 3D modeling for concept design	Fast modeling, extensions, and real-time visualization	Designers, Concept Developers
Unreal Engine / Unity	Game engines adapted for BIM visualization & VR	Real-time rendering, VR/AR experiences, stakeholder engagement	Designers, Clients, Marketing
Point Cloud Scanning	Reality capture for existing conditions	3D scans, accurate as-built models, integration with BIM tools	Surveyors, Retrofit Engineers

Source : www.techture.global

Within this landscape, the present study pairs Tekla Structures with Autodesk Navisworks, linked through Microsoft Project. Two considerations drive the choice. First, Tekla Structures is purpose-built for structural detailing, representing every cast unit and reinforcement bar as a discrete object from which quantities can be extracted directly, which suits a study whose schedule is derived entirely from a structural quantity take-off. Second, Autodesk Navisworks reads the Tekla geometry through the open IFC format and its TimeLiner feature accepts the schedule exported from Microsoft Project, so the three applications form an established and interoperable chain from model to quantities to schedule to simulation. Synchro Pro offers comparable 4D capability, but it carries scheduling and resource management features beyond the needs of this study, and the Navisworks route offered the more direct fit with the Tekla model and the Microsoft Project schedule already in use.

In the context of structural works, BIM 4D plays a crucial role in managing the interdependencies between structural elements. For example, the sequence of reinforcing, formwork installation, and concrete casting for columns must be properly synchronized before the construction of beams and slabs can proceed (Muzaffar et al., 2025). Without integrated scheduling, these dependencies often lead to idle time for labor and equipment or even rescheduling on site, which increases project costs and risks. BIM 4D allows project teams to optimize the sequence of structural tasks to minimize idle resources, ensure proper curing time for concrete, and maintain structural stability during each construction stage. Moreover, by providing clear time-based visualization, BIM 4D reduces the possibility of scheduling errors that could affect concrete quality and work safety, particularly in projects with repetitive structural components. Thus, the use of BIM 4D is highly relevant for addressing the inherent complexity of structural work compared to conventional methods.

3.6 Building Structure

Structural work is part of the construction that serves to bear the load and ensure the stability of the building. The main components in structural work are foundations, columns, beams, floor slabs, and other stiffener elements. The main function of the structural system is to safely transfer loads vertically and horizontally to the ground. The type of structure and materials used will determine the quality and durability of the building. Therefore, structural work is a crucial stage that cannot be ignored in the construction process (Turu'allo & Anggara, 2023).

Building structures generally have two major types based on their materials, which are concrete structures and steel structures. Reinforced concrete structures are widely used because they are strong, durable, and have good fire-resistant properties, which are suitable for high-rise buildings (Hostetter et al., 2022).

Meanwhile, steel structures are advantageous in terms of flexibility, speed of installation, and light weight. they are widely used in industrial buildings and modern high-rise buildings (De'Nan et al., 2023). The choice between concrete and steel usually considers the cost factor, implementation time, and building load design. Each type of structure has different characteristics and construction methods, so the planning must be adapted to the needs of the project.

Structural work has a direct connection to the stability and safety of the building. A well-designed structure will be able to withstand earthquake, wind, and live and dead loads from the building itself. Structural failure can cause fatal damage and even collapse of the building, so the safety aspect must be a top priority (Raisinghani et al., 2022). Therefore, structural analysis must be carried out carefully by professionals using appropriate software. This safety aspect is not only important at the design stage, but also in the field implementation process.

In addition to proper design, the implementation of structural works must also follow a systematic sequencing. This sequence includes stages such as casting the foundation first, followed by columns, beams, and slabs in stages from bottom to top (Nagaraja, 2022). Proper sequencing aims to maintain the stability of the building during the construction process and prevent temporary structural failures. In addition, a good sequence of work also improves the efficiency of labor and material usage. If the sequence of work is not observed, it may cause waste of time, cost, and risk of failure of the structure.

3.7 Formwork Area Calculation

Formwork area refers to the surface area of structural elements that requires temporary moulding during concrete placement. Because Tekla Structures models the finished concrete geometry rather than the formwork itself, the contact area of each element is calculated analytically from its cross-sectional dimensions (Ervianto, 2006). The faces requiring formwork differ by element type, a beam or sloof is formed on three faces (two vertical sides and the soffit), a column on all four vertical faces, a slab only on its soffit, and a pile cap on its four vertical sides. The bore pile requires no formwork as the bored hole serves as the mould. The formwork area for a beam or sloof is given by Equation (3.1).

$$A_f = (2h + b) \times L \tag{3.1}$$

where:

A_f = formwork contact area of the element (m²),

h = section height (mm),

b = section width (mm),

L = element length (mm).

For a column with the same section notation and L taken as the column height, all four vertical faces require forming, as given by Equation (3.2).

$$A_f = 2(h + b) \times L \tag{3.2}$$

where:

A_f = formwork contact area of the column (m²),

h = section height (mm),

b = section width (mm),

L = column height (mm).

For a slab, only the soffit requires forming. The formwork area equals the plan area defined by its plan dimensions, as given by Equation (3.3).

$$A_f = p \times l \tag{3.3}$$

where:

A_f = formwork contact area of the slab (m²),

p = slab plan length (mm),

l = slab plan width (mm).

For a pile cap of plan dimensions L and W and height h, the four vertical sides are formed, giving the perimeter multiplied by the height, as given by Equation (3.4).

$$A_f = 2(L + W) \times h \tag{3.4}$$

where:

A_f = formwork contact area of the pile cap (m²),

L = pile cap plan length (mm),

W = pile cap plan width (mm),

h = pile cap height (mm).

All linear dimensions in Equations (3.1) to (3.4) are taken in millimetres; the result is divided by 1,000,000 to convert to square metres. The total formwork area of a pour phase is obtained by summing across all elements in that phase, as given by Equation (3.5).

$$A_{f,total} = \Sigma(A_{f,i} \times n_i) \quad (3.5)$$

where:

$A_{f,total}$ = total formwork area of the pour phase (m^2),

$A_{f,i}$ = formwork area of element type i, calculated from Equations (3.1)–(3.4) (m^2),

n_i = number of identical elements of type i in the pour phase.

3.8 Activity Duration Calculation

The duration of each structural activity is derived by dividing the quantity of work by the productive output of the assigned crew per working day (Ervianto, 2005). The working calendar assumes seven hours per working day and six working days per week, consistent with the Monday-to-Saturday pattern observed on site. For each activity type, the duration formula is given by Equation (3.6).

$$D = \lceil \frac{Q}{P \times n} \rceil \quad (3.6)$$

where:

D = activity duration (working days),

Q = quantity of work (m^2 for formwork, kg for reinforcement, m^3 for concrete),

P = single-worker daily productivity from AHSP CK 2023,

n = number of workers assigned to the activity,

$\lceil\rceil$ = ceiling function — rounds up to the next whole day.

Rounding up is deliberate, any work that spills even slightly into a second day still occupies that full day on site. For a complete pour phase, the reinforcement duration is always shorter than the formwork duration and is absorbed within the formwork window. The controlling phase duration is therefore the formwork duration added to the concreting duration, as given by Equation (3.7).

$$D_{phase} = \lceil D_{fw} \rceil + \lceil D_{co} \rceil \quad (3.7)$$

where:

D_p^{hase} = total pour phase duration (working days),

D^{fw} = formwork activity duration from Equation (3.6) (working days),

D^{co} = concreting activity duration from Equation (3.6) (working days).

CHAPTER IV
RESEARCH METHODOLOGY

4.1 Research Method

This research uses a mixed methods approach that combines quantitative and qualitative methods within a single study. The quantitative component is used to calculate and compare the scheduling duration between the conventional method and the BIM 4D method. Numerical data such as activity durations, weekly progress, and the resulting total duration are analysed systematically and compared against the actual duration recorded on site. The qualitative component is used to describe the modeling and simulation process and to interpret the operational results that the numbers alone do not explain. The qualitative work in this study takes the form of direct observation, document analysis, and interpretation, and it does not involve interviews or questionnaires. Combining the two components is the most appropriate way to answer the research objectives, because the study asks not only how long the structural works take but also why the schedule behaves the way it does.

The quantitative approach aims to provide a clear picture of how efficient the project duration is when the BIM 4D method is used. The analysis compares the schedule produced from the BIM 4D simulation with the conventional S-curve schedule and with the actual duration derived from the project weekly reports. The comparison is carried out by examining the deviation in working days between the three figures. Through this approach the advantages and limitations of each scheduling method can be shown objectively, and the results form the basis of the final conclusions.

The qualitative approach was carried out through three activities. The first is direct observation of the modeling and integration process in Tekla Structures and Autodesk Navisworks, drawn from the researcher's involvement during the internship, through which the workflow was described step by step from 3D modeling to schedule preparation and 4D integration. The second is interpretation of the results, focusing on whether the BIM 4D construction sequence aligns with real construction logic, on identifying which resource governs the duration of the structural works, and on the implications of that sequence for coordination and work efficiency. The third is document analysis, in which the construction sequence assumed in the BIM 4D model was cross-checked against the project weekly reports from W1 to W28 to confirm that the order modeled matches the order actually followed on site. This document-based validation replaces any reliance on personal opinion, so that the qualitative findings remain traceable to recorded project evidence rather than to subjective judgement.

Bringing the two components together produces a more comprehensive and applicable result. The study reports not only the duration figures but also the reasoning and the practical benefits behind them, including the visualization advantage of the 4D simulation. In this way the research addresses both technical precision and practical usefulness, and it focuses not only on the final numbers but also on the modeling and scheduling process that produced them. The methodology as a whole is structured to answer the problem formulation and the research objectives through both an analytical and a practical lens.

4.2 Research Object

The object used in this research is the Gedung Pelayanan Arsip, Universitas Negeri Yogyakarta, DIY. More specifically on structural works such as foundation, sloofs, columns, beam, and floor slabs. The project data can be seen below.

1. Project Name : Pengadaan Pekerjaan Konstruksi Pembangunan Gedung Layanan Arsip Universitas Negeri Yogyakarta in 2024, Sebanyak 1 Paket
2. Project Location : Universitas Negeri Yogyakarta, Jalan Karang Malang, Karang Gayam, Caturtunggal, Kecamatan Depok, Kabupaten Sleman, DIY.
3. Project Costs : Rp. 15.950.000.000, -
4. Source of Fund : Universitas Negeri Yogyakarta
5. Project Owner : Universitas Negeri Yogyakarta

6. MEP Planner : PT. Adji Saka Konsultan
7. Structure Planner : PT. Adji Saka Konsultan
8. Contractor : PT. Heri Jaya Palung Buana
9. Architecture Planner : PT. Adji Saka Konsultan
10. Supervisor Consultants : PT. Hira Permata

The structural works of the project consist of reinforced concrete elements including foundations, columns, beams, and slabs. Based on the project documents, the total number of cast units is 541 elements, with a total concrete volume of approximately 1,209.67 m^3. The planned duration for the structural works was 17 weeks, which reflects the significant scale and sequencing complexity of the project. The project was executed in 2024, with site work commencing on 3 June 2024 and the structural package reaching its final recorded progress in early November 2024. All productivity coefficients used in this study are therefore taken from AHSP CK 2023, issued as SE Dirjen Bina Konstruksi No. 73 of 2023, because it was the standard in force at the time the project was carried out and is consequently the applicable regulation for the duration calculations, regardless of any edition issued after the project period. In addition, the site conditions are relatively constrained, as the building is located within the Universitas Negeri Yogyakarta campus area, resulting in limited space for material storage, worker movement, and equipment access. These conditions make the coordination of structural schedules more challenging and highlight the necessity of applying BIM 4D to optimize sequencing, minimize delays, and improve overall resource utilization..

4.3 Research Location

This research takes a case study located at Jalan Colombo, Karang Malang, Caturtunggal, Kecamatan Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta. This project was located near the Rectorate Office, beside the Museum of Indonesia Education. The location of the project can be seen in Figure 4.1 below.

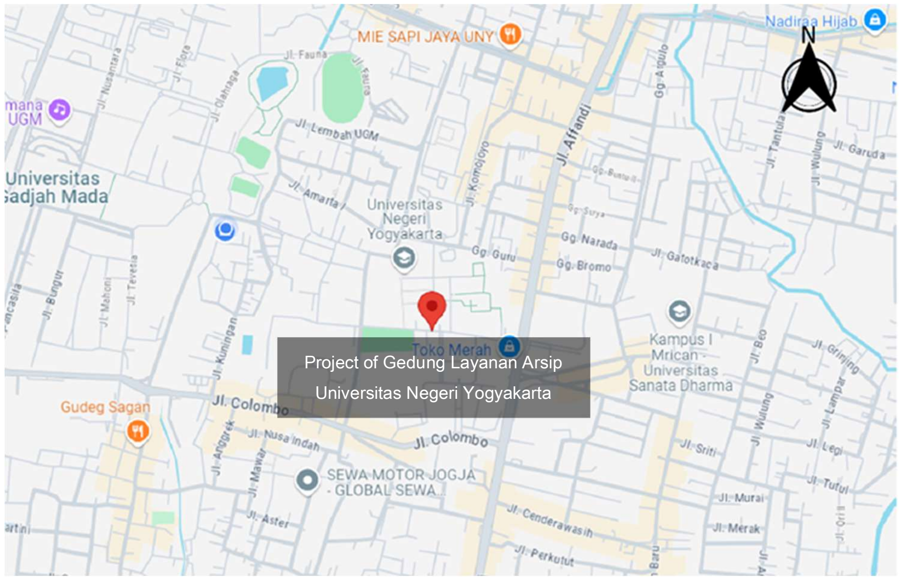


Figure 4. 1 Location of Gedung Pelayanan Arsip UNY
Coordinate 7°46'29.83"S 110°23'12.84"E

Source : Google Maps (2025)

4.4 Data Collection

The data used in this research is secondary data obtained from the construction project of the *Gedung Pelayanan Arsip Universitas Negeri Yogyakarta*. The data was collected by the researcher during the internship and through coordination with the project team. The data collection method was carried out documentatively by collecting project documents that are relevant and needed in the modeling and scheduling process.

The main data used in this study include:

1. Shop drawings (DED - Detailed Engineering Design), which are used as the basis for the 3D structural element modeling process using Tekla Structures software.
2. S-curve, which consists of a bar chart, will be used as a reference for the conventional schedule and as a comparison with the results of the 4D BIM simulation.
3. Project weekly reports (W1–W28), which document the cumulative physical progress of each work package on a weekly basis. The weekly reports serve two purposes in this study. First, they are used to verify that the construction

sequence assumed in the BIM 4D model corresponds to the sequence actually followed on site. Second, the cumulative structural progress recorded in the reports is used to derive the actual structural duration, which provides an empirical benchmark for evaluating the accuracy of both the BIM 4D schedule and the conventional S-curve.

In addition to technical data from the project, researchers also collected additional references through literature studies. This study was conducted by tracing scientific journals, previous theses, reference books, and software usage guides related to Building Information Modeling (BIM), Tekla Structures, and Autodesk Navisworks. This literature data is used to strengthen the theoretical basis, analysis methods, and support the simulation process carried out in the research.

4.5 Supporting Software

In conducting this research, researchers used several supporting software that played an important role in the process of modeling, scheduling, and visual simulation. The selection of applications is tailored to the needs of the research, namely to compare conventional scheduling methods and 4D Building Information Modeling (BIM)-based methods.

The applications used in this research include:

1. Tekla Structures

   Tekla is used to model building structural elements in three-dimensional (3D) form. Modeling is done based on the project working drawings obtained. This software was chosen because it is able to detail structural elements such as beams, columns, plates, and foundations accurately according to design specifications.

2. Microsoft Excel

   Excel was used as an intermediary tool for organizing and refining the results of the Quantity Take Off (QTO). The volume data of each structural element was processed to determine activity durations based on productivity rates. This data was then arranged in tabular form as a basis for scheduling, and later exported into Microsoft Project for further structuring and formatting of the construction timeline.

3. Microsoft Project

   Microsoft Project was utilized to create structured activity schedules based on the QTO results. Activity durations and sequences were arranged logically and exported into a format compatible with Autodesk Navisworks. This step ensured a smooth integration between the time data and the model components during the 4D simulation process.

4. Autodesk Navisworks

   Navisworks was used to integrate the 3D model created in Tekla with the scheduling data compiled from the project S-curves. This software was also used to compile the construction simulation in 4D form, allowing visualization of the sequence of work based on time. The main feature used in this research is TimeLiner.

The use of the three software supports each other in the research implementation process. Integration between platforms was done manually and gradually, adjusting to the export-import format of each application.

4.6 Research Implementation Method

The research stages are arranged systematically and structurally to answer the problem formulation and achieve the research objectives effectively. The research was carried out through the following stages, which can be seen below.

1. Literature Review

   The researcher studied various literature sources, including journals, previous theses, and reference books related to BIM, project scheduling, Tekla Structures, and Autodesk Navisworks. This review served as the theoretical foundation for the research methodology.

2. Data Collection

   The data collected consisted of detailed engineering design (DED) drawings and S-curve from the *Gedung Pelayanan Arsip Universitas Negeri Yogyakarta* Project. These data were used as the basis for structural modeling and scheduling.

3. Modeling and Analysis

A 3D model of the structural elements was created using Tekla Structures. The model was then integrated with the construction schedule in Autodesk Navisworks to produce a 4D visual simulation. After the simulation was completed, a comparative analysis was conducted between the 4D BIM schedule and the conventional schedule in terms of duration and work sequence.

a. 3D Modeling in Tekla Structures

A flowchart of 3D modeling stages is shown below.

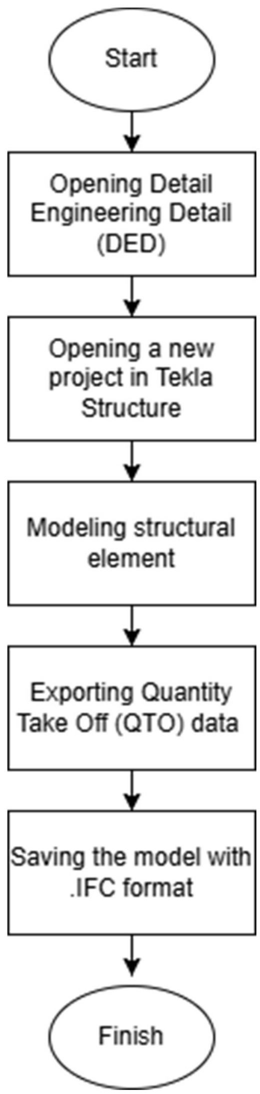


Figure 4. 2 Modeling in Tekla Structure Flowchart

b. Schedule preparation

A flowchart of schedule preparation stages is shown below.

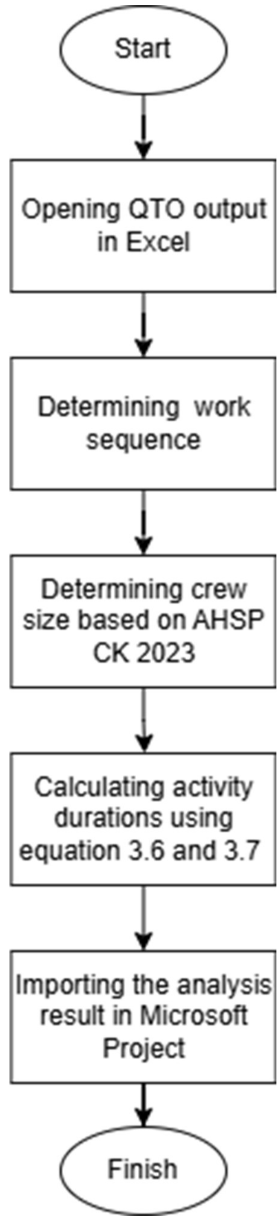


Figure 4. 3 Schedule Preparation Flowchart

c. 4D integration in Autodesk Navisworks

A flowchart of 4D integration stages is shown below.

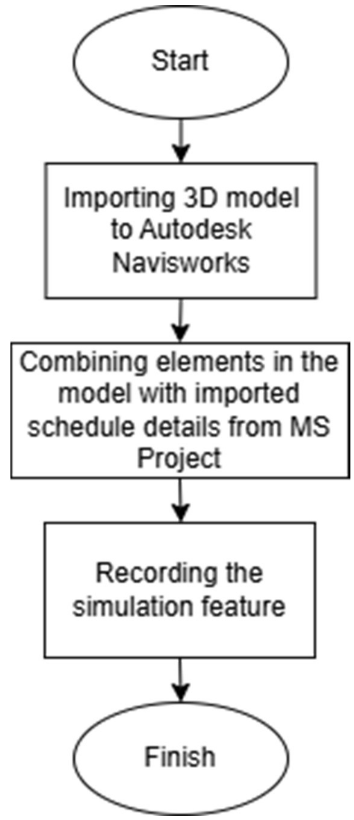


Figure 4. 4 BIM 4D Integration Flowchart

d. Evaluation and Validation Flowchart

A flowchart of evaluation and validation stages is shown below.

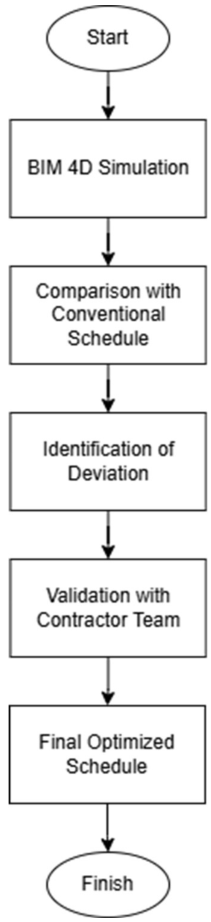


Figure 4. 5 Evaluation and Validation Flowchart

4. Discussion

This stage involved analyzing the results of the 4D BIM simulation and comparing them with the conventional S-curve schedule. The discussion focused on schedule efficiency, visualization clarity, and the potential benefits of implementing 4D BIM in similar future projects.

5. Conclusion and Suggestion

The final stage involved drawing conclusions based on the analysis results and providing recommendations for further development of scheduling methods using BIM technology, particularly in structural work applications.

4.7 Research Flow Chart

In implementing this research, several stages need to be completed. Which can be seen in Figure 4.6 below.

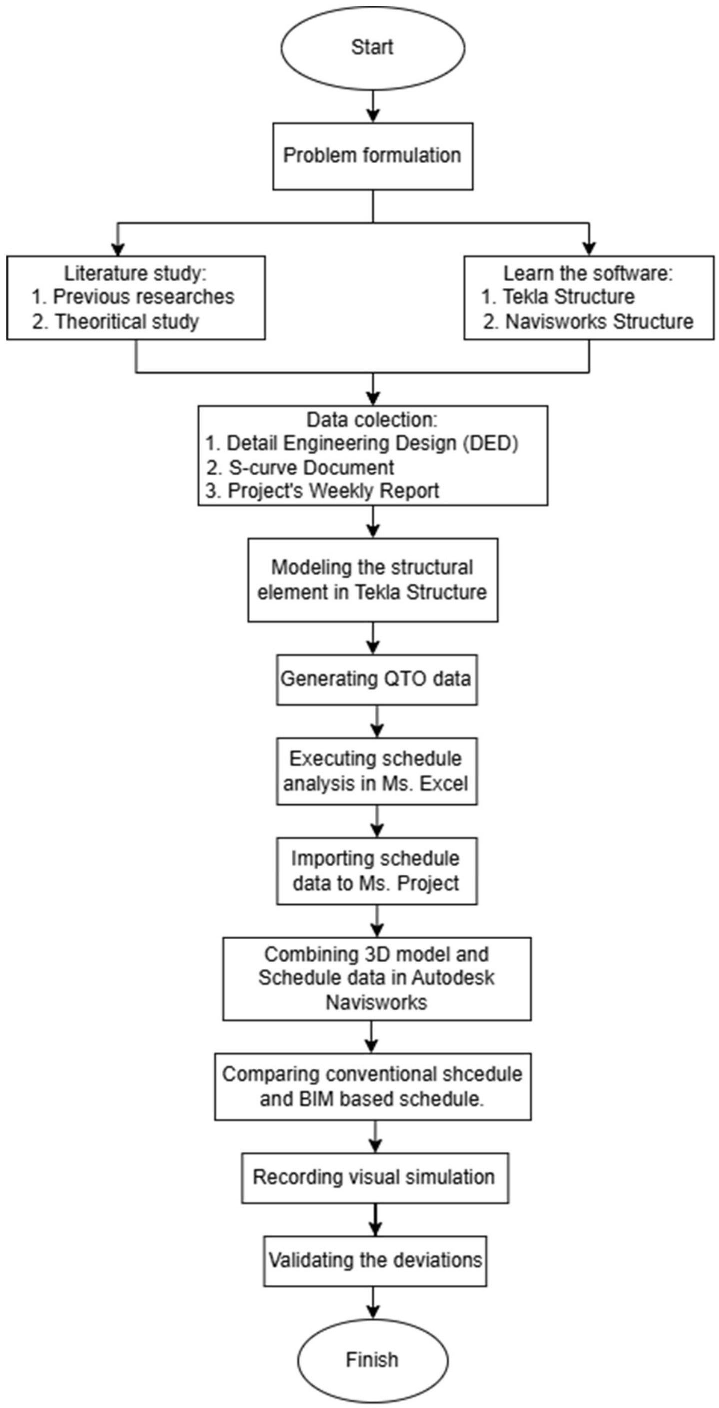


Figure 4. 6 Research Implementation Flowchart

CHAPTER V
ANALYSIS AND DISCUSSION

5.1 General Overview

This chapter reports what came out of the applying the BIM 4D workflow to the structural works of Gedung Pelayanan Arsip Universitas Negeri Yogyakarta. The Discussion is arranged to follow the order in which work was carried out, so that the reasoning can be traced step by step rather than presented as a finished set of numbers. It begins with the project data that fed the analysis, moves into three-dimensional simulation and the comparison between the BIM 4D duration and the conventional schedule recorded on the project S-curve.

Each result is read against three references. The first is the set of standards that govern the calculation, principally the AHSP CK 2023 productivity coefficients. The second is the actual condition of the project, its scale, its site, and its sequence, because a schedule that ignores field reality is of little use. The third is the body of previous studies reviewed in Chapter II, which provide a benchmark for judging whether the figures obtained here are reasonable. The aim throughout is not merely to display quantities but to explain why they came out the way they did, and to be candid about the points where the method shows its limits.

5.2 Research Data

All of the data used in this study were secondary, gathered from the project during the internship period and through coordination with the project team. Four sets of data carried the analysis, which are the general project information, the Detailed Engineering Design, the project S-curve, and the project weekly reports. Each one played a different role in the workflow, and the way they fit together is described in the subsections that follow.

5.2.1 Project Information

The case study is the construction of the Gedung Pelayanan Arsip Universitas

Negeri Yogyakarta, located on Jalan Colombo, Karang Malang, in the Depok district of Sleman, Yogyakarta. The building stands inside the Universitas Negeri Yogyakarta campus, close to the rectorate office and beside the Museum of Indonesian Education. The work was carried out by the contractor PT. Heri Jaya Palung Buana under the supervision of the consultant PT. Hira Permata, with the structural, architectural, and mechanical design prepared by PT. Adji Saka Konsultan. According to the project documents the contract was valued at approximately Rp 15.95 billion, and the structural works were planned to run for seventeen weeks.

It is worth describing the structure in a little detail, because both its physical scale and its site conditions shaped the analysis that follows. The building is a reinforced concrete frame made up of bore pile foundations, pile caps, sloofs, columns, beams, and slabs, topped by a steel roof truss, and it comprises 541 cast units in total. The general information of the project is summarized in Table 5.1.

Table 5. 1 Project General Information

Item	Information
Project Name	Gedung Pelayanan Arsip UNY
Location	Jl. Colombo, Karang Malang, Depok, Sleman, D.I. Yogyakarta
Owner	Universitas Negeri Yogyakarta (UNY)
Contractor	PT. Heri Jaya Palung Buana
Supervising Consultant	PT. Hira Permata
Design Consultant	PT. Adji Saka Konsultan
Contract Value	Rp 15,950,000,000
Total Cast Units (BIM Model)	541 cast units
Total Modeled Concrete Volume	1,148.5 m^3
Total Reinforcement Weight	±143.74 tons
Total Formwork Area	5,406.98 m^2
Planned Structural Duration (S-Curve)	17 weeks (±102 working days)
BIM 4D Structural Duration	127 working days (≈ 22 weeks)
Working Hours per Day	7 hours/day
Working Days per Week	6 days/week (Mon–Sat)
Productivity Reference	AHSP CK 2023 (SE Dirjen Bina Konstruksi No. 73/2023)

Source : Personal Document (2026)

As Table 5.1 shows, the project is of a moderate institutional scale, but the figure that matters most for scheduling is the number of cast units, because each unit eventually has to be placed somewhere in the construction sequence. A second condition that does not appear in any single number is the tightness of the site. Hemmed in by existing campus facilities, the project has limited room for material storage, for the movement of workers, and for equipment access. Constraints of this kind never show up directly in a volume calculation, yet they make the sequencing of structural work harder to manage in practice, and they are exactly the sort of problem a four-dimensional simulation is meant to surface before it reaches the field. This is part of the reason the project was considered a suitable case for a BIM 4D study in the first place.

5.2.2 Detailed Engineering Design (DED)

The Detailed Engineering Design, in the form of the structural shop drawings, was the geometric foundation for everything that followed. The drawings carried the dimensions, elevations, and reinforcement details of every structural member, and they were the only source from which the Tekla model could be built. The structural plan that fixes the column grid and the layout of beams and slabs is shown in Figure 5.1.

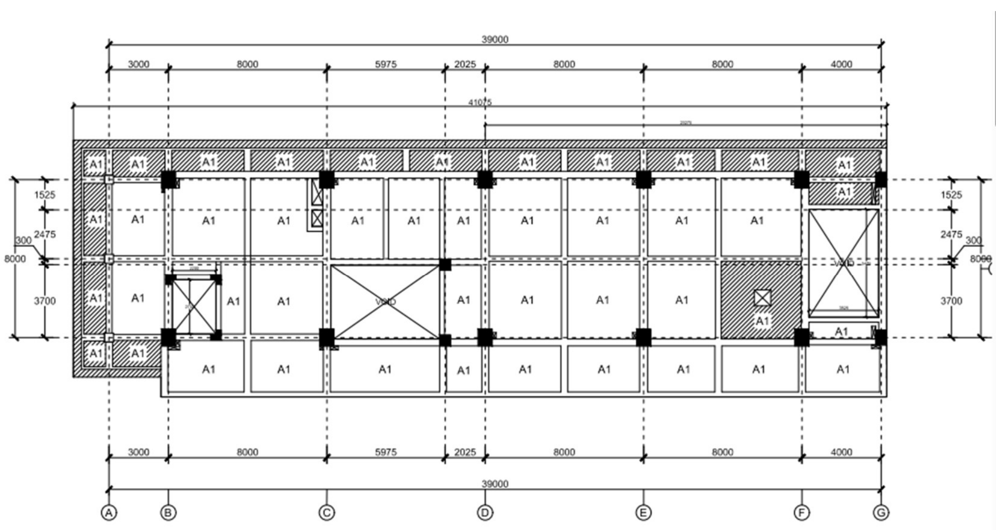


Figure 5. 1 Structural Plan of the Building
Source: PT. Heri Jaya Palung Buana (2024)

The complete set of structural shop drawings that served as the modeling basis is compiled in Appendix 1 The plan in Figure 5.1 establishes the column lines and the span arrangement that were later reproduced as the structural grid in Tekla. Reading the grid carefully at this stage was important, because the same grid governs both the geometry of the model and the division of the floor into work zones used in the schedule. The vertical arrangement of the structure, including the foundation level, the five upper floors, and the roof, is shown in the structural section in Figure 5.2.

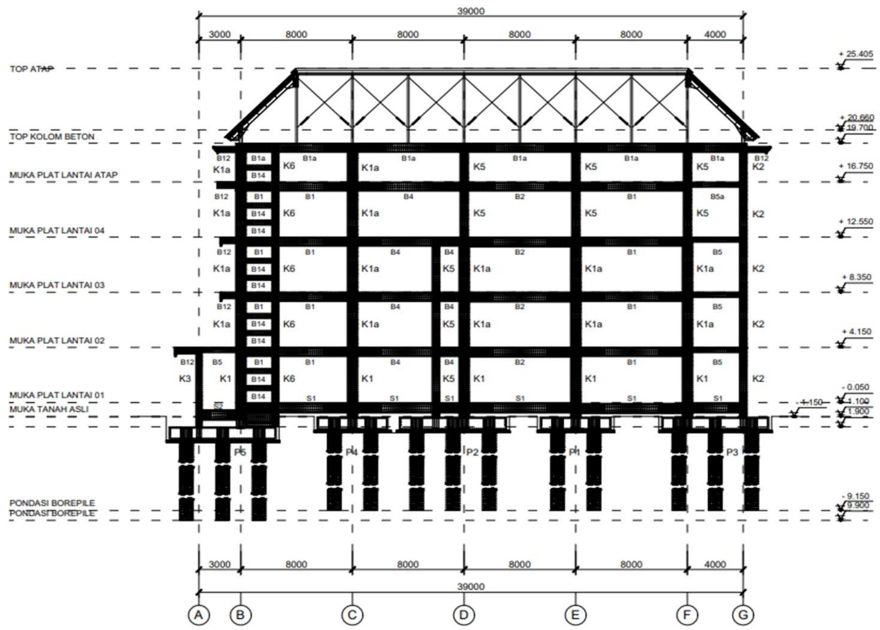


Figure 5. 2 Structural Section of the Building
Source : PT. Heri Jaya Palung Buana (2024)

The section in Figure 5.2 makes the floor-to-floor relationship explicit and confirms the bottom-up dependency that the schedule would have to respect each floor physically rests on the one below it. One of the research limitations is that the model reproduces the original design without modification, so in practice the DED set a hard boundary on the geometry, and nothing was added, removed, or resized. That decision keeps the study honest as a representation of the as-designed structure, but it also ties the quality of the take-off directly to the completeness of the drawings. Any dimension missing from the DED simply could not appear in the model, a point that becomes relevant when the reinforcement data are discussed in Subsection 5.3.2.

5.2.3 S-Curve as the Conventional Schedule

The project S-curve served as the reference for the conventional schedule, against which the BIM 4D result would later be measured. It was issued on 13 May 2024 by the contractor and approved by the supervising consultant, and it expresses the planned progress of the entire building as weighted percentages spread across a twenty-two week execution period, equivalent to 150 calendar days of physical work followed by a 180-day maintenance period. The original S-curve document covering the whole building is reproduced in Figure 5.3.

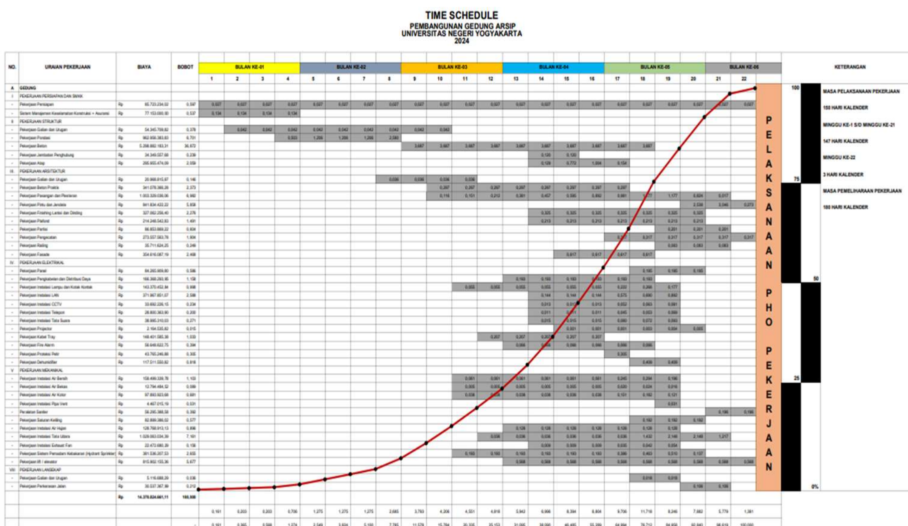


Figure 5. 3 Project Time Schedule (S-Curve) for the Whole Building
Source : PT. Heri Jaya Palung Buana (2024)

A full-resolution copy of the approved time schedule is provided in Appendix 2 for detailed inspection of the package weights. Figure 5.3 captures the whole building, not just the structure, so the first task was to lift the relevant packages out of it. The structural packages are the foundation, the concrete works, and the roof. Their weights, and the span of weeks over which each is distributed in the curve, are collected in Table 5.2.

Table 5. 2 Structural Work Packages and Their Weights from the S-Curve

No.	Work Package	Contract Value	S-Curve Span
1	Earthwork & Site Preparation	37,860%	Weeks 1–3
2	Foundation Works	67,076%	Weeks 2–7
3	Concrete Works (Superstructure)	36,8720%	Weeks 5–15
4	Steel Roof Structure	20,615%	Weeks 13–17
	Total Structural Packages	**~46.25% of contract value**	**Weeks 1–17**

Source : PT. Heri Jaya Palung Buana (2024)

The figures in Table 5.2 carry an important message about where the project's time and money really sit. Taken together the structural packages account for roughly 46.25 percent of the total contract weight, and the concrete works alone carry 36.872 percent, which is by a wide margin the single heaviest item in the entire schedule. In other words, the structural concrete is not just one work package among many. It is the dominant driver of the whole project. That dominance is precisely what justifies concentrating the 4D analysis on the structural works rather than spreading it thinly across every trade, and it also explains why even a modest difference in how the structural duration is calculated has a large effect on the apparent length of the project.

5.2.4 Project Weekly Report

The project weekly reports covered the full execution period from Week 1, the period of 3 to 9 June 2024, through to Week 28, and recorded on a rolling basis how the work progressed against the planned programme. Each report contains a cumulative physical progress table, in which every work package is assigned a percentage weight against the total contract value and the realised completion to date is stated for each week. For the structural package, which carries a total weight of 46.297 percent of the contract, the reports therefore provide a week-by-week record of how much of the structural works had been executed up to that point in the project.

In this study the weekly reports serve two distinct purposes, and it is important to state both here so that the way they appear later in the analysis is not a surprise. The first purpose is sequence verification. The BIM 4D schedule is built on the assumption that the structure was erected in a specific order, foundation first, then columns, beams, and slabs floor by floor, and the steel roof truss last. Before committing to that sequence in the model, the reports were read to confirm that the field team followed it. The reports confirmed what was expected: the structure went up from the bottom, starting with the bore piles and pile caps, then climbing floor by floor through the reinforced concrete elements, and finishing with the steel roof truss. Because the realised sequence and the assumed sequence agreed, the planned sequence could be carried into the model with confidence, and the comparison drawn later in Section 5.4 rests on a construction logic that the site followed.

The second purpose is duration validation. The cumulative progress figures in the weekly reports make it possible to determine when the structural package reached its final recorded completion on site, and therefore how long the structural works took from project start to structural finish. This realised duration provides an empirical benchmark that neither the conventional S-curve nor the BIM 4D schedule can supply by itself, since both are planned durations rather than measured outcomes. The comparison between the three figures, planned by the S-curve, predicted by the BIM 4D schedule, and realised on site as read from the weekly reports, is developed in Section 5.4 and forms one of the principal means of evaluating the accuracy of the two scheduling approaches.

Because the weekly reports are internal project documents that have not been released for public distribution, they are not reproduced as an attachment to this thesis. Their key data points are instead summarised in Table 5.3 below, which extracts the cumulative structural progress at ten milestone weeks selected to show the rate of advance, the point at which the S-curve target passed without structural completion, the commencement of the steel roof truss, and the week in which the structural package reached its final recorded value. The complete weekly report series is available for review upon request and was examined in full by the researcher to produce this summary. The full week-by-week cumulative structural progress underlying this summary is tabulated in Appendix 3

Table 5. 3 Structural Works Cumulative Progress at Key Milestones Extracted from Weekly Reports W1–W28

Weekly Report	Period	Structural Cumulative	Key Event
W1	3–9 June 2024	0.000%	Project commencement; site preparation and bored pile installation begin
W5	1–7 July 2024	5.561%	Concrete structural works begin (pile cap and sloof)
W10	5–11 August 2024	21.065%	Second floor structural works under way
W14	2–8 September 2024	33.008%	Fourth floor structural works under way
W17	23–29 September 2024	35.889%	S-curve planned structural completion (Week 17 target)
W18	30 Sep–6 October 2024	35.889%	No structural progress recorded; roof truss not yet commenced
W19	7–13 October 2024	39.361%	Steel roof truss erection commences
W20	14–20 October 2024	40.451%	Roof truss erection continues
W21	21–27 October 2024	41.374%	Roof truss erection continues
W22	28 Oct–3 November 2024	42.527%	Structural works reach final recorded progress — structural completion

Source : PT. Heri Jaya Palung Buana (2024) Unpublished Project Document

Table 5.3 reveals the two features of the structural execution that matter most for the comparison in Section 5.4. First, the cumulative progress held flat between Week 17 and Week 18 at 35.889 percent of the contract weight, meaning the site reached the end of the S-curve's structural window with the roof package untouched. Second, the roof truss erection that the S-curve had planned within the same seventeen-week window did not begin until Week 19 and extended through to Week 22, the week ending 3 November 2024, at which point the structural package reached its final recorded cumulative progress of 42.527 percent. The duration implied by this record, from the project commencement on 3 June 2024 to the structural completion on 3 November 2024, spans 154 calendar days, equivalent to approximately 132 working days at six days a week. This figure is the empirical benchmark against which the two scheduling methods are compared in Section 5.4.

Table 5.3 differs from the planned picture in Table 5.2 in two respects, and both deserve to be stated plainly. The first is timing. The plan placed structural completion at Week 17, while the site reached it only at Week 22, and this difference has been narrated above and is quantified in Section 5.4. The second is weight, and it requires its own note, because the final cumulative figure in Table 5.3 does not coincide with the planned structural weight in Table 5.2. The S-curve assigns the structural packages a combined planned weight of about 46.25 percent of the contract value, while the weekly reports record a final structural cumulative of 42.527 percent. The two figures measure different things. The first is the weight the packages were planned to carry in the approved schedule, while the second is the progress actually recorded and approved for the work executed on site. During execution the realised quantities of several structural elements did not match the shop drawings exactly, a condition observed directly during the researcher's involvement on the project, and progress in the weekly reports is recorded against the quantities actually installed and approved rather than against the planned weights. Adjustments of this kind are a normal condition of a live project, so the gap of roughly 3.7 percentage points is read here as a project condition rather than as an error in data processing. For the purpose of this study the discrepancy has no effect on the duration benchmark, because the actual structural duration is determined by the week in which the structural package reached its final recorded value, not by the absolute magnitude of that value.

5.3 Data Analysis

The data analysis is the stage that turned the project documents into the quantitative inputs the schedule needed. It runs through eight steps, beginning with the three-dimensional model and ending with the four-dimensional simulation. The earlier steps are concerned with geometry and quantities, the later ones with sequence, resources, duration, and integration. Each step is treated in its own subsection, and together they form an unbroken chain in which the output of one becomes the input of the next. The model produces the quantities, the quantities and the sequence produce the durations, and the durations and the geometry produce the simulation.

5.3.1 3D Structural Modeling Using Tekla Structures

Modeling was the necessary first move, because without an accurate model there is no reliable quantity take-off and no geometry to attach to the schedule later. The model was built in Tekla Structures by working through the DED drawing by drawing, following the stages set out in the methodology. The subsections below describe how the model came together, from the empty project file to the finished structure, and present the model of each structural element as it was developed. Because reinforced concrete elements were modeled both as concrete bodies and as reinforcement, most elements are shown twice, once for the concrete and once for the reinforcement, since these are exported separately in the take-off.

The work began by opening a new model in Tekla Structures and configuring it for a metric environment, so that every dimension, material grade, and profile would be expressed in the units used in the drawings. The startup interface and the new-model configuration are shown in Figure 5.4.

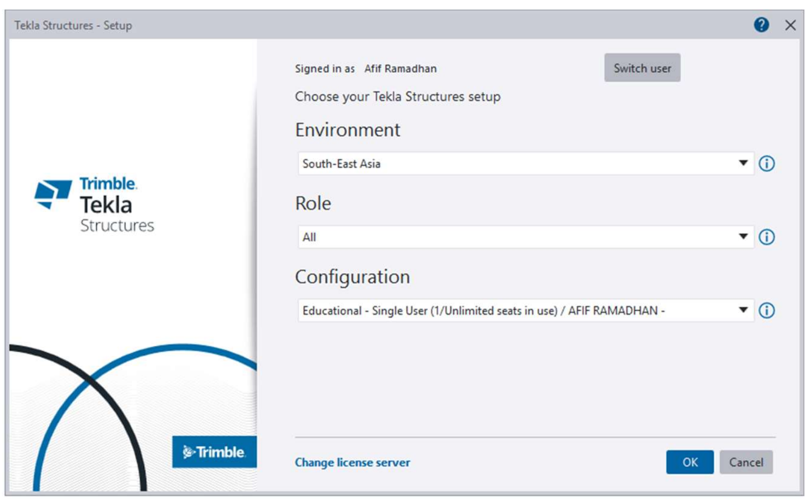


Figure 5. 4 Initial Interface of Tekla Structures
Source : Personal Document (2026)

Getting the environment right at the point shown in Figure 5.4 matters more than it appears, because an environment mismatch propagates quietly into every quantity drawn from the model afterwards. A model built in the wrong unit system can look entirely correct on screen and still yield volumes that are off by orders of magnitude. With the environment fixed, the column and beam axes from the DED were laid down as a structural grid, shown in Figure 5.5.

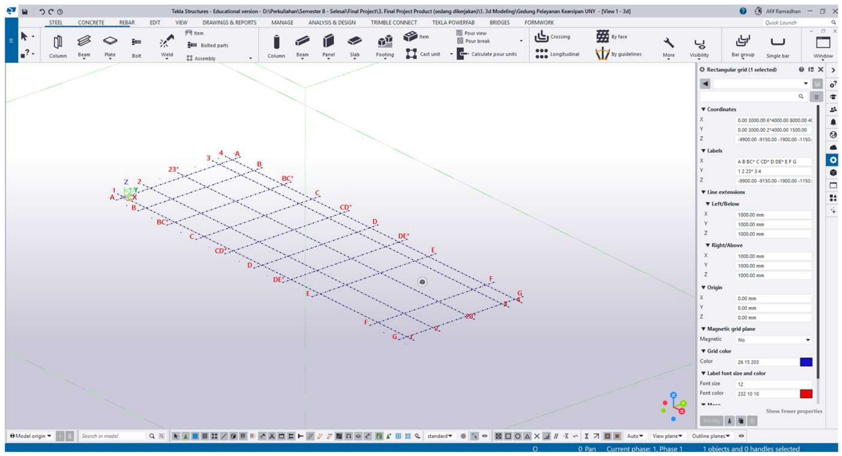


Figure 5. 5 Creation of the Structural Grid
Source : Personal Document (2026)

The grid in Figure 5.5 acts as the spatial skeleton for everything that follows. Every member modeled afterwards was snapped to this grid, which is what kept elements created at different times correctly aligned with one another, and it is also the reference against which the floor was later divided into work zones. To make modeling manageable, plan and elevation views were then generated along the grid lines, as shown in Figure 5.6.

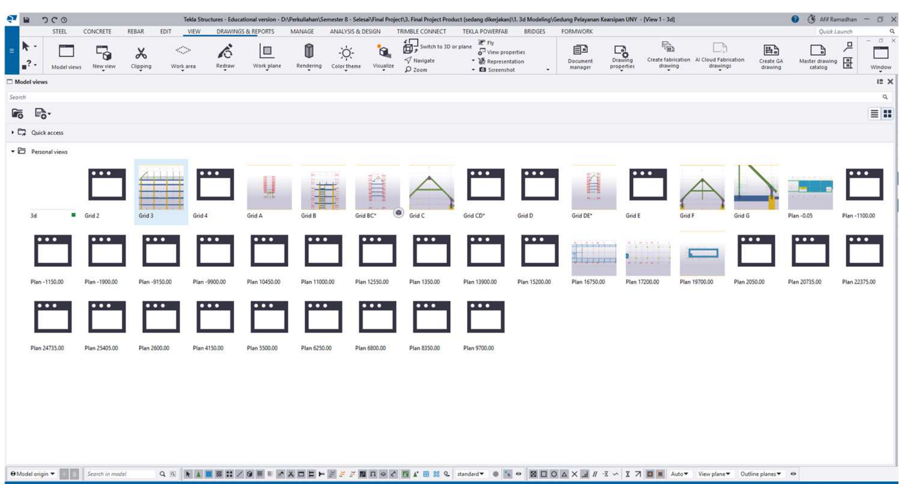


Figure 5. 6 Generation of Model Views Based on the Grid
Source : Personal Document (2026)

Working view by view, as in Figure 5.6, rather than in a single crowded three-dimensional window, made it far easier to catch geometry errors early and to model each floor and each axis on its own terms. With the working environment, the grid, and the views in place, the modeling of the structural elements could begin, starting from the lowest level of the structure and moving upward in the same order the building would be constructed.

The foundation was modeled first. The bore piles and pile caps were placed at the elevations given in the DED, beginning with their concrete bodies, as shown in Figure 5.7.

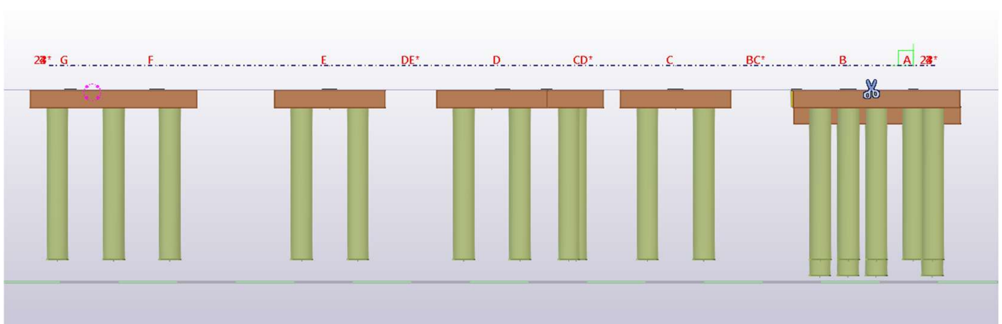


Figure 5. 7 Concrete Model of the Bore Pile and Pile Cap
Source : Personal Document (2026)

The foundation elements in Figure 5.7 are the heaviest concrete members in the building, and as the base on which the entire sequence depends they were given careful attention. Once the concrete bodies were in place, their reinforcement was modeled, shown in Figure 5.8.

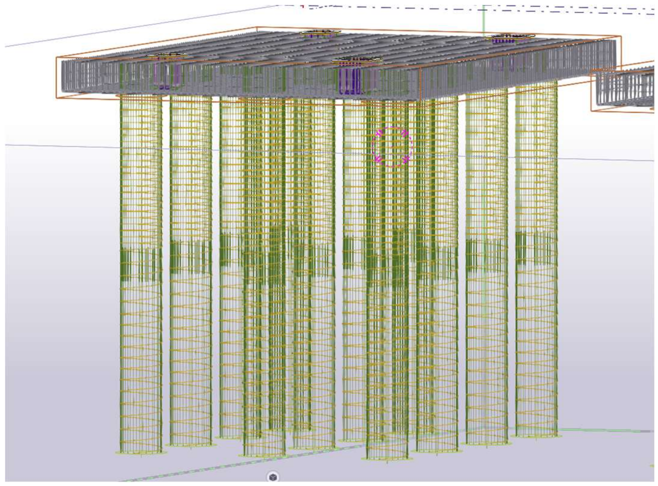


Figure 5. 8 Reinforcement Model of the Bore Pile and Pile Cap
Source : Personal Document (2026)

The reinforcement in Figure 5.8 is dense, particularly in the bore pile cages, and this density is the reason a comparatively large ironworker crew was later assigned to the foundation reinforcement. With the foundation complete, the columns were modeled next, story by story, beginning with their concrete bodies as shown in Figure 5.9.

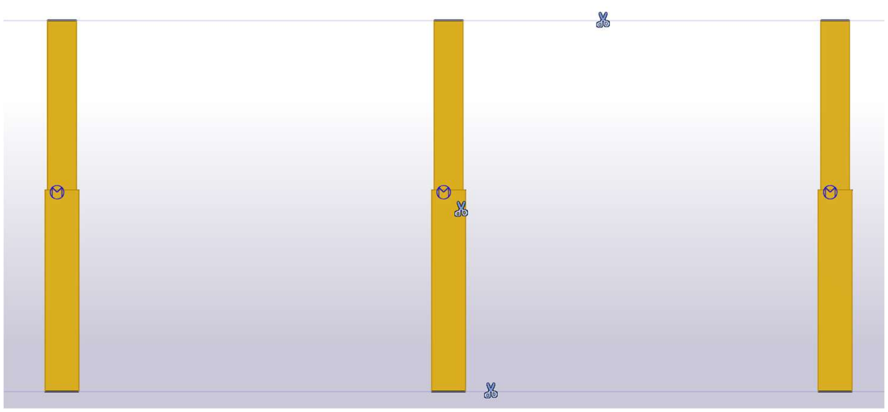


Figure 5. 9 Concrete Model of the Columns
Source : Personal Document (2026)

A detail visible in Figure 5.9 is that the column cross-sections shrink toward the upper floors, following the design, because the axial load they carry falls off as the building rises. The model reproduces this taper rather than assuming a single column size throughout, which keeps the column volume realistic floor by floor.

The column reinforcement was then added, as shown in Figure 5.10.

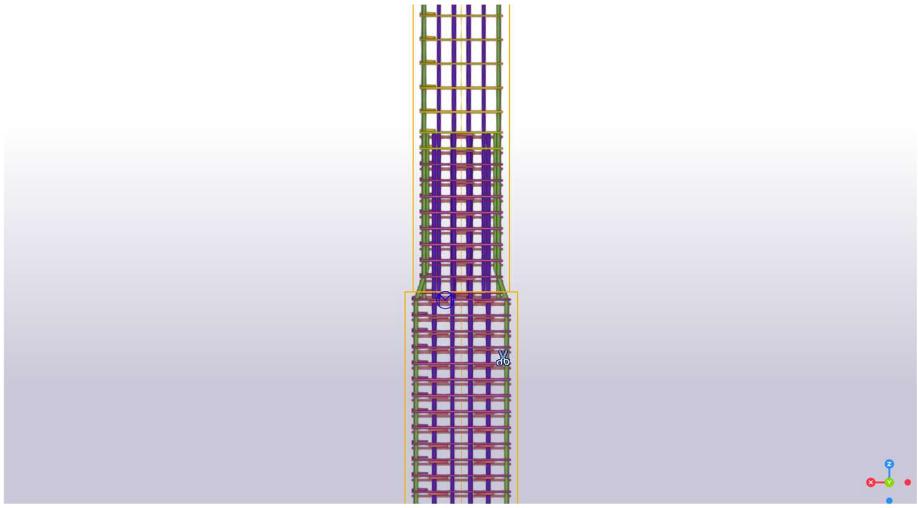


Figure 5. 10 Reinforcement Model of the Columns
Source : Personal Document (2026)

The reinforcement shown in Figure 5.10 is concentrated, and although the column rebar tonnage is high relative to the small concrete volume of each column, the reinforcement work is not what governs the column phase duration, as the duration analysis later shows. After the columns, the beams were modeled, beginning with their concrete bodies in Figure 5.11.

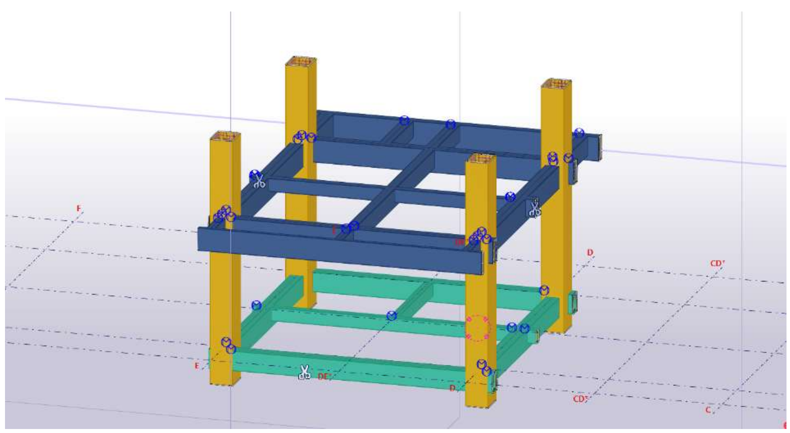


Figure 5. 11 Concrete Model of the Beams and Sloofs
Source : Personal Document (2026)

The beams and sloofs in Figure 5.11 are the members that tie the columns together and carry the slabs, and because of their length they contribute a large formwork contact area, a fact that turns out to dominate the schedule. Their reinforcement, comprising longitudinal bars and stirrups, was modeled next, as shown in Figure 5.12.

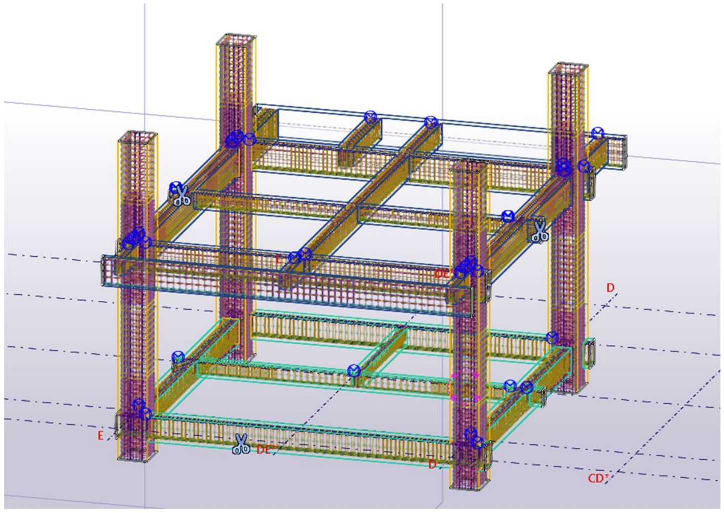


Figure 5. 12 Reinforcement Model of the Beams and Sloofs
Source : Personal Document (2026)

The reinforcement in Figure 5.12 was modeled per span so that it could be associated with the correct pour phase later. With the beams in place, the floor slabs were modeled as area objects framed by the surrounding beams, shown in their concrete form in Figure 5.13.

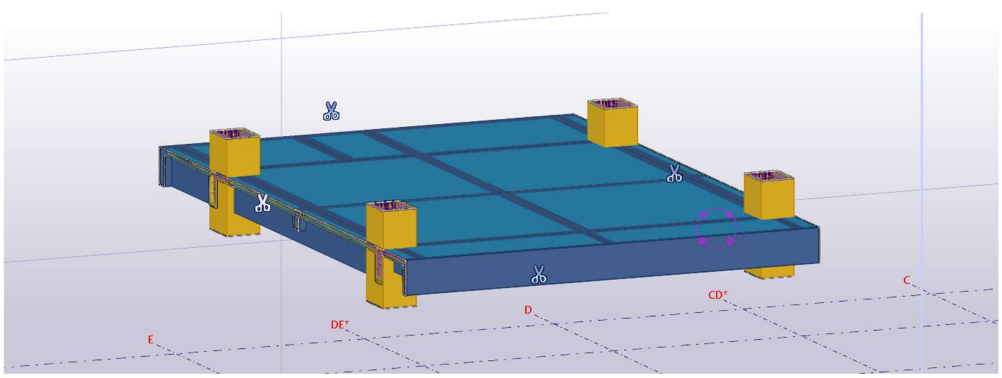


Figure 5. 13 Concrete Model of the Slabs
Source : Personal Document (2026)

The slabs in Figure 5.13 have a wide, flat geometry, which is the reason their formwork and concreting crews were later sized a little larger than those for the beams. A large horizontal surface genuinely takes more hands to form, to place, and to finish. The slab reinforcement, lighter per unit area than the beam steel, was modeled as shown in Figure 5.14.

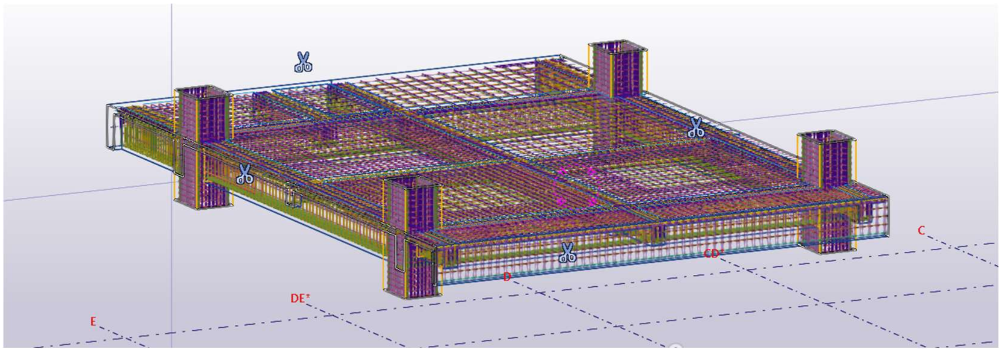


Figure 5. 14 Reinforcement Model of the Slabs
Source : Personal Document (2026)

The lighter slab reinforcement seen in Figure 5.14 is reflected in the AHSP coefficient used for it, which assumes a higher productivity than the heavier bar work in beams and columns. Finally, the roof was modeled in steel rather than concrete, including its trusses, purlins, pedestal columns, and bracing, as shown in Figure 5.15.

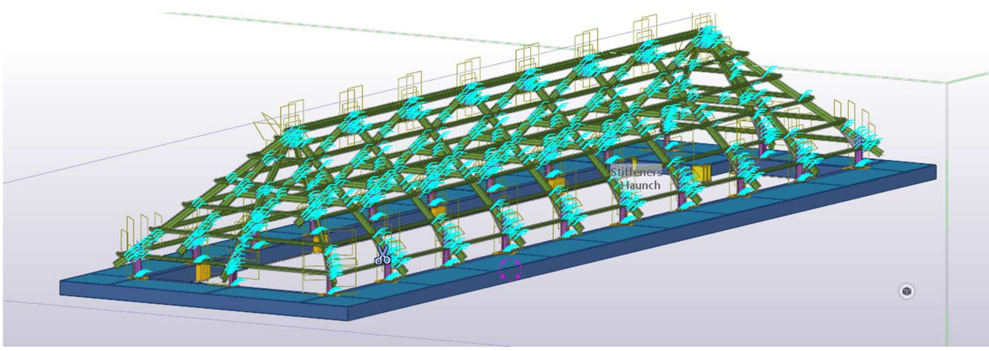


Figure 5. 15 Model of the Steel Roof Truss
Source : Personal Document (2026)

As the only steel work package in the structure, the roof truss in Figure 5.15 follows a different fabrication-and-bolting logic from the concrete elements and sits at the very end of the construction sequence, dependent on the completion of the topmost concrete floor. With every element modeled, the complete structure was assembled into a single coordinated model, shown in Figure 5.16.

Figure 5. 16 Final Complete 3D Structural Model
Source : Personal Document (2026)

The finished model in Figure 5.16 integrates all of the reinforced concrete and steel work into one assembly of 541 cast units. This model is the single source from which both the quantity take-off and the four-dimensional simulation were later drawn, so its accuracy underwrites every result that follows. Having confirmed that the geometry matched the DED, the next step was to extract the quantities the schedule would be built from.

A word should be said about the level of development of the model, because it determines what the model can and cannot be used for. The structural elements were modeled with their true geometry and with their reinforcement, which places the model at roughly the level of development reported in comparable studies such as Salman & Hamadeh (2023), who worked at LOD 200. For the purpose of this study that level is sufficient and, in fact, appropriate. The model carries enough geometric and quantity information to drive an accurate take-off and a credible schedule, without the fabrication-level connection detailing that a higher level of development would add and that a scheduling study does not need. Modeling beyond what the analysis requires would have consumed time without improving the result, so the level of development was matched deliberately to the purpose.

5.3.2 Quantity Take-Off Extraction

Once the model was complete, the quantities were pulled directly out of it rather than measured by hand from the drawings, which is the central advantage of working in BIM. Tekla generates these quantities through its report function, using templates that read the model and return the volumes and weights of the selected elements. The report menu and the template selection used for the extraction are shown in Figure 5.17.

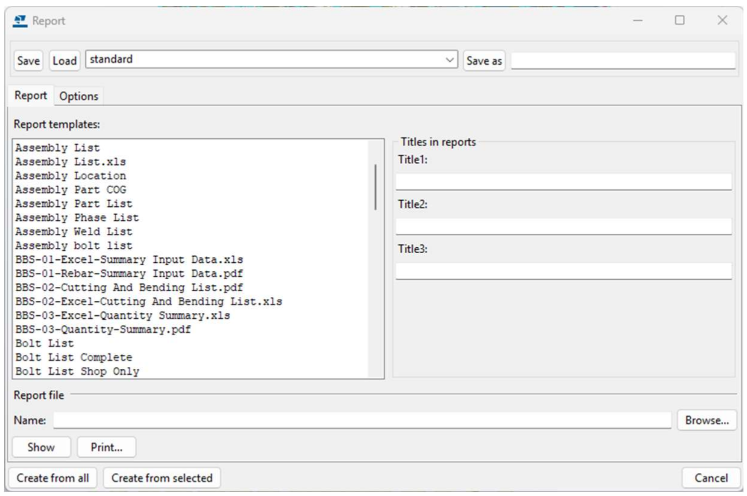


Figure 5. 17 Report Menu and Template Selection in Tekla Structures
Source : Personal Document (2026)

Two outputs mattered for this study, and both were generated from Tekla Structures Report and Organizer. The first is the concrete body of each member, read from Organizer, and the second is the reinforcement, read from BBS Sumary Input Data. In each case the elements were selected per pour phase before running the report, so that the quantities could be tied back to the schedule zones rather than arriving as a single undifferentiated total. The concrete output produced by the Organizer is shown in Figure 5.18.

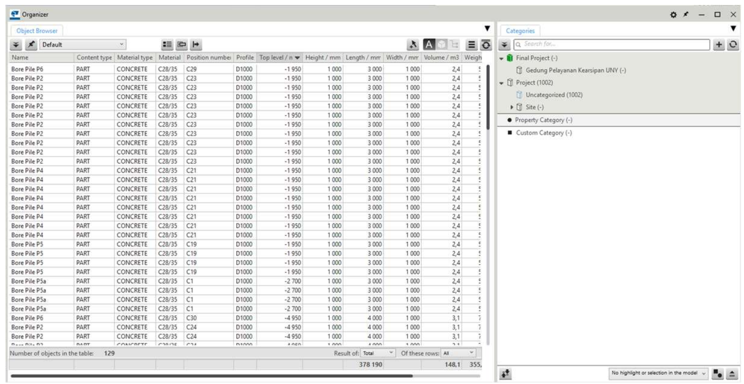


Figure 5. 18 Quantity Output for Concrete Elements
Source : Personal Document (2026)

The concrete output in Figure 5.18 returns the volume of each cast unit directly in cubic meters, which can be summed per element type and per zone without further conversion. The reinforcement output, obtained from the BBS Summary Input Data exported to an Excel file, is shown in Figure 5.19.

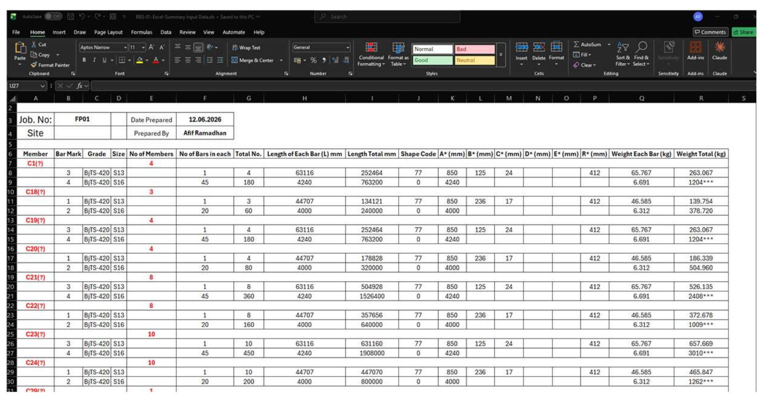


Figure 5. 19 Quantity Output for Reinforcement
Source : Personal Document (2026)

The reinforcement output in Figure 5.19 returns the weight of steel in kilograms, again traceable to individual elements. The complete concrete-volume and reinforcement take-off reports exported from Tekla Structures are presented in Appendix 4. Two practical issues came up during this extraction and are worth recording honestly, because they affected the effort involved even though they did not change the totals. The first is that the reinforcement data did not sit neatly inside the standard quantity export template. The rebar had to be drawn through a separate cast unit rebar export and then recapitulated per pour phase by hand. The second is that several elements in the model carried position numbers that had not been formally assigned, appearing as unconfirmed entries, which meant they had to be checked manually before their quantities could be attributed to the correct phase. Neither of these is a data error in the strict sense, they are configuration shortcomings in the model. They are recorded here because they are exactly the kind of issue a later researcher would want to resolve at the modeling stage rather than the extraction stage, and this point is taken up again in the recommendations.

5.3.3 Formwork Area Calculation

Among the three quantities that drive the structural activity durations, two come straight out of the model which are the concrete volume and the reinforcement weight, both read directly from the Tekla cast unit and rebar reports. The third quantity, the formwork contact area, does not. This is an important methodological point and it is the reason the formwork area is treated in its own subsection before the quantities are recapitulated. The formwork area matters not only because it feeds the duration calculation but because it is the basis on which the BIM 4D schedule is later compared with the conventional plan. If the formwork quantity were unreliable, the whole comparison would be too.

Tekla Structures cannot generate a formwork contact area from the structural geometry on its own. The structural model represents the finished concrete and steel members, not the temporary moulds that shape them, so to obtain a true formwork quantity from the software the formwork itself would have to be modeled as a separate set of objects wrapped around every beam, column, slab, and pile cap. Building that secondary model for 541 cast units would have consumed a large amount of time for a quantity that, in the end, is a simple function of the concrete dimensions. To keep the work within the time available for the study, the formwork area was therefore not modeled separately but calculated directly from the element dimensions already obtained in the quantity take-off, applying a standard formwork rule to each element type. This is a deliberate scope decision, and its consequences for accuracy are discussed at the end of this subsection.

Formwork of a member is the area of the surface that have to be moulded, which depends on the element type and on which of its surface are cast against forms and which are not. The surfase that require formwork for each structural element type are illustrated in Figure 5.20.

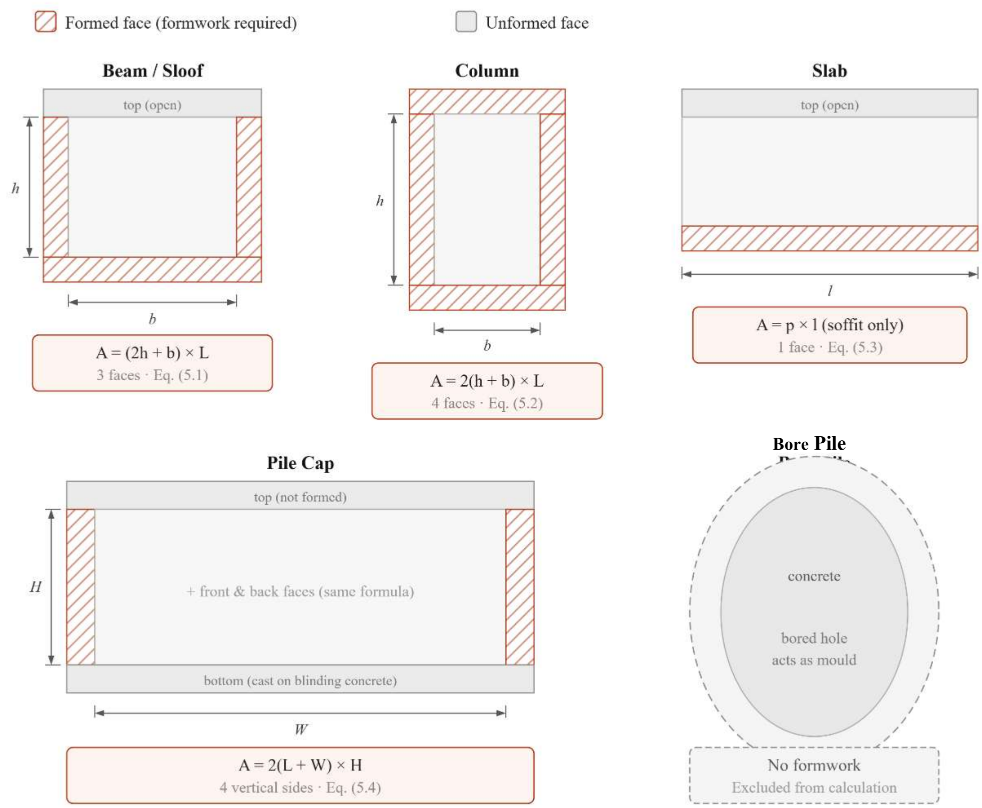
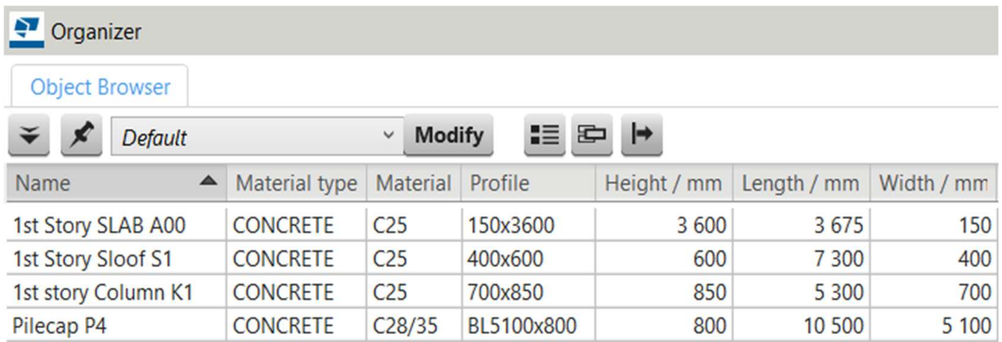


Figure 5. 20 Illustration of Formed Faces per Structural Element Type
Source : Generated by Claude.Ai (2026)

As Figure 5.20 shows, a beam is formed on three faces, its two sides and its soffit, while its top is left open because the slab is cast over it, a column is formed on all four of its vertical faces, a slab is formed only on its soffit, the underside that needs support during casting, and a pile cap is formed on its four vertical sides with no top or bottom formwork. The bore pile is the one element with no formwork at all, because it is cast directly into the bored hole in the ground, which acts as its own mould. Applying the formwork area equations established in Section 3.7 which are Equations (3.1) to (3.4) for individual elements and Equation (3.5) for the phase total. The contact area of each structural element was computed from its cross-sectional dimensions as exported from the Tekla model and summed per pour phase.The element dimensions that feed these equations are the same height, length, and width values exported from the Tekla model for the concrete take-off, an example of which is shown in Figure 5.21.



Name	Material type	Material	Profile	Height / mm	Length / mm	Width / mm
1st Story SLAB A00	CONCRETE	C25	150x3600	3 600	3 675	150
1st Story Sloof S1	CONCRETE	C25	400x600	600	7 300	400
1st story Column K1	CONCRETE	C25	700x850	850	5 300	700
Pilecap P4	CONCRETE	C28/35	BL5100x800	800	10 500	5 100

Figure 5. 21 Element Dimensions (H, L, W) Exported from Tekla Structures
Source : Tekla Structure (2026)

Using the dimensions shown in Figure 5.21, the calculation can be demonstrated on a single element. Taking a first-storey sloof of section height 600 mm, section width 400 mm, and length 7,300 mm, Equation (3.1) gives a formwork area of $(2 \times 600 + 400) \times 7{,}300 = 1{,}600 \times 7{,}300 = 11{,}680{,}000$ mm², which is 11.68 m² after conversion. Repeating this for every beam, column, slab, and pile cap, and summing per pour phase with Equation (3.5), yields the formwork area of each phase. The full element-by-element calculation, organized by pour phase and element type, is presented in Appendix 5. The recapitulation can be seen in Table 5.4 below.

Table 5. 4 Formwork Area Calculation per Structural Element

No.	Structural Element	Formula Applied	Formwork Area (m²)	Percentage
1	Pile Cap	$A = 2(L + W) \times H$	437,10	8.1%
2	Sloof	$A = (2H + W) \times L$	214,69	4.0%
3	Column	$A = 2(H + W) \times L$	990,29	18.3%
4	Beam	$A = (2H + W) \times L$	2.152,12	39.8%
5	Slab (Floor Plate)	$A = p \times l$	1.612,78	29.8%
6	Bore Pile	(no formwork)	—	—
		TOTAL	**5.406,98**	**100.0%**

Source : Personal Document (2026)

The calculation summarized in Table 5.4 produces a total formwork contact area of 5,406.98 m² for the whole structure, of which the beams and sloofs contribute the largest share at about 2,366.81 m², followed by the slabs at 1,612.78 m², the columns at 990.29 m², and the pile caps at 437.10 m². This distribution is itself worth noting, because the dominance of the beam and slab formwork in the total foreshadows the finding, developed later, that formwork governs the duration of the superstructure. The formwork area are carried forward together with the concrete and reinforcement quantities into the recapitulation that follows.

It is important to be candid about what this approach does and does not capture, since the choice not to model the formwork separately is a simplification. The equations assume that formwork follows the concrete geometry exactly, and they do not account for construction joints, for the overlap or splicing of formwork panels, for waste, or for the additional forming sometimes required at openings and irregular junctions. For the purpose of this study, which is scheduling rather than formwork procurement, this level of accuracy is acceptable to the durations depend on the order of magnitude of the contact area and on its relative distribution between elements, both of which the method captures faithfully. A study aimed at material take-off or formwork cost would need the separate formwork model that was deliberately set aside here, and this is noted again among the recommendations as a possible extension of the work.

5.3.4 Recapitulation of the Quantity Take-Off

The extracted quantities were organized in Microsoft Excel into the three work packages that drive structural activity durations: concrete volume, reinforcement weight, and formwork area. Recapitulating them this way, rather than leaving them as a raw export, is what makes them usable for scheduling, because each activity duration is computed from one of these three numbers. The recapitulation of concrete volume by element type is presented in Table 5.5.

Table 5. 5 Recapitulation of Concrete Volume by Structural Element Type

No.	Structural Element	Volume (m^3)	Percentage
1	Bore Pile	258,2	22.5%
2	Pile Cap	251,6	21.9%
3	Sloof / Ground Beam	29,3	2.6%

No.	Structural Element	Volume (m³)	Percentage
4	Column	158,5	13.8%
5	Beam	246,5	21.5%
6	Slab (incl. stair slab)	204,4	17.8%
7	Steel Roof Truss	0	0.0%
	TOTAL	**1148,5**	**100.0%**

Source : Personal Document (2026)

Table 5.5 shows a total modeled concrete volume of about 1,148.5 cubic meters. Set against the planned volume of 1,209.67 cubic meters in the project documents, the modeled figure comes out roughly 4.8 percent lower, a difference of about 57 cubic meters. This gap is not an error. It reflects the way BIM measures concrete along clean spans, so that the overlapping regions where members meet, for example where a beam frames into a column, are not counted twice, whereas conventional estimation tends to carry that double count. The same effect was reported by Ulil Albab & Erizal (2021) using Tekla Structures, and seeing it appear again here is a small but reassuring sign that the model is behaving the way a BIM model is expected to.

The distribution within Table 5.5 also tells a clear story, the bore pile and pile cap together account for 510 cubic meters, about 44 percent of the total, which is a heavy foundation by any measure and reflects the bearing conditions the design had to deal with on this site, while the beams and slabs dominate the superstructure and the columns, and sloofs make up the balance. Distributing the same concrete by floor, rather than by element type, gives a complementary view that is useful for understanding how the workload is spread vertically through the building. This floor-by-floor recapitulation is presented in Table 5.6.

Table 5. 6 Recapitulation of Concrete Volume by Floor

No.	Floor Level	Volume (m³)	Percentage
1	Foundation	509,8	44.4%
2	1st Floor	118,1	10.3%
3	2nd Floor	134,8	11.7%
4	3rd Floor	131,3	11.4%
5	4th Floor	124,5	10.8%
6	5th Floor	79,6	6.9%
7	Roof Level	50,4	4.4%

No.	Floor Level	Volume (m³)	Percentage
8	Steel Truss	0	0.0%
	TOTAL	**1148,5**	**100.0%**

Source : Personal Document (2026)

Table 5.6 confirms that the foundation level carries by far the largest concrete volume, at roughly 510 cubic meters, while the upper floors each carry between about 78 and 135 cubic meters and the volume tapers toward the top of the building. This vertical taper matters for scheduling because it means the upper-floor phases are individually lighter than the foundation phases, yet there are many more of them, so the cumulative duration of the superstructure is built up from a long series of relatively short phases rather than a few long ones. The reinforcement and formwork quantities, recapitulated per pour phase so that they align with the construction zones, are presented together in Table 5.7.

Table 5. 7 Recapitulation of Reinforcement Weight, Formwork Area, and Concrete Volume per Pour Phase

No.	Floor	Zone	Structural Element	Pour Phase	Concrete Volume (m³)	Reinforcement Weight (kg)	Formwork Area (m²)
1	Foundation	1	Bore Pile	1	165,00	16190,22	0,00
2	Foundation	2	Bore Pile	2	93,20	9169,57	0,00
3	Foundation	1	Pile Cap	3	163,90	12734,52	232,58
4	Foundation	2	Pile Cap	4	87,70	6773,88	204,52
5	1st Floor	3	Sloof	5	17,50	3532,74	128,72
6	1st Floor	3	Slab	6	21,70	3144,00	145,19
7	1st Floor	4	Sloof	7	11,80	2372,99	85,97
8	1st Floor	4	Slab	8	20,80	3013,00	142,07
9	1st Floor	3	Column	9	23,30	8642,33	126,14
10	1st Floor	4	Column	10	23,00	7503,07	166,72
11	2nd Floor	5	Beam	11	31,40	2388,97	283,81
12	2nd Floor	5	Slab	12	22,30	3012,76	186,73
13	2nd Floor	6	Beam	13	27,10	2020,95	237,51
14	2nd Floor	6	Slab	14	20,60	2568,26	174,93
15	2nd Floor	5	Column	15	18,50	5022,41	99,96
16	2nd Floor	6	Column	16	14,90	3206,90	102,06
17	3rd Floor	7	Beam	17	32,20	1997,65	258,05
18	3rd Floor	7	Slab	18	23,20	3858,99	181,97
19	3rd Floor	8	Beam	19	25,40	2251,47	216,77
20	3rd Floor	8	Slab	20	17,10	2942,50	141,72
21	3rd Floor	7	Column	21	18,50	4992,47	99,96
22	3rd Floor	8	Column	22	14,90	3859,45	102,06
23	4th Floor	9	Beam	23	32,20	1997,64	258,05
24	4th Floor	9	Slab	24	22,60	4417,32	184,05
25	4th Floor	10	Beam	25	26,10	1541,19	222,62
26	4th Floor	10	Slab	26	16,90	3090,88	140,21

No.	Floor	Zone	Structural Element	Pour Phase	Concrete Volume (m^3)	Reinforcement Weight (kg)	Formwork Area (m^2)
27	4th Floor	9	Column	27	14,90	4451,17	90,69
28	4th Floor	10	Column	28	11,80	3096,86	82,04
29	5th Floor	11	Beam	29	18,10	1213,41	162,82
30	5th Floor	11	Slab	30	7,70	892,90	64,04
31	5th Floor	12	Beam	31	23,30	1609,88	204,44
32	5th Floor	12	Slab	32	11,80	1504,23	92,48
33	5th Floor	11	Column	33	10,40	2699,48	63,13
34	5th Floor	12	Column	34	8,30	2311,56	57,53
35	Roof Level	13	Beam	35	30,70	2066,74	308,05
36	Roof Level	13	Slab	36	19,70	1650,68	159,39
37	Roof Truss	14	Steel Truss	37	0,00	16190,22	0,00
	TOTAL				**1148,5**	**143740**	**5406,98**

Source : Personal Document (2026)

Table 5.7 brings the three driving quantities together in the form the schedule actually uses. Across all phases the reinforcement totals roughly 143.74 tons of reinforcing steel, the formwork totals about 5,406.98 square meters of contact area, and the steel roof truss adds a further 11.51 tons of structural steel together with 250 high-strength bolts. The relative magnitude of the formwork figure is worth noting even at this stage. More than five thousand square meters of forming surface is a substantial quantity of work, and it foreshadows the finding, developed in Subsection 5.3.7, that formwork rather than concrete or reinforcement is the resource that ends up controlling the schedule. The share of total concrete contributed by each element type is shown graphically in Figure 5.22.

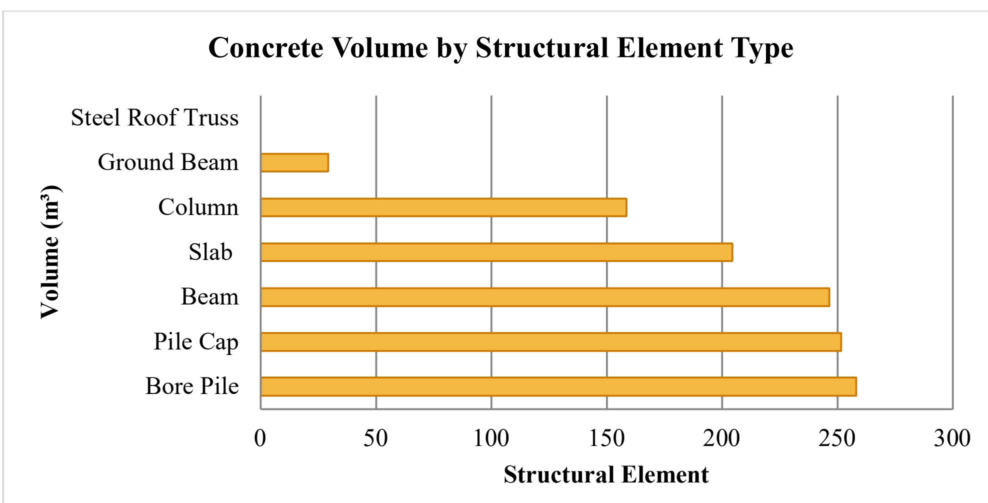


Figure 5. 22 Distribution of Concrete Volume by Structural Element Type
Source : Personal Document

Figure 5.22 makes the dominance of the foundation immediately visible, with the bore pile and pile cap together forming the largest single block, followed by the beams and slabs of the superstructure. The way the same volume is distributed vertically through the building is shown in Figure 5.23.

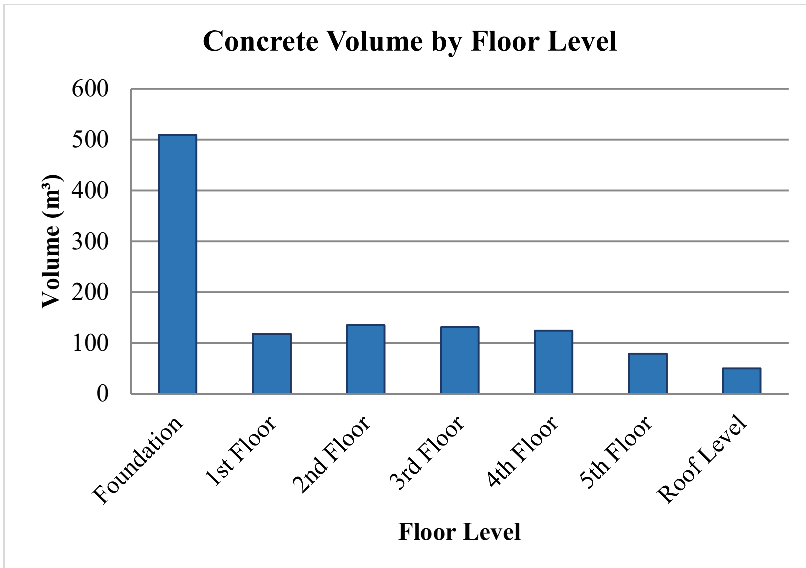


Figure 5. 23 Distribution of Concrete Volume by Floor
Source : Personal Document (2026)

Figure 5.23 reinforces the reading of Table 5.6, showing the heavy foundation followed by the gradual reduction in volume up the building. Together, Tables 5.4 to 5.6 and Figures 5.20 and 5.21 establish the complete physical input to the schedule. Every activity duration calculated later traces back to one of these quantities, so the care taken in recapitulating them here is what gives the schedule its quantitative foundation.

5.3.5 Determination of Work Sequence and Zoning

With the quantities established, the next task was to decide the order in which the work would be done, because a duration without a sequence is meaningless. The structural works were broken into 26 pour phases spread across 14 work zones, following the bottom-up logic the weekly reports had already confirmed. The foundation came first, with the bore piles and pile caps each split into two zones.

The structure was then raised floor by floor, and within every floor the work was deliberately organized so that its two zones could advance side by side. The complete sequence, with the predecessor of each phase, is presented in Table 5.8. Table 5.8 lists the pour phases in their execution order, with the zone of each phase stated explicitly, so that the two zones of every floor, which carry the same element types but run on different schedules, can be told apart at a glance. To keep the repeated element types distinguishable across the tables that follow, each row is identified by a code combining the element type and the zone, so that Bore Pile Z1, for example, denotes the bore pile group of Zone 1. The same coding is used consistently through the remaining tables of this chapter and in Appendix 7.

Table 5. 8 Work Sequence of Structural Activities

No.	Floor	Pour Phase	Structural Element	Predecessor	Relation
1	Foundation	1	Bore Pile Z1		
2	Foundation	2	Bore Pile Z2	1	FS
3	Foundation	3	Pile Cap Z1	1	FS
4	Foundation	4	Pile Cap Z2	2	FS
5	1st Floor	5	Sloof Z3	3	FS
6	1st Floor	5	Slab Z3	5	FF
7	1st Floor	6	Sloof Z4	4	FS
8	1st Floor	6	Slab Z4	7	FF
9	1st Floor	7	Column Z3	6	FS
10	1st Floor	8	Column Z4	8	FS
11	2nd Floor	9	Beam Z5	9	FS
12	2nd Floor	9	Slab Z5	11	FF
13	2nd Floor	10	Beam Z6	10	FS
14	2nd Floor	10	Slab Z6	13	FF
15	2nd Floor	11	Column Z5	12	FS
16	2nd Floor	12	Column Z6	14	FS
17	3rd Floor	13	Beam Z7	15	FS
18	3rd Floor	13	Slab Z7	17	FF
19	3rd Floor	14	Beam Z8	16	FS
20	3rd Floor	14	Slab Z8	19	FF
21	3rd Floor	15	Column Z7	18	FS
22	3rd Floor	16	Column Z8	20	FS
23	4th Floor	17	Beam Z9	21	FS
24	4th Floor	17	Slab Z9	23	FF

No.	Floor	Pour Phase	Structural Element	Predecessor	Relation
25	4th Floor	18	Beam Z10	22	FS
26	4th Floor	18	Slab Z10	25	FF
27	4th Floor	19	Column Z9	24	FS
28	4th Floor	20	Column Z10	26	FS
29	5th Floor	21	Beam Z11	27	FS
30	5th Floor	21	Slab Z11	29	FF
31	5th Floor	22	Beam Z12	28	FS
32	5th Floor	22	Slab Z12	31	FF
33	5th Floor	23	Column Z 11	30	FS
34	5th Floor	24	Column Z12	32	FS
35	Roof Level	25	Beam Z13	33	FS
36	Roof Level	25	Slab Z13	33	FF
37	Roof Truss	26	Steel Truss Z14	35	FS

Source : Personal Document (2026)

The dependencies in Table 5.8 are set as FS and FF relationships, which simply reflects physical reality on a concrete frame. A member cannot be started until the member it rests on is finished. A column waits for the beam and slab below it, the beams and slabs of the next floor wait for those columns, and the steel roof truss waits, at the very end, for the topmost concrete floor to be complete. None of this ordering is arbitrary, it is the only order in which the building can actually be built, which is why the same sequence appears in both the planned and the realized records. The arrangement of the two parallel work zones on each floor is shown in Figure 5.24.

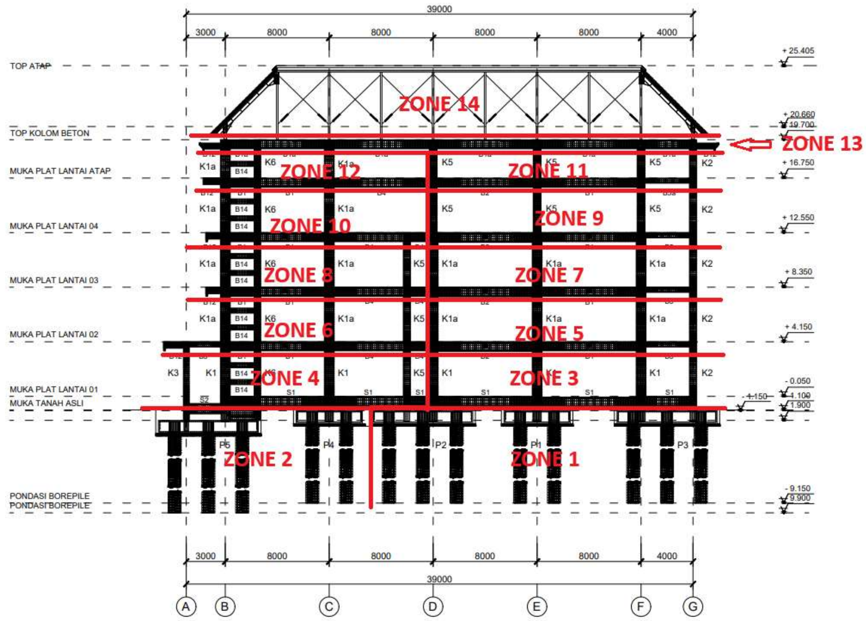


Figure 5. 24 Zoning Plan Showing Two-Zone Parallel Arrangement per Floor
Source : Personal Document (2026)

The zoning shown in Figure 5.24 is the single most consequential choice in the whole schedule, and it deserves to be flagged here rather than left buried in the duration tables. Its importance is that it lets the curing of one zone overlap with active work in the adjacent zone. On a single-zone schedule, every curing period would sit idle on the critical path, accumulating dead time phase after phase. With two zones, the crew simply moves next door while the first zone cures and the concrete continues to gain strength in the background. This is ordinary site practice on multi-zone buildings, and it is the mechanism that keeps the schedule from inflating, a point that becomes central when the BIM 4D duration is compared with the conventional plan in Section 5.4.

The way the fourteen zones were delineated also deserves a brief explanation, since the zoning is not arbitrary. The foundation was divided into two zones each for the bore piles and the pile caps, following the natural split of the foundation plan, while each of the upper floors was divided into two zones along the central grid line that separates the building into two roughly equal halves. Dividing each floor into two rather than three or four was a deliberate balance because too few zones would leave the curing of a large area idling on the critical path, while too many would fragment the crews into inefficiently small teams and demand more formwork sets than the site could hold. Two zones per floor matched the size of the crews assumed in the labour analysis and kept each pour to a volume that a single day's concreting could handle, which is why the same two-zone pattern recurs on every floor.

5.3.6 Worker Allocation and Productivity Determination

Before any duration could be calculated, two things had to be fixed which are how productive each kind of work is, and how many workers are assigned to it. The productivity figures were taken from the AHSP CK 2023 standard, issued through the Circular Letter of the Director General of Construction Development Number 73 of 2023. This is the same standard the project itself used to build its unit price analysis, so anchoring the schedule to it keeps the cost basis and the time basis of the study consistent rather than drawn from two unrelated sources. Two further reasons anchor the choice of edition. The project was executed in 2024, as stated in Subsection 4.2, so AHSP CK 2023 was the standard in force throughout the construction period, and applying an edition issued after the works were completed would detach the calculation from the regulatory basis under which the project was actually priced and executed. Newer editions of the standard are therefore acknowledged but deliberately not used, because the purpose of the schedule is to reconstruct the project as it was carried out, not as it would be priced today. The relevant work-composition pages reproduced from AHSP CK 2023 are compiled in Appendix 6. The coefficients used, and the single-worker productivities derived from them, are collected in Table 5.9.

Table 5. 9 AHSP CK 2023 Productivity Coefficients Used in the Analysis

No.	Work Description	AHSP Code	Worker Coefficient (OH/unit)	Unit	Productivity per Worker (unit/day)
1	Formwork (Pile Cap)	D.04.02	0,1	m²	10
2	Formwork (Column)	D.04.04	0,33	m²	3,03
3	Formwork (Sloof/Beam)	D.04.05	0,26	m²	3,85
4	Formwork (Floor Slab)	D.04.06	0,33	m²	3,03
5	Reinforcement (Column/Beam)	D.01.01	0,0016	kg	625

No.	Work Description	AHSP Code	Worker Coefficient (OH/unit)	Unit	Productivity per Worker (unit/day)
6	Reinforcement (Slab)	D.01.01a	0,0008	kg	1250
7	Concrete Pouring (all element)	D.02.07	0,1	m³	10
8	Steel Installation (Truss)	D.05.xx	0,0125	kg	80
9	Bolting (Steel Truss)	D.09.2.2	0,00875	pcs	114,32

Source : SE Dirjen Bina Konstruksi No. 73 Tahun 2023 (AHSP CK 2023), Part IV Cipta Karya

The productivity of a single worker, shown in the last column of Table 5.9, was obtained from the inverse of the relevant AHSP labor coefficient. For reinforcement of bars twelve millimeters and larger, code D.01.01 gives a coefficient of 0.0016 working-days per kilogram, which inverts to a productivity of 625 kilograms per worker per day for the lighter slab reinforcement, code D.01.01a gives 0.0008, or 1,250 kilograms per worker per day. Concrete pouring under code D.02.07 carries a coefficient of 0.1 working-days per cubic meter, giving 10 cubic meters per worker per day. Formwork under code D.04.05 varies with the element, from a high productivity of 10 square meters per worker per day for the simple pile-cap forming down to about 3.03 square meters for columns and slabs and 3.85 for beams, reflecting the genuinely different difficulty of forming these shapes. The team productivity for any activity is then this single-worker rate multiplied by the number of workers on the crew.

One important limitation of the formwork productivity figures needs to be acknowledged before the duration calculation proceeds. The AHSP CK 2023 codes used in this study, namely D.04.04 for column formwork, D.04.05 for beam formwork, and D.04.06 for slab formwork, each carry a labour coefficient of 0.33 OH per m^2, which translates to a single-worker productivity of approximately 3.03 m^2 per day. This figure was derived from a work composition that lists *dolken kayu* Ø 8–10 cm poles as the primary vertical support material, together with timber class-II members and 12 mm plywood panels. *Dolken* poles are traditional round-timber props that must be cut to the required storey height on site, erected one by one, and laterally braced before any panel can be fixed. This process is labour-intensive and noticeably slower than what modern scaffolding systems require. The project studied here used prefabricated steel cross-brace scaffolding, a modular system whose components connect without on-site cutting and whose erection and stripping cycle is faster than a *dolken*-supported arrangement. Because no published AHSP coefficient exists for this type of system, the *dolken*-based figure was kept as the closest available official reference. As a result, the durations produced in this study tend toward the conservative side, and the implications of this are discussed further in Section 5.5.

The number of workers was the point that needed the most careful treatment, and it is where the analysis departs most clearly from its first draft. In the original calculation a single uniform crew size had been assumed for every activity, regardless of element or task. That assumption could not survive scrutiny, and rightly so, because the labor intensity of formwork, reinforcement, and concreting is simply not the same from one element to the next. Fixing reinforcement in a bore pile cage is not the same job as laying a slab mesh, and pretending they need identical crews makes every duration that follows suspect. The crews were therefore differentiated by element type and by work type, and each figure was given a technical reason rather than left as a round number. The determination followed three rules applied in order. First, each crew was built from the labour composition implied by the AHSP CK 2023 analysis for that work item, keeping the proportion between skilled workers and helpers that the standard assumes, so that the single-worker productivities in Table 5.9 remain valid when multiplied up to a team. Second, each crew was rounded to a practical working unit that matches how the trade actually deploys on site, a forming gang or a steel-fixing gang rather than an arbitrary head count. Third, every crew was checked against the working area of the zone it serves, so that no allocation exceeds what the floor plate can safely and productively hold. The full set of allocations, each with the justification produced by these rules, is presented in Table 5.10.

Table 5. 10 Worker Allocation and Team Productivity Estimation

No	Structural Element	Work Type	No. of Workers	Worker Productivity (unit/day)	Team Productivity (unit/day)	Technical Justification
1	Bore Pile	Reinforcement	10	625,00	6250,00	10 workers for 12–15 m cage handling and lowering
2	Bore Pile	Concreting	6	10,00	60,00	6 workers for high volume concrete
3	Pile Cap	Formwork	10	10,00	100,00	10 workers to complete wide area of pile cap
4	Pile Cap	Reinforcement	6	625,00	3750,00	6 ironworkers for Phase 1 dominant zone (12,735 kg)
5	Pile Cap	Concreting	4	10,00	40,00	4 workers, 2 pump hose, 2 levelling & vibrating
6	Column	Formwork	6	3,03	18,18	6 workers (3 pairs) per zone, confirmed across Phases 7–24
7	Column	Reinforcement	3	625,00	1875,00	3 workers, column section limits simultaneous crew size
8	Column	Concreting	2	10,00	20,00	2 workers for narrow column
9	Sloof / Beam	Formwork	6	3,85	23,08	6 workers consistent across all beam phases
10	Sloof / Beam	Reinforcement	4	625,00	2500,00	4 workers, small volume per zone, efficient < 1 day
11	Sloof / Beam	Concreting	2	10,00	20,00	2 workers working together with slab
12	Slab	Formwork	8	3,03	24,24	8 workers for large slab areas (64–308 m²/zone)
13	Slab	Reinforcement	4	1250,00	5000,00	4 workers, high productivity

No	Structural Element	Work Type	No. of Workers	Worker Productivity (unit/day)	Team Productivity (unit/day)	Technical Justification
						coefficient (0.0008 OH/kg)
14	Slab	Concreting	2	10,00	20,00	2 workers working together with beam
15	Steel Truss	Fabrication / Erection	10	80,00	800,00	10 workers: riggers, spotters, welders, safety checkers
16	Steel Truss	Bolting	8	114,32	914,60	8 workers (4 pairs), parallel bolting halves duration

Source : Personal Document (2026)

The reasoning behind Table 5.10 can be read element by element. The bore pile reinforcement was given a larger crew, in the order of eight to ten ironworkers, because the cages are large in diameter and have to be assembled and lowered as units, while its concreting used a smaller crew of about six working through a single tremie. The pile-cap forming needs comparatively few workers because the AHSP coefficient for its simple formwork is favourable, but its reinforcement crew is larger to handle the dense bottom mat. The column crews are modest across the board, with concreting handled by only about three workers because each column pour is small in volume. The beam crews are balanced between forming, fixing, and pouring, while the slab crews for forming and concreting are deliberately the largest, in the range of seven to eight, because the wide horizontal area genuinely demands more hands to deck, place, and screed. The steel truss has its own dedicated crews for fabrication and bolting, reflecting that it is a different trade altogether. What this differentiation achieves is the point that matters most for the credibility of the study that every duration in the schedule can now be traced back to a crew size that carries a stated engineering reason, which directly addresses the principal critique raised during supervision.

It is worth making the link between the coefficient and the crew explicit, because this is where the schedule is most exposed to challenge and therefore where the reasoning has to be clearest. The AHSP coefficient fixes the productivity of a single worker. The crew size then scales that productivity to a team rate, and the team rate divides into the quantity to give a duration. Choosing a crew size is therefore not a free parameter but a statement about how many workers can productively occupy the work face at once without getting in each other's way. A slab pour can absorb a five-person concreting crew because its area is large enough for several workers to place and screed simultaneously. Meanwhile, a column pour cannot usefully employ more than about three, because the cross-section is small and additional workers would simply stand idle. The crew sizes in Table 5.10 were chosen on exactly this physical basis, which is what makes them defensible rather than convenient.

To show the full chain from coefficient to duration in one place, the derivation is worked through for several representative phases in Table 5.11, covering a foundation, a column, a beam, and a slab phase. Reading across the table, the quantity is divided by the team productivity, which is itself the single-worker productivity multiplied by the crew, and the result is rounded up to the phase duration. Presenting the calculation in this explicit form means that any reader, or any examiner, can reproduce every duration in the schedule from first principles rather than having to take the figures on trust.

Table 5. 11 Worked Derivation of Team Productivity and Duration for Representative Phases

PP	Element	Work Type	Quantity	AHSP Prod. (per worker per day)	Amount of Worker	Team Prod. (per day)	Raw Dur. (days)	Round Up Dur. (days)
3	Pile Cap (Foundation Z1)	**Formwork**	**232,58** m²	10,000	8	80,00	**2,91**	3
		Reinforcement	12.734,52 kg	625,000	8	5.000,00	2,55	3
		Concreting	163,90 m³	10,000	6	60,00	2,73	3
9	Column (1st Floor Z3)	**Formwork**	**126,14** m²	3,030	6	18,18	**6,94**	7
		Reinforcement	8.642,33 kg	625,000	4	2.500,00	3,46	4
		Concreting	23,30 m³	10,000	3	30,00	0,78	1
11		**Formwork**	**283,81** m²	3,846	8	30,77	**9,22**	10

PP	Element	Work Type	Quantity	AHSP Prod. (per worker per day)	Amount of Worker	Team Prod. (per day)	Raw Dur. (days)	Round Up Dur. (days)
	Beam (2nd Floor Z5)	Reinforcement	2.388,97 kg	625,000	4	2.500,00	0,96	1
		Concreting	31,40 m³	10,000	4	40,00	0,78	1
12	Slab (2nd Floor Z5)	**Formwork**	**186,73** m²	3,030	8	24,24	**7,70**	8
		Reinforcement	3.012,76 kg	1.250,000	4	5.000,00	0,60	1
		Concreting	22,30 m³	10,000	5	50,00	0,45	1

Source : Personal Document (2026)

The pattern in Table 5.11 anticipates the central duration finding. In every phase the formwork line carries by far the longest duration, while the reinforcement and concreting lines resolve to a fraction of a day. This is the first point at which the dominance of formwork becomes numerically visible, and it is developed fully in the next subsection.

5.3.7 Activity Duration Calculation

The duration of each activity is derived from a single controlling principle. The quantity of work assigned to a phase is divided by the productivity of the crew executing it, and the result is raised to the next whole number using the ceiling function. The ceiling function is applied deliberately, because any portion of work that spills into a second day still occupies that day on the site calendar and must be accounted for in the schedule. The working calendar adopted for this study assumes seven hours per working day and six working days per week, in accordance with the Monday-to-Saturday pattern observed in the project construction records.

The duration of each activity type is computed using Equation (3.6) from Section 3.8, in which the quantity of work is divided by the team productivity and the result rounded up to the nearest whole working day. The team productivity is obtained by multiplying the single-worker coefficient from AHSP CK 2023 by the number of workers assigned. Three AHSP codes apply across the three work types: code D.04.05 for formwork, code D.01.01 for reinforcement of bars 12 mm diameter and above, code D.01.01a for the lighter slab mesh reinforcement at 1,250 kg per OH, and code D.02.07 for concrete placement. The controlling phase duration is then obtained using Equation (3.7). The formwork duration is added to the concreting duration, with the reinforcement window absorbed inside the formwork period.

The three component durations are combined into a single controlling phase duration using a rule that incorporates three revisions from the initial draft of the schedule. First, because rebar fixing can begin as soon as the first bays of formwork are ready, the reinforcement work is allowed to overlap with forming rather than being treated as a strictly sequential successor. Since Dr is shorter than Df in every concrete phase, the rebar work is fully absorbed within the forming window and does not lengthen the phase. Second, concrete curing is modelled as a one-day technological lag running in parallel with the adjacent zone through the two-zone arrangement described in Subsection 5.3.5, rather than as a day added individually to the critical path of each phase. Third, the calendar conversion uses the six-day working week defined in the project documents, correcting an earlier inconsistency.

A worked example makes the corrected calculation concrete. Consider the slab pour in pour phase 12, on the second floor, which carries a concrete volume of 22.3 cubic meters, a reinforcement weight of about 3,013 kilograms, and a formwork area of 186.73 square meters. With a forming crew of eight at a single-worker productivity of 3.03 square meters per day, the team forms 24.24 square meters per day, so the formwork takes 186.73 divided by 24.24, or about 7.70 days. The reinforcement crew of four, at 1,250 kilograms per worker per day, fixes 5,000 kilograms per day, so the steel takes about 0.60 days, comfortably inside the forming window. The concreting crew of five, at 10 cubic meters per worker per day, places 50 cubic meters per day, so the pour takes about 0.45 days. The phase duration is then the ceiling of the larger of the forming and fixing durations plus the concreting, that is the ceiling of 7.70 plus 0.45, which rounds up to 9 working days. The same procedure applied to a beam phase, such as pour phase 11 on the second floor, gives a formwork duration of about 9.22 days against a concreting duration of 0.79 days, and a phase duration of 11 working days. These two cases show clearly how strongly the formwork governs the result.

The component durations for every phase are presented in three tables, one for each work package, so that the contribution of forming, fixing, and pouring can be compared directly. The formwork durations are given in Table 5.12.

Table 5. 12 Formwork Duration per Pour Phase

Element	Pour Phase	n of element	Formwork Vol. (m²)	Formwork Prod. (m²)	No. Workers	Formwork Dur. (days)
Bore Pile Z1	1	30	0	0	-	0,0
Bore Pile Z2	2	17	0	0	-	0,0
Pile Cap Z1	3	3	232,58	10,00	10	2,3
Pile Cap Z2	4	4	204,52	10,00	8	2,6
Sloof Z3	5	15	128,72	3,85	6	5,6
Slab Z3	5	8	145,19	3,03	6	8,0
Sloof Z4	6	11	85,97	3,85	6	3,7
Slab Z4	6	4	142,07	3,03	8	5,9
Column Z3	7	8	126,14	3,03	6	6,9
Column Z4	8	12	166,72	3,03	6	9,2
Beam Z5	9	35	283,81	3,85	6	12,3
Slab Z5	9	21	186,73	3,03	8	7,7
Beam Z6	10	48	237,51	3,85	6	10,3
Slab Z6	10	25	174,93	3,03	8	7,2
Colum Z5	11	8	99,96	3,03	6	5,5
Column Z6	12	9	102,06	3,03	6	5,6
Beam Z7	13	35	258,05	3,85	6	11,2
Slab Z7	13	21	181,97	3,03	8	7,5
Beam Z8	14	40	216,77	3,85	6	9,4
Slab Z8	14	19	141,72	3,03	8	5,8
Column Z7	15	8	99,96	3,03	6	5,5
Column Z8	16	9	102,06	3,03	6	5,6
Beam Z9	17	35	258,05	3,85	6	11,2
Slab Z9	17	21	184,05	3,03	8	7,6
Beam Z10	18	41	222,62	3,85	6	9,6
Slab Z10	18	18	140,21	3,03	8	5,8
Column Z9	19	8	90,69	3,03	6	5,0

Element	Pour Phase	n of element	Formwork Vol. (m²)	Formwork Prod. (m²)	No. Workers	Formwork Dur. (days)
Column Z10	20	7	82,04	3,03	6	4,5
Beam Z11	21	26	162,82	3,85	6	7,1
Slab Z11	21	10	64,04	3,03	8	2,6
Beam Z12	22	41	204,44	3,85	6	8,9
Slab Z12	22	16	92,48	3,03	8	3,8
Column Z11	23	8	63,13	3,03	6	3,5
Column Z12	24	7	57,53	3,03	10	1,9
Beam Z13	25	44	308,05	3,85	7	11,4
Slab Z13	26	27	159,39	3,03	8	6,6

Source : Personal Document (2026)

Table 5.12 shows that the formwork durations of the larger beam and slab phases run to between seven and ten days, far longer than any other component. By contrast, the reinforcement durations, presented in Table 5.13, are uniformly short.

Table 5. 13 Reinforcement Duration per Pour Phase

Element	Pour Phase	n of element	Rebar Vol. (kg)	Rebar Prod. (kg)	No. Workers	Rebar Duration (days)
Bore Pile Z1	1	30	16190,22	625	10	2,6
Bore Pile Z2	2	17	9169,57	625	10	1,5
Pile Cap Z1	3	3	12734,52	625	6	3,4
Pile Cap Z2	4	4	6773,88	625	4	2,7
Sloof Z3	5	15	3532,74	625	3	1,9
Slab Z3	0	8	3144,00	1250	4	0,6
Sloof Z4	6	11	2372,99	625	4	0,9
Slab Z4	0	4	3013,00	1250	4	0,6
Column Z3	7	8	8642,33	625	3	4,6
Column Z4	8	12	7503,07	625	3	4,0
Beam Z5	9	35	2388,97	625	4	1,0
Slab Z5	0	21	3012,76	1250	4	0,6
Beam Z6	10	48	2020,95	625	4	0,8

Element	Pour Phase	n of element	Rebar Vol. (kg)	Rebar Prod. (kg)	No. Workers	Rebar Duration (days)
Slab Z6	0	25	2568,26	1250	4	0,5
Column Z5	11	8	5022,41	625	3	2,7
Column Z6	12	9	3206,90	625	3	1,7
Beam Z7	13	35	1997,65	625	4	0,8
Slab Z7	0	21	3858,99	1250	4	0,8
Beam Z8	14	40	2251,47	625	4	0,9
Slab Z8	0	19	2942,50	1250	4	0,6
Column Z7	15	8	4992,47	625	3	2,7
Column Z8	16	9	3859,45	625	3	2,1
Beam Z9	17	35	1997,64	625	4	0,8
Slab Z9	0	21	4417,32	1250	4	0,9
Beam Z10	18	41	1541,19	625	4	0,6
Slab Z10	0	18	3090,88	1250	4	0,6
Column Z9	19	8	4451,17	625	3	2,4
Column Z10	20	7	3096,86	625	3	1,7
Beam Z11	21	26	1213,41	625	4	0,5
Slab Z11	0	10	892,90	1250	4	0,2
Beam Z12	22	41	1609,88	625	4	0,6
Slab Z12	0	16	1504,23	1250	4	0,3
Column Z11	23	8	2699,48	625	3	1,4
Column Z12	24	7	2311,56	625	10	0,4
Beam Z13	25	44	2066,74	625	3	1,1
Slab Z13	0	27	1650,68	1250	3	0,4

Source : Personal Document (2026)

Almost every reinforcement duration in Table 5.13 falls below a single day, which is precisely why the rebar work can be absorbed within the forming window without lengthening the phase. The concreting durations, presented in Table 5.14, are shorter still.

Table 5. 14 Concreting Duration per Pour Phase

Element	Pour Phase	n of element	Concrete Vol. (m³)	Concrete Prod. (m³)	No. Workers	Concreting Duration (days)
Bore Pile Z1	1	30	165,00	10	6	2,8
Bore Pile Z2	2	17	93,20	10	6	1,6
Pile Cap Z1	3	3	163,90	10	4	4,1
Pile Cap Z2	4	4	87,70	10	2	4,4
Sloof Z3	5	15	17,50	10	2	0,9
Slab Z3	0	8	21,70	10	2	1,1
Sloof Z4	6	11	11,80	10	2	0,6
Slab Z4	0	4	20,80	10	2	1,0
Column Z3	7	8	23,30	10	2	1,2
Column Z4	8	12	23,00	10	2	1,2
Beam Z5	9	35	31,40	10	2	1,6
Slab Z5	0	21	22,30	10	2	1,1
Beam Z6	10	48	27,10	10	2	1,4
Slab Z6	0	25	20,60	10	2	1,0
Column Z5	11	8	18,50	10	2	0,9
Column Z6	12	9	14,90	10	2	0,7
Beam Z7	13	35	32,20	10	2	1,6
Slab Z7	0	21	23,20	10	2	1,2
Beam Z8	14	40	25,40	10	2	1,3
Slab Z8	0	19	17,10	10	2	0,9
Column Z7	15	8	18,50	10	2	0,9
Column Z8	16	9	14,90	10	2	0,7
Beam Z9	17	35	32,20	10	2	1,6
Slab Z9	0	21	22,60	10	2	1,1
Beam Z10	18	41	26,10	10	2	1,3
Slab Z10	0	18	16,90	10	2	0,8
Column Z9	19	8	14,90	10	2	0,7
Column Z10	20	7	11,80	10	2	0,6
Beam Z11	21	26	18,10	10	2	0,9
Slab z11	0	10	7,70	10	2	0,4

Element	Pour Phase	n of element	Concrete Vol. (m³)	Concrete Prod. (m³)	No. Workers	Concreting Duration (days)
Beam Z12	22	41	23,30	10	2	1,2
Slab Z12	0	16	11,80	10	2	0,6
Column Z11	23	8	10,40	10	2	0,5
Column Z12	24	7	8,30	10	5	0,2
Beam Z13	25	44	30,70	10	2	1,5
Slab Z13	0	27	19,70	10	2	1,0

Source : Personal Document (2026)

Table 5.14 confirms that pouring is rarely the activity that governs the duration of a phase. With ready-mix concrete delivered by truck and a placing crew of four or five workers, even the largest pours in the table are completed in well under a working day, and the reinforcement work behaves the same way, being absorbed within the formwork window as set out in Section 3.8. The governing component is the formwork, whose durations of up to twelve working days per phase dwarf the single day that placing requires, and this is what makes formwork the rate-limiting resource of the concrete structure. The consequence of this imbalance for the shape of the whole programme, and the reason the constraint lies in the sequence of zones rather than in the size of the crews, are developed at the end of Subsection 5.3.7 and taken up again in the Discussion. Combining the three components according to the corrected rule, and rounding up, gives the controlling duration of each phase, which is then sequenced through the predecessor network to give the start and finish of every activity. These results are presented in Table 5.15 The consolidated calculation workbook linking the take-off, the labour allocation, and the resulting durations is provided as a digital attachment in Appendix 7.

Table 5. 15 Total Phase Duration and Critical-Path Start and Finish Times

Element	Pour Phase	n of element	Formwork Duration (days)	Rebar Duration (days)	Concreting Duration (days)	Total Phase Duration (days)	Predecessor	Start (day no.)	Finish (day no.)	Relation
Bore Pile Z1	1	30	0,0	2,6	2,8	6	—	1	6	
Bore Pile Z2	2	17	0,0	1,5	1,6	4	1	7	10	FS
Pile Cap Z1	3	3	2,3	3,4	4,1	8	1	7	14	FS
Pile Cap Z2	4	4	2,6	2,7	4,4	8	2	11	22	FS
Sloof Z3	5	15	5,6	1,9	0,9	7	3	15	21	FS
Slab Z3		8	8,0	0,6	1,1	10	3	15	24	FF
Sloof Z4	6	11	3,7	0,9	0,6	5	4	25	29	FS
Slab Z4		4	5,9	0,6	1,0	7	4	25	31	FF
Column Z3	7	8	6,9	4,6	1,2	9	6	25	33	FS
Column Z4	8	12	9,2	4,0	1,2	11	8	34	44	FS
Beam Z5	9	35	12,3	1,0	1,6	14	9	34	45	FS
Slab Z5		21	7,7	0,6	1,1	9	9	34	42	FF
Beam Z6	10	48	10,3	0,8	1,4	12	10	45	56	FS
Slab Z6		25	7,2	0,5	1,0	9	13	45	53	FF
Column Z5	11	8	5,5	2,7	0,9	7	12	45	51	FS
Column Z6	12	9	5,6	1,7	0,7	7	14	54	60	FS
Beam Z7	13	35	11,2	0,8	1,6	13	15	54	66	FS

Element	Pour Phase	n of element	Formwork Duration (days)	Rebar Duration (days)	Concreting Duration (days)	Total Phase Duration (days)	Predecessor	Start (day no.)	Finish (day no.)	Relation
Slab Z7		21	7,5	0,8	1,2	9	17	54	62	FF
Beam Z8	14	40	9,4	0,9	1,3	11	16	63	73	FS
Slab Z8		19	5,8	0,6	0,9	7	19	63	69	FF
Column Z7	15	8	5,5	2,7	0,9	7	18	63	69	FS
Column Z8	16	9	5,6	2,1	0,7	7	20	70	76	FS
Beam Z9	17	35	11,2	0,8	1,6	13	21	70	82	FS
Slab Z9		21	7,6	0,9	1,1	9	23	70	78	FF
Beam Z10	18	41	9,6	0,6	1,3	11	22	79	89	FS
Slab Z10		18	5,8	0,6	0,8	7	25	79	85	FF
Column Z9	19	8	5,0	2,4	0,7	6	24	79	84	FS
Column Z10	20	7	4,5	1,7	0,6	6	26	86	91	FS
Beam Z11	21	26	7,1	0,5	0,9	8	27	86	93	FS
Slab Z11		10	2,6	0,2	0,4	4	29	86	89	FF
Beam Z12	22	41	8,9	0,6	1,2	11	28	92	102	FS
Slab Z12		16	3,8	0,3	0,6	5	31	92	96	FF
Column Z11	23	8	3,5	1,4	0,5	4	30	92	95	FS
Column Z12	24	7	1,9	0,4	0,2	3	32	97	99	FS
Beam Z13	25	44	11,4	1,1	1,5	13	33	100	112	FS

Element	Pour Phase	n of element	Formwork Duration (days)	Rebar Duration (days)	Concreting Duration (days)	Total Phase Duration (days)	Predecessor	Start (day no.)	Finish (day no.)	Relation
Slab Z13		27	6,6	0,4	1,0	8	33	100	107	FF
Steel Truss Z14	26	106	**Assembly Dur. (days)**	**Bolting Dur. (days)**	0	15	35,36	113	**127**	FS
			14,4	0,3						

Source : Personal Document (2026)

Tracing the dependencies through the 37 activities in Table 5.15 gives a total structural duration of 127 working days. Expressed in the project's own units, that is about 22 working weeks at six days a week. It is worth identifying which activities actually drive this total, because not every activity lies on the critical path. The activities that do lie on it are collected in Table 5.16.

Table 5. 16 Activities on the Critical Path

Element	Pour Phase	Formwork Duration (Days)	Rebar Duration (Days)	Concreting Duration (Days)	Total Phase Duration (Days)
Bore Pile Z1	1	0,0	2,6	2,8	6
Bore Pile Z2	2	0,0	1,5	1,6	4
Pile Cap Z1	3	2,3	3,4	4,1	8
Pile Cap Z2	4	2,6	2,7	4,4	8
Sloof Z3	5	5,6	1,9	0,9	7
Slab Z3		8,0	0,6	1,1	10
Sloof Z4	6	3,7	0,9	0,6	5
Slab Z4		5,9	0,6	1,0	7
Column Z3	7	6,9	4,6	1,2	9
Column Z4	8	9,2	4,0	1,2	11
Beam Z5	9	12,3	1,0	1,6	14
Slab Z5		7,7	0,6	1,1	9
Beam Z6	10	10,3	0,8	1,4	12
Slab Z6		7,2	0,5	1,0	9
Column Z5	11	5,5	2,7	0,9	7
Column Z6	12	5,6	1,7	0,7	7
Beam Z7	13	11,2	0,8	1,6	13
Slab Z7		7,5	0,8	1,2	9
Beam Z8	14	9,4	0,9	1,3	11
Slab Z8		5,8	0,6	0,9	7
Column Z7	15	5,5	2,7	0,9	7
Column Z8	16	5,6	2,1	0,7	7
Beam Z9	17	11,2	0,8	1,6	13
Slab Z9		7,6	0,9	1,1	9
Beam Z10	18	9,6	0,6	1,3	11
Slab Z10		5,8	0,6	0,8	7
Column Z9	19	5,0	2,4	0,7	6
Column Z10	20	4,5	1,7	0,6	6
Beam Z11	21	7,1	0,5	0,9	8
Slab Z11		2,6	0,2	0,4	4
Beam Z12	22	8,9	0,6	1,2	11
Slab Z12		3,8	0,3	0,6	5
Column Z11	23	3,5	1,4	0,5	4
Column Z12	24	1,9	0,4	0,2	3
Beam Z13	25	11,4	1,1	1,5	13
Slab Z13		6,6	0,4	1,0	8
Steel Truss Z14	26	14,3	0,3	0	15

Source : Personal Document (2026)

Table 5.16 shows that the single longest item on the critical path is the steel roof truss, at about 15 working days, weighed down by the fabrication and erection of 11.51 tons of steel, followed by the foundation phases and the larger upper-floor beam pours. The most revealing pattern, however, is not the identity of the longest activity but the internal composition of the pour phases that fill the path. For the bigger beam and slab pours, the formwork duration governs the phase almost entirely while the reinforcement and concreting are dispatched in a day or two. This composition is shown graphically in Figure 5.25.

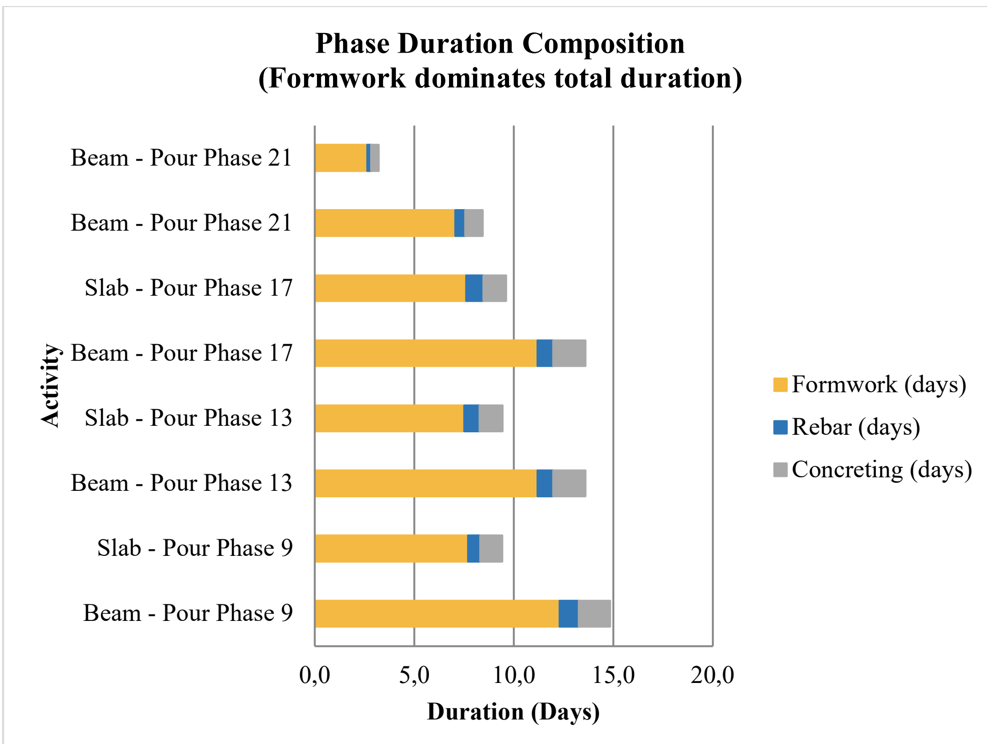


Figure 5. 25 Composition of Phase Duration
Source : Personal Document

Figure 5.25 makes the imbalance unmistakable. The formwork bar dwarfs the reinforcement and concreting bars in every concrete phase shown. What this is really saying is that formwork, not concrete supply and not steel fixing, is the rate-limiting resource of the superstructure. It is an unglamorous finding, but it is a concrete one, and it carries a direct practical consequence that is developed in the discussion.

Beyond the total, the schedule can be read by floor, which exposes a pattern that the single 127-day figure conceals. Grouping the activities by level gives the duration each floor occupies within the programme, and these are collected in Table 5.17.

Table 5. 17 Structural Duration Span per Floor

No.	Floor Level	Start Day	Finish Day	Span (working days)	Span (weeks)	No. of Pour Phases
1	Foundation	1	22	22	4	4
2	1st Floor	15	44	30	5	6
3	2nd Floor	34	60	27	5	6
4	3rd Floor	54	76	23	4	6
5	4th Floor	70	91	22	4	6
6	5th Floor	86	99	14	2	6
7	Roof Level	100	107	8	1	2
8	Steel RoofTruss	113	127	15	3	1
	Overall (1– 127)	**1**	**127**	127	21	**37**

Source : personal Document (2026)

Table 5.17 shows that the foundation occupies about 22 working days, each of the lower upper-floors occupies between 14 and 30 working days of overlapping work, and the floors become faster toward the top of the building as their concrete volumes fall, with the fifth floor and the roof level completing in 8 and 15 working days respectively. The individual floors overlap one another because the upper zone of one floor can begin once the floor below it is structurally complete, which is why the floor spans add up to more than the 127-day total. The point worth drawing out is that the superstructure is not built from a few long phases but from a long chain of relatively short, overlapping ones, so the total duration is sensitive less to any single activity than to the cumulative effect of the formwork allowance repeated across every floor. This per-floor span is shown graphically in Figure 5.26.

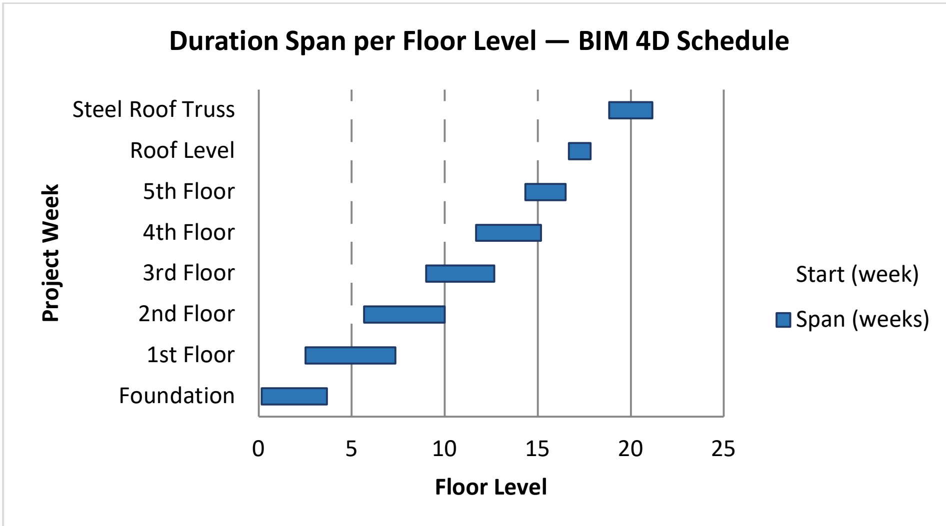


Figure 5. 26 Structural Duration Span per Floor
Source : Personal Document (2026)

Figure 5.26 makes the overlap between consecutive floors visible and shows how the programme advances as a moving front rather than as a set of discrete, sequential blocks. A further output that the explicit schedule makes available, and that the conventional S-curve cannot provide, is the concurrent demand for labour. By summing the crews active on each working day across the parallel zones, the manpower required at each point in the programme can be estimated, and this demand is shown in Figure 5.27.

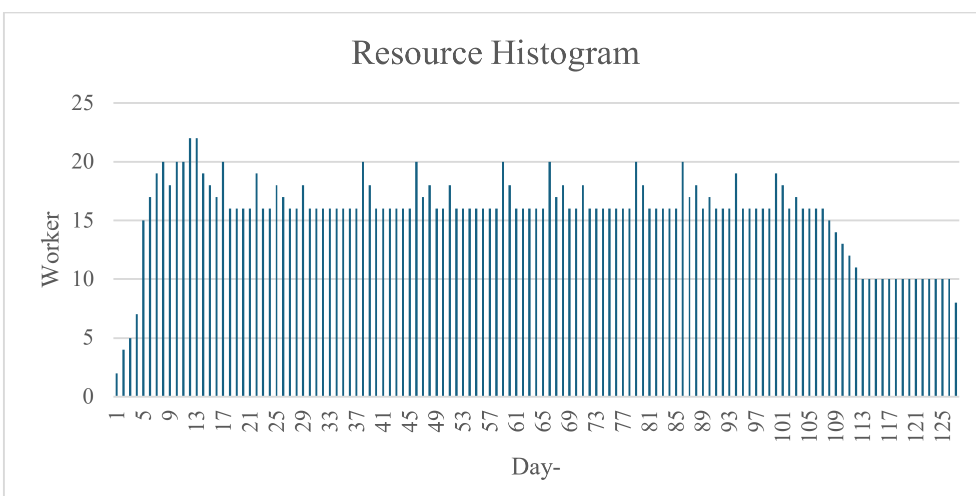


Figure 5. 27 Estimated Concurrent Manpower Demand over the Schedule
Source : Personal Document (2026)

Figure 5.27 presents the daily workforce demand across the full 127-working-day programme, derived by summing the active crew members on each calendar day from the activity schedule. The histogram has a distinctive three-part shape that directly reflects the structure of the work.

The first segment, spanning roughly Days 1 to 13, shows a ramp-up from two workers on the opening day to a programme peak of 22 workers on Days 12 and 13. This peak coincides with the late foundation phase, when the bore pile reinforcement, pile cap forming, and pile cap reinforcement across two concurrent zones are all active simultaneously. It is the one point in the programme at which the maximum number of foundation sub-tasks overlap, and it represents the highest single-day crew demand of the entire project.

The second and longest segment, from approximately Day 14 to Day 107, corresponds to the concrete superstructure across all five floors. Here the histogram settles into a notably stable band, with a base level of 16 workers on most days and brief spikes to 18–20 workers on pouring days when the two-person concreting crew is added to the active total. This regularity is a direct consequence of the constant-crew model adopted in the scheduling analysis. The formwork crew of ten workers and the reinforcement crew of five workers advance through the zones in a fixed rotation, so the daily demand does not fluctuate arbitrarily but instead reflects a predictable, repeating cycle of forming, fixing, and casting. The absence of large swings across this segment confirms that resource levelling has been achieved through sequencing rather than through arbitrary adjustment.

The third segment, Days 108 to 127, captures the steel truss installation phase. As the concrete works conclude and the specialised steel erection crew takes over, the total daily workforce tapers from 15 workers down to 8, reflecting the smaller but dedicated team required for fabrication, erection, and bolting. The programme closes at this reduced level rather than returning to zero, because truss installation continues until the last working day.

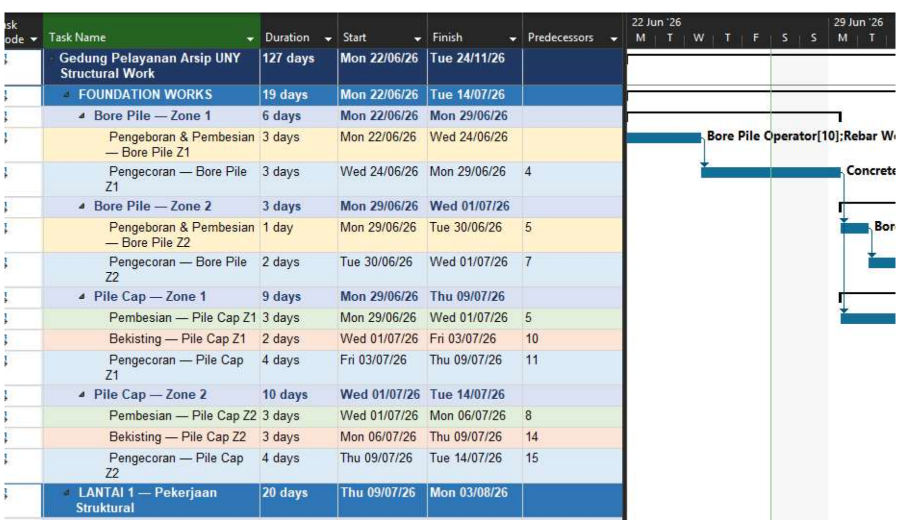
Taken together, the histogram shows a programme that carries a workforce of between 16 and 22 workers through most of its duration, with a peak mobilisation that is relatively modest for a five-storey reinforced concrete structure. This is a direct consequence of the two-zone-per-floor sequencing strategy because rather than opening all zones simultaneously at the cost of a very large concurrent crew, the programme advances the zones in series, keeping the peak demand low and the workforce distribution smooth throughout. The day-by-day tabulation of active crews from which this manpower profile was derived is provided in Appendix 8.

One further property of the schedule is worth drawing out, because it speaks to how much flexibility the programme actually has. Of the thirty-seven activities, sixteen lie on the critical path and carry no float, while the remaining twenty-one carry some slack, meaning they could start later or run longer without delaying the project as a whole. The activities with slack are, broadly, the second zone of each floor pair and the lighter column phases, which can absorb minor delays because they are not the activities the following floor waits on. For a site manager this distinction is valuable in its own right because it identifies which activities must be protected at all costs and which can be allowed to flex when labour or materials are tight. The conventional S-curve, presenting progress as a single aggregate line, gives no comparable information about where the schedule is rigid and where it can bend.

The pattern of float in the network also explains why the schedule cannot be shortened simply by enlarging the crews, and the point deserves an explicit example because it recurs in the discussion. Consider the beam and slab phases of a typical floor. Zone 1 formwork occupies its full calculated duration of roughly ten working days, its pour follows, and only then can Zone 2 formwork begin, because the two zones share formwork sets and follow the approved casting sequence of the structure. Doubling the forming crew in Zone 1 would compress the forming of that one zone by several days, and the site could physically hold such a crew, since the floor plate measures about 40 m by 16 m, roughly 640 m², so that even at the observed peak of twenty-two formwork workers each carpenter has on the order of 29 m² of working area, several times the envelope of about 3 m by 3 m that safe and productive forming requires. What a larger crew cannot do is release Zone 2 any earlier than the completion of the Zone 1 pour, nor allow the columns of the next floor to start before the slab beneath them exists. The chain of pour phases therefore sets a floor on the total duration that additional labour cannot break, and this is the precise sense in which the bottleneck of the programme is the zone dependency rather than the crew capacity. The distinction matters practically, because a contractor reading the 127-day figure as a labour shortage would mobilise more workers to no effect, while one reading it correctly as a sequencing constraint would look instead at the zoning strategy and the number of formwork sets.

5.3.8 Bar Chart Scheduling Using Microsoft Project

The 37 activities, with their durations, predecessors, and finish-to-start links, were entered into Microsoft Project to produce the structural bar chart. The scheduling method applied here is the Precedence Diagram Method introduced in Section 3.3, in which each activity is a node and the logic between activities is expressed as finish-to-start relationships, and the analysis performed on that network is the critical path calculation of CPM. Microsoft Project implements PDM natively, so once the network was entered the software computed the early start and finish of every activity from the dependency logic and identified the critical path without manual intervention. PERT was not applied because the durations in this study are deterministic values derived from the AHSP CK 2023 coefficients rather than probabilistic estimates. The resulting Gantt chart is shown in Figure 5.28.



Task Name	Duration	Start	Finish	Predecessors
Gedung Pelayanan Arsip UNY Structural Work	127 days	Mon 22/06/26	Tue 24/11/26	
FOUNDATION WORKS	19 days	Mon 22/06/26	Tue 14/07/26	
Bore Pile — Zone 1	6 days	Mon 22/06/26	Mon 29/06/26	
Pengeboran & Pembesian — Bore Pile Z1	3 days	Mon 22/06/26	Wed 24/06/26	
Pengecoran — Bore Pile Z1	3 days	Wed 24/06/26	Mon 29/06/26	4
Bore Pile — Zone 2	3 days	Mon 29/06/26	Wed 01/07/26	
Pengeboran & Pembesian — Bore Pile Z2	1 day	Mon 29/06/26	Tue 30/06/26	5
Pengecoran — Bore Pile Z2	2 days	Tue 30/06/26	Wed 01/07/26	7
Pile Cap — Zone 1	9 days	Mon 29/06/26	Thu 09/07/26	
Pembesian — Pile Cap Z1	3 days	Mon 29/06/26	Wed 01/07/26	5
Bekisting — Pile Cap Z1	2 days	Wed 01/07/26	Fri 03/07/26	10
Pengecoran — Pile Cap Z1	4 days	Fri 03/07/26	Thu 09/07/26	11
Pile Cap — Zone 2	10 days	Wed 01/07/26	Tue 14/07/26	
Pembesian — Pile Cap Z2	3 days	Wed 01/07/26	Mon 06/07/26	8
Bekisting — Pile Cap Z2	3 days	Mon 06/07/26	Thu 09/07/26	14
Pengecoran — Pile Cap Z2	4 days	Thu 09/07/26	Tue 14/07/26	15
LANTAI 1 — Pekerjaan Struktural	20 days	Thu 09/07/26	Mon 03/08/26	

Figure 5. 28 Structural Works Bar Chart (Gantt Chart) in Microsoft Project

Source : Ms. Project (2026)

The total returned by Microsoft Project in Figure 5.28 matched the 127 working days obtained by hand, which was a useful confirmation that the manual logic and the software agreed and that no dependency had been miscoded. Beyond confirming the number, the Gantt chart makes the schedule legible in a way a table of figures cannot, showing the two zones of each floor running in parallel and the clean hand-off from one floor to the next. From here the schedule was exported in a format Autodesk Navisworks could read, so that it could serve as the time source for the four-dimensional simulation.

Figure 5.28 presents the opening segment of the bar chart, showing the project start date and the sequencing of foundation works. The complete Gantt chart, encompassing all 155 scheduled tasks across 14 zones, is provided in Appendix 9 for full reference.

5.3.9 4D Integration in Autodesk Navisworks

The four-dimensional model was assembled by bringing the geometry from Tekla and the schedule from Microsoft Project together inside Autodesk Navisworks. The work fell into three steps: importing the model, importing the schedule, and linking the two in the TimeLiner. The imported structural model is shown in Figure 5.29.

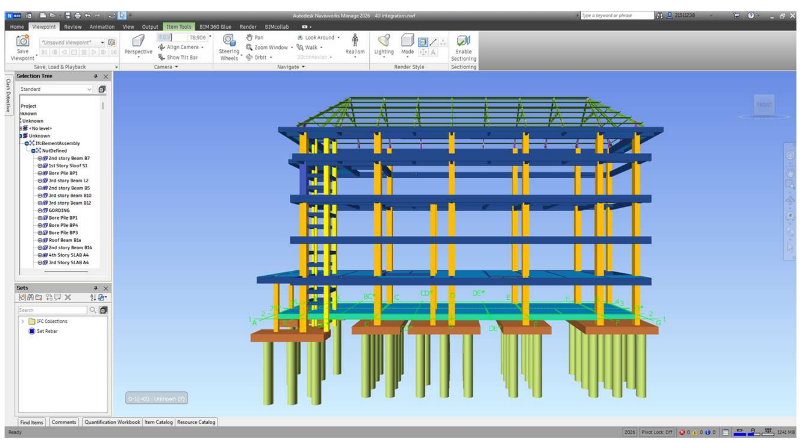


Figure 5. 29 Imported Structural Model in Autodesk Navisworks
Source : Autodesk Navisworks (2026)

The model in Figure 5.29 was transferred through the IFC format, using the IFC file that had already been prepared so that no re-export from Tekla was needed.

On import, the model kept its element hierarchy and the identifying properties of each cast unit, which were exactly the properties needed to tie the geometry to the right scheduled task. A check that the element count and the layout in Navisworks matched the source model confirmed the transfer had not dropped or distorted anything. The schedule was then brought into the TimeLiner and linked to the model elements, as shown in Figure 5.30.

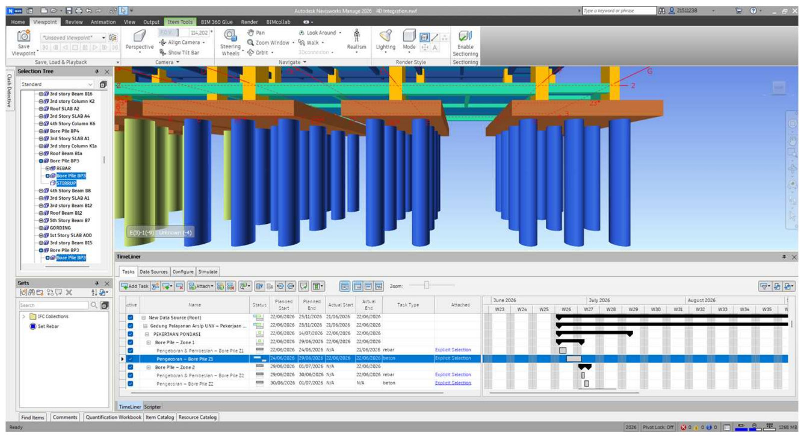


Figure 5. 30 Linking Tasks to Model Elements in the TimeLiner
Source : Autodesk Navisworks (2026)

In the linking step shown in Figure 5.30, each task carried its planned start, planned finish, and task type from the Microsoft Project file, so that the dependency-driven timeline was reconstructed inside Navisworks without changing any of the durations, and each task was then attached to its corresponding set of model elements using selection sets defined by pour phase. With both the geometry and the time data in place, running the simulation produced a time-based animation of the structure being built. Representative frames from this simulation are shown in Figure 5.31.

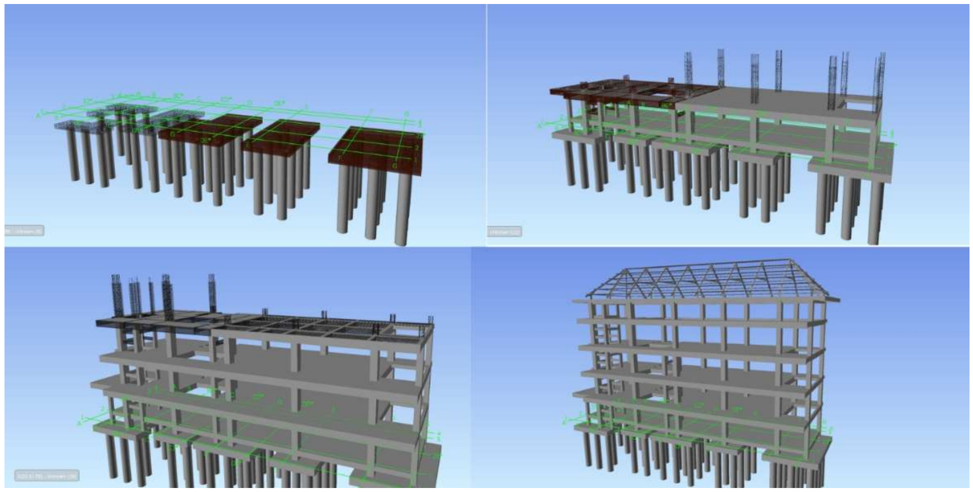


Figure 5. 31 Representative Frames of the 4D Construction Simulation
Source : Autodesk Navisworks (2026)

The four frames shown in Figure 5.31 represent key milestones in the structural work progression. The complete 4D simulation video can be accessed by scanning the QR code provided in Figure 5.32

Figure 5. 32 QR Code for 4D BIM Simulation Video
Source : Personal Document (2026)

The frames in Figure 5.31 show the structure rising foundation first and roof truss last, with the two zones of each floor advancing together, and this animation is the visual project output called for by the second research objective. Its value is not that it changes any number, since the durations are identical to the schedule it was built from, but that it makes the spatial and temporal progress of the work visible at a glance. A project participant who would struggle to read the Gantt chart in Figure 5.28 can watch the building assemble itself and immediately grasp the sequence, and any clash in that sequence would reveal itself on screen before it ever reached the site. This legibility is the clearest qualitative advantage the BIM 4D approach holds over the conventional bar chart.

5.4 Duration Comparison Analysis

The central quantitative question of this study is how the structural duration from the BIM 4D method compares with the conventional schedule in the project S-curve. The conventional plan allowed about seventeen weeks for the structural works, a figure that fits the span of the structural packages within the S-curve, where the foundation, concrete, and roof work occupy roughly the first fifteen to seventeen weeks of the twenty-two week execution period. The BIM 4D method, after the corrections described in Subsection 5.3.7, produced 127 working days, or about twenty-one working weeks. The two figures are set side by side in Table 5.18

Table 5. 18 Conventional S-Curve and BIM 4D Comparison

No.	Method	Duration (working days)	Duration (weeks)	Basis	Source
1	Conventional S-Curve	±102 working days	17 weeks	Calendar-based weighted progress (150 calendar days)	Project S-Curve, PT. Heri Jaya Palung Buana, 13 May 2024
2	BIM 4D (this study)	127 working days	≈ 22 weeks	Explicit activity-based scheduling, 7 hrs/day × 6 days/week	Tekla QTO + AHSP CK 2023, Author's Analysis (2024)
3	**Difference (BIM4D − Conv.)**	**+25 working days**	**≈ 5 weeks**	**+24.7%**	–

Source : Personal Document (2026)

As Table 5.18 records, the BIM 4D schedule is around four weeks, or roughly twenty-four percent, longer than the conventional plan. At first glance a longer duration looks like a worse result, and it is tempting to read it that way. It is not. Two things explain the gap, and both are about transparency rather than inefficiency.

The first is simply that the two schedules count time in different units. The S-curve distributes weighted progress across calendar weeks and is expressed in 150 calendar days, whereas the BIM 4D schedule is built from effective working days of seven hours each, six days a week. A schedule made of explicit working days will always look longer than one read off a calendar-based progress curve, because the calendar curve quietly folds the non-working time into its distribution of weights instead of putting it on display. Comparing the two without acknowledging this would be comparing two different clocks. The second reason runs deeper. The BIM 4D schedule models every technological constraint as a discrete activity with its own duration and its own dependencies, so that every formwork operation, every reinforcement operation, every pour, and every curing lag is there to be counted. The S-curve does none of this, expressing progress instead as a smooth aggregate of cost weight that never exposes the sequential constraints between individual operations. This distinction is not merely a matter of presentation. Doukari et al (2022) observe that conventional construction schedules rarely state every project activity or define all of the operational dependencies explicitly, whereas a 4D BIM schedule requires the full dependency chain to be declared for each model element before the simulation can run. A schedule that accounts for constraints the conventional plan left implicit will therefore read longer, and by a margin that grows with the number of such constraints present in the works. The longer BIM 4D figure is, on this reading, not a less efficient plan but a more complete one.

The size of this unit-of-time effect can be shown directly. The conventional plan of seventeen weeks, read off a calendar that runs seven days, corresponds to a far smaller number of effective working days once weekends and non-working time are removed, whereas the BIM 4D figure of 127 days is already net of that time. Converting both onto the same six-day working week brings them much closer together than the raw comparison of seventeen against twenty-one weeks suggests, and confirms that a substantial part of the apparent gap is a matter of how time is counted rather than how much work there is. The residual difference that remains after this adjustment is the genuine, work-related part of the gap, and it is this residual that the formwork analysis explains.

The comparison also points to where the conventional plan is most optimistic. Because formwork governs the larger concrete phases, and because the S-curve never isolates formwork as a constraint, the conventional plan implicitly assumes either a higher formwork productivity or a degree of overlap that the explicit calculation does not support at the crew sizes actually assigned. That, more than anything else, is the likely origin of the four-week gap. The distribution of the difference across the building is shown floor by floor in Figure 5.33.

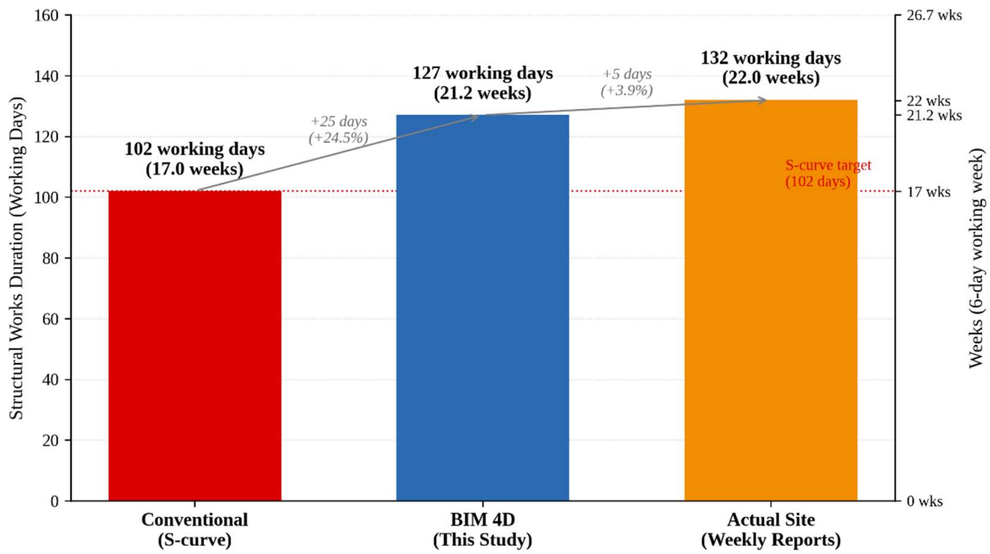


Figure 5. 33 Comparison of Structural Works Duration
Source : Personal Document (2026)

Figure 5.33 sets the BIM 4D result against both the conventional plan and a third reference that has not so far been brought into the comparison, namely the duration the structural works actually took on site. This third figure is developed in detail below, but its position in the chart already makes the essential point that the BIM 4D estimate does not stand apart from reality as the longest of three bars, but sits between the optimistic conventional plan and the slightly longer actual outcome. Splitting the comparison by work package, rather than looking only at the total, shows precisely where the four-week difference between the BIM 4D schedule and the S-curve comes from, and this breakdown is presented in Table 5.19.

Table 5. 19 Duration Comparison by Structural Work Package

No.	Work Package	BIM 4D Duration (working days)	BIM 4D Duration (weeks)	Conventional Span (weeks)	Actual Duration	Difference (weeks)	Key Finding
1	Foundation (Bore Pile + Pile Cap)	17	2.8	~5	~4	−2.2	BIM 4D foundation shorter. No mobilisation/ exploratory time in BIM calculation
2	Concrete Superstructure (Lt. 1–Roof)	86	14.3	~10	~13	+4.3	Almost all duration difference concentrated here. Repetitive formwork accumulates
3	Steel Roof Truss	24	4.0	~4	~5	≈ 0	Steel erection duration matches conventional estimate
4	**OVERALL STRUCTURAL**	**127**	**≈ 22**	**17**	**22**	**≈ 5**	**BIM 4D result is longer by +24.7%. Formwork is the dominant constraint**

Source : Personal Document (2026)

Table 5.19 is revealing. The foundation and the roof come out broadly comparable between the two methods, at roughly three and four weeks respectively, but the concrete superstructure is where the two diverge. The BIM 4D method assigns it about fifteen weeks against the ten weeks implied by the concrete package in the S-curve. In other words, almost the entire four-week difference between the two schedules is concentrated in the superstructure concrete, not spread evenly across the project. This is exactly what the formwork finding would predict, because the superstructure is where all of the repetitive beam and slab forming lives, while the foundation and the roof carry comparatively little formwork relative to their other work. Locating the difference this precisely is only possible because the BIM 4D schedule breaks the work into explicit, resource-driven activities. The S-curve, treating concrete as a single smooth block, offers no way to see that the gap lives almost entirely inside the forming of the upper floors.

Reading the actual spans alongside the two plans brings out a finding with practical weight for the contractor. A conventional plan that allots seventeen weeks to a structure that realistically needs about twenty-two does not merely misinform, it exposes the contractor to the appearance of delay, with the contractual and reputational consequences that follow, even when the site is in fact performing normally. The five-week shortfall is in this sense a planning error embedded in the conventional schedule rather than a performance failure on site, and the BIM 4D schedule, landing within a week of the realised duration, is the estimate that would have set the correct expectation from the start. For a contractor, a resource-driven 4D schedule prepared at the planning stage is therefore not only a visualisation aid but a protection against committing to a duration that the sequencing of the work cannot deliver.

The comparison to this point has set one plan against another, the BIM 4D schedule against the conventional S-curve. A stronger test is available, because the project documented its own structural execution week by week in the site weekly reports, and these records make it possible to ask which of the two plans came closer to what happened. The weekly reports track the cumulative physical progress of each work package against its planned weight, so the structural package, which carries a total weight of 46.297 percent of the contract, can be followed from the first week of work through to the point where it reaches its final recorded value. Reading the structural progress in this way converts the weekly reports from a simple archive into a direct benchmark for the two schedules, and the duration that results from it is the third reference already introduced alongside the conventional plan and the BIM 4D schedule in Figure 5.33.

The weekly records tell a clear story. For the first sixteen weeks the reported structural progress kept pace with the contractor’s plan, because the concrete structure went up broadly on programme through the foundation and the lower floors. The agreement ends there. The plan placed structural completion at Week 17, which is the seventeen-week figure carried into the conventional comparison, but the site did not reach it. The reports show that the concrete works reached about ninety-eight percent of their planned quantity by Week 17 and then effectively stalled, holding flat through Week 18 with no further structural progress recorded. The reason becomes plain in the following weeks. The roof package, comprising the steel truss erection that the conventional plan had positioned within the same seventeen-week window, did not begin on site until Week 19, corresponding to the report period beginning 7 October 2024, and it continued through to Week 22. The structural works reached their final recorded progress only at Week 22, the report period ending 3 November 2024, which is calendar day 154 from the project start of 3 June 2024.

Translating that calendar span into the same unit used by the BIM 4D schedule places the actual structural duration at about 132 working days on a six-day week, equivalent to twenty-two working weeks. Set against this benchmark, the two plans diverge sharply in accuracy. The conventional S-curve, at seventeen weeks or about 102 working days, underestimated the actual structural execution by roughly thirty working days, a shortfall of almost a quarter of the realised duration. The BIM 4D schedule, at 127 working days, fell only about five working days short of the actual figure, a difference of under four percent. The longer duration that the BIM 4D method produced, and which at first reading looked like a penalty, turns out to be the more accurate of the two forecasts by a wide margin. The gap between the BIM 4D schedule and the S-curve is therefore not the distance between a correct answer and an inflated one, but very nearly the opposite: it is close to the distance between the conventional plan and what the site delivered.

Expressed as relative errors against the realised duration, these deviations take a simple numerical form. The BIM 4D schedule missed the actual duration by five working days out of 132, which is an error of 3.8 percent, while the conventional S-curve missed it by thirty working days out of 132, which is an error of 22.7 percent. These two figures are the direct answer to the second research question, and they are the values carried into the abstract and the conclusions of this study.

It is worth being clear about the limits of this comparison, because the weekly reports measure realised progress rather than a controlled re-run of the schedule, and the actual duration carries within it the ordinary disruptions of a live site, including weather, material delivery, and the idle periods between trades that no pre-construction schedule sets out to predict. The BIM 4D figure is a planned duration and the 132-day figure is an outcome, so the two are not identical in kind. What the comparison does establish, and establishes firmly, is the direction and the rough magnitude of the error in each plan. A conventional schedule that finishes the structure five weeks before the site does is optimistic in a way that matters for planning, while a BIM 4D schedule that lands within a week of the realised duration is, for practical purposes, a dependable forecast. This is the sense in which the actual record corroborates the BIM 4D result rather than merely coexisting with it.

5.5 Discussion

Pulling the results together, the analysis answers both research purposes set at the start. On the first purpose, the BIM 4D method produced a structural duration of 127 working days that, although about a quarter longer than the conventional plan of 102 working days, can be defended line by line, since every figure traces back to a standardized productivity, a justified crew, and an enforced dependency. On the second purpose, measuring both schedules against the actual structural duration of about 132 working days shows that the BIM 4D schedule deviated from the realised outcome by only five working days, a 3.8 percent error, while the conventional S-curve deviated by roughly thirty working days, a 22.7 percent error. The two findings reinforce the argument made in the introduction, that the value of BIM 4D in structural scheduling lies less in producing a shorter programme than in producing a transparent, auditable, and demonstrably more accurate one. The time-based simulation assembled in Navisworks supports this conclusion by making the governing sequence visible, and it stands as the practical output that accompanies the measured comparison.

The strongest single piece of evidence for that argument comes from the project's own execution record. As Subsection 5.4 set out, the structural works took about 132 working days on site, reaching completion in Week 22, whereas the conventional S-curve had allowed only seventeen weeks. The BIM 4D schedule, at 127 working days, came within five working days of the realised duration, while the S-curve fell short of it by roughly thirty. This is the clearest possible demonstration that the longer BIM 4D figure reflects planning accuracy rather than modelling error. The mechanism behind the difference is the one identified by Doukari et al. (2022), who note that a 4D BIM schedule forces every model element to be linked to a discrete, explicitly sequenced activity, so that operational dependencies which a conventional progress curve leaves implicit are made visible and counted. On this project the dependency that the S-curve concealed was the one between the completion of the concrete structure and the start of the steel roof truss, which could not begin in earnest until the supporting floors were complete. The S-curve folded the roof into the same seventeen-week window as the concrete; the site could not, and the truss did not start until Week 19. The BIM 4D schedule, by modelling that hand-off as an explicit predecessor relationship, anticipated the very delay that the conventional plan had hidden.

The most useful single insight to come out of the analysis is the dominance of formwork. Across the beam and slab phases the formwork duration governs almost completely, while reinforcement and concreting are dispatched in a day or two. The practical implication is unusually clear. If this project needed to be accelerated, the place to spend effort is formwork capacity, whether more formwork sets or larger forming crews, and not concrete supply or rebar fixing, because adding resources to the latter two would leave the critical path essentially untouched. The conventional S-curve hides this completely, showing concrete as a single smooth block of progress and giving a planner no way to see that the constraint living inside that block is the formwork. Surfacing a constraint that the conventional tool conceals is, in itself, a worthwhile result for the method, and it is the kind of insight a contractor could act on directly.

This finding also connects back to the literature in a useful way. The studies reviewed in Chapter II approached 4D BIM from several different angles. Doukari et al. (2022) concentrated on improving the workflow for generating 4D schedules efficiently, while Caldart and Scheer (2022) and Salman and Hamadeh (2023) demonstrated its value for site-layout planning and multi-party coordination. Abma et al. (2026) showed that BIM-based quantity take-off can produce accurate concrete and reinforcement quantities for structural elements, establishing the reliability of the BIM model as a data source. Ulil Albab and Erizal (2021) worked closest to the present scope, applying 4D BIM to a reinforced concrete building and comparing the planned S-curve against realised site progress, finding delays driven primarily by logistics and weather. None of these studies, however, used the explicit activity breakdown to identify a specific governing resource within the structural works and then test the resulting schedule duration against the realised site record. The present study extends from where Abma et al (2026). left off, taking the quantity data that BIM produces and using it as the direct input to a resource-driven schedule, then closing the loop by measuring that schedule against what the project actually achieved. The identification of formwork as the rate-limiting resource, confirmed by a BIM 4D schedule that landed within five working days of the actual structural duration, is therefore a modest but genuine addition. It shows that the value of an explicit 4D schedule is not only visualisation and duration comparison, but also diagnosis, the ability to say which trade actually controls the programme, and prediction, the ability to produce a duration estimate that holds up against what the project went on to achieve.

The resource demand estimated in Subsection 5.3.7 adds a second practical dimension to this conclusion. A peak of around sixty concurrent workers is not a trivial mobilisation on a tight campus site with limited space for movement and storage, and it interacts directly with the formwork finding, because increasing the forming crews to shorten the critical path would push that peak higher still, against the constraint of a congested site. The honest implication is that acceleration on this particular project is not simply a matter of adding workers, but of adding forming capacity in a way the site can physically absorb, perhaps by staggering the zones differently or by investing in faster formwork systems rather than more labour. This is the kind of trade-off that becomes visible only once the schedule is resource-aware, and it would remain entirely hidden in a conventional progress curve.

It is worth stating precisely why the governing constraint is the dependency between zones rather than the size of the crews, because the two explanations lead to very different responses on site. The peak of around sixty concurrent workers cited above is the total across all trades on the busiest days, while the formwork trade that governs the critical path runs at a steady sixteen carpenters and reaches twenty-two only when two pours are being prepared at once. Space is not what caps these numbers. The building floor plate measures about 40 m by 16 m, roughly 640 m^2, so even the peak formwork crew of twenty-two workers enjoys on the order of 29 m^2 of working area each, several times the envelope of about 3 m by 3 m that a carpenter needs to work productively and safely, and the site could therefore physically absorb a substantially larger crew. What prevents a larger crew from shortening the programme is the predecessor logic between the zones, as illustrated at the end of Subsection 5.3.7. The formwork of one zone cannot begin until the pour of the preceding zone on the same floor is complete, and the columns of the next floor cannot start until the slab beneath them has been cast, so the pour phases form a chain in which each link waits on the one before it. Enlarging the crew inside any single phase shortens that phase by at most a few days but does nothing to the waiting imposed by the chain itself, which is why the 127-day duration is held in place by the zone-to-zone dependencies rather than by any shortage of labour. In scheduling terms the constraint is logical rather than resource-based, and it is exactly the kind of distinction that only an explicit, dependency-linked schedule can make visible.

There is a point of method worth drawing out here, concerning the productivity standard used. The durations in this study rest on the AHSP CK 2023 coefficients, and the formwork coefficient in particular is calibrated for conventional timber forming rather than for the prefabricated steel-framed formwork the contractor actually used on site. In principle a faster forming system should have produced shorter forming durations than the standard coefficient predicts, which would have pulled the BIM 4D figure below 127 days. That this did not translate into a realised duration shorter than the BIM 4D estimate, but rather into one slightly longer, is itself informative. It suggests that whatever time the faster formwork saved at the level of the individual pour was absorbed by the sequencing and site constraints that operate at the level of the whole programme, the zone-to-zone dependencies and the hand-offs between trades that govern the critical path. The coefficient choice is thus best understood as a documented limitation of the inputs rather than as a flaw in the result, since the realised duration confirms that the schedule as a whole was not optimistic. The point is noted again among the recommendations, where calibrating the coefficients against measured site productivity is proposed as a refinement.

The revision of the crew sizes deserves a closing reflection, because it was the part of the work that changed most and taught the most. The original uniform assumption produced numbers that looked tidy but could not be defended, precisely because it ignored that different work types carry different labor intensities. Differentiating the crews by element and task, and tying each one to the labor composition implied by the AHSP coefficients, turned the schedule from a set of plausible-looking estimates into a calculation that can be reproduced and challenged. The general lesson is one worth carrying beyond this project: a duration is only as credible as the resource assumption beneath it, and any crew size that cannot be justified is a weak point in the schedule no matter how reasonable the final total happens to look.

The experience of carrying the workflow end to end also bears out the suitability of the software chain argued in Chapter III. Tekla Structures proved appropriate for the structural scope because every cast unit and reinforcement bar existed in the model as a discrete object, which allowed the quantity take-off to be extracted per element and per pour phase without remodeling, and it is this element-level granularity that made the later task-to-element linking possible at all. Autodesk Navisworks proved appropriate on the integration side because it accepted the Tekla geometry through the IFC file without loss of the element structure, and because its TimeLiner feature attached the Microsoft Project tasks to the model elements directly, reconstructing the dependency-driven timeline inside the simulation without manual re-entry of dates. The practical measure of this suitability is that the 541 cast units, the 155 scheduled tasks, and the simulation were connected using nothing beyond the standard export formats of each application, which supports the argument made in Chapter III that this chain is an established and interoperable route for 4D scheduling of structural works.

Finally, it is worth reflecting on how far this workflow could travel beyond the present case. Nothing in the chain from Tekla Structures through Microsoft Project to Autodesk Navisworks is specific to this building, and the same sequence of modeling, take-off, duration calculation against AHSP coefficients, and 4D integration could be applied to any reinforced concrete frame for which shop drawings exist. What would change from one project to the next is the zoning, the crew sizes, and the quantities, all of which are inputs rather than fixed features of the method. This generality is part of the practical value of the approach, since it offers not just a result for one archive building but a repeatable procedure that a contractor or a student could follow on a different project, with the confidence that every duration it produces can be traced back to a standard coefficient and a justified crew. In that sense the most transferable outcome of the study is not the 127-day figure but the workflow that produced it, and the demonstration that the figure it produces can be trusted against the record of a real site.

CHAPTER VI
CONCLUSION AND SUGGESTION

6.1 Conclusion

Drawing on the analysis and discussion of the previous chapter, the following conclusions answer the two problem statements of this study directly.

1. On the difference in structural duration between the conventional method and the BIM 4D simulation, the BIM 4D method produced a duration of 127 working days, about twenty-one working weeks at six days a week, against the roughly seventeen weeks or about 102 working days allowed by the project S-curve. The BIM 4D schedule is therefore some four weeks, or about twenty-four percent, longer than the conventional plan. This difference is not a sign of a less efficient programme. It arises because the BIM 4D schedule is built from explicit working days and models every formwork, reinforcement, concreting, and curing operation as a discrete, dependency-linked activity derived from the quantity take-off and the AHSP CK 2023 productivity standard, whereas the S-curve spreads weighted progress over calendar time and leaves these constraints hidden. This direction of difference is consistent with the property of 4D BIM scheduling described by Doukari et al. (2022), namely that linking each model element to an explicitly sequenced activity surfaces the operational dependencies a conventional progress curve leaves invisible. A specific technical finding of the comparison is that formwork, rather than concrete or reinforcement, is the rate-limiting resource of the superstructure, something the conventional schedule gives no way of seeing.
2. On the deviation of the two schedules from the actual duration of the structural works, the site weekly reports place the realised structural duration at about 132 working days, with the structural package reaching its final recorded progress in the week ending 3 November 2024. Measured against

this benchmark, the BIM 4D schedule of 127 working days fell short by only five working days, an error of 3.8 percent, while the conventional S-curve of about 102 working days underestimated the realised duration by roughly thirty working days, an error of 22.7 percent. The BIM 4D schedule is therefore not merely the longer of the two plans but by a wide margin the more accurate one, and the deviation analysis shows that its additional length reflects real sequencing constraints that the site also experienced, most visibly the hand-off from the concrete structure to the steel roof truss that the S-curve had folded into its seventeen-week window but that did not begin on site until Week 19. The four-dimensional simulation produced by integrating the Tekla Structures model with the Microsoft Project schedule in Autodesk Navisworks remains a supporting output of the study, communicating this sequence visually, but the substantive answer to the second problem statement is the measured accuracy of the two methods.

6.2 Suggestion

In light of the results and the limitations identified, the following suggestions are offered for practice and for further research.

1. For the contractor, any effort to accelerate the structural works should be aimed at formwork capacity rather than at concrete or reinforcement, because the analysis shows formwork to be the activity that governs the duration of the larger concrete phases. Providing more formwork sets, or enlarging the forming crews, would shorten the critical path more directly than any change to the other trades, whereas adding resources to concreting or reinforcement would yield little because those operations are already completed well within a day.
2. For future research, the planned productivities taken from the AHSP CK 2023 standard should be replaced or supplemented with productivities measured from the project weekly reports, so that the schedule can be calibrated against real site performance. The present study has already shown that the realised structural duration of about 132 working days sits close to the BIM 4D

estimate; a calibrated set of coefficients, particularly for the steel-framed formwork actually used on site, would allow that correspondence to be tightened further and the source of the residual difference to be isolated activity by activity.

3. The position numbering of every element in the Tekla model should be completed before the quantities are exported, and a dedicated reinforcement export should be configured, so that the rebar quantities can be obtained without the separate manual checking that was needed in this study, reducing both the effort and the room for error in preparing the data.

4. The four-dimensional model could be extended beyond the structural works to take in the architectural and the mechanical, electrical, and plumbing works, and then developed further toward the cost dimension (5D) and beyond, so that a single integrated model supports not only scheduling but also cost control and clash detection across all of the project's disciplines. Extending the simulation in this direction would also make the most of the visualization advantage demonstrated here, since the benefit of seeing the sequence grows as more trades are brought into the same model.

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APPENDIX

Appendix 1 Related Detailed Engineering Design (DED)

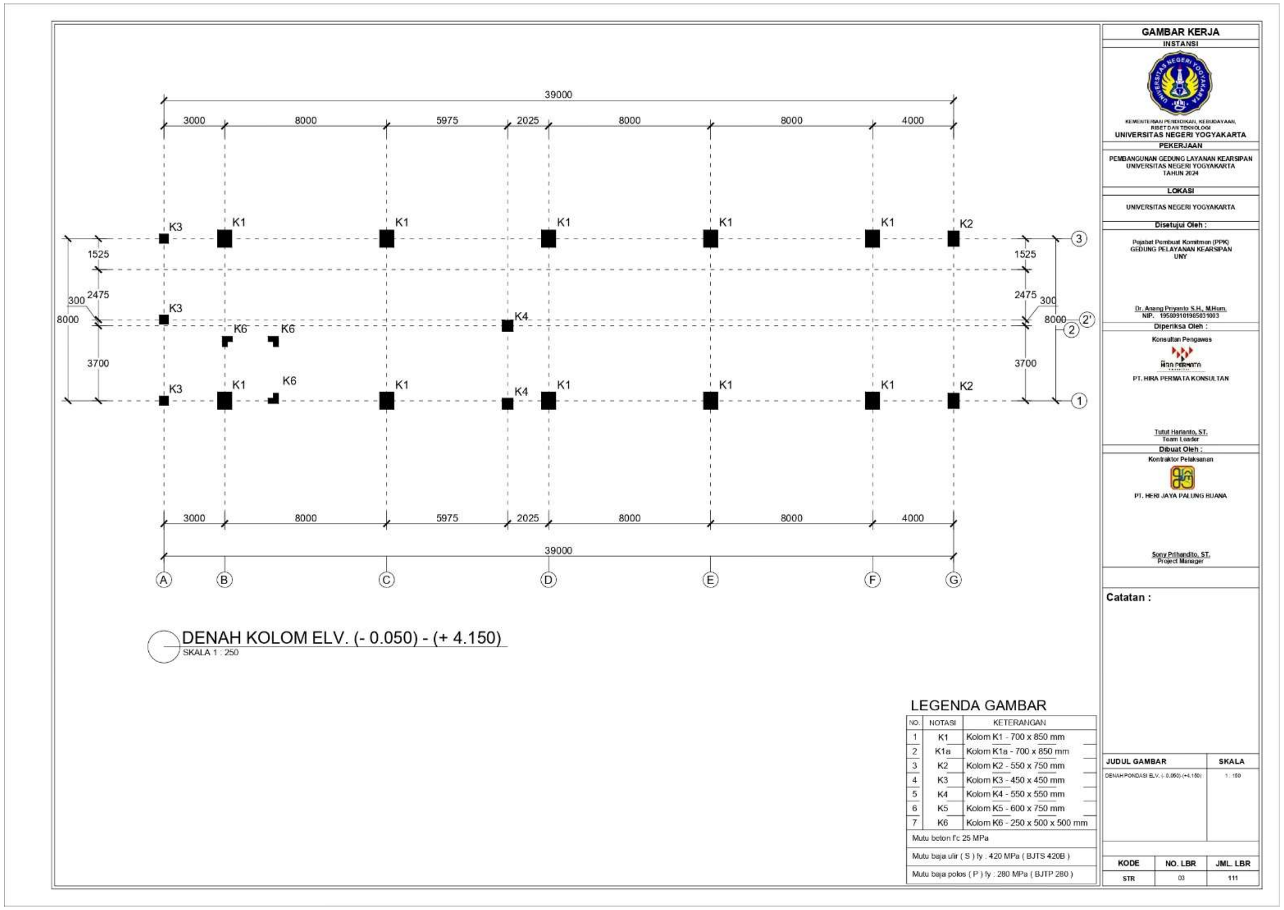


Figure A-1. 1 Site Plan of Elv. (-0.050) – (+4.150) Column

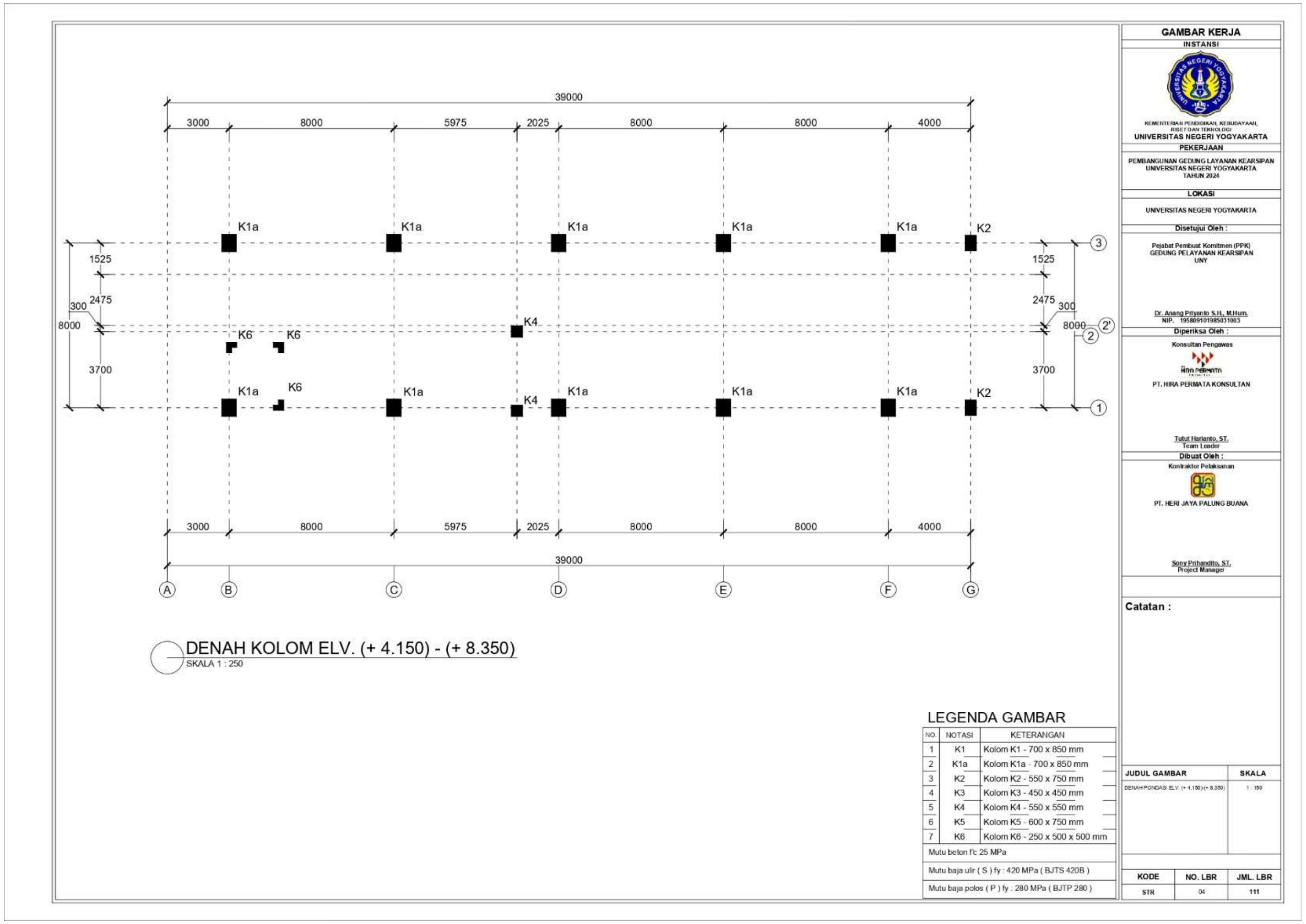


Figure A-1. 2 Column Site Plan of Elv. (+4.150) – (+8.350)

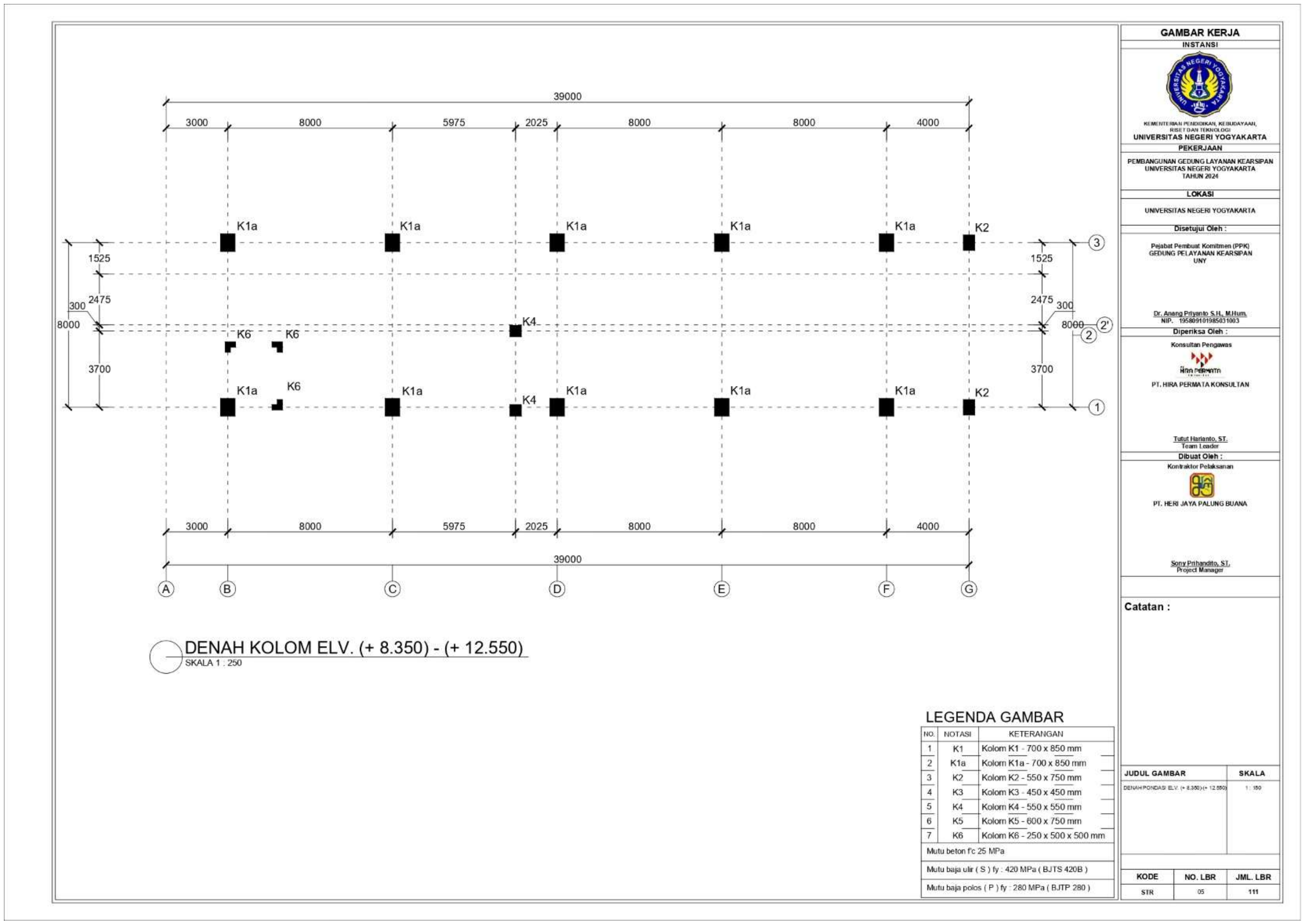


Figure A-1. 3 Column Site Plan of Elv. (+8.350) – (+12.550)

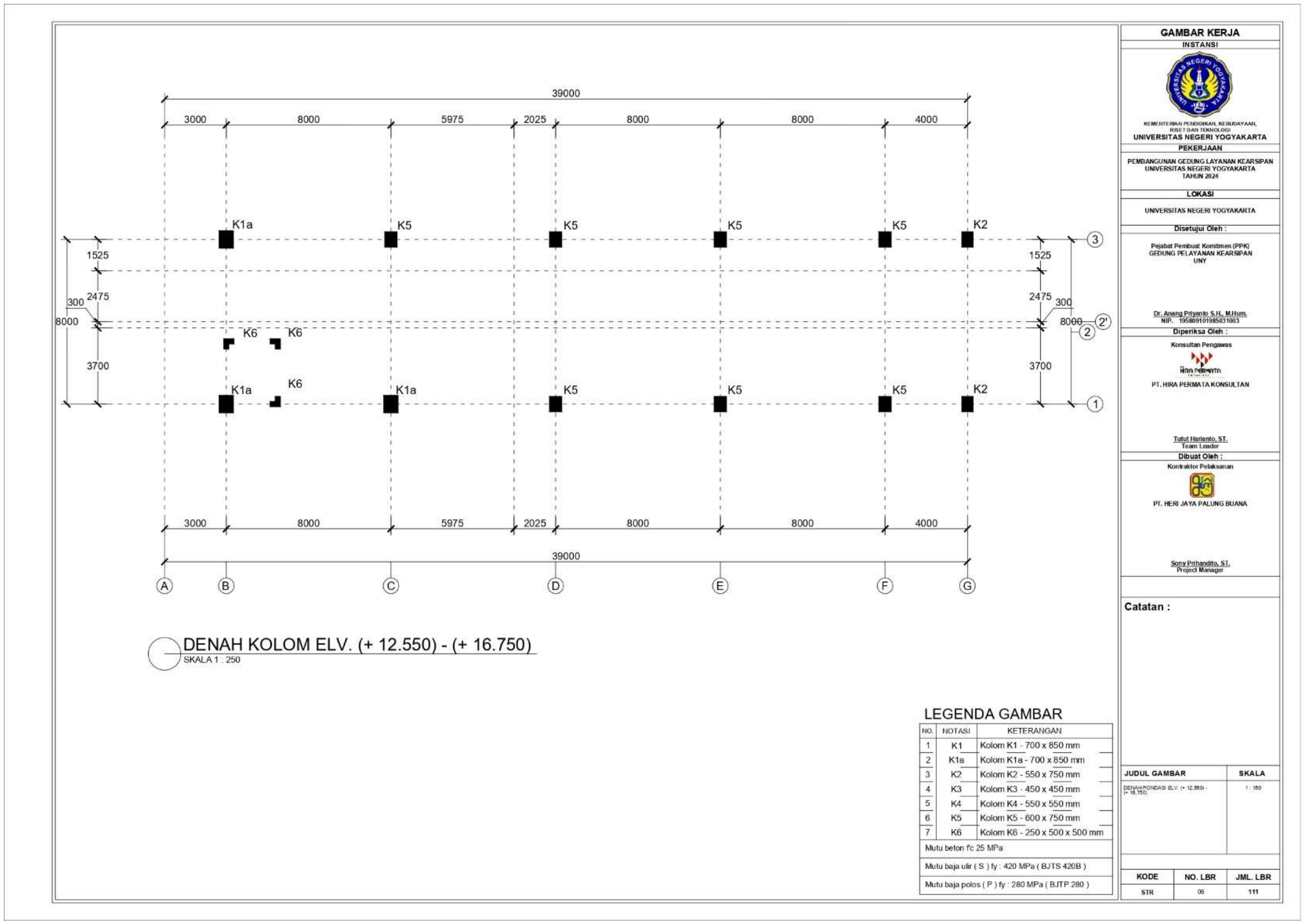


Figure A-1. 4 Column Site Plan of Elv. (+12.550) – (+16.750)

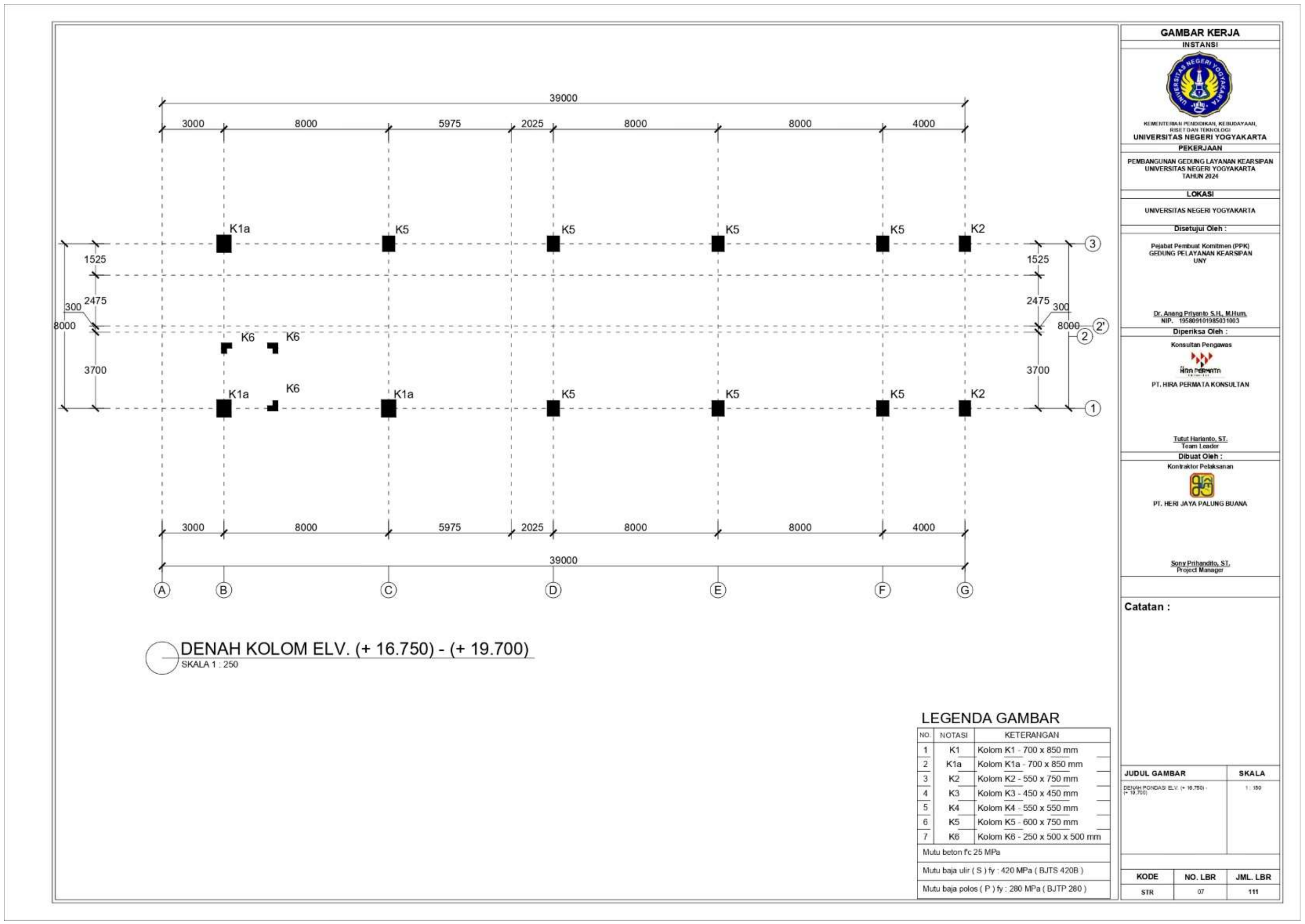
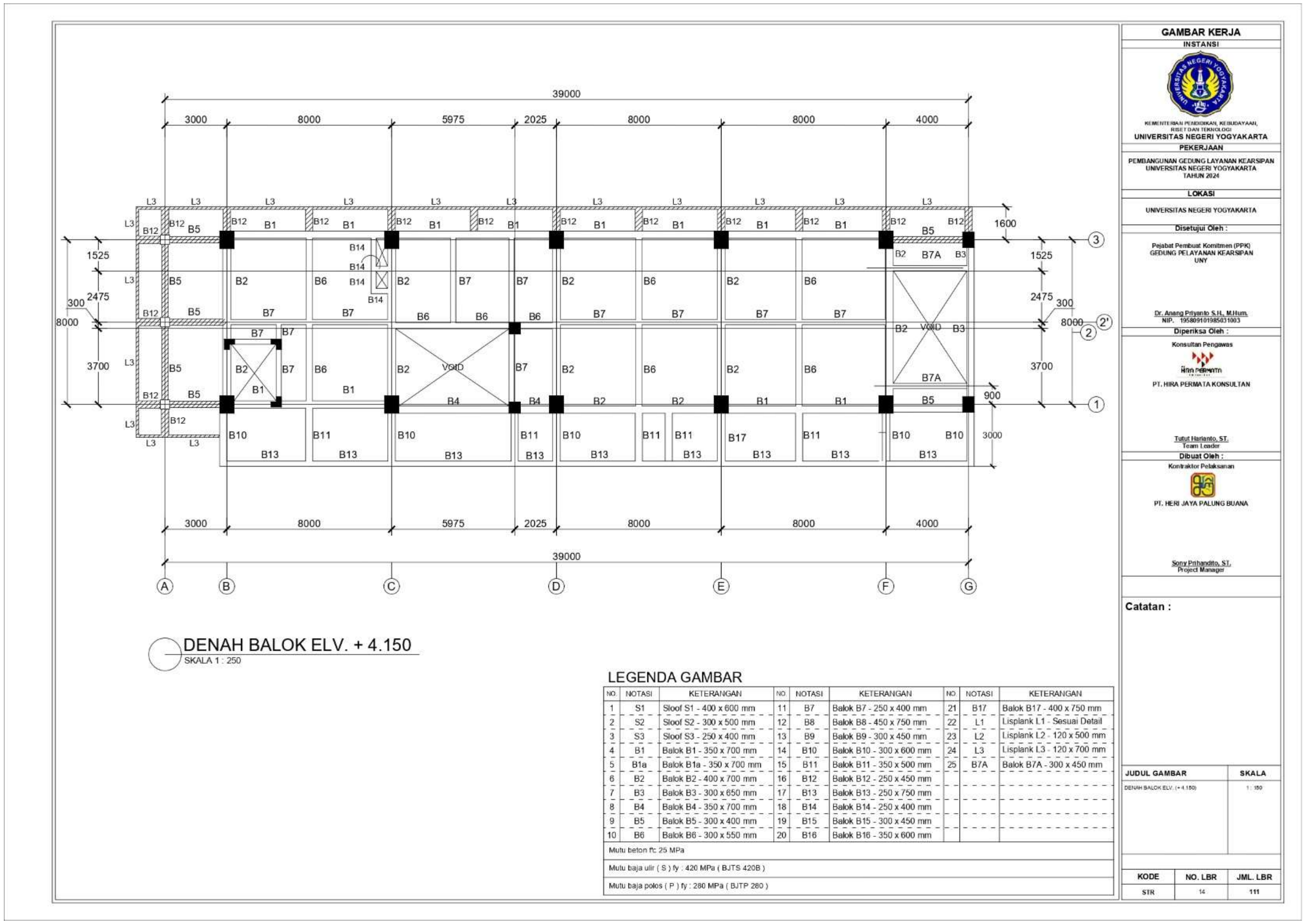


Figure A-1. 5 Column Site Plan of Elv. (+16.750) – (+19.700)



LEGENDA GAMBAR

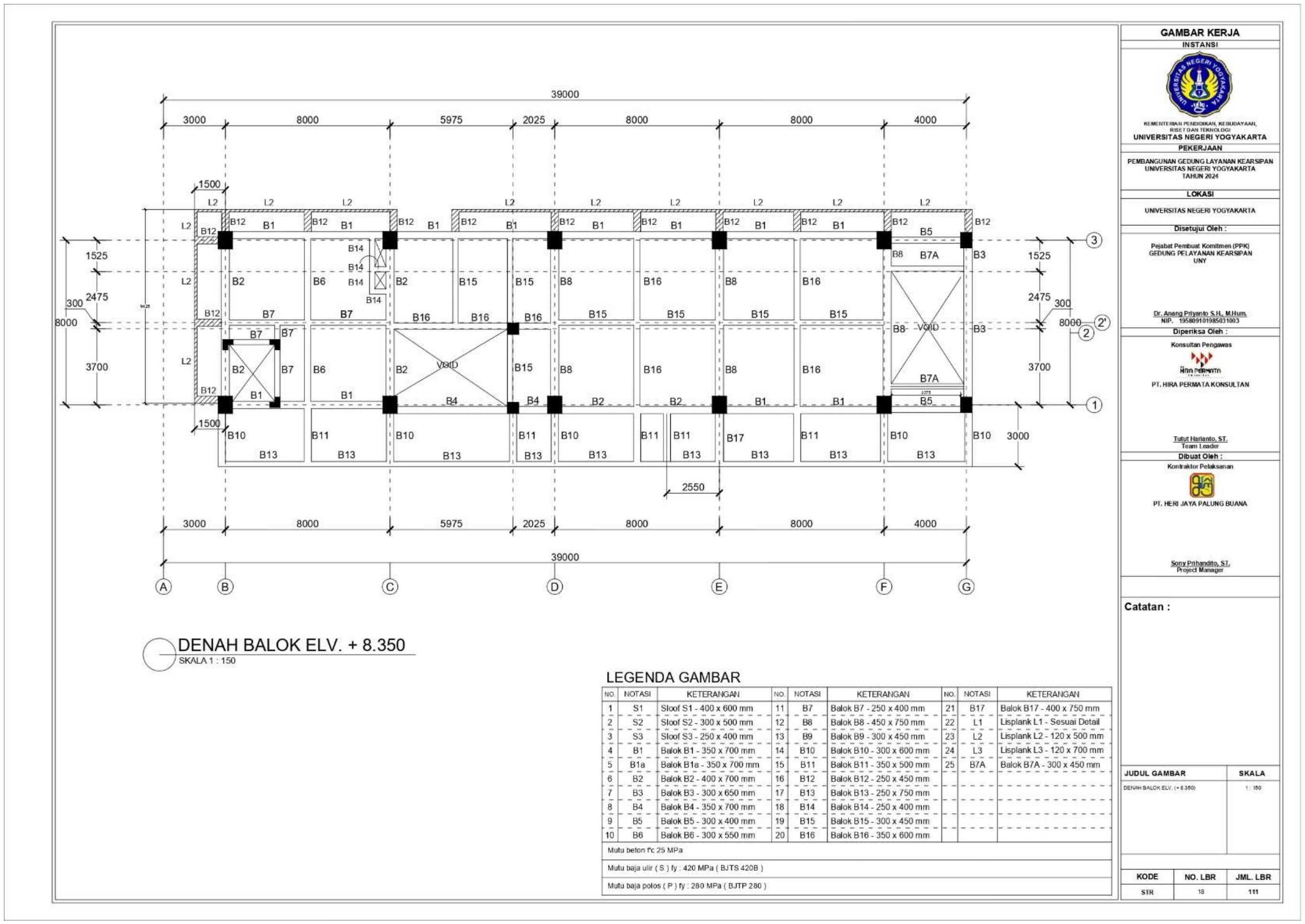
NO.	NOTASI	KETERANGAN	NO.	NOTASI	KETERANGAN	NO.	NOTASI	KETERANGAN
1	S1	Sloof S1 - 400 x 600 mm	11	B7	Balok B7 - 250 x 400 mm	21	B17	Balok B17 - 400 x 750 mm
2	S2	Sloof S2 - 300 x 500 mm	12	B8	Balok B8 - 450 x 750 mm	22	L1	Lisplank L1 - Sesuai Detail
3	S3	Sloof S3 - 250 x 400 mm	13	B9	Balok B9 - 300 x 450 mm	23	L2	Lisplank L2 - 120 x 500 mm
4	B1	Balok B1 - 350 x 700 mm	14	B10	Balok B10 - 300 x 600 mm	24	L3	Lisplank L3 - 120 x 700 mm
5	B1a	Balok B1a - 350 x 700 mm	15	B11	Balok B11 - 350 x 500 mm	25	B7A	Balok B7A - 300 x 450 mm
6	B2	Balok B2 - 400 x 700 mm	16	B12	Balok B12 - 250 x 450 mm			
7	B3	Balok B3 - 300 x 650 mm	17	B13	Balok B13 - 250 x 750 mm			
8	B4	Balok B4 - 350 x 700 mm	18	B14	Balok B14 - 250 x 400 mm			
9	B5	Balok B5 - 300 x 400 mm	19	B15	Balok B15 - 300 x 450 mm			
10	B6	Balok B6 - 300 x 550 mm	20	B16	Balok B16 - 350 x 600 mm			

Mutu beton f'c 25 MPa

Mutu baja ulir (S) fy : 420 MPa (BJTS 420B)

Mutu baja polos (P) fy : 280 MPa (BJTP 280)

Figure A-1. 6 Beam Site Plan of Elv. +4.150



LEGENDA GAMBAR

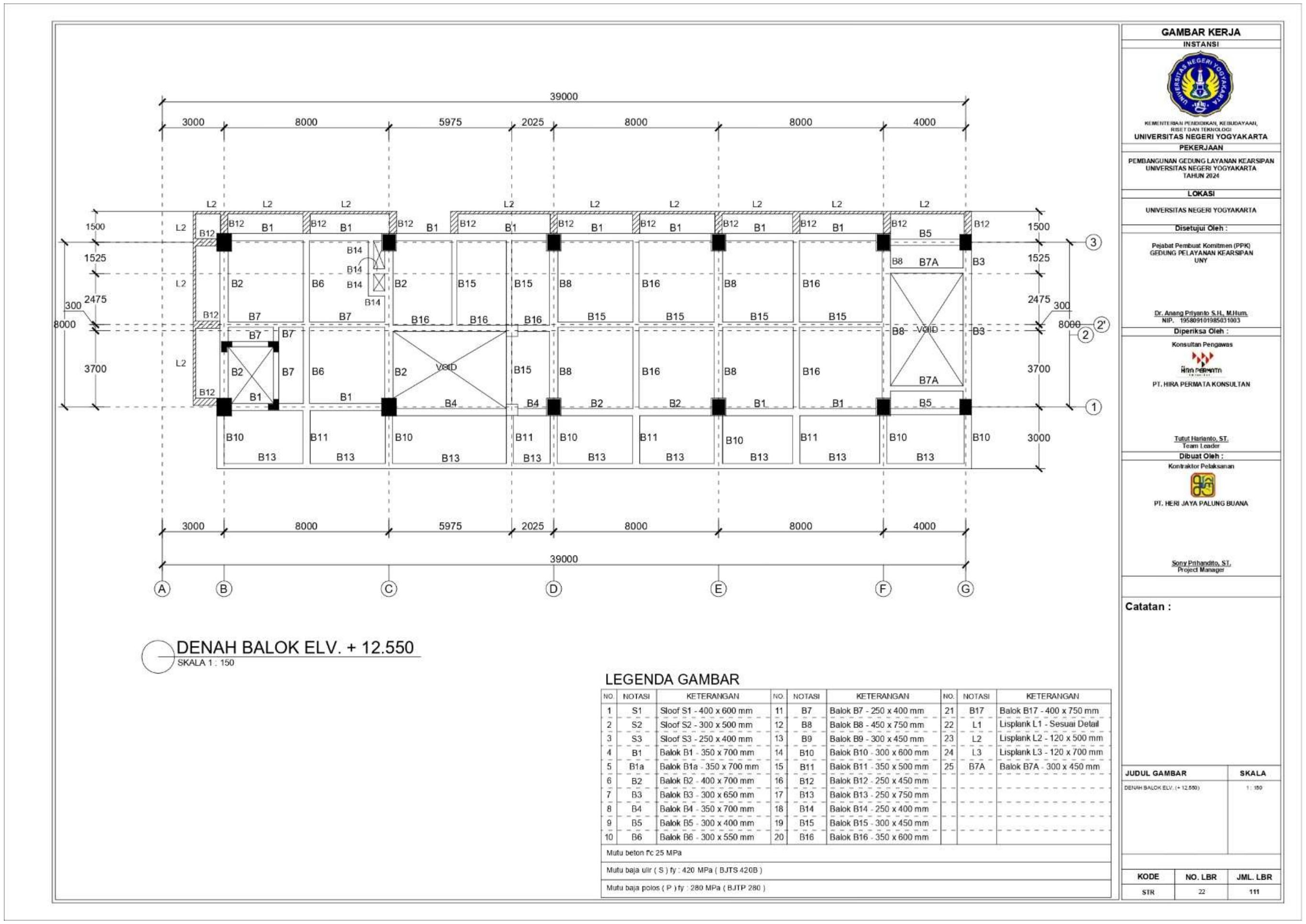
NO.	NOTASI	KETERANGAN	NO.	NOTASI	KETERANGAN	NO.	NOTASI	KETERANGAN
1	S1	Sloof S1 - 400 x 600 mm	11	B7	Balok B7 - 250 x 400 mm	21	B17	Balok B17 - 400 x 750 mm
2	S2	Sloof S2 - 300 x 500 mm	12	B8	Balok B8 - 450 x 750 mm	22	L1	Lisplank L1 - Sesuai Detail
3	S3	Sloof S3 - 250 x 400 mm	13	B9	Balok B9 - 300 x 450 mm	23	L2	Lisplank L2 - 120 x 500 mm
4	B1	Balok B1 - 350 x 700 mm	14	B10	Balok B10 - 300 x 600 mm	24	L3	Lisplank L3 - 120 x 700 mm
5	B1a	Balok B1a - 350 x 700 mm	15	B11	Balok B11 - 350 x 500 mm	25	B7A	Balok B7A - 300 x 450 mm
6	B2	Balok B2 - 400 x 700 mm	16	B12	Balok B12 - 250 x 450 mm			
7	B3	Balok B3 - 300 x 650 mm	17	B13	Balok B13 - 250 x 750 mm			
8	B4	Balok B4 - 350 x 700 mm	18	B14	Balok B14 - 250 x 400 mm			
9	B5	Balok B5 - 300 x 400 mm	19	B15	Balok B15 - 300 x 450 mm			
10	B6	Balok B6 - 300 x 550 mm	20	B16	Balok B16 - 350 x 600 mm			

Mutu beton f'c 25 MPa

Mutu baja ulir (S) fy : 420 MPa (BJTS 420B)

Mutu baja polos (P) fy : 280 MPa (BJTP 280)

Figure A-1. 7 Beam Site Plan of Elv. +8.350



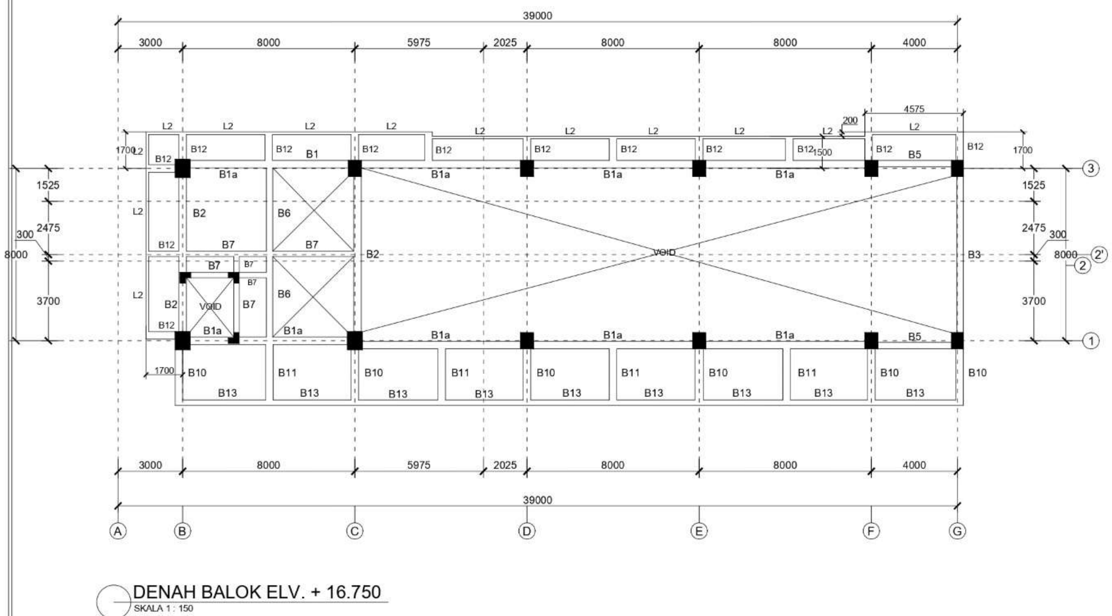
NO.	NOTASI	KETERANGAN	NO.	NOTASI	KETERANGAN	NO.	NOTASI	KETERANGAN
1	S1	Sloof S1 - 400 x 600 mm	11	B7	Balok B7 - 250 x 400 mm	21	B17	Balok B17 - 400 x 750 mm
2	S2	Sloof S2 - 300 x 500 mm	12	B8	Balok B8 - 450 x 750 mm	22	L1	Lisplank L1 - Sesuai Detail
3	S3	Sloof S3 - 250 x 400 mm	13	B9	Balok B9 - 300 x 450 mm	23	L2	Lisplank L2 - 120 x 500 mm
4	B1	Balok B1 - 350 x 700 mm	14	B10	Balok B10 - 300 x 600 mm	24	L3	Lisplank L3 - 120 x 700 mm
5	B1a	Balok B1a - 350 x 700 mm	15	B11	Balok B11 - 350 x 500 mm	25	B7A	Balok B7A - 300 x 450 mm
6	B2	Balok B2 - 400 x 700 mm	16	B12	Balok B12 - 250 x 450 mm			
7	B3	Balok B3 - 300 x 650 mm	17	B13	Balok B13 - 250 x 750 mm			
8	B4	Balok B4 - 350 x 700 mm	18	B14	Balok B14 - 250 x 400 mm			
9	B5	Balok B5 - 300 x 400 mm	19	B15	Balok B15 - 300 x 450 mm			
10	B6	Balok B6 - 300 x 550 mm	20	B16	Balok B16 - 350 x 600 mm			

Mutu beton f'c 25 MPa

Mutu baja ulir (S) fy : 420 MPa (BJTS 420B)

Mutu baja polos (P) fy : 280 MPa (BJTP 280)

Figure A-1. 8 Beam Site Plan of Elv. +12.550



LEGENDA GAMBAR

NO.	NOTASI	KETERANGAN	NO.	NOTASI	KETERANGAN	NO.	NOTASI	KETERANGAN
1	S1	Sloof S1 - 400 x 600 mm	11	B7	Balok B7 - 250 x 400 mm	21	B17	Balok B17 - 400 x 750 mm
2	S2	Sloof S2 - 300 x 500 mm	12	B8	Balok B8 - 450 x 750 mm	22	L1	Lisplank L1 - Sesuai Detail
3	S3	Sloof S3 - 250 x 400 mm	13	B9	Balok B9 - 300 x 450 mm	23	L2	Lisplank L2 - 120 x 500 mm
4	B1	Balok B1 - 350 x 700 mm	14	B10	Balok B10 - 300 x 600 mm	24	L3	Lisplank L3 - 120 x 700 mm
5	B1a	Balok B1a - 350 x 700 mm	15	B11	Balok B11 - 350 x 500 mm	25	B7A	Balok B7A - 300 x 450 mm
6	B2	Balok B2 - 400 x 700 mm	16	B12	Balok B12 - 250 x 450 mm			
7	B3	Balok B3 - 300 x 650 mm	17	B13	Balok B13 - 250 x 750 mm			
8	B4	Balok B4 - 350 x 700 mm	18	B14	Balok B14 - 250 x 400 mm			
9	B5	Balok B5 - 300 x 400 mm	19	B15	Balok B15 - 300 x 450 mm			
10	B6	Balok B6 - 300 x 550 mm	20	B16	Balok B16 - 350 x 600 mm			

Mutu beton f'c 25 MPa

Mutu baja ulir (S) fy : 420 MPa (BJTS 420B)

Mutu baja polos (P) fy : 280 MPa (BJTP 280)

GAMBAR KERJA

INSTANSI

KEMENTERIAN PENDIDIKAN, KEBUDAYAAN, RISET DAN TEKNOLOGI
UNIVERSITAS NEGERI YOGYAKARTA

PEKERJAAN

PEMBANGUNAN GEDUNG LAYANAN KEARSIPAN
UNIVERSITAS NEGERI YOGYAKARTA
TAHUN 2024

LOKASI

UNIVERSITAS NEGERI YOGYAKARTA

Disetujui Oleh :

Pejabat Pembuat Komitmen (PPK)
GEDUNG PELAYANAN KEARSIPAN
UNY

Dr. Anang Priyanto S.H., M.Hum.
NIP. 195809101985031003

Diperiksa Oleh :

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Team Leader

Dibuat Oleh :

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Sony Prihandito, ST.
Project Manager

Catatan :

JUDUL GAMBAR	SKALA
DENAH BALOK ELV. (+ 16.750)	1 : 150

KODE	NO. LBR	JML. LBR
STR	25	111

Figure A-1. 9 Beam Site Plan of Elv. +16.750

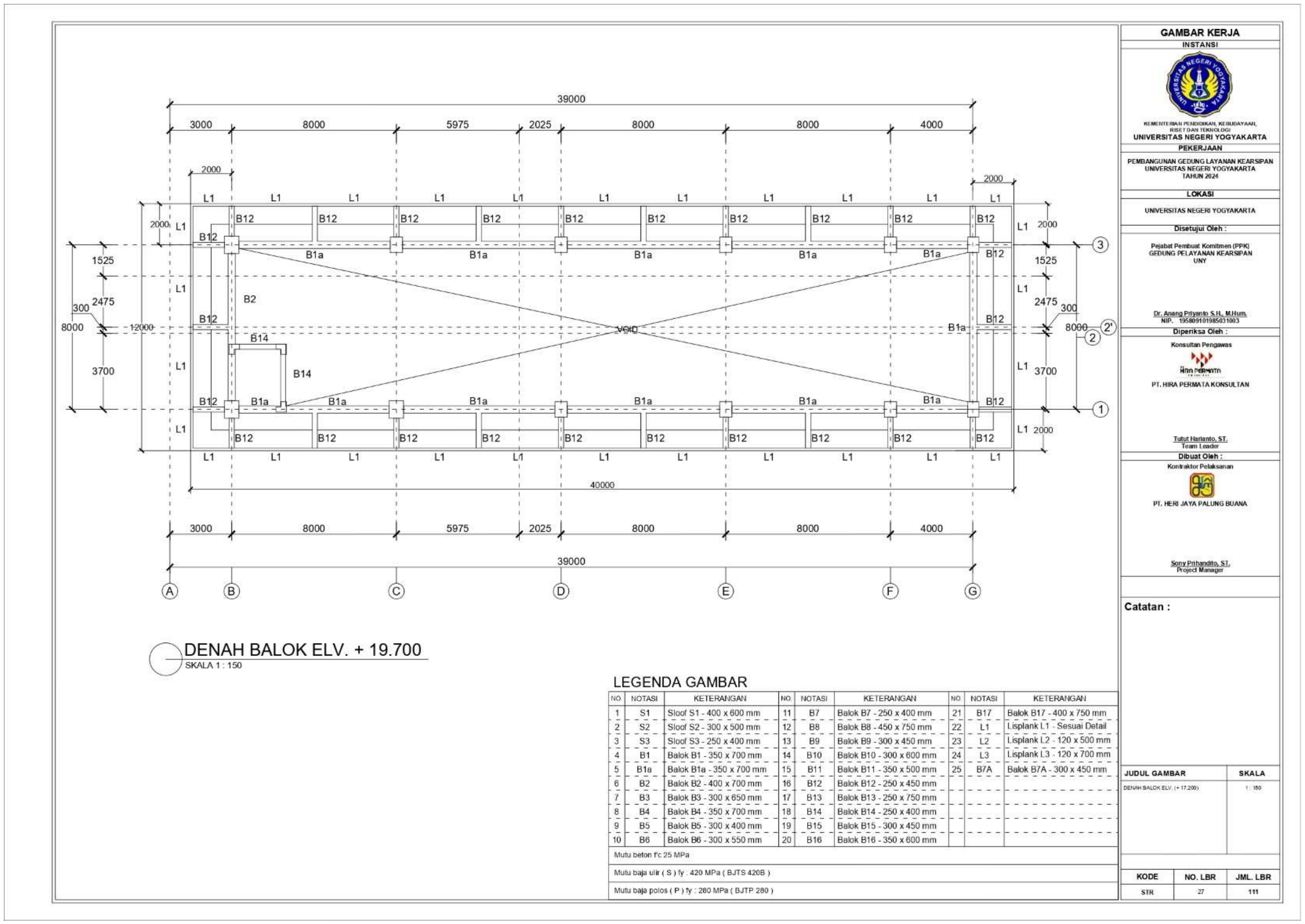


Figure A-1. 10 Beam Site Plan of Elv. +19.700

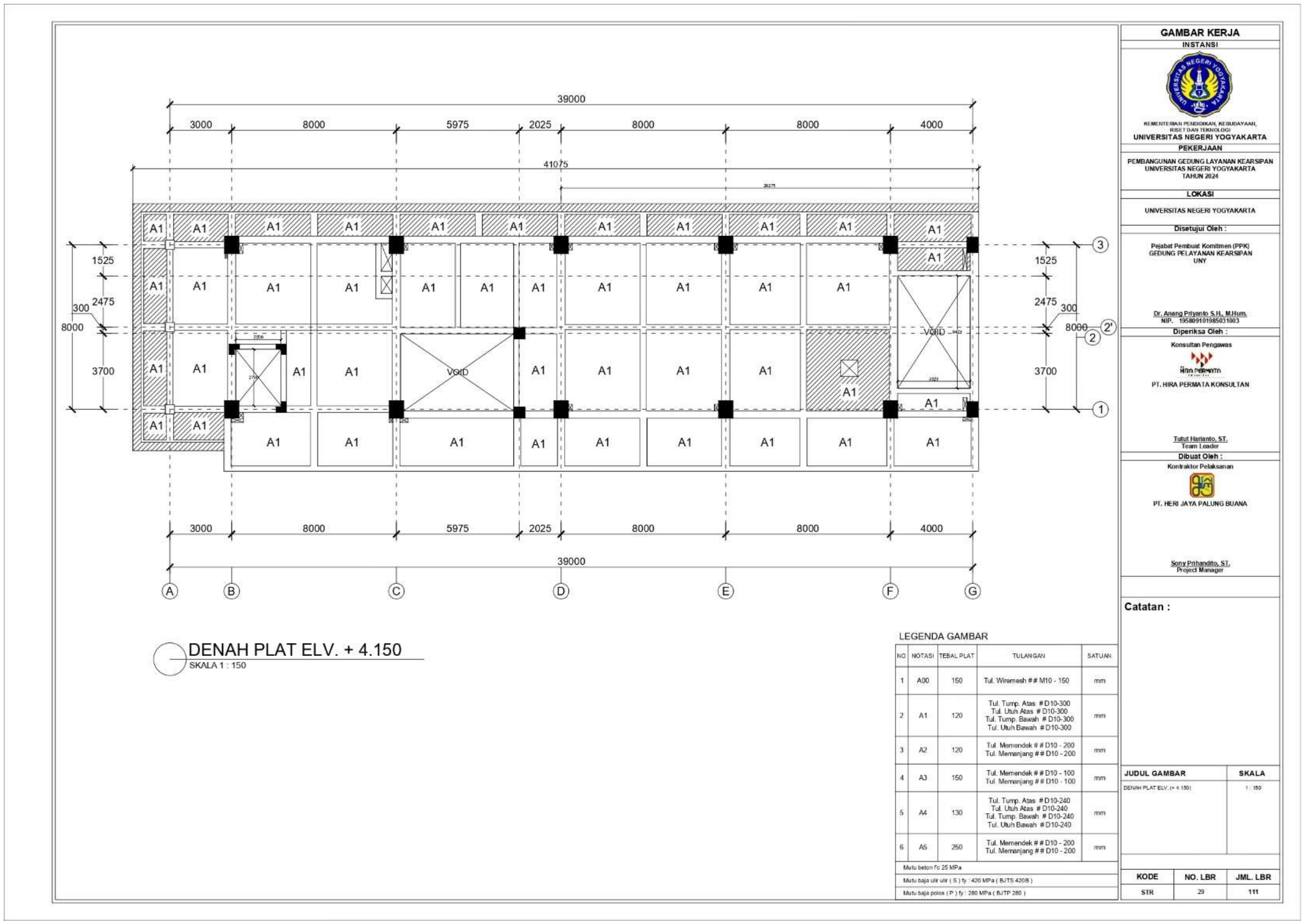


Figure A-1. 11 Slab Site Plan of Elv. +4.150

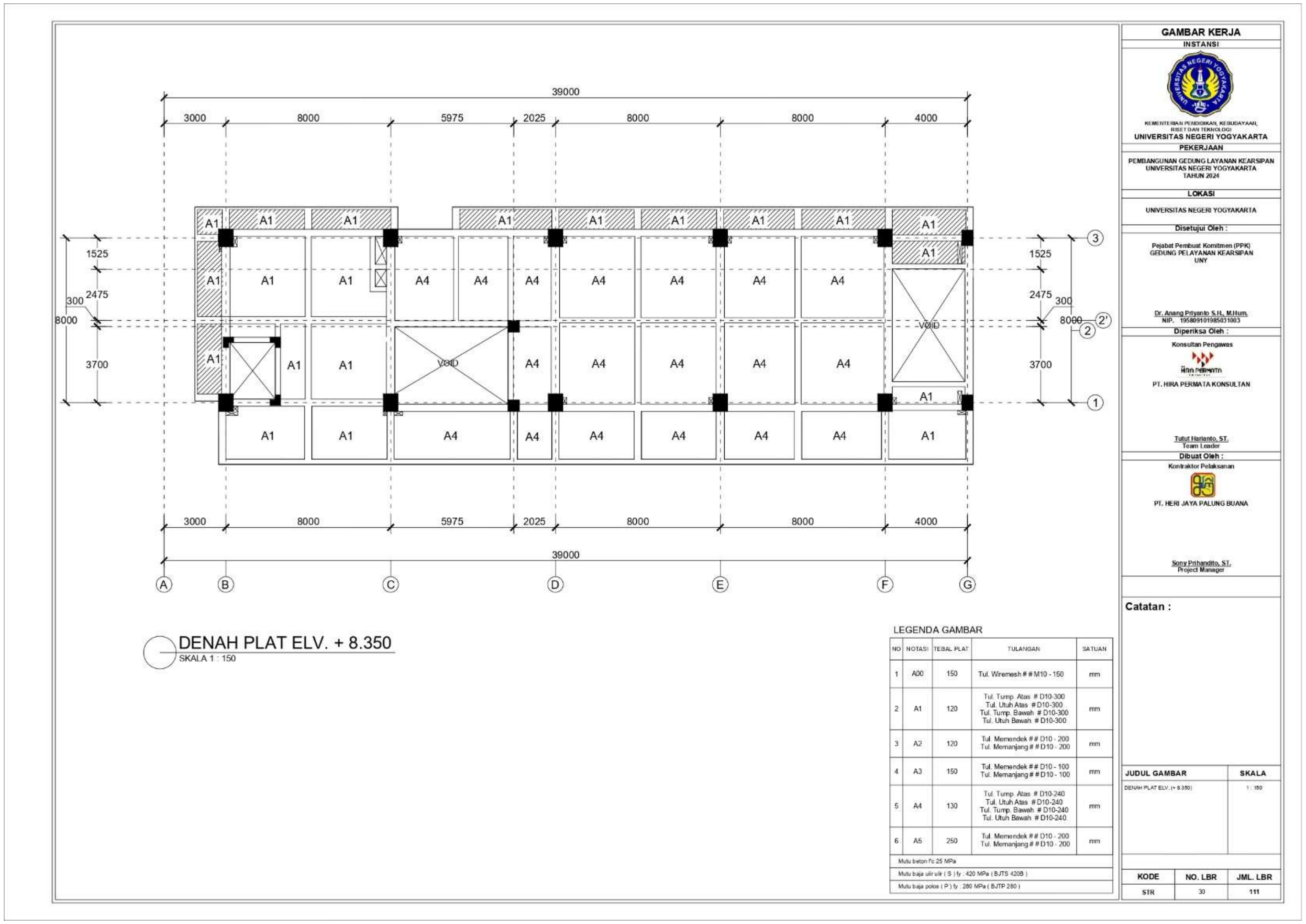


Figure A-1. 12 Slab Site Plan of Elv. +8.350

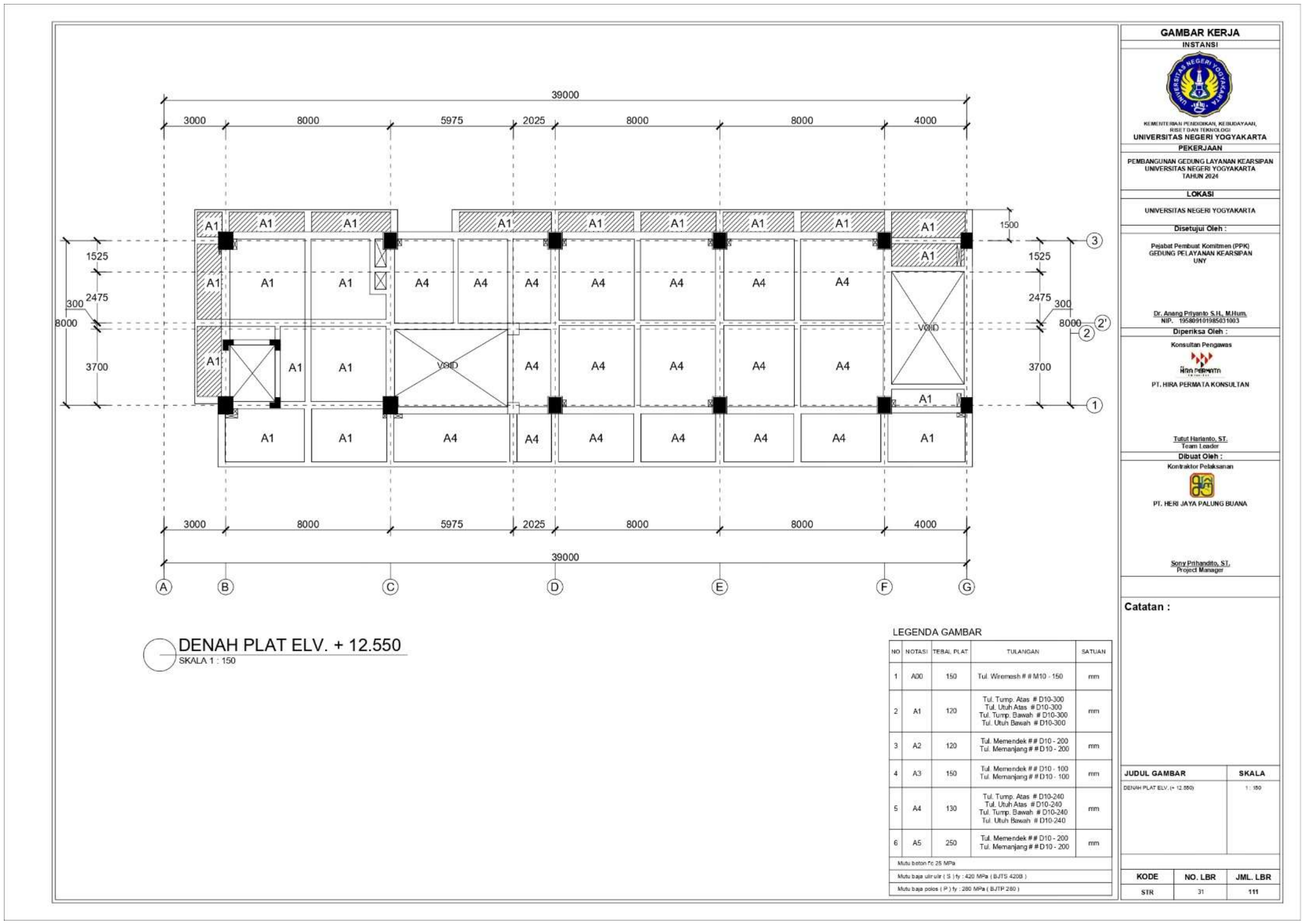


Figure A-1. 13 Slab Site Plan of Elv. +12.550

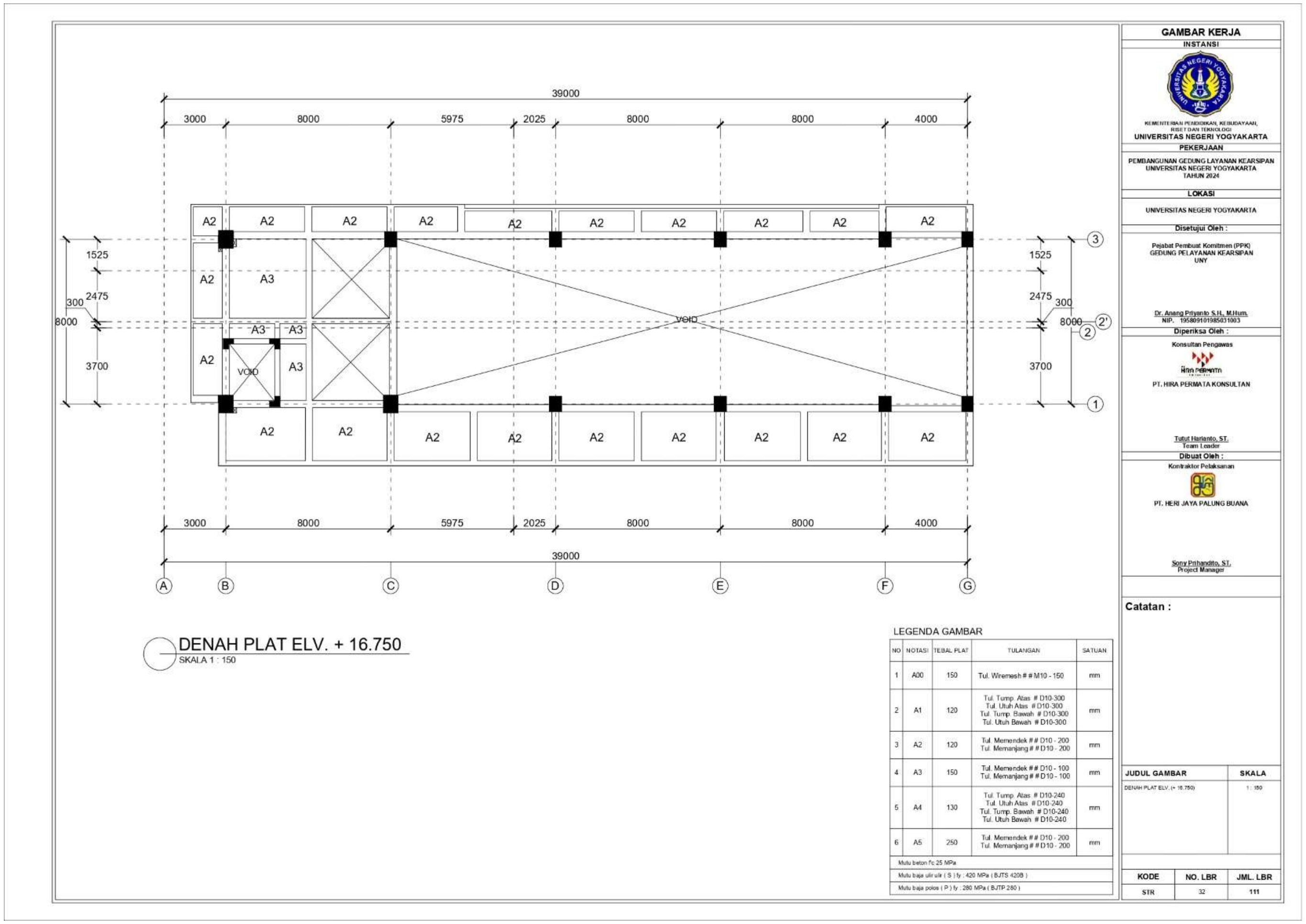


Figure A-1. 14 Slab Site Plan of Elv. +16.750

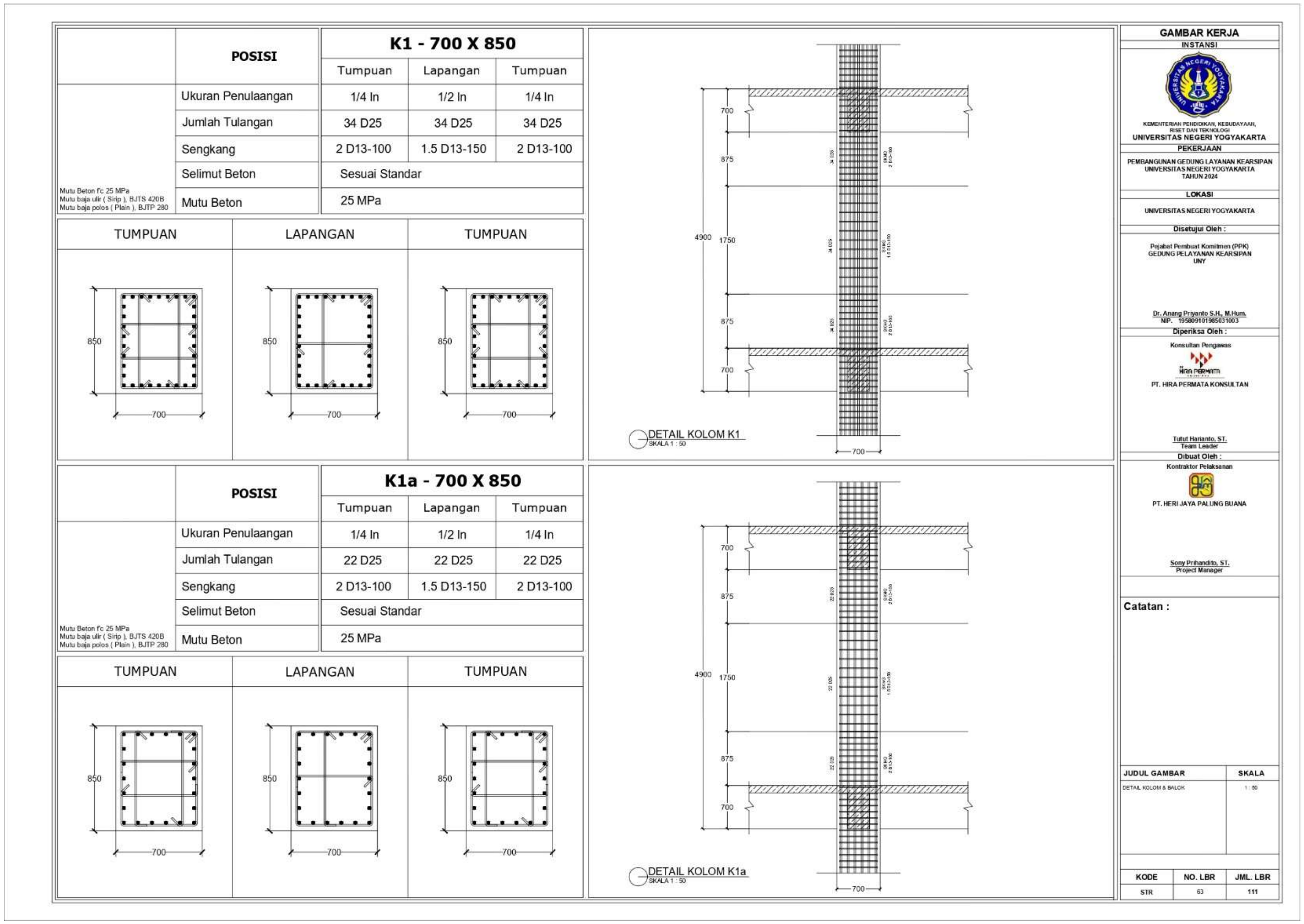


Figure A-1. 15 Detail of Column K1 and K1a

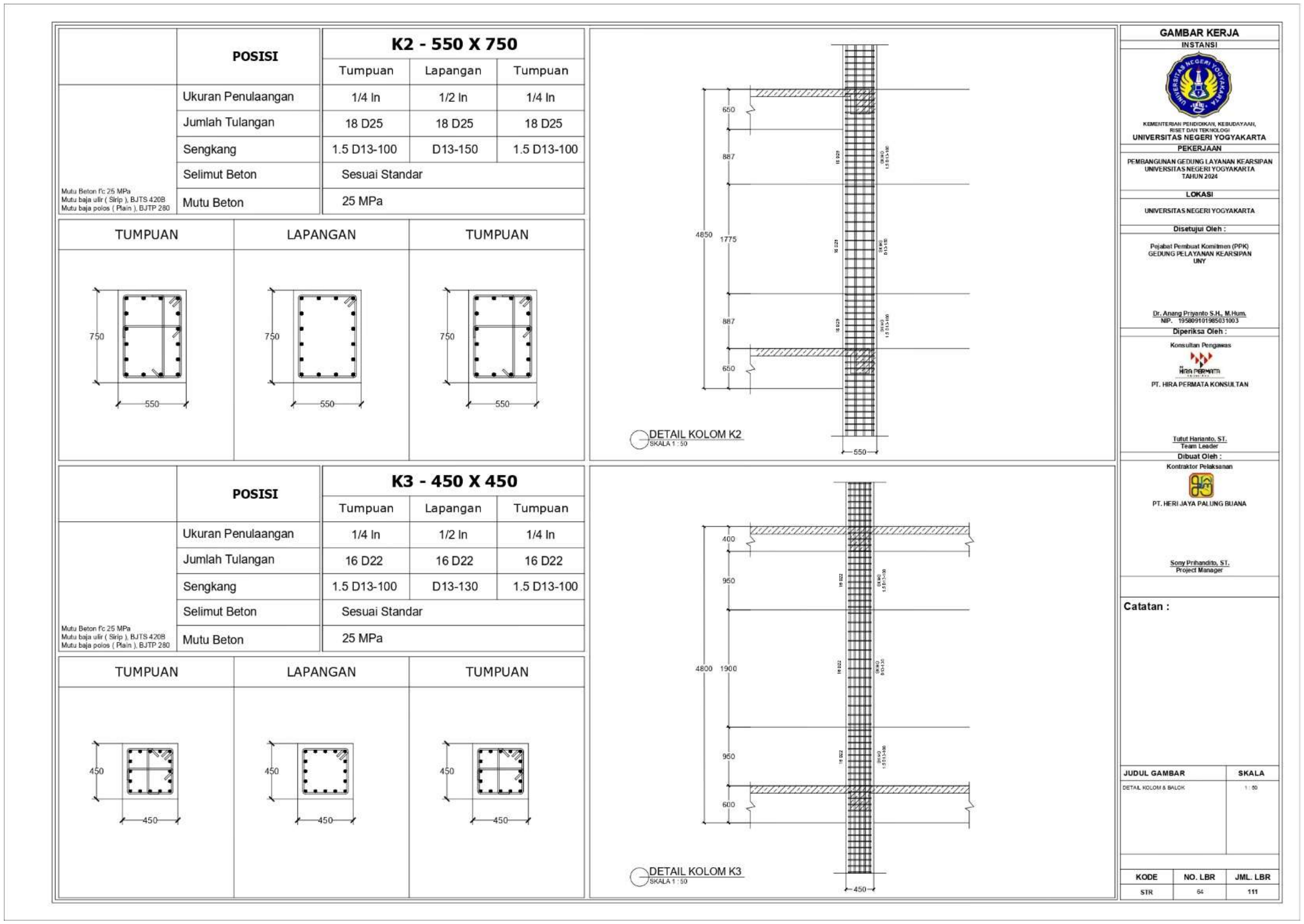


Figure A-1. 16 Detail of Column K2 and K3

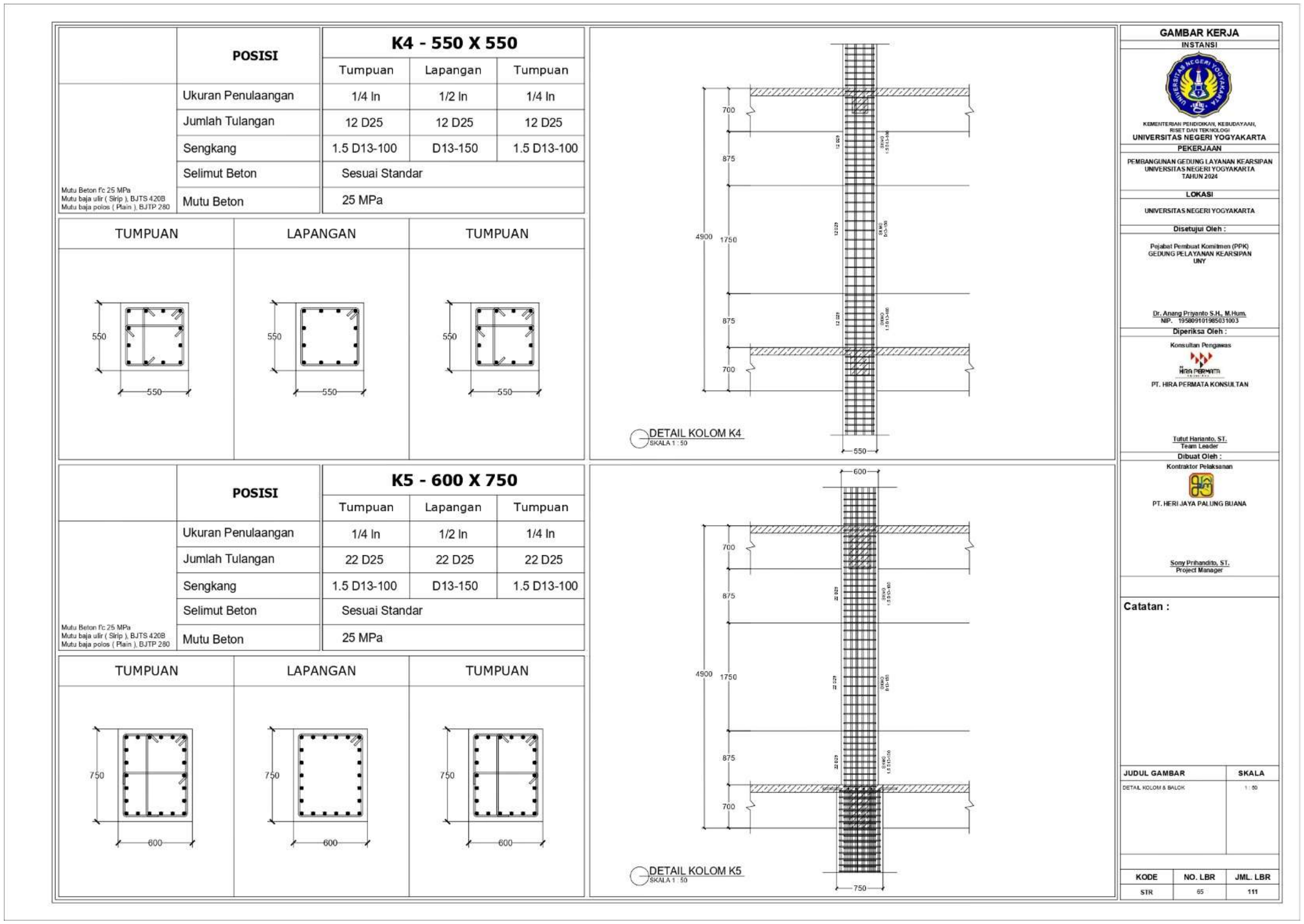


Figure A-1. 17 Detail of Column K4 and K5

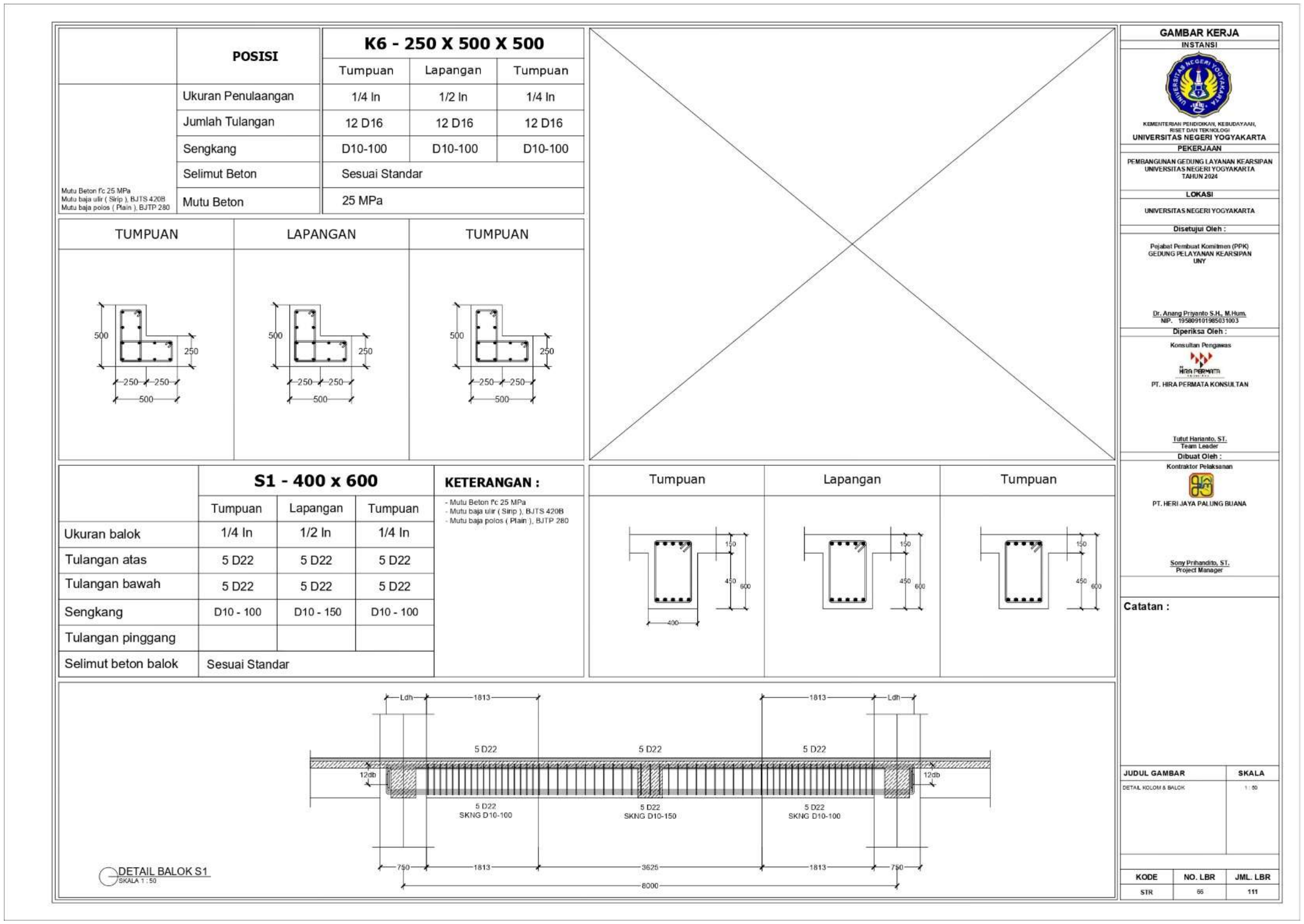


Figure A-1. 18 Detail of Column K6 and Beam S1

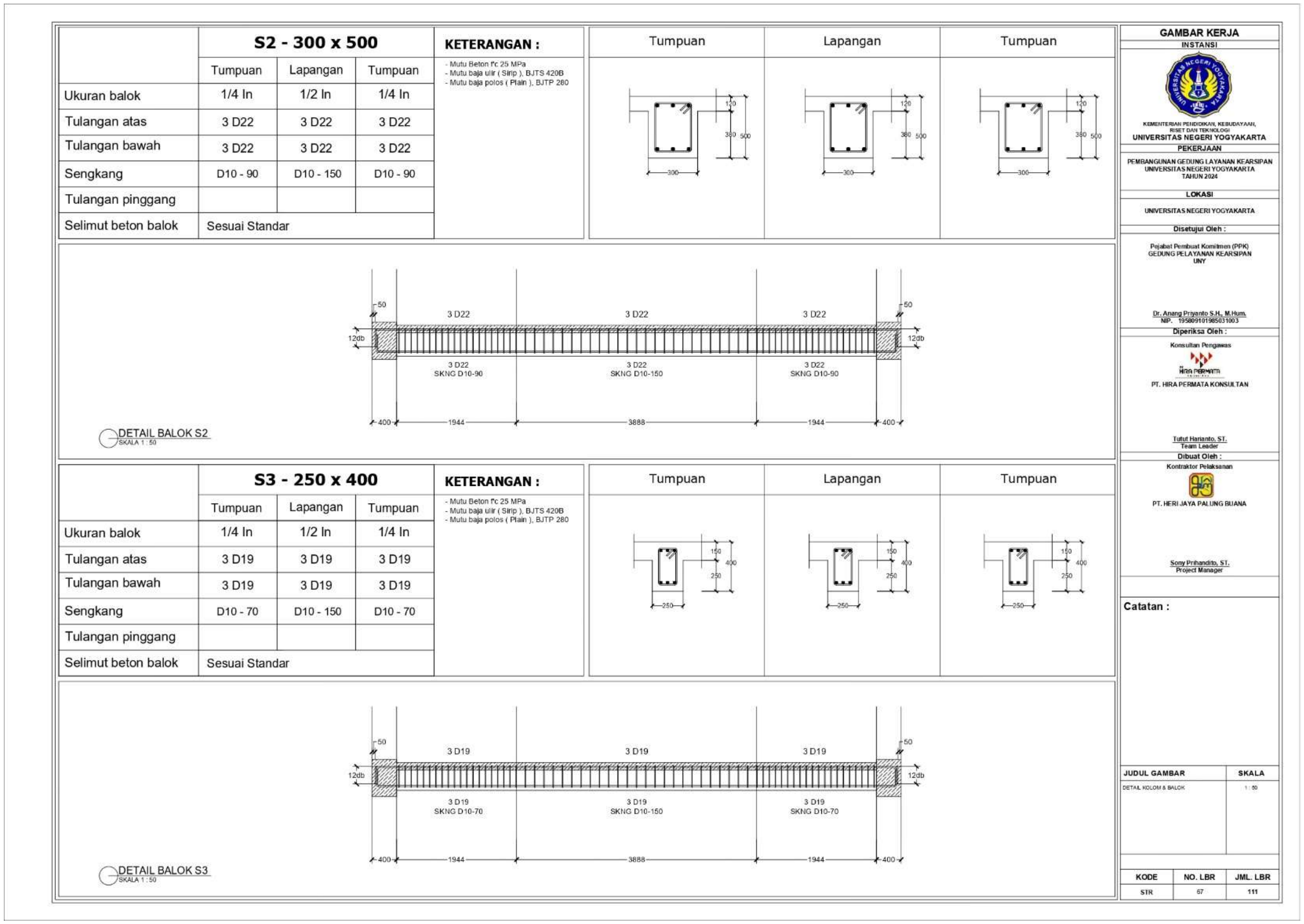


Figure A-1. 19 Detail of Beam S2 and S3

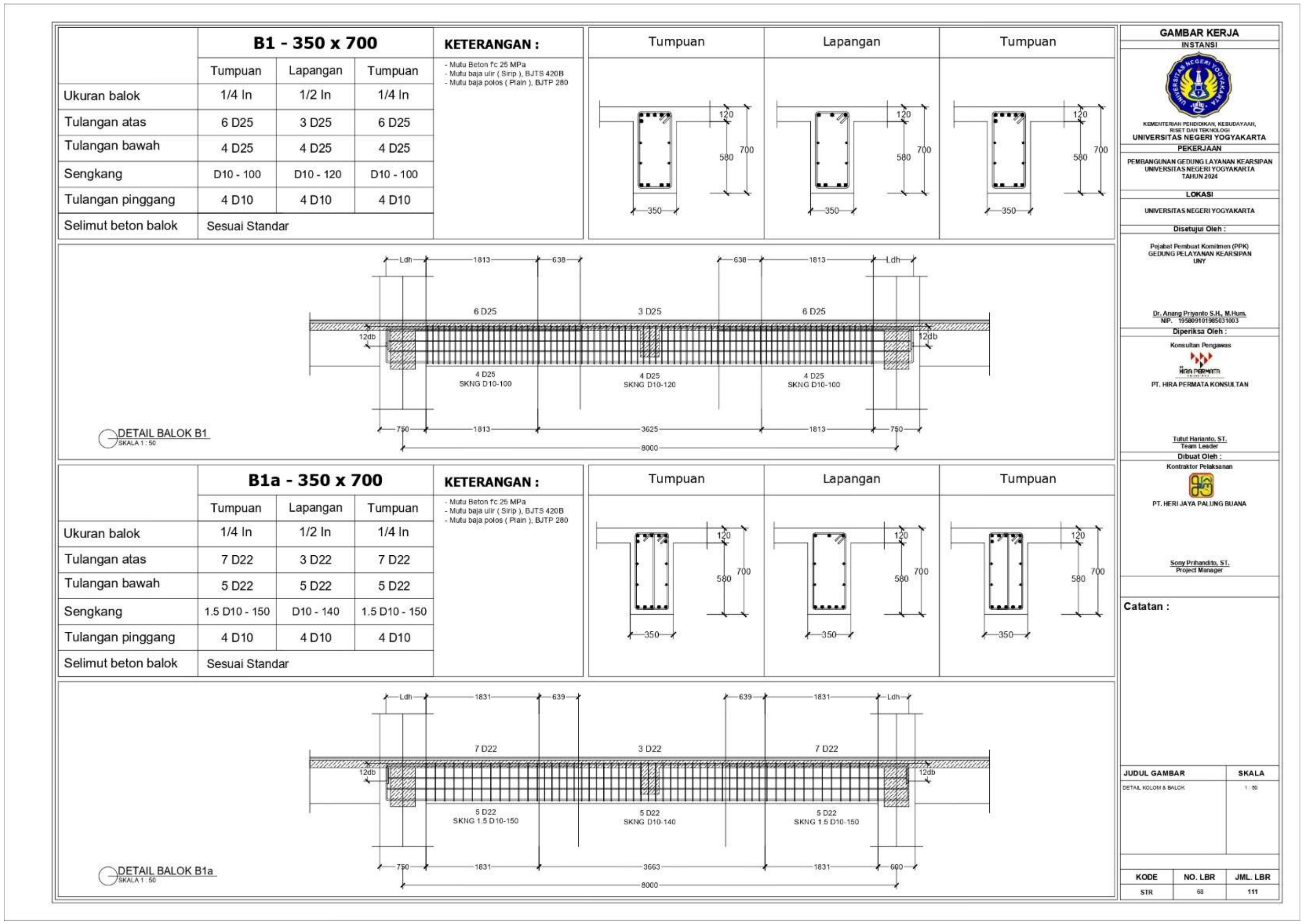


Figure A-1. 20 Detail of Beam B1 and B1A

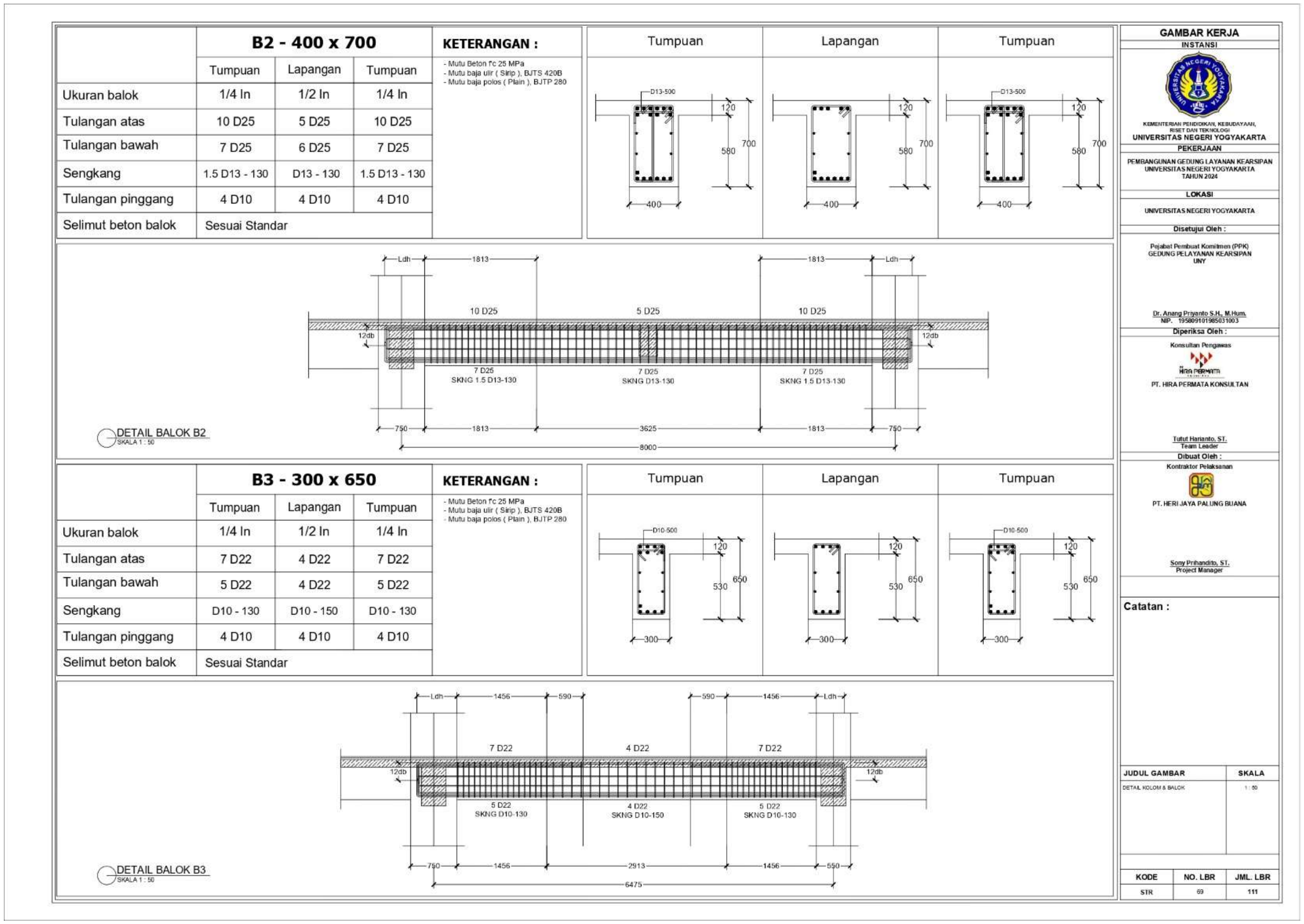


Figure A-1. 21 Detail of Beam B2 and B3

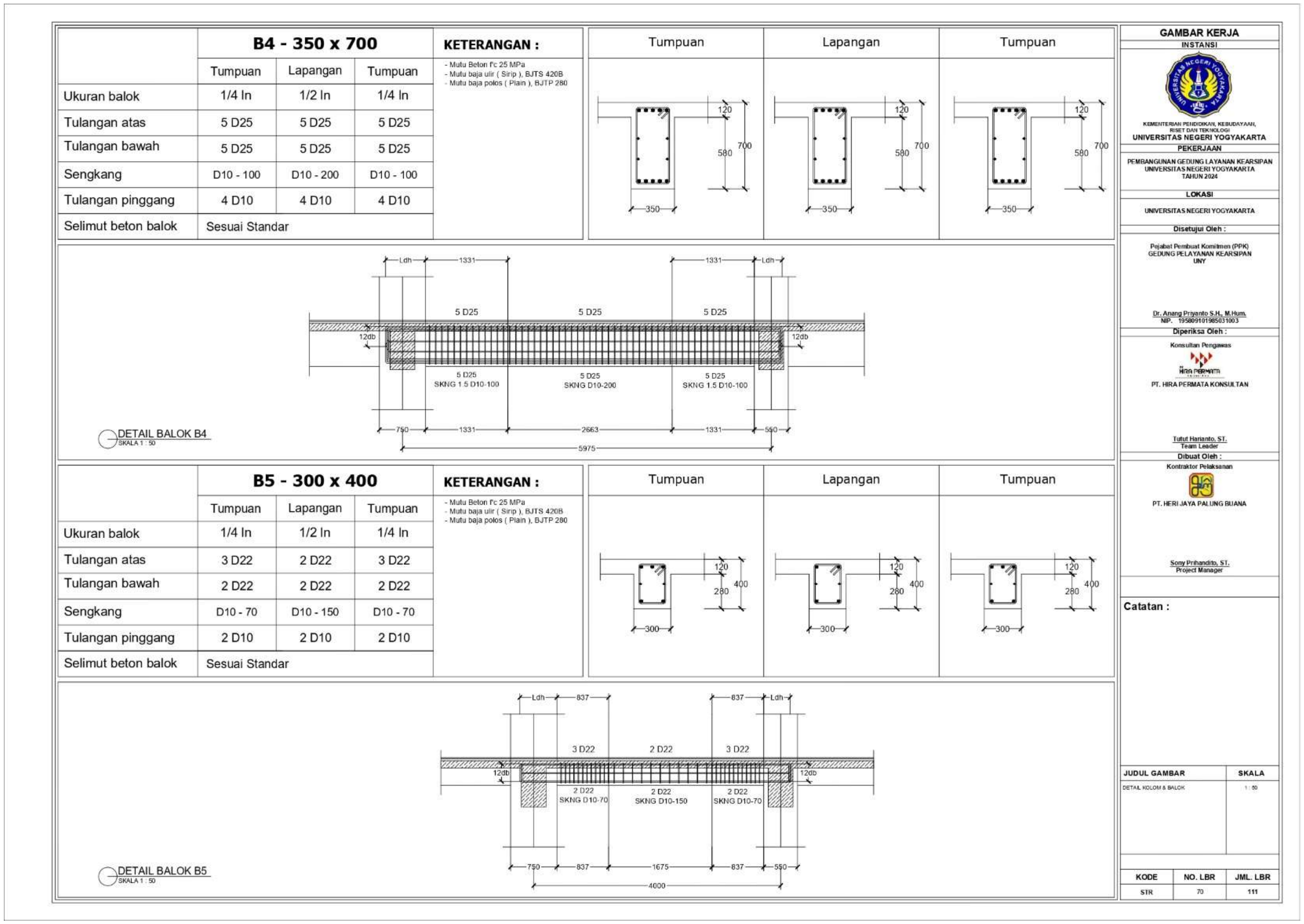


Figure A-1. 22 Detail of Beam B4 and B5

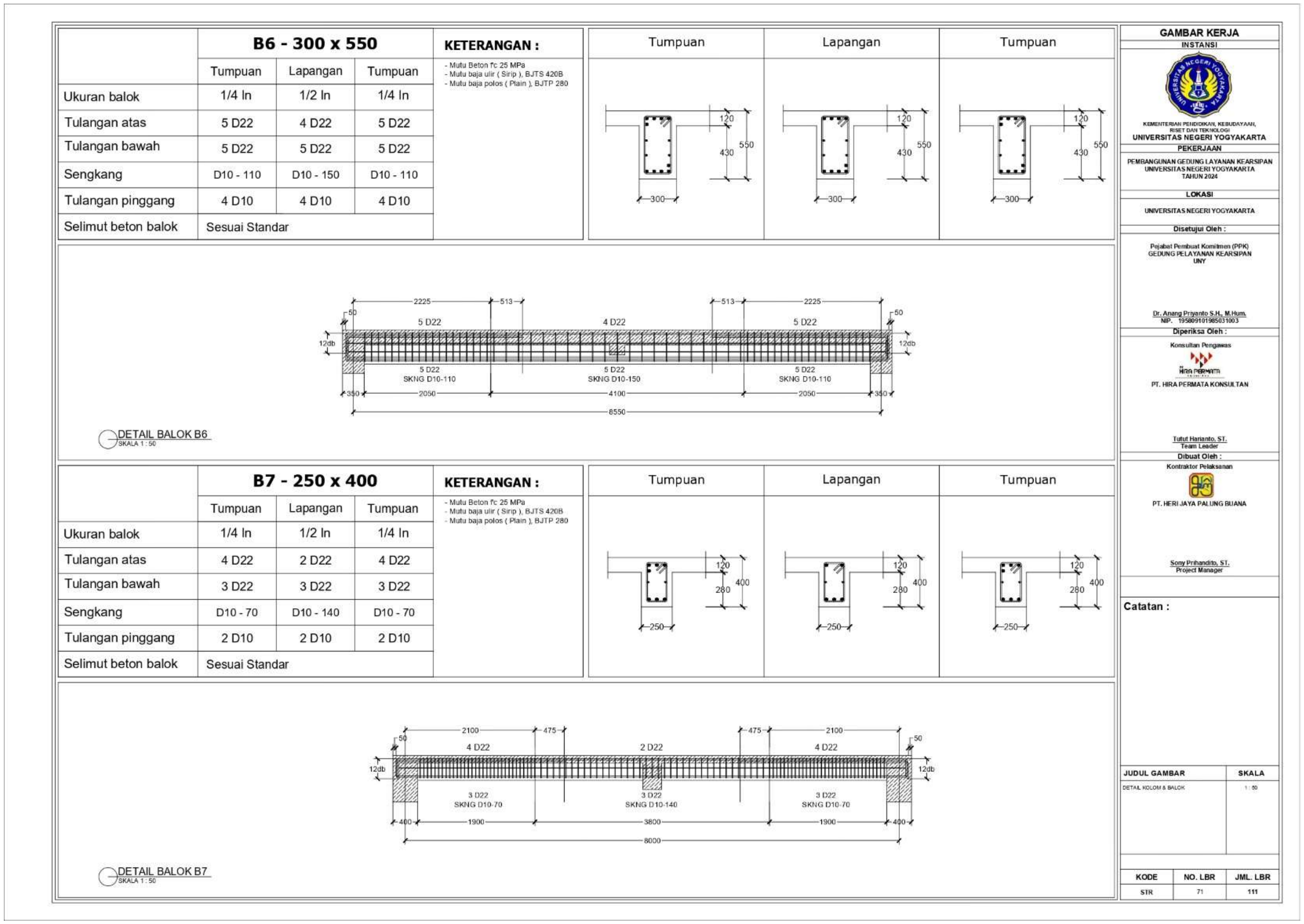


Figure A-1. 23 Detail of Beam B6 and B7

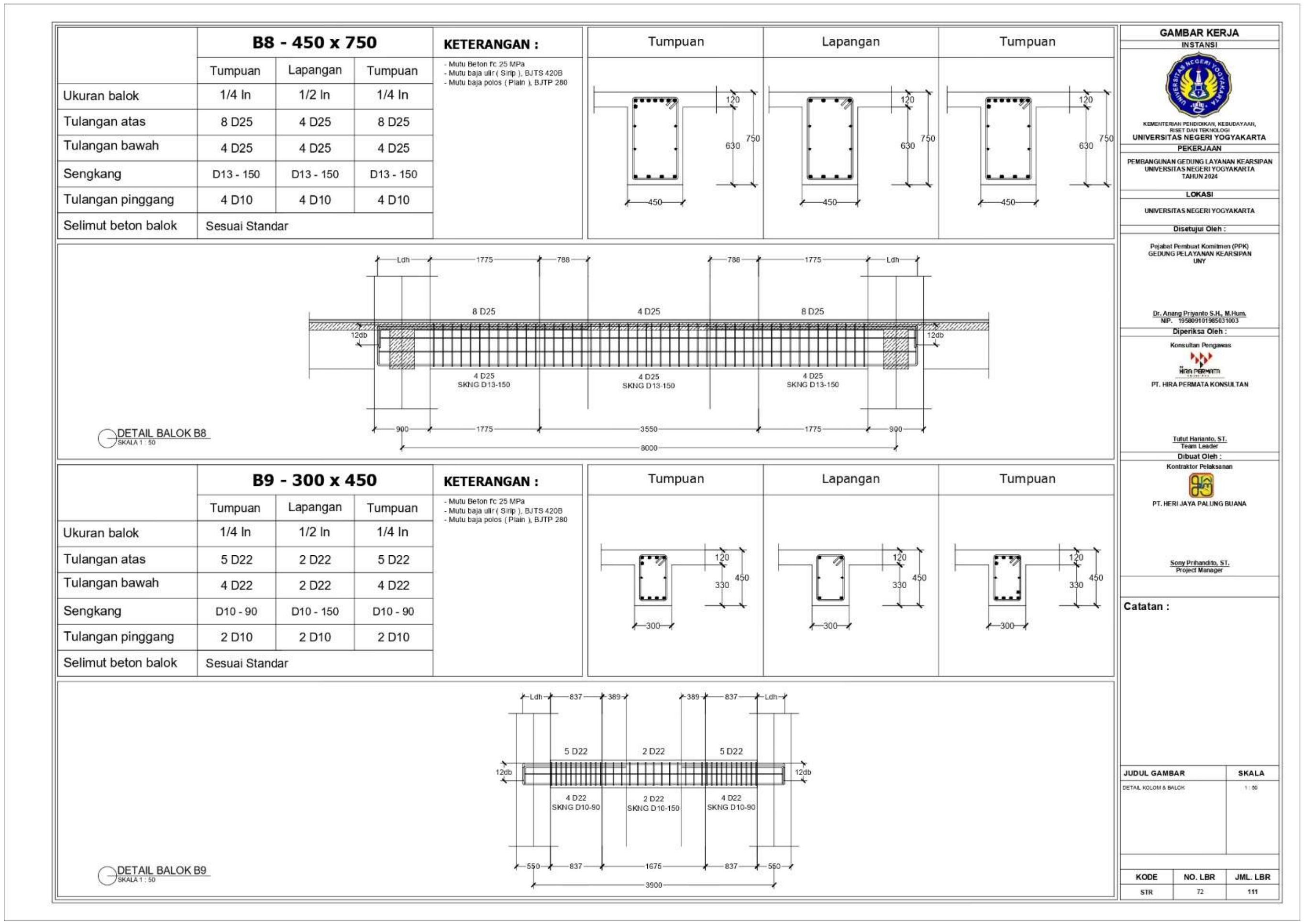


Figure A-1. 24 Detail of Beam B8 and B9

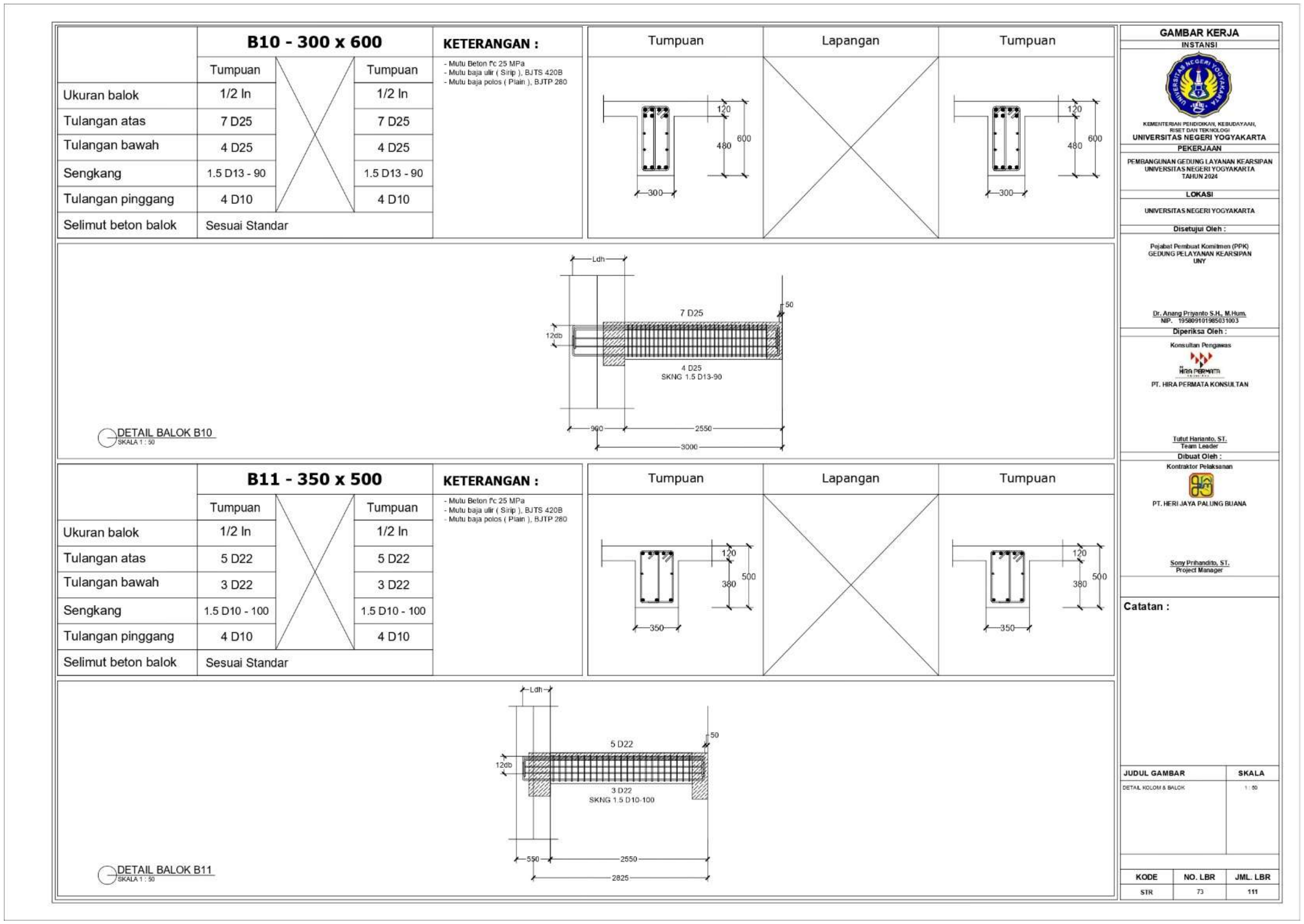


Figure A-1. 25 Detail of Beam B10 and B11

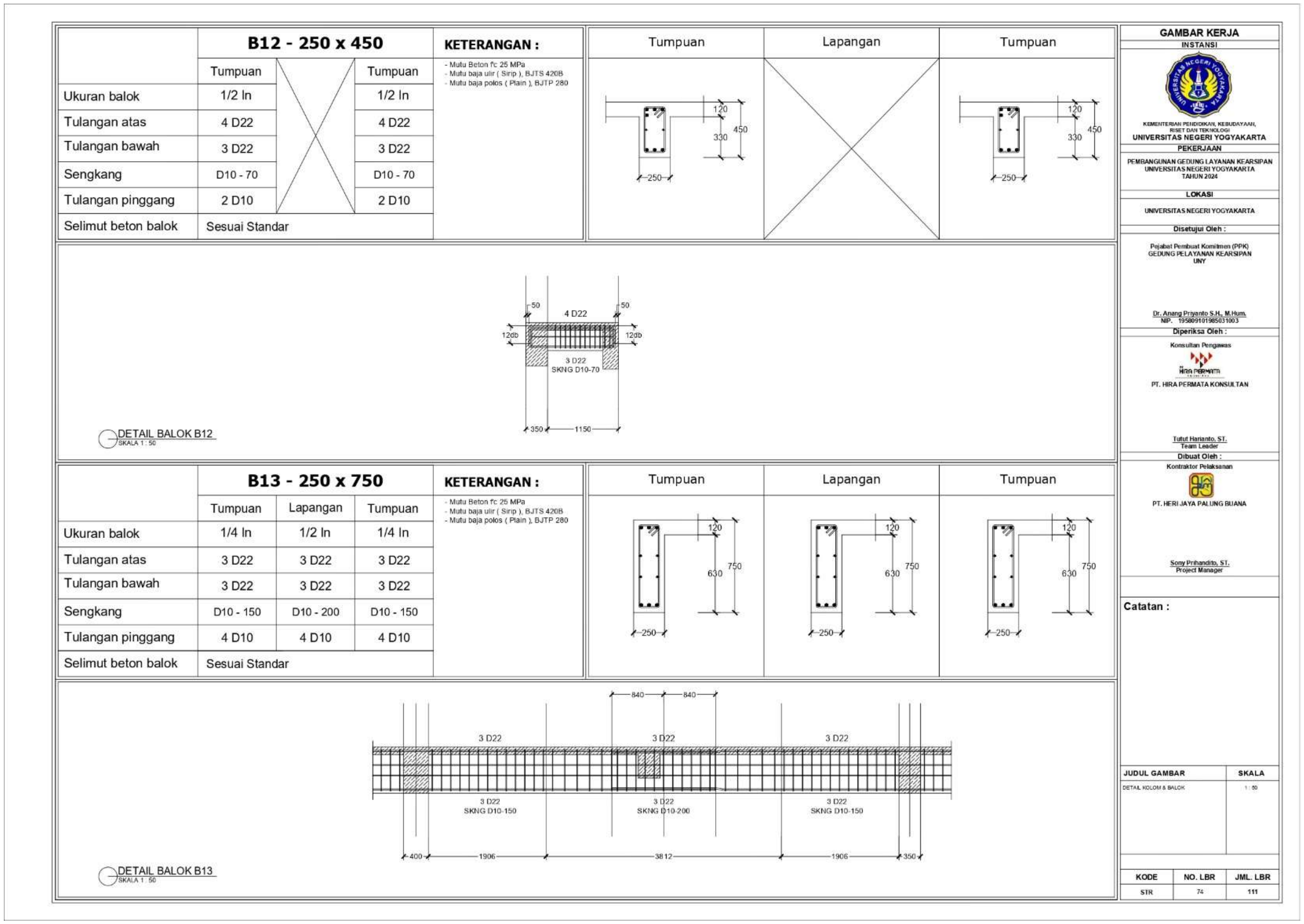


Figure A-1. 26 Detail of Beam B12 and B13

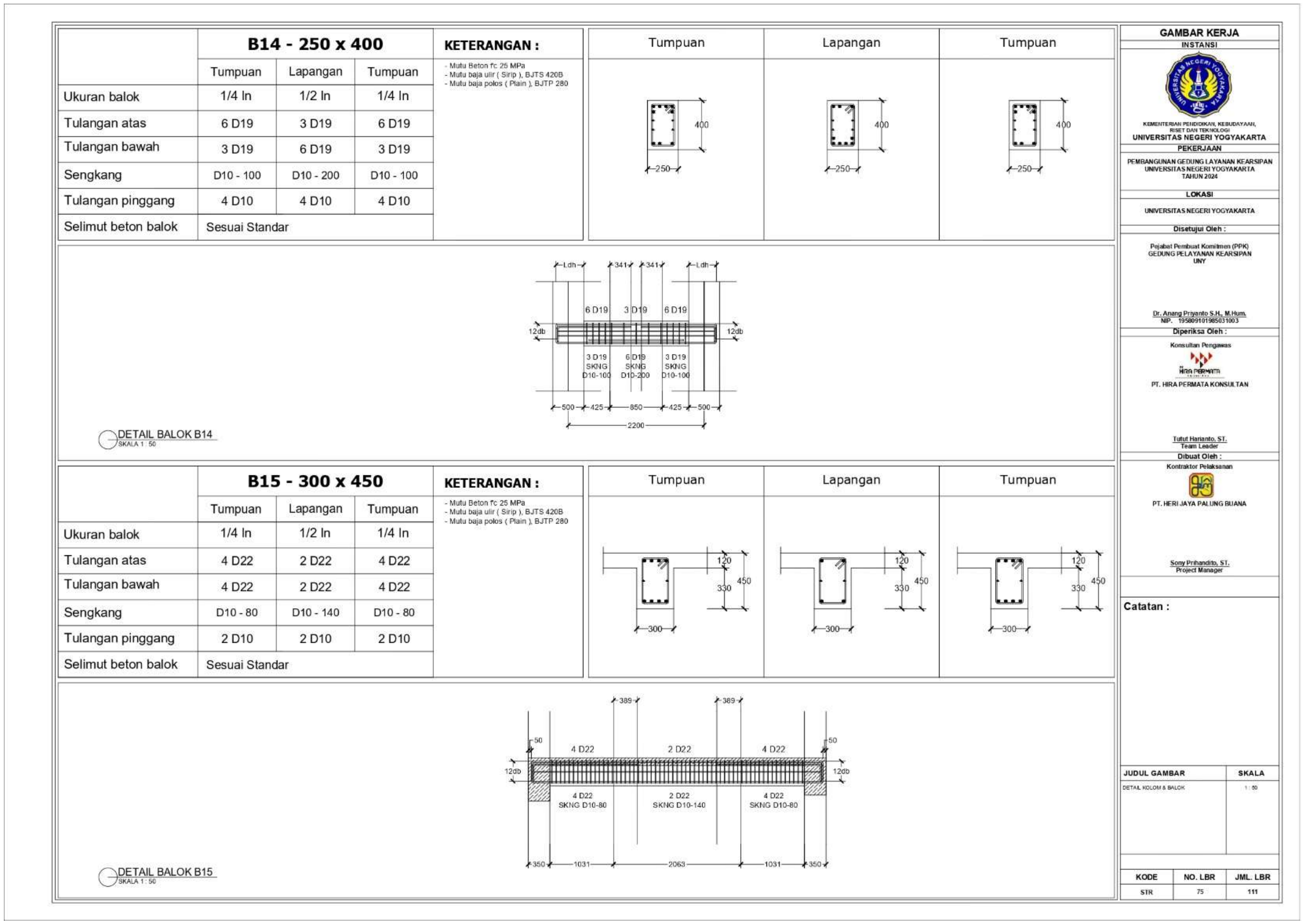


Figure A-1. 27 Detail of Beam B14 and B15

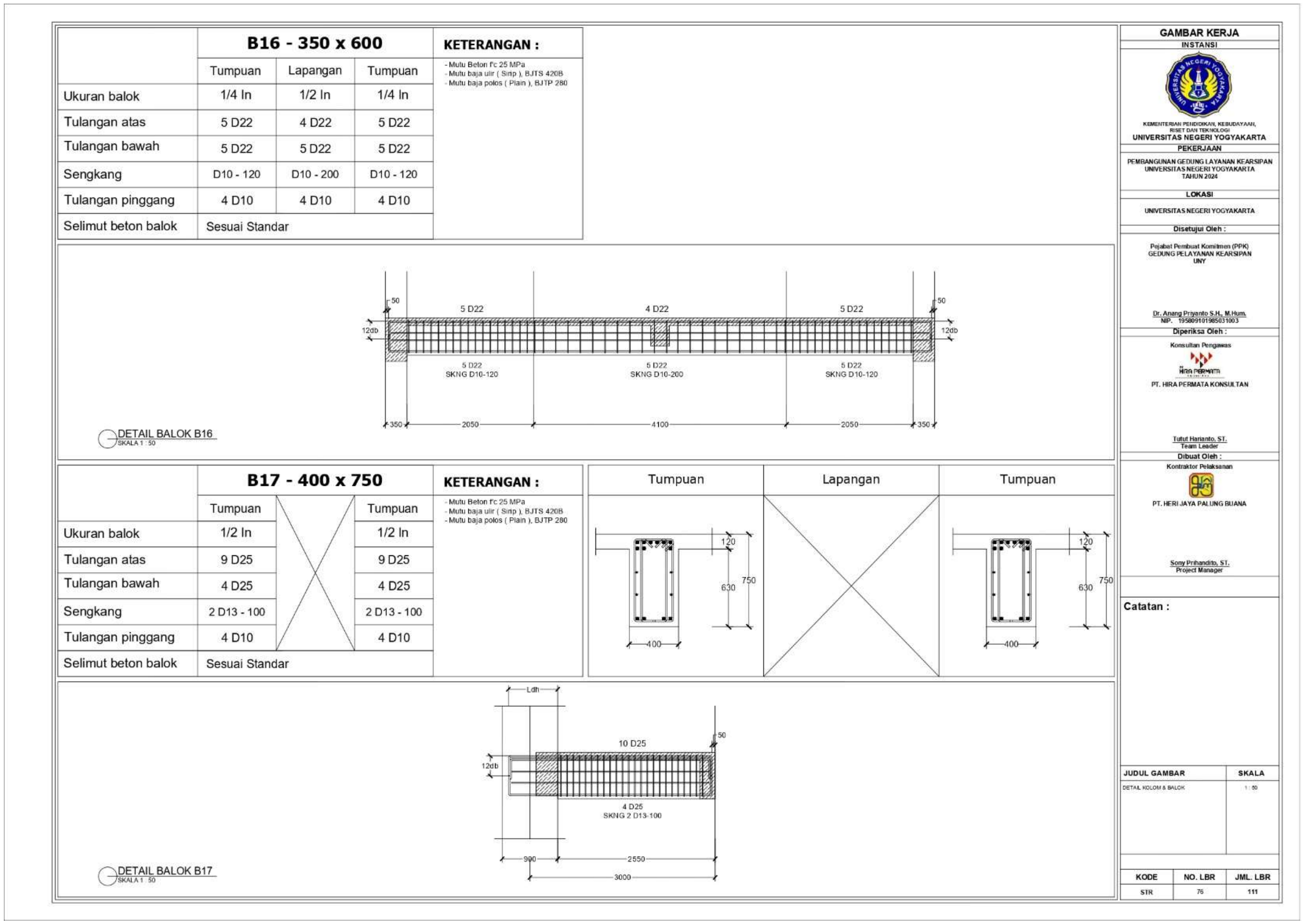
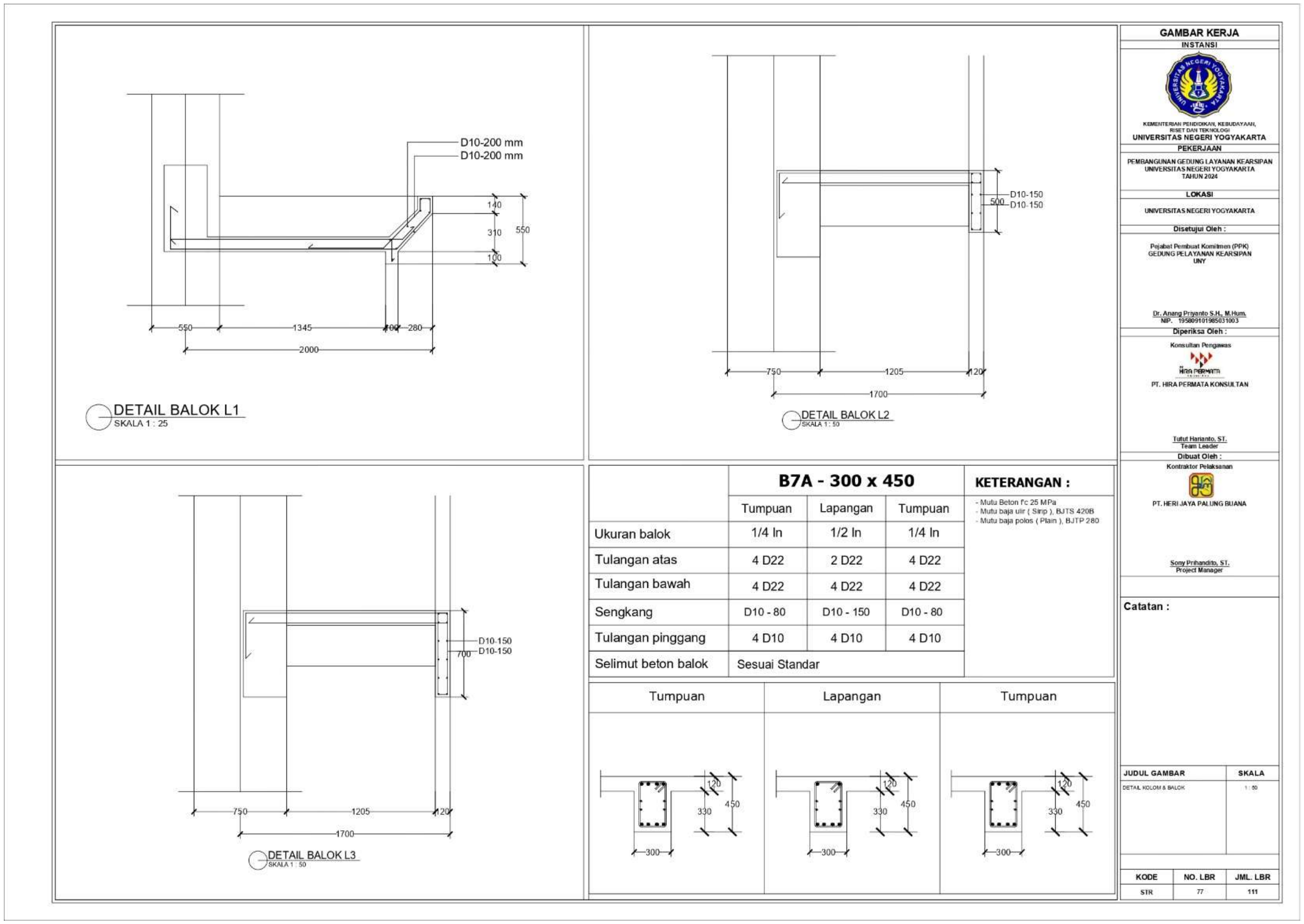


Figure A-1. 28 Detail of Beam B16 and B17



	B7A - 300 x 450		
	Tumpuan	Lapangan	Tumpuan
Ukuran balok	1/4 In	1/2 In	1/4 In
Tulangan atas	4 D22	2 D22	4 D22
Tulangan bawah	4 D22	4 D22	4 D22
Sengkang	D10 - 80	D10 - 150	D10 - 80
Tulangan pinggang	4 D10	4 D10	4 D10
Selimut beton balok	Sesuai Standar		

Figure A-1. 29 Detail of Beam B7A, L1, L2, and L3

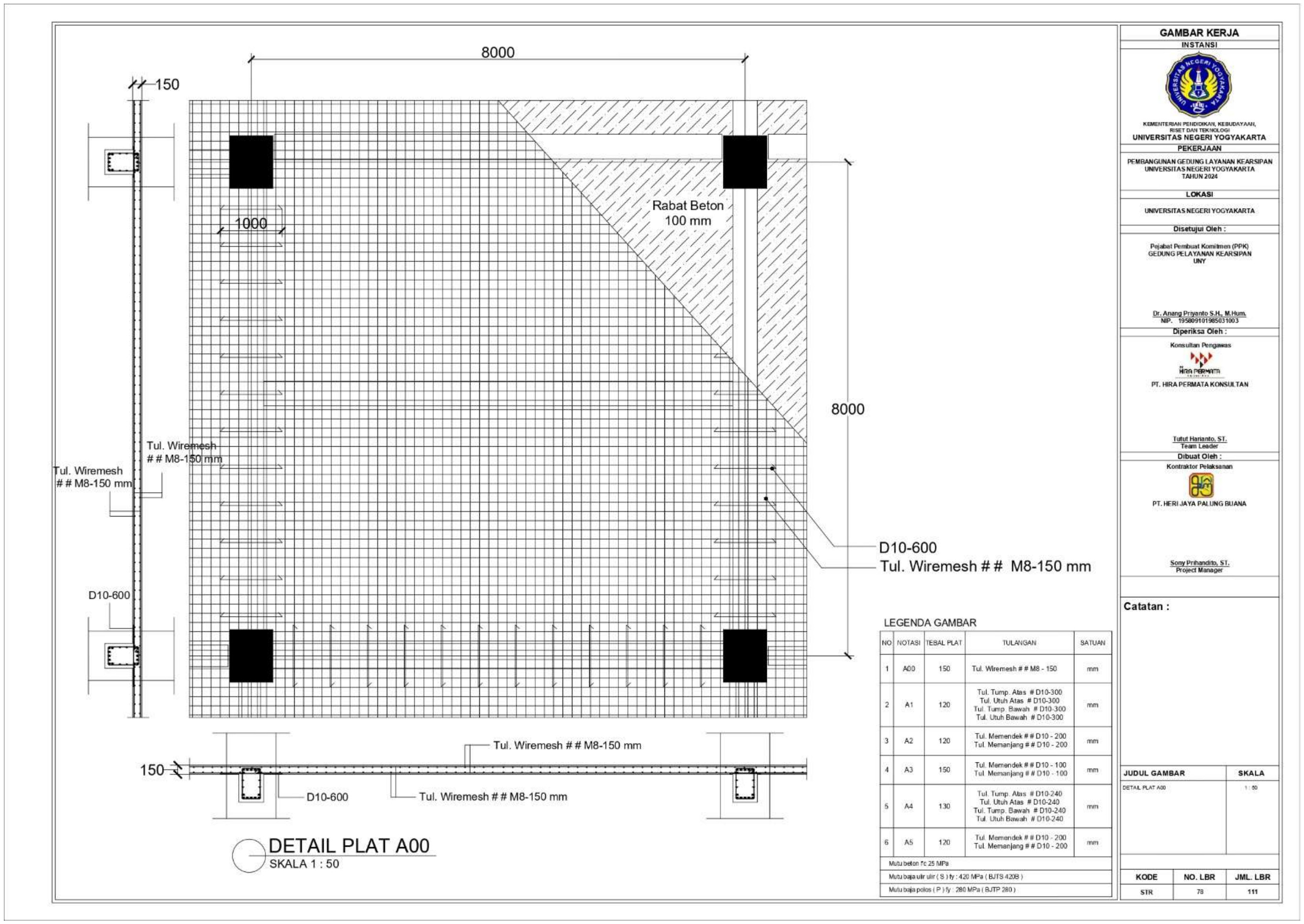


Figure A-1. 30 Detail of Slab A00

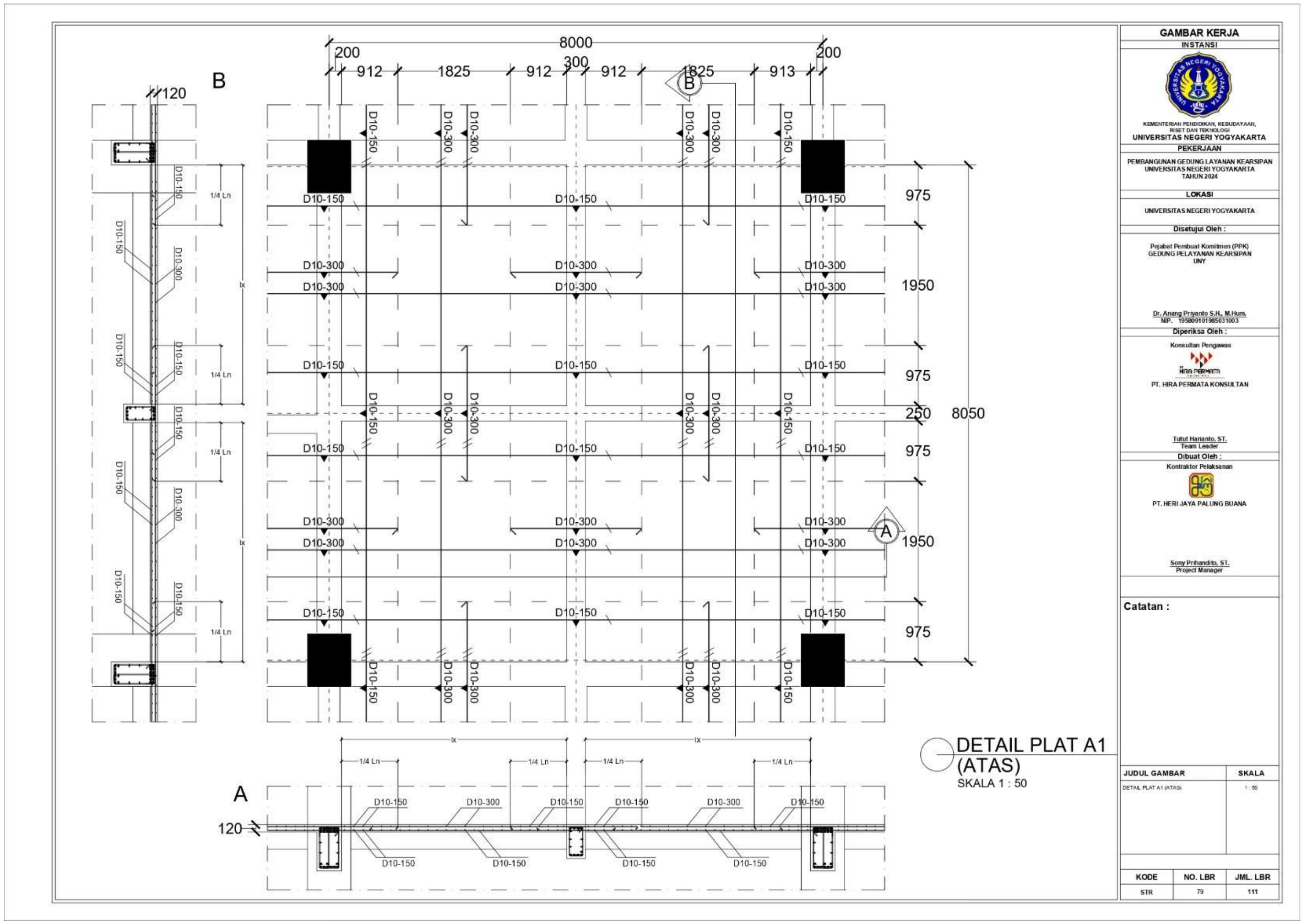


Figure A-1. 31 Detail of Slab A1 Top

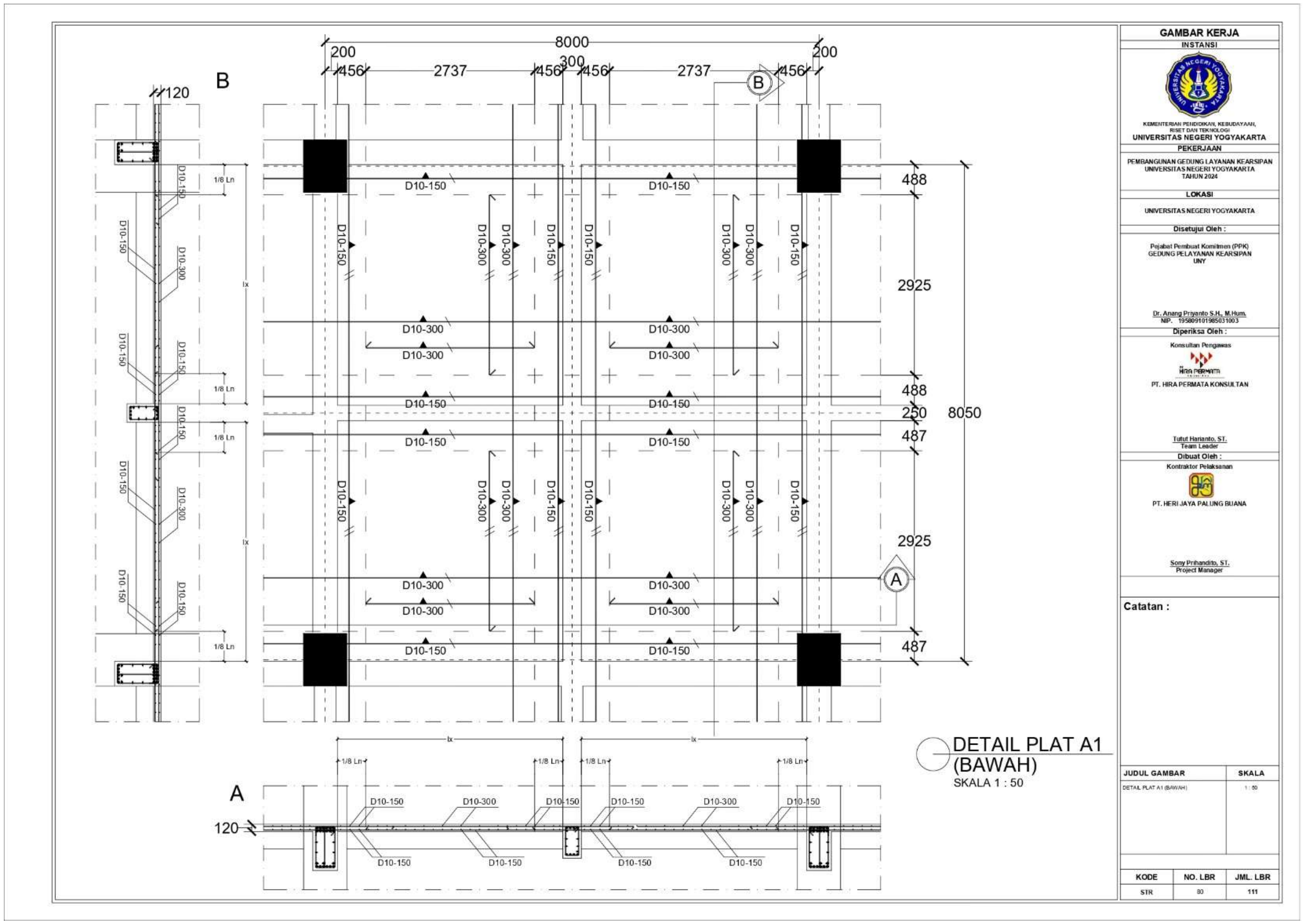


Figure A-1. 32 Detail of Slab A1 Bottom

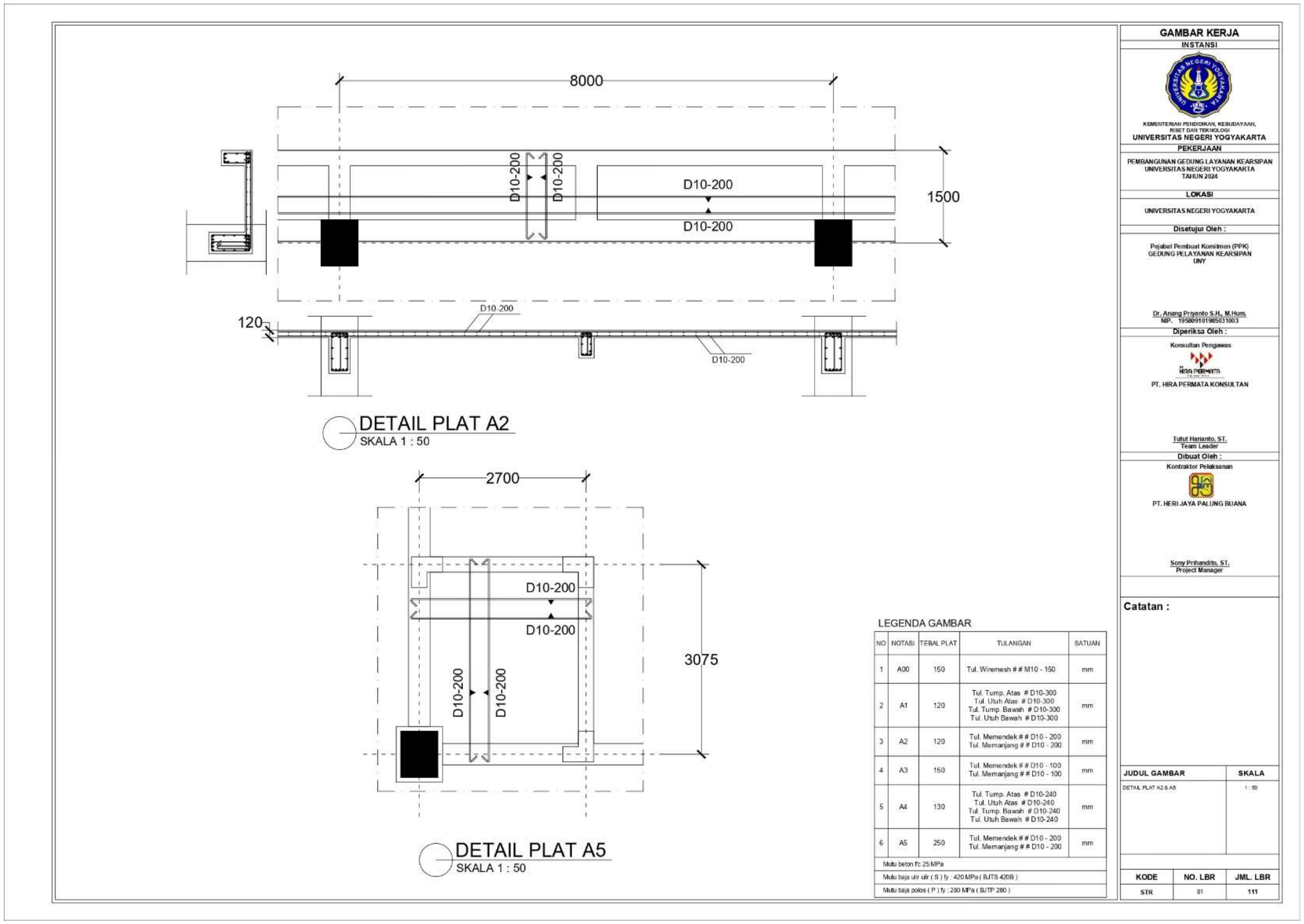
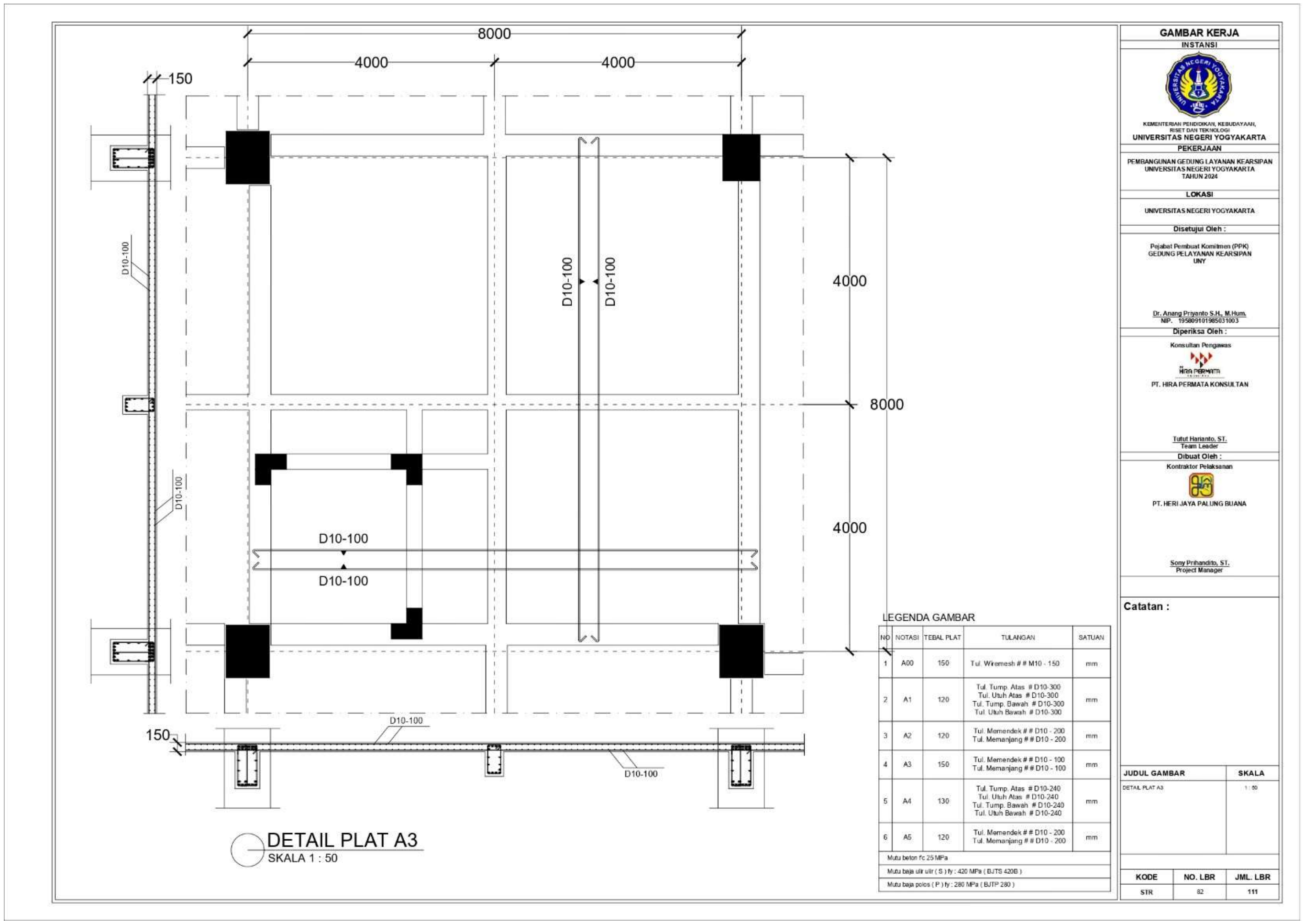


Figure A-1. 33 Detail of Slab A2 and A5



NO	NOTASI	TEBAL PLAT	TULANGAN	SATUAN
1	A00	150	Tul. Wiremesh # # M10 - 150	mm
2	A1	120	Tul. Tump. Atas # D10-300 Tul. Utuh Atas # D10-300 Tul. Tump. Bawah # D10-300 Tul. Utuh Bawah # D10-300	mm
3	A2	120	Tul. Memendek # # D10 - 200 Tul. Memanjang # # D10 - 200	mm
4	A3	150	Tul. Memendek # # D10 - 100 Tul. Memanjang # # D10 - 100	mm
5	A4	130	Tul. Tump. Atas # D10-240 Tul. Utuh Atas # D10-240 Tul. Tump. Bawah # D10-240 Tul. Utuh Bawah # D10-240	mm
6	A5	120	Tul. Memendek # # D10 - 200 Tul. Memanjang # # D10 - 200	mm
Mutu beton f'c 25 MPa				
Mutu baja ulir ulir (S) fy : 420 MPa (BJTS 420B)				
Mutu baja polos (P) fy : 280 MPa (BJTP 280)				

Figure A-1. 34 Detail of Slab A3

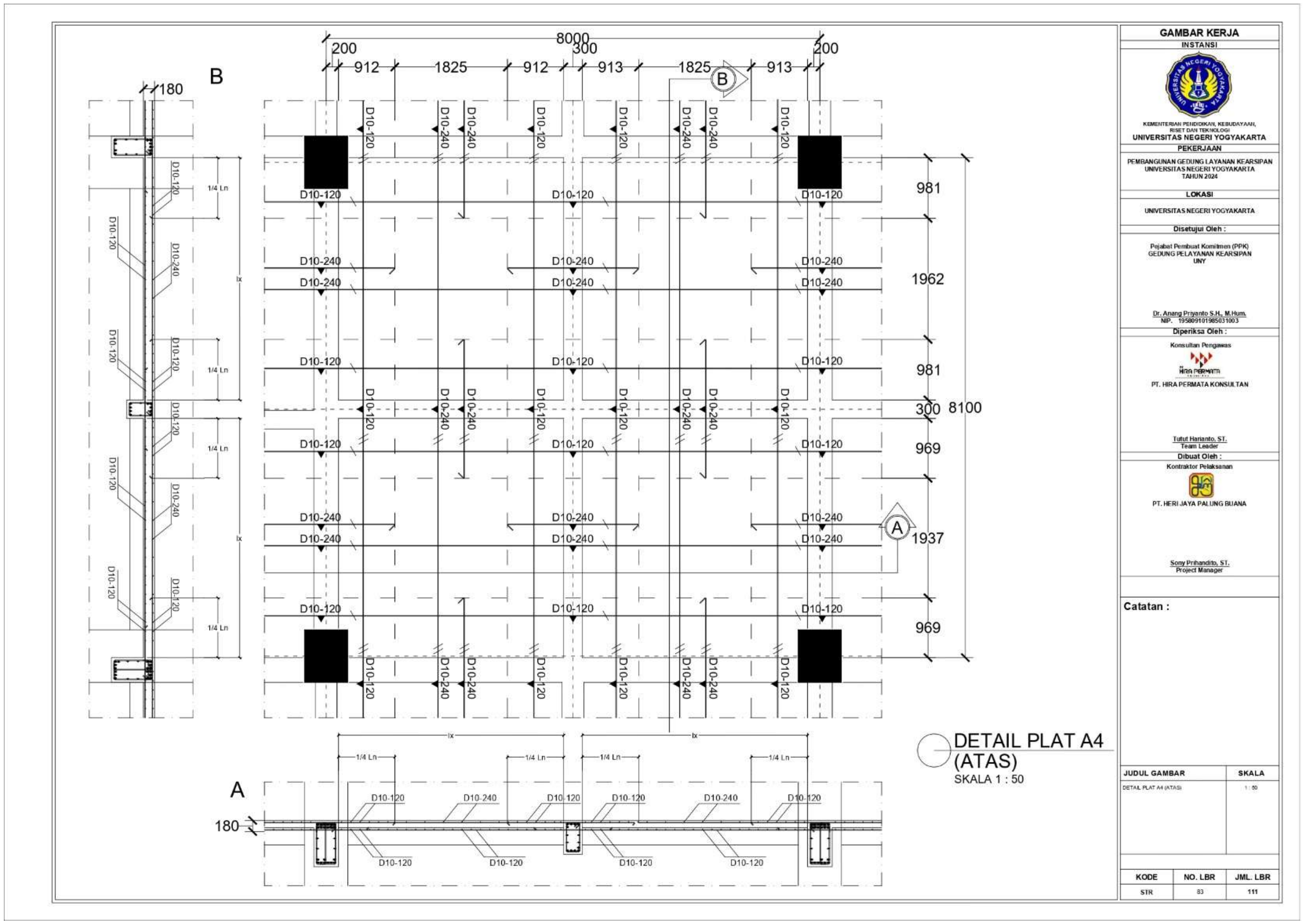


Figure A-1. 35 Detail of Slab A4 Top

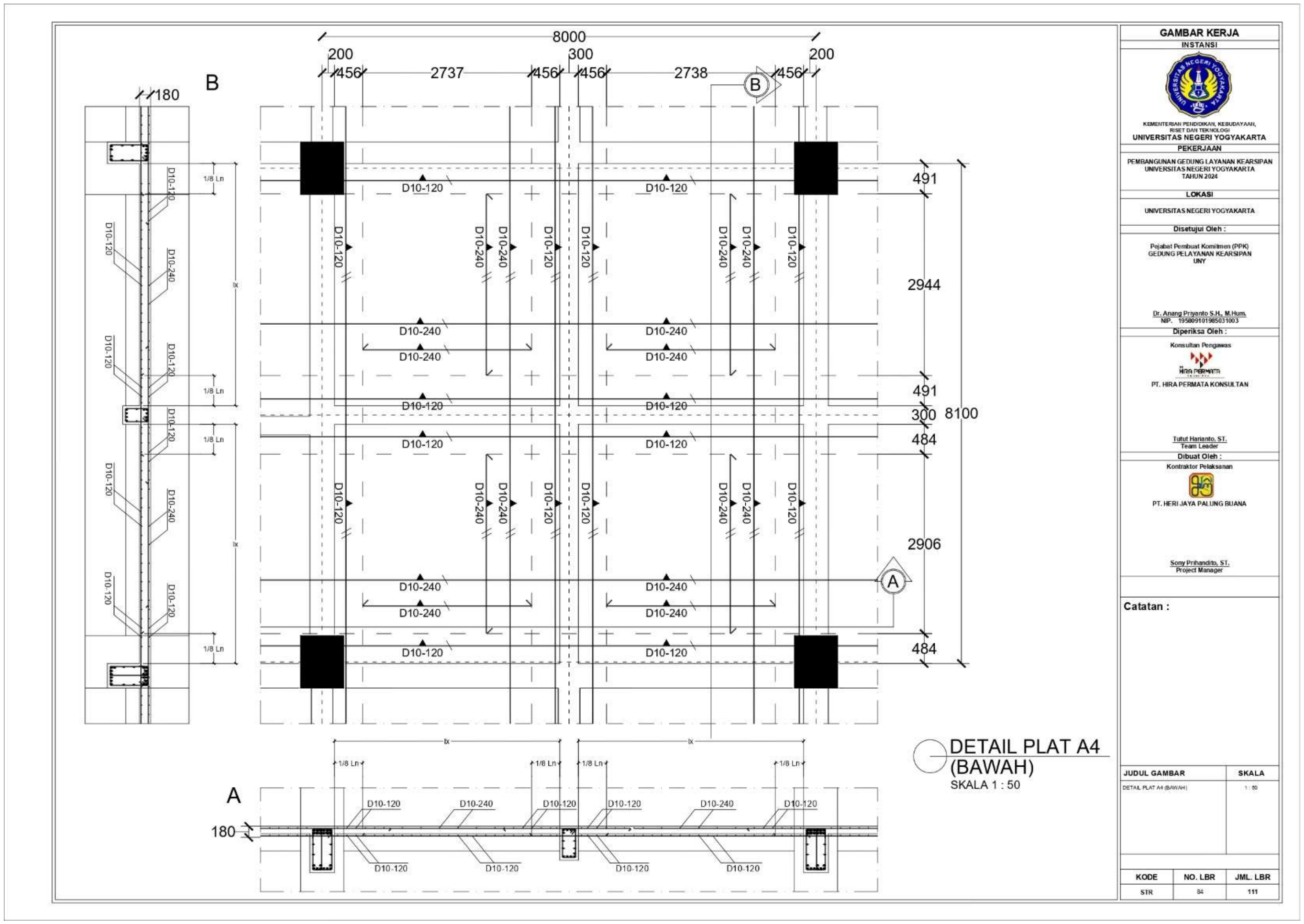
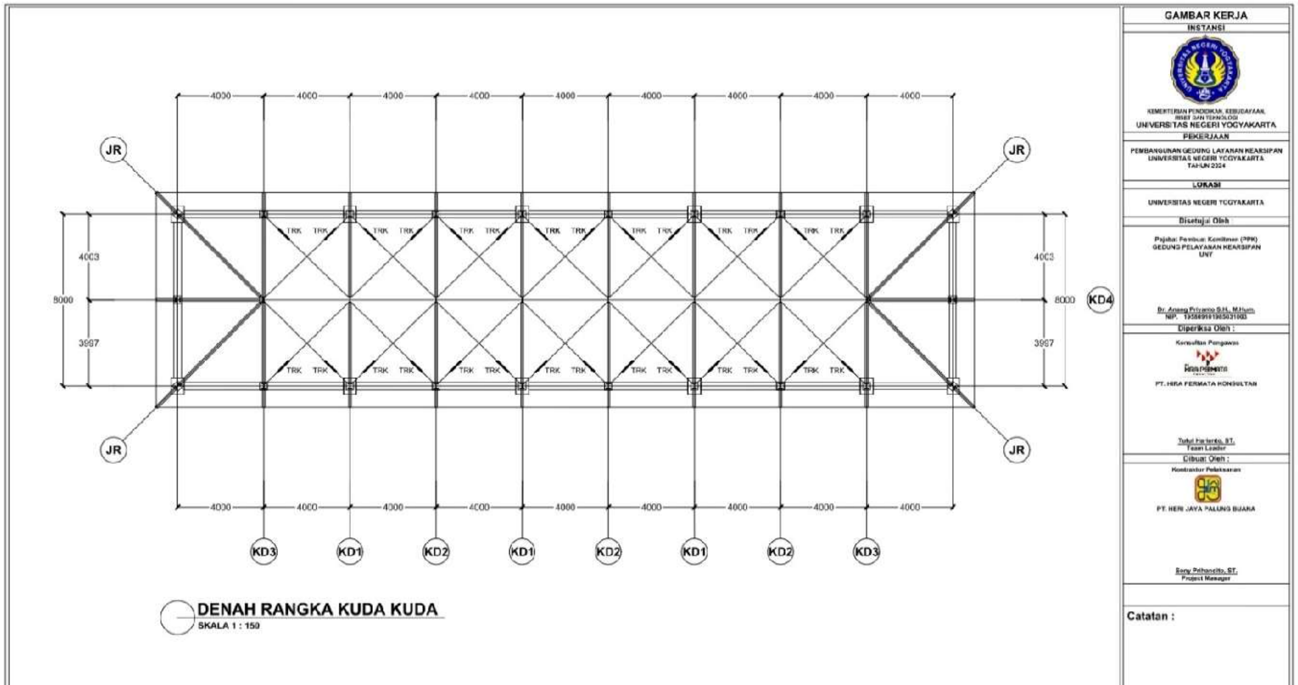


Figure A-1. 36 Detail of Slab A4 Bottom

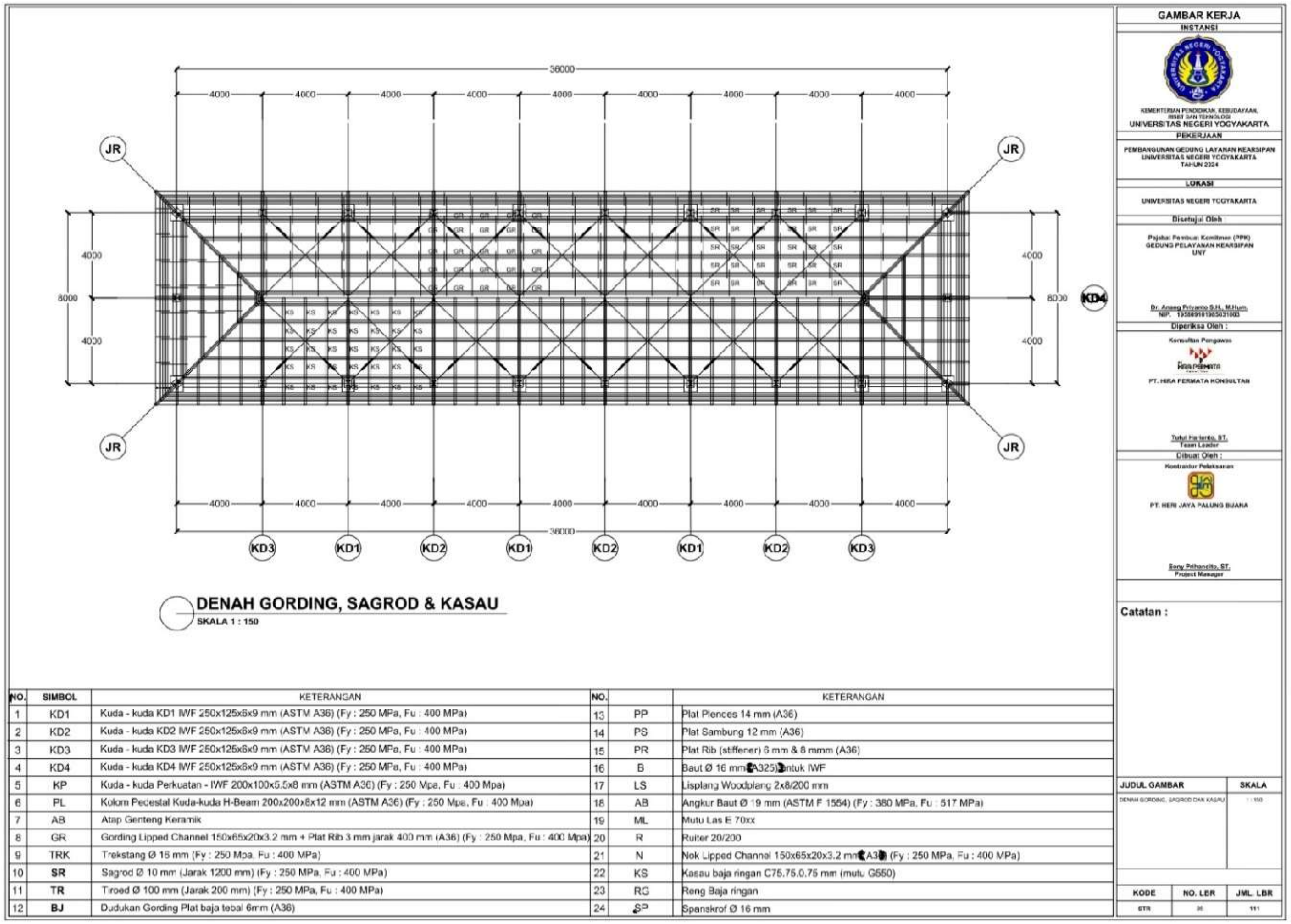


NO.	SIMBOL	KETERANGAN	NO.		KETERANGAN
1	KD1	Kuda - kuda KD1 IWF 250x125x6x9 mm (ASTM A36) (Fy : 250 MPa, Fu : 400 MPa)	13	PP	Plat Plences 14 mm (A36)
2	KD2	Kuda - kuda KD2 IWF 250x125x6x9 mm (ASTM A36) (Fy : 250 MPa, Fu : 400 MPa)	14	PS	Plat Samburg 12 mm (A36)
3	KD3	Kuda - kuda KD3 IWF 250x125x6x9 mm (ASTM A36) (Fy : 250 MPa, Fu : 400 MPa)	15	PR	Plat Rib (stiffener) 6 mm & 8 mmm (A36)
4	KD4	Kuda - kuda KD4 IWF 250x125x6x9 mm (ASTM A36) (Fy : 250 MPa, Fu : 400 MPa)	16	B	Baut Ø 16 mm (A325) untuk IWF
5	KP	Kuda - kuda Perkuatan - IWF 200x100x5.5x8 mm (ASTM A36) (Fy : 250 Mpa, Fu : 400 Mpa)	17	LS	Lisplang Woodplang 2x8/200 mm
6	PL	Kolom Pedestal Kuda-kuda H-Beam 200x200x8x12 mm (ASTM A36) (Fy : 250 Mpa, Fu : 400 Mpa)	18	AB	Angkur Baut Ø 19 mm (ASTM F 1554) (Fy : 380 MPa, Fu : 517 MPa)
7	AB	Atap Genteng Keramik	19	ML	Mutu Las E 70xx
8	GR	Gording Lipped Channel 150x65x20x3.2 mm + Plat Rib 3 mm jarak 400 mm (A36) (Fy : 250 Mpa, Fu : 400 Mpa)	20	R	Ruiter 20/200
9	TRK	Trekstang Ø 16 mm (Fy : 250 Mpa, Fu : 400 MPa)	21	N	Nok Lipped Channel 150x65x20x3.2 mm (A36) (Fy : 250 MPa, Fu : 400 MPa)
10	SR	Sagrod Ø 10 mm (Jarak 1200 mm) (Fy : 250 MPa, Fu : 400 MPa)	22	KS	Kasau baja ringan C75.75.0.75 mm (mutu G550)
11	TR	Tiroed Ø 100 mm (Jarak 200 mm) (Fy : 250 MPa, Fu : 400 MPa)	23	RG	Reng Baja ringan
12	BJ	Dudukan Gording Plat baja tebal 6mm (A36)	24	SP	Spanskrof Ø 16 mm

JUDUL GAMBAR	SKALA
DENAH RANGKA KUDA KUDA	1 : 150

KODE	NO. LBR	JML. LBR
STR	25	111

Figure A-1. 37 Roof Truss Framework Plan



NO.	SIMBOL	KETERANGAN	NO.		KETERANGAN
1	KD1	Kuda - kuda KD1 IWF 250x125x6x9 mm (ASTM A36) (Fy : 250 MPa, Fu : 400 MPa)	13	PP	Plat Pience s 14 mm (A36)
2	KD2	Kuda - kuda KD2 IWF 250x125x6x9 mm (ASTM A36) (Fy : 250 MPa, Fu : 400 MPa)	14	PS	Plat Samburg 12 mm (A36)
3	KD3	Kuda - kuda KD3 IWF 250x125x6x9 mm (ASTM A36) (Fy : 250 MPa, Fu : 400 MPa)	15	PR	Plat Rib (stiffener) 6 mm & 8 mmm (A36)
4	KD4	Kuda - kuda KD4 IWF 250x125x6x9 mm (ASTM A36) (Fy : 250 MPa, Fu : 400 MPa)	16	B	Baut Ø 16 mm (A325) untuk IWF
5	KP	Kuda - kuda Perkuatan - IWF 200x100x5.5x8 mm (ASTM A36) (Fy : 250 Mpa, Fu : 400 Mpa)	17	LS	Lisplang Woodplang 2x8/200 mm
6	PL	Kolom Pedestal Kuda-kuda H-Beam 200x200x8x12 mm (ASTM A36) (Fy : 250 Mpa, Fu : 400 Mpa)	18	AB	Angkur Baut Ø 19 mm (ASTM F 1554) (Fy : 380 MPa, Fu : 517 MPa)
7	AB	Atap Genteng Keramik	19	ML	Mutu Las E 70xx
8	GR	Gording Lipped Channel 150x65x20x3.2 mm + Plat Rib 3 mm jarak 400 mm (A36) (Fy : 250 Mpa, Fu : 400 Mpa)	20	R	Ruiter 20/200
9	TRK	Trekstang Ø 16 mm (Fy : 250 Mpa, Fu : 400 MPa)	21	N	Nok Lipped Channel 150x65x20x3.2 mm (A36) (Fy : 250 MPa, Fu : 400 MPa)
10	SR	Sagrod Ø 10 mm (Jarak 1200 mm) (Fy : 250 MPa, Fu : 400 MPa)	22	KS	Kasau baja ringan C75.75.0.75 mm (mutu G550)
11	TR	Tiroed Ø 100 mm (Jarak 200 mm) (Fy : 250 MPa, Fu : 400 MPa)	23	RG	Reng Baja ringan
12	BJ	Dudukan Gording Plat baja tebal 6mm (A36)	24	SP	Spanskrof Ø 16 mm

Figure A-1. 38 Purlin, Sagrod, and Rafter Plan

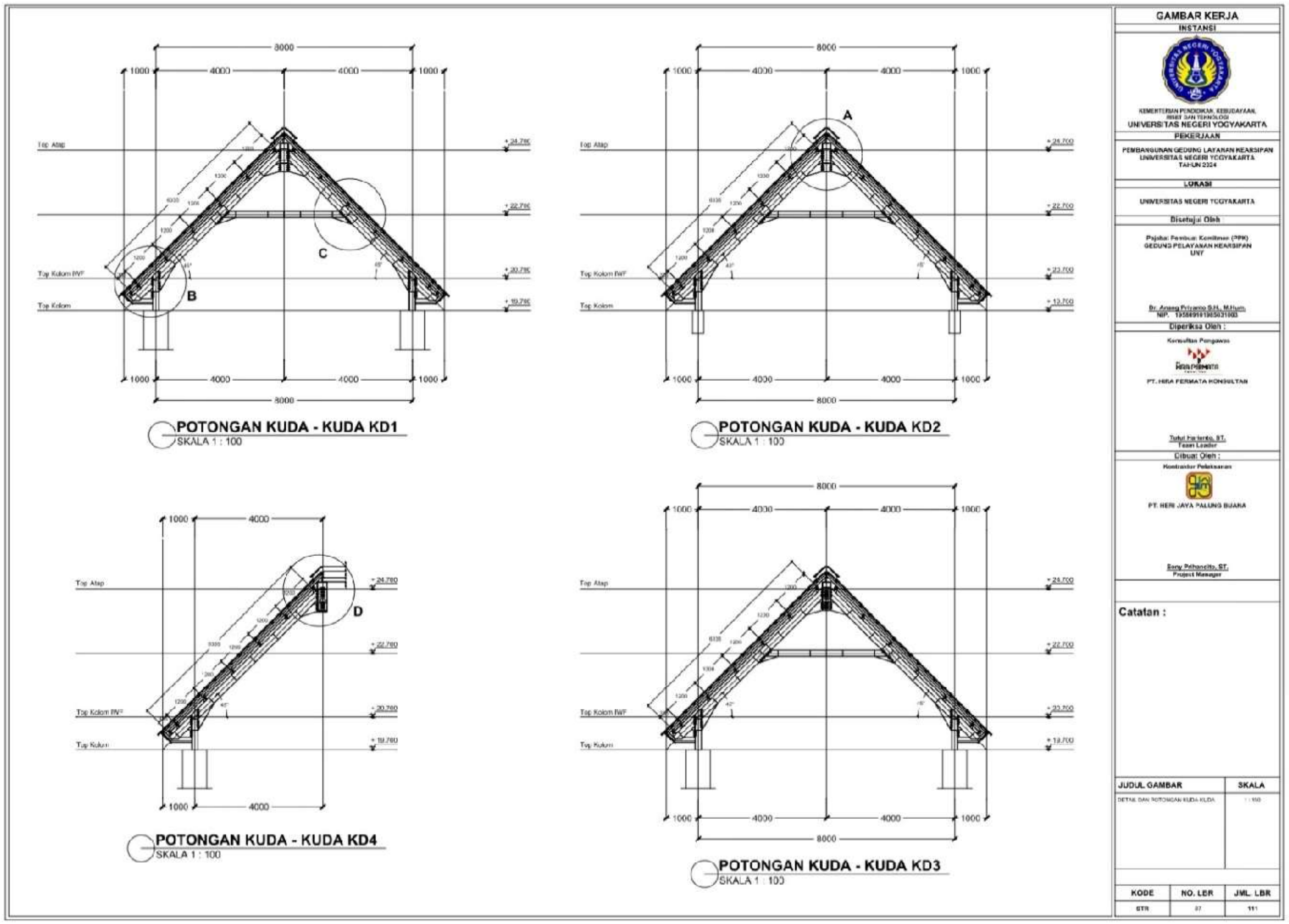


Figure A-1. 39 Cross-Section of Roof Truss KD1, KD2, KD3, and KD4

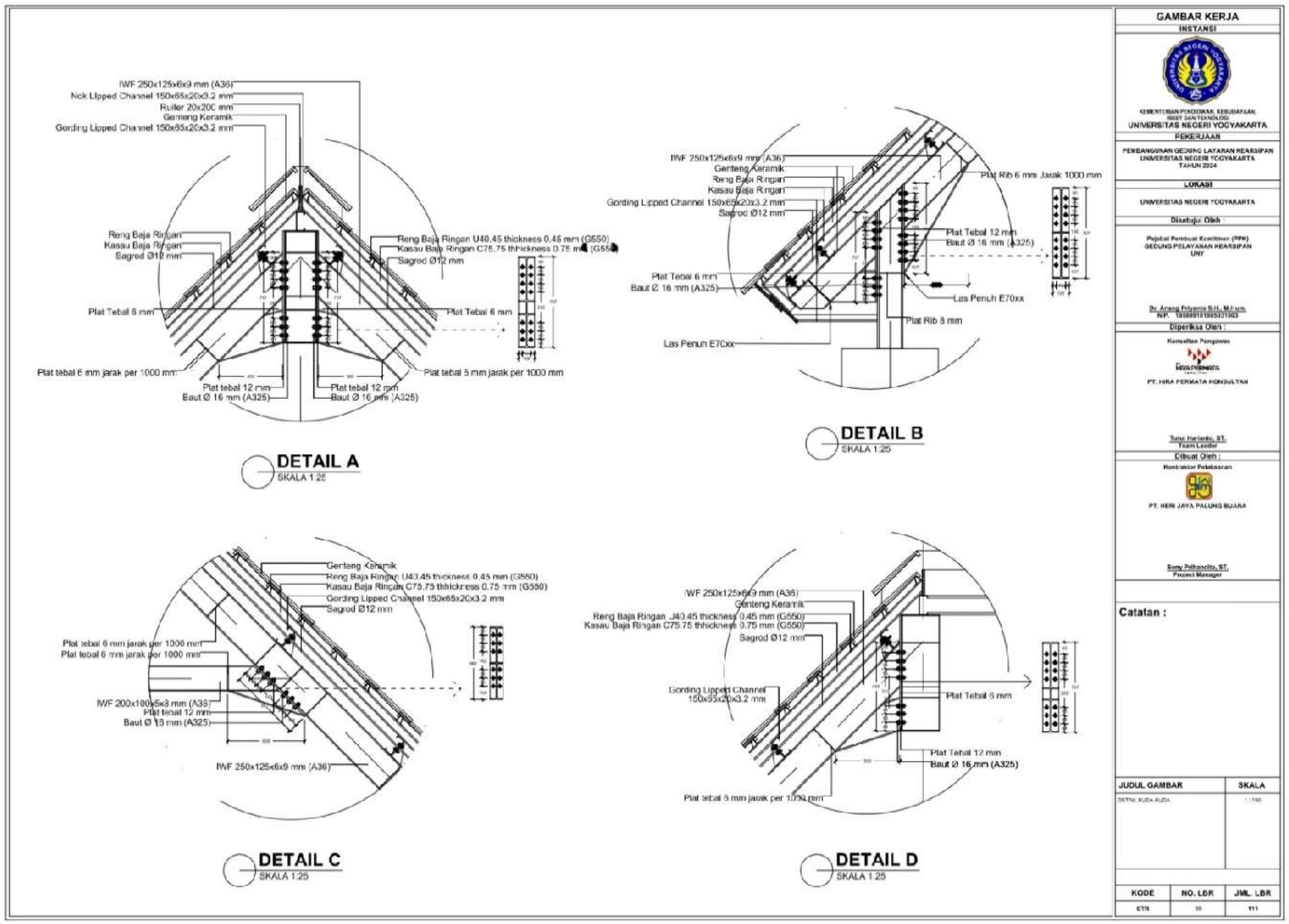


Figure A-1. 40 Roof Truss Detail

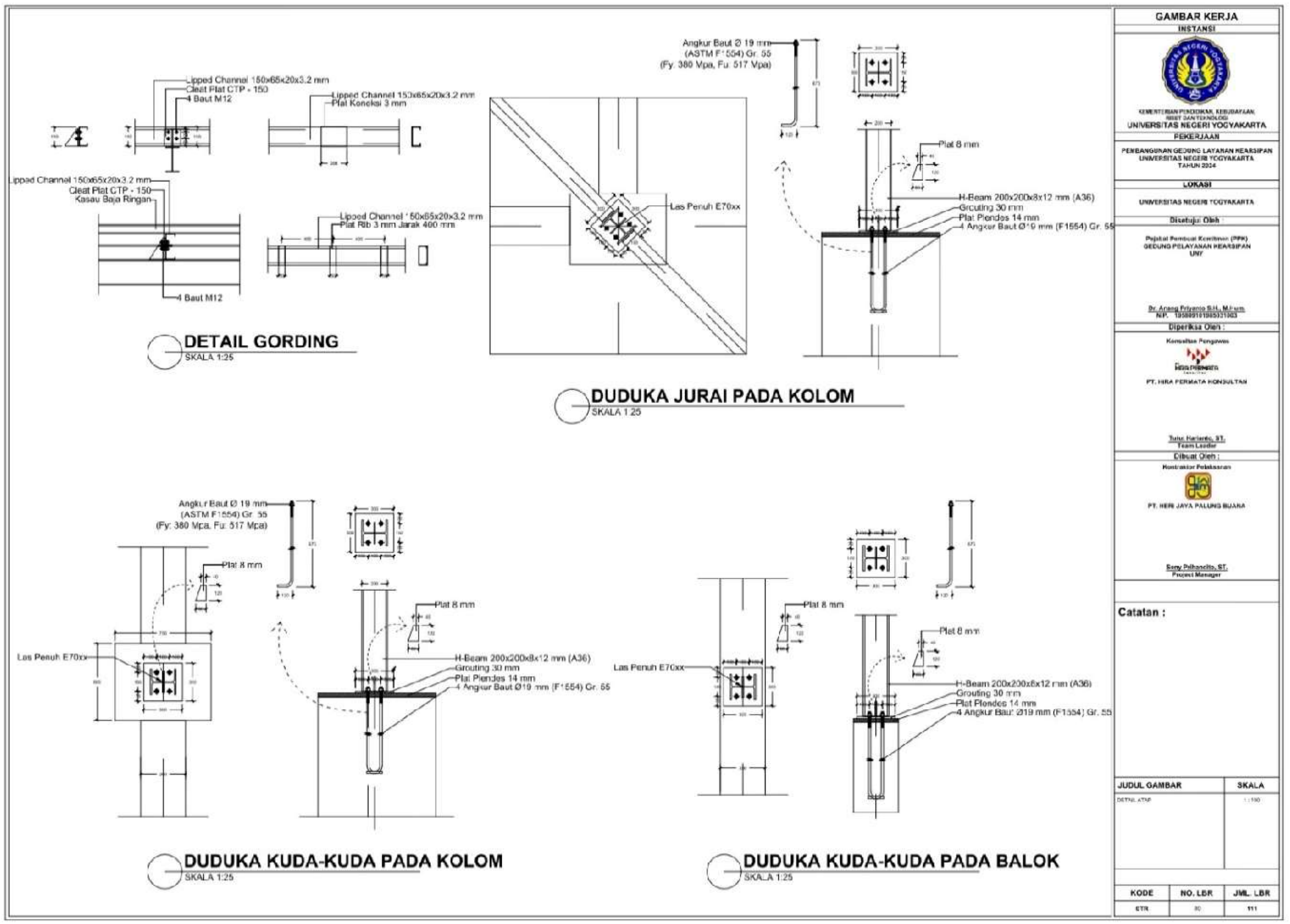


Figure A-1. 41 Roof Truss Detail 2

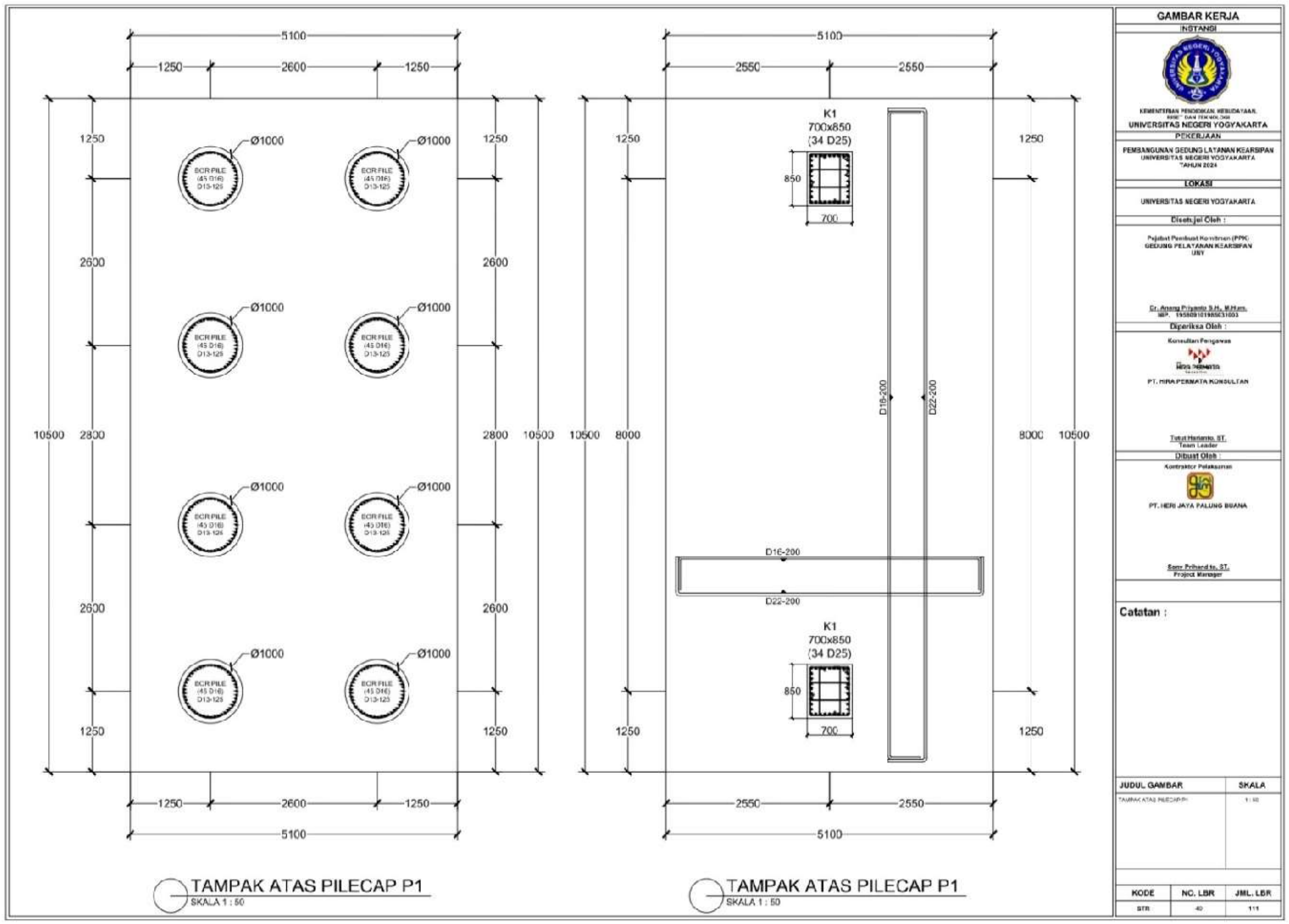


Figure A-1. 42 Top View of Pile Cap P1

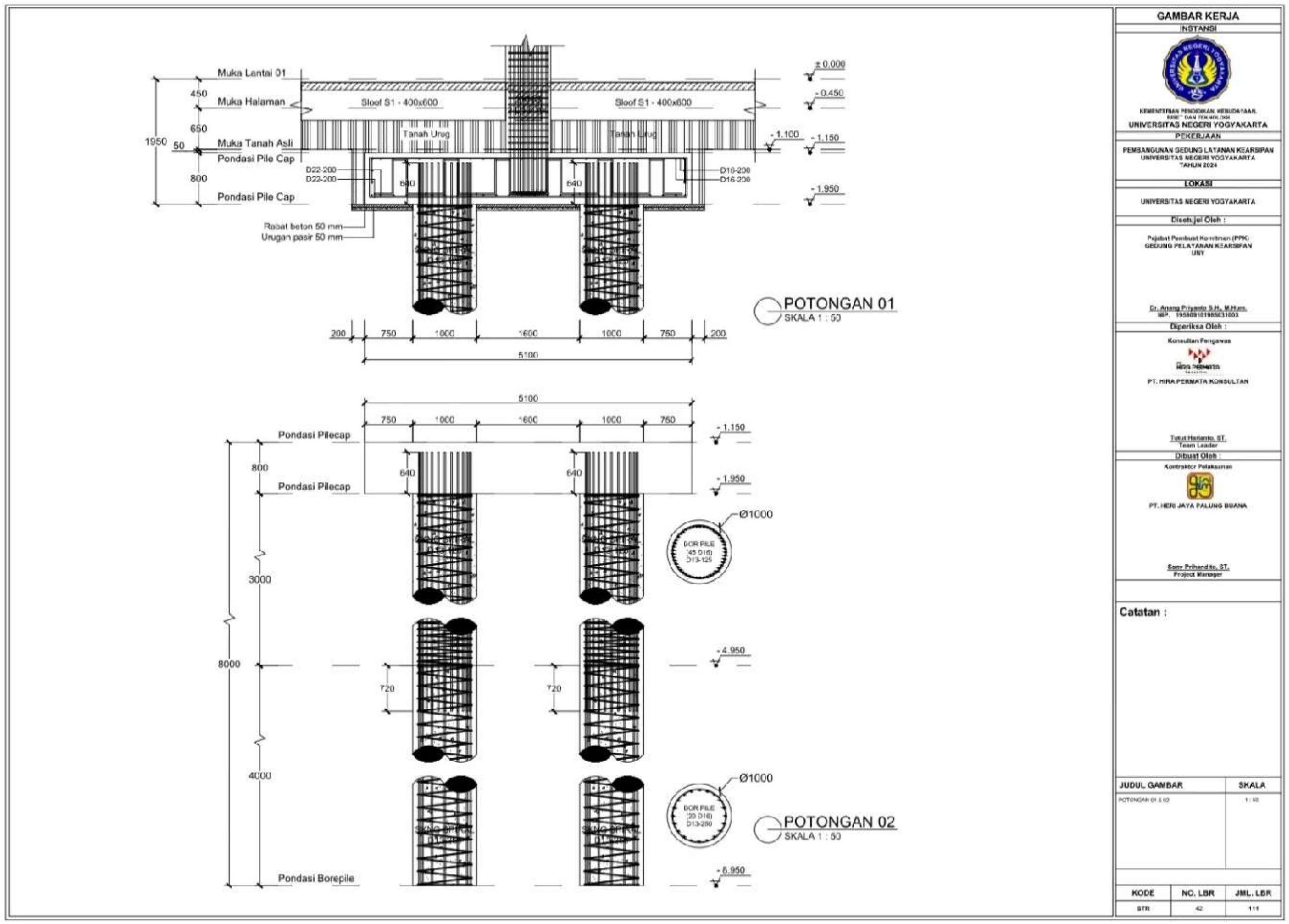


Figure A-1. 43 Detail of Pile Cap P1

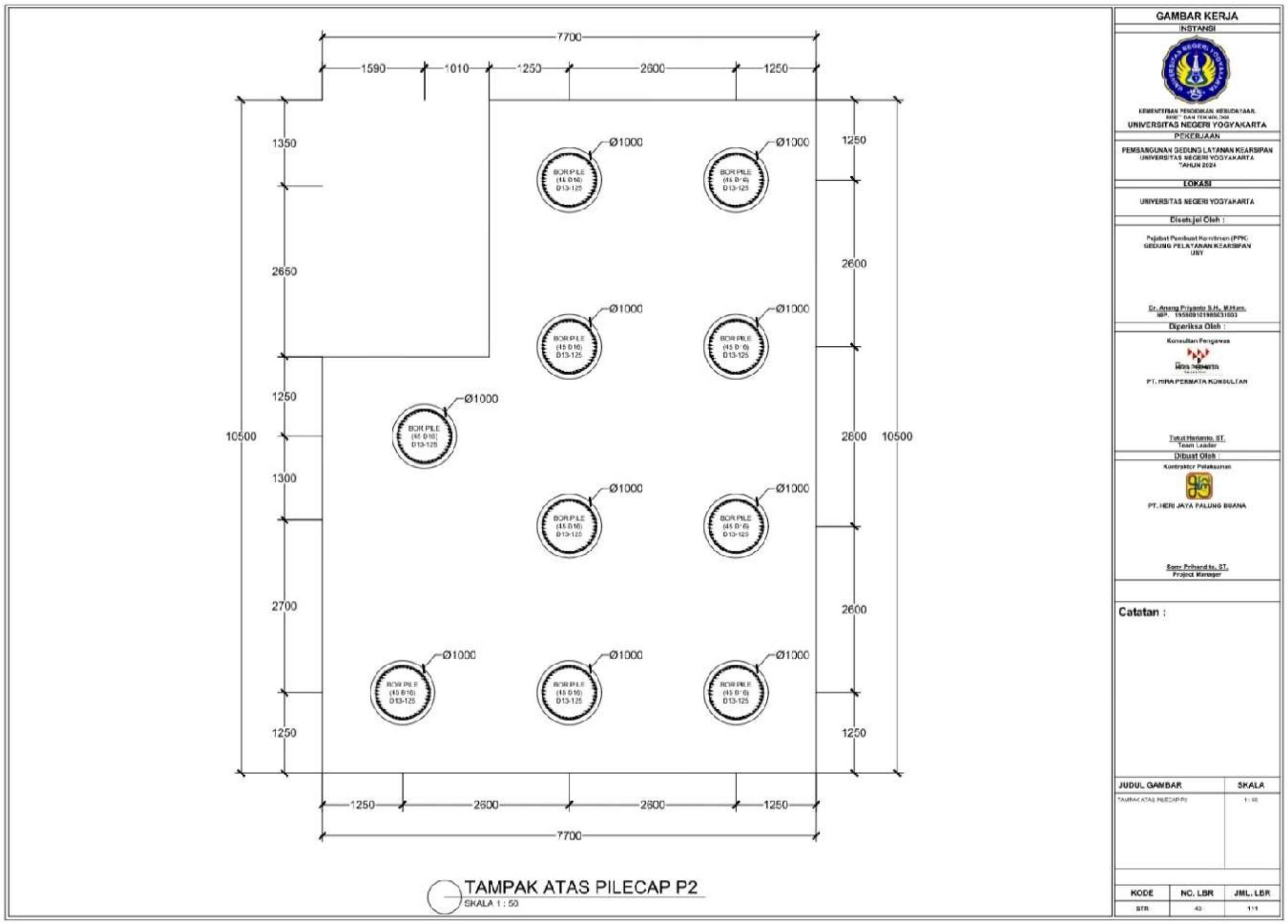


Figure A-1. 44 Top View of Bore Pile on Pile Cap P2

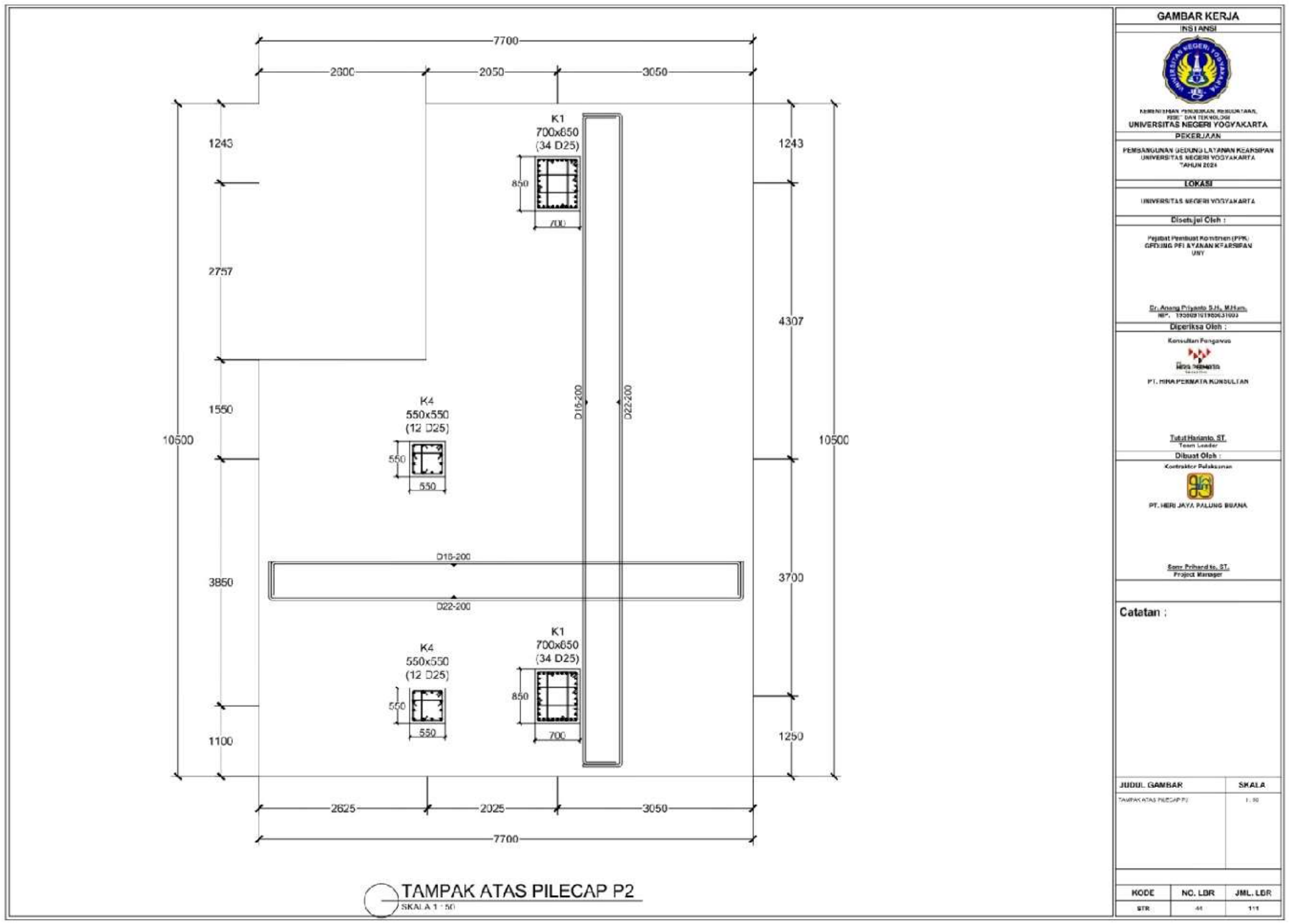


Figure A-1. 45 Top View of Pile Cap P2

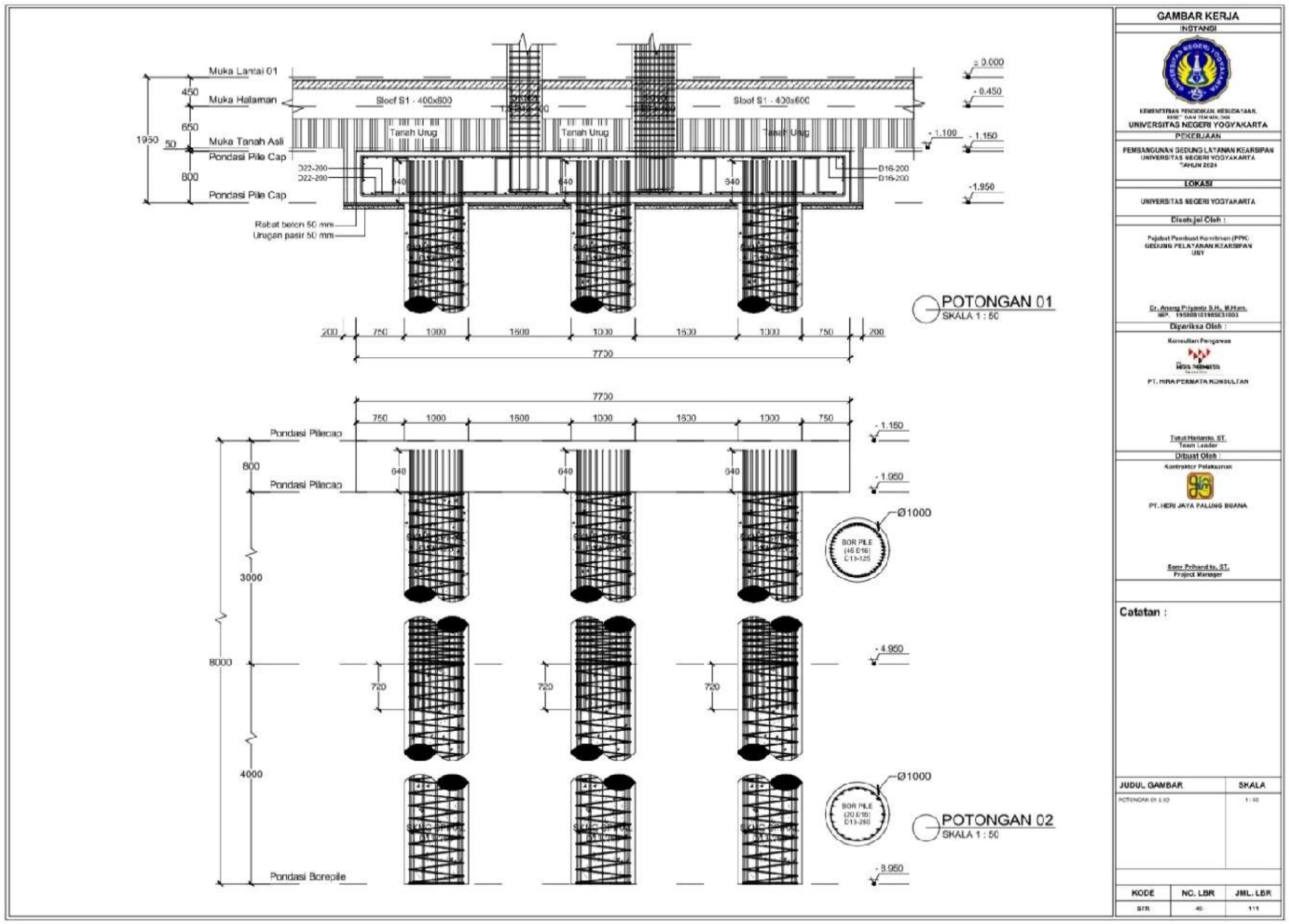


Figure A-1. 46 Detail of P2

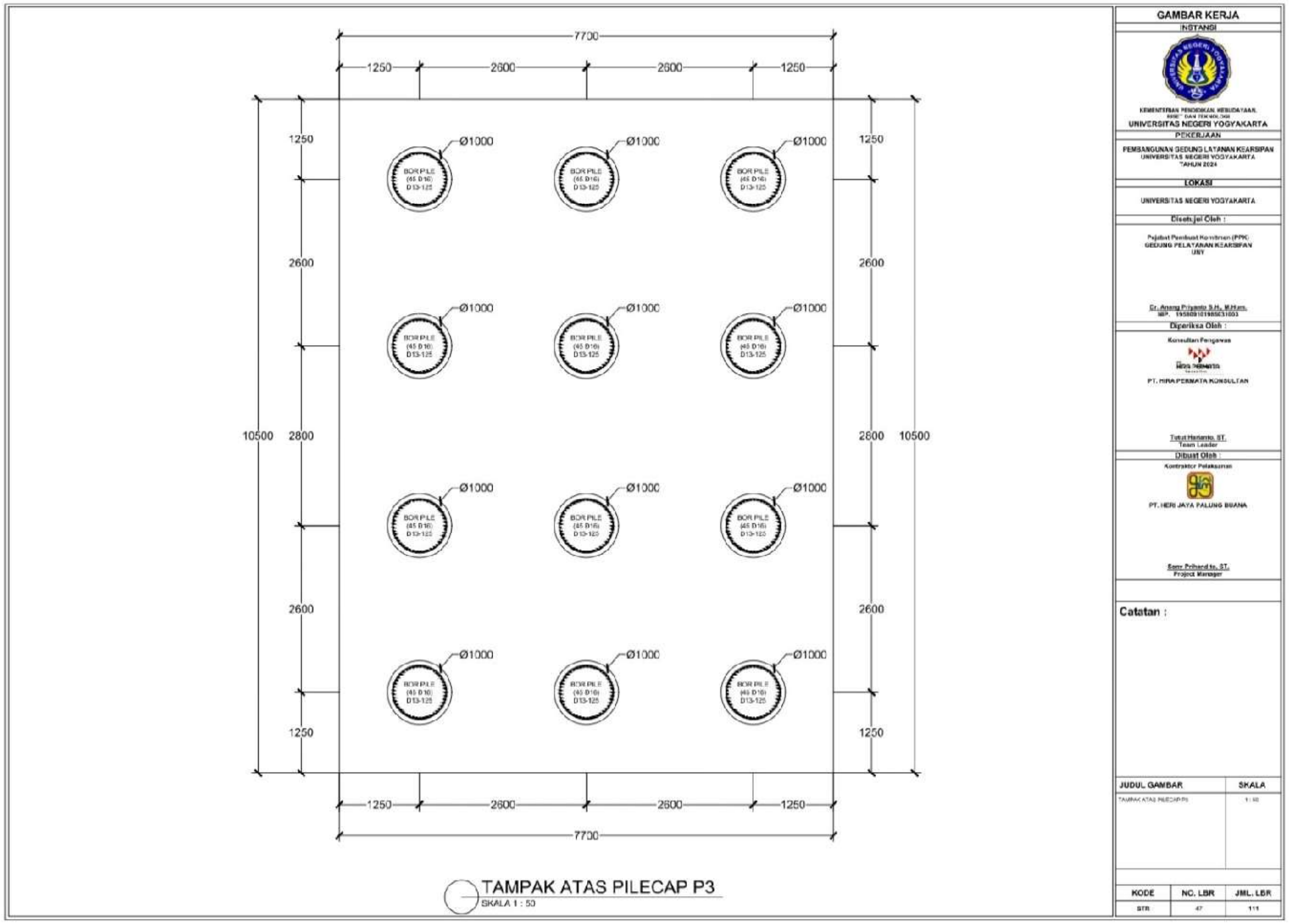


Figure A-1. 47 Top View of Bore Pile on Pile Cap P3

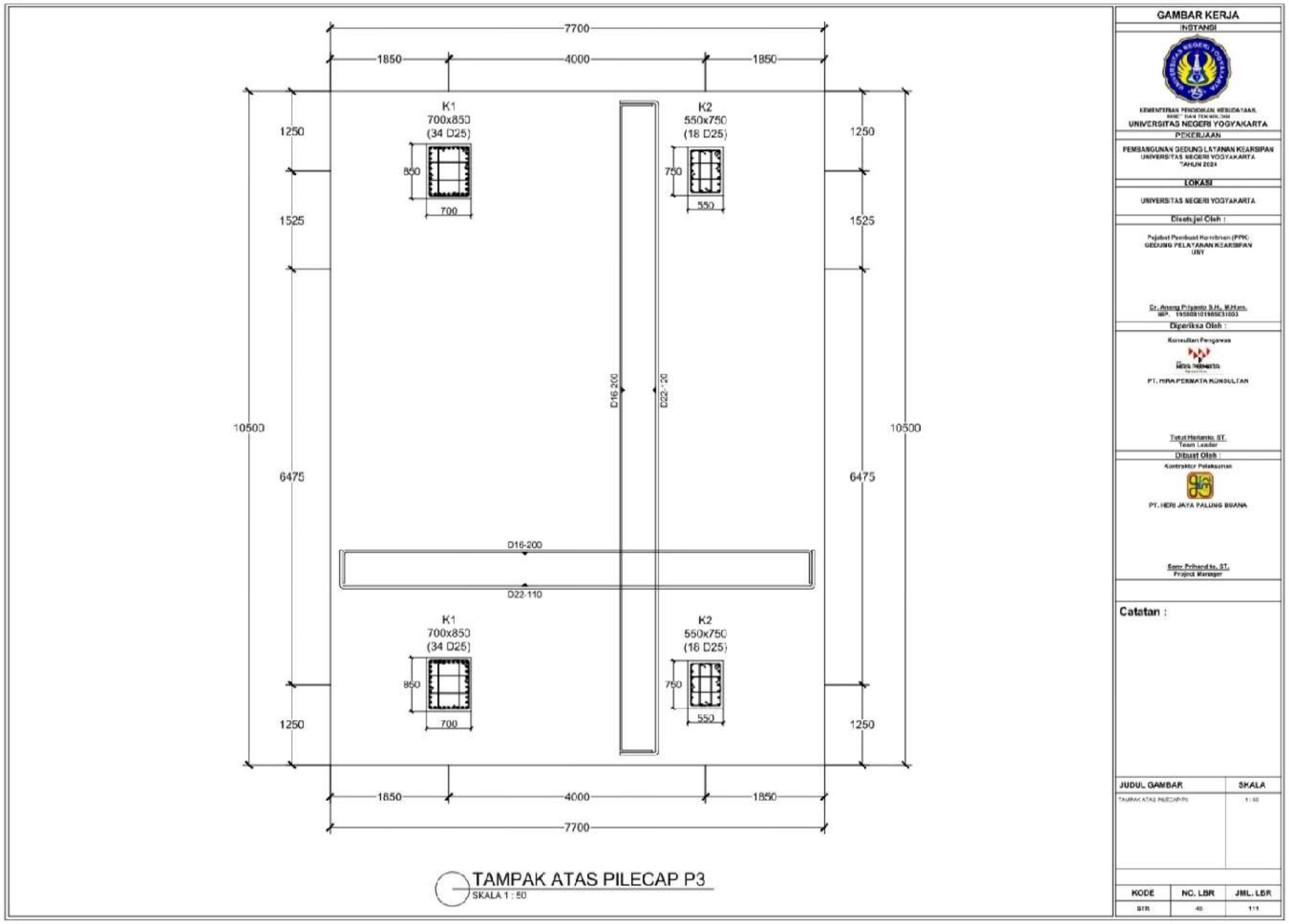


Figure A-1. 48 Top View of Pile Cap P3

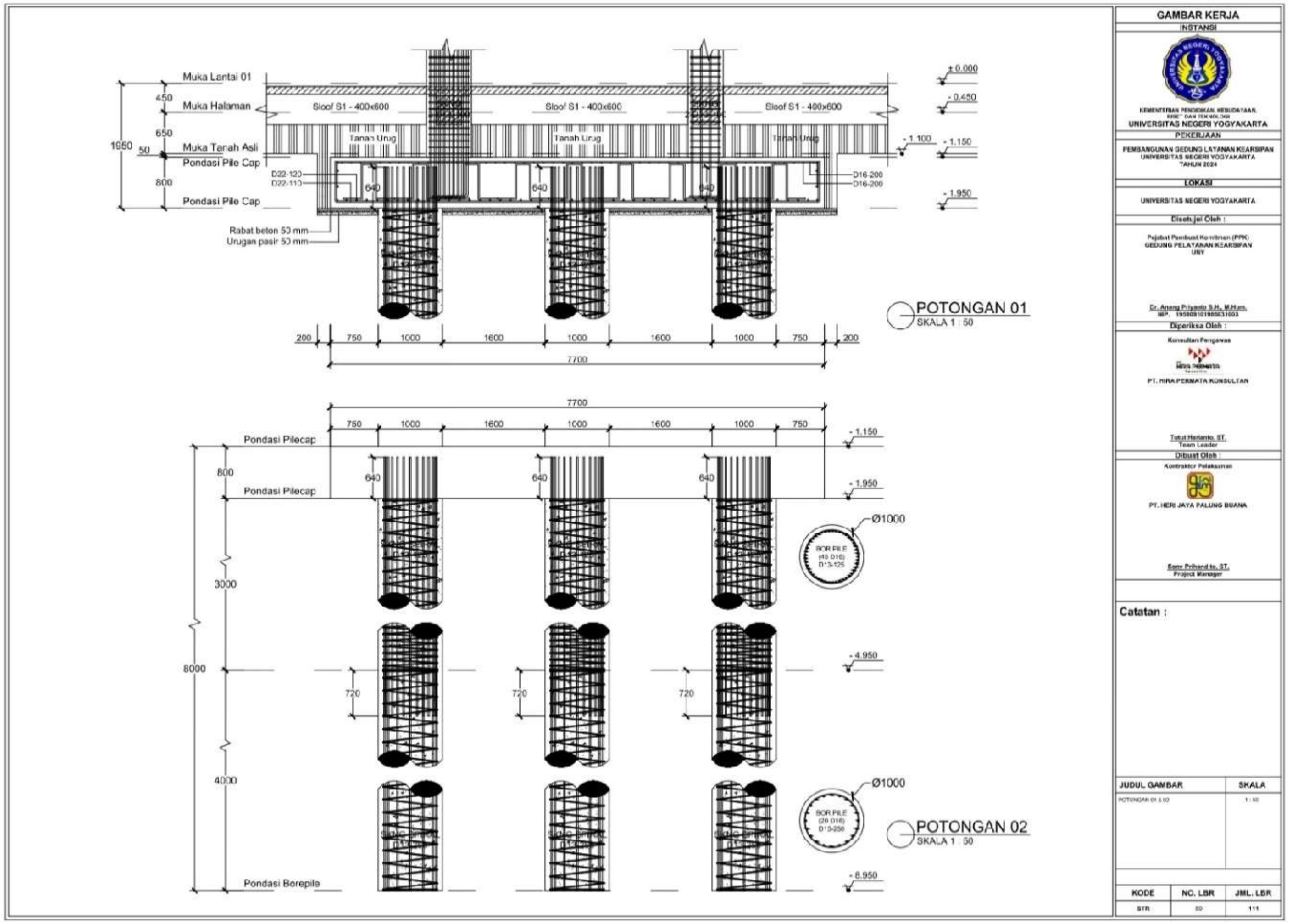


Figure A-1. 49 Detail of Pile Cap P3

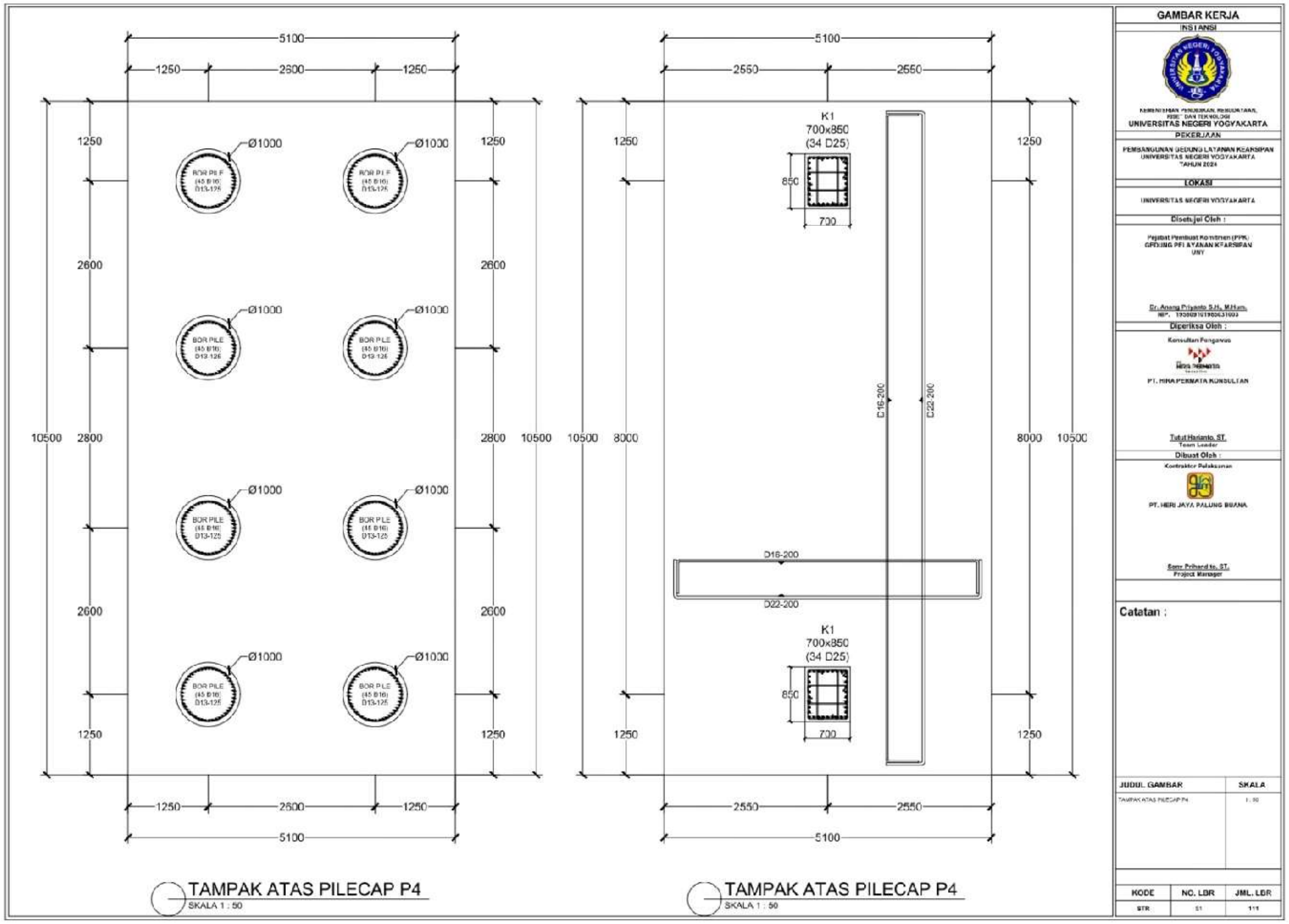


Figure A-1. 50 Top View of Pile Cap P4

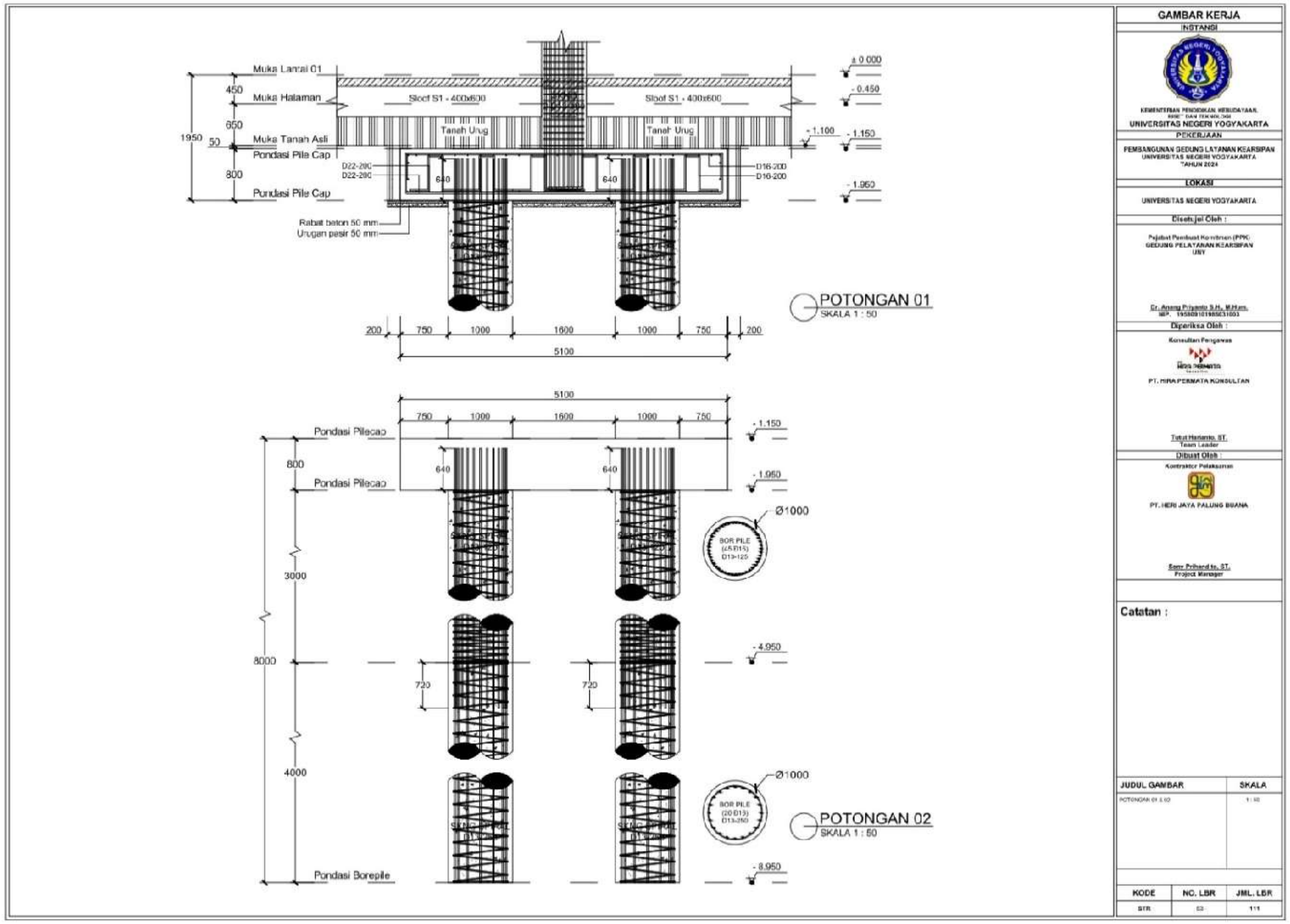


Figure A-1. 51 Detail of Pile Cap P4

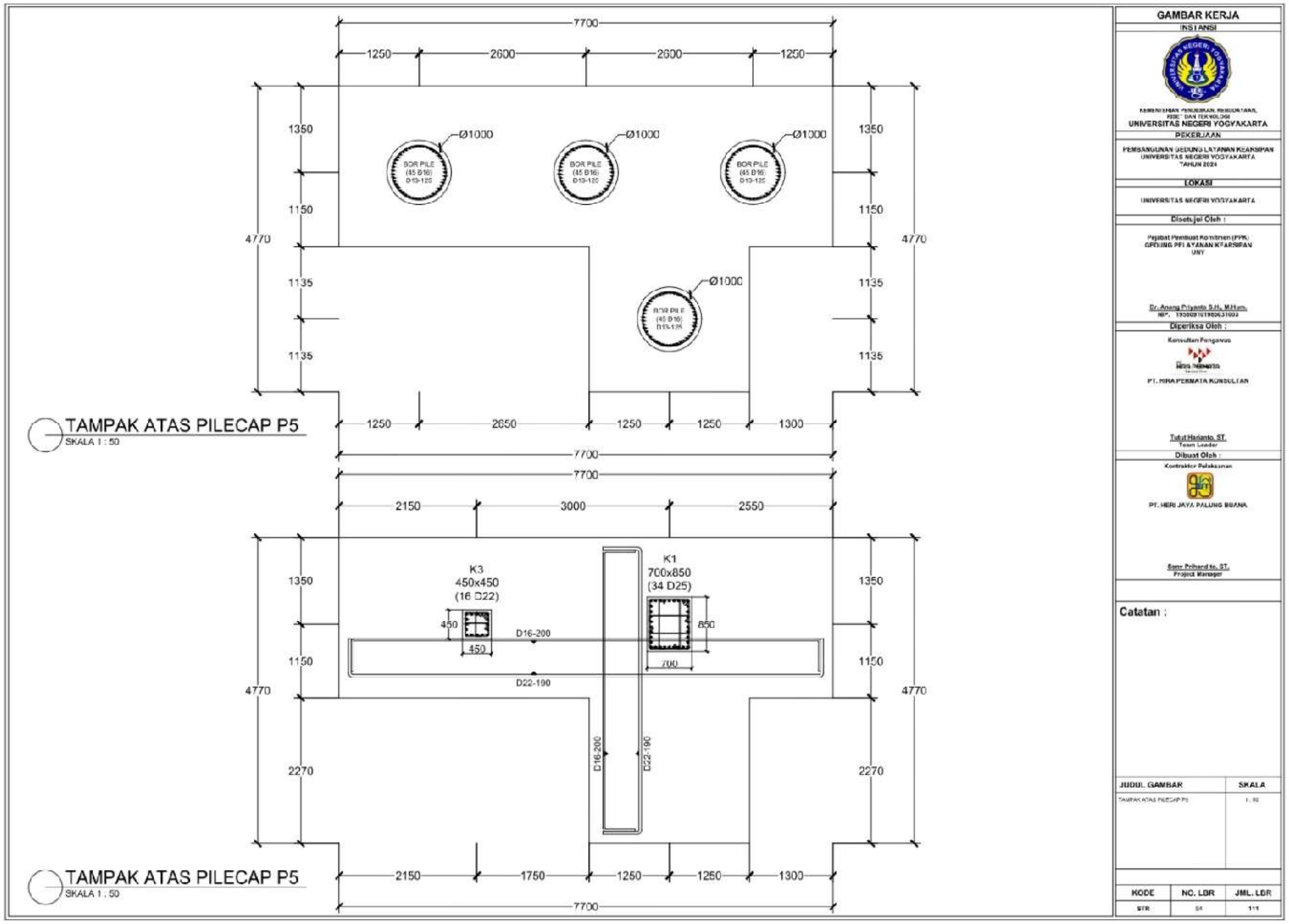


Figure A-1. 52 Top View of Pile Cap P5

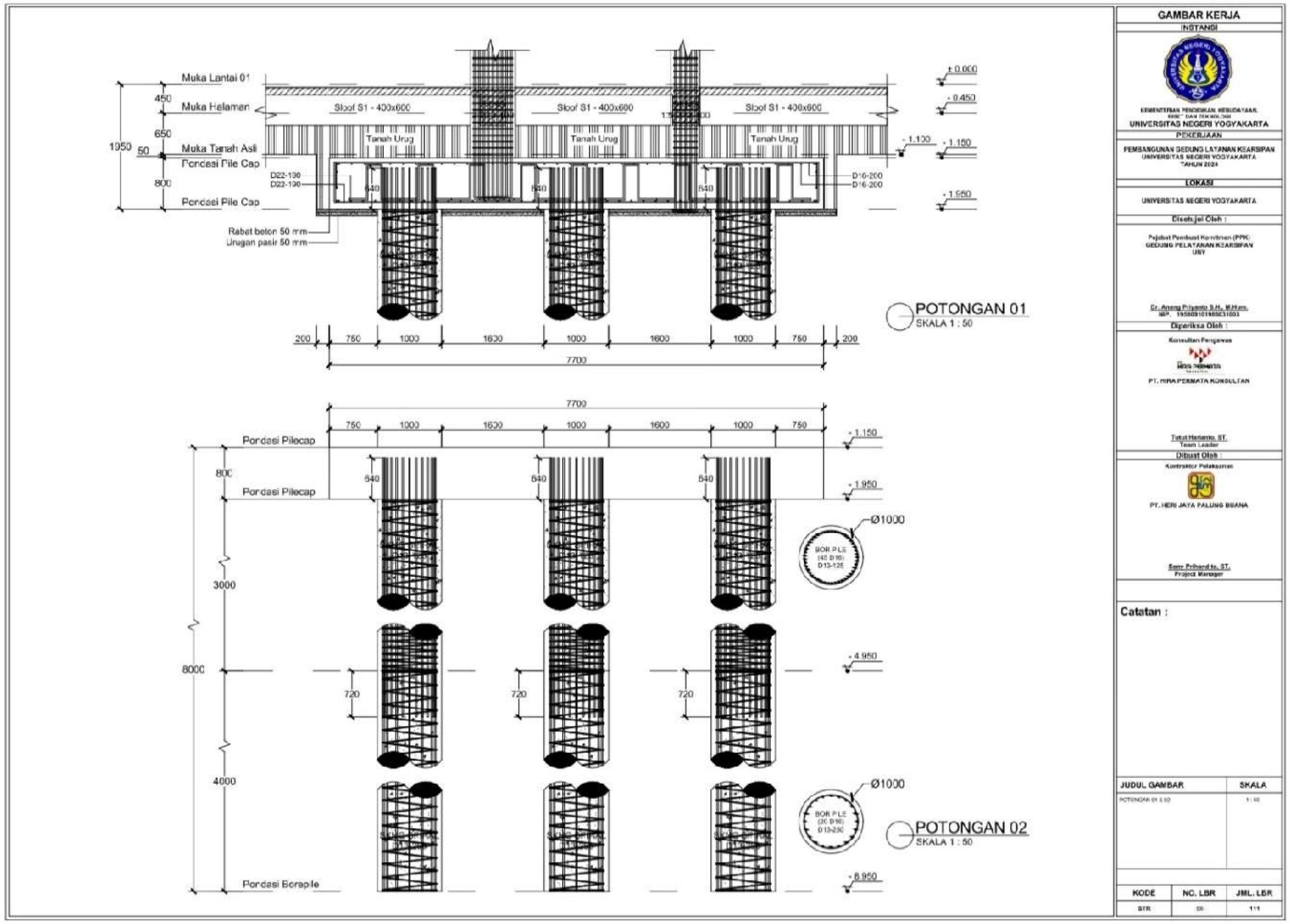


Figure A-1. 53 Detail of Pile Cap P5

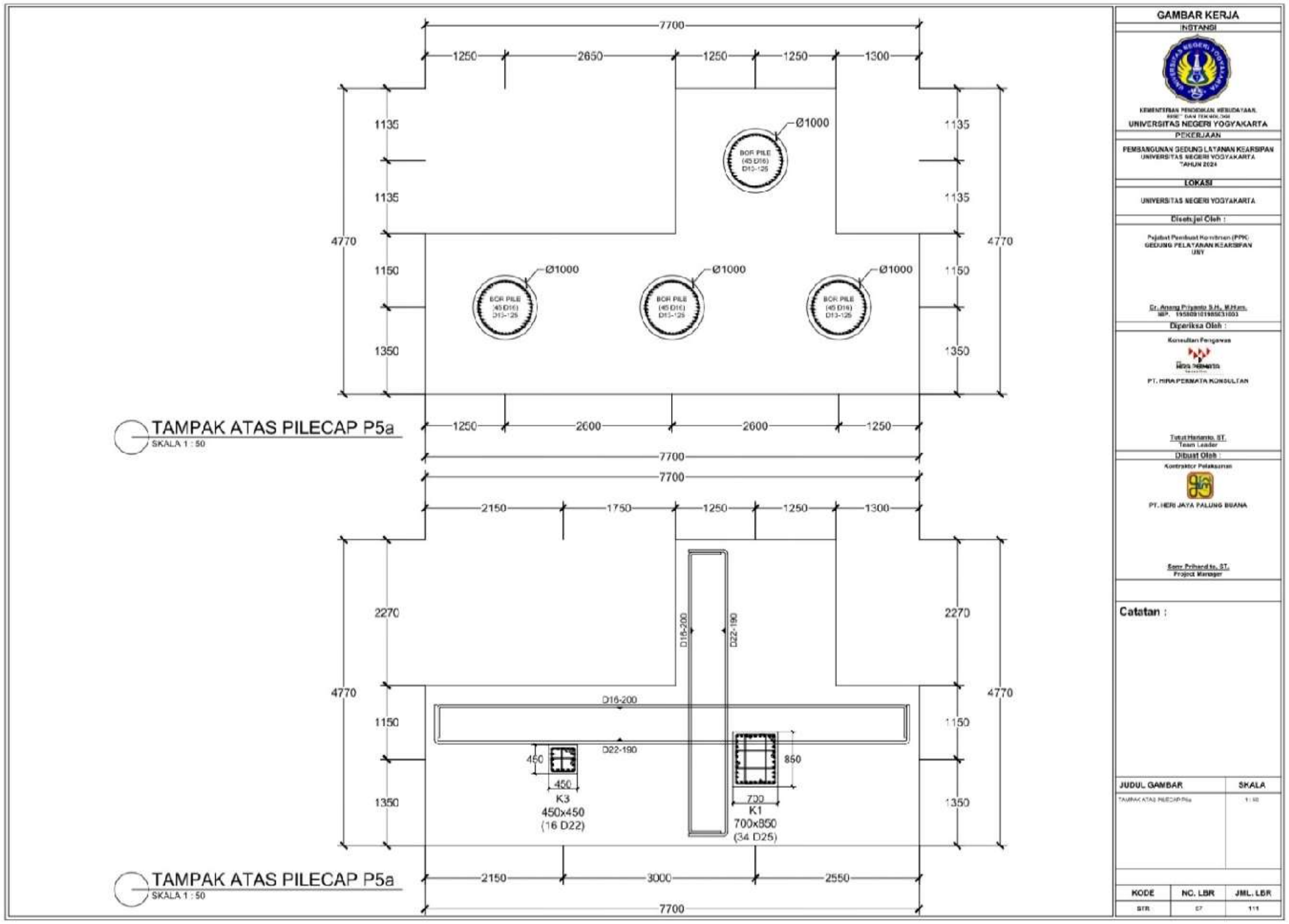


Figure A-1. 54 Top View of Pile Cap P5a

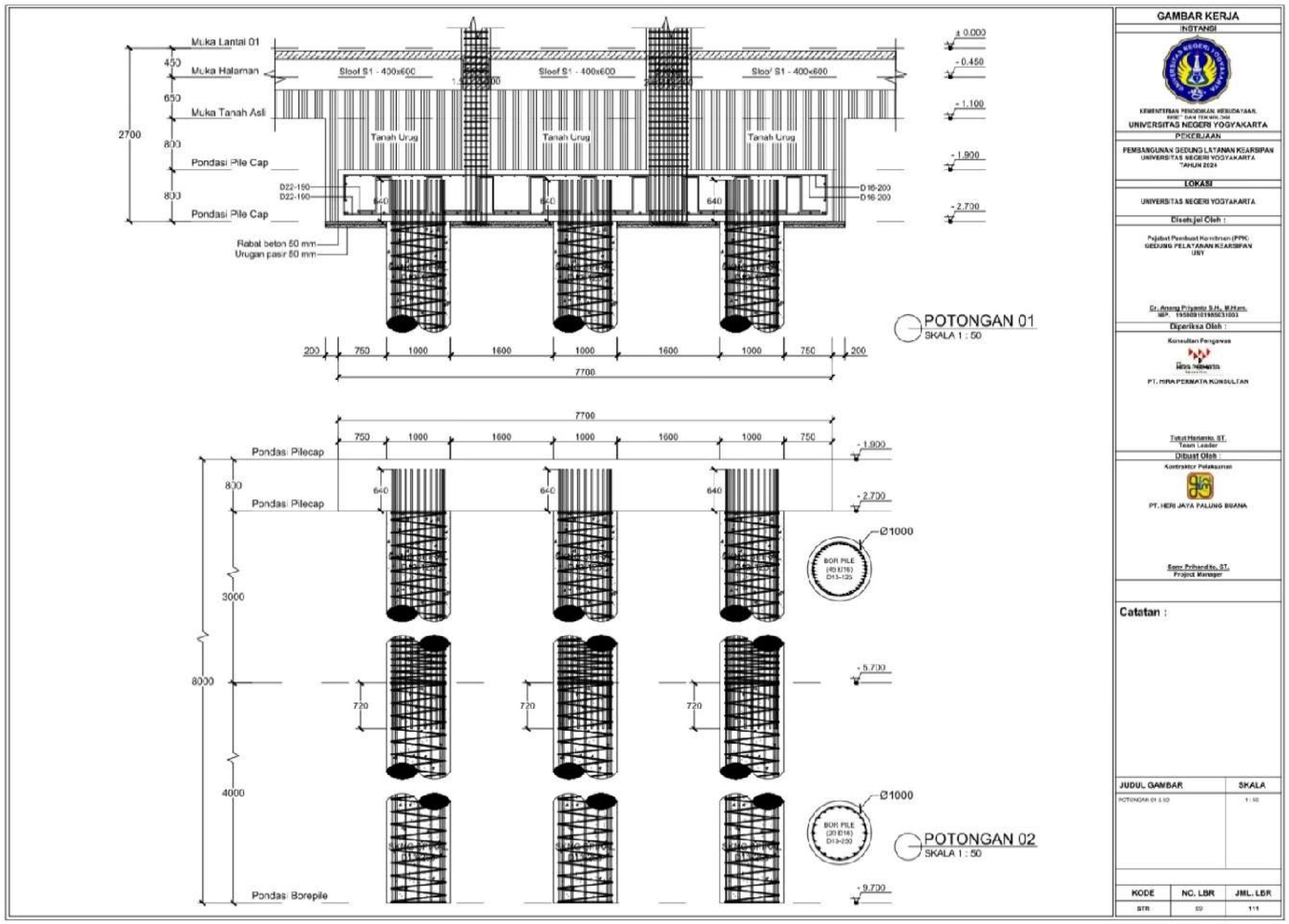


Figure A-1. 55 Detail of Pile Cap P5a

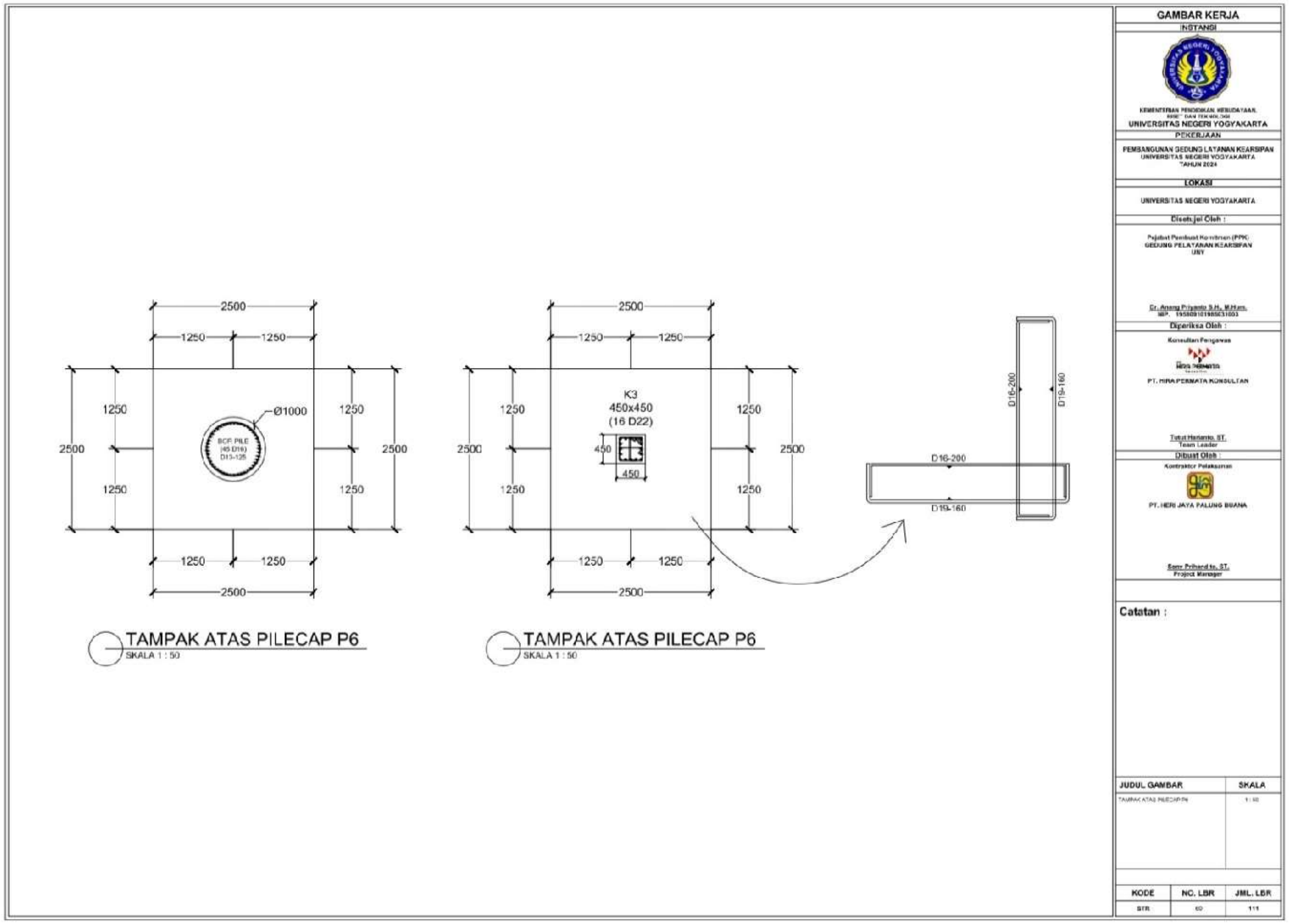


Figure A-1. 56 Top View of Pile Cap P6

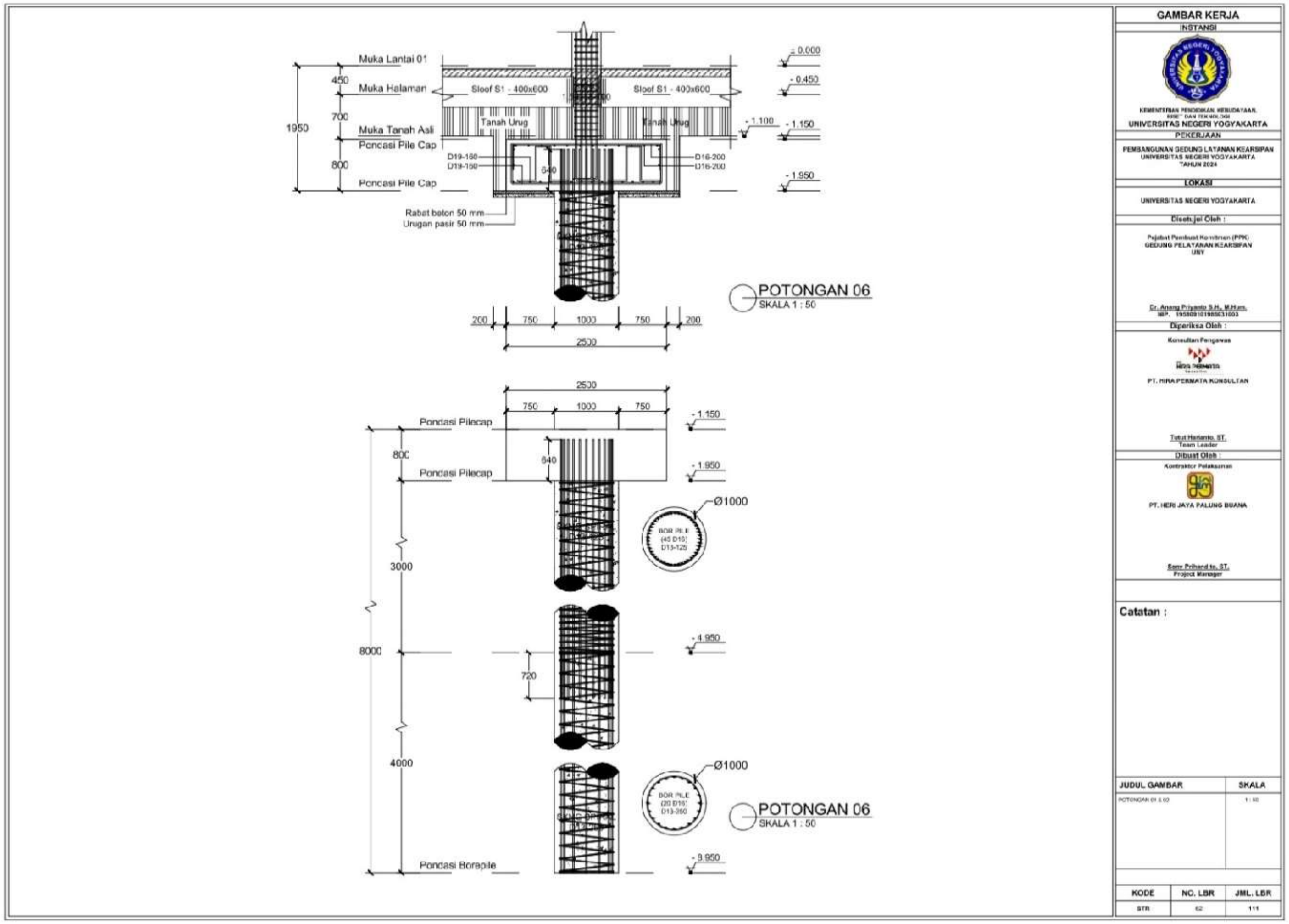
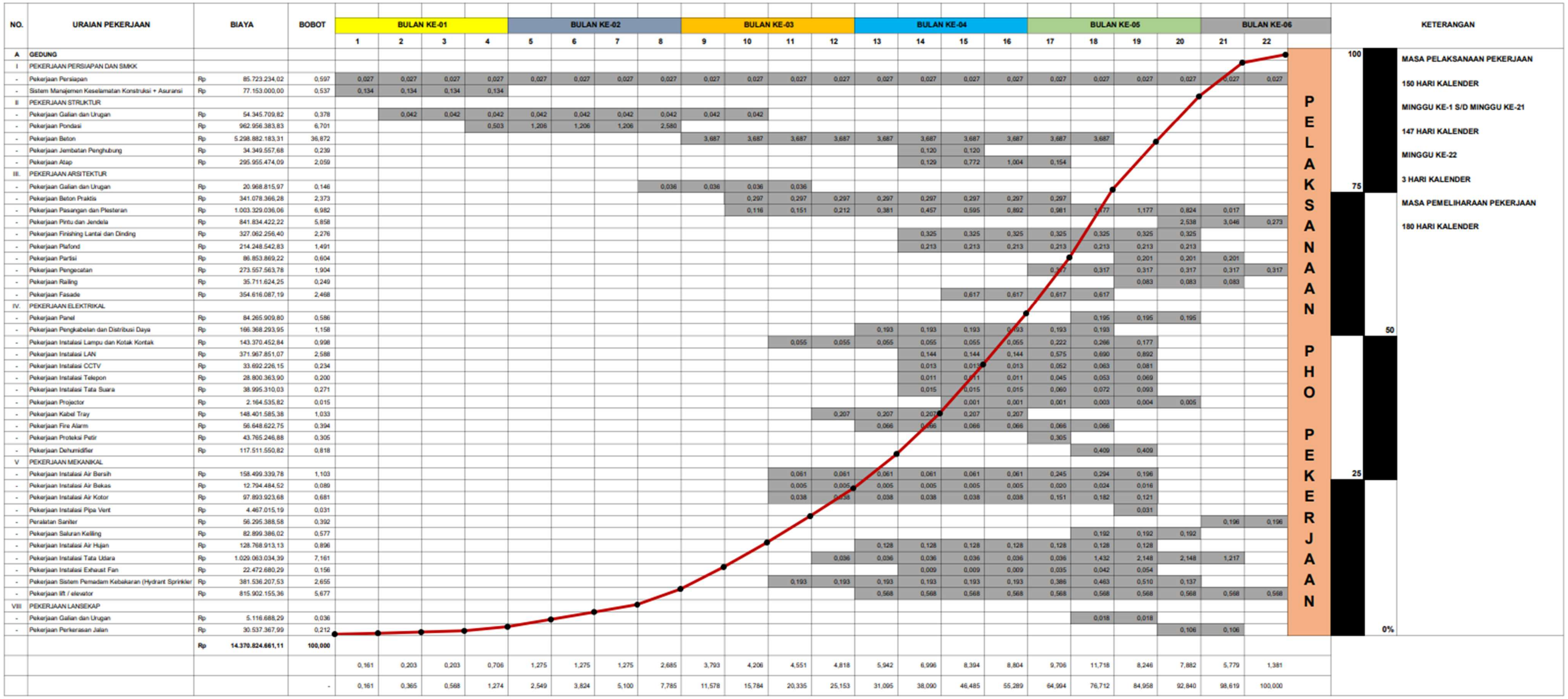


Figure A-1. 57 Detail of Pile Cap P6

Appendix 2 Original Contractor S-Curve



TIME SCHEDULE
PEMBANGUNAN GEDUNG ARSIP
UNIVERSITAS NEGERI YOGYAKARTA
2024

NO.	URAIAN PEKERJAAN	BIAYA	BOBOT	BULAN KE-01				BULAN KE-02				BULAN KE-03				BULAN KE-04				BULAN KE-05				BULAN KE-06	
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	GEDUNG																								
I	PEKERJAAN PERSIAPAN DAN SMKK																								
-	Pekerjaan Persiapan	Rp 85.723.234,02	0,597	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027
-	Sistem Manajemen Keselamatan Konstruksi + Asuransi	Rp 77.153.000,00	0,537	0,134	0,134	0,134	0,134																		
II	PEKERJAAN STRUKTUR																								
-	Pekerjaan Galian dan Urugan	Rp 54.345.709,82	0,378		0,042	0,042	0,042	0,042	0,042	0,042	0,042	0,042	0,042												
-	Pekerjaan Pondasi	Rp 962.956.383,83	6,701				0,503	1,206	1,206	1,206	2,580														
-	Pekerjaan Beton	Rp 5.298.882.183,31	36,872									3,687	3,687	3,687	3,687	3,687	3,687	3,687	3,687	3,687	3,687				
-	Pekerjaan Jembatan Penghubung	Rp 34.349.557,68	0,239														0,120	0,120							
-	Pekerjaan Atap	Rp 295.955.474,09	2,059														0,129	0,772	1,004	0,154					
III.	PEKERJAAN ARSITEKTUR																								
-	Pekerjaan Galian dan Urugan	Rp 20.968.815,97	0,146								0,036	0,036	0,036	0,036											
-	Pekerjaan Beton Praktis	Rp 341.078.366,28	2,373										0,297	0,297	0,297	0,297	0,297	0,297	0,297	0,297					
-	Pekerjaan Pasangan dan Plesteran	Rp 1.003.329.036,06	6,982										0,116	0,151	0,212	0,381	0,457	0,595	0,892	0,981	1,177	1,177	0,824	0,017	
-	Pekerjaan Pintu dan Jendela	Rp 841.834.422,22	5,858																				2,538	3,046	0,273
-	Pekerjaan Finishing Lantai dan Dinding	Rp 327.062.256,40	2,276														0,325	0,325	0,325	0,325	0,325	0,325	0,325		
-	Pekerjaan Plafond	Rp 214.248.542,83	1,491														0,213	0,213	0,213	0,213	0,213	0,213	0,213		
-	Pekerjaan Partisi	Rp 86.853.869,22	0,604																			0,201	0,201	0,201	
-	Pekerjaan Pengecatan	Rp 273.557.563,78	1,904																	0,317	0,317	0,317	0,317	0,317	0,317
-	Pekerjaan Railing	Rp 35.711.624,25	0,249																			0,083	0,083	0,083	
-	Pekerjaan Fasade	Rp 354.616.087,19	2,468															0,617	0,617	0,617	0,617				
IV.	PEKERJAAN ELEKTRIKAL																								
-	Pekerjaan Panel	Rp 84.265.909,80	0,586																		0,195	0,195	0,195		
-	Pekerjaan Pengkabelan dan Distribusi Daya	Rp 166.368.293,95	1,158													0,193	0,193	0,193	0,193	0,193	0,193				
-	Pekerjaan Instalasi Lampu dan Kotak Kontak	Rp 143.370.452,84	0,998											0,055	0,055	0,055	0,055	0,055	0,055	0,222	0,266	0,177			
-	Pekerjaan Instalasi LAN	Rp 371.967.851,07	2,588														0,144	0,144	0,144	0,575	0,690	0,892			
-	Pekerjaan Instalasi CCTV	Rp 33.692.226,15	0,234														0,013	0,013	0,013	0,052	0,063	0,081			
-	Pekerjaan Instalasi Telepon	Rp 28.800.363,90	0,200														0,011	0,011	0,011	0,045	0,053	0,069			
-	Pekerjaan Instalasi Tata Suara	Rp 38.995.310,03	0,271														0,015	0,015	0,015	0,060	0,072	0,093			
-	Pekerjaan Projector	Rp 2.164.535,82	0,015															0,001	0,001	0,001	0,003	0,004	0,005		
-	Pekerjaan Kabel Tray	Rp 148.401.585,38	1,033												0,207	0,207	0,207	0,207	0,207						
-	Pekerjaan Fire Alarm	Rp 56.648.622,75	0,394													0,066	0,066	0,066	0,066	0,066	0,066				
-	Pekerjaan Proteksi Petir	Rp 43.765.246,88	0,305																	0,305					
-	Pekerjaan Dehumidifier	Rp 117.511.550,82	0,818																		0,409	0,409			
V	PEKERJAAN MEKANIKAL																								
-	Pekerjaan Instalasi Air Bersih	Rp 158.499.339,78	1,103											0,061	0,061	0,061	0,061	0,061	0,061	0,245	0,294	0,196			
-	Pekerjaan Instalasi Air Bekas	Rp 12.794.484,52	0,089											0,005	0,005	0,005	0,005	0,005	0,005	0,020	0,024	0,016			
-	Pekerjaan Instalasi Air Kotor	Rp 97.893.923,68	0,681											0,038	0,038	0,038	0,038	0,038	0,038	0,151	0,182	0,121			
-	Pekerjaan Instalasi Pipa Vent	Rp 4.467.015,19	0,031																			0,031			
-	Peralatan Saniter	Rp 56.295.388,58	0,392																					0,196	0,196
-	Pekerjaan Saluran Keliling	Rp 82.899.386,02	0,577																		0,192	0,192	0,192		
-	Pekerjaan Instalasi Air Hujan	Rp 128.768.913,13	0,896													0,128	0,128	0,128	0,128	0,128	0,128	0,128			
-	Pekerjaan Instalasi Tata Udara	Rp 1.029.063.034,39	7,161												0,036	0,036	0,036	0,036	0,036	0,036	1,432	2,148	2,148	1,217	
-	Pekerjaan Instalasi Exhaust Fan	Rp 22.472.680,29	0,156														0,009	0,009	0,009	0,035	0,042	0,054			
-	Pekerjaan Sistem Pemadam Kebakaran (Hydrant Sprinkler	Rp 381.536.207,53	2,655											0,193	0,193	0,193	0,193	0,193	0,193	0,386	0,463	0,510	0,137		
-	Pekerjaan lift / elevator	Rp 815.902.155,36	5,677													0,568	0,568	0,568	0,568	0,568	0,568	0,568	0,568	0,568	0,568
VIII	PEKERJAAN LANSEKAP																								
-	Pekerjaan Galian dan Urugan	Rp 5.116.688,29	0,036																		0,018	0,018			
-	Pekerjaan Perkerasan Jalan	Rp 30.537.367,99	0,212																				0,106	0,106	
		Rp 14.370.824.661,11	100,000																						
				0,161	0,203	0,203	0,706	1,275	1,275	1,275	2,685	3,793	4,206	4,551	4,818	5,942	6,996	8,394	8,804	9,706	11,718	8,246	7,882	5,779	1,381
			-	0,161	0,365	0,568	1,274	2,549	3,824	5,100	7,785	11,578	15,784	20,335	25,153	31,095	38,090	46,485	55,289	64,994	76,712	84,958	92,840	98,619	100,000

KETERANGAN

MASA PELAKSANAAN PEKERJAAN
150 HARI KALENDER
MINGGU KE-1 S/D MINGGU KE-21
147 HARI KALENDER
MINGGU KE-22
3 HARI KALENDER
MASA PEMELIHARAAN PEKERJAAN
180 HARI KALENDER

Mengetahui,	Menyetujui,	Yogyakarta, 13 Mei 2024
Universitas Negeri Yogyakarta	Konsultan Pengawas	Di buat Oleh,
Pejabat Pembuat Komitmen	**PT. HIRA PERMATA**	Penyedia Jasa
		PT. HERI JAYA PALUNG BUANA

Figure A-2. 1 Original Contractor S-Curve

Appendix 3 Weekly Report Cumulative Weekly Progress

Data source and validation note. The weekly cumulative figures tabulated in this appendix were extracted by the researcher from the project weekly reports of PT. Heri Jaya Palung Buana (2024), which are unpublished internal project documents covering reporting periods W1 to W28 and prepared contemporaneously during execution as part of the project's routine reporting to the supervising consultant. The figures are reproduced as recorded in the reports and have not been subjected to independent third-party validation, since no external audit of the weekly reports was available to the researcher. This reliance on the contractor's own progress records is acknowledged as a limitation of the study. The original reports remain with the contractor and are available for inspection upon legitimate request.

Table A-3. 1 Weekly Report Cumulative Progress Extract W1–W28

Week	Calendar Day	Period	Concrete Actual (%)	Concrete S-curve (%)	Structural Total Actual (%)	Structural Total S-curve Plan (%)	% of Final Structural	Key Note
1	7	3-9 Jun 2024	0,000%	0,000%	0,000%	0,000%	0,0%	Site prep, bored pile started
2	14	10-16 Jun 2024	0,000%	0,000%	0,000%	0,500%	0,0%	Bored pile ongoing
3	21	17-23 Jun 2024	0,000%	0,000%	0,160%	1,500%	0,4%	Bored pile, pile cap excavation
4	28	24-30 Jun 2024	0,000%	1,473%	1,873%	3,500%	4,4%	Pile cap, tie beam started
5	35	1-7 Jul 2024	1,489%	2,945%	5,561%	6,000%	13,1%	Concrete works started
6	42	8-14 Jul 2024	5,046%	4,418%	11,797%	9,000%	27,7%	Column Fl.1, beam Fl.1

Week	Calendar Day	Period	Concrete Actual (%)	Concrete S-curve (%)	Structural Total Actual (%)	Structural Total S-curve Plan (%)	% of Final Structural	Key Note
7	49	15-21 Jul 2024	6,699%	5,890%	13,452%	12,000%	31,6%	Beam, slab Fl.1
8	56	22-28 Jul 2024	7,991%	7,363%	14,745%	15,000%	34,7%	Slab Fl.1, column Fl.2
9	63	29 Jul-4 Aug 2024	10,188%	8,835%	17,045%	18,000%	40,1%	Fl.2 structure
10	70	5-11 Aug 2024	14,208%	10,308%	21,065%	21,000%	49,5%	Fl.2 complete, Fl.3 started
11	77	12-18 Aug 2024	17,716%	11,780%	24,573%	24,000%	57,8%	Fl.3 structure
12	84	19-25 Aug 2024	21,142%	13,253%	27,999%	27,000%	65,8%	Fl.3 complete, Fl.4 started
13	91	26 Aug-1 Sep 2024	23,682%	16,197%	30,539%	30,500%	71,8%	Fl.4 structure
14	98	2-8 Sep 2024	26,139%	19,141%	33,008%	34,000%	77,6%	Fl.4 complete, Fl.5 started
15	105	9-15 Sep 2024	27,777%	22,085%	34,656%	37,500%	81,5%	Fl.5 structure
16	112	16-22 Sep 2024	28,879%	25,029%	35,757%	41,000%	84,1%	Fl.5, rooftop slab
17	**119**	**23-29 Sep 2024**	**28,983%**	**28,000%**	**35,889%**	**44,500%**	**84,4%**	**Concrete 98% - S-CURVE TARGET END**
18	**126**	**30 Sep-6 Oct 2024**	**28,983%**	**28,983%**	**35,889%**	**46,297%**	**84,4%**	**CONCRETE STAGNANT, roof not yet started**
19	**133**	**7-13 Oct 2024**	**30,041%**	**28,983%**	**39,361%**	**46,297%**	**92,6%**	**Roofing STARTED (steel truss)**
20	140	14-20 Oct 2024	30,112%	28,983%	40,451%	46,297%	95,1%	Steel truss erection

Week	Calendar Day	Period	Concrete Actual (%)	Concrete S-curve (%)	Structural Total Actual (%)	Structural Total S-curve Plan (%)	% of Final Structural	Key Note
21	147	21-27 Oct 2024	30,140%	28,983%	41,374%	46,297%	97,3%	Steel truss ongoing
22	**154**	**28 Oct- 3 Nov 2024**	**30,140%**	**28,983%**	**42,527%**	**46,297%**	**100,0%**	**STRUCTURE COMPLETE (Day 154)**
23	161	4-10 Nov 2024	30,140%	28,983%	42,527%	46,297%	100,0%	Plateau - finishing only
24	168	11-17 Nov 2024	30,140%	28,983%	42,527%	46,297%	100,0%	Plateau
25	175	18-24 Nov 2024	30,140%	28,983%	42,527%	46,297%	100,0%	Plateau

Appendix 4 Complete Tekla Quantity Take-Off Report

Table A-4. 1 Concrete QTO per Pour Phase

CONCRETE VOLUME PER POUR PHASE								
Element	**Material**	**Profile**	**H (mm)**	**L (mm)**	**W (mm)**	**Qty (pcs)**	**Unit Vol (m^3)**	**Total Vol (m^3)**
POUR PHASE 1								
Bore Pile BP3	C28/35	D1000	1.000	3.000	1.000	12	2,40	28,80
Bore Pile BP1	C28/35	D1000	1.000	3.000	1.000	8	2,40	19,20
Bore Pile BP2	C28/35	D1000	1.000	3.000	1.000	10	2,40	24,00
Bore Pile BP3	C28/35	D1000	1.000	4.000	1.000	12	3,10	37,20
Bore Pile BP1	C28/35	D1000	1.000	4.000	1.000	8	3,10	24,80
Bore Pile BP2	C28/35	D1000	1.000	4.000	1.000	10	3,10	31,00
Subtotal — Pour Phase 1								**165,00**
POUR PHASE 2								
Bore Pile BP6	C28/35	D1000	1.000	3.000	1.000	1	2,40	2,40
Bore Pile BP4	C28/35	D1000	1.000	3.000	1.000	8	2,40	19,20
Bore Pile BP5	C28/35	D1000		3.000	1.000	1	2,40	2,40
Bore Pile BP5	C28/35	D1000	1.000	3.000	1.000	3	2,40	7,20
Bore Pile BP5a	C28/35	D1000	1.000	3.000	1.000	4	2,40	9,60
Bore Pile BP6	C28/35	D1000	1.000	4.000	1.000	1	3,10	3,10
Bore Pile BP4	C28/35	D1000	1.000	4.000	1.000	8	3,10	24,80
Bore Pile BP5	C28/35	D1000	1.000	4.000	1.000	4	3,10	12,40
Bore Pile BP5a	C28/35	D1000	1.000	4.000	1.000	4	3,10	12,40

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
Subtotal — Pour Phase 2								**93,50**
POUR PHASE 3								
Pilecap PC2	C28/35	RCL5100x10500-7700x6500	10.500	800	7.700	1	56,40	56,40
Pilecap PC4	C28/35	BL5100x800	800	10.500	5.100	1	42,80	42,80
Pilecap PC3	C28/35	BL7700x800	800	10.500	7.700	1	64,70	64,70
Subtotal — Pour Phase 3								**163,90**
POUR PHASE 4								
Pilecap PC5	C28/35	RCX2500x7700-4770x2500x3900	7.700	800	4.770	1	19,90	19,90
Pilecap PC6	C28/35	BL2500x800	800	2.500	2.500	1	5,00	5,00
Pilecap PC4	C28/35	BL5100x800	800	10.500	5.100	1	42,80	42,80
Pilecap PC5a	C28/35	RCX2500x7700-4770x2500x3900	7.700	800	4.770	1	19,90	19,90
Subtotal — Pour Phase 4								**87,60**
POUR PHASE 5								
1st Story Sloof S3	C25	250x400	400	3.450	250	1	0,30	0,30
1st Story Sloof S1	C25	400x600	600	7.150	400	3	1,70	5,10
1st Story Sloof S1	C25	400x600	600	7.250	400	1	1,70	1,70
1st Story Sloof S2	C25	300x500	500	3.375	300	2	0,50	1,00
1st Story Sloof S3	C25	250x400	400	7.750	250	1	0,80	0,80
1st Story Sloof S3	C25	250x400	400	3.600	250	2	0,40	0,80
1st Story Sloof S1	C25	400x600	600	7.300	400	4	1,80	7,20
1st Story Sloof S3	C25	250x400	400	7.600	250	1	0,80	0,80
1st Story SLAB A00	C25	150x1550	1.550	3.450	150	1	0,80	0,80
1st Story SLAB A00	C25	150x3450	3.450	6.350	150	1	3,30	3,30

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
1st Story SLAB A00	C25	150x3600	3.600	3.825	150	1	2,00	2,00
1st Story SLAB A00	C25	150x3600	3.600	3.675	150	3	2,00	6,00
1st Story SLAB A00	C25	150x4200	4.200	7.750	150	1	4,90	4,90
1st Story SLAB A00	C25	150x4200	4.200	7.600	150	1	4,80	4,80
Subtotal — Pour Phase 5								**39,50**
POUR PHASE 6								
1st Story Sloof S1	C25	400x600	600	7.300	400	4	1,80	7,20
1st Story Sloof S2	C25	400x600	600	7.150	400	1	1,70	1,70
1st Story Sloof S2	C25	300x500	500	3.300	300	1	0,50	0,50
1st Story Sloof S3	C25	250x400	400	7.600	250	1	0,80	0,80
1st story Sloof S2	C25	300x500	500	3.550	300	2	0,50	1,00
1st story Sloof S2	C25	300x500	500	2.425	300	2	0,40	0,80
1st Story SLAB A00	C25	150x7875	7.875	10.650	150	1	12,10	12,10
1st Story SLAB A00	C25	150x3600	3.600	5.627	150	1	3,00	3,00
1st Story SLAB A00	C25	150x4200	4.200	7.600	150	1	4,80	4,80
1st Story SLAB A00	C25	150x1672.9	1.673	3.600	150	1	0,90	0,90
Subtotal — Pour Phase 6								**32,80**
POUR PHASE 7								
1st story Column K2	C25	550x750	750	5.300	550	2	2,20	4,40
1st story Column K1	C25	700x850	850	5.300	700	6	3,20	19,20
Subtotal — Pour Phase 7								**23,60**
POUR PHASE 8								
1st story Column K4	C25	550x550	550	5.300	550	2	1,60	3,20

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
1st story Column K1	C25	700x850	850	5.300	700	3	3,20	9,60
1st story Column K3	C25	450x450	450	6.050	450	1	1,20	1,20
1st story Column K3	C25	450x450	450	5.300	450	2	1,10	2,20
1st story Column K1	C25	700x850	850	6.050	700	1	3,60	3,60
1st Story Column K6	C25	250x250	250	6.050	250	3	0,40	1,20
1st Story Column K6	C25	250x500	500	6.050	250	3	0,80	2,40
Subtotal — Pour Phase 8								**23,40**
POUR PHASE 9								
2nd story Beam B13	C25	250x750	750	3.975	250	1	0,70	0,70
2nd story Beam B13	C25	250x750	750	3.802	250	1	0,70	0,70
2nd story Beam B13	C25	250x750	750	4.223	250	1	0,80	0,80
2nd story Beam B13	C25	250x750	750	4.250	250	1	0,80	0,80
2nd story Beam B10	C25	300x600	600	2.375	300	1	0,40	0,40
2nd story Beam B10	C25	300x600	600	2.324	300	2	0,40	0,80
2nd story Beam B11	C25	350x500	500	2.324	350	3	0,40	1,20
2nd story Beam B17	C25	400x750	750	2.325	400	1	0,70	0,70
2nd story Beam B13	C25	250x750	750	3.950	250	1	0,70	0,70
2nd Story Beam B1	C25	350x700	700	7.300	350	4	1,80	7,20
2nd story Beam B5	C25	300x400	400	3.375	300	2	0,40	0,80
2nd story Beam B7	C25	250x400	400	3.625	250	2	0,40	0,80
2nd story Beam B7	C25	250x400	400	7.600	250	1	0,80	0,80
2nd story Beam B7	C25	250x400	400	7.750	250	1	0,80	0,80
2nd story Beam B3	C25	300x650	650	7.250	300	1	1,40	1,40

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
2nd story Beam B2	C25	400x700	700	7.150	400	3	2,00	6,00
2nd story Beam B6	C25	300x550	550	8.125	300	2	1,30	2,60
2nd story Beam B12	C25	250x450	450	1.105	250	1	0,10	0,10
2nd story Beam B12	C25	250x450	450	1.055	250	3	0,10	0,30
2nd story Beam B12	C25	250x450	450	1.080	250	2	0,10	0,20
2nd story Listplank L3	C25	120x700	700	40.455	120	1	3,40	3,40
2nd Story Slab A1	C25	120x850	850	3.625	120	1	0,40	0,40
2nd Story SLAB A1	C25	120x2372.4	2.372	3.825	120	1	1,10	1,10
2nd Story Slab A1	C25	120x2324.1	2.324	3.898	120	1	1,10	1,10
2nd Story Slab A1	C25	120x2324.2	2.324	3.427	120	1	1,00	1,00
2nd Story Slab A1	C25	120x2150	2.150	2.324	120	1	0,60	0,60
2nd Story Slab A1	C25	120x1100	1.100	2.324	120	1	0,30	0,30
2nd Story Slab A1	C25	120x2324.2	2.324	3.700	120	1	1,00	1,00
2nd Story Slab A1	C25	120x3650	3.650	3.950	120	2	1,70	3,40
2nd Story Slab A1	C25	120x3427.3	3.427	3.950	120	1	1,60	1,60
2nd Story Slab A1	C25	120x3950	3.950	4.023	120	1	1,90	1,90
2nd Story Slab A1	C25	120x1100	1.100	3.625	120	1	0,50	0,50
2nd Story Slab A1	C25	120x3925	3.925	4.023	120	1	1,90	1,90
2nd Story Slab A1	C25	120x3427.3	3.427	3.925	120	1	1,60	1,60
2nd Story Slab A1	C25	120x3650	3.650	3.925	120	2	1,70	3,40
2nd Story Slab A1	C25	120x1080	1.080	3.750	120	2	0,50	1,00
2nd Story Slab A1	C25	120x1080	1.080	3.527	120	1	0,50	0,50
2nd Story Slab A1	C25	120x1080	1.080	3.973	120	1	0,50	0,50

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
2nd Story Slab A1	C25	120x1330	1.330	3.800	120	1	0,60	0,60
Subtotal — Pour Phase 9								**53,60**
POUR PHASE 10								
2nd story Beam B13	C25	250x750	750	2.100	250	1	0,40	0,40
2nd story Beam B13	C25	250x750	750	5.975	250	1	1,10	1,10
2nd story Beam B13	C25	250x750	750	3.950	250	1	0,70	0,70
2nd story Beam B13	C25	250x750	750	4.400	250	1	0,80	0,80
2nd story Listplank L3	C25	120x700	700	3.930	120	1	0,30	0,30
2nd story Beam B12	C25	250x450	450	1.255	250	2	0,10	0,20
2nd story Beam B10	C25	300x600	600	2.324	300	2	0,40	0,80
2nd story Beam B11	C25	350x500	500	2.574	350	1	0,50	0,50
2nd story Beam B11	C25	350x500	500	2.324	350	1	0,40	0,40
2nd story Beam B4	C25	350x700	700	7.300	350	1	1,80	1,80
2nd Story Beam B1	C25	350x700	700	7.300	350	3	1,80	5,40
2nd Story Beam B5	C25	300x400	400	2.425	300	2	0,30	0,60
2nd story Beam B12	C25	250x450	450	1.055	250	5	0,10	0,50
2nd story Beam B5	C25	300x400	400	3.550	300	2	0,40	0,80
2nd story Beam B7	C25	250x400	400	3.500	250	1	0,30	0,30
2nd story Beam B7	C25	250x400	400	3.300	250	1	0,30	0,30
2nd story Beam B6	C25	300x550	550	7.600	300	1	1,30	1,30
2nd story Beam B7	C25	250x400	400	7.600	250	1	0,80	0,80
2nd story Beam B5	C25	300x400	400	2.575	300	1	0,30	0,30
2nd story Beam B2	C25	400x700	700	7.150	400	2	2,00	4,00

2nd story Beam B6	C25	300x550	550	7.875	300	1	1,30	1,30
2nd story Beam B14	C25	250x400	400	2.664	250	1	0,30	0,30
2nd story Beam B14	C25	250x400	400	548	250	2	0,10	0,20
2nd story Beam B7	C25	250x400	400	4.075	250	2	0,40	0,80
2nd story Listplank L3	C25	120x700	700	11.200	120	1	0,90	0,90
2nd story Beam B12	C25	250x450	450	1.080	250	2	0,10	0,20
1st story Beam B14	C25	250x400	400	2.300	250	1	0,20	0,20
1st story Beam B14	C25	250x400	400	1.775	250	2	0,20	0,40
1st story Beam B14	C25	250x400	400	2.250	250	2	0,20	0,40
1st story Beam B14	C25	250x400	400	1.802	250	2	0,20	0,40
1st Story Beam B9	C25	300x450	450	3.300	300	1	0,40	0,40
2nd Story Slab A1	C25	120x2572.4	2.572	3.650	120	1	1,10	1,10
2nd Story Slab A1	C25	120x2572.6	2.573	3.900	120	1	1,20	1,20
2nd Story Slab A1	C25	120x1330.1	1.330	2.525	120	1	0,40	0,40
2nd Story Slab A1	C25	120x1155	1.155	1.355	120	2	0,20	0,40
2nd Story Slab A1	C25	120x1130.1	1.130	3.750	120	1	0,50	0,50
2nd Story Slab A1	C25	120x2650	2.650	3.700	120	2	1,20	2,40
2nd Story Slab A1	C25	120x700	700	2.202	120	1	0,20	0,20
2nd Story Slab A1	C25	120x1198.2	1.198	3.700	120	1	0,50	0,50
2nd Story Slab A1	C25	120x3650	3.650	3.700	120	1	1,60	1,60
2nd Story Slab A1	C25	120x3648.3	3.648	3.925	120	1	1,50	1,50
2nd Story Slab A1	C25	120x3650	3.650	3.925	120	1	1,70	1,70
2nd Story Slab A1	C25	120x1130	1.130	3.750	120	1	0,50	0,50
2nd Story Slab A1	C25	120x1330	1.330	2.750	120	1	0,40	0,40
2nd Story Slab A1	C25	120x1080	1.080	3.750	120	4	0,50	2,00

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
2nd Story Slab A1	C25	120x2324.2	2.324	5.651	120	1	1,60	1,60
2nd Story Slab A1	C25	120x1699.7	1.700	2.324	120	1	0,50	0,50
2nd Story Slab A1	C25	120x1847.9	1.848	3.750	120	1	0,80	0,80
2nd Story Slab A1	C25	120x1849.7	1.850	4.075	120	1	0,90	0,90
2nd Story Slab A1	C25	120x2584.9	2.585	4.075	120	1	1,30	1,30
2nd Story Slab A1	C25	120x2665.3	2.665	4.075	120	1	1,30	1,30
Subtotal — Pour Phase 10								**47,60**
POUR PHASE 11								
2nd story Column K2	C25	550x750	750	4.200	550	2	1,70	3,40
2nd story Column K1a	C25	700x850	850	4.200	700	6	2,50	15,00
Subtotal — Pour Phase 11								**18,40**
POUR PHASE 12								
2nd story Column K4	C25	550x550	550	4.200	550	2	1,30	2,60
2nd story Column K1a	C25	700x850	850	4.200	700	4	2,50	10,00
2nd Story Column K6	C25	250x500	500	4.200	250	2	0,50	1,00
2nd Story Column K6	C25	250x250	250	4.200	250	3	0,30	0,90
2nd Story Column Column K6	C25	250x500	500	4.200	250	1	0,50	0,50
Subtotal — Pour Phase 12								**15,00**
POUR PHASE 13								
3rd story Beam B13	C25	250x750	750	3.950	250	1	0,70	0,70
3rd story Beam B13	C25	250x750	750	3.975	250	1	0,70	0,70
3rd story Beam B13	C25	250x750	750	3.802	250	1	0,70	0,70
3rd story Beam B13	C25	250x750	750	4.223	250	1	0,80	0,80

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
3rd story Beam B13	C25	250x750	750	4.250	250	1	0,80	0,80
3rd story Beam B10	C25	300x600	600	2.375	300	1	0,40	0,40
3rd story Beam B10	C25	300x600	600	2.324	300	2	0,40	0,80
3rd story Beam B11	C25	350x500	500	2.324	350	3	0,40	1,20
3rd story Beam B17	C25	400x750	750	2.325	400	1	0,70	0,70
3rd story Beam B2	C25	400x700	700	7.300	400	1	2,00	2,00
3rd story Beam B1	C25	350x700	700	7.300	350	3	1,80	5,40
3rd story Beam B5	C25	300x400	400	3.375	300	2	0,40	0,80
3rd story Beam B7a	C25	250x400	400	3.625	250	2	0,40	0,80
3rd story Beam B15	C25	300x450	450	7.675	300	1	1,00	1,00
3rd story Beam B15	C25	300x450	450	7.550	300	1	1,00	1,00
3rd story Beam B8	C25	450x750	750	7.150	450	3	2,40	7,20
3rd story Beam B16	C25	350x600	600	8.075	350	1	1,70	1,70
3rd story Beam B16	C25	350x600	600	8.127	350	1	1,70	1,70
3rd story Beam B3	C25	300x650	650	7.250	300	1	1,40	1,40
3rd story Beam B12	C25	250x450	450	1.005	250	1	0,10	0,10
3rd story Beam B12	C25	250x450	450	955	250	3	0,10	0,30
3rd story Beam B12	C25	250x450	450	980	250	2	0,10	0,20
3rd story Beam L2	C25	120x500	500	25.275	120	1	1,50	1,50
3rd Story SLAB A1	C25	120x851.8	852	3.625	120	1	0,40	0,40
3rd Story SLAB A1	C25	120x2372.4	2.372	3.825	120	1	1,10	1,10
3rd Story SLAB A4	C25	130x2321.6	2.322	3.873	130	1	1,20	1,20
3rd Story SLAB A4	C25	130x2321.6	2.322	3.427	130	1	1,00	1,00

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
3rd Story SLAB A4	C25	130x2150	2.150	2.322	130	1	0,60	0,60
3rd Story SLAB A4	C25	130x1100	1.100	2.322	130	1	0,30	0,30
3rd Story SLAB A4	C25	130x2321.6	2.322	3.700	130	1	1,10	1,10
3rd Story SLAB A4	C25	130x3600	3.600	3.900	130	2	1,80	3,60
3rd Story SLAB A4	C25	130x3352.3	3.352	3.952	130	1	1,70	1,70
3rd Story SLAB A4	C25	130x3951.8	3.952	3.973	130	1	2,00	2,00
3rd Story SLAB A1	C25	120x1098.2	1.098	3.625	120	1	0,50	0,50
3rd Story SLAB A4	C25	130x3875	3.875	3.973	130	1	2,00	2,00
3rd Story SLAB A4	C25	130x3352.3	3.352	3.875	130	1	1,70	1,70
3rd Story SLAB A4	C25	130x3600	3.600	3.875	130	2	1,80	3,60
3rd Story SLAB A1	C25	120x980.1	980	3.753	120	1	0,40	0,40
3rd Story SLAB A1	C25	120x970.1	970	3.750	120	1	0,40	0,40
3rd Story SLAB A1	C25	120x980.1	980	3.530	120	1	0,40	0,40
3rd Story SLAB A1	C25	120x979.2	979	4.150	120	1	0,50	0,50
3rd Story SLAB A1	C25	120x1231.8	1.232	3.725	120	1	0,50	0,50
Subtotal — Pour Phase 13								**54,90**
POUR PHASE 14								
3rd story Beam B13	C25	250x750	750	4.400	250	1	0,80	0,80
3rd story Beam B13	C25	250x750	750	3.950	250	1	0,70	0,70
3rd story Beam B13	C25	250x750	750	5.975	250	1	1,10	1,10
3rd story Beam B13	C25	250x750	750	2.100	250	1	0,40	0,40
3rd story Beam B16	C25	350x600	600	3.300	350	1	0,70	0,70
3rd story Beam B11	C25	350x500	500	2.324	350	1	0,40	0,40

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
3rd story Beam B4	C25	350x700	700	7.300	350	1	1,80	1,80
3rd story Beam B10	C25	300x600	600	2.324	300	2	0,40	0,80
3rd story Beam B11	C25	350x500	500	2.574	350	1	0,50	0,50
3rd story Beam B12	C25	250x450	450	1.031	250	1	0,10	0,10
3rd story Beam B12	C25	250x450	450	1.181	250	1	0,10	0,10
3rd story Beam B7	C25	250x400	400	7.600	250	1	0,80	0,80
3rd story Beam B16	C25	350x600	600	7.575	350	1	1,60	1,60
3rd story Beam B15	C25	300x450	450	4.100	300	2	0,60	1,20
3rd story Beam B2	C25	400x700	700	7.150	400	2	2,00	4,00
3rd story Beam B14	C25	250x400	400	548	250	2	0,10	0,20
3rd story Beam B14	C25	250x400	400	2.664	250	1	0,30	0,30
3rd story Beam B6	C25	300x550	550	7.875	300	1	1,30	1,30
3rd story Beam B12	C25	250x450	450	1.030	250	1	0,10	0,10
3rd story Beam L2	C25	120x500	500	9.304	120	1	0,60	0,60
3rd story Beam B12	C25	250x450	450	955	250	2	0,10	0,20
3rd story Beam B12	C25	250x450	450	980	250	2	0,10	0,20
3rd story Beam L2	C25	120x500	500	9.850	120	1	0,60	0,60
3rd story Beam B1	C25	350x700	700	7.300	350	3	1,80	5,40
3rd story Beam B7	C25	250x400	400	3.500	250	1	0,30	0,30
3rd story Beam B7	C25	250x400	400	1.775	250	1	0,20	0,20
2nd story Beam B14	C25	250x400	400	2.250	250	2	0,20	0,40
2nd story Beam B14	C25	250x400	400	1.775	250	2	0,20	0,40
2nd story Beam B14	C25	250x400	400	2.300	250	1	0,20	0,20

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
2nd story Beam B14	C25	250x400	400	1.802	250	1	0,20	0,20
3rd Story SLAB A1	C25	120x2571.5	2.572	3.900	120	1	1,20	1,20
3rd Story SLAB A1	C25	120x2571.5	2.572	3.651	120	1	1,10	1,10
3rd Story Slab A1	C25	120x2324.2	2.324	5.651	120	1	1,60	1,60
3rd Story SLAB A4	C25	130x1699.7	1.700	2.322	130	1	0,50	0,50
3rd Story SLAB A4	C25	130x1722.9	1.723	3.700	130	1	0,80	0,80
3rd Story Slab A1	C25	120x3650	3.650	3.700	120	1	1,60	1,60
3rd Story SLAB A1	C25	120x1198.2	1.198	3.700	120	1	0,50	0,50
3rd Story SLAB A1	C25	120x698.2	698	2.202	120	1	0,20	0,20
3rd Story SLAB A1	C25	120x1181.4	1.181	3.500	120	1	0,50	0,50
3rd Story SLAB A1	C25	120x1180.9	1.181	3.750	120	1	0,50	0,50
3rd Story SLAB A1	C25	120x1205.4	1.205	1.304	120	1	0,20	0,20
3rd Story SLAB A1	C25	120x980.1	980	3.750	120	1	0,40	0,40
3rd Story Slab A1	C25	120x3650	3.650	3.925	120	1	1,70	1,70
3rd Story SLAB A1	C25	120x3648.3	3.648	3.925	120	1	1,50	1,50
3rd Story SLAB A1	C25	120x980.1	980	4.025	120	1	0,50	0,50
3rd Story SLAB A4	C25	130x2800	2.800	4.075	130	1	1,50	1,50
3rd Story SLAB A4	C25	130x2402.1	2.402	4.075	130	1	1,30	1,30
3rd Story SLAB A1	C25	120x980.1	980	4.625	120	1	0,50	0,50
3rd Story SLAB A4	C25	130x1772.9	1.773	4.075	130	1	0,90	0,90
Subtotal — Pour Phase 14								**42,60**
POUR PHASE 15								
3rd story Column K2	C25	550x750	750	4.200	550	2	1,70	3,40

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
3rd story Column K1a	C25	700x850	850	4.200	700	6	2,50	15,00
Subtotal — Pour Phase 15								**18,40**
POUR PHASE 16								
3rd story Column K1a	C25	700x850	850	4.200	700	4	2,50	10,00
3rd Story Column K6	C25	250x500	500	4.200	250	3	0,50	1,50
3rd Story Column K6	C25	250x250	250	4.200	250	3	0,30	0,90
3rd story Column K4	C25	550x550	550	4.200	550	2	1,30	2,60
Subtotal — Pour Phase 16								**15,00**
POUR PHASE 17								
4th Story Beam B13	C25	250x750	750	4.250	250	1	0,80	0,80
4th Story Beam B13	C25	250x750	750	4.223	250	1	0,80	0,80
4th Story Beam B13	C25	250x750	750	3.802	250	1	0,70	0,70
4th Story Beam B13	C25	250x750	750	3.975	250	1	0,70	0,70
4th Story Beam B13	C25	250x750	750	3.950	250	1	0,70	0,70
4th Story Beam B10	C25	300x600	600	2.324	300	2	0,40	0,80
4th Story Beam B11	C25	350x500	500	2.324	350	2	0,40	0,80
4th story Beam B11	C25	350x500	500	2.324	350	1	0,40	0,40
4th story Beam B17	C25	400x750	750	2.325	400	1	0,70	0,70
4th Story Beam B10	C25	300x600	600	2.373	300	1	0,40	0,40
4th Story Beam B7a	C25	250x400	400	3.625	250	2	0,40	0,80
4th Story Beam B5	C25	300x400	400	3.375	300	2	0,40	0,80
4th Story Beam B1	C25	350x700	700	7.300	350	3	1,80	5,40
4th Story Beam B2	C25	400x700	700	7.300	400	1	2,00	2,00

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
4th Story Beam B15	C25	300x450	450	7.550	300	1	1,00	1,00
4th Story Beam B15	C25	300x450	450	7.675	300	1	1,00	1,00
4th Story Beam B3	C25	300x650	650	7.250	300	1	1,40	1,40
4th Story Beam B8	C25	450x750	750	7.150	450	3	2,40	7,20
4th Story Beam B16	C25	350x600	600	8.127	350	1	1,70	1,70
4th Story Beam B16	C25	350x600	600	8.075	350	1	1,70	1,70
4th Story Beam B12	C25	250x450	450	1.005	250	1	0,10	0,10
4th Story Beam B12	C25	250x450	450	955	250	3	0,10	0,30
4th Story Beam B12	C25	250x450	450	980	250	2	0,10	0,20
4th Story Beam L2	C25	120x500	500	25.275	120	1	1,50	1,50
4th Story SLAB A4	C25	130x2321.6	2.322	3.700	130	1	1,10	1,10
4th Story SLAB A4	C25	130x1100	1.100	2.322	130	1	0,30	0,30
4th Story SLAB A4	C25	130x2150	2.150	2.322	130	1	0,60	0,60
4th Story SLAB A4	C25	130x2321.6	2.322	3.427	130	1	1,00	1,00
4th Story SLAB A4	C25	130x2321.6	2.322	3.873	130	1	1,20	1,20
4th Story SLAB A1	C25	120x2372.4	2.372	3.825	120	1	1,10	1,10
4th Story SLAB A1	C25	120x851.8	852	3.625	120	1	0,40	0,40
4th Story Slab A1	C25	120x3950	3.950	4.023	120	1	1,90	1,90
4th Story Slab A1	C25	120x3427.3	3.427	3.950	120	1	1,60	1,60
4th Story SLAB A4	C25	130x3600	3.600	3.900	130	2	1,80	3,60
4th Story Slab A1	C25	120x3650	3.650	3.925	120	2	1,70	3,40
4th Story SLAB A1	C25	120x980.1	980	3.753	120	1	0,40	0,40
4th Story SLAB A1	C25	120x970.1	970	3.750	120	1	0,40	0,40

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
4th Story Slab A1	C25	120x3427.3	3.427	3.925	120	1	1,60	1,60
4th Story SLAB A1	C25	120x980.1	980	3.530	120	1	0,40	0,40
4th Story Slab A1	C25	120x3925	3.925	4.023	120	1	1,90	1,90
4th Story SLAB A1	C25	120x979.2	979	4.150	120	1	0,50	0,50
4th Story SLAB A1	C25	120x1098.2	1.098	3.625	120	1	0,50	0,50
4th Story SLAB A1	C25	120x1231.8	1.232	3.725	120	1	0,50	0,50
Subtotal — Pour Phase 17								**54,30**
POUR PHASE 18								
4th Story Beam B13	C25	250x750	750	4.400	250	1	0,80	0,80
4th Story Beam B13	C25	250x750	750	9.925	250	1	1,90	1,90
4th Story Beam B13	C25	250x750	750	2.100	250	1	0,40	0,40
4th Story Beam B11	C25	350x500	500	2.324	350	1	0,40	0,40
4th Story Beam B10	C25	300x600	600	2.324	300	2	0,40	0,80
4th Story Beam B11	C25	350x500	500	2.574	350	1	0,50	0,50
4th Story Beam B4	C25	350x700	700	7.300	350	1	1,80	1,80
4th Story Beam B12	C25	250x450	450	1.031	250	1	0,10	0,10
4th Story Beam B16	C25	350x600	600	7.575	350	1	1,60	1,60
4th Story Beam B7	C25	250x400	400	7.600	250	1	0,80	0,80
4th Story Beam B12	C25	250x450	450	1.181	250	1	0,10	0,10
4th Story Beam B6	C25	300x550	550	7.875	300	1	1,30	1,30
4th Story Beam B14	C25	250x400	400	548	250	2	0,10	0,20
4th Story Beam B14	C25	250x400	400	2.664	250	1	0,30	0,30
4th Story Beam B2	C25	400x700	700	7.150	400	2	2,00	4,00

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
4th Story Beam B15	C25	300x450	450	4.100	300	2	0,60	1,20
4th Story Beam B1	C25	350x700	700	7.300	350	3	1,80	5,40
4th Story Beam B12	C25	250x450	450	1.030	250	1	0,10	0,10
4th Story Beam L2	C25	120x500	500	9.850	120	1	0,60	0,60
4th Story Beam L2	C25	120x500	500	9.304	120	1	0,60	0,60
4th Story Beam B12	C25	250x450	450	955	250	2	0,10	0,20
4th Story Beam B12	C25	250x450	450	980	250	2	0,10	0,20
4th Story Beam B16	C25	350x600	600	3.300	350	1	0,70	0,70
4th Story Beam B7	C25	250x400	400	3.500	250	1	0,30	0,30
4th Story Beam B7	C25	250x400	400	1.775	250	1	0,20	0,20
3rd story Beam B14	C25	250x400	400	1.802	250	2	0,20	0,40
3rd story Beam B14	C25	250x400	400	2.300	250	1	0,20	0,20
3rd story Beam B14	C25	250x400	400	1.775	250	2	0,20	0,40
3rd story Beam B14	C25	250x400	400	2.250	250	2	0,20	0,40
3rd story Beam B9	C25	300x450	450	3.300	300	1	0,40	0,40
4th Story SLAB A1	C25	120x2571.5	2.572	3.900	120	1	1,20	1,20
4th Story SLAB A1	C25	120x2571.5	2.572	3.651	120	1	1,10	1,10
4th Story Slab A1	C25	120x2324.2	2.324	5.651	120	1	1,60	1,60
4th Story SLAB A4	C25	130x1699.7	1.700	2.322	130	1	0,50	0,50
4th Story SLAB A4	C25	130x1722.9	1.723	3.700	130	1	0,80	0,80
4th Story Slab A1	C25	120x3650	3.650	3.700	120	1	1,60	1,60
4th Story Slab A1	C25	120x1198.2	1.198	3.700	120	1	0,50	0,50
4th Story SLAB A1	C25	120x1181.4	1.181	3.500	120	1	0,50	0,50

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
4th Story SLAB A1	C25	120x1180.9	1.181	3.750	120	1	0,50	0,50
4th Story SLAB A1	C25	120x1205.4	1.205	1.304	120	1	0,20	0,20
4th Story SLAB A1	C25	120x980.1	980	3.782	120	1	0,40	0,40
4th Story Slab A1	C25	120x3650	3.650	3.925	120	1	1,70	1,70
4th Story Slab A1	C25	120x3648.3	3.648	3.925	120	1	1,50	1,50
4th Story SLAB A1	C25	120x980.1	980	4.025	120	1	0,50	0,50
4th Story SLAB A4	C25	130x2800	2.800	4.075	130	1	1,50	1,50
4th Story SLAB A4	C25	130x2402.1	2.402	4.075	130	1	1,30	1,30
4th Story SLAB A4	C25	130x1772.9	1.773	4.075	130	1	0,90	0,90
4th Story SLAB A1	C25	120x980.1	980	4.625	120	1	0,50	0,50
Subtotal — Pour Phase 18								**43,10**
POUR PHASE 19								
4th story Column K2	C25	550x750	750	4.200	550	2	1,70	3,40
4th story Column K5	C25	600x750	750	4.250	600	6	1,90	11,40
Subtotal — Pour Phase 19								**14,80**
POUR PHASE 20								
4th Story Column K6	C25	250x250	250	4.200	250	3	0,30	0,90
4th Story Column K6	C25	250x500	500	4.200	250	3	0,50	1,50
4th story Column K1a	C25	700x850	850	4.200	700	3	2,50	7,50
4th story Column K5	C25	600x750	750	4.250	600	1	1,90	1,90
Subtotal — Pour Phase 20								**11,80**
POUR PHASE 21								
5th Story Beam B13	C25	250x750	750	4.000	250	4	0,70	2,80

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
5th Story Beam B13	C25	250x750	750	4.275	250	1	0,80	0,80
5th Story Beam B11	C25	300x600	600	2.375	300	1	0,40	0,40
5th Story Beam B10	C25	300x600	600	2.375	300	3	0,40	1,20
5th Story Beam B11	C25	300x600	600	2.376	300	2	0,40	0,80
5th Story Beam B1a	C25	350x700	700	7.400	350	3	1,80	5,40
5th Story Beam B1a	C25	350x700	700	7.399	350	1	1,80	1,80
5th Story Beam B5	C25	300x400	400	3.425	300	2	0,40	0,80
5th Story Beam B3	C25	300x650	650	7.250	300	1	1,40	1,40
5th Story Beam B12	C25	250x450	450	1.004	250	1	0,10	0,10
5th Story Beam B12	C25	250x450	450	1.005	250	3	0,10	0,30
5th Story Beam B12	C25	250x450	450	1.204	250	2	0,10	0,20
5th Story Lisplank L2	C25	120x500	500	4.575	120	1	0,30	0,30
5th Story Lisplank L2	C25	120x500	500	20.100	120	1	1,20	1,20
5th Story SLAB A2	C40	120x2375	2.375	3.700	120	4	1,10	4,40
5th Story SLAB A2	C40	120x2375	2.375	3.825	120	1	1,10	1,10
5th Story SLAB A2	C40	120x1204.1	1.204	4.075	120	1	0,60	0,60
5th Story SLAB A2	C40	120x1005	1.005	3.663	120	1	0,40	0,40
5th Story SLAB A2	C40	120x1004.8	1.005	3.663	120	1	0,40	0,40
5th Story SLAB A2	C40	120x1004.7	1.005	3.750	120	1	0,50	0,50
5th Story SLAB A2	C40	120x1004.4	1.004	3.750	120	1	0,50	0,50
Subtotal — Pour Phase 21								**25,40**
POUR PHASE 22								
5th Story Beam B7A	C25	250x450	450	2.251	250	1	0,30	0,30

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
5th Story Beam B7A	C25	250x450	450	1.775	250	1	0,20	0,20
5th Story Beam B7A	C25	250x450	450	1.802	250	1	0,20	0,20
5th Story Beam B7A	C25	250x450	450	2.300	250	1	0,30	0,30
5th Story Beam B7	C25	250x400	400	1.775	250	1	0,20	0,20
5th Story Beam B7	C25	250x400	400	2.300	250	1	0,20	0,20
5th Story Beam B1a	C25	350x700	700	7.350	350	2	1,80	3,60
5th Story Beam B11	C25	300x600	600	2.376	300	1	0,40	0,40
5th Story Beam B13	C25	250x750	750	4.000	250	3	0,70	2,10
5th Story Beam B10	C25	300x600	600	2.375	300	2	0,40	0,80
5th Story Beam B13	C25	250x750	750	4.150	250	1	0,80	0,80
5th Story Beam B11	C25	350x500	500	2.575	350	1	0,50	0,50
5th Story Beam B1a	C25	350x700	700	7.300	350	1	1,80	1,80
5th Story Beam B12	C25	250x450	450	1.230	250	2	0,10	0,20
5th Story Beam B7	C25	250x400	400	1.198	250	1	0,10	0,10
5th Story Beam B7	C25	250x400	400	700	250	1	0,10	0,10
5th Story Beam B12	C25	250x450	450	1.380	250	1	0,20	0,20
5th Story Beam B7	C25	250x400	400	3.650	250	1	0,40	0,40
5th Story Beam B7	C25	250x400	400	3.750	250	1	0,40	0,40
5th Story Beam B2	C25	400x700	700	7.199	400	1	2,00	2,00
5th Story Beam B6	C25	300x550	550	7.850	300	1	1,30	1,30
5th Story Beam B2	C25	400x700	700	7.150	400	1	2,00	2,00
5th Story Beam B1a	C25	350x700	700	7.400	350	1	1,80	1,80
5th Story Beam B12	C25	250x450	450	1.205	250	3	0,10	0,30

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
5th Story Beam B12	C25	250x450	450	1.155	250	1	0,10	0,10
5th Story Lisplank L2	C25	120x500	500	9.705	120	1	0,60	0,60
5th Story Lisplank L2	C25	120x500	500	13.300	120	1	0,80	0,80
4th Story Beam B14	C25	250x400	400	2.300	250	1	0,20	0,20
4th Story Beam B14	C25	250x400	400	1.802	250	2	0,20	0,40
4th Story Beam B14	C25	250x400	400	2.250	250	2	0,20	0,40
4th Story Beam B14	C25	250x400	400	1.775	250	2	0,20	0,40
5th Story Beam SLAB A3	C25	150x2276.8	2.277	2.798	150	1	0,90	0,90
5th Story SLAB A2	C40	120x2375	2.375	3.700	120	2	1,10	2,20
5th Story SLAB A2	C40	120x2575	2.575	3.675	120	2	1,10	2,20
5th Story SLAB A3	C40	150x1198.2	1.198	2.750	150	1	0,50	0,50
5th Story SLAB A3	C40	150x700	700	1.198	150	1	0,10	0,10
5th Story SLAB A3	C40	150x700	700	2.202	150	1	0,20	0,20
5th Story SLAB A2	C40	120x1380	1.380	3.750	120	1	0,60	0,60
5th Story SLAB A3	C40	150x3650	3.650	3.900	150	1	2,10	2,10
5th Story SLAB A2	C40	120x1380	1.380	3.749	120	1	0,60	0,60
5th Story SLAB A2	C40	120x1455	1.455	1.456	120	1	0,20	0,20
5th Story SLAB A2	C40	120x1205	1.205	3.750	120	2	0,50	1,00
5th Story SLAB A2	C40	120x1205	1.205	3.225	120	1	0,50	0,50
5th Story SLAB A2	C40	120x1004.2	1.004	4.275	120	1	0,50	0,50
Subtotal — Pour Phase 22								**34,70**
POUR PHASE 23								
5th story Column K5	C25	600x750	750	2.950	600	6	1,30	7,80

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
5th story Column K2	C25	550x750	750	2.950	550	2	1,20	2,40
Subtotal — Pour Phase 23								**10,20**
POUR PHASE 24								
5th Story Column K6	C25	250x250	250	2.950	250	3	0,20	0,60
5th Story Column K6	C25	250x500	500	2.950	250	3	0,40	1,20
5th story Column K1a	C25	700x850	850	2.950	700	3	1,80	5,40
5th story Column K5	C25	600x750	750	2.950	600	1	1,30	1,30
Subtotal — Pour Phase 24								**8,50**
POUR PHASE 25								
Roof Beam B12	C25	250x450	450	1.706	250	4	0,20	0,80
Roof Beam B12	C25	250x450	450	1.456	250	1	0,20	0,20
Roof Beam B12	C25	250x450	450	1.455	250	1	0,20	0,20
Roof Beam B12	C25	250x450	450	1.530	250	2	0,20	0,40
Roof Beam B12	C25	250x450	450	1.705	250	1	0,20	0,20
Roof Beam B1a	C25	350x700	700	7.300	350	1	1,70	1,70
Roof Beam B14	C25	250x400	400	2.300	250	1	0,20	0,20
Roof Beam B14	C25	250x400	400	1.775	250	1	0,20	0,20
Roof Beam B1a	C25	350x700	700	7.151	350	1	1,70	1,70
Roof Beam B1a	C25	350x700	700	7.350	350	2	1,80	3,60
Roof Listplank L1	C25	120x500	500	12.000	120	1	0,70	0,70
Roof Beam B12	C25	250x450	450	1.454	250	1	0,20	0,20
Roof Beam B12	C25	250x450	450	1.704	250	4	0,20	0,80
Roof Beam B12	C25	250x450	450	1.505	250	7	0,20	1,40

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
Roof Beam B1a	C25	350x700	700	7.400	350	5	1,80	9,00
Roof Listplank L1	C25	120x500	500	39.880	120	2	2,40	4,80
Roof Beam B1a	C25	350x700	700	3.425	350	2	0,80	1,60
Roof Beam B12	C25	250x450	450	1.605	250	2	0,20	0,40
Roof Beam B12	C25	250x450	450	1.680	250	1	0,20	0,20
Roof Beam B1a	C25	350x700	700	7.249	350	1	1,80	1,80
Roof Listplank L1	C25	120x500	500	11.760	120	1	0,70	0,70
Roof Beam B12	C25	250x450	450	1.504	250	2	0,20	0,40
Roof SLAB A2	C25	120x1705	1.705	3.750	120	5	0,80	4,00
Roof SLAB A2	C25	120x1704.4	1.704	3.750	120	2	0,80	1,60
Roof SLAB A2	C25	120x1704.2	1.704	3.750	120	4	0,80	3,20
Roof SLAB A2	C25	120x1755	1.755	1.755	120	1	0,40	0,40
Roof SLAB A2	C25	120x1755	1.755	1.756	120	2	0,40	0,80
Roof SLAB A3	C25	250x2226.8	2.227	2.750	250	1	1,50	1,50
Roof SLAB A2	C25	120x1755.8	1.756	3.750	120	1	0,80	0,80
Roof SLAB A2	C25	120x1717.4	1.717	3.753	120	1	0,80	0,80
Roof SLAB A2	C25	120x1710.7	1.711	3.775	120	1	0,80	0,80
Roof SLAB A2	C25	120x1716.7	1.717	3.725	120	1	0,80	0,80
Roof SLAB A2	C25	120x1705.8	1.706	3.750	120	1	0,80	0,80
Roof SLAB A2	C25	120x1717.5	1.718	3.750	120	2	0,80	1,60
Roof SLAB A2	C25	120x1711.5	1.712	3.750	120	1	0,80	0,80
Roof SLAB A2	C25	120x1716.7	1.717	3.750	120	1	0,80	0,80
Roof SLAB A2	C25	120x1680	1.680	3.750	120	2	0,80	1,60

Element	Material	Profile	H (mm)	L (mm)	W (mm)	Qty (pcs)	Unit Vol (m^3)	Total Vol (m^3)
Roof SLAB A2	C25	120x1754.2	1.754	1.755	120	1	0,40	0,40
Subtotal — Pour Phase 25								**51,90**
GRAND TOTAL — CONCRETE VOLUME (m^3)								**1148,50**

Table A-4. 2 Rebar QTO per Pour Phase

REINFORCEMENT BAR (REBAR) PER POUR PHASE				
Pour Phase	**Element**	**Grade**	**Bar Sizes**	**Rebar Weight (ton)**
POUR PHASE 1				
1	Bore Pile	BjTS-420	S13, S16	16,190
Subtotal — Pour Phase 1				**16,190**
POUR PHASE 2				
2	Bore Pile	BjTS-420	S13, S16	9,170
Subtotal — Pour Phase 2				**9,170**
POUR PHASE 3				
3	Pile Cap	BjTS-420	S19, S22, S16	12,735
Subtotal — Pour Phase 3				**12,735**
POUR PHASE 4				
4	Pile Cap	BjTS-420	S19, S22, S16	6,774
Subtotal — Pour Phase 4				**6,774**
POUR PHASE 5				

Pour Phase	Element	Grade	Bar Sizes	Rebar Weight (ton)
5	Ground Beam	BjTS-420	S10, S22, S19	3,533
5	Slab	BjTS-420	S10, S22, S19	3,144
Subtotal — Pour Phase 5				**6,677**
POUR PHASE 6				
6	Ground Beam	BjTS-420	S10, S22, S19	2,373
6	Slab	BjTS-420	S10, S22, S19	3,013
Subtotal — Pour Phase 6				**5,386**
POUR PHASE 7				
7	Column	BjTS-420	S13, S25	8,642
Subtotal — Pour Phase 7				**8,642**
POUR PHASE 8				
8	Column	BjTS-420	S10, S16, S13, S25	7,503
Subtotal — Pour Phase 8				**7,503**
POUR PHASE 9				
9	Beam	BjTS-420	S10, S25, S13, S22, S8	2,389
9	Slab	BjTS-420	S10, S25, S13, S22, S8	3,013
Subtotal — Pour Phase 9				**5,402**
POUR PHASE 10				
10	Beam	BjTS-420	S10, S19, S22, S25, S13, S8, S16	2,021
10	Slab	BjTS-420	S10, S19, S22, S25, S13, S8, S16	2,568
Subtotal — Pour Phase 10				**4,589**
POUR PHASE 11				
11	Column	BjTS-420	S13, S25	5,022

Pour Phase	Element	Grade	Bar Sizes	Rebar Weight (ton)
Subtotal — Pour Phase 11				**5,022**
POUR PHASE 12				
12	Column	BjTS-420	S10, S16, S13, S25	3,207
Subtotal — Pour Phase 12				**3,207**
POUR PHASE 13				
13	Beam	BjTS-420	S10, S22, S25, S13	1,998
13	Slab	BjTS-420	S10, S22, S25, S13	3,859
Subtotal — Pour Phase 13				**5,857**
POUR PHASE 14				
14	Beam	BjTS-420	S10, S22, S25, S19, S8, S16, S13	2,251
14	Slab	BjTS-420	S10, S22, S25, S19, S8, S16, S13	2,943
Subtotal — Pour Phase 14				**5,194**
POUR PHASE 15				
15	Column	BjTS-420	S13, S25	4,992
Subtotal — Pour Phase 15				**4,992**
POUR PHASE 16				
16	Column	BjTS-420	S10, S16, S13, S25	3,859
Subtotal — Pour Phase 16				**3,859**
POUR PHASE 17				
17	Beam	BjTS-420	S10, S22, S13, S25	1,998
17	Slab	BjTS-420	S10, S22, S13, S25	4,417
Subtotal — Pour Phase 17				**6,415**
POUR PHASE 18				

Pour Phase	Element	Grade	Bar Sizes	Rebar Weight (ton)
18	Beam	BjTS-420	S10, S19, S22, S25, S8, S16, S13	1,541
18	Slab	BjTS-420	S10, S19, S22, S25, S8, S16, S13	3,091
Subtotal — Pour Phase 18				**4,632**
POUR PHASE 19				
19	Column	BjTS-420	S13, S25	4,451
Subtotal — Pour Phase 19				**4,451**
POUR PHASE 20				
20	Column	BjTS-420	S10, S16, S13, S25	3,097
Subtotal — Pour Phase 20				**3,097**
POUR PHASE 21				
21	Beam	BjTS-420	S10, S22, S8, S16	1,213
21	Slab	BjTS-420	S10, S22, S8, S16	0,893
Subtotal — Pour Phase 21				**2,106**
POUR PHASE 22				
22	Beam	BjTS-420	S10, S22, S8, S16, S19	1,610
22	Slab	BjTS-420	S10, S22, S8, S16, S19	1,504
Subtotal — Pour Phase 22				**3,114**
POUR PHASE 23				
23	Column	BjTS-420	S13, S25	2,699
Subtotal — Pour Phase 23				**2,699**
POUR PHASE 24				
24	Column	BjTS-420	S10, S16, S13, S25	2,312
Subtotal — Pour Phase 24				**2,312**

Pour Phase	Element	Grade	Bar Sizes	Rebar Weight (ton)
POUR PHASE 25				
25	Beam	BjTS-420	S10, S22, S19	2,067
25	Slab	BjTS-420	S10, S22, S19	1,651
Subtotal — Pour Phase 25				**3,717**
GRAND TOTAL — REBAR WEIGHT (ton)				**143,743**

Raw Quantity Take-off can be seen in QR below.

Figure A-4. 1 Raw Quantity Take-Off Document

Appendix 5 Formwork Area Calculation per Pour Phase

Table A-5. 1 FORMWORK AREA PER POUR PHASE

FORMWORK AREA PER POUR PHASE		
Pour Phase	**Element**	**Formwork Area (m²)**
POUR PHASE 1		
1	Bore Pile	-
Subtotal — Pour Phase 1		**0,00**
POUR PHASE 2		
2	Bore Pile	-
Subtotal — Pour Phase 2		**0,00**
POUR PHASE 3		
3	Pile Cap	232,58
Subtotal — Pour Phase 3		**232,58**
POUR PHASE 4		
4	Pile Cap	204,52
Subtotal — Pour Phase 4		**204,52**
POUR PHASE 5		
5	Ground Beam	128,72
5	Slab	145,19
Subtotal — Pour Phase 5		**273,91**
POUR PHASE 6		
6	Ground Beam	85,97

Pour Phase	Element	Formwork Area (m²)
6	Slab	142,07
Subtotal — Pour Phase 6		**228,04**
POUR PHASE 7		
7	Column	126,14
Subtotal — Pour Phase 7		**126,14**
POUR PHASE 8		
8	Column	166,72
Subtotal — Pour Phase 8		**166,72**
POUR PHASE 9		
9	Beam	283,81
9	Slab	186,73
Subtotal — Pour Phase 9		**470,54**
POUR PHASE 10		
10	Beam	237,51
10	Slab	174,93
Subtotal — Pour Phase 10		**412,44**
POUR PHASE 11		
11	Column	99,96
Subtotal — Pour Phase 11		**99,96**
POUR PHASE 12		
12	Column	102,06
Subtotal — Pour Phase 12		**102,06**
POUR PHASE 13		
13	Beam	258,05

Pour Phase	Element	Formwork Area (m²)
13	Slab	181,97
Subtotal — Pour Phase 13		**440,02**
POUR PHASE 14		
14	Beam	216,77
14	Slab	141,72
Subtotal — Pour Phase 14		**358,49**
POUR PHASE 15		
15	Column	99,96
Subtotal — Pour Phase 15		**99,96**
POUR PHASE 16		
16	Column	102,06
Subtotal — Pour Phase 16		**102,06**
POUR PHASE 17		
17	Beam	258,05
17	Slab	184,05
Subtotal — Pour Phase 17		**442,10**
POUR PHASE 18		
18	Beam	222,62
18	Slab	140,21
Subtotal — Pour Phase 18		**362,83**
POUR PHASE 19		
19	Column	90,69
Subtotal — Pour Phase 19		**90,69**
POUR PHASE 20		

Pour Phase	Element	Formwork Area (m²)
20	Column	82,04
Subtotal — Pour Phase 20		**82,04**
POUR PHASE 21		
21	Beam	162,82
21	Slab	64,04
Subtotal — Pour Phase 21		**226,86**
POUR PHASE 22		
22	Beam	204,44
22	Slab	92,48
Subtotal — Pour Phase 22		**296,92**
POUR PHASE 23		
23	Column	63,13
Subtotal — Pour Phase 23		**63,13**
POUR PHASE 24		
24	Column	57,53
Subtotal — Pour Phase 24		**57,53**
POUR PHASE 25		
25	Beam	308,05
25	Slab	159,39
Subtotal — Pour Phase 25		**467,44**
GRAND TOTAL — FORMWORK AREA (m²)		**5406,98**

Element-by-Element Formwork Area Calculation also can be seen in Figure A-4. 2

Appendix 6 AHSP CK 2023 Productivity Coefficient Extract

Table A-6. 1 Related AHSP CK 2023 Productivity Coefficient

AHSP CK 2023 TABLE USED (Source:SE Dirjen Bina Konstruksi No. 73 Tahun 2023, Bagian IV Cipta Karya)				
NO.	**KODE**	**KOEFISIEN**	**SATUAN**	**URAIAN**
1	**D.01.01**	**1 Kg Penulangan kolom, balok, ring balk, sloof, dan shearwall untuk BjTP atau BjTS diameter ≥ 12 mm secara Semi-Mekanis**		
		Bahan :		
		1,02000	kg	Besi beton
		0,02800	kg	Kawat ikat beton
		Tenaga Kerja :		
		0,00160	OH	Tukang besi
		0,00016	OH	Kepala tukang besi
		0,00160	OH	Pekerja
		0,00016	OH	Mandor
		Peralatan :		
		0,00040	Hari	Bar cutter
		0,00040	Hari	Bar bender
2	**D.01.01.a**	**1 Kg Penulangan slab untuk BjTP atau BjTS diameter ≥ 12 mm, cara semi mekanis**		
		Bahan :		
		1,02000	kg	Besi beton
		0,01500	kg	Kawat ikat beton
		Tenaga Kerja :		
		0,00080	OH	Tukang besi
		0,00040	OH	Kepala tukang besi

NO.	KODE	KOEFISIEN	SATUAN	URAIAN
		0,00004	OH	Pekerja
		0,00008	OH	Mandor
		Peralatan :		
		0,00020	Hari	Bar cutter
		0,00020	Hari	Bar bender
3	**D.01.03**	**1 kg Pembuatan Baja Profil**		
		Bahan :		
		1,15000	kg	Besi Baja IWF
		0,05300	kg	kawat las listrik
		Tenaga Kerja :		
		0,01250	OH	Tukang besi
		0,01250	OH	Tukang las
		0,00250	OH	Kepala tukang besi
		0,03750	OH	Pekerja
		0,00080	OH	Mandor
		Peralatan :		
		0,03300	jam	sewa alat las listrik
		0,00130	jam	Crane mobile 7 ton
4	**D.04.03**	**1 m2 Pemasangan bekisting untuk sloof (3 kali pakai)**		
		Bahan :		
		0,01800	m3	Papan Kayu kelas III
		0,30000	kg	Paku 5 cm - 12 cm
		0,10000	ltr	Minyak bekesting
		Tenaga Kerja :		

NO.	KODE	KOEFISIEN	SATUAN	URAIAN
		0,26000	OH	Tukang Kayu
		0,02600	OH	Kepala Tukang Kayu
		0,52000	OH	Pekerja
		0,00900	OH	Mandor
5	**D.04.04**	**1 m2 Pemasangan bekisting untuk kolom (3 kali pakai)**		
		Bahan :		
		0,40000	kg	Paku 5 cm - 12 cm
		0,20000	ltr	Minyak bekisting
		0,00465	m3	Balok kayu kelas II
		0,65000	btg	Dolken kayu Ø 8-10cm –panjang 4 m
		0,12705	lbr	Multiplek, tebal 12 mm
		Tenaga Kerja :		
		0,33000	OH	Tukang kayu
		0,03300	OH	Kepala tukang kayu
		0,66000	OH	Pekerja
		0,01100	OH	Mandor
6	**D.04.05**	**1 m2 Pemasangan bekisting untuk balok (3 kali pakai)**		
		Bahan :		
		0,00558	m3	Balok kayu kelas II
		0,20000	ltr	Minyak bekisting
		0,40000	kg	Paku 5 cm - 12 cm
		0,65000	btg	Dolken kayu Ø 8-10cm –panjang 4 m
		0,12705	lbr	Multiplek, tebal 12 mm

NO.	KODE	KOEFISIEN	SATUAN	URAIAN
		Tenaga Kerja :		
		0,33000	OH	Tukang kayu
		0,03300	OH	Kepala tukang kayu
		0,66000	OH	Pekerja
		0,01100	OH	Mandor
7	**D.04.06**	**1 m2 Pemasangan bekisting untuk plat lantai (3 kali pakai)**		
		Bahan :		
		0,00465	m3	Balok kayu kelas II
		0,20000	ltr	Minyak bekisting
		0,40000	kg	Paku 5 cm - 10 cm
		1,95000	btg	Dolken kayu Ø 8-10cm –panjang 4 m
		0,12700	lbr	Multiplek, tebal 12 mm
		Tenaga Kerja :		
		0,33000	OH	Tukang kayu
		0,03300	OH	Kepala tukang kayu
		0,66000	OH	Pekerja
		0,01100	OH	Mandor
8	**D.02.03**	**1 m3 Pengecoran pakai pompa beton, T = 18 m'**		
		Peralatan :		
		0,08000	hari	Pompa Beton Long Boom
9	**D.02.04**	**1 m3 Pemadatan beton pada saat pengecoran dengan Vibrator untuk beton**		
		Peralatan :		
		0,08000	hari	Vibrator

NO.	KODE	KOEFISIEN	SATUAN	URAIAN
10	**D.02.06**	**1 m3 Pengecoran beton menggunakan ready mixed f'c 25 MPa**		
		Bahan :		
		1,01000	m3	Beton ready mix f'c = 25 MPa
		Tenaga Kerja :		
		0,10000	OH	Tukang batu
		0,01000	OH	Kepala tukang batu
		0,40000	OH	Pekerja
		0,04000	OH	Mandor
11	**D.02.07**	**1 m3 Pengecoran beton menggunakan ready mixed f'c 28 MPa**		
		Bahan :		
		1,01000	m3	Beton ready mix f'c = 28 MPa
		Tenaga Kerja :		
		0,10000	OH	Tukang batu
		0,01000	OH	Kepala tukang batu
		0,40000	OH	Pekerja
		0,04000	OH	Mandor
12	**D.02.10**	**1 m3 Pengecoran beton menggunakan ready mixed f'c 25 MPa + pompa + vibrator**		
		Analisa harga satuan :		
		1,00000	m3	Pengecoran beton menggunakan ready mixed f'c 25 MPa
		1,00000	m3	Pengecoran pakai pompa beton, T = 18 m'
		1,00000	m3	Pemadatan beton pada saat pengecoran dengan vibrator

NO.	KODE	KOEFISIEN	SATUAN	URAIAN
13	**D.02.11**	**1 m3 Pengecoran beton menggunakan ready mixed f'c 28 MPa + pompa + vibrator**		
		Analisa harga satuan :		
		1,00000	m3	Pengecoran beton menggunakan ready mixed f'c 28 MPa
		1,00000	m3	Pengecoran pakai pompa beton, T = 18 m'
		1,00000	m3	Pemadatan beton pada saat pengecoran dengan vibrator
14	**B.02.2**	**1 m' Pengeboran bore pile Ø 1000 mm (kedalaman 8 m, 55 titik) — Analisa non-standar**		
		Peralatan :		
		1000	m'	Pekerjaan pengeboran
		440	m3	Pengadaan dan aplikasi slurry stabilizer
		35200	kg	Angkat besi
15	**Pile Cap**	**Pile cap = Pembesian (2.2.1.1.4) + Pengecoran beton f'c 28 MPa (D.02.07). Bekisting minim (cor lawan tanah).**		
		A. Pembesian (per 1 kg) — Kode 2.2.1.1.4		
		Bahan :		
		1,02	kg	Besi beton
		0,028	kg	Kawat ikat beton
		Tenaga Kerja :		
		0,0016	OH	Tukang besi
		0,00016	OH	Kepala tukang besi
		0,0016	OH	Pekerja
		0,00016	OH	Mandor

NO.	KODE	KOEFISIEN	SATUAN	URAIAN
		Peralatan :		
		0,0004	Hari	Bar cutter
		0,0004	Hari	Bar bender
		B. Pengecoran beton (per 1 m³) — Kode D.02.07 (ready mix f'c 28 MPa)		
		Bahan :		
		1,01	m3	Beton ready mix f'c = 28 MPa
		Tenaga Kerja :		
		0,1	OH	Tukang batu
		0,01	OH	Kepala tukang batu
		0,4	OH	Pekerja
		0,04	OH	Mandor
16	**D.04.02**	**1 m2 Pemasangan bekisting bata merah (5x11x22) cm tebal ½ batu (camp. 1SP : 5PP)**		
		Bahan :		
		70,00000	bh	Bata merah
		9,68000	kg	Semen portland (PC)
		0,04500	m3	Pasir pasang
		Tenaga Kerja :		
		0,10000	OH	Tukang batu
		0,01000	OH	Kepala tukang batu
		0,30000	OH	Pekerja
		0,01500	OH	Mandor
17	**D.09.2.1**	**1 bh Pemasangan Baut A325 Ø 12 x 100 mm & Ring plat**		

NO.	KODE	KOEFISIEN	SATUAN	URAIAN
		Bahan :		
		1,00000	bh	Baut A325 Ø 12 x 100 mm
		2,00000	bh	Ring plat M12
		Peralatan :		
		0,00268	hari	Kunci momen / torsi
		Tenaga Kerja :		
		0,00268	OH	Tukang besi
		0,00027	OH	Kepala tukang besi
		0,00268	OH	Pekerja
		0,00009	OH	Mandor
18	**D.09.2.2**	**1 bh Pemasangan Baut A325 Ø 16 x 100 mm & Ring plat**		
		Bahan :		
		1,00000	bh	Baut A325 Ø 16 x 100 mm
		2,00000	bh	Ring plat M16
		Peralatan :		
		0,00875	hari	Kunci momen / torsi
		Tenaga Kerja :		
		0,00875	OH	Tukang besi
		0,00088	OH	Kepala tukang besi
		0,00875	OH	Pekerja
		0,00029	OH	Mandor

Appendix 7 Scheduling Analysis Workbook

Table A-7. 1 Scheduling Analysis Workbook

No.	Floor	Zone	Structural Element	Pour Phase	n of element	Formwork Vol. (m^2)	Formwork Prod. (m^2)	No. Workers	Rebar Vol. (kg)	Rebar Prod. (kg)	No. Workers	Concrete Vol. (m^3)	Concrete Prod. (m^3)	No. Workers	Formwork Duration (days)	Rebar Duration (days)	Concreting Duration (days)	TOTAL PHASE DURATION (days)	Predecessor	Start (day no.)	Finish (day no.)	Relation	element / day
1	F	1	Bore Pile	1	30	0	0,00	-	16190	625	10	165,0	10	6	0	2,6	2,8	**6**	—	1	6		6
2	F	2	Bore Pile	2	17	0	0,00	-	9170	625	10	93,2	10	6	0	1,5	1,6	**4**	1	7	10	FS	6
3	F	1	Pile Cap	3	3	232,58	10,00	10	12735	625	6	163,9	10	4	2,3	3,4	4,1	**8**	1	7	14	FS	0
4	F	2	Pile Cap	4	4	204,52	10,00	8	6774	625	4	87,7	10	2	2,6	2,7	4,4	**8**	2	15	22	FS	1
5	1	3	Ground Beam	5	15	128,72	3,85	6	3533	625	3	17,5	10	2	5,6	1,9	0,9	**7**	3	15	21	FS	3
6	1	3	Slab		8	145,19	3,03	6	3144	1250	4	21,7	10	2	8,0	0,6	1,1	**10**	3	15	24	SS	1
7	1	4	Ground Beam	6	11	85,97	3,85	6	2373	625	4	11,8	10	2	3,7	0,9	0,6	**5**	4	25	29	FS	3
8	1	4	Slab		4	142,07	3,03	8	3013	1250	4	20,8	10	2	5,9	0,6	1,0	**7**	4	25	31	SS	1
9	1	3	Column	7	8	126,14	3,03	6	8642	625	3	23,3	10	2	6,9	4,6	1,2	**9**	6	25	33	FS	1
10	1	4	Column	8	12	166,72	3,03	6	7503	625	3	23,0	10	2	9,2	4,0	1,2	**11**	8	34	44	FS	1
11	2	5	Beam	9	35	283,81	3,85	6	2389	625	4	31,4	10	2	12,3	1,0	1,6	**14**	9	34	47	FS	3
12	2	5	Slab		21	186,73	3,03	8	3013	1250	4	22,3	10	2	7,7	0,6	1,1	**9**	9	34	42	SS	3
13	2	6	Beam	10	48	237,51	3,85	6	2021	625	4	27,1	10	2	10,3	0,8	1,4	**12**	10	45	56	FS	4
14	2	6	Slab		25	174,93	3,03	8	2568	1250	4	20,6	10	2	7,2	0,5	1,0	**9**	13	45	53	SS	3
15	2	5	Column	11	8	99,96	3,03	6	5022	625	3	18,5	10	2	5,5	2,7	0,9	**7**	12	45	51	FS	1
16	2	6	Column	12	9	102,06	3,03	6	3207	625	3	14,9	10	2	5,6	1,7	0,7	**7**	14	54	60	FS	2
17	3	7	Beam	13	35	258,05	3,85	6	1998	625	4	32,2	10	2	11,2	0,8	1,6	**13**	15	54	66	FS	3
18	3	7	Slab		21	181,97	3,03	8	3859	1250	4	23,2	10	2	7,5	0,8	1,2	**9**	17	54	62	SS	3
19	3	8	Beam	14	40	216,77	3,85	6	2251	625	4	25,4	10	2	9,4	0,9	1,3	**11**	16	63	73	FS	4
20	3	8	Slab		19	141,72	3,03	8	2943	1250	4	17,1	10	2	5,8	0,6	0,9	**7**	19	63	69	SS	3
21	3	7	Column	15	8	99,96	3,03	6	4992	625	3	18,5	10	2	5,5	2,7	0,9	**7**	18	63	69	FS	1
22	3	8	Column	16	9	102,06	3,03	6	3859	625	3	14,9	10	2	5,6	2,1	0,7	**7**	20	70	76	FS	2
23	4	9	Beam	17	35	258,05	3,85	6	1998	625	4	32,2	10	2	11,2	0,8	1,6	**13**	21	70	82	FS	3
24	4	9	Slab		21	184,05	3,03	8	4417	1250	4	22,6	10	2	7,6	0,9	1,1	**9**	23	70	78	SS	3
25	4	10	Beam	18	41	222,62	3,85	6	1541	625	4	26,1	10	2	9,6	0,6	1,3	**11**	22	79	89	FS	4
26	4	10	Slab		18	140,21	3,03	8	3091	1250	4	16,9	10	2	5,8	0,6	0,8	**7**	25	79	85	SS	3
27	4	9	Column	19	8	90,69	3,03	6	4451	625	3	14,9	10	2	5,0	2,4	0,7	**6**	24	79	84	FS	2
28	4	10	Column	20	7	82,04	3,03	6	3097	625	3	11,8	10	2	4,5	1,7	0,6	**6**	26	86	91	FS	1
29	5	11	Beam	21	26	162,82	3,85	6	1213	625	4	18,1	10	2	7,1	0,5	0,9	**8**	27	86	93	FS	4
30	5	11	Slab		10	64,04	3,03	8	893	1250	4	7,7	10	2	2,6	0,2	0,4	**4**	29	86	89	SS	3
31	5	12	Beam	22	41	204,44	3,85	6	1610	625	4	23,3	10	2	8,9	0,6	1,2	**11**	28	92	102	FS	4
32	5	12	Slab		16	92,48	3,03	8	1504	1250	4	11,8	10	2	3,8	0,3	0,6	**5**	31	92	96	SS	4
33	5	11	Column	23	8	63,13	3,03	6	2699	625	3	10,4	10	2	3,5	1,4	0,5	**4**	30	92	95	FS	3
34	5	12	Column	24	7	57,53	3,03	10	2312	625	10	8,3	10	5	1,9	0,4	0,2	**3**	32	97	99	FS	4
35	R	13	Beam	25	44	308,05	3,85	7	2067	625	3	30,7	10	2	11,4	1,1	1,5	**13**	33	100	112	FS	4
36	R	13	Slab		27	159,39	3,03	8	1651	1250	3	19,7	10	2	6,6	0,4	1,0	**8**		100	107	SS	4
37	T	14	Steel Truss	26	106	**Reinforcement (kg)**	**Steel Prod. (kg)**	**No. Workers**	**Bolting (pcs)**	**Bolting Prod. (pcs)**	**No. Workers**	-			**Reinforcement Duration**	**Bolting Duration**							
						11509		10	250		8	0,0			14,4	0,3	0,0	**15**	35,36	113	127	FS	8
																	TOTAL PROJECT DURATION (working days)	**127**			**127**		

Appendix 8 Daily Concurrent Manpower Tabulation

Table A-8. 1 Element and Labor per Day

Week	Pour Phase	Floor	Zone	Number of Elements Worked (pcs)						Work Phase (Checklist)			Number of Workers			Total Workers	Day
				Borepile	Pilecap	Column	Beam	Slab	Truss	Formwork	Rebar/steel	Concrete/Bolting	Formwork	Rebar/steel	Concrete/Bolting		
W1	**PP-01**	Foundation	Z-01	2,3							2,3			2		**2**	**1**
W1	**PP-01**	Foundation	Z-01	4,6							4,6			4		**4**	**2**
W1	**PP-01**	Foundation	Z-01	5,8							5,8			5		**5**	**3**
W1	**PP-01**	Foundation	Z-01	8,1							8,1			7		**7**	**4**
W1	**PP-01**	Foundation	Z-01	20,2							9,3	10,9		8	6	**14**	**5**
	PP-02	Foundation	Z-02	1,2							1,2			1		**1**	**5**
W1	**PP-01**	Foundation	Z-01	10,9								10,9			6	**6**	**6**
	PP-02	Foundation	Z-02	12,7							12,7			11		**11**	**6**
W2	**PP-01**	Foundation	Z-01	7,3								7,3			4	**4**	**7**
	PP-02	Foundation	Z-02	7,1							3,5	3,6		3	2	**5**	**7**
	PP-03	Foundation	Z-01		1,5						1,5			10		**10**	**7**
W2	**PP-02**	Foundation	Z-02	10,9								10,9			6	**6**	**8**
	PP-03	Foundation	Z-01		1,6					0,4	1,6		3	11		**14**	**8**
W2	**PP-02**	Foundation	Z-02	3,6								3,6			2	**2**	**9**
	PP-03	Foundation	Z-01		2,1					2,1			16			**16**	**9**
W2	**PP-03**	Foundation	Z-01		1,1					0,4		0,7	3		4	**7**	**10**

Week	**Pour Phase**	**Floor**	**Zone**	**Number of Elements Worked (pcs)**						**Work Phase (Checklist)**			**Number of Workers**			**Total Workers**	**Day**
				Borepile	**Pilecap**	**Column**	**Beam**	**Slab**	**Truss**	**Formwork**	**Rebar/steel**	**Concrete/Bolting**	**Formwork**	**Rebar/steel**	**Concrete/Bolting**		
	PP-04	Foundation	Z-02		4,0					0,4	4,0		2	11		**13**	**10**
W2	**PP-03**	Foundation	Z-01		0,7							0,7			4	**4**	**11**
	PP-04	Foundation	Z-02		3,1					3,1			16			**16**	**11**
W2	**PP-03**	Foundation	Z-01		0,7							0,7			4	**4**	**12**
	PP-04	Foundation	Z-02		1,3					0,4		0,9	2		2	**4**	**12**
	PP-05	Fl. 1	Z-03				8,4	8,0		2,3	16,4		8	6		**14**	**12**
W3	**PP-03**	Foundation	Z-01		0,7							0,7			4	**4**	**13**
	PP-04	Foundation	Z-02		0,9							0,9			2	**2**	**13**
	PP-05	Fl. 1	Z-03				2,9	1,6		4,5			16			**16**	**13**
	PP-04	Foundation	Z-02		0,9							0,9			2	**2**	**14**
	PP-05	Fl. 1	Z-03				4,2	4,5		4,0	8,7		14	3		**17**	**14**
W3	**PP-04**	Foundation	Z-02		0,9							0,9			2	**2**	**15**
	PP-05	Fl. 1	Z-03				2,9	1,6		4,5			16			**16**	**15**
W3	**PP-04**	Foundation	Z-02		0,5							0,5			1	**1**	**16**
	PP-05	Fl. 1	Z-03				2,9	1,6		4,5			16			**16**	**16**
W3	**PP-05**	Fl. 1	Z-03				17,0	9,1		3,1		23,0	11		4	**15**	**17**
	PP-06	Fl. 1	Z-04				5,1	3,7		0,3	8,8		1	4		**5**	**17**
	PP-06	Fl. 1	Z-04				2,5	0,9		3,4			16			**16**	**18**
W4	**PP-06**	Fl. 1	Z-04				2,6	1,9		3,0	4,5		14	2		**16**	**19**

Week	Pour Phase	Floor	Zone	Number of Elements Worked (pcs)						Work Phase (Checklist)			Number of Workers			Total Workers	Day
				Borepile	Pilecap	Column	Beam	Slab	Truss	Formwork	Rebar/steel	Concrete/Bolting	Formwork	Rebar/steel	Concrete/Bolting		
W4	PP-06	Fl. 1	Z-04				2,5	0,9		3,4			16			16	20
W4	PP-06	Fl. 1	Z-04				2,5	0,9		3,4			16			16	21
W4	PP-06	Fl. 1	Z-04				7,7	2,8		1,3		9,2	6		2	8	22
	PP-07	Fl. 1	Z-03			6,4					6,4			11		11	22
	PP-07	Fl. 1	Z-03			2,5				2,5	1,7		13	3		16	23
W4	PP-07	Fl. 1	Z-03			3,1				3,1			16			16	24
W5	PP-07	Fl. 1	Z-03			5,9				2,5		3,4	13		1	14	25
	PP-08	Fl. 1	Z-04			4,0					4,0			4		4	25
	PP-08	Fl. 1	Z-04			8,0				2,0	8,0		9	8		17	26
W5	PP-08	Fl. 1	Z-04			3,5				3,5			16			16	27
W5	PP-08	Fl. 1	Z-04			3,5				3,5			16			16	28
W5	PP-08	Fl. 1	Z-04			13,7				3,3		10,4	15		2	17	29
	PP-09	Fl. 2	Z-05				4,0	4,9			8,9			1		1	29
	PP-09	Fl. 2	Z-05				8,1	9,7		5,8	17,8		14	2		16	30
W6	PP-09	Fl. 2	Z-05				4,1	2,5		6,6			16			16	31
W6	PP-09	Fl. 2	Z-05				4,1	2,5		6,6			16			16	32
W6	PP-09	Fl. 2	Z-05				4,1	2,5		6,6			16			16	33
W6	PP-09	Fl. 2	Z-05				8,1	9,7		5,8	17,8		14	2		16	34
W6	PP-09	Fl. 2	Z-05				4,1	2,5		6,6			16			16	35

Week	Pour Phase	Floor	Zone	Number of Elements Worked (pcs)						Work Phase (Checklist)			Number of Workers			Total Workers	Day
				Borepile	**Pilecap**	**Column**	**Beam**	**Slab**	**Truss**	**Formwork**	**Rebar/steel**	**Concrete/Bolting**	**Formwork**	**Rebar/steel**	**Concrete/Bolting**		
W6	**PP-09**	Fl. 2	Z-05				4,1	2,5		6,6			16			**16**	**36**
W7	**PP-09**	Fl. 2	Z-05				4,1	2,5		6,6			16			**16**	**37**
W7	**PP-09**	Fl. 2	Z-05				28,9	17,3		4,5		41,7	11		4	**15**	**38**
	PP-10	Fl. 2	Z-06				19,6	20,4		1,2	40,0		2	3		**5**	**38**
W7	**PP-09**	Fl. 2	Z-05				6,5	3,9				10,4			1	**1**	**39**
	PP-10	Fl. 2	Z-06				6,8	3,6		10,4			17			**17**	**39**
W7	**PP-10**	Fl. 2	Z-06				6,4	3,3		9,7			16			**16**	**40**
W7	**PP-10**	Fl. 2	Z-06				6,4	3,3		9,7			16			**16**	**41**
W7	**PP-10**	Fl. 2	Z-06				13,1	13,6		8,5	26,7		14	2		**16**	**42**
W8	**PP-10**	Fl. 2	Z-06				6,4	3,3		9,7			16			**16**	**43**
W8	**PP-10**	Fl. 2	Z-06				6,4	3,3		9,7			16			**16**	**44**
W8	**PP-10**	Fl. 2	Z-06				6,4	3,3		9,7			16			**16**	**45**
W8	**PP-10**	Fl. 2	Z-06				42,7	22,3		3,7		61,3	6		4	**10**	**46**
	PP-11	Fl. 2	Z-05			8,0				0,5	8,0		2	8		**10**	**46**
W8	**PP-10**	Fl. 2	Z-06				10,1	5,2				15,3			1	**1**	**47**
	PP-11	Fl. 2	Z-05			3,9				3,9			16			**16**	**47**
W8	**PP-11**	Fl. 2	Z-05			11,6				3,6		8,0	15		2	**17**	**48**
	PP-12	Fl. 2	Z-06			1,8					1,8			1		**1**	**48**
W9	**PP-12**	Fl. 2	Z-06			7,0				3,2	7,0		12	4		**16**	**49**

Week	Pour Phase	Floor	Zone	Number of Elements Worked (pcs)						Work Phase (Checklist)			Number of Workers			Total Workers	Day
				Borepile	Pilecap	Column	Beam	Slab	Truss	Formwork	Rebar/steel	Concrete/Bolting	Formwork	Rebar/steel	Concrete/Bolting		
W9	**PP-12**	Fl. 2	Z-06			4,3				4,3			16			**16**	**50**
W9	**PP-12**	Fl. 2	Z-06			7,3				1,3		6,0	5		1	**6**	**51**
	PP-13	Fl. 3	Z-07				11,2	13,4		4,0	24,6		9	3		**12**	**51**
W9	**PP-13**	Fl. 3	Z-07				4,4	2,6		7,0			16			**16**	**52**
W9	**PP-13**	Fl. 3	Z-07				4,4	2,6		7,0			16			**16**	**53**
W9	**PP-13**	Fl. 3	Z-07				4,4	2,6		7,0			16			**16**	**54**
W10	**PP-13**	Fl. 3	Z-07				11,2	13,4		5,7	24,6		13	3		**16**	**55**
W10	**PP-13**	Fl. 3	Z-07				4,4	2,6		7,0			16			**16**	**56**
W10	**PP-13**	Fl. 3	Z-07				4,4	2,6		7,0			16			**16**	**57**
W10	**PP-13**	Fl. 3	Z-07				4,4	2,6		7,0			16			**16**	**58**
W10	**PP-13**	Fl. 3	Z-07				27,8	16,7		4,0		40,5	9		4	**13**	**59**
	PP-14	Fl. 3	Z-08				19,3	18,3		1,8	37,6		3	4		**7**	**59**
W10	**PP-13**	Fl. 3	Z-07				12,6	7,6				20,2			2	**2**	**60**
	PP-14	Fl. 3	Z-08				6,2	2,9		9,1			16			**16**	**60**
W11	**PP-14**	Fl. 3	Z-08				6,2	2,9		9,1			16			**16**	**61**
W11	**PP-14**	Fl. 3	Z-08				6,2	2,9		9,1			16			**16**	**62**
W11	**PP-14**	Fl. 3	Z-08				9,6	9,1		8,0	18,7		14	2		**16**	**63**
W11	**PP-14**	Fl. 3	Z-08				6,2	2,9		9,1			16			**16**	**64**
W11	**PP-14**	Fl. 3	Z-08				6,2	2,9		9,1			16			**16**	**65**

Week	**Pour Phase**	**Floor**	**Zone**	**Number of Elements Worked (pcs)**						**Work Phase (Checklist)**			**Number of Workers**			**Total Workers**	**Day**
				Borepile	**Pilecap**	**Column**	**Beam**	**Slab**	**Truss**	**Formwork**	**Rebar/steel**	**Concrete/Bolting**	**Formwork**	**Rebar/steel**	**Concrete/Bolting**		
W11	**PP-14**	Fl. 3	Z-08				39,5	18,8		2,8		55,5	5		4	**9**	**66**
	PP-15	Fl. 3	Z-07			8,0				0,7	8,0		3	8		**11**	**66**
W12	**PP-14**	Fl. 3	Z-08				9,4	4,5				13,9			1	**1**	**67**
	PP-15	Fl. 3	Z-07			3,9				3,9			16			**16**	**67**
W12	**PP-15**	Fl. 3	Z-07			11,4				3,4		8,0	14		2	**16**	**68**
	PP-16	Fl. 3	Z-08			2,9					2,9			2		**2**	**68**
W12	**PP-16**	Fl. 3	Z-08			5,8				3,2	5,8		12	4		**16**	**69**
W12	**PP-16**	Fl. 3	Z-08			4,3				4,3			16			**16**	**70**
W12	**PP-16**	Fl. 3	Z-08			7,3				1,3		6,0	5		1	**6**	**71**
	PP-17	Fl. 4	Z-09				10,2	12,3		4,0	22,5		9	3		**12**	**71**
W12	**PP-17**	Fl. 4	Z-09				4,4	2,6		7,0			16			**16**	**72**
W13	**PP-17**	Fl. 4	Z-09				4,4	2,6		7,0			16			**16**	**73**
W13	**PP-17**	Fl. 4	Z-09				4,4	2,6		7,0			16			**16**	**74**
W13	**PP-17**	Fl. 4	Z-09				10,2	12,3		5,7	22,5		13	3		**16**	**75**
W13	**PP-17**	Fl. 4	Z-09				4,4	2,6		7,0			16			**16**	**76**
W13	**PP-17**	Fl. 4	Z-09				4,4	2,6		7,0			16			**16**	**77**
W13	**PP-17**	Fl. 4	Z-09				4,4	2,6		7,0			16			**16**	**78**
W14	**PP-17**	Fl. 4	Z-09				28,5	17,1		4,8		40,8	11		4	**15**	**79**
	PP-18	Fl. 4	Z-10				11,1	9,7		1,7	20,8		3	2		**5**	**79**

Week	Pour Phase	Floor	Zone	Number of Elements Worked (pcs)						Work Phase (Checklist)			Number of Workers			Total Workers	Day
				Borepile	Pilecap	Column	Beam	Slab	Truss	Formwork	Rebar/steel	Concrete/Bolting	Formwork	Rebar/steel	Concrete/Bolting		
W14	**PP-17**	Fl. 4	Z-09				6,4	3,8				10,2			1	**1**	**80**
	PP-18	Fl. 4	Z-10				6,7	2,9		9,6			17			**17**	**80**
W14	**PP-18**	Fl. 4	Z-10				6,3	2,8		9,1			16			**16**	**81**
W14	**PP-18**	Fl. 4	Z-10				6,3	2,8		9,1			16			**16**	**82**
W14	**PP-18**	Fl. 4	Z-10				11,1	9,7		7,9	20,8		14	2		**16**	**83**
W14	**PP-18**	Fl. 4	Z-10				6,3	2,8		9,1			16			**16**	**84**
W15	**PP-18**	Fl. 4	Z-10				6,3	2,8		9,1			16			**16**	**85**
W15	**PP-18**	Fl. 4	Z-10				40,5	17,7		3,4		54,8	6		4	**10**	**86**
	PP-19	Fl. 4	Z-09			7,9				0,8	7,9		3	7		**10**	**86**
W15	**PP-18**	Fl. 4	Z-10				9,5	4,2				13,7			1	**1**	**87**
	PP-19	Fl. 4	Z-09			4,3				4,3			16			**16**	**87**
W15	**PP-19**	Fl. 4	Z-09			8,6				3,2		5,4	12		1	**13**	**88**
	PP-20	Fl. 4	Z-10			7,0					7,0			5		**5**	**88**
W15	**PP-20**	Fl. 4	Z-10			4,1				4,1			16			**16**	**89**
W15	**PP-20**	Fl. 4	Z-10			8,7				2,8		5,9	11		1	**12**	**90**
	PP-21	Fl. 5	Z-11				15,4	10,0		1,7	25,4		3	2		**5**	**90**
W16	**PP-21**	Fl. 5	Z-11				6,6	2,5		9,1			16			**16**	**91**
W16	**PP-21**	Fl. 5	Z-11				6,6	2,5		9,1			16			**16**	**92**
W16	**PP-21**	Fl. 5	Z-11				7,7	5,9		8,5	13,6		15	1		**16**	**93**

Week	Pour Phase	Floor	Zone	Number of Elements Worked (pcs)						Work Phase (Checklist)			Number of Workers			Total Workers	Day
				Borepile	Pilecap	Column	Beam	Slab	Truss	Formwork	Rebar/steel	Concrete/Bolting	Formwork	Rebar/steel	Concrete/Bolting		
W16	**PP-21**	Fl. 5	Z-11				30,9	11,9		6,8		36,0	12		3	**15**	**94**
	PP-22	Fl. 5	Z-12				24,7	16,0		0,7	40,7		1	3		**4**	**94**
W16	**PP-22**	Fl. 5	Z-12				7,8	3,1		10,9			16			**16**	**95**
W16	**PP-22**	Fl. 5	Z-12				7,8	3,1		10,9			16			**16**	**96**
W17	**PP-22**	Fl. 5	Z-12				7,8	3,1		10,9			16			**16**	**97**
W17	**PP-22**	Fl. 5	Z-12				8,2	6,4		10,2	14,6		15	1		**16**	**98**
W17	**PP-22**	Fl. 5	Z-12				7,8	3,1		10,9			16			**16**	**99**
W17	**PP-22**	Fl. 5	Z-12				36,5	14,3		2,1		48,7	3		3	**6**	**100**
	PP-23	Fl. 5	Z-11			7,4				3,5	7,4		9	4		**13**	**100**
	PP-23	Fl. 5	Z-11			12,3				4,6		7,7	12		1	**13**	**101**
	PP-24	Fl. 5	Z-12			7,0				0,4	7,0		1	4		**5**	**101**
W17	**PP-24**	Fl. 5	Z-12			5,9				5,9			16			**16**	**102**
W18	**PP-24**	Fl. 5	Z-12			7,7				0,7		7,0	2		1	**3**	**103**
	PP-25	Roof	Z-13				22,2	27,0		5,8	49,2		11	3		**14**	**103**
W18	**PP-25**	Roof	Z-13				5,3	3,3		8,6			16			**16**	**104**
W18	**PP-25**	Roof	Z-13				5,3	3,3		8,6			16			**16**	**105**
W18	**PP-25**	Roof	Z-13				5,3	3,3		8,6			16			**16**	**106**
W18	**PP-25**	Roof	Z-13				5,3	3,3		8,6			16			**16**	**107**
W18	**PP-25**	Roof	Z-13				7,4	9,1		7,4	16,5		14	1		**15**	**108**

Week	**Pour Phase**	**Floor**	**Zone**	**Number of Elements Worked (pcs)**						**Work Phase (Checklist)**			**Number of Workers**			**Total Workers**	**Day**
				Borepile	**Pilecap**	**Column**	**Beam**	**Slab**	**Truss**	**Formwork**	**Rebar/steel**	**Concrete/Bolting**	**Formwork**	**Rebar/steel**	**Concrete/Bolting**		
W19	**PP-25**	Roof	Z-13				4,6	2,8		7,4			14			**14**	**109**
W19	**PP-25**	Roof	Z-13				4,3	2,6		6,9			13			**13**	**110**
W19	**PP-25**	Roof	Z-13				4,0	2,4		6,4			12			**12**	**111**
W19	**PP-25**	Roof	Z-13				10,7	6,6		3,2		14,1	6		1	**7**	**112**
	PP-26	Roof (Truss)	Z-14						2,9		2,9			4		**4**	**112**
	PP-26	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**113**
W19	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**114**
W20	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**115**
W20	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**116**
W20	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**117**
W20	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**118**
W20	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**119**
W20	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**120**
W21	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**121**
W21	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**122**
W21	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**123**
W21	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**124**
W21	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**125**
W21	**PP-26**	Roof (Truss)	Z-14						7,4		7,4			10		**10**	**126**

Week	Pour Phase	Floor	Zone	Number of Elements Worked (pcs)						Work Phase (Checklist)			Number of Workers			Total Workers	Day
				Borepile	Pilecap	Column	Beam	Slab	Truss	Formwork	Rebar/steel	Concrete/Bolting	Formwork	Rebar/steel	Concrete/Bolting		
W22	**PP-26**	Roof (Truss)	Z-14						250,0			250,0			8	**8**	**127**

Appendix 9 Complete Ms. Project Gantt Chart

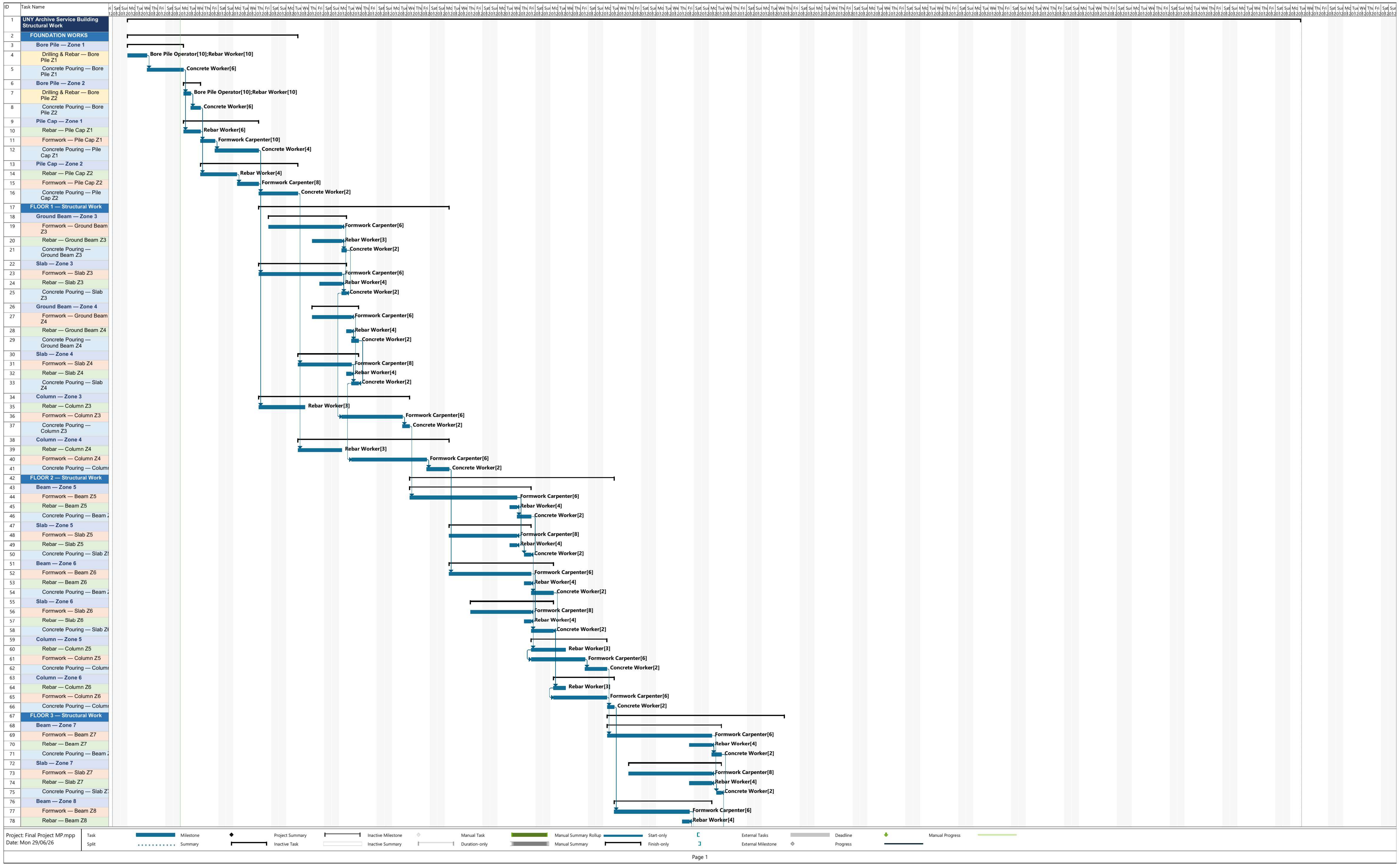


Figure A-8. 1 Microsoft Project's Gantt Chart

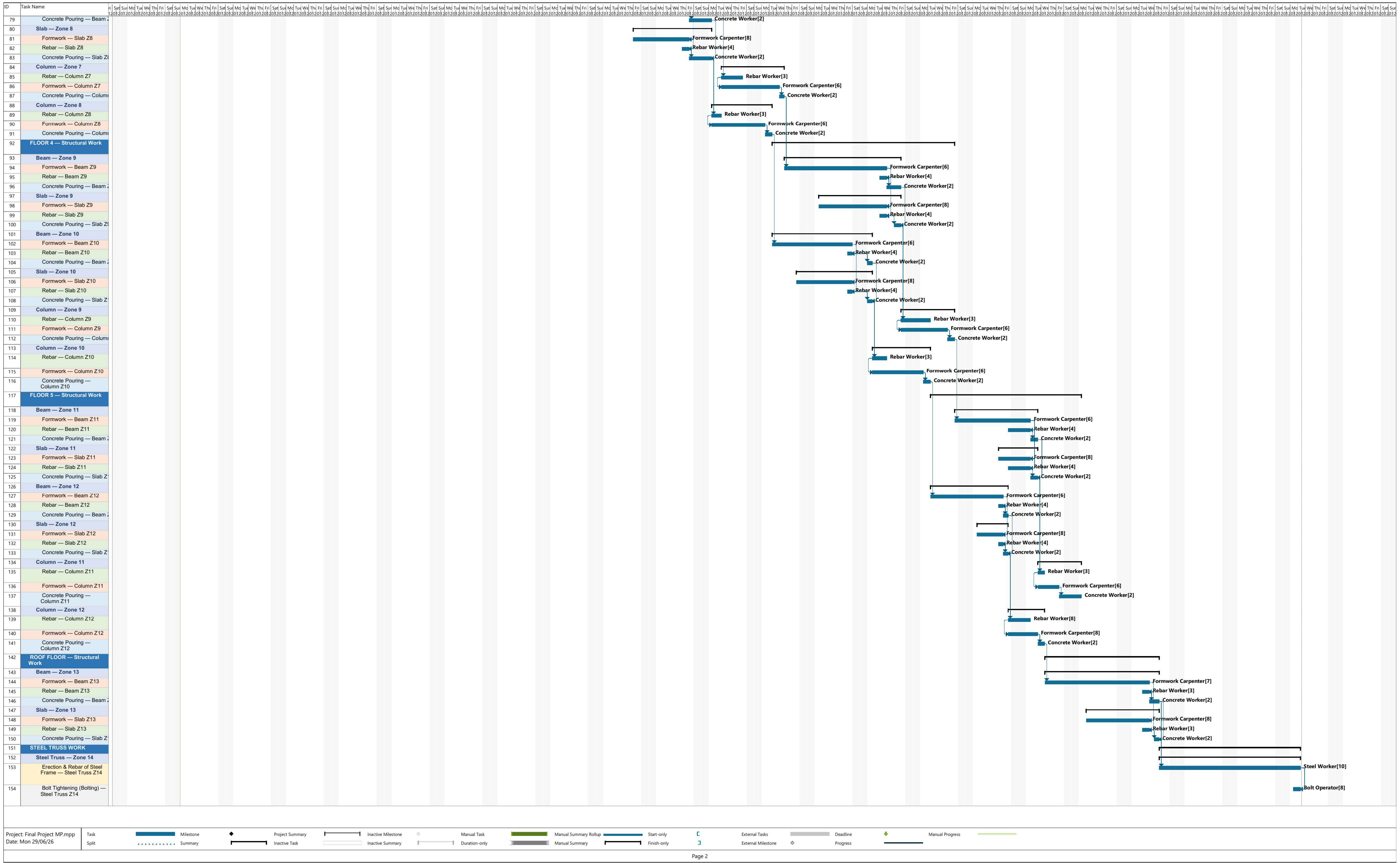


Figure A-8. 2 Microsoft Project's Gantt Chart