ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

COLLEGE OF CIVIL ENGINEERING AND ARCHITECTURE

DEPARTMENT OF CIVIL ENGINEERING (BSc.)

INTERNSHIP-I (CEng3200) REPORT

HOSTING COMPANY: ENGINEERING CORPORATION OF OROMIA (CONSULTANT), SHAGGAR CITY (CLIENT), AND GUTEMA FIRISA CONSTRUCTION PLC JV WITH MCG CONSTRUCTION PLC (CONTRACTOR)

PROJECT NAME: CONSTRUCTION OF SHAGGAR ONE GENERAL HOSPITAL AT GEFERSA GUJE SUB-CITY

FROM JUNE 09, 2025, TO SEPTEMBER 08, 2025 (THREE MONTHS)

BY: NAOL TEREFE BANGO

ID NUMBER: UGR/31007/15

ACADEMIC ADVISOR: ENG. BEKELE KUSHU
IMMEDIATE SUPERVISOR: ENG. TOKUMMA JABESSA
SUBMISSION DATE: SEPTEMBER 23, 2025 G.C
SUBMITTED TO THE DEPARTMENT'S OFFICE
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DECLARATION

I, **Naol Terefe Bango**, a seventh-semester Dual Major Bachelor of Science student in Civil Engineering and Water Resource Engineering at Adama Science and Technology University (ASTU), hereby declare that this internship report is submitted in partial fulfillment of the requirements for the internship-I program. This report is based on the practical training I undertook at the Engineering Corporation of Oromia (ECO) for a period of three months, from June 09, 2025, to September 08, 2025 G.C., under the supervision of Mr. Bekele Kushu, Geotechnical Engineer, Department of Civil Engineering, Adama Science and Technology University, Ethiopia.

I further declare that this report is my original and independent work and has not been submitted or presented to any other institution or program for academic or professional purposes. All sources of information, ideas, data, and quotations used in this report have been properly cited and acknowledged in accordance with educational and ethical standards.

I confirm that no part of this report has been copied, plagiarized, or reproduced from any other report, publication, or project without appropriate attribution.

Name of the Student: **Naol Terefe Bango**

ID Number: **UGR/31007/15**

Signature:__________

Date: September 8, 2025 G.C

"The starting point of all achievement is desire."

\- *Napoleon Hill*

APPROVAL AND CERTIFICATION

This is to certify that the internship report entitled "Internship-I Report", prepared and submitted by Naol Terefe Bango (ID: UGR/31007/15), has been reviewed and approved as fulfilling the requirements for the Internship Program in the Department of Civil Engineering, Adama Science and Technology University, Ethiopia.

Approval of the Academic Advisor

I hereby confirm that, to the best of my knowledge and belief, the statements made in this report are correct. This report has been reviewed and approved for presentation.

Advisor's Name: **Mr. Bekele Kushu**

Position/Title: **Geotechnical Engineer, Department of Civil Engineering**

Signature: ______

Date: September 24, 2025 G.C

Members of the Examining Board:

Name of examiners:	**Signature:**	**Date:**
1. **Mr. Estifanos Berhanu Atnafu** [Head of Civil Engineering Department]	______	Oct 07. 2025
2. **Mr. Bedane Hailu Dessie** [Deputy Head of Civil Engineering Department]	______	Oct 07. 2025
3. **Mr. Abdissa Geredaw Gudeta** [Head, CoCEA registrar]	______	Oct 6, 2025

ACKNOWLEDGEMENTS

First and foremost, I extend my deepest gratitude and praise to God Almighty for His abundant blessings and guidance throughout my internship journey, which enabled me to complete this program and submit this report successfully. I am sincerely grateful to my advisor, Mr. Bekele Kushu, for his invaluable guidance, insightful comments, and constructive advice during my internship and in the preparation of this report. My heartfelt thanks also go to Adama Science and Technology University (ASTU), particularly the Department of Civil Engineering, for providing me with a strong academic foundation and the opportunity to apply my theoretical knowledge in practical, real-world settings. I am profoundly grateful to the Engineering Corporation of Oromia (ECO) for providing me with the opportunity to learn, grow, and develop my professional skills beyond my initial expectations.

I extend my deepest appreciation to my beloved parents, Pastor Terefe Bango and Obse Kebeba, as well as my brothers, for their unwavering love, encouragement, and support throughout my journey. My sincere gratitude also goes to all the Shaggar One General Hospital's site employees of ECO and Gutema Firisa Contractor teams, especially Resident Engineer Tesfaye and Quantity Engineer Tokumma Jabessa, for their mentorship and willingness to share their time and expertise. Finally, I would like to thank Structural Engineer Marsimoyi T. and my course instructor, Structural Engineer Wendimu Tolessa, at ASTU, for their guidance and invaluable contributions to my professional growth, as well as their dedication to enriching my knowledge and skills in the field of civil engineering.

EXECUTIVE SUMMARY

This report presents a comprehensive overview of my three-month internship program carried out at the Shaggar One General Hospital Project, located at Gefersa Guje Construction Site. The project was managed by the Engineering Corporation of Oromia (ECO) as the consultant, with Shaggar City serving as the client, and Gutema Firisa Construction PLC, in joint venture with MCG Construction PLC, serving as the contractor. The primary goal of this internship was to bridge the gap between classroom learning and practical application, allowing me to gain real-world experience and develop problem-solving skills in a professional construction environment. During this period, I was exposed to the entire process of building construction, from site preparation and foundation work to material testing and inspection, architectural design layout review, and structural design management. I also gained hands-on experience in quantity surveying, quality control of construction materials, and coordination between engineers, supervisors, and laborers.

The report is structured into four main chapters: an introduction and background of the host organization, a detailed description of the tasks and responsibilities I carried out, the benefits and professional growth gained from the internship, and a final section with conclusions and recommendations. This internship significantly enhanced my technical expertise, workplace communication skills, and leadership abilities, while building my confidence in solving real-world engineering challenges. Overall, the experience was invaluable in preparing me for my future career as a civil engineer, as it demonstrated the importance of integrating theoretical knowledge with practical fieldwork to deliver high-quality and sustainable construction solutions.

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3D	Three-Dimensional
AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ABQCS	As-Built Quantity Comparison Sheet
ACI	American Concrete Institute
API	Application Programming Interfaces
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
ASTU	Adama Science and Technology University
AutoCAD	Automatic Computer-Aided Design
B+G+4	Basement plus Ground floor plus four-story floor
BASF	Badische Anilin-und Soda-Fabrik Construction Chemicals
BaTCoDA	Building and Transport Construction Design Authority
BBS	Bending Bar Schedule
BIM	Building Information Modeling
BMSH	Burayu Menagesha Shaggar Hospital
BOQ	Bill of Quantity
BS EN	British Standard European Norm
BSc	Bachelor of Science
CAD	Computer-Aided Design
CBR	California Bearing Ratio
CC	Carbon Copy
CEng	Civil Engineering
CQA	Construction Quality Assurance
CW	Civil Works
DB	Design-Build
DBB	Design-Bid-Build
DIC	Drug Information Center
E.C	Ethiopian Calendar
EBCS	Ethiopian Building Code Standards
ECO	Engineering Corporation of Oromia
EPA	Environmental Protection Authority
ERA	Ethiopian Roads Authority
ESIA	Environmental and Social Impact Assessment
ETABS	Extended Three-dimensional Analysis of Building Systems
ETB	Ethiopian Birr
FF	Fixed Face (a wall that is restrained and has significantly less flexural movement)
FIDIC	Fédération Internationale Des Ingénieurs-Conseils (International Federation of Consulting Engineers)
G.C	Gregorian Calendar
G+0	Ground floor only
G+1	Ground floor plus one floor
BB	Basement Beam
GCC	General Condition of Contract
GFC	Gutema Firisa Construction
HCB	Hollow Cement Block
HVAC	Heating, Ventilation, and Air Conditioning

HYD	High-Yield Deformed Steel
IS	Indian Standard (Code of Practice for Plain and Reinforced Concrete)
ISO	International Organization for Standardization
JV	Joint Venture
KOICA	Korea International Cooperation Agency
kPa	Kilo Pascal
LSD	Limit State Design Method
MCG	MCG Construction PLC; Used as a name, it’s not an acronym
MDD	Maximum Dry Density
MEP	Mechanical, Electrical, and Plumbing
MHB	Main Hospital Building
MMP	Materials Management Plan
MoC	Ministry of Culture and Sport (Ethiopia)
MoM	Minutes of Meetings
MS	Microsoft
MVP	Minimum Viable Product.
NCB	National Competitive Bidding
NF	Near Face/Free Face (unrestrained or "soft" face of the wall)
OCC	Oromia Construction Corporation
OCTG	Oil Country Tubular Goods pipes
OMC	Optimum Moisture Content
OSHA	Occupational Safety and Health Administration.
OWWDSE	Oromia Water Works Design and Supervision
PBEE	Performance-Based Earthquake Engineering
PPC	Portland Pozzolana Cement
PDS	Project Delivery System
PGA	Peak Ground Acceleration
PLC	Private Limited Company
PPE	Personal Protective Equipment
PtD	Prevention through Design
QIS	Qualified Internship System
QMS	Quality Management System
RC	Reinforced Concrete
RE	Resident Engineer
RFI	Request for Information
RPC	Running Payment Certificate
SAFE	Slab Analysis by Finite Element
SAP2000	Structural Analysis Program 2000
SBD	Standard Bidding Document
SC	Shaggar City
SCC	Specific Condition of Contract
TD	Tender Dossier
ULS-DM	Ultimate limit state (Limit state of collapse) Design Method
UNICEF	United Nations International Children’s Emergency Fund
USD	Ultimate Strength Design Method
VAT	Value Added Tax
VO	Variation Order
W.B	World Bank
WREN	Water Resource Engineering
WSD	Working Stress Design Method

CHAPTER ONE

INTRODUCTION TO THE INTERNSHIP PROGRAM

1.1. Company Backgrounds and Descriptions of Project Stakeholders

1.1.1. The Consultant of the Project, Engineering Corporation of Oromia (ECO)

The Engineering Corporation of Oromia (ECO), formerly known as Oromia Water Works Design and Supervision Enterprise (OWWDSE), is a state-owned consulting firm established under Regulation No. 214/2020 [1]. Headquartered in Akaki Kality, Addis Ababa (Finfinne), ECO has over 15 years of experience delivering multidisciplinary engineering services across Ethiopia and internationally, including in Djibouti. With a workforce of 1,191 professionals and a fleet of over 145 vehicles and machines, ECO has successfully completed more than 142 projects. Backed by a registered capital of one (1) billion ETB, the corporation provides comprehensive services in study and design, construction supervision, contract administration, and engineering laboratory testing [2].

ECO was founded by the Oromia Regional Government as part of a strategic initiative to strengthen regional autonomy in infrastructure development. It operates alongside Oromia Construction Corporation (OCC), the region's dedicated public contractor, with both entities headquartered in the same building in Akaki Kality. This integrated model enables Oromia to independently manage large-scale infrastructure projects, ranging from irrigation and dam construction to public buildings, roads, and real estate development, without relying solely on external firms. Through this collaboration, ECO and OCC have become instrumental in meeting the region's growing demand for sustainable infrastructure, while promoting technical excellence and regional self-reliance [3].

Figure 1.1 ECO Headquarters, Akaki Kality, Finfinne (Addis Ababa).

Table 1.1 Engineering Corporation of Oromia's Major Fields of Services [4].

The Study & Design of	Construction Supervision of	Survey and Drafting for	Project Management of	Laboratory Service For
• Water resources, hydrology and hydraulics • Dams, irrigation and drainage • Sewerage disposal and industry (environment issues) • Different source of energy • Urban planning rural land planning • Watershed management • Transportation, roads and building • Geological & Geotechnical, • Mineral Resource Exploration & Feasibility Study	• Water supply schema construction • Irrigation & drainage systems construction • Water wells drilling & construction • Water & waste water treatment plant construction • Water storage facilities; • Pumping (water) station construction; • Bridges and accessory roads • Source of power/ Energy construction • Road and Building construction	• Conduct all surveying and Performs survey of built projects • Prepares land survey on project areas for road and water related works, • Prepares topographic maps from field survey data. • Makes linked drawings from sketches produced by engineers and architects.	• Providing detail plans and specification of how to achieve the projects goals; • Co-ordination of activities, resources and plans • Reporting: keeping stakeholders and clients informed of project; progress, • Preparation of progress report, Preparation study and design reports and submission • Preparation of payment certificate; • Preparation of Contract Document and Administration of Contract	• Water Quality Test & Analysis; • Soil Fertility Test & Analysis • Soil & Rock Material Test & Analysis; • Construction Material Test & Analysis • Geochemical Test & Analysis

1.1.1.1. Engineering Corporation of Oromia Quality Policy

Engineering Corporation of Oromia (ECO) is committed to deliver confident high quality professional consultancy services to satisfy the needs and expectations of its relevant internal and external interested parties through effective and efficient study and design, contract administration and construction supervision, capacity building and result oriented research for better way of life in accordance with the requirement of ISO 9001:2015 standards considering risks and opportunities with regard to its context, aligning the quality management system with its strategic direction of continual improvement by reviewing measurable quality objectives and updating it to implement the policies and procedures [4].

ECO strives to support the national efforts for social and economic development by providing reliable services for its national and international customers. Ensure the quality policy and quality objectives have been set and are maintained as part of the QMS internal auditing, monitoring, and management review processes, in order to enhance customer satisfaction.

ECO is dedicated to ensuring that this policy is determined, communicated, and implemented throughout the organization and any other interested parties; under the top Management's ultimate responsibility, with regular reporting and communication of the status and effectiveness at all levels [4].

1.1.1.2. Engineering Corporation of Oromia's Mission, Vision, and Values

Mission

To augment the economic development of the region and the country in stabilizing engineering service market prices, promoting excellence in engineering and construction management consultancy services, and building a sound financial base to sustain its mission by providing high-quality, reliable, cost-effective, and high-tech engineering services in studies, design, and construction management services [2].

Vision

ECO aspires to be one of the most innovative and reliable engineering services providers in Africa by 2030 G.C [2].

Values:

- Excellence in all things we do (Consultancy services)
- Make a valuable difference to our stakeholders
- Considerate, flexible, and responsive to ensure Client satisfaction
- Reliable and trustworthy, integrity and ethics
- Corporate Social Responsibility

The Engineering Corporation of Oromia (ECO) has been involved in several high-impact projects across Ethiopia. Some of its most notable works include the Ethiopia to Djibouti Trans-boundary Water Supply Project, which enhances regional water access, and the Arjo-Didessa Dam Project, a major infrastructure effort spanning multiple administrative zones in Oromia. ECO also played a key role in urban development through projects like the Oromia Media Complex Building and the Supreme Court of Oromia Building, both located in Addis Ababa (Finfine) and designed with cultural and architectural significance in mind. In the transport sector, the Gelan Asphalt Concrete Road Project and Adele Road Project have improved connectivity within the region. Additionally, the Negelle Town and Surrounding Villages Water Supply Project has brought clean water to over half a million people and nearly two million livestock in the Guji Zone. These projects reflect ECO's broad expertise in engineering, environmental planning, and infrastructure development [2].

1.1.2. The Contractor of the Project, Gutema Firisa Construction PLC JV with MCG Construction PLC

Due to the complexity of the project and the difficulty in meeting the tender requirements individually, Gutema Firisa Construction PLC and MCG Construction PLC entered into a Joint Venture (JV) agreement. This collaboration enabled them to combine their resources, expertise, and capabilities to meet the bid criteria as a single contractor. The joint venture was formed with the purpose of sharing resources, responsibilities, risks, and profits associated with the project. As a result, the JV successfully won the tender and subsequently signed the contract agreement with the client on May 13, 2024 G.C.

Gutema Firisa Construction is a well-established, private engineering firm based in Ethiopia, licensed under Ethiopian commercial law since 2000 E.C. The company operates primarily in civil engineering and infrastructure development, including roads and bridges, and has grown into a competitive Class One (1) Building Contractor. Headquartered in Gerji Mabrat Hail, Bole, Finfine (Addis Ababa), and it's situated in Burayu town to provide general construction works and services. It is led by General Manager Engineer Gutema Firisa, whose vision and experience have shaped the firm's steady rise. With a strong organizational structure, skilled professionals, and modern construction equipment, the company has contributed to major national development goals and partnered with international agencies such as the World Bank, UNICEF, and KOICA [5].

Gutema Firisa Constructor has contributed to several impactful projects that support local development and infrastructure in Ethiopia. One notable example is the Nekemte Bus Terminal Project, which enhances regional transportation and urban mobility, particularly in western Oromia. The company has also been involved in various road and bridge construction projects, improving access to remote areas and facilitating trade and social services. Through its partnerships with organizations like the World Bank, UNICEF, and KOICA, Gutema Firisa Construction has participated in development initiatives that often include community-focused infrastructure, such as schools, health centers, and water systems. These projects not only create jobs during construction but also leave lasting benefits by strengthening public services and regional connectivity [5].

MCG Construction PLC is a privately held civil engineering and infrastructure development firm headquartered on Senegal Street in Addis Ababa, established in August 2013 G.C. Initially classified as a Grade 5 General Contractor, the firm rapidly achieved Grade 1 status through its proven execution of high-complexity projects. MCG organizes its operations through dedicated divisions in Engineering, Construction Operations, and Support Services, often outsourcing non-core segments to boost efficiency and cost-effectiveness [6].

With a clear vision to become a leading Ethiopian and East African contractor, MCG emphasizes integrity, client satisfaction, environmental care, innovation, and project safety in all its endeavors. The company's portfolio includes over 50 completed infrastructure and building projects nationwide, while currently managing more than 15 active sites, ranging from road and bridge construction to institutional facilities and utility systems. Noteworthy projects include Chereti-Gorobekaksa-Gorodamole Road Lot III under the Ethiopian Roads Administration, which delivered 83km of roadway and 11 bridges, and multiple Rural Transformation Center developments for Oromia Industrial Parks [6].

1.1.3. Client of the Project, Shaggar City Health Office

The Shaggar City Administration, established in 2022, is a newly formed urban governance structure that consolidates six towns surrounding Addis Ababa: Sebeta, Burayu, Legatafo, Lededadi, Sululta, and Gelan into a unified metropolitan entity. This initiative aims to address disparities in infrastructure, service delivery, and urban planning by creating a shared development framework across the region. Within this context, the construction of Shaggar One General Hospital at the Gefersa Guje site in Burayu City represents a strategic response to the growing demand for accessible and comprehensive healthcare services in the area [7].

Burayu, as one of the rapidly urbanizing towns within Shaggar City, has experienced significant population growth, which has outpaced the availability of essential public services, particularly in health. The new hospital is designed to fill this critical gap by offering a wide range of medical services to residents of Burayu and neighboring districts. Its location at Gefersa Guje is especially important, as it lies at a junction that connects several rural and per-urban communities, making it a vital hub for emergency care, maternal health, and disease prevention [7].

The project aligns with Shaggar City's broader development goals of improving quality of life, reducing health disparities, and fostering inclusive urban growth. This hospital project can be highlighted as a model of integrated urban planning and social infrastructure investment where engineering, governance, and public health intersect to meet the needs of a transforming city.

1.2. Statement of the Problem

In many construction projects across Ethiopia, there is a consistent gap between theoretical knowledge acquired in classrooms and the practical skills required on-site. Most students graduate without hands-on experience in managing real-world challenges such as material estimation, scheduling, safety management, and site supervision. This lack of exposure limits their readiness to join the industry effectively. My internship at Gefersa Guje, Shaggar One General Hospital, was intended to address this gap by providing an opportunity to observe and participate in actual construction processes, bridge the theory-practice divide, and understand the organizational and technical systems involved in project execution.

1.3. Objectives of the Internship

As part of the ASTU revised curriculum, the internship program is designed to give every engineering student a chance to gain real-world experience before graduation. Its goals are to bridge the gap between academic learning and industry demands by making students more employable, equipping them with practical knowledge, and connecting universities more closely with industry. The program also aims to foster research and innovation, encourage business development skills, and ensure that graduates are ready to meet the evolving needs of the labor market [8].

For my internship, my main goal is to apply what I've learned in the classroom to real civil engineering projects. I'm particularly focused on gaining hands-on experience in areas like site surveying, materials testing, structural analysis, cost estimation, scheduling, and quality control. I also want to deepen my technical skills using tools such as AutoCAD, MS Project, and Quantity Surveying methods. I plan to follow each phase of the project lifecycle, from design review and procurement to on-site execution, while learning best practices in health and safety, environmental standards, and regulatory compliance. Beyond the technical side, I'm aiming to strengthen my teamwork, communication, and project management skills by actively participating in project activities and learning from professionals in the field.

1.4. Scope of the Internship Program

The scope of my internship at the Shaggar One General Hospital project was deliberately broad, allowing me to engage with every major phase of a civil engineering venture, from the initial design and procurement stages all the way through to on-site execution and close-out. I spent time in the consultant's office learning how architectural, structural, sanitary, electrical, and mechanical drawings are prepared and coordinated, then watched as those plans were translated into bills of quantities and cost estimates. On site, I rotated through key tasks: surveying and setting out the building footprint, performing material tests in the field and in the lab, supervising excavation and foundation works, and observing concrete placement and curing procedures. I also shadowed the project team during progress meetings, gaining insight into scheduling with MS Project, quality-control protocols, and health and safety inspections. By assisting with quantity take-offs, updating as-built drawings in AutoCAD, and logging site observations, I was able to connect the dots between theory and practice. This hands-on exposure to both office and field activities gave me a comprehensive view of how multidisciplinary teams collaborate to deliver a complex infrastructure project on time, on budget, and in compliance with regulatory and environmental standards.

1.5. Outputs Expected

The internship program is designed to deliver meaningful, hands-on experience that bridges academic learning with the realities of professional work. One of its key outcomes is to increase students' employability by helping them understand how engineering knowledge is applied in real-world settings. Through the internship, students become familiar with the structure, systems, and processes of the industry, gaining a clearer view of how organizations function day-to-day. It also helps graduating students better understand the world of work and workplace expectations. By transferring their theoretical knowledge into practice, interns not only sharpen their technical abilities but also build critical soft skills like teamwork, communication, and adaptability. The program also strengthens the trust and professional cooperation between universities and industry, creating long-term partnerships that benefit both sides [9].

1.6. Significance of the Internship Program

As per the ASTU curriculum, the Bachelor of Science BSc. requires a two-summer semester internship after at 6th semester of the academic curriculum [10]. The Internship-I program is taken after completing the 3rd year (6th semester), and it's believed to play a pivotal role in transforming classroom theories into professional know-how by placing students at the heart of live civil engineering projects. It empowers aspiring civil engineering concepts, ensuring that students do more than learn theory; they apply it in real-world settings. By embedding three months of supervised, on-site experience into the seventh semester, the program sharpens technical competencies like surveying, materials testing, and cost estimation, while also instilling industry norms for health and safety, environmental compliance, and quality control. It cultivates essential soft skills: teamwork, communication, problem-solving, and professional ethics. So graduates step into the labor market both confident and capable. Beyond individual growth, the internship strengthens the Adama Science and Technology University's ties with industry partners, laying a foundation for collaborative research, knowledge transfer, and a reliable talent pipeline that ultimately elevates Ethiopia's engineering standards and economic competitiveness [8].

1.7. Organization of the Internship Report

This report follows the ASTU guidelines to present a clear, logical account of my internship journey. Chapter One (Introduction) covers the host organization's profile, the problem statement, and the program's objectives, scope, and significance, concluding with an overview of the report's structure. Chapter Two (Overall Internship Experience) narrates how I joined the project, describes the host company and its assigned works, and details office and site-based tasks. Chapter Three (Overall Benefits) analyzes challenges encountered, lessons learned in communication and leadership, ethical insights, and the transformation of theoretical knowledge into hands-on skills. Finally, Chapter Four concludes and offers recommendations for future interns and program enhancements. Each chapter opens with its purpose and closes with key takeaways, guiding the reader smoothly from context to reflection [8].

CHAPTER TWO

OVERALL INTERNSHIP EXPERIENCES

2.1. Internship Placement Process

After the announcement to find a suitable company for my internship, I used my semester break to search for an organization where I could gain valuable experience and broaden my practical knowledge. During this time, I observed several construction projects near my family's home and learned that a general hospital project was being built in our zone by the Shaggar City Health Bureau. Curious to learn more, I visited the site and located the offices of the Engineering Corporation of Oromia (ECO) and Gutema Firisa Construction PLC. Carrying an official referral letter from my university, I met with the project's Resident Engineer, Mr. Tesfaye Erro, and submitted my application. After carefully reviewing my credentials and the internship requirements, the company (ECO) approved my request to join the project. Within three days, I was issued an official acceptance letter, which was carbon copied (CC) to the contractor, the consultant (ECO), and me as the student. I promptly submitted this letter to the Department of Civil Engineering at Adama Science and Technology University (ASTU) for final registration and approval. Upon completing my third-year second semester, I returned home for the summer break, and **on June 9, 2025**, I officially began my first internship program in line with the ASTU curriculum.

2.2. Description of Project Undertaken During the Internship

In response to the rapidly growing population in Shaggar City, Oromia Region, and the rising demand for accessible healthcare services, the city administration launched a phased hospital development initiative. The first phase of this initiative, referred to as the "Shaggar One General Hospital" project, was endorsed by a dedicated steering committee. Upon recognizing the urgency and strategic importance of the project, the committee presented the proposal to the President of Shaggar City, who subsequently approved it and allocated the necessary funds in coordination with the city's budget office [7]. Following this, the Shaggar City Health Office engaged a group of professionals to prepare a conceptual design outlining the scope and functional requirements of the hospital. To formalize the process and ensure technical soundness, the office makes an agreement with the Engineering Corporation of Oromia (ECO) as the consultant to formalize the design and transform the concept into a feasible and comprehensive design plan. ECO meticulously planned and designed the hospital based on the client's requirements, addressing potential constraints such as land availability and infrastructure integration.

The site selection was a critical aspect of the project, as the goal was to minimize the displacement of residents while securing adequate space for a full-fledged hospital. A forested area near Mount Menagesha, in close proximity to Kellaa in Burayu City, was ultimately chosen. This location provided several advantages: it reduced the need for demolition of existing homes, offered readily available open land, and was strategically located at the convergence of major transportation routes connecting **Addis Ababa**, **Burayu, Holota**, and **Melkaa Nanno at Kellaa transit**. As such, the site ensures high accessibility and connectivity for surrounding urban and rural communities. The final design of site plan encloses a **2.5 hector** site within a perimeter fence and allocates space for an: Administration Building, Main Hospital Building, Community Pharmacy, Power Station with backup generators, Ambulance and parking bay, Green areas, Sanitation Pump House and waste-management zones, a Telecommunication Station, Four distinct entrances (Main, Emergency, Pedestrian, Supportive), and Future-expansion plots for Staff Housing, and Supportive facilities [64]. All of these components of the project were laid out to ensure holistic care, smooth patient and service flow, and sustainable infrastructure for Shaggar City’s health development.

Figure 2.1 Site Plan of Shaggar One General Hospital Project.

The architect's 3D rendering of Shaggar One General Hospital (Figure 2.2) demonstrates a carefully optimized orientation and set of sustainable design features that fully comply with modern civil-engineering standards. The building's long axis is rotated 15° east of true north to capture gentle morning sunlight into patient wards and clinical areas, in accordance with ASHRAE 90.1 daylighting recommendations [11]. Computational wind-rose analysis guided the placement of operable vertical louvers and stack-venting atria, enabling natural cross-ventilation and reducing mechanical cooling loads as per ISO 16814 [12]. South-facing overhangs and brise-soleil provide solar shading against high-angle summer sun, while low-emissivity glazing balances daylight admission with thermal performance, meeting the energy-efficiency requirements of the Ethiopian Urban Planning and Building Proclamation [13]. The stepped massing toward the north minimizes heat gain on west façades, and east-oriented public circulation routes improve way-finding and patient comfort. Together, these 3D alignment strategies and material choices not only satisfy but exceed the standards for climate-responsive hospital architecture.

Figure 2.2 3D Rendering of Shaggar One General Hospital showing sustainable design features.

2.3. Detailed Account of My Internship Activities and Responsibilities

2.3.1. Office Works

2.3.1.1. Contract Administration

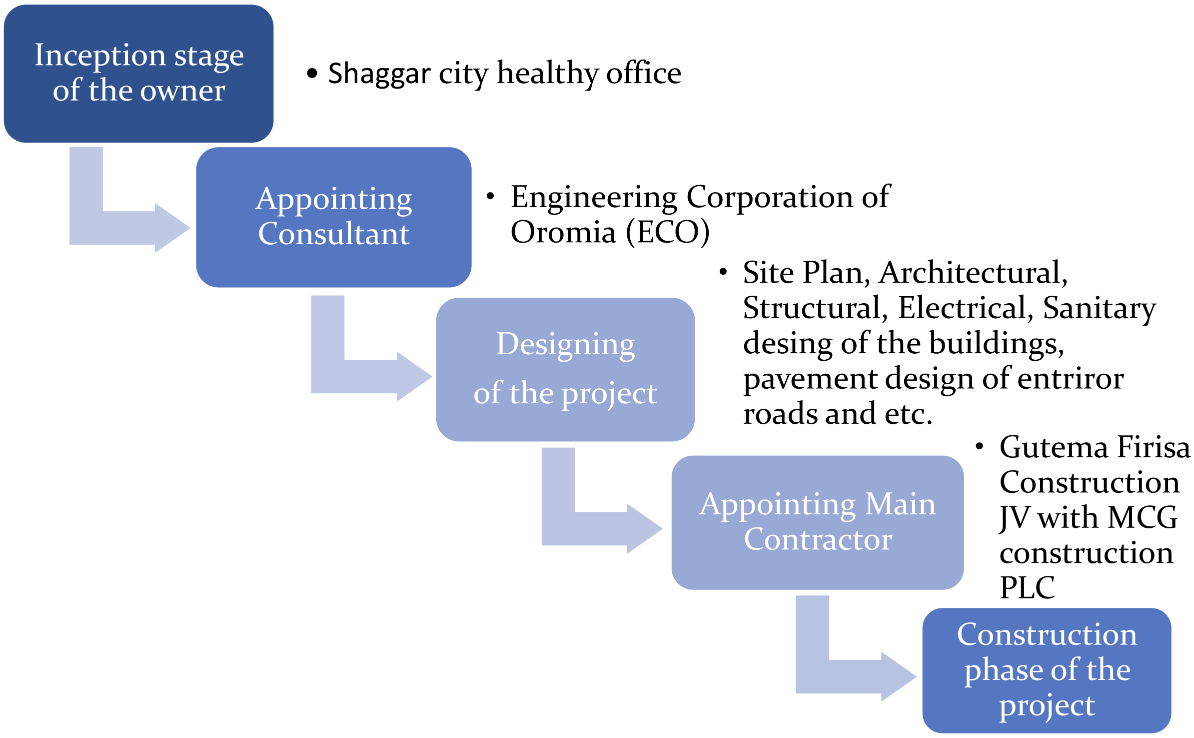
To begin my discussion of the office work experiences during my internship, it is essential to explain the contract system adopted for the Shaggar One General Hospital Project. The contract delivery system refers to the strategic decisions made by the client in selecting how the design and construction services are structured, procured, and executed. For this particular project, a Single Prime Contract approach was selected which is the one of the most common models used in large-scale public works. In this system, the Shaggar City Health Office, as the client, entered into ***separate contractual agreements*** with the consultant (Engineering Corporation of Oromia) and the contractor (Gutema Firisa Construction PLC in Joint Venture with MCG Construction PLC). However, the consultant and the contractor themselves do not have a direct contractual relationship; instead, they coordinate their duties through the client.

In terms of financial arrangements, the project is implemented using a Unit Price Method under a traditional Design-Bid-Build (DBB) model [14]. This payment method allocates both time and cost risks between the client and the contractor. Any significant deviations in quantities or market price fluctuations are handled by adjusting the unit rates, ensuring a fair distribution of financial impact. This system also demands accuracy and foresight in the Bill of Quantities (BOQ) and quantity surveying processes, which play a pivotal role during project implementation and payment certification.

The Project Delivery System (PDS) used for this project is **Outsourced Design-Bid-Build** (DBB) [15]. Under this approach, the design and construction responsibilities are clearly delineated between separate entities. First, the client hired ECO to complete all feasibility studies, site selection analysis, and detailed design documentation. Once the design phase was completed and approved, the construction contract was awarded through a public bidding process. This traditional delivery method promotes specialization; ECO focused solely on professional design and supervision, while the contractor concentrated on physical execution.

In the following chart, I present a summarized overview of the formal stages involved in the construction of the Shaggar One General Hospital project. This visual representation outlines the key phases from initial inception and stakeholder engagement to design development, contractor appointment, and execution of construction works. It reflects the collaborative roles of the client, consultant, and contractor, and highlights the structured process that guided the project from concept to implementation [15].

Table 2.1 Construction and Contract System (DBB Model).



During the pre-construction phase, the Shaggar City Health Office made an official agreement with ECO to initiate the early groundwork of the project. ECO conducted a full feasibility study, including site surveys, subsoil exploration, and geotechnical investigations using borehole methods to determine the soil's bearing capacity, which was confirmed to be **300 KPa** [16]. These early-stage studies were crucial for verifying the technical viability of the selected site at Gefersa Guje and establishing the foundation for the structural design. Based on these findings, ECO prepared comprehensive architectural, structural, and civil engineering designs that reflected both the technical requirements and the functional expectations of a modern general hospital.

Following the completion of the design phase, ECO developed a detailed and priced BOQ along with comprehensive technical specifications, referencing key national standards such as BaTCoDA 1994, MoC 2014, and ERA Standard 2002 [17], [18], [19]. These documents were packaged as part of the Tender Dossier used for contractor selection. The procurement process was conducted transparently, following the Standard Bidding Document (SBD) for procurement of works under National Competitive Bidding (NCB), through a public bidding mechanism where interested firms submitted both technical and financial proposals [20]. This stage was critical to identify a capable construction firm with the necessary experience, equipment, and personnel.

The winning bidder was Gutema Firisa Construction PLC JV with MCG Construction PLC, which demonstrated both the technical capacity and the most competitive financial offer for the implementation of the project. The evaluation process was rigorous and compliant with the public procurement regulations of Ethiopia. Upon selection, a Letter of Acceptance was issued, followed by the Notice to Proceed, officially marking the start of the construction phase. The contract, signed under the reference number **BMSH/G/Guje State/SC/CW/0213/2016**, had a total value of **ETB 3,678,021,899.63 (Three billion, six hundred seventy-eight million, twenty-one thousand, eight hundred ninety-nine birr and sixty-three cents)**, inclusive of VAT, and specified a 36-month duration with a 365-day (during which the contractor must repair defects that appear after project completion) defects liability period by 5% (Retention Monies) of the contract price [21].

The cover page of the official Contract Agreement for the Shaggar One General Hospital project prominently features the logos of Shaggar City Administration and the Oromia Health Bureau, symbolizing the joint commitment to advancing public health infrastructure. It also includes a rendered 3D architectural visualization of the hospital, reflecting the project's design intent and scale. Key project details are clearly presented, including the project title, client, contractor, consultant, procurement reference number, and site location. This document, formally confirmed by the contractor, was stamped by Gutema Firisa Construction PLC in May 2024, serves as the foundational agreement guiding the construction works at Gefersa Guje Sub-City. The Shaggar City Health Office, located in Mamo Area, Finfinne, acts as the client and central coordinating body for this transformative healthcare initiative.

The official contract document for the Shaggar One General Hospital project is printed in hard copy and securely archived at multiple locations: the site office, the head offices of Shaggar City Health Office, the Engineering Corporation of Oromia (ECO), and the contractor, Gutema Firisa Construction PLC, in joint venture with MCG Construction PLC. This comprehensive document includes the letter of forwarding addressed to the contractor, the formal agreement form, and all relevant **general conditions of contract** (GCC) comprising the internationally recognized **89 articles/clauses** [22], along with the **specific conditions of contract (SCC)** duly adapted to align with the Ethiopian legal and regulatory framework. It also contains the complete Bill of Quantities (BOQ) for each work item, along with a grand summary of the project's estimated costs. The final section of the document features an appendix that includes recognitions, awards, contractor nationality, certificates of completed projects by Gutema Firisa and MCG Construction PLC, and other essential attachments. The document concludes with a detailed reference section, ensuring transparency and traceability throughout the project lifecycle.

Table 2.2 Contract Document Cover Page.

SHAGGAR

CONTRACT AGREEMENT
FOR
THE CONSTRUCTION OF SHEGGER ONE
GENERRAL HOSPITAL

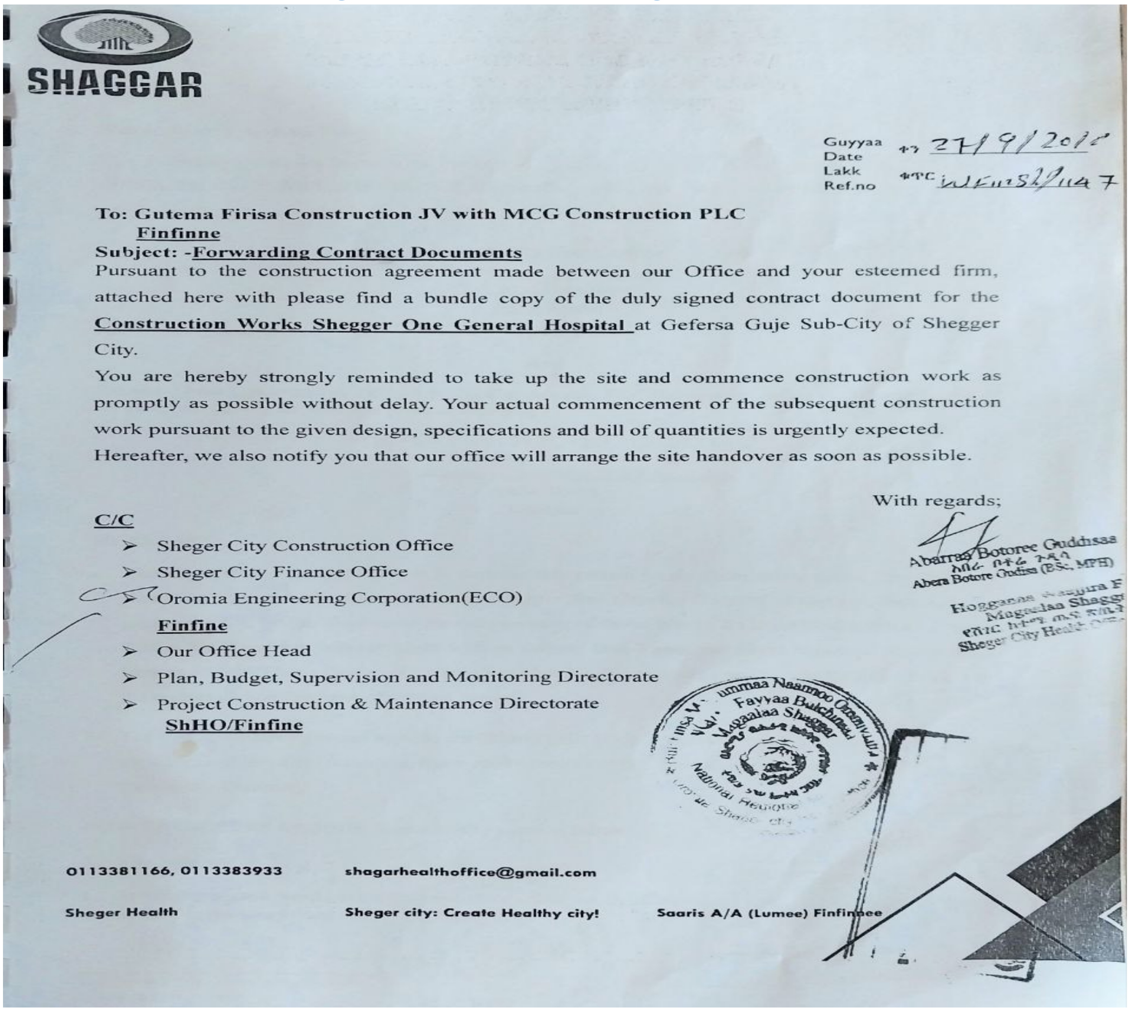
Project Name: *Construction of Shegger One General Hospital Project*
Client: *Shegger City Health Office*
Contractor: *Gutema Firisa Construction PLC JV with MCG Construction PLC*
Consultant: Engineering Corporation of Oromia (ECO)
Procurement Reference Number: *BMSH/G/Guje State/SC/CW/0213/2016*
Location: *Gefersa Guje Sub-City*

May, 2024
Sheger City Health Office
Mamo Area, Finfinne

The letter shown below is an official correspondence from the Shaggar City Health Office, addressed to Gutema Firisa Construction PLC JV with MCG Construction PLC. It confirms the formal signing of the contract agreement for the Shaggar One General Hospital project at

Gefersa Guje Sub-City and authorizes the contractor to commence construction activities. It underscores the urgency of commencing construction in alignment with the approved design, specifications, and bill of quantities. It also reflects the administrative coordination between client and contractor, reinforcing the procedural integrity of public infrastructure development.

Table 2.3 Official Contract Agreement Letter Authorizing Construction.



SHAGGAR

Guyyaa / Date ቀን 27/9/2018

Lakk / Ref.no ቁጥር

To: Gutema Firisa Construction JV with MCG Construction PLC
Finfinne
Subject: -Forwarding Contract Documents

Pursuant to the construction agreement made between our Office and your esteemed firm, attached here with please find a bundle copy of the duly signed contract document for the **Construction Works Shegger One General Hospital** at Gefersa Guje Sub-City of Shegger City.

You are hereby strongly reminded to take up the site and commence construction work as promptly as possible without delay. Your actual commencement of the subsequent construction work pursuant to the given design, specifications and bill of quantities is urgently expected.

Hereafter, we also notify you that our office will arrange the site handover as soon as possible.

With regards;

Abarraa Botoree Guddisaa
አበራ ቦቶሬ ጉዲሳ
Abera Botore Gudisa (BSc, MPH)

C/C

- Sheger City Construction Office
- Sheger City Finance Office
- Oromia Engineering Corporation(ECO)

Finfine

- Our Office Head
- Plan, Budget, Supervision and Monitoring Directorate
- Project Construction & Maintenance Directorate

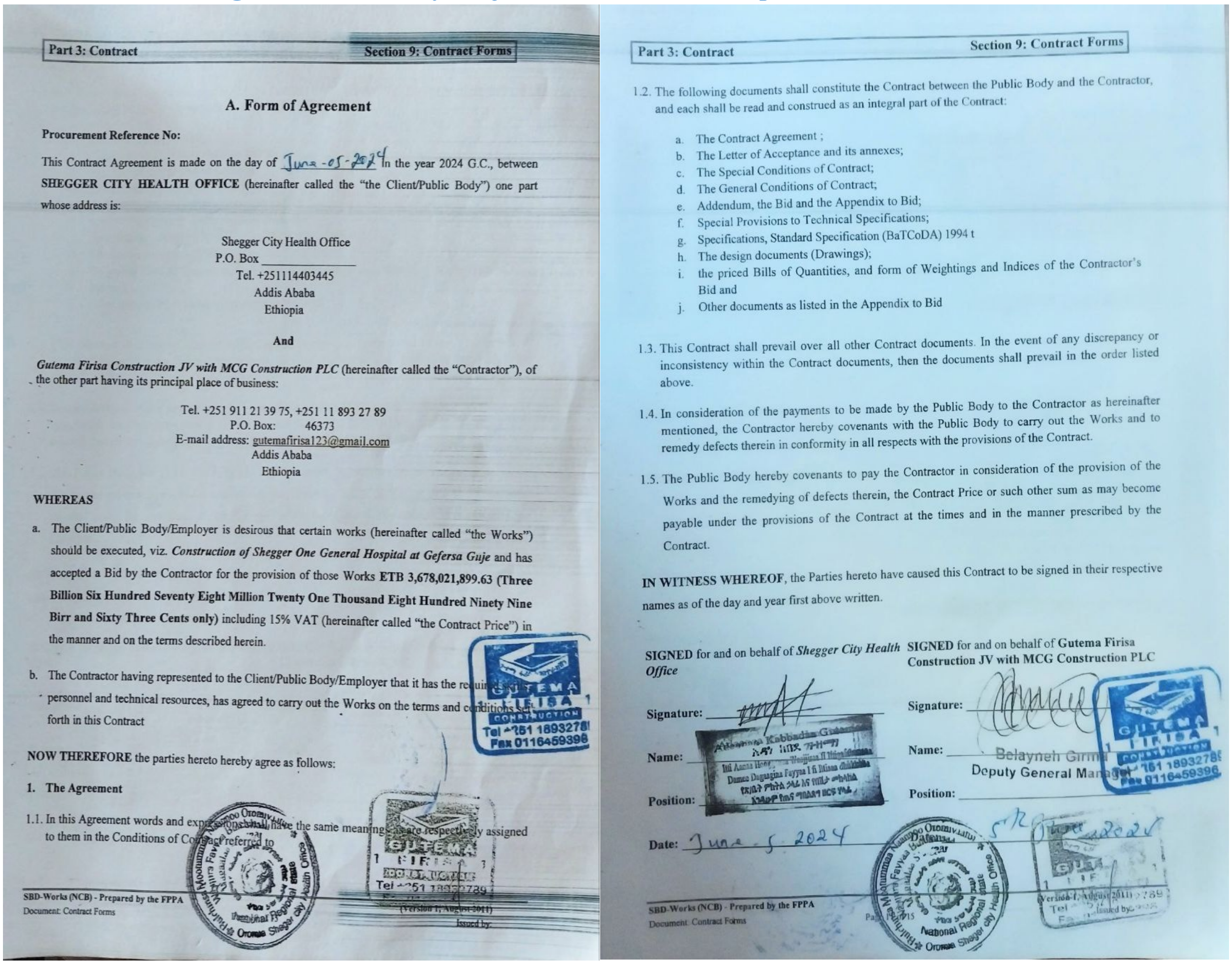
ShHO/Finfine

0113381166, 0113383933 shagarhealthoffice@gmail.com

Sheger Health Sheger city: Create Healthy city! Saaris A/A (Lumee) Finfinnee

The figure below presents the standardized Form of Agreement used for the Shaggar One General Hospital project, as issued by the Shaggar City Health Office. This form, found on the second page, then continues until the third page of the official contract document, adheres to Ethiopia’s civil code and reflects common legal frameworks used in public infrastructure contracts. While the general structure and clauses of the agreement are fixed and non-editable, project-specific details such as the contract date, client and contractor names, project title, contract sum, and duration are customized to suit the particular engagement. This standardized format ensures legal consistency, transparency, and enforceability across government-funded construction projects. Its use aligns with international best practices in contract administration, similar to FIDIC [23] and World Bank procurement templates, reinforcing the project's credibility and procedural integrity [24]. Both the Shaggar City Health Office and the contractor have officially stamped and signed these two pages, confirming mutual agreement and legal commitment to the project.

Table 2.4 Form of Agreement with Key Project Details under Ethiopian civil code.



Part 3: Contract — Section 9: Contract Forms

A. Form of Agreement

Procurement Reference No:

This Contract Agreement is made on the day of June-05-2024 in the year 2024 G.C., between **SHEGGER CITY HEALTH OFFICE** (hereinafter called the "the Client/Public Body") one part whose address is:

Shegger City Health Office
P.O. Box ____________
Tel. +251114403445
Addis Ababa
Ethiopia

And

Gutema Firisa Construction JV with MCG Construction PLC (hereinafter called the "Contractor"), of the other part having its principal place of business:

Tel. +251 911 21 39 75, +251 11 893 27 89
P.O. Box: 46373
E-mail address: gutemafirisa123@gmail.com
Addis Ababa
Ethiopia

WHEREAS

a. The Client/Public Body/Employer is desirous that certain works (hereinafter called "the Works") should be executed, viz. ***Construction of Shegger One General Hospital at Gefersa Guje*** and has accepted a Bid by the Contractor for the provision of those Works **ETB 3,678,021,899.63 (Three Billion Six Hundred Seventy Eight Million Twenty One Thousand Eight Hundred Ninety Nine Birr and Sixty Three Cents only)** including 15% VAT (hereinafter called "the Contract Price") in the manner and on the terms described herein.

b. The Contractor having represented to the Client/Public Body/Employer that it has the required skills, personnel and technical resources, has agreed to carry out the Works on the terms and conditions set forth in this Contract

NOW THEREFORE the parties hereto hereby agree as follows:

1. The Agreement

1.1. In this Agreement words and expressions shall have the same meanings as are respectively assigned to them in the Conditions of Contract referred to

SBD-Works (NCB) - Prepared by the FPPA
Document: Contract Forms
(Version 1, August 2011)
Issued by:

Part 3: Contract — Section 9: Contract Forms

1.2. The following documents shall constitute the Contract between the Public Body and the Contractor, and each shall be read and construed as an integral part of the Contract:

a. The Contract Agreement ;
b. The Letter of Acceptance and its annexes;
c. The Special Conditions of Contract;
d. The General Conditions of Contract;
e. Addendum, the Bid and the Appendix to Bid;
f. Special Provisions to Technical Specifications;
g. Specifications, Standard Specification (BaTCoDA) 1994 t
h. The design documents (Drawings);
i. the priced Bills of Quantities, and form of Weightings and Indices of the Contractor's Bid and
j. Other documents as listed in the Appendix to Bid

1.3. This Contract shall prevail over all other Contract documents. In the event of any discrepancy or inconsistency within the Contract documents, then the documents shall prevail in the order listed above.

1.4. In consideration of the payments to be made by the Public Body to the Contractor as hereinafter mentioned, the Contractor hereby covenants with the Public Body to carry out the Works and to remedy defects therein in conformity in all respects with the provisions of the Contract.

1.5. The Public Body hereby covenants to pay the Contractor in consideration of the provision of the Works and the remedying of defects therein, the Contract Price or such other sum as may become payable under the provisions of the Contract at the times and in the manner prescribed by the Contract.

IN WITNESS WHEREOF, the Parties hereto have caused this Contract to be signed in their respective names as of the day and year first above written.

SIGNED for and on behalf of ***Shegger City Health Office***	**SIGNED** for and on behalf of **Gutema Firisa Construction JV with MCG Construction PLC**
Signature:	**Signature:**
Name:	**Name:** Belayneh Girma, Deputy General Manager
Position:	**Position:**
Date: June 5 2024	

SBD-Works (NCB) - Prepared by the FPPA
Document: Contract Forms
Version 1, August 2011
Issued by:

On this contract form, under **1.2** it's the Contract between the Public Body and the Contractor is composed, in strict descending order of precedence, of the Contract Agreement, the Letter of Acceptance and its annexes, the Special Conditions of Contract, the General Conditions of Contract, any Addendum together with the Bid and its Appendix, the Special Provisions to the Technical Specifications, the Standard Specifications (BaTCoDA 1994), the design drawings, the priced Bills of Quantities (and Weighting and Index sheets), and any other documents listed in the Appendix to Bid; if any two or more of these documents conflict, the one appearing earlier in this list governs. Establishing this firm hierarchy ensures that the most critical terms, such as the Agreement itself and the Letter of Acceptance, always prevail, eliminates ambiguity, safeguards the parties' rights, and provides clear legal certainty throughout the project's execution.

The construction officially commenced on July 15, 2024, with site setting-out works initiated by the contractor under the oversight of ECO. From that point onward, ECO, acting as the resident consultant (Eng. Tesfaye, Resident Engineer), assumed the critical role of contract administrator, ensuring that the execution of the works adhered to the contract specifications, technical standards, and approved designs.

A key component of my office work during the internship involved observing and supporting the contract administration tasks carried out by ECO. These responsibilities included evaluating the contractor's requests for design modifications, checking progress reports, verifying payment certificates, and ensuring that all work complied with design drawings and technical specifications. Any proposed design modifications by the contractor were carefully reviewed by ECO's technical team and either approved, rejected, or revised based on their technical feasibility, cost implications, and alignment with the project's objectives.

The experience I gained through this part of my internship deepened my understanding of the dynamic interaction between design intent, construction realities, and contractual obligations. I also learned how critical it is for the consultant to balance quality assurance with timely approval processes, and how proper contract administration safeguards the interests of all stakeholders while guiding the project toward successful completion.

2.3.1.2. Quantity Surveying and Technical Documentation

Another major aspect of my office-based responsibilities was supporting the quantity surveying (QS) and documentation activities managed by ECO, the consulting firm. These tasks are at the heart of cost control, contract administration, and project planning. As part of the Quantity Surveying team, I had the opportunity to closely observe how the Bill of Quantities (BOQ) was organized, analyzed, and updated based on actual field progress and design changes.

In the beginning, I familiarized myself with the original priced BOQ, which had been developed during the design and tendering stages by the consultant. This document outlines detailed descriptions of work items, units of measurement, quantities, and corresponding unit rates. The BOQ serves not only as the contractor's pricing guide but also as a benchmark for measuring executed works during construction.

During my internship, I was given access to progress reports and payment certificate drafts. My task included cross-checking quantities of executed work against the BOQ and assisting in the preparation of quantity take-offs. These take-offs were typically extracted from architectural and structural drawings using manual calculation methods as well as software tools such as AutoCAD. I also learned how to apply appropriate formulas for calculating quantities of concrete, reinforcement bars, block work, plastering, excavation, and backfilling.

In addition to quantity take-offs, I was involved in reviewing the Request for Information (RFI) documents sent by the contractor to the consultant whenever there were design ambiguities or practical site constraints. My role was to check how these RFIs affected the BOQ, timelines, or specifications, and then observe how ECO's engineers responded to them. This process gave me insight into how technical documentation is updated and how field realities can influence originally estimated quantities.

Furthermore, I participated in the review and tracking of material submittals and approval processes. Contractors are required to submit technical specifications, datasheets, and compliance documents for every material they plan to use: from reinforcement bars and cement to electrical fixtures and HVAC components. My task involved organizing and labeling these documents and ensuring that they were filed correctly for review by the relevant discipline engineers. Once approved, these materials would be released for use on-site, and their respective costs would be reflected in the monthly interim payment applications.

I also assisted the quantity engineer in updating the running payment certificates (RPCs), which included calculating the value of completed work for each activity as per the BOQ and comparing that with the quantities certified for payment by the consultant. This was a critical activity that demanded both accuracy and accountability. Every miscalculation or inconsistency in quantities could lead to disputes or delays in payment processing. Another useful task I was part of was preparing As-Built Quantity Comparison Sheets, where the initially estimated quantities were compared with those measured on-site. These sheets help determine whether the actual work aligns with the design assumptions and are essential during variation order (VO) evaluations. This exposed me to practical aspects of cost management, especially how to handle variations, omissions, or additions that arise due to design changes or unforeseen site conditions.

2.3.1.2.1. Design Analysis and Quantity Take-off for the Community Pharmacy

As part of my practical engagement with Quantity Engineer Tokumma Jabessa, I was entrusted with the task of conducting a design analysis and preparing a comprehensive Bill of Quantities (BOQ) for a Community Pharmacy Building. This assignment provided a valuable opportunity to apply quantity surveying principles in a real-world context. Given the building's modest scale, a single-story (G+0) structure, it was well-suited for the limited timeframe available and served as an ideal example to include in this report.

The facility comprises several functional spaces, including a DIC Room/Head Office, Accountant's Office, Dispensing Waiting Area, Dispensing Pharmacy, Main Drug Store, Compounding Room, and Restroom. My process began with a thorough review of the architectural and structural drawings, focusing on plan views, elevations, and sectional details to gain a clear understanding of the spatial layout and intended use of each area. The following sections detail the methodology and outcomes of my quantity take-off and BOQ preparation.

2.3.1.2.1.1. Architectural Design of Community Pharmacy Building

Architectural working drawings are detailed technical drawings used in construction to show the design, dimensions, and materials of a building. They guide builders and engineers to accurately construct each part of the structure. It provides the detailed dimensions and material specifications needed for accurate quantity takeoff, which is a key task in quantity surveying. These drawings help quantity surveyors measure and estimate the cost of materials, labor, and other resources required for construction.

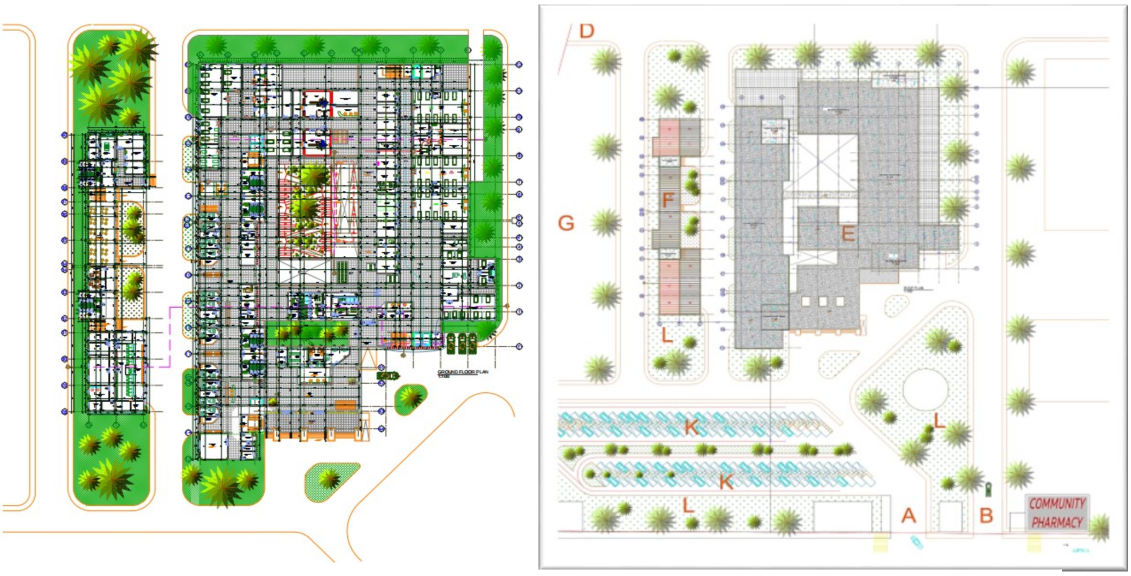
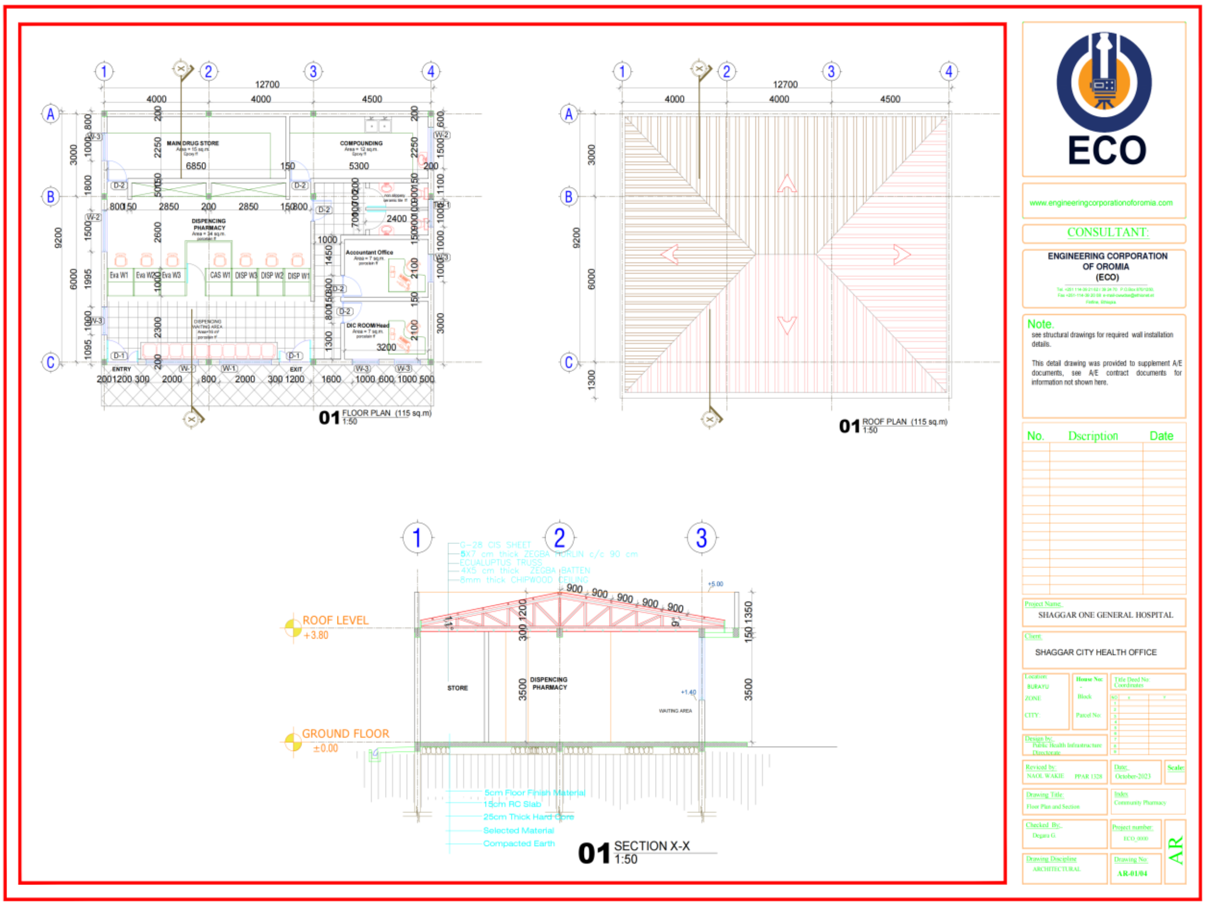


Figure 2.3 Architectural Layout and Ground Floor Plan for Administration and MHB



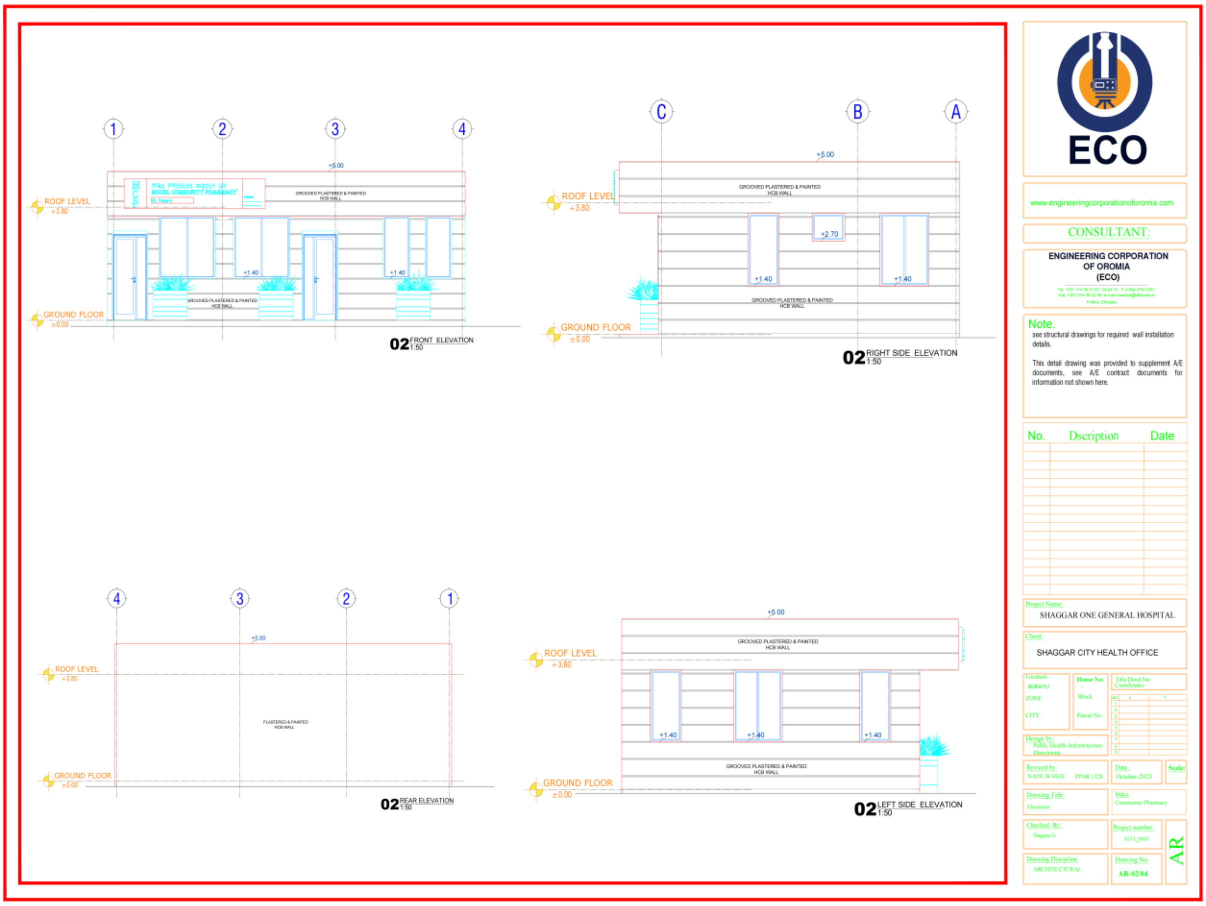
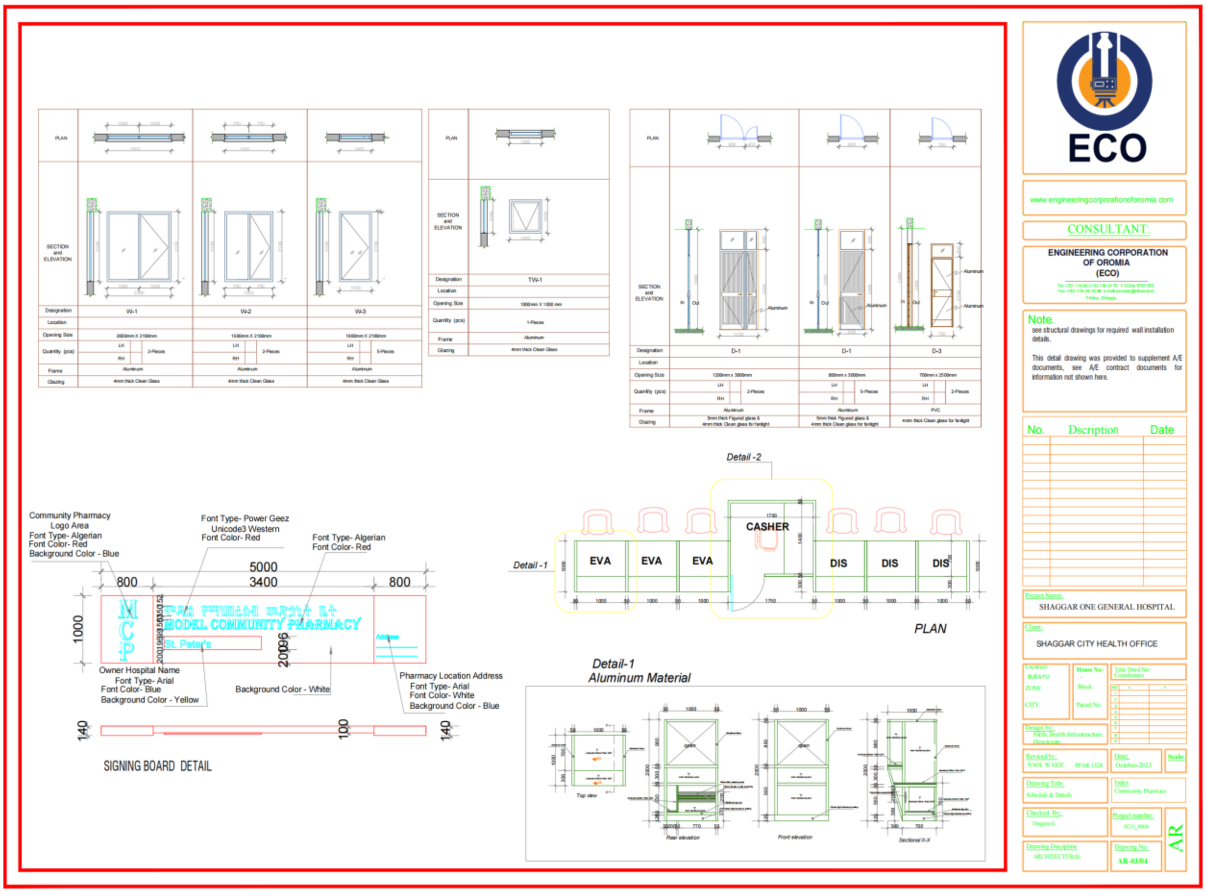


Figure 2.4 Floor, Roof, Section, and Elevation Views of Community Pharmacy.



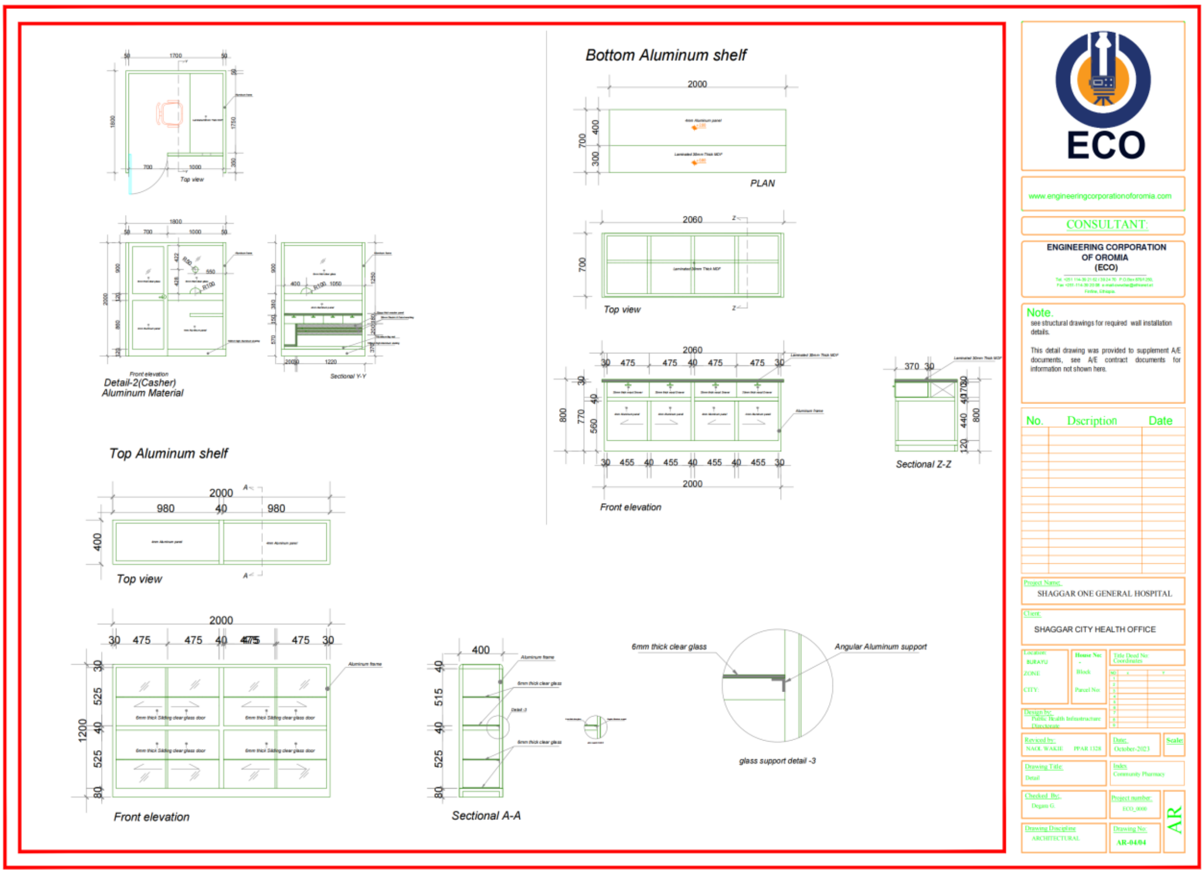


Figure 2.5 Door, Window, and Cabinet Schedule of Community Pharmacy.

2.3.1.2.1.2. Foundation and Structural Design of Community Pharmacy Building

To begin the structural take-off process, I carefully studied the foundation and structural drawings of the Community Pharmacy Building, which illustrate the skeletal framework of the structure, covering elements like footings, columns, beams, ground slab, and reinforcement details. These drawings are essential for understanding the size, type, and placement of structural components, and they serve as a vital communication tool between the structural designer and construction team. By interpreting these drawings, I was able to extract accurate dimensions and calculate material quantities for both the substructure (foundation, footings, ground beams, and ground slabs) and superstructure (columns, top tie beams, roof, lintels, etc.). This task not only enhanced my ability to read structural drawings but also helped me understand the importance of precision and consistency in quantity surveying. In the following section, I will first present the major structural components designed for the Community Pharmacy Building, and then proceed with the quantity take-off based on those elements.

Table 2.5 General Notes for Main Building Structural Design.

GENERAL NOTES

1. DRAWINGS:
   -ALL STRUCTURAL DRAWINGS SHALL BE READ IN CONJUNCTION WITH VALID ARCHITECTURAL, ELECTRICAL AND SANITARY DRAWINGS.
   - DO NOT SCALE DRAWINGS ; ALL DIMENSIONS SHALL BE READ FROM DRAWINGS
   - IT IS BETTER TO PREPARE WORKING DRAWING BY CAREFULL UNDERSTANDING OF THIS DRAWING AND MAKE ALL NECESSARY AMENDMENT WHERE NECESSARY.
2. REINFORCED CONCRETE:
   -ALL REINFORCED CONCRETE SHALL BE WELL VIBRATED DURING CASTING.
   -GRADE OF CONCRETE:
   C-7 FOR LEAN CONCRETE
   C-35/45 FOR BEAMS, COLUMNS AND FOUNDATION
   C-30/37 FOR FLOOR SLABS AND OTHERS
   -USE CONCRETE COVER FOR SLAB= 15MM, BEAM= 25 MM, COLUMN = 25 MM AND FOOTING= 50MM
   NOTE: IT IS BETTER TO REVISE THE COVER FOR SECTIONS WITH REBAR GREATER THAN 16MM
3. STEEL REINFORCEMENT BAR:
   -LAP LENGTHS OF REINFORCEMENT BARS SHALL BE AS SHOWN ON THE DRAWINGS BUT NOT LESS THAN :
   40Ø FOR DEFORMED BARS
   50Ø FOR PLAIN BARS.
   - USE S-500 GRADE STEEL REINFORCEMENT BAR FOR FOUNDATION REINFORCEMENT, BEAMS & COLUMNS LONGITUDINAL REINFORCEMENTS.
   - USE S-400 GRADE STEEL REINFORCEMENT BAR FOR SLABS REINFORCEMENTS, COLUMNS & BEAMS SHEAR/CONFINMENT REINFORCEMENTS.
   -OVERLAP LOCATION FOR SUPPORT REBAR AT MID SPAN & FOR SPAN REBAR AT SUPPORT UNLESS INDICATED ON DRAWING)
4. DESIGN PHILOSOPHY:
   -DESIGN IS IN ACCORDANCE WITH THE ETHIOPIAN STANDARDS 2015.
5. FOR SETTING OUT:
   -USE STRUCTURAL COLUMN LAYOUT DRAWING INCONJUNCTION WITH ARCHITECTURAL DRAWINGS.
6. ***300 KPa*** Allowable soil bearing Capacity is used for foundation design
7. RECOMMENDATIONS:
   -PERFORM CONCRETE COMPREHENSIVE STRENGTH TEST FOR CONCRETE CUBE SAMPLES TO CONFIRM THE REQUIRED STRENGTH
   -DETAILING IS VERY IMPORTANT DURING WORKING DRAWING PREPARATION WHERE NECESSARY
   -EXCAVATED MATERIAL SOIL SHOULD NOT BE USED AS A BACK FILL AROUND THE FOOTING AND MASONRY
   -FOUNDATIONS SHOULD ALWAYS BE PLACED ON STABLE GROUND.
   -IF WEAK SOIL IS ENCOUNTERED, IT SHOULD BE REPLACED WITH COMPACTED SELECTED MATERIAL FILL
   -IF ROCK IS ENCOUNTERED, IT SHOULD BE LEVELED
   - THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE DESIGN OF ALL TEMPORARY BRACING SHORING AND FORM WORK THAT MAY BE NECESSARY DURING CONSTRUCTION
   -COLUMNS SHOULD BE CENTERED WITH RESPECT TO HORIZONTAL AXIS. THESE AVOID CONCENTRICALLY LOADED COLUMNS

ECO

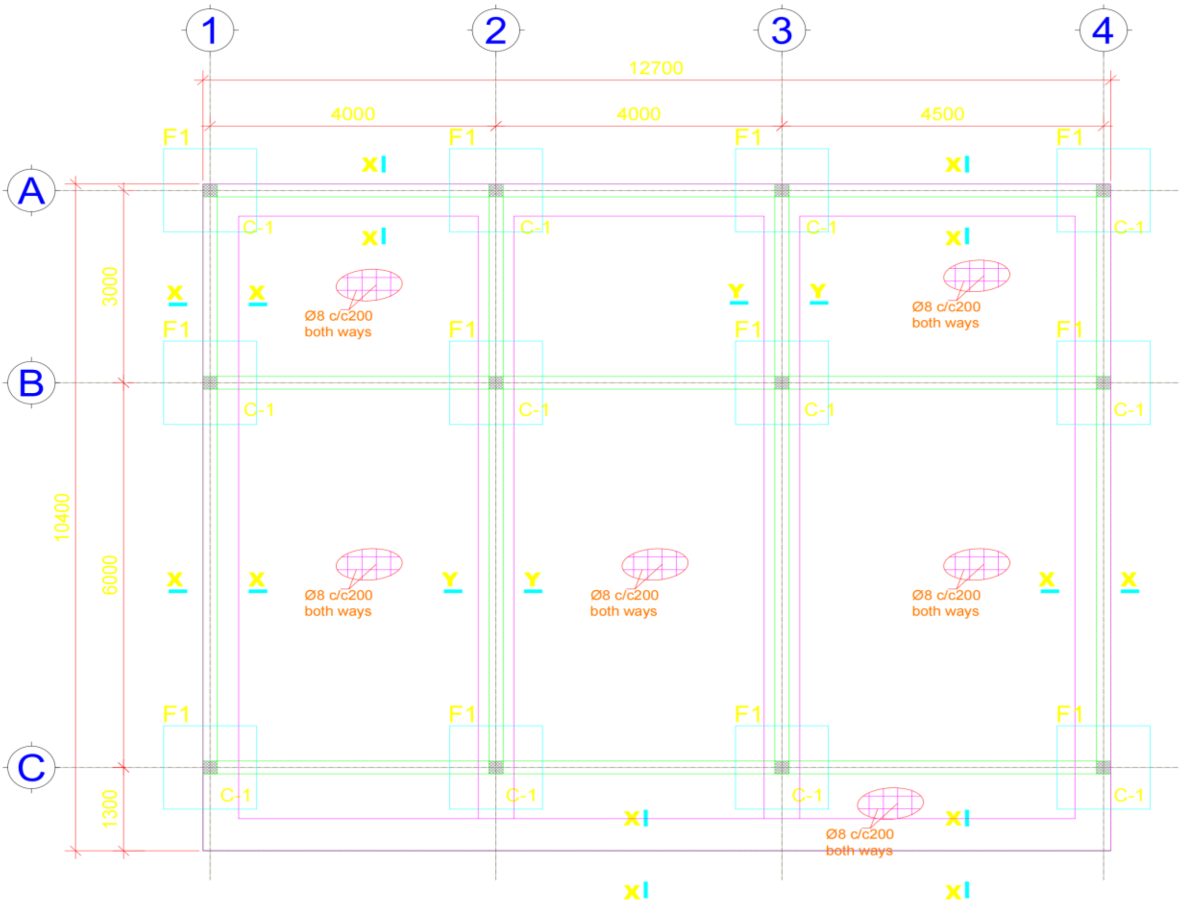
www.engineeringcorporationoforomia.com

CONSULTANT:

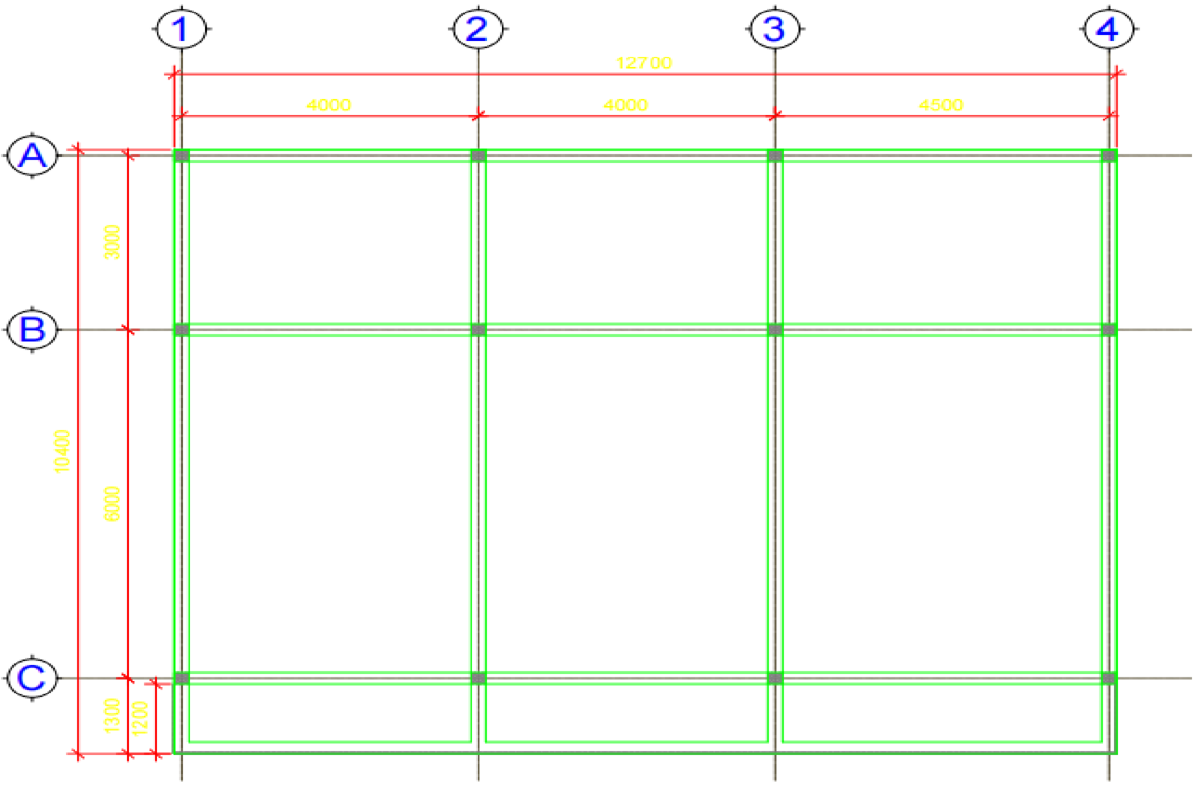
ENGINEERING CORPORATION OF OROMIA (ECO)

Note.

No.	DSCription	Date



GROUND FLOOR SLAB REINFORCMENT (115 sq.m)



TOP TIE BEAM LAYOUT PLAN

Figure 2.6 Foundation Plan, Footing & Beams Layout, and Slabs Rebar Details of Pharmacy building.

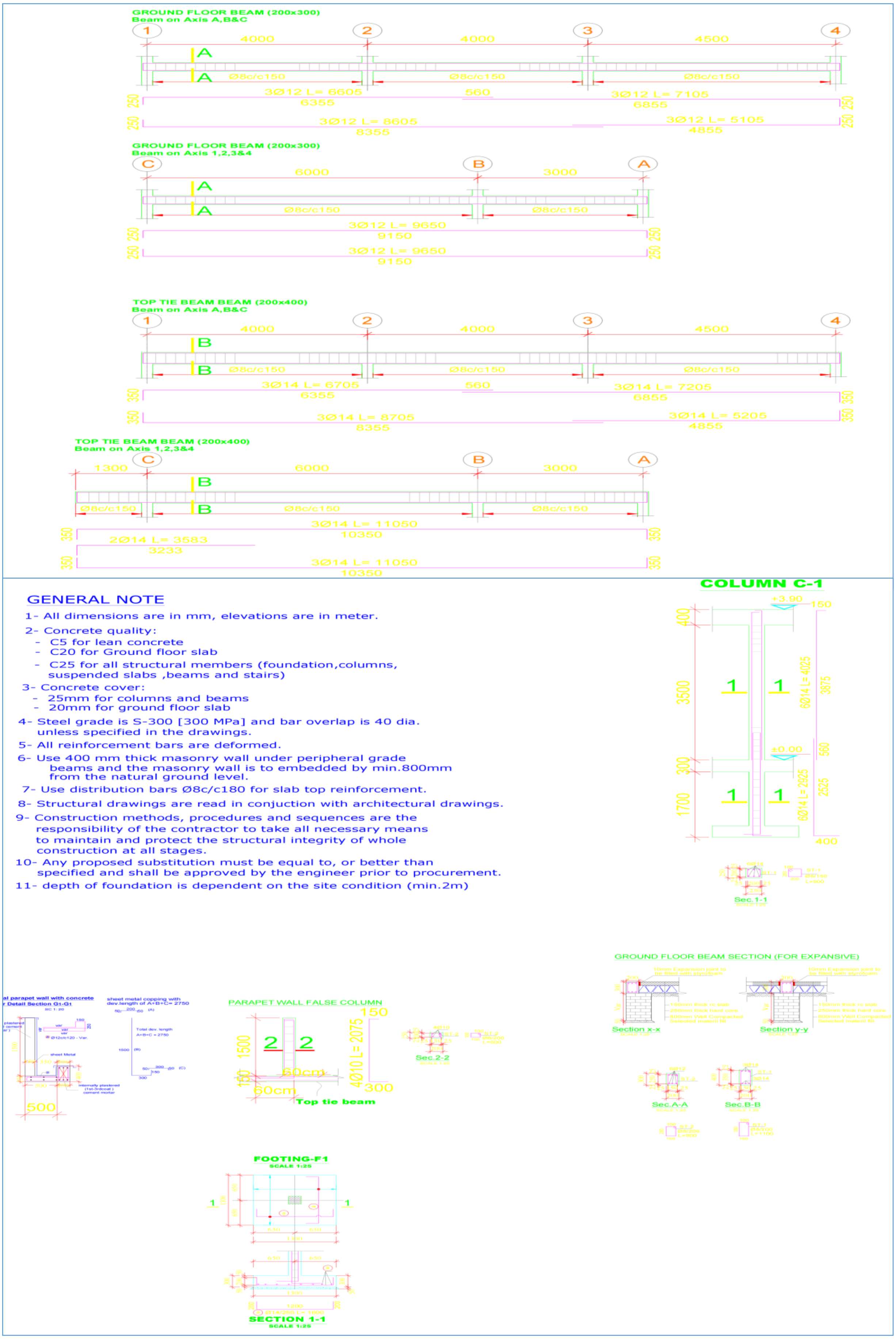


Figure 2.7 Footings & Beams Rebar Details and General Structural Notes of Community Pharmacy.

In preparing the Bill of Quantities (BOQ) for the Community Pharmacy Building, this section presents systematic take-off measurements using the English Method of Quantity Surveying on dimension paper [25]. The process follows civil engineering best practices, emphasizing accuracy in linear, area, and volume calculations; logical sequencing from foundation to superstructure; clear referencing of drawings; and consistency in units and notations. These features, sharpened over decades of engineering innovation, ensure transparency, facilitate cost control, and provide a reliable basis for tendering and contract administration. Each table records measured items in a structured format, aligning with established standards for professional documentation.

2.3.1.2.1.3.Take off for the Community Pharmacy Building

To begin the quantity surveying process for the Community Pharmacy Building, I carefully analyzed the architectural and structural working drawings provided by the consultant. These drawings formed the foundation for extracting accurate dimensions and calculating the required quantities of materials for each construction element [26]. Using a standardized take-off sheet, I recorded all dimensions in a clear format, ensuring each item was measured systematically based on its plan, elevation, and section views. The measurements were taken in the order of Length, Width, and Height/Thickness, and recorded alongside brief descriptions and the calculated quantities. The take-off process not only sharpened my technical skills but also helped me understand how drawing interpretation directly translates into material planning, budgeting, and construction control. Below is the take-off sheet I personally prepared for key structural and architectural components of the Community Pharmacy Building [25].

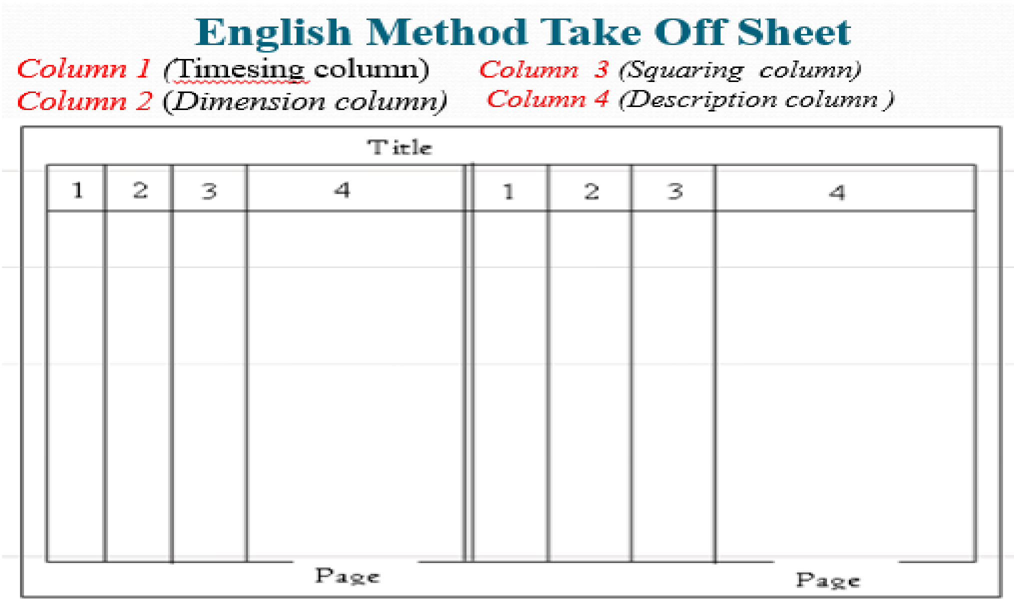


Table 2.6 English Method Quantity Take-Off Sheet.

Table 2.7 Substructure Excavation and Earthwork Take-Off (Pharmacy).

TITLE: TAKE OFF SHEET

Project:-SHAGGAR ONE GENERAL HOSPITAL

LOCATION:- SHAGGAR CITY,OROMIA,ETHIOPIA

Block type:-Community Pharmacy

Client:-SHAGGAR CITY HEALTH OFFICE

Consultant:-ENGINEERING CORPORATIONOF OROMIA

CONTRACTOR: GUTEMA FIRISA CONSTRUCTION JV WITH MCG CONSTRUCTION PLC

ECO

Timizing		Dimen.	Quantity	Item	Description
				A.	SUB STRUCTURE
				1	Excavation & Earth work
				1.01	Site clearance
					(allowing 1.0m working space)
1	1	14.80			
		11.98	177.30		
			177.30	m2	Total to Item 1.01
				1.02	Bulk excavation up to 150cm
1	1	177.30			(allowing 0.50m working space)
		1.00			1.5
		1.50	265.95		
			265.95	m3	Total to Item 1.02
				1.04	Pit Excavation up to 150cm
					2611.3
1	12	1.80			F-1
		1.80			
		1.50	58.32	m3	
			58.32	m3	Total to Item 1.04
				1.06	Ditto but Pit excavation in ordinary soil to a depth not exceeding 300 cm.
1	12	1.80			(allowing 0.5m working space)
		1.80			F-1
		0.10	3.89	m3	
			3.89	m3	Total to Item 1.06
				1.13	Cartaway (Disposal)
1	1	177.30			site clearance
		0.20	35.46	m3	
			265.95	m3	Bulk excavation up to 150cm
			58.32	m3	Pit excavation from up to 150 fromRGL
			3.89	m3	Pit excavation from 150 to 300 cm
			-	m3	Soft rock excavation up to 300 cm
			-	m3	Hard rock excavation up to 300 cm
			-	m3	Trench excavation
			363.62	m3	Total to Item 1.13
				1.10	Back fill around footing & F. column
1	1	265.95			TOTAL EXCAVATION for bulk
		1.00			
		1.00	265.95	m3	
1	1	58.32			TOTAL EXCAVATION for pit
		1.00			
		1.00	58.32	m3	
-1	1	6.08			DEDUCT CONCRETE FOOTING
		1.00			F-1
		1.00	(6.08)	m3	
-1	1	1.20			DEDUCT CONCRETE FOOTING COL
		1.00			C-1 &C-2
		1.00	(1.20)	m3	
-1	1	44.20			DEDUCT masonary wall
		1.00			
		1.00	(44.20)	m3	
			272.79	m3	Total to Item 1.10

Timizing		Dimen.	Quantity	Item	Description
				1.12	Back Fill under hard core
1	1	2.8			axis A-B/1-4
		11.9			
		1.20	39.98	m3	
1	1	5.8			axis B-C/1-4
		11.9			
		1.20	82.82	m3	
1	1	1			axis C-C'/1-4
		12.7			
		1.20	15.24	m3	
			138.04	m3	Total to Item 1.12
				1.14	Basaltic or equivalent stone hardcore
					axis A-B/1-4
1	1	2.8			
		11.9	33.32	m^2	
					axis B-C/1-4
1	1	5.8			
		11.9	69.02	m^2	
					axis C-C'/1-4
1	1	1			
		37.045	37.05	m^2	
			139.39	m^2	Total to Item 1.14
	0.25	139.39	34.85	m3	Total to Item 1.14

Prepared By: Naol Terefe Bango
Checked By: Tokumma Jabessa
Approved By: Tesfaye Erro (RE)

Table 2.8 Substructure Concrete and Masonry Work Quantities (Pharmacy).

TITLE: TAKE OFF SHEET

Project:-SHAGGAR ONE GENERAL HOSPITAL

LOCATION:- SHAGGAR CITY,OROMIA,ETHIOPIA

Block type:-Community Pharmacy

Client:-SHAGGAR CITY HEALTH OFFICE

Consultant:-ENGINEERING CORPORATIONOF OROMIA

CONTRACTOR: GUTEMA FIRISA CONSTRUCTION JV WITH MCG CONSTRUCTION PLC

Timizing		Dimen.	Quantity	Item		Description
					A.	SUB STRUCTURE
					2	Concrete Work
					2.1	Lean concrete
						B. Under footing
						allowing 10cm width additi
1	12	1.50				F-1
		1.50	27.00	m^2		
			27.00	m^2		Total to Item 2.1 B
						A. Under masonry wall
1	1	88.40				allowing 10cm width addition
		0.70	61.88	m^2		
			61.88	m^2		Total to Item 2.1 A
						C. Under Ground floor beams
1	1	42.80				allowing 10cm width addition
		0.40	17.12	m^2		
			17.12	m^2		Total to Item 2.1 C
					2.02	Reinforced concrete (C-25)
						A. In footing pad
1	12	1.30				F-1
		1.30				
		0.30	6.08	m3		
			6.08	m^3		Total to Item 2.02 A
						B. In footing COLUMN
1	2	0.50				FC-1
		0.50				
		2.40	1.20	m3		
			1.20	m^3		Total to Item 2.02 B

Timizing		Dimen.	Quantity	Item		Description
						C. In Ground floor beams
1	4	11.90				on axis A,B,C,C'
		0.20				
		0.30	2.86	m3		
1	4	9.80				on axis 1,2,3,4
		0.20				
		0.30	2.35	m3		
			5.21	m^3		Total to Item 2.02 C
						D. In Ground floor slab (10cm thick)
						axis A-B/1-4
1	1	2.8				
		11.9	33.32	m^2		
						axis B-C/1-4
1	1	5.8				
		11.9	69.02	m^2		
						axis C-C'/1-4
1	1	1				
		12.7	12.70	m^2		
			115.04	m^2		Total to Item 2.02 D
					2.03	Formwork
						A. To footing pad
1	12	5.20				F-1
		0.30	18.72	m^2		
			18.72	m^2		Total to Item 2.03 A
						B. To foundation column
						FC-1
						P=0.2*2+0.2*2=0.8m
1	12	0.80				
		2.40	23.04	m^2		
			23.04	m^2		Total to Item 2.03 B
						C. To Ground floor beam
1	4	11.90				on axis A,B,C,C'
		0.60	28.56	m^2		P=0.3*2=0.6m
1	4	9.80				on axis 1,2,3,4
		0.60	23.52	m^2		P=0.3*2=0.6m
			52.08	m^2		Total to Item 2.03 C

Timizing		Dimen.	Quantity	Item		Description
					A.	SUB STRUCTURE
					3	Masonry work
					3.1	Masonry below NGL (50cm thick)
						Length found Via Auto CAD measurement
						on axis 1&2
1	2	9.80				
		0.50				
		1.00	9.80	m3		
1	2	9.80				on axis 4&3
		0.50				
		1.00	9.80	m3		
1	2	11.90				on axis A&B
		0.50				
		1.00	11.90	m3		
1	2	12.70				on axis C&C'
		0.50				
		1.00	12.70	m3		
			44.20	m3		Total to Item 3.1.a

Timizing		Dimen.	Quantity	Item		Description
					3.2	Masonry Above NGL (50cm thick)
						Length found Via Auto CAD measurement
						on axis 1&2
1	2	9.80				
		0.50				
		1.20	11.76	m3		
1	2	9.80				on axis 4&3
		0.50				
		1.20	11.76	m3		
1	2	11.90				on axis A&B
		0.50				
		1.20	14.28	m3		
1	2	12.70				on axis C&C'
		0.50				
		1.20	15.24	m3		
			53.04	m3		Total to Item 3.1.b

Prepared By: Naol Terefe Bango **Checked By: Tokumma Jabessa** **Approved By: Tesfaye Erro (RE)**

Table 2.9 Superstructure Concrete, Formwork, Block, and Carpentry Take-Off (pharmacy).

TITLE: TAKE OFF SHEET

Project:-SHEGGER ONE GENERAL HOSPITAL

Block type:-Community Pharmacy

LOCATION:- SHEGGER CITY,OROMIA,ETHIOPIA

Client:-SHEGGER CITY HEALTH OFFICE

Consultant:-ENGINEERING CORPORATION OF OROMIA

CONTRACTOR: GUTEMA FIRISA CONSTRUCTION JV WITH MCG CONSTRUCTION PLC

Times	No.	Dimensions	Quantity	Unit / Item	Description
				A.	SUPER STRUCTURE
				1	Concrete Work
				1.01	C-25 Reinforced concrete
					I. In Elevation column
					A. On Ground floor
1	12	0.20 0.20 3.30	1.58	m3	EC-1
			1.58	m3	Total to Item 1.01.I.a
					Concrete work for Beam
					B. Roof Floor Beam
1	4	11.90 0.20 0.40	3.81	m3	on axis A,B,C,C'
1	4	9.80 0.20 0.40	3.14	m3	on axis 1,2,3,4
			6.95	m3	Total to Item 1.01 II.a
					c) In Parapet Wall & Gutter
1	2	12.70 0.50 0.15	1.91	m3	on axis A,B,C'
1	2	11.40 0.50 0.15	1.71	m3	on axis 1,2,3,4
1	12	0.20 0.20 1.20	0.58	m3	parapet columns
			4.20	m3	Total to Item 1.01 II.a
				1.03	BLOCK WORK
	1	12.70 3.50			Front Side on Axis 1,2,3 and 4 L=12.7m, D=3.5m
			44.45	m2	Gross Area of HCB for front side Fence
	1	12.70 3.50			Rear Side on Axis 1,2,3 and 4 L=12.7m, D=3.5m
			44.45	m2	ditto but for Rear side Fence
	1	10.40 3.50			Right Side on Axis A,B and B L=10.4m, D=3.5m
			36.40	m2	ditto but for Right side of Fence
	1	10.40 3.50			Side on Axis A,B and C L=10.4m, D=3.5m
			36.40	m2	ditto but for Right side of Fence
	-10	0.25 3.50			
			-8.750	m2	Deduct for colums
	-2	1.20 3.0			L=1.2m and H=3m
			-7.200	m2	Deduct for Door one(D1)
	-3	2.00 2.1			L=2m and H=2.1m
			-12.600	m2	Deduct for Window one(W1)
	-2	1.50 2.1			L=1.5m and H=2.1m
			-6.300	m2	Deduct for Window Two (W2)
	-5	1.00 2.1			L=1.5m and H=2.1m
			-10.500	m2	Deduct for Window Three (W3)
	-1	1.00 1.0			L=1m and H=1m
			-1.000		Deduct for Window (Tw-1)
			115.35	m2	Total Area of 40*20*20 HCB for External Wall
					2.02.) Ditto item 2.01 but 150mm thick.
	2	12.70 1.50	38.100	m2	Area of HCB for parapet wall on Front and Rear side
	2	12.70 1.50	38.100		Area of HCB for parapet wall on Front and side
			76.200	m2	Total Area of HCB for prapet Wall
					HCB(40*20*15)cm for internal wall
	2	12.70 1.50	38.100	m2	Area of HCB for parapet wall on Front and Rear side
	1	26.70 3.50			Ltot=26.7m, H=3.5m
			93.450	m2	Total Area of HCB(40*20*15)cm for internal wall
			169.650	m2	Total Area of HCB(40*20*15)cm

Times	No.	Dimensions	Quantity	Unit / Item	Description
				1.02	FORMWORK
					A. To elevation column
1	12	0.80 3.30	31.68	m^2	EC-1 P=0.2*2+0.2*2=0.8m
			31.68	m2	Total to Item 1.02 .a
					B. Roof Floor Beam
1	4	11.90 1.00	47.60		on axis A,B,C,C' P=0.4*2+0.2=1.0m
1	4	9.80 1.00	39.20		on axis 1,2,3,4 P=0.4*2+0.2=1.0m
			86.80	m2	Total to Item 1.02. b
					C. In Parapet Wall & Gutter
1	2	12.70 0.65	16.51		on axis A,B,C' P=0.5+0.15=0.65m
1	2	11.40 0.65	14.82		on axis 1,2,3,4 P=0.5+0.15=0.65m
1	12	0.20 0.80	1.92		parapet columns P=0.2*2+0.2*2=0.8m
			33.25	m2	Total to Item 1.02. c
				1.04	CARPENTRY AND JOINERY
				4.1	Construct and put in position eucalyptus truss
1	14	10.68 1.00	149.52	ml	a) diameter 10-12cm eucalyptus top and bottom cored member total to item no.4.1.a
1	14	13.00 1.00	182.00	ml	b)diameter 8-10cm eucalyptus vertical and diagonal cored member total to item no.4.1.b

Prepared By: Naol Terefe Bango **Checked By: Tokumma Jabessa** **Approved By: Tesfaye Erro (RE)**

Table 2.10 Substructure Reinforcement Bar Schedule and Summary of Rebar (Pharmacy).

TITLE: REINFORCING BAR SCHEDULE FOR SUBSTRUCTURE

Project:-SHAGGAR ONE GENERAL HOSPITAL
Block type:-Community Pharmacy
Location:- SHAGGAR CITY,OROMIA REGION ,ETHIOPIA
Client:-SHAGGAR CITY HEALTH OFFICE
Consultant:-ENGINEERING CORPORATION OF OROMIA
CONTRACTOR: GUTEMA FIRISA CONSTRUCTION JV WITH MCG CONSTRUCTION PLC

Item	Position	DR. N°.	Dia (mm)	Shape	N°. of bars	N°. of floor	N° of	Length	6	8	10	12	14	16	20	24	28	32
	Footing pad								---	---	---	---	---	---	---	---	---	---
	F-1								---	---	---	---	---	---	---	---	---	---
	X-axis	1	14		6	1	12	1.6	---	---	---	---	115.2	---	---	---	---	---
	Y-axis	1	14		6	1	12	3.3	---	---	---	---	237.6	---	---	---	---	---
	dist/n bar X-axis	1	12		3	1	0	2.5	---	---	---	0.00	---	---	---	---	---	---
	dist/n bar Y-axis	1	12		3	1	0	2.5	---	---	---	0.00	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
					Total Length				0.00	0.00	0.00	0.00	352.80	0.00	0.00	0.00	0.00	0.00
					Kg. Per Meter				0.222	0.395	0.617	0.888	1.209	1.579	2.466	3.552	4.834	6.314
					Weight in Kg.				0.0	0.0	0.0	0.0	426.5	0.0	0.0	0.0	0.0	0.0

Item	Position	DR. N°.	Dia (mm)	Shape	N°. of bars	N°. of floor	N° of	Length	6	8	10	12	14	16	20	24	28	32
	Foundation column								---	---	---	---	---	---	---	---	---	---
	FC-1								---	---	---	---	---	---	---	---	---	---
	Main bar		14		6	1	12	4.05	---	---	---	---	291.60	---	---	---	---	---
	Stirrups 1		8		17	1	12	1.9	---	387.6	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
					Total Length				0.00	387.60	0.00	0.00	291.60	0.00	0.00	0.00	0.00	0.00
					Kg. Per Meter				0.222	0.395	0.617	0.888	1.209	1.579	2.466	3.552	4.834	6.314
					Weight in Kg.				0.0	153.0	0.0	0.0	352.4	0.0	0.0	0.0	0.0	0.0

Item	Position	DR. N°.	Dia (mm)	Shape	N°. of bars	N°. of floor	N° of	Length	6	8	10	12	14	16	20	24	28	32
	Ground floor slab								---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
	axis A-B/1-4		8		61	1	1	2.8	---	170.8	---	---	---	---	---	---	---	---
			8		15	1	1	11.9	---	178.5	---	---	---	---	---	---	---	---
	axis B-C/1-4		8		49	1	1	5.8	---	284.2	---	---	---	---	---	---	---	---
			8		24	1	1	11.9	---	285.6	---	---	---	---	---	---	---	---
	axis C-C'/1-4		8		52	1	1	1	---	52	---	---	---	---	---	---	---	---
			8		5	1	1	12.7	---	63.5	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
					Total Length				0.00	1034.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
					Kg. Per Meter				0.222	0.395	0.617	0.888	1.209	1.579	2.466	3.552	4.834	6.314

Item	Position	DR. N°.	Dia (mm)	Shape	N°. of bars	N°. of floor	N° of	Length	6	8	10	12	14	16	20	24	28	32
	Grade beam								---	---	---	---	---	---	---	---	---	---
	on axis A,B,C,C'								---	---	---	---	---	---	---	---	---	---
	Main bar		14		3	1	4	13.6	---	---	---	---	163.20	---	---	---	---	---
			14		3	1	4	13.7	---	---	---	---	164.40	---	---	---	---	---
	Stirrups 1		8		80	1	4	1.4	---	448	---	---	---	---	---	---	---	---
	on axis 1,2,3,4								---	---	---	---	---	---	---	---	---	---
	Main bar		14		3	1	4	11.05	---	---	---	---	132.60	---	---	---	---	---
			14		3	1	4	11.05	---	---	---	---	132.60	---	---	---	---	---
			14		2	1	4	3.58	---	---	---	---	28.64	---	---	---	---	---
	Stirrups 1		8		53	1	4	1.4	---	296.8	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
					Total Length				0.00	744.80	0.00	0.00	621.44	0.00	0.00	0.00	0.00	0.00
					Kg. Per Meter				0.222	0.395	0.617	0.888	1.209	1.579	2.466	3.552	4.834	6.314
					Weight in Kg.				0.0	293.9	0.0	0.0	751.1	0.0	0.0	0.0	0.0	0.0

SUMMARY OF REINFORCING BAR SCHEDULE

SUB-STRUCTURE

DIAMETER	6	8	10	12	14	16	20	24	28	32
TOTAL KG	-	855.17	-	-	1,530.01	-	-	-	-	-

Prepared By: Naol Terefe Bango   **Checked By:** Tokumma Jabessa   **Approved By:** Tesfaye Erro (RE)

Table 2.11 Superstructure Reinforcement Bar Schedule and Summary of Rebar (Pharmacy).

TITLE: REINFORCING BAR SCHEDULE FOR SUPERSTRUCTURE

Project:-SHAGGAR ONE GENERAL HOSPITAL
Block type:-Community Pharmacy
Location:- SHAGGAR CITY,OROMIA REGION ,ETHIOPIA
Client:-SHAGGAR CITY HEALTH OFFICE
Consultant:-ENGINEERING CORPORATION OF OROMIA
CONTRACTOR: GUTEMA FIRISA CONSTRUCTION JV WITH MCG CONSTRUCTION PLC

Item	Position	DR. Nº	Dia (mm)	Shape	Nº of bars	Nº of floor	Nº of member	Length	6	8	10	12	14	16	20	24	28	32
	column								---	---	---	---	---	---	---	---	---	---
	Ground floor								---	---	---	---	---	---	---	---	---	---
	C-1								---	---	---	---	---	---	---	---	---	---
	Main bar		14		6	1	12	4.025	---	---	---	---	289.8	---	---	---	---	---
	Stirrups 1		8		24	1	12	1.9	---	547.2	---	---	---	---	---	---	---	---
	parapet								---	---	---	---	---	---	---	---	---	---
	C-1								---	---	---	---	---	---	---	---	---	---
	Main bar		10		4	1	12	2.1	---	---	100.8	---	---	---	---	---	---	---
	Stirrups 1		8		9	1	12	0.6	---	64.8	---	---	---	---	---	---	---	---
	roof floor beam								---	---	---	---	---	---	---	---	---	---
	on axis A,B,C,C'								---	---	---	---	---	---	---	---	---	---
	Main bar		14		3	1	4	13.6	---	---	---	---	163.2	---	---	---	---	---
			14		3	1	4	13.7	---	---	---	---	164.4	---	---	---	---	---
	Stirrups 1		8		80	1	4	1.4	---	448	---	---	---	---	---	---	---	---
	on axis 1,2,3,4								---	---	---	---	---	---	---	---	---	---
	Main bar		14		3	1	4	11.05	---	---	---	---	132.6	---	---	---	---	---
			14		3	1	4	11.05	---	---	---	---	132.60	---	---	---	---	---
			14		2	1	4	3.58	---	---	---	---	28.64	---	---	---	---	---
	Stirrups 1		8		53	1	4	1.4	---	296.8	---	---	---	---	---	---	---	---
	parapet slab								---	---	---	---	---	---	---	---	---	---
									---	---	---	---	---	---	---	---	---	---
	on axis A,B,C'		8		4	1	2	12.7	---	101.6	---	---	---	---	---	---	---	---
			8		65	1	2	0.5	---	65	---	---	---	---	---	---	---	---
	on axis 1,2,3,4		8		3	1	2	11.4	---	68.4	---	---	---	---	---	---	---	---
			8		47	1	2	0.5	---	47	---	---	---	---	---	---	---	---
					Total Length				0.00	1638.80	100.80	0.00	911.24	0.00	0.00	0.00	0.00	0.00
					Kg. Per Meter				0.222	0.395	0.617	0.888	1.209	1.579	2.466	3.552	4.834	6.314
					Weight in Kg.				0.0	647.3	62.2	0.0	1101.7	0.0	0.0	0.0	0.0	0.0

SUMMARY OF REINFORCING BAR SCHEDULE

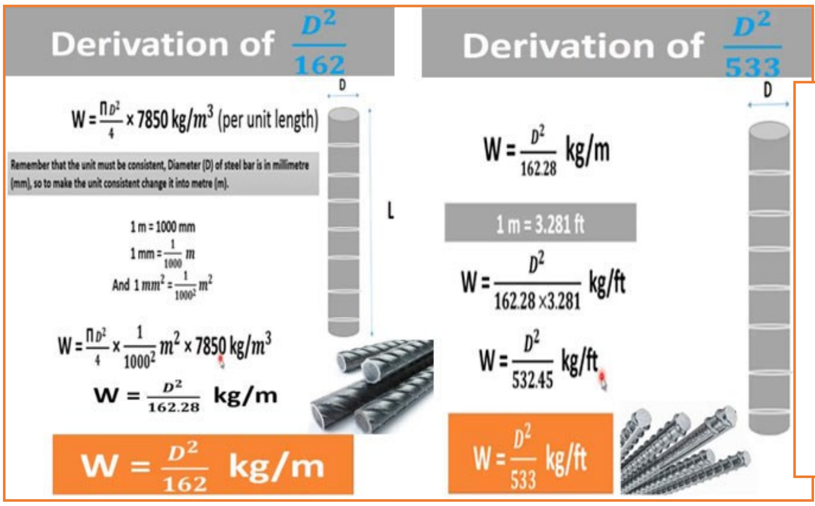
SUPER-STRUCTURE

DIAMETER	6	8	10	12	14	16	20	24	28	32
TOTAL KG	-	647.33	62.19	-	1,101.69	-	-	-	-	-

Prepared By: Naol Terefe Bango **Checked By: Tokumma Jabessa** **Approved By: Tesfaye Erro (RE)**

Accurate estimation of reinforcement weight is critical in civil engineering and quantity surveying for both cost control and structural integrity. A widely adopted formula for calculating the unit weight of circular steel bars is $\frac{D^2}{162.28}$, where D is the diameter in millimeters. This expression is derived from the cross-sectional area and the standard density of steel $(7850\ kg/m^3)$, applicable to mild and carbon steels. At Shaggar One General Hospital, only circular bars were used throughout the structural works, and this formula has consistently guided all my previous bar schedules. A brief proof is presented below to validate its accuracy.

Table 2.12 Weight Formula for Circular Reinforcement Bars [72].



Volume of bar per meter is given by:

$V = \frac{\pi D^2}{4} \times 1$

Where:

- D = diameter in meters
- Length = 1m

Weight; $W = V \times \rho$

$$W = \frac{\pi D^2}{4} \times \rho$$

Table 2.13 BOQ for Excavation and Substructure Concrete Work (Pharmacy).

Project:- Shaggar One General Hospital
Location:- Gafarsa Guje Subcity
Consultant:- Engineering Corporation Of Oromia
Contractor:-Gutema Firisa
Client: Shaggar city Healthy office

ECO

BILL OF QUANTITY FOR COMMUNITY PHARMACY BUILDING

Item No	Description	Unit	Quantity	Rate	Amount
	A-SUB STRUCTURE				
	1. EXCAVATION & EARTH WORK				
1.01	Surface dressing of the ground including removing and grubbing of all type of trees irrespective of tree height and girth, removal of vegetation, removal of ground inequality not exceeding 200mm deep in all kinds of soil and disposal of rubbish either within the site or outside the site boundary as directed by the Engineer in charge.	M3	203.82	488.00	99,464.16
1.02	Bulk excavation in ordinary soil from reduced level to a depth not exceeding 1500mm,inclusive of shoring ,strutting and bailing out water wherever necessary,depositing the surplus earth in shown by the Engineer in charge,clearing and levelling the site as specified hereunder etc ,all complete in all respects complying with relevant standard specifications.	M3	110.88	380.00	42,134.40
1.03	Ditto,but				
	a) Soft rock	M3	6.11	660.00	4,032.60
	b) Bolder rock	M3	3.20	820.00	2,624.00
	c) Hard rock	M3	2.10	1,310.00	2,751.00
1.04	Pit excavation for foudation in all soils and sub soils to a depth not exceeding 1500mm,except in hard rock requiring ,blasting , but incusive of shoring ,strutting and bailing out water wherever necessary(Excluding refilling the sides of foundation) and depositing the earth in places shown clearing and levelling the site including all the lead and lift etc ,completion of work in satsfactory manner and in all respects complying with relevant standard specifications. (Excluding refilling).	M3	27.54	380.00	10,465.20
1.05	Ditto,but				
	a) Soft rock	M3	1.62	660.00	1,069.20
	b) Bolder rock	M3	1.62	820.00	1,328.40
	c) Hard rock	M3	1.62	1,310.00	2,122.20
1.06	Ditto exceeding 150 cm but not exceed 300 cm.	m^3	18.36	460.00	8,445.60
1.07	Ditto,but				-
	a) Soft rock	M3	1.08	810.00	874.80
	b) Bolder rock	M3	1.08	1,180.00	1,274.40
	c) Hard rock	M3	1.08	1,950.00	2,106.00
1.08	Trench excavation for masonry foudation in all soils and sub soils to a depth not exceeding 1500mm,except in hard rock requiring ,blasting , but incusive of shoring ,strutting and bailing out water wherever necessary(Excluding refilling the sides of foundation) and depositing the earth in places shown clearing and levelling the site including all the lead and lift etc ,completion of work in satsfactory manner and in all respects complying with relevant standard specifications. (Excluding refilling).	M3	49.80	560.00	27,888.00
1.09	Ditto,but				
	a) Soft rock	M3	2.10	880.00	1,848.00
	b) Bolder rock	M3	1.80	1,180.00	2,124.00
	c) Hard rock	M3	1.50	1,950.00	2,925.00
1.10	Back fill around footing columns with good selected material from quarry waste and compact in layers not exceeding 20 cm thick.	M3	42.00	1,610.00	67,620.00
1.11	Back fill around foundation with good selected material from quarry waste and compact in layers not exceeding 20 cm thick.	M3	124.17	1,610.00	199,913.70
1.12	Fill under hard core with good selected material from quarry waste and compact with layers not exceeding 20 cm thick.	M3	62.09	1,610.00	99,956.85
1.13	Load and cart away surplus excavated material from the site to distance not more than 5 km from the site.	M3	169.97	380.00	64,588.60
1.14	25 cm thick basaltic stone hardcore well rolled, consolidated and blinded with crushed stone .	M3	119.31	1,140.00	136,013.40
	Total carried to Summary				781,569.51

Item No	Description	Unit	Quantity	Rate	Amount
	2. CONCRETE WORK				
2.01	Providing and laying lean concrete grade C-5, (150 kg of cement/m3) to a thickness of 50mm inclusive of shoring ,strutting and bailing out water wherever necessary , form work ,ramming and curring etc.,Complete in all respects complying with relevant standard specifications and as directed by the Engineer in charge.				
	a) under stone Masonry	M2	32.90	580.00	19,082.00
	b) under Footing pad	M2	20.28	580.00	11,762.40
	c) under Ground floor beam	M2	16.60	580.00	9,628.00
2.02	Providing Cement concrete grade C-25 (360 kg of cement/m3)design mix for all reinforcement cement concrete works namely footings,foundation column ,grade beam ,staircase etc. ,Excluding the cost reinforcement bars ,fabrication charges ,shuttering and centering but including vibrating and laying,curing etc all complete in all respects complying with relevant standard specifications and as directed by the Engineer in charge.Mix design data has to be get approved by the Engineer in charge before commencement of work				
	a) In footing pads	M3	6.08	15,290.00	92,963.20
	b) In foundation columns	M3	0.96	15,290.00	14,678.40
	c) In grade beams	M3	6.64	15,290.00	101,525.60
	d)15 cm floor slab	M2	119.31	2,294.00	273,697.14
2.03	Providing form work for reinforced cement concrete work in column ,floor and roof beam ,suspended slab,staircase ,overhead tank ,fin wall ,pergola and lintel beam using sawn wooden or steel whichever is appropriate which includes cutting and fixing in position,shuttering ,centering and removing the same after a specified period without damaging the RCC works complying with relevant standard specifications and as directed by the Engineer in charge. The quoted rate shall be same for all the floor levels incuding lead and lifting charges.				
	a) To footings	M2	18.72	1,220.00	22,838.40
	b) To foundation columns	M2	19.20	1,220.00	23,424.00
	c) To grade beams	M2	62.40	1,220.00	76,128.00
2.04	Providing and laying of reinforcing steel grade S -500 for reinforced cement concrte work as specified in the structural drawing ,price including cost of binding wire ,labor charge for cutting ,bending ,placing in position and tying wires,chairs ,spacers,concrete cover block and wastage etc complete.				
	a) Dia 8 mm deformed bar	kg	1,100.00	209.00	229,900.00
	b) Dia 12 mm deformed bar	kg	95.00	209.00	19,855.00
	c) Dia 14 mm deformed bar	kg	524.96	209.00	109,716.64
	Total carried to Summary				1,005,198.78

Prepared By: Naol Terefe Bango **Checked By: Tokumma Jabessa** **Approved By: Tesfaye Erro (RE)**

Table 2.14 BOQ for Masonry, Superstructure Concrete, and Roofing Works (Pharmacy).

BILL OF QUANTITY FOR COMMUNITY PHARMACY BUILDING

Item No	Description	Unit	Quantity	Rate	Amount
	3. MASONERY WORK				
3.01	500mm thick hard trachytic roughly dressed stone masonary foundation wall bedded in cement mortar mix ratio(1:3)				
	a) below ground level	M3	34.50	8,200.00	282,900.00
	b) above ground level	M3	34.50	8,900.00	307,050.00
	Total carried to Summary				**589,950.00**
	B-SUPER STRUCTURE				
	1. CONCRETE WORK				
1.01	Providing Cement concrete grade C-25 (360 kg of cement/m3)design mix for all reinforcement cement concrete works namely columns ,floor and roof beams,suspended floor slab ,staircase,overhead tank ,fin wall and pergola.. etc. ,Excluding the cost reinforcement bars ,fabrication charges ,shuttering and centering but including vibrating and laying,curing etc all complete in all respects complying with relevant standard specifications and as directed by the Engineer in charge.Mix design data has to be get approved by the Engineer in charge before commencement of work.The quoted rate shall be same for all the floor levels incuding lead and lifting charges.				
	a) In elevation columns	M3	8.00	15,290.00	122,320.00
	b) In roof beams	M3	6.64	15,290.00	101,525.60
	c) In Parapet Wall & Gutter	M3	27.10	15,290.00	414,359.00
1.02	Providing form work for reinforced cement concrete work in column ,floor and roof beam ,suspended slab,staircase ,overhead tank ,fin wall ,pergola and lintel beam using sawn wooden or steel whichever is appropriate which includes cutting and fixing in position,shuttering ,centering and removing the same after a specified period without damaging the RCC works complying with relevant standard specifications and as directed by the Engineer in charge. The quoted rate shall be same for all the floor levels incuding lead and lifting charges.				
	a) To elevation columns	M2	48.00	1,220.00	58,560.00
	b) To roof beams	M2	33.20	1,220.00	40,504.00
	c) Parapet Wall & Gutter	M2	271.04	1,220.00	330,668.80
1.03	Providing and laying of reinforcing steel grade S -400 for reinforced cement concrte work as specified in the structural drawing ,price including cost of binding wire ,labor charge for cutting ,bending ,placing in position and tying wires,chairs ,spacers,concrete cover block and wastage etc complete.				
	a) Dia 8 mm deformed bar	kg	862.00	209.00	180,158.00
	b) Dia 10 mm deformed bar	kg	576.00	209.00	120,384.00
	c) Dia 12 mm deformed bar	kg	1,110.00	209.00	231,990.00
	d) Dia 14 mm deformed bar	kg	-	209.00	-
	Total carried to Summary				**1,600,469.40**
	2. BLOCK WORK				
2.01	Providing block work in cement mortar mix (1:3) using Class C Hollow concrte block of size 200x200x400 mm in super structure including material cost ,labor charges ,scaffolding ,striking joints on unexposed faces ,pointing with cement mortar (1:3) on exposed faces ,proper setting curing etc all complete with relevant standard specifications and as directed by the Engineer in charge.The quoted rate shall be same for all the floor levels incuding lead and lifting charges.	M2	110.00	1,480.00	162,800.00
2.02	Ditto item 2.01 but 150mm thick.	M^2	110.78	1,370.00	151,768.60
	TOTAL CARRIED TO SUMMARY				**314,568.60**

BILL OF QUANTITY FOR COMMUNITY PHARMACY BUILDING

Item No	Description	Unit	Quantity	Rate	Amount
	3. ROOFING				
3.01	Providing and fixing 0.5mm thick pre-coated EGA 500 roofing cover fixed to steel lattice purlin according to the drawing. Price shall include ridge cap , J- bolts , water proof washer and all the necessary accessories .(roof measured in horizontal projection)	M2	126.48	3,460.00	437,620.80
3.02	Supply and fix G-28 galvanized flat metal sheet copings with development length of 330mm. Price shall include all necessary accessories including metal bracket holder,psinting of two coats of antirust and one coat of metal paint .	ML	46.00	3,020.00	138,920.00
3.03	G-28 0.4mm thick flat metal sheet gutter development length 100 cm welded at joints. Provide 2% slope	ml	46.00	3,490.00	160,540.00
3.04	Supply and fix Bitaminus memeberane type water profing material . The method of application shall be as per manufacture instruction for exposed , gutter	m^2	46.00	1,820.00	83,720.00
3.05	Supply and fix **uPVC(PN 6)** Down pipes with mass concrete support at ground level and complete with basket strainer at inlet, galvanized clips at every elbows,joints and at every 1m interval complete with all accessories.The pipes, accessories, fittings & method of welding shall comply with the requirement of BS 4514or equivalent Institution. Unit price shall include all the necessary assistances to the installation works.				
	a) Size: - Dia.110mm	ml	32.00	250.00	8,000.00
	TOTAL CARRIED TO SUMMARY				**828,800.80**
4.00	**CARPENTRY AND JOINERY**				
4.01	Construct and put in position eucalyptus truss				
	a) diameter 10-12cm eucalyptus top and bottom cored member	ml	144.00	500.00	72,000.00
	b)diameter 8-10cm eucalyptus vertical and diagonal cored member	ml	128.00	450.00	57,600.00
	TOTAL CARRIED TO SUMMARY				**129,600.00**
	5. METAL WORK				
5.01	Supply and fix anodized aluminum profiles of the following specifications: AA 6063, Norm EN 573-3/ EN 755-2/ EN 755 & EN 12020; tensile strength 215 N/mm2 ; thickness of anodizing layer 15micrometer. Accessories: handles, door closer, arms, locks; Italian GIESSE & German Dorma or equivalent. Glazing tinted glass 6mm, with appropriate structural silcon. Section of profile and thickness should be determined based on structural requirement of each type of façade items, but minimum thickness of profile shall not be less than 2mm. Price shall include all necessary related activities. workmanship & material quality , color selection and work methodology shall be as per the approval from the consulting Architect.				
	WINDOWS				
	a) W1, Size 200 x 210 cm	No	2.00	75,642.00	151,284.00
	b) TW1 Size 150 * 210 cm	No	2.00	56,732.00	113,464.00
	c) TW2 Size 100 * 210 cm	No	5.00	37,821.00	189,105.00
5.03	**Ditto but Door**				
	a)D1, Size 120 x 300 cm	No	2.00	64,836.00	129,672.00
	b)D2, Size 80 x 300 cm	No	5.00	43,224.00	216,120.00
	C)D3, Size 70 x 250 cm	No	2.00	31,518.00	63,036.00
	TOTAL CARRIED TO SUMMARY				**862,681.00**
6.00	**Plastering work**				
6.01	Apply two coats of plastering in cement mortar (1:3) and one coat of Gypsum plastered finish. Price shall include pre-cleaning and preparation of the surface.				
	a) To internal wall surface	m^2	374.85	540.00	202,419.00
	b) To exposed beams and columns.	m^2	374.85	540.00	202,419.00
	c) To external wall surface.	m^2	91.23	540.00	49,264.20
	TOTAL CARRIED TO SUMMARY				**454,102.20**
7.00	**Finishing work**				
7.01	Supply and fix Non slippery imported Porcelin size 600*600*10mm thick approved porcelin tile flooring bedded on appropraite cementious mortar or adhesive as per engineer's approval.	m^2	93.00	4,220.00	392,460.00
7.02	10x100mm high porcelain skirting stuck to wall with approved type of adhesive.	m^2	88.00	780.00	68,640.00
7.03	Apply 2 mm thick Fosroc Nitoflor conductive or equivalent floor toping material over 48 mm cement screed to as per the manufacture's instruction .The application shall be carried by the supplier or strict supervision shall be carried by the supplier of the material .The unit price shall includes primary necessary under coats of 2mm thick EPOXY floor toping and the necessary works to complete .The colours shall be determined by the Architect.	m^2	30.00	3,890.00	116,700.00

Prepared By: Naol Terefe Bango **Checked By: Tokumma Jabessa** **Approved By: Tesfaye Erro (RE)**

Table 2.15 BOQ for Plastering, Painting, and Sanitary System Installation (Pharmacy).

BILL OF QUANTITY FOR COMMUNITY PHARMACY BUILDING

Item No	Description	Unit	Quantity	Rate	Amount
7.04	Supply and fix 400x400x9mm non slippery ceramic floor tiles .Quality, type, color & pattern approved by the engineer. Price includes mortar bed grouting and all other necessary works needed to complete the work.	m²	28.00	2,910.00	81,480.00
7.05	280x30mm Granite window sill cut to appropriate size, weathered and mounted on and including 30mm thick cement mortar (1:3) bedding. Price includes making water drip and edge chamfering as shown on the Architectural detail drawing.	ml	13.00	3770	49,010.00
7.06	Supply and lay 25x30mm thick approved type Granite door threshold and frames including mortar bed.	ml	6.20	3,350.00	20,770.00
7.07	10 cm thick C-20 RC, 1m wide pavement around the building (including 4Ø 8 deformed bar mesh ,expansion joint at every 1.2 m length, 80 cm bulk excavation, 55 cm thick selected fill, 20 cm basaltic hard core and cart away).	m²	46.00	5,500.00	253,000.00
7.08	Supply and lay storm water half concrete pipe of diameter 30cm with a minimum slope of 2% or natural ground slope which ever is greater on and including a firm bed of red ash 100mm thick below. The joints shall be grouted in cement sand mortar of (1:3). Price shall include 15cm thick concret curb stone and all the necessary earth work	ml	39.00	8,500.00	331,500.00
7.09	Supply & fix high quality white color acoustically transparent membrane; CAC backing Armstrong or other equivalent Ceiling Systems under concrete slab as per the detail drawings. The size is 600x600x13 mm with complete framing. The panel shall be factory-applied latex painted with Class A Fire Performance. The price shall include suspension systems and all other accessories.	m²	111.11	4,300.00	477,773.00
7.1	Supply and fix high quality Wet-formed mineral fiber Armstrong or equivalent Ceiling Systems for Toilets/ Janitor rooms as per the detail drawing. The panels shall have brighter visual with 20% more light reflectance than vinyl-covered gypsum, Durable – Water-repellent, Washable, Scratch-resistant, Soil-resistant. Factory-applied vinyl latex paint Surface Finish and ASTM E84 and CAN/ULC S102 surface burning characteristics Fire performance. Flame Spread Index 25 or less. Smoke Developed Index 50 or less. (UL labeled) Fire Class A ASTM E1264. Price shall include all accessories.	m²	8.2	4,300.00	35,260.00
	Total Carried to Summary				**1,826,593.00**
8.00	**PAINTING**				
8.01	Supply and paint for walls and celling , according to manufacture instruction and recommended system .work include clean the surface ,repair hair cracks ,primary coat , two or three basic coats and two final with approved materials (Jotun or equivalent), all materials and specification . Type , color and samples shall be submitted by the contractor and approved by the consultant engineer .				
	a) To all Internal wall surface.	m²	280.00	240.00	67,200.00
	b) To exposed beams and columns.	m²	59.00	240.00	14,160.00
8.02	Apply Fine Quartz paint to all exposed external beams, columns and wall surface according to complete manufacturers application instruction .Price shall include pre-cleaning and preparation of surfaces.	m2	340.00	850.00	289,000.00
8.02	Ditto but synthetic paint	m²	28.00	1,500.00	42,000.00
	Total Carried to Summary				**412,360.00**
	8-SANITERY INSTALLATION				
	SANITARY EQUIPMENT (FIXTURES)				
	All fixtures and pipes which are specified below shall subject to the Consultants or Owner's approval based on samples, brochures and catalogues presented by the contractor. Unit Price shall include all the necessary fixing brackets or hooks and all assistnace civil works such as chiselling of walls, floors, beams etc...				
	SANITARY FIXTURES				
8.01	Supply and fix **Rak** or equivalent hand wash basins made of white vitreous china ceramics, with milano or equivalent stainless steel cold and hot water mixer tap complete with pedastel stand, chrome plated chain holder, 60cm long flex-italy or equivalent flexible hoses, P-smell trap with connection pipe and with all other necessary accessories that complete the set.				
	Size :- 500 x 400 mm	No	3	34,500.00	103,500.00
8.02	Supply and fix **Rak or equivalent Water Closet** (WC) of wash down action,floor mounted (S-Trap), close coupled, made of white vitreous China. The fixture shall conform to BS5503-2 or equivalent institution. The plastic seat cover, low flush cistern, waste fittings, connecting pieces, fixing & supporting element, 60cm long flex-italy or equivalent flexible hose, approved quality shut up hose and other accessories which complete the set shall comply with the relevant clauses of BS standard or equivalent institution.				-
	a) Size 670 x 365mm	Nº	2	47,055.00	94,110.00
8.03	Supply and fix RAK or equivalent toilet paper holder with chrome plated brass wall flanged roll with chrome plated fastening screws and other accessories.	No	2	1,620.00	3,240.00
8.04	Supply and fix crystal glass mirrors for toilets and wash basins with copper back protection, size: 500/400 mm including chrome plated brass mirror clips with chrome plated screws and etc... for hand wash basins.	No	3	2,369.00	7,107.00

BILL OF QUANTITY FOR COMMUNITY PHARMACY BUILDING

Item No	Description	Unit	Quantity	Rate	Amount
8.05	Supply and fix approved quality swing pattern **Towel Hanger** made of chrome plated copper alloys, single tubular, surface mounted,bar length of 600mm with 3mm minimum thickness near shower complete with fastening screws white vitreous china ceramic support and other accessories.	No	1	2,326.00	2,326.00
8.06	**SOAP DISPENSER**				-
	Supply and fix stainless steel Dolphin or equivalent soap dispenser of the following characters. • High quality ABS construction • High quality disc pump • Keyless dispenser • Bulk fill • 2ml per pump – 500 dispenses per 1000ml refill. • Uses standard liquid hand soap, anti-bacterial soap & alcohol hand sanitizer (max 70% alcohol content). Price shall include chrome plated fastening screws, drilling, fixing and other necessary accessories and works while fixing.	Nº	1	18900	18,900.00
8.07	Supply and fix aqua or equivalent laboratory **Sink** with double bowl as where shown on the drawing. Complete with milano or equivalent cold and hot water mixing tap, chrome plated chain, flex-italy or equivalent flexible hoses, plug, P-smell trap, 60cm long flex-italy or equivalent flexible hoses and with all other accessories.				-
	Size: 1200 x 500 mm	No	1	128,315.00	128,315.00
8.08	Supply and mount 6kg **Fire Extinguishers** of carbon dioxide type inside kitchen room complete with brackets and all approved standards (exceptionally effective on class B, C & E fire).Unit price shall include all the necessary assistance work.	No	1	21,600.00	21,600.00
	WATER SUPPLY PIPE LINE AND VALVES				-
	Supply, lay install and commission approved quality **PPR pressure pipes (PN20)**, for hot & cold water distribution system to sanitary fixtures. The pipes shall be complete with all the necessary connecting pieces such as bends,Ys, Ts, reducers, nipples, unions, hangers & supported with compatible clips all as per manufacturer's recommendation to the walls, floors, slabs,beams, ceilings, etc...Unit price shall include, disinfection of the pipes with Chlorine and all the necessary assistance to the installation works. The installation shall be tested at a pressure of 10kg/cm2 at the expense of the contractor. The pipes and fittings shall conform to BS3505/DIN8062 or equivalent institution.The PPR pipe shall be UV resistant at the exposed areas. Pipe sizes are external.				-
8.10	Supply and install PPR, PN-20 pipes to internal cold water distribution system as shown on the drawing. Complete with all the necessary fittings and accessories.The pipe diameter is External.				-
	Dia. 20 mm	ml	24	218.00	5,232.00
	Dia. 25 mm	ml	12	405.00	4,860.00
	Dia. 32 mm	ml	6	607.00	3,642.00
8.11	Supply and fix **PPR ball Valves** of approved standard,on water supply distribution lines where shown on the drawing The valves shall be compatable with PPR pipes and complete with adaptors,unions, elastic water proofing , hand wheels of normal quality and all other necessary accessories.				-
	a) Diameter 25mm	No	1	850.00	850.00
	b) Diameter 32mm	No	1	1,200.00	1,200.00
8.12	Supply and fix 15mm dia, PN 20 chrome plated brass quarter turn **angle valves** with chrome plated copper connecting pipe, union nut and chrome plated brass wall flanges, and accessories complete in all respects. The Angle valve should be capable resisting of PN-20 before hand washbasins, water closets, shut up hoses, sinks and water heaters				-
	Dia. 20 mm	No	6	2,075.00	12,450.00
8.13	**WASTE, VENT AND RAIN WATER PIPES AND ACCESSORIES**				-
	All domestic waste, vent and storm water pipe lines shall be uPVC pipes and shall be provided with a minimum slope as indicated on the drawing towards the outlet unless specified. All uPVC pipes and necessary fittings shall be standard quality and be free from damage during storage, transportation, construction etc. Unit price shall include all the necessary assistance civil works, such as excavation cartaway, fixing or hanging to walls, beams or slabs. etc., necessary fittings such as bends, Y, T, etc. Storm water PVC pipes shall resist the external temperature and the quality shall meet the purpose.				-
	Providing, laying and jointing of internal uPVC PN-6 waste pipes with all uPVC pipe fittings including jointing with solvent cement joints and testing of joints etc. according to where shown on the drawings. Complete with all the necessary fittings. Provide cleaning detail for all waste water riser pipes as per the detail drawing. The pipe diameter is external.				-
	Dia. 50 mm	ml	12	150.00	1,800.00
	Dia. 75 mm	ml	4	233.00	932.00
	Dia. 110 mm	ml	18	516.00	9,288.00

Prepared By: Naol Terefe Bango **Checked By: Tokumma Jabessa** **Approved By: Tesfaye Erro (RE)**

Table 2.16 BOQ for Electrical System Installation (Pharmacy).

BILL OF QUANTITY FOR COMMUNITY PHARMACY BUILDING

Item No	Description	Unit	Quantity	Rate	Amount
8.14	Supply and fix floor drains made of uPVC circular box of approved quality for grey water with 4- side openings, complete with P-smell trap with 6cm water seal, treaded drain/clean bottom outlet, approved standard stainless steel cover and all other necessary fittings and accessories.				-
	Size:- Dia. 50/50/50/75 mm	No	3	1,500.00	4,500.00
8.15	Supply and install vent caps made of rigid uPVC to be connected to the roof terminal of vent pipe. Unit price shall include flushing works to prevent roof leakage: -				-
	a) Size: - Dia.110mm	No	1	475.00	475.00
8.16	**ROOF RUNOFF DRAINAGE SYSTEM**				-
	Supplying & fixing of 110 dia uPVC rain water **down pipes:** fixed sloping to feed rainwater harvest uPVC tank (2000Litres capacity)measured separately; including all necessary accessories to complete the installation	ml	9	625.00	5,625.00
	ROOF WATER TANK & WATER SUPPLY SYSTEM				-
8.17	***ELEVATED FIBER GLASS WATER TANK***				-
	Supply and place properly (fix) 1m3 ground water tank for rain water storage where as shown on the sanitary site plan, made of best quality and acceptable thickness fiber glass including all the necessary connecting fittings and pipes such as outlet pipe with gate valve, inlet pipe with gate valve, drain pipe with gate valve, over flow pipe, vent pipe including manhole cover and vent cap.Provide manhole with a strong ,lockable and easily openable cover (lid) just above the inlet pipe.Complete with :-				-
	-Diameter 20mm inlet pipe (PN16) with bronze gate valve and float valve.				-
	-Diameter 40mm over flow pipe				-
	-70cm*70cm manhole cover				-
	•Sufficient free board and sludge zone for air circulation, proper functioning of the float valve (ball) and accumulation of the accidentally entering solid particles respectively.				-
	•Strong solid supporting legs(no space for				-
	water to be retained inside).				-
	•Prior to the approval of the material submittal of the detail drawings of the tank is mandatory.				-
	complete with all accessories.				-
	•The fiber glass shall be warranted by the supplier against all defects and malfunction of materials and workmanship for a period of Ten years from the date of completion of works. If problems arise with the system during the warranty period,all necessary repairs or replacement shall be made by the contractor in an expendient manner at no additional cost. Price shall include lifting the tank to lift roof slab level with crane	No	1	40,000.00	40,000.00
8.20	**SEPTIC TANK & OTHERS**				-
8.21	Brick manhole				-
	a) Manhole in bricks and with concrete base internally of 1000x1000x700mm including concrete cover with lifting hole.	No	2	179,000.00	358,000.00
8.23	Construct half precast 400mm open ditch on a base of 50mm sand & 100mm compacted selected material all as per the given detail drawing	ml	54	2500	135,000.00
8.24	Ditto as item No 14 but grill covered as per the given detail drawing	ml	12	1400	16,800.00
	TOTAL CARRIED TO SUMMARY				**979,752.00**
	9. ELECTRICAL INSTALATION				
	All distribution boards, breakers, switches, accessories etc should be genuine Legrand, ABB, Siemens or approved equivalents complying with IEC standards. Distribution boards should be made of sheet metal and have separate phase, neutral and ground busbars. All units in the distribution boards should be labled to give the reference and duty of the unit.				
	SUPPLY AND INSTALL:				
	DISTRIBUTION BOARDS				
9.1	Flush mount Sub Distribution Board (SDB-CPHAR) in metalic				
	enclosure, for recess mounting with lockable door including phase,				
	neutral and earth bars rate of 50 amp, connection terminals , etc.				
	and consisting of :				
	1 pc MCB of 25A, 1-phase (main)				
	2 pcs MCB of 16A, 1-phase				
	2 pcs MCB of 10A, 1-phase				
	with 25% reserve space of MCBs and complete with				
	cable/wire connectors, earthing terminals & fixing accessories.	No.	1	15,845.00	15,845.00
9.2	**LIGHT POINTS**				
9.2.1	Light points fed through PVC sheated copper conductor of 2x2.5				
	sqmm in thermoplastic conduit of 13mm in/under surface including				
	Junction boxes with covers and screw type connectors with				
	Insulating caps .	No.	26	4,900.00	127,400.00
9.3	**EXTRA OVER LIGHT POINTS FOR SWITCHES TYPE**				
	LEGRAND DECOR or EQUIVALENT APPROVED WITH				
	JUNCTION BOX 31301				
9.3.1	Flush mounting single pole switch.	No.	3	821.00	2,463.00
9.3.2	Flush mounting double pole switchs.	No.	5	801.00	4,005.00
9.3.3	Flush mounting 2-way switchs.	No.	2	748.00	1,496.00

BILL OF QUANTITY FOR COMMUNITY PHARMACY BUILDING

Item No	Description	Unit	Quantity	Rate	Amount
9.3.4	Flush mounting intermidate switchs.	No.	1	801.00	801.00
9.4	**SOCKET OUTLETS (SCHUKO type or approved equivalent)**				
9.4.1	Flush mounting socket outlet of 16A/1P +N+E	No.	14	828.00	11,592.00
9.5	**SOCKET OUTLET POINTS (wiring/cabling)**				
9.5.1	Socket out let points fed through PVC sheathed copper conductor of 3x2.5 sqmm in thermoplastic conduits of dia. 16 mm in/under surface with all nesessary accessories.	No.	14	5,457.00	76,398.00
10	**TV/TVRO terminal outlets and points**	No.			
9.6.1	Flush mounted co-axil type tv-socket out let and point with cable in conduit of 19mm diameterin/under surface inculding junction boxes and riser with all accessories	No.	1	2,278.00	2,278.00
9.6.2	Flush mounted PVC Tv terminal box with lockable door and other necessary accessories & size of, 10x10x10 cm.	No.	1	5,500.00	5,500.00
9.7	**TELE/DATA COM TERMINAL OUTLETS AND POINTS**				
9.7.1	Telephone terminal outlet, RJ11 type LEGRAND category 6 with 4 contacts complete with clip on support frame and other accessories .	No.	4	3,787.00	15,148.00
9.7.2	Tele terminal points fed through 2x category 6 UTP cable (double UTP cable) inside PVC conduit of 19 mm. diameter.	No.	4	4,057.00	16,228.00
9.7.3	Tele terminal junction box with lockable door and other necessary accessories & size of 25x25x10 cm. made of PVC.	No.	1	496.00	496.00
9.8	**LIGHT FITTINGS AND LAMPS (specified or approved equivalent)**				
	Supply, fix and test including lamps with all accessories				
9.8.1	1- Philips TMS 022/236 HFD C6 with 2x'TL'D 36w/ 840 flt.lamp	No.	16	8,922.00	142,752.00
9.8.2	2- Philips TMS 022/136 HFD C6 with 1x'TL'D 36w/ 840 flt.lamp	No.	7	6,492.00	45,444.00
9.8.3	3- Melissa 0780.127 FC 22w G10Q	No.	2	6,897.00	13,794.00
9.8.4	4- Philips FBH 170 /1xPL-C18w/CF-20/ 540 flt.lamp (Board-sinage)	No.	1	7,572.00	7,572.00
9.9	**Supply and install FEEDER CABLE /power supply cable of type SIEMENS NYY 0.6/1KV or approved equivalent**				
	a) 3x6 Sqmm. from EEPCo line to Kwhm to SDB	Mt	75	821.00	61,575.00
	b) 1x6 Sqmm from SDB to LV earth copper rod/electrode	Mt	15	375.00	5,625.00
9.1	**Rigid PVC PIPES**				
9.11	50 mm diameter PVC pipe	Mt	36	622.00	22,392.00
9.12	25 mm diameter PVC pipe	Mt	30	303.00	9,090.00
9.2	**MANHOLES**				
	Construct manhole with double brick wall internally plastered with removable reinforced concrete cover with lifting lug,				
	size : 50x50x60 cm, cover thickness 8 cm.	No.	2	18,435.00	36,870.00
9.3	**LOW VOLTAGE EARTH SYSTEM**				
9.31	Supply and install LV copper bond electrod rod of Diam. 16mm, length 1600mm, inside 50x50x60cm manhole with all the necessary accessories.	No.	1	9,762.00	9,762.00
9.32	Supply and install 15mt bare copper conductor of 1x6 sqmm.from main distribution boards earthing bar to Lv copper bond earth electrode rod with all the necessary accessories.	No.	1	7,488.00	7,488.00
	TOTAL CARRIED TO SUMMARY				**642,014.00**

Prepared By: Naol Terefe Bango **Checked By: Tokumma Jabessa** **Approved By: Tesfaye Erro (RE)**

Table 2.17 BOQ Summary for Community Pharmacy Block.

SUMMARY OF BILL OF QUANTITIES
FOR
COMMUNITY PHARMACY BLOCK

Item No	Description	Unit	Amount
	A. SUBSTRUCTURE		
1	Excavation and Earth Works	Birr	781,577.56
2	Concrete Works	Birr	1,005,198.78
3	Masonry works	Birr	589,950.00
	TOTAL CARRIED TO SUMMARY A		**2,376,726.34**
	B. SUPER STRUCTURE		
1	Concrete Work	Birr	1,600,469.40
2	Block Work	Birr	314,568.60
3	Roofing work	Birr	828,800.80
4	Carpentary & Joinery	Birr	129,600.00
5	Metal Works	Birr	862,681.00
6	Plastering work	Birr	454,102.20
7	Finishing work	Birr	1,826,593.00
8	Painting Work	Birr	412,360.00
9	Sanitary Installation Work	Birr	979,752.00
10	Electrical Installation Works	Birr	642,014.00
	TOTAL CARRIED TO SUMMARY B		**8,050,941.00**
	GRAND TOTAL A + B		**10,427,667.34**
	GRAND TOTAL		**10,427,667.34**

In line with standard quantity surveying procedures, the Bill of Quantities (BOQ) for each component of the Shaggar One General Hospital project was prepared through a systematic process. This involved four key stages: (1) Taking Off, where measurements were extracted from drawings; (2) Squaring, where quantities were calculated; (3) Abstracting, which organized the data into trade sections; and (4) Final Writing, where unit rates were applied based on current market conditions to produce the final BOQ. Accordingly, the Grand Total Cost for each major work item of the Shaggar One General Hospital has been summarized as follows.

Table 2.18 Grand Cost Summary of Major Work of the Shegger One General Hospital Project [21].

Item No.	Item of Work	Unit	Grand Total Cost Amount (Birr)
1	Main Hospital Building	Birr	2,546,490,418.93
2	Administration Office	Birr	200,063,427.95
3	Community Pharmacy	Birr	10,427,667.34
4	Generator House	Birr	4,477,216.06
5	Pump House	Birr	9,396,704.03
6	General Site Work	Birr	265,098,886.82
7	Road Work	Birr	162,325,591.59
	Subtotal		**3,198,279,912.72**
	15% VAT		**479,741,986.91**
	Grand Total		**3,678,021,899.63**

2.3.1.2.2. Material Cost Estimation and Rate Breakdown Analysis

During my internship I prepared itemized unit-rate analyses to price the Community Pharmacy building works, following standard BOQ methodology. For each activity I quantified inputs per unit of work from drawings and specifications, then built up the rate from materials, labor, and equipment, with overheads and profit added at the end. For example, the 15 cm HCB wall (both sides left for plaster) was analyzed per $1m^2$: 13 pcs of 15 cm HCB blocks, 0.08 quintal of cement, $0.02m^3$ sand, and $0.004m^3$ water produced a materials cost of about $121.47 Birr/m^2$ Labor was based on a crew output of $0.75m^2/hr$ with one foreman, one mason, and two helpers, yielding $37.24 Birr/m^2$; hand tools contributed roughly$1.07 Birr/m^2$. Applying 20% overhead and 15% profit resulted in a composite unit rate of approximately $215.70 Birr/m^2$. I used this same structured approach clear take-off, current market rates, realistic productivity, and transparent mark-ups to develop the full material cost estimate and rate breakdowns across the Pharmacy building trades.

To maintain brevity in this report, I have presented only the general rate analysis table that illustrates how direct material, labor, and equipment costs are built up for civil engineering works. The detailed step-by-step breakdowns for each activity have not been included here. It is important to note the distinction between the rate analysis and the Bill of Quantities (BOQ): while rate analysis is the detailed process of calculating unit rates by combining direct costs with overheads, profit, and risk allowances, the BOQ is the compiled document that summarizes these results into measurable work items with their respective unit rates and total costs. In other words, rate analysis provides the basis for determining the cost of each activity, whereas the BOQ presents the finalized, all-inclusive costs (covering direct and indirect expenses) in a structured format for tendering, payment, and project cost control [15].

Table 2.19 General Table for rate analysis of Direct Cost of Project

PROJECT NAME	
BOQ REFERENCE	
ACTIVITY CODE	
UNIT OF MEASURE	

ACTIVITY DESCRIPTION

DIRECT MATERIAL COST					DIRECT LABOR HOURLY COST						DIRECT EQUIPMENT HOURLY COST				
Material Description	Unit	Quantity	Unit cost	Total cost	Labor by trade	No of labor	Basic salary	Labor index	UF	Total cost	Equipment description	No of equipments	Hourly cost	UF	Total cost
A – TOTAL DIRECT MATERIAL COST					B - TOTAL DIRECT LABOR HOURLY COST						C – TOTAL EQUIPMENT HOURLY COST				

D – Hourly crew productivity	Data
E – Direct material cost	A
F – Direct labor cost	B/D
G – Direct equipment cost	C/D
H – DIRECT UNIT COST	E + F + G
I – Site overhead costs	K1 * H
J – Head office overhead costs	K2 * H
K – INDIRECT UNIT COST	I + J

L – RISK ALLOWANCE	R1*E + R2*F + R3*G + R4*I +R5*J
M – GROSS PROFIT	P%/0.7 * (H + K + L)
N – TOTAL UNIT PRICE WITHOUT VAT	H + K + L + M
O – VALUE ADDED TAX (VAT)	0.15 * N
P – TOTAL UNIT PRICE WITH VAT	N + O
REMARK	

Through this experience, I learned that quantity surveying is not only about calculations but also about interpreting designs, understanding technical specifications, and maintaining transparent documentation. It taught me the importance of attention to detail and how closely tied engineering accuracy is to financial accountability. Being part of these tasks gave me a solid foundation in how engineering documentation translates into practical project execution and contract payment systems.

2.3.1.3. Design Review, Shop-Drawing, and Document Control Systems

In civil engineering projects, design review is a structured process where the client, consultant, and contractor jointly evaluate design documents to ensure that proposed solutions are functional, cost-effective, and constructible. When modifications are necessary, the consultant verifies the client's request, assesses technical feasibility, and issues recommendations; the contractor then incorporates the approved revisions into the works. Such reviews may result in changes to the project scope, contract cost, or construction methodology, and are critical for maintaining quality, avoiding design conflicts, and ensuring compliance with standards and codes of practice.

But now I want to discuss my own design review of the project's design. During my internship, I also took part in reviewing design documents prepared by different departments within the consultant office. This included architectural layouts, structural framing plans, electrical circuits, and plumbing drawings. My role was mostly observational, but I was guided by the engineers to understand how design coordination is done across disciplines. I compared the drawings against site conditions and spotted minor inconsistencies between plans, sections, and elevations. This experience taught me how interdisciplinary coordination is critical to prevent clashes on-site, and how even small design errors can lead to major execution delays or cost overruns. I also learned to use AutoCAD for minor edits and to support updating revised layouts with proper layering and referencing techniques.

In a Design-Bid-Build (DBB) contract delivery system, the contractor is responsible for preparing workshop (shop) drawings based on the consultant's issued-for-construction designs. These workshop drawings serve as detailed working documents that verify dimensions, clarify constructability issues, and accommodate practical adjustments on site. Contractors may submit shop drawings to highlight dimensional inconsistencies discovered during execution, or to propose innovative modifications that improve functionality without altering the overall design intent. In the Shaggar One General Hospital project, an example of such coordination occurred on the basement floor, where a request for revision was submitted to correct the alignment of the mortuary (corpse) evacuation door with the adjoining corpse storage room. The contractor, represented by Project Manager Eng. Tariku prepared and submitted the revised workshop drawing, which was reviewed by the consultant and subsequently approved. This change ensured accurate dimensional coordination, improved operational functionality, and demonstrated how shop drawings act as a crucial interface between design intent and on-site execution in DBB projects, whereas in the DB system, the contractor innovate directly [27].

I was also introduced to the document control system used by ECO for managing all project-related files and correspondence. The system followed a standardized filing structure that categorized documents by type (letters, drawings, submittals, RFIs, approvals, etc.) and tracked their status, whether pending, under review, or approved. I helped organize and label files, check for missing documents, and support the team during audit preparations. This task improved my attention to detail and helped me understand how document traceability is maintained in a professional environment. It also emphasized how crucial it is to have an accurate and up-to-date record of the project's documentation flow to ensure accountability and smooth coordination.

2.3.1.4. Project Correspondence and Meeting Participation

In addition to contract administration and quantity surveying tasks, I was also involved in project correspondence and attending coordination meetings, which gave me exposure to the professional communication and collaborative side of construction management. These activities, while often seen as administrative, play a crucial role in keeping large-scale projects like the Shaggar One General Hospital on track in terms of quality, schedule, and cost. One of my key responsibilities was assisting in managing incoming and outgoing correspondence between the contractor, consultant, and client. These documents included letters, memos, RFIs (Requests for Information), submittal responses, and site instructions. Most of the correspondence was written formally, often referencing contract clauses, drawing numbers, or BOQ item codes. My job involved reviewing these letters, registering them into the document control system, and ensuring they were delivered to the right personnel on time. I was also taught how to draft response letters, although they were reviewed and finalized by the site engineer.

From this, I learned the importance of professional documentation. Every instruction, comment, or decision must be officially written and archived, because in a project of this scale, verbal communication is not enough. There must be a clear record of what was said, who said it, and when, to avoid conflicts and delays. This also helped me improve my formal technical writing skills, especially how to keep communication clear, objective, and to the point. Aside from handling letters, I was allowed to attend weekly progress meetings between the client (Shaggar Health Office), consultant (ECO), and contractor (Gutema Firisa JV with MCG). These meetings were held to evaluate site progress, resolve technical issues, approve design changes, and discuss delays or material shortages. As an intern, I mostly observed during these sessions, but I took detailed notes and later reviewed the Minutes of Meetings (MoM) to understand how decisions were documented and followed up on.

What impressed me most was the level of coordination required between the different disciplines: structural, electrical, mechanical, and sanitary engineers all had to present updates and flag concerns. The consultant often had to verify if the work being executed was as per the latest approved drawings and whether the contractor was complying with the technical specifications. Sometimes, disputes were raised by the contractor regarding BOQ items or time extensions, and I saw how the consultant referred to the contract documents to evaluate such claims professionally.

Another area I was exposed to was technical submittal meetings, where samples of materials (like reinforcement bars, concrete mix designs, insulation materials, or tiles) were presented for approval. These meetings helped me understand how quality assurance works before materials even reach the site. As an intern, I helped prepare and organize the documents for these reviews and learned the standards against which materials are evaluated. Overall, being part of the project communication and meeting process showed me that construction is not just about physical work on-site; it's a highly organized system where every action is backed by formal communication, documentation, and approvals. It gave me a real appreciation for the coordination and professionalism required in large infrastructure projects. This part of my internship strengthened not only my technical skills but also my understanding of project governance, professional communication, and the broader process of decision-making and coordination among stakeholders.

2.3.2. Site Work Experiences

2.3.2.1. Introduction to Construction Site Works

Construction site work in civil engineering encompasses all preparatory and external activities required to transform raw land into a build-ready environment. It involves all activities that transform a designed structure from concept to reality at a physical location. It includes surveying, grading, excavation, site utilities, paving, concrete work, and landscaping. These tasks ensure the site is safe, stable, and ready for construction, forming the foundation for a structurally sound and functional building. Thus, the building would be compliant with technical specifications [28].

For the Shaggar One General Hospital project at Gefersa Guje, the site selection and preparation were critical. The location was chosen based on technical, regulatory, and budgetary criteria, ensuring optimal conditions for the hospital's entire building structure and future expansions. This broad scope typically includes:

- **Site Investigation & Selection:** Evaluating multiple potential locations for geotechnical, environmental, regulatory, and logistical suitability.
- **Mobilization & Temporary Facilities:** Establishing site offices, storage yards, utilities, worker accommodations, and health-and-safety signage.
- **Site Clearance & Earthworks:** Removing vegetation, topsoil, and obstructions; bulk excavation; site grading; and stockpiling or disposal of excavated material.
- **Utilities & Drainage:** Installing or reconnecting water, sewer, electrical, and telecom services, as well as designing and constructing temporary and permanent drainage systems.
- **Access Roads & Paving:** Creating haul roads for construction vehicles, permanent site access drives, and parking areas.
- **Temporary Works & Fencing:** Erecting perimeter security fences, temporary retaining walls, and protective barriers.
- **Landscaping, Leveling, and Final Grading:** Shaping the terrain to design levels, planting, and preparing for hardscape finishes.

This foundational phase ensures that subsequent structural, architectural, and mechanical works proceed safely, efficiently, and in compliance with all technical and regulatory requirements.

2.3.2.2. Site Selection Criteria for the Shaggar One General Hospital Project

The construction site at Gefersa Guje was selected based on a comprehensive evaluation of various factors from all shaggar City Subcity towns:

- **Climatic Conditions:** The site's climate, including temperature, rainfall, and wind patterns, was analyzed to ensure durability and patient comfort. Design adaptations for ventilation and insulation were integrated to mitigate extreme weather conditions.
- **Sub-Soil Investigation:** Geotechnical boreholes across the site confirmed a uniform soil bearing capacity of 300 KPa with groundwater encountered below 9 m, ensuring both structural stability and alignment with cost estimates. Seismic assessments further indicate that the site lies within a low-to-moderate earthquake risk zone, validating that all foundation & structural designs meet the applicable seismic code requirements [16].
- **Availability of Modern Services**: Proximity to essential services, including water, electricity, sewage, and telecommunications, reduces initial costs, with backup generator systems planned for added reliability.
- **Local Authority Regulations:** Compliance with zoning laws, building codes, and environmental guidelines was confirmed on the ESIA draft report of the project [29].
- **Surroundings and Accessibility:** The site's proximity to a forested area minimized resident displacement, and its strategic location along major transit routes (Finfinne, Burayu, Holota) ensured accessibility for patients and staff. The project site is located within the Shaggar City Administration of the Oromia Regional State, situated at a geographic location of UTM-37P, 0455996E and 1001150N. Access to the project area is possible via the 23-kilometre Asphalt Road that leads from Finfinne to Burayu, as well as an additional **1km** gravel road [16]. The topographic level of the site is also good for surface drainage.

Figure 2.8 Project Location in Shaggar City relative to Finfinne (Google Earth).

2.3.2.3. Site Preparation

Before the arrival of heavy machinery, the construction team initiated a meticulous site preparation process to ensure operational efficiency and compliance with safety and quality protocols. The first step involved establishing permanent benchmarks and boundary lines, using the existing perimeter fence as a reference grid for all future measurements. With these control points in place, strategic locations were designated for material storage areas, the main site office, labor shelters, guard posts, and internal access roads. These placements were carefully chosen to optimize workflow, reduce congestion, and minimize unnecessary movement across the site.

Soil testing and geotechnical investigations to assess bearing capacity, slope stability, and groundwater levels, which are critical for foundation design and excavation safety, were executed as part of site work, but these were done before designing the project because all of the design must use the data for the reliability of the building as per the geology of the area. The site was also surveyed for underground utilities to prevent service disruptions, and termite treatment was conducted to protect future structural integrity. In addition to logistical planning, safety and environmental considerations were prioritized. A full suite of safety signage was installed along the fence perimeter, including prominent "Danger: Construction Work in Progress" warnings facing outward, and internal site rules such as "No Hats, No Boots, No Job" to reinforce a culture of hazard awareness. These preparatory steps not only ensured regulatory compliance but laid the groundwork for a resilient and well-coordinated construction phase.

Figure 2.9 Site Layout before Mobilization, showing key facilities (i.e. Site Offices) and safety signage.

2.3.2.4. Setting out of the Building

Setting out is the precise process of translating the approved building design from drawings to physical ground coordinates, ensuring the structure's exact location and dimensions are achieved. On this project, Theodolites and Leveling instruments were employed to establish horizontal and vertical alignments as well as the level of each work for basement beams, slabs, column erection, shear walls, and all footing/foundation layouts, as well as for the interior road network. Permanent benchmarks were set and regularly checked against site control points to prevent cumulative deviations. In accordance with civil engineering best practices, the work also involved total station verification for fine tolerances, profile boards, and batter boards to guide excavation, as well as as-built surveys before concreting. Considerations for instrument calibration, environmental influences on measurements, and geodetic corrections for long spans ensured dimensional accuracy and long-term structural alignment integrity.

Figure 2.10 Building setting out using Theodolite and Total Station.

2.3.2.5. Site Clearance (Grubbing) Work

Site clearance was undertaken to prepare a clean and stable platform for subsequent excavation and foundation works. This involved the removal of vegetation, debris, and unsuitable topsoil, with reusable topsoil stockpiled for later landscaping. All roots, stumps, and obstructions were removed to the specified depth, and unsuitable materials were disposed of at approved locations. Activities included the diversion or protection of existing utilities, application of dust suppression and erosion control measures, and safeguarding of adjacent structures. Where hard rock was encountered, mechanical breaking was preferred over blasting to reduce vibration impacts. In line with Ethiopian public works and environmental guidelines, archaeological and cultural heritage checks were performed before work commenced. These procedures ensured the site was fully compliant with safety, environmental, and regulatory requirements prior to foundation operations.

Figure 2.11 Site Clearance and Grubbing Activities of the project.

2.3.2.6. Substructure Work of the Main Hospital Building

2.3.2.6.1. Excavation Earthwork Activities

The excavation works for the foundation of the Main Hospital Building at Gefersa Guje were executed with precision and technical rigor, strictly adhering to the specifications outlined in the contract's Bill of Quantities (BOQ). The primary objective was to reach soil strata with sufficient bearing capacity to safely support the structural loads of the hospital's multi-block configuration. Unlike conventional practices that rely on average depth assumptions, this project followed detailed excavation profiles derived from structural design levels, ensuring both safety and cost-efficiency.

Before excavation, a comprehensive site clearance operation was undertaken to remove vegetation, topsoil, and surface irregularities. This was executed over an area of 9,100 m^2, priced at 108 ETB per m^2, totaling 982,800.00 ETB. This step was essential not only for leveling the site but also for establishing a clean working surface for subsequent excavation and foundation works.

The BOQ classified excavation into multiple categories in terms of Ditto (abbreviated as **"do"** to repeat the same description or to specify a variation (rocky soil)) based on soil type and depth, each with distinct execution methods and unit rates. These included:

Ordinary Soil Excavation:

- Depth ≤ 1500mm: 9,521.25 m^3 by 380 ETB per $1m^3$; Totally 3,618,075.00 ETB.
- Depth ≤ 3000mm: 9,418.50 m^3 by 460 ETB per $1m^3$; Totally 4,332,510.00 ETB
- Depth ≤ 4500mm: 8,814.75 m^3 by 560 ETB per $1m^3$; Totally 4,936,260.00 ETB

Soft Rock Excavation:

- Depth ≤ 1500mm: 1,203.50 m^3 by 660 ETB per $1m^3$; Totally 794,310.00 ETB
- Depth ≤ 3000mm: 1,328.30 m^3 by 810 ETB per $1m^3$; Totally 1,075,923.00 ETB
- Depth ≤ 4500mm: 1,449.00 m^3 by 880 ETB per $1m^3$; Totally 1,275,120.00 ETB

Boulder Rock Excavation:

- Depth ≤ 1500mm: 845.30 m^3 by 820 ETB per $1m^3$; Totally 693,146.00 ETB
- Depth ≤ 3000mm: 845.30 m^3 by 970 ETB per $1m^3$; Totally 819,941.00 ETB
- Depth ≤ 4500mm: 1,086.80 m^3 by 1,180 ETB per $1m^3$; Totally 1,282,424.00 ETB

Hard Rock Excavation:

- Depth ≤ 1500mm: 603.80 m^3 by 1,310 ETB per $1m^3$; Totally 790,978.00 ET
- Depth ≤ 3000mm: 483.00 m^3 by 1,560 ETB per $1m^3$; Totally 753,480.00 ETB
- Depth ≤ 4500mm: 724.50 m^3 by 1,950 ETB per $1m^3$; Totally 1,412,775.00 ETB

These quantities reflect a meticulous breakdown of excavation volumes across varying soil conditions and depths, demonstrating the project's commitment to precision and cost control. The total excavation volume exceeded 46,000 m^3, and the cumulative cost for excavation alone amounted to over 25 million ETB, excluding backfill and site clearance [21].

Post-excavation, two types of backfilling were performed: one using selected quarry material compacted to 100% Modified AASHTO density, and the other using selected excavated material compacted to 95% dry density [30]. These backfilling operations were not initiated immediately after excavation but were strategically scheduled following the completion of footing works. Once the structural concrete for footings was cast and cured, and the reinforcement for column starter bars was securely installed and cast with concrete, backfilling commenced around and between the footings. The fill was carefully placed and compacted in layers until it reached the designed elevation of the basement beam level, ensuring a stable base for subsequent structural elements. This approach not only protected the exposed reinforcement from environmental degradation but also provided a clean, level surface for lean concrete placement and basement beam reinforcement setup.

To stabilize the foundation base, 6,371.72 m^3 of basaltic stone hardcore was laid, compacted, and blinded with crushed stone to a thickness of 25cm. This was priced at 1,140 ETB per m^3, totaling 7,263,760.80 ETB. This layer acts as a load-distribution medium and moisture barrier, enhancing the durability of the substructure.

Surplus excavated material was carted away to designated disposal sites, totaling 46,879.34 m^3 by 380 ETB per $1m^3$, amounting to 17,814,149.20 ETB. This disposal was critical for maintaining site cleanliness and avoiding congestion during structural works.

From a civil engineering standpoint, the excavation process integrates several key principles:

- Shrinkage and Swell Factors: Excavated soil typically swells when removed and shrinks upon compaction. Proper estimation of these factors is vital for accurate BOQ preparation and cost forecasting.
- Geotechnical Validation: Borehole tests confirmed a bearing capacity of 300 kPa, aligning with Ethiopian seismic and soil standards. This ensured that excavation depths were not arbitrary but structurally justified.
- Safety and Efficiency: The inclusion of a 1-meter offset around the foundation footprint allowed for safe working space, formwork installation, and waterproofing. A detail often overlooked but essential for quality assurance.
- Environmental Compliance: Disposal and backfill operations were conducted in line with local environmental regulations, minimizing ecological disruption and ensuring sustainable site management.

The total cost of excavation works for the Main Hospital Building at Gefersa Guje reflects a comprehensive and technically sound execution of earthwork activities across multiple soil categories and depths. Based on the detailed Bill of Quantities, the cumulative expenditure for excavation, including ordinary soil, soft rock, boulder rock, and hard rock, amounted to approximately 25,266,967.00 ETB. When combined with associated operations such as site clearance (982,800.00 ETB), backfilling with selected quarry and excavated materials (29,308,044.00 ETB), disposal of surplus soil (17,814,149.20 ETB), and hardcore bedding (7,263,760.80 ETB), the grand total for all excavation-related activities reached over 80 million ETB. This figure underscores the scale and complexity of the project's substructure phase, where precision in measurement, cost estimation, and execution was paramount. The BOQ's itemized structure ensured transparency and accountability, while the engineering supervision guaranteed that each activity met the required technical standards. This investment in foundational works not only secured the structural integrity of the hospital but also demonstrated best practices in civil engineering, cost management, and site preparation [21].

The excavation earthwork for the Shaggar One General Hospital project stands as a model of technical excellence and contractual discipline. Every cubic meter was measured, priced, and executed with engineering precision. The integration of BOQ data, structural design requirements, and field supervision ensured that the excavation phase laid a solid foundation both literally and figuratively for the hospital's long-term structural integrity.

Table 2.20 BOQ for Main Hospital Excavation Work.

Project:- Shaggar One General Hospital
Location:- Gafarsa Guje Subcity
Consultant:- Engineering Corporation Of Oromia
Contractor:-Gutema Firisa JV with MCG Construction plc
Client: Shaggar city Healthy office

BILL OF QUANTIT FOR MAIN HOSPITAL BUILDING

Item No	Description	Unit	Quantity	Rate	Amount
	A-SUB STRUCTURE				
	1. EXCAVATION & EARTH WORK				
1.01	Surface dressing of the ground including removing and grubbing of all type of trees irrespective of tree height and girth, removal of vegetation, removal of ground inequality not exceeding 200mm deep in all kinds of soil and disposal of rubbish either within the site or outside the site boundary as directed by the Engineer in charge.	M2	9,100.00	108.00	982,800.00
1.02	Bulk excavation in ordinary soil from reduced level to a depth not exceeding 1500mm,inclusive of shoring ,strutting and bailing out water wherever necessary,depositing the surplus earth in shown by the Engineer in charge,clearing and levelling the site as specified hereunder etc ,all complete in all respects complying with relevant standard specifications.	M3	9,521.25	380.00	3,618,075.00
1.03	Ditto,but				
	a) Soft rock	M3	1203.50	660.00	794,310.00
	b) Bolder rock	M3	845.30	820.00	693,146.00
	c) Hard rock	M3	603.80	1,310.00	790,978.00
1.04	Ditto but bulk excavation in ordinary soil to deoth not exceeding 300 cm	M3	9418.5	460	4332510
1.05	Ditto,but				
	a) Soft rock	M3	1328.30	810.00	1,075,923.00
	b) Bolder rock	M3	845.30	970.00	819,941.00
	c) Hard rock	M3	483.00	1,560.00	753,480.00
1.06	Ditto BUT bulk excavation in ordinary soiil to a depth not exceeding 450 cm	m^3	8,814.75	560.00	4,936,260.00
1.07	Ditto,but				-
	a) Soft rock	M3	1449.00	880.00	1,275,120.00
	b) Bolder rock	M3	1086.80	1,180.00	1,282,424.00
	c) Hard rock	M3	724.50	1,950.00	1,412,775.00
1.08	Pit excaavation In ordinary soil to a depyh not exceeding 150 cm	M3	3,756.87	380.00	1,427,610.60
1.09	Ditto,but				
	a) Soft rock	M3	1054.60	660.00	696,036.00
	b) Bolder rock	M3	922.70	820.00	756,614.00
	c) Hard rock	M3	856.80	1,950.00	1,670,760.00
1.10	Pit excaavation In ordinary soil to a depyh not exceeding 300 cm	M3	3,163.68	450.00	1,423,656.00
1.11	Ditto,but				
	a) Soft rock	M3	1318.20	802.00	1,057,196.40
	b) Bolder rock	M3	1186.40	970.00	1,150,808.00
	c) Hard rock	M3	922.70	1,560.00	1,439,412.00
1.12	Back fill using selected material from quarry, compacted in layers, each layer not exceeding 200mm and compaction level to 100% modified AASHTO density. As per Engineers approval	M3	16,794.00	1,610.00	27,038,340.00
1.13	Backfill with selected excavated material from the site. Compacted thickness should not be more than 200mm and the field density should attain 95% of the maximum dry density.	M3	4,450.40	510.00	2,269,704.00
1.14	Load and cart away surplus excavated material away from the project site to waste -area in compliance with all administrative and environmental regulation of the project site.	M3	46,879.34	380.00	17,814,149.20
1.15	Basaltic or equivalent stone hardcore well rolled, consolidated and blinded with crushed stone to a finished thickness of 25cm.	M3	6,371.72	1,140.00	7,263,760.80
	Total carried to Summary				**86,775,789.00**

2.3.2.6.2. Foundation Reinforced Concrete Works of the Main Hospital Building

To initiate the structural works for the Main Hospital Building, foundation concrete activities were undertaken as the first major step. According to the structural design, the building incorporates a combination of **19 combined footing** types and **61 single footing** types to support a diverse arrangement of columns. In addition to standard columns and stairwells, the foundation includes elevator pits and a wheelchair-accessible ramp, ensuring inclusive vertical mobility across all levels from the basement to the fourth floor (B+G+4 configuration) [64].

The main Hospital building is constructed over a total area of **6,740 square meters**. Due to the building's large footprint and complex load distribution, the structural design includes **five independent structural blocks, separated by expansion joints**. This strategy minimizes the risk of progressive structural failure, allowing localized damage, if it occurs, to remain isolated and not propagate throughout the entire structure over its lifetime.

As per standard civil engineering practice, lean concrete was poured at the base of all footings after the completion of excavation. The lean concrete used was designed for a compressive strength of 7MPa (by mix ratio of, 1:4:8), primarily to prevent direct contact between soil and reinforcement bars, thereby reducing the risk of corrosion and ensuring a clean, level working surface for further reinforcement placement.

The lean concrete was mixed on-site using a Drum Batch Mixer and placed directly according to the footing layout. The mix ratio adopted was 1:4:8 (Cement: Sand: Coarse Aggregate), which complies with the specified proportions for non-structural concrete pads.

Figure 2.12 Lean Concrete Mixing using a Drum Batch Mixer and Placement under MHB Footings.

This lean concrete layer served as a preparatory base for reinforcement placement, formwork, and structural concrete casting, ensuring dimensional accuracy and improved quality control during subsequent stages of the foundation work.

After the lean concrete was adequately cured and hardened, reinforcement bars were placed on top of it in accordance with the structural design of each footing type. These reinforcement arrangements were tailored for both single and combined footings, following the specific detailing outlined in the Structural design drawings.

The polished formwork timber with oil for the purpose of removal was precisely aligned using the Pythagorean Theorem and dimensional checks to ensure stability and adequate support for the anticipated concrete loads. In compliance with the Ethiopian Reinforced Concrete Design Code CES 149:2015, a nominal concrete cover of 50 mm was provided for structural elements exposed to external conditions. This cover protects the reinforcement against corrosion, ensures adequate fire resistance, and allows for proper bond development between steel and concrete.

To achieve this, 50 mm spacers were fabricated on site from mortar, incorporating *shiboo* (binding wire) to securely attach them to the outer bars. Once all reinforcement was placed according to the approved structural drawings, the spacers were fixed at regular intervals to maintain a uniform gap between the outermost reinforcement and the formwork. The formwork was then erected with the spacer-controlled clearance, ensuring the specified cover was maintained throughout. This process not only met code requirements for durability and safety but also minimized the risk of dimensional deviations during concreting.

Figure 2.13 Footing Formwork of MHB with 50 mm Cover.

After completing the timber formwork for each footing pad, I observed that the reinforcement installation was finalized. For the combined footing, both the bottom and top layers of rebar were properly placed, while the single footing featured only the bottom rebar as per the structural design. The reinforcement bars were meticulously arranged to ensure correct spacing, cover, and anchorage, following the detailed bar bending schedule and the footing types specified in the project drawings.

Once the reinforcement cage for the footing pad was fully secured, the next critical step involved fixing the column starter bars. These vertical reinforcements were tied to the footing bars at the correct positions and dimensions by developing the development length (ℓ_b) required for the column, corresponding precisely to each column's structural requirements. This ensured structural continuity between the substructure and the upcoming vertical elements.

Following this setup, preparations were made for casting the structural concrete, which was designed to have a compressive strength of 45MPa, as stated in the foundation specifications. The arrangement of rebar and formwork was thoroughly checked by Mr. Eyuel, Assistant Resident Engineer (ECO), along with other supervising staff, before concrete pouring to confirm compliance with safety, alignment, and structural integrity standards.

While combined footings had both top and bottom reinforcement, all single footings were designed with reinforcement only at the bottom, placed directly above the lean concrete. This design choice was made to optimize material usage and reduce construction costs without compromising structural safety. Each footing had a unique size and volume, tailored according to the estimated dead and live loads at its respective location for this Main Hospital Building's partition room function as per CES 142 (Actions on Structures-Part 1-1: General actions - densities, self-weight, imposed loads for buildings) [31]. By customizing the reinforcement layout and dimensions based on actual load demands, the structural design effectively eliminated unnecessary bar arrangements, ensuring both efficiency and economy.

Figure 2.14 Rebar Placement for Isolated and Combined Footings Spaced by 5cm from the formwork.

Once the arrangement and installation of the footing reinforcement bars and column starter bars (S-500MPa, $\phi 20mm$) and polished formwork for each footing were completed, the consultant engineers inspected the work to check for any workmanship errors before granting approval for concrete casting.

Following this approval, the concrete pour was scheduled using a pump truck ordered from Dugda Construction PLC, with the required volume (in cubic meters) calculated from the total volume of all footing pads. The concrete was purchased per cubic meter and mixed with an accelerating admixture, MasterSet AC 53, a non-chloride accelerator from Master Builders Solutions (formerly BASF Construction Chemicals) [32]. This was done to ensure early strength gain of the concrete, allowing for the removal of formwork after just 24 hours. This approach ensured that each footing and column could adequately withstand their respective loads as well as environmental factors. The dosage of the admixture used was less than 2% of the cement weight, adhering to standard practices in the industry. By the third day, the formwork was removed. Immediately afterwards, formwork for the columns was assembled, maintaining the same **5 cm** spacing between the reinforcement bars and the formwork using spacers. Concrete for the columns starter was then poured using the pump truck, with volumes calculated based on the column dimensions for each footing.

Figure 2.15 Placement of Concrete for Footing Pads and Column Starters via Pump Truck.

During the concrete pouring process, samples were taken and cast into cubes for compressive strength testing. This was carried out both by Dugda Construction and off-site by the project's engineers, including ECO Assistant Resident Engineer Eyuel, at external laboratories such as ICT Engineering PLC and the Ethiopian Engineering Corporation. The cube samples were then tested under a compression machine to verify the concrete's strength. Once the results met the required specifications, the footing works for the Main Hospital Building were officially approved as complete.

A few days after the approval, work commenced on constructing the retaining walls around the entire perimeter of the building, reaching up to the Basement beam level. In the same way, for the six shear walls (SW-1 to SW-6), the reinforcement bars were organized as per the structural design requirements. Spacers were employed to ensure the necessary clear cover was maintained, and the concrete was poured using a pump truck to facilitate the process. With all foundational concrete works completed, the area was backfilled with selected coarse-grained soil delivered from an external source by Sinotrack. The fill material was tested and confirmed to meet project specifications through grain size distribution analysis (ASTM C136), Atterberg limits determination (ASTM D4318), and maximum dry density (optimum moisture content testing) via the Modified Proctor method (ASTM D1557). In addition, in-situ field density tests using the sand-cone method (ASTM D1556) were conducted on each compacted lift to verify compliance with the specified compaction level. The approved material was then compacted using a roller compactor and leveled to meet the basement beam elevation for the basement floor [33].

Figure 2.16 Backfill Compaction of MHB to Achieve Maximum Dry Density.

2.3.2.6.3. RC Works for Basement Beam Construction in the MHB

Before the arrangement and placement of the basement beam reinforcement bars, a layer of lean concrete was poured over the compacted fill material beneath the entire footprint of the beam layout. This lean concrete, designed with a compressive strength of 7MPa [34], was mixed on-site using a drum batch mixer and carefully placed to cover not only the exact beam footprint but also extended slightly beyond it to ensure safety, cleanliness, and dimensional accuracy during reinforcement works. The purpose of this lean concrete was to provide a stable, level, and non-eroding surface for bar placement, prevent direct contact between reinforcement and soil, and reduce the risk of corrosion. It also helped in maintaining proper alignment and spacing of the reinforcement bars, especially during formwork installation and concrete casting. This preparatory step was essential for achieving high-quality structural performance and ensuring that the basement beams were constructed on a clean and controlled surface.

After completing the lean concrete work, the contractor initiated the reinforcement works for the basement beams of the Main Hospital Building. According to the structural drawings, the basement level comprises **42 distinct basement beams** (BB), each designed to accommodate varying load conditions and span requirements across the five structural blocks of the hospital. Where each beam varies by its bar diameter, whether it has a negative bar or not, span length, effective depth, and the designed bending moment diagram, which depends on the load distribution on the beams in each region of the building. These beams serve as critical load-transferring elements between the foundation and the superstructure, ensuring stability and continuity of the building's framework.

Including the basement beam of this building, all building in this project was designed by Limit state design philosophy (which combines the best features of WSD and USD and has gained acceptance in many countries throughout the world, including Ethiopia), it is both a safe and economical structural design method for Composite structures such as reinforced concrete structures [35]. A beam (where the applied axial load is equal to zero) is a structural member that supports applied loads and its own weight primarily by internal moments and shears. The conventional design of elastic beam theory results in the equation $\boldsymbol{\sigma = \frac{M * y}{I,}}$ which is for an un-cracked, homogeneous rectangular beam without reinforcement, where this equation cannot be used to design non-homogeneous structural members [36]. In RC structures, the compressive stress-strain relationship for concrete becomes nonlinear at higher strain values and concrete cracks at low tensile stresses, making it necessary to provide steel reinforcement to carry the tensile force T, so that we call such structures 'Reinforced concrete structure' [37].

The theory of bending for reinforced concrete at **ULS** assumes that:

- Concrete will crack in the regions of tensile strains, and after cracking, all the tension is carried by the reinforcement.
- Plane sections of a structural member remain plane after bending, so that across the section, there must be a linear distribution of strains.
- There are three different types of stress distribution in the concrete: Triangular stress distribution (Used at the serviceability limit state when loading levels encountered under working conditions), Rectangular-parabolic stress block (Used at the ultimate limit state where stresses are not proportional to the strains and compressive strains are within the plastic range), and Equivalent rectangular stress block (which is a simplified alternative to the rectangular parabolic stress distribution).

Accordingly, the basic equations for the flexural design of RC beams (i.e., the basement beam for our case) based on the above basic principles and assumptions at ultimate limit state design include:

- The strain in bonded reinforcement, whether in tension or in compression, is the same as that in the surrounding concrete because the concrete and the reinforcement must act together to carry the load (there is no slip between steel bars and the adjacent concrete).
- Sections perpendicular to the axis of bending that are plane before bending remain plane after bending, ignoring the deflection due to the shear force.
- The tensile strength of concrete is ignored, and reinforcement is assumed to take all the tension due to flexure.
- The stresses in the concrete in compression are derived from the design stress-strain relationship.
- The stresses in the reinforcing steel are derived from the design curve

The ULS Design criterion is summarized with the following expression:

$$\frac{f_d}{W_d} \geq 1.0$$

Where:

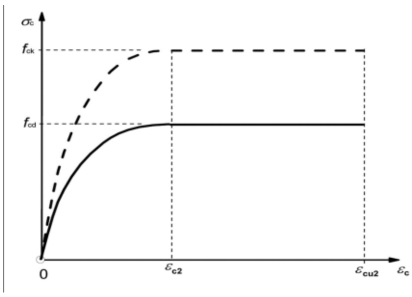
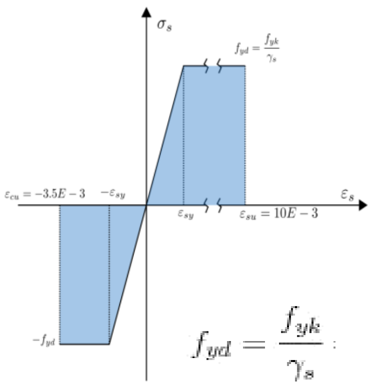
- f_d = Design resistance of the structure $\left(\frac{f_k}{\gamma_m}\right)$, in MPa
- W_d = A design load effect $(\gamma_f * W_n)$, in term MPa

$$\sigma = \frac{M * y}{I}$$

- W_n = Nominal load (N(KN))
- γ_m = Partial safety factor for materials
- γ_f = Partial safety factor for loads, $W_d = 1.35G_k + 1.5Q_k$
- f_k = Characteristic material strength
- G_k = Characteristic dead load & Q_k = Characteristic live load
- ***σ***= Bending stress at a specific point in the beam (in Pascals or N/m²)
- ***M***= Bending moment at the section (in Newton-meters, Nm)
- ***y***= Distance from the neutral axis to the point where stress is calculated
- $I = \frac{bh^3}{12}$ is Moment of inertia of the beam's cross-sectional area about the neutral axis; b is width & h is height of the geometry cross-section

As per ES EN 1992:2015 section 3.1.7 (stress-strain relations for the design of cross-sections):

Table 2.21 Stress-Strain relations for the design of cross-sections in RC structures [31], [38].

Design stress-strain diagram for the Concrete	Design stress-strain diagram for the reinforcement bars
 $f_{cd} = \frac{0.85 f_{ck}}{\gamma_c}$; $\varepsilon_c \geq 0 \quad \sigma_c = 0$	 $f_{yd} = \frac{f_{yk}}{\gamma_s}$
$\sigma_c = f_{cd}\left[1-\left(1-\frac{\varepsilon_c}{\varepsilon_{c2}}\right)^n\right]$ — $for\ 0 \leq \varepsilon_c \leq \varepsilon_{c2}$	$-\varepsilon_{cu} \leq \varepsilon_s \leq -\varepsilon_{sy} \quad \sigma_s = -f_{yd}$
$\sigma_c = f_{cd}$ — $for\ 0 \leq \varepsilon_{c2} \leq \varepsilon_c \leq \varepsilon_{cu2}$	$-\varepsilon_{sy} < \varepsilon_s \leq \varepsilon_{sy} \quad \sigma_s = \varepsilon_s E_s$
n is the exponent $n = 2.0\ for\ f_{ck} < 50Mpa$ and $n = 1.4 + 23.4\left[\left(\frac{90 - f_{ck}}{100}\right)\right]^4\ for\ f_{ck} \geq 50Mpa$	$\varepsilon_{sy} < \varepsilon_s \leq \varepsilon_{su} \quad \sigma_s = f_{yd}$
ε_{c2} is the strain at reaching the maximum strength	$E_s = 200GPa$ is design young modulus
ε_{cu} is the ultimate strain	Maximum possible strain is limited at $\varepsilon_{su} = 0.01$
f_{cd} is design yield strength of the concrete	Design yield strain of steel is $\varepsilon_{sy} = \frac{f_{yd}}{E_s}$
f_{yd} is design yield strength of the Rebar steel	
γ_c = Partial factors for concrete = 1.5; γ_s = Partial factors for rebar steel = 1.15 — Under Persistent & Transient Design situations	

In civil engineering, strain domains describe how a reinforced concrete section behaves under bending and axial loads, considering that concrete cannot resist tension. As the strain profile changes, the depth of the neutral axis shifts, altering the section's resistance. Five domains represent progressive failure stages: from full tension (Domain I) to full compression (Domain IV), and finally rotation of the strain profile beyond the section (Domain V) [38]. Each domain corresponds to a unique moment-axial force (M-N) pair, used to define the section's resistance envelope. This approach aligns with Ultimate Limit State (ULS) design philosophy for safe structural performance [39].

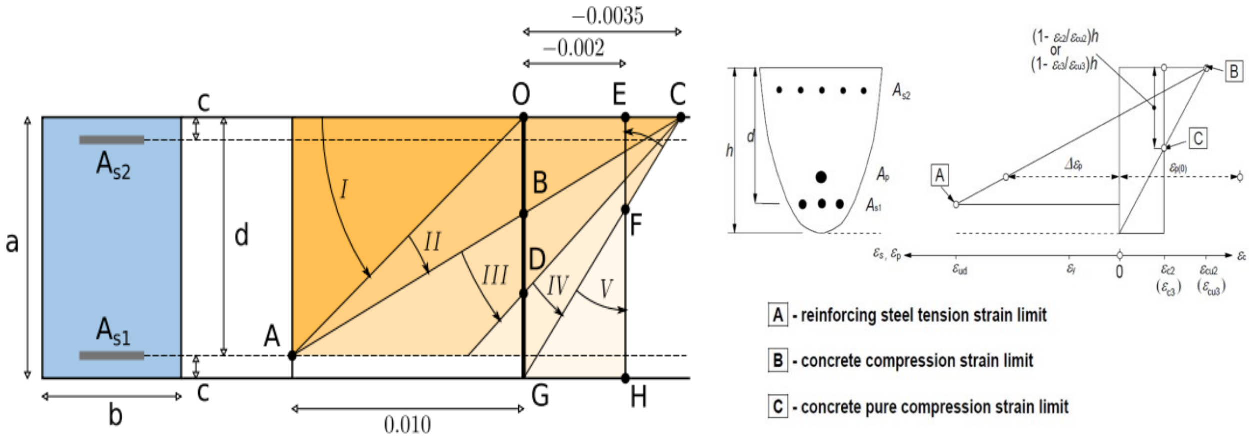


Figure 2.17 Possible range of strain distributions in RC Beams at ULS.

Concrete failure in compression at ULS is universally defined by a limiting compressive strain, though exact values vary by design code. For strengths $\leq 50MPa$, ES EN sets the limit at 0.0035 for flexure and combined loading, reducing to $0.002 - 0.0035$ when the entire section is under compression [40].

For concrete strengths $f_{ck} \geq 50Mpa$; $\varepsilon_{cu}(\%) = 2.6 + 35\left[\left(\frac{90-f_{ck}}{100}\right)\right]^4 for\ f_{ck} \geq 50Mpa$ [40]

Depending on the amount of steel used by section, there are three types of flexural failures of reinforced concrete sections: Balanced, Tension, and Compression failures. For the Shaggar One General Hospital the structural design method of all the RC structures including the Main Hospitals Building's Basement Beam was based on Tension failure (Under-reinforced Section) method, which stated as ''If the steel content $\boldsymbol{A_s}$ of the section is small, the steel will reach $\boldsymbol{f_{yd}}$ before the concrete reaches its maximum strain of $\boldsymbol{\varepsilon_{cu}}$''. With further increase in loading, the steel force remains constant at $A_s f_{yd}$ but results a large plastic deformation in the steel, wide cracking in the concrete and large increase in compressive strain in the extreme fiber of concrete. This type of failure is preferable and used in this design of most RC structures were it allows yield failure is gradual and preceded by visible signs of distress such as the widening and lengthening of cracks and the marked increase in deflection such that building fails in a ductile manner and the occupant have an opportunity to leave the building before the final collapse [31].

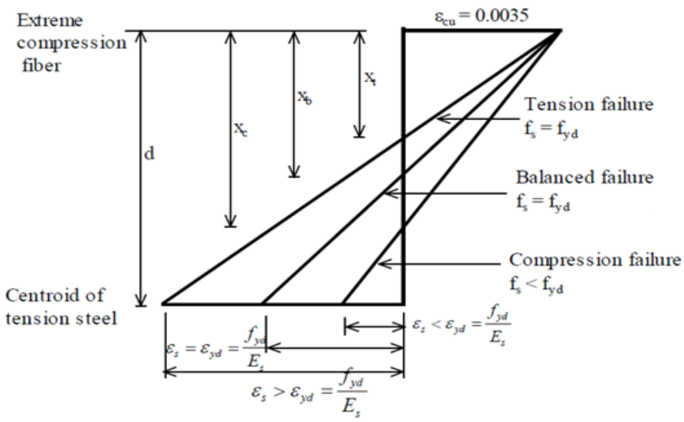
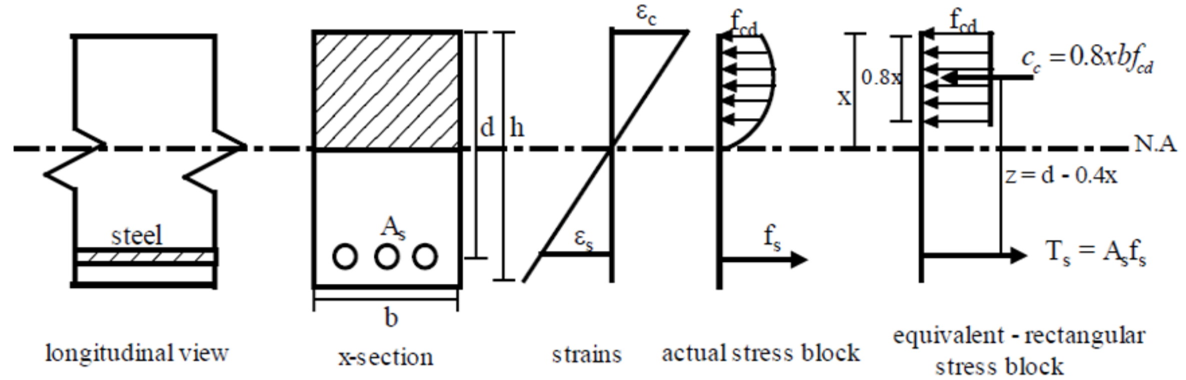


Figure 2.18 Strain profiles at the flexural strength of a RC section.

Generally, ductility is a design requirement in RC structures. To ensure ductility, in practice the maximum amount of tension steel is fairly below the amount corresponding to the balanced one. ACI 318 code recommends a maximum reinforcement ratio ensuring ductility as $\boldsymbol{\rho_{max} \leq 0.75\rho_b}$ [41]. For seismic load resisting member, the same code recommends $\boldsymbol{\rho_{max} \leq 0.5\rho_b}$. EN 1992:2015 limits the depth of the neutral axis of the beam $\boldsymbol{x}$ to $\boldsymbol{0.45d}$ for concrete strength classes less than or equal to $\boldsymbol{C50/60}$ (concrete with cylinder strength/cube strength after 28 days, respectively) and $\boldsymbol{0.35d}$ for concrete classes $\boldsymbol{C55/67}$ and greater in order to provide a ductile, i.e. under reinforced section [42].

The purpose of I'm outlining the fundamental principles of RC structural member design is to explain how the bar quantity, size, spacing, and depth were determined for the Main Hospital Building BB, in accordance with its design load requirements. As previously discussed, the number and arrangement of reinforcement, whether single or double, depend on the moment ratio between the section's resistance and the expected design moment. In the basement, the beams are designed as double-reinforced rectangular sections, incorporating tensile and three compressive ϕ24mm, S-500 MPa steel bars, with additional negative reinforcement provided in specific beams per the structural design. The effective depth (d′) is 50 cm for typical beam. I will now present the formula used to calculate the reinforcement area for a singly reinforced beam and extend it to the case of double reinforcement.

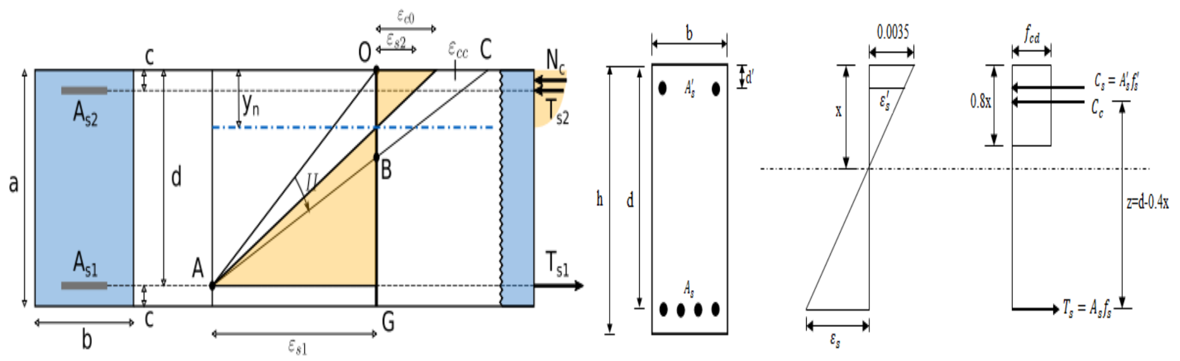
Table 2.22 Design equations for Singly Reinforced Beam & Balanced section in Tension failure method.



Basic Equations	Statics (Equilibrium of Forces/Moments) of the Beam section
$Pressure = \frac{Force}{Area}$ $f_s = \frac{T_s}{A_s}, T_s = A_s f_{yd}$ $f_{cd} = \frac{C_c}{A_c}, C_c = f_{cd}ba$ $a = 0.8x$ $For \leq C50/60$ $x_{bal} = 0.45d$ $a = 0.8x_{bal}$ $a = 0.8 * 0.45d$ $a = 0.36d$ $C_c = abf_{cd}$ $C_c = 0.36bdf_{cd}$ $Z_{bal} = d - \frac{0.36d}{2}$ $Z_{bal} = 0.82d$ $M_{bal} = C_c Z_{bal}$ $M_{bal} = 0.29bd^2 f_{cd}$ $K_{bal} = \frac{M_d}{0.295bd^2 f_{cd}}$ $K_{bal} = 0.295$	Ultimate design moment M must be balanced by the moment of resistance of the section so that: $M = C_c Z = T_s Z$ Z is *the lever arm between the resultant forces* C_c *and* T_s $$Z = d - \frac{a}{2} \Rightarrow a = 2d - 2Z$$ $$M = 2f_{cd}b(d - Z)Z$$ Divide both sides by $f_{cd}bd^2$: $\frac{M}{f_{cd}bd^2} = \frac{2(d-Z)Z}{d^2}$ Let $K = \frac{M}{bd^2 f_{cd}}$, Which is known as the Moment ratio by $\frac{KNm}{KNm}$ $$K = \frac{2(d-Z)Z}{d^2}$$ *Rearranging;* $\left(\frac{Z}{d}\right)^2 - \frac{Z}{d} + \frac{K}{2} = 0$ $Z = \frac{d}{2}\left[1 + \sqrt{1 - 2K}\right]$ *Solving the above quadratic equation* Now, taking moment about C_c the moment of resistance of the section is computed as: $M = A_s f_{yd} Z ; Therefore,\ A_s = \frac{M}{Zf_{yd}}$, Which is the area of rebar steel required for the rectangular single reinforced section. $$\sum F_H = 0 \rightarrow T_s = C_c$$ $$A_{s,bal} f_{yd} = 0.36bdf_{cd}$$ $A_{s,bal} = \frac{0.36bdf_{cd}}{f_{yd}}$; Area of steel for balanced section

To generalize, when $\frac{M_d}{0.295bd^2f_{cd}} > K_{bal} = 0.295$, then the section cannot be singly reinforced (i.e., Tension bars and have nominal compression bars for holding stirrup, etc.), and compression reinforcing steel is required in the compression zone of the section. The Shaggar One General Hospital's Main Hospital Building's Basement Beam is a doubly reinforced rectangular beam as previously described, which resulted from $\frac{M_d}{0.295bd^2f_{cd}} > K_{bal} = 0.295$, and if a beam cross section is limited because of architectural or other considerations, it may happen that the concrete cannot develop the compression force required to resist the given bending moment. In this case, reinforcement is added in the compression zone, resulting in a doubly reinforced beam (i.e., one with compression as well as tension reinforcement) to reduce sustained-load deflections, increase ductility, fabrication ease, and change of mode of failure from compression to tension.

Table 2.23 Design equations for Doubly Reinforced Rectangular Beam section in Tension failure method.



Basic Equations	Statics (Equilibrium of Forces/Moments) of the Beam section
With the compression reinforcement at yield: $(\boldsymbol{\varepsilon'_s > \varepsilon_{yd} \rightarrow f'_s = f_{yd}})$ Depth of neutral axis $\boldsymbol{x < 0.45d}$ to ensure a tension failure with a ductile section. Therefore: $\boldsymbol{Z = d - 0.4x_{bal}}$ $\boldsymbol{Z = d - 0.4(0.45d)}$ $\boldsymbol{Z = 0.82d}$	$\sum F_H = 0 \quad ; \quad C_c + C_s = T_s$ $0.8x_{bal}bf_{cd} + A'_sf_{yd} = A_sf_{yd}$ $0.8(0.45d)bf_{cd} + A'_sf_{yd} = A_sf_{yd}$ $\boldsymbol{0.36bdf_{cd} + A'_sf_{yd} = A_sf_{yd}}$ … … … … … … … …* $M = C_cZ + C_s(d - d')$ $M = 0.36bdf_{cd}(0.82d) + A'_sf_{yd}(d - d')$ $A'_s = \frac{M - 0.295bd^2f_{cd}}{f_{yd}(d-d')}$; $\boldsymbol{A'_s = \frac{(K - K_{bal})bd^2f_{cd}}{f_{yd}(d-d')}}$ $\boldsymbol{0.36bdf_{cd}(0.82d) + A'_sf_{yd}(Z) = A_sf_{yd}(Z)}$ … … … … .** $0.295bd^2f_{cd} + A'_sf_{yd}(Z) = A_sf_{yd}(Z)$ $\boldsymbol{A_s = \frac{0.295bd^2f_{cd}}{Zf_{yd}} + A'_s}$; $\boldsymbol{A_s = \frac{K_{bal}bd^2f_{cd}}{Zf_{yd}} + A'_s}$ Applicable only if *compression steel has yielded otherwise, if compression steel has not yielded* $(\varepsilon'_s \le \varepsilon_{yd} \rightarrow f'_s = E_s\varepsilon'_s)$ *To obtain* ε'_s: $\frac{0.0035}{x} = \frac{\varepsilon'_s}{x-d'}$

To design the beam, Preliminary analysis and member sizing is the begging which is used to determine beam dimensions required: Cover to the reinforcement, Effective depth (d), Breadth (b), and Overall depth (h). The strength of a beam is affected considerably more by its depth than its breadth. Start with span-depth ratios, which usually vary between say 14 and 30, but for large spans, the ratios can be greater, given by [31]:

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_0}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right] if\ \rho \leq \rho_0 \ldots 7.16a$$

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_0}{\rho - \rho'} + 3.2\sqrt{f_{ck}}\sqrt{\frac{\rho'}{\rho_0}}\right] if\ \rho > \rho_0 \ldots\ldots 7.16b$$

The basement beams were designed in accordance with the structural requirements derived from the building’s load distribution across various zones. To optimize material usage and construction cost, the effective depth of beams was varied depending on the functional zone and load intensity. This approach ensures structural efficiency while maintaining safety and serviceability.

During my internship, I consulted with the project’s structural engineer, Marsimoyi T, who guided me through the entire design workflow. The structural analysis and load modeling were performed using ETABS and SAP2000, which allowed for precise adjustment of beam geometry and reinforcement based on applied loads. SAFE was employed for the design of footings and foundation systems, ensuring compliance with geotechnical constraints. For construction sequencing and clash detection, Navisworks was used in conjunction with BIM integration. Final drafting and detailing, including bar arrangements and dimensional specifications, were completed using AutoCAD. A typical basement beam section, shown below, observed on-site after construction, was finalized as a doubly reinforced rectangular beam. It incorporated: Three tension bars & three compression bars and one negative bar, Concrete cover of 50mm to reinforcement, and Overall depth (h) of 550mm.

Figure 2.19 Typical doubly Reinforced BB Section of MHB & after construction.

The reinforcement process commenced with the bending and accurate placement of longitudinal bars in accordance with the approved structural drawings. For the primary basement beams, ϕ24 mm high-yield deformed (HYD) S-500MPa bars were installed as the main reinforcement on both the tension and compression faces where total reinforcement area provided at the mid span section of the typical beam is $A_{s,pro} = \frac{6\times\pi\times(12mm)^2}{4} = 2714.34mm^2$. At column-beam junctions, negative moment reinforcement by ϕ24 mm S-500MPa was provided by anchoring additional top bars with a development length of 2.0 m on either side of the column. This detailing ensures that tensile forces generated at supports are effectively transferred into the adjoining members without slippage, thereby maintaining structural integrity under service and ultimate loads.

In line with CES 149:2015 and international best practice (ACI 318, IS 456), the following key criteria were observed [31]:

- **Development Length (ℓ_b):** The length of the bar required to develop a desired bond strength between concrete and steel is known as development length, or anchorage length, and is provided in accordance with bar diameter, steel grade, and concrete strength to ensure full stress transfer before bar termination.

$$\text{Development length } \alpha \ \frac{1}{compressive\ strength\ of\ the\ concrete}$$

- **Bar Spacing:** Maintained clear spacing ≥ bar diameter and ≥ 25 mm (or as per code) to allow proper concrete compaction and avoid honeycombing.
- **Concrete Cover:** Minimum 50 mm for beams in contact with soil or exposed to weather, as per durability requirements.
- **Anchorage at Supports:** Negative reinforcement extended beyond the theoretical cut-off point to counteract peak bending moments at fixed or continuous supports.
- **Bar Bending Accuracy:** All bends and hooks are formed to code-specified radii to prevent steel micro-cracking and ensure bond performance.
- **Stirrup Placement:** Shear reinforcement positioned at code-specified spacing to resist diagonal tension and confine longitudinal bars.

This systematic approach to reinforcement placement not only complied with the project's structural specifications but also aligned with recognized engineering standards, ensuring durability, safety, and serviceability of the basement structure.

To resist design shear forces of the BB, ϕ10 mm closed stirrups were provided at specified intervals, typically ranging from 150 mm to 250 mm, depending on the calculated shear demand and beam span. These stirrups were securely tied and uniformly spaced to ensure effective confinement of the concrete core and to prevent diagonal (shear) cracking under load.

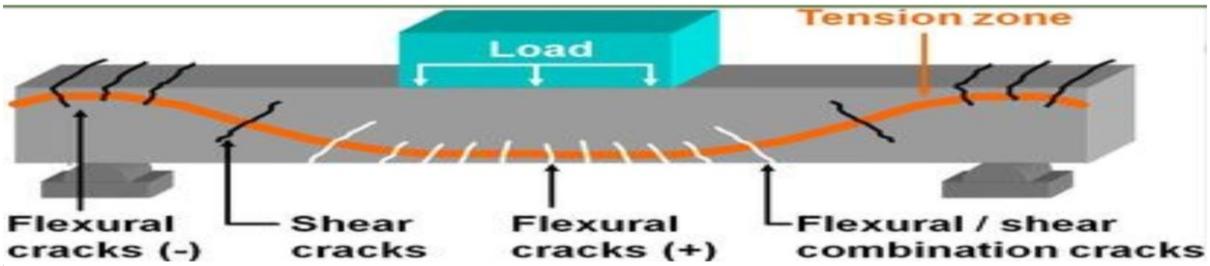


Figure 2.20 Common Beam Cracks [72], to Resist by Shear Reinforcement (Stirrup).

In reinforced concrete basement beams, the arrangement of stirrups depends on the variation of shear forces along the span:

- Vertical stirrups are commonly provided in the mid-span region of the beam, where shear forces are relatively low.
- Near the supports and around columns, where shear demand is higher, closer spacing of stirrups is adopted within a distance equal to the effective depth ($\leq d$) from the face of the support.
- In some cases, inclined stirrups are provided near columns and within a distance equal to the effective depth (d) of the beam, as they are more effective in resisting diagonal shear cracks.

However, for beams in seismic-resistant frames, where shear reversal occurs during earthquakes, inclined stirrups are avoided. Instead, vertical stirrups with closer spacing and adequate anchorage are used, as recommended in earthquake-resistant design codes. This ensures proper energy dissipation, ductility, and prevents premature brittle shear failure. By following this arrangement, the beam satisfies the requirements of design codes regarding shear reinforcement, bar anchorage, and ductility, thereby ensuring both structural integrity and serviceability throughout its design life.

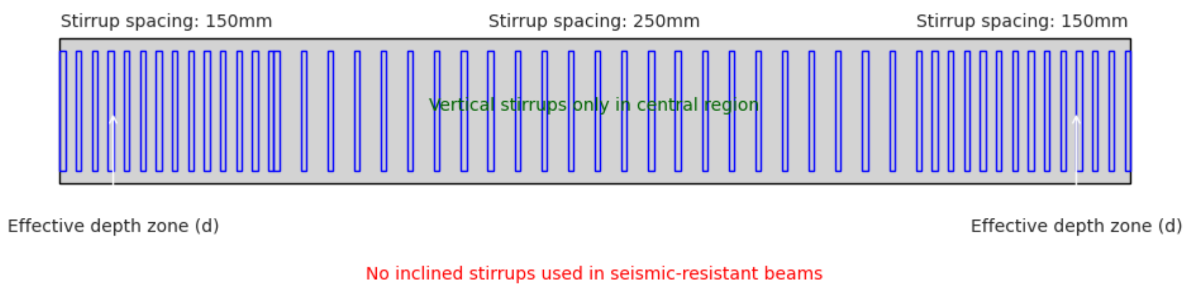


Figure 2.21 Shear Rebar Arrangement for Seismic-Resistant Beams.

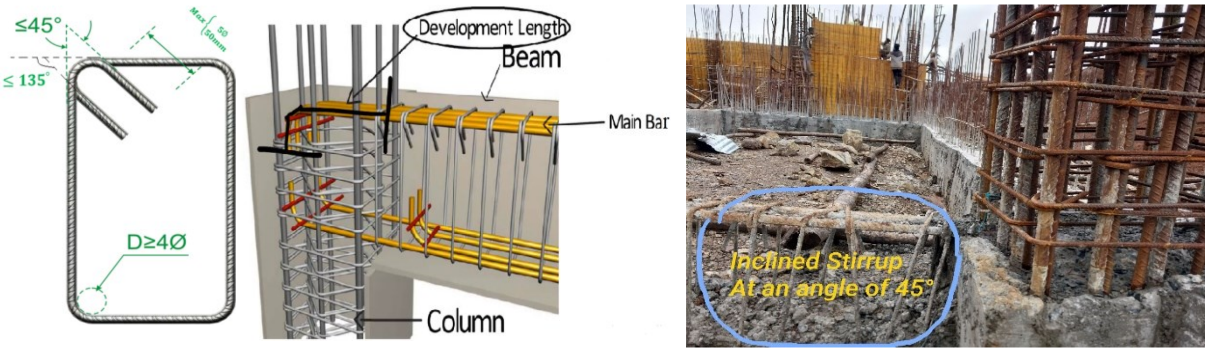


Figure 2.22 Stirrups and Bar Development [73], at Beam-Column Junctions of

During rebar installation (fabrication), I observed that the lap splices for the compression bars were strategically positioned near the mid-span of the beams, where compressive stresses dominate [43]. Conversely, the tension bars were kept continuous at the column faces to counteract the negative moments effectively. The Minimum lap length in the compression zone is $\mathbf{24d}$ ($\mathbf{24 \times 24\,mm = 576\,mm}$); if in the tension zone, the development length is **30d.** This detailing approach aligns with standard engineering practices and moment distribution principles, minimizing the risk of placing lap splices in high-tension zones and ensuring adequate development lengths.

To maintain proper concrete cover and durability, spacers made from mortar were used to keep the reinforcement **5cm** away from the formwork. The formwork itself was constructed using polished timber coated with release oil to facilitate easy removal after curing. Before concrete casting, the entire reinforcement setup was inspected by the consultant engineers, including ECO's Assistant Resident Engineer, to verify compliance with the design specifications.

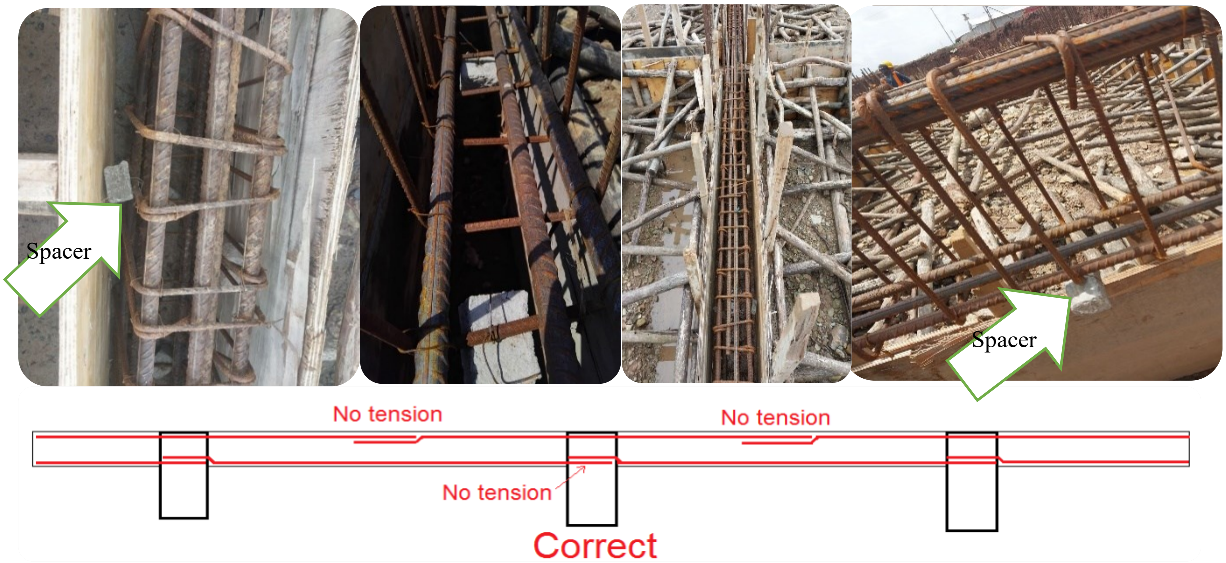


Figure 2.23 Main Bar and Splice Locations for Continuous Basement Beams (closer stirrup at lapping).

The concrete used for the basement beams was designed to achieve a compressive strength of 35MPa. It was mixed off-site at Dugda Construction PLC [44] and placed using a pump truck to ensure consistency and time-efficient construction. During casting, cube samples were prepared in three layers for compressive strength testing as part of the quality control protocol. These tests were conducted at an external laboratory. After 7 days of curing and 28 days of curing for the full strength test, the results confirmed that the concrete met the specified strength requirements, validating the structural integrity of the basement beam system.

In the design of the basement beams, I observed that these beams were significantly larger in both effective depth (d) and width compared to all other suspended beams in the building. This increase in size is intentional and reflects the engineering need to resist higher loads and pressures at the foundation level. Moreover, the dimensions of the beams were progressively reduced from floor to floor, a strategy rooted in structural load optimization and cost-effectiveness, which is a key principle in civil engineering design.

Functionally, basement beams are subjected to a complex combination of forces. They must resist:

- Upward pressure from compacted backfill soil beneath the structure
- Lateral pressure from adjacent soil or crushed stone fill between the beams
- Vertical loads from the basement slab, including both dead loads (self-weight of materials) and live loads (occupant and equipment loads)

These beams act as grade beams, distributing loads horizontally and tying together the foundation elements to prevent differential settlement. Their design must also account for uplift resistance, shear forces, and bending moments, especially in areas with expansive soils or seismic activity [45].

One notable feature I observed is that the bending moment diagram for basement beams differs from that of upper suspended beams. While suspended beams typically experience maximum bending moments at mid-span due to vertical loads, basement beams often show peak moments near supports or at points of lateral soil pressure. This is because they not only carry vertical loads but also resist horizontal earth pressures and uplift forces from below. According to structural engineering principles, bending moment diagrams help visualize these internal forces and are essential for determining reinforcement requirements and ensuring safe load transfer.

As a final note, the basement beam system is a critical structural component that anchors the building, resists multidirectional forces, and ensures long-term stability. My hands-on experience with its design and execution deepened my understanding of how theoretical concepts like moment distribution, load paths, and reinforcement detailing are applied in real-world construction. The basement beam reinforcement process was executed with precision and adherence to structural design standards. The detailing not only ensured safety and performance but also reflected a deep understanding of load paths, moment behavior, and construction best practices. This experience significantly enhanced my ability to interpret structural drawings, understand reinforcement logic, and appreciate the importance of meticulous execution in civil engineering projects.

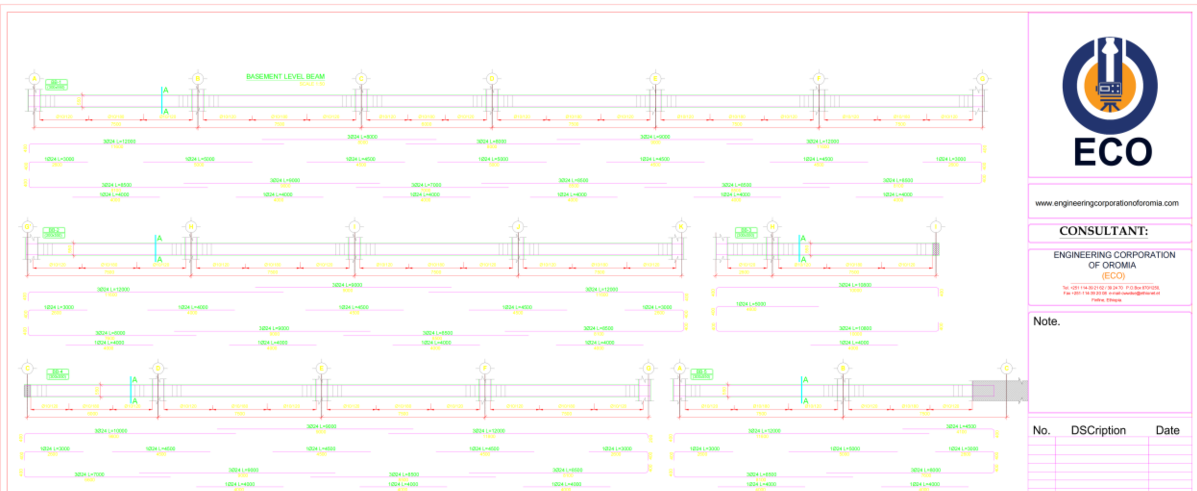


Figure 2.24 MHB Basement Beam Structural Reinforcement and Dimensional Details.

2.3.2.6.4. Expansion Joint Integration in the Basement Beam of the MHB

As previously described, the Main Hospital Building was divided into five structural zones using expansion joints to prevent progressive failure across the entire structure. During the construction of the basement beam, expansion joints were strategically incorporated to isolate load transfer between adjacent zones. This approach ensures that any structural failure occurring in one zone does not propagate to others.

The expansion joint was formed using timber and placed between separate columns. These columns were founded on a shared footing pad using a combined footing system. However, above the footing level, the columns were cast independently to preserve the integrity of the expansion joint.

In alignment with this strategy, the basement beams were also constructed separately for each zone, respecting the expansion joint layout. This zoning approach allows each beam to function independently within its designated structural segment, further enhancing the building's resilience against differential movement and localized failure. This method reflects principles established in the aftermath of the 1994 Northridge Earthquake in California, where failures in rigid structural connections highlighted the importance of flexible joints and seismic zoning [46]. The use of expansion joints also aligns with discoveries from the Ronan Point collapse in 1968, which emphasized the need for compartmentalized structural systems to prevent progressive collapse. Furthermore, the concept of isolating structural zones is rooted in the development of Performance-Based Earthquake Engineering (PBEE) [47], which promotes designing buildings to withstand localized damage without compromising overall integrity. The independent casting of columns above a shared footing is a practical application of the "fail-safe" design philosophy, where redundancy and separation are used to enhance structural robustness.

Figure 2.25 Expansion Joint Construction Layout on Site, at basement Columns and Beams of MHB.

2.3.2.6.5. Concrete Placement Process for Basement Beam of MHB

For the casting of the basement beams, timber formwork was constructed on the rebar installed following the same methodology used during the footing works. Alignment was corrected using the Pythagorean Theorem for formwork braces or supports. This involved fixing kickers to the ground and nailing or hammering braces to the kickers. Timber batter boards, which served as the formwork material, were spaced 5cm from the reinforcement bars and stirrups to ensure geometric precision across the beam layout. Spacers were installed in all directions to maintain the required concrete cover and ensure durability against environmental exposure. To facilitate smooth removal after curing, the formwork was treated with a form-release oil to prevent adhesion. Once the formwork was inspected and approved, the contractor’s site engineer, Werkina, calculated the total concrete volume required for the basement beam casting to be 675 m^3, based on the beam dimensions, onsite formwork executed, and structural drawings. Concrete was ordered from Dugda Construction PLC, a supplier known for consistent quality and reliable batching [44].

On June 30, 2025, G.C., the concrete was poured using ready-mix truck mixers with capacities of 9 m^3 and 12 m^3. The concrete was first discharged into a truck-mounted concrete pump, which then pumped it directly into the basement beam formwork. The placement was coordinated through signal-based communication between the pump operator and site crew to ensure controlled and uniform distribution across the beam sections. The mix included a chemical accelerator, which reduced the early strength gain of the concrete to 3 days, and it reduced the Initial and final setting times of the concrete, allowing for faster progress without compromising strength. The concrete was selected for its high consistency and workability, outperforming typical site-mixed alternatives.

During the concrete placement process on June 30, 2025 G.C., I closely observed the site activities to ensure quality and structural integrity. Skilled workmanship employed mechanical vibrators during pouring to eliminate entrapped air, thereby preventing voids or honeycombing within the concrete matrix. This practice is essential in achieving a dense and durable structure, as confirmed by the absence of air pockets after setting, which is an indicator of proper consolidation and a rigid final product. I also monitored the slump test procedures conducted both at Dugda’s batching plant and on-site, which verified the concrete’s workability and compliance with the specified mix design. These tests are critical in assessing the fluidity and placement suitability of fresh concrete, aligning with established standards such as ASTM C143. Furthermore, I witnessed laboratory verification of cement consistency, a key factor in maintaining uniform hydration and strength development. This attention to quality control reflects the broader principles of modern structural engineering, where empirical testing and field validation converge to ensure long-term performance. My direct involvement in these procedures reinforced the importance of integrating site observations with laboratory data; a practice rooted in civil engineering advancements that prioritize safety, durability, and precision in concrete construction.

Figure 2.26 Basement Beam Concrete Placement, Vibration for Air Removal, Cube prepared for casting, and Formwork Removed beam.

After three days of concrete placement, the formwork was safely removed without damaging the cast beams. The concrete was tested on both the seventh and 28th days from the cube samples taken at ICT Engineering PLC, and Dugda Mix Plant, confirming that it achieved its design compressive strength. This validated the effectiveness of the mix and curing process.

With the basement beam work completed, the next phase involved erecting reinforced concrete (RC) columns, retaining wall, and shear walls up to ground level. Afterward, the spaces between the beams were filled with selected crushed stone. This layer serves as a sub-base for the upcoming basement slab reinforcement, which will be arranged in accordance with the structural plans and load distribution requirements.

2.3.2.6.6. RC Works of Basement Columns Construction of the MHB

Following the completion of the basement beam works, construction activities have progressed to the erection of basement columns, retaining wall, and shear walls up to the ground level. The structural system of the hospital building is based on reinforced concrete (RC), selected for its high rigidity, durability, and load-bearing capacity, which is essential for a healthcare facility requiring robust infrastructure, as described in my previous foundation and BB topics.

The basement columns serve as critical vertical load-bearing elements that transfer loads from the superstructure, including slabs, beams, walls, finishes, and both permanent and variable live loads, down to the subsoil via the foundation system. These loads are primarily axial compressive forces, though bending moments may also be induced due to lateral forces (e.g., wind or seismic loads), end moments, or eccentricity in axial loading.

According to standard structural classification:

- A column is defined as a vertical member where the section depth h does not exceed four times its width b, and the overall height L is at least three times the section depth.
- If $h > 4b$, the member is categorized as a shear wall, designed to resist lateral loads and provide additional stiffness to the structure.

In strict accordance with ES EN 1992-1-1:2015 (Section 5.3.1) [40], each building's column is a "short" member ($h \leq 4b, L \geq 3h$), and all bays are braced by adjacent shear walls and elevators, stairwell shafts, qualifying them as non-sway. The short columns are columns with low slenderness ratio ($\boldsymbol{\lambda} < \boldsymbol{\lambda_{lim}}$), and their strengths are governed by the strength of the materials and the geometry of the cross-section. Effective lengths (L_o) were calculated with end-fixity factors $\boldsymbol{k_1 = k_2 = 0.7}$, Where $\boldsymbol{k = 1.7 - r_m}$ (if $\boldsymbol{r_m} = \frac{\boldsymbol{M_{01}}}{\boldsymbol{M_{02}}}$; $\boldsymbol{moment\ ratio}$ such that $\boldsymbol{M_{01}, M_{02}}$ are the first order end moments can be neglected for braced members in which the first order moments arise only from or predominantly due to imperfections or transverse loading, Therefore $\boldsymbol{r_m = 1}$ and k = $\boldsymbol{0.7}$ may be used), yielding slenderness ratios $\lambda = \frac{L_0}{i} \leq 20$ well below the ES EN 1992:2015 section 5.8.3.1 code limit, so sensitivity to second order effect due to lateral displacements (P−Δ) were conservatively neglected.

Where:

- $\boldsymbol{L_0}$ is the effective length
- $\boldsymbol{P}$ is the axial force

- Δ is the relative displacements of the ends of the column
- $\boldsymbol{i}$ is the radius of gyration of the un-cracked concrete section
- Limit Slenderness ratio $\boldsymbol{\lambda_{lim}} = \frac{20*A*B*k}{\sqrt{\eta}}$
- $\boldsymbol{A = 1/(1 + 0.2\varphi_{ef})}$ (if φ_{ef} is not known, $A = 0.7$ used); φ_{ef} effective creep ratio
- $\boldsymbol{B = \sqrt{1+\omega}}$ (if ω is not known, $\boldsymbol{B = 1.1}$ used); $\boldsymbol{\omega} = \frac{A_s f_{yd}}{A_c f_{cd}}$ reinforcement ratio
- $\boldsymbol{k = 1.7 - r_m}$ (if r_m is not known $\boldsymbol{k = 0.7}$ may be used)
- $\boldsymbol{\eta} = \frac{N_{Ed}}{A_c f_{cd}}$; relative normal force and $\boldsymbol{A_s}$ is the total area of longitudinal reinf't

At the Shaggar One General Hospital site, the basement column construction commenced with the fabrication, rebar installation, and erection of vertical reinforcement bars in accordance with the approved structural drawings. The vertical bars were anchored to the starter bars previously extended from the basement beams by **1m. This length was** calculated based on the local building, IS Code 456, using the formula: $\boldsymbol{50 \times d = 50 \times 20mm = 1000mm}$, which was applied in the construction of this project [48]. The reinforcement splicing method adopted was lapping, a widely accepted technique for continuity in RC members.

As per ES EN 1992-1-1:2015 section 8.7.3 [40], the design lap length is given by:

$$l_0 = \alpha_1\alpha_2\alpha_3\alpha_5\alpha_6 l_{b,rqd} \geq l_{0,min} \qquad \textbf{Where,} \qquad l_{0,min} > Max\begin{cases} 0.3\alpha_6 l_{b,rqd} \\ 15\phi \\ 200mm \end{cases}$$

Where:

- $\boldsymbol{\rho_1}$ Is the percentage of reinforcement lapped within $0.65l_0$ from the center of the lap length considered.
- $\boldsymbol{\alpha_6} = \left(\frac{\rho_1}{25}\right)^{0.5}$ but not exceeding 1.5 nor less than 1.0
- $\boldsymbol{l_{b,rqd}}$ is the required anchorage length, $\boldsymbol{l_{b,rqd}} = \frac{\phi\sigma_{sd}}{4f_{bd}}$ for anchoring the force $A_s f_{yd}$
- $\boldsymbol{f_{bd}}$ constant bond stress in a straight bar
- $\boldsymbol{\sigma_{sd}}$ Is the design stress of the bar at the position from where the anchorage is measured.
- $\boldsymbol{\alpha_i}$ Are modification factors accounting for bar diameter, concrete strength, confinement, and bar coating.

The basement column lap length ($\boldsymbol{\ell_o = 1000mm = 1m}$) and development length ($\boldsymbol{\ell_b}$) were verified in accordance with ES EN 1992-1-1:2015, Section 8.7.3, ensuring compliance with anchorage and reinforcement standards. **In the lapping zone:**

- Concrete cover was maintained uniformly around the overlapped bars to ensure proper bond and protection against corrosion.
- The lapping was done in a staggered manner to avoid weak zones and improve load distribution, so that it reduces the risk of cracking due to localized stress concentrations.
- Six-legged closed rectangular stirrup ties were installed at reduced spacing to enhance confinement, prevent buckling of longitudinal bars, and mitigate spalling under lateral loads.
- The stirrups also contribute to shear resistance and ductility, especially critical in seismic-prone regions like Finfinne and Shaggar city. Both cities are located in the Rift Valley region of Ethiopia, a geologically active area susceptible to seismic events.

The reinforcement bars used in the Main Hospital Building basement columns are grade S-500MPa, all of which underwent and passed rigorous tensile and bend tests before delivery to the site, ensuring compliance with CES 149:2015 and international quality assurance protocols. For this building, there are 20 distinct column types, each varying based on their termination point within the structure, the shape and geometry of the column, the diameters of the longitudinal bars used, and the diameter, shape, and spacing of the stirrups. These variations are driven by the specific design loads acting on each column and the structural zones they occupy to avoid buckling [49]. By tailoring the reinforcement specifications to meet the structural requirements of each zone, the design achieves cost optimization without compromising safety.

The structural design of the column was conducted using RC analysis and design of short columns, design aids, and ETABS [50]. Consequently, the geometry, dimensions, rebar size and numbers, and stirrup type & spacing of the columns were determined, ensuring both safety and cost effectiveness. As a result, column bar diameters in this building vary from ϕ20 mm in heavily loaded regions to ϕ16 mm where demands are lower. This gradation, driven by the structural design of the RC column member design procedure, yielded a 10% reduction in total steel tonnage without compromising safety. Even though some columns found in the center of the building are circular in geometry, most columns are square in shape and reinforced with 16 longitudinal bars, enclosed by three layers of $\phi 10mm$ stirrups spaced at 100mm centers. In the lap-splice zones, the stirrup spacing was intentionally reduced to enhance confinement, improve structural integrity, and ensure continuous load transfer across the spliced reinforcement. This approach reflects recent research findings in seismic-resistant design, where increased transverse reinforcement density in splice zones significantly improves energy dissipation and crack control.

The confinement strategy aligns with the Mander model for confined concrete behavior, which demonstrates that closely spaced stirrups increase the compressive strength and strain capacity of concrete cores. This approach is supported by Eurocode 2 and echoed in CES 100:1999, reinforcing the importance of transverse reinforcement in maintaining column integrity under axial and lateral loads. Additionally, lessons from post-earthquake forensic studies, such as those following the 2010 Chile and 2015 Nepal earthquakes, highlight the critical role of lap-splice confinement in preventing brittle failure modes [51]. By integrating these findings into the column design, the project not only meets Ethiopian standards but also embodies global best practices in structural resilience and material efficiency.

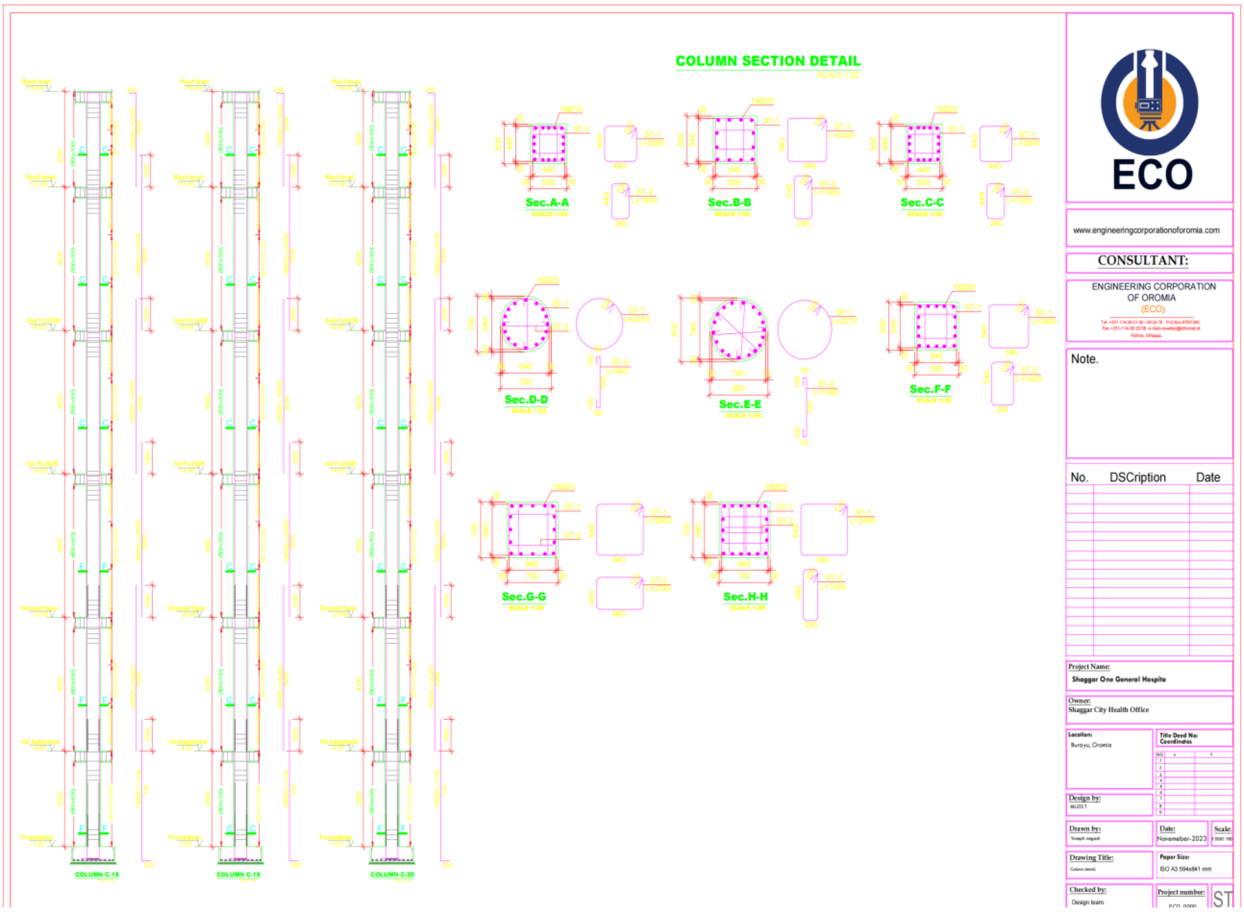


Figure 2.27 MHB Structural Design Column C-18, C-19, and C-20 and Section details of Column stirrups used in the MHB from Footing to Roof Level.

The above two structural drawings present a detailed basement column design, illustrating all essential reinforcement specifications. It includes bar lengths, stirrup length & geometry, bend angles, anchorage lengths, and the number and arrangement of longitudinal reinforcements. The design sequence is shown from the footing level upward, highlighting the development length of column bars into the footing and their continuity through to the roof-level beam or top tie beam connections. This figure serves to visually reinforce the structural integrity and detailing principles applied throughout the column design.

During the erection of the basement columns, the construction team employed both manual and instrumental methods to ensure verticality and precise alignment. Workers used a plumb bob ($Tumbi$) guided checks in conjunction with a Theodolite and Leveling to maintain the exact vertical orientation of each column. After completing the reinforcement assembly, tying longitudinal bars and stirrups according to the structural design, the team installed 5cm mortar spacers secured with binding wire. These spacers were typically attached to the edge bars, often at stirrup intersections, following the same methodology used in the previously executed BB foundation works.

Due to the large footprint of the Main Hospital Building (6,740 m^2, B+G+4), the structure was divided into five independent structural zones using expansion joints designed to accommodate thermal movement, seismic effects, and differential settlement. At the joint locations, columns and their adjoining basement beams were constructed with complete structural separation between zones. Each column's reinforcement cage was arranged independently for its respective zone, and formwork incorporated timber separators to maintain the joint gap without rigid connectivity. Basement beams intersecting the expansion joint were terminated separately for each side, with no shared reinforcement across zones, ensuring the joint remained flexible and functional. This detailing maintained structural independence from the foundation level through the basement columns and beam connections up to the ground-level columns, which was the stage reached during the observed construction phase. The detailing observed adhered to reinforced concrete best practices for expansion joint execution in large institutional buildings, allowing the system to continue seamlessly to the roof level as per design.

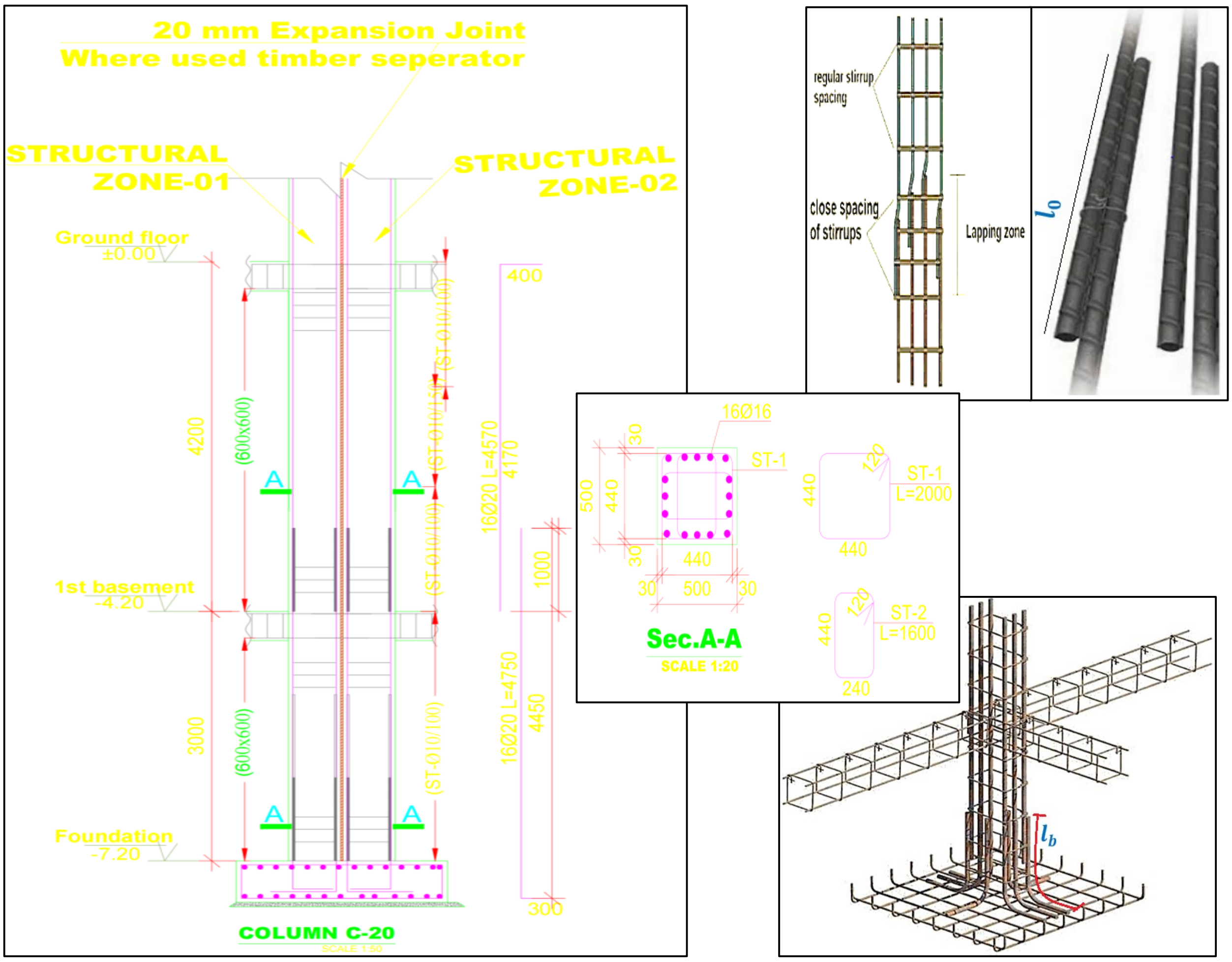


Figure 2.28 Expansion Joint and Lap Length Layout for Column C-20 of MHB.

To prepare for concrete placement, timber formwork was constructed around each column. The formwork was treated with release oil to facilitate smooth removal and to ensure a clean surface finish on the concrete. Before finalizing the setup, the column alignment was rechecked using a Total Station and manual plumb bob (i.e., stones tied to string, bottle filled with sand and tied to string...) verification to confirm straightness and verticality. We measured the distance between the string of the plumb bob and the column formwork at both the top and bottom, checking all points for accuracy. This phase of work was meticulous and labor-intensive, requiring close supervision and quality control. Each step was thoroughly inspected by the site engineers and the Assistant Resident Engineer, Eyuel (ECO), to ensure compliance with design specifications and workmanship standards.

For columns located along the building's perimeter, casting was carried out monolithically with the adjacent retaining wall of the Main Hospital Building (MHB), as well as with the columns integrated into the interior shear walls (SW-1 through SW-6). This monolithic construction approach ensures structural continuity, proper load transfer, and enhanced overall stability of the structure, particularly in resisting lateral forces such as wind and seismic loads. According to ACI 318-19 and EBCS 2:2015, monolithic casting of interconnected structural elements improves bonding between concrete members, minimizes potential weak joints, and significantly enhances the building's seismic performance and durability [41].

Once all columns, Shear walls, and retaining wall formworks were completed, a comprehensive inspection was conducted to identify any workmanship defects and verify that reinforcement placement matched the structural design. Verticality was confirmed across all columns. Following this, a joint approval meeting was held between the contractor's engineers and the consultant's site engineers to validate the readiness of the columns and finalize the concrete casting schedule.

Concrete placement was executed by Dugda Construction PLC on August 19 and 20, 2025 G.C., using truck-mounted mixers with a designated volume of $9m^3$ and $12m^3$, in which the total concrete ordered was calculated from column dimensions, retaining wall, and the shear wall dimensions. Concrete was placed together. The concrete was poured into the columns and the shear wall via a guided pouring track system, supported by remote control and manual supervision. During casting, mechanical vibrators were used to eliminate air voids and ensure proper compaction, thereby enhancing the concrete's homogeneity and surface finish. This process was critical to achieving durable, gap-free column and shear wall structures that meet both structural and aesthetic requirements.

Formwork removal for the vertical columns was executed on the second day after placement. This was made possible by the inclusion of a curing time accelerator in the mix, which enhances early strength gain. As per civil engineering practice and guidelines (e.g., IS 456:2000 and ACI 347), vertical elements such as columns can support their own weight and resist lateral loads earlier than horizontal members like beams and slabs. Therefore, formwork for vertical members can be safely removed after 24 hours, provided the concrete has attained sufficient strength. The basement columns were cast simultaneously with the basement shear walls, and the work was completed efficiently. This approach aligns with best practices in structural sequencing and load path continuity, ensuring monolithic behavior and improved structural integrity.

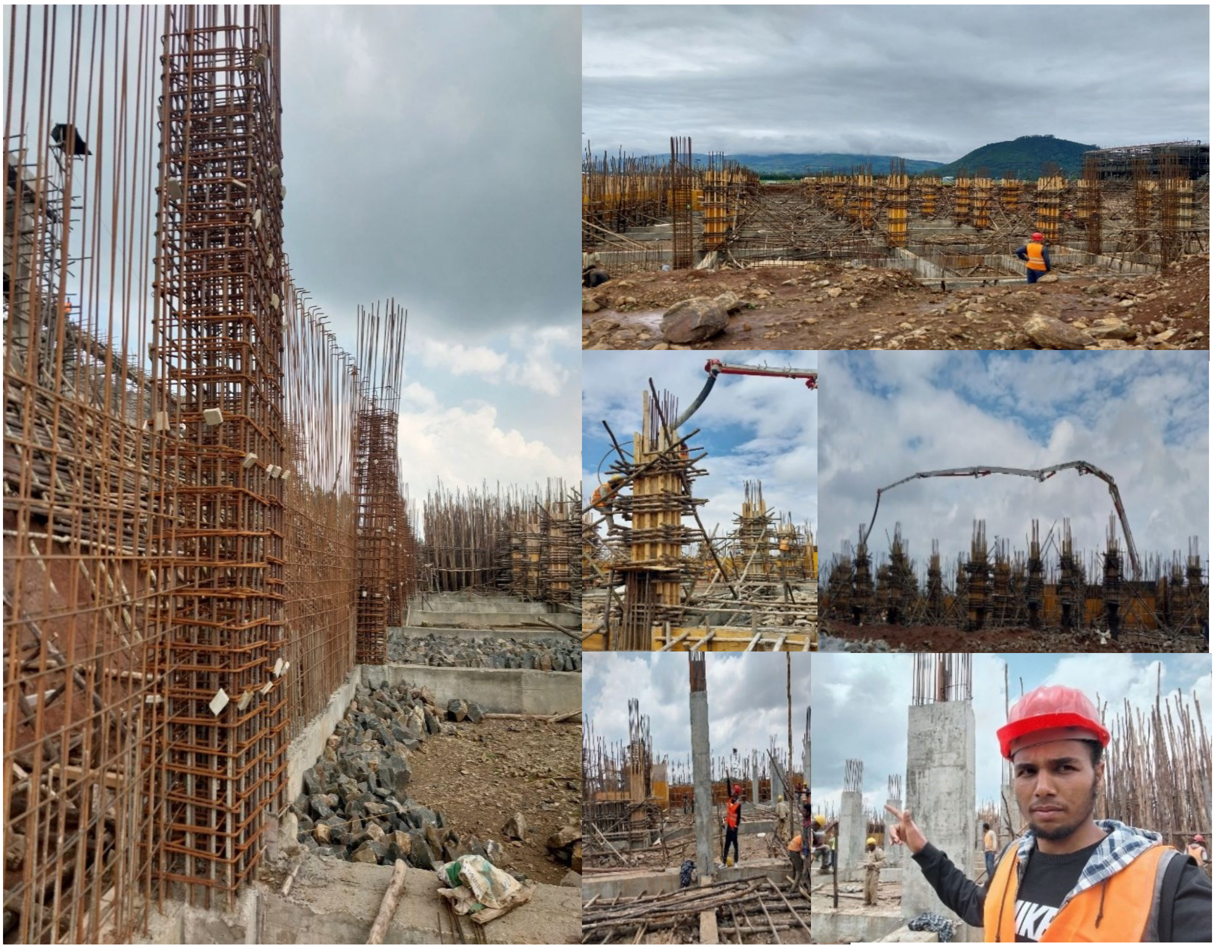


Figure 2.29 Basement Column Preparation, Formwork, and Concrete Pouring and executed column.

2.3.2.6.7. RC Work of Retaining Wall Construction of the MHB

In the Main Hospital Building (MHB), reinforced concrete (RC) retaining walls were constructed along the entire basement perimeter. These walls were structurally integrated with the corner footings and basement columns, extending up to the ground floor slab. Their primary role is to resist lateral earth pressures generated by backfilled soil and rocks, as well as surcharge loads, hydrostatic pressure, and uplift forces that would otherwise cause failure if hollow cement block (HCB) walls were used.

Retaining walls function by counteracting earth pressures acting perpendicular to their face, whereas shear walls resist lateral forces acting parallel to their plane. This distinction arises from their moments of inertia:

- **Shear walls** possess high in-plane stiffness, enabling them to effectively transfer lateral loads (wind, seismic) to the foundation with minimal deformation.

- **Retaining walls** have relatively lower out-of-plane stiffness, making them more susceptible to bending under soil pressure.

In this project, retaining walls were combined with six types of shear walls to enhance the overall stability of the hospital. Retaining walls at the basement perimeter provided resistance to soil loads, while shear walls were strategically placed near heavy mechanical equipment rooms, along the wind direction, and in high-vibration hospital zones. This integration improves resistance against lateral sway, torsion, and seismic forces, which is critical for a multi-story healthcare facility in Ethiopia, even though moderate seismic earthquake activity has been recorded for the project site.

Furthermore, to resist seismic activities, not only the wall but also the foundation work and all other structural designs and work were executed based on the expected seismic conditions found in the Geotechnical Investigation and Foundation Recommendation of a B+G+4 Hospital Building at Guje Gafarsa Sub-City (draft report) of the project before proceeding with actual design work. The structural design, including foundations, retaining walls, Columns, Beams, and shear walls, was carried out in compliance with the Geotechnical Investigation and Environmental and Social Impact Assessment (ESIA) Draft Report recommendations [29]. These measures ensured that the hospital structure meets the required safety, serviceability, and durability standards under seismic and wind loading conditions.

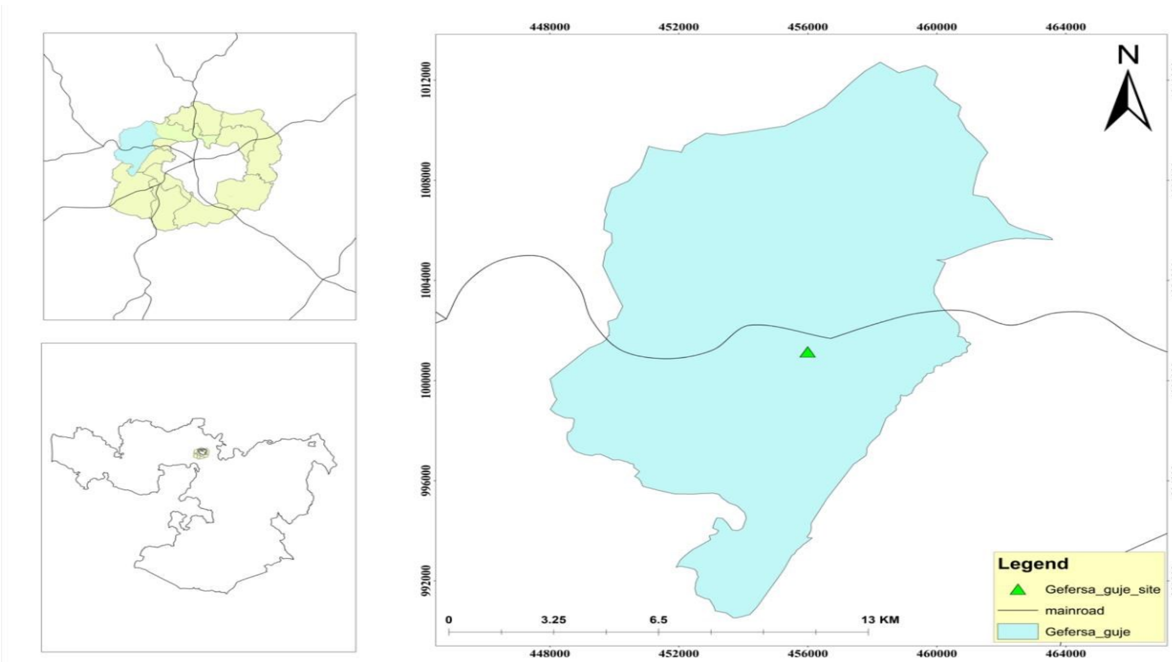


Figure 2.30 Project Location and Accessibility Map; Gefersa Guje, Shaggar City, Oromia.

The seismicity assessment of the project site is a key consideration for ensuring structural safety, as earthquake forces can cause significant damage. Since detailed seismic investigation is complex, Ethiopian building projects often rely on national seismic risk maps derived from geological and instrumental earthquake data. According to the Ethiopian Building Code Standard (ES EN 1998:2015), Ethiopia is divided into seismic zones with approximately uniform hazard levels, based on historical earthquake distribution and a **475-year** return period (10% probability of exceedance in 50 years) with an importance factor of **1.0**. The parameter **αo**, representing the ratio of bedrock acceleration to gravity, varies with each seismic zone. From the updated Ethiopian seismic hazard map, the project site at Gefersa Guje, Shaggar City, falls within Zone 4, categorized as a low seismic hazard zone. For this zone, a peak ground acceleration (PGA) of **0.15g** is considered, allowing the application of simplified seismic design procedures for certain structural categories [16].

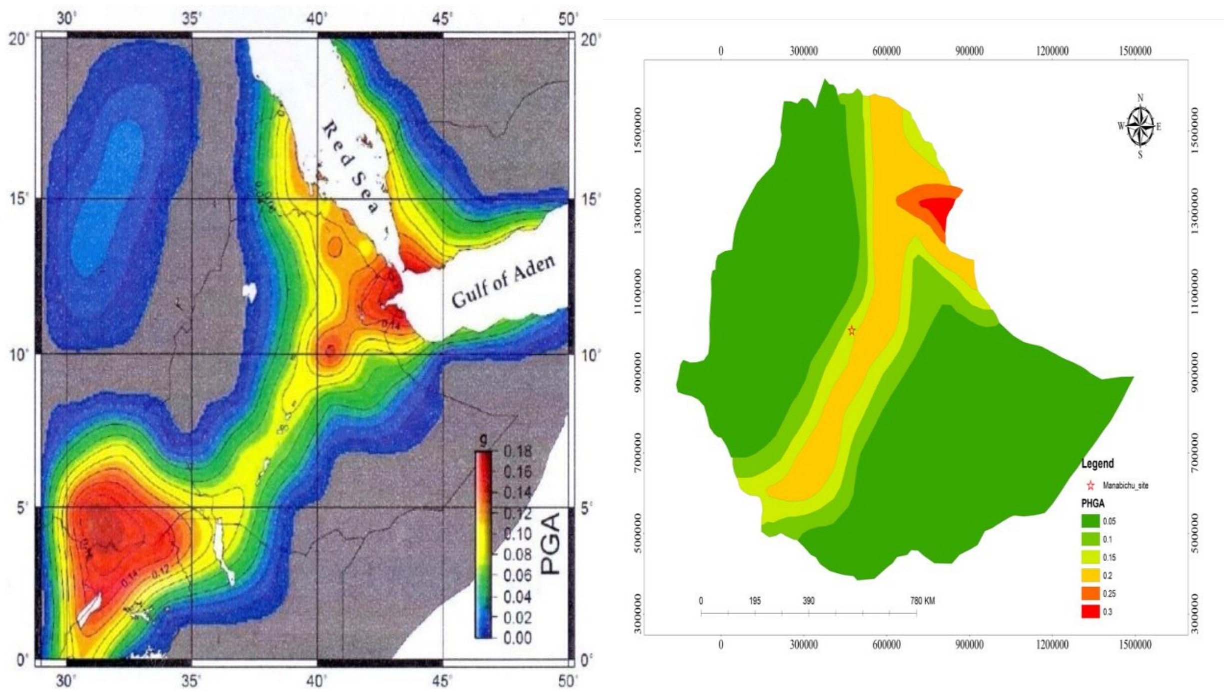


Figure 2.31 Seismic Hazard Map of Ethiopia and Horn of Africa in terms of PGA (ES EN 1998-1:2015).

Now, to be specific to my main topic 'RC Work of Retaining Wall Construction of the MHB', The retaining wall was constructed in accordance with the structural design, extending from the foundation up to the ground level. During construction, the footings and columns located at the perimeter corners were cast monolithically with the retaining wall using the specified design concrete strength, while reinforcement bars were properly lapped and intersected as per the structural drawings to ensure uniformity and effective load transfer. At and up to the basement level, the retaining wall served a dual function: on the interior side, it resisted the pressure of selected backfill materials compacted around the foundation, while on the exterior side, it retained soils and stones placed in the working spaces excavated for foundation works. From the basement beam up to the ground level, the retaining wall provided stability by resisting lateral earth pressure from the surrounding backfill and natural soil, thereby safeguarding the structure against sliding and overturning. Unlike hollow cement block (HCB) walls, which are unsuitable for resisting such loads, the reinforced concrete retaining wall provided the required stiffness, durability, and structural integrity, ensuring long-term stability of the building.

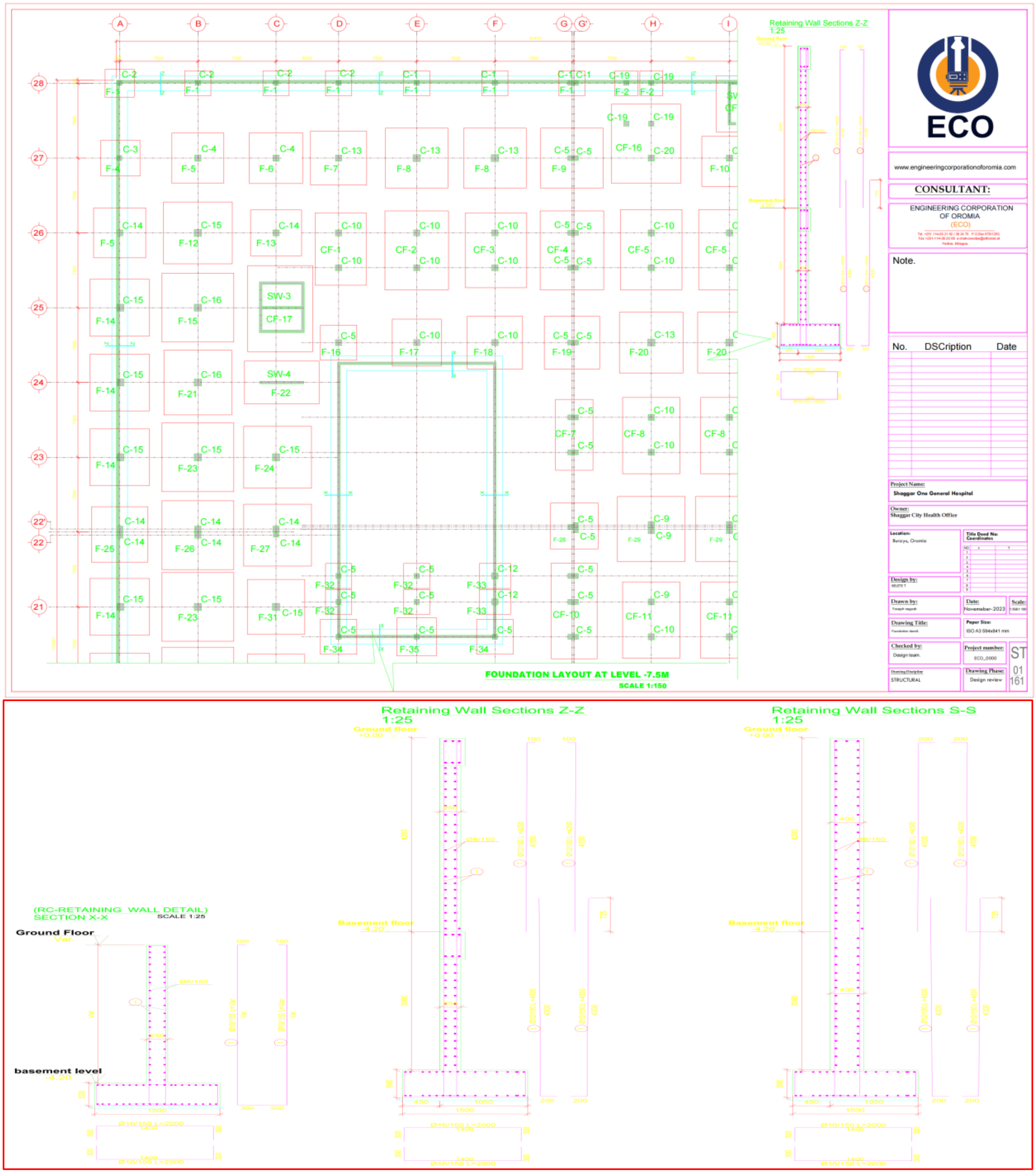


Figure 2.32 Retaining Wall Section Detail and Layout within Foundation of MHB

The concrete placement of the retaining wall and the installation of reinforcement bars were carried out monolithically with the adjacent structural part of the MHB, in accordance with the construction progress and structural design requirements. The works were integrated with the adjacent footings, columns, basement beams, and grade beams to ensure continuity and structural stability. The sequence of construction followed a systematic approach: first, the foundation footings and foundation retaining wall were cast together; next, the basement beams were constructed in combination with the basement retaining wall; and finally, the basement columns were cast monolithically with the corresponding sections of the retaining wall. This step-by-step integration provided uniform load transfer between structural elements, minimized potential weak joints, and ensured the retaining wall's effectiveness in resisting lateral earth pressure and supporting the overall stability of the Main Hospital Building. Waterproofing measures were integrated into the foundation and basement retaining wall system to address hydrostatic pressure and soil moisture ingress, considering the site's geotechnical profile.

Figure 2.33 Retaining Wall Reinforcement installation and formwork erection.

2.3.2.6.8. RC Works of Shear Wall Construction of the MHB

Reinforced-concrete shear walls were provided in selected interior zones of the Main Hospital Building, specifically around heavy equipment rooms (e.g., X-ray, CT, MRI) and elevator/lift shafts & ramp at the central space of the building, where high lateral and concentrated vertical loads are expected. Six (6) structurally distinct shear-wall types were constructed at designated locations, including orientations aligned with prevailing wind directions. Each shear wall originates at subgrade level, at the same elevation as the footing pads, and was integrated with adjacent structural elements (footings, columns, beams, slabs and retaining walls) to ensure monolithic behavior, efficient load transfer, and structural continuity. These shear walls resist lateral loads primarily by vertical bars (axial/flexure) and horizontal bars (crack control/shear). Both directions are required and specified by code/minimums. During my internship-I observed construction of these shear walls from basement level up to ground level.

The shear wall enclosing the elevator shaft incorporated a spring-based safety system at its base to absorb impact forces in the unlikely event of a braking failure; the wall therefore provides both rigid enclosure and the necessary stiffness to support the elevator mechanism and its safety devices under dynamic loading. Other shear walls were positioned to receive loads from heavy medical equipment and to reduce stress concentrations in those sensitive zones. Working together with basement columns, the shear walls form a stiff, continuous structural frame that resists lateral (seismic and wind) forces, supports vertical loads, and provides a durable below-grade enclosure.

The purpose of these shear walls is:

- Provide lateral stability against soil pressure, wind, and seismic earthquake effects.
- Anchor heavy medical machinery to a vibration-resistant structure.
- Form rigid elevator shafts with minimal deflection under live loads.
- It acts as a waterproof barrier when combined with membrane systems.

The variation in shear wall design above ground level is strategically driven by functional and architectural requirements, such as the positioning of vertical transportation systems (e.g., elevators, ramp, lifts), specialized medical rooms (e.g., radiology and X-ray suites), and the anticipated lateral load demands due to environmental forces like wind and seismic activity. These design adaptations are essential to optimize the building's lateral load resistance, enhance seismic performance, and ensure long-term structural durability and occupant safety.

Eurocode-2 [40], sets detailed rules for bar sizes, minimum/maximum spacing, cover, and arrangement for shear walls as well as any civil engineering structures. For Shear Walls**:**

- Minimum vertical reinforcement: $0.002 \times$ wall area (each face)
- Maximum spacing: $3 \times$ wall thickness or 400 mm (whichever is lesser)
- Horizontal reinforcement at each face: minimum $0.001 \times$ wall area or 25% of vertical area; max spacing 400 mm

The structural designs of the building's typical shear walls are presented below, complete with reinforcement layouts, bar bending schedule, and precise dimensional specifications.

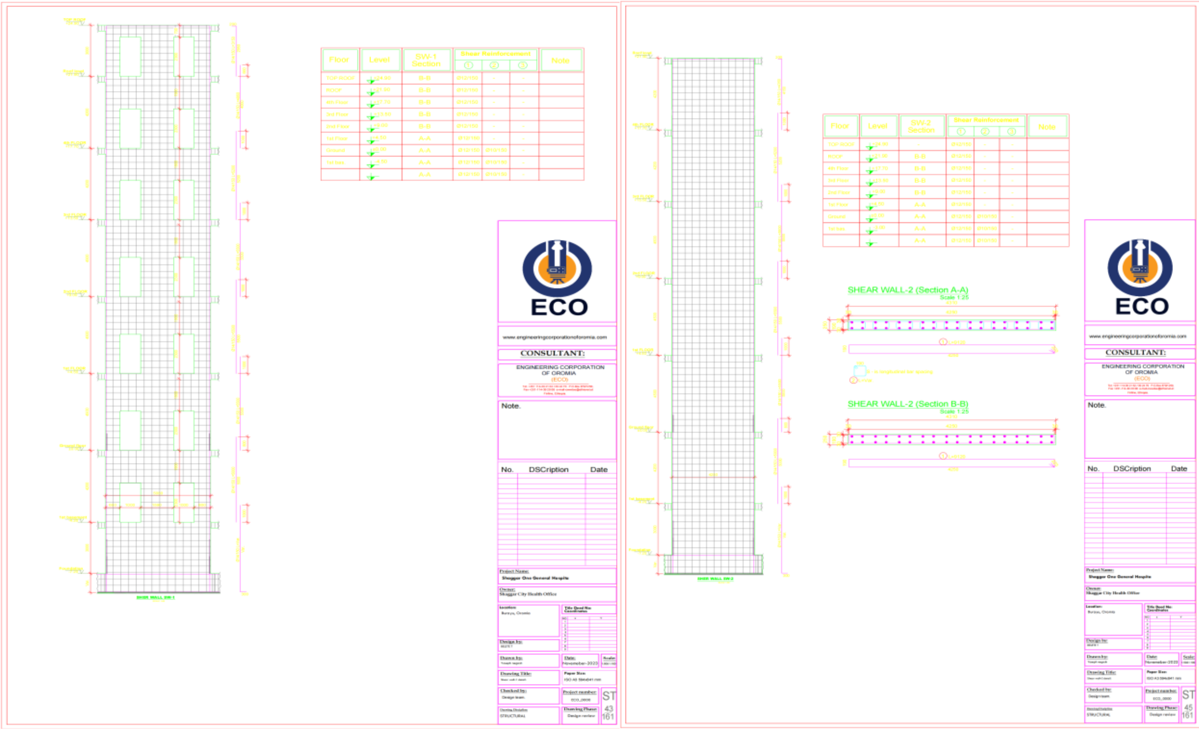


Figure 2.34 Typical Shear Wall (SW-1 & SW-2) Layout, Reinforcement, and Connection Details.

Particular attention was given to the reinforcement design at critical stress regions, including wall boundaries, openings (doors and windows), and interfaces with the diaphragm. In these zones, additional vertical and horizontal reinforcement was specified for both the near and fixed faces (NF/FF). The detailing of this enhanced reinforcement is illustrated in enlarged detail views and cross-sectional drawings.

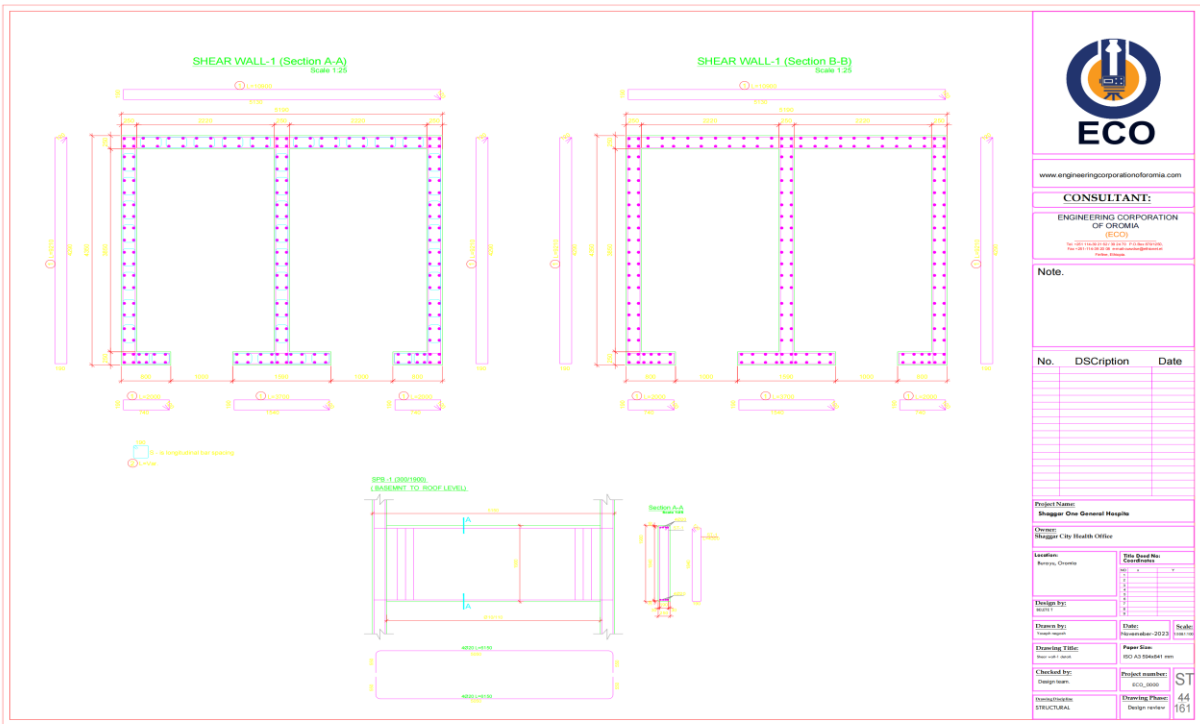


Figure 2.35 Elevator Shear Wall (SW-1) Structural Section Detail.

On-site construction of the basement shear walls proceeded in parallel with the basement column and retaining wall works. First, the contractor lap-spliced ϕ12mm longitudinal bars from the basement beam shear wall starter bars, following the reinforcement development lengths specified in CES 149:2015. Once these main bars were positioned, ϕ8mm closed shear reinforcement (Horizontal bars of the shear wall) were tied at the designer's prescribed spacing to provide adequate shear resistance and confinement; an approach reinforced by recent findings in seismic-resilient detailing, which emphasize tightly spaced transverse reinforcement in critical zones. After installation of the reinforcement, carpenters installed polished timber formwork on both faces, treating it with release oil and securing 50 mm mortar spacers to maintain the required concrete cover. This ensured a monolithic connection between the shear walls, the adjacent columns, the retaining wall and the underlying beams without sacrificing durability.

Figure 2.36 Shear Wall reinforcement installation formwork constructing

With the formwork and reinforcement verified by the site engineers, Dugda Construction PLC placed C-45MPa concrete mixed with accelerator on August 20, 2025 G.C., using truck-mounted pump mixers. Mechanical vibration removed entrapped air and prevented honeycombing, while cube specimens were cast in three layers for compressive-strength testing under ASTM and BS EN standards [33]. The accelerator admixture enabled early-age strength gain, allowing the removal of vertical formwork after just two days. Upon successful laboratory validation of the test cubes and a joint inspection by ECO's consulting engineers, the contractor received formal acceptance and interim payment for the completed shear walls, retaining wall and basement columns.

After the concrete achieved its required early-age strength (24 hours), for the basement shear & retaining walls and columns, the formwork was dismantled and all construction materials, including timber and temporary supports used during erection and concrete casting, were cleared from the building footprint. The next operation consisted of placing a crushed-stone layer between the basement beams and mechanically compacting it to the specified maximum dry density to form a stable sub-base. This will be followed by the installation of the reinforcement grid for the basement slab, which will be executed in strict compliance with the approved structural slab design and specifications. To maintain the project's critical path, the contractor advanced the formwork and reinforcement for the grade beams and ground slab and cast them monolithically before executing the basement slab. The basement slab required extensive embedded MEP (mechanical, electrical, and plumbing) installations: sanitary drainage runs, conduits, sleeves, and other service penetrations, which are time-consuming to lay out and inspect. By casting the grade beams and ground slab earlier, the contractor avoided delaying above-grade works while MEP crews completed service routing and coordination within the basement zone.

2.3.2.6.9. RC Works of Basement Slabs Construction of the MHB

My internship from June 09, 2025, to September 08, 2025 (three months) on-site construction work of the main hospital building lasted while the work was on placing and mechanically and manually compacting a layer of selected black crushed stone between the basement beams. After concluding the laying and compaction of the stone, the work will proceed with bending the bar for the basement slab by the rebar foreman per the structural design of the slab.

Until I was on the site they have almost on the verge to start the slabs reinforcement work for both basement floor slab and on the other side of the building ground floor slab. What an important thing I was recognized until then was all of the basement slabs are beam supported slab (no flat slab) for the basement beam slab and mostly flat slab for the ground floor slab were used. I noted that most basement panels behave as two-way slabs. I recognized this by comparing the longer span (breadth) to the shorter span (width) between consecutive basement beams; an approach consistent with ES EN 1992-1-1 and my RC Structures-I coursework. We classify slabs as one-way when $L_y/L_x > 2.0$ and as two-way when $L_y/L_x \leq 2.0$ (longer span to short span ratio of the slab). Under loading one way slab (slab supported on two opposite edges only) has only one plane of bending and the load is transferred to those two supports forming cylindrical bending curve, whereas two-way slabs (supported on all the four edges) warp into a dish-shaped surface rather than a simple cylindrical curve. Because of two way slab's corners lift up under bending, tensile reinforcement must be provided in both orthogonal directions to control crack widths and achieve compatible curvature, as taught in reinforced concrete theory [52].

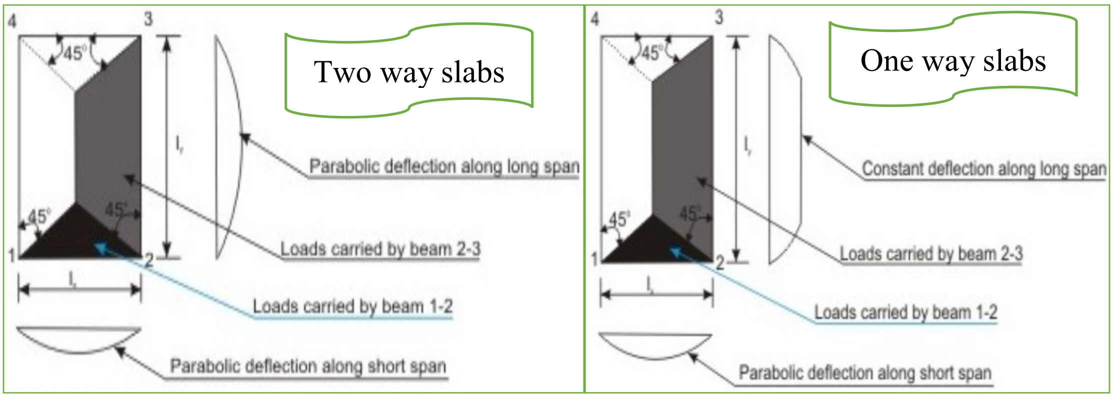


Figure 2.37 Two-Way and One-Way Slab Load Sharing.

To design one way slab we select a slab thickness for deflection requirement and Flexural design is carried out by considering the slab as series of rectangular beams side by side. So, slabs are designed as singly reinforced section without shear reinforcement. Check thickness of slab for flexural $\mathbf{d_{min.}} \geq \sqrt{\frac{\mathbf{M_d}}{\mathbf{0.295bf_{cd}}}}$ and the required area of tension steel is determined using by $\mathbf{A_s} = \frac{\mathbf{M_d}}{\mathbf{z*f_{yd}}}$ and spacing per the design code. However some additional bars/secondary reinforcement/distribution reinforcement may be placed in the other direction to carry temperature and shrinkage stresses

On the structural design of the two way basement slabs, were they are fully fixed at their edges into the basement beams, with torsional corner restraints to prevent uplift. Structural Engineers used ETABS software to Analysis and design the slabs were they run iteratively the software for proposed design loads which was initially determined from functional use of each rooms/slabs and interior partition wall load per CES-142-2015-ES-1991-Part-1-1 [31] for imposed loads in uniformly distributed load to verify that the provided thickness of the slab from deflection requirements fits the design load. After reaching the final thickness, reinforcement area of the slab, spacing of the slab's both longitudinal & transverse reinforcement, and appropriate range of span to depth ratio per the code, they have drafted the structural design of the slabs and their reinforcement detailing using AutoCAD. ETABS operates by modeling each slab as a network of shell (plate) finite elements endowed with both in-plane and bending stiffness [53]. This software works for any kind of slabs (whether two or one way) and any structural members, which is a widely used software in the world. Under the applied uniform distributed load $\boldsymbol{q}$, the software assembles and solves the global stiffness matrix by effectively discretizing the classical elastic theory of homogeneous isotropic plate bending higher order differential equation to determine internal forces, which is given as [54]:

$$\frac{\partial^2 \mathrm{M_x}}{\partial \mathrm{x}^2} + \frac{\partial^2 \mathrm{M_y}}{\partial \mathrm{y}^2} - \frac{2\,\partial^2 \mathrm{M_{xy}}}{\partial \mathrm{x}.\partial \mathrm{y}} = -\mathrm{q}$$

This is used to extract the slab's bending moments developed in M_x , M_y, and the twisting moment M_{xy} (as well as shear forces) in every panel. Important note about ETABS is that it considers and inputs dead load directly from material specification and geometry of the structural member (i.e., Thickness) and no need for manual provision of dead load, as such as live load. It also accounts for Wood-Armer moment combinations, punching-shear verifications, and moment redistribution rules before finalizing the reinforcement layout.

From my Reinforced Concrete Structures-I (CEng3204) course, there are many methods to analysis and design two way slab such as Rankine-Grashoff's (if slab corners are not held down or it's simply supported), Yield-Line Theory (governed by flexure alone and shear effects are ignored) and Finite element method (for any kind of slabs) analysis exist for two-way slabs, we adopt the Coefficient Method per ES EN 1992-1-1:2015 code which provide moment coefficient table.

The procedures used to design two way RC slabs as per CES-149-2015-ES-1991 are:

1) Check whether the slab behaves as one-way or two-way.
2) Determine slab thickness from deflection requirements.
3) Calculate factored design load by combining dead and live loads per room function.
4) Select appropriate moment coefficients from the code's tables based on the aspect ratios L_y/L_x and support conditions of slab panel with torsional restraint.

5) Adjust unequal edge moments by using moment distribution method
6) Determine design constants from specs of materials
7) Check thickness of the slab required for flexure, which is given by: $\mathbf{d_{min.}} \geq \sqrt{\frac{\mathbf{M_d}}{\mathbf{0.295bf_{cd}}}}$
8) Calculate and check minimum & maximum flexural reinforcement area ($\mathbf{A_s}$)

$$A_{s,min} = Max\begin{cases} 0.26\frac{f_{ctm}}{f_{yk}}b_t d \\ 0.0013b_t d \end{cases} \quad \text{and} \quad A_{s,max} = 0.04A_c$$

9) Check minimum and maximum spacing of reinforcement area per ES EN 1992:2015 clause 8.2 &9.3.1; where spacing of reinforcement is given by: $S = \frac{ba_s}{A_s}$
10) Check the adequacy of the slab thickness for shear
11) Check deflection and cracking control per the code
12) Detailing of reinforcements
13) Design the supporting beam by distributed reaction load (shear force) from the slab per the code by a coefficient based on the aspect ratios L_y/L_x and support conditions of the slab panel.
14) Drafting the structural design of the slabs and their reinforcement detailing using AutoCAD

The structural design of the slabs arrives at the required bar area and spacing in both directions per m^2 of the slab, then for the entire size of the slabs by the procedure defined above.

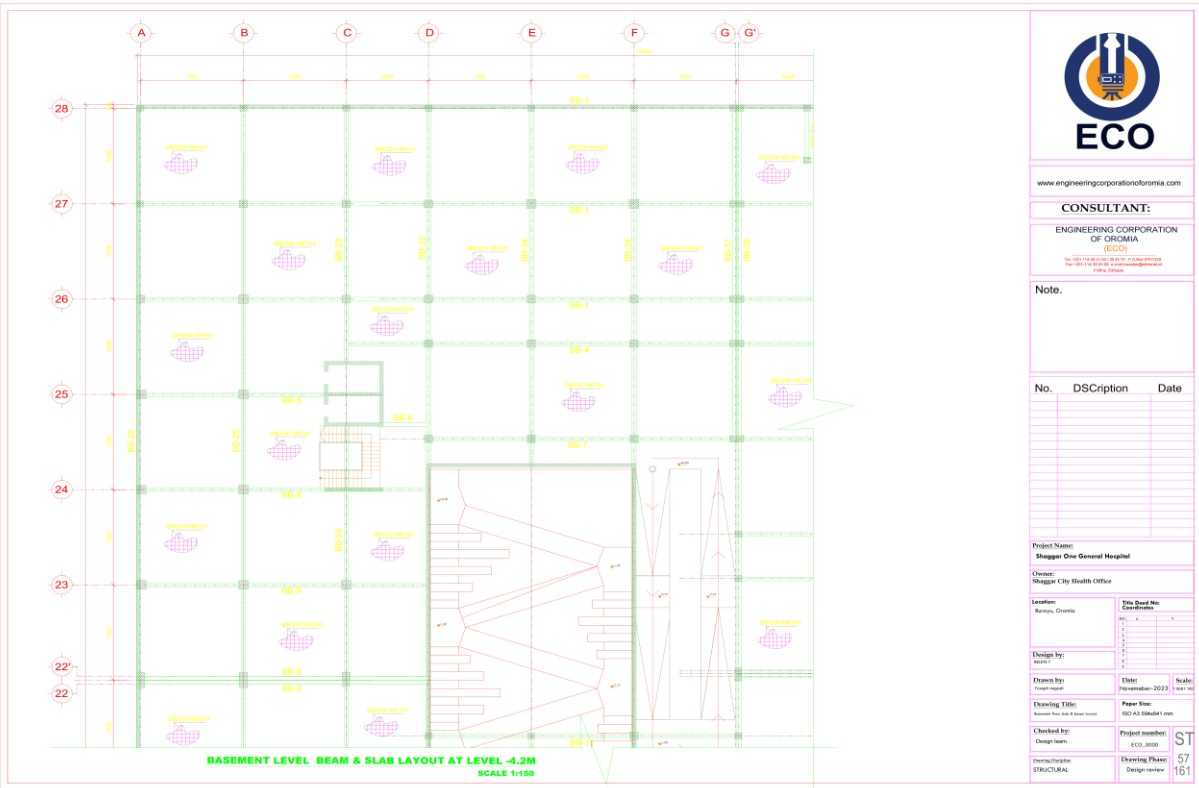


Figure 2.38 Basement Floor Slab and Beam Layout of MHB.

On-site execution of the basement slab commenced by compacting and leveling the crushed stone sub-base, which serves as a stable foundation to evenly distribute loads and prevent differential settlement. Following this, the construction team will place the slab reinforcement grid for both the bottom and upper part of the slab by keeping the space between the grids by Z-bar, which needs to be secured in strict accordance with the approved structural design specifications. A Z-bar is a Z-shaped bar used in construction sites, mainly in RC slab, used to keep the space between the bottom and upper reinforcement. The reinforcement placement is vital for resisting tensile stresses, controlling cracking, and enhancing the overall structural integrity of the slab under various load conditions. This phase marks the completion of my direct involvement in the substructure works of the MHB. The subsequent section of this report will discuss further civil engineering activities, including the installation of perforated drain tubes for the construction of the substructure drainage network designed to maintain soil stability and protect the foundation system.

Figure 2.39 Crushed Stone Sub-Base for Basement Slab of MHB.

2.3.2.7. Substructure Perforated Tube and Drainage Systems of the Project

Effective substructure drainage is a critical component in the long-term durability and functionality of any major civil infrastructure. For the Shaggar One General Hospital project, the Main Hospital Building, which spans 6,740 m² across six levels (Basement + Ground + 4 floors), a comprehensive water removal system was implemented to mitigate water ingress from both groundwater and surface runoff. Perforated drainage tubes, they installed OCTG drain tubes around every foundation block were strategically installed throughout the substructure and extended into upper structural zones to intercept and channel infiltrated water.

These tubes collect water from various sections of the building, filter out solid particles, and direct the flow into an external holding tank, designed in accordance with the sewerage layout and pipe loop configuration developed by the water resources engineering team. The project encompasses a Pump House designed for sanitary and water distribution control for the finally constructed hospital. This G+0 structure is equipped with pumps, motors, and associated control valves, all strategically sized and located in accordance with the sewerage, sanitary layout, and pipe loop configuration devised by the water-resources engineering team. The scope of the Pump House, which includes piping, pump procurement, and installation, is detailed in the contract and has a total value of ETB 9,396,704.03.

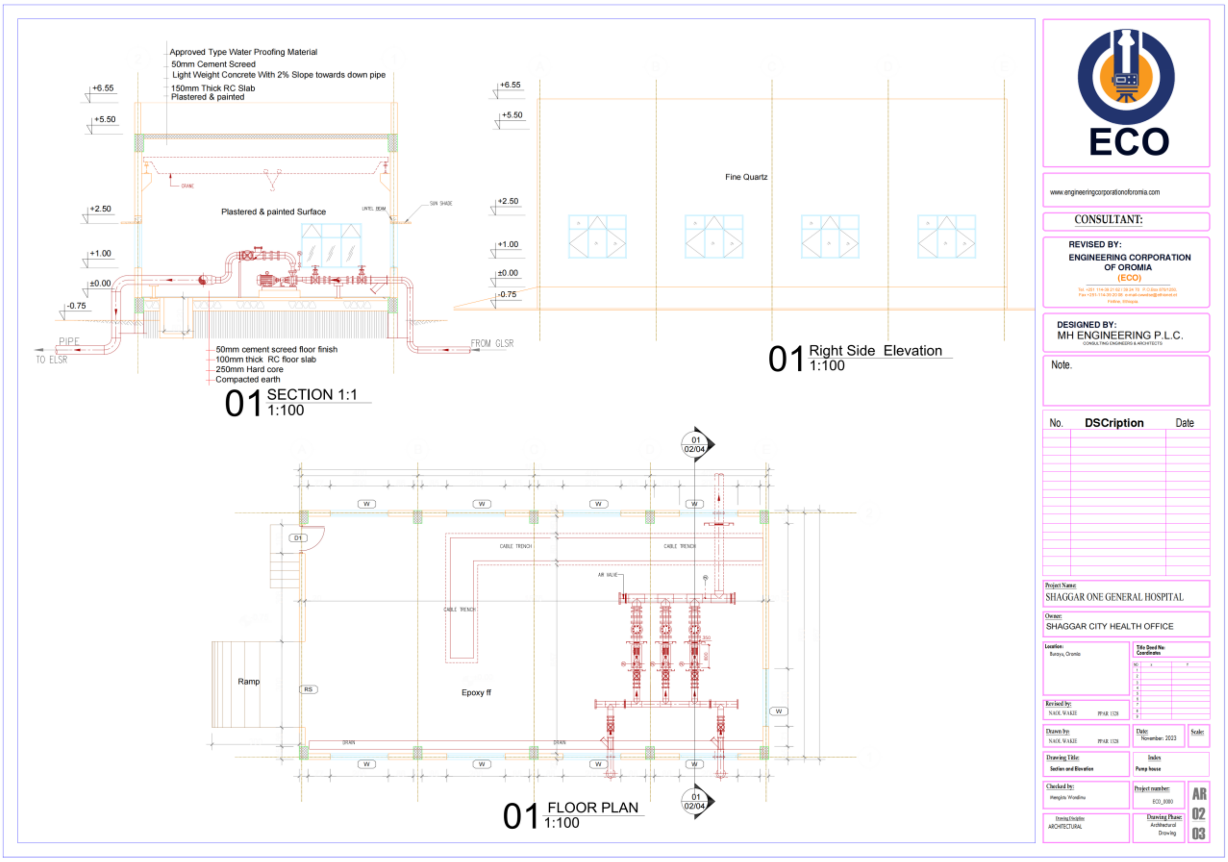


Figure 2.40 Pump house architectural drawing

This system of perforated tubes under buildings was uniformly applied across all auxiliary structures, including the administration block, community pharmacy, generator house, and internal road networks. The integration of such drainage infrastructure reflects best practices in both civil and water resources engineering, particularly in regions with seasonal rainfall and high groundwater tables like Oromia. During my internship, which coincided with the rainy season, I observed firsthand the accumulation of water around the foundation and basement levels. The collected water was efficiently evacuated using motorized pumps connected to the tank of the drainage loops. This experience deepened my understanding of key water resources engineering principles, including:

- Pipe loop design and branching systems.
- Hydraulic loss calculations at bends and main passes by the Darcy-Weisbach Equation.
- Pump sizing and power requirements for water evacuation by a pump whose power ($P = \frac{\rho g Q H}{\eta}$) met the expected peak infiltration rate plus a 20% safety margin.
- Solid-liquid separation and sewerage discharge mechanisms.
- Detail filtration trenches and drop-bucket inlets to prevent clogging in accordance with IS 456 and Ethiopian drainage codes.

From an academic standpoint, this exposure bridged theoretical coursework with practical implementation, reinforcing concepts from fluid mechanics, hydrology, and environmental engineering. Professionally, it enhanced my competency in designing and supervising integrated drainage systems, skills that are essential for both urban infrastructure development and sustainable building practices [55].

As a dual BSc candidate at Adama Science and Technology University, majoring in Civil Engineering and Water Resources Engineering, this hands-on project bridged classroom theory with field realities. I applied fluid-mechanics equations to real pipe networks, integrated geotechnical drainage design with structural layouts, and oversaw execution under rainy-season conditions. Academically, it solidified my grasp of groundwater control, sewer hydraulics, and pump station design. Professionally, it sharpened my ability to deliver multidisciplinary infrastructure solutions, an essential skill set for my future career as a civil-water resources engineer in urban development and public health facilities.

Figure 2.41 OCTG Pipes and Pump Removing Accumulated Water.

2.3.2.8. Bar Bending Schedule work of the Project

Reinforced Concrete (RC) is a composite material widely used in construction, combining the high compressive strength of concrete with the high tensile strength of steel. The synergy between these two materials allows RC structures to withstand various loads and stresses, making them suitable for a wide range of applications, from residential buildings to bridges and dams. Reinforcement is a term form military or police organizations. It means to increase the existing strength of concrete as well as control the effect of shrinkage and temperature changes [56]. Components of RC are:

- **Concrete:** A mixture of cement, sand, aggregates, and water. It provides compressive strength and forms the bulk of the structure.
- **Steel Reinforcement:** Typically in the form of rebar (reinforcing bars), it provides tensile strength and ductility to the concrete.

Advantages of RC structures are:

- High strength and durability
- High stiffness (rigidity)
- Ability to be cast
- Low thermal and electrical conductivity
- Energy-efficient
- Versatility in design and construction.
- Resistance to fire and weathering
- Economical for a wide range of applications
- Aesthetic properties
- Onsite fabrication

Steel reinforcement is crucial in RC construction as it addresses the inherent weakness of concrete in tension. The primary role of steel reinforcement is to absorb tensile stresses, distribute loads evenly, and enhance the structural integrity of the concrete elements [56].

A Bar Bending Schedule (BBS) is a comprehensive list detailing the type, size, length, and quantity of steel reinforcement bars needed for a construction project. The BBS serves as a tabulated summary of all reinforcement bars required for a specific structural element. It includes [57]:

- Bar mark and reference to drawing
- Bar type and shape code (e.g., straight, L-bend, crank, stirrup)
- Diameter (typically HYD S-500MPa bars of $\phi 8, \phi 10, \phi 12, \phi 16, \phi 20, \phi 24mm$)
- Number of bars and spacing
- Cut length and total length

- Hook and bend details
- Weight per meter and total weight

This schedule ensures accurate cutting, bending, and placement of reinforcement, minimizes wastage, and facilitates cost estimation & budgeting, and quality control. It is an important document in the construction business since it ensures that steel bars are cut, bent, and put correctly according to the structural plan.

Bar Bending Schedule (BBS) preparation was a critical component of the reinforcement detailing process during the construction of Shaggar One General Hospital. As part of the site execution team, I actively participated in the development, verification, and application of BBS for various structural elements, including columns, beams, and shear walls. This task required precision, adherence to design specifications, and coordination between the site engineers and the steel fabrication crew. The BBS preparation followed a systematic workflow [57]:

I. **Drawing Interpretation**: Structural drawings were reviewed to identify bar types, locations, and configurations.

II. **Bar Marking**: Each bar was assigned a unique mark corresponding to its position and function (e.g., T_1 for top bars, B_1 for bottom bars, S_1 for stirrups).

III. **Length Calculation**: Bar lengths were calculated considering bends, hooks, lap lengths, and development lengths as per CES 149:2015 and ES EN 1992-1-1:2015.

IV. **Weight Estimation**: Using the standard formula:

$\text{Weight (kg)} = (\frac{D^2}{162.28}) \times L$; Where: D is the diameter in mm and Length (L) in m

V. **Tabulation**: All data were compiled into a structured BBS sheet using Excel and AutoCAD references.

The reinforcement used specifically for this project is grade S-500MPa, Twisted Deformed Bars. This conforms to $STB\ 1704-2012/DIN\ 488/NS\ EN\ 10080$ and $ASTM\ A615/A615M$ Grade 60, offering a minimum yield strength of 500 MPa, an ultimate-to-yield strength ratio of 1.03– 1.10, and elongation at break of at least 5%, with cold-twisted ribs for superior bond and reliable seismic bend/re-bend performance. Their chemical composition limits include $\text{C} \leq 0.22\%, \text{P/S} \leq 0.05\%, \text{Cu} \leq 0.80\%, \text{N} \leq 0.012\ \%$, carbon equivalent $\leq 0.50\%$, diameter tolerances of $\pm\ 0.5\ mm$, and they are supplied with full mill test certificates.

Proper tools and equipment are essential for accurately cutting, bending, and placing reinforcement bars. For this project steel fabrication crew used Hacksaws and Metal cutting with a handheld machine with a cutting disc. They have used Hand Benders and a steel made plate for bending the bars. Tape measures and rulers are used to accurately measure bar lengths. Additionally, chalk and markers are employed to mark cutting and bending points on the bars. In the Shaggar One General Hospital project, steel bars are stored off the ground and protected from groundwater moisture to prevent corrosion, but steel bars are left stored outdoors with direct exposure to rain and ambient moisture, leading to accelerated surface corrosion.

I observed that the fabrication team used black annealed binding wire for inserting and securing rebar to form the structural element. This wire is heat-treated to enhance its softness and flexibility, making it ideal for tying reinforcement bars together efficiently. The wire typically ranges in diameter from 16 gauge (1.6 mm) to 18 gauge (1.2 mm), depending on the specific requirements of the structure.

Figure 2.42 Bar Storage, Cutting, and Bending Area on Site.

Reinforcement Cutting Length Calculations and Bend Deductions

Accurate determination of cutting length is essential in reinforcement work to ensure proper fit, minimize material waste, and maintain structural integrity. The cutting length of a reinforcement bar is calculated by summing the linear dimensions of the bar configuration and subtracting bend deductions based on the angle and diameter of the bar. During bending, the length of reinforcement increases. To balance this, a reduction in length is made depending on the bend angle [56]:

- $For\ 45°\ bend \rightarrow Deduct\ 1 \times D$
- $For\ 90°\ bend \rightarrow Deduct\ 2 \times D$
- $For\ 135°\ bend \rightarrow Deduct\ 3 \times D$
- $For\ 180°\ bend \rightarrow Deduct\ 4 \times D$;   Where D is the diameter of the bar

Example for typical rectangular stirrup Cutting length of basement beam one (BB-1):

$$= \text{Perimeter} + 2\ \text{no's of hook length} - \text{Total bend deduction}$$

$$= (2 \times long\ side\ of\ stirrup) + (2 \times\ short\ side\ of\ stirrup) + (2\ \times hook\ length) - (3 \times 90° bend) - (2 \times 135° bend)$$

$$= 2 * 450mm + 2 * 200mm + 2 * 100mm - 3 * (2 * 24mm) - 2 * (3 * 24mm)$$

$$= 1212mm = 1.212m$$

In short, cutting length is the total length of a reinforcement bar to be cut from the original length of imported bars for forming the stirrup before bending, calculated to ensure the final shape fits exactly as designed after all bends and hooks are made. The cut length is the length of bars used in the reinforcement take-off sheet. It accounts for the bar's geometry minus bend deductions due to elongation during bending.

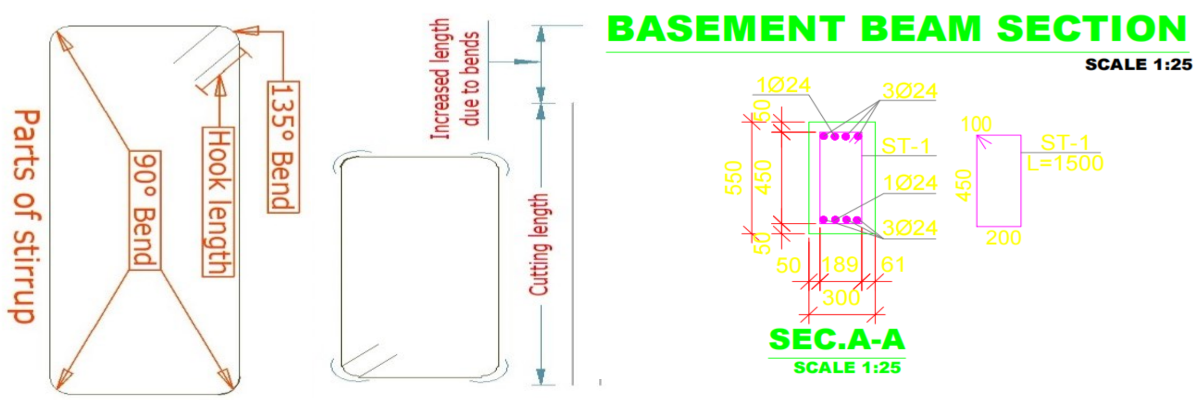


Figure 2.43 Bending Deduction for Rectangular Stirrups (BB-1) of MHB.

Now, let us calculate the ordered quantity in kg of this BB-1 stirrup:

$$Total\ quantity\ in\ kg\ of\ single\ stirrup = \left(\frac{D^2}{162.28}\right) \times L = \frac{10^2}{162.28} * 1.212m = 0.747kg$$

The BB-1 has a length of 7.00m, and the stirrup is spaced at 10cm. It takes 70 stirrups from the edge of the column to the last edge of another column, so the total quantity of stirrups for the beam is:

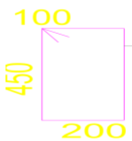
$$Total\ quantity of\ all\ stirrup = \left(\frac{D^2}{162.28}\right) \times L \times 70 = \frac{10^2}{162.28} * 1.212m * 70 = 52.28kg$$

Adding 2% wastage, the ordered quantity in kg of the stirrup for the BB-1 is:

Ordered quantity in kg (10mm) = $22.40kg + \frac{2}{100} * 22.40kg = 53.325kg$

The bar-bending schedule for BB-1 was prepared as a representative sample, and the same methodology was consistently applied across all stirrups throughout the project. For circular stirrups, the cutting length was calculated using the formula $Cutting\ Length = \pi * Diameter + 2 * Hook\ Length - 2 * Bend\ Deduction\ of 135°$. In addition to stirrups, the cutting lengths and quantities of all longitudinal bars in beams, footings, columns, and shear walls were computed using standard reinforcement principles. This approach was extended to all transverse bars and bar arrangements defined in the structural design, ensuring accurate execution of reinforcement work on site in alignment with design specifications and construction standards [57].

Table 2.24 BBS for Basement Beam BB-1 of Main Hospital.

BAR BENDING SCHEDULE FOR BASEMENT BEAM-1 OF THE MAIN HOSPITAL BUILDING									
Sr. No:	Descriptions	Shape and size of bars	Bar type (D) in mm	Cutting bar length in m	No. of bars	Total length (m)	Unit weight (kg/m)	Total weight (kg)	REMARK
						Bar length * No. of bars	$\frac{D^2}{162.28}$	Unit weight * Total length	
1	BB-1 Main bars		A (24mm)	8.972	6	53.832	3.549	191.049	S-500 MPa
2	BB-1 Negative bars		A (24mm)	2	2	4	3.549	14.196	S-500 MPa
3	BB-1 Stirrup		B (10mm)	$1.212m$	70	84.84	0.616	52.28	S-500 MPa
							TOTAL	257.525	
							Adding 2% wastage	262.675	

Observations and Learning Outcomes of my BBS work during the Internship

- I learned to interpret reinforcement drawings and translate them into actionable fabrication data.
- I gained proficiency in calculating bar lengths, weights, and understanding the logic behind lap zones and development lengths.

- I observed how BBS integrates with BOQ and payment certification, linking technical detailing with financial accountability.
- I contributed to the preparation of BBS for basement beams, columns, and shear walls, which were later verified by the consultant (ECO) and approved for execution.

2.3.2.9. Finishing Work on the Admin and Community Pharmacy Buildings

During my Internship-I at Shaggar One General Hospital Project, the finishing works of the Administration and Community Pharmacy buildings were actively progressing. The Administration building was undergoing internal partitioning, plastering, and roofing, while the Community Pharmacy building was focused on plastering and electrical conduit installation. Internal partitioning in the Admin building was executed using 15cm Hollow Concrete Blocks (HCB) laid in a stretcher bond pattern, while 20cm HCB was employed for the external walls of the building. This method is a standard practice for non-load-bearing walls due to its simplicity and structural reliability. To create the walls, a **mortar joint** was utilized to bind the HCB together. Construction site equipment (Trowels, Wooden Float, Spackle Knife, Water level or spirit level, etc.) was employed to level both the mortar and the blocks, ensuring the straightness and integrity of the building. The plastering process began with the erection of wooden **scaffolding** from the ground level of the admin building (G+2) up to the roof level, carefully braced for safety and stability. Workers prepared the surfaces of columns and beams by making them irregular using hammers and steel rulers to enhance mortar adhesion, which aligns with best practices in surface preparation. Mortar was mixed on-site using sand, cement, and water, following the specified mix ratio. Before application of the mortar (First coat (*Bereragirf*), Second coat and coats for smoothening the wall) the surfaces were wetted to prevent rapid moisture absorption, and timber battens were fixed at building corners and at door/window jambs to control straightness and thickness. Curing was performed diligently for seven days, both morning and evening, which is essential for preventing shrinkage cracks and ensuring durability. I observed that the sand used for plastering was stored outdoors, and the HCB blocks were stored partially in open space and partially indoors. This practice exposes materials to environmental moisture, which can compromise their quality and performance; ideally, such materials should be stored in dry, covered areas.

For the roofing of the Admin building, metal trusses fabricated off-site were lifted using a crane and installed by welding and bolting them to bars extended from the columns through the roof-level beams, and bolted with the purlins used to lay the roof cover. The trusses, purlins, and all the metals were polished by chemicals to prevent them from rusting. This method is structurally sound and commonly used in medium-scale construction projects. The Community Pharmacy building followed a similar approach for plastering and roofing. An additional architectural feature I observed was the construction of decorative structures made of HCB, extending approximately 70cm above the top tie beam, which were then plastered to enhance the building's visual appeal. Furthermore, the electrical conduit system was concealed within the ceiling of the building, installed according to the electrical drawings and specifications. Concealed conduit systems are preferred for safety and aesthetics, provided they adhere to local electrical codes.

Figure 2.44 Finishing Work of Administration and Pharmacy Buildings.

Before importing, the HCBs were verified to meet ES 1377 compressive strength requirements, and plaster mix proportions were executed in accordance with EN 998-1 specifications. Scaffolding erection and inspection followed BS EN 12811 and BS 5975 guidelines to ensure structural stability and worker safety, while surface roughening of columns and beams complied with ES 1785-1 protocols to optimize mortar adhesion. Curing cycles adhered to EN 13670 recommendations, and metal truss welding was qualified under ISO 15614-1 welding procedures. Concealed electrical conduits were installed per ES 358 and IEC 60364 regulations, and sand and block storage was moved to covered, ventilated sheds in line with ES 1758 to prevent moisture ingress. Overall, the finishing works demonstrated a combination of practical execution and attention to detail, although certain material storage practices could be improved to align with civil engineering standards. This experience provided valuable insights into site-level construction processes and highlighted the importance of adhering to technical specifications and best practices in building finishing works [58].

2.3.2.10. Groundwater Exploration and Provision of Water for the Project

Groundwater extraction for the Shaggar One General Hospital project was executed at the contractor's expense by Gutema Firisa Construction PLC in joint venture with MCG Construction PLC, who elected to develop an on-site supply to optimize costs rather than procure water from an external supplier. This part of the work is not in the contract agreement. Site selection began with a hydrogeological survey to identify favorable aquifer zones beneath the site; the optimum location was selected at the southwest corner of the site. A tractor-mounted rotary drilling rig, supported by a diesel generator for drilling power, was mobilized, and a deep borehole was advanced through variable soil and rock strata to the water table. The reliable aquifer was encountered at approximately **150 m** depth.

During drilling, steel casing was installed to stabilize the borehole and prevent contamination. A gravel pack and well screen were placed at the aquifer interval to facilitate efficient inflow while filtering out particulates. After drilling, a submersible pump and associated extraction piping were installed and connected to a surface storage tank to supply construction activities. Water quality testing was undertaken to assess potability in accordance with applicable standards before distribution. The contractor indicated that, subject to a formal agreement with the client, the well could be retained and transferred for long-term supply to the hospital and potentially to the surrounding community; otherwise, the well would be decommissioned and surface works reinstated at project completion.

This groundwater development exercise reinforced my practical understanding of hydrogeological investigation, well construction, and on-site water supply systems, topics that align closely with my coursework and provided a potentially significant resource for the hospital and local residents, who currently experience intermittent piped water service. The work was therefore critical to supporting the project's construction needs and the hospital's operational readiness and long-term sustainability.

General procedures of the groundwater exploration are [59]:

01. Integrated hydrogeological & geophysical investigation of the proposed site.
02. Choice of open well or bore well. A bore well was selected for this project.
03. Design the well (i.e., diameter of the well & casing, screen length, shape & percentage open area, etc.) depending upon topography, geological conditions of the underlying strata, depth to water table, rainfall, climate, and the quantity of water required
04. Drilling, construction & development phase of the project.
05. Design and the execution of water supply systems (powered by a pump) and their maintenance are an integral part of the scheme of exploration and management.

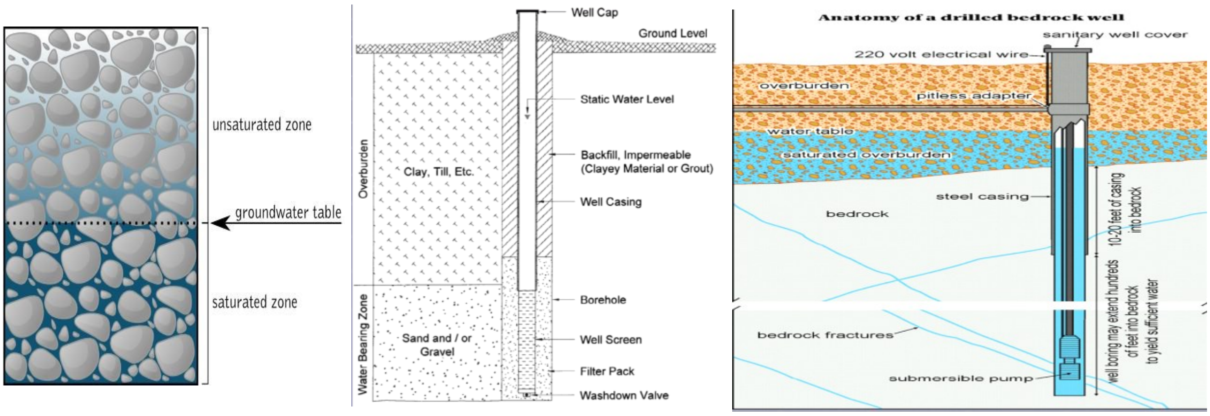


Figure 2.45 Groundwater Zones and Borehole Pipe Installation.

Aquifer Properties Relevant to Borehole Extraction checked for the project are [60]:

- Porosity (n): determines total groundwater storage capacity
- Specific yield (S_y): volume of water releasable by gravity, guides sustainable yield estimation
- Specific retention (S_r): water retained in pore spaces, influences residual moisture after pumping
- Coefficient of permeability (K): hydraulic conductivity, governs inflow rate into the borehole
- Transmissivity (T): K integrated over aquifer thickness, estimates maximum continuous discharge
- Storage coefficient (S): volume change per unit head change, critical for drawdown and recovery analysis

Subject to a formal agreement by the client to reimburse the contractor for well retention, pump installation, and associated equipment and operating costs (works not included in the original contract), the borehole could be transferred for long-term use. In my view, the client should formalize such an arrangement to secure a dependable water supply for hospital operations and, where feasible, extend benefits to the surrounding community. This would address the issues of local water supply intermittency and provide special advantages for the community resulting from the hospital project. In the context of Shaggar One General Hospital, the installation of a borehole water supply system was essential to complement the existing urban piped water network and ensure a reliable and uninterrupted source of water for hospital operations. As a dual major BSc degree student in Civil Engineering and Water Resources Engineering at ASTU, this experience was particularly significant because it directly related to the core principles of water resources engineering and hydraulics (i.e., my Ground Water Engineering (WREN4205) course). Where groundwater exploration is governed by Darcy's Law (valid for laminar flows only), which describes the movement of water through porous media, expressed as [61]:

$$Q = -KA\frac{\Delta h}{\Delta L}$$

$$K = K_i K_w$$

$$K_i = C * (d_m)^2$$

$$K_w = \frac{\gamma}{\mu} = \frac{\rho_w g}{\mu} = \frac{g}{\upsilon}$$

$$\upsilon = \frac{\mu}{\rho_w}$$

$$K = \frac{C * (d_m)^2 g}{\upsilon}$$

Or K is given by Kozeny-Carman's formula as follows:

$$K = \frac{\rho_w g}{\mu} * \frac{n^3}{(1-n)^2}\left[\frac{(d_m)^2}{180}\right]$$

Where:

- Q = volumetric flow rate (m^3/s)
- A = cross-sectional area perpendicular to the direction of flow (m^2)
- K = hydraulic conductivity of the aquifer, is the proportionality constant reflecting the ease with which water flows through a material (m/s)
- K_i = Intrinsic permeability depending on soil mass rock properties (such as grain size & packing)
- K_w = Permeability depending on fluid properties (such as density and viscosity of water)
- μ = Dynamic viscosity of the fluid $(N \cdot s/m^2 = kg/m \cdot s)$
- υ = kinematic viscosity = f (temperature) (m^2/s)
- ρ_w = Density of the fluid (water) (kg/m^3)
- γ = Unit weight of the fluid (kg/m^2s^2) or N/m^3
- g = acceleration due to gravity (m/s^2)
- d_m =Mean pore size of the porous medium (m)
- C = a shape factor which depends on the porosity, packing, shape of grains, and grain-size distribution of the porous medium
- n = porosity, is the ratio of volume of the open space in the rock or soil to the total volume of soil or rock,

$$\boldsymbol{h_l = \frac{fLV^2}{2gD}}$$

$$f = F\left(R_N, \frac{e}{D}\right)$$

$$R_N = \frac{\rho VD}{\mu} = \frac{VD}{\upsilon}$$

$$f = F\left(\frac{VD}{\upsilon}, \frac{e}{D}\right)$$

which is a measure of water holding capacity of the geological formation.

- Δh = difference in hydraulic head between two measuring points, $h_2 - h_1$, where h_2 is head at a location beyond the location of h_1 in the direction of flow (m)
- ΔL = length along flow path between locations where hydraulic heads are measured (m)
- $\frac{\Delta h}{\Delta L} = I$ = gradient of hydraulic head (dimensionless)

By nature, the earth is created by geological activity, which creates soil mass as a layer of stratum downward due to age variation and composition. When groundwater moves through each layer to the borehole well, the water faces vertical resistance due to the vertical stratifications of the soil and horizontal resistance due to horizontal stratifications to move through each layer. Therefore, we need to calculate the horizontal coefficient of permeability and the vertical coefficient of permeability. By using the Continuity equation, head loss in each layer, and flow area to calculate $K_{effective}$ for both the horizontal and vertical stratifications separately, as per Darcy's law in analogy with series-and-parallel combination rules used in electrical circuit analysis. For both combinations, the final formula is given as:

$$K_{x,(eq)} = \frac{1}{H_o}(z_1K_{x1} + z_2K_{x2} + \cdots + z_nK_{xn})$$

$$K_{z,(eq)} = \frac{H_o}{z_1/K_{z1} + z_2/K_{z2} + \cdots + z_n/K_{n1}}$$

Where $K_{x,(eq)}$ is equivalent hydraulic conductivity in the horizontal (x) direction, $K_{z,(eq)}$ is equivalent hydraulic conductivity in the Vertical (z) direction, H_o is the total thickness of the soil mass, z_1 *to* z_n are the thicknesses of the first to the n^{th} layer, K_{x1} *to* K_{xn} are the horizontal hydraulic conductivities of the first to the n^{th} layer, and K_{z1} *to* K_{zn} are the vertical hydraulic conductivities of the first to the n^{th} layer [62].

The engineers have made investigations that typically include hydrogeological surveys, aquifer testing, and pumping tests to evaluate the sustainable yield and quality of the groundwater. In distributing water to the hospital buildings construction work, the piping network was engineered to minimize hydraulic losses in accordance with the Darcy-Weisbach equation

$\left(h_l = \frac{fLV^2}{2gD}\right)$ and optimized to deliver the required flow within the pump's available power [63]. The practical application of these principles in a real project environment emphasized the importance of integrating engineering theory with fieldwork to design reliable and sustainable water supply systems. This work not only strengthened my technical knowledge but also highlighted the critical role of groundwater in supporting vital facilities such as construction work and hospitals, where water availability is directly linked to public health and operational efficiency.

Figure 2.46 Drilling operation of a borehole to access underground water for the Project.

2.3.2.11. Asphalt Road Construction and Leveling Work of the Project

During my internship at the Shaggar One General Hospital project, I had the opportunity to closely follow the construction of the internal and external access roads, which represent an essential part of the hospital's overall infrastructure. The roadwork was valued at **ETB 162,325,591.59,** covering both asphalt-paved two-lane carriageways and cobblestone pedestrian walkways. While the asphalt roads were designed primarily to accommodate vehicular traffic and ensure smooth access for ambulances and service vehicles, cobblestone sections were integrated into the design for aesthetic enhancement and pedestrian circulation, reflecting the client's architectural and urban design requirements.

The construction followed a staged pavement process in accordance with AASHTO and ERA (Ethiopian Roads Authority) standards [30], [19]. Work began with site clearance, grubbing, and excavation, where unsuitable and expansive soils were cut and hauled off-site to reach a stable subgrade capable of supporting long-term pavement loads. Subgrade preparation was critical, requiring the removal of weak soil layers and replacement with engineered fill. The subgrade was then compacted using high-capacity rollers (**10-16 tons** per project drawing) to achieve the specified density, which is fundamental to preventing rutting and future undulations. Accurate leveling and alignment were ensured using theodolite and total station instruments, providing both horizontal curves and vertical profiles strictly in accordance with the geometric design principles established for the project.

Pavement Structure and Layering

The design of the hospital's road section adheres to contemporary Ethiopian and international standards for pavement engineering. According to the architectural drawings and technical specifications provided, the road cross-section consists of **flexible pavement layers** [64]:

- **Sub-base Layer:** 400 mm thick, composed of imported crushed stone where imported to the site via Sino trucks, compacted to a California Bearing Ratio (CBR) of 30. This provides foundational support, stability, and moisture resistance.
- **Base Course:** 150 mm thick, placed over the sub-base, with a high CBR of 80 and made from select aggregate to ensure load distribution.
- **Asphalt Surface:** A triple surface treatment, 30 mm thick, applied as the final wear layer, designed for weather resistance, skid reduction, and longevity. Quality of the asphalt involves bitumen content, aggregate gradation, and thickness; each is critical for attaining desired pavement performance.

The vertical layering of the road can be expressed as:

$$Total\ thickness = t_{sub-base} + t_{base} + t_{asphalt}$$

Where: $t_{sub-base} = 400mm,\ t_{base} = 150mm,\ t_{asphalt} = 30mm$

Proper layer compaction and sequential placement according to standards such as AASHTO and Ethiopian Road Authority requirements mitigate the risk of settlement and premature structural failure. Throughout all the layers of the road work, compaction quality was verified through the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) relationship derived from the Proctor Test [30]:

$$\gamma_d = \frac{W_s}{V_t}$$

$$\%\ Compaction = \frac{\gamma_{d(field)}}{\gamma_{d(Max)}} * 100$$

Where:

- γ_d = is the dry density
- W_s = is the weight of solids
- V_t = is the total volume

A minimum of 95% of MDD was required to satisfy the specification.

The CBR method was used in pavement design to ensure that the structural layers could adequately distribute wheel loads without exceeding the soil's bearing capacity. The CBR value directly influences the pavement thickness as follows [30]:

$$CBR\ (\%) = 100\left(\frac{x}{y}\right)$$

$$t = k * \left(\frac{P}{CBR}\right)^{0.5}$$

Where:

- t = thickness of pavement layer
- x = Unit load (pressure) on the piston for a penetration
- y = Standard unit load (pressure) for well-graded crushed stone
- k = design constant determined from empirical charts.
- P = wheel load

To ensure proper geometric alignment, the road centerlines and curves were set out using a theodolite and total station. Maintaining both horizontal alignment (curvature, super-elevation) and vertical alignment (gradients, cross-slopes) was essential for safety and functionality. The cross-section drawings specified a **2.5% cross fall (Normal Crown)** on both sides of the carriageway to facilitate surface drainage, reducing the risk of water stagnation and pavement deterioration. The alignment was verified using the theodolite, ensuring compliance with the design radius, sight distance, and super-elevation requirements. These parameters are governed by the following geometric design equations [65]:

$$R_{min} = \frac{(v_d)^2}{g * (e + f_s)}$$

$$e + f_s = \frac{(v_d)^2}{gR}$$

$$e = \tan \emptyset = \frac{\Delta h}{\omega}$$

Where:

- R_{min} = Minimum horizontal Curve Radius (m)
- SSD = Stopping Sight Distance
- v = design speed in **m/s,** which depends on topography/terrain type, Mid-life design traffic flow (AADT)**,** Roads functional classification, Horizontal and Vertical Curves and etc.
- e = Super-elevation (%) for horizontal curve centrifugal force balancing, Δh = height rise, ω is road Width

$$SSD = vt + \frac{(v_d)^2}{2g(f_l \pm \frac{G}{100})}$$

- t = perception-reaction time (typically 2.5s per ERA)
- f_s= side friction factor & f_l= Longitudinal Coefficient of friction
- g = gravitational acceleration (9.81 m/s²)
- G = grade in **%**

For road safety and durability, Curbstone installation was performed using both pre-fabricated and in-situ cast methods. Curbs demarcate roadway boundaries, aid stormwater control, and visually enhance the connection between vehicular and pedestrian zones. The architectural drawings detail 40x12 cm C-20 concrete curbstones with 320 kg/m³ density, installed at both carriageway edges and at specified intervals for drainage openings (every 5m as per the detail drawing). At each phase, construction operations were validated by supervision teams. Field density tests, thickness checks, and material sampling ensured compliance with design CBR, layer thickness, and bitumen specifications. This aligns with professional civil engineering discoveries that attribute pavement failure predominantly to poor subgrade preparation and insufficient field compaction, confirming the criticality of rigorous control adopted on-site.

Figure 2.47 Expansive Soil Removal and Asphalt Road Layering of the project.

From an engineering perspective, this work highlighted the importance of accurate surveying works (leveling using level and theodolite, etc.) and compaction control in pavement construction. The sight distance and curve radii were carefully developed to conform to geometric design standards (ERA 2013), ensuring visibility and smooth flow within the hospital premises and toward the connecting village roads. Overall, the road construction and leveling works for Shaggar One General Hospital demonstrate integration of classical civil engineering methods, Ethiopian specification compliance, and modern pavement technology. Structurally, the equation for vertical stress in pavement under load is given by the Boussinesq formula [66]:

$$\sigma_z = \frac{3Q}{2\pi r^2}\left[\frac{h^3}{(r^2 + h^2)^{5/2}}\right]$$

Where:

- σ_z = is vertical stress at depth h
- Q = is the applied load
- h = depth
- r = is radial distance

Depending on the design stress developed using ultimate vehicle loads that may be applied on this road, the material and thickness of each layer of the pavement were finalized as part of the final design of the road. The design and construction process consistently referenced such engineering fundamentals, ensuring the hospital's accessibility roads are robust, durable, and in harmony with both environmental and architectural requirements.

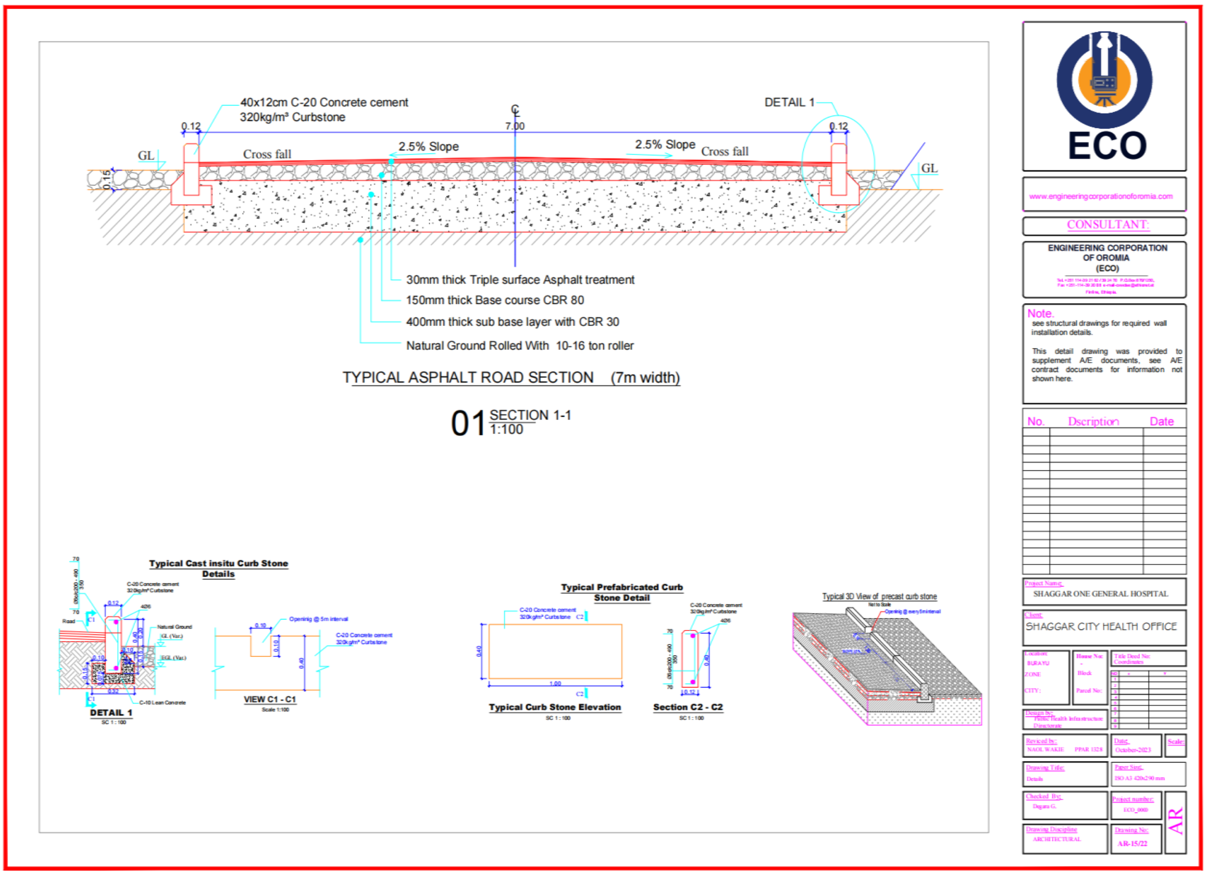


Figure 2.48 Asphalt Road Architectural Design [64].

In summary, my involvement in this road work phase reinforced critical civil engineering principles:

a) The relationship between soil mechanics and pavement stability

b) The importance of layered system design in asphalt pavements

c) The role of architectural considerations in integrating cobblestone walkways and curbstone details to achieve both functional and aesthetic outcomes.

2.3.2.12. Materials Stacking and Storage of the Project

Material storage and stacking are placed under site work because they mainly involve field operations such as handling materials, arranging stockpiles, ensuring quality preservation, and applying safety measures on site. Although there is also an administrative side, like record-keeping, authorization, and cost allocation, these activities are still part of site management rather than general office work. In civil engineering practice, proper material storage and stacking are fundamental to ensuring quality, durability, and compliance with engineering specifications and codes. During my internship-I at the Shaggar One General Hospital project, executed by Gutema Firisa Construction PLC JV with MCG Construction PLC, I observed how the site team managed both bulk and sensitive construction materials in alignment with recognized engineering protocols. In general, the system was well-organized and adhered to best practices, though, as in most projects, environmental exposure presented challenges that required close supervision, and certain improvements could further enhance efficiency and protection for this site.

Large-scale materials such as reinforcement bars, sand, coarse aggregates, hollow concrete blocks (HCBs), and heavy equipment (batching plants, tractors, and pipelines for groundwater exploration) were stored outdoors in designated zones. While this approach is practical due to the volume of materials and space constraints, it introduces risks such as corrosion of reinforcement bars, aggregate contamination, and block saturation. According to ACI 318 and the Ethiopian Building Code Standards (EBCS), reinforcement bars must be free from oil, mud, or loose rust before use, as these conditions reduce bond strength with concrete [42]. Aggregates, when exposed to rainfall, may absorb excess water, affecting the water-cement ratio in concrete mixes. To mitigate this, stockpiles were compacted, sloped for drainage, and frequently inspected to control moisture content and segregation.

More sensitive materials, particularly 32.5N grade cement (Dangote Pozzolanic Portland Cement (PPC)), were stored under well-prepared shelters. The shelters were constructed with corrugated metal sheets (*qorqorroo*) and wood platforms raised above ground level to prevent contact with soil moisture. The cement bags were also covered with plastic sheets to reduce humidity exposure, in line with ASTM C150 recommendations. Timber materials used for formwork were housed in closed sheds, protecting them from warping, fungal growth, and dimensional instability caused by exposure to varying temperatures. Similarly, metal sheets (*lamera*) used for roofing trusses were stacked flat under shelters to avoid bending and deformation.

In terms of hazardous and flammable materials, fuels, and lubricants for heavy machinery were stored separately in a dedicated fuel storage facility. This facility was ventilated, isolated from other storage areas, and managed with fire safety protocols in mind. Such segregation aligns with occupational safety standards and reduces risks of contamination of construction materials or accidents on site.

The site also incorporated overhead facilities as part of the contractor's indirect costs (site overheads), which are recognized under FIDIC Red Book guidelines as reimbursable but separate from direct construction activities [23]. These overheads included temporary offices for both the consultant team (ECO's Resident Engineer, Assistant Resident Engineer, and Quantity Surveying Engineer) and the contractor's engineering staff, as well as first aid stations, meeting rooms, a cafeteria, labor shelters, and dedicated storage houses. All of these structures were constructed using prefabricated corrugated steel sheets for durability and quick installation. Inside the offices, engineers were provided with desktops and laptops, allowing real-time monitoring of construction progress, preparation of payment certificates, and coordination of correspondence.

From an international perspective, the project's material management practices resonate with the ISO 9001:2015 Quality Management System (QMS) [67], which emphasizes risk-based thinking, documentation, and continual improvement. Proper material stacking and storage directly support two of ISO's core principles: "control of externally provided processes, products, and services" and "preservation of product conformity." By ensuring that cement is dry, aggregates are clean, and reinforcement is corrosion-free, the contractor not only adheres to Ethiopian standards but also aligns with global quality benchmarks [67].

On this project, all materials, whether stored in designated shelters or outdoor stockpiles, were systematically managed by two site material monitors, both female personnel assigned to oversee the storage and distribution process. Their role was critical in ensuring that materials complied with contractual and engineering requirements. Before any material could be imported to the site, released for use, or exported/disposed of, the material monitors' required formal written authorization, stamped and signed by the Contractor's Construction Manager Directorate. This authorization acted as a form of material gate pass, ensuring accountability at every stage of material handling.

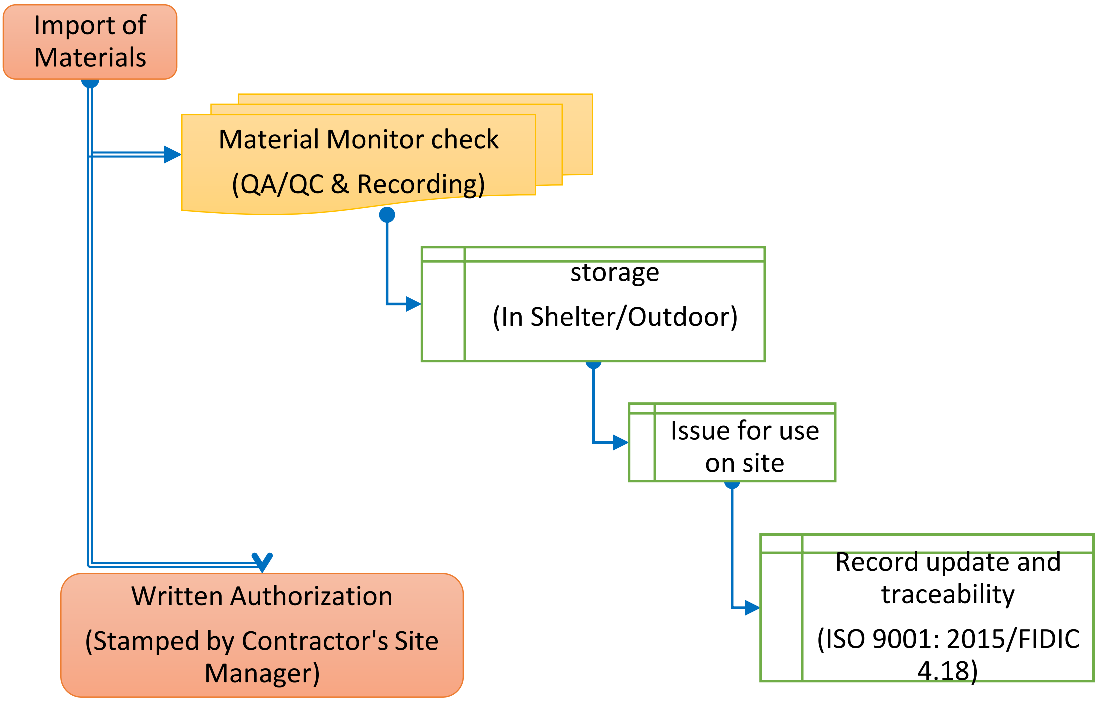
For each transaction, the material monitors recorded details such as material type, quantity, source, and intended usage. This practice aligns with FIDIC Red Book [23] (1999, Clause 4.18 - Protection of the Environment and Material Storage), which requires contractors to keep accurate records of materials and ensure they are properly stored, preserved, and used in accordance with the specifications. It also reflects the principles of ISO 9001:2015 (Quality Management Systems) [67], particularly the clauses on "Control of Documented Information" (Clause 7.5) and "Control of Externally Provided Products and Services" (Clause 8.4). By demanding written approvals and maintaining stamped records, the project established a traceable chain of custody, preventing material misuse, unauthorized disposal, or quality compromise.

From a civil engineering materials management perspective, this system safeguards the project against:

- Material wastage (by tracking quantities before and after use),
- Quality deterioration (by ensuring timely use of cement, aggregates, and steel),
- Financial disputes (by keeping a verified log for auditing and payment certificates), and
- Safety risks (by controlling hazardous materials such as fuels and lubricants through proper authorization).

Furthermore, such structured control supports Ethiopian Roads Authority (ERA) specifications and EBCS construction management requirements, which emphasize proper site record-keeping, stock supervision, and compliance with contract documents. In larger international projects, this system is often referred to as a Materials Management Plan (MMP), which integrates storage, inspection, and release protocols as part of the overall Construction Quality Assurance (CQA) framework [42].

Table 2.25 Material flow and Control system of the project.



By observing this workflow, I realized that material storage is not just about physical protection but also about administrative control, documentation, and accountability. The involvement of dedicated monitors and stamped authorizations provided a transparent and professional mechanism for ensuring that every material, from reinforcement bars to fuel, was properly accounted for, safeguarded, and utilized according to the contract and engineering standards.

Figure 2.49 Material Storage and Stalking on the site.

In summary, the material stacking and storage practices at the Shaggar One General Hospital project demonstrate a balanced application of local codes (EBCS, ERA) and international standards (ACI, ASTM, FIDIC, ISO 9001:2015). This hybrid approach ensures that construction quality is preserved, wastage is minimized, and safety is maintained. My observations confirmed that effective material storage is not only a matter of logistics but also a cornerstone of engineering quality control and project sustainability [23].

2.3.3. Laboratory Test Experiences

2.3.3.1. Cube Compressive Strength Test of Concrete

As part of my quality control and laboratory test experiences at Shaggar One General Hospital Project, I discovered a variety of different material tests, both on-site and at an external laboratory with different firms. During the concrete placement of the basement Beam, columns, and for all concrete work of the project, both the concrete casting company engineer and the site consultant, Assistant Resident Engineer (Eyuel), independently conducted cube tests to verify compliance with the specified designed concrete grade for each structural part of the buildings. The test specimens were standard cubes measuring $150mm \times 150mm \times 150mm$, and the test was conducted both on the seventh day and on the 28^{th} day, where for each test, they had cast and prepared a different cube. Concrete was poured into the molds in three layers, with each layer compacted using a metal rod to eliminate air voids and ensure uniform density. After filling, the surface was leveled and finished properly.

The cubes were then submerged in water for curing, following standard procedures outlined in ASTM C192 and BS EN 12390-2. On the 7^{th} day, compressive strength testing was performed, as early-age strength typically reaches 65%-70% of the design strength. The cubes were removed from the curing tank and placed in a compression testing machine, which calculates strength using the formula [33]:

$$f_c = \frac{P}{A}$$

Where:

- f_c = compressive strength (MPa or N/mm^2)
- P = applied load (N)
- A = cross − sectional area of the cube (mm^2)

The compressive strength tests for the concretes poured for each work were conducted both at the concrete mixing plant (Dugda Construction PLC, i.e., Slump test, Cube strength test…) and off-site by the consultant engineers at **Ethiopian Engineering Corporation** for sample cube compressive strength tests, which I attached under Appendix-B. The results showed that the concrete achieved approximately 65% of its design strength (i.e., 29.25 MPa), which is acceptable for 7-day testing. According to ACI 318 and Eurocode 2, full design strength is typically verified at 28-days, and the concrete is expected to meet or exceed its target design compressive strength at that time [41].

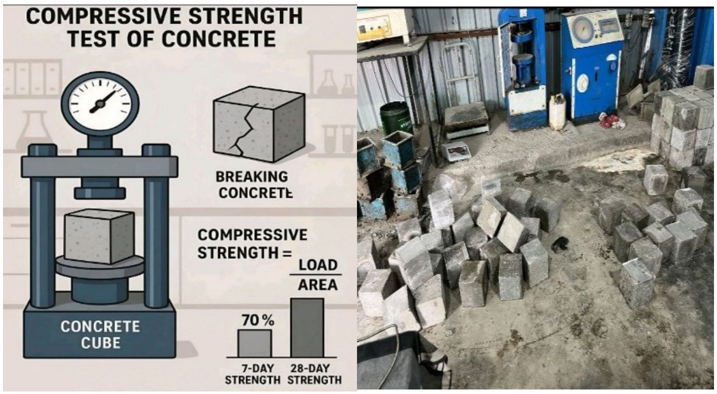


Figure 2.50 Concrete Cube Strength Test.

2.3.3.2. Tensile Strength Test of Reinforcement Bars

The tensile strength test for reinforcement bars (rebar) is a controlled uniaxial test used to determine key mechanical properties of reinforcing steel: yield strength, ultimate tensile strength, elongation (ductility), and reduction of area. These properties verify whether supplied bars meet the product specification and code requirements, and they are essential for structural design checks (bond, anchorage, ductility, and seismic performance). Testing is performed on representative specimens using a calibrated universal testing machine and, when required, an extensometer to measure extension over a defined gauge length. Routine test procedures and reporting requirements for rebar are given in internationally accepted standards (ISO 15630-1, ASTM A370 / A615, and related metal tensile standards) [33].

As part of specimen preparation and instrumentation used to test the tensile strength of bars, the straight length of the bar is cut for testing; the effective gauge length (the length over which extension is measured) must be recorded. For routine rebar tensile tests, many standards require a gauge length of at least 100-200 mm (commonly 100 mm for routine ISO tests or $\approx 200\,mm$ / 8 in per ASTM A370 guidance when full-length extensometers are used); extensometers should meet the accuracy classes referenced in the standard (ISO 9513 / ASTM references). Grip selection (wedge, serrated, or threaded) and alignment are important to avoid premature failure at the grips. Test rate, temperature, and specimen condition must follow the chosen standard's procedure.

Procedures for tensile test of bars:

i. Cut and mark specimens and measure original cross-section A_o and gauge length L_o(note original gauge length used).
ii. Mount the specimen centrally in the universal testing machine with correct grips and align the extensometer if used.
iii. Apply axial load at the standard loading rate; continuously record load and extension until fracture.
iv. Determine f_y (yield) by observed drop/offset method, $f_u = \frac{Maximum\ Load}{A_o}$, total elongation, and reduction of area.
v. Report the full stress-strain curve, the numerical results, and any nonconformance to the rebar specification. (Follow ISO 15630-1/ASTM A370/the product spec.)

Results are reported as follows (key quantities):

- Engineering stress, $\boldsymbol{\sigma}$ ($\boldsymbol{MPa\ or\ N/mm^2}$) $= \boldsymbol{\sigma} = \frac{\boldsymbol{P}}{\boldsymbol{A_o}}$
- Engineering strain, $\boldsymbol{\varepsilon}$ $\left(\boldsymbol{unitless\ or \frac{mm}{mm}}\right) = \boldsymbol{\varepsilon} = \frac{\boldsymbol{\Delta L}}{\boldsymbol{L_o}} = \frac{\boldsymbol{L_f - L_o}}{\boldsymbol{L_o}}$
- Young's modulus, $\boldsymbol{E} = \frac{\boldsymbol{\sigma}}{\boldsymbol{\varepsilon}}$
- Yield strength, $f_y = (or\ R_p 0.2$ for 0.2% offset method) stress at which permanent plastic deformation begins.
- Ultimate tensile strength, $f_{u,}$ is the maximum engineering stress attained.
- Total elongation at fracture (%) = $\frac{\Delta L}{L_o} * 100\%$
- Reduction of area (%) = $\frac{A_o - A_f}{A_o} * 100\%$. Where A_f is the minimum fractured cross-section.

Stress-Strain Curve: five major regions [68]**:**

- **Elastic region (linear portion) (point 1-2):** In the elastic region, stress and strain are proportional (Hooke's law). If the load is removed in this zone, the bar returns to its original length. The slope is Young's modulus E (typical steel: $\approx 200\ GPa$). This region defines material stiffness.
- **Yield point/Yield plateau (onset of plasticity) (point-2):** The yield point marks the end of essentially linear behavior and the beginning of permanent (plastic) deformation.

For many modern deformed bars, the yield is determined using an offset method (commonly 0.2% plastic strain) in accordance with the test standard. The yield strength (f_y) is a primary design parameter for reinforcement (point-3).

- **Strain-hardening (plastic zone):** After yield, the steel may carry increased loads as dislocation mechanisms and microstructure changes, because additional stress capacity until the maximum (ultimate) stress is reached. This strain-hardening region governs the energy-absorption capacity and post-yield stiffness of the bar.
- **Necking (localized reduction) and softening:** Past the ultimate tensile stress, the specimen starts to localize deformation (necking); engineering stress falls while true stress at the neck may still increase until fracture. Necking indicates imminent failure and shows the limit of uniform plastic deformation.
- **Fracture (break) (point-5):** Final rupture occurs at the weakest cross-section. The fractured surface and reduction of area are recorded; ductile fracture with significant elongation is desirable for seismic/damage-tolerant reinforcement.

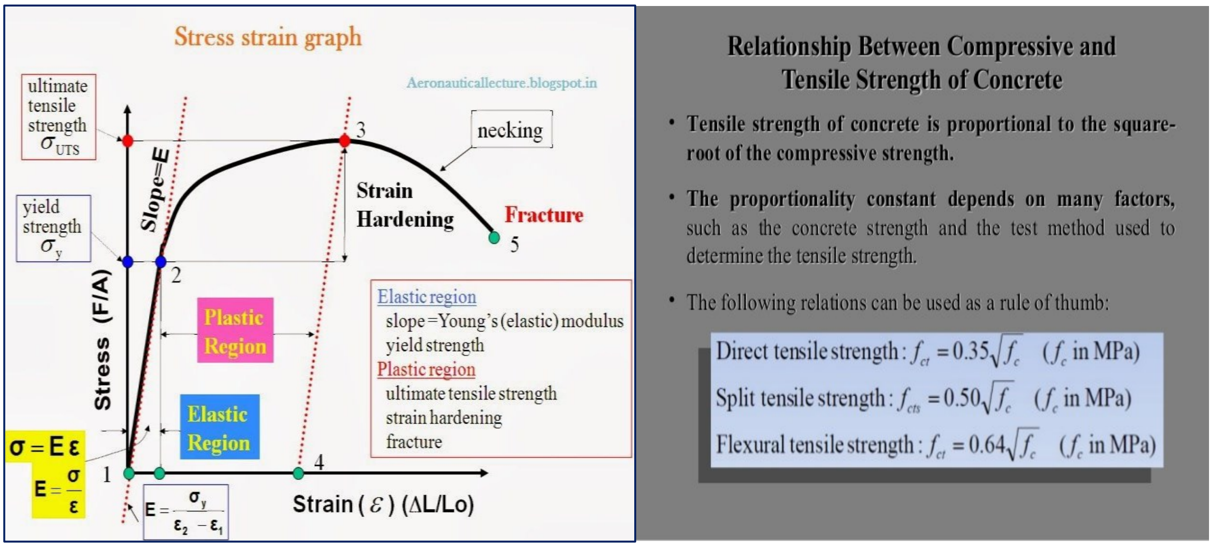


Figure 2.51 Typical engineering stress–strain curve for a reinforcing bar and tensile strength of concrete

Concrete is weak in tension; designers therefore rely on reinforcing steel to carry tensile forces. Common lab tensile checks for concrete include the splitting (Brazilian) test and the flexural (modulus of rupture) test:

01. **Splitting tensile strength (cylindrical specimen):** For a cylinder of length **L** and diameter **D** loaded through two diametrically opposite lines, the splitting tensile stress at failure is calculated as: $\boldsymbol{f_{ct,sp} = \frac{2P}{\pi DL}}$, Where P is the maximum applied load. This is the standard formula used in ASTM C496 style splitting tests.

02. **Empirical mean tensile strength (Eurocode approach):** Eurocode 2 provides expression(s) for the mean tensile strength f_{ctm} as a function of concrete strength f_{ck} (for normal strength classes typically $\boldsymbol{f_{ctm}} \approx \mathbf{0.3}^* \boldsymbol{f_{ck}}^{2/3}\ in\ MPa$). These relationships are used to estimate cracking loads and check serviceability [40].

Reinforcing bars must yield and develop sufficient ductility (elongation) before concrete cracks propagate catastrophically; ductile steel permits plastic redistribution and warning before collapse. **In this hospital project**, verifying the delivered bars' yield, ultimate strength, and elongation ensures adequate ductility, correct lap lengths, and reliable behavior under service and seismic loads, reducing the risk of brittle failure in structural elements. Results from the tensile testing program confirmed that the reinforcement met the specified minimum yield and ductility requirements (see Appendix-B for the sample tensile test of $\phi 14mm$ done at **Ethiopian Conformity Assessment Enterprise** test report), ensuring that reinforcement used on the Shaggar One General Hospital will provide the required bond, ductility, and seismic performance expected by the design codes.

2.3.3.3. Laboratory Tests for Hollow Cement Blocks (HCB)

Hollow cement blocks used on the Shaggar One General Hospital project were checked by routine unit tests to confirm dimensional tolerance, unit weight, water absorption, and compressive strength. The primary control is the block crushing (compressive strength) test carried out on representative units in an accredited laboratory; complementary checks for water absorption and surface defects ensure durability and proper bond with mortar. Typical industry practice in Ethiopia accepts HCB compressive strengths in the approximate range of 3-10 MPa, depending on whether the unit is intended for non-loadbearing or loadbearing use, with loadbearing units commonly specified at or above 5 MPa; the contract documents and national guidance (EBCS / BaTCoDA referenced in the tender) determine the final acceptance limit.

2.3.3.4. Laboratory Tests for Backfill Material

Backfill materials for the Shaggar One General Hospital project underwent a series of trial tests and standard geotechnical laboratory evaluations before and during placement. Key tests included particle size distribution (sieve analysis), Atterberg limits for fine materials, Proctor compaction tests to establish Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), as well as in-situ density and moisture verification during compaction operations. These tests are essential to ensure that the backfill meets requirements for stiffness and bearing capacity, limits post-construction settlement, and provides proper drainage beneath slabs and pavements. The target for compaction control adhered to standard practices, typically aiming for at least 95% of the MDD, with field moisture content maintained close to the OMC within a ±2% range. Any materials that failed to meet these criteria were either reworked or replaced to ensure optimal performance [30].

During Chapters One and Two, I introduced the project stakeholders (Engineering Corporation of Oromia as the consultant; Gutema Firisa-MCG JV as the contractor; and Shaggar City as the client), summarized the project scope and contract delivery system, and documented my three-month placement at the Shaggar One General Hospital site. I actively participated in office and site activities, including contract administration, quantity take-offs and cost estimation, design review and documentation control, setting-out, excavation and substructure reinforced concrete works, finishing and pavement operations, and routine laboratory testing (concrete cubes, reinforcement tensile tests, HCB checks, and compaction/Proctor control for backfill). The record in Chapter Two links these practical tasks to the design assumptions and quality control procedures required by the contract and national standards, and it includes the laboratory certificates and progress records used for acceptance. Chapter Three now examines the professional benefits gained from this experience: the technical skills, management and communication improvements, ethical and safety insights, challenges encountered with the corrective actions taken, and final lessons that shaped my readiness for professional practice.

CHAPTER THREE

PROFESSIONAL GROWTH AND LEARNING OUTCOMES

Internship programs play a vital role for students in bridging the gap between academic knowledge and the realities of professional practice. During my time at the Shaggar One General Hospital Project, I gained invaluable exposure to both on-site construction activities and office-based consulting tasks. This hands-on experience allowed me to translate theoretical concepts learned in the classroom into practical applications, while also developing essential professional skills such as communication, teamwork, and problem-solving. Beyond technical skills, the internship provided me with a deeper understanding of industry standards, work ethics, and the dynamic environment of the construction sector. This experience has significantly enhanced my confidence and equipped me with the skills required to take on future responsibilities, positioning me as a promising candidate for professional roles in Civil Engineering, Water Resources Engineering, and Environmental Management.

From the company's perspective, internship programs create a mutually beneficial relationship. While interns gain practical knowledge and professional growth, companies benefit from fresh perspectives, innovative ideas, and support in executing ongoing projects. In my case, I initially expected to focus primarily on technical learning. However, by the end of the internship, I realized that I had also acquired skills in leadership, project coordination, and professional networking. These benefits extended beyond personal growth to include meaningful contributions to the hosting company's operations, demonstrating the true value of a well-structured internship program.

3.1. Challenges Encountered and Mitigation Strategies Implemented

During my internship period at the Shaggar One General Hospital Project, I encountered a variety of challenges that tested my technical knowledge, problem-solving ability, and adaptability. These challenges arose from the complex and dynamic nature of a large-scale hospital construction project, which involved multiple stakeholders, strict quality and safety requirements, and difficult environmental conditions. Each challenge provided valuable learning opportunities, helping me develop as an engineer by applying theoretical knowledge to practical situations. The major challenges I faced and the mitigation strategies I applied are described below.

Table 3.1: Summary of Challenges Encountered and Mitigation Strategies Taken.

List No_;	Challenges I have faced:	Mitigation Strategies I have taken:
1) Adverse Weather Conditions	The internship took place during the rainy season (*Ganna*) in Oromia, when frequent and intense rainfall disrupted excavation, concrete curing, and material transportation. The rain often caused flooding in excavated areas, reduced soil bearing capacity, and delayed scheduled activities.	I used proper personal protective equipment (PPE) provided by the contractor, including waterproof clothing and a hard hat helmet, to ensure safety during wet conditions. To address work interruptions, I supported the team in implementing temporary drainage channels and using submersible pumps to remove accumulated water from excavated foundations. Additionally, I observed how concrete curing schedules were adjusted by using waterproof covers and accelerators to ensure proper strength development despite weather-related delays.
2) Poor Site Accessibility and Logistics	The access road to the construction site was still under development and consisted of a muddy two-lane carriageway. Heavy rain worsened the situation, creating unsafe and slippery conditions for vehicles and workers. This limited the efficient transportation of materials such as cement, rebar, and aggregates, leading to occasional delays in the construction schedule.	To adapt personally, I purchased BOGS Workman Composite Toe leather safety shoes, which allowed me to move safely around the site. At a broader level, I supported the contractor's efforts to create temporary gravel access routes and participated in material planning discussions to ensure that essential supplies were delivered during dry weather windows to avoid transportation bottlenecks.
3) Limited Supervisor Availability	At times, my immediate site supervisor was not readily available due to his numerous responsibilities across different project areas. This initially left me without direct guidance for certain tasks, causing uncertainty in decision-making and slowing down my learning process.	To address this, I proactively improved my communication and interpersonal skills, engaging with other engineers, subcontractors, and skilled workers on-site. By observing their work and asking targeted questions, I gained practical insights and built strong professional relationships. This sense of belonging to the team significantly boosted my confidence and accelerated my learning.
4) Complex and Diverse Project Designs	The Shaggar One General Hospital Project involved a wide range of structural, electrical, mechanical, and sanitary systems. Understanding and interpreting the diverse sets of drawings, especially for specialized hospital facilities such as operating theaters and diagnostic centers, was initially overwhelming.	I dedicated time to systematically study the drawings with the guidance of my academic advisor and the contractor's site engineer, Eng. Workine. By correlating drawings with actual on-site components, I developed the ability to visualize three-dimensional relationships between systems. I also learned to use AutoCAD and BIM-based tools to interpret layouts more efficiently, which significantly improved my technical proficiency.

5) Health, Safety, and Environmental (HSE) Concerns	Large construction sites like this hospital involve significant safety risks, including falling objects, electrical hazards, and working around heavy machinery. Additionally, improper waste disposal during construction posed environmental risks to nearby communities.	I strictly adhered to the site's HSE guidelines, wearing appropriate PPE at all times and participating in daily safety briefings. I also observed and reported unsafe practices to supervisors, contributing to a safer work environment. Furthermore, I supported efforts to implement environmentally friendly practices such as proper waste segregation and temporary sediment control measures to reduce runoff pollution.
6) Bridging the Gap Between Theory and Practice	One of the initial difficulties I faced was translating the theoretical knowledge I had gained at the university into practical application on-site. Concepts such as reinforced concrete design, soil mechanics, and project management appeared straightforward in the classroom but were more complex in the field due to site constraints, resource limitations, and coordination requirements. For instance, variations in soil strata during excavation affected foundation stability and required adjustments to design assumptions.	To overcome this, I actively engaged in site supervision and collaborated closely with experienced engineers and contractors. I reviewed structural drawings and specifications in detail, cross-checking them against actual site conditions. Whenever uncertainties arose, I raised Requests for Information (RFIs) to clarify design ambiguities and attended technical meetings to discuss solutions. This hands-on involvement enhanced my ability to interpret design documents and improved my engineering judgment.

Each of these challenges provided practical lessons that deepened my understanding of construction management, site safety, and engineering problem-solving. By facing and addressing these real-world obstacles, I developed resilience, adaptability, and a proactive approach, qualities essential for a professional engineer. This experience has strengthened my confidence and positioned me to contribute effectively to future civil and water resources engineering projects.

3.2. Enhancement of Professional and Interpersonal Skills

The three-month internship provided a valuable platform for developing both professional and interpersonal skills essential for a career in civil engineering. Beyond strengthening my technical abilities, this experience allowed me to grow in areas such as communication, leadership, teamwork, entrepreneurship, and problem-solving.

Through active participation in weekly coordination and progress meetings involving the client, consultant, and contractor, I significantly enhanced my communication and documentation skills. I learned to prepare and follow up on formal project correspondence, including Requests for Information (RFIs), submittals, and meeting minutes. This experience highlighted the importance of clarity, accountability, and precision in project documentation, which is vital for effective construction management. Additionally, observing the business aspects of construction, such as cost estimation, contract administration, and procurement, helped me appreciate the link between technical decisions and financial considerations. This fostered entrepreneurial thinking, preparing me to align engineering solutions with both client expectations and project budgets.

Through collaboration with professionals, including engineers, quantity surveyors, and site supervisors, I developed leadership qualities and teamwork skills. I witnessed how effective leaders motivate crews, enforce safety protocols, and ensure timely project delivery. This immersive experience gave me a practical understanding of professional ethics, conflict resolution, and multidisciplinary collaboration skills that are critical for future project leadership roles.

3.2.1. Technical Skills Gained

During the internship, I applied theoretical knowledge from my academic studies to real-life situations on the hospital construction site. Key technical skills I developed include:

- Applying engineering judgment in field decisions related to concrete works, reinforcement placement, and structural integrity.
- Understanding and implementing quality control measures such as slump tests and cube tests**,** following ASTM and EBCS standards.
- Improving proficiency in civil engineering software such as AutoCAD for drawing review and ETABS for structural analysis.
- Strengthen problem-solving and critical thinking by addressing technical challenges during reinforcement detailing, excavation, and formwork preparation.
- Efficiently managing resources and time to meet project deadlines and maintain workflow continuity.

This hands-on exposure bridged the gap between theory and practice, improving my competence in construction supervision and site engineering.

3.2.2. Management skills gained

Effective management plays a crucial role in construction projects. Throughout the internship, I observed how site managers and resident engineers coordinated labor, materials, and equipment to ensure smooth operations. From this experience, I learned key principles of leadership and management, including:

- Making sound and timely decisions to resolve site challenges.
- Keeping team members informed about project goals and daily activities.
- Assigning responsibilities clearly and ensuring proper supervision.
- Motivating and inspiring workers to achieve higher levels of performance.
- Maintaining ethical awareness and considering the broader impacts of engineering decisions.

By observing and assisting in these processes, I gained insight into managing diverse teams and complex tasks, which will be invaluable for my future career.

3.2.3. Knowledge Gained Through Communication

The internship significantly enhanced my interpersonal communication skills. Working with professionals and laborers from diverse cultural and educational backgrounds allowed me to practice respectful, clear, and effective communication. Through this experience, I became more confident in:

- Asking questions to gain clarity on design and construction processes.
- Engaging in technical discussions during coordination meetings.
- Handling and sharing information accurately and professionally.
- Building strong relationships with colleagues through teamwork and mutual respect.

Good communication proved essential not only for collaboration but also for fostering a safe and productive site environment.

3.2.4. Entrepreneurship Skills

The internship also provided exposure to the entrepreneurial side of construction. By observing tendering processes, cost estimation, and contract administration, I developed an understanding of how engineering decisions are intertwined with business objectives. From this experience, I learned that successful engineers require skills such as:

- Technical expertise combined with economic awareness.
- The ability to make informed decisions based on cost, quality, and client needs.

- Strong organizational and problem-solving skills.
- Effective communication and negotiation with stakeholders.
- Persistence, self-discipline, and adaptability in the face of challenges.

This knowledge motivated me to consider future opportunities beyond employment, such as establishing my own consulting or contracting firm, where innovation and sound business practices are essential for success.

3.2.5. Improvement of Interpersonal Communication Skills

During the internship, I interacted with a wide range of professionals, including engineers, consultants, and fellow interns from different universities. This exposure helped me develop interpersonal skills critical for teamwork and leadership. I learned to:

- Listen actively and respectfully to others' ideas.
- Communicate technical information clearly and concisely.
- Persuade and motivate team members to achieve shared goals.
- Build rapport with diverse individuals through open and respectful dialogue.

These skills will be essential for managing multidisciplinary teams and maintaining productive professional relationships in future projects.

3.2.6. Teamwork Skills

Construction projects are inherently collaborative, requiring coordinated efforts from individuals across various disciplines. My teamwork abilities improved through observing and participating in the cooperative work culture of the Shaggar One General Hospital project. Key lessons I learned about teamwork include:

- Establishing a common understanding of project objectives and tasks.
- Sharing ideas openly while respecting different perspectives.
- Actively participating and contributing to group discussions.
- Providing support and encouragement to colleagues.
- Building trust and mutual commitment within the team.

Strong teamwork not only improved productivity but also created a supportive work environment that fostered innovation and high-quality results.

3.2.7. Leadership Skills

Leadership is about guiding and inspiring others to achieve common goals while addressing challenges effectively. During my internship, I observed resident engineers and site managers leading by example, motivating workers, enforcing safety measures, and ensuring tasks were completed efficiently. Through this exposure, I learned that effective leadership requires:

- Self-awareness and continuous self-improvement.
- Technical proficiency and confidence in decision-making.
- Fair treatment of all team members to foster respect and trust.
- Clear and timely communication with workers and stakeholders.
- Accountability and responsibility for project outcomes.
- Setting clear goals, visions, and expectations for the team.

These experiences gave me a deeper understanding of the complexities of leadership and inspired me to develop my own leadership potential through practice and reflection.

The internship at the Shaggar One General Hospital construction site was instrumental in shaping my professional identity. It allowed me to apply academic knowledge to real-world scenarios, develop essential soft skills, and gain practical insights into the technical, managerial, and entrepreneurial aspects of civil engineering. These experiences have prepared me to take on future challenges in the construction industry with competence, confidence, and integrity.

3.3. Work Ethics and Professional Conduct in Construction Projects

Work ethics and professional conduct are foundational pillars of civil engineering practice, ensuring safety, quality, and accountability in every stage of a construction project. During my three-month internship on the Shaggar One General Hospital project, I was able to closely observe and practice these principles. This experience profoundly shaped my professional outlook and deepened my understanding of my responsibilities as a future civil engineer.

The hospital project was a large-scale development involving multiple stakeholders, including the client, consultant (ECO), and contractor (Gutema Firisa Construction PLC JV with MCG Construction PLC). Such a complex project demanded strict adherence to professional standards, contractual obligations, and regulatory frameworks. Throughout the internship, I witnessed how effective ethical practices directly contributed to project success, team cohesion, and community trust.

3.3.1. Commitment to Punctuality and Responsibility

Punctuality was highly emphasized on-site. Every day, work commenced at exactly 2:00 local time (8:00 AM), ensuring that tasks such as concrete placement and reinforcement checks were performed in the cooler morning hours, minimizing material waste and maximizing safety. Being consistently punctual not only demonstrated respect for others' time but also reinforced accountability within the team.

Responsibility was equally important. As interns, we were assigned specific tasks such as supervising concrete mixing, preparing site reports, and checking reinforcement placement under the guidance of site engineers. These responsibilities had to be carried out diligently and in accordance with engineering codes like EBCS, ACI 318, and Eurocode-2, which govern quality and safety in structural works.

3.3.2. Ethical Duty to Ensure Safety and Environmental Protection

One of the most critical lessons learned was the ethical responsibility to protect human life and the environment. Civil engineers are bound by codes of practice to prioritize worker safety and minimize environmental impacts.

During my internship, this was evident in:

- Strict enforcement of Personal Protective Equipment (PPE) use, such as helmets, safety boots, and gloves, for all personnel.
- Implementation of safety procedures during excavation, crane operations, and concrete pouring to prevent accidents.
- Following the Ethiopian Environmental Protection Authority (EPA) guidelines to manage construction waste and prevent contamination of nearby water resources.
- Proper site drainage and storm water management practices, essential in water resource engineering, are used to prevent erosion and flooding during heavy rains.

Through daily safety briefings and close supervision, I developed a deep appreciation for the engineer’s role in safeguarding workers and the surrounding community.

3.3.3. Integrity, Honesty, and Transparency

Integrity is central to professional conduct in civil engineering. I observed this through transparent documentation processes, including:

- Daily site logs to track progress and identify challenges.
- Accurate reporting of concrete test results and reinforcement inspections to ensure compliance with structural design requirements.
- Proper management of contractual documents, such as submittals, RFIs (Requests for Information), and material approval forms.

This transparency built trust among stakeholders and ensured that decisions were made based on accurate, verifiable data. Dishonesty, such as misreporting material quantities or skipping inspections, was strictly prohibited, as it could compromise structural safety and violate engineering ethics.

3.3.4. Corporate Social Responsibility and Community Impact

The ultimate goal of the Shaggar One General Hospital project was to improve healthcare access for the surrounding community. Understanding this broader social impact reinforced my sense of duty as an engineer. By participating in a project with such a meaningful purpose, I realized that civil engineering is not only about technical excellence but also about serving society. Examples of socially responsible practices included:

- Designing accessible infrastructure for all community members, including persons with disabilities.
- Ensuring a reliable water supply through borehole drilling and pump system design, critical for hospital operations.
- Reducing construction disruptions to nearby communities through effective noise and dust control measures.

This experience strengthened my motivation to uphold corporate social responsibility in all future engineering endeavors.

3.3.5. Types of Ethics in Civil Engineering Practice

Work ethics in civil engineering can generally be categorized into personal ethics and professional ethics. Both are essential for maintaining harmony, trust, and effectiveness in the workplace.

3.3.5.1. Personal ethics

Personal ethics are values that guide individual behavior in everyday life and professional interactions. During my internship, I learned the following core values:

- **Honesty**: Being truthful in reporting work progress and test results.
- **Fairness**: Treating all workers, from laborers to senior engineers, with equal respect and consideration.
- **Respect for laws and regulations:** Following safety rules, environmental laws, and local construction codes.
- **Benevolence**: Striving to do well for the project and the community, rather than seeking personal gain.
- **Rejecting unfair advantage**: Avoiding practices such as corruption, favoritism, or exploitation of others.

These principles fostered mutual trust and a positive working environment among diverse stakeholders.

3.3.5.2. Professional ethics

Professional ethics are the formalized moral standards specific to the civil engineering profession. These standards ensure that engineers maintain the highest levels of competence, accountability, and social responsibility. During my internship, I observed and practiced the following professional ethical principles:

01. Punctuality and Reliability

- Consistently arriving on time for work and meetings, ensuring tasks were completed within scheduled deadlines.
- Being dependable and skilled in the roles assigned, whether supervising reinforcement works or conducting water pump installation inspections.

02. Workplace Discipline

- Maintaining a quiet and focused working environment, free from distractions such as loud conversations or inappropriate behavior.
- Following proper procedures for handling sensitive information, including structural drawings and cost estimates.

03. Accountability in Decision-Making

- Ensuring that technical decisions, such as changes in structural detailing, were approved by licensed engineers and based on sound engineering analysis.
- Taking ownership of assigned tasks and being willing to accept constructive feedback.

04. Cooperation and Teamwork

- Actively collaborating with multidisciplinary teams, including structural engineers, water resource specialists, and quantity surveyors.
- Sharing knowledge and supporting colleagues to solve site challenges effectively.

05. Public Safety and Welfare

- Prioritizing public health by ensuring safe hospital design and proper water supply systems.
- Avoiding shortcuts that might compromise the safety of future users of the facility.

3.3.6. Ethical Integration with Civil and Water Resource Engineering Work

The Shaggar One General Hospital project combined structural engineering and water resource engineering elements, requiring strict ethical adherence in both fields:

01. Civil/Structural Engineering Ethics

- Following ACI 318, Eurocode 2, and CES 149:2015 for reinforced concrete design and construction.
- Performing quality control tests like slump and cube tests with integrity, ensuring accurate results to verify concrete strength and durability.
- Upholding safety standards during high-risk activities such as formwork removal, shear wall installation, and slab casting.

02. Water Resource Engineering Ethics

- Properly managing groundwater exploration and borehole drilling to avoid contamination of aquifers.
- Designing sustainable pumping systems to provide a reliable hospital water supply while minimizing energy consumption.
- Complying with Ethiopian water resource management policies to protect local communities and ecosystems.

This multidisciplinary exposure highlighted the interconnectedness of engineering disciplines and reinforced the need for ethical decision-making across all project components.

My internship experience solidified my belief that strong work ethics are as critical as technical expertise in civil engineering. Punctuality, honesty, teamwork, and social responsibility are not optional they are essential for ensuring the safety, quality, and sustainability of engineering projects. By integrating these principles into my daily practice, I am better prepared to contribute meaningfully to the construction industry and to serve society with integrity.

3.4. Advancing Theoretical Knowledge and Practical Skills

The internship at Shaggar One General Hospital served as a vital bridge between academic theory and real-world engineering practice. It provided a structured environment where I could apply concepts learned in the classroom to actual construction challenges, fostering both professional growth and technical competence. Through active involvement in structural works, water resource systems, and project management tasks, I developed a deeper understanding of the principles that underpin civil engineering and their practical applications.

This experience significantly enhanced my ability to interpret and implement engineering codes such as EBCS, ACI 318, Eurocode 2, and ASTM standards, ensuring that all construction activities were performed safely and to the highest quality standards. By engaging directly with the project team, including civil engineers, water resource specialists, and quantity surveyors, I learned to approach engineering problems holistically, integrating theoretical knowledge with practical field solutions.

3.4.1. Upgrading My Theoretical Knowledge

While my academic coursework provided a strong foundation in structural analysis, hydraulics, materials science, and project management, the internship transformed this theoretical understanding into actionable expertise. Key areas where my theoretical knowledge was strengthened include:

01. Structural Engineering Applications

- Applying limit state design concepts to reinforced concrete elements such as slabs, beams, columns, and shear walls.
- Interpreting structural drawings and reinforcement detailing to ensure proper execution on site.
- Understanding how soil mechanics principles guide excavation depth, retaining wall design, and foundation stability.
- Observing and reviewing structural load calculations using software such as ETABS and validating designs with field realities.

02. Materials Science and Quality Control

- Linking theoretical material behavior to field testing by conducting slump tests, concrete cube strength tests, and rebar inspections.
- Understanding curing methods and their impact on concrete durability.
- Relating laboratory mix design concepts to on-site batching processes.

03. Water Resource Engineering

- Learning the hydraulic principles behind borehole drilling for the hospital's water supply.
- Gaining exposure to pump selection, pipe sizing, and distribution network design, aligning with Ethiopian water resource management policies.
- Understanding groundwater protection techniques to prevent aquifer contamination during drilling and pumping operations.

Through these experiences, I gained clarity on how engineering theories directly influence field decisions, improving both my academic understanding and professional readiness.

3.4.2. Improving My Practical Skills

The practical training provided during the internship allowed me to develop hands-on skills essential for a competent civil engineer. Under the supervision of site engineers and senior professionals, I engaged in various field tasks, including:

01. Concrete Works and Reinforcement Supervision

- Inspecting reinforcement placement to ensure compliance with structural drawings.
- Overseeing proper formwork construction and alignment before casting.
- Monitoring concrete pouring, vibration, and curing processes to maintain quality and prevent structural defects.

02. Quantity Surveying and Cost Estimation

- Assisting in preparing Bills of Quantities (BOQs) and performing quantity take-offs for structural and water system components.
- Participating in rate analysis and understanding the financial implications of design decisions.

03. Water Supply System Implementation

- Observing borehole drilling operations, pump installation, and pipe network testing for the hospital's water system.
- Learning practical water management strategies to ensure a reliable supply for healthcare facilities.

04. Safety and Environmental Protection

- Implementing safety protocols, including proper PPE usage, hazard identification, and emergency response planning.
- Participating in environmental management activities such as stormwater drainage and construction waste handling.

These hands-on experiences enabled me to translate theoretical learning into practical expertise, improving my confidence in handling technical tasks independently.

3.4.3. Integration of Theory and Practice

The most profound impact of the internship was realizing the interconnectedness of theory and practice. "***Learning theory without practice is lame and practice without theory is blind***" (Albert Einstein). For example:

- The structural analysis methods I studied in class became essential when supervising shear wall reinforcement or checking column formwork stability.
- Knowledge of hydraulics and fluid mechanics was crucial during the design and testing of the hospital's water distribution network.
- Project management theories, including critical path scheduling and cost control, were applied in weekly site progress meetings and documentation reviews.

This integration demonstrated that civil engineering is not simply about calculations or drawings, but about implementing sound designs safely, ethically, and economically to serve communities.

3.4.4. Professional Growth through Ethical Practice

The internship also emphasized the ethical dimension of engineering. By adhering strictly to professional standards and codes of conduct, I learned the importance of integrity in every aspect of work:

- Reporting accurate, concrete test results without bias.
- Ensuring safe working conditions for all personnel.
- Protecting natural water resources through sustainable drilling practices.
- Respecting confidentiality in handling project documents and client communications.

These lessons reinforced that professional success in engineering is built on a foundation of technical excellence and ethical responsibility.

In conclusion, this internship was transformative in advancing both my theoretical knowledge and practical skills. It allowed me to:

- Apply academic principles to real-world structural and water resource engineering challenges.
- Gain proficiency in technical tasks such as reinforcement supervision, material testing, and water system implementation.
- Strengthen my professional ethics and understanding of sustainable engineering practices.

The experience prepared me to transition confidently from the classroom to the construction site, equipped with the competence, discipline, and integrity required to excel in the civil engineering profession.

CHAPTER FOUR

CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion of the Internship Program

The internship program at Shaggar One General Hospital Project has been a transformative experience, bridging the gap between academic theory and real-world construction practice. Over three months, I gained extensive exposure to multidisciplinary activities involving structural works, water resource systems, and project management under the guidance of the Engineering Corporation of Oromia (ECO) and the Gutema Firisa Construction PLC joint venture.

This project, being a large-scale healthcare facility, required strict adherence to engineering codes, including EBCS, ACI 318, Eurocode-2, and ASTM standards, as well as rigorous quality assurance and safety practices. The opportunity to actively participate in diverse project phases from foundation excavation and reinforcement supervision to material testing, groundwater drilling, and pump installation has significantly deepened my technical understanding and enhanced my professional skills.

Key areas of learning included:

- **Reinforced Concrete Works:** Observing and supervising structural elements such as columns, beams, shear walls, and slabs, while applying theoretical concepts like limit state design and reinforcement detailing.
- **Water Resource Engineering Applications:** Participating in borehole drilling, water pumping system design, and stormwater management, ensuring a sustainable and reliable water supply for the hospital facility, as well as construction work.
- **Quality Control and Testing:** Conducting slump tests, cube strength tests, and rebar inspections to maintain compliance with codes and ensure the durability of structures.
- **Project Management:** Engaging in BOQ preparation, cost estimation, contract administration, and weekly coordination meetings, which highlighted the importance of documentation and stakeholder communication.

Beyond technical growth, this internship reinforced critical soft skills such as leadership, teamwork, ethical decision-making, and time management. Working with multidisciplinary teams strengthened my ability to collaborate and communicate effectively in a professional engineering environment. In summary, this internship was highly successful in preparing me for the transition from student life to professional practice. It provided practical experience, enhanced problem-solving abilities, and instilled a strong sense of ethical and social responsibility as a future civil engineer committed to serving the community.

4.2. Recommendations

Based on my internship experience, several recommendations are proposed to improve future internship programs, enhance project execution, and strengthen collaboration between universities and industry. These recommendations are categorized for clarity.

4.2.1. Recommendations for the Host Company / Project Stakeholders

The Shaggar One General Hospital project demonstrated commendable efforts in management and technical execution. However, there are areas where improvements can lead to more efficient and sustainable outcomes:

01. Enhance Site Management and Supervision

- Increase the number of dedicated supervisors to ensure better oversight of critical activities such as reinforcement placement, material handling, and safety compliance.
- Provide regular training for daily laborers to reduce rework and improve workmanship quality. During my internship, I observed certain site practices that highlighted the need for stronger supervision and training. For example, in one of the shear wall constructions, the reinforcement bars were not lapped according to the design specifications and standard guidelines, which could compromise the structural integrity of the element. Additionally, during the concrete pouring of the basement beam by Dugda Company, additional water was added to the already mixed and delivered concrete at the site. When I inquired about this practice, the workers explained that it was done to ease the pumping process because the concrete mix was too stiff to flow properly through the pump. However, this action potentially altered the water-cement ratio, which may reduce the concrete’s design strength and durability. Such incidents underscore the need for continuous supervision and adherence to standards like ACI 318 and EBCS 2:2015 to ensure the quality and safety of structural works.

02. Use Proper and Standard Construction Materials

- Ensure all construction materials comply with Ethiopian Building Code Standards (EBCS) and international codes such as ASTM and ACI.

- ❖ Conduct regular inspections and testing to verify the quality and suitability of materials before use. During my internship, I observed the use of non-standard and unapproved methods, such as using stones and bottles filled with sand in place of proper plumb bobs to align basement columns. This practice compromises construction accuracy and deviates from the standard procedures and instruments taught in class for proper building alignment and quality control. It is strongly recommended to use proper alignment equipment, such as plumb bobs, laser levels, and adjustable steel props, to ensure precise column positioning and compliance with design specifications.

03. Use Modern construction Materials.

- ❖ Adopt modern formwork and scaffolding systems, such as steel, aluminum, or modular plastic formwork, instead of traditional timber and plywood. During my internship, I observed that all formwork and scaffolding used on the site were made from wood and plywood. While these materials are common, they are increasingly discouraged in modern construction due to several disadvantages. Timber formwork often results in poor surface finishes on reinforced concrete (RC) structures and requires significant rework. Moreover, wooden scaffolding poses serious safety risks to workers because of its limited strength and stability. To improve quality and safety, the project stakeholders should transition to metal or engineered formwork systems, which provide smoother concrete finishes, reduce maintenance costs, and comply with international safety standards such as OSHA and ISO 45001:2018 [69].

04. Improve Quality Control Practices

- ❖ Upgrade material storage facilities to protect HCB, reinforcement bars, cements, and sand from moisture and contamination. During my internship, I observed that reinforcement bars were stored outdoors without adequate protection, exposing them to rain, moisture, and other environmental factors. As a result, the reinforcement bars developed significant rust, with some reaching a level of corrosion where visible brushing of the bar surface was required to remove the rust. This not only compromises the proper bond formation between the steel and the surrounding concrete but also leads to additional labor and material costs for cleaning or replacing the affected bars. According to civil engineering best practices and standards such as ACI 318 and EBCS 2:2015, severely corroded reinforcement must not be used for structural works, as rusted bars fail to form a proper bond with concrete. This can lead to cracking and premature structural failure, well before the designed service life of the structure.

- Introduce digital testing equipment to improve the accuracy of material strength evaluations.

05. Promote Safety and Environmental Protection

- Although the site enforces a strict policy requiring all individuals to wear helmets and high-visibility work-wear (locally called *Balaqqesistu*) before entering active construction zones, there are still notable gaps in the implementation of comprehensive safety measures. Visitors or workers must first report to the site office manager, after which they are provided with the required helmet and high-visibility jacket to access the construction area.

  However, other essential personal protective equipment (PPE), such as earplugs, safety gloves, protective eyewear, and advanced safety gear, were not consistently available or enforced during the internship period. To align with international safety standards, such as ISO 45001:2018 and OSHA guidelines, it is recommended that project stakeholders introduce a broader range of safety equipment and implement regular safety training sessions. This will not only reduce the risk of workplace injuries but also foster a stronger safety culture and environmental responsibility throughout the project lifecycle.

06. Use Potable Water for any Construction work and Strengthen Water Resource Management

- Adopt sustainable water pumping technologies to reduce energy consumption and operational costs, and utilize potable (drinkable) water for all construction work.
- Regularly monitor borehole operations to prevent aquifer depletion and contamination.

07. Integrate Modern Technologies

- Encourage the use of Building Information Modeling (BIM) and digital project tracking tools to improve efficiency, coordination, and data accuracy [70].

08. Maintain Internship Support

- Continue hosting interns and assign dedicated mentors who provide structured guidance, ensuring students gain meaningful hands-on experience while contributing to project success. Additionally, provide interns with regular, structured work accompanied by fair compensation, enabling them to gain valuable experience not only from a technical perspective but also from an economic standpoint. This support helps interns cover their living expenses during the internship period, supplementing the stipend provided by the university.

4.2.2. Recommendations for Future Interns

To maximize learning and professional growth, future interns should consider the following:

01. Academic Preparation

- ❖ Review relevant coursework before starting the internship, particularly in structural analysis, reinforced concrete design, hydraulics, and project management.
- ❖ Gain familiarity with design and drafting software such as AutoCAD, ETABS, and SAP2000, all MS Products, which are widely used in construction projects.

02. Focus Areas During Internship

- ❖ Engage actively in both office tasks (e.g., Contract administration, BOQ preparation, cost estimation) and site tasks (e.g., reinforcement checking, quality control testing) to develop a well-rounded skillset.
- ❖ Observe and practice adherence to codes and standards, which are critical for structural safety and integrity.

03. Professional Development

- ❖ Cultivate soft skills such as teamwork, communication, and leadership by actively collaborating with engineers, technicians, and site workers.
- ❖ Maintain a strong work ethic by demonstrating punctuality, responsibility, and a willingness to learn.

4.2.3. Recommendations for the University (ASTU)

For the internship program to achieve its full potential, ASTU should strengthen its role in preparing and supporting students before, during, and after internships:

01. Curriculum and Industry Alignment

- ❖ Continuously update the curriculum to reflect evolving industry needs, incorporating courses on digital construction tools, sustainable water resource management, and advanced project management techniques.
- ❖ Introduce practical elective courses and workshops that simulate real-world challenges students will face on-site.

02. Pre-Internship Preparation

- ❖ Provide comprehensive orientation programs covering safety protocols, field ethics, and construction codes before deployment.
- ❖ Equip students with essential site knowledge, including reading structural drawings and understanding project documentation.

03. Strengthening Industrial Linkages

- Foster stronger partnerships with contractors, consultants, and government agencies to secure quality internship placements.
- Assign academic mentors to monitor and support students throughout the internship period from the first date of beginning the program.

04. Financial and Logistical Support

- Increase budget allocations to cover inflation and provide students with adequate stipends during internships.
- Offer health insurance coverage to ensure student well-being while on-site.

05. Practical Exposure During Coursework

- Organize field visits and mini-projects during academic semesters to give students early exposure to real-world applications.
- Group students strategically for collaborative tasks to enhance teamwork and mutual learning.

06. Strengthen Internship Placement Opportunities

- Encourage Adama Science and Technology University (ASTU) to maintain strong partnerships with the Engineering Corporation of Oromia (ECO), Gutema Firisa Construction PLC, and MCG Construction PLC. These organizations demonstrated a strong commitment to professional mentorship and practical training throughout my internship period. Future students would greatly benefit from being placed in these companies, as they provide hands-on experience, exposure to large-scale construction projects, and guidance from experienced engineers.

4.3. My Final Reflection

My three-month internship at the Shaggar One General Hospital Project was a transformative experience that significantly shaped my professional outlook and clarified my career goals. Before this internship, my primary focus was on structural design and theoretical civil engineering concepts. However, exposure to the dynamic interactions between consultants (ECO), contractors (Gutema Firisa Construction PLC and MCG Construction PLC), and clients (Shaggar City) broadened my perspective. I realized that construction management, quality control, Water Resources system design & planning, and site supervision are equally vital components of a successful engineering career. While my long-term goal remains to become a licensed professional civil engineer, I now have a stronger desire to specialize in project management and structural quality assurance, with the aim of contributing to sustainable and safe infrastructure development in Ethiopia and across the world.

This internship is closely aligned with my career aspirations by bridging the gap between academic theory and practical fieldwork. Tasks such as quantity surveying, structural drawing reviews, contract administration, reinforcement inspection, and participation in progress meetings allowed me to apply my classroom knowledge to real-world challenges. For instance, observing improper practices such as inadequate bar lapping, uncontrolled water addition during concrete pumping, and improper material storage reinforced the importance of strict adherence to engineering standards like ACI 318, EBCS 2:2015, and OSHA safety guidelines [71]. These experiences enhanced my confidence and practical skills, giving me a clearer vision of my professional pathway.

I firmly believe that this internship has been of immense value to my personal and professional development. It allowed me to develop not only technical skills but also essential soft skills such as teamwork, communication, and leadership. Working with experienced engineers at ECO and Gutema Firisa taught me how to manage challenges, solve problems collaboratively, and understand the complex decision-making processes involved in large-scale public health projects. This internship also gave me a sense of purpose, as I could directly see how civil engineering impacts communities by providing essential facilities like hospitals.

Through my observations and activities, I identified several potential research areas and thesis topics that could make a meaningful contribution to the field.

Suggested Novel Thesis Topics are:

01. **Adaptive Water-Cement Ratio Control for On-Site Pumped Concrete Using Real-Time Viscosity Monitoring**
    - **Why it's novel:** Although improper water addition on site is a known issue, there's little literature on real-time, adaptive systems that monitor concrete viscosity and adjust water content automatically during pumping.
    - **Potential impact:** Enhances concrete strength consistency and reduces deterioration due to human error.
02. **Development of Eco-Friendly, Locally Fabricated Modular Formwork Systems for Improved RC Surface Finish**

- **Why it's novel:** While modular formwork exists, designing cost-effective, locally manufactured options using sustainable materials (e.g., recycled composites or bamboo-based panels) is underexplored, especially for Ethiopian construction environments.
- **Potential impact:** Enhances quality, safety, and sustainability while supporting local industry.

03. Quantification of Risk and Structural Impact from Rusted Reinforcement Using Structural Health Monitoring Techniques

- **Why it's novel:** Instead of broadly studying rust effects, this proposal focuses on applying sensors and nondestructive testing (like ultrasonic or magnetic methods) to quantify bond loss and early-stage damage from rust in real-world settings.
- **Potential impact:** Introduces predictive maintenance to avoid early structural failure.

04. Integrating Prevention-through-Design (PtD) into RC Construction Workflows in Emerging Markets

- **Why it's novel:** PtD is a proactive safety philosophy, yet research applying it specifically to RC construction in developing countries where resource constraints and local practices differ remains rare.
- **Potential impact:** Shifts the feasibility of safety from reactive to preventive, tailored to local conditions.

05. Framework for Generative AI–Assisted Construction Documentation Quality Control

- **Why it's novel:** Building on emerging generative AI trends, there's limited research on AI that auto-checks construction drawings, test results, or material certificates against design and code. Creating a domain-specific generative model for this is cutting-edge.
- **Potential impact:** Boosts accuracy, reduces administrative time, and integrates modern AI into daily construction workflows globally.

06. Development of an Integrated Civil Engineering Project Management and Analysis Software Beyond BIM

- **Topic Idea (Thesis Title):** "Beyond BIM; Design and Development of an Integrated Multi-Module Civil Engineering Software for Seamless Structural Analysis, Quantity Surveying & Cost Estimation, and Project Scheduling in a Single Platform"
- **Problem Statement:** Currently, civil engineering professionals use multiple separate software tools to manage different phases of a project:
  - Structural Analysis and Design: ETABS, SAP2000, SAFE.

- Quantity Takeoff and Cost Estimation: Excel sheets, CostX, or manual BOQs.
- Scheduling and Resource Planning: MS Project, Primavera P6.
- Drawing and Drafting: AutoCAD, Revit, BIM tools.

Switching between these platforms is time-consuming, error-prone, and requires multiple data exports/imports, which often leads to data loss and inconsistencies.

- **Proposed Solution:** Develop a single integrated software that combines these core modules into one ecosystem, enabling real-time updates across all phases of construction.
- **Key Integrated Features:**
  - Structural Analysis & Design Module: similar to ETABS/SAP2000 for modeling and load analysis.
  - Quantity Takeoff and Cost Estimation Module: auto-generates BOQs from the structural model.
  - Project Scheduling Module: automatically links BOQs with Gantt charts like MS Project.
  - 2D/3D Visualization Module: lightweight visualization for collaboration, beyond standard BIM.
  - Quality Control and Safety Module: integrates checklists based on ACI 318, EBCS, and OSHA standards.
- **Novelty & International Relevance**; Unlike BIM tools like Revit, this system:
  - Goes beyond modeling by combining design, costing, and scheduling in a single dynamic workflow.
  - Uses AI-based algorithms to optimize material usage, detect design conflicts, and reduce construction waste.
  - Provides a simpler user interface, specifically tailored for developing countries where BIM adoption is still limited.
- **Sample Workflow:** Design a shear wall in the structural module → auto-updates quantities in the BOQ module → automatically schedules tasks in the project planning module.

  This eliminates repeated manual data entry and ensures real-time integration.
- **Potential Research Methodology**
  - Requirement Analysis: Survey engineers and contractors (e.g., ECO, Gutema Firisa, MCG) to identify pain points.

- Software Design: Use open-source frameworks like Python, C#, and Blender APIs for 3D modeling.
- Prototype Development: Build a lightweight MVP integrating two key modules first.
- Testing: Validate accuracy with a real project like Shegger One General Hospital.
- Comparison: Measure efficiency against current workflows using separate software tools.

In conclusion to my report, this internship was a vital step in shaping my career path and deepening my passion for civil engineering. It not only equipped me with hands-on skills but also inspired me to pursue research that addresses real challenges in the Ethiopian construction industry. I am committed to applying the knowledge gained during this experience to future projects and academic endeavors, with the ultimate goal of contributing to the development of safe, sustainable, and innovative infrastructure solutions.

GLOSSARY OF LOCAL AND TECHNICAL TERMS

- **Anati (Carpenter):** a worker specializing in cutting, shaping, and joining wood.
- **Armata (አርማታ):** Site term for structural concrete.
- **Balaqqesistu:** High-visibility Construction site work-wear.
- **Barela:** A measuring box or container used for batching construction materials.
- **Bega (ቤጋ):** Steel lever or tool used to bend reinforcement bars to the desired shape.
- **Bereragirf (በረራ ግርፍ):** First coat of plaster applied to walls.
- **Berga:** A full-length reinforcement bar, typically 12 meters long.
- **Birr (ETB):** The official currency of Ethiopia, commonly used in construction contracts and estimates.
- **Bishaan (ውኃ):** Water.
- **Boyacá:** Cement-water slurry used for bonding new concrete to old surfaces (bonding grout).
- **Buhaka (ቡሃካ):** Cement grouting for filling cracks or voids.
- **Buqqistuu (መዶሻ):** Hammer.
- **Cracher:** A Wooden strut used to support column formwork or panels.
- **Cresti/Kristy (ክርስቲ):** Vertical support under slab panels, transferring load from formwork to the ground.
- **Ferroye:** Bar bender laborer responsible for cutting, bending, and fixing reinforcement steel.
- **Finfinne:** The Afaan Oromo name for Addis Ababa, the capital city of Ethiopia.
- **Fondo (ፎንዶ):** Bottom formwork for beams or slabs (soffit).
- **Fuka:** Expansion joint or intentional crack in concrete to prevent uncontrolled cracking.
- **Gamoo (ህንፃ):** Building.
- **Gancho (ጋንቾ):** Small steel wire or bar tie (approx. 6 mm) used to tie reinforcement or support slab/column formwork.
- **Gefersa Guje:** A sub-city area in Shaggar City, Oromia Region, Ethiopia, where part of the project is located.
- **Gindela/Gindilla (ጊኒዲላ):** Diagonal bracing support for formwork structures.
- **Goma Wuhalik (ጎማ ዉሃልክ):** Water tube level used to check leveling.
- **Grila:** Footing pad or isolated foundation block.
- **Hojii (ሥራ):** Work.
- **Hojjetota (ግንበኛ):** Construction worker.
- **Ijaarsa (ግንባታ):** Construction.
- **Ijaaruu (መገንባት):** To construct/build.
- **Junta (ጁንታ):** Joint mortar; general site term for a joint in concrete or masonry.
- **Kara Bat:** Timber support attached to formwork at intervals (approximately 50 cm).
- **Kebeleto/Kugno (ኩኞ):** Spacer used to separate top and bottom reinforcement layers.
- **Kisit (ቅስት):** Horizontal bracing used in formwork systems.

- **Lamera (ላሜራ)**: Corrugated or flat sheet metal (usually steel) commonly used for roofing, wall sheeting, or temporary structures in Ethiopian construction.
- **Ligna (ሊኛ):** String line used for alignment and layout.
- **Mason:** Skilled laborer who constructs walls with stone, blocks, or bricks.
- **Mehandis (መሐንዲስ):** Civil Engineer.
- **Hundee/Meseret (መሰረት):** Foundation.
- **Mismar (ሚስማር):** Nail.
- **Modino/Modini:** Profile board used for site setting-out works.
- **Muka (Tee):** Wooden support framework for carrying slab or beam formwork.
- **Mulet (ሙሌት):** Second coat of plaster applied to walls.
- **Panel (ፓኔል):** Steel sheet formwork used for slabs and beams.
- **Ponte:** Horizontal support for slab formwork at the top.
- **Qorqorroo (ቆርቆሮ):** Corrugated galvanized metal sheet, widely used for sheds, shelters, and site offices.
- **Riga:** Timber used by carpenters to level slab concrete.
- **Seggeto:** Cutting tool used for medium-diameter reinforcement bars.
- **Selota/Soleta (ሶሌታ):** Bottom surface (soffit) of slab.
- **Siminto (ሲሚንቶ):** Cement.
- **Sofit (Soffit):** Underside of a slab, beam, or staircase formwork.
- **Sponda (ስፖንዳ):** Vertical side formwork for beams or slabs.
- **Squadra:** L-shaped tool used to check and measure right angles (90°).
- **Staffa (ስታፋ):** Stirrup reinforcement used to resist shear and hold longitudinal bars.
- **Stanga:** Inclined prop or bracing used to keep column formwork vertical.
- **Teter (ጠጠር):** Gravel Sub-Base, a layer of crushed stone used beneath foundations or pavements for drainage and load distribution.
- **Tumbi (ቱምቢ):** Plumb bob, a tool used to check the verticality of columns and masonry walls.
- **Wihalik:** Spirit level used to check horizontal levels.
- **Winch (ዊንች):** Manual lifting device used during plastering and painting works.

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APPENDICES

Appendix A: Location & Contour Map of Shaggar One General Hospital Project

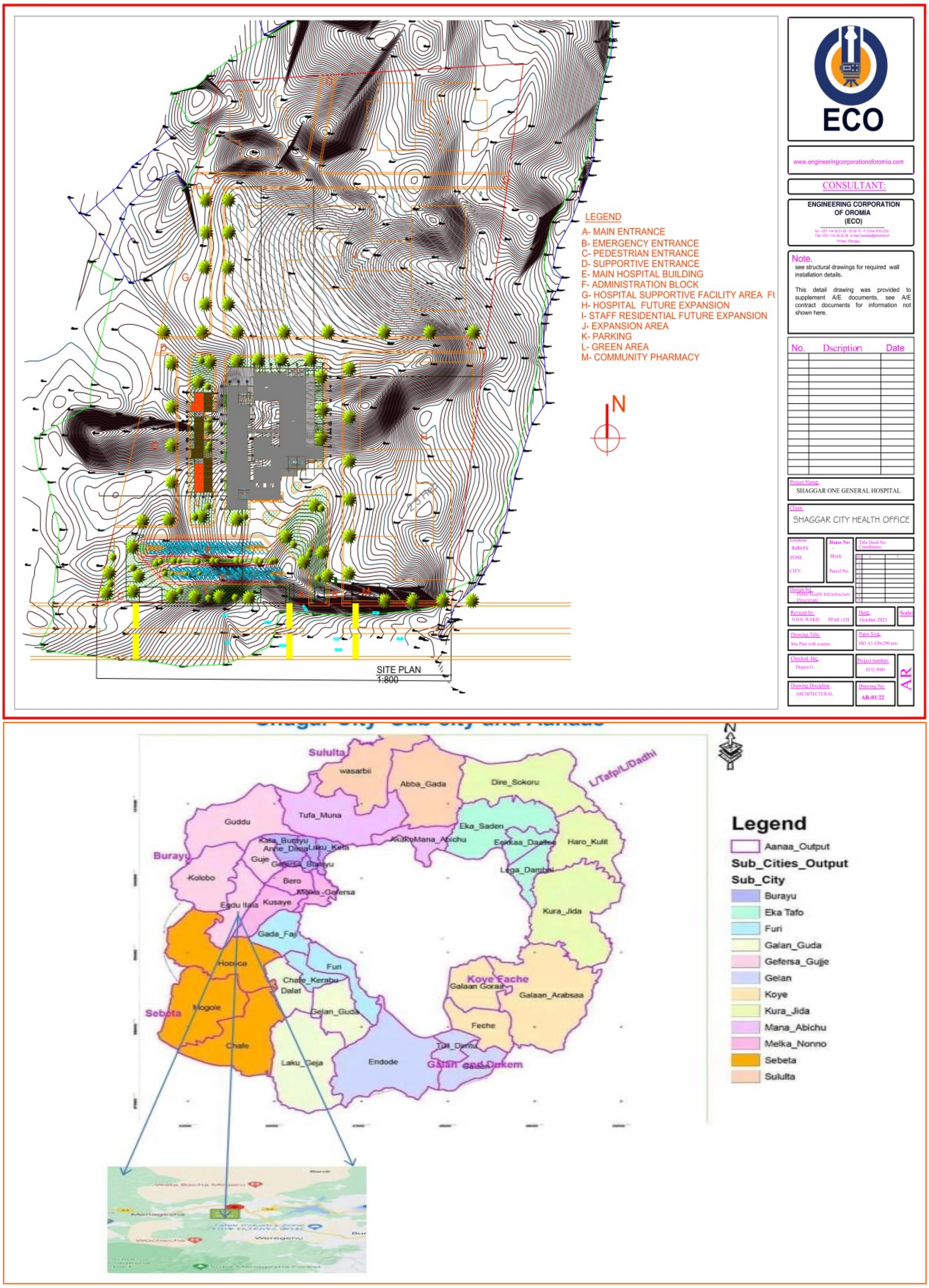

Figure: Appendix.0.1 Project Site Location in the Shaggar City and Contour Map Information.

Appendix B: Material (Concrete and Rebar) laboratory: a Few Records

Table: Appendix.1 Tensile and Compressive Laboratory Test Receipts

ICT ENGINEERING PLC
Precision in every task

ICT ENGINEERING PRIVATE LIMITED COMPANY

Compressive Strength

LAB. No.	: SGH 1596/24	DATE OF CAST	: 25.11.2024
REQUESTED BY	: Gutema Firisa Construction	DATE OF TEST	: 02.12.2024
PROJECT	: Sheger One General Hospital	DATE OF ISSUE	: 02.12.2024
MATERIAL TYPE	: Concrete Cube		
CLASS OF CONCRETE	: C 35 Sample 1		
SAMPLE STATION	: Footing Pad (Administration Building)		
SAMPLED BY	: Jointly		
SUBMITTED BY	: Gutema Firisa Construction		

CUBE MARKING	(NO.)	1	2	3
DIMENSIONS OF CUBE	(mm)	150x150x150	150x150x150	150x150x150
AGE OF CUBE	(Days)	7	7	7
WEIGHT OF CUBE IN AIR	(gm)	7876	7690	7716
AREA OF CUBE	(mm2)	22500	22500	22500
DENSITY	(gm/cc)	2.334	2.279	2.286
MAXIMUM LOAD AT FAILURE	(KN)	526	745	728
COMPRESSIVE STRENGTH	(MPa)	23.4	33.1	32.4
AVERAGE. COMPRESSIVE STRENGTH	(MPa)		29.6	

Remark : - Sample was cast, cured and supplied by the Gutema Firisa Construction. Test conducted in presence of Consultant's and Contractor's Representative.

Tested by: Checked by: Approved by:

ICT ENGINEERING PLC

We stand Committed to the highest performance standards, fully complying with requirements of the Quality Management System (QMS) and our esteemed Clients.

BUISNESS OFFICE:
Sub City : Kirkos,Woreda: 03
House # 524 near Senay Higher Clinic
P.O Box: 120563-Gotera Post Office, Addis Ababa, ETHIOPIA
Tel.: +251 11 470 2517 Mob: +251 911 68 04 87
E-mail: ictepic@ethionet.et

CENTRAL LABORATORY:
Sub City : Kirkos,Woreda: 03
House # 524 near Senay Higher Clinic
P.O Box: 120563-Gotera Post Office, Addis Ababa, ETHIOPIA
Mob: +251 911 68 04 87 +251 912 62 31 28
E-mail: n.akhtar1974@yahoo.com

Company Name: የኢትዮጵያ ኢንጂነሪንግ ኮርፖሬሽን
Ethiopian Engineering Corporation
Material Laboratory Tel: 251-11-872-2285/+251-11-872-3628/+251-11-872-3698 Fax: +251-11-6615371 E-mail: info@ecdswc.com Po.Box: 2561

Title	Document No	Issue No.	Page No.
Compressive Strength test Report	OF/EEC/0854	2	1 of 1

Code: 5491/17
Client Name: Gutema firisa Construction
Project: Shegar One General Hospital
Sample Type: Concrete Cube/C-35
Sampling Date: 24-Nov-24
Station/Location : Foundation Pad
Reported To: Engineering Corporation of Oromia
Performance Date: 23/12/2024

Client Ref.:-
Contact Info: 924112710
Date of Receipt: 23/12/2024
Reported On: 24/12/2024

Test Method :BS 1881-Part 116:1983

Marking	Date		Age in Days	Dimension - m			Unit Weight, Kg/m³	Compressive Strength	
	Poured	Tested		L	W	H		Mpa	PSI
1	24/11/2024	23/12/2024	29	0.15	0.15	0.15	2341	38.40	5569
2	24/11/2024	23/12/2024	29	0.15	0.15	0.15	2370	34.60	5017
3	24/11/2024	23/12/2024	29	0.15	0.15	0.15	2370	40.76	5910

Remark: The samples were collected and submitted to the laboratory by the client. This laboratory test result relates only to the items tested under the specified ...

Tested By:	Reported by:	Checked by:	Approved by:
Date: 24/12/2024	Date: 24/12/2024	Date: 24/12/2024	Date: 24/12/24
Samson Wakjira	Adanech T.Haimanot	Tesfaye Birru	Rediet Gashaw
Testing Expert	Material Engineer	Senior Material Engineer	Material Lab.S/P Manager

Among the major services rendered by the Geotechnical and Material Laboratory Testing S/processes of Ethiopian Engineering Corporation are:
- In Geotechnical Laboratory - Testing the engineering properties of Soil Mechanics and Rock Mechanics
- In Material Testing Laboratory - Testing the engineering properties of various Construction materials, such as Aggregates, Asphalts /Bitumen/,Cements, Rocks, Water, and Reinforcement Steel Bars, Hollow blokes, Bricks, Ceramics, Tiles, Asphalt and Concrete Core Tests, Concrete Mix Designs, Asphalt Mix Designs, sampling of the Soil and Construction Materials and so on.

Please make sure that this document is the correct version before use.

ECAE

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Ethiopian Conformity Assessment Enterprise

Title:	Document No: TLD/F7.08-1	Copy No: -	Rev No: 3
TEST REPORT የፍተሻ ሪፖርት	Page No: 1 of 1	Effective Date: 25 Oct 22	

Name and address of client:	Gutema Firisa Construction, Addis Ababa	Test Report No:	MTR/0887/17
Tel:	+251-118-96-54-14	Test Order No:	GFsop/002/24
Fax:	--	Reported date:	24/08/2024
E-mail:	--	Date of sampling	21/08/2024
Date sample Received:	21/08/2024	Place of sampling	Shagere One General Hospital
Client Sample code: (Brand)	Engineering Corporation of Oromia	Sampled and submitted by	Client
Type of sample:	Ribbed Steel reinforcement bar ϕ8mm	Date tested:	22/8/2024-24/8/2024
Laboratory Designation Number: 16345046		Method Specification:	CES 101:2021

S/N	Characteristics tested	Test Method/ Specification	Standard Requirements (B500BWR)			Test result	Comment According to grade (B500BWR)
			Min	Nom	Max		
1.	Mass per unit length (Kg/m)	ES ISO 15630-1: 2023 / CES 101:2021	0.363	0.395	0.427	0.367	-
2.	Tensile strength Rm (Mpa)		-	-	-	750	-
3.	Upper yield strength,ReH (Mpa)		500	-	-	663	Pass
4.	Characteristics value of Rm/ReH		-	-	-	-	-
5.	Elongation, A (%)		14	-	-	20.0	Pass
6.	Bend test		No crack and rapture observed			No crack and rapture	Pass
7.	Carbon (%)		-	-	0.24	0.19	Pass
8.	Silicon (%)		-	-	0.65	0.18	Pass
9.	Manganese (%)		-	-	1.66	0.73	Pass
10.	Phosphorous (%)		-	-	0.058	0.030	Pass
11.	Sulfur (%)		-	-	0.058	0.053	Pass
12.	Nitrogen (%)		-	-	0.014	0.004	Pass

Remark
1 This test report relates only to the specific sample product which has been tested by ECAE testing laboratory.
2 The parameter indicated under serial No. 7 – 12 is covered by our scope of accreditation.
3 The mass per unit length test parameter was done by extrapolating from 90cm.

Test report authorized by, Name Daniel Ketema, Position Analyst II, Sign

ISO/IEC 17025:2017 Accredited Testing Laboratory

11145 ☎ 011 6 46-05-69, Fax. 011 6 45-97-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA

ilac-MRA EAS Testing Laboratory T0028

ECAE

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Ethiopian Conformity Assessment Enterprise

Title:	Document No: TLD/F7.08-1	Copy No: -	Rev No: 3
TEST REPORT የፍተሻ ሪፖርት	Page No: 1 of 1	Effective Date: 25 Oct 22	

Name and address of client:	Gutema Firisa Construction, Addis Ababa	Test Report No:	MTR/0890/17
Tel:	+251-118-96-54-14	Test Order No:	GFsop/002/24
Fax:	--	Reported date:	24/08/2024
E-mail:	--	Date of sampling	21/08/2024
Date sample Received:	21/08/2024	Place of sampling	Shagere One General Hospital
Client Sample code: (Brand)	Engineering Corporation of Oromia	Sampled and submitted by	Client
Type of sample:	Ribbed Steel reinforcement bar ϕ14mm	Date tested:	22/8/2024-24/8/2024
Laboratory Designation Number: 16345049		Method Specification:	CES 101:2021

S/N	Characteristics tested	Test Method/ Specification	Standard Requirements (B500BWR)			Test result	Comment According to grade (B500BWR)
			Min	Nom	Max		
1.	Mass per unit length (Kg/m)	ES ISO 15630-1; 2023 / CES 101:2021	1.15	1.21	1.27	1.18	-
2.	Tensile strength Rm (Mpa)		-	-	-	653	-
3.	Upper yield strength, ReH (Mpa)		500	-	-	551	Pass
4.	Characteristics value of Rm/ReH		-	-	-	-	-
5.	Elongation, A (%)		14	-	-	21.4	Pass
6.	Bend test		No crack and rapture observed			No crack and rapture	Pass
7.	Carbon (%)		-	-	0.24	0.19	Pass
8.	Silicon (%)		-	-	0.65	0.19	Pass
9.	Manganese (%)		-	-	1.66	0.55	Pass
10.	Phosphorous (%)		-	-	0.058	0.035	Pass
11.	Sulfur (%)		-	-	0.058	0.048	Pass
12.	Nitrogen (%)		-	-	0.014	0.004	Pass

Remark
1 This test report relates only to the specific sample product which has been tested by ECAE testing laboratory.
2 The parameter indicated under serial No. 7 - 12 is covered by our scope of accreditation.
3 The mass per unit length test parameter was done by extrapolating from 90cm.

Test report authorized by, Name Daniel Ketema, Position Analyst II, Sign

ISO/IEC 17025:2017 Accredited Testing Laboratory

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BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA

ilac-MRA EAS Testing Laboratory T0028

Appendix C: ETABS Structural Analysis and SAFE Modeling for B+G+4 & G+2 Building of the Project

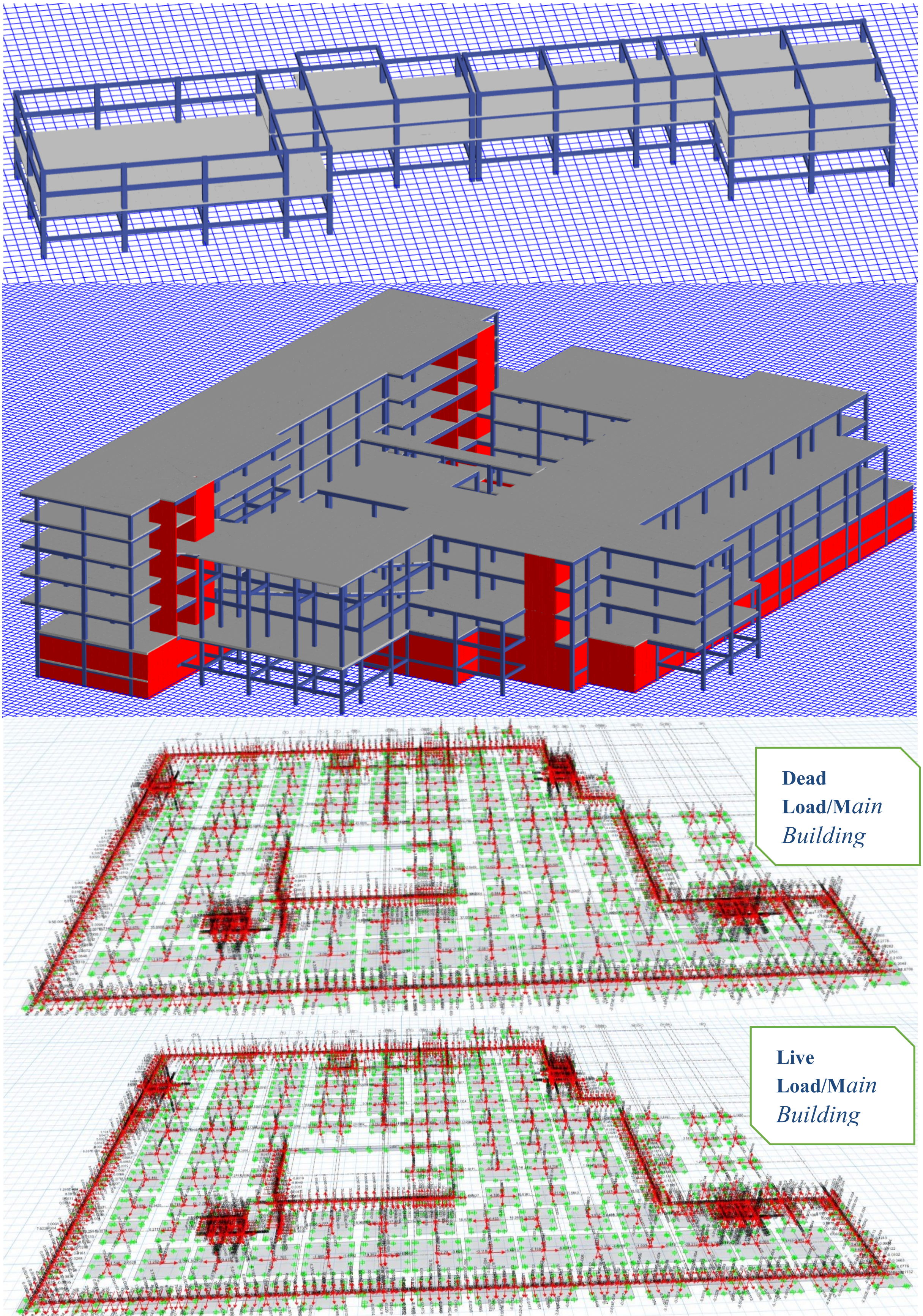

Figure: Appendix.0.2 ETABS Structural modeling B+G+4 & G+2 of the Project

Appendix D: Foundation Structural Layout of Main Hospital Building

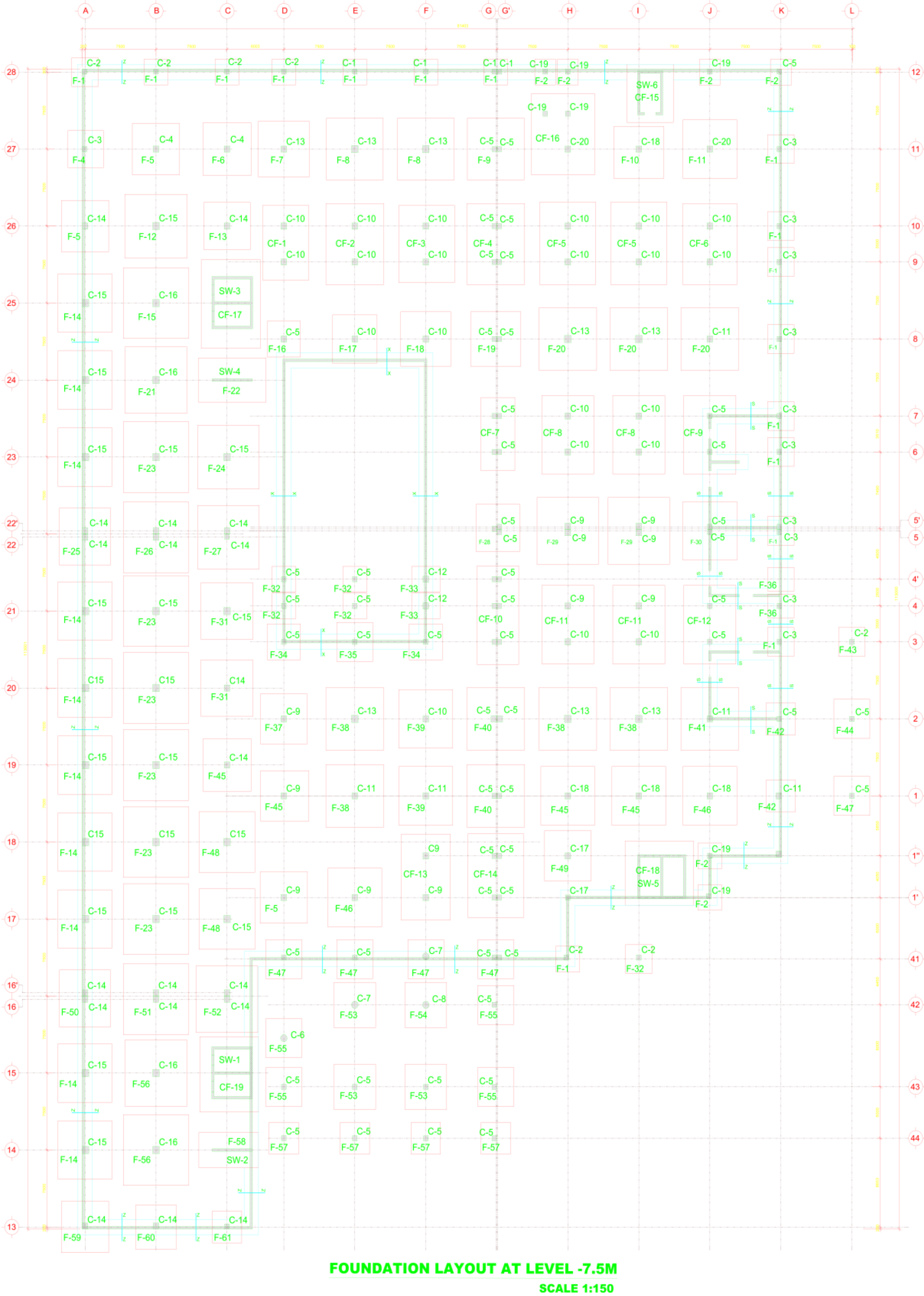

Figure: Appendix.0.3 MHB Foundation layout at -7.5m below the ground level

Appendix E: Geotechnical Investigation and Geological Cross Section of the Soil under the Project Site

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BEST CONSULTING ENGINEERS PRIVATE LIMITED COMPANY

Geotechnical Laboratory Tel. 011-557-2416/17 Fax. 011– 557-2415 P.O.Box 101472 A.A. Ethiopia

Project : Detail Geotechnical Investigation Service Under Shaggar City Administration, Guje Gefersa General Hospital Building
Client : Shaggar City Administration
Contractor: Engineering Corporation Of Oromia (ECO)
Sub Contractor : Jurassic Consulting Engineers PLC
Sampled by : The Client
Test Specified by: The Client
Material Type : Disturbed Soil
Date Reported : December 28, 2023

SUMMARY OF TEST RESULTS

Sr No	BH-ID	Depth (m)	NMC, %	SG	Wet Sieve Analysis (AASHTO T88), Percent Pass			Atterberg Limit (AASHTO T89&90)			Unified Soil Classification
					2mm	0.425mm	0.075mm	LL (%)	PL(%)	PI(%)	
1	BH-01	3.00-3.45	33.3	2.38	99.8	99.0	94.6	52	36	17	MH
2		6.00-6.45	34.7	2.40	99.9	95.7	87.2	51	35	16	MH
3		7.50-7.95	49.0	2.42	99.7	93.9	82.4	46	32	14	ML
4		10.50-10.95	34.8	2.39	99.9	97.6	89.0	56	37	20	MH
5	BH-02	4.50-4.95	28.4	2.42	99.9	99.0	93.8	48	29	19	ML
6		9.50-9.95	35.0	2.39	100.0	98.2	95.0	54	30	24	MH
7		11.50-11.95	36.5	2.42	100.0	99.2	95.8	49	31	19	ML

Remark :

Reported by: Checked by: Approved by :

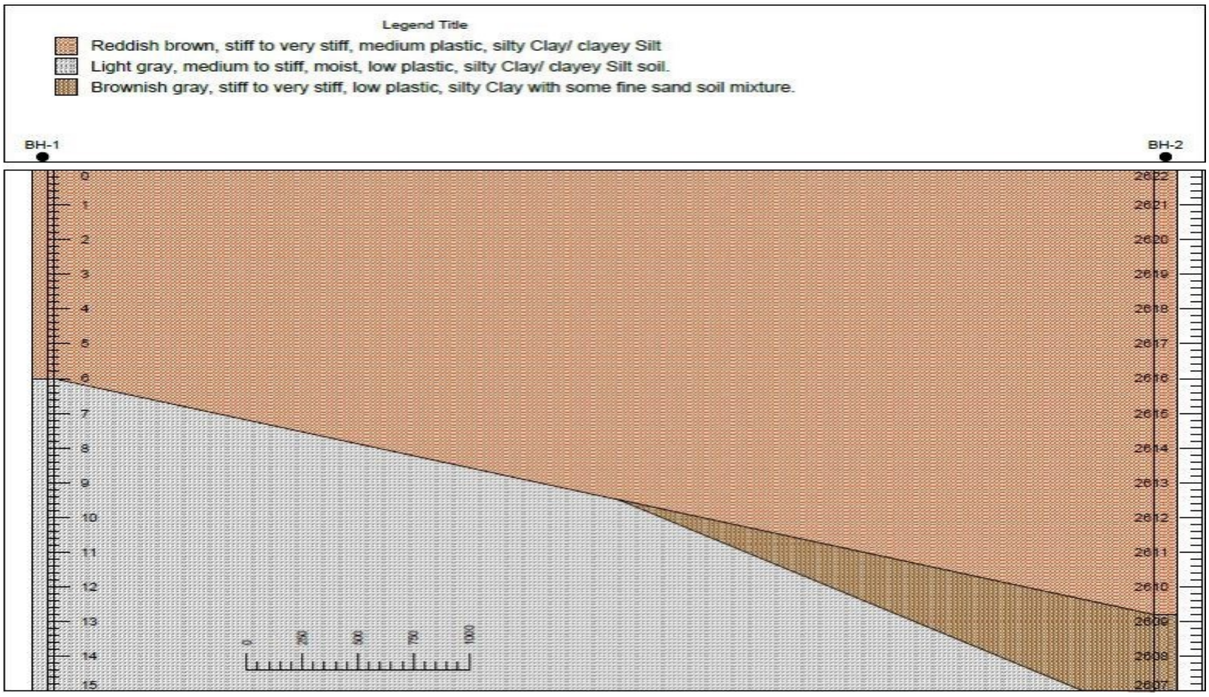


Figure: Appendix.0.4 Geotechnical investigation and Geological Cross Section of soil

Appendix F: Progress on Site Best Photos Taken During My Internship-I

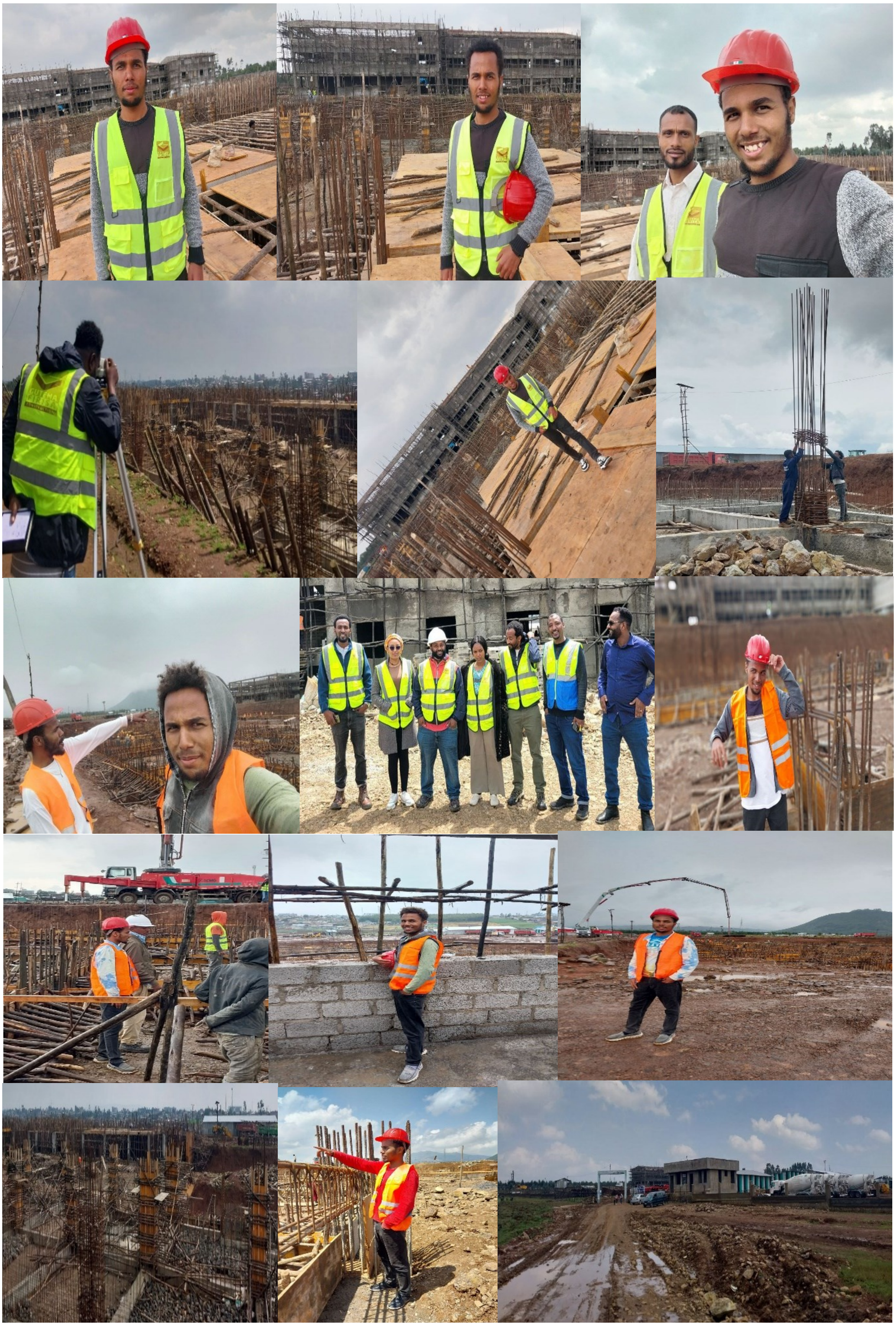
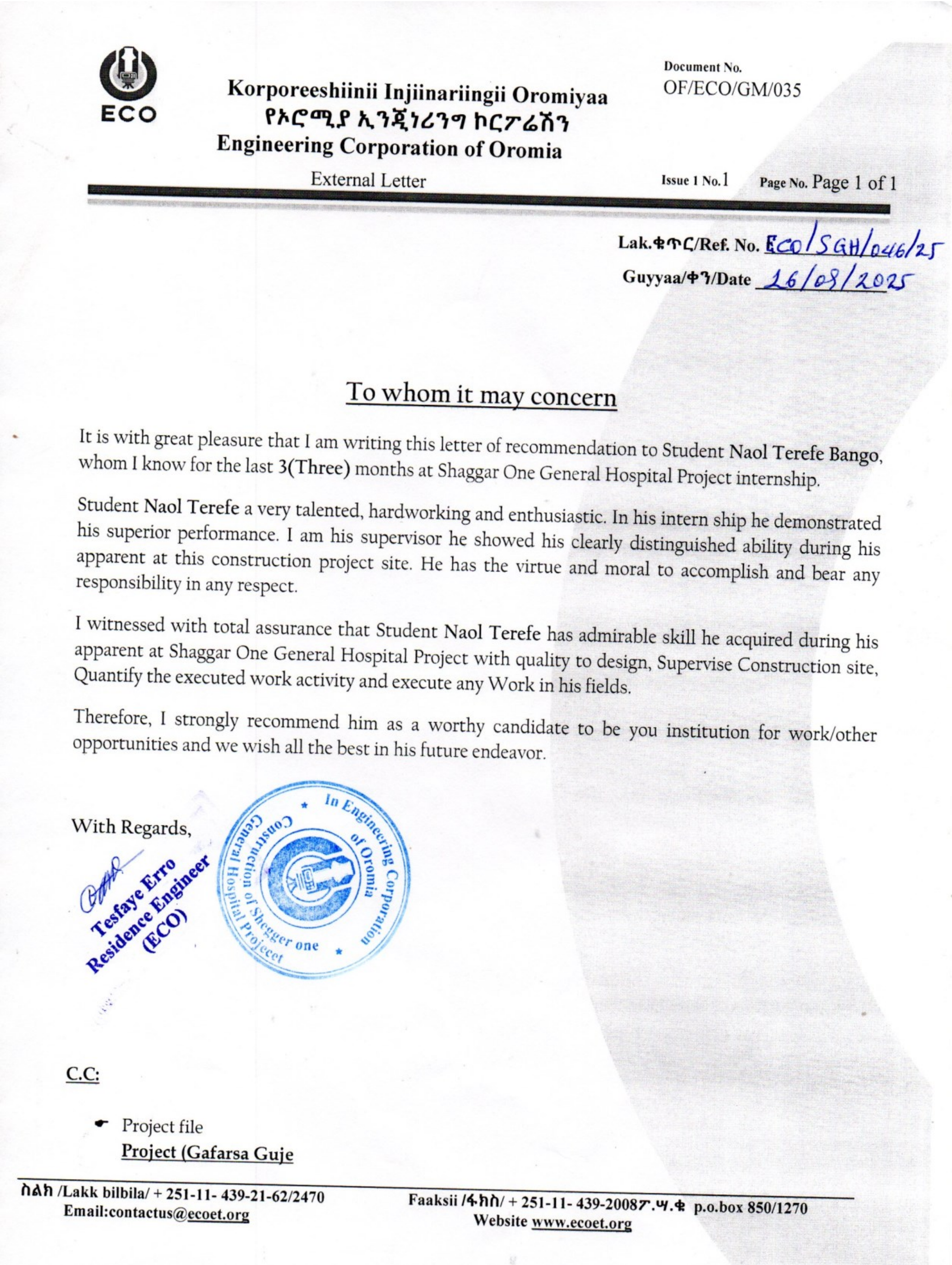


Figure: Appendix.0.5 On-Site Best Photos Taken During the Internship

Appendix G: Internship Recommendation letter issued for Naol Terefe by ECO's site Resident Engineer, Tesfaye Erro



ECO

Korporeeshiinii Injiinariingii Oromiyaa
የኦሮሚያ ኢንጂነሪንግ ኮርፖሬሽን
Engineering Corporation of Oromia

External Letter

Document No.
OF/ECO/GM/035

Issue 1 No. 1 Page No. Page 1 of 1

Lak.ቁጥር/Ref. No. ECO/SGH/046/25
Guyyaa/ቀን/Date 16/08/2025

To whom it may concern

It is with great pleasure that I am writing this letter of recommendation to Student **Naol Terefe Bango**, whom I know for the last **3(Three)** months at Shaggar One General Hospital Project internship.

Student **Naol Terefe** a very talented, hardworking and enthusiastic. In his intern ship he demonstrated his superior performance. I am his supervisor he showed his clearly distinguished ability during his apparent at this construction project site. He has the virtue and moral to accomplish and bear any responsibility in any respect.

I witnessed with total assurance that Student **Naol Terefe** has admirable skill he acquired during his apparent at Shaggar One General Hospital Project with quality to design, Supervise Construction site, Quantify the executed work activity and execute any Work in his fields.

Therefore, I strongly recommend him as a worthy candidate to be you institution for work/other opportunities and we wish all the best in his future endeavor.

With Regards,

Tesfaye Erro
Residence Engineer
(ECO)

In Engineering Corporation of Oromia
Construction of Shegger one General Hospital Project

C.C:

- Project file
  Project (Gafarsa Guje

ስልክ /Lakk bilbila/ + 251-11- 439-21-62/2470
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Faaksii /ፋክስ/ + 251-11- 439-2008ፖ.ሣ.ቁ p.o.box 850/1270
Website www.ecoet.org

Figure: Appendix.6 Internship's Recommendation letter issued for Naol Terefe Bango