DESIGN OF A TWO-STOREY PRIMARY SCHOOL BUILDING IN SAVAR, DHAKA

A Capstone project submitted in partial fulfillment of the Requirements for the award of a degree of

Bachelor of Science in Civil Engineering

by

Nur Mohamud Salah

(ID: 211-47-438)

Osman Bashir Mohamed

(ID: 211-47-439)

Supervised by

Md. Mehedi Hassan Bhuiyan

Lecturer

Department of Civil Engineering
Daffodil International University

Department of Civil Engineering

Faculty of Engineering

DAFFODIL INTERNATIONAL UNIVERSITY

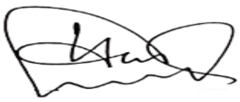
December– 2024

This certifies that the student shown below completed the Capstone Project titled "**DESIGN OF A TWO -STOREY PRIMARY SCHOOL BUILDING IN SAVAR, DHAKA**" under my supervision. as part of the requirements for the Bachelor of Science in Civil Engineering degree. The presentation of the work was successfully held on 18 December 2024.

BOARD OF EXAMINERS

Supervisor

Md. Mehdi Hassan Bhuiyan
Lecturer
Department of CE, DIU

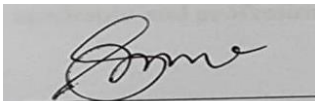


Dr. Mohammad Hannan Mahmud Khan
Associate Professor & Head Department of CE
Department of CE, DIU

Chairman

Mr. Md. Masud Alom
Assistant Professor
Department of CE, DIU

Internal Member



Mr. Saurav Barua
Assistant Professor
Department of CE, DIU

Internal Member

ACKNOWLEDGEMENTS

First and foremost, we express our heartfelt gratitude to **Almighty Allah**, whose guidance and blessings enabled us to successfully complete this practicum work and the report for our Capstone Project.

We are deeply thankful to our families for their unwavering support, encouragement, and love, which have been a source of strength throughout this journey.

We extend our sincere thanks to the **Department of Civil Engineering** for entrusting us with this Capstone Project. This opportunity has been invaluable in bridging theoretical knowledge with practical experience.

Our deepest gratitude goes to **Mr. Mehedi Hasan Bhuiyan**, whose unwavering support and exceptional guidance went beyond our expectations. His expert advice during the report-writing process, coupled with his mentorship, patience, and encouragement, motivated us to overcome challenges and achieve success. His belief in our abilities and his constant motivation have been instrumental in the completion of this project. Words cannot express our appreciation for his kindness, dedication, and genuine care throughout this journey.

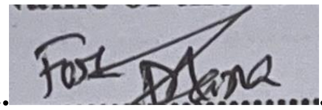
We are also profoundly grateful to **Dr. Mohammad Hannan Mahmud Khan**, Associate Professor and Head of the Department of Civil Engineering, for granting us this opportunity to engage in the Capstone Project and prepare this report through valuable fieldwork.

Lastly, we extend our heartfelt thanks to **Mr. Md. Masud Alom**, Assistant Professor, for his guidance and for emphasizing the significance of the Capstone Project in our academic and professional growth.

DECLARATION

The dissertation, titled " design of a two-stored primary school building with structural and environmental considerations" was completed under the supervision of Mr. Mehedi Hasan Bhuiyan (Lecturer), Department of Civil Engineering, Daffodil International University, Dhaka, Bangladesh, and was approved in partial fulfillment of the requirement for the capstone project part of the Bachelorof Science in Civil Engineering

Name of the reviewer

................................

Mr. Mehedi Hasan Bhuiyan

Lecturer

Department of Civil Engineering

Daffodil International University

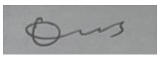
BY

Nur mohamud salah

ID: 211-47-438

Osman Bashir Mohamed

ID: 211-47-439



ABSTRACT

This capstone project focuses on the design and detailing of a two-story primary school building, integrating theoretical knowledge with practical applications to create a safe, functional, and sustainable structure. The structural design was conducted using the ETABS finite element software in compliance with the Bangladesh National Building Code (BNBC, 2020) Key components such as beams, columns, slabs, and foundations were designed to ensure the building's stability and strength. To facilitate precise execution during construction, detailed construction drawings—including floor plans, elevations, and reinforcement layouts—were created using CAD tools like AutoCAD and Revit. Additionally, Excel was utilized to prepare the Bill of Quantities (BOQ), enabling accurate cost estimation, efficient resource management, and aiding in various design calculations. The project emphasizes two primary aspects: environmental considerations, which involve designing a septic tank for effective waste management, and structural design, covering all essential structural elements. Together, these components ensure the successful realization of a primary school structure.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

Chapter 1
INTRODUCTION

1.1 Proposed Structure

The Proposed Two-Storey Primary School is to be built completely by RCC with Isolated foundations. The structure is approximately 100 ft by 100 ft on the plan and 24 ft high which contain 8 classrooms, common room, teachers' room, computer lab and office. A layout Plan is given in Fig. 1.1 and Fig. 1.2 and an isometric view of the building is provided in Fig. 1.3:

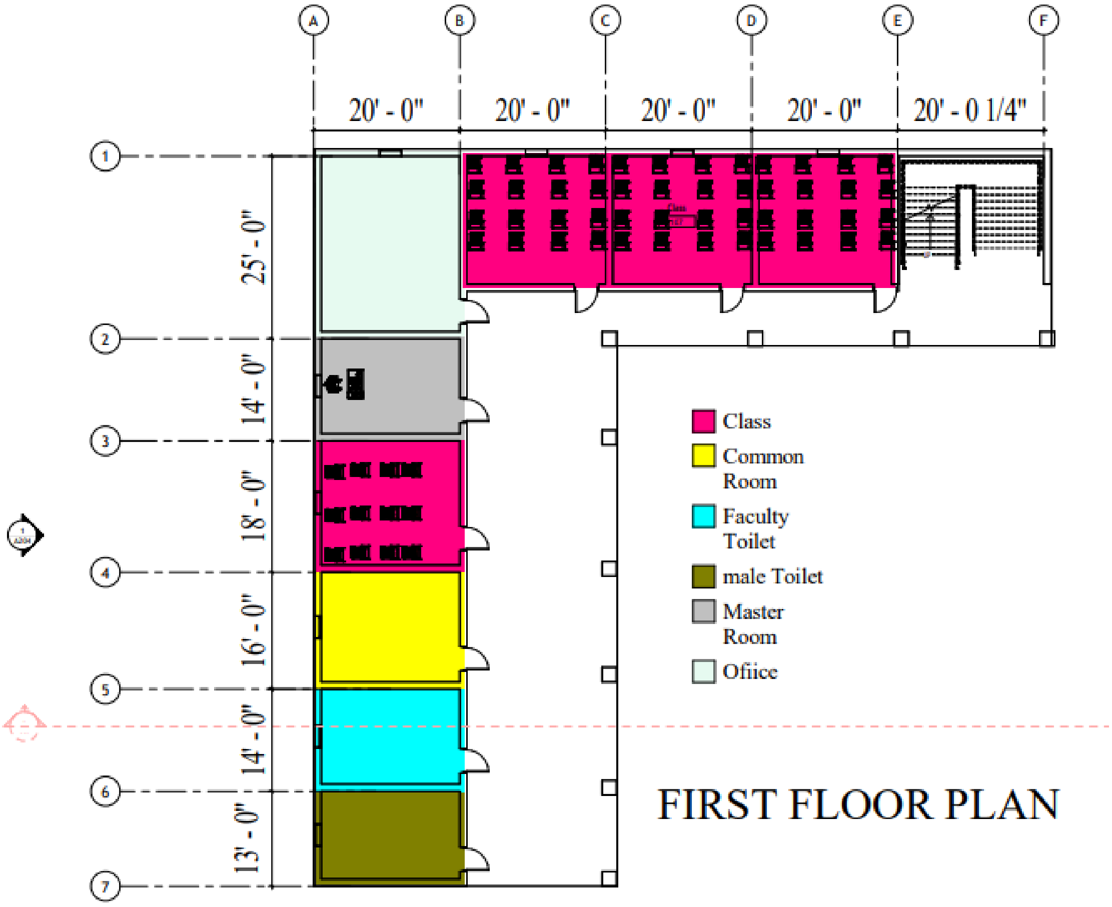


Fig. 1.1: First Floor Plan

Fig. 1.2: Second Floor Plan

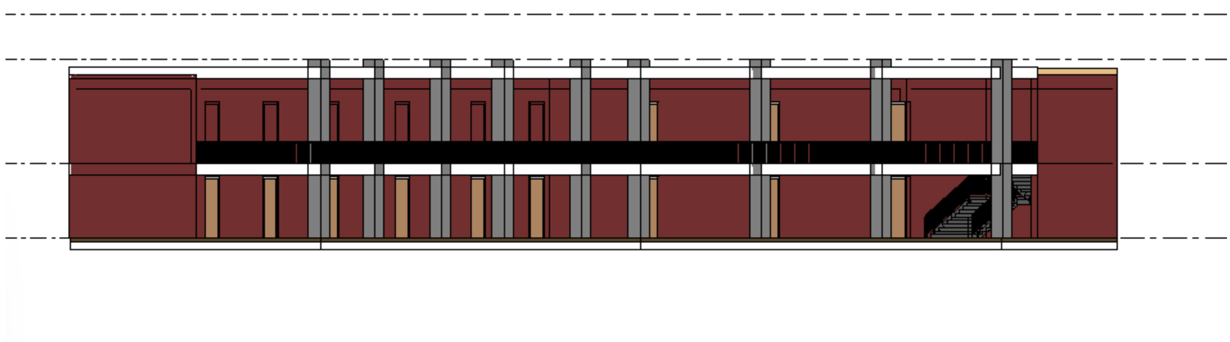


Fig. 1.3: Isometric view of the structure

1.2 Basic Information

In this project, an Intermediate Moment Resisting Frame (IMRF) structural system is used to construct a two-story reinforced concrete (RC) educational facility as shown in Table 1.1. The foundation is built using isolated footings to withstand the loads, while the floor system is made out of edge-supported slabs. Prioritizing structural safety and functionality, the building will be examined and constructed to support the designated floor loads and ensure compliance to essential gravity and lateral force codes.

Table 1.1: Basic information of the building

Building Usage Type	Educational building
Structural System	RC Beam-Column frame (Intermediate Moment Resisting)
Floor System	Edge supported Slab
No. of Stories	2-storey Building
Floor Load	Mentioned in Load Plan
Foundation Type	Isolated footing

1.3 According infrastructure plan and planning guideline

1. The total open area in a school should be kept around 50%(minimum) of the school area. the open area could be used as playground, laying items and etc.
2. For the classroom, there will be not less than 4(four) minimum and male and female wash blocks should be separate.
3. The classroom should be same size (Education, 2018)
4. At least 1(one) room for teacher and one separate HT room for the school having more than 600 students
5. Classroom size should be 16ft *19ft and stair case size 10ft*19ft

1.4 Outline of Capstone project

Chapter 1: Provide introduction of the capstone project

Chapter 2: Codes and materials to be used of this project

Chapter 3: Design of Structural Elements and Output

Chapter 4: Discusses of Cost Estimation of the project and timeline of the project

Chapter 5: Design and consideration of septic tank

Chapter 6: Conclusion of the project and Recommendations.

Chapter 2

Design Codes, Structural Design and Requirements

The purpose of following to a design code is to provide minimum requirements for the layout, construction, material quality, use and occupancy, placement, and upkeep of all buildings in Bangladesh in order to protect life, limb, health, property, and public welfare, within reasonable bounds. To accomplish the same goal, regulations are also in place regarding the installation and usage of specific tools, services, and accessories related to connected to, or affixed to such buildings. (BNBC, 2020) was widely used to refer to the specifications and coefficients that will be employed in the structural design of this building. Additionally, Etabs 2020 was analyzed using (BNBC, 2020).

2.1 Design code

A) All structural drawings shall be read in conjunction with relevant architectural drawings.

B) Analyses and design have been carried out following Bangladesh National BuildingCode (BNBC, 2020)

C) Follow (BNBC, 2020) for specifications/structural requirements not mentioned in the drawings or in this design report.

2.2 Foundation and soil

A) Footing foundation has been proposed as foundation.

B) Minimum clear cover = 3.0 inches is recommended.

C) Depth of foundation shall be as per drawing.

2.3: material properties

Minimum f'_c (28 days cylinder crushing strength)

Foundation and Column = 5000 psi with Mix Ratio = 1:1:2

Beams and Slabs = 5000 psi with Mix Ratio = 1:1:2

2.3 Lapping Zone of Beam

Lap Length: The grade of concrete, the diameter of the reinforcement bars, and their placement (tension or compression zones) all affect the minimum lap length that

(BNBC, 2020) requires. The lap length is usually a multiple of the bar diameter (for example, 40D, where D is the bar's diameter).

Lap length of bar shall be

1: For Tension = 40D

2: For Compression = 30D

D is the Diameter of the Bar

N.B: Column lap is tension lap.

2.4 Corner reinforcement

Corner reinforcement is required by the Bangladesh National Building Code (BNBC, 2020) in order to strengthen structural corners and resist concentrations of tension, particularly in seismic zones. To manage shear and torsional forces, (BNBC, 2020) suggests adding more diagonal bars, closely spaced stirrups, and ties for beams, slabs, and column-beam connections. For bars at corners to avoid slipping under load, proper anchorage and minimum lap lengths are necessary as shown in Fig. 2.1. In order to assist structures better handle lateral stresses and avoid cracking or brittle failure, this reinforcement technique guarantees ductility, energy absorption, and structural integrity at critical spots.

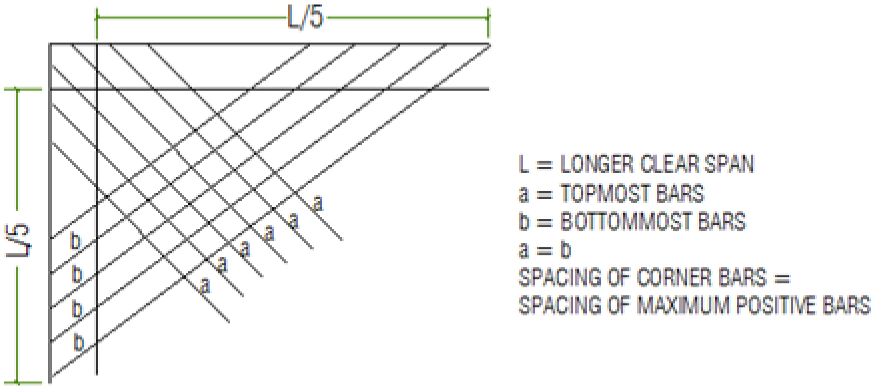


Fig. 2.1: Corner reinforcement

2.5 Material strength

According to the project, the concrete strength (f'c) for all structural elements including the foundation, pedestal columns, grade beams, columns, beams, and slabs must exceed 5000 psi. The yield strength (fy) of the reinforcement steel is 60,000 psi, in Table 2.1, guaranteeing consistency and adherence to accepted design principles for every structural component.

Table 2.1: Material Strength

		Concrete, f'_c	***Unit***	***Rebar Strength, f_y***
	Foundation	5000	psi	60000 psi
	Pedestal Column	5000	psi	60000 psi
	Grade Beams	5000	psi	60000 psi
	Column	5000	psi	60000 psi
	Beams and Slabs	5000	psi	60000 psi

2.6 Development length

The development length (L d) for reinforcement in beams and slabs is the bare minimum of rebar that needs to be implanted in concrete in order to prevent sliding and attain full structural strength, according to the Bangladesh National Building Code (BNBC, 2020) The formula is used to calculate it Ld.= ϕ *fy/4*Tb where ϕ is the diameter of the bar, f y is the steel yield strength, and τb τ b is the concrete bond strength, which varies depending on the concrete's strength, the type of rebar, and its location. Because beams experience larger loads than slabs, they usually require longer development lengths, and (BNBC, 2020) requires adjustment factors for things like rebar type and top reinforcement placement. Through the specification of appropriate anchorage lengths for various load circumstances, these regulations guarantee the stability and safety of concrete structures.

2.7 Concrete Clear Cover for Reinforcing Bars

Concrete clear cover, which is necessary to protect the reinforcing steel bars from fire, corrosion, and other environmental harm, is the bare essential of space between them and the concrete's exterior. Usually measuring 1.5 inches, the clear cover for columns provides sufficient protection and longevity. It is typically 1 inch for interior beams; however, exposure conditions may cause it to grow. Slabs often have a 0.75–1-inch clear cover, depending on their thickness and exposure to the elements. The typical clear cover for staircases is 0.75 inches, which offers adequate protection without compromising structural soundness shown in Table 2.2. An appropriate transparent cover guarantees a long-lasting and dependable construction by improving fire resistance, protecting the reinforcement from moisture and chemicals, and ensuring the structure's endurance.

Table 2.2: Concrete clear cover

Member	Location or Combination	Thickness of Cover
Column	Not in contact with ground or water	1.5"
	In contact with ground or water	2.5"
Beam	Indoors face: Top. Side & Bottom	1.5"
	Outdoors's face: Top, Side &Bottom	1.5"
Slab and Stair	Bottom	1"
	Top	3/4"

2.8 Summary

To ensure safety and adherence to building, material, and service requirements, the building design adheres to BNBC 2020. ETABS 2020 was used for structural analysis and design in accordance with BNBC 2020 requirements.

Chapter 3

Structural Analysis and Output

3.1 Introduction

using ETABS in this project to design the G+1 building's beams, columns, footings, slabs, and staircases, among other structural components. I specified the proper span lengths and stress conditions for the beam design so that ETABS could calculate the necessary reinforcement for both shear and bending. I checked for cracks and deflections to make sure the beams adhered to serviceability limitations. In order to determine the necessary reinforcement, I applied axial loads and moments while modelling the columns as vertical frame elements and following the interaction equations provided by the applicable design codes. Before designing the footing, I assessed the foundation system using the applied loads and the characteristics of the soil. I then used ETABS to confirm the bearing capacity and create the reinforcement for provides sufficient stability and strength. To make sure the design satisfied safety and serviceability requirements, I determined the proper thickness for the slabs, applied loads, and examined the findings for deflection and moment capacities. In order to ensure that the stairs' dimensions and load-bearing capability complied with code standards, I finally created them by modelling them as a sequence of slabs and beams. An integrated methods for structural design was made possible by the thorough analyses carried out in ETABS, which verified the effectiveness and safety of every component inside the building's structure

After completing the structural design of the G+1 building in ETABS, it was moved on to detailing the various elements using AutoCAD. This step was important for visualizing and clearly presenting the design. In AutoCAD it is created detailed drawings for the beams, columns, slabs, footings, and stairs, making sure to include all necessary dimensions, reinforcement layouts, and material specifications. This detailing process helped me see how different structural components fit together, like how beams connect to columns and how slabs are supported. I also added labels and symbols to make the drawings easy to understand. By combining the analysis results from ETABS with detailed drawings in AutoCAD, and ensured that the designs were not only structurally sound but also clear for the construction team, helping to ensure the project could be built successfully

3.2 Load consideration

The loads are separated into three categories in ETABS when creating a model for a primary school building in accordance with (BNBC, 2020) standards: dead load, live load, and floor finish load. Dead load is the total weight of the building's fixed installations, such as ceilings and partitions, as well as all of its permanent structural components, such as floors, walls, beams and columns. This load is determined by the weight of the materials (such as steel, brick, or concrete).

Live Load takes into consideration the building's occupants, furnishings, and moveable objects. Given the usual use and occupancy, primary schools should assign a live load of around 2 to 4 kN/m^2 in classrooms. To manage higher foot traffic in busy areas like assembly areas and corridors, raise the Live Load to 4 to 5 kN/m^2. Lastly,

The floor finish load, which is usually set at 1 to 1.5 kN/m2, is the weight of the flooring components, such as carpeting or tiles. Then, in accordance with the (BNBC, 2020) load combination rules, these loads should be coupled in ETABS to precisely model the structural performance of the building under different circumstances.

3.3 Design of Slab and detailing

While designing of slab in ETABS, take into consideration a number of important factors when designing slabs to ensure both their structural integrity and compliance to building requirements. Slab geometry, thickness, material characteristics, load types (including dead, live, and environmental loads), and boundary conditions are all analyzed by the program. It evaluates the stresses, deflections, and reinforcement needs throughout the slab using finite element analysis. Additionally, ETABS considers the slab's behavior under different load combinations, load distribution, and support conditions (e.g., simply supported, fixed, or continuous). Furthermore, it includes regionally unique safety elements and design codes, enabling engineers to verify adherence to local standards. In order to improve the slab's longevity and functionality, reinforcement details and crack width restrictions are also taken into consideration.

The detailed Slab and reinforcing specifications were completed and exported to AutoCAD once the structural design had been completed in ETABS. These detailed drawings ensure that the design satisfies structural requirements and allows for perfect execution throughout construction by providing specific information in Fig. 3.1 and Fig. 3.2 .

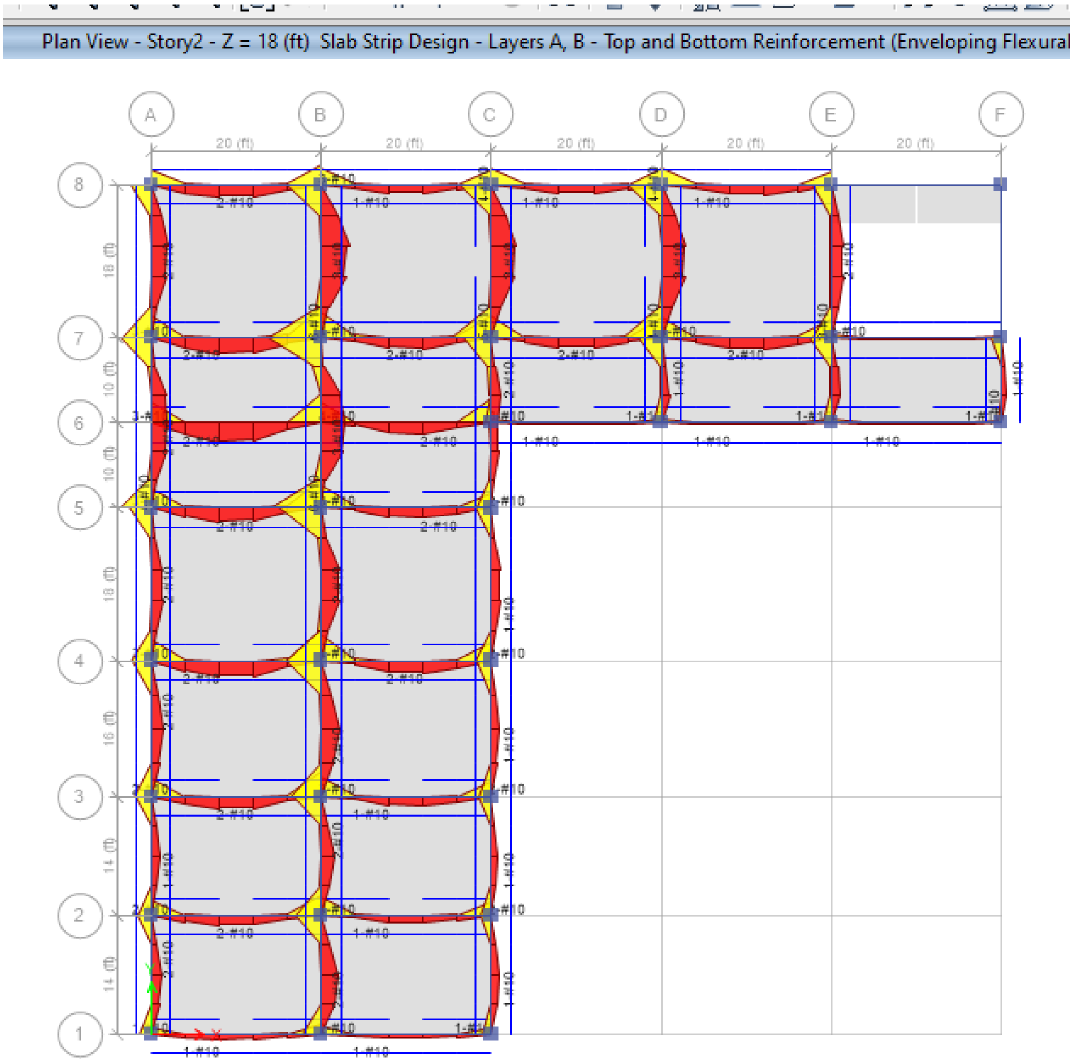


Fig. 3.1: Top and Bottom reinforcement of slab

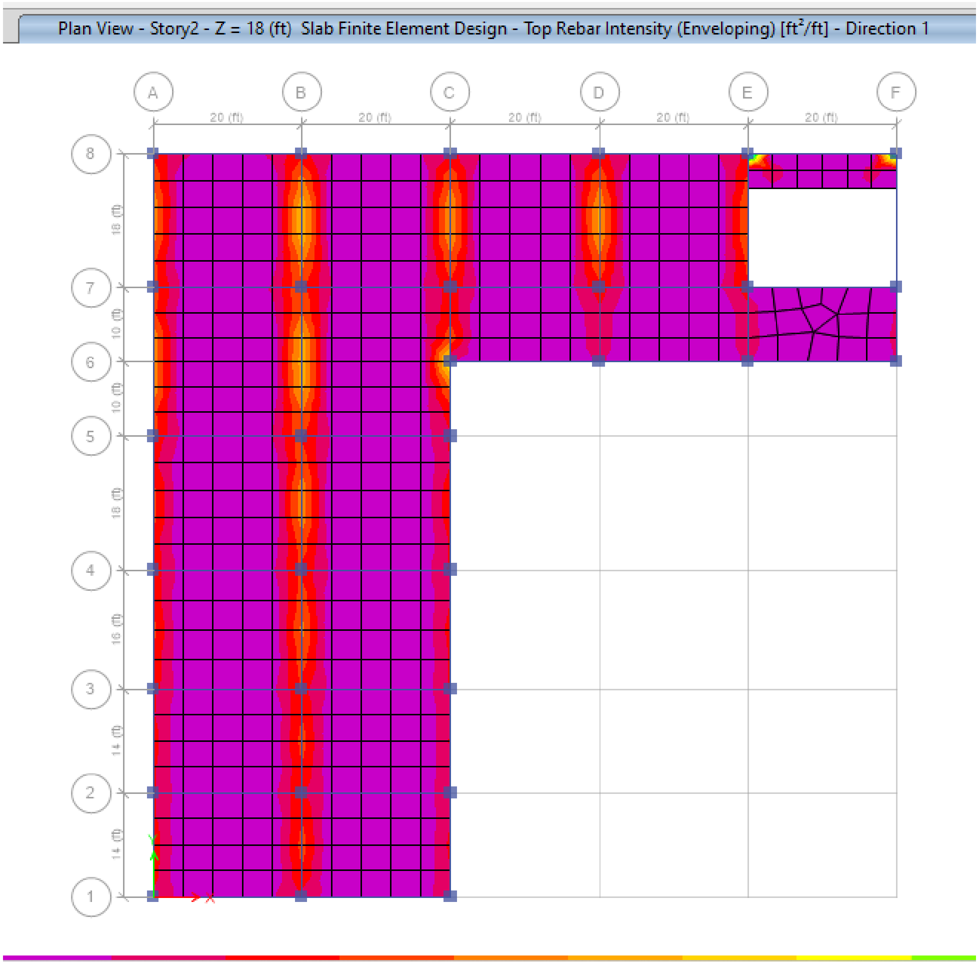


Fig. 3.2: Finite Element Design

3.4 Design of Beam and Detailing

For ETABS beam design process for the G+1 building by establishing the beam's size and outlining the loading circumstances, such as dead and live loads, in accordance with the applicable standards. After the model had been set up, we used ETABS to analyses the beams for shear forces and bending moments as shown in Fig. 3.. By automatically calculating the necessary reinforcement for both positive and negative moments, the software made sure the beams complied with structural safety regulations. To make sure the determined deflections were within allowable bounds for serviceability, verified that the reinforcement layout met the minimal code criteria and successfully withstood the applied loads after looking over the analysis findings. All things considered.

3.4.1 Lap Location

A) For beam bottom bar lap should not be provided in the middle third zone of the span.

B) For beam top bar lap may be provided at middle third zone of the span. (Fig. 3.6).

C) Not more than 50% of the bars shall be spliced at one place.

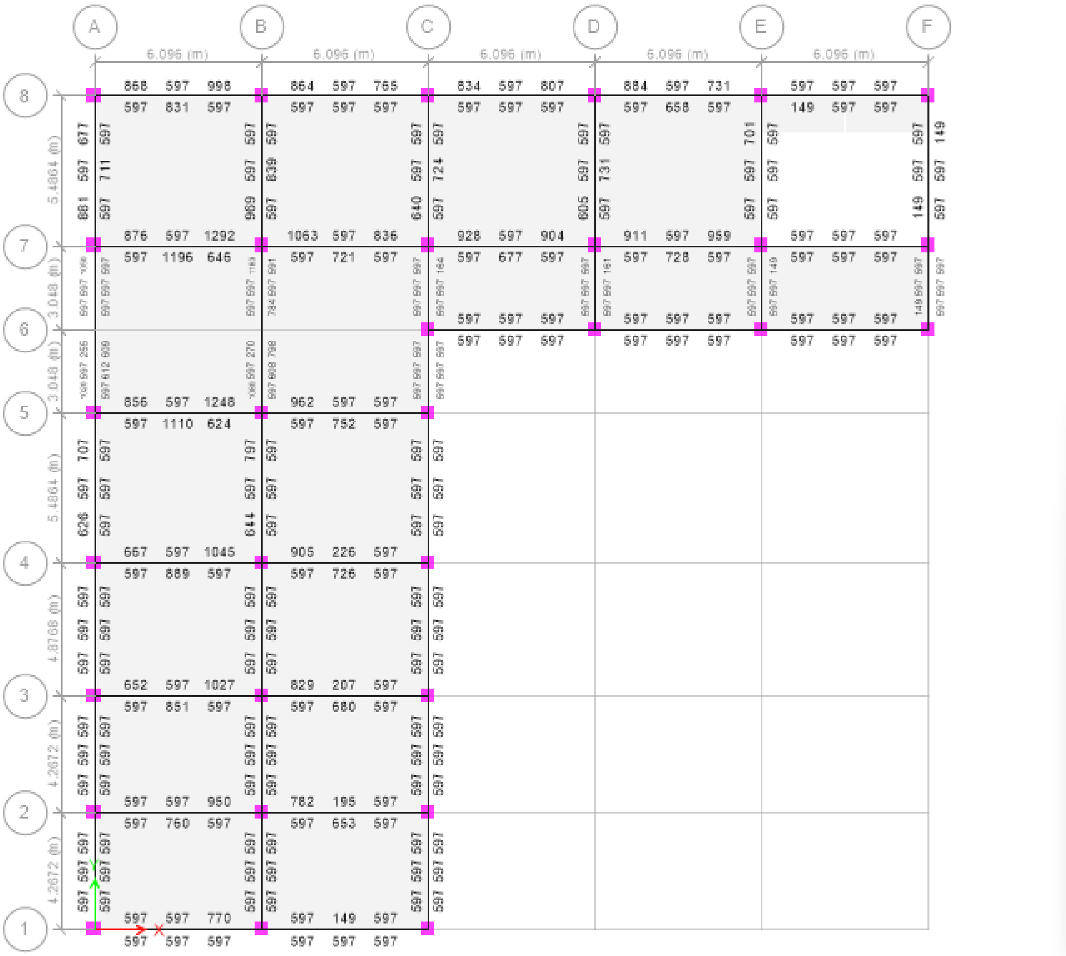


Fig. 3.3: Longitudinal Reinforcement Area of 1st floor beam

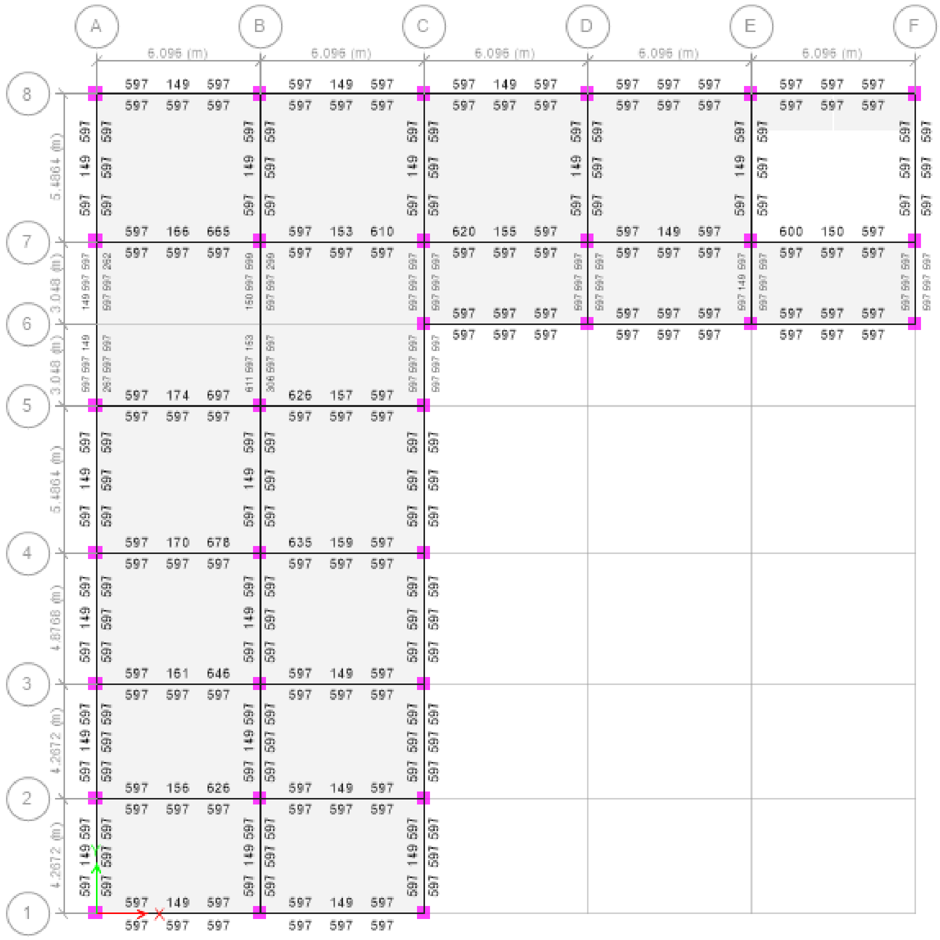


Fig. 3.4: Longitudinal Reinforcement Area of 2nd floor beam

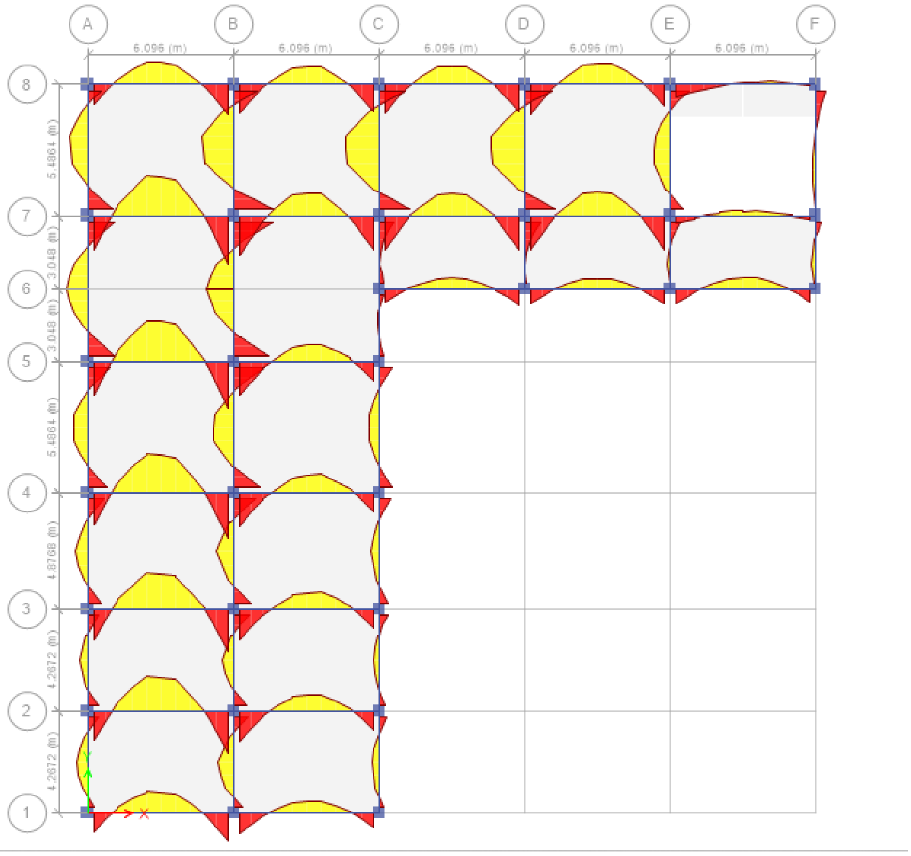


Fig. 3.5: Bending moment diagram

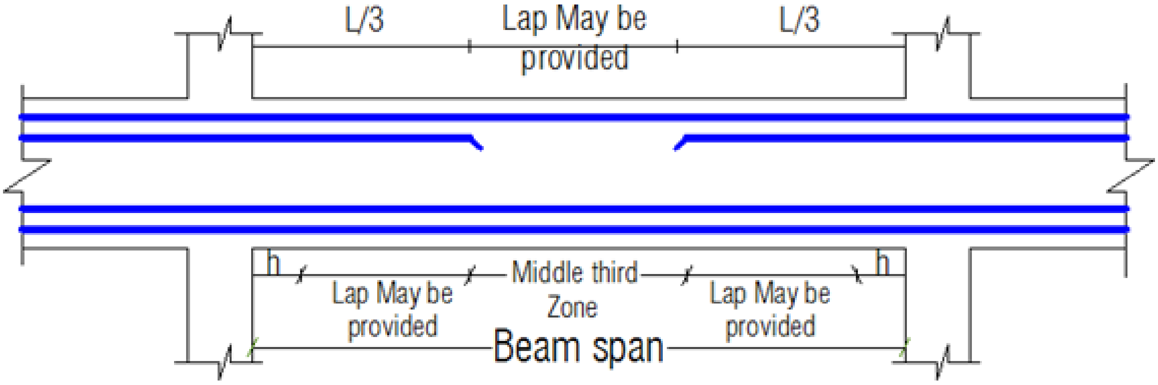


Fig. 3.6: Lap position

Table 3.1: Beam details

Beam of Roof				
Beam No	**Dimension**	**Bottom Rebar**	**Top Rebar**	**Stirrups**
B1	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B2	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B3	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B4	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B5	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B6	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B7	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B8	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B(A)	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B(b)	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B(c)	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B(d)	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B(e)	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c
B(f)	12’’x18’’	2# 16mm Dia	2# 16mm Dia	10mm @ 8" c/c

3.5 Design of Column and detailing.

In a structural model, ETABS takes into consideration a number of important aspects while designing columns. It starts by assessing the axial loads and moments that are affecting the columns, which are essential for figuring out how strong and stable they are. Dead loads, live loads, are among the loads that ETABS examines in order to determine how they affect column performance. Furthermore, the program considers the cross-sectional area, reinforcing details, and column stiffness and buckling capacity, all of which affect the column's resistance to compression and bending. ETABS employs pertinent design regulations and takes into account slenderness effects to guarantee that the column satisfies performance and safety requirements. ETABS helps structural engineers in designing columns for buildings in a way that is both efficient and complies with codes by combining all of these factors.

ETABS. These detailed drawings ensure that the design satisfies structural requirements and allows for perfect execution throughout construction by providing specific information on column dimensions, reinforcing configurations, and bar sizes.

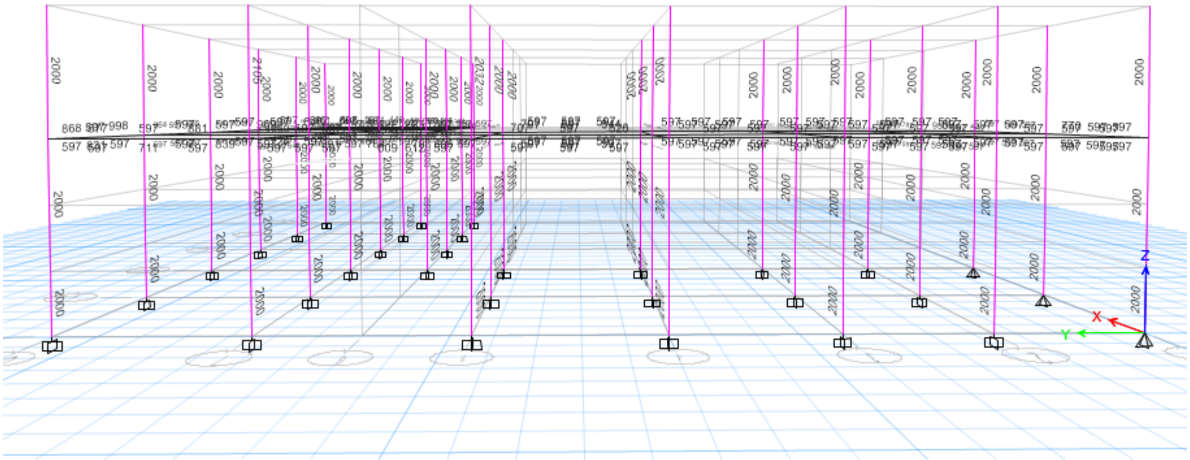


Fig. 3.7: Longitudinal Area Reinforcement of Column

Table 3.2: Detailed of Ground to roof column

Columns at Basement to Ground Floor			
Column No.	Size of Column	Main Reinforcement	Lateral Ties
1	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
2	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
3	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
4	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
5	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
6	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
7	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
8	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
9	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
10	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
11	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
12	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
13	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
14	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
15	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
16	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
17	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
18	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
19	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
20	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
21	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
22	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
23	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
24	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
25	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
26	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
27	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
28	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
29	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
30	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c
31	15"x15"	8# of 16mm dia	10mm @ 5"/10"c/c

3.6 Design of Foundation and detailing.

The design of isolated footings in ETABS takes into consideration a number of variables to ensure structural stability and obeying to design guidelines. The soil carrying capacity is a crucial factor that influences the size of the footing and the need for reinforcement. The footing load from columns, including dead, live, and other applied loads, is evaluated by ETABS and distributed to guarantee sufficient support while staying within soil restrictions. It also takes into account the shear pressures and moments at the base, especially when comparing to the bending and punching shear requirements. The program makes sure that settlement stays within reasonable bounds while assessing the footing depth and reinforcement to withstand bending forces. The design is optimized and compliance with local construction rules and safety laws is ensured by taking into account parameters such as concrete strength, footing shape, and dimensions and all detailing mention in Fig. 3.8 and Table 3.3.

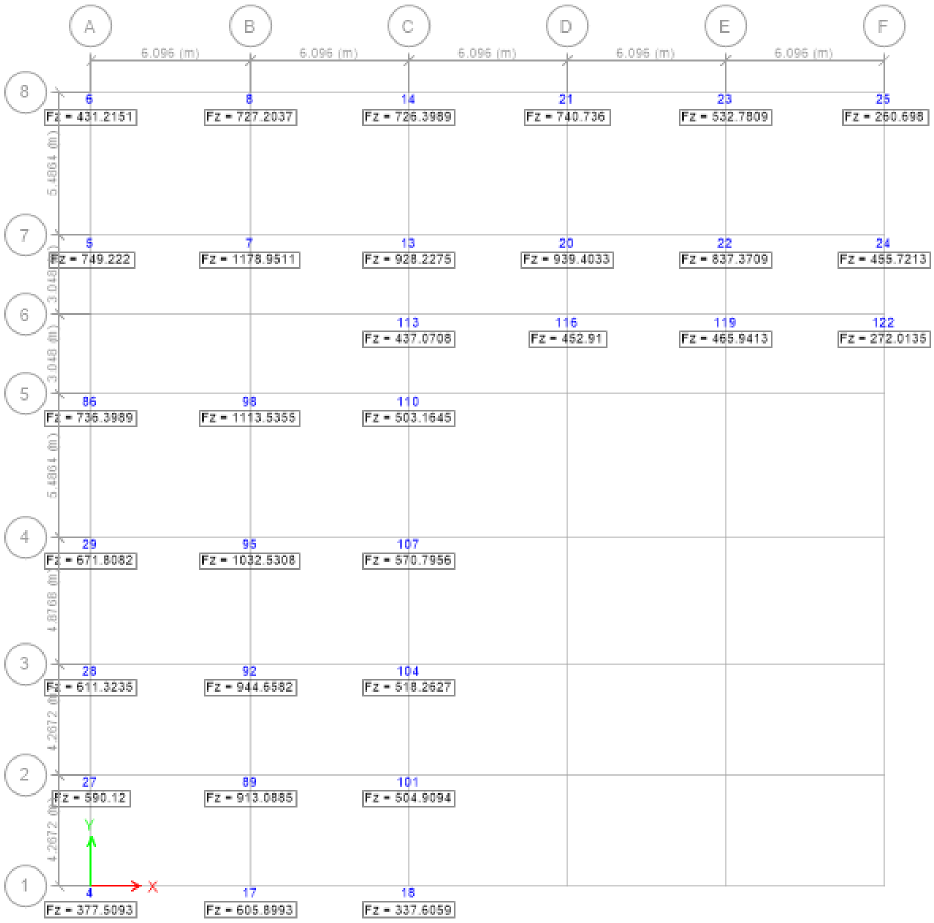


Fig. 3.8: Footing load

Table 3.3: Final detailing of footing

NO. OF COLUMN	TDL (KIP)	TLL (KIP)	QA (KSF)	Square Column Size (Inch)	Final Detailing
4	60.62	5.51	3	20	Footing Size 5' x 5' x 17.5" and both direction #6 @ 13inch C/C
10	94.76	12.946	3	20	Footing Size 6' x 6' x 16.5" and both direction #9 @ 11inch C/C
8	118.249	23.968	3	20	Footing Size 7' x 7' x 16.5" and both direction #9 @ 14inch C/C
5	149.053	37.883	3	20	Footing Size 8' x 8' x 16.5" and both direction #9 @ 13inch C/C
3	178.809	59.332	3	20	Footing Size 9' x 9' x 18.5" and both direction #9 @ 0inch C/C
1	189.313	59.733	3	20	Footing Size 10' x 10' x 18.5" and both direction #9 @ inch C/C

3.7 Design of Staircase and detailing

To ensure both safety and functionality, a number of structural and load considerations are crucial when designing a staircase in ETABS. To satisfy architectural specifications, ETABS will examine the staircase's geometry, taking into account the rise, run, and overall slope. It takes into consideration the strength and stiffness of the materials, like steel or concrete, in order to account for their structural qualities. In order to comply with architectural rules, load considerations must take into account both dead loads (like the structure's self-weight) and living loads (like the weight of people and moving things on the steps). Whether the staircase is cantilevered, supported at both ends, or resting on intermediate landings, the software also assesses boundary conditions and support kinds, as shown in Fig. 3.9.

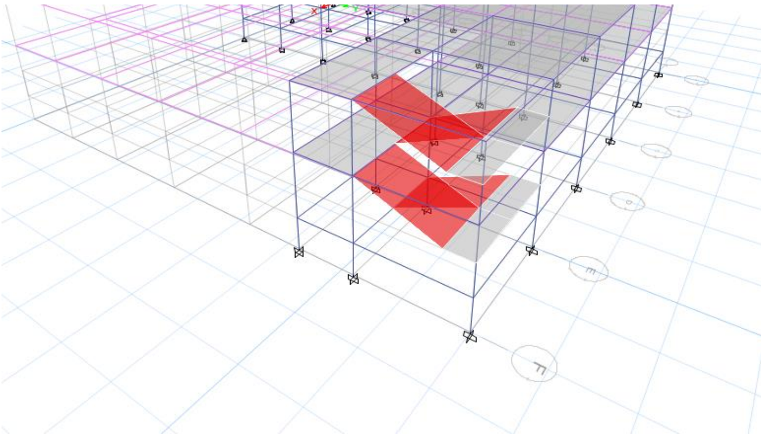


Fig. 3.9: Stair view from ETABS

3.8 Summary

This project involved designing the structural components of a G+1 building, such as footings, slabs, columns, beams and stairs, using ETABS. The safety and serviceability of every component has been ensured by careful modelling, analysis, and reinforcement in compliance with applicable design codes. AutoCAD then provided clear and accurate drawings of the designs, complete with labels, reinforcement layouts, and dimensions. Because of this integrated approach, the design was safe for practical implementation and the structure's stability and adherence to code requirements were verified.

Chapter 4
Cost Estimation And Gantt Chart

4.1 Introduction

In construction, a Bill of Quantities (BOQ) is crucial because it lists all the resources and materials needed for every structural component, particularly for a G+1 (ground floor plus one) building. In the BOQ, the concrete and reinforcement requirements for each major structural component slabs, beams, columns, isolated footings, and stairs are broken down. This distinction guarantees structural integrity by allowing for clear budgeting and ensuring that materials meet design specifications. This is a thorough examination of every component in the BOQ, in table… is covering the requirements for concrete, reinforcement and the cost estimation of the building as a summary of Slab, Beam, Column, Footing and staircase, and summary of all mentioned in Table 4.1.

4.2 Slabs

Slabs are horizontal components that transfer loads to beams and columns to form the roof and floors. Based on the area and thickness of the slab, the BOQ for slabs specifies concrete in cubic meters, The BOQ typically specifies M25 grade concrete, which strikes a balance between strength and affordability. For concrete requirement 1359 cement of bags 1655 cubic feet (CF) of sand 3300 Cf of aggregate and 23597 liters of water and it is cost estimated about $4702.

Reinforcement in slabs is listed separately, detailing the type, diameter, and quantity of steel bars. Based on the span and load-bearing requirements of the slab, reinforcement is measured in tons and it is required is 9 tons and cost estimated is $6375.

Commonly, slabs use a steel grid layout with main bars and distribution bars spaced approximately 150–200 mm apart, depending on the load. The BOQ specifies these details to ensure tensile strength, which concrete alone cannot provide.

4.3 Beams

Beams transfer loads from slabs to columns and are vital in handling bending and shear forces. The BOQ determines the amount of concrete needed based on the length and cross-sectional area of the beam. For instance, A beam at 1st floor which has a dimension of 0.3 × 0.45 × 4.5 = 0.6 cubic meters of concrete are needed to construct a beam that is 5 meters long and has a cross-section 0.3 × 0.45 m. Because of its compressive strength, which counteracts bending moments, M25 grade concrete is frequently specified. For the concrete it is needed 1343 cement bags 1632 cubic feet (CF) of sand 3262 CF of aggregate and 23319 liters of water therefore the estimated cost for concrete is almost $9800.

The reinforcement BOQ for beams provides details about the main tension bars, compression bars, and stirrups. Tension bars are placed at the bottom to counteract tensile stress, while compression bars may be added at the top. For a standard G+1 beam, most common bars have been used are two bar of 16mm in diameter, while stirrups (smaller bars wrapped around the main bars to resist shear) are typically 10mm in diameter, spaced at 150mm intervals. Reinforcement weight calculations consider the length and diameter of each bar, ensuring beams can handle both bending and shear stresses without excessive deflection or cracking. And the reinforcement needed for beam is 11.5 ton and cost estimated about $10,355.

4.4 Columns

Columns are essential vertical structural elements that transfer loads from the upper floors to the foundation. The Bill of Quantities (BOQ) for columns calculates both concrete and reinforcement quantities, ensuring the column can withstand compressive and lateral forces.

Concrete in columns is calculated based on the column's cross-sectional area and height. For example, consider one of the columns which is a square cross-section measuring 0.48 meters on each side and a height of 4 meters. The concrete volume for this column can be calculated as:

Concrete volume=area x height = (0.38 m×0.38 m) × 4 m= 0.5772cubic meters.

In the BOQ, the concrete volume has been used with the grade of concrete M25 which depends on the load requirements and structural safety considerations. To cast the column, it was needed 558 cement bags 665.43 cubic feet (CF) of sand 1330.86 Cf of aggregate and 9686.88 liter of water and for the cost estimation is about $4063.

The **reinforcement** in the column is specified separately in the BOQ. This typically includes longitudinal bars, which resist axial loads, and lateral ties (or stirrups) that prevent buckling of the longitudinal bars. For a 0.38 m×0.38 m column, the BOQ might specify:

- The main reinforcement bar was used is 16mm diameter.
- Ties of 10mm diameter spaced 150mm apart.

The total quantity of reinforcement (measured in kilograms or tons) is calculated based on the number of bars, their lengths, and diameters. For example, the BOQ might list the total weight of reinforcement required for the column, accounting for the specific bar lengths and the reinforcement required for each section of the column. This ensures that the column can safely transfer vertical loads without risk of failure. Therefore, the total quantity of reinforcement in tons is 10.45 ton and the estimated cost being $7402.

4.5 Isolated Footings

Isolated footings, also known as pad footings, are used to support individual columns and distribute the load to the soil. The BOQ for isolated footings details both **concrete** and **reinforcement** requirements based on the footing's dimensions and the column load it is designed to support.

Concrete for isolated footings is calculated similarly to other elements but focuses on the footprint of the footing, which typically has a square or rectangular shape. For example, let’s consider a rectangular footing with dimensions 1.75 meters by 1.75 meters and a depth of 0.6 meters. The concrete volume required for this footing is calculated as:

Concrete volume=length x width × depth = 1.75m × 1.75m × 0.6 m=2.4 cubic meters.

M25 concrete would typically be specified, as this grade provide the necessary strength to withstand the forces transmitted by the column and the pressure from the underlying soil. To cast the footing the requirements were 1018 cement bags 1227 Cf of sand 2441 Cf of aggregate and 17684 liters of water for that the estimated cost is about $7420.

Reinforcement for footings is crucial to ensure the footing can resist bending moments and shear forces, especially in the top and bottom areas of the footing. The BOQ would list reinforcement as follows:

Reinforcements in Both Directions commonly was used 12mm dia. @200mm c/c. and the total quantity of reinforcement required was 2 ton. For the estimation of the cost is $1417

4.6 Staircase

Stairs provide vertical circulation between floors, transferring loads to supporting structures like beams and columns. The BOQ determines the volume of concrete needed based on the dimensions of the stair flight, tread, riser, and landing. For example, a staircase with dimensions of 6 m (width) × 0.15 m (riser height) × 0.3 m (tread depth) requires approximately 1.8 cubic meters of concrete for a single flight. M25 grade concrete, known for its compressive strength, is often specified for stairs to resist loads effectively. For this concrete, approximately 158 cement bags 288 cubic feet (CF) of sand 576 CF of aggregate, and 4972 liters of water are required, estimating a total concrete cost of around $889.

The reinforcement BOQ for stairs details the main reinforcement bars, distribution bars, and additional support at the landings. Typically, main reinforcement bars of 12mm diameter are placed along the span of the stairs, while distribution bars of 8mm diameter are used perpendicularly to ensure structural integrity. The spacing of the distribution bars is often 200mm on center. Reinforcement weight calculations account for bar length and diameter to ensure the stairs can handle both bending and shear forces safely. In total 2 tons of reinforcement are required for the stair structure, with an estimated cost of $1,370.

Table 4.1: Summary of BOQ

Estimation		Estimated
A	Estimation of Foundation and Footing	1,124,124.00৳
B	Estimation of Column	1,375,846.00৳
D	Estimation of Floor Beam	2,153,091.00৳
E	Estimation of slab	1,329,158.00৳
F	Estimation of Stair	271,038.00৳
G	Estimation of labor	991,300.00৳
H	Estimation of Brick masonry, Plaster, & Painting work	1,222,356.00৳
I	Estimation of Septic Tank	265,200.00৳
	Grand Total =	8,732,113.00৳

4.7 Introduction Of Gantt chart

For construction projects like a G+1 school building, a Gantt chart is an essential project management tool since it provides a clear, visual timeline of all the important tasks involved in the project. It makes it possible for engineers, construction crews, and project managers to effectively plan, oversee, and coordinate operations. A Gantt chart helps make sure that every stage of work is in line with the overall project goals and deadlines by showing the length of time and order of structural tasks including excavation, footing, column casting, and slab building. This method reduces delays and maximizes resource utilization, which helps to improve workflow, adhere to budgets, and finish projects on schedule in Table 4.2.

Table 4.2: Gantt chart

Task No.	Task Description	Duration	Start Date	End Date
1	Foundation Excavation	2 weeks	Day 1	Day 14
2	Isolated Footing Construction	3 weeks	Day 15	Day 35
3	Column Casting (Ground Floor)	2 weeks	Day 36	Day 50
4	Ground Floor Beam Construction	3 weeks	Day 51	Day 71
5	Ground Floor Slab Casting	2 weeks	Day 72	Day 86
6	Staircase Construction	1 week	Day 87	Day 93
7	1st Floor Column Casting	2 weeks	Day 94	Day 108
8	1st Floor Beam Construction	3 weeks	Day 109	Day 129
9	1st Floor Slab Casting	2 weeks	Day 130	Day 144
10	Septic Tank Construction	2 weeks	Day 50	Day 64
11	Plastering (All Walls)	4 weeks	Day 145	Day 172
12	Final Staircase Work	1 week	Day 173	Day 179

4.8 Summary

A G+1 school building's Bill of Quantities (BOQ), which ensures effective resource allocation and structural integrity, lists the materials, reinforcing, and cost estimates for important structural components. 1359 cement bags, 1655 cubic feet of sand, and nine tonnes of steel are needed for slabs, which cost $4702 for concrete and $6375 for reinforcement. 1343 cement bags, 1632 cubic feet of sand, and 11.5 tonnes of steel are required for beams; these items cost $9800 and $10,355, respectively. 558 cement bags, 665 cubic feet of sand, and 10.45 tonnes of steel which cost $4063 and $7402—are needed for columns. Footings require 2 tonnes of steel, 1018 cement bags, and 1227 cubic feet of sand, which cost $7420 and $1417, respectively.158 cement bags, 288 cubic feet of sand, and two tonnes of steel are needed for the stairs. The cost of the concrete is $889, and the reinforcing is $1370. A Gantt chart also arranges these tasks into a visual schedule, guaranteeing effective project planning, coordination, and timely completion.

Chapter 5
DESIGN AND CONSIDERATION OF SEPTIC TANK

5.1 Introduction

An underground wastewater treatment system called a septic tank is frequently utilized in places without centralized sewer access. Anaerobic bacteria can decompose organic material in a watertight chamber (often made of concrete, fiberglass, or plastic) that separates solids from liquids. The tank's partially treated liquid, known as effluent, travels to a drain field where it passes through soil to undergo more filtration. A proper design includes selecting long-lasting materials, calculating the appropriate tank size based on household water usage, and making sure the tank is far enough away from water sources to prevent contamination. Regular pumps and inspections are advised every two to five years, as maintenance is crucial. Local laws provide requirements for layout, positioning, and installation in order to safeguard groundwater quality and public health.

5.2 Component of Septic tank

Several essential parts of a septic tank combine to treat wastewater from homes. Wastewater from the house is directed into the tank via an inlet pipe, where the liquids and solids start to separate. Lighter substances, such as fats and oils, float to the top of the tank to produce a scum layer, while heavier contents settle at the bottom to form a sludge layer. Water that has been partially treated is stored in the effluent layer between them. To ensure that effluent flows easily from the tank into the drain field for additional treatment, baffles and tees are placed close to the input and outflow pipes to help manage the flow and avoid clogs. Additionally, the tank has access ports, also known as risers, which enable routine sludge and scum pumping, maintenance, and inspections.

5.3 Design Consideration of Septic Tank

Important recommendations are provided by the Bangladesh National Building Code (BNBC, 2020) for the design of septic tanks to ensure their safe and efficient handling of wastewater and To design a septic tank for **210 users**, where each classroom accommodates 25 students with a space requirement of 16 sq ft per student, the primary considerations will revolve around user count, daily water usage per person, and wastewater retention time. Below is the step-by-step process to determine the size and design features of the septic tank:

How much water the household uses each day should determine the size of the tank, which should have enough capacity to keep wastewater for one to two days so that the solids can settle and decompose. Strong, waterproof materials like concrete, fiberglass, or plastic should be used to build tanks in order to stop leaks and safeguard groundwater. In order to enhance cleaning, tanks are usually separated into two areas by walls or baffles.

The outlet pipe should be a little lower to permit wastewater to flow properly, and the inlet and outlet pipes should be positioned with fittings to control flow smoothly. In order to release gases, avoid unpleasant odors, and promote bacterial activity, proper ventilation is required. In order to facilitate routine pumping and inspection, the (BNBC, 2020) also needs access points, or risers; these must be well sealed to prevent contamination. The design of the drain field, where wastewater exits the tank, should take into account the soil's capacity to absorb water and should be situated at a safe distance from water sources, buildings and wells.

The septic tank should be positioned deep enough to prevent freezing problems and at a safe distance from buildings and water sources. To maintain the tank functioning properly and safeguard the public's health, routine maintenance is advised, such as pumping out solids every two to five years. And drawing mentioned in Fig. 5.1 and Fig. 5.2

5.4 Design of Septic Tank.

Population, P =	**210**	persons	Length, L =	6.008	m
Per capita water use, q =	**25**	lpcd	Width, W =	2.003	m
Cleaning cycle, N =	**1**	years	Liquid depth, H =	2.210	m
Design temp, T =	25	°C			
Solids accumulation rate, C =	0.06	m^3/person/yr			
Scum zone					
V_{sc} =	5.04	m^3	'd_{sc} =	0.419	m
Sedimentation zone					
t_h =	0.384	days	'd_h =	0.375	m
V_h =	2.016	m^3			
Digestion zone					
t_d =	42.3	days	'd_d =	0.369	m
V_d =	4.443	m^3			
Sludge zone					
V_{sl} =	12.6	m^3	'd_{sl} =	1.047	m
Total					
V =	24.099	m^3	'd =	2.210	m
'a =	**3**		A =	12.0330	m^2
'b =	**1**				
'c =	**1**				
'x =	2.002749972				

Comprehensive specifications and design guidelines for the septic tank are provided in the Appendix for detailed reference.

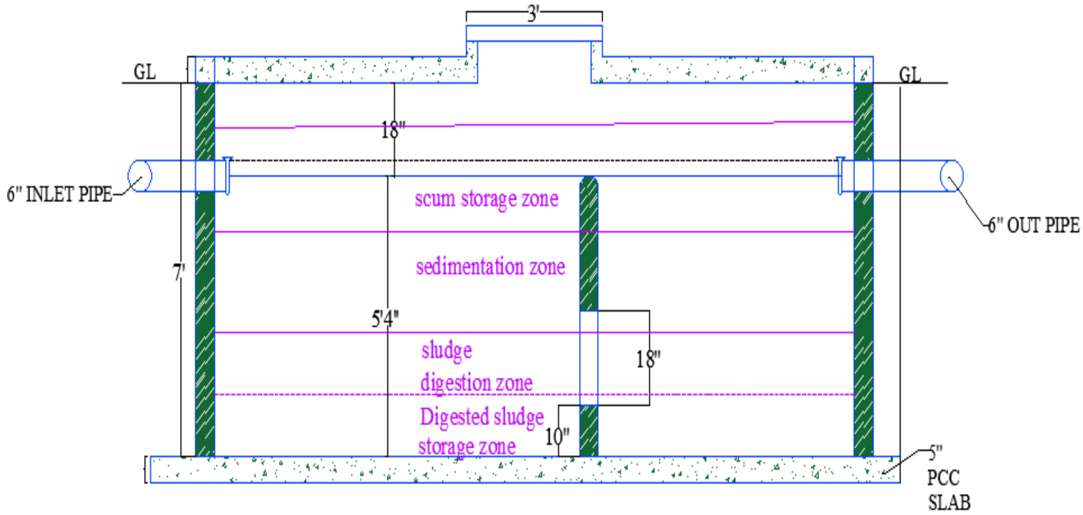


Fig. 5.1: Section view of Septic tank

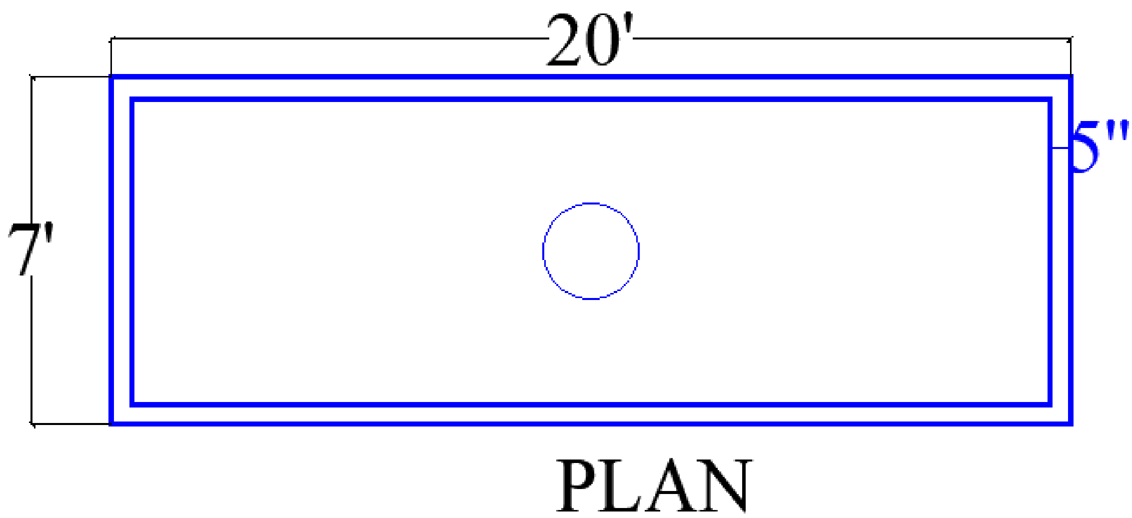


Fig. 5.2: Plan of septic tank

5.5 Summary

An underground system called a septic tank is used to treat wastewater in places where sewers are not available. It separates trash into three layers: effluent (treated liquid), sludge (heavy solids), and scum (oils and fats). After passing through a drain field, the effluent undergoes further filtration. To prevent leaks, the tank is constructed from sturdy materials like fiberglass or concrete, has baffles and maintenance access ports, and is scaled according to home water demand. In order to release gasses and prevent odors, proper ventilation is required. The tank needs to be deep enough to avoid freezing and placed away from structures, water sources, and wells. Maintaining the system and safeguarding the public's health requires routine maintenance, which includes pumping out sludge every three to five years.

Chapter 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This capstone project focuses on designing a two-story primary school building by integrating structural and architectural principles. The structural design was carried out using ETABS to analyze and design key elements such as beams, columns, and slabs, ensuring they meet safety and code requirements. AutoCAD and Revit were used to create detailed plans and elevations, providing a clear visualization of the building layout.

In addition to the structural analysis, cost estimation was performed using Excel to prepare the Bill of Quantities (BOQ), covering materials and construction costs. This step ensures the project is both practical and economical.

The environmental aspect of the project involved designing a septic tank to handle the wastewater needs of the school. The design adheres to BNBC 2020 standards, considering factors such as capacity, dimensions, and proper disposal systems to promote sustainability.

This project allowed students to apply their theoretical knowledge in a practical setting while improving their skills in structural analysis, software tools, and cost estimation. It also provided an opportunity to address real-world challenges in designing safe, functional, and sustainable buildings

6.2 Recommendation

For future projects, it is recommended to continue using ETABS for structural design, as it is effective for analyzing and designing structural elements. To improve the detailing process, AutoCAD can be used alongside Revit to ensure better coordination between structural and architectural plans. Revit is also highly useful for creating detailed architectural layouts, and its visualization tools could be explored further to present more realistic designs.

For cost estimation, while Excel has been effective, using more advanced tools or integrating cost estimation with Revit or other BIM software can make the process more accurate and efficient. This would reduce manual errors and save time.

It is also important to maintain a consistent workflow between the tools used, such as ETABS, AutoCAD, and Revit, to avoid errors and improve the overall design quality. Additionally, regular training on software tools and updates on building codes like (BNBC, 2020) should be prioritized to ensure compliance and the best outcomes in future projects

Reference

BNBC. (2020). *Bangladesh National Building Code*. HBRI.

Education, D. of P. (2018). *Infrastructure Plan and Planning Guidelines for primary school (Part-A)*. Directorate of Primary Education.

B. Gazette, "Government of the People's Republic of Bangladesh Ministry of Housing and Public Works BANGLADESH NATIONAL BUILDING CODE 2020," 2021.

ACI Committee 318. and American Concrete Institute., Building code requirements for structural concrete (ACI 318-11) and commentary. American Concrete Institute, 2011.

APPENDIX A

DESIGN OF SEPTIC TANK

Design of a septic tank to serve a primary school of 210 persons who produce 25 lpcd of wastewater and the tank is to be desludged every two years.

Solution

P = 210 persons

N = 5 years

C= 0.04 m3/person/yr.

T= 25 °C

q = 25 lpcd.

Volume calculation (m^3)

Sedimentation Zone V_h

T_h= 1.5-0.3 log (Pq)

= 1.5-0.3 log (210 * 25) = 0.38days
The volume required by Sedimentation Zone

$V_h=10^{-3}(Pq)*t_h$

$= 10^{-3} \times (210 \text{ X } 25) \times 0.38 = 2.016 \text{ m}^3$

Sludge Digestion Zone V_d

Assuming a design temperature of 25°C

$T_d= 30(1.035)^{35-T}= 30(1.035)^{35-25} = 42.3$ days

$V_d=0.5*10^{-3} *P*t_d = 0.5 \times 10^{-3} \times 210 \times 42.3 = 4.4 \text{ m}^3$

Sludge Zone

V_{sl} = CPN = 0.04 x 210 x 5 = 42m^3

Scum Zone (Sc)

$V_{sc}= 0.4V_{Sl} = 0.4 \times 12.6 = 16.8 \text{ m}^3$

Total Volume $V = V_{sc}+ V_h+ V_d+ V_{sl}$

V = 16.8+2.016+4.4+42= 65.3 m^3

Depth Calculation

Cross-sectional area A = 23.4 m^2

The maximum depth of sludge $d_{sl} = V_{sl} /A$ = 42/ 23.4 = 1.797 m

The maximum submerged scum d_{ss} = 0.4*V_{sl} / A = 0.4 x 42/ 23.4 = 0.72 m

Sludge clear depth = 0.3 m is adopted

Total clear space = 0.3 + 0.075 = 0.375m

Depth of digestion zone d_d = V_d / A = 4.4 / 23.4 = 0.19 m

Depth required for sedimentation = Vh / A = 2.016/ 23.4 = 0.086 m < 0.375 m

d_h = 0.375 m is adopted

Total effective depth = 1.797 + 0.72 + 0.19 +0.375 = 3.080 m

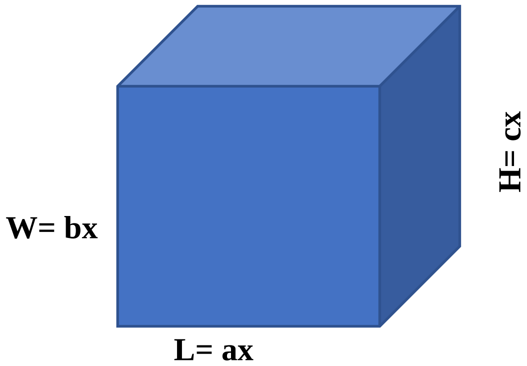
The suitable overall internal dimension of the septic tank can be chosen as

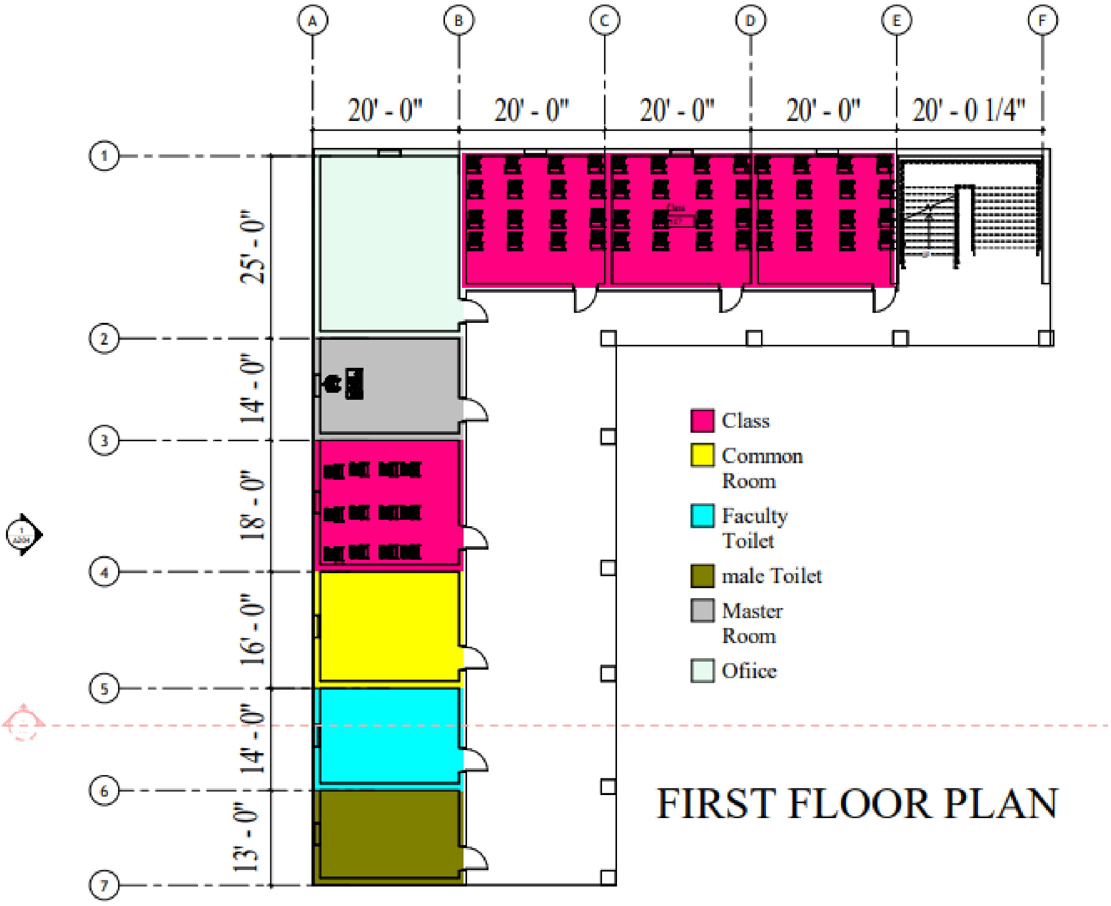
6 m x 2.1 m x 2.21 m

V= L * W * H

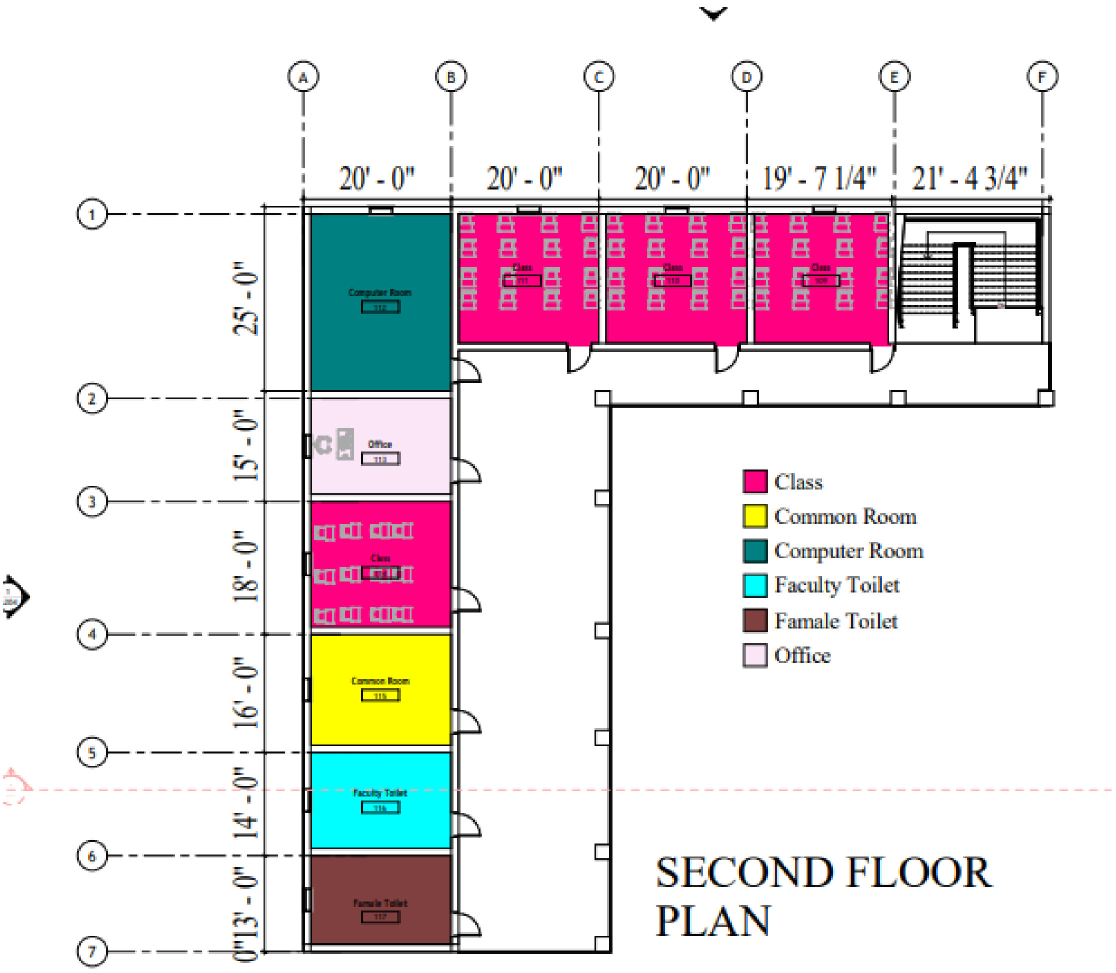
X= $\sqrt[3]{v/abc}$

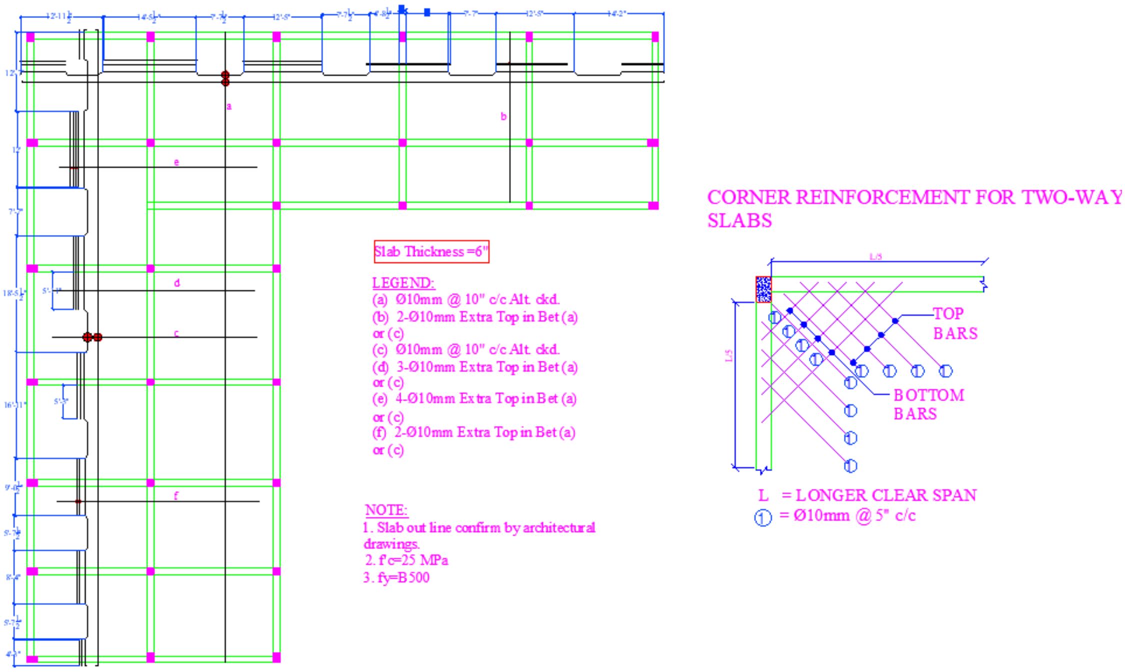
A= abx²



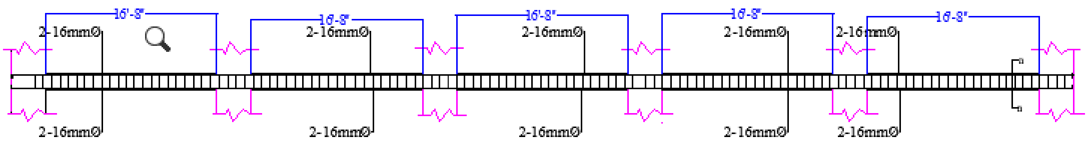


FIRST FLOOR PLAN

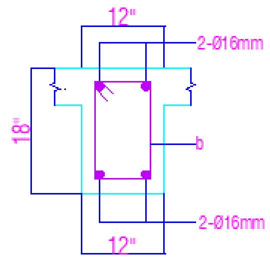




Slab reinforcement details

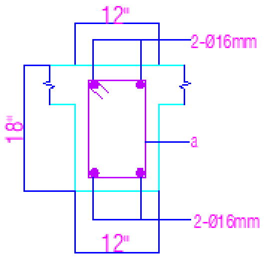


Longitudinal beam



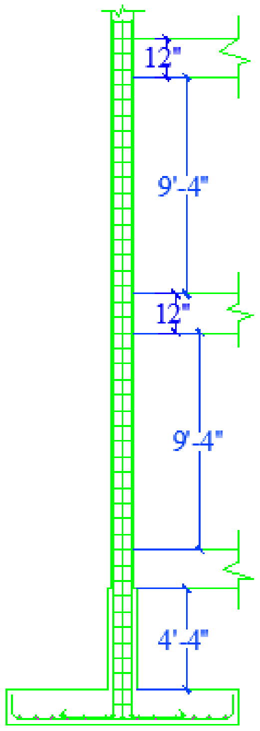
1ST and ROOF FLOOR BEAM SECTION 1a

Scale: $\frac{1}{2}$"=1'-0"



PLINTH BEAM SECTION

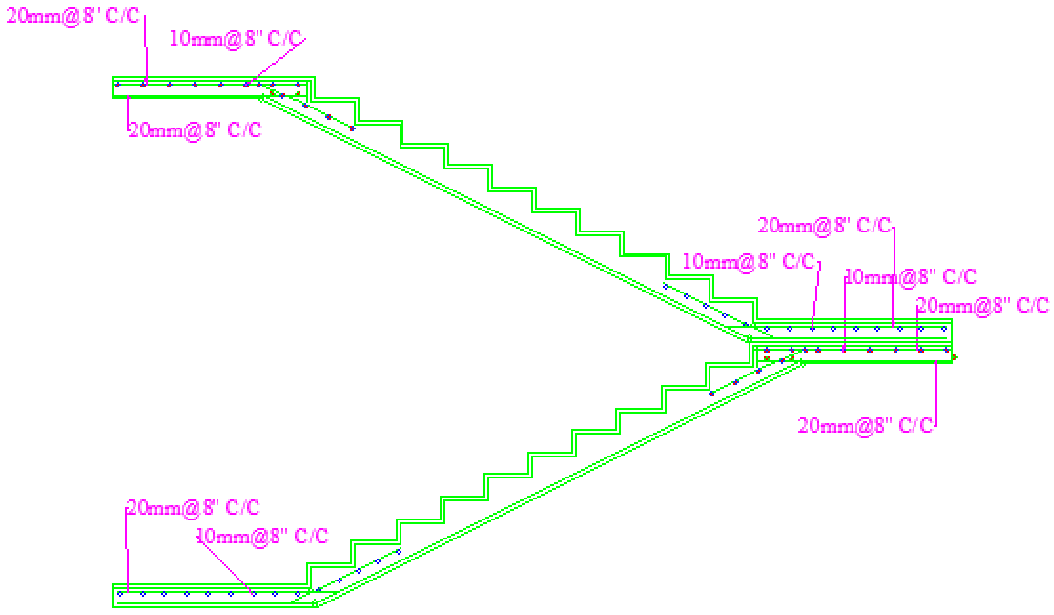
Scale: $\frac{1}{2}$"=1'-0"



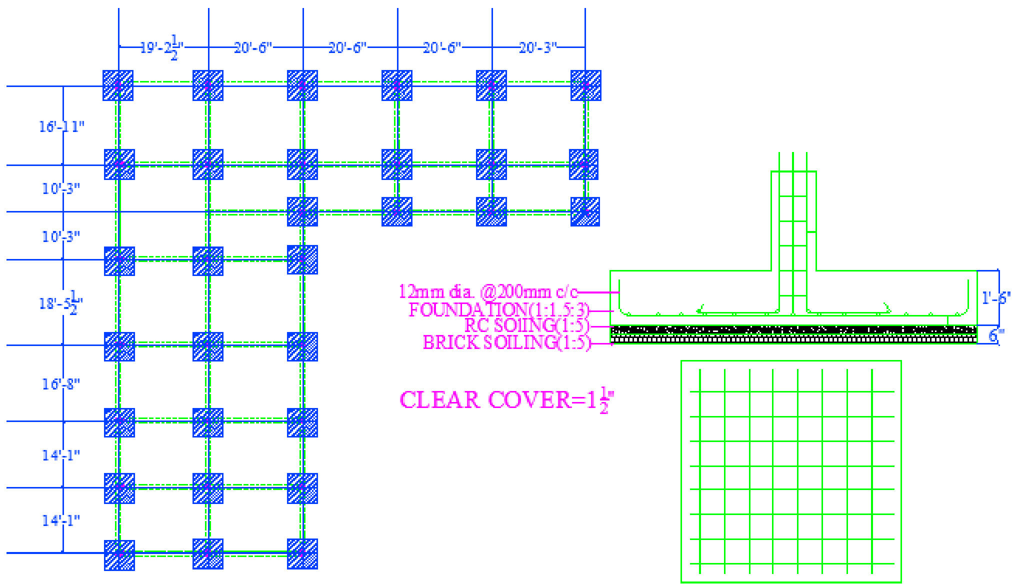
Long section for typical column

COLUMN SCHEDULE		
COLUMN ID.	C1(EXTERNAL)	C2(INTERNAL)
COLUMN NO.	16	15
1TH FLOOR TO TOP CLEAR COVER=1½"	15" × 15" 8-Ø16mm 3R-Ø10 @ 5"/10" C/C	15" × 15" 8-Ø16mm 3R-Ø10 @ 5"/10" C/C
GF FLOOR TO 1TH FLOOR CLEAR COVER=1½"	15" × 15" 8-Ø16mm 3R-Ø10 @ 5"/10" C/C	15" × 15" 8-Ø16mm 3R-Ø10 @ 5"/10" C/C

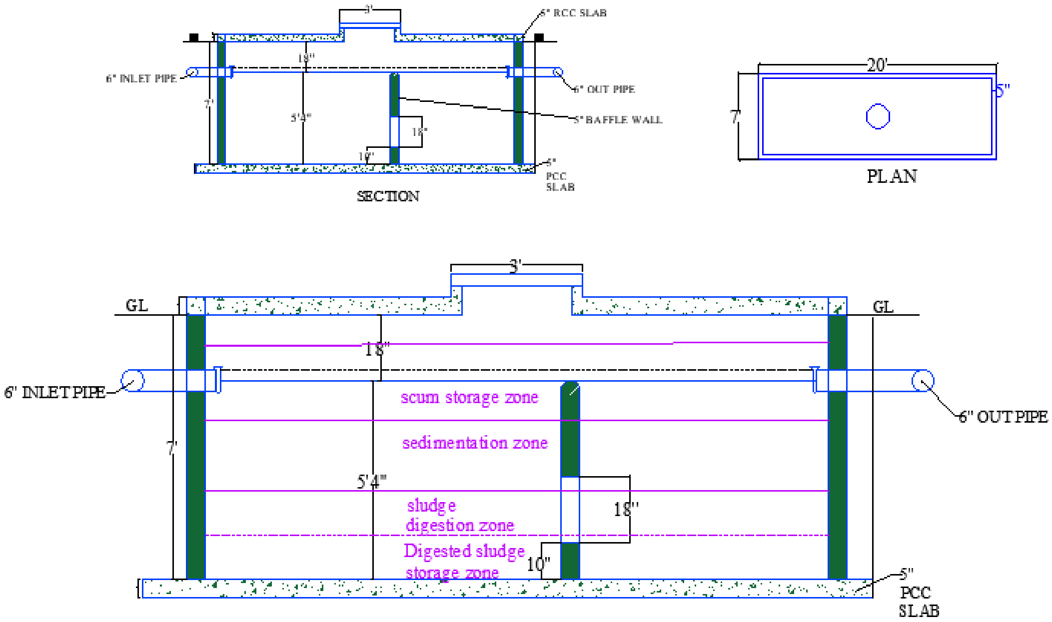
Column reinforcement



Stair
Reinforcement



Foundation layout and Footing reinforcement


3'
6" RCC SLAB
18"
6" INLET PIPE
6" OUT PIPE
5" BAFFLE WALL
7'
5'4"
18"
10"
5"
PCC
SLAB
SECTION
20'
5"
7'
PLAN
3'
GL
GL
18"
6' INLET PIPE
6" OUT PIPE
scum storage zone
sedimentation zone
7'
5'4"
sludge
digestion zone
18"
Digested sludge
storage zone
10"
5"
PCC
SLAB

Septic tank

List of Deliverables

No.	Deliverable	Timeline	Format	Date of Submission
Level-4/Term-1				
1	Project Proposal	Week 1-3	Writeup	Not applicable.
2	Detail planning, methodology, data/survey requirement, stakeholder identification, and identification of external expert requirement, Gantt Chart	Week 4-5	Writeup, Presentation	18/08/2024
3	Data/survey Summary	Week 6-9	Writeup	20/08/2024
4	Preliminary Analysis and Design	Week 10-12	Writeup	28/08/2024
5	Analysis of Alternatives and preliminary cost estimation	Week 13	Writeup and Presentation	12/09/2024
6	Feasibility Study (Technical, Social, Environmental, Economic and Financial)	Week 14-15	Writeup and Presentation	18/09/2024
Level-4/Term-2				
7	Analysis scheme for detail design	Week 1-2	Writeup	02/10/2024
8	Analysis output	Week 3-4	Writeup	05/10/2024
9	Detail Design Report	Week 5-9	Writeup, Drawings, and Presentation	2/11/2024
10	Final BOQ, and Cost Estimation	Week 10-11	Writeup, and Presentation	20/11/2024
11	Tender Document, Implementation Schedule	Week 12-13	Writeup, Gantt Chart	Only Gantt Chart were submitted at

No.	Deliverable	Timeline	Format	Date of Submission
12	Final Report (Including Ethical aspects, lifelong learning)	Week 14	Writeup and Drawings	08/12/2024
13	Final Presentation	Week 15	Presentation	Presented to supervisor twice a week and the final One presented to examiner board at 18/12/2024

Self-assessment of COs with Knowledge Profile, Complex Engineering Problem Solving and Complex Engineering Activities

COs	Description	Criteria	Justification
CO1 (K6, P1, A1)	Application of modern engineering tools	Applied tools for design, drawings, etc.	Used CAD for design and ETABS for structural analysis, ensuring precision.
CO2 (K7)	Work on a Team	Attendance	Collaborated effectively through regular meetings and task integration. Name: Nur Mohamud Salah. ID: 211-47-438 Name: Osman Bashir Mohamed. ID: 211-47-4390
CO3 (K7, P2, A2)	Alternative analysis presented	Economic, environmental, social, ethical aspects, health and safety considered	Conducted alternative analysis, balancing cost, sustainability, and ethics.
CO4 (K7)	Societal and environmental benefit evaluation	Environmental, social and ethical obligation considered	Incorporated eco-friendly materials and energy-efficient designs. i.e., Fly Ash Concrete, Recycled Steel.
CO5 (K7)	Professional and ethical responsibility	Punctuality based on presentations in the specified weeks	Maintained punctuality, adhered to deadlines, and

COs	**Description**	**Criteria**	**Justification**
			upheld professionalism.
CO6 (P5, A3)	Lifelong learning	Demonstrate the ability to learn new skills (based on the statement in accordance with the lifelong learning in Final report)	Demonstrated the ability to learn new skills, **i.e.,** advanced skills in ETABS, **Building Information Modeling (BIM),** and project management like **Microsoft Project.**
CO7 (A1)	Effective project management – time, financial	Prepared Tender Document	Due to time limitations, incomplete.
		Prepared BOQ	ensuring accurate financial and material planning for the project.
		Show Financial Assessment	Due to time limitations, incomplete
		Show time management skill	Used a Gantt chart to manage project timelines and ensure timely completion.

COs	Description	Criteria	Justification
CO8 (K7)	Communication	Drawing	Created precise technical drawings in A3 paper for clear demonstration of detailing.
		Presentation	Presented the visibility of the project by showcasing its innovative design and functionality.
		Report	i. Design of Slab and detailing. ii. Design of Beam and detailing. iii. Design of Column and detailing. iv. Design of Footing and detailing. v. Design of Stairs and detailing, vi. Design of Septic tank

* K: Knowledge Profile, P: Complex Engineering Problem Solving and A: Complex Engineering Activities