DESIGN OF A TWO-STORED PRIMARY SCHOOL BUILDING IN SAVAR, ASHULIA, 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

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This certifies that the student depicted below completed the Capstone Project named "**DESIGN OF A TWO-STOREY PRIMARY SCHOOL BUILDING IN SAVAR, ASHULIA DHAKA**" under my supervision. It is a prerequisite for the Bachelor of Science in Civil Engineering degree. On September 20, 2025, the work was successfully presented.

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DECLARATION

The dissertation, titled "Design of a two-stored Primary School Building with structural and Environmental Considerations" was completed under the supervision of Mr. Kazi Obaidur Rahman (Assistant professor), 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 Bachelor of Science in Civil Engineering

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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.

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1.1 Proposed Structure

RCC will construct the entire two-story primary school with isolated foundations. With nine classrooms, a common area, a teacher's room, a computer lab, an office, a head teacher's room, a prayer room, and two restrooms, the building measures roughly 185 feet long on the plan and 22 feet high. The layout plan is shown in Figures 1.1 and 1.2.

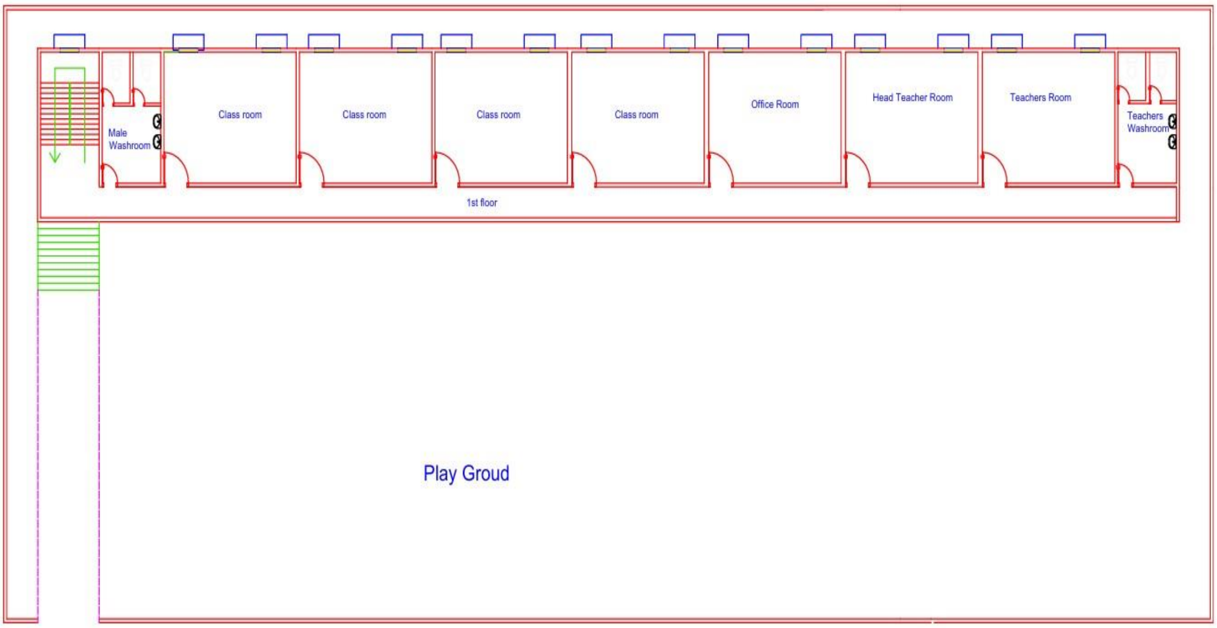


Fig. 1.1: First Floor Plan

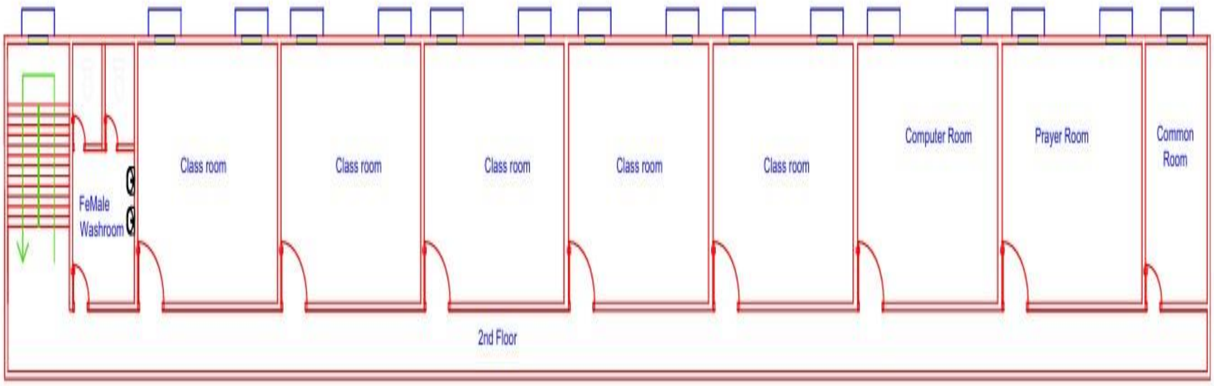


Fig. 1.2: Second Floor Plan

1.2Basic 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 to the infrastructure plan and planning guideline

1. A school's overall open space should not exceed half of its total area. The vacant space could be utilized for laying things, playing, etc.
2. There will be a minimum of four (four) in the classroom, and the restrooms for men and women should be kept apart.
3. The size of the classroom ought to be uniform (Education, 2018).
4. A minimum of one teacher's room and a separate HT room for schools with more than 600 pupils.
5. The classroom and staircase should measure 18 by 22 feet and 18 by 22 feet, respectively.

1.4 Objectives of the Project

1. Structural Design

- To design a safe and stable two-storied primary school building using RCC with an Intermediate Moment Resisting Frame system.

- To ensure structural elements like slabs, beams, columns, footings, and staircases meet safety and serviceability requirements.

2. Compliance with Standards

- To perform analysis and design following the Bangladesh National Building Code (BNBC, 2020) and international practices.

- To apply software tools (ETABS, AutoCAD, Excel) for accurate design, detailing, and estimation.

3. Environmental Considerations

- To design a septic tank system for effective wastewater management, ensuring environmental sustainability and public health safety.

4. Cost Estimation & Project Planning

- To prepare a Bill of Quantities (BOQ) for accurate cost estimation and resource allocation.

- To develop a Gantt chart for systematic project scheduling and time management.

5. Integration of Theoretical & Practical Knowledge

- To connect classroom knowledge of structural engineering with real-world construction practices.

- To gain practical skills in design software, cost analysis, and sustainable construction methods.

6. Sustainability & Functionality

- To provide a functional, durable, and cost-effective educational facility that accommodates classrooms, labs, offices, and common spaces.

- To incorporate eco-friendly materials and ensure long-term usability.

1.5 Outline of Capstone project

Chapter 1: The capstone Project an Overview

Chapter 2: Project codes and resources to be employed

Chapter 3: Output and Structural Elements Design

Chapter 4: Talks about Project Cost Estimation and Project Schedule

Chapter 5: Septic tank design and consideration

Chapter 6: Project Conclusion and Suggestions.

Chapter 2

Design Codes, Structural Design and Requirements

In order to preserve life, limb, health, property, and public welfare, all buildings in Bangladesh must adhere to basic regulations for layout, construction, material quality, use and occupancy, placement, and maintenance, all within acceptable limitations. Regulations about the installation and use of particular tools, services, and accessories associated with or attached to such buildings are likewise in place to achieve the same objective. The specifications and coefficients that will be used in this building's structural design were commonly referred to as (BNBC, 2020). Additionally, (BNBC, 2020) was used to assess Etabs 2020.

2.1 Design code

A) All it is necessary to read all structural drawings with the pertinent architectural drawings.

B) The Bangladesh National Building Code has done design and analysis.

C) For specifications or structural requirements not specified in the drawings or this design report, refer to (BNBC, 2020).

2.2 Foundation and soil

A) The suggestion for a foundation is a footing foundation.

B) Minimum transparent cover = 3.0 inches is recommended.

C) The foundation's depth must match the sketch.

Material properties

Minimum f'c (crushing strength of a 28-day cylinder) 4000 psi for the foundation and column, with a 1:1:2 mix ratio Slabs and beams at 4000 psi with a 1:1:2 mix ratio.

2.3 Lapping Zone of Beam

Lap Length: The minimum lap length required by BNBC (2020) depends on the grade of the concrete, the diameter of the reinforcement bars, and where they are placed (stress or compression zones). Typically, the lap length is a multiple of the bar diameter (for

instance, 40D, where D is the diameter of the bar).
1: The lap length of the 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) to strengthen structural corners and resist concentrations of tension, particularly in seismic zones. More diagonal bars, closely spaced stirrups, and ties for beams, slabs, and column-beam connections are recommended by (BNBC, 2020) as ways to control shear and torsional pressures. As seen in Fig. 2.1, adequate anchorage and minimum lap lengths are required for bars at corners to prevent slippage under load. This reinforcement approach ensures ductility, energy absorption, and structural integrity at important locations to help structures better withstand lateral stresses and prevent cracking or brittle failure.

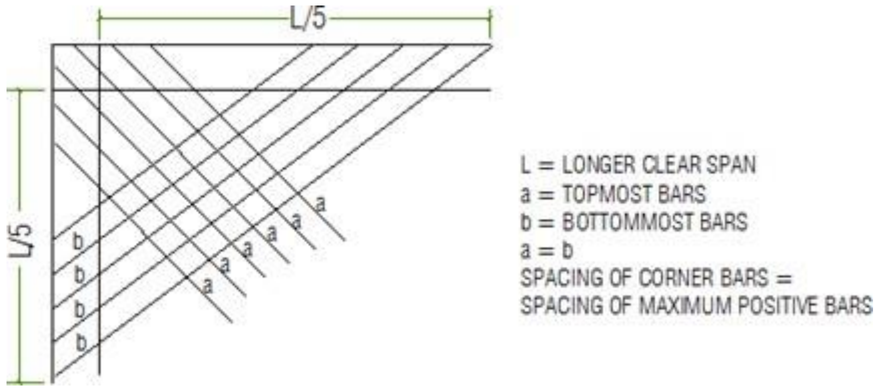


Fig. 2.1: Corner reinforcement

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 4000 psi. The yield strength (fy) of the reinforcement steel is 60,000 psi, as shown in Table 2.1, which guarantees 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	4000	psi	60000 psi
	Pedestal Column	4000	psi	60000 psi
	Grade Beams	4000	psi	60000 psi
	Column	4000	psi	60000 psi
	Beams and Slabs	4000	psi	60000 psi

2.6 Development length

According to the Bangladesh National Building Code (BNBC, 2020), the development length (L d) for reinforcement in beams and slabs is the bare minimum of rebar that must be implanted in concrete in order to avoid sliding and obtain full structural strength. It is computed using the formula. Depending on the strength of the concrete, the type of rebar, and its position, Ld.= ϕ *fy/4*Tb, where ϕ is the bar's diameter, f y is the steel yield strength, and τb τ b is the concrete bond strength. According to BNBC (2020), beams often require longer development lengths and adjustment factors for things like rebar type and top reinforcement placement since they receive larger loads than slabs. By defining suitable anchorage lengths for different types of concrete structure.

2.7 Concrete Clear Cover for Reinforcing Bars

Concrete clear cover is the basic minimum of space between the reinforcing steel bars and the concrete's outside that is required to protect them from fire, corrosion, and other environmental effects. The clear cover for columns, which typically measures 1.5 inches, offers adequate longevity and protection. For internal beams, it is normally 1 inch, however exposure conditions can allow it to expand. Depending on their thickness and exposure to the weather, slabs typically have a clear cover that is 0.75 to 1 inch thick. Staircases often have a 0.75-inch clear cover, which provides sufficient protection without sacrificing the structural soundness indicated in Table 2.2. By enhancing fire resistance, shielding the reinforcement from moisture and chemicals, and assuring the structure's endurance, a suitable transparent cover ensures a sturdy and reliable construction.

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

The building design complies with BNBC 2020 to guarantee safety and compliance with building, material, and service regulations. In compliance with the standards of BNBC 2020, structural analysis and design were conducted using ETABS 2020.

Chapter 3
Structural Analysis and Output

3.1 Introduction

In this project, the G+1 building's beams, columns, footings, slabs, and stairs, among other structural elements, were designed using ETABS. In order for ETABS to determine the required reinforcement for both shear and bending, I provided the appropriate span lengths and stress conditions for the beam design. To ensure the beams met serviceability requirements, I looked for cracks and deflections. I modeled the columns as vertical frame elements and used the interaction equations given by the relevant design codes to apply axial loads and moments in order to calculate the required reinforcement. I evaluated the foundation system utilizing the applied loads and the properties of the soil prior to building the footing. After that, I created the reinforcement to offer adequate stability and strength using ETABS to verify the bearing capacity. I calculated the appropriate slab thickness, applied loads, and looked at the results for deflection and moment capacities to make sure the design met safety and serviceability standards. I ultimately designed the stairs by modeling them as a series of slabs and beams to make sure their dimensions and load-bearing capacity met code requirements. The comprehensive studies conducted in ETABS enabled an integrated approach to structural design, confirming the efficacy and safety of each element within the building's framework. The structural design of the G+1 building was finished in ETABS, and then AutoCAD was used to detail the different components. For the design to be visualized and presented clearly, this phase was crucial. For the beams, columns, slabs, footings, and staircases, thorough drawings are made in AutoCAD, ensuring that all required measurements, reinforcement schemes, and material specifications are included. I was better able to understand how various structural elements work together thanks to this detailing procedure, such as how beams attach to columns and how slabs are supported. To make the designs easier to interpret, I also included labels and symbols. By merging the ETABS analysis results with intricate AutoCAD drawings, it was made guaranteed that, helping to ensure the project could be built successfully.

3.2 Load consideration

According to BNBC (2020) requirements, while developing a model for a primary school building, the loads are divided into three groups in ETABS: dead load, live load, and floor finish load. The total weight of the building's permanent structural elements, including floors, walls, beams, and columns, as well as its fixed installations, including ceilings and partitions, is known as the dead load.

The building's occupants, furnishings, and movable items are all taken into account by Live Load. Primary schools should assign a live load of around 2 to 4 kN/m² in classrooms due to normal use and occupancy. To manage higher foot traffic in busy areas like assembly areas and corridors, raise the Live Load to 4 to 5 kN/m². 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

When designing slabs in ETABS, numerous crucial elements should be taken into account to guarantee both the structural integrity of the slabs and their adherence to building regulations. The program analyzes slab shape, thickness, material properties, load categories (such as dead, live, and environmental loads), and boundary conditions. Using finite element analysis, it assesses the stresses, deflections, and reinforcement requirements across the slab. Furthermore, ETABS takes into account how the slab will behave under various load distributions, load combinations, and support circumstances (such as simply supported, fixed, or continuous). Additionally, it has safety features and design codes that are specific to a certain country, allowing engineers to confirm that local standards are being followed. In order to increase the slab's lifetime and functionality, reinforcement details and crack width restrictions are also taken into account.

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.

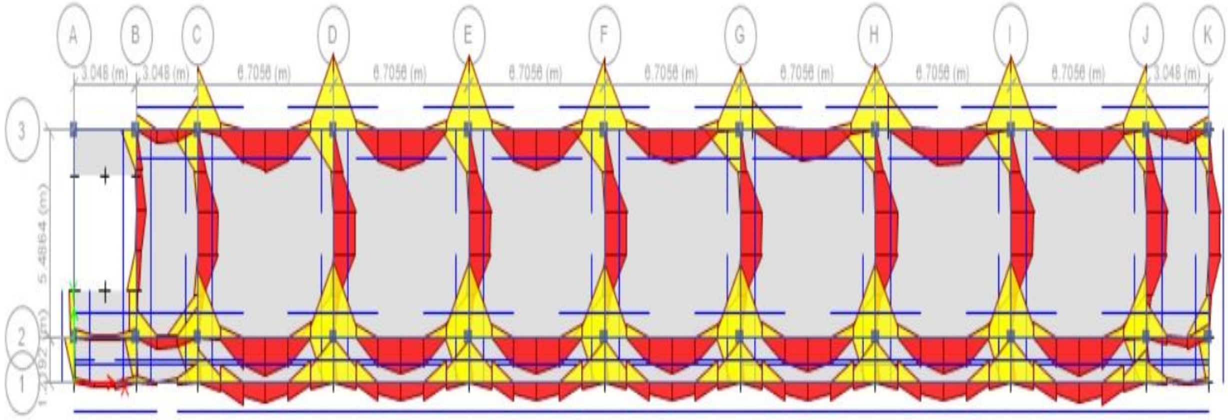


Fig. 3.1: Top and Bottom reinforcement of slab

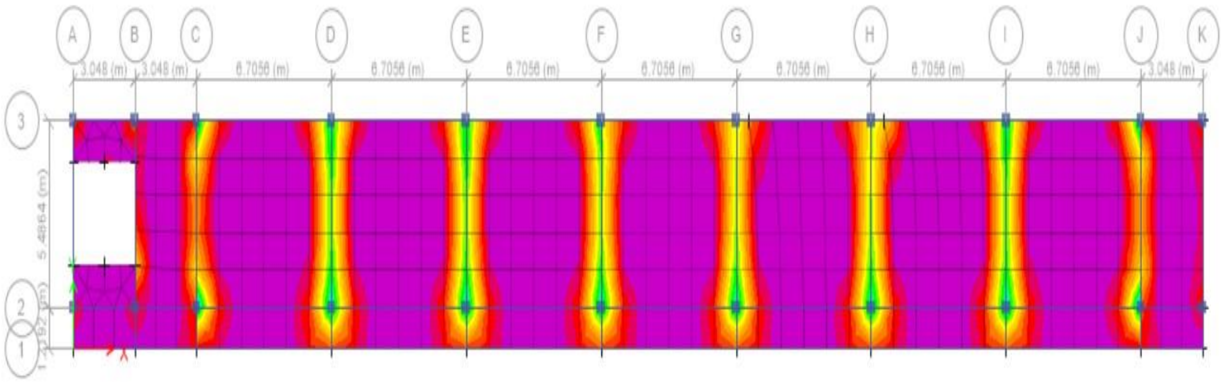


Fig. 3.2: Finite Element Design

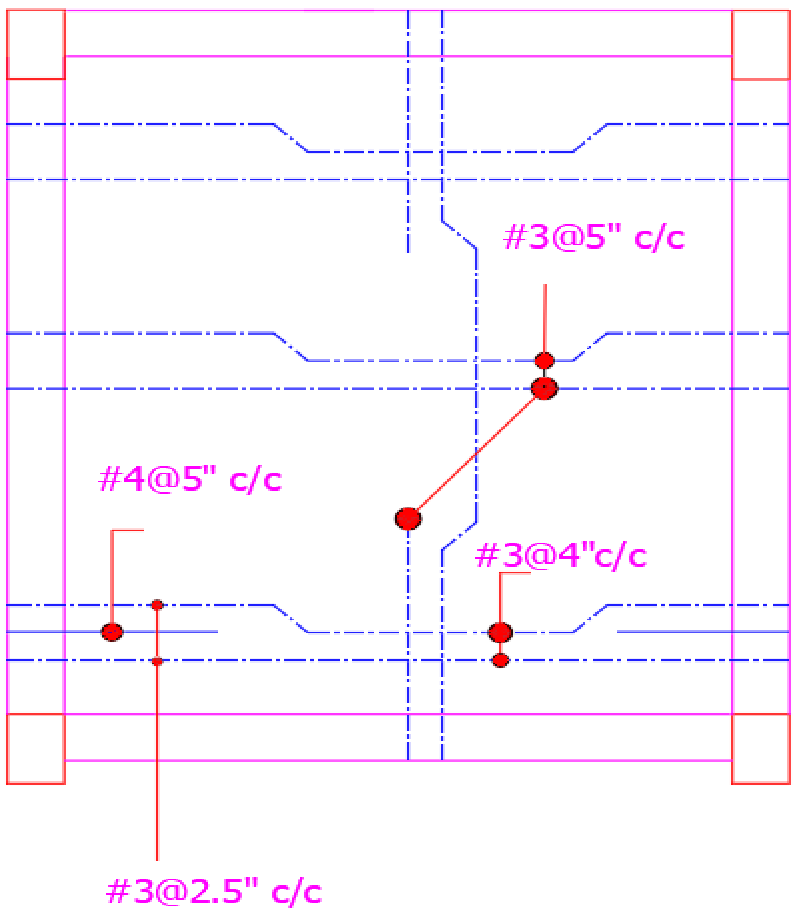


Table 3: Slab details

Slab Reinforcement				
Slab No	**Dimension**	**Bottom Rebar**	**Top Rebar**	**Middle Rebar**
S1	10’x18’	#3@2.5”c/c	#3@2.5”c/c	#3@5”c/c
S2	10’x18’	#3@2.5”c/c	#3@2.5”c/c	#3@5”c/c
S3	22’x18’	#3@2.5”c/c	#3@2.5”c/c	#3@5”c/c
S4	22’x18’	#3@2.5”c/c	#3@2.5”c/c	#3@5”c/c
S5	22’x18’	#3@2.5”c/c	#3@2.5”c/c	#3@5”c/c
S6	22’x18’	#3@2.5”c/c	#3@2.5”c/c	#3@5”c/c
S7	22’x18’	#3@2.5”c/c	#3@2.5”c/c	#3@5”c/c

3.4 Design of Beam and Detailing

Establishing the beam's dimensions and describing the loading conditions, including dead and live loads, in compliance with the relevant standards, are important steps in the ETABS beam design process for the G+1 building. Following model setup, we analyzed the beams for shear forces and bending moments using ETABS, as illustrated in Fig. 3. The software ensured that the beams met structural safety standards by automatically determining the reinforcing required for both positive and negative moments. After reviewing the analysis results, it was confirmed that the reinforcement layout satisfied the minimal code requirements and could withstand the applied loads to ensure that the calculated deflections were within permissible ranges for serviceability. Everything taken into account.

3.5 Lap Location

A) The center part of the span should not have a bottom bar lap for the beam.

B) The middle third zone of the span may have a lap bar for the beam top. (Figure 3.6).

C) A maximum of 50% of the bars must be spliced together.

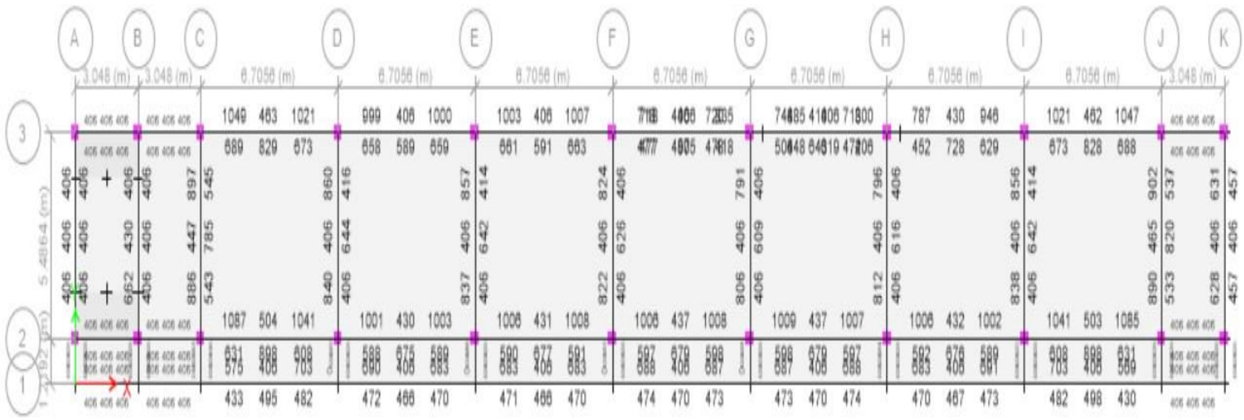


Fig. 3.3: Longitudinal Reinforcement Area of 1st floor beam

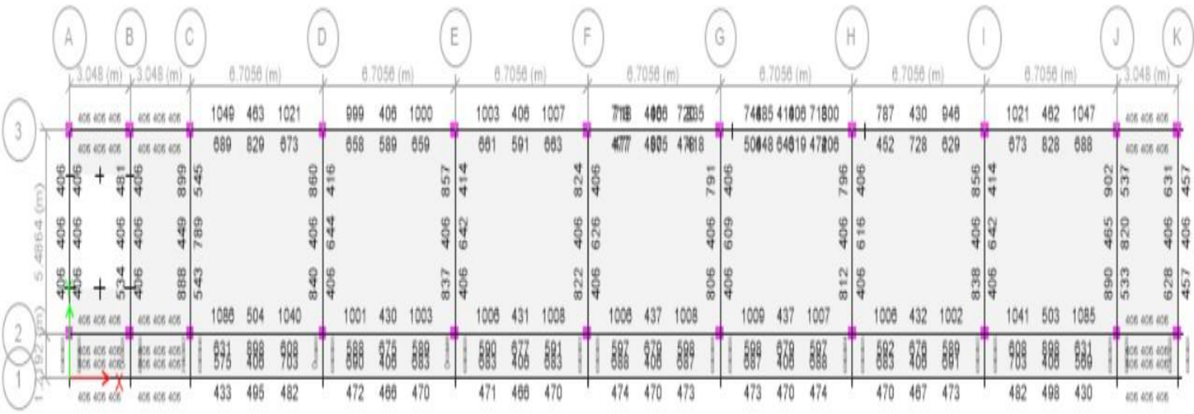


Fig. 3.4: Longitudinal Reinforcement Area of 2nd floor beam

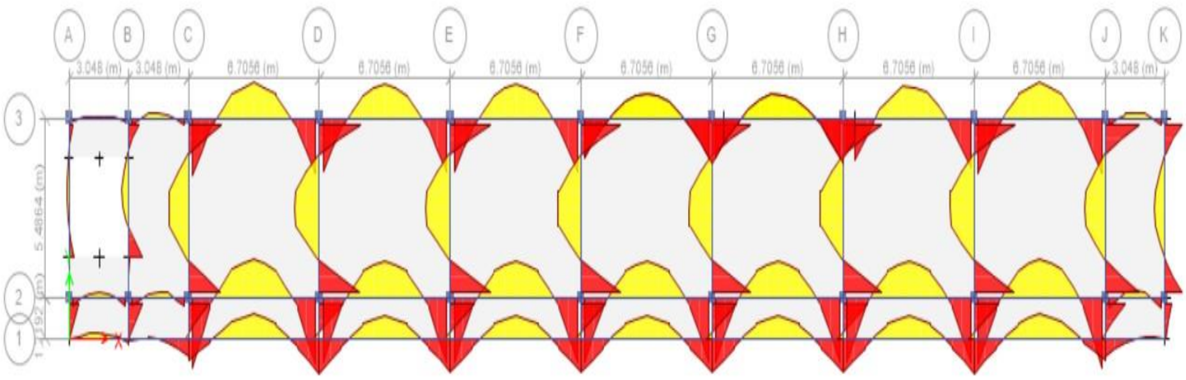


Fig. 3.5: Bending moment diagram

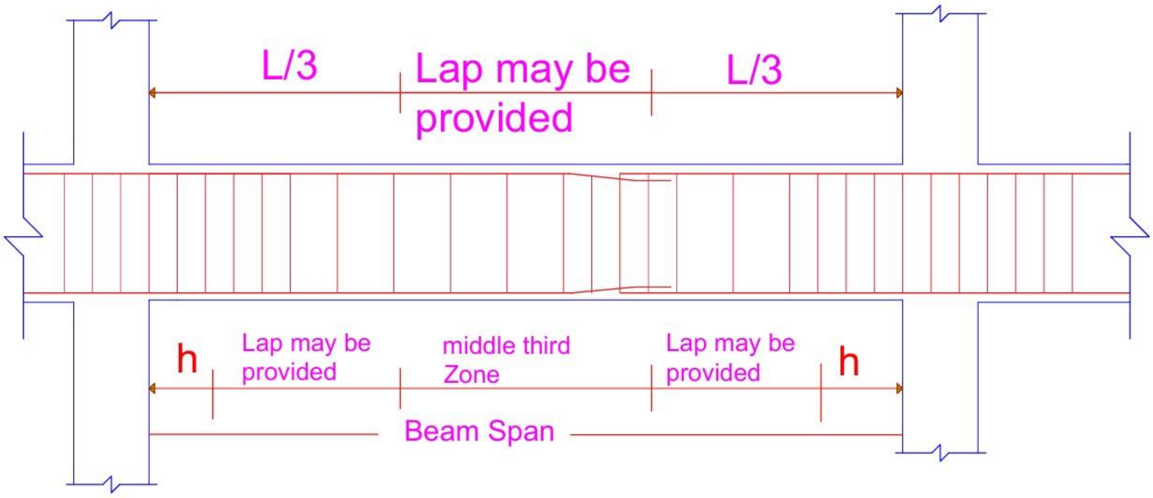


Fig. 3.6: Lap position

Table 3.1: Beam details

Beam of Roof				
Beam No	**Dimension**	**Bottom Rebar**	**Top Rebar**	**Stirrups**
B1	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B2	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B3	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B4	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B5	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B6	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B7	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B8	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B9	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B10	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B11	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B12	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B13	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B14	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B15	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B16	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B17	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c
B18	14’’x16’’	3# 20mm Dia	4# 20mm Dia	10mm @ 8" c/c

3.6 Design of Column and detailing.

When designing columns, ETABS considers a number of crucial factors in a structural model. In order to determine how strong and stable the columns are, one begins with evaluating the axial loads and moments that are affecting them. ETABS looks at loads such as dead loads and live loads to see how they impact column performance. The software also takes into account the column's stiffness and buckling capacity, cross-sectional area, and reinforcing features, all of which have an impact on the column's resistance to bending and compression. To ensure that the column meets performance and safety criteria, ETABS uses relevant design laws and considers slenderness effects.

ETABS helps structural engineers design columns for buildings in a way that is both efficient and complies with codes by combining all of these factors.

ETABS. By giving precise details on column diameters, reinforcing configurations, and bar sizes, these detailed drawings guarantee that the design meets structural standards and permits flawless execution throughout construction.

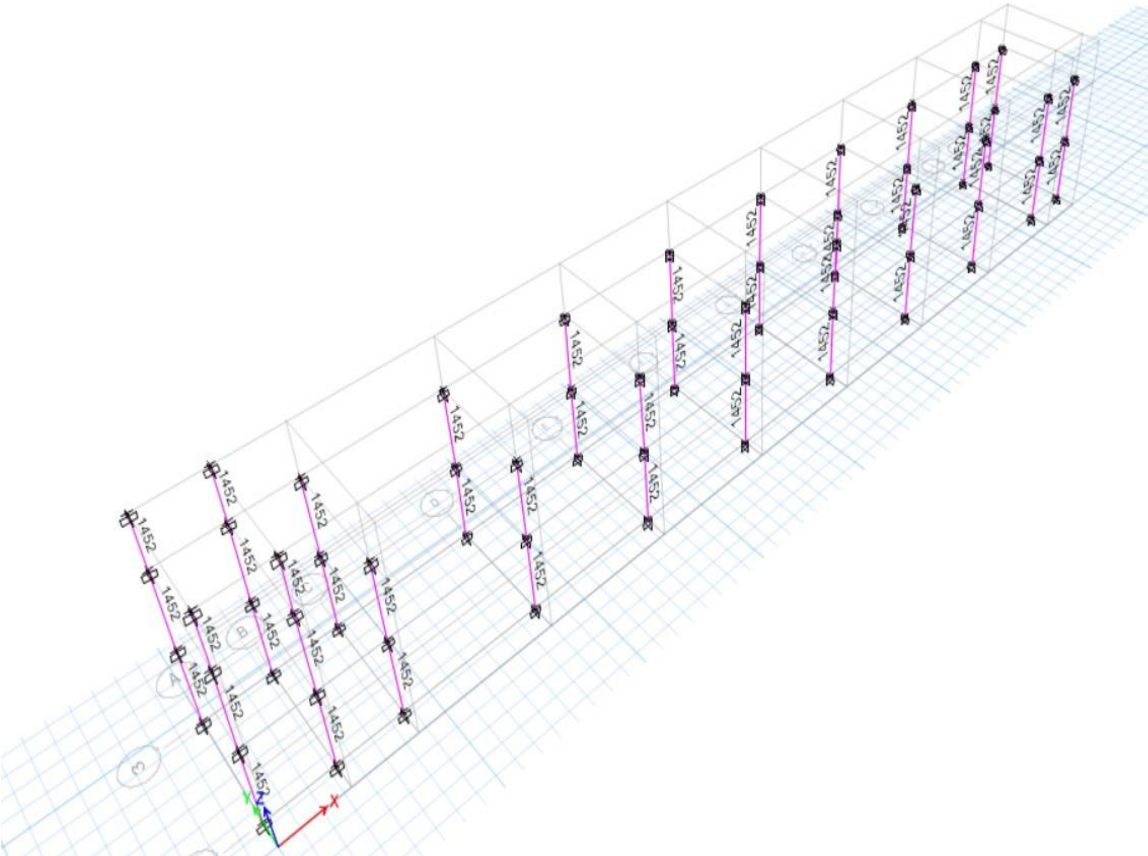


Fig. 3.7: Longitudinal Area Reinforcement of Column

Table 3.2: Details 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" c/c
2	15"x15"	8# of 16mm dia	10mm @ 5" c/c
3	15"x15"	8# of 16mm dia	10mm @ 5"c/c
4	15"x15"	8# of 16mm dia	10mm @ 5" c/c
5	15"x15"	8# of 16mm dia	10mm @ 5" c/c
6	15"x15"	8# of 16mm dia	10mm @ 5 "c/c
7	15"x15"	8# of 16mm dia	10mm @ 5" c/c
8	15"x15"	8# of 16mm dia	10mm @ 5” c/c
9	15"x15"	8# of 16mm dia	10mm @ 5"c/c
10	15"x15"	8# of 16mm dia	10mm @ 5"c/c
11	15"x15"	8# of 16mm dia	10mm @ 5" c/c
12	15"x15"	8# of 16mm dia	10mm @ 5"c/c
13	15"x15"	8# of 16mm dia	10mm @ 5" c/c
14	15"x15"	8# of 16mm dia	10mm @ 5" c/c
15	15"x15"	8# of 16mm dia	10mm @ 5" c/c
16	15"x15"	8# of 16mm dia	10mm @ 5" c/c
17	15"x15"	8# of 16mm dia	10mm @ 5" c/c
18	15"x15"	8# of 16mm dia	10mm @ 5" c/c
19	15"x15"	8# of 16mm dia	10mm @ 5" c/c
20	15"x15"	8# of 16mm dia	10mm @ 5" c/c
21	15"x15"	8# of 16mm dia	10mm @ 5" c/c
22	15"x15"	8# of 16mm dia	10mm @ 5" c/c

3.7 Design of Foundation and detailing.

ETABS's isolated footing design takes into account a variety of factors to guarantee structural stability and adherence to design specifications. The size of the footing and the requirement for reinforcement are significantly influenced by the soil carrying capacity. To ensure adequate support while adhering to soil constraints, ETABS assesses and distributes the footing load from columns, including dead, live, and other applied loads. Additionally, it considers the shear pressures and moments at the base, particularly regarding the shear needs for punching and bending. The algorithm evaluates the footing depth and reinforcement to withstand bending forces while ensuring that settlement stays within acceptable ranges.

By considering criteria such as concrete strength, footing shape, dimensions, and all the details mentioned in Fig. 3.8 and Table 3.3, the design is optimized and compliance with local building norms and safety legislation is guaranteed.

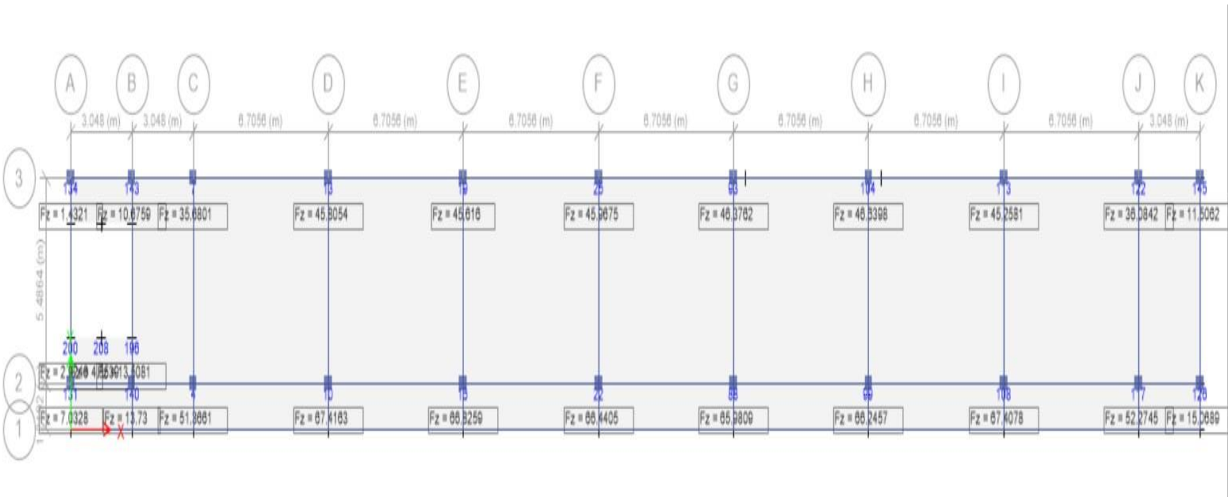


Fig. 3.8: Footing load

Table 3.3: Final detailing of footing

DESIGN RESULTS			
Footing No.	Size (in m)	Thickness(in m)	Reinforcements in Both Directions
1	1.5x1.5	0.45	12mm dia. @8” c/c
2	1.5x1.5	0.45	12mm dia. @8” c/c
3	1.5x1.5	0.45	12mm dia. @8” c/c
4	1.5x1.5	0.45	12mm dia. @8” c/c
5	1.5x1.5	0.45	12mm dia. @8” c/c
6	1.5x1.5	0.45	12mm dia. @8” c/c
7	1.5x1.5	0.45	12mm dia. @8” c/c
8	1.5x1.5	0.45	12mm dia. @8” c/c
9	1.5x1.5	0.45	12mm dia. @8” c/c
10	1.5x1.5	0.45	12mm dia. @8” c/c
11	1.5x1.5	0.45	12mm dia. @8” c/c
12	1.5x1.5	0.45	12mm dia. @8” c/c
13	1.5x1.5	0.45	12mm dia. @8” c/c
14	1.5x1.5	0.45	12mm dia. @8” c/c
15	1.5x1.5	0.45	12mm dia. @8” c/c
16	1.5x1.5	0.45	12mm dia. @8” c/c
17	1.5x1.5	0.45	12mm dia. @8” c/c
18	1.5x1.5	0.45	12mm dia. @8” c/c

3.8 Design of Staircase and detailing

A staircase in ETABS must be designed with several structural and load considerations in order to guarantee both safety and functionality. ETABS will analyze the staircase's geometry, considering the rise, run, and overall slope, in order to meet architectural criteria. In order to account for their structural features, it considers the materials' strength and stiffness, such as concrete or steel. Both dead loads, such as the structures self-weight, and live loads, such as the weight of people and objects being moved up and down the stairs, must be taken into account when calculating load considerations in order to adhere to architectural regulations. Whether the stairway is supported at both ends, cantilevered, resting on intermediate landings, the software also assesses boundary conditions and support kinds, as shown in Fig. 3.9.

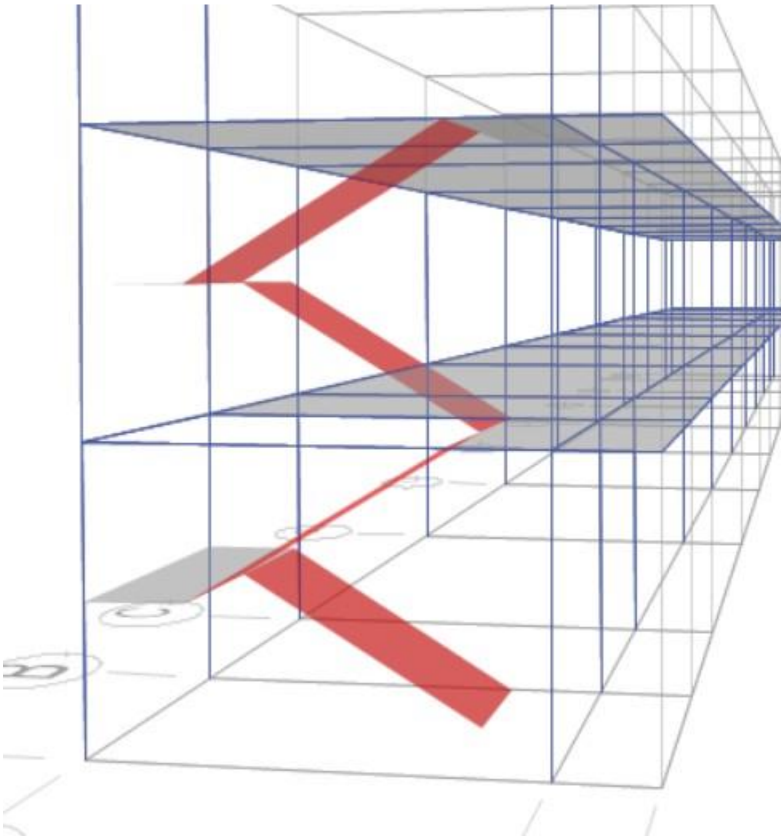


Fig. 3.9: Stair view from ETABS

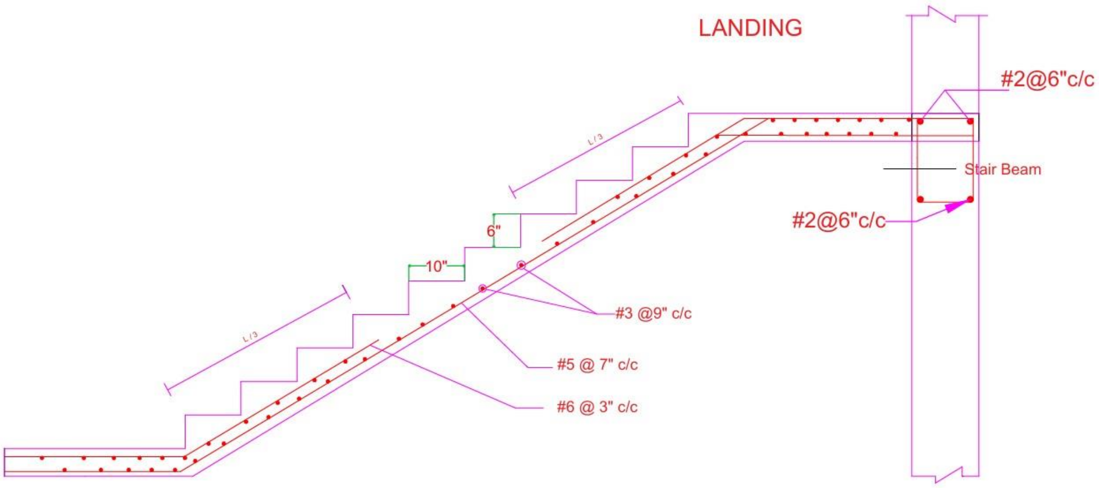


Table 3.4: Final detailing of Stair

Stair Reinforcement			
Stair Beam	**Extra. Rebar**	**Top Rebar**	**Stair Main Rebar**
#2 @6" c/c	#6 @ 3"c/c	#5 @ 7"c/c	#3 @ 9"c/c

3.9 Summary

For this project, ETABS was used to design the footings, slabs, columns, beams, and stairs—the structural elements of a G+1 structure. Careful modeling, analysis, and strengthening in accordance with relevant design requirements have guaranteed each component's safety and serviceability. The designs were then accurately and clearly drawn by AutoCAD, replete with dimensions, labels, and reinforcement schemes. This integrated method ensured that the structure's stability and compliance with code requirements were confirmed, and the design was safe for practical implementation.

Chapter 4

DESIGN AND CONSIDERATION OF SEPTIC TANK

4.1 Introduction

In areas lacking centralized sewer access, a septic tank—an underground wastewater treatment system—is commonly used. In a waterproof chamber (often constructed of concrete, fiberglass, or plastic) that isolates solids from liquids, anaerobic bacteria can break down organic material. The effluent, or partially treated liquid, from the tank is sent to a drain field where it is further filtered by passing through soil.

Long-lasting materials should be chosen, the tank's size should be determined by the amount of water used in the home, and the tank should be placed far enough from water sources to avoid contamination. Because maintenance is so important, it is recommended that pumps and inspections be performed every two to five years. To protect public health and groundwater quality, local regulations specify requirements for installation, placement, and layout.

4.2 Components of a Septic Tank

A septic tank's many vital components work together to treat household wastewater. An entrance line directs household wastewater into the tank, where the liquids and solids begin to separate. Heavy materials sink at the bottom of the tank to form a sludge layer, while lighter materials, including fats and oils, float to the top to create a scum layer.

The layer of effluent between them contains partially treated water. Baffles and tees are positioned near the input and outflow pipes to help control the flow and prevent obstructions, ensuring that effluent flows readily from the tank into the drain field for further treatment. The tank also features access openings, sometimes referred to as risers, which allow for regular maintenance, inspections, and pumping of sludge and scum.

4.3 Design Consideration of Septic Tank

The Bangladesh National Building Code (BNBC, 2020) offers significant guidelines for septic tank design that guarantee the safe and effective treatment of wastewater and The number of users, daily water consumption per person, and wastewater retention time will be the main factors taken into account when designing a septic tank for 210 users, where each classroom has 25 pupils and requires 16 square feet of space per student. The detailed procedure for figuring out the septic tank's dimensions and design elements is provided below:

The tank should be large enough to hold wastewater for one to two days, allowing the solids to settle and break down, depending on how much water the household consumes on a daily basis. To prevent leaks and protect groundwater, tanks should be constructed from sturdy, waterproof materials like concrete, fiberglass, or plastic. Tanks are typically divided into two sections by walls or baffles to improve cleaning.

Both the inlet and outlet pipes should be positioned with fittings to manage flow smoothly, and the outlet pipe should be somewhat lower to allow wastewater to flow correctly. Proper ventilation is necessary to release gasses, prevent offensive odors, and encourage bacterial activity. The (BNBC, 2020) also requires access points, or risers, to enable regular pumping and inspection; they need to be properly sealed to avoid contamination. The soil's ability to absorb water should be considered in the construction of the drain field, which is where wastewater leaves the tank. It should also be placed safely away from buildings, wells, and water sources.

The septic tank must to be placed far enough away from structures and water sources to avoid freezing issues. Regular maintenance, such as pumping out solids every two to five years, is recommended to keep the tank operating correctly and protect the public's health. Additionally, the drawing shown in Figures 5.1 and 5.2.

4.4 Design of Septic Tank

Population, P =	**225**	persons
Per capita water use, q =	**25**	lpcd
Cleaning cycle, N =	**1**	years

Length, L =	6.008	m
Width, W =	2.003	m
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.

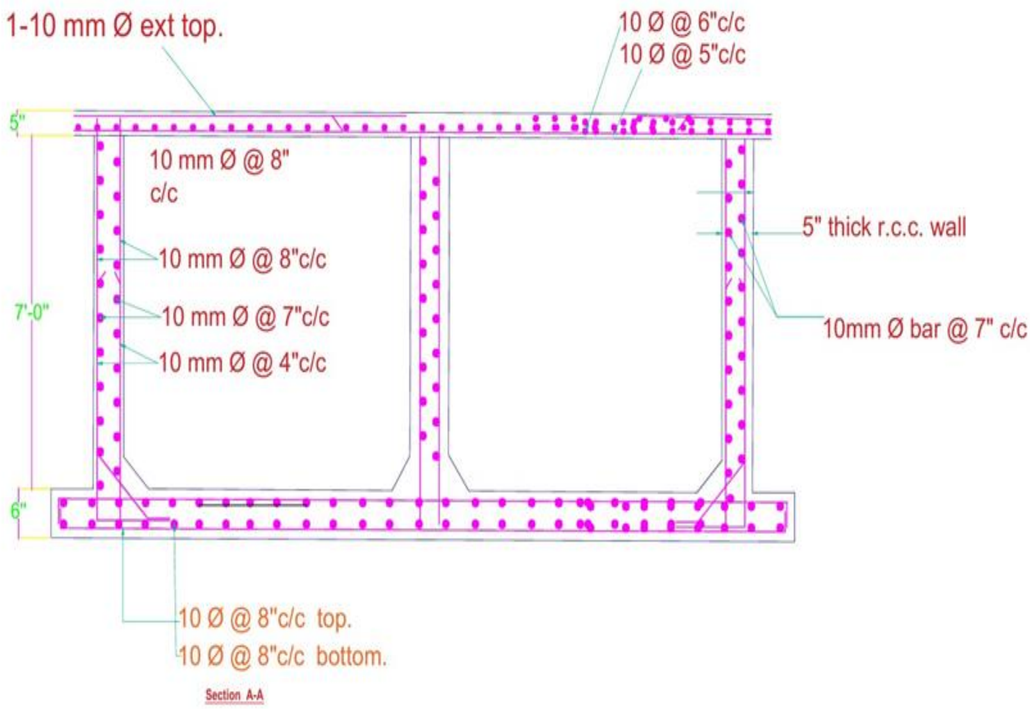


Fig. 4.1: Section view of Septic tank

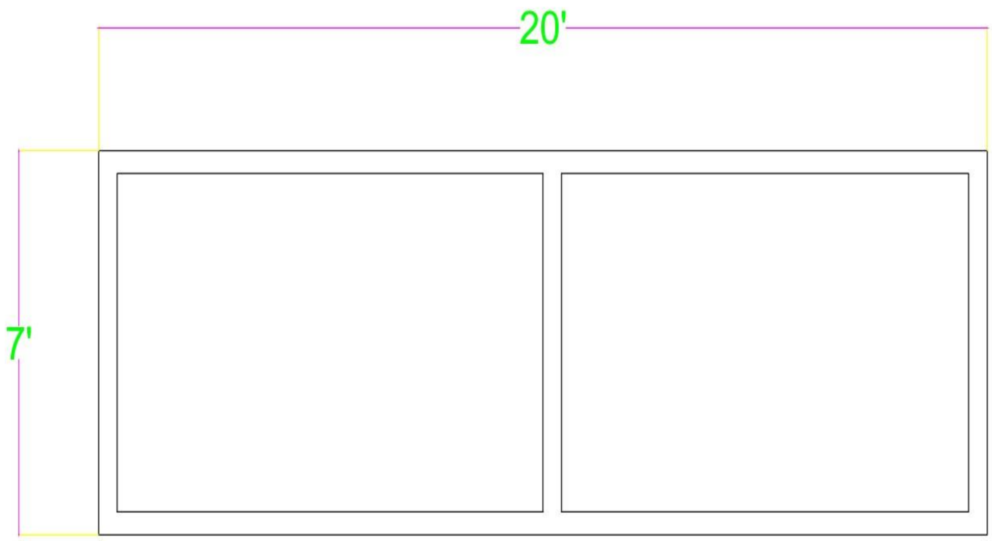


Fig. 4.2: Plan of septic tank

4.5 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. To release gases 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 5
Cost Estimation and Gantt chart

5.1 Introduction

A Bill of Quantities (BOQ) is essential to construction since it enumerates all the materials and resources required for each structural element, especially for a G+1 (ground floor plus one) project. Each main structural component—slabs, beams, columns, isolated footings, and stairs—has its concrete and reinforcing requirements broken down in the BOQ. By enabling transparent budgeting and guaranteeing that materials fulfill design criteria, this differentiation ensures structural integrity. Every element in the BOQ is carefully examined in this table, which also covers the requirements for concrete, reinforcement, and the building's estimated cost as well as a summary of the slab, beam, column, footing, and staircase, all of which are listed in Table 4.1.

5.2 Slabs

Slabs are horizontal pieces that construct the roof and floors by transferring loads to beams and columns. The BOQ for slabs specifies concrete in cubic meters based on the slab's area and thickness. M25 grade concrete, which balances strength and cost, is usually specified. The anticipated cost of the concrete, which requires 1302 cement bags, 15575 cubic feet (CF) of sand, 2950 Cf of aggregate, and 20147 liters of water, is $4209. The kind, diameter, and amount of steel bars used for reinforcement in slabs are specified separately. According to the slab's span and load-bearing specifications, reinforcement is measured in tons; seven tons are needed, and the anticipated cost is $5745.

Slabs typically have a steel grid design, with distribution bars and main bars positioned 150–200 mm apart, depending on the load. In order to guarantee tensile strength—something that concrete by itself cannot provide—the BOQ includes these specifics.

5.3 Beams

Beams are essential for managing bending and shear pressures and for transferring loads from slabs to columns. The BOQ uses the beam's length and cross-sectional area to calculate how much concrete is required. For example, to build a beam that is 5 meters long and has a cross-section of 0.3 × 0.45 meters, 0.6 cubic meters of concrete are required for a beam at the first floor that has dimensions of 0.3 × 0.45 × 4.5. M25 grade concrete is commonly required due to its compressive strength, which counteracts bending forces. The estimated cost of concrete is over $8600 since it requires 1123 cement bags, 1023 cubic feet (CF) of sand, 3012 CF of aggregate, and 20106 liters of water.

The primary tension bars, compression bars, and stirrups are described in detail in the reinforcing BOQ for beams. Compression bars may be put at the top, while tension bars are positioned at the bottom to counterbalance tensile stress. Stirrups, which are smaller bars wrapped around the main bars to withstand shear, are usually 10 mm in diameter and placed 150 mm apart. The most frequent bars used for a normal G+1 beam are two bars, each 16 mm in diameter. In order to ensure that beams can withstand both bending and shear pressures without experiencing excessive deflection or breaking, reinforcement weight calculations take into account the length and diameter of each bar. Additionally, the projected cost of the 9.5-ton reinforcement required for the beam is $8,215.

5.4 Columns

Crucial vertical structural components that transmit weights from the upper stories to the foundation are columns. In order to make sure the column can sustain compressive and lateral forces, the Bill of Quantities (BOQ) for columns determines the quantities. Calculations for concrete in columns are dependent on the height and cross-sectional area of the column. One of the columns, for instance, has a square cross-section that is 4 meters high and 0.48 meters on each side. Concrete volume = area x height = (0.38 m×0.38 m) × 4 m = 0.5772 cubic meters is the formula for calculating the concrete volume for this column.

The BOQ uses the concrete volume with the grade M25, which is determined by the structural safety considerations and load requirements. 525 cement bags, 601 cubic feet (CF) of sand, 1143 Cf of aggregate, and 9560.10 liters of water were required to cast the column, which is estimated to have cost $3821. The BOQ contains distinct specifications for the column's reinforcing. This usually consists of lateral ties (sometimes called stirrups) that keep the longitudinal bars from buckling and longitudinal bars that withstand axial loads. For a column measuring 0.38 m by 0.38 m, the BOQ may state:

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

The overall amount of reinforcement, expressed in kilos or tons, is determined by the number of bars, as well as their diameters and lengths. The BOQ might, for instance, specify the overall weight of reinforcement needed for the column, taking into consideration the precise bar lengths and the reinforcement needed for every column segment. This guarantees that there is no chance of failure and that the column can securely transfer vertical weights. Thus, the expected cost is $7011 and the total amount of reinforcement in tons is 9.20 tons.

5.5 Isolated Footings

The purpose of isolated footings, sometimes referred to as pad footings, is to support individual columns and disperse the weight onto the earth. Based on the size of the footing and the column load it is intended to support, the BOQ for isolated footings specifies the concrete and reinforcing needs. Similar calculations are made for concrete for isolated footings, but the footing's footprint—which is usually square or rectangular—is the main focus. As an illustration, let's look at a rectangle footing that is 1.75 meters by 1.75 meters and 0.6 meters deep. The volume of concrete needed for this footing is determined by:

Volume of concrete = length x breadth × depth = 1.75 × 1.75 × 0.6 m = 2.4 cubic meters. Usually, M25 concrete is specified because it has the strength required to endure the pressure from the underlying soil and the forces communicated by the column. 1028 cement bags, 1016 cubic feet of sand, 2106 cubic feet of aggregate, and 14621 liters of water were needed to cast the footing; the anticipated cost was $6913. For footings to be able to withstand shear stresses and bending moments, reinforcement is essential, particularly in the top and bottom sections of the footing. The following is how the BOQ would list reinforcement:

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 $1305

5.6 Staircase

Between levels, stairs provide for vertical circulation, which transfers weight to beams and columns for support. Based on the measurements of the stair flight, tread, riser, and landing, the BOQ calculates the amount of concrete required. For instance, a single flight of a staircase of 6 m in width, 0.15 m in riser height, and 0.3 m in tread depth would require about 1.8 cubic meters of concrete. For staircases to efficiently withstand loads, M25 grade concrete—which is renowned for its compressive strength—is frequently specified. About 1489 cement bags, 275 cubic feet (CF) of sand, 561 CF of aggregate, and 4768 liters of water are needed for this concrete, which should cost about $764 in total.

The major reinforcement bars, distribution bars, and extra support at the landings are described in the stairs' reinforcement BOQ. To maintain structural integrity, distribution bars with an 8mm diameter are typically utilized perpendicularly to the main reinforcement bars, which are typically positioned along the stair's span and have a 12mm diameter. The distribution bars are frequently spaced 200 mm apart. To make sure the stairs can safely withstand both bending and shearing pressures, reinforcement weight estimates take bar length and diameter into account. The projected cost of the 2 tons of reinforcing needed for the stair construction is $1,321.

Table 5.1: Summary of BOQ

Estimation		Estimated
A	Estimation of Foundation and Footing	1,105,025.00৳
B	Estimation of Column	1,124,975.00৳
D	Estimation of Floor Beam	1,981,184.00৳
E	Estimation of slab	1,214,027.00৳
F	Estimation of Stair	230,691.00৳
G	Estimation of labor	874,752.00৳
H	Estimation of Brick masonry, Plaster, & Painting work	1,035,790.00৳
I	Estimation of Septic Tank	248,925.00৳
	Grand Total =	7,815,369.00৳

5.7 Introduction of Gantt chart

Since it offers a clear, visual timeline of all the significant tasks involved in the project, a Gantt chart is a crucial project management tool for construction projects like a G+1 school building. It enables engineers, construction teams, and project managers to efficiently plan, supervise, and coordinate operations. A Gantt chart illustrates the duration and sequence of structural tasks, such as excavation, footing, column casting, and slab building, to help ensure that each phase of work is by the overall project goals and deadlines. In Table 4.2, this approach helps to enhance productivity, stick to budgets, and complete projects on time by minimizing delays and optimizing resource use.

Table 5.2: Gantt chart

Task No.	**Task Description**	**Duration**	**Start Date**	**End Date**
1	Foundation Excavation	2 weeks	Day 1	Day 13
2	Isolated Footing Construction	2 weeks	Day 15	Day 30
3	Column Casting (Ground Floor)	2 weeks	Day 31	Day 50
4	Ground Floor Beam Construction	3 weeks	Day 51	Day 70
5	Ground Floor Slab Casting	2 weeks	Day 71	Day 85
6	Staircase Construction	1 week	Day 86	Day 92
7	1st Floor Column Casting	2 weeks	Day 95	Day 105
8	1st Floor Beam Construction	3 weeks	Day 106	Day 130
9	1st Floor Slab Casting	3 weeks	Day 131	Day 145
10	Septic Tank Construction	2 weeks	Day 51	Day 65
11	Plastering (All Walls)	3 weeks	Day 140	Day 165
12	Final Staircase Work	2 week	Day 166	Day 180

5.8 Summary

The materials, reinforcing, and estimated costs for key structural elements are listed in the Bill of Quantities (BOQ) for a G+1 school building, which guarantees efficient resource allocation and structural integrity. For slabs, which cost $4103 for concrete and $5951 for reinforcing, 1145 cement bags, 1235 cubic feet of sand, and nine tons of steel are required. Beams require 9.5 tons of steel, 1213 cubic feet of sand, and 1043 cement bags, which cost $9240 and $10,316, respectively. The materials required for columns are 516 cement bags, 623 cubic feet of sand, and 9.45 tons of steel, which cost $4067 and $6962, respectively. Footings require 1227 cubic feet of sand, 1018 cement bags, and 2 tons of steel, which cost $1015 and $6830, respectively. The stairs require two tons of steel, 137 cement bags, and 265 cubic feet of sand. The reinforcement costs $1120, and the concrete costs $847. Additionally, a Gantt chart organizes these tasks into a visual timeline, ensuring efficient project planning, coordination, and timely output.

Chapter 6
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Designing a two-story elementary school building by combining structural and architectural concepts is the main goal of this capstone project. In order to ensure that important components like beams, columns, and slabs satisfy safety and regulatory criteria, the structural design was completed using ETABS. The building arrangement was clearly seen thanks to the precise plans and elevations made with AutoCAD and Revit. The Bill of Quantities (BOQ), which covers materials and construction costs, was prepared using Excel cost estimation in addition to the structural study. This stage guarantees that the project is both realistic and cost-effective.

The project's environmental component included developing a septic tank to manage the school's wastewater requirements. To enhance sustainability, the design complies with BNBC 2020 criteria, taking into account elements like capacity, dimensions, and appropriate disposal methods. Through this project, students were able to put their theoretical knowledge to use in a real-world situation while honing their skills in cost estimation, software tools, and structural analysis. Additionally, it offered a chance to tackle practical issues in the construction of sustainable, safe, and useful structures.

6.2 Recommendation

Since ETABS is a useful tool for analyzing and creating structural elements, it is advised that it be used for structural design in future projects. AutoCAD and Revit can be used together to enhance the detailing process by ensuring that the structural and architectural plans are better coordinated. In order to present more realistic ideas, Revit's visualization tools could be further explored. Revit is also very helpful for developing comprehensive architectural layouts. Excel has proven useful for cost estimation, but more sophisticated tools or integrating cost estimation with Revit or other BIM applications can improve accuracy and efficiency. Time would be saved and fewer manual errors would occur.

To prevent mistakes and raise the overall caliber of the design, it's also critical to keep the workflow between the various tools—ETABS, AutoCAD, and Revit—consistent. To guarantee compliance and the best results in next projects, ongoing software tool training and updates on building codes such as (BNBC, 2020) should also be given top priority.

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 = 225 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 (225 * 25) = 0.41 days
The volume required by Sedimentation Zone

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

$= 10^{-3}$ x (225 X 25) x 0.41 = 2.015 m^3

Sludge Digestion Zone V_d

Assuming a design temperature of 25ºC

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

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

Sludge Zone

V_{sl} = CPN = 0.04 x 225 x 5 = 43m^3

Scum Zone (Sc)

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

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

V = 16.8+2.015+4.4+42= 65.2m^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 = 2.015/ 23.4 = 0.085 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

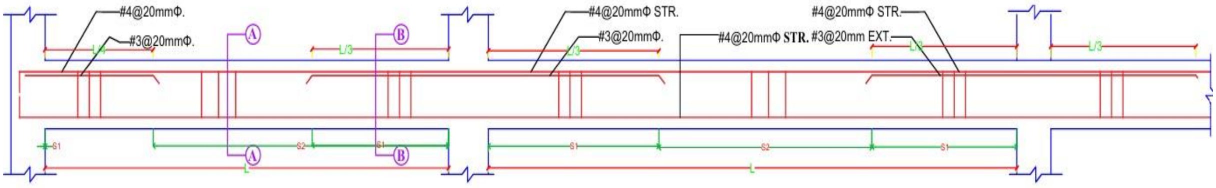
The suitable overall internal dimension of the septic tank can be chosen as

6 m x 2.1 m x 2.21 m

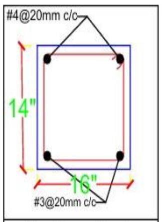
V= L * W * H

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

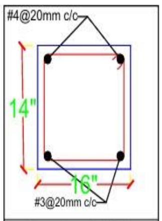
A= abx²



Longitudinal Beam



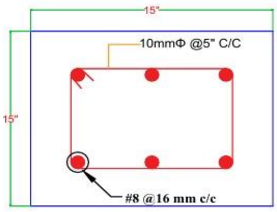
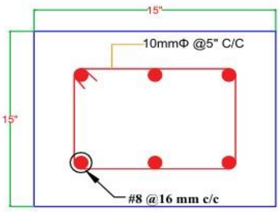
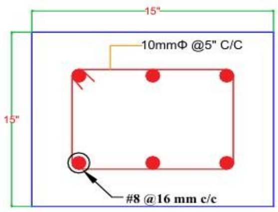
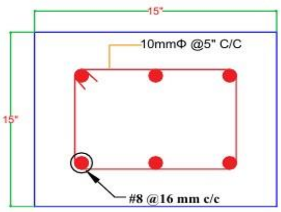
Section A-A



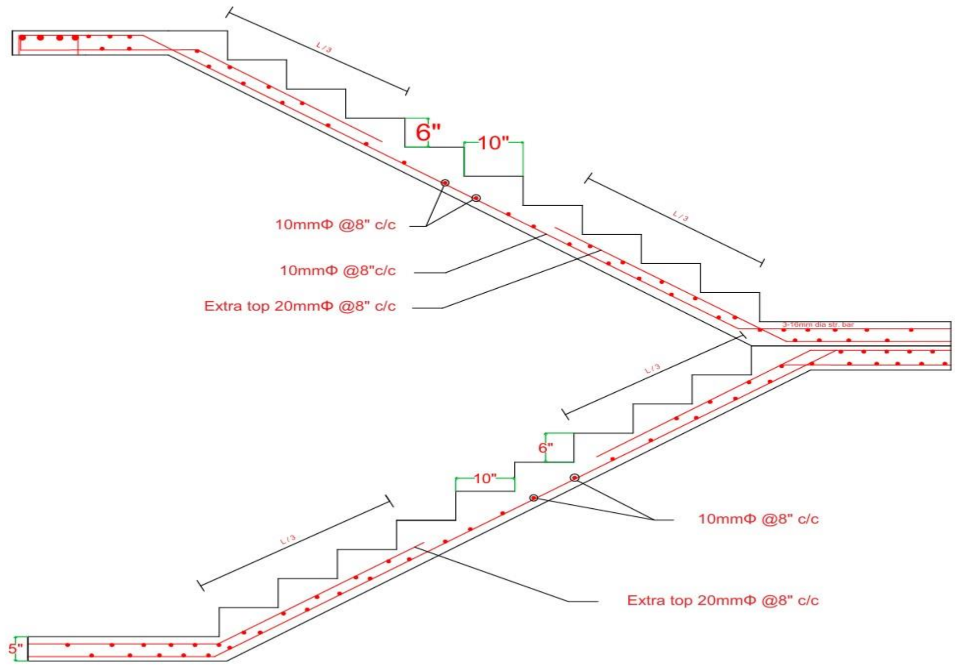
Section B-B

1st and Roof Floor Beam Section

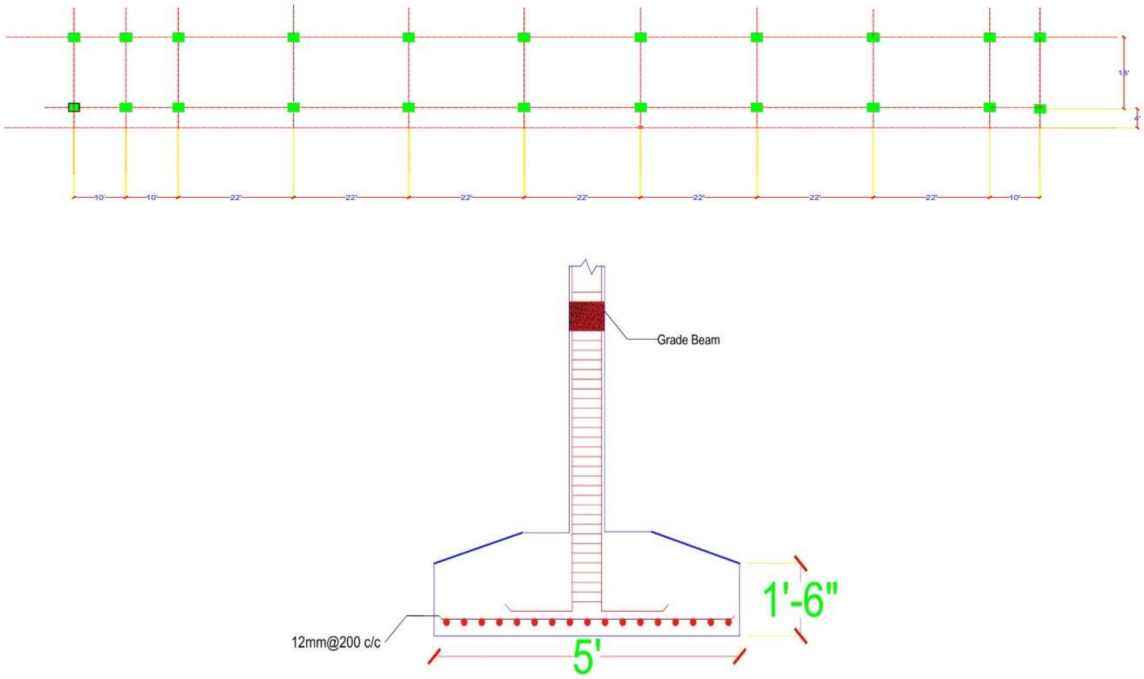
Plinth Beam Section

Column Schedule		
Column Id.	**Column 1**	**Column 2**
1st Floor to Top		
Ground floor to 1st floor		

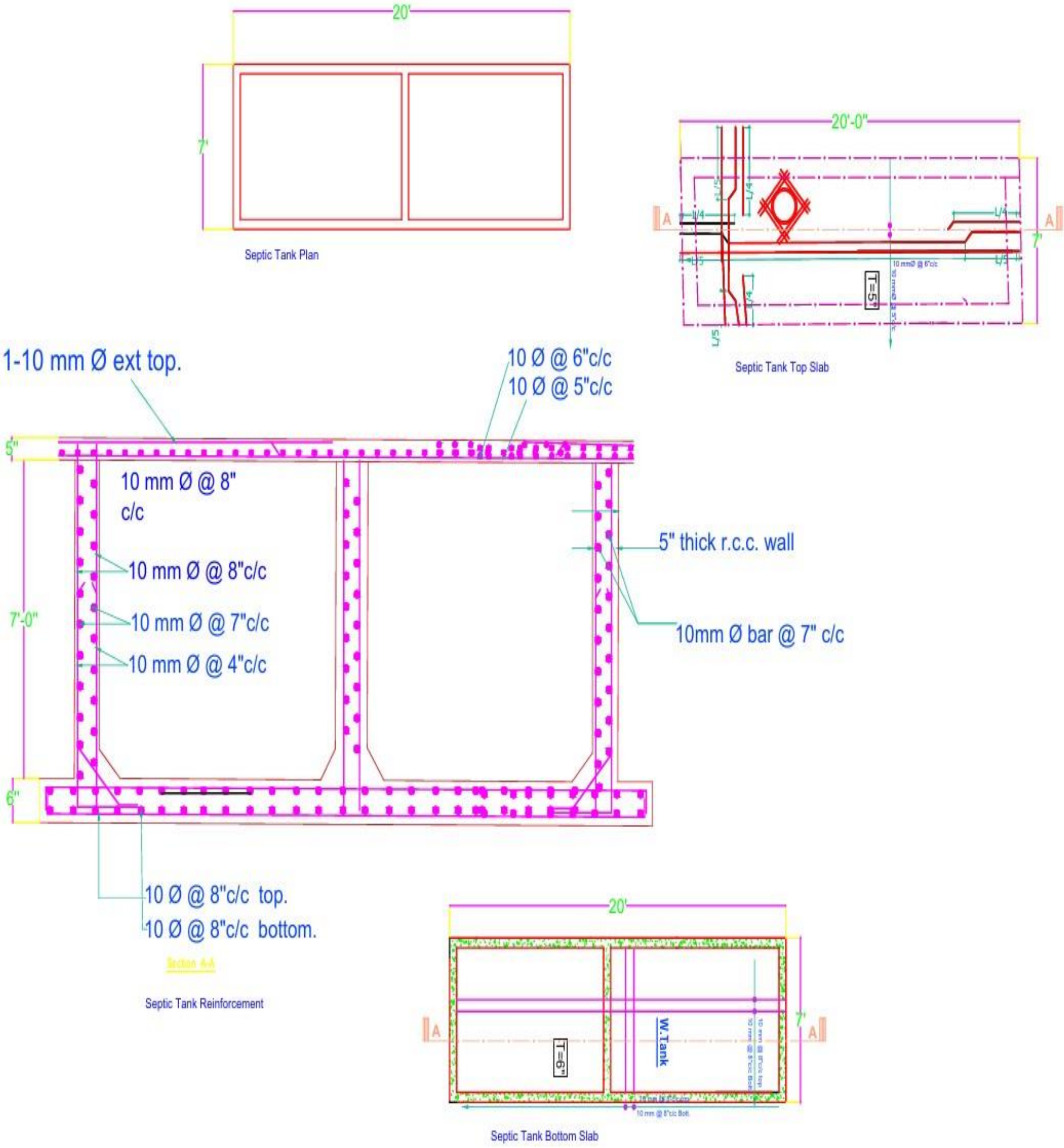
Column Schedule



Stair Reinforcement



Footing layout and footing reinforcement Detailing


20'
7'
Septic Tank Plan
20'-0"
7'
T=5"
Septic Tank Top Slab
1-10 mm Ø ext top.
10 Ø @ 6"c/c
10 Ø @ 5"c/c
5"
10 mm Ø @ 8"
c/c
10 mm Ø @ 8"c/c
10 mm Ø @ 7"c/c
10 mm Ø @ 4"c/c
7'-0"
5" thick r.c.c. wall
10mm Ø bar @ 7" c/c
6"
10 Ø @ 8"c/c top.
10 Ø @ 8"c/c bottom.
Septic Tank Reinforcement
20'
7'
T=6"
W.Tank
Septic Tank Bottom 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	17/07/2024
4	Preliminary Analysis and Design	Week 10-12	Writeup	29/07/2024
5	Analysis of Alternatives and preliminary cost estimation	Week 13	Writeup and Presentation	12/08/2024
6	Feasibility Study (Technical, Social, Environmental, Economic and Financial)	Week 14-15	Writeup and Presentation	15/08/2024
Level-4/Term-2				
7	Analysis scheme for detail design	Week 1-2	Writeup	01/09/2024
8	Analysis output	Week 3-4	Writeup	20/09/2024
9	Detail Design Report	Week 5-9	Writeup, Drawings, and Presentation	2/10/2024
10	Final BOQ, and Cost Estimation	Week 10-11	Writeup, and Presentation	25/11/2024
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 0/0/2024

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: MD Hamim Islam ID: 211-47-435 Name: Seneasish roy ID: 211-47-440
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