DESIGN OF A TWO-STORY 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

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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 20 September 2025.

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DECLARATION

The dissertation, titled "Design of a Two-Story Primary School Building with Structural and Environmental Considerations," was conducted under the supervision of Mr. Md. Masud Alom, Assistant Professor in the Department of Civil Engineering at Daffodil International University, Dhaka, Bangladesh. It was accepted as a partial completion of the criteria for the capstone project of the Bachelor of Science in Civil Engineering.

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ABSTRACT

This capstone is for the designing and detailing of a two-story primary school building. It fuses theory with practice to produce a safe, functional, and durable work of construction. The building was designed using the ETABS finite element software based on the Bangladesh National Building Code (BNBC, 2020). Every one of the beams, columns, slabs, and foundations was meticulously planned to make the structure stable and strong. To facilitate smooth building, there were complex construction drawings developed with CAD programs like AutoCAD. These drawings were comprised of floor plans, elevations, and reinforcement details. Excel was used to create the Bill of Quantities (BOQ), which helped in efficient cost estimation, adequate resource management, and computation of different 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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Chapter 1

INTRODUCTION

1.1 Proposed Structure

The Proposed Two-Story Primary School is to be built completely by RCC with Isolated foundations. The structure is approximately 108 ft by 28 ft on the plan and 24 ft high which contain 8 rooms,6 classrooms, common room, teachers' room, head teacher room. A layout Plan is given in Fig. 1.1 and Fig. 1.2:

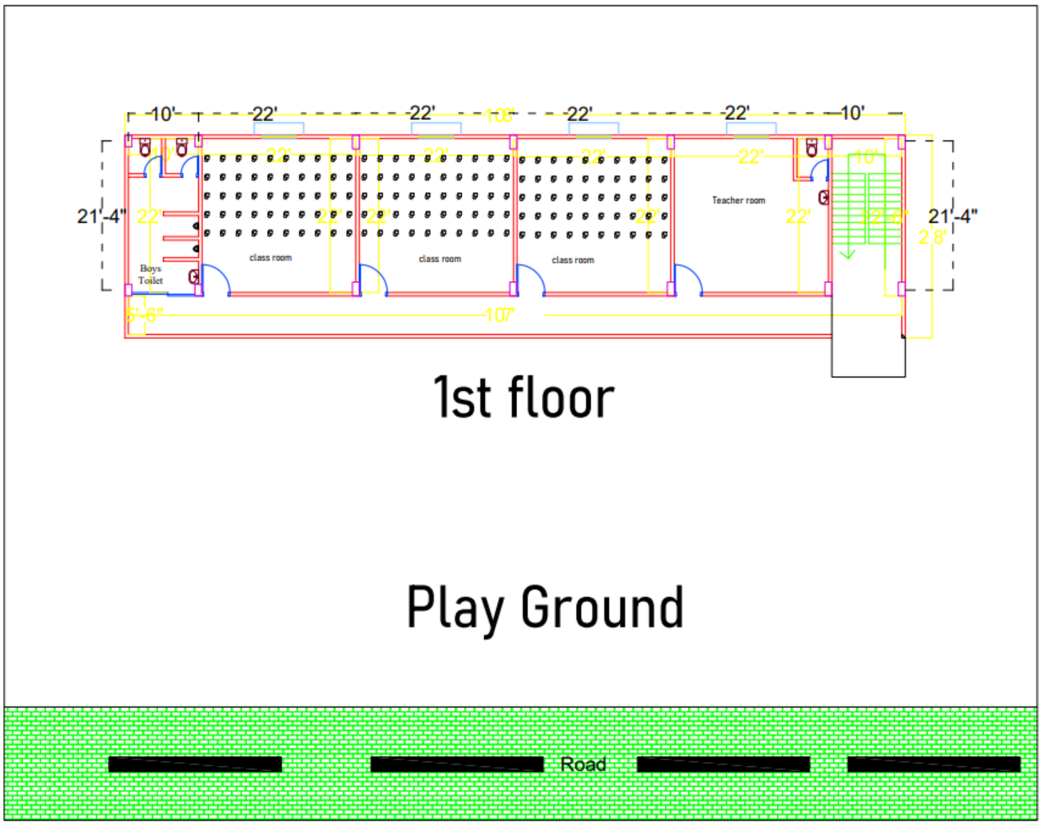


Fig. 1.1: First Floor Plan

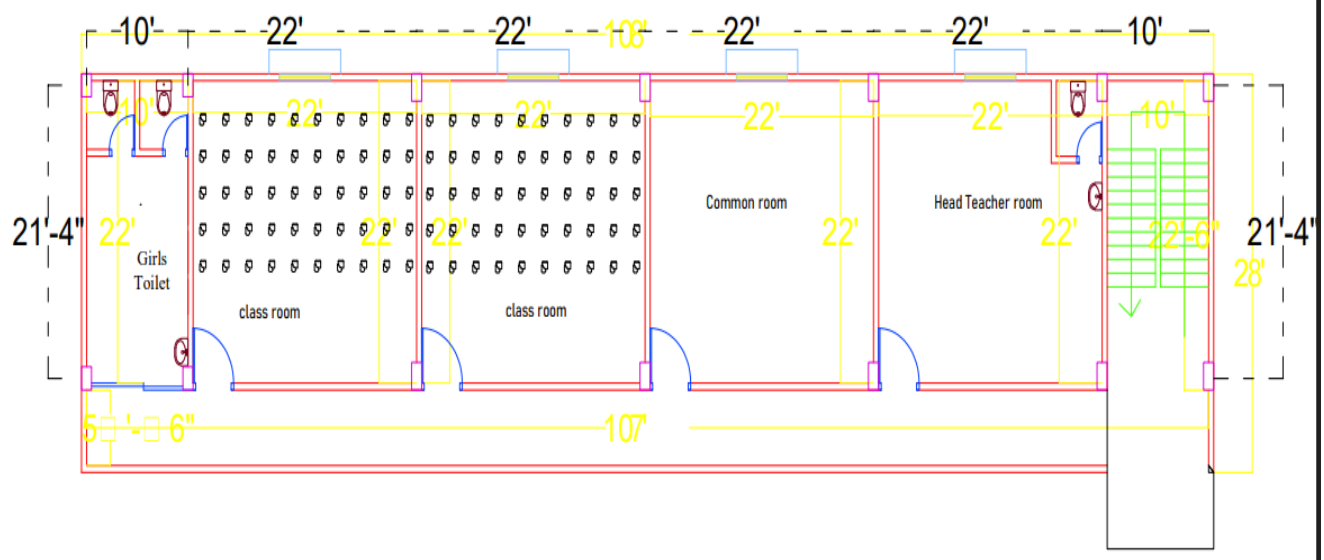


Fig. 1.2: Second Floor Plan

1.2 Project Objectives

- To design a structurally safe two-story primary school building in compliance with BNBC 2020 and ACI 318-19 codes.
- To integrate an environmentally sustainable septic tank system for effective waste management.
- To prepare a detailed Bill of Quantities (BOQ) ensuring financial feasibility within the project budget.
- To develop a scalable and transferable model for future educational infrastructure projects in Bangladesh.
- To bridge academic knowledge with practical implementation using modern tools like ETABS, AutoCAD, and Excel.

1.3 Basic Information

This project employs an Intermediate Moment Resisting Frame (IMRF) structural system to create a two-story reinforced concrete (RC) educational institution, as detailed in Table 1.1. The foundation employs isolated footings to carry the loads, while the floor system consists of edge-supported slabs. The building will be assessed and erected to prioritize structural safety and functioning, supporting the specified floor loads and adhering to fundamental gravity and lateral force regulations.

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-story Building
Floor Load	Mentioned in Load Plan
Foundation Type	Isolated footing

1.4 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

1.5 Outline of Capstone project

Chapter 1: Introduction

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

Chapter 3: Design of Structural Elements

Chapter 4: Design and consideration of septic tank

Chapter 5: Discusses of Cost Estimation of the project and timeline of the project

Chapter 6: Conclusion of the project and Recommendations.

Chapter 2

Structural Design and Analysis

2.1 Introduction

The objective of adhering to a design code is to provide minimum standards for the layout, construction, material quality, usage and occupancy, positioning, and maintenance of all buildings in Bangladesh, aimed at safeguarding life, health, property, and public welfare within acceptable limits. Regulations are established for the installation and use of certain tools, services, and accessories associated with or attached to such buildings to achieve the same objective. The Bangladesh National Building Code (BNBC, 2020) was extensively utilized to denote the requirements and coefficients that would be applied in the structural design of this edifice. In line with this, ETABS 2021 was employed to design key structural components of the G+1 (two-story) building, including beams, columns, footings, slabs, and staircases, ensuring that all elements met the prescribed safety and performance standards.

In the application of ETABS, span lengths and stress parameters for beams were carefully delineated, allowing the software to compute the requisite reinforcement for shear and bending. We checked the cracks and changes to make sure they satisfied the serviceability standards. The interaction equations in the design code demonstrated that columns were vertical frame parts that could hold axial loads and moments. Before building the foundation, the suitable kind of reinforcement was utilized to make sure that the structure would be stable and that the bearing capacity was right. The BNBC required that staircases be constructed as structural sections so that they could hold and measure weights. People found out how thick slabs should be and how to produce them by bending and moving them.

After ETABS did the structural analysis and design, AutoCAD was utilized to add the details. This phase was needed to see and discuss about the design parameters. AutoCAD produced the comprehensive drawings for all of the structural sections, such beams, columns, slabs, footings, and stairs. All the dimensions, reinforcing plans, and material needs were in these designs. These drawings showed how structural parts are connected, such the joints between beams and columns and the support for slabs. The designs were not only powerful, but they were also easy for construction workers to grasp since they employed the right AutoCAD details and ETABS analytical data. This link makes it simpler and more precise to get things done on site.

2.2 Foundation System

The foundation is a very significant feature of a structure because it holds the building up and sends its weight to the earth. Isolated footings are commonly employed in low-rise reinforced concrete buildings because they are inexpensive, simple to use, and work well in light stress situations (BNBC, 2020). Das (2015) says that the design of isolated footings must take into consideration the soil's trustworthy carrying capacity, which may change based on geotechnical investigations.

This project used isolated footings because they performed well with the site's subsoil and the modest axial forces that were expected for a two-story structure. The detailing for the reinforcement meets the specifications given by BNBC (2020) and ACI 318 to make sure it can bear bending and punching shear. If the steel is the appropriate size and in the right place, it will halt differential settling and make the structure unstable. ETABS works out the right cover, the minimum depth, and how to disperse the weight. AutoCAD checks these.

Fig. 2.1: Foundation

2.3 Columns

Columns are the vertical load-carrying members designed primarily for axial compressive forces, though they may also resist bending and shear due to lateral loads. For reinforced concrete buildings, column design is guided by axial load and moment interaction diagrams based on the principles outlined in ACI 318-19 and BNBC (2020).

Research by Park and Pauley (1998) emphasized the importance of ductility and confinement in reinforced concrete columns, especially for structures located in seismic zones. Given Bangladesh's moderate seismic risk, the design of columns in this project included transverse reinforcement (ties) at appropriate spacing to prevent buckling of longitudinal bars and to ensure energy dissipation capacity. ETABS was used for accurate load modeling, while column sizes and reinforcement details were optimized to avoid slenderness issues and to satisfy interaction checks.

Fig. 2.2: Column

2.4 Beams

In reinforced concrete structures, horizontal components known as beams transfer weights from slabs to columns and ultimately to the foundation. made to resist bending moments and shear pressures produced on by live, dead, and seismic loads. The maintenance of classroom spans and the preservation of continuous operation under dynamic load conditions are determined by beam safety in school buildings.

BNBC (2020) specifies requirements for clear cover, lap splicing restrictions, and minimum and maximum reinforcement ratios, among other reinforcement detail specifications. In this study, beams were constructed using ETABS to determine the necessary reinforcement based on bending moment and shear force diagrams. Additionally, provisions were included for corner reinforcement, development length, and lap zones. To ensure building clarity, extensive cross-sectional and longitudinal drawings were created using AutoCAD.

Fig. 2.3: Beam

2.5 Slabs

Roofs and floors are constructed using horizontal plate components known as slabs. Their design ensures seamless, structurally sound load transfer to columns and beams. While being strong enough to withstand live loads generated by students, furniture, and equipment, slabs in educational buildings must meet serviceability norms for deflection and cracking.

This project uses edge-supported slabs flat slabs supported by beams. Structural loads and span lengths under BNBC (2020) and ARE 456:2000 define slab thickness, span-to-depth ratio, and reinforcing details. Finite element analysis in ETABS helped to simplify the computation of deflection across slab panels, shear forces, and bending moments. Drawings in AutoCAD guided construction; completed reinforcing plans considered durability and crack width control.

Fig. 2.4: Slab Reinforcement

2.6 Staircase

While providing vertical circulation between floors, staircases have to follow structural and architectural criteria. For large class numbers, school building staircases should be roomy, safe and inviting ones. The Infrastructure Plan and Planning Guidelines for Primary Schools (DPE, 2018) and the BNBC (2020) provide standards for tread-riser proportions and minimum width criteria.

The stairs in this project were designed in ETABS as inclined slab systems to include both dead and live loads. Particular focus went to boundary circumstances, support details, and landing reinforcement. The integration of stairs with the whole frame system was also investigated to provide structural compatibility and load sharing with neighboring beams and slabs.

Fig. 2.5: Stair

2.7 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 Building Code (BNBC, 2020)

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

2.8 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.

Material properties

Minimum f'_c (28 days cylinder crushing strength) Foundation and Column

= 4000 psi with Mix Ratio = 1:1:2 Beams and Slabs = 4000 psi with Mix

Ratio = 1:1:2

2.9 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 is the Diameter of the Bar N.B: Column lap is tension lap.

2.10 Corner reinforcement

The Bangladesh National Building Code (BNBC, 2020) mandates corner reinforcement to enhance the strength of structural corners and mitigate stress concentrations, especially in seismic zones. To mitigate shear and torsional pressures, the BNBC (2020) recommends using additional diagonal bars, closely spaced stirrups, and ties for beams, slabs, and column-beam connections. To prevent slippage under load, adequate anchoring and minimum lap lengths for corner bars are essential, as illustrated in Fig. 2.1. This reinforcing approach enhances structures' capacity to manage lateral loads, preventing cracking or brittle failure, while ensuring ductility, energy absorption, and structural integrity at important locations.

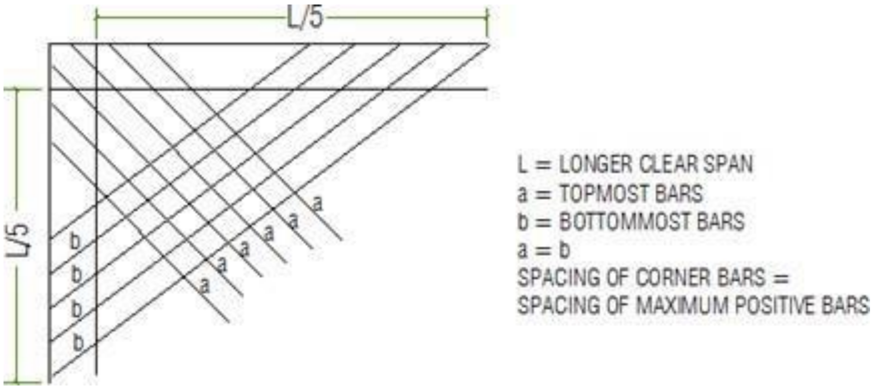


Fig. 2.6: Corner reinforcement

2.11 Material strength

The project stipulates that the concrete strength (f'c) for all structural components, including the foundation, pedestal columns, grade beams, columns, beams, and slabs, must surpass 4000 psi. The yield strength (fy) of the reinforcing steel is 60,000 psi, as indicated in Table 2.1, ensuring uniformity and compliance with established design standards for all structural elements.

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

2.12 Development length

The development length (L d) for reinforcement in beams and slabs is the minimum length of rebar required to be embedded in concrete to avoid slippage and achieve full structural strength, as stipulated by the Bangladesh National Building Code (BNBC, 2020). The formula is employed to compute it. Ld. = ϕ * fy / 4 * Tb, where ϕ represents the bar diameter, fy denotes the steel yield strength, and τb indicates the concrete bond strength, which fluctuates based on the concrete's strength, the rebar type, and its positioning. Because they can hold more weight, beams frequently need longer development lengths than slabs. The BNBC (2020) says that adjustment factors must be used for things like the kind of rebar and where the top reinforcement is put. By setting the proper anchoring lengths for various load scenarios, these rules make sure that concrete structures are safe and sturdy.

2.13 Concrete Clear Cover for Reinforcing Bars

The clear concrete cover is needed to protect the reinforcing steel bars from fire, rust, and other damage from the environment. There is the least amount of space between them and the concrete. The clear cover for columns is normally 1.5 inches thick and is sturdy enough to protect them. The usual size for internal beams is 1 inch, however they may go bigger if the environment changes. A clear cover that is between 0.75 and 1 inch thick is normally on top of the slab. The thickness of the slab and how much it is exposed to the weather will determine this Table 2.2 shows that the typical thickness for a transparent cover for stairs is 0.75 inches. This keeps the structure sturdy while giving it enough protection. A good clear cover makes the construction stronger and more trustworthy by making it less likely to catch fire, preventing chemicals and moisture from getting to the reinforcement, and retaining the structure's strength.

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"

2.14 Load consideration and Load Combination

In ETABS, the building was modeled with the following loads per BNBC (2020):

- Dead Load (D): Self-weight of structural and permanent elements.
- Live Load (L): Occupants, furniture; 2–4 kN/m^2 in classrooms, 4–5 kN/m^2 in corridors/assembly.
- Floor Finish (F): 1–1.5 kN/m^2.
- Other Loads: Roof Live (L_r), Rain (R), Wind (W), Earthquake (E), and Soil/Fluid Pressure (H).

These loads were combined in ETABS using BNBC 2020 provisions:

Strength Design (LRFD):

1. 1.4D
2. 1.2D + 1.6L + 0.5(Lr/S/R)
3. 1.2D + 1.6W + L + 0.5(Lr/S/R)
4. 1.2D + 1.0E + L + 0.2S
5. 0.9D ± (1.6W or 1.0E)

Allowable Stress Design (ASD):

1. D
2. D + L
3. D + (Lr/S/R)
4. D + 0.75L + 0.75(Lr/S/R)
5. D + (0.6W or 0.7E)
6. 0.6D ± 0.6W / 0.7E

2.15 Design of Slab and detailing

While designing slabs in ETABS, consider many critical variables to maintain structural integrity, and adherence to building codes. The program calculates slab shape, thickness, material properties, load types (dead, live, and environmental loads), and boundary conditions. The program also determines the stresses, deflections, and reinforcement required throughout the slab using finite element analysis. ETABS also computes the performance of the slab for various combinations of loads, load distributions, and support conditions (e.g., simply supported, fixed, or continuous). Besides, it integrates regionally specific safety aspects and design requirements so that engineers can check conformity to regional standards. For the purpose of improving the slab's performance and durability, reinforcing details and crack width restrictions are also taken into account.

The comprehensive slab and reinforcement parameters were finalized and exported to AutoCAD following the completion of the structural design in ETABS. These comprehensive drawings guarantee that the design meets structural specifications and facilitates flawless implementation throughout construction by offering precise information in Figures 3.1 and 3.2.

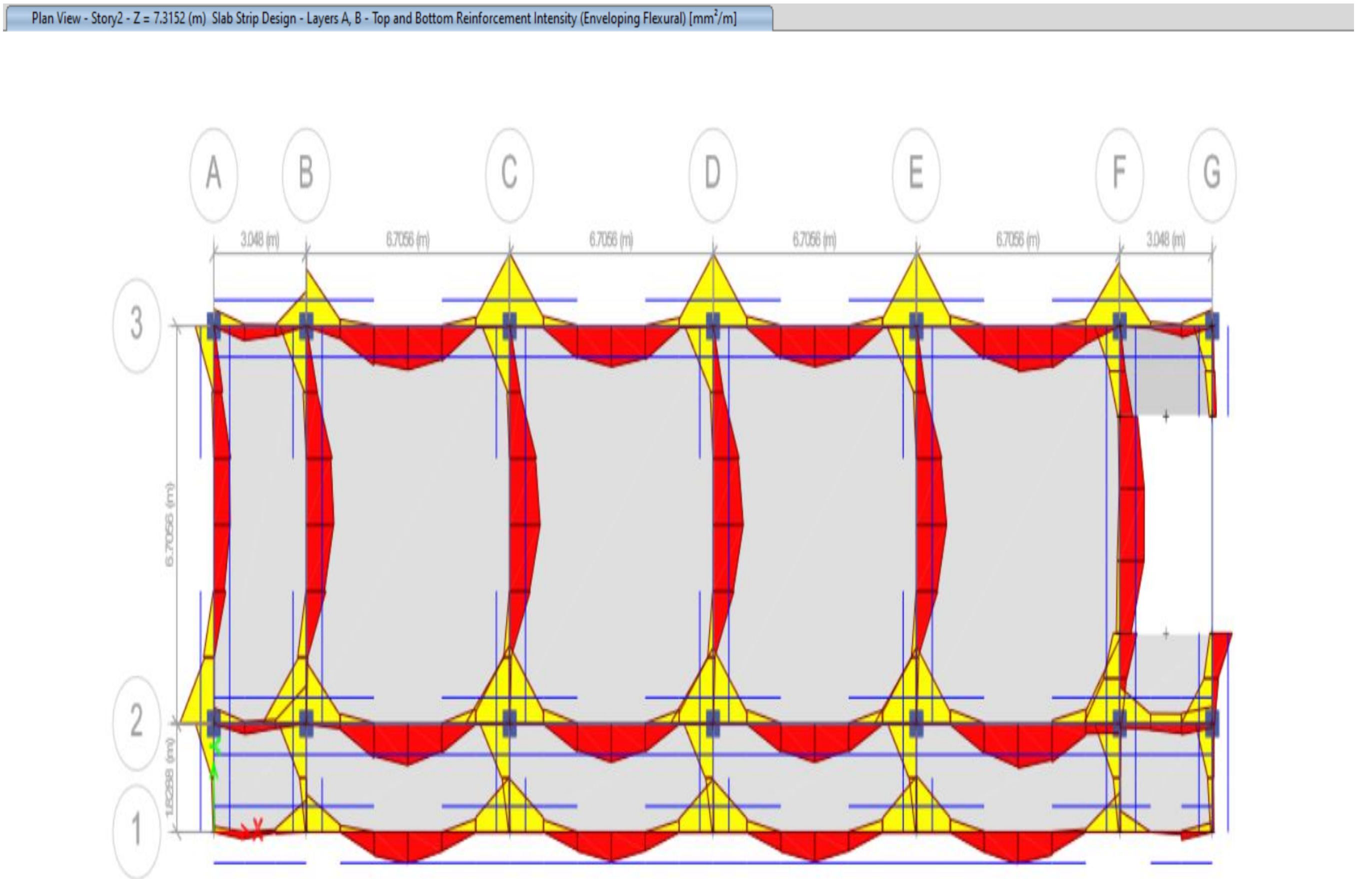


Fig. 2.7: Top and Bottom reinforcement of slab

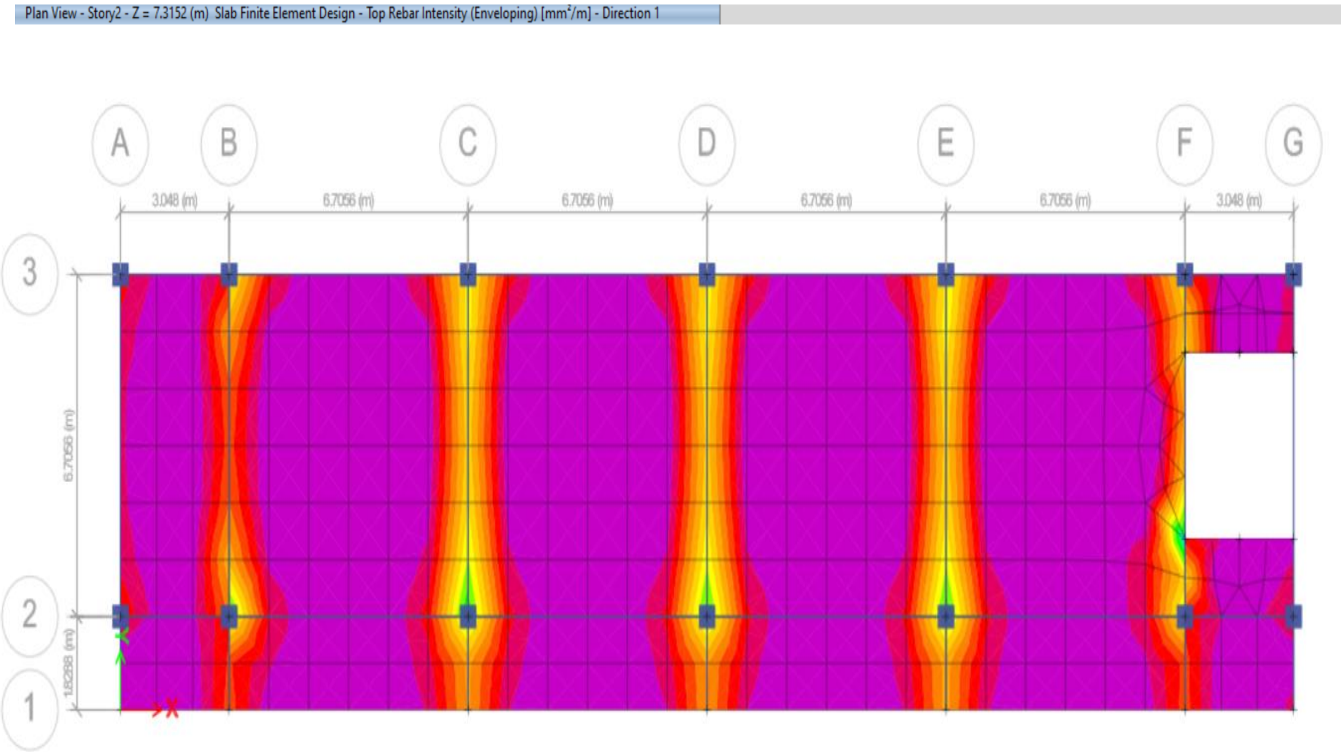


Fig. 2.8: Finite Element Design

2.16 Design of Beam and Detailing

The ETABS beam design procedure for the G+1 structure involves determining the beam dimensions and specifying the loading conditions, including dead and live loads, in compliance with relevant standards. Upon establishing the model, we utilized ETABS to analyze the beams for shear forces and bending moments, as seen in Fig. 3. The program ensured compliance with structural safety norms by automatically estimating the required reinforcement for both positive and negative moments in the beams. To ensure that the calculated deflections were within permissible limits for serviceability, it was confirmed that the reinforcement configuration adhered to the minimum code requirements and effectively resisted the applied loads after reviewing the analytical results. Taking everything into account.

2.16.1 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.

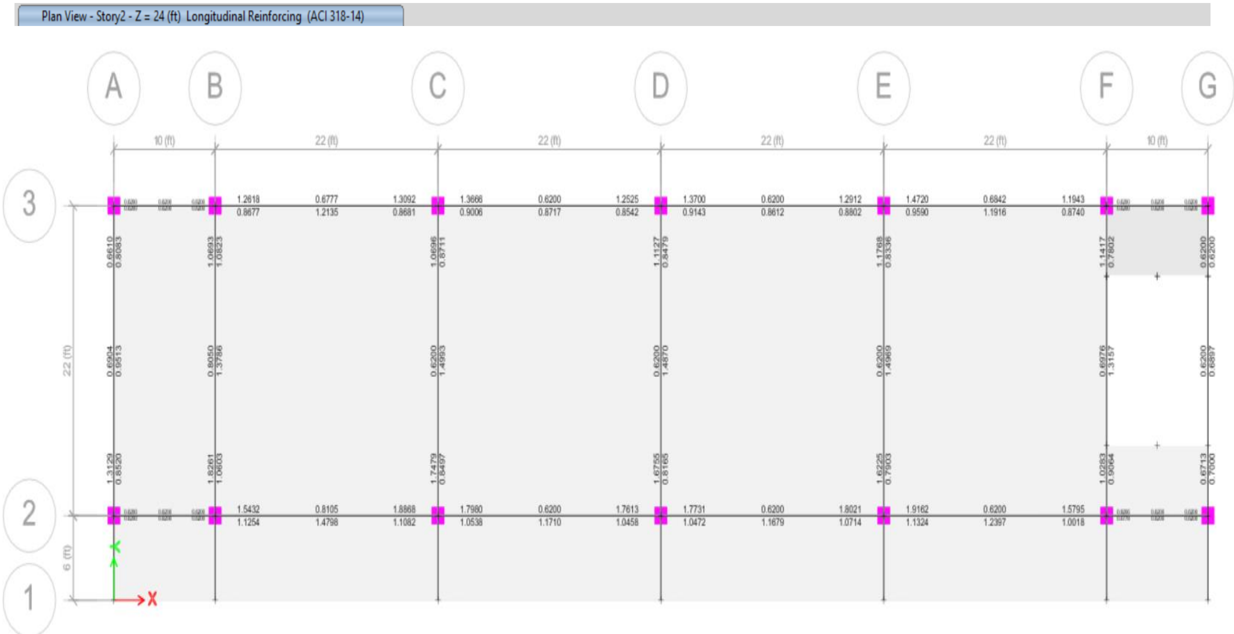


Fig. 2.9: Longitudinal Reinforcement Area of 1st floor beam

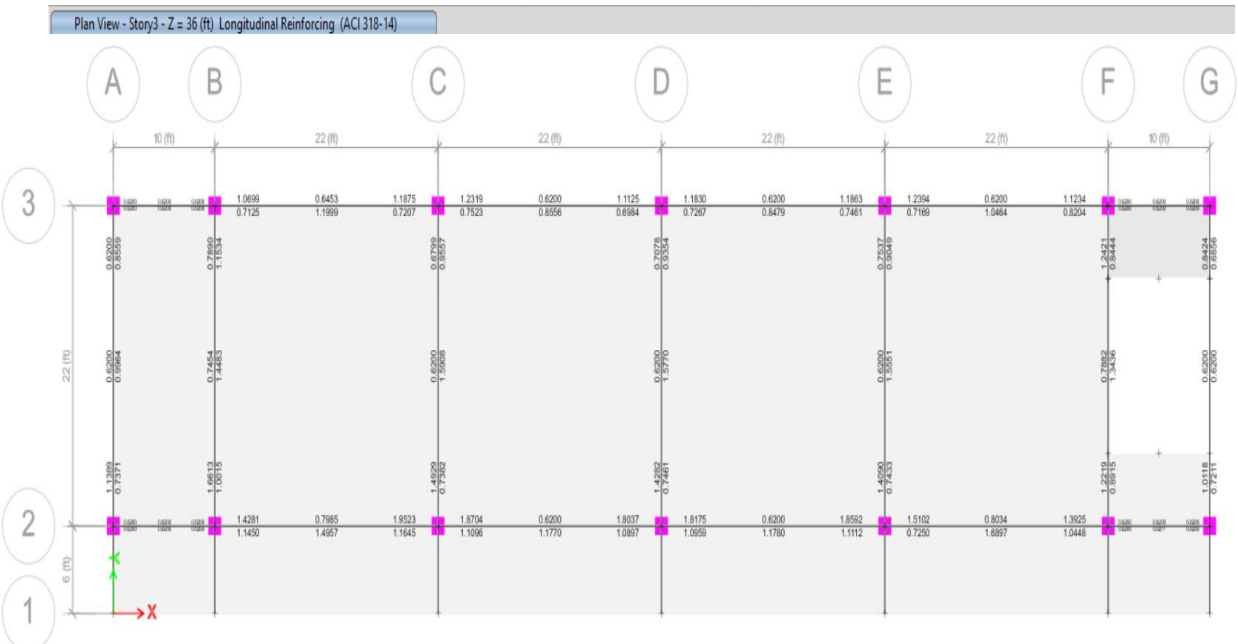


Fig. 2.10: Longitudinal Reinforcement Area of 2nd floor beam

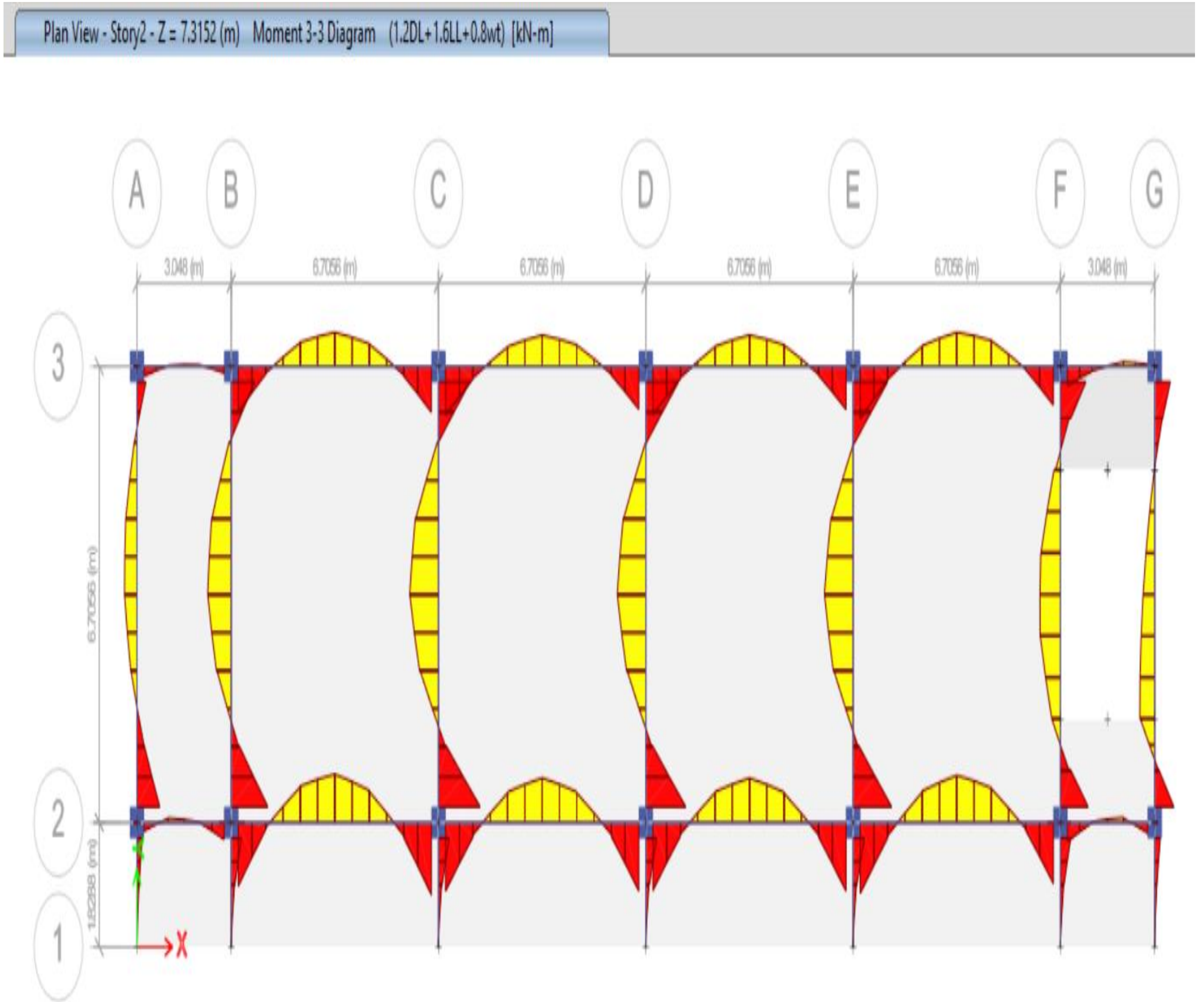


Fig. 2.11: Bending moment diagram

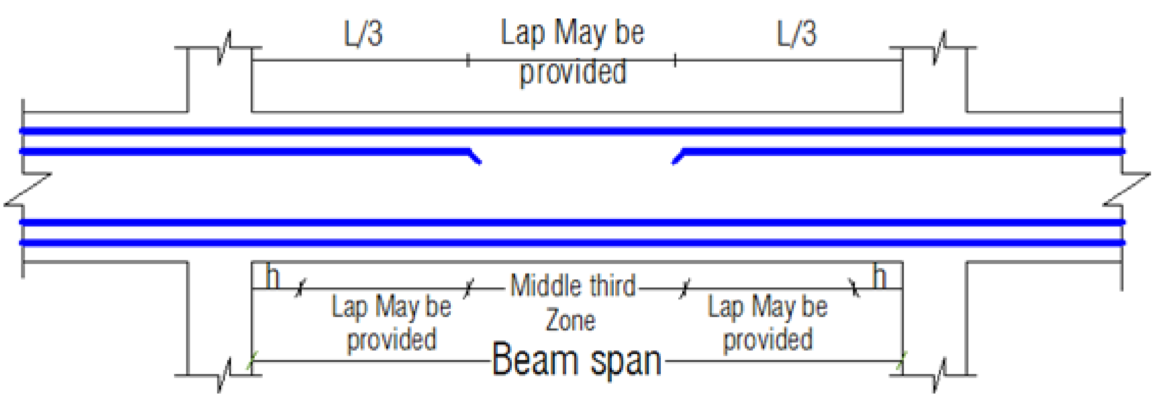


Fig. 2.12: Lap position

Table 2.3: Beam details

Beam of Roof				
Beam No	**Dimension**	**Bottom Rebar**	**Top Rebar**	**Stirrups**
B1	12''x18''	4# 6 Dia	4# 6 Dia	#4 @ 4-9" c/c

2.17 Design of Column and Detailing

ETABS performs extensive calculations when it generates columns within its structural models. The first step involves examining the moments and axial loads which affect the columns. The assessment of column strength and stability depends heavily on this factor. The analysis of column performance by ETABS includes both dead loads and active loads. The program evaluates the column's cross-sectional area together with its reinforcement requirements and bending stiffness and flexibility. The overall performance of a column depends on these multiple factors which determine its resistance to bending and compression. The column design process in ETABS involves safety and performance checks through proper design code application and thinness consideration. ETABS integrates all necessary components to enable structural engineers to create building columns that meet all standards. ETABS. The detailed drawings ensure that the design meets structural requirements. The drawings provide precise data about bar diameters and column proportions and reinforcement arrangements to ensure construction progresses without issues.

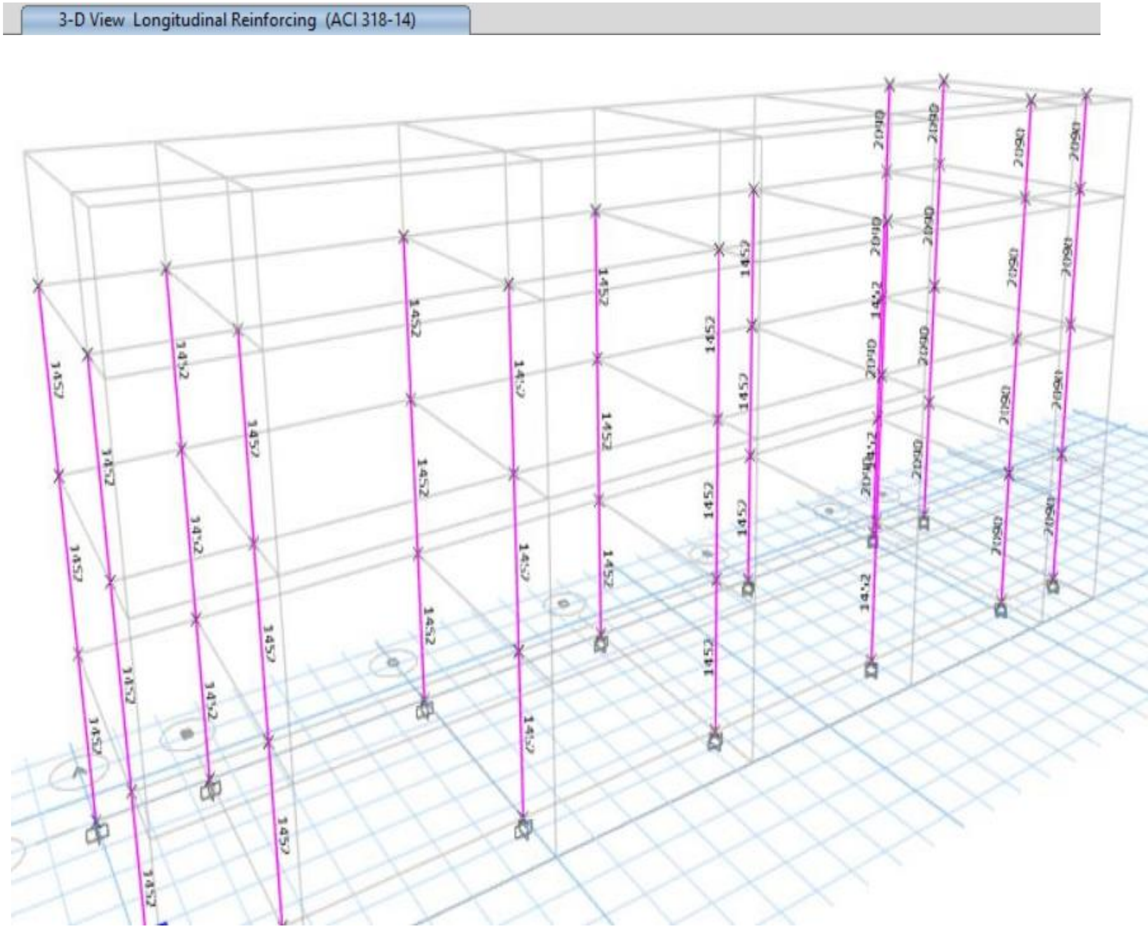


Fig. 2.13: Longitudinal Area Reinforcement of Column

Table 2.4: Detailed of Ground to roof column

Columns at Basement to Ground Floor			
Column No.	Size of Column	Main Reinforcement	Lateral Ties
C1	15"x15"	12# 6 dia	#3@ 6-18"c/c

2.18 Design of Foundation and detailing.

The design of isolated footings in ETABS considers several factors to ensure structural stability and conformity with design criteria. The capacity of the soil and, in particular, the soil bearing capacity, is an important determining factor that influences the size of the footing and whether or not it requires reinforcement. The load that the column footing carries, which consists of dead, live, and any additional applied loads, is determined and distributed in ETABS to ensure that the footings are supported without exceeding the soil bearing capacity. Shear forces and moments acting at the bas of the footing are also considered mainly in terms of bending and punching shear. The software ensures that settlement remains below acceptable limits while evaluating footing depth and strengthening to resist bending stresses. The design is optimized, ensuring compliance with local building regulations and safety legislation by considering criteria such as concrete strength, footing form, dimensions, and all details shown in Fig. 3.8 and Table 3.3.

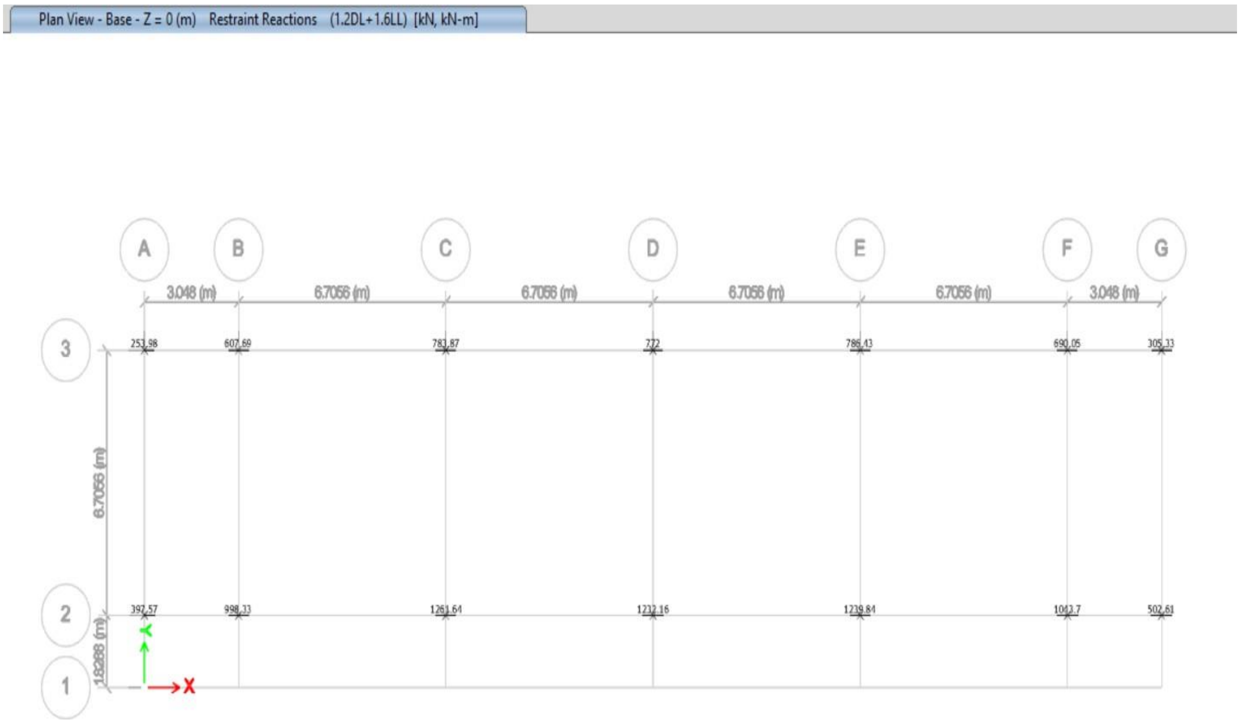


Fig. 2.14: Footing load

Table 2.5: Final detailing of footing

NO. OF COLUMN	TDL (KIP)	TLL (KIP)	QA (KSF)	Square Column Size (Inch)	Final Detailing
5	98.371	20.459	2.5	15	Footing Size 7' x 7' x 12.5" and both direction #10 @ 5.5inch C/C
2	121.227	51.055	2.5	15	Footing Size 9' x 9' x 16.5" and both direction #11 @ 3.5inch C/C
1	125.305	39.328	2.5	15	Footing Size 9' x 9' x 15.5" and both direction #11 @ 3inch C/C
1	118.204	49.587	2.5	15	Footing Size 9' x 9' x 17.5" and both direction #11 @ 4.5inch C/C
1	47.818	9.937	2.5	15	Footing Size 5' x 5' x 10.5" and both direction #5 @ 3inch C/C
1	33.114	3.701	2.5	15	Footing Size 4' x 4' x 12.5" and both direction #3 @ 4inch C/C
1	**98.672**	**37.821**	2.5	15	Footing Size 8' x 8' x 14.5" and both direction #10 @ 3.5inch C/C
1	68.307	16.503	2.5	15	Footing Size 6' x 6' x 11.5" and both direction #9 @ 5.5inch C/C
1	**62.338**	7.012	2.5	15	Footing Size 6' x 6' x 12.5" and both direction #9 @ 9inch C/C

2.19 Design of Staircase and detailing

Structural and load considerations are essential for ensuring safety and usefulness while constructing a staircase in ETABS. ETABS will evaluate the staircase's geometry to meet architectural criteria, including the climb, run, and overall slope. It considers the strength and stiffness of materials, such as steel or concrete, to account for their structural properties. To adhere to architectural regulations, load assessments must encompass both dead loads (such as the structure's self-weight) and live loads (including the weight of occupants and movable objects on the stairs). Regardless of whether the staircase is cantilevered, supported at both extremities,

or

The program evaluates boundary conditions and types of support while resting on intermediate landings, as seen in Fig. 3.9.

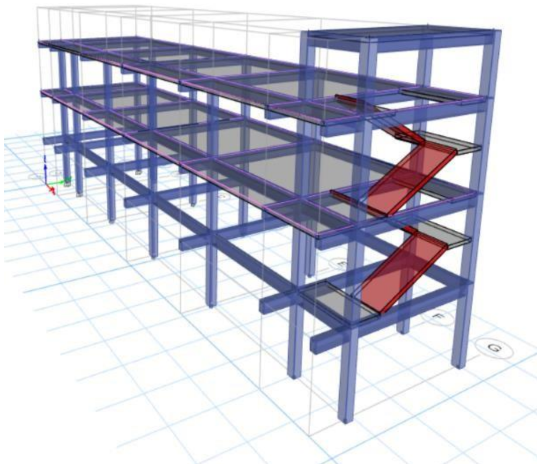


Fig. 2.15: Stair view from ETABS

2.20 Summary

This project entailed the design of the structural elements of a G+1 building, including footings, slabs, columns, beams, and staircases, utilizing ETABS. The safety and functionality of each component have been guaranteed by meticulous modeling, analysis, and reinforcing in accordance with relevant design requirements. AutoCAD subsequently generated precise and detailed drawings of the designs, inclusive of labels, reinforcement configurations, and measurements. This comprehensive method ensured the design's safety for practical execution, while confirming the structure's stability and compliance with code requirements.

Chapter 3

DESIGN OF SEPTIC TANK

3.1 Introduction

When a town doesn't have access to a public sewer, a septic tank is most often used as an underground wastewater treatment system. In a sealed chamber, which is commonly built of concrete, fiber glass, or plastic, anaerobic bacteria may break down organic materials. The tank keeps the solids and liquids apart. Effluent is the liquid that has been partly treated by anaerobic bacteria. It then travels to a drain field, where it goes through soil to be treated even further. When designing a septic system, the operators will pick strong materials for the tank, make sure the tank is the right size for the amount of water used in the home, and put the tank far enough away from drinking water sources to prevent contamination. It is best to pump and check every two to five years; the most important thing is to stay up with maintenance. Local rules may spell out how to build, position, and install an architectural structure such that it protects the quality of groundwater and human health.

3.2 Septic Tank System

Onsite sanitation systems are crucial for sanitary waste disposal in many regions of Bangladesh, particularly peri-urban areas (e.g. Savar) where a larger infrastructure does not yet exist. If designed correctly, a septic tank system can be an environmentally sustainable method for the disposal of waste on-school site.

The septic tank must be constructed according to BNBC (2020) and WHO sanitation standards with respect to user capacity, average daily water usage, sludge buildup ratio and long-term maintenance. The septic tank system in the school was built to accommodate 270 users based on sludge build-up, hydraulic residence time and requirements of the breakdown (digestion) area. The tank was therefore designed to included septic system components for settling (sedimentation), breakdown (digestion), scum layer, and venting gas from the risers, access to the tank for repairs and servicing. Then used reinforced concrete for the system and resilient materials to ensure durable, safe and environmentally friendly constructions.

Fig. 3.1: Septic Tank

3.3 Component of Septic tank

There are several working components of a septic tank, all which are involved in the wastewater treatment of homes. Wastewater from the home enters the septic tank flow-through inlet pipe, separating solids from liquids. The less dense solids float to the top of the tank as scum, while denser solid materials sink and build up at the bottom of the tank as sludge. The effluent layer, containing partially treated wastewater, lies between the scum layer and sludge layer. There are baffles and tees near the inlet and outlet pipes to allow the effluent to flow from the septic tank to the drain field for further treatment thereby controlling what's moving in and out of the tank, in addition to reducing the chances of clogging. Access ports (called risers) with watertight covers allow for periodic pumping, maintenance, and inspection of sludge and scum.

3.4Design Consideration of Septic Tank

The Bangladesh National Building Code (BNBC, 2020) provides essential guidance for the design of septic tanks to provide proper waste water treatment. To design a septic tank for 270 users, which includes 25 students in each classroom and requires 16 sq ft of carpeted space per student, the designer must account for the number of users, daily water usage per person, and the time wastewater sits or retains in the septic tank. Below are the step-wise procedures for determining the septic tank size and its design parameters:

The household's daily water consumption should determine the septic tank size to allow for adequate detention of the waste water for one to two days to allow the solids to settle and decay. To avoid leaking and possible contaminating the groundwater, strong water-proof materials such as concrete, fiberglass or plastic, should be used to construct tanks. Tanks are typically divided into two sections by walls or baffles to improve the cleaning process.

The outlet pipe needs to be positioned slightly lower to ensure proper wastewater flow, and the inlet and outlet pipes should be arranged with fittings to facilitate smooth flow control. To facilitate the release of gases, eliminate unpleasant odors, and enhance bacterial activity, adequate ventilation is essential. To enable regular pumping and inspection, the (BNBC, 2020) also requires access points, or risers; these should be properly sealed to avoid contamination. The drain field's design, which is where wastewater leaves the tank, must consider the soil's ability to absorb water and should be placed at a safe distance from water sources, building & wells.

The septic tank must be placed sufficiently deep to avoid freezing issues and at a safe distance from structures and water sources. To ensure the tank operates effectively and protect public health, regular maintenance is recommended, including the removal of solids every two to five years. Refer to the drawings illustrated in Fig. 4.1 and Fig. 4.2.

3.5 Design of Septic Tank

Population, P =	**270**	persons	Length, L =	9.098	m
Per capita water use, q =	**25**	lpcd	Width, W =	3.033	m
Cleaning cycle, N =	**5**	years	Liquid depth, H =	3.322	m
Design temp, T =	25	°C			
Solids accumulation rate, C =	0.04	m^3/person/yr			
Scum zone					
V_{sc} =	21.6	m^3	$'d_{sc}$ =	0.783	m
Sedimentation zone					
t_h =	0.351	days	$'d_h$ =	0.375	m
V_h =	2.371	m^3			
Digestion zone					
t_d =	42.3	days	$'d_d$ =	0.207	m
V_d =	5.713	m^3			
Sludge zone					
V_{sl} =	54	m^3	$'d_{sl}$ =	1.957	m
Total					
V =	83.7	m^3	'd =	3.322	m
'a =	**3**		A =	27.6	m^2
'b =	**1**				
'c =	**1**				
'x =	3.03277139				

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

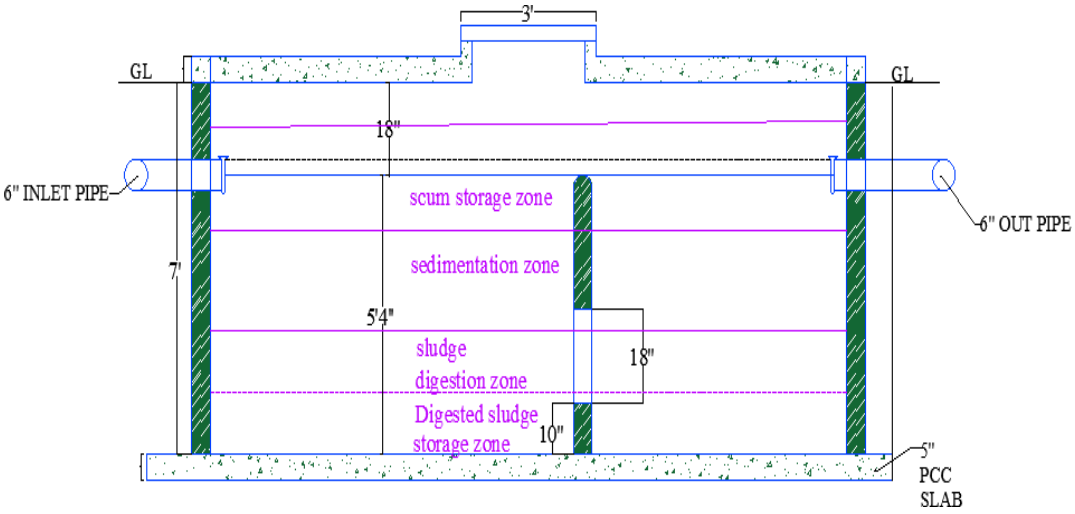


Fig. 3.2: Section view of Septic tank

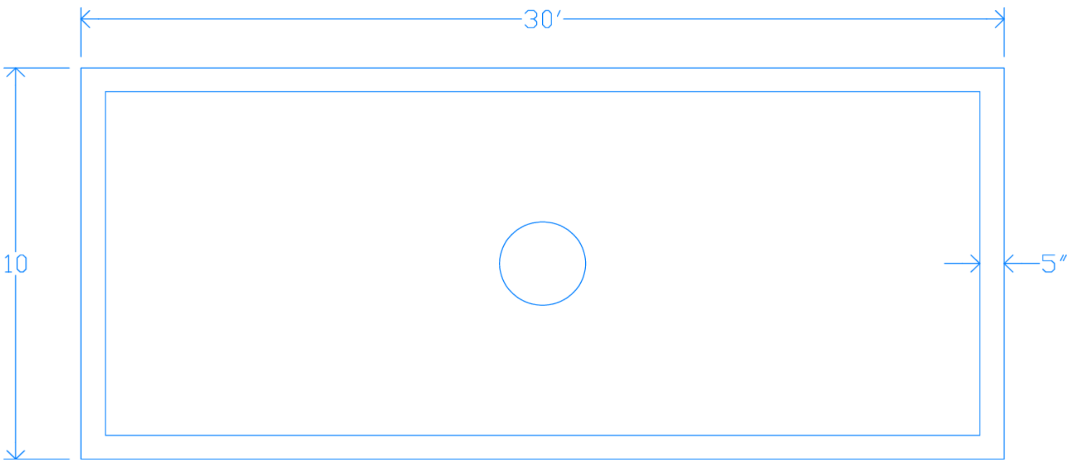


Fig. 3.3: Plan of septic tank

3.6 Summary

A septic tank is an underground system utilized for treating wastewater in areas lacking sewer access. It divides waste into three distinct layers: effluent (treated liquid), sludge (heavy solids), and scum (oils and fats). Following its passage through a drain field, the effluent experiences additional filtration. The tank is designed to prevent leaks by utilizing durable materials such as fiberglass or concrete, incorporating baffles and maintenance access ports, and being sized appropriately to meet the water demand of the home. To effectively release gases and prevent odors, adequate ventilation is essential. The tank should be sufficiently deep to prevent freezing and located at a distance from structures, water sources, and wells. To ensure the system operates effectively and protects public health, regular maintenance is essential, including the removal of sludge every three to five years.

Chapter 4
Cost Estimation

4.1 SLABS

General Description

Horizontal elements that transmit loads to beams and columns to support floors and roof.

Materials Specification

- **Concrete Grade**: M30.
- **Reinforcement**: 10mm diameter steel bars (0.188 kg/ft). The slabs require 6.62 tons of steel, equal to 6620 kilograms, as per the ETABS detailing. The cost of slab reinforcement is calculated as 6620 × 86 = 569,320 BDT, which includes both the main reinforcement and distribution bars used on each floor.

Table 4.1: Quantity Takeoff (Slabs)

Material	Quantity	Unit Price (Taka)	Amount (Taka)
Cement	990 bags	550 per bag	544,500
Sand	1,857 cft	27 per cft	50,139
Coarse Aggregate	3,711 cft	115 per cft	426,765
Reinforcement (10mm dia)	6620 kg	86 per kg	569320
TOTAL COST FOR SLABS			**15,90,724**

Technical Notes

- Slab volume: 1,512 cubic feet
- Distribution bars: 395 nos × 32.82m
- Total steel requirement: 2,779.56 kg

4.2 BEAMS

General Description

Essential structural elements that transfer loads from slabs to columns, designed to withstand bending and shear stresses.

Materials Specification

- **Concrete Grade**: M30
- **Reinforcement**: The Beams, the ETABS detailing indicates a total steel requirement of

  12.6 tons, or 12,600 kilograms. At the unit price of 86 BDT/kg, the beam reinforcement cost is 12,600 × 86 = 1,083,600 BDT. This covers the top and bottom bars, stirrups, and any additional reinforcement used in both primary and secondary beams.
- **Beam Size**: 18 in × 12 in

Table 4.2: Quantity Takeoff (Beams)

Material	Quantity	Unit Price (Taka)	Amount (Taka)
Cement	320 bags	550 per bag	176000
Sand	599 cft	27 per cft	16173
Coarse Aggregate	1198 cft	115 per cft	137770
Reinforcement	12600 kg	86 per kg	1083600
TOTAL COST FOR BEAMS			**1413543**

4.3 COLUMNS

General Description

Vertical structural elements that transfer loads from upper floors to the foundation, designed to withstand compressive and lateral forces.

Materials Specification

- **Concrete Grade**: M30
- **Reinforcement**: The column reinforcement weight, as obtained from ETABS, is 5.61 tons, which equals 5610 kilograms. Hence, the total cost for column reinforcement becomes 5610 × 86 = 482,460 BDT. This includes all vertical bars, ties, and necessary laps for both ground and first-floor columns.
- **Column Size**: 15 in × 15 in

Table 4.3: Quantity Takeoff (Columns)

Material	Quantity	Unit Price (Taka)	Amount (Taka)
Cement	189 bags	550 per bag	103950
Sand	354 cft	27 per cft	9558
Coarse Aggregate	707 cft	115 per cft	81305
Reinforcement	5610 kg	86 per kg	482460
TOTAL COST FOR COLUMNS			**677273**

4.4 FOOTINGS (ISOLATED)

General Description

Used to support individual columns and distribute loads to the ground, designed to withstand shear stresses and bending moments.

Materials Specification

- **Concrete Grade**: M30
- **Reinforcement**: 20mm diameter steel bars (0.75 kg/ft)

Table 4.4: **Quantity Takeoff (Footings)**

Material	Quantity	Unit Price (Taka)	Amount (Taka)
Cement	328 bags	550 per bag	180400
Sand	580 cft	27 per cft	15660
Coarse Aggregate	810 cft	115 per cft	93150
Reinforcement	3,330 kg	86 per kg	286380
TOTAL COST FOR FOOTINGS			**575590**

4.5 STAIRS

General Description

Provides vertical circulation between different floor levels.

Materials Specification

- **Concrete Grade**: M30
- **Reinforcement**: The total reinforcement weight for the stair is 376 kilograms. With the local price of reinforcement rod in Bangladesh being 86 BDT/kg, the cost of stair reinforcement is calculated as 376 × 86 = 32,336 BDT. This includes all steel used in stair slabs, waist slabs, and landings.

Table 4.5: Quantity Takeoff (Stairs)

Material	Quantity	Unit Price (Taka)	Amount (Taka)
Cement	66 bags	550 per bag	36300
Sand	252 cft	27 per cft	6804
Coarse Aggregate	334 cft	115 per cft	38410
Reinforcement	752 kg	86 per kg	64672
TOTAL COST FOR STAIRS			**146186**

Table 4.6: Quantity Takeoff

Material	Unit	Unit Price (Taka)
Cement	Bag (50 kg)	550
Sand	Cubic Foot	27
Coarse Aggregate	Cubic Foot	115
Reinforcement	Kilogram	86

Table 4.7: Summary of BOQ

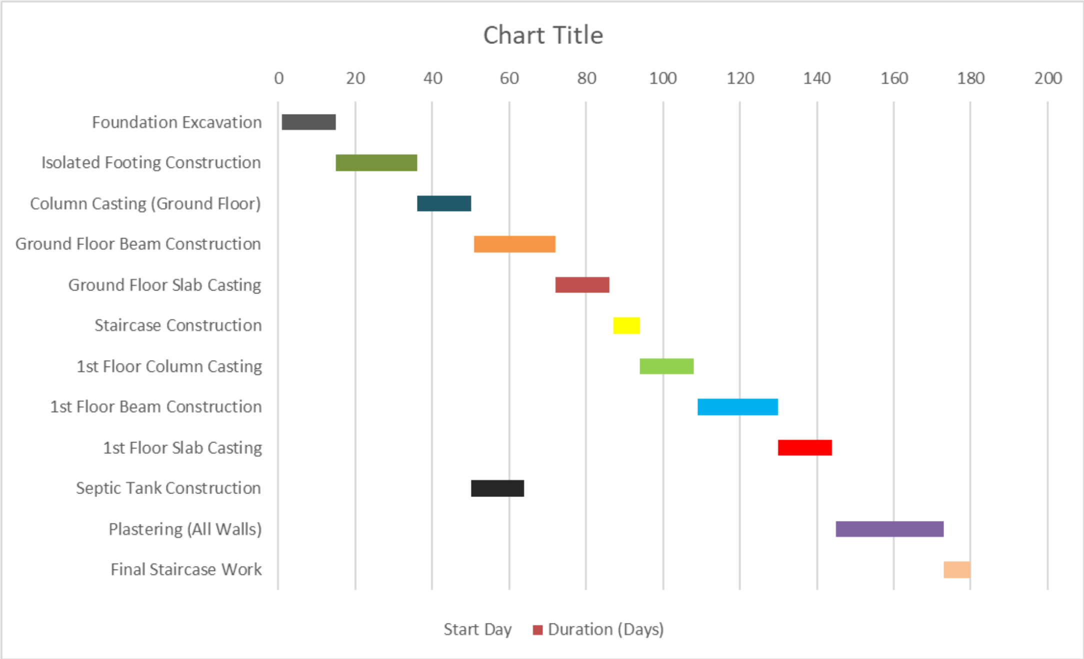
	Estimation	Estimated
	Estimation of Foundation and Footing	5,75,590.00৳
	Estimation of Column	6,77,273.00৳
	Estimation of Floor Beam	14,13,543.00৳
	Estimation of slab	15,90,724.00৳
	Estimation of Stair	1,46,186.00৳
	Estimation of labor	9,91,300.00৳
	Estimation of Brick masonry, Plaster, & Painting work	10,12,356.00৳
	Estimation of Septic Tank	381,494.00 ৳
	Grand Total =	67,88,466.00 ৳

4.6 Introduction of Gantt chart

A Gantt chart is a vital project management tool for construction projects such as a G+1 school building, as it offers a clear and visual timeline of all the key tasks involved in the project. This enables engineers, construction teams, and project managers to efficiently plan, manage, and coordinate operations. A Gantt chart ensures that each phase of work aligns with the overall project objectives and timelines by illustrating the duration and sequence of essential tasks such as excavation, footing, column casting, and slab construction. This approach minimizes delays and optimizes resource use, contributing to enhanced workflow, budget compliance, and timely project completion as outlined in Table 4.8.

Table 4.8: 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



4.7 Summary

The reinforcement determination for the two-story school primary was constructed from a body of work in ETABS 2021 Auto Detailing design, stair, columns, beams and slabs.

In construction projects like a G+1 school building a Gantt chart is an extremely valuable project management tool depicting a sole, clear and visual timeframe for all the key tasks involved. It allows for planning, timely management of construction workers and construction crews and for the project managers and engineers to manage whilst being able to co-ordinate with one another with respect to project construction activities at the relevant times.

When determining the duration and sequence of what structural tasks need to be completed, for example excavation, footing, column casting and slab casting, the use of a Gantt chart means that project construction activities can be sequenced and planned so that construction activities and tasks assist to accomplish project goals and objectives within the relevant timeframe. The process streamlines delays and maximize productivity, including but not limited to construction management, cost containment and on-time delivery of the project as stated in table 4.2.

Chapter 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The purpose of this capstone project was to permit a holistic and physical investigation into the built, environmental and economic aspects of civil engineering through the design of a two-story primary school in Savar, Dhaka. This project challenged the students to not only complete a project for academic purposes but reapplied design methodology in a context that ultimately challenged existing real-world standards while serving a wider societal and educational need; meeting the challenge of the growing education demand in Bangladesh for safe, sustainable and inclusive educational infrastructure.

The structural design components of this project followed the Bangladesh National Building Code (BNBC, 2020), and ACI 318-19 to provide the maximized safety, stability and usability of the structure. Throughout the structural analysis and modeling aspect of the structural design process, ETABS 2021 was used to design the structural elements (i.e slabs, beams, columns, foundations and stairs), paying particular note to elements bearing maximum dead and live load, and resisting maximum vertical and lateral load forces. It was important to take into account stress limits, deflection control, and ductility for each of the elements of the design due to the nature of the project being built in an earthquake zone. Construction layout plans and reinforcing details were produced using AutoCAD. AutoCAD were also used to ensure the product provided to the builder was consistent with the design intent of the project.

A key strength of this project was its multi-dimensional option. In addition to a physical structure, equal attention was given to environmental sustainability and practical sanitation design. The septic tank feature- a modestly engineered system to handle a daily wastewater output of 270 users- is a good example of the importance of emerging environmental engineering in infrastructure projects. The septic tank design addressed contamination factors including sludge accumulation, hydraulic retention time, and gas venting to provide a long term, low cost and environmentally sustainable sanitation solution for a peri-urban community that does not have a municipal sewer system.

Another crucial consideration was the list of items and the fact I calculated the costs for materials and resources. The Bill of Quantities (BOQ) was done on Microsoft Excel, with accurate quantity take-offs and reasonable unit costs. The final project budget is 67,88,466Taka and the final financial model for similar educational infrastructure projects in resource-poor contexts is financially viable. The Gantt chart in the report also provided a timeline for the project and a step-by-step framework for project management, scheduling and resource linking. This capstone project also provided an educational experience and cross disciplinary learning for the student team. The project allowed them to connect practice with theory of their academic shelter, become accustomed to industry standard programs and methods (ETABS, AutoCAD, Excel), and build collaborative skills. The project allowed the student team to comprehend the entire life cycle of a building project, from concept and analysis to design development and construction documentation.

In sum, this project has exemplified the values of 21st century civil engineering: safety, sustainability, function and efficiency. It has generated a model that is transferable and scalable for future school projects in Bangladesh and similar countries. It also illustrated the importance of engineers and civil engineering as an occupation with an important role in the creation of infrastructure that improves communities and promotes education in support of national development goals. The lessons learned and challenges faced in this project have better prepared the team for higher-level professional responsibility and engaging in life-long learning as civil engineers.

5.2 Recommendation

Going forward on future projects, it is beneficial to continue using ETABS for the structural design since it can analyze and design structural elements extremely well. Using AutoCAD can help with the detailing process by allowing better coordination of structural and architectural plans.

For cost estimating, although Excel is very usable, using more advanced tools or linking the cost estimating with other BIM software can improve the estimating process and allow for improved accuracy and efficiency, reducing manual errors, and saving time.

Having a consistent process among ETABS, AutoCAD, is crucial for avoiding errors and improving the overall quality of the design. In addition, it is important to have frequent training on software tools and updates on building codes (BNBC, 2020) to ensure compliance and achieve good outcomes on future projects.

Reference

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

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APPENDIX

DESIGN OF SEPTIC TANK

Design of a septic tank to serve a primary school of 270 persons who produce 25 lpcd of wastewater and the tank is to be dislodged every five years.

Solution

P = 270 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 (270 * 25) = 0.351days

The volume required by Sedimentation Zone $V_h=10^{-3}(Pq)*t_h$

= 10^{-3} x (270 X 25) x 0.351 = 2.371 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 x 10^{-3} x 270 x 42.3 = 5.713 m^3

Sludge Zone

V_{sl} = CPN = 0.04 x 270 x 5 = 54m^3

Scum Zone (Sc)

$V_{sc}= 0.4V_{Sl}$ = 0.4 x 54 = 21.6 m^3

Total Volume V = $V_{sc}+ V_h+ V_d+ V_{sl}$ V = 21.6+2.371+5.713+54= 83.7 m^3

Depth Calculation

Cross-sectional area A = 27.6 m^2

The maximum depth of sludge $d_{sl} = V_{sl}/A$ = 54/ 27.6 = 1.957m

The maximum submerged scum $d_{ss} = 0.4*V_{sl}$ / A = 0.4 x 54/ 27.6 = 0.78 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 = 5.713 / 27.6 = 0.207 m

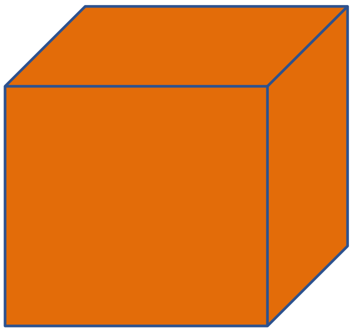
Depth required for sedimentation = Vh / A = 2.371/ 27.6 = 0.086 m < 0.375 m d_h = 0.375 m is adopted

Total effective depth = 1.957 + 0.783 + 0.207 +0.375 = 3.322 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

$$\mathbf{X=\sqrt[3]{v/abc}} \quad \mathbf{A= abx^2}$$



H= cx

W= bx

L= ax

SAFETY TANK COST ESTIMATE

Two-Story Primary School in Bangladesh

PROJECT SPECIFICATIONS

- Length: 9.098 m
- Width: 3.033 m
- Liquid depth: 3.322 m
- Total volume: 83.7 m^3
- Population: 270 persons
- Design life: 5 years

EXCAVATION CALCULATION

- Excavation volume = (L + 1m) × (W + 1m) × (H + 0.5m)
- Excavation volume = (9.098 + 1) × (3.033 + 1) × (3.322 + 0.5)
- Excavation volume = 10.098 × 4.033 × 3.822
- Excavation volume = 155.48 m^3

CONCRETE WORK

Base Slab:

- Area = 9.098 m × 3.033 m = 27.6 m^2
- Thickness = 0.15 m
- Volume = 27.6 m^2 × 0.15 m = 4.14 m^3
- M15 grade concrete cost = 5,500 BDT/m^3
- Cost = 4.14 m^3 × 5,500 BDT/m^3 = 22,770 BDT

Walls:

- Perimeter = 2 × (9.098 m + 3.033 m) = 24.262 m
- Wall height = 3.322 m + 0.3 m (freeboard) = 3.622 m
- Wall thickness = 0.23 m
- Wall volume = 24.262 m × 3.622 m × 0.23 m = 20.19 m^3
- M20 grade concrete cost = 6,200 BDT/m^3
- Cost = 20.19 m^3 × 6,200 BDT/m^3 = 125,178 BDT

Top Slab/Cover:

- Area = 9.098 m × 3.033 m = 27.6 m^2
- Thickness = 0.15 m
- Volume = 27.6 m^2 × 0.15 m = 4.14 m^3
- M15 grade concrete cost = 5,500 BDT/m^3
- Cost = 4.14 m^3 × 5,500 BDT/m^3 = 22,770 BDT

REINFORCEMENT STEEL

- Standard reinforcement ratio = 80 kg/m³ of concrete
- Total concrete volume = 4.14 + 20.19 + 4.14 = 28.47 m³
- Steel required = 28.47 m³ × 80 kg/m³ = 2,277.6 kg
- Steel cost in Bangladesh = 85 BDT/kg
- Cost = 2,277.6 kg × 85 BDT/kg = 193,596 BDT

PIPING AND ACCESSORIES

- PVC inlet pipe (150mm) = 6m × 450 BDT/m = 2,700 BDT
- PVC outlet pipe (150mm) = 6m × 450 BDT/m = 2,700 BDT
- Ventilation pipes = 2 × 2m × 320 BDT/m = 1,280 BDT
- Manhole covers (CI) = 3 × 3,500 BDT = 10,500 BDT
- Total = 17,180 BDT

BASIC CONCRETE MATERIALS BREAKDOWN (M20 & M15)

M30 Grade Concrete (Walls - 20.19 m³):

- Cement: 163 bags × 550 BDT/bag = 89,650 BDT
- Sand: 299 ft³ × 27 BDT/ft³ = 8,073 BDT
- Coarse Aggregate: 599 ft³ × 115 BDT/ft³ = 68,885 BDT

M15 Grade Concrete (Slabs - 8.28 m³):

- Cement: 59 bags × 550 BDT/bag = 32,450 BDT
- Sand: 146 ft³ × 27 BDT/ft³ = 3,942 BDT
- Coarse Aggregate: 292 ft³ × 115 BDT/ft³ = 33,580 BDT

Total Basic Materials:

- Cement: 222 bags = 122,100 BDT
- Sand: 445 ft³ = 12,015 BDT
- Coarse Aggregate: 891 ft³ = 102,465 BDT
- Cost: 236,580 BDT

TOTAL MATERIAL COST SUMMARY

Material Component	Cost (BDT)
Base Slab	22,770
Walls	125,178
Top Slab/Cover	22,770
Reinforcement Steel	193,596
Piping and Accessories	17,180
Total Material Cost	381,494 BDT

Cost Estimation

Calculate cement, sand, aggregate using M30 grade concrete.

Column Dimensions

- Width (b) = 18 inches = 1.5 feet
- Depth (h) = 18 inches = 1.5 feet
- Height (L) = 12 feet

Volume Calculation for One Column

- Cross-sectional area = b × h = 1.5 ft × 1.5 ft = 2.25 ft^2
- Volume of one column = Area × Height = 2.25 ft^2 × 12 ft = 27 ft^3

Concrete Mix Ratio (M20 grade)

- Cement: Sand: Aggregate = 1 : 1.5 : 3
- Sum of ratio parts = 1 + 1.5 + 3 = 5.5

Dry Volume Calculation

- Wet volume of one column = 27 ft^3
- Conversion factor (wet to dry) = 1.5 (accounts for air gaps in dry materials)
- Dry volume of one column = 27 ft^3 × 1.5 = 40.5 ft^3

Material Calculation for One Column

- Cement volume = (Dry volume × Cement ratio) ÷ Sum of ratio = (40.5 ft^3 × 1) ÷ 5.5 = 7.36 ft^3
- Sand volume = (Dry volume × Sand ratio) ÷ Sum of ratio = (40.5 ft^3 × 1.5) ÷ 5.5 = 11.05 ft^3
- Aggregate volume = (Dry volume × Aggregate ratio) ÷ Sum of ratio = (40.5 ft^3 × 3) ÷ 5.5 = 22.09 ft^3

Total Materials for 32 Columns

- Total cement volume = 7.36 ft^3 × 32 = 235.52 ft^3
- Total sand volume = 11.05 ft^3 × 32 = 353.6 ft^3
- Total aggregate volume = 22.09 ft^3 × 32 = 706.88 ft^3

Converting Cement to Bags

- 1 bag of cement = 50 kg = 1.25 ft^3
- Number of cement bags = Total cement volume ÷ Volume per bag = 235.52 ft^3 ÷ 1.25 ft^3/bag = 188.42 bags ≈ 189 bags

Final Material Requirements

- Cement: 189 bags

- Sand: 353.45 ft^3 (or 9.99 $m^3 \approx$ 15.98 tonnes at 1600 kg/m^3)
- Aggregate: 706.91 ft^3 (or 20.01 $m^3 \approx$ 29.01 tonnes at 1450 kg/m^3)

The Concrete estimation for the two-storied primary school building the stair, columns, beams, and slabs are same calculation.