DESIGN OF A TWO-STOREY PRIMARY SCHOOL BUILDING (ZONE 3)

By

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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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DAFFODIL INTERNATIONAL UNIVERSITY

November 2025

This certifies that the student Asikur Rahman Santo (213-47-472) and Abdur Rahman Saikat(213-47-477) finished the "DESIGN OF A TWO-STOREY PRIMARY SCHOOL BUILDING" capstone project under my guidance, which was a prerequisite for the Bachelor of Science in Civil Engineering degree. On November 15, 2025, the work was successfully complete.

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DEDICATION

I am dedicating this work to all those who have persistently supported, encouraged and inspired me all along my academic experience. To my wonderful family to their constant love and faith in me. The continuous support and sacrifice they have given me has pushed me into excellence and in this regard, I am extremely thankful and humbled.

ACKNOWLEDGEMENTS

First and foremost, we express our deepest gratitude to Almighty Allah, whose boundless mercy, guidance, and blessings have enabled us to successfully complete the practicum work and the report of our Capstone Project.

We are sincerely thankful to our beloved families, whose constant support, encouragement, and unconditional love have been a source of strength and motivation throughout our academic journey.

We would like to thank the Department of Civil Engineering for providing us this wonderful opportunity to do Capstone Project. This has continued to be an essential part of integrating our academic knowledge with real-world experience and further enhancing out learning and professional growth.

A word of appreciation goes to Joy Das for his constant guidance and exceptional mentoring. He also had an insightful guidance, unwavering support, and never-ending encouragement which played a key role in helping me prepare this report and execute the project. His faith in our abilities and his constant encouragement motivated us to overcome all difficulties. For his patience, kindness, and generous contribution to our work.

We are very grateful to Dr. Mohammad Hannan Mahmud Khan, Associate Professor and Head of Department of Civil Engineering in DIU for providing us the opportunity to do this Capstone Project.

Last but not least, we are obliged to Prof. Md. Masud Alom for his valuable instructions of Capstone Project which is essential in our academic as well as future professional life.

With love and gratitude to all who took part in this adventure with us.

DECLARATION

This study entitled "The Design of Two-Storied Primary School Building with Structural and Environmental Consideration" was performed under the supervision of **Joy Das** (Lecturer), Department of Civil Engineering, Daffodil International University, Ashulia, Savar and submitted for the partial fulfillment in a capstone project, part of the Bachelor of Science degree in Civil Engineering.

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ABSTRACT

This Capstone Project, titled *"Design of a Two-Story Primary School Building with Structural and Environmental Considerations,"* demonstrates a comprehensive and practical approach to designing a safe, functional, and environmentally responsible educational facility. The project effectively combines theoretical knowledge gained during the undergraduate program with real-world engineering practices, with an emphasis on structural integrity and sustainable design.The structural analysis and design of the building were carried out using **ETABS**, a finite element software, following the standards set by the **Bangladesh National Building Code (BNBC), 2020**. Major structural elements—including **beams, columns, slabs, and foundations**—were carefully designed to ensure safety, durability, and adequate load-bearing capacity. To support construction accuracy, detailed **construction drawings** were created using industry-standard tools like **AutoCAD** and **Revit**, covering **floor plans, elevations, sections, and reinforcement details** essential for execution on-site. Additionally, **Microsoft Excel** was used to prepare a comprehensive **Bill of Quantities (BOQ)** to ensure accurate cost estimation, efficient resource planning, and streamlined structural calculations throughout the project lifecycle.

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CHAPTER 1

Introduction

1.1 Proposed Structure

The proposed two-story primary school building will be constructed entirely with **reinforced cement concrete (RCC)** and will utilize **isolated foundations**. The building footprint measures approximately **101.6 feet by 46 feet**, with a total height of **24 feet**. The layout includes **five classrooms**, a **teachers' room**, an **office room**, and a **head teacher's room,10 washrooms**. The overall **layout plans** are illustrated in **Figures 1.1, 1.2, and 1.3**, while the **elevation view** of the building is shown in **Figure 1.4.**

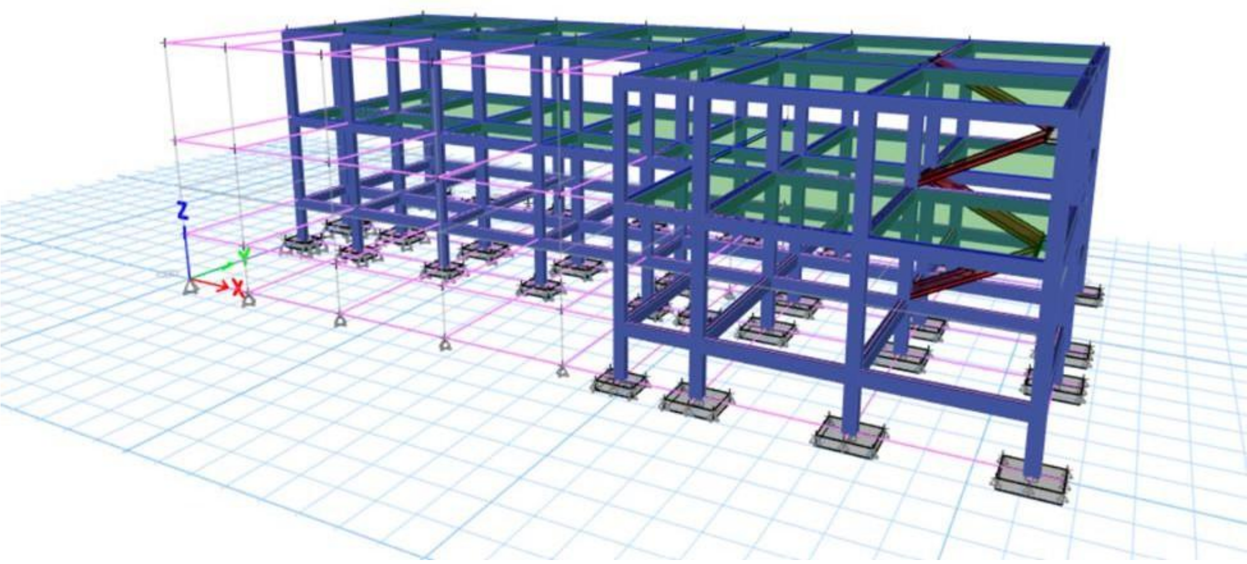


Figure 1.1 : Full Layout Plan

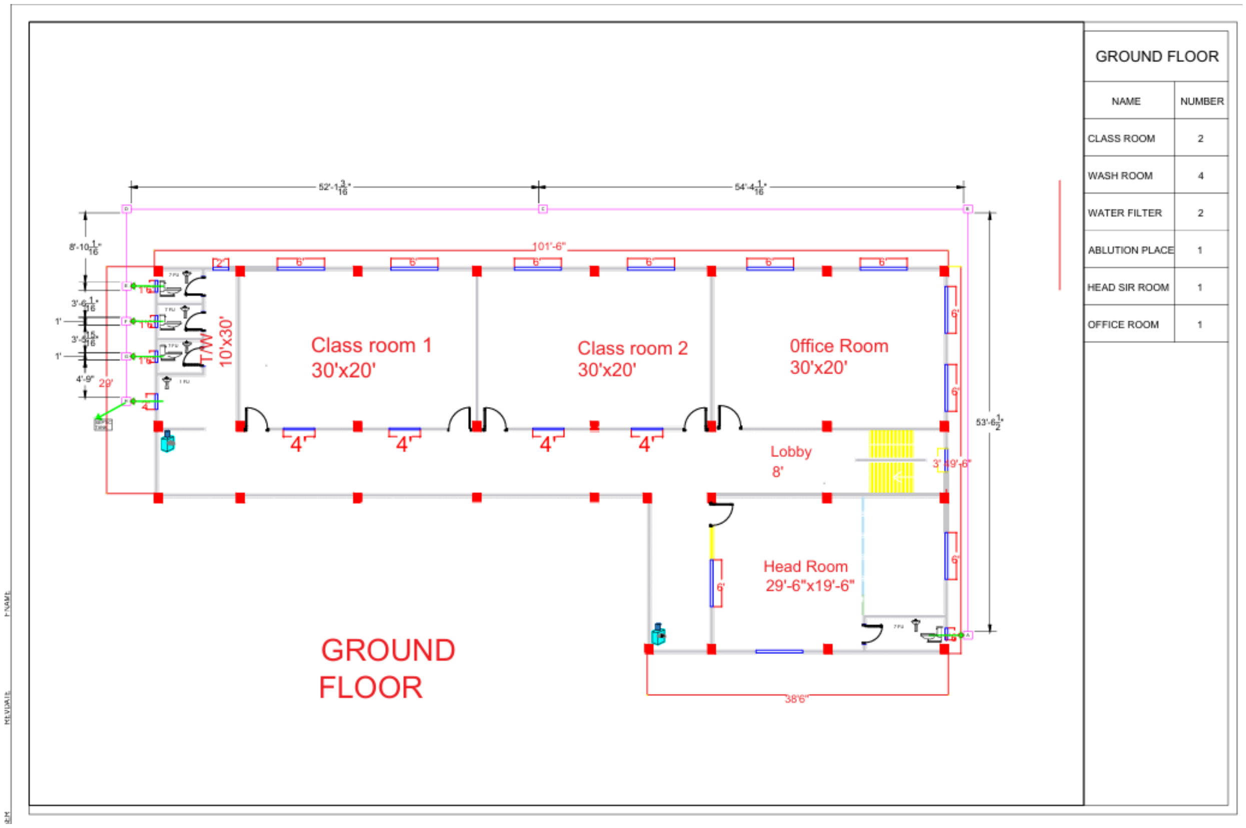


Figure 1.2 : Ground floor

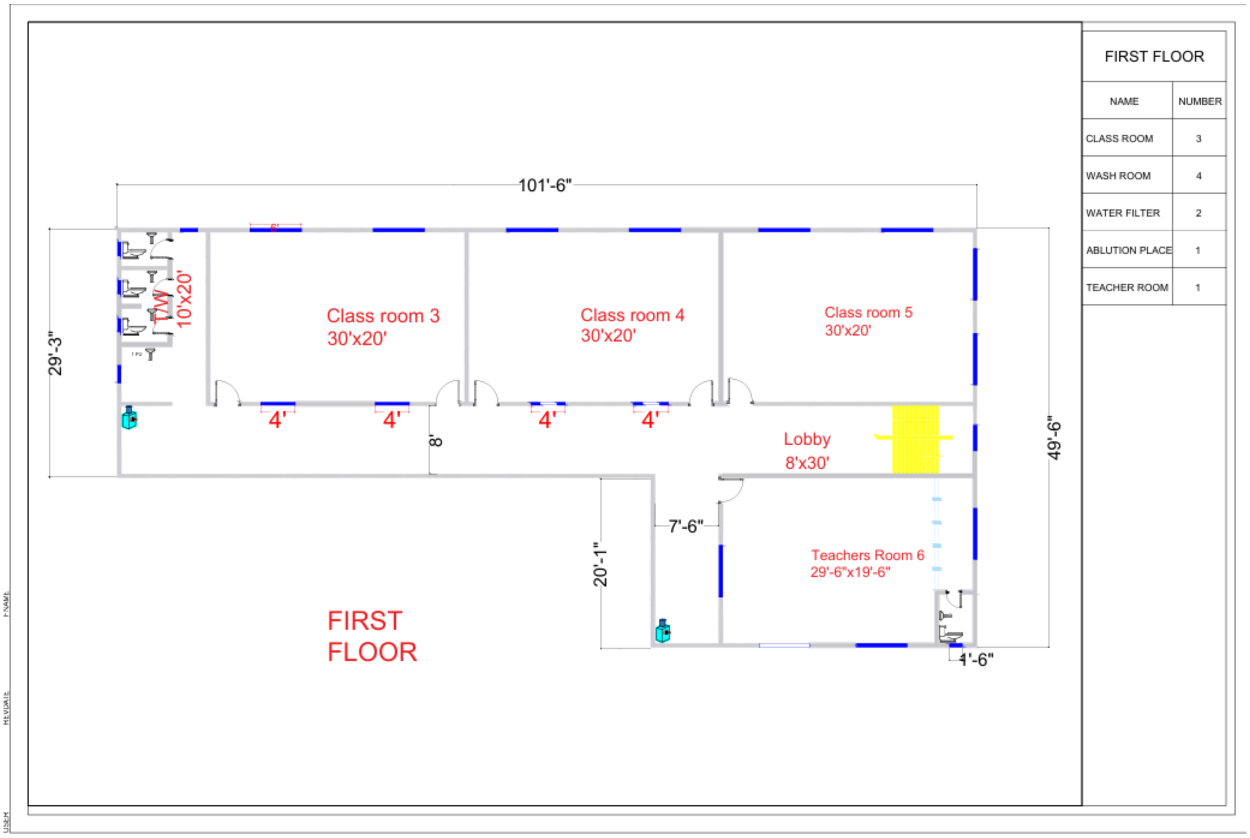


Figure 1.3 : First Floor

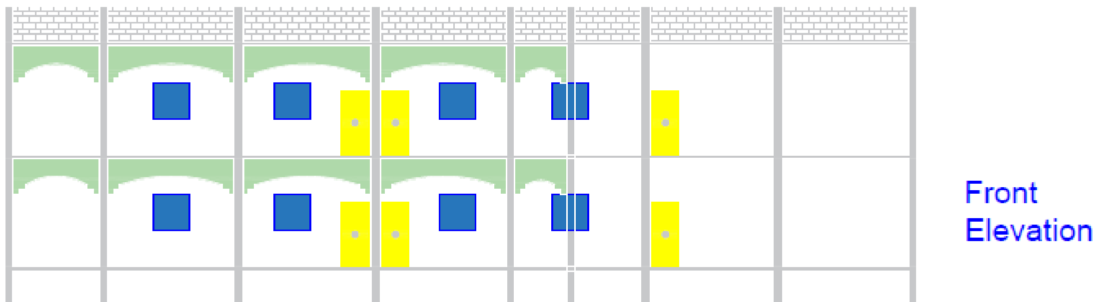


Figure 1.4: Elevation

1.2 Basic Information

The proposed building is a **two-story educational facility** designed using a **reinforced concrete (RC) beam-column frame system**, classified as an **Intermediate Moment Resisting Frame (IMRF)**. This structural system provides **moderate resistance to lateral forces** such as wind and earthquakes. The **floor system** features **edge-supported slabs**, where the slabs are carried by surrounding beams or walls. The **design loads** are specified in the load plan to ensure both **structural safety** and **functional efficiency**. For foundation support, **isolated footings** are provided under each column, offering a **stable and cost-effective solution** suitable for typical soil conditions and **low-rise construction**. The basic information of building are given bellow table 1.1

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

As per standard guidelines for educational facilities, **at least 50% of the total school area** should be kept **open** to accommodate functions such as **playgrounds** or **storage spaces**. A **minimum of five classrooms** is required, all of which must be **uniform in size**. Separate **washroom facilities** for **male and female students** are also mandatory. For schools with an enrollment of **over 200 students**, additional spaces such as **a teacher's room**, a **separate head teacher's (HT) room**, and a **library** are required. Each **classroom** should have dimensions of **30 feet by 20 feet**, while

staircases should be **8 feet wide** and **22 feet 6 inches long** to ensure safe and efficient movement. The building has 10 washrooms, 8 washrooms for students ,1 for Head sir and one for teachers. According to BNBC code (Table 8.6.1) per 25 students need 1 washroom. And the building has 4 drinking water filters because according to BNBC code(Table 8.6.1) per 50 students needs 1 drinking water filter.

CHAPTER 2

Design Codes, Structural Design and Requirements

2.1 Design code

Standard design codes, to some extent, safeguard the life, limb, health, property and public welfare by adopting a minimum level of standards for design specification in terms of every aspect of layout construction quality materials utilization occupancy location and maintenance of all constructions within economical bounds throughout the country. Similarly, rules have also been published on the installation and operation of certain devices, services, and items which are used in relation to or associated with such buildings to achieve the same objective. These equations and specifications referred to what is used in the structural design of this building sometimes (BNBC, 2020). In (BNBC, 2020), Etabs 2020 evaluation was also perform. The Bangladesh National Building Code (BNBC, 2020) has been followed in the analysis and design process, and all structural drawings must be examined in combination with pertinent architectural drawings. For specifications or structural requirements not included in the drawings or this design report, refer to (BNBC, 2020).

2.2 Foundation and soil

- A footing foundation has been proposed as a foundation.
- Minimum clear cover = 3.0 inches is recommended.
- Depth of foundation shall be as per drawing. 2.3: material properties Minimum f’c (28 days cylinder crushing strength) Foundation and Column = 4000 psi with Mix Ratio =   1:1:2

2.3 Lapping Zone of Beam

The minimum lap length required by (BNBC, 2020) depends on the grade of concrete, the diameter of the reinforcement bars, and where they are placed (tension 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). The bar's lap length should be 40D for tension and 30D for compression (where D is the bar's diameter).

2.4 Corner reinforcement

Corner reinforcement is required by the Bangladesh National Building Code (BNBC, 2020) in order to strengthen structural corners and sustain concentrations of strain, particularly in seismic zones. To manage shear and torsional loads, BNBC 2020 suggests adding more diagonal bars, closely spaced stirrups, and ties for beams, slabs, and column-beam connections. To avoid slippage under load, bars at corners must have minimum lap lengths and proper anchoring, as shown in Figure. 2.1. In order to assist buildings better, tolerate lateral loads and avoid cracking or brittle failure, this reinforcing technique guarantees ductility, energy absorption, and structural integrity at critical areas.

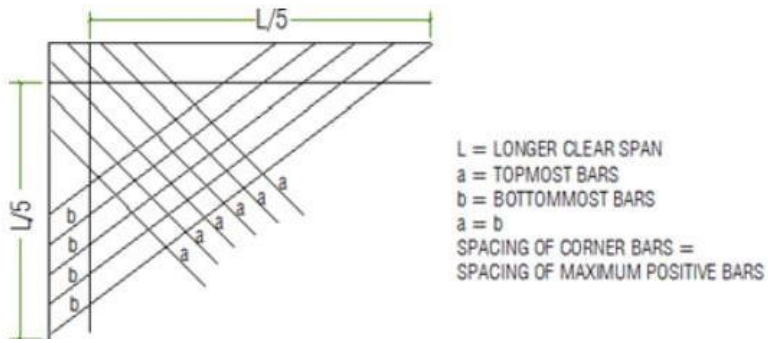


Figure 2.1: Corner reinforcement

2.5 Material strength: The material Strength are given bellow table 2.1

Table 2.1: Material Strength

	Concrete, f'c	*Unit*	*Rebar Strength, f*
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 kind of rebar, and its placement, Ld.= ϕ *fy/4*Tb, where ϕ is the bar's diameter, fy is the steel yield strength, and τb τ b is the concrete bond strength. Beams often require longer development lengths because to the higher loads they face compared to slabs, and BNBC (2020) calls for adjustment factors for things like the kind of rebar and the location of the top reinforcement. These laws ensure the stability and safety of concrete buildings by specifying the proper anchoring lengths for different load scenarios.

2.7 Concrete Clear Cover for Reinforcing Bars

The concrete clear cover is the minimum distance between the outermost surface of the reinforcement bar and the outer surface of the concrete. Its purpose is to protect the rebar from corrosion, fire, and other environmental factors. This section would specify the required clear cover values for various structural elements (e.g., foundations, columns, beams, slabs), often based on the condition of soil. The table 2.1 provides standard clear cover requirements for reinforced concrete structural elements to protect against corrosion and ensure durability. For columns, a 40 mm- cover is used when not in contact with ground or water, while a 60 mm cover is required when in contact with them. Beams, whether exposed outdoors or placed indoors, require a uniform clear cover of 40 mm on the top, sides, and bottom. For slabs, the clear cover is 30 mm at the bottom and 20 mm at the top, reflecting lower exposure levels and loading requirements compared to columns and beam.

Table 2.2: Clear Cover on building codes. **(BNBC 2020 Section 6.1.11.2)**

Member	Location or Combination	Thickness of Cover(mm)
Column	Not in contact with the ground or water	40
	In contact with the ground or water	60
Beam	Indoors face: Top. Side & Bottom	40
	Outdoors' face: Top, Side, & Bottom	40
Foundation	contact with soil direct	70
	a lean concrete layer	40
Slab	Bottom	30
	Top	20

CHAPTER 3

Structural Analysis and Output

3.1 Introduction

The Capstone Project, titled "Design of a Two-Story Primary School Building with Structural and Environmental Considerations," presents a practical and integrated approach to developing a safe, functional, and environmentally sustainable educational facility. An integration of academic theory and actual design practice in the context about the structural performance, sustainability. For structural design of the building using Finite Element Analysis (ETABS) as per Bangladesh National Building Code (BNBC), 2020 was completed. Careful analysis and design of major components such as beams, columns, slabs & foundations to be strong enough to resist loads imposed by the environment. These were done in AutoCAD and Revit (for more detailed designs) to develop the architectural as well as structural drawings which subsequently guaranteed precise construction procedures on-site, securing accurate detailing for floor plans, elevations, sections, fire exits, & reinforcement details. A Bill of Quantities(BOQ) is built on Microsoft Word to include a material estimation, structural calculation, and budgeting for the whole project.

3.2 Load consideration

In the structural analysis of primary school building, loads are divided into three general categories such as dead load, live load and floor finish load using ETABS based on BNBC 2020

- In which self weight of all permanent structural elements is known as dead load i.e slabs, beams, columns and walls. It also contains the weight of permanent installations such as ceilings and divisions. This load is determined according to the specific weight of material such as concrete, steel, brick etc
- Live load is related to transient or movable forces in the building. For classrooms in educational buildings, which includes primary schools, the floor to ceiling height is 3m (10 feet), and the regular live load used would be between 2 kN/m² and 4 kN/m². Conversely, in zones which have higher occupancy rates like corridors or assembly area.

- Load on floor finish is the weight of the finishing materials such as tiles, carpet or wood panel. The standard load is accepted specific to the type of finishing employed as 1.0–1.5 kN/m^2 .

Thein ETABS, these single load types need to be combined according to Load Combination rules of BNBC 2020, so that the building can perform safely and economically under various loading scenarios.

3.3 Load Combinations

DL = Dead + SDL

1) Service capability check
S1 = DL + Live (L)
S2 = DL + 0.5L
S3 = DL + 0.5L + 0.7Wx
S4 = DL + 0.5L - 0.7Wx
S5 = DL + 0.5L + 0.7Wy
S6 = DL + 0.5L - 0.7Wy

2) Strength Check & Concrete Frame Design (Part 6, Chapter 2, Article 2.7**.)**
S1 = 1.4DL
S2 = 1.2DL + 1.6L + 0.5Lr
S3a = 1.2DL + 1.6Lr + L
S3b = 1.2DL + 1.6Lr + 0.8Wx
S3c = 1.2DL + 1.6Lr - 0.8Wx
S3d = 1.2DL + 1.6Lr + 0.8Wy
S3e = 1.2DL + 1.6Lr - 0.8Wy
S4a = 1.2DL + 1.6Wy + L + 0.5Lr
S4b = 1.2DL - 1.6Wx + L + 0.5Lr
S4c = 1.2DL + 1.6Wy + L + 0.5Lr
S4d = 1.2DL - 1.6Wy + L + 0.5Lr
S5a = 1.2DL + EQx + L
S5b = 1.2DL - EQx + L
S5c = 1.2DL + EQy + L
S5d = 1.2DL - EQy + L
S6a = 0.9DL + 1.6Wx
S6b = 0.9DL - 1.6Wx
S6c = 0.9DL + 1.6Wy
S6d = 0.9DL - 1.6Wy

S7a = 0.9DL + EQx
S7b = 0.9DL + EQx
S7c = 0.9DL + EQy
S7d = 0.9DL – Eqy
According to BNBC code 2020 for Strength Check & Concrete Frame Designs 24 formula but it is a two storied building that’s why we consider only dead load and live load.

3.4 Serviceability Check

Sway Limit= $\frac{1}{500} * Building\ hieght$

$= \frac{1}{500}$ *20*12=0.48 in

In table 3.1 shown serviceability load combination, maximum positive - negative displacement and Sway limit. Fig 3.1 shown deflection due to load.

Table 3.1: Serviceability Check

Serviceability load combination	Displacement(in)	Sway Limit(in)	Serviceability Check
S1	Max=+0.01 Min=-0.06	0.48	OK
S2	Max=+0.01 Min=-0.05		OK
S3	Max=+0.01 Min=-0.04		OK
S4	Max=+0.01 Min=-0.027		OK
S5	Max=+0.03 Min=-0.089		OK
S6	Max=+0.03 Min=-0.13		OK
S7	Max=+0.07 Min=-0.3		OK
S8	Max=0.10 Min=0.37		OK

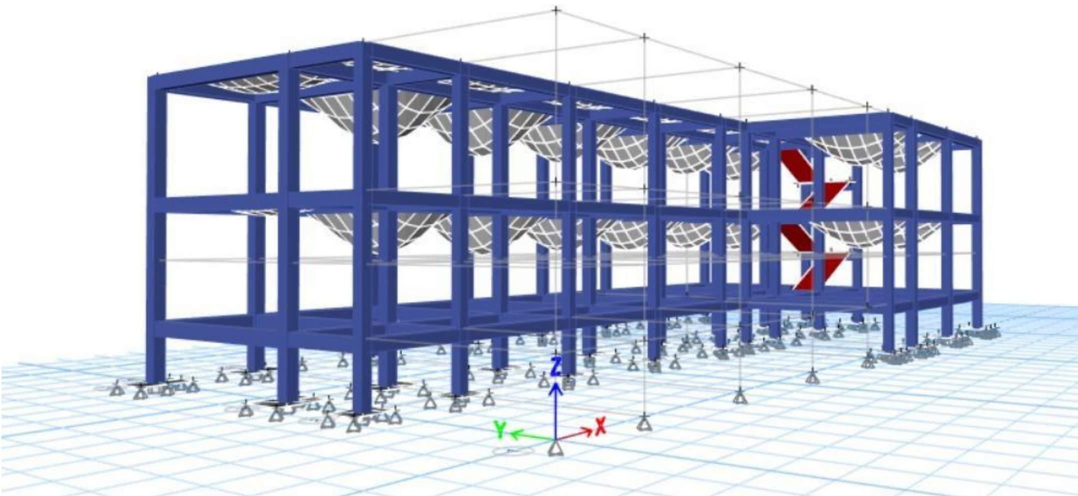


Figure 3.1: Deflection due to load

3.5 Design of Slab and detailing

When designing slabs using ETABS, several key factors must be evaluated to ensure the structural integrity and compliance with local building regulations. The software takes into account parameters such as slab geometry, thickness, material characteristics, and loading conditions including dead, live, and environmental loads. Using finite element analysis (FEA), ETABS evaluates stresses, displacements, and the amount of reinforcement required across the entire slab system. It also examines the effect of various support conditions like simply supported, fixed, or continuous and different loading patterns under prescribed load combinations. Design checks in ETABS include serviceability limits such as deflection and crack control, as well as reinforcement detailing to enhance both strength and durability. The software also ensures alignment with regional safety codes and design standards, such as those specified in BNBC 2020. Once the slab analysis and design are completed in ETABS, all reinforcement and detailing information is exported to AutoCAD for drafting purposes. The deflection of slab due to flexural stress, as shown in Figures 3.1, 3.3, and 3.4, offer accurate guidance for construction, helping ensure that the implemented design is both safe and structurally sound. The detailing of slab are as shown in Figure 3.2. We also design slab by hand calculation. As hand calculation is more accurate that's why we shown hand calculation in **appendix 1.** Overall slab thickness 6 inch. Main Bar bottom

10 mm Alt. Ckd.@ 7in c/c and top 10 mm Alt. Ckd.@ 12in c/c. And extra top 10 mm between alt Ckd.

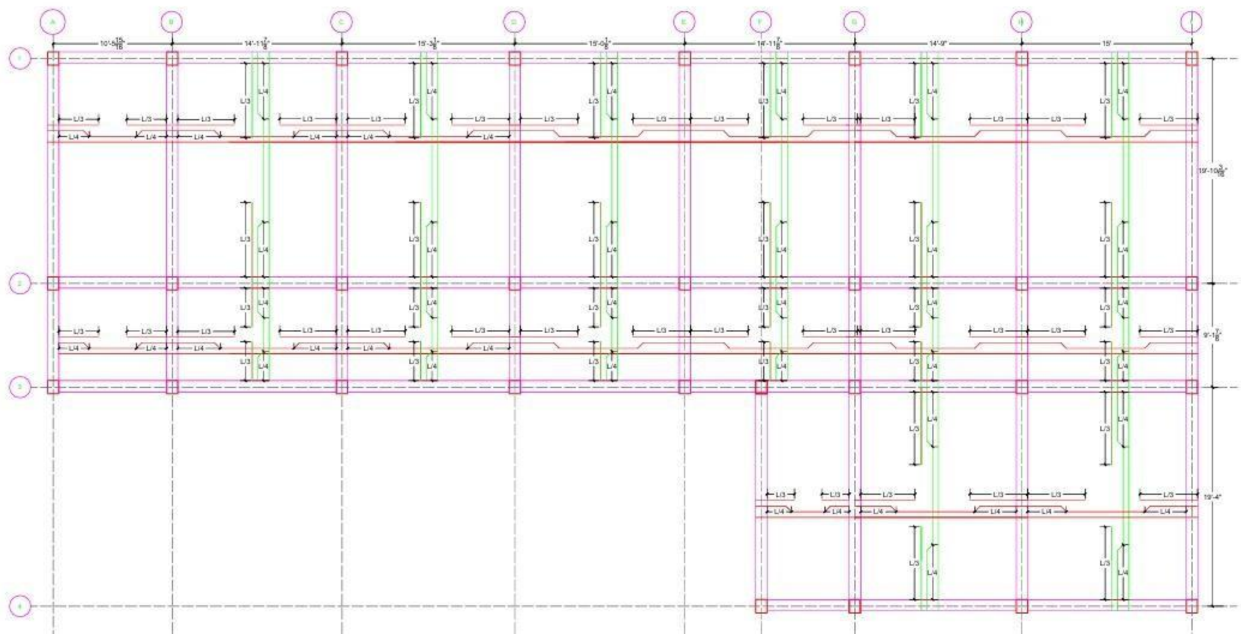


Figure 3.2: Slab details

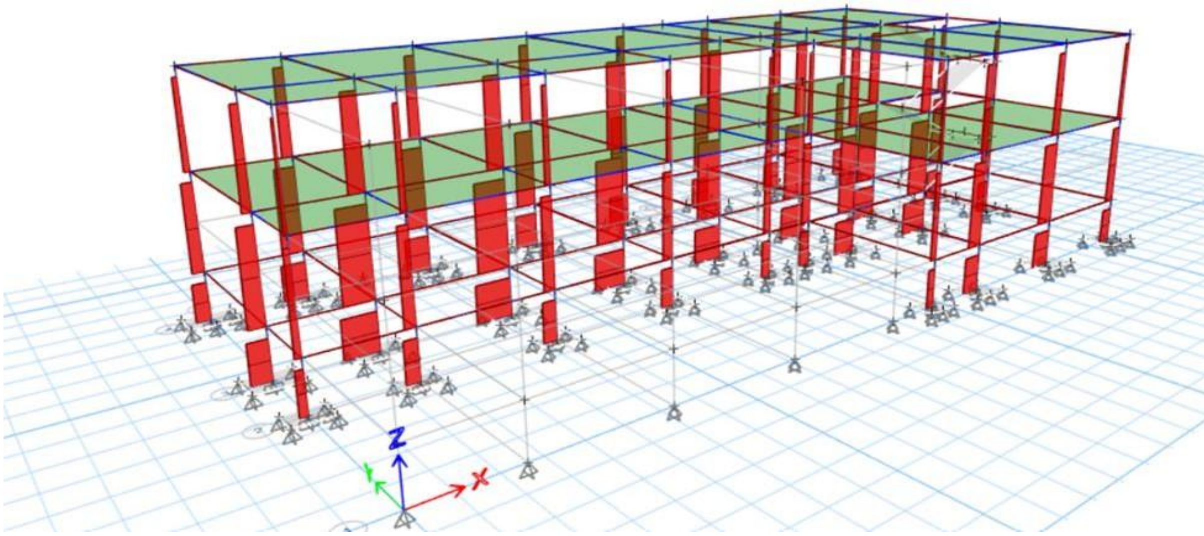


Figure 3.3: Flexural Stress

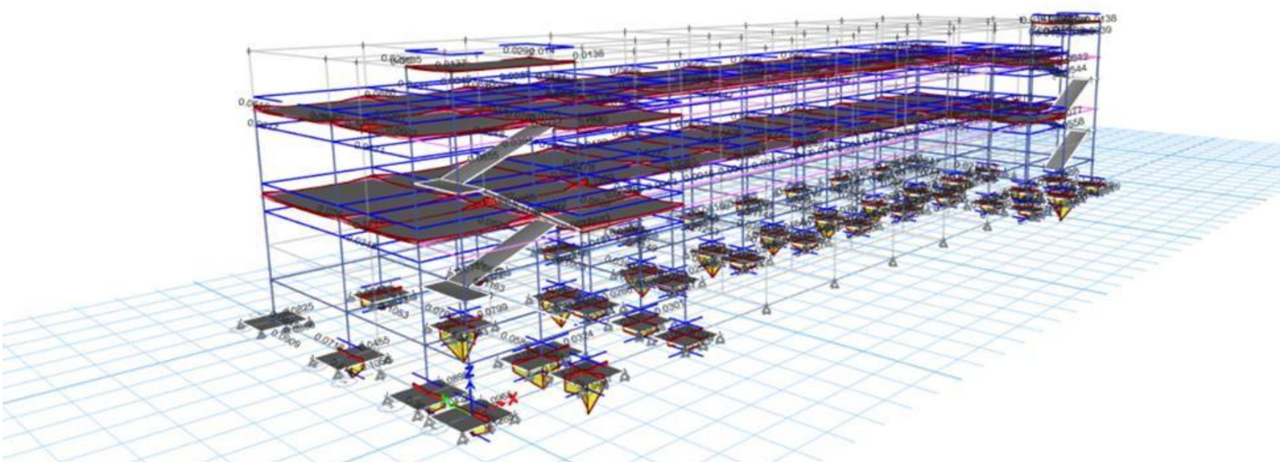


Figure 3.4: Flexural Stress (Slab)

3.6 Design of Beam and Detailing

All beam dimension is 12”*15”. The beam detailing are shown in Figure 3.10. Figure 3.5 is Grid line of beam and Figure 3.6 is 3D Dimension Beam Rebar Profile. The hand calculation of beam are shown in Appendix 2.

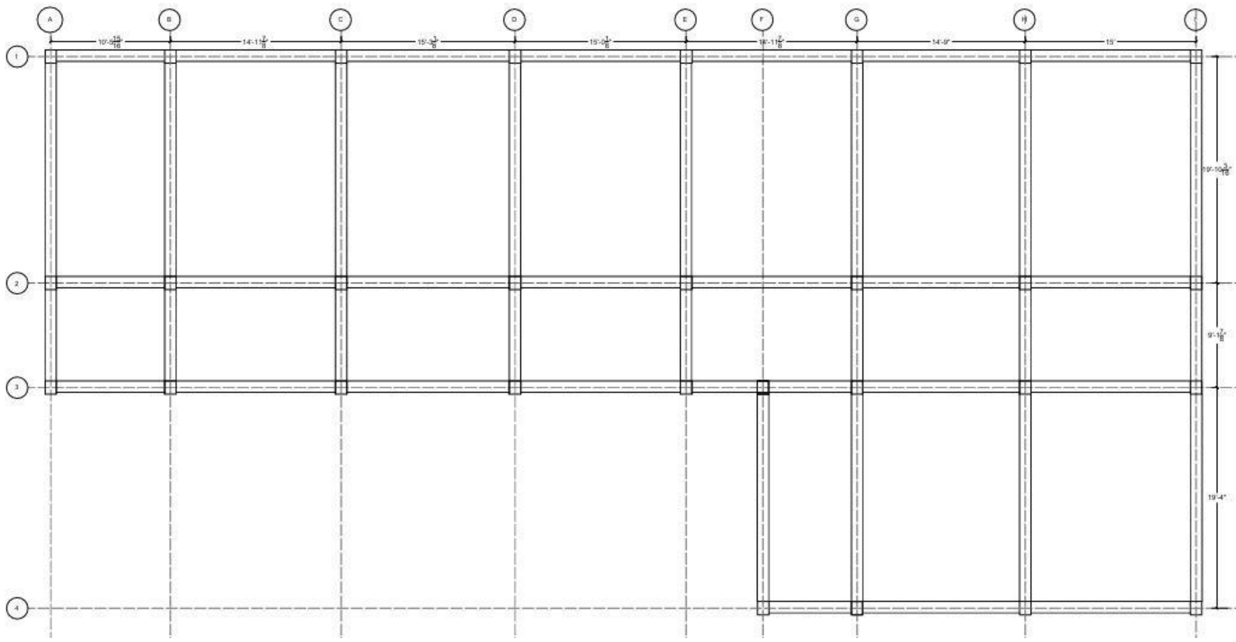


Figure 3.5: Grid line of Beam

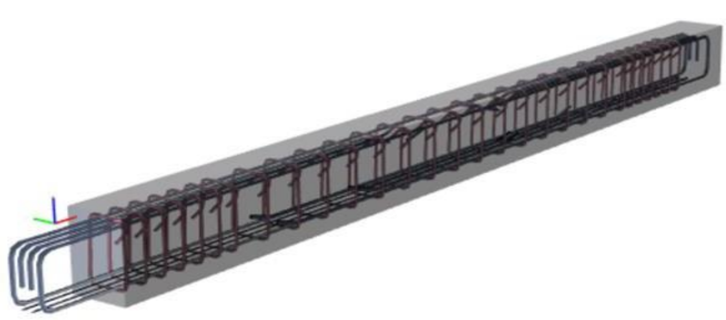


Figure 3.6: 3D Dimension Beam Rebar Profile

3.7 Lap Location

Fig. 3.6 Rebar Percent: This figure shows "Rebar Percent" and seems to be related to "CB-10 Rebar Profiles" and "CB-10 Elevation All Rebars." While it doesn't explicitly state "Lap Location," the varying rebar percentages along the length of the beam (implied by the profiles) indicate where additional rebar (laps) might be needed to maintain continuity and strength. In structural design, lap locations are strategically placed where bending moments are typically lower to ensure proper force transfer between reinforcing bars. The specific details of lap lengths would be determined by relevant building codes (e.g., ACI, IS, Eurocode) based on bar diameter, concrete strength, and rebar type. Figure 3.9 are shown lap position . Beam details are shown as table 3.2.

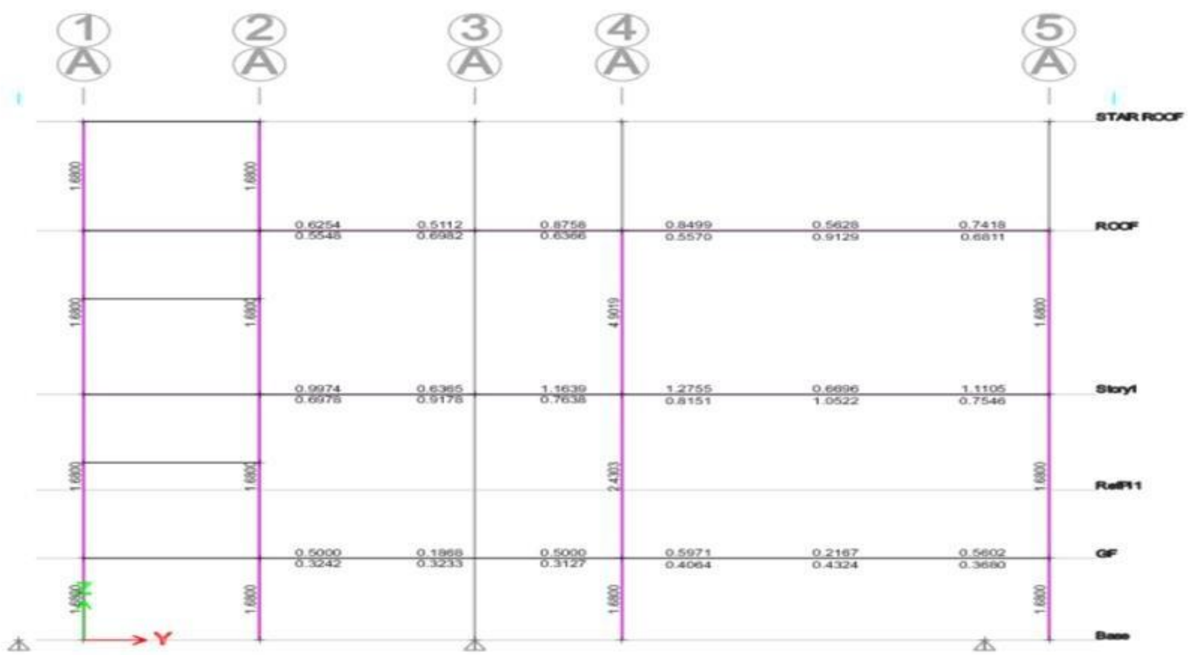


Figure 3.7: Elevation 1 (A) Reinforcement

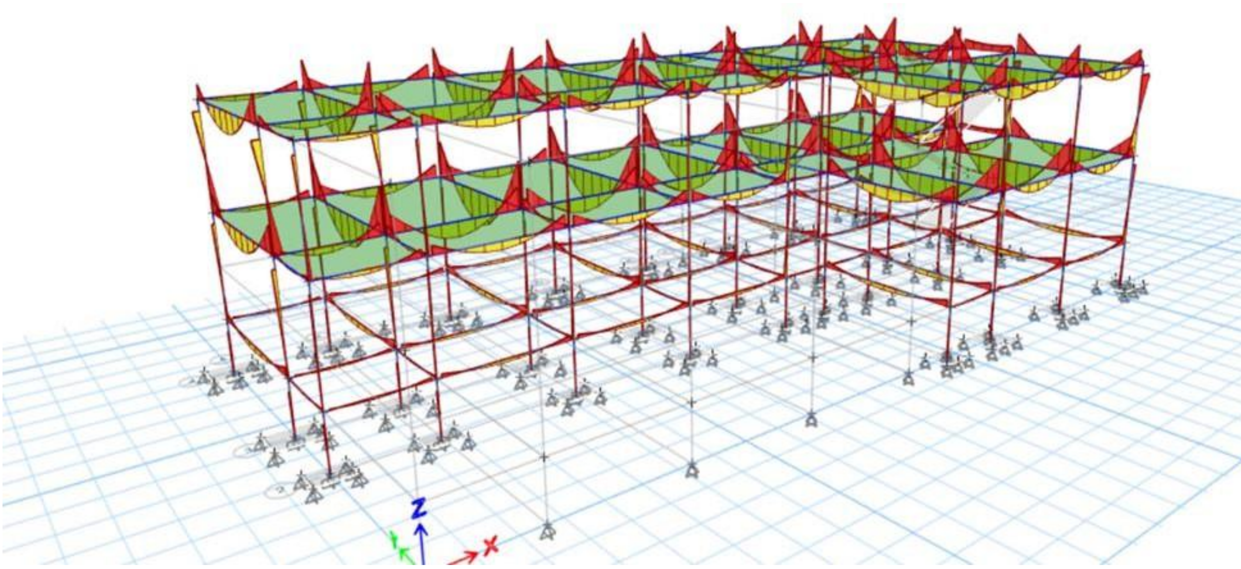


Figure 3.8: Bending Moment Diagram (Dead load Kip-ft)

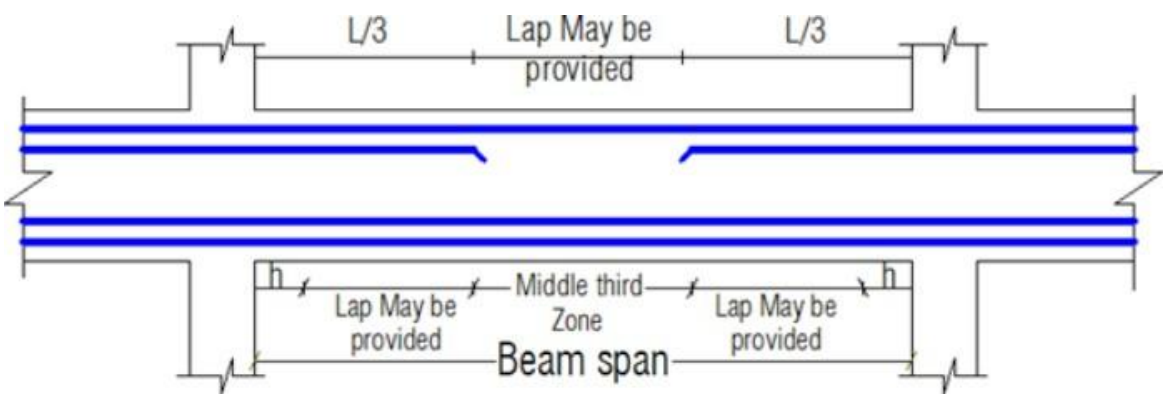


Figure 3.9: Lap position

Table 3.2: Beam details

Beam No	***Dimension***	***Bottom Rebar***	***Top Rebar***	***Stirrups***
ALL	**(12”x15”)**	**4# 20mm Dia**	**4# 20mm Dia**	**12mm@ 7.5”c/c**

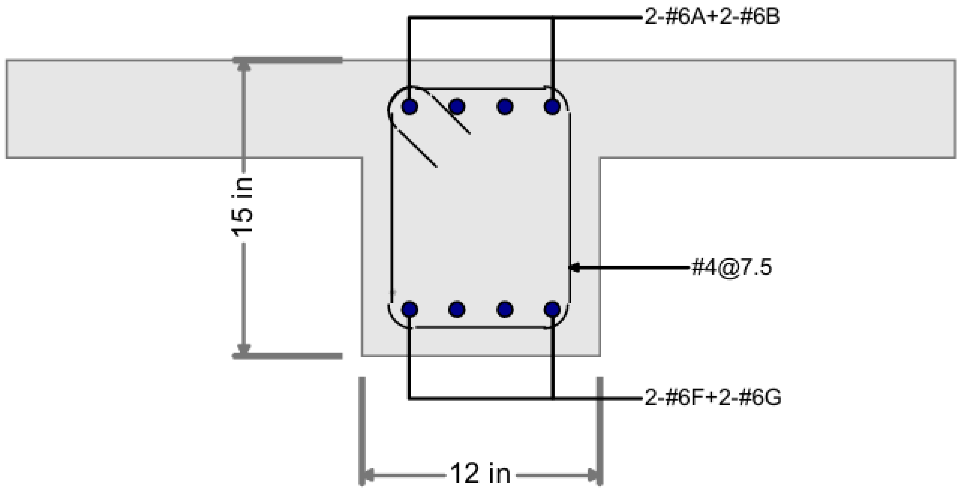


Figure 3.10: Beam details

3.8 Design of Column and detailing

All column are same dimension 12” * 14” . The hand calculation of column is shown in **Appendix 3.** Column details are shown as table 3.3**.** The detailing of column and grid line of column is shown Fig 3.11and Fig 3.12. The details of column are given in Table 3.3.

Columns from Basement to Ground Floor:

* Column No.: 1, 2, 3, 4, 5 (and likely more, as the table continues)
* Size of Column: 12"x14" for all listed columns.
* Main Reinforcement: #6 of 20mm Dia for all listed columns.
* Lateral Ties: 10mm @ 7.5" C/C for all listed columns..

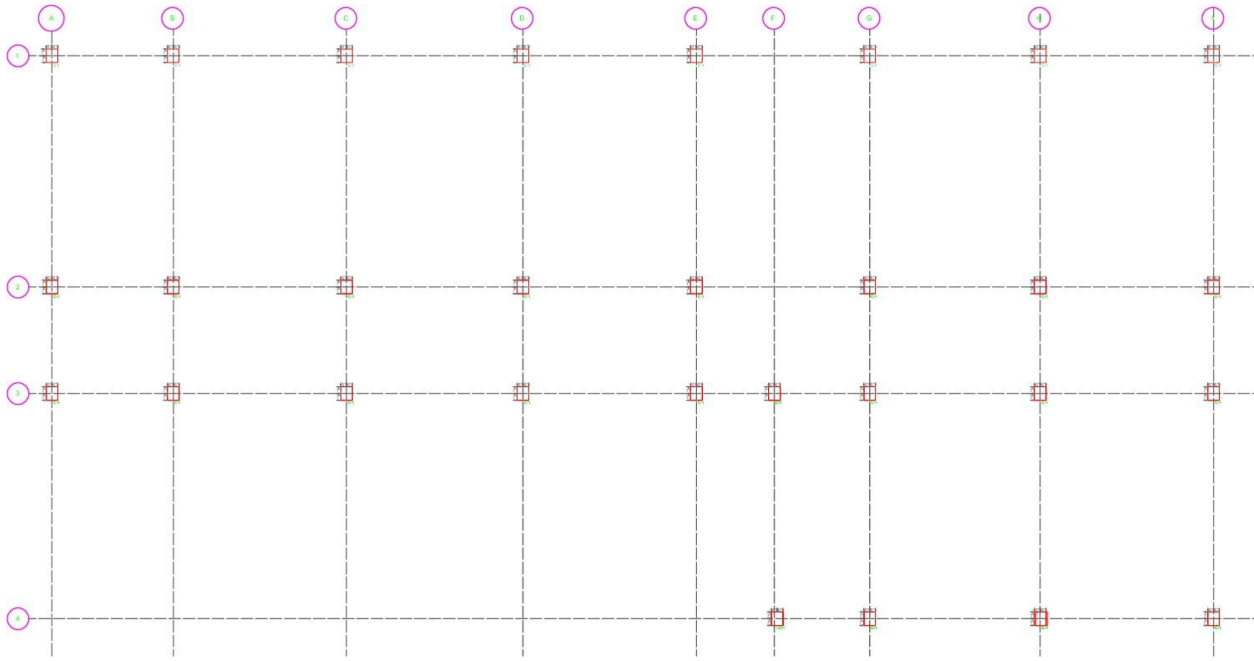


Figure 3.11: Grid line of Column

Table 3.3: Details of Ground to Roof Column

Column No.	*Size of Column*	*Main Reinforcement*	*Lateral Ties*
All	12”x14”	20mm Dia	10mm @ 6”C/C

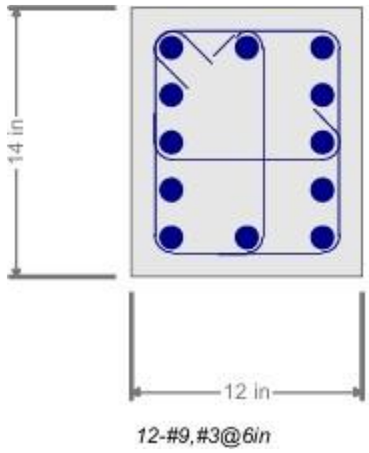


Figure 3.12: Column details

3.9 Design of Foundation and detailing

While the design of Isolated Footings in ETABS extensive checks are performed for different parameters to have overall stability and confirm that it can follow design criteria. Width and reinforcement of the footing are influenced greatly by the capacity of the soil to bear loads. ETABS checks and re-distributes the footing load from i.e. dead, live, etc loads into soil limits to keep the support safe enough. Then we consider the shear stresses and moments at the base, in particular those caused by the need to punch or bend. It also checks that the settlement does not exceed safe/acceptable limits while calculating footing depth and reinforcement for bearing bending pressure. The hand calculation of footing shown as Appendix 4. Grid line of Footing, Footing Force and Footing Details are shown in Figure 3.13 & Figure 3.14 and Figure 3.15. The details of footing are given in table 3.4.

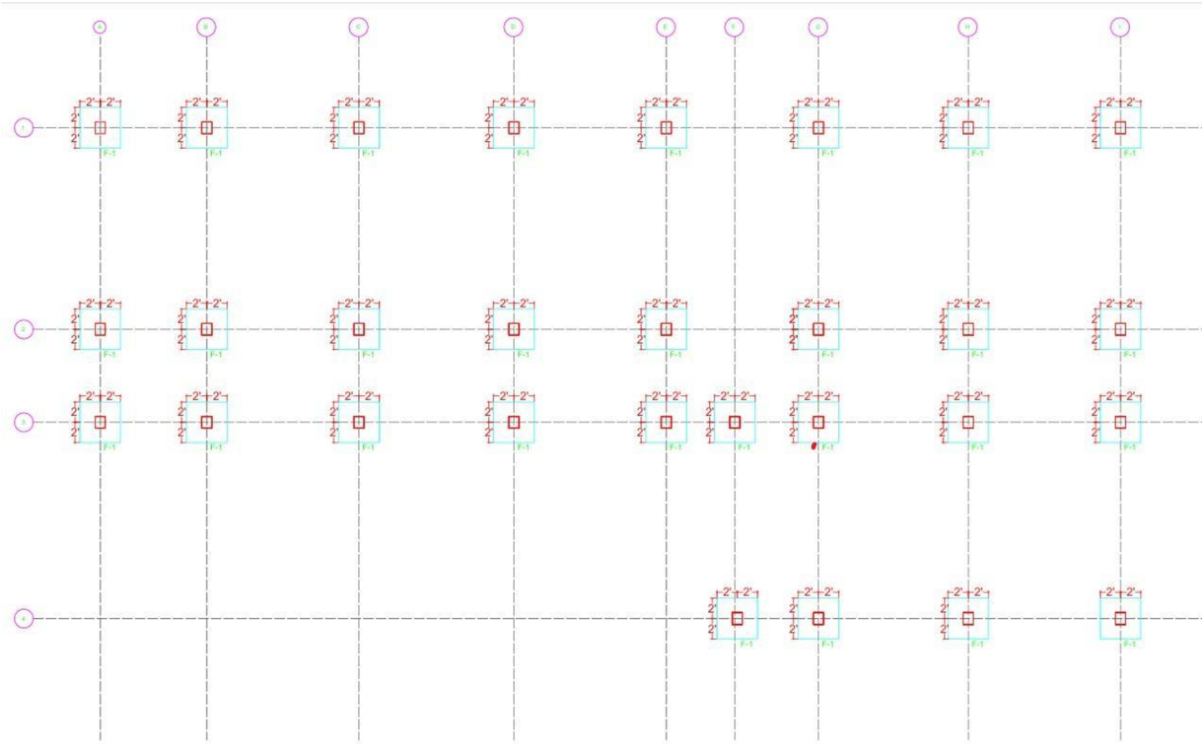


Figure 3.13: Grid line of Footing

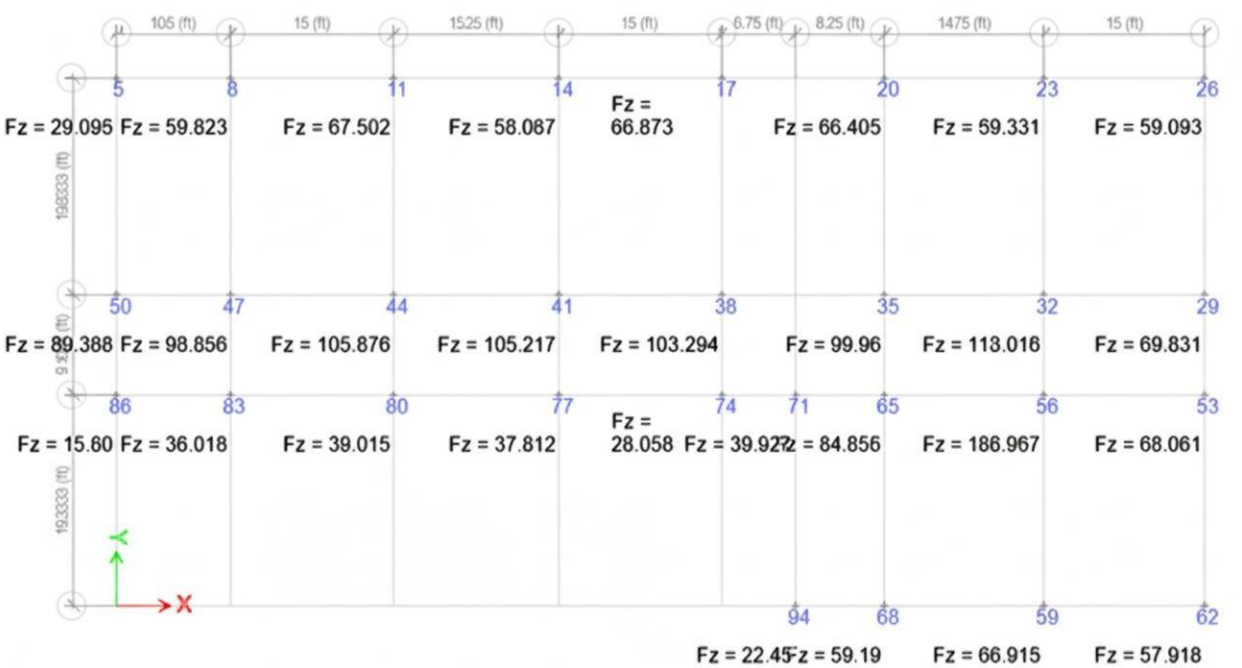


Figure 3.14: Footing Force

Table 3.4: Details of Footing

Footing No.	Size of Footing	Reber
All	4’*4’	20 mm @ 6”C/C

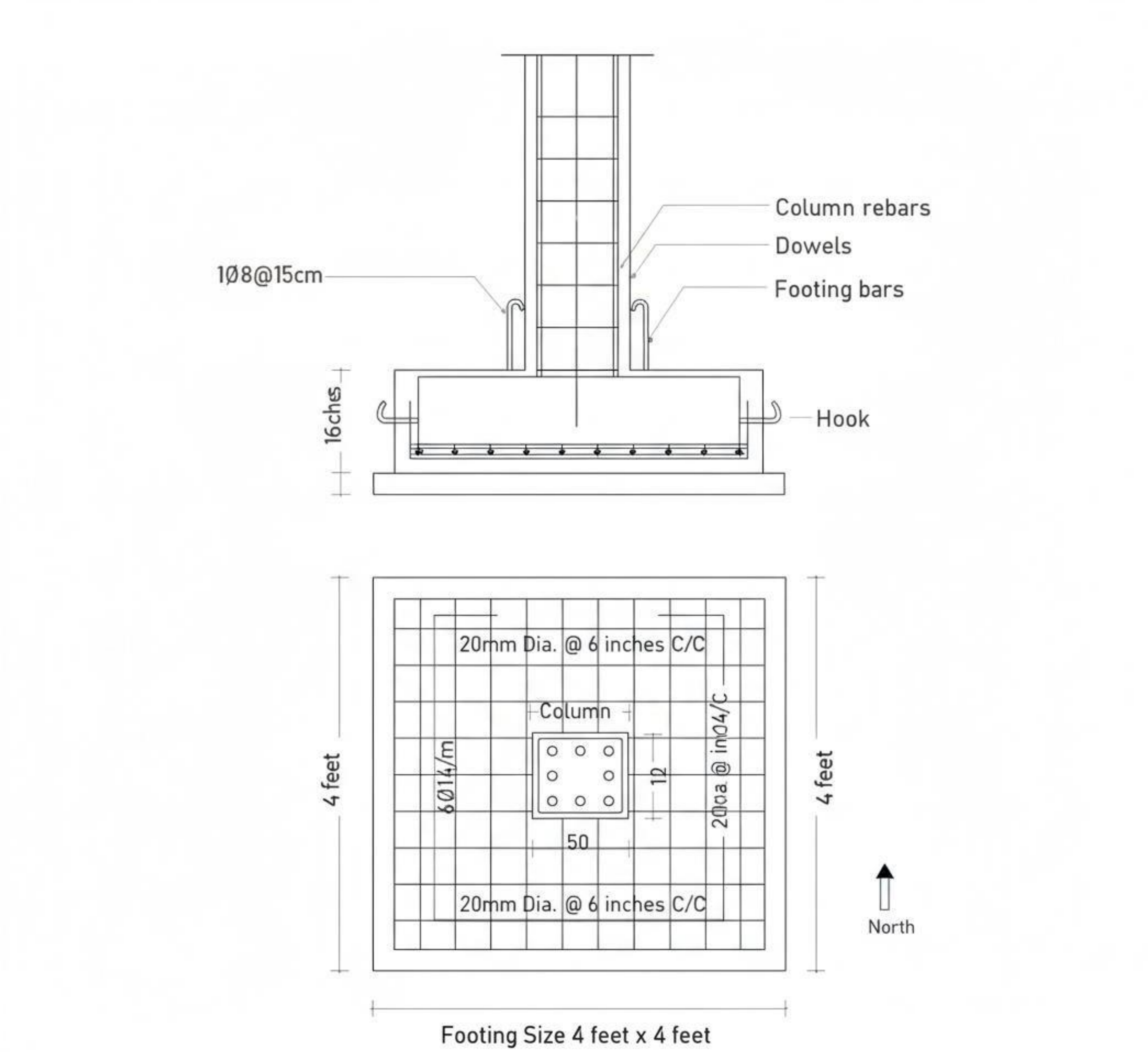


Figure 3.15: Footing Details

3.10 Design of Staircase and detailing

Designing staircases in ETABS requires careful attention to both structural integrity and functional requirements. The software assesses the staircase's **geometric configuration**, including rise, tread depth, and slope angle, to ensure it aligns with architectural specifications. Material properties, such as **stiffness and strength of concrete or steel**, are incorporated into the model to reflect the actual behavior under load. Both **dead loads** (e.g., self-weight of the structure) and **live loads** (e.g., occupants and moving objects) are factored in, following code-prescribed values to maintain safety standards. ETABS also takes into account the **support conditions** and **boundary definitions**—whether the staircase is **cantilevered**, **simply supported**, or includes **intermediate landings**—to accurately simulate its structural response. These considerations allow engineers to optimize the design for strength, stability, and code compliance. The design is shown by **Apendix 8.** The figure 3.16 shown that Stair & Technical Rebar Bindings.

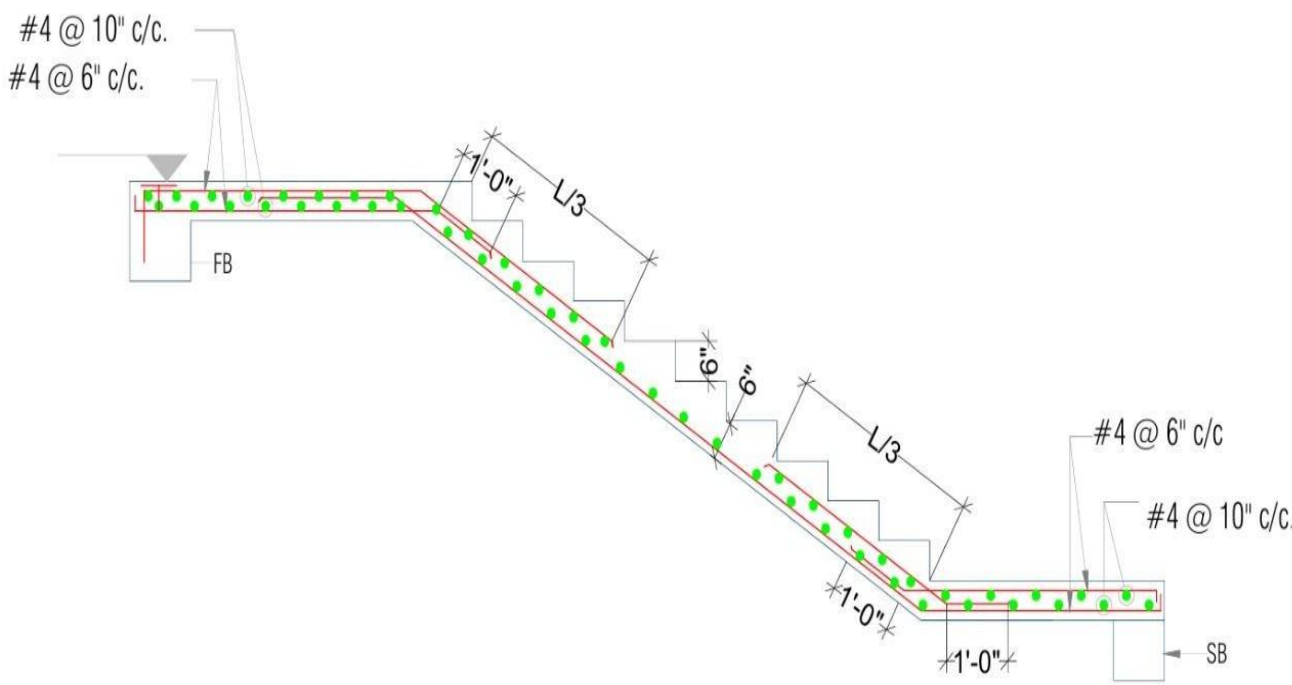


Figure 3.16: Stair & Technical Rebar Bindings

Table 3.4: Details of Rebar

Name of the Rebars	Types of Rebar
Main Bar	#4@6"C/C
Distribution Bar	#4@10"C/C

CHAPTER 4

Design of Overhead Water Tank, Septic Tank & Building Wastewater System

4.1 Overhead Water tank

In school buildings, overhead tanks are crucial components of the water supply system, particularly for daily potable water usage, sanitation, and emergency needs. The BNBC 2020 Volume III, Part 8 (Building Services) covers water supply systems.

Key considerations under BNBC include:

- Safe and consistent supply of potable water under variable conditions.
- Structural integrity, ensuring tanks withstand loads without compromising building safety.
- Serviceability, preventing leakage, undue deflection, or vibration that may impair functionality or safety.

The Design is provided in **Appendix 6**. The dimension of overhead tank is given Figure 4.1.

4.2 Design Considerations

Overhead (gravity or rooftop) tanks impose significant dead loads (from the tank structure) and live loads (due to water weight). These must be factored into structural design as per BNBC 2020's load combination criteria outlined in Volume II, Chapter 2, Section 2.7 . Tanks should not just be statically supported but designed to handle loads under combined scenarios—such as dead + live + wind/earthquake loads—especially in school zones prone to natural hazards.
Minimum Septic Tank Requirements (BNBC Part 8 – Sanitary Drainage)

- Minimum liquid capacity: 2,000 liters (2 m^3).
- Minimum width: 3 ft
- Minimum liquid depth: 3ft

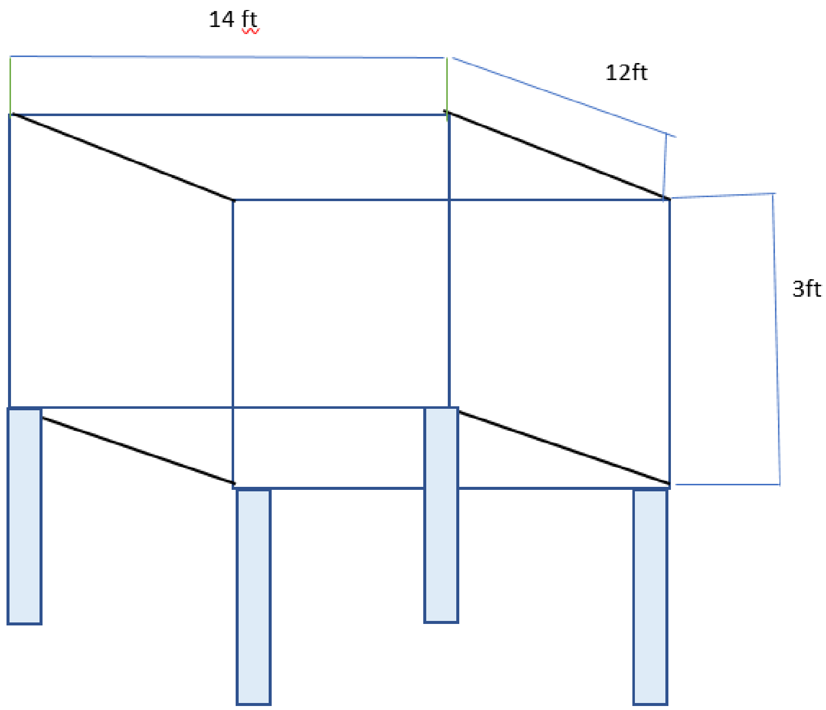


Figure 4.1: Overhead Water tank

4.3 SEPTIC TANK

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

4.4 Components of a Septic tank

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

4.5 Design Considerations of a Septic Tank

Important recommendations are provided by the Bangladesh National Building Code (BNBC, 2020) for the design of septic tanks to ensure their safe and efficient handling of wastewater and To design a septic tank for 200 users, where each classroom accommodates 40 students with a space requirement of 16 sq ft per student, the primary considerations will revolve around user count, daily water usage per person, and wastewater retention time. Below is the step-by-step process to determine the size and design features of the septic tank: How much water the household uses each day should determine the size of the tank, which should have enough capacity to keep wastewater for one to two days so that the solids can settle and decompose. Strong, waterproof materials like concrete, fiberglass, or plastic should be used to build tanks in order to stop leaks and safeguard groundwater. In order to enhance cleaning, tanks are usually separated into two areas by walls or baffles. The outlet pipe should be a little lower to permit wastewater to flow properly, and the inlet and outlet pipes should be positioned with fittings to control flow smoothly. In order to release gases, avoid unpleasant odors, and promote bacterial activity, proper ventilation is required. In order to facilitate routine pumping and inspection, the (BNBC, 2020) also needs access points, or risers; these must be well sealed to prevent contamination. The design of the drain field, where wastewater exits the tank, should take into account the soil's capacity to absorb water and should be situated at a safe distance from water sources, buildings, and wells. The septic tank should be positioned deep enough to prevent freezing problems and at a safe distance from buildings and water sources. To maintain the tank functioning properly and safeguard the public's health, routine maintenance is advised, such as pumping out solids every two to five years. The Design is provided in **Appendix 5**. The dimension of Septic tank is given figure 4.2.

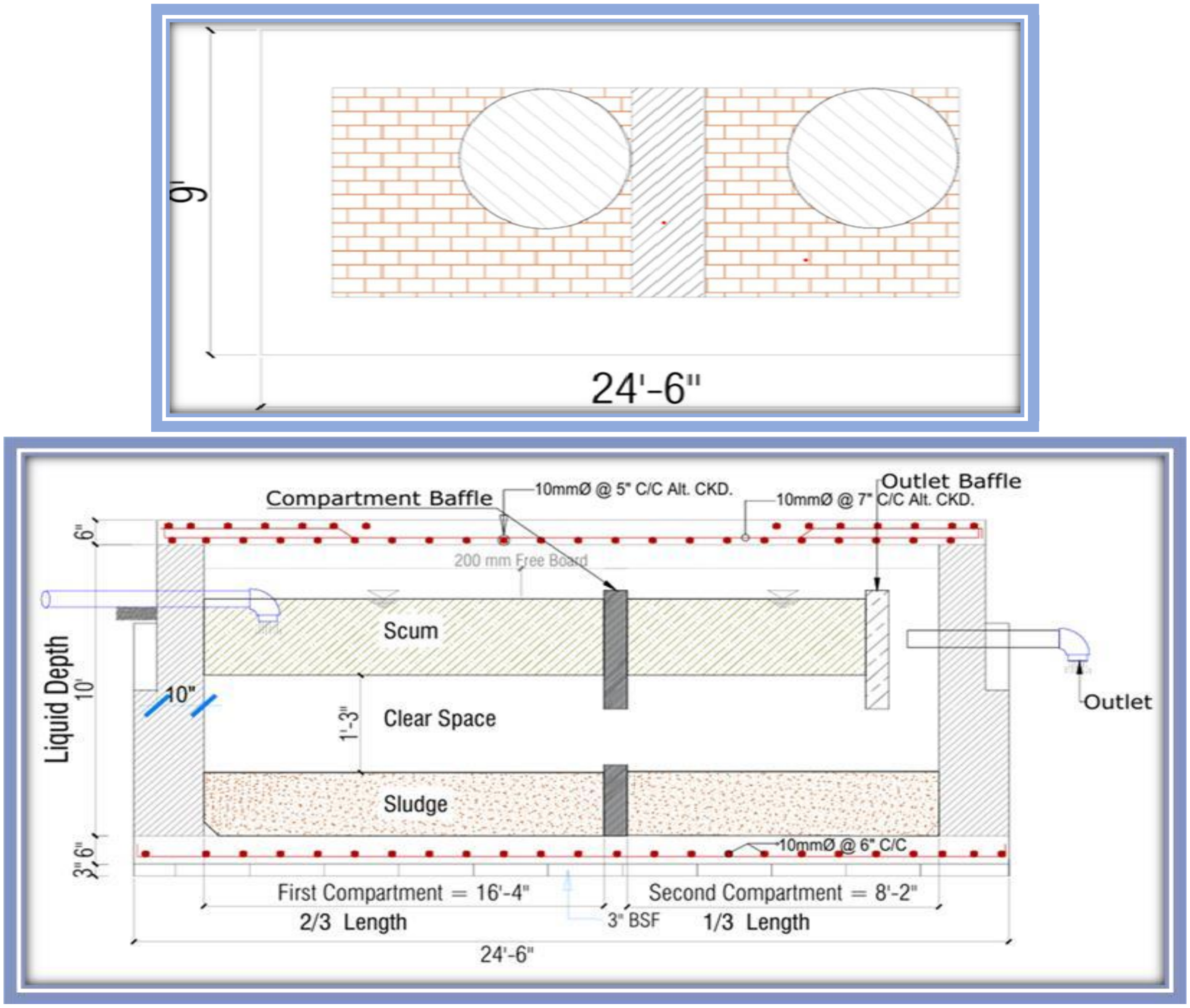


Figure 4.2 : Septic Tank

4.6 Soakaway

A VIP latrine with adjacent soakaway increases the pit life. The latrine pit is completely sealed with cement mortar or mortared brickwork and a PVC pipe of 75mm dia which leads to the adjacent soakaway is attached at a height of about 2.25m above the pit base.The soakaway has a diameter of 1.5 m and a depth of 2m. It is lined with mortared ricks to a depth of 1.4 m. At this depth a reinforced concrete cover slab is placed on the bricks and the remaining space above it is backfilled. The Design is provided in **Appendix 7.** The dimension of Soakaway is given Fig 4.3.

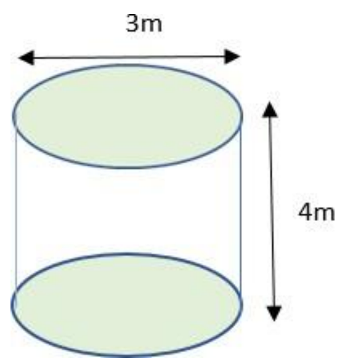


Figure 4.3 : Soakaway

4.7 Building wastewater system: Design

Components of Building wastewater system

1. Fixtures
2. Traps
- Floor Trap
- Gully Trap
- P-trap, q-trap, S-trap
3. Branch pipes
4. Vertical pipes / Stack
- Single stack system
- One pipe system
- Two pipe system

5. Building drain

6. Building sewer

In Fig 4.4 are shown Building Wastewater System. In table 4.1 are mentioned Fixture Units for Different Sanitary Appliances or Group (BNBC). Table 4.2 are shown the Maximum Number or Fixture that can be connected to be Branches and Stacks (BNBC). Table 4.3 is shown the Maximum Number or Fixture Units that can be connected to Building Drains and Sewers (BNBC). Table 4.4 is the Design the following building drains for the plan.

Table 4.1: Fixture Units for Different Sanitary Appliances or Group (BNBC table 8.6.5)

Type of Fixture	Fixture Unit Value as Load Factors
One bathroom group consisting of water closet, wash basin and bath tub or shower stall :	
a) Flush Tank water closet	6
b) Flush-valve water closet	8
Bathtub*	3
Bidet	3
Combination sink and tray (drain board)	3
Drinking fountain	0.5
Floor traps†	1
Kitchen sink, domestic	2
Wash basin, ordinary‡	1
Wash basin, surgeon's	2
Shower stall, domestic	2
Shower (group) per head	3
Urinal, wall lip	4
Urinal, stall	4
Water closet, tank operated	4
Water closet, valve operated	8

* A shower head over a bath tub does not increase the fixture unit value.
† Size of floor trap shall be determined by the area of surface water to be drained.
‡ Wash basin with 32 mm and 40 mm trap have the same load value.

Table 4.2: Maximum Number or Fixture that can be connected to be Branches and Stacks (BNBC table 8.6.6)

Diameter of Pipe (mm)	Maximum Number of Fixture Units that can be Connected			
	Any Horizontal Fixture Branch[a]	One Stack of 3 Storeys in Height or 3 Intervals	More than 3 Storeys in Height	
			Total for stack	Total at One Storey or Branch Interval
30	1	2	2	1
40	3	4	8	2
50	6	10	24	6
65	12	20	42	9
75	20	30	60	16
100	160	240	500	90
125	360	540	1100	200
150	620	960	1900	350
200	1400	2200	3600	600
250	2500	3800	5600	1000
300	3900	6000	8400	1500
375	7000	b	b	b

a Does not include branches of the building sewer.
b Sizing load based on design criteria.

Table 4.3: Maximum Number or Fixture Units that can be connected to Building Drains and Sewers (BNBC table 8.6.7)

Diameter of Pipe (mm)	Maximum Number of Fixture Units that can be Connected to any Portion* of the Building Drain or the Building Sewer for Various Slopes			
	1/200	1/100	1/50	1/25
100	-	180	216	250
150	-	700	840	1000
200	1400	1600	1900	2300
250	2500	2900	3500	4200
300	2900	4600	5600	6700
375	7000	8300	10000	12000

* Includes branches of building sewer

Table 4.4: Design the following building drains for the plan.

Pipe	Length(m)	FU	Diameter(mm)	Slope
Branch	-	7	65	-
Vertical pipes	6	14	65	-
AB	15.9	14	100	1/100
BC	16.6	14	100	1/100
CD	15.9	14	100	1/100
DE	2.75	14	100	1/100
EF	1	14	100	1/100
FG	1	21	100	1/100
GH	1.5	28	100	1/100

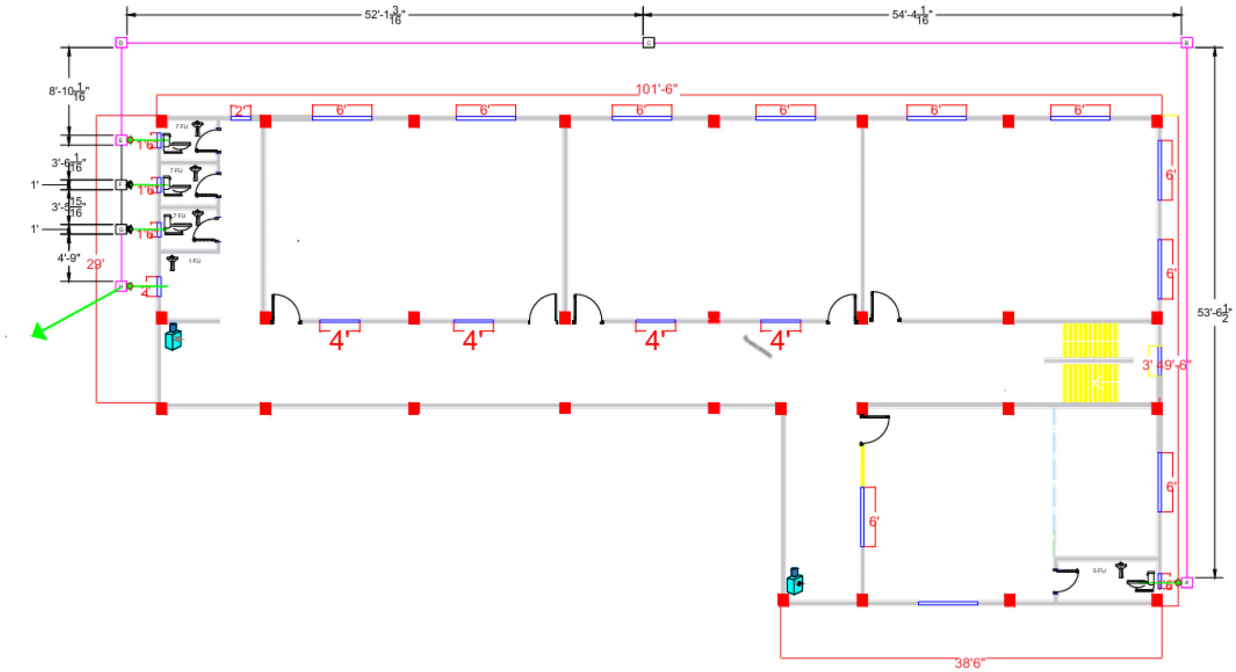


Figure 4.4: Building Wastewater System

Chapter 5

Cost Estimation

5.1 Introduction:

In engineering and building projects, a Bill of Quantities (BOQ) is a document that lists the amounts and specifications of the supplies, labor, and machinery required to finish the job. In essence, it is an exhaustive list that lists every element needed for a project, enabling precise project management, tendering, and cost estimation. A Bill of Quantities (BOQ) is important because it provides accurate cost estimations, a standardized and transparent tendering process, and efficient project management. It serves as a detailed roadmap by listing all materials, labor, and tasks, which helps control costs, manage budgets, and ensure clear communication between owners and contractors throughout a project. The BOQ are create base on PWD schedule 2022. Table 5.1 shown the Estimation of Civil Work, SUBSTRUCTURE, SUPERSTRUCTURE & FINISHING WORK. The Table 5.1 shown that the cost gap between superstructure and substructure is very high. Because more columns are used in the superstructure, the cost has increased a lot.

Table 5.1: Estimation of Civil Work, SUBSTRUCTURE, SUPERSTRUCTURE & FINISHING WORK

ESTIMATION OF 2 STORIED SCHOOL BUILDING						
A:Civil Work						
Sl No.	Description of Items	Unit	Drawing Qty	Unit Rate (BDT)	Total Amount (BDT)	Remark
DIVISION A:GENERAL & SITE FACILITIES						

A	Erection and maintenance of site office and removal of the same after completion of work in accordance with the conditions of contract. In addition to the office required for his own use, the contractor shall provide and maintain furnished field office for the use of the Engineer-in-charge and his staff. The field office is to have a concrete floor, adequate foundation, brick walls, false ceiling of hard board with seasoned Garjan wood frame and painted, and all windows are to be glazed and provided with steel grill. Outside and inside wall surface are to be painted on plaster acceptable to the Engineer-in-charge. The field office shall be maintained in a secure and watertight condition by the contractor until the completion of the contract and shall be provided with electricity, running water and sewerage. All doors shall be fitted with approved locks and windows shall be provided with screen/blinds. Before construction the contractor shall submit plans and drawings showing proposed details and location for the field office, including foundations, access roads, shades, layout of electrical and water supply and hard standings thereto for the approval of the Engineer-in-charge. The Engineer-in-					

	charge may require revision of the plans prior to giving approval for construction. The contractor shall also submit details proposed furniture, fittings and other items of equipment and plant to the Engineer-in-charge for approval. These items shall be of the standard quality suitable for site. The office, complete with furnishings, fittings, access roads and hard standings shall be ready for occupation by the Engineer-in-charge within 28 days of the date when the contractor first occupies the site. The contractor will provide day and night guards and a tea boy for the field office. At the end of the project all materials, equipment and plant, furniture, fittings recovered from dismantling the office and removing access road will be the property of the contractor. No interim payment shall be certified unless engineer's office with required facilities are constructed and accepted by the Engineer-in-charge.(This is a time related item; proportionate payment for this item shall be made distributing in each bill on the basis of percentage progress of the whole works under contract)					
A.1	Erect and Remove Engineer's site office (minimum 10 sqm	Ls	1.00	120000.00	120000.00	

	pilinth area) with required facilities.					
A.2	Providing and maintenance one project profile signboards of the size not exceeding 1 m x 2 m, to be placed at a suitable place of the site including submission of proposals for the materials of the signboards and text layout to the Engineer-in-charge for approval which will be positioned as directed by the Engineer-in-charge and removing the same on completion of the works or as instructed by the Engineer-in-charge.	sqm	1.00	3200.00	3200.00	
A.3	Mobilization of men, materials and equipment and preparation of site by cutting & up rooting of trees,stacking the same at a desired place, construction of appurtenances, etc. and prepare site for pile work for commencing the work as per specification direction of the Engineer-in-charge.	Ls	1.00	500000.00	500000.00	
	Total DIVISION A=				523200.00	
DIVISION B: SUBSTRUCTURE :						
B.1	Layout and marking for earthwork in excavation in foundation accepted by the Engineer-in-charge.	sqm	330.00	19.00	6270.00	

B.2	Earth work in excavation in all kinds of soil for foundation trenches in/c. layout, providing center lines, bench-mark pillars, leveling, ramming and preparing the base, fixing bamboo spikes & marking layout with chalk powder, providing necessary tools and plants, protecting and maintaining the trench dry etc., stacking the excavated earth at a safe distance of up to 10m lead, removing the spoils etc. all complete as per direction of engineer-in-charge.	Cum	143.50	168.00	24108.00	
B.3	Disposal of all surplus earth from site and deposited at suitable place as per direction of the Engineer-in-charge	Cum	143.50	168.00	24108.00	
B.4	Maccadam Compaction: Macadam Filling With Compaction(1:6:12): Cement, Sand, Bricks Chips Including Screening , Mixing, Laying, Compacting, To Levels Etc. All Complete As Per The Direction The Engineer In Charge.	Cum	12.78	870.00	11118.60	
B.5	Supplying and laying of single layer polythene sheet weighing one kilogram per 6.5 square meter in floor or any where below cement concrete complete in all respect and accepted by the Engineer -in-charge.	sqm	42.45	47.00	1995.15	

B.6	Mass concrete (1:2:4) in foundation or floor with cement, sand (F.M. 1.2) and picked brick chips including breaking chips, screening, mixing, laying, compacting to levels and curing including the supply of water, electricity and other charges and costs of tools and plants etc. all complete and accepted by the Engineer -in-charge.	Cum	3.18	10504.00	33402.72	
B.7	One layer of brick flat soling in foundation or in floor with 1st class or picked jhama bricks in/c preparation of bed and filling the interstices with local sand, leveling in/c the supply of water, electricity and other charges and costs of tools and plants etc. all complete as per direction of the engineer-in-charge.	sqm	728.34	636.00	463224.24	
B.8	Providing, mixing, Placing in position, matchine batched, machine mixed and machine vibrated design mix(C20~C30) as per approved mix ratio stone chips, sand & cement all should be approved from clinet including proper vibration curing and finishing all complete as per approved drawing and specification but excluding form work and reinforcement. For liquid retaining structures, contractor to ensure water tightness. In case of water leakage,					

	injection grouting shall be done at no cost to owner					
B8.a	Footing	Cum	53.95	16534.00	892009.30	
B8.b	pedestal column	Cum	22.81	16534.00	377140.54	
B8.c	Grade Beam	Cum	24.59	16534.00	406571.06	
B.9	Supply, fabrication and fixing to details as per design M.S deformed bar Grade 500 (B500DWR: complying BDS ISO 6935-2:2016 / ASTM A615) ribbed or deformed bar produced and marked according to Bangladesh standard, with minimum yield strength, fy (ReH)= 500 MPa and whatever is the yield strength within allowable limit as per BNBC/ ACI 318, the ratio of ultimate tensile strength fu to actual yield strength fy, shall be at least 1.25 and minimum elongation after fracture and minimum total elongation at maximum force is 17% and 8% respectively.					
B9.a	Footing	kg	1130.00	124.00	140120.00	
B9.b	pedestal column	kg	1905.00	124.00	236220.00	
B9.c	Grade Beam	kg	1377.68	124.00	170832.32	

B.10	Providing and fixing steel/wooden Form work for concrete elements like foundations, footing, pedestals, grade beam, floor beam, roof beam, slab at different levels, column, drop wall, lintel, sun-shade, coping etc as per approved drawing and specifications including supply loading, unloading and lifting of all materials, making, fixing, giving all kind of support(horizontal and vertical), scaffolding and after concreteing stripping at appropriate time, all complete as per specifications.					
B10.a	Steel shuttering	sqm	326.50	1678.00	547867.00	
		Total DIVISION B=			2334986.93	
DIVISION C: SUPERSTRUCTURE :						
1	Slab on Grade:					
1.1	One layer of brick flat soling in foundation or in floor with 1st class or picked jhama bricks in/c preparation of bed and filling the interstices with local sand, leveling in/c the supply of water, electricity and other charges and costs of tools and plants etc. all complete as per direction of the engineer-in-charge.	sqm	301.00	636.00	191436.00	
1.2	Supplying and laying of single layer polythene sheet weighing one kilogram per 6.5 square meter in floor or any where below cement concrete complete in all respect and	sqm	301.00	47.00	14147.00	

	accepted by the Engineer -in-charge.					
1.3	Mass concrete (1:2:4) in foundation or floor with cement, sand (F.M. 1.2) and picked brick chips including breaking chips, screening, mixing, laying, compacting to levels and curing including the supply of water, electricity and other charges and costs of tools and plants etc. all complete and accepted by the Engineer -in-charge.	Cum	30.58	10504.00	321212.32	
1.4	Providing and fixing steel/wooden Form work for concrete elements like foundations, footing, pedestals, grade beam, floor beam, roof beam, slab at different levels, column, drop wall, lintel, sun-shade, coping etc as per approved drawing and specifications including supply loading, unloading and lifting of all materials, making, fixing, giving all kind of support(horizontal and vertical), scaffolding and after concreteing stripping at appropriate time, all complete as per specifications.	sqm	102.30	1678.00	171659.40	
1.5	Supply, fabrication and fixing to details as per design M.S deformed bar Grade 500 (B500DWR: complying BDS ISO 6935-2:2016 / ASTM A615) ribbed or deformed bar produced and marked according to Bangladesh	kg	2606.48	124.00	323203.52	

	standard, with minimum yield strength, fy (ReH)= 500 MPa and whatever is the yield strength within allowable limit as per BNBC/ ACI 318, the ratio of ultimate tensile strength fu to actual yield strength fy, shall be at least 1.25 and minimum elongation after fracture and minimum total elongation at maximum force is 17% and 8% respectively.					
1.6	Providing, mixing, Placing in position, matchine batched, machine mixed and machine vibrated design mix(C20~C30) as per approved mix ratio stone chips, sand & cement all should be approved from clinet including proper vibration curing and finishing all complete as per approved drawing and specification but excluding form work and reinforcement. For liquid retaining structures, contractor to ensure water tightness. In case of water leakage, injection grouting shall be done at no cost to owner					
1.6.1	Column					
	1st Floor	cum	38.32	16900.00	647608.00	
	2nd Floor	cum	38.32	16900.00	647608.00	
1.6.2	Floor Beam					
	1st Floor	cum	25.59	16900.00	432471.00	
	2nd Floor	cum	25.59	16900.00	432471.00	

1.6.3	Slab					
	1st Floor	cum	45.90	16900.00	775710.00	
	2nd Floor	cum	45.90	16900.00	775710.00	
1.6.4	Stair					
	1st Floor	cum	36.60	16900.00	618540.00	
	2nd Floor	cum	36.60	16900.00	618540.00	
	Slab	cum	53.76	16900.00	908544.00	
1.7	Providing and fixing steel/wooden Form work for concrete elements like foundations, footing, pedestals, grade beam, floor beam, roof beam, slab at different levels, column, drop wall, lintel, sun-shade, coping etc as per approved drawing and specifications including supply loading, unloading and lifting of all materials, making, fixing, giving all kind of support(horizontal and vertical), scaffolding and after concreteing stripping at appropriate time, all complete as per specifications.					
1.7.1	Column					
	1st Floor	sqm	111.27	1678.00	186711.06	
	2nd Floor	sqm	111.27	1678.00	186711.06	
1.7.2	Floor Beam					
	1st Floor	sqm	142.08	1678.00	238410.24	
	2nd Floor	sqm	142.08	1678.00	238410.24	
1.7.3	Slab					
	1st Floor	sqm	375.70	1678.00	630424.60	

	2nd Floor	sqm	375.70	1678.00	630424.60	
1.7.4	Stair					
	1st Floor	sqm	65.33	1678.00	109623.74	
	2nd Floor	sqm	65.33	1678.00	109623.74	
	Slab	sqm	20.25	1678.00	33979.50	
1.8	Supply, fabrication and fixing to details as per design M.S deformed bar Grade 500 (B500DWR: complying BDS ISO 6935-2:2016 / ASTM A615) ribbed or deformed bar produced and marked according to Bangladesh standard, with minimum yield strength, fy (ReH)= 500 MPa and whatever is the yield strength within allowable limit as per BNBC/ ACI 318, the ratio of ultimate tensile strength fu to actual yield strength fy, shall be at least 1.25 and minimum elongation after fracture and minimum total elongation at maximum force is 17% and 8% respectively.					
1.8.1	Column					
	1st Floor	kg	3605.25	124.00	447051.00	
	2nd Floor	kg	3605.25	124.00	447051.00	
1.8.2	Floor Beam					
	1st Floor	kg	1477.85	124.00	183253.40	
	2nd Floor	kg	1477.85	124.00	183253.40	
1.8.3	Slab					
	1st Floor	kg	14590.68	124.00	1809244.32	

	2nd Floor	kg	14590.68	124.00	1809244.32	
1.8.4	Stair					
	1st Floor	kg	700.00	124.00	86800.00	
	2nd Floor	kg	700.00	124.00	86800.00	
	Slab	kg	380.00	124.00	47120.00	
1.9	125mm Brick works with first class bricks in cement sand (F.M. 1.2) mortar including raking out joints, filling the interstices with mortar, cleaning and soaking the bricks at least for 24 hours before use and washing of sand, necessary scaffolding and accepted by the Engineer - in-charge.					
1.9.1	1st Floor	sqm	355.00	1408.00	499840.00	
	2nd Floor	sqm	355.00	1408.00	499840.00	
	Total DIVISION (C)=				9342676.46	
DIVISION D: SUPERSTRUCTURE :(FINISHING WORK)						
1	Supplying, fitting and fixing protection /window grills: Supplying, fitting and fixing protection /window grills area of any design made with12 mm square bar in fabricating, welding, painting with two coats of synthetic enamel paint over a coat of priming etc.					
1.1	1st Floor	sqm	45.00	2825.00	127125.00	
1.2	2nd Floor	sqm	45.00	2826.00	127170.00	

2	Plaster Work (Brick Surface/ Concrete Surface): Minimum 12mm thick cement plaster (1:6) to wall both inner and outer surface, finishing the corner and edges in/c washing of sand cleaning the surface, scaffolding and curing at least for 7 days etc. all complete as per direction of the Engineer in-charge.					
2.1	1st Floor	sqm	2500.00	470.00	1175000.00	
2.2	2nd Floor	sqm	2500.00	470.00	1175000.00	
2.3	Roof Top	sqm	130.00	470.00	61100.00	
3	Aluminium works: Supplying, fitting and fixing of Aluminium sliding window asper the U.S Architectural Aluminium Manufac-turer's Association (AAMA) standard specification having 1.5mm thick outer bottom (size 75.50mm, 32mm) 1.5mm thick outer top (size 75.50mm, 26.80mm), 1.5mm thick shutter bottom (size 60mm, 24mm), 1.5mm thick outer side (size 75.50mm, 19.90mm) 1.5mm thick shutter lock (size 49.20mm, 26.20mm) 1.5mm thick inter lock (size 34.40mm, 2.10mm) & 1.5mm thick shutter divider (size 31.75mm) sections alll aluminium members will be anodized to Aluminium Bronze/Silver colour with acoat not less than 15 micrones in thick ness anddensity of 4mg per square cm etc including all					

	accessories. keeping provision for fitting 5mm thick glass including neoprene, sealant etc. complete in all respect as per drawing and direction of the Engineer in-charge					
3.1	1st Floor	sqm	45.00	4814.00	216630.00	
3.2	2nd Floor	sqm	45.00	4815.00	216675.00	
4	Supplying and making door frames: (Mehogani)					
4.1	1st Floor	pcs	6.00	9000.00	54000.00	
4.2	2nd Floor	pcs	6.00	9000.00	54000.00	
4.3	Roof Top	pcs	1.00	9000.00	9000.00	
5	Supplying, fiting and fixing 38mm thick well flash door.					
5.1	1st Floor	pcs	6.00	17000.00	102000.00	
5.2	2nd Floor	pcs	6.00	17000.00	102000.00	
5.3	Roof Top	pcs	1.00	17000.00	17000.00	
6	Supplying and fixing UPVC plastic door (RFL Cosmic) for toilet (Frame & Shutter) for all floors. size (7'-0" x 2'-2")					
6.1	1st Floor	pcs	3.00	9000.00	27000.00	
6.2	2nd Floor	pcs	3.00	9000.00	27000.00	

7	Paint Work (Weather Coat): Weather coat paint of best quality and color delivery from authorized local agent of the manufacturer in a sealed container, made from water based powder mixed with water (1:1), applying first coat, curing the same after six hours for 24 hours, second coat applied and curing the same for 7 (seven) days etc. taking care and paints, line wash, fungus, algae etc. sand papering the surface before applying 1st and 2nd coat, complete in/c cost of electricity, water & other charges as per direction of the engineer in change.					
7.1	1st Floor	sqm	535.71	514.00	275354.94	
7.2	2nd Floor	sqm	535.71	514.00	275354.94	
7.3	Roof Top	sqm	65.00	514.00	33410.00	
8	Plastic emulsion paint.(Interior ceiling and wall).: Plastic emulsion painting of best quality and approved colour to wall and ceiling two coats over a coat of primer or sealer including cleaning, sand papering the surface and necessary scaffolding etc as per direction of the engineer in change.					
8.1	1st Floor	sqm	1964.25	376.00	738558.00	
8.2	2nd Floor	sqm	1964.25	376.00	738558.00	
8.3	Roof Top	sqm	75.00	376.00	28200.00	

9	Floor tiles (24" x 24" local origin) Main floor and skirting: Supplying, fitting and fixing Floor tiles (Size: 24" x 24", standard local origin) with on 20 mm thick cement sand (F.M 1.8) mortar (1:4) base and raking out the joint.					
9.1	1st Floor	sqm	239.00	1830.00	437370.00	
9.2	2nd Floor	sqm	239.00	1830.00	437370.00	
10	Floor tiles in Toilet (Size:16" x 16" local origin): Supplying, fitting and fixing Floor tiles in Toilet (Size: 16" x 16", standard local origin) with on 20 mm thick cement sand (F.M 1.8) mortar (1:4) base and raking out the joint.					
10.1	1st Floor	sqm	7.81	1830.00	14292.30	
10.2	2nd Floor	sqm	7.81	1830.00	14292.30	
11	Wall tiles (Size: 10" x 20", local origin): Supplying, fitting and fixing wall tiles (Size: 10" x 20", standard local origin) with on 20 mm thick cement sand (F.M 1.8) mortar (1:3) base and raking out the joint.					
11.1	1st Floor	sqm	38.48	1869.00	71919.12	
11.2	2nd Floor	sqm	38.48	1869.00	71919.12	
12	Stair tiles in Toilet (Size:12" x 12" local origin).: Supplying, fitting and fixing Stair tiles(Size: 12" x 12", standard local origin) with on 20 mm thick cement sand					

	(F.M 1.8) mortar (1:4) base and raking out the joint.					
12.1	1st Floor	sqm	15.17	1860.00	28216.20	
12.2	2nd Floor	sqm	15.17	1860.00	28216.20	
	Total DIVISION (D)=				6683731.12	
	GROSS TOTAL DIVISION (A+B+C+D)=				18884594.51	

Reference

- BNBC. (2020). Bangladesh National Building Code. HBRI.
- ACI Committee 318 and American Concrete Institute., Building code requirements for structural concrete (ACI 318-11) and commentary. American Concrete Institute, 2011.
- PWD SCHEDULE OF RATES 2022 FOR CIVIL WORKS
- Design of Concrete Structures Fourteenth Edition Arthur H. Nilson
- Solid Waste Management for Economically Developing Countries. Ahmed and Rahman.

Appendix 1

Slab Design

Slab 1: (span length 30)

Span $l_a = 30ft$

$l_b = 20ft$

Live load $= 2kn/m^2$ (According to BNBC code for classroom)

$= 2 \times 20.89$ [1 $kn/m^2 = 20.89psf$]

$= 42psf$

$f'_c = 4ksi$

$f_y = 60ksi$

Thickness $t = \frac{perimeter}{180}$

$= \frac{2(30'+20')}{180}$

$= 0.56ft$

$= 6\ in$

Effective depth, $D = t - 1$

$= (6 - 1)in$

$= 5\ in$

Dead load, $D.L = t \times 150\ psf$

$= 0.42 \times 150\ psf$

$= 63\ psf$

Factored Dead load, $W_D = 1.2 \times 63$

$= 75.6\ psf$

	Location	Moment (k-ft/ft)	d (in)	As in^2/ft	Bar
l_a	Cont.	$M_a neg = C_a neg\, W_T l_a^2$ $= 0.075 \times 143 \times 15.42^2$ $= 2.55$	4	0.15	#3@ 8.5" c/c
	Mid	$M_a pos,\ d_l = C_a d_l \times W_D \times la^2$ $= 0.521$ $M_a pos,\ l_l = C_a l_l \times W_D \times la^2$ $= 0.042 \times 67.2 \times 15.42^2$ $= 0.671$ $M_a pos, = 0.521 + 0.671$ $= 1.19$	4	0.11	#3@ 8.5" c/c
	Cont.	$M_a neg = 2.55$	4	0.15	#3@ 8.5" c/c
l_b	Dis-Cont.	$\frac{1}{3} \times M_b pos = \frac{1}{3} \times 0.76$ $= 0.25$	4	0.11	#3@ 12" c/c
	Mid	$M_b pos,\ d_l = C_a d_l \times W_D \times la^2$ $= 0.010 \times 75.6 \times 20^2$ $= 0.303$ $M_b pos,\ l_l = C_a l_l \times W_D \times la^2$ $= 0.017 \times 67.2 \times 20^2$ $= 0.457$	3.5	0.11	#3@ 12" c/c

		$M_b pos, = 0.303 + 0.0.457$ $= 0.76$			
	Cont.	$M_b neg = C_b neg\ W_T l_b^2$ $= 0.017 \times 143 \times 20^2$	4	0.11	#3@ 12" c/c

Factored Live load, $W_L = 1.6 \times 42$

$= 67.2\ psf$

Total Load, $W_T = 75.6 + 67.2$

$= 142.8\ psf$

$= 143\ psf$

$l_a = 15.42\ ft$

$l_b = 20\ ft$

$$m = \frac{l_a}{l_b} = \frac{15.42}{20} = 0.8$$

$A_{S(\min)} = 0.0018bt$

$= 0.0018 \times 12 \times 5$

$= 0.11\ in^2/ft$

Depth Check,

If,

$f'_c \leq 4000 \quad \beta_1 = 0.85$

$\theta = 0.9 \quad \epsilon_u = 0.003 \quad \epsilon_t = 0.005$

$$\rho = 0.85\beta_1 \frac{f'_c}{f_y} \times \frac{\epsilon_u}{\epsilon_u + \epsilon_t}$$

$$= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003+0.005}$$

$= 0.018$

Here, $M_u = 2.55$

$$M_u = \emptyset \rho b d^2 f_y \left(1 - \frac{\rho f_y}{1.7 f'_c}\right)$$

$$\Rightarrow 2.55 \times 12 = 0.90 \times 0.018 \times 12 \times d^2 \times 60\left(1 - \frac{0.018 \times 60}{1.7 \times 4}\right)$$

$d = 1.77$ which is less than 4
So, depth is adequate.

A_s Check: (l_a)

$A_s = \frac{M_u}{0.9 \times f_y \times (d - \frac{a}{2})}$ and $a = \frac{A_s f_y}{0.85 \times f'_c \times b}$

$$\therefore A_s = \frac{M_u}{0.9 \times f_y \times (d - \frac{\frac{A_s f_y}{0.85 \times f'_c \times b}}{2})}$$

For continuous side of l_a,

$$A_s = \frac{2.55 \times 12}{0.9 \times 60 \times (4 - \frac{\frac{A_s \times 60}{0.85 \times 4 \times 12}}{2})}$$

$A_s = 0.067 < 0.11$

For continuous side of l_a,

$$A_s = \frac{2.55 \times 12}{0.9 \times 60 \times (4 - \frac{\frac{A_s \times 60}{0.85 \times 4 \times 12}}{2})}$$

$A_s = 0.15$

For discontinuous side of l_b,

$$A_s = \frac{0.25 \times 12}{0.9 \times 60 \times (4 - \frac{\frac{A_s \times 60}{0.85 \times 4 \times 12}}{2})}$$

$A_s = 0.013 < 0.11$

For mid side l_b,

$$A_s = \frac{0.76 \times 12}{0.9 \times 60 \times (4 - \frac{\frac{A_s \times 60}{0.85 \times 4 \times 12}}{2})}$$

$A_s = 0.042 < 0.11$

For continuous side of l_b,

$$A_s = \frac{0.973 \times 12}{0.9 \times 60 \times (4 - \frac{\frac{A_s \times 60}{0.85 \times 4 \times 12}}{2})}$$

$A_s = 0.054 < 0.11$

New Spacing:

$1.5t < s < 3t$

$1.5t = 7.5in$

3 t=15in

For l_a direction $S = \frac{Bar\ \ Area}{Required\ Area} \times 12$

$S = \frac{0.11}{0.15} \times 12$

$= 8.8'' \cong 8.5''$

$\therefore 3@\ 8.5'' c/c$

For l_a direction $S = \frac{0.11}{0.11} \times 12$

=12”

$\therefore 3@\ 12'' c/c$

Slab 2 :Classroom-(span length 30)

Live load = $42\ psf$ (From BNBC Code)

Dead load = $0.42 \times 150 = 63\ psf$

Thickness= $2(20 + 30) \times \frac{12}{180}$

$= 6\ in$

D.L= $1.2 \times 63 = 75.6psf = W_{D.L}$

L.L= $1.6 \times 42 = 67.2psf = W_{L.L}$

Total Load= $75.6 + 67.2$

$= 142.8\ psf$

$m = \frac{19.92}{20} = 1$ $\quad l_a = 15.42ft \quad and \quad l_b = 20ft$

Effective depth, $D = t - 1$

$= 6 - 1 = 5in$

Minimum Area of Steel,

$A_s = 0.018 \times 12 \times 6 \quad = 0.11$ in^2

		Location	Moment (k-ft/ft)	d (in)	As in^2/ft	Bar
l_a		Dis-cont.	$\frac{1}{3} \times 1.65 = 0.55$	4	0.11	#3@ 8.5" c/c
		Mid	$M_a pos,\ d_l = 0.027 \times 75.6 \times 19.92^2$ $= 0.80$ $M_a pos,\ l_l = 0.032 \times 67.2 \times 19.92^2$ $=0.85$ $M_a pos, = 0.80 + 0.85$ $= 1.65$	4	0.11	#3@ 8.5" c/c
		Cont.	$M_a neg = 0.050 \times 142.8 \times 19.92^2$	4	0.15	#3@ 8.5" c/c
l_b		Dis-Cont.	$\frac{1}{3} \times 1.67 \quad = 0.56$	4	0.11	#3@ 12" c/c
		Mid	$M_b pos,\ d_l = C_a d_l \times W_D \times la^2$ $= 0.027 \times 75.6 \times 20^2$ $= 0.81$ $M_b pos,\ l_l = C_a l_l \times W_D \times la^2$ $= 0.032 \times 67.2 \times 20^2$ $= 0.86$ $M_b pos, = 0.81 + 0.586$ $= 1.67$	3.5	0.11	#3@ 12" c/c

		Cont.	$M_b neg = C_b neg\, W_T l_b^2$ $= 0.050 \times 142.8 \times 20^2$ $= 2.86$	4	0.18	#3@ 7" c/c

Depth Check,

If,

$f'_c \leq 4000 \quad \beta_1 = 0.85$

$\theta = 0.9 \qquad \epsilon_u = 0.003 \qquad \epsilon_t = 0.005$

$$\rho = 0.85\beta_1 \frac{f'_c}{f_y} \times \frac{\epsilon_u}{\epsilon_u + \epsilon_t}$$

$$= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003+0.005}$$

$$= 0.018$$

Here, $M_u = 2.86$

$$M_u = \emptyset \rho b d^2 f_y (1 - \frac{\rho f_y}{1.7f'_c})$$

$$\Rightarrow 2.86 \times 12 = 0.90 \times 0.018 \times 12 \times d^2 \times 60(1 - \frac{0.018 \times 60}{1.7 \times 4})$$

$d = 1.9$ which is less than 4"

So, design is ok.

A_s Check: (l_a),

$A_s = \frac{M_u}{0.9 \times f_y \times (d - \frac{a}{2})}$ and $a = \frac{A_s f_y}{0.85 \times f'_c \times b}$

$$\therefore A_s = \frac{M_u}{0.9 \times f_y \times (d - \frac{\frac{A_s f_y}{0.85 \times f'_c \times b}}{2})}$$

For continuous side of l_a,

$$A_s = \frac{2.83 \times 12}{0.9 \times 60 \times (4 - \frac{\frac{A_s \times 60}{0.85 \times 4 \times 12}}{2})}$$

$A_s = 0.18 > 0.11$

For continuous side of l_b,

$$A_s = \frac{2.86 \times 12}{0.9 \times 60 \times (4 - \frac{\frac{A_s \times 60}{0.85 \times 4 \times 12}}{2})}$$

$A_s = 0.18 > 0.11$

Spacing:

For the direction of l_a,

$$S = \frac{0.11}{0.18} \times 12$$

$$= 7.33'' \cong 7''$$

$\therefore 3@\ 7'' c/c$

For the direction of l_b,

$$S = \frac{0.11}{0.18} \times 12$$

$$= 7.33'' \cong 7''$$

$\therefore 3@\ 7''\ c/c$

At direction l_a

$$V_u = 1.15 \times \frac{142.8 \times 15.42}{2} - 142.8 \times \frac{4}{12}$$

$$= 1218.54lb$$

$$V_n = V_c = 2\sqrt{4000} \times 12 \times 4 = 6071.57lb$$

At direction l_b,

$$V_u = 1.15 \times \frac{142.8 \times 20}{2} - 142.8 \times \frac{4}{12}$$

$$= 1594.6lb$$

The design strength of the slab,

$\emptyset V_c = 0.75 \times 6071.5$

$= 4553.63lb$

Is well above 1594.6 lb.

Corridor (span length 6’10’’)

Span $= 6'10'' = 6 + \frac{10}{12} = 6.83'$

Live load $= 4.8kn/m^2$ (According to BNBC code)

$= 4.8 \times 20.89$ [$1kn/m^2 = 20.89psf$]

$W_l = 100\,psf$

Estimate slab thickness for simply supported slab:

suggests minimum slab thickness of $\frac{l}{20}$

$$t = \frac{l}{20} = \frac{6.83}{20} = 0.34' \times 12 = 4.098''$$

But we assumed 5 in slab.

Estimate effective depth:

$$d = t - 1 = 5 - 1 = 4in$$

Compute design load and moment:

$$W_d = \frac{5}{12} \times 150 \frac{lb}{ft^3} = 62.5psf$$

$$W_u = 1.5W_D + 1.6W_L$$

$$= 1.2 \times 62.5 + 1.6 \times 100$$

$$= 235psf$$

$$= 0.235\ k/ft^2$$

Moment at:

Exterior:

$$M = \frac{0.235 \times (6.83)^2}{16}$$

$$= 0.69\ k - ft/ft$$

Mid:

$$M = \frac{0.235 \times (6.83)^2}{14}$$

$$= 0.0783\ k - ft/ft$$

Interior:

$$M = \frac{0.235 \times (6.83)^2}{9}$$

$$= 1.22\ k - ft/ft$$

Depth check:

Compressive strength of concrete $f'_c = 4\ ksi$

Tensile strength of concrete $f_y = 60\ ksi$

$$\theta = 0.9$$

$$\rho = 0.85\beta_1 \frac{f'_c}{f_y} \times \frac{\epsilon_u}{\epsilon_u + \epsilon_t}$$

$$= 0.85 \times 0.75 \times \frac{4}{60} \times \frac{0.003}{0.003+0.005}$$

$$= 0.016$$

$$M_u = 1.37\ k - ft/ft$$

$$\therefore M_u = \emptyset \rho b d^2 f_y (1 - \frac{p f_y}{1.7 f'_c}$$

$$d^2 = \frac{1.22 \times 12}{0.9 \times 0.016 \times 12 \times 60 \times (1 - \frac{0.016 \times 60}{1.7 \times 4})}$$

$$d^2 = 1.64$$

$$d = 1.28\ in < 4\ in$$

So, depth is adequate.

$$A_{s(\min)} = 0.0018bt$$

$$= 0.0018 \times 12 \times 5$$

$$= 0.11$$

We know,

$$a = \frac{A_s f_y}{0.85 \times f'_c \times b}$$

$$A_s = \frac{M_u}{0.9 \times f_y \times (d - \frac{a}{2})}$$

$$= \frac{1.22 \times 12}{0.9 \times 60 \times (4 - \frac{\frac{A_s \times 60}{0.85 \times 4 \times 12}}{2})}$$

$$= 0.072 < 0.11$$

Spacing

S$\leq$ [$3h$ to 18 in]

and,

$1.5t < s < 3t$

$1.5t = 7.5in$

$3\ t = 15in$

$S = \frac{0.11}{0.12} \times 12$

$= 12"$

$\therefore$ #3@12"c/c

$$V_u = 1.15 \times \frac{143 \times 6.83}{2} - 143 \times \frac{4}{12}$$

$= 513.93lb$

$V_n = V_c = 2\sqrt{4000} \times 12 \times 4$

$= 6071.57lb$

The design strength of concrete slab $\emptyset V_c = 0.75 \times 6071.5$

$= 4553.63lb$

Is well above $513.93lb$

Appendix 2

Beam Design Calculations

Beam design - CBI section 3

Span length = 15.25'

h = 15 in

d = 15-1.5

= 13.5 in

From Etabs

Mu = 99.57 k-ft

Rn=Mu/qbd²

= 99.57 x12/0.9 x12 x13.5²

=0.60

$$\rho = \frac{0.85f'_c}{f_y}[1 - \frac{2R_n}{0.85f'_c}]$$

$$\rho = 0.0112$$

As = pbd = 0.0112 x 12 x 13.5 = 1.58 in²

Use #4 bars

No. bar required = $\frac{1.58}{2}$ = 7.9 ≈ 8 nos

Use 8#4 bars

Appendix 3

Column design (C1)

Total load Load $W_u = 148.26\ kip$

$f'_c = 4ksi$ $\qquad$ $f_y = 60ksi$

$\rho_g = 1\% - 8\%\ (use = 1\%)$

	∝	∅
Tied	0.8	0.65

$\Rightarrow \frac{W_u}{\propto\emptyset} = A_g[0.85f'_c(1-\rho_g) + \rho_g f_y]$

$\Rightarrow \frac{148.26}{0.8 \times 0.65} = A_g[0.85 \times 4(1 - 0.01) + 0.01 \times 60]$

$A_g = 71.89in^2$

Use 12×18 $column$

$\Rightarrow \frac{W_u}{\propto\emptyset} = 0.85f'_c(A_g - A_s) + A_s f_y$

$\Rightarrow \frac{148.26}{0.8\times0.65} = 0.85 \times 4(71.89 - A_s) + A_s \times 60$

$\Rightarrow A_s = 0.71in^2$

$A_{s(min)} = 1\%\ of\ A_g = 0.01 \times 71.89$

$= 0.71\ in^2$

Number of Bar needed:

Area of #5 bar=0.31 in^2

Bar needed = $\frac{0.71}{0.31} = 2.29 \cong 3$

But In column we should use at least 4 bars

Use 4#5 bars

Tie Design of Column

Minimum size of the bar $\geq \#3\ bar$, if longitudinal bar is $\leq \#10\ bar$

We use #5 bar, so tie bar #3

Spacing:

01. $S \leq 16d_b$ $\qquad$ $[d_b = diameter\ of\ main\ reinforcement]$

02. $S \leq 48d_t$ $\qquad$ $[d_t = diameter\ of\ tie]$

03. $S \leq Least\ diameter\ of\ the\ column.$

Design: Use #3 tie bar

01. $S = 16 \times \frac{5}{8} = 10''$
02. $S = 48 \times \frac{3}{8} = 18''$
03. $S = 12''$

$\therefore Spacing = 10''@\ c/c$

The neutral axis for the balanced failure condition is easily found with

ε_u = 0.003 and ε_y = 60/29000 = 0.0021

C_b = 11.5 × 0.003 / 0.0051 = 6.76 in

a = 0.85 × 6.76 = 5.75

$f'_s = 0.003 \times \frac{29000\ (6.76 - 2.5)}{6.76}$ = 54.83 kips

C = 0.85 × 4 × 5.75 × 12 = 239.6 kips

P_b=0.85f'c ab+fs'As'

= 234.6 + 60 × 5 = 200.75 kips

$M_b = 0.85\ f'c\ ab\ (\ (\frac{h}{2} - \frac{a}{2}) + f's\ A's\ (\ \frac{h}{2}\text{-d})\ )\text{+Fs As(d-}\frac{h}{2})$

= 234.6 (7 – $\frac{5.75}{2}$) + 54.83 (7 – 11.5)+60×5(11.5-7)

= 2433 kip-in

= 202.75 kip-ft

Eccentricity = $\frac{2433}{208.75}$ = 11.65 in

Yaxis

$\gamma = \frac{11.6}{14}$ = 0.82

e_{in} = $\frac{6}{14}$= 0.4

$\frac{Act}{bh}$= s$\frac{12}{138}$ = 0.08

Using Graph A.7(γ=0.8)

and A.8=(γ=0.9)

$\frac{\text{Pny}}{\text{f'C} \times \text{Ag}} = \frac{(0.62 + 0.66)}{2}$= 0.64 kips

Pny0=0.64×4×138=353.28 Kips

X axis Y= $\frac{7}{12}$=0.58 Sasy 0.6

$\frac{PnX0}{\text{f'c} \times \text{Ag}}$ = 0.65

PnX0 = 0.65×4× 138 = 358.8 kips

$\frac{P0}{\text{f'c} \times \text{A0}} = \frac{0.4}{0.58}$= 0.7

Po = 0.7 × 4 × 138 = 386.4 kips

$\frac{1}{\text{Pn}} = \frac{1}{353.28} + \frac{1}{358.28} - \frac{1}{386.4}$ = 0.003

Pn = 330.06 kip

Pu = 0.65 × 330.06 = 214.54 kip

Appendix 4

Footing Design:

Gravel, sandy gravel, silty sandy gravel; very dense and offer high resistance to penetration during excavation (soil shall include the groups GW, GP, GM, GC)

Safe bearing capacity= $400kpa$ [$According\ to\ BNBC\ page - 731$, Table 6.3.7]

$= 8.35\ ksf$

$D_L = 92\ kip$

$L_L = 32\ kip$

$P_u = 152\ kip$

Self-weight of footing $= 10\%(D_L + L_L)$

$= 0.1(92 + 32)$

$= 12.442$ kip

Allowable bearing capacity= 8.35 ksf

Allowable bearing Area, $A_b = \frac{Total\ Load}{\text{Allowable bearing capacity}}$

$= \frac{92+32+12.442}{8.35}$

$= 16\ ft^2$

Take $(4' \times 4')$ footing $[A_b = 16ft^2]$

$$P_{net} = \frac{P_u}{A_b} = \frac{148.26}{16} = 9.27\ ksf$$

Punching shear check:

$f_y = 60\ ksi$

$f'_c = 4\ ksi$

Allowable punching shear stress:

$$VP_n = 4\varphi\sqrt{f'_c}$$

$$= 4 \times 0.85\sqrt{4000}$$

$$= 215.03\ psi$$

$$d = 2\sqrt{A_b}$$

$$= 2\sqrt{16} = 8in \qquad Assume, d = 10in$$

Punching Shear Force, $V_{P_n} = P_n - Punching\ Area \times \rho_{net}$

$$= 148.26 - \frac{22\times28}{144} \times 9.27$$

$$= 108.605\ kip$$

Actual punching shear stress, $V_{P_n} = \frac{V_{P_n}}{Punching\ perameter \times Depth}$

$$= \frac{108.605\times1000}{2\times(22+28)\times10} = 108.605\ psi\ < 215.03\ psi\ (ok)$$

Critical Shear Check:

Allowable critical shear stress, $V_{t(all)} = 2\varphi0.85\sqrt{4000}$

$$= 107.51\ psi$$

Critical shear force = Critical Area × P_{net}

$$= 1 \times \frac{8}{12} \times 9.27$$

$$= 6.18\ kips$$

Actual critical shear stress $V_f = \frac{6.18\times100}{12\times10}$

$$= 51.5\ psi\ < 107.51\ psi\ (ok)$$

Moment calculation:

$$M_{long} = \frac{WL^2}{2} = \frac{P_{net} \times L^2}{2} = \frac{9.27 \times (\frac{18}{12})^2}{2}$$

$$= 10.42\ k - ft/ft$$

$$= 125.15\ k - in/ft$$

$$M_{short} = \frac{WL^2}{2} = \frac{9.27 \times (\frac{18}{12})^2}{2}$$

$$= 07.24\ k - ft/ft$$

$$= 86.91\ k - in/ft$$

Balance Steel ratio, $\rho_b = 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003+0.005}$

$$= 0.018$$

$\rho_{max} = 0.75 \times 0.018 = 0.0135$

Note: $\varphi = 0.9$ for moment
$\varphi = 0.75$ for shear

Depth Check:

$M_{max} = 125.15\ k - in/ft$

$$d = \sqrt{\frac{125.15 \times 12}{0.9 \times 0.018 \times 12 \times 60 \times (1 - 0.59 \times 0.018 \times \frac{60}{4})}}$$

$$d = 3.49in < 10in \ (ok)$$

Reinforcement Design:

A_s Check:

$A_s = \frac{M_u}{0.9 \times f_y \times (d - \frac{a}{2})}$ and $a = \frac{A_s f_y}{0.85 \times f'_c \times b}$

$$\therefore A_s = \frac{M_u}{0.9 \times f_y \times (d - \frac{\frac{A_s f_y}{0.85 \times f'_c \times b}}{2})}$$

For long direction,

$$A_{s\,min} = \frac{200bd}{f_y}$$
$$= \frac{200 \times 12 \times 10}{60000}$$
$$= 0.4in^2$$

$$A_s = \frac{125.15 \times 12}{0.9 \times 60 \times (10 - \frac{\frac{A_s \times 60}{0.85 \times 4 \times 12}}{2})}$$

$$A_s = 0.236 \ in^2$$

For short direction,

$$A_s = 0.163 \ in^2$$

Spacing:

$$S = \frac{0.20}{0.4} \times 12$$
$$= 6"$$
$$\therefore \#8@ \ 6"c/c$$

Footing thickness= $10 + 2 = 12$” $\therefore \#8@ \ 6"c/c$

Appendix 5

DESIGN OF SEPTIC TANK

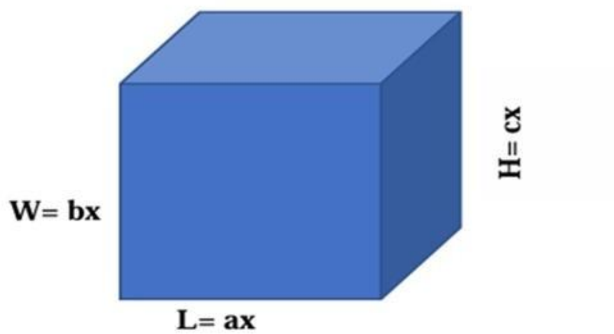
Design of a septic tank to serve a primary school of 200 persons who produce 30 lpcd of wastewater, and the tank is to be dislodged every two years.

Solution:

$V = L * W * H$

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

$A = abx^2$



Designing a septic tank for 200 students according to the Bangladesh National Building Code (BNBC) involves several key steps:

P = 200 persons

N = 5 years

C= 0.04 m3/person/yr.

T= 25 °C

q = 30 lpcd. (BNBC 2020, Volume 3, Section 5, Article 5.5.2)

Volume calculation (m^3)

Sedimentation Zone Vh

Th = 1.5 - 0.3 log (Pq)

= 1.5 - 0.3 log (200 × 30)

$= 1.5 - 0.3 \log(6000)$

$= 1.5 - 0.3 \times 3.778$

$= 1.5 - 1.1334$

$= 0.3666$ days

The volume required by the Sedimentation Zone:

$Vh = 10^{-3} (Pq) \times Th$

$= 10^{-3} \times (200 \times 30) \times 0.3666$

$= 2.1996\ m^3$

Sludge Digestion Zone V_d

Assuming a design temperature of 25°C

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

$V_d = 0.5 \times 10^{-3} \times P \times Td$

$= 0.5 \times 10^{-3} \times 200 \times 42.3 = 4.23\ m^3$)

Sludge Zone V_{sl}

$V_{sl} = C \times P \times N$

$= 0.04 \times 200 \times 5$

$= 40\ m^3$

Scum Zone S_c

$V_{sc} = 0.4 \times Vs$

$= 0.4 \times 40$

$= 16\ m^3$

Total Volume V = Vh + Vd + Vs + Vsc

$V = 2.1996 + 4.23 + 40 + 16 = 62.43\ m^3$

Depth Calculation

Cross-sectional area $A = 22.7\ m^2$ (ratio of B:L = 1:3)

Minimum width 1 m and minimum liquid depth 1 m. The minimum length of a septic tank shall be at least thrice its width. It is recommended that the maximum length of a septic tank shall be not more than 4 times its width. (BNBC 2020 section 6.9.12.8)

The maximum depth of sludge:

dsl = $\frac{Vsl}{A} = \frac{40}{22.7}$ = 1.76 m

The maximum submerged scum

dss = $\frac{0.4 \times Vsl}{A} = \frac{0.4 \times 40}{22.7}$ = 0.704 m

Sludge clear depth = 0.3 m is adopted

Total clear space = 0.3 + 0.075 = 0.375 m

Depth of the digestion zone

dd = $\frac{Vd}{A} = \frac{4.23}{22.7}$ = 0.186 m< 0.375

Depth required for sedimentation

dh = $\frac{Vh}{A} = \frac{2.1996}{22.7}$ = 0.097 m

Since dh < 0.375 m,

dh = 0.375 m is adopted

Total effective depth

= dsl + dss + dd + dh

= 1.76 + .704+ 0.186 + 0.375

= 3 m

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

8.25m × 2.75 m × 3 m

24.6 ft × 9 ft ×10 ft

Appendix 6

Overhead Tank Calculation

Roof top water reservoir (Overhead water reservoir)

Assumptions and considerations

F′c= 4 ksi

Fy=60 ksi

Total Floor 2

Units 2

Per Unit Member 100

Water consumption for big multi-family apartment/flat in city corporation area, considering full facility = 45 liters per capita per day (Part VIII, Table 8.5.1 (a), BNBC 2020: Page 4815

=45 lpcd

b) Water Reservoir size Calculation

Total 200 Persons

Total Cater Consuming = 900 liters for full day

= 9 m^3

= 317.832 ft^3

Inner length & width of Reservoir are,

Length = 14 ft

Width = 12 ft

So, Height of the Reservoir = **3 ft**

c) Vertical Reinforcement of wall

Let wall Thickness = 5 in

Effective Depth = 4 in

$\rho = p_{0.005}$= 0.85 fy×∈ u

∈ u + 0.005

=0.135468

Mu = $\phi \times \rho 0.005 \times fy \times b \times d2 \times (1-0.59 \times \rho 0.005 \times fy\ fc)$

Mu=$\sqrt{\frac{M_{d\,req}\ M_{u,max}}{\emptyset \rho F_y\ b\ (1-0.59\rho * \frac{f_y}{f_c})}}$

d_{req}= 0.55 < provided 4 (Ok)

As_{min}= 0.12 in^2/ft

As=$\frac{Mu}{\emptyset f_y (d-\frac{a}{2})}$ = 0.13 in^2/ft

a=$\frac{Mu}{0.85 f_c b}$ = 0.003 in^2/ft

Bar No	Cross Sectional area in^2	Bar mm
3	0.11	10
4	0.20	12
5	0.31	16
6	0.44	20
7	0.60	22
8	0.79	25
9	0.99	29
10	1.23	32
11	1.48	36
14	2.41	43
18	3.98	57

Large As = 0.11, Spacing = 12

Use 10mm @ 12 inch c/c

d) Horizontal reinforcement of wall

Force = $\gamma * h * (14.52 + 14.52)$ = 5437.5 lb/ft

Again, force/stress=0.091 in^2/ft

Use 10mm @ 12 inch c/c

e) Design of Bottom slab

Table 3: Minimum thickness of non-prestressed one-way slabs

Element	Simply Supported	One end continuous	Both ends continuous	Cantilever
One way solid slabs	l/20	l/24	l/28	l/10

Here, l is the clear span

Multiplying factor= $0.4+\frac{f_y}{100}$

If,

Thickness <6 inch then upper rounding to nearest 0.2

Thickness > 6 inch then upper rounding to nearest 0.50

Thickness 9 in

Self-weight of slab= 112.5 psf

Floor finish = 25 psf

WA= 32.69 psf Total load, w= 0.693 ksf

WB= 79.81 psf

As min = 0.2 in^2/ft

As=$\frac{Mu}{\emptyset f_y(d-\frac{a}{2})}$ = 1.04 in^2/ft

a=$\frac{Mu}{0.85 f_c b}$ = 0.28 in^2/ft

Bar No	Cross Sectional area	Bar mm
3	0.11	10
4	0.20	13
5	0.31	16

6	0.44	19
7	0.60	22
8	0.79	25
9	0.99	29
10	1.23	32
11	1.48	36
14	2.41	43
18	3.98	57

Spacing= 2.5 in

Use #3 @ 2 inch c/c

Appendix 7

Soakaways design

Solution:

Effluent flow from septic tank

= 30x 200 = 6000 litres/day

Long-term infiltration rate

= 30 litres / m day

The infiltration area required = Q/I

= 900/30 = 200 m

Assuming a 3 m diameter, the effective depth of the soak pit will be

$$= \frac{200}{(\pi \ \text{x} \ 3)}$$

= 21.22 m

However, 6 soak pits each of 3 m diameter and 4.0 m deep may be provided.

Appendix 8

DESIGN OF A DOG-LEGGED STAIRCASE SUPPORTED LONGITUDINALLY

Floor to floor height 3.66 m

Riser (R)= 150 mm

Tread (T)= 250 mm

First landing width (L1)= 1000 mm

Second landing width (L2)= 1000 mm

Number of risers in all flights (N)= 12

Width of stair= 1000 mm

Impose load= 3 KN/m²

Floor finishes= 1.25 KN/m²

Beam width (B)= 304.8 mm

Unit wt. of concrete (ϒ)= 22.5 KN/m³

Grade of steel (fy)= 500 N/mm²

Grade of concrete (f'c)= 20 N/mm²

Step 1: Calculation of effective span

Effective span (Left)

$= \{(N-1) \times T\}+L1+L2+(\frac{B}{2})+(\frac{B}{2})$

= {(12-1) ×250}+1000+1000+304.8

= 5054.8 mm

Step2: Calculation of effective depth

clear cover (c)= 15 mm

Adopt the diameter of the bar (0)= 12 mm

(assuming constant 30-40)

Effective depth (d)= ($\frac{Leff}{30}$) = 168.493 mm

Overall Depth (D)= d+($\frac{b}{2}$)+c = 168.493+($\frac{12}{2}$)+15

= 189.493 mm ≈190 mm

Provided eff. depth= 169 mm

Step 3: Calculation of load

(i) Load on going on the projected plan area

Live load = 3×1

= 3KN / m

Floor finish = 1.25 ×1

= 1.25KN / m

wt. of waist slab =Upsilon×D× V$\frac{(R^2 + T^2)}{T}$

= 5.5394KN / m

wt. of steps = Upsilon ×0.5^ × R

= 1.875KN / m

Total load l = 11.66KN / m

Factored load = 1.5 ×11.66

= 17.497KN / m

Live load = 3 ×1

(i) Load on landing

Floor finish = 1.25 ×1

= 3KN / m

self wt. of slab J = Upsilon×D×1

= 1.25KN / m

= 4.75KN / m

Total Load = 9KN / m

Factored load = 1.5×9 = 13.5KN / m

Step 4: Calculation of maximum bending moment and maximum shear force

Taking the moment of all forces about point B

Ra×5.0548= (13.5×1.1524× ($\frac{1.1524}{2}$+ 2.75 + 1.1524) ×17.5×2.75× ($\frac{2.752}{2}$+1.1524)

+{13.5×1.1524× $\frac{1.1524}{2}$}]

Ra×5.0548

= 200.247 Ra

= 39.62KN

Ra+Rb (13.5×1.1524)+(17.5×2.75)+(13.5×1.1524)

39.62 + Rb = 79.23 Rb = 39.62KN

V_{max} =13.5× $\frac{(1.1524 + 1.1524) + (17.5\times 2.75))}{2}$= 39.62 KN

M_{max} =[13.5×1.1524×{($\frac{1.1524}{2}$) + ($\frac{2.75}{2}$)}]-[17.5× ($\frac{2.75}{2}$) × ($\frac{2.75}{2}$ ×2)]+[39.62×{1.1524 + ($\frac{2.75}{2}$)}]

= 53.23 KN-m

Step 5: Check for depth against bending moment

M_{max} =0.133×fck×b× $dreq^2$53.23× 10^6

=0.133×20×1000× $dreq^2$ × dreq

= 141.46 mm

(dreg=dprov).

Hence OK

Step 6: Designing the reinforcement

53.23× 10^6= 0.87×500×Ast×169× [1-{(500×Ast)/(20×1000×169)}]

Ast= 824.642 mm²

(Ast)min.= 0.12% of b×D

= ($\frac{0.12}{100}$) ×1000×190

= 228 mm²

Spacing= [$\frac{1000}{4824.64}$ × $\frac{(3.142\times 12^2)}{4}$]

= 137.147 mm ≈150 mm

Provide 12mm dia. bar @ 150mm c/cf

(Ast)prov.= [$\frac{1000}{150}$× $\frac{(3.142\times 12^2)}{4}$}

= 753.982 mm² % of steel prov.

= 0.45%

Step 7: Check for shear force

For M20 concrete

Shear strength (Tc)= 0.280 N/mm²

IS 456:2000, Table-19

Mmax= $\frac{(39.62\times10^{3})}{(1000\times169)}$ = 0.234 N/mm² (OK)

Step 8: Check for deflection

(Leff/d)prov.= $\frac{5054.8}{169}$ = 29.91

Basic values

Basic value: (α) = 20

Modification factor (β) = 1

For Tension Reinforcement (y) = 1.5

For Compression Reinforcement (8) = 1

Reduction factor for flanged beam (λ) = 1

For calculating the factor y

Steel Stress of service load (ts)= 0.58fy

= 0.58×500× [$\frac{(Ast.reg.)}{(\text{Ast.provided})}$Ast.provided)] = 317.177

($\frac{As}{bd}$) %= [$\frac{753.982}{(1000\times169)}$] ×100×0.446

(γ) = 1.5

Now,

alpha×beta×y×delta×lambda

=20× 1×1.5× 1×1 = 30

(I / (d)) <= alpha×beta×chi×delta×lambda (OK)

Step 9: Development length

Ld. =sigma equip underline ×0.87

=(12 × 0.87×500)/(4×1.2× 1.6))

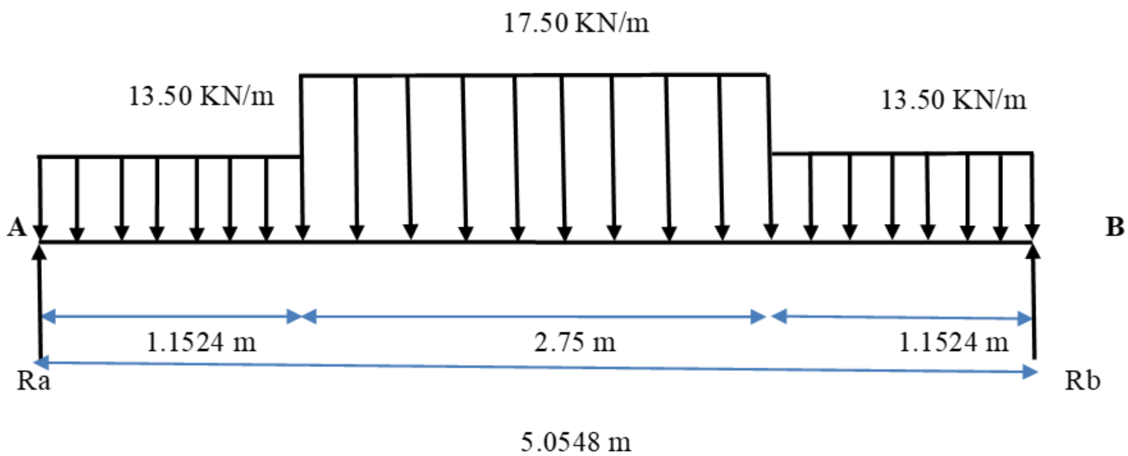
= 679.688mm

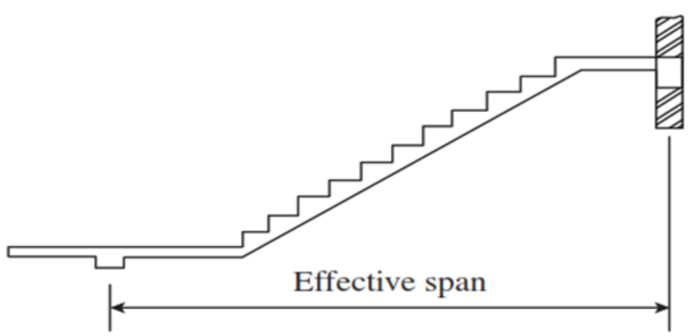
Step 10: Distribution bar reinforcement detailing

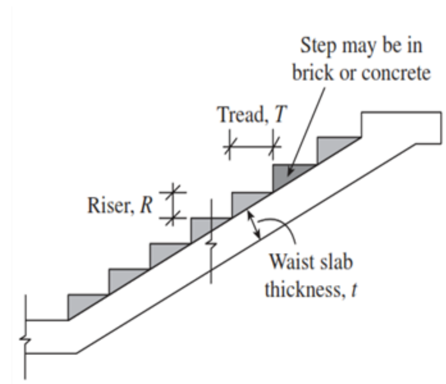
Spacing $=1000\times \frac{228}{(3.142\times4\times144}$

= 496.041mm <= 450mm <= 845mm Spacing provided = 250mm

Provide a distribution bar of 12mm diameter. @ 250mm c/c







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: Asikur Rahman Santo Student ID: 213-47-472 Name: Abdur Rahman Saikat Student ID: 213-47-462
CO3 (K7, P2, A2)	Alternative analysis presented	Economic, environmental, social, ethical aspects, health and safety considered	Conducted alternative analysis, balancing cost, 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 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	incomplete.

		Prepared BOQ	ensuring accurate financial and material planning for the project.
		Show Financial Assessment	incomplete
		Show time management skill	incomplete
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 vii Design of Soakway viii Design of Overhead Tank ix Design of pipe line

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