

# **DESIGN OF A TWO-STORY PRIMARY SCHOOL BUILDING**

**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  
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**November 2025**

This confirms that the student under was the completion of the capstone project of the Bachelor of Science in Civil Engineering degree requirement of the **Design of a Two-Story Primary School Building**, which occurred under my supervision. The work was successfully presented on 15 November 2025.

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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

To begin with, we would like to thank **Almighty Allah** with our heart and soul because He gave us the power, patience and prudence to finish our **Capstone Project**. This would not have been the case without blessings and direction.

It is our great pleasure to thank our respected supervisor, **Professor Dr. M. R. Kabir**, Professor, Department of Civil Engineering, Daffodil International University, to have helped us with his continuous support, wise supervision and invaluable advice at all the phases of this project. The result of our work is largely due to his experience, support and positive recommendations.

We are much grateful to **Dr. Mohammad Hannan Mahmud Khan**, Associate Professor and Head of the Department of Civil Engineering, who gave us the chance and the facilities to complete this Capstone Project and who contributed and encouraged us during the process.

We are also grateful to **Md. Masud Alom**, Assistant Professor and Convener of the Research Committee that research is an important aspect to be considered in engineering education.

**Ms. Lamiya Fariha**, Lecturer, Department of Architecture is also owed special thanks as she provided great guidance and architectural experience that helped us greatly in aesthetic and functional elements of this project. Her expertise was able to assist us in designing and developing our design style.


We should also like to thank **Mr. Dino Bondhu Saha** and **Mr. Ijaj Ahmed** Teaching Assistants of **Professor Dr. M. R. Kabir** and their constant help, technical support and encouragement. They helped a lot in the process of analyzing, modelling and documentation of this project.

And last but not least we would like to thank our families, friends and classmates, who have constantly encouraged, been patient and morally supportive through the past years of our study and this Capstone Project.

## DECLARATION

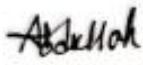
The study titled "Design of Two-Storeyed Primary School Building with Structural and Environmental Consideration" was carried out under the supervision of **Professor Dr. M. R. Kabir**, Department of Civil Engineering, Daffodil International University, Dhaka, Bangladesh and approved for the partial fulfillment of the requirement for the capstone project part of the Bachelor of Science in Civil Engineering.

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## **ABSTRACT**

This capstone project focuses on the structural design and cost analysis of a two-story reinforced concrete (RC) primary school building situated in Seismic Zone 3 of Bangladesh. The proposed land area 50,055 square feet & building with an approximate floor area of 9,151 square feet, accommodates eight classrooms, a teacher`s room, library, computer lab, head teacher`s office, waiting room, storeroom, and separate sanitation facilities for both male-female students and teachers. The design is done in accordance with the Bangladesh National Building Code (BNBC 2020) that governs structural safety, stability, and serviceability when the structure has gravity and seismic loads.

ETABS 2020 was used to conduct the structural analysis in which the building was modelled as an Intermediate Moment Resisting Frame (IMRF) system. Reinforced concrete components such as slabs, beams, columns, and isolated footings were designed considering load combinations, material strength, and deflection limits. For example, 20mm diameter reinforcing bars were used in columns, while isolated footings were provided to safely transmit loads to the soil with a bearing capacity of 2,500 psf. Detailed structural drawings were produced in AutoCAD, and the Bill of Quantities (BOQ), material estimates, cost calculations were managed using Microsoft Excel and ASDIP Foundation was used to measure the footing dimension. The total estimated project cost is BDT 24,356,465 with a projected construction period of 241 days.

Measures such as tree plantation, proper sanitation. A septic tank of 64 m<sup>3</sup> capacity was designed to serve 450 users along with an overhead water tank to ensure a continuous water supply.

Overall, this project bridges academic knowledge and real-world engineering practice, demonstrating the comprehensive process of designing a safe, functional, and environmentally sustainable educational facility for rural Bangladesh.

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# CHAPTER 1

## INTRODUCTION

### 1.1 Proposed Structure

RCC will build the proposed two-story primary school entirely on separate foundations. The building, which is around 9,151 square feet on the design, has eight classrooms, a teacher`s room, a library, a head teacher room, computer lab, waiting room, store room, male teacher`s washroom, female teacher`s washroom, student`s male washroom and student`s female washroom. The layout plan is shown in Figures 1.2, and 1.3. Fig. 1.4 shows an elevation view of the building:

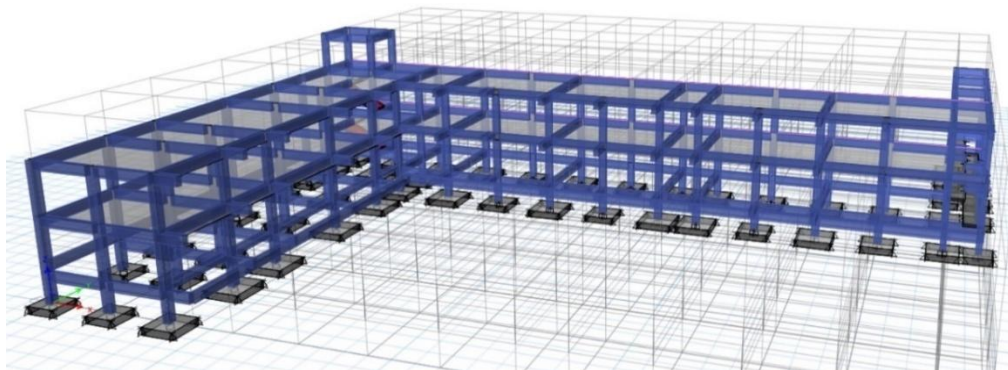


Figure 1.1: 3D View

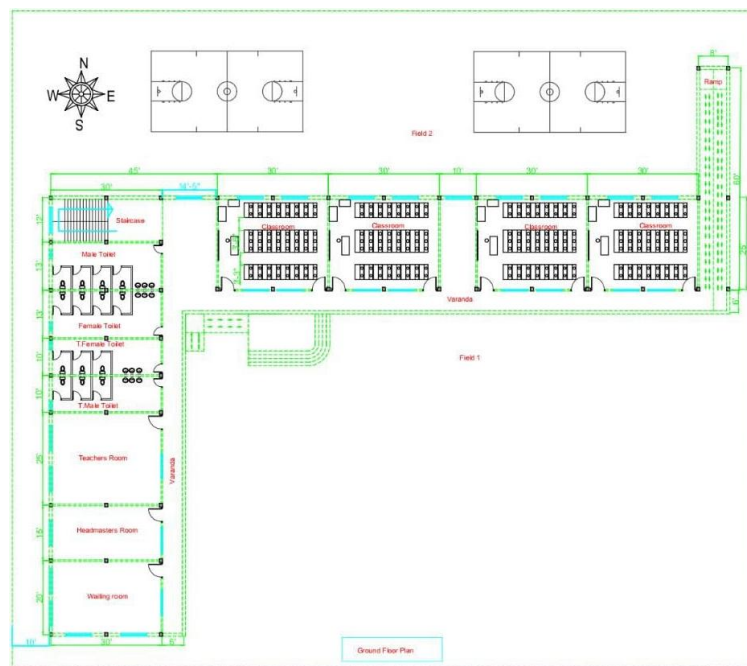
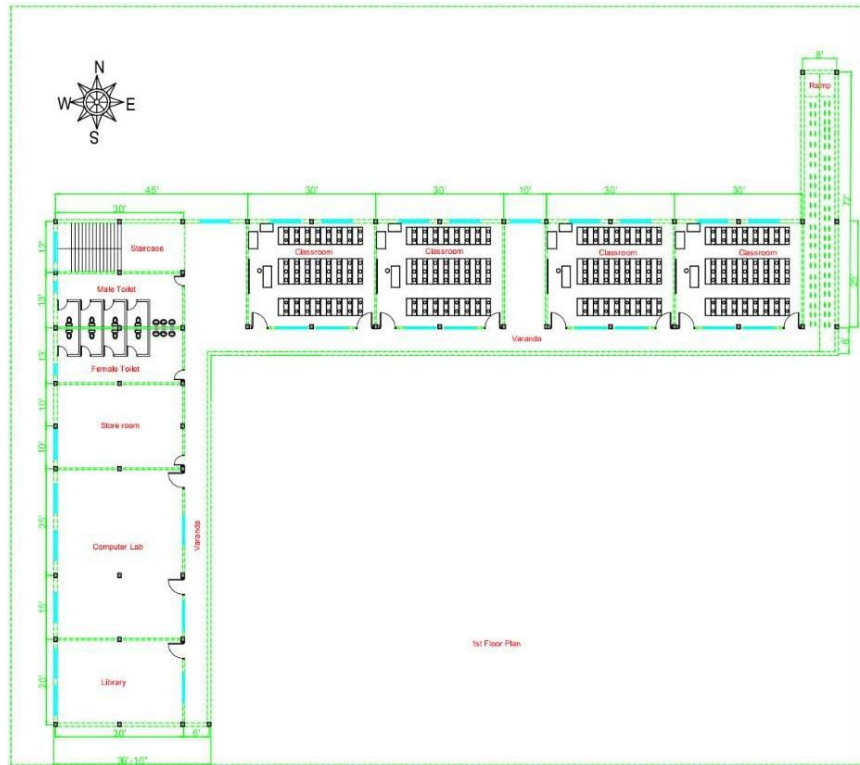
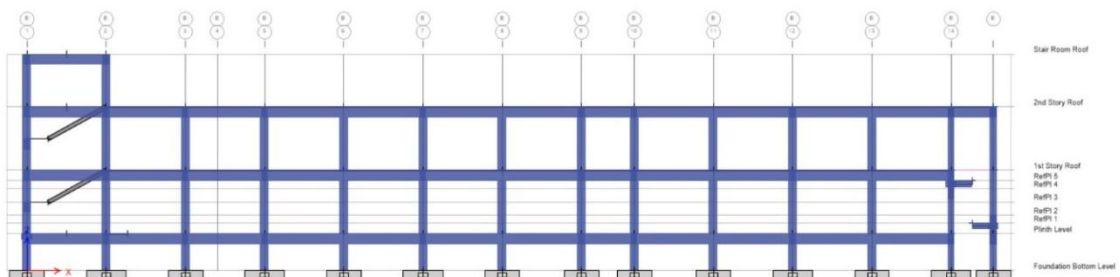


Figure 1.2: Ground floor



**Figure 1.3: First floor**



**Figure 1.4: Elevation**

## 1.2 Objectives of the Project

1. To construct a two-story primary school building using reinforced concrete, ensuring structural safety and compliance with the Bangladesh National Building Code (BNBC), with particular emphasis on Seismic Zone 3.
2. To apply theoretical knowledge of civil engineering through practical implementation, using AutoCAD to detail key structural components such as slabs, beams, columns and ASDIP Foundation software for foundations design and designed septic tank and overhead water tank in accordance with BNBC 2020 guidelines. ETABS 2025 for structural analysis.

3. To create accessibility for physically disabled users by providing a properly designed RCC ramp and to ensure sustainability, economic efficiency, and functionality through effective space planning, precise material estimation, and the promotion of eco-friendly techniques such as energy-efficient design.

An Intermediate Moment Resisting Frame (IMRF) structural system is being used in this project to construct a two-story reinforced concrete (RC) educational institution, as shown in Table 1.1. The foundation is built with independent footings to carry the loads, whilst the floor system is made up of edge-supported slabs.

### **1.3 Basic Information**

Capstone project is the end-stage of an academic program, it allows students to combine and apply their previously acquired knowledge and skills, to solve real-life previously unwritten topics or research problems. During our final year, we are expected to design an two-story primary school building in a rural region in the seismic zone 3 where special consideration is required of the building in terms of structural stability and safety levels. The design should accommodate at least 8 classrooms that are supposed to comprise of 50 students each with classroom dimensions pegged to 30 feet and 25 feet length and width respectively calculated on the basis of 0.75 square meters per student according to BNBC. The soil on the site can support 2500 psf and this is used to determine the foundation design to achieve stability in the long term. The school is located on the second floor as the first floor, which consists of 4 classrooms, 4 toilets and 3 basins of male students, 4 toilets and 3 basins of female students, 3 toilets and 3 basins of male teachers. Other rooms in this floor are the teacher`s room, office of the headmaster and the visitor waiting room. There are 4 additional classrooms, 4 toilets and 3 male and female basins on the first floor. According to BNBC 2020, PART VIII, Chapter 6, Table 8.6.1, water closets required for boys 1 per 40 and 1 per 25 for girls. The other functional areas including a storeroom, a computer lab and a library are also present in the first floor to facilitate the educational activities. The design will be based on accessibility by having a ramp to support students with physical impairments to move freely, making the design inclusive. In addition to the building, the school campus has two separate playgrounds to serve the students of various ages: Field 1, which is situated in the middle, is planned to serve older students, and it is equipped with sporting activities such as cricket and football, whereas Field 2 is used by younger students, where they can have a lot of space, run, and a separate basketball court. There

is a 15-foot road in front of the main entrance that improves the access to the school. A special parking place is included in the site layout to accommodate the daily transportation of the students, parents, and staff in order to park cars, motorcycles, and bicycles. The general design is informed by the safety regulations, comfort of the users, environmental conservation, and maximization of space with the view of supporting a fostering and interactive academic atmosphere.

**Table 1.1: Basic Information of the Building**

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

#### **1.4 Outdoor Sports and Recreational Facilities**

The school campus includes two distinct outdoor fields designed to promote physical education, extracurricular activities, and student recreation while optimizing the available land area and accessibility.

##### **1.4.1 Field 1 - Multipurpose Cricket and Football Ground**

Field 1 is a multipurpose open field which is 118 ft x 147 ft in size and is used in playing cricket and football. Its rectangular shape permits a flexible zoning configuration of varying sports structures:

- **Cricket Pitch Zone:** The pitch area in the middle is of normal proportions that can be used by school level outdoor cricket and inter-school cricket. Outfield provides adequate space on which to run off safely.

- **Football Ground:** The width of the field holds a small ground in which the goals have specific end goal posts. The surface is graded and smooth to play the ball safely and to allow the players to move.
- **Shared Utility:** I can divide the field with the aid of portable goal posts and boundary markers in order that parallel cricket play or small football can be practiced during events or the physical education sessions.

Buffering of the boundary improves aesthetics and also offers the students places to spectate during the sporting events. Drainage gradients will be integrated to facilitate the rainwater runoff so that the use of the ground can be all-seasonal.

#### **1.4.2 Field 2 - Dual Basketball Court Complex**

Field 2 will include two full-sized basketball courts that will be placed side-by-side (185 ft x 57 ft). The plan is formed in such a way that it maximizes the linear dimension to be used simultaneously:

- The standard dimensions of the courts are kept uniform across all the courts so that they can meet the training and school-level competitions.
- The synthetic paint applied to the concrete surface is non-slip and the boundaries of the court, major areas and center circles are well marked.
- Slopes of drainage and peripheral concrete edging are used to avoid waterlogging and wear of the surface.

The field is also characterized by less space to seat spectators and wait to be picked by the players in the longer side and the availability of floodlights to be played on during the event or physical training.

#### **1.4.3 Design Integration and Purpose**

The two fields are arranged in a balanced way between team sports (football, cricket) and court based (basketball) sports making sure that the physical development program is inclusive. The space planning facilitates:

- **Good circulation:** The fields can be approached by the students and staff through walkways that are paved and linked to the main academic block.
- **Safety and supervision:** Sharp boundaries help avoid overlapping of playing fields, and an orderly movement is maintained during times of sports.

- **Environmental harmony:** Green belts enclose the fields and helps in the microclimate control of the campus as well as aesthetics.

#### **1.4.4 Benefits to Students Health and Wellbeing**

Outdoor sporting facilities are planned well, which can be a great contribution to the health and development of students:

- **Physical Fitness:** Sports activities would be beneficial to the cardiovascular health, muscle strength and endurance.
- **Mental Wellness:** Teamwork and outdoor play relieve stress, improve mood, and improve mental health.
- **Teamwork and Discipline:** Students learn how to socialize, see abilities of leading others and being disciplined with the help of structured physical activities.
- **Academic Improvement:** It has been revealed that students who regularly participate in sports have better focus, memory and classroom performance.
- **Lifelong Habits:** Exposure to a variety of sports will promote life-long interest in health, fitness, and recreational balance.

## **CHAPTER 2**

# **DESIGN CODES, STRUCTURAL DESIGN AND REQUIREMENTS**

This study aims to analyze the impact of internal factors in order to protect life, health, property, and public welfare. It is important to follow design codes that establish basic standards for the layout, construction, material quality, use and occupancy, placement, and maintenance of all buildings in Bangladesh, within reasonable limits. To achieve the same objective, regulations are also in place concerning the installation and use of specific tools, services, and accessories related to or associated with such buildings. The equations and specifications used in the structural design of this building were sometimes referred to as (BNBC, 2020). ETABS 2025 was also assessed using (BNBC, 2020).

### **2.1 Design code**

The Bangladesh National Building Code (BNBC, 2020) has been followed in the analysis and design process. All structural drawings must be examined in combination with pertinent architectural drawings. For specifications or structural requirements not included in the drawings, refer to BNBC 2020.

### **2.2 Foundation and soil**

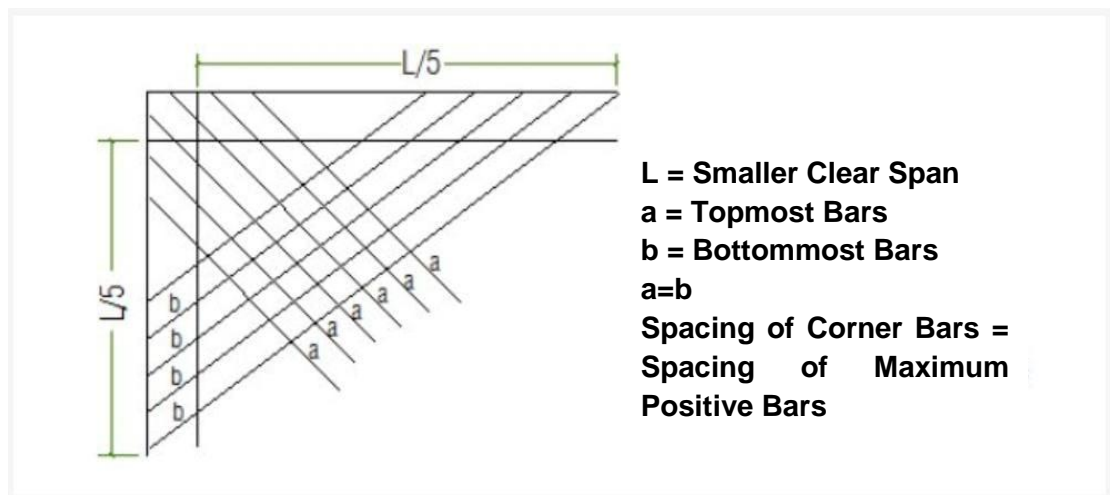
One suggested foundation type is a footing foundation. It is advised to have a minimum clear cover of 3.0 inches. The foundation's depth must match the sketch. The characteristics of the material include a minimum compressive strength of 4000 psi for the foundation and column, with a 1:1:2 mix ratio. Slabs and beams should also be at 4000 psi with a 1:1:2 mix ratio.

### **2.3 Lapping Zone of Beam**

The shortest distance between the laps as required by the BNBC (2020) is contingent on the type of concrete, the size of the reinforcement bars, and their location either in tension or compression areas. Normally, lap length is multiple to bar diameter (D). The lap length in tension zone is to be 40D and that of compression zone is to be 30D where D is the diameter of the bar.

## 2.4 Corner reinforcement

The paper will examine how internal factors impact the structure as per the Bangladesh National Building Code (BNBC) to reinforce structural corners and control the concentration of stress particularly in seismic areas. In order to address shear and torsional forces, BNBC (2020) suggests that more diagonal bars, close spacing stirrups, and beams, slabs, and column-beam connections ties are to be added. Corner reinforcers should be enhanced to avoid slipping during the load bearing, this is achieved by ensuring that the lap lengths are minimum, and the same should be anchored as shown in Fig. 2.1. Such a method of reinforcement guarantees ductility, energy absorption and structural integrity in critical points, which allow buildings to resist lateral loads and avoid cracking or brittle fracture.



**Figure 2.1: Corner reinforcement**

## 2.5 Material strength

**Table 2.1: Material Strength**

Components	Concrete, $f_c$	Unit	Rebar Strength, $f_y$
Foundation	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

The minimum length of the reinforcement to be introduced into the concrete to prevent sliding and give the full strength is the Development Length ( $L_d$ ) of the reinforcement in beams and slabs, as specified by the Bangladesh National Building Code (BNBC 2020). It is determined as  $L_d = f_y/4b$ ; where  $b$  is the bar diameter,  $f_y$  is the steel compressive strength and  $b$  is the concrete bond strength. This is on top of the increased development lengths that beams normally have than slabs, as they have to handle the increased loads. Other kinds of linear adjustments as laid down in BNBC (2020) are also taken into account including the type of bar and the cover. These regulations are introduced so as to safeguard the safety and body of the concrete structures so that the proper specifications of the anchor length can be made according to the specified loads.

## 2.7 Concrete Clear Cover for Reinforcing Bars

Concrete: There is a minimum amount of space required between the bars and the surface of the concrete to protect them from fire, corrosion, and other environmental damage. This is called concrete clear cover. It covers the column, which usually has a 1.5-inch size and is very durable and protective. Normally, this is 1 inch for interior beams, but depending on exposure, it may increase. Typically, slabs have a 3/4- to 1-inch-thick transparent cover depending on their exposure and thickness. The cover stabilizes the stair concrete slab and is secured on the edge, as shown in Figure 2-3, and results can be seen in Table 2.2. Reinforcement does not corrode; there is no attack on

the structure by moisture and chemicals, and fire resistance is enhanced. In sum, all characteristics of a durable and lasting construction are provided.

**Table 2.2: Concrete Clear cover**

<b>Member</b>	<b>Location or Combination</b>	<b>Thickness of Cover</b>
Column	Not in contact with the ground or water	1.5"
	In contact with the ground or water	3"
Beam	Indoors face: Top, Side & Bottom	1.5"
	Outdoors' face: Top, Side, & Bottom	1.5"
Slab	Bottom	1"
	Top	$\frac{3}{4}$ "

# CHAPTER 3

## STRUCTURAL ANALYSIS AND DESIGN

### **Introduction**

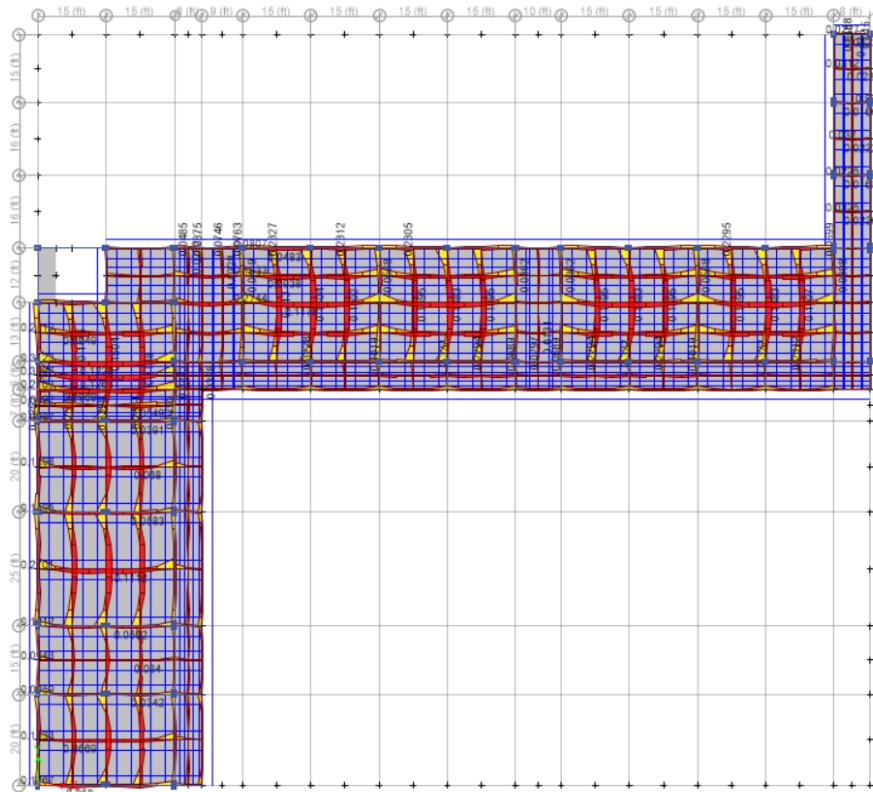
The beams, columns, footings, slabs and stairs of this project were modeled in ETABS which is a building. I established the right span lengths and stress conditions of the beams in such a way that ETABS would compute the required reinforcement both on the shear and bending. I inspected the cracks and the extent to which the beams were bent so that it would work properly under the normal use. The columns were considered as vertical frame elements and I referred to the design code equations to apply the load and moments at the axial direction to determine the amount of reinforcement required. I also estimated the loads and determined the forces which the structure will exert according to my assumptions before making the footings and performed a structural check of the foundation system to ensure that the foundation system could withstand the estimated loads using the properties of the soil. As a result, I created the footings in ETABS and made the reinforcement to provide sufficient stiffness and strength to accommodate the loads. I ensured the real thickness of slabs, loads, deflection, and moment capacity of the results were at safety and serviceability standards. To ensure that the stairs were in accordance to all the rules, I made them assuming a series of beams and slabs. The elaborate analysis carried out in ETABS assist in developing the entire and combined structural design, which demonstrates the entire safety and strength of all the sections in the building. My ETABS work in the building involved the detailing of the building in AutoCAD after structurally designing it. The primary aim of this part is to ensure that the design is readable and can be adequately presented. After that, I created AutoCAD drawings of the beams, columns and slabs, the footings and stairs and all was drawn with the correct measurements such as the material takeoffs and the RC structural drawings. It was a technique that made me realize more about the structural interactions between different parts such as the way the beams are attached to the columns or the way the slabs are attached to them. I also included some straight forward labels and symbols of the designs. To ensure that the drawings would be constructed in a reasonable manner, we integrated well-structured ETABS and ASDIP Foundation analysis into an elaborate AutoCAD drawing to ensure that the plans were structurally viable and also comprehensible to the builders.

### **3.1 Load consideration**

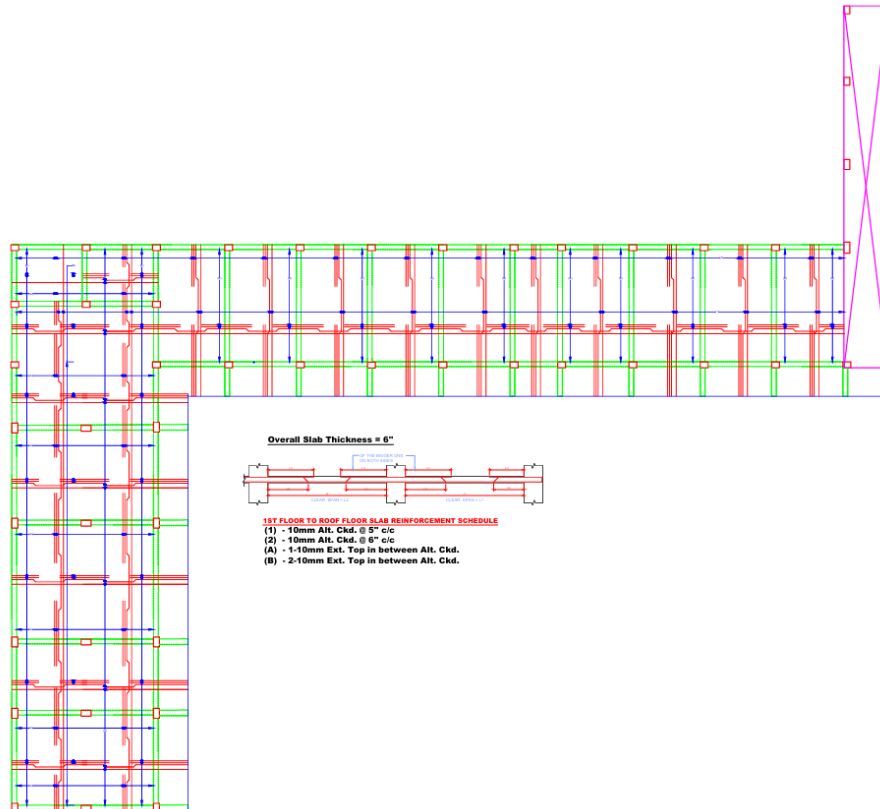
In ETABS, the loads in a building of a primary school designed in accordance with BNBC are divided into three groups, dead load, live load, and floor finish load, 2020 regulations. Dead load is the total weight of the permanent structural components of the building such as floors, walls, beams, columns and fixed installations such as ceiling and partitions. The weight of the materials such as concrete, brick or steel determines this load. Live load accounts for the weight of the building's occupants, furniture, and movable items. Primary schools should assign a live load of approximately 2 to 4 kN/m<sup>2</sup> in classrooms due to normal use and occupancy. However, in areas with high foot traffic such as assembly rooms and hallways, the live load should be increased to 4 to 5 kN/m<sup>2</sup>. Floor finish load refers to the weight of the flooring elements, such as carpet or tiles, and is typically set between 1 and 1.5 kN/m<sup>2</sup>. These loads should be combined in ETABS according to the load combination guidelines specified in BNBC, 2020, to ensure accurate structural analysis.

### **3.2 Design of Slab and detailing**

In this way, many important aspects are considered while designing slabs in ETABS so that the resultant slabs will be structurally sound and code compliant. The Slab Analysis program considers the following factors: slab geometry, material data for flat plates, load types (dead, live, and environmental) and working conditions. By means of finite element analysis, it checks the stresses, deflections, and reinforcement required through the slabs. Additionally, ETABS analyses the performance of slabs subjected to different types of load distributions (live and dead), load combinations, and support conditions (such as simply supported, fixed, or continuous). It also includes safety features and regional design requirements to ensure compliance with local standards for the specific location.



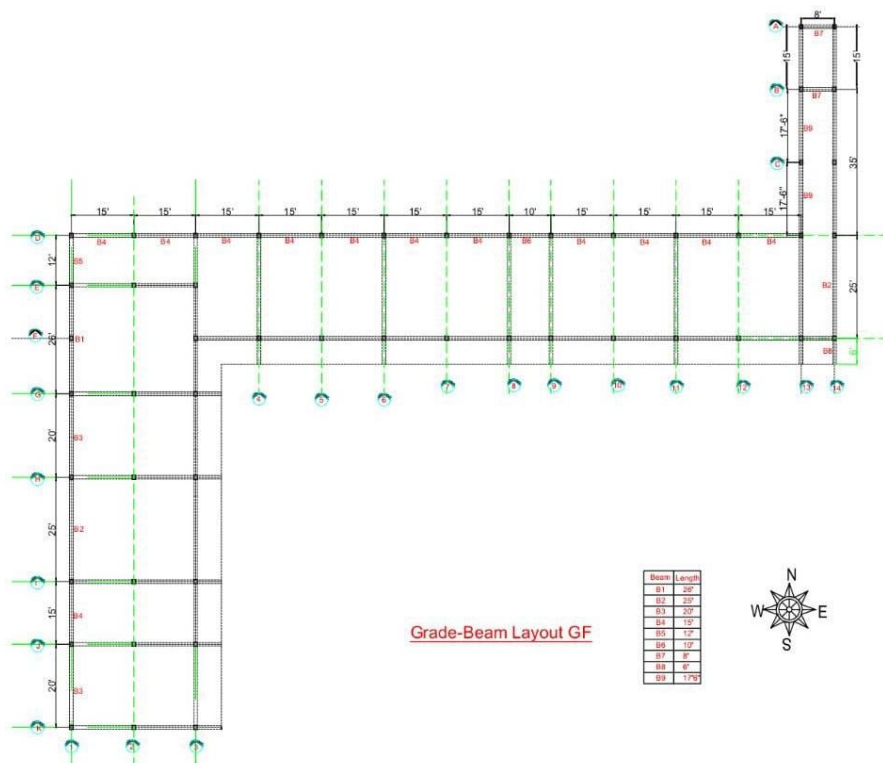
**Figure 3.1: Top and Bottom Reinforcement of slab**



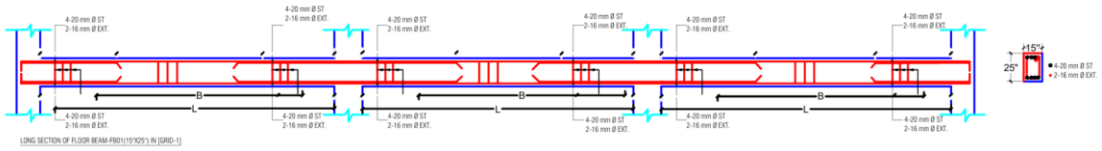
**Figure 3.2: Reinforcement Detailing of Slab**

### 3.3 Design of Beam and Detailing

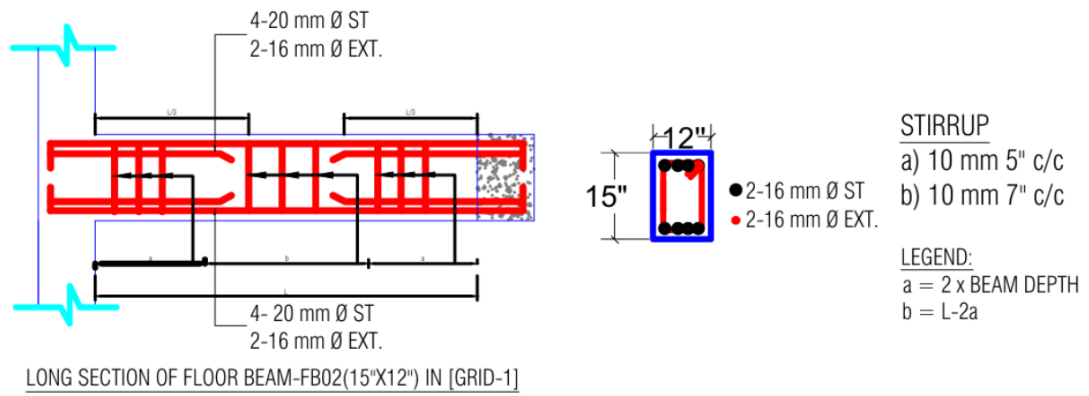
The building's ETABS beam design method involves determining the beam's dimensions and outlining the loading conditions, including dead and live loads, in compliance with the relevant standards. Once the model was configured, we examined the beams for bending moments using ETABS, as seen in Fig. 3.10. The program ensured that the beams met structural safety standards by automatically determining the reinforcing required for both positive and negative moments. After reviewing the analytical results, it was confirmed that the reinforcement scheme satisfied the basic code requirements, successfully resisted the applied loads, and that the calculated deflections were within permissible boundaries for serviceability. Taking everything into account



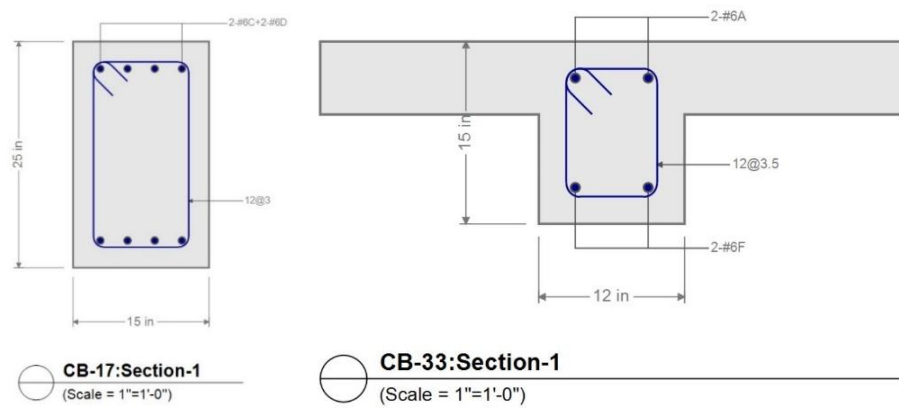
**Figure 3.3: Grade Beam Layout Plan**



**Figure 3.4: Beam Reinforcement Detailing**



**Figure 3.5: Beam Reinforcement Detailing**



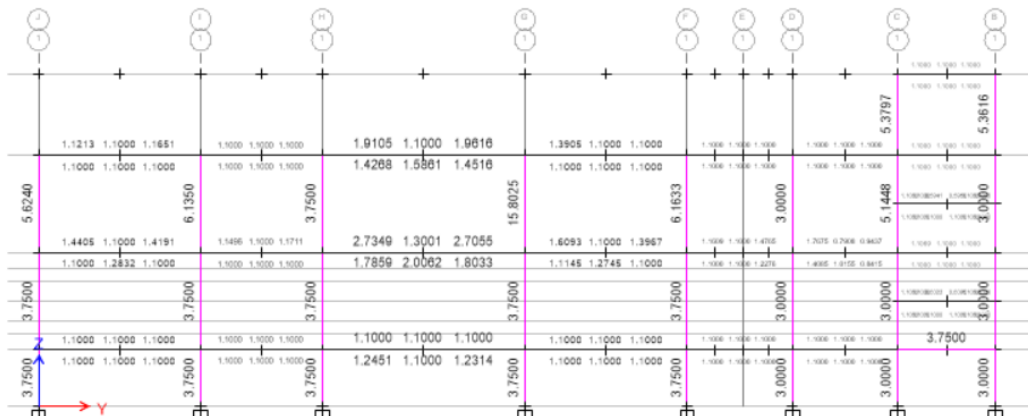
**Figure 3.6: Beam Section**



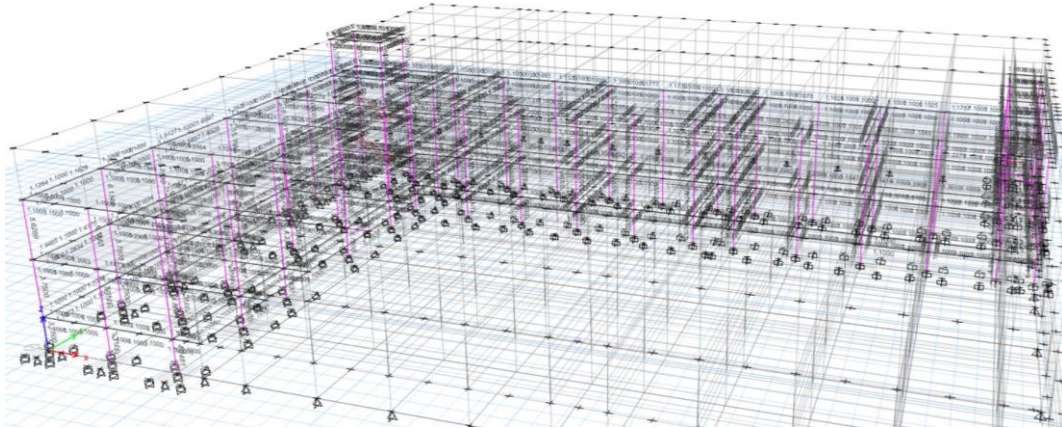
**Figure 3.7: 3D Dimension Beam Rebar Profile**

### 3.4 Lap Location

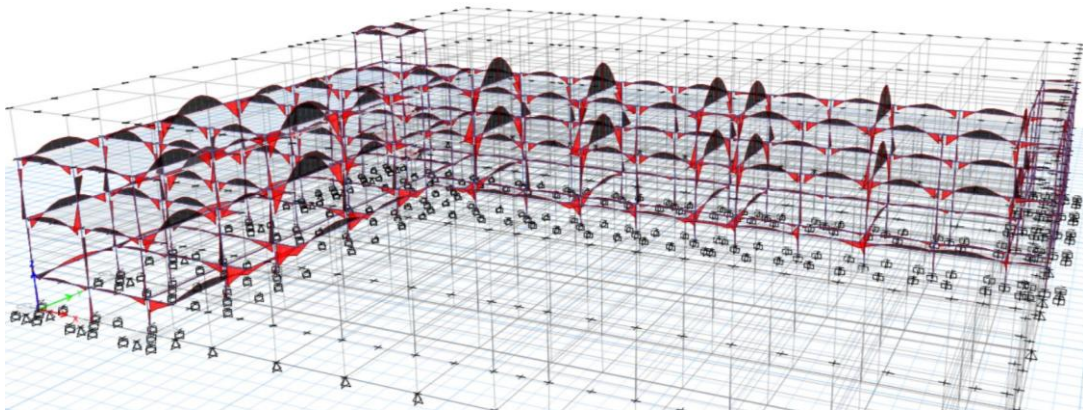
- In the middle third part of the span, there should be no bottom bar lap for the beam.
- In the middle third part of the span, a lap bar for the top of the beam may be allowed.
- See Figures 4.12 No more than 50% of the bars should be spliced together.



**Figure 3.8: Elevation 1 Longitudinal Reinforcement**



**Figure 3.9: 3D Dimensional All Floor Slab Beams Reinforcement**



**Figure 3.10: Bending Moment Diagram (Dead load Kip-ft)**

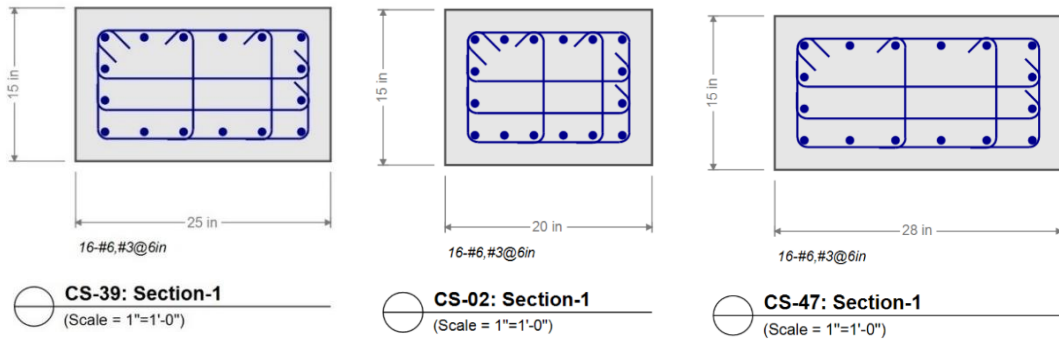


**Table 3.1: Beam details**

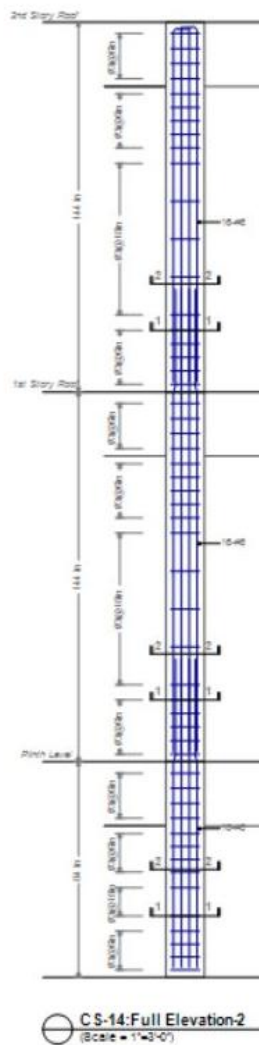
<b>Beam No</b>	<b>Dimension</b>	<b>Bottom Rebar</b>	<b>Top Rebar</b>	<b>Stirrups</b>
FB1	(15"X25")	4# 20mm	4# 20mm	8mm @ 4.5"c/c at end & 6" at middle
FB2	(12"X15")	2# 20mm	2# 20mm	8mm @ 5"c/c at end & 7" at middle
GB	(15"X25")	4# 20mm	4# 20mm	8mm @ 4.5"c/c at end & 6" at middle

### **3.5 Design of Column and detailing**

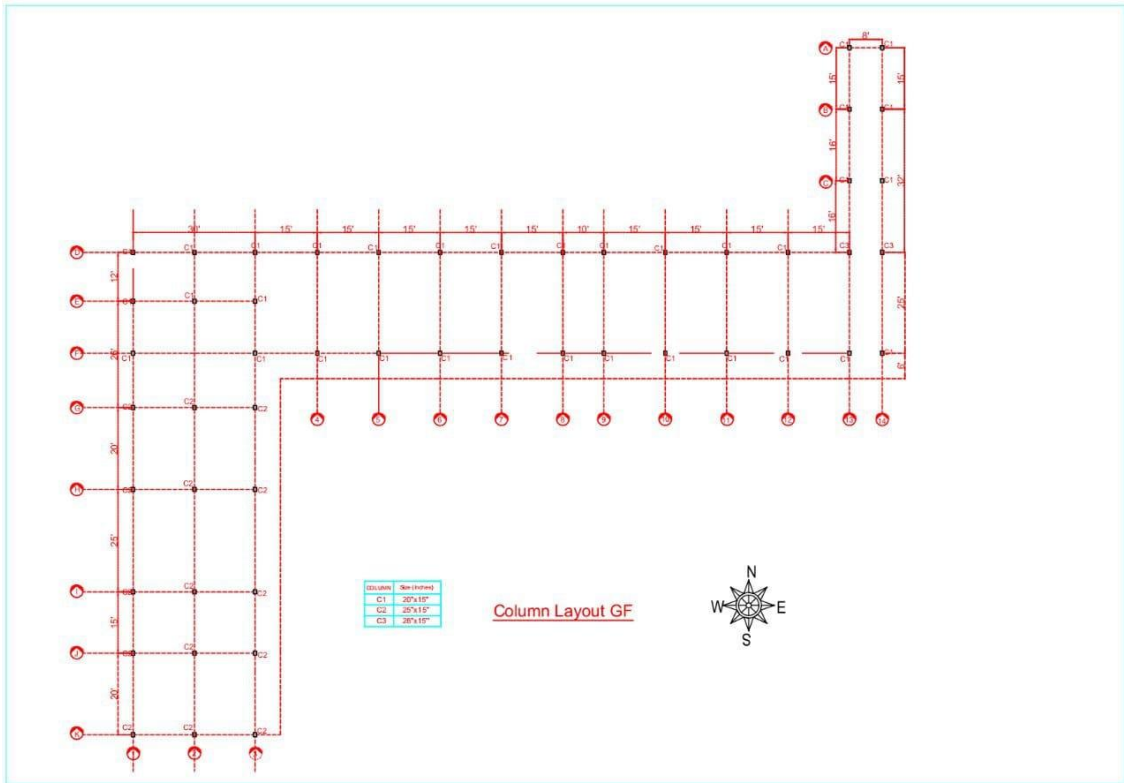
Creation of columns in a structural model ETABS takes into account different essential factors. In an attempt to find the strength and the stability of columns, it begins by examining the axial loads and moments that exist on the columns. The software analyses various forms of loads to comprehend the effects of loads on the column work like dead loads and live loads. Moreover, ETABS checks the stiffness of the column, buckling capacity, cross-sectional area, and reinforcing details because these factors affect the compression and bending strength of the column. The software strategies are used to implement pertinent design codes and consider the effects of slenderness in order to ensure the column satisfies safety and performance. A combination of all these factors enables ETABS to assist structural engineers to design efficient columns that are structurally conforming. This information is very precise through these detailed drawings of sizes of columns, reinforcement patterns, and bar sizes and makes sure that the design is designed to the standards of the structural design and to help in proper execution of the construction work.



**Figure 3.13: Column Section**



**Figure 3.14: Column Full Elevation**



**Figure 3.15: Column Layout Plan**

**Table 3.2: Details of Column**

<b>Column</b>	<b>Size of Column</b>	<b>Main Reinforcement</b>	<b>Lateral Ties</b>
C1	15"x20"	20mm Dia	8mm @ 6" C/C
C2	15"x25"	20mm Dia	8mm @ 6" C/C
C3	15"x28"	20mm	8mm @ 6" C/C

## **3.6 Ramp**

### **Definition of a Ramp**

Ramp is like an inclined surface or a sloping plane that joins two distinct heights of a structure, such that people and items have an opportunity to travel unassisted and with ease without resorting to the stairs.

In a primary school, students, teachers, and visitors can use a ramp to access their businesses in a safe and convenient manner, particularly the physically challenged children, who struggle to use the steps.

It is a feature pillar in enhancing accessibility and inculcating an inclusive learning environment to everyone.

### **3.6.1 Advantages of a Ramp**

A ramp constructed in a school has a number of significant advantages:

#### **Accessibility for All:**

- The school can be easily accessible to students with disabilities particularly the ones using wheelchairs, crutches, or walkers as ramps make the school easily accessible.
- It can also assist the elder teachers, parents or visitors who may have problems with stairs.

#### **Safety and Comfort:**

- Youth who can easily trip are better off using ramps as opposed to stairs.
- A ramp will enable safer and quicker evacuation particularly in the event of an emergency like a fire or an earthquake.

#### **Easy Movement of Goods:**

- School furniture such as desks, benches or trolleys can easily be moved over a ramp.

#### **Inclusive Environment:**

- It promotes the concept of inclusive education in which all the children, irrespective of their ability, can enjoy the same facilities.

#### **Low Maintenance:**

- A properly designed RCC (reinforced concrete) ramp is durable and easy to clean, requiring less maintenance than stairs.

### **3.6.2 BNBC (Bangladesh National Building Code) Considerations on Ramps**

According to the BNBC 2020, ramps are an important part of universal accessibility design, especially in educational and public buildings.

When constructing a ramp in a primary school, the following key points must be followed:

#### **Slope (Gradient):**

- The slope of the ramp should be gentle.
- BNBC recommends a maximum slope of 1:12 - meaning for every 12 units of horizontal length, the ramp can rise 1 unit vertically. (PART III, Chapter 1, BNBC 2020)

#### **Width:**

- The minimum clear width of a ramp should be 1.2 meters. (1.2 m (Minimum 4 ft, PART III, Appendix D, D.11.1, BNBC 2020)

#### **Landings:**

- If the ramp is long, landings (flat resting spaces) must be provided every 9 meters of ramp length.
- A landing should be at least 5 ft long to allow users to rest or turn safely. (Minimum 5 ft, PART III, Appendix D, D.11.1, BNBC 2020)

#### **Handrails:**

- Ramps must have handrails on both sides for safety.
- The height of handrails should be 38 in from the surface of the ramp. (PART III, Appendix D, D.9.2, BNBC 2020)
- Handrails should have a smooth and comfortable grip.

#### **Surface Material:**

- The ramp surface should be non-slippery, especially during rain.
- Materials like rough-finished concrete or anti-skid tiles are recommended.

#### **Edge Protection:**

- If the ramp has open sides, curbs or edge guards of at least 75 mm height must be provided to prevent wheelchairs or feet from slipping off.

#### **Lighting and Drainage:**

- The ramp should be well-lit and properly drained to avoid water accumulation.

### Signage:

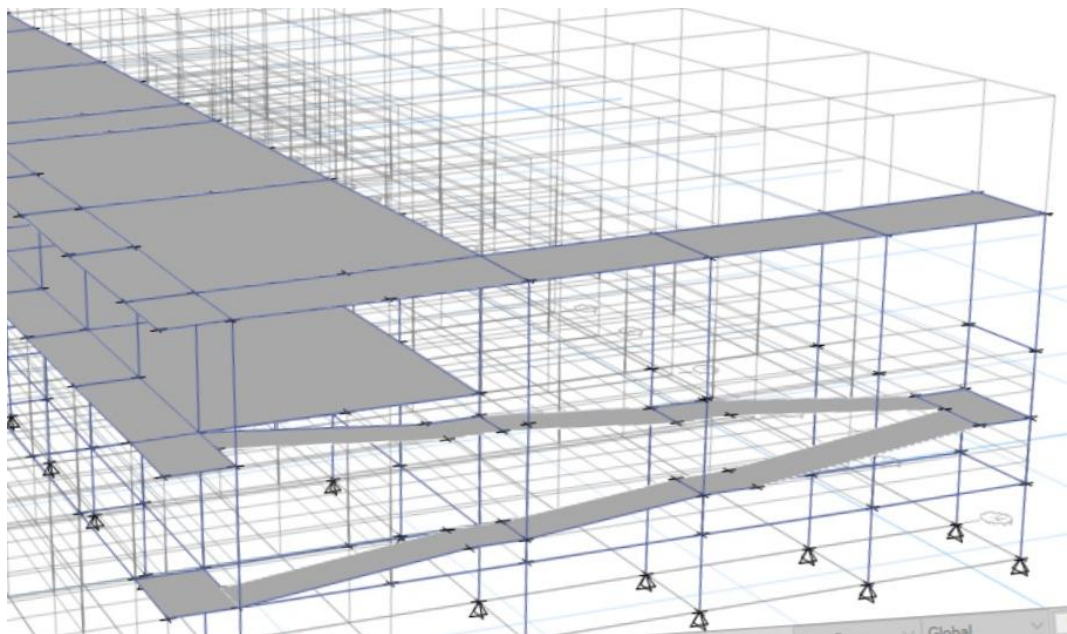
- BNBC also encourages clear signs indicating accessible routes for differently-abled persons.

### 3.6.3 Ramp in a Primary School in Bangladesh

At a primary school in a rural area of Bangladesh

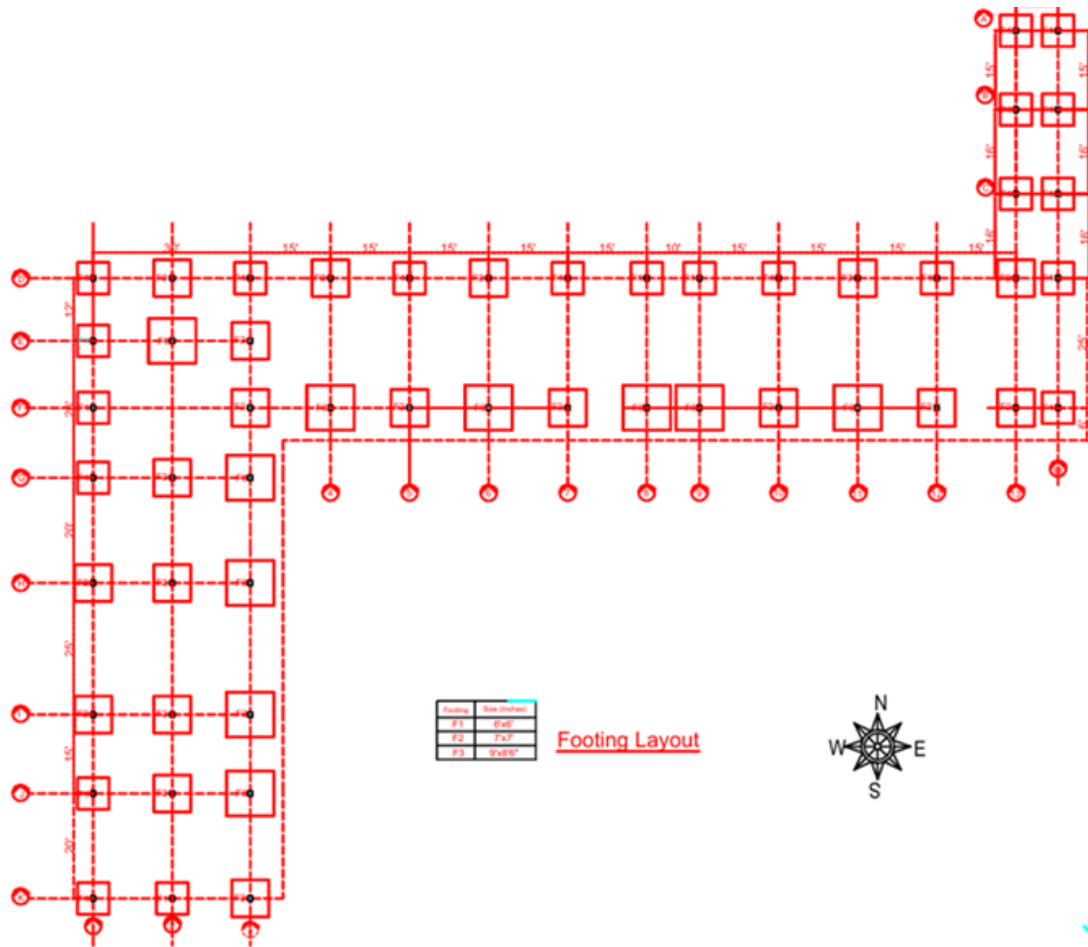
- The main entrance ramp is built with reinforced concrete, having a 1:12 slope.
- It is 4 ft wide, with metal handrails on both sides.
- The surface is non-slippery, and a landing platform is provided after every 9 meters of length.
- The design follows BNBC 2020 and supports the government's goal of creating disability-friendly educational institutions.

This ensures that every student, teacher, and visitor can enter and move around the school safely and independently.



**Figure 3.16: Elevation of Ramp**

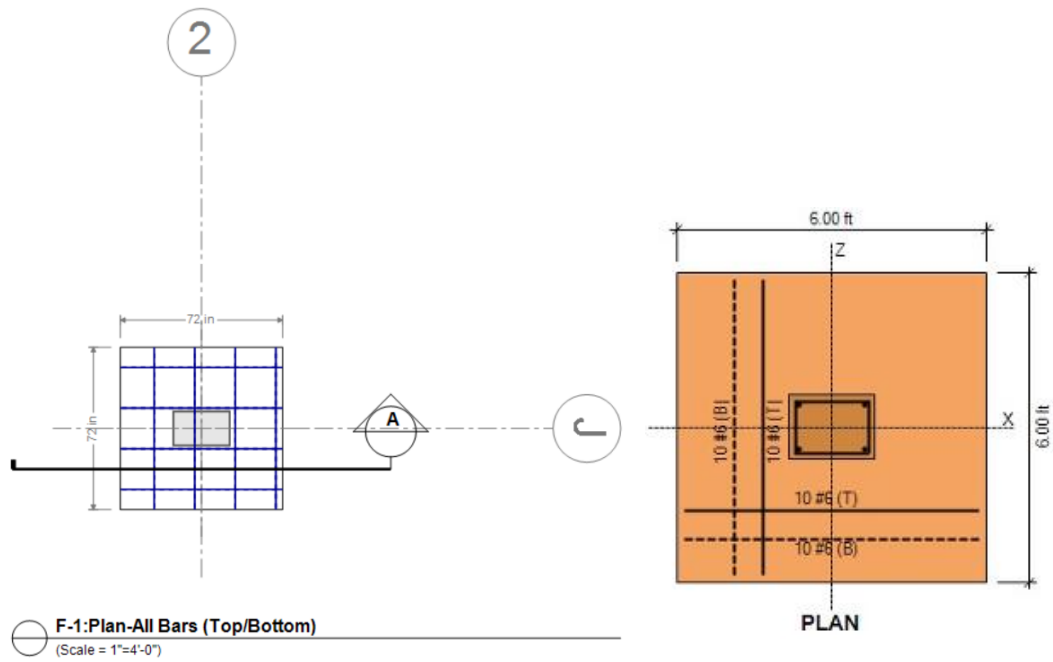




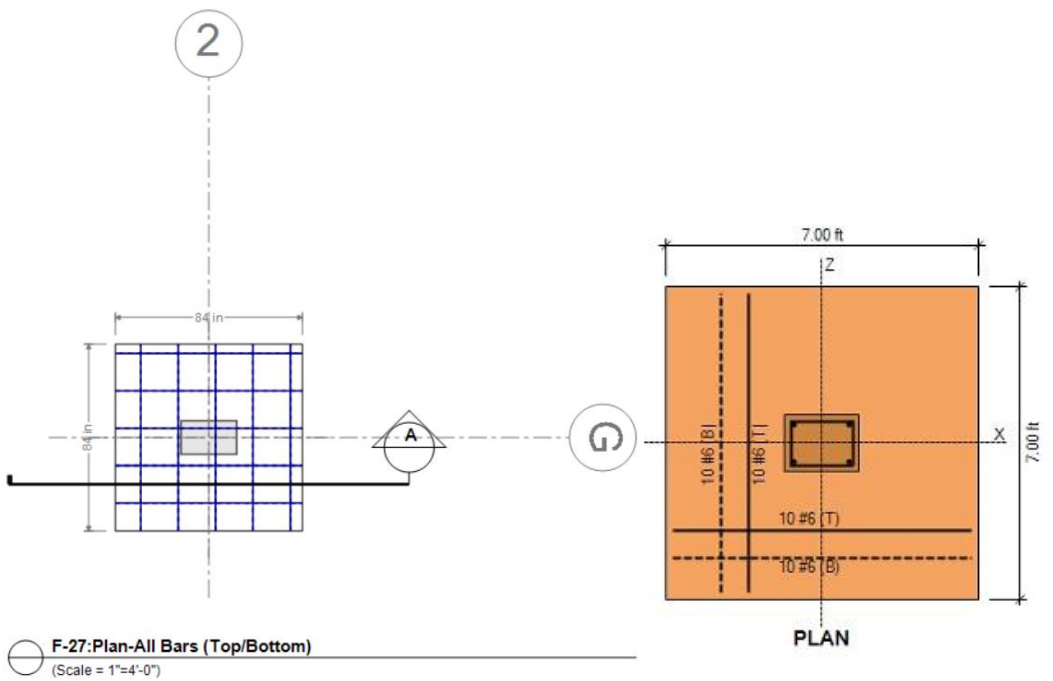
**Figure 3.18: Footing Size & Position**

**Table 3.3: Footing Schedule**

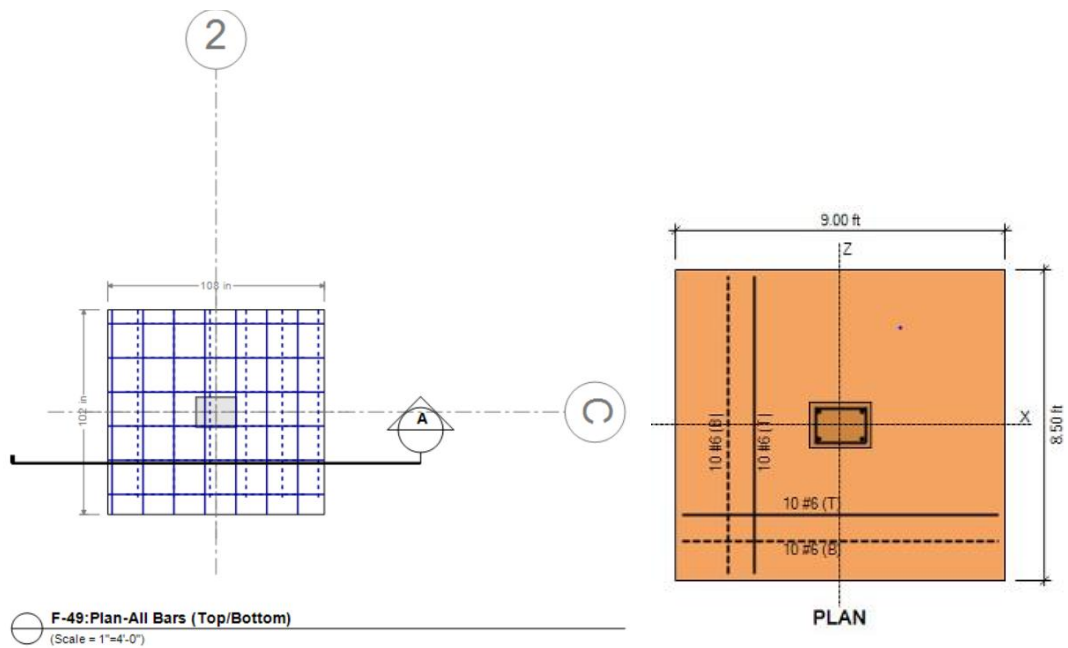
Item	Bar Dia	Thickness	Length	Width	Reinforcement
F1	#6	15"	72"	72"	#10 @ 6.5in c/c
F2	#6	15"	84"	84"	#10 @ 7.5in c/c
F3	#6	15"	102"	108"	#10 @ 10in c/c #10 @ 9.5in c/c



**Figure 3.19: F1 Pan Top/Bottom Bars (72”X72”), Thickness 15”**



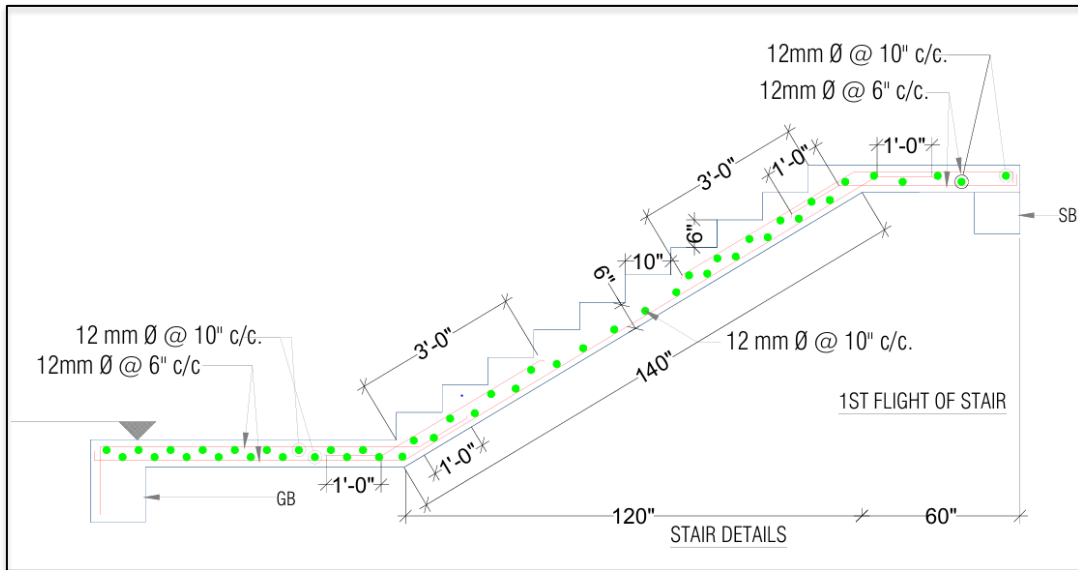
**Figure 3.20: F- 27 Plan -Top/Bottom Bars (84”x84”), Thickness 15”**



**Figure 3.21: F- 46 Plan -Top/Bottom Bars (102”x108”), Thickness 15”**

### 3.8 Design of Staircase and detailing

When constructions of a stair case in ETABS are involved, there are some construction and weight considerations that must be made to ensure the stair case is not only safe, but also practical. ETABS considers the form of the staircase and the height of each step (rise), the distance of each step (run), and the overall slope, to fit the design requirements. It even considers the power and rigidity of the materials employed such as concrete or steel to be in a position to handle whatever the staircase is supposed to handle. To comply with the building regulations, the software determines the various kinds of loads such as the weight carried by people and items (live loads), and the weight of the staircase itself (dead loads). Also, ETABS examines the way the staircase is supported e.g. whether it is suspended on one lower part, or is supported at both ends, or is resting on platforms between.



**Figure 3.22: Stair Reinforcement Detailing**

**Table 3.4: Stair Reinforcement Schedule**

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

## CHAPTER 4

### COST ESTIMATION AND PROJECT SCHEDULE

#### Introduction

It can be concluded that a Construction Bill of Quantities (BOQ) is a highly valuable document that is employed in the construction industry, especially when it comes to such projects as building. It is used as an elaborate account of all materials, quantities, and resources that will be used to accomplish each phase of the construction work. The principal aim of the BOQ is to give breakdown of construction elements in a systematic manner where all the items required to undertake the construction process are captured and rightly quantified. In building, the BOQ would indicate the exact amount of concrete, reinforcement steel, formwork etcetera needed to be used in main structural elements like slabs, beams, columns, isolated footings, and stair cases. All the structural elements are listed with great detail including the volume of concrete to be placed, the reinforcement considerations, the bars size, spacing, and total weight of the steel. This assists the engineers, contractors and clients to know the exact and precise requirements of the material and labor prior to the actual construction of the construction.

The BOQ is a very important budgetary management and cost control tool. It assists in creating a clear and reasonable cost estimate because it entails giving accurate measurements and descriptions of every part. This transparency will guarantee that no secret costs will be spent and all stakeholders of the project will be able to trace the movement of materials and money easily. In addition, it helps to prevent conflicts between the client and the contractor as one can clearly establish what materials and quantities should be used. Besides enumerating materials, there are much more concise BOQs of summarizing and classifications between various sections of the building like the foundation work, superstructure, and finishing works. The BOQ provides a complete outline of the way the construction will be done, both in terms of material specification and the amount of the material and the cost per unit of the material, which gives a complete picture of how the construction will be carried out in its entirety. Moreover, the BOQ is a key-source of reference in the process of project implementation and control. The site engineers and the supervisors use it to ensure that the materials they are using are within the specifications of the design and that the quantity they are currently using on site is in line with the approximated figures. This

also ensures that the whole construction process is more orderly, effective, and managed.

#### 4.1 Column

**Table 4.1: All RC Columns – Rebar Summary**

<b>Sr. No.</b>	<b>Size</b>	<b>Area (in<sup>2</sup>)</b>
1	#3	0.11
2	#6	0.44

**Table 4.2: All RC Columns – BOQ Summary**

<b>Item</b>	<b>Materials</b>	<b>Cost</b>
Cement	494 Bag's	271700 Tk
Sand	925.79 Cft	52186 Tk
Stone Chip's	1851.57 Cft	395653 Tk
Reinforcement	22065 Kg	2108269 Tk
Total Cost		2827808 Tk

## 4.2 Beam

**Table 4.3: ALL Floor: RC Beams – Rebar Summary**

<b>Sr. No.</b>	<b>Size</b>	<b>Area (in<sup>2</sup>)</b>
1	#3	0.11
2	#6	0.44

**Table 4.4: ALL Floor: RC Beams – BOQ Summary**

<b>Item</b>	<b>Materials</b>	<b>Cost</b>
Cement	1907 Bag's	781870 Tk
Sand	3574.39 Cft	214464 Tk
Stone Chip's	7148.77 Cft	1501242 Tk
Reinforcement	48053 Kg	4372798 Tk
Total Cost		6870374 Tk

### 4.3 Slab/Footing

**Table 4.5: All Floor Slab-Rebar Summary**

<b>Sr. No.</b>	<b>Size</b>	<b>Area (in<sup>2</sup>)</b>
1	#4	0.20

**Table 4.6: All Floor Slab – BOQ Summary**

<b>Item</b>	<b>Materials</b>	<b>Cost</b>
Cement	504 Bag's	277,200 TK
Sand	944 Cft	49,108 TK
Stone Chip's	1889 Cft	426,856 TK
Reinforcement	64436 Kg	5,863,663 TK
Total Cost		6616827 TK

**Table 4.7: Footing– Rebar Summary**

<b>Sr. No.</b>	<b>Size</b>	<b>Area (in<sup>2</sup>)</b>
1	#6	0.44

**Table 4.8: Footing – BOQ Summary**

<b>Item</b>	<b>Materials</b>	<b>Cost</b>
Cement	697 Bag's	383350 Tk
Sand	1307 Cft	67964 Tk
Stone Chip's	2613 Cft	590538 Tk
Brick's For Soling	485 Brick's	6783 Tk
Total Brick	24002 Brick's	336021 Tk
Reinforcement	6044 Kg	513759 Tk
Total Cost		1898415 Tk

**4.4 Stair****Table 4.9: Stair– Rebar Summary**

<b>Sr. No.</b>	<b>Size</b>	<b>Area (in<sup>2</sup>)</b>
1	#3	0.11
2	#4	0.20

**Table 4.10 : Stair– BOQ Summary**

<b>Item</b>	<b>Materials</b>	<b>Cost</b>
Cement	25 Bag's	13,586 TK
Sand	62 Cft	3,211 TK
Stone Chip's	124 Cft	27,914 TK
Reinforcement	324 Kg	29,500 TK
Total Cost		74211 TK

#### **4.5 Brick Work**

**Table 4.11: Brick wall Cost Summary**

<b>Item</b>	<b>Materials</b>	<b>Cost</b>
Brick	49625 nos	694750 TK
Cement	234 bag`s	128700 TK
Sand	1168 Cft	60736 TK
Total Cost		884186 TK

## 4.6 Septic Tank

**Table 4.12: Septic Tank – BOQ Summary**

<b>Item</b>	<b>Materials</b>	<b>Cost</b>
Cement	144 Bag`s	79200 TK
Sand	268 Cft	13936 TK
Stone Chip's	538 Cft	121588 TK
Reinforcement	2602 Kg	236782 TK
Total Cost		451506 TK

#### 4.7 Cost of table (BDT)

Table 4.13: Cost Of Table

Sr	Item	Quantity	Unit Price (BDT)	Item Cost (BDT)
1	Rebar	143.5	91000/ton	13058500
2	CC Brick	74112	14/piece	1037568
3	Cement (all)	4005	550/bag	2202750
4	Sand (total)	8250	52 /cft	429000
5	Aggregate (total)	14165	226/cft	3201290
6	Excavation Work	28650	8.50/cft	243525
7	Filling Work (Sand)	20132	26/cft	523432
8	Labor Cost	18,302	200/sft	3,660,400
<b>Grand Total Cost (BDT)</b>				<b>24,356,465</b>

**Grand Total Estimated Cost: BDT 24,356,465**

#### 4.8 Project Schedule Chart

A Gantt chart is one of the important management tools that are vital in construction projects to give a simple yet clear schedule of all the key activities. It aids the engineers, construction teams and project managers in planning, overseeing and coordinating activities. The diagram shows the time and order of structural works, e.g. excavation, footing, column casting, construction of slab, making sure every activity is in line with the overall project target and the project deadlines. The approach is useful in reducing delays, resource utilization, enhancing the workflow, staying organized within budgets, and scheduling projects.

Redrawn Project Schedule - 2 story School Building with Ramp (8 months). This new project plan will increase the overall construction time of 7 months to about 8 months (about 241 calendar days). The adjustment can be used to achieve realistic scheduling of works, time of curing, inspection, and any delays because of weather.

**Table 4.14: Project Schedule**

Sl. No	Activity	Duration (days)	Start Day	End Day	Remarks
1	Site Preparation	12	Day 1	Day 12	Clearing, fencing, layout setup
2	Excavation & Earthwork (footings + septic tank)	19	Day 13	Day 31	For footing trenches and septic pit
3	Foundation Work (PCC, footing, starter column)	25	Day 32	Day 56	Rebar, formwork, concrete, curing
4	Ground Floor Columns & Beams	25	Day 45	Day 69	Columns, tie beams, formwork, casting
5	Ground Floor Slab Casting	20	Day 62	Day 81	Rebar, formwork, concreting

6	Brick Work (Ground Floor)	25	Day 69	Day 93	External & internal partition walls
7	First Floor Columns	25	Day 82	Day 106	Columns, slab supports
8	First Floor Slab, Beam Casting	20	Day 99	Day 118	Rebar, formwork, casting
9	Roof Casting (Top Slab)	17	Day 111	Day 135	Masonry walls and partitions
10	Brick Work (First Floor)	25	Day 136	Day 152	Rebar, formwork, casting
11	Staircase & Ramp Construction	20	Day 136	Day 155	Ramp 72'×8', stair reinforcement, handrail
12	Plumbing & Septic Tank Completion	20	Day 144	Day 163	Waterline, drainage, septic concreting
13	Electrical & Conduit Works	17	Day 156	Day 172	Concealed wiring, conduit, light points
14	Plastering (internal & external)	25	Day 163	Day 187	Masonry finishing, surface smoothing
15	Flooring Works (tiles, skirting)	17	Day 172	Day 188	Tiles in classrooms, labs, washrooms
16	Door & Window Installation	15	Day 182	Day 196	Frame and shutter fixing
17	Painting (interior & exterior)	15	Day 198	Day 212	Primer + 2 coats paint
18	Fixture & Fittings (sanitary,	12	Day 205	Day 216	Washroom fixtures,

	electric, furniture)				lights, switches
19	Overhead Tank & Pump Installation	10	Day 210	Day 219	Water tank, motor, plumbing test
20	External Works (field, basketball court, boundary)	20	Day 215	Day 234	Leveling, concreting, landscaping
21	Final Cleaning & Handover	7	Day 235	Day 241	Site cleanup, testing, handover

**Total Project Duration: Approximately 241 days (≈ 8 months).**

**Notes:**

- The sequence and remarks are based on the original 7-month plan.
- Durations were increased to reflect realistic working pace, curing, and coordination time.
- Some activities overlap for efficiency.
- Can be adjusted further to meet specific client or contractor preferences.

# **CHAPTER 5**

## **DESIGN OF SEPTIC TANK AND OVERHEAD TANK**

### **Introduction**

Water supply and sanitation are the necessary components of the building infrastructure and they directly influence the theme of health, hygiene, and the general quality of life of people. The design and construction of individual facilities like the septic tanks and overhead tanks becomes important in the regions where centralized system of sewage and water supply are few or absent. A septic tank is an underground, airtight vessel that is used to treat and process domestic wastewater by means of sedimentation, anaerobic digestion and by seepage into the surrounding soil. It is an essential condition of efficient waste treatment, environmental care, and durability of the structure in place and proper sizing and material selection. An overhead water tank is a tank that serves as a storage system installed at a high height to supply a building with regular supply of water through gravity flow. The design should take into account such aspects as water needs, supporting structure, materials, and accessibility to maintenance to ensure quality performance and safety. The capstone project aims at the design principles, structural aspects and capacity calculations that are necessary in the design of septic tanks and overhead tanks especially in small to medium scale structures. The focus is put on adherence to the local building codes, factors protecting the environment, and cost-effectiveness, yet the solutions have to be sustainable, durable, and applicable to different site conditions. Through the combination of engineering, applied standards of design, and safety, this work is expected to serve as a one-stop information source to students, engineers, and practitioners engaged in planning and construction of water supply and sanitation systems.

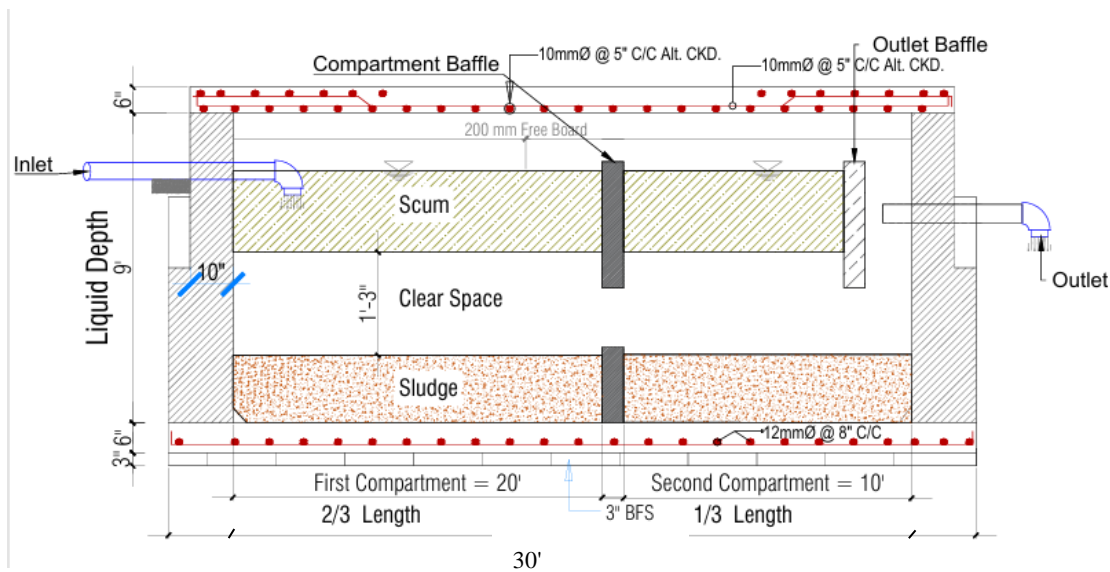
### **5.1 Components of a Septic tank**

The various essential components of a septic tank work together to purify household wastewater. Wastewater from homes enters the tank through an inlet pipe, where liquids and solids begin to separate. Lighter substances, such as fats and oils, float to the top to form a scum layer, while heavier substances sink to the bottom to create a sludge layer. Between these layers is the effluent layer, containing water that has undergone partial treatment. Baffles and tees are installed near the inlet and outlet pipes to help manage

the flow and prevent blockages, ensuring wastewater flows smoothly from the tank into the drain field for further treatment. The tank also features access ports, commonly referred to as risers, which allow for regular sludge and scum removal, maintenance, and inspections.

## **5.2 Design Considerations of a Septic Tank**

The Bangladesh National Building Code (BNBC, 2020) outlines specific design guidelines for septic tanks to ensure the safe and efficient treatment of wastewater, supporting the structure, facilitating movement, and protecting vital organs. The tank should be large enough to hold at least one to two days' worth of wastewater, allowing for natural particle separation as they break down over time based on the amount of water used by the household. Tanks should be constructed from leak-resistant materials such as concrete, fiberglass, or plastic to prevent groundwater contamination. Baffles or walls inside the tank create compartments that aid in the cleaning process. Fittings at the inlet and outlet pipes must be correctly positioned to ensure proper wastewater flow, with the outlet pipe slightly angled downward. Proper ventilation is essential to release gases, control odors, and support bacterial activity. Risers should provide access for regular pumping and inspection by contractors, who will seal them to avoid contamination (BNBC 2020). The drain field, where wastewater exits the tank, must be placed in soil with adequate permeability to allow water to pass through. It should be located at a safe distance from wells, buildings, and water sources. The septic tank should be positioned far enough from structures and water sources to prevent freezing. Maintenance involves pumping out sediments every two to five years, depending on usage, and more frequent emptying if necessary to ensure proper function and protect public health.



**Figure 5.1: Reinforcement detailing of Septic Tank**

### 5.3 Components of an Overhead Tank

An overhead tank is an essential building that is meant to store and distribute water at a high level so that there is enough pressure as well as water flow to a building. It has a number of key components, which carry a certain purpose. The tank body serves as the primary storage vessel in most cases which is made of reinforced cement concrete (RCC) or steel or high-density polyethylene (HDPE) to make it strong and long-lasting. The cover slab or the roof protects the stored water against dust, debris and pollutants and reduces evaporation. The inlet pipe enables the water to flow in to the tank either via a pump or via a municipal supply usually provided with a float valve to stop overflow. The outlet pipe supplies water to the distribution system through gravity flow. In order to avoid flooding, an overflow pipe is placed close to the top of the tank. A vent pipe will help in the circulation of air, which will not allow the vacuum or excessive pressure to occur. The tank has a drain pipe at its lowest point so that it can be emptied completely during either cleaning or maintenance. To facilitate inspection and repair, a ladder and a hatch are installed to make it easy to access the turbines. The tank is then lifted by the supporting structure which may be the RCC column, steel frame or masonry tower to create the necessary water pressure. This structure has to be strong to hold the tank as well as the weight of the water stored. The overhead tank is well installed and is well maintained to operate efficiently by providing a safe, reliable and continuous supply of water whether at home, a business or institution.

#### **5.4 Design Considerations of an overhead Tank**

Designing An overhead tank is planned carefully, so that its structure can be safe and sustainable in the long run and it can efficiently store water. These are some of the significant factors put into consideration in the design process: Water Capacity - These factors are based on the requirement of daily water consumption, peak demand and reserve storage. It depends on the type of the building (residential, commercial, institutional), the population using it and the needs of the facility. Material Choice - Normally used are reinforced cement concrete (RCC), steel and high-density polyethylene (HDPE). Materials used are determined by the budget, materials needed to withstand and their environmental conditions of the environment. Shape and Design - Tanks are circular, rectangular or spherical. Circular tanks tend to be cheaper and more effective in the redistribution of the stress, though rectangular tanks can be easier to build. Structural Integrity - The supporting structure should be made to support the entire weight of the water, the self-weight of the tank, the wind forces, and the seismic activity and any dynamic loads. Tank Height - The height will be calculated to maintain adequate pressure of water in the building due to gravity flow on all outlets. Inlet, Outlet and Overflow Well-designed piping allows the flowing of water in and out and an overflow water pipe is fitted in case the water spills over. Ventilation and Access - A vent pipe permits sufficient circulation of air and ladders and hatches are used to ensure safe access to verify and maintain the equipment. Leakage Prevention - Waterproofing and building skills should be applied to prevent leakage and subsequent water contamination. Maintenance Access- The design must be easy to clean, repair as well as safe maintenance. At present, the overhead tank is constructed to accommodate 110 students; however, there are 400 students in total and therefore the current tank has a very small capacity of nearly a quarter of the total water requirement. The overhead tank presently is in a form that will cater to a number of 110 students and the total number of students will be 400 and therefore the current capacity of the tank is almost a quarter of the required water demand.

# CHAPTER 6

## CONCLUSION

### 6.1 Conclusion

This final phase project, the Design of a Two-Story Primary School Building in Seismic Zone 3, proves that the author has been able to grasp the whole knowledge of structural design, estimation of cost, project management according to the principles of the Bangladesh National Building Code (BNBC 2020). The project was to combine academic knowledge and the real-world engineering which would make sure that the safety, functionality and sustainability of an educational center meant to serve a rural community in Gacha, Gazipur Sadar, Gazipur, Division Dhaka is achieved.

The structural behavior of the building under lateral and gravity load was correctly determined through analysis, modeling and design of the building via ETABS 2025, AutoCAD and ASDIP foundation software. RC elements such as slabs, beams, columns, footings, and staircases were made to be stable, strong, and ductile in accordance with BNBC guidelines on Seismic Zone 3. The Intermediate Moment Resisting Frame (IMRF) system became adopted to make the buildings more resistant to earthquakes and the safety in general. The chosen structural system is cost effective and stable to vertical and horizontal forces.

Realistic parameters used in the design process included the bearing capacity of soil of 2,500 psf, concrete strength of 4000 psi and the reinforcement steel of 60,000 psi. These made sure that the structural elements were capable of sustaining anticipated loads of service and serviceability and durability. ETABS was used to check stress, bending moment, and shear forces in various components and reinforcement detailing was correctly done. The incorporation of the AutoCAD of structural drawing also helped to provide a professional and buildable set of plans that are in accordance with the field implementation standards.

The cost estimation, and the project scheduling as well as the bill of quantities (BOQ) of the project indicate the practical construction management practices. Estimated cost of BDT 24,356,465 was spread out as per local market rates and the material consumption was realistic making it economically viable. The project was scheduled to last instead of a planned 7 months to a more viable 8 months in the light of construction

real-life delays, curing, and coordination needs. Such a change of schedule gives a realistic plan that facilitates the control of quality and management of resources. Also, the design of needed facilities, including the septic tank and the overhead water tank, highlights the interest in hygiene and sanitation and the supply of water throughout the project. The septic tank was so designed that its capacity (64 m<sup>3</sup>) can accommodate 450 users and the overhead tank is to maintain continuous supply of water by the gravitational flow. The two systems are made according to the BNBC guidelines in order to enhance the health and environmental safety. Likewise, the RCC ramp will be included, which is in line with the standards of accessibility to make sure that all the users are mobile, such as differently-abled students, teachers and visitors. Holistically, the project is able to incorporate environmental awareness, community benefit and engineering design. It offers a repeatable prototype of rural educational infrastructure in Bangladesh of a combination of safety, sustainability and cost effectiveness. The interdisciplinary character of the work proves that the students can cope with technical, social and environmental issues in professional engineering situation.

**The results of this capstone project point out a number of important accomplishments:**

- Seismic safe and serviceable structural design that is fully code compliant.
- Real and precise cost estimation and schedule management of the projects.
- Sustainability components to include solar power, plantation of trees, and proper waste disposal.
- Ramp and barrier-free design with the aim of accessibility and inclusiveness.

In general, it is not only that the project fulfills the academic and technical goals, but also it plays a significant role in the wider aim of Bangladesh that is to achieve quality education, sustainable development, and a robust infrastructure. The results confirm the significance of incorporating the current engineering software, field-related data, and societal requirements to design safe, serviceable, and sustainable built environments.

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# APPENDIX

## Design Of Septic Tank

Design of a septic tank to serve a primary school of 450 persons who produce 30 lpcd of wastewater, and the tank is to be dislodged every two years.

### Solution:

$$P = 450 \text{ persons}$$

$$N = 1 \text{ years (Part VIII, Chapter 6, 6.9.12.12, BNBC 2020)}$$

$$C = 0.04 \text{ m}^3/\text{person}/\text{yr.}$$

$$T = 25 \text{ }^\circ\text{C}$$

$$q = 30 \text{ lpcd.}$$

### Volume calculation (m<sup>3</sup>)

#### Sedimentation Zone V<sub>h</sub>:

$$\begin{aligned} T_h &= 1.5 - 0.3 \log (Pq) \\ &= 1.5 - 0.3 \log (450 \times 30) \\ &= 1.5 - 0.3 \log (13500) \\ &= 1.5 - 0.3 \times 4.130 \\ &= 1.5 - 1.239 \\ &= 0.261 \text{ days} \end{aligned}$$

#### The volume required by the Sedimentation Zone:

$$\begin{aligned} V_h &= 10^{-3} (Pq) \times T_h \\ &= 10^{-3} \times (450 \times 30) \times 0.261 \\ &= 3.524 \text{ m}^3 \end{aligned}$$

#### Sludge Digestion Zone V<sub>d</sub>:

Assuming a design temperature of 25°C

$$T_d = 30 (1.035)^{(35-T)} = 42.32 \text{ days}$$

$$\begin{aligned} V_d &= 0.5 \times 10^{-3} \times P \times T_d \\ &= 0.5 \times 10^{-3} \times 450 \times 42.32 = 9.52 \text{ m}^3 \end{aligned}$$

#### Sludge Zone V<sub>sl</sub>:

$$\begin{aligned} V_{sl} &= C \times P \times N & C &= \text{Sludge accumulation constant } 0.04 \text{ m}^3/\text{person}/\text{year} \\ &= 0.04 \times 450 \times 2 & & \text{(Part VIII, Chapter 6, 6.9.12.10 BNBC 2020)} \\ &= 36 \text{ m}^3 \end{aligned}$$

**Scum Zone (Sc):**

$$V_{sc} = 0.4 \times V_{sl}$$

$$= 0.4 \times 36$$

$$= 14.4 \text{ m}^3$$

$$\text{Total Volume } V = V_h + V_d + V_s + V_{sc}$$

$$V = 3.524 + 9.52 + 36 + 14.4 = 63.44 \text{ m}^3$$

**Depth Calculation**

$$\text{Cross-sectional area } A = 31.72 \text{ m}^2$$

The maximum depth of sludge:

$$d_{sl} = V_{sl} / A = 36 / 31.72 = 1.13 \text{ m}$$

The maximum submerged scum

$$d_{ss} = 0.4 \times V_{sl} / A = 0.4 \times 36 / 31.72 = 0.454 \text{ m}$$

**Sludge clear depth = 0.3 m is adopted**

$$\text{Total clear space} = 0.3 + 0.075 = 0.375 \text{ m}$$

Depth of the digestion zone

$$d_d = V_d / A = 9.52 / 31.72 = 0.300 \text{ m} < 0.375$$

**Depth required for sedimentation**

$$d_h = V_h / A = 3.524 / 31.72 = 0.111 \text{ m}$$

Since  $d_h < 0.375 \text{ m}$ ,

$$d_h = 0.375 \text{ m is adopted}$$

Total effective depth

$$= d_{sl} + d_{ss} + d_d + d_h$$

$$= 1.13 + 0.454 + 0.375 + 0.375$$

$$= 2.75 \text{ m. [Including free board}=0.3 \text{ m, 6.9.12.10 BNBC 2020]}$$

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

$$\mathbf{9 \text{ m} \times \mathbf{3 \text{ m} \times \mathbf{2.75 \text{ m} \text{ or } \mathbf{30 \text{ ft} \times \mathbf{10 \text{ ft} \times \mathbf{9 \text{ ft}}$$

(L:W=3:1, Part VIII, Chapter 6, 6.9.12.8, BNBC 2020)

**Design of Dog-Legged Staircase Supported Longitudinally**

$$\text{Floor to floor height} = 3.66 \text{ m}$$

$$\text{Riser (R)} = 150 \text{ mm}$$

$$\text{Tread (T)} = 250 \text{ mm}$$

$$\text{First landing width (L1)} = 1752 \text{ mm}$$

Second landing width (L2)= 1752 mm

Number of riser in all flights (N)= 12

Width of stair= 3657 mm

Impose load= 3 KN/m<sup>2</sup>

Floor finishes= 1.25 KN/m<sup>2</sup>

Beam width (B)= 304.8 mm

Unit wt. of concrete (Y)= 25 KN/m<sup>3</sup>

Grade of steel (fy)= 500 N/mm<sup>2</sup>

Grade of concrete (fck)= 20 N/mm<sup>2</sup>

### Step-1: calculation of effective span

$$\begin{aligned}\text{Effective span (L}_{\text{eff}}) &= \{(N-1) \times \\ &T\} + L_1 + L_2 + (B/2) + (B/2) \\ &= \{(12-1) \times 250\} + 1752 + 1752 + 304.8 \\ &= 6558.8 \text{ mm}\end{aligned}$$

### Step-2: calculation of effective depth

clear cover (c)= 15 mm IS 456:2000, Table 16

Adopt diameter of bar ( $\Phi$ )= 12 mm

$L_{\text{eff}}/d=30$  (assuming constant= 30-40)

Effective depth (d)= ( $L_{\text{eff}}/30$ )

$$= 218.627 \text{ mm}$$

Overall Depth (D)=  $d + (\Phi/2) + c$

$$= 218.627 + (12/2) + 15$$

$$= 239.627 \text{ mm} \approx 240 \text{ mm}$$

Provided eff. depth= 219 mm

### Step-3: calculation of load

(i) Load on going on projected plan area

Live load=  $3 \times 1 = 3 \text{ KN/m}$

Floor finish=  $1.25 \times 1 = 1.25 \text{ KN/m}$

wt. of waist slab=  $\{Y \times D \times \sqrt{(R^2 + T^2)}\} / T$

$$= 6.9971 \text{ KN/m}$$

wt. of steps=  $Y \times 0.5 \times R$

$$= 1.875 \text{ KN/m}$$

Total load= 13.12 KN/m

Factored load=  $1.5 \times 13.12$

$$= 19.683 \text{ KN/m}$$

(ii) Load on landing

$$\text{Live load} = 3 \times 1 = 3.00 \text{ KN/m}$$

$$\text{Floor finish} = 1.25 \times 1 = 1.25 \text{ KN/m}$$

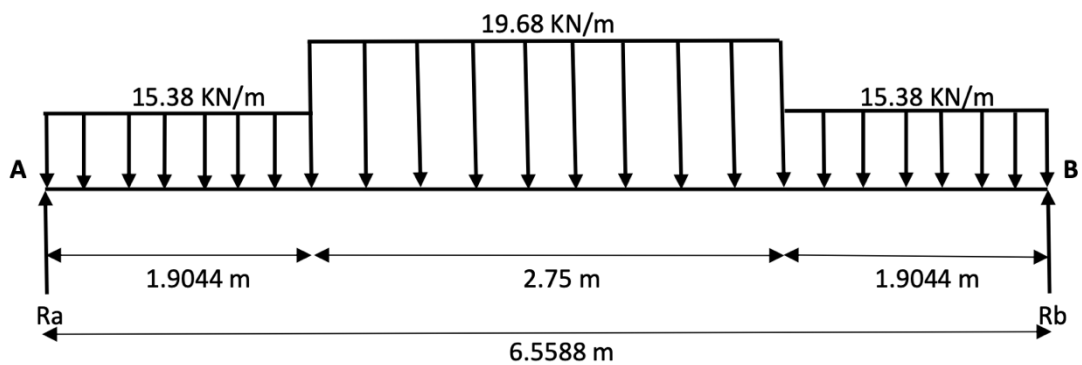
$$\text{self wt. of slab} = \gamma \times D \times 1$$

$$= 6 \text{ KN/m}$$

$$\text{Total Load} = 10.25 \text{ KN/m}$$

$$\text{Factored load} = 1.5 \times 10.25$$

$$= 15.375 \text{ KN/m}$$



**Step-4: calculation of maximum bending moment and maximum shear force**

Taking moment of all forces about point B.

$$R_a \times 6.5588 = \{ (15.38 \times 1.9044 \times (1.9044/2 + 2.75 + 1.9044)) \} + \{ 19.68 \times 2.75 \times (2.75/2 + 1.9044) \}$$

$$+ \{ 15.38 \times 1.9044 \times 1.9044/2 \}$$

$$R_a \times 6.5588 = 369.553$$

$$R_a = 56.34 \text{ KN}$$

$$R_a + R_b = (15.38 \times 1.9044) + (19.68 \times 2.75) + (15.38 \times 1.9044)$$

$$56.34 + R_b = 112.689$$

$$R_b = 56.34 \text{ KN}$$

$$V_{\max} = (W \times L)/2$$

$$= \{ 15.375 \times (1.9044 + 1.9044) \} + (19.68 \times 2.75)/2$$

$$= 56.34 \text{ KN}$$

$$M_{\max} = -[15.38 \times 1.9044 \times \{ (1.9044/2) + (2.75/2) \}] - [19.68 \times (2.75/2) \times (2.75/2 \times 2)]$$

$$+ [56.34 \times \{ 1.9044 + (2.75/2) \}]$$

$$= 98.03 \text{ KN-m}$$

**Step-5: Check for depth against bending moment**

$$M_{max} = 0.133 \times f_{ck} \times b \times d_{req}^2$$

$$98.03 \times 10^6 = 0.133 \times 20 \times 1000 \times d_{req}^2$$

$$d_{req} = 191.97 \text{ mm} \quad (d_{req} < d_{prov}). \text{ Hence OK}$$

**Step-6: Designing the reinforcement**

$$M_{max} = 0.87 \times f_y \times A_{st} \times d_{prov.} \times \{1 - (f_y \times A_{st} / f_{ck} \times b \times d_{prov.})\}$$

$$98.03 \times 10^6 = 0.87 \times 500 \times A_{st} \times 219 \times [1 - \{(500 \times A_{st}) / (20 \times 1000 \times 219)\}]$$

$$A_{st} = 1190.92 \text{ mm}^2$$

$$(A_{st})_{min.} = 0.12\% \text{ of } bD$$

$$= (0.12/100) \times 1000 \times 240$$

$$= 288 \text{ mm}^2$$

$$\text{Spacing} = [1000 / \{1190.92 / (3.142 \times 12^2) / 4\}]$$

$$= 94.9667 \text{ mm} \approx 150 \text{ mm}$$

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

$$(A_{st})_{prov.} = [1000 / \{150 / (3.142 \times 12^2) / 4\}]$$

$$= 753.982 \text{ mm}^2$$

$$\% \text{ of steel prov.} = 0.34 \%$$

**Step-7: Check for shear force**

For M20 concrete

$$\text{Shear strength } (\tau_c) = 0.280 \text{ N/mm}^2 \quad \text{IS 456:2000, Table-19}$$

$$\tau_{max} = V_{max} / bd$$

$$= (56.34 \times 10^3) / (1000 \times 219)$$

$$= 0.257 \text{ N/mm}^2$$

OK

**Step-8: Check for deflection**

IS 456:2000 Clause 23.2.1 (a)

IS 456:2000 Clause 23.2.1 (b)

IS 456:2000 Clause 23.2.1 (c) fig 4

IS 456:2000 Clause 23.2.1 (d) fig 5

IS 456:2000 Clause 23.2.1 (e) fig 6

$$(L_{eff}/d)_{prov.} = 6558.8/219$$

$$= 29.95$$

IS 456:2000, Table-19

Basic values

Basic value: ( $\alpha$ ) = 20 Modification factor

( $\beta$ ) = 1 For Tension Reinforcement ( $\gamma$ ) = 1.5 For Compression Reinforcement ( $\delta$ ) = 1

Reduction factor for flanged beam ( $\lambda$ ) = 1

For Calculating the the factor  $\gamma$

Steel Stress of service load ( $f_s$ )=

$0.58f_y \{ (\text{Area of cross-section of steel required}) / (\text{Area of cross-section of steel provided}) \}$

$= 0.58 \times 500 \times [(\text{Ast.req.}) / (\text{Ast.provided})]$

$= 458.056$

( $A_s/bd$ ) % =  $[753.982 / (1000 \times 219)] \times 100$

0.344

From fig. 4 of IS 456:2000, ( $\gamma$ ) = 1.5

Now,

$\alpha\beta\gamma\delta\lambda = 20 \times 1 \times 1.5 \times 1 \times 1$

$= 30 (l/d) < \alpha\beta\gamma\delta\lambda$  OK

#### Step-9: Development length

$$L_d = (\Phi \times \sigma_s) / 4 \times \tau_b d = \Phi \times 0.87 \times f_y / 4 \times \tau_b d$$

$$= (12 \times 0.87 \times 500) / (4 \times 1.2 \times 1.6)$$

$$= 679.688 \text{ mm}$$

#### Step-10: Distribution bar reinforcement detailing

$$\text{Spacing} = 1000 / \{ 288 / (3.142 / 4 \times 12^2) \}$$

$$= 392.699 \text{ mm}$$

$$\leq 450 \text{ mm}$$

$$\leq 1095 \text{ mm}$$

Spacing provided = 10 in

Provide a distribution bar of 12mm dia. @ 10 in c/c

## Overhead Tank Calculation

Roof top water reservoir (Overhead water reservoir)

Assumptions and considerations

$F'_c = 4 \text{ ksi}$

Fy=60 ksi

Total Floor 1

Units 1

Per Unit Member 225

Water consumption for Educational Facilities up to Higher Secondary Levels, considering restricted facility = 45 liters per capita per day (Part VIII, Table 8.5.1 (d), Occupancy group B1, BNBC 2020: Page 4817)

### b) Water Reservoir size Calculation

Total 225 Persons

Total water Consuming = 10125 liters for full day

$$= 10.125 \text{ m}^3$$

$$= 357.29 \text{ ft}^3$$

Inner length & width of Reservoir are,

Length = 15 ft

Width = 12 ft

So, Height of the Reservoir = 3 ft (Including Freeboard 0.5ft)

### c) Vertical Reinforcement of wall

Let wall Thickness = 5 in

Effective Depth = 4 in

$$\rho = \rho_{0.005} = 0.85 f_y \times \epsilon_u$$

$$\epsilon_u = 0.005$$

$$= 0.135468$$

$$M_u = \phi \times \rho \times 0.005 \times f_y \times b \times d^2 \times (1 - 0.59 \times \rho \times 0.005 \times f_y / f_c)$$

$$M_u = \sqrt{\frac{M_{d req} M_{u, max}}{\phi \rho F_y b (1 - 0.59 \rho \times \frac{f_y}{f_c})}}$$

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

$$A_{smin} = 0.12 \text{ in}^2/\text{ft}$$

$$A_s = \frac{M_u}{\phi f_y (d - \frac{a}{2})} = 0.13 \text{ in}^2/\text{ft}$$

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

Bar No	Cross Sectional area in <sup>2</sup>	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  $A_s = 0.11$ , Spacing = 12

Use 10mm @ 12 in c/c

**d) Horizontal reinforcement of wall**

Force =  $\gamma \times h \times (14.52 + 14.52) = 5437.5 \text{ lb/ft}$

Again, force/stress =  $0.091 \text{ in}^2/\text{ft}$

Use 10mm @ 12 in 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	1/20	1/24	1/28	1/10

Here,  $l$  is the clear span

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

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<sup>2</sup>/ft

$$A_s = \frac{M_u}{\phi f_y (d - \frac{a}{2})} = 1.04 \text{ in}^2/\text{ft}$$

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

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 10 mm @ 2.5 in c/c

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

<b>COs</b>	<b>Description</b>	<b>Criteria</b>	<b>Justification</b>
CO1 (K6, P1, A1)	Application of modern engineering tools	Applied tools for design, drawings, etc.	Used AutoCAD for design and ETABS for structural analysis, ASDIP Foundation for footing design, ensuring precision.
CO2 (K7)	Work on a Team	Attendance	Collaborated effectively through regular meetings and task integration. Name: Md Abu Bokor Siddik ID: 213-47-461 Name: Abdullah Faraje ID: 213-47-479 Name: Md. Rezaul Karim ID: 213-47-476
CO3 (K7, P2, A2)	Analysis Presented	Economic and safety considered	Conducted balancing cost and ethics.
CO4 (K7)	Benefit evaluation	Ethical obligation considered	Incorporated eco-friendly materials and energy-efficient designs.
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, <b>i.e.</b> , advanced skills in ETABS and ASDIP Foundation.
CO7 (A1)	Effective project management – time, financial	Prepared Tender Document	Due to time limitations, incomplete.
		Prepared BOQ	Ensuring accurate financial and material planning for the project.
		Show Financial Assessment	Due to time limitations, incomplete
		Show time management skill	Used project scheduling to manage project timelines and ensure timely completion
<b>Cos</b>	<b>Description</b>	<b>Criteria</b>	<b>Justification</b>

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	<ul style="list-style-type: none"> <li>i Design of Slab and detailing.</li> <li>ii Design of Beam and detailing.</li> <li>iii Design of Column and detailing.</li> <li>iv Design of Footing and detailing.</li> <li>v Design of Stairs and detailing,</li> <li>vi Design of Ramp</li> <li>vii Design of Septic tank</li> <li>viii Design of Overhead Tank</li> </ul>

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