

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

**By**

**Zubaer Ahmed Zidan (213-47-458)**

**Md. Faisal Siddik Piash (213-47-462)**

**Supervised By**

**Dr. Miah M. Hussainuzzaman**

**Associate Professor**

**Department of Civil Engineering**

**Daffodil International University**

**A Capstone project submitted in partial fulfillment of the  
Requirements for the award of a degree of Bachelor of Science in  
Civil Engineering**



**Department of Civil Engineering**

**Faculty of Engineering**

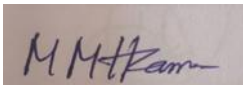
**Daffodil International University**

**November 2025**

# DECLARATION

This is to certify that the following students worked on the capstone project under my direct supervision titled “**Design and Analysis of a Two-story Primary School Building**”

## Signature of the candidates



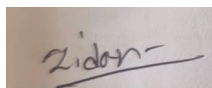
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Supervisor

Dr. Miah M. Hussainuzzaman

Associate Professor, Department of Civil Engineering

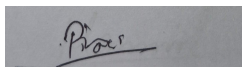
Daffodil International University, Daffodil Smart City, Savar, Dhaka



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Name: Zubaer Ahmed Zidan

Student ID: 213-47-458



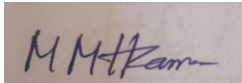
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Name: Md. Faisal Siddik Piash

Student ID: 213-47-462

This thesis titled “**Design and Analysis of A Two-story Primary School Building**” submitted Zubaer Ahmed Zidan and Md. Faisal Siddik Piash , Student ID: 213-47-458, 213-47-462 accordingly has been accepted as satisfactory in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Civil Engineering on November 2025

## **BOARD OF EXAMINERS**



**(Supervisor)**

**Dr. Miah M. Hussainuzzaman**

Associate Professor,

Department of Civil Engineering

Daffodil International University, Daffodil Smart City, Savar, Dhaka

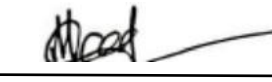


**(Chairman)**

**Dr. Mohammad Hannan Mahmud Khan**

Associate Professor & Head, Department of Civil Engineering

Daffodil International University

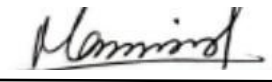


**(Member-1)**

**Md. Masud Alom**

Assistant Professor, Department of Civil Engineering

Daffodil International University

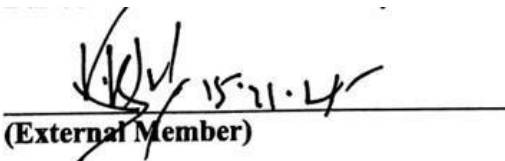


**(Member-2)**

**Mohammad Mominul Hoque**

Assistant Professor, Department of Civil Engineering

Daffodil International University



**(External Member)**

**Kabir Iqbal**

General Manager, Building Technology & Ideas Ltd. (BTI)

## **DEDICATION**

**I would like to dedicate this work to my parents and beloved teachers, who raised and guided me in every single moment of my life.**

## ACKNOWLEDGEMENT

We humbly submit this meager work by bowing down in front of Allah Almighty, the most generous and merciful, who has given us his limitless blessings, mercy and guidance to do this capstone project successfully. All the steps of this work since the first idea up to the last preparation could be done only with His grace.

We would like to say thank you with all our hearts to our families. Their support, motivation and encouragement, which has been unwavering, has been our biggest strength. They have been patient in our lengthy hours of study, they believe in us and in what we are capable of doing, they have been praying and this has made us stay motivated all through this academic process and we have been confident.

We also wish to thank the Department of Civil Engineering, Daffodil international university, on a personal note, as it presents us to a vibrant academic atmosphere that is constantly motivating in terms of creativity and practical learning. This experience is highly important to the students as the department has tried to tie classroom theory with engineering practice by giving them real life projects in design.

We would like to express our sincere appreciation to Dr. Miah M. Hussainuzzaman, Associate Professor, Department of Civil Engineering, who has always accompanied us, provided us with great feedback, and had discussions with him. His mentorship has not only been technical oversight as he has imparted to us the ability to think critically, approach problems in a systematic and methodical manner and how to present ourselves with a sense of confidence. His eagerness to see our progress was a motivating factor that made us work diligently and with precision.

We also owe a lot of gratitude to all teachers of the Department of Civil Engineering who instilled knowledge on different specialized fields of civil engineering which were the basis of this project. We also wish to thank our classmates, friends and lab assistants who helped us with the process of teamwork, constructive suggestions and mutual cooperation in the process of conducting the analysis and drafting.

Lastly, we would like to demonstrate our profound respect to the administration and staff of Daffodil International University whose on-going support in the academic and technical facilities enabled us to make it in preparing this report.

## ABSTRACT

The project book shows development of entire design, analysis and cost estimation of the proposed two-storied reinforced concrete (RCC) primary school building that is going to be constructed in a rural community in Bangladesh. The aim was to design a safe, economical, and sustainable educational building that can comply with Bangladesh National Building Code (BNBC 2020) and up-to-date engineering standards.

Architecture planning, structural analysis and environmental concern were incorporated in the designing process to promote functionality, safety and efficiency. The structural design and analysis of important members such as beam, column, slabs and footings were done using the ETABS software to ensure that the structural members would be strong and serviceable in all the load combinations. The architectural and structural drawings were prepared using AutoCAD and Revit which gave a vivid picture of spatial insight and visualization of the proposed school building.

The Bill of Quantities (BOQ) and cost estimation was done on Microsoft excel based on the local construction rates and the standard rates of the Public Works Department (PWD). The entire estimated project price is about 8.12 million BDT which includes all the major construction elements. As well, special plans were worked out on the septic tank and overhead water tank, which were planned according to the BNBC and Public Health Engineering Department (DPHE) standards to guarantee hygiene and water security to the 420 envisaged users.

To plan and monitor the construction schedule with the time-sensitive completion of every phase, a Gantt chart is also included in the project. The incorporation of environmental and community health infrastructure e.g. wastewater treatment and water storage systems contributes to school environment sustainability.

On the whole, this work is an integration of theoretical and practical work, which illustrates the process of work on modern civil engineering projects, starting with conceptual design and ending with technical, as well as cost calculation. The paper emphasizes the role of the engineering software, standard codes, and sustainable design in enhancing the creation of sustainable and cheap educational infrastructure in rural Bangladesh. The result can be used as a guideline to future academic research and practical rural infrastructure development programs.

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# CHAPTER-I

## INTRODUCTION

### 1.1 Background and Project

Education has been viewed as one of the most crucial pillars towards the development of any given country and the quality of education is usually expressed through the setting in which the education is being taught. In rural area, the infrastructure education is important in enabling the children to have a favorable learning environment. An appropriate primary school building does not only enhance the students with safety and comfort, but promotes effective teaching and learning.

The project is aimed at designing and analysis of a two-storied primary school structure that is to serve as an example of a school building in rural areas. It also contains classrooms, teacher's room, headmaster's room, and male, female, and teacher washrooms according to the minimum architectural and functional designs of primary educational institutions.

### 1.2 Basic Information of the Project

The proposed two-storied primary school building has been structural designed by critically taking into consideration all the relevant loading conditions including dead load, live load and seismic load combinations as stipulated in the Bangladesh National Building Code (BNBC 2020). The code is the main criteria used to determine the design forces, safety factors and load combination to make sure that the building is stable and serviceable during its planned service.

The dead load is the self-weight of all permanent structural parts like slabs, beams, columns and walls and non-structural ones like floor finishings and plaster. The live load is the movable or temporary loads which arise in the normal use such as the weight of students, furniture and equipment's. Such load is calculated based on the occupancy of each space such as in classrooms, teachers' room, headmaster's office, corridors, and staircases as per the value of BNBC load intensity.

The seismic load has also been taken into account in the design of the building because the building is in an area that fits under the Seismic Zone 2 which provides the seismic resistance of the structure to withstand the forces caused by the earthquakes as stated in the requirements of BNBC Part 6: Structural Design. The seismic design takes into

consideration the height of the building, the distribution of its mass, and ductility to provide security against the moderate earthquakes occurrences.

Besides codal compliance, the rural environment of the project has been a major factor that has been put into consideration during the design process. The surrounding, accessibility of construction materials and the workmanship available locally have been put into consideration in order to give rise to a design that is practical as well as economical. The main structural material adopted is reinforced concrete due to its locality, affordability, and familiarity by the rural construction workers. The structural system and layout of building are deliberately maintained simple and symmetrical and enhances stability as well as constructability.

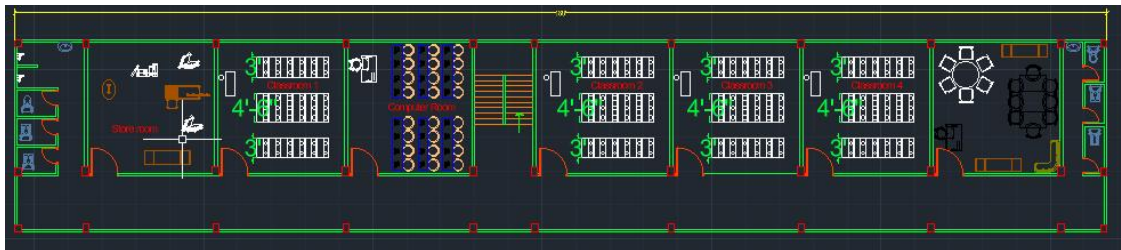


Figure 1. 1 The layout of the building

### 1.3 Objectives of the Project

The overall aim of the project will be to design and analyze a two-storied structure of the building construction of a primary school which will comply with the functional and safety requirements. The targeted objectives are:

- In order to create a structural layout that is appropriate in a rural educational setting.
- To undertake structural analysis and design through the new modern software like ETABS, AutoCAD and MS Excel.
- In order to make sure the design is in conformance with seismic zone 2 and sufficient stability against lateral and vertical loads.
- To approximate the dimensions and reinforcements of the structural components according to the guidelines of Bangladesh National Building Code (BNBC).
- To write a comprehensive project book that illustrates a knowledge of structural design processes, their practice and documentation.

## **1.4 Scope of the Project**

The passive analysis of the major structural components like beams, slabs, columns and foundation will be carried out under the scope of this project; planning, structural modelling, calculation of the loads, analysis and design. Such architectural features as classroom and facility organization are already provided to have a functional use. The design has been carried out in regards to the needs of a typical rural school with moderate occupancy and low to medium level of seismic activity that represents Zone 2.

The given project is limited to the structural and architectural aspects in accordance with which the academic design is going to be submitted. This report does not encompass the electrical, plumbing and finishing details, but standard provisions have been taken into consideration where required to estimate the load.

## **1.5 Methodology**

The systematic steps taken in this project are steps to guarantee efficient and reliable outcomes of the design. The process includes:

1. Collection of data: The collection of the required data the building codes, design standards, material properties and load considerations.
2. Architectural Planning: Floor layout will be prepared in AutoCAD making sure that there is functional distribution of rooms and circulation space.
3. Structural Modeling and Analysis: With ETABS, a 3D building model will be created, materials will be assigned, load cases will be defined, and an analysis will be conducted to calculate the bending moments in the building, shear forces, and displacements.
4. Design of Structural Members: The design of the beams, columns, slabs, and foundations with the help of the analytical data obtained in ETABS and their verification with the help of MS Excel.
5. Result Evaluation: The inspection of design outcomes by checking against the standards of BNBC and the correctness of safety and servicing.
6. Documentation: Preparing all the data, findings, and discussions of the design into a set project report.

## **1.6 Expected Outcomes**

At the end of this project, it is anticipated to yield the following results:

- A total structural and architectural planning of a two-storied country pre-school building.
- Outputs of ETABS model demonstrating load distribution, bending moments and structural behavior.
- Plan, elevation, and structural drawings that have been drawn using AutoCAD.
- A project report that will show how the theoretical knowledge has been applied in the practical structural design.

## **1.7 Significance of the Project**

The project is of great importance, both in an academic and a social and practical point of view. In the rural communities, there is a need to develop safe, affordable, and sustainable educational facilities. This project will be used as an example of the development of low-cost, safe, and durable infrastructure of rural schools in the future by using the modern design software and considering the standards of BNBC. In addition, it enables students and future engineers to appreciate the combination of theory, software application, and design requirements in the real world.

The general aim of the design is to make sure that the building is safe, durable, and functional as well as easy to build and maintain in the rural environment. The design parameters, such as load considerations, material strengths, seismic safety considerations, etc., are established in compliance with the BNBC 2020 guidelines so that the school building would be a safe and comfortable place where people will reside.

## CHAPTER-II

### DESIGN CODES AND STRUCTURAL REQUIREMENTS

#### 2.1 Introduction

Structural design refers to the methodical and scientific process of providing the safety of a building structure, stability, and serviceability of the building structure under different loads and environmental conditions. In case of the proposed two-storied primary school construction, the design has been done as per the standard codes and practices given in Bangladesh National Building Code (BNBC 2020), ACI 318-19 and other applicable ASTM material standards.

The aim of this chapter is to provide the design philosophy, codes, material properties, load assumptions and structural requirements upon which the building will be analyzed and designed.

It is a rural structure and belongs to the category of educational buildings and it needs moderate load-bearing capacity, high durability, and withstand earthquakes. The design of the building is Seismic Zone 2 meaning that the building has a moderate seismic risk and therefore requires close consideration of the vertical and lateral load-resisting systems.

#### 2.2 Design Codes and Standards Used

The design and detailing of the entire structure have been performed in accordance with the following codes and standards:

Code/Standard	Purpose/Description
<b>BNBC 2020</b>	Provides the fundamental design guidelines for structural loads (dead, live, wind, earthquake), material specifications, and safety factors applicable in Bangladesh.
<b>ACI 318-19</b>	Serves as a reference for reinforced concrete design based on the strength design method, covering slab, beam, column, and footing design.
<b>ASTM Standards</b>	Used for determining material testing procedures, reinforcing bar grades, and concrete quality control (ASTM A615, ASTM C39, etc.).
<b>ACI 315</b>	Guidelines for detailing of reinforcement and bar placement.
<b>ASCE 7-16</b>	Used for load combination and definition of environmental load effects.

## **2.3 Design Philosophy**

The building structural design has been developed with reference to the Limit State Design approach that provides the building with sufficient strength and serviceability under all the probable loading conditions.

### **2.3.1 Strength Design Method**

Under this technique, the members should offer adequate reinforcement and concrete section strength to resist ultimate loads. The structure is checked at different combinations of loads, which are prescribed in BNBC 2020 and ACI 318.

### **2.3.2 Serviceability Criteria**

Besides strength, the structure is also examined in terms of serviceability- this is to make sure that the deflections, crack widths and vibrations are within the acceptable levels to provide comfort and a long life.

### **2.3.3 Ductility and Earthquake Resistance**

Given that the building is in the Seismic Zone 2, the architectural design has sufficient ductile detailing and correct reinforcement anchorage to allow dissipation of energy during an earthquake incident. Lateral resisting structures like RC frames are developed to sustain dynamism load.

## **2.4 Material Properties**

### **Concrete:**

Grade:  $f'_c = 4 \text{ ksi}$

Unit weight:  $24 \text{ kN/m}^3$

Modulus of Elasticity,  $E_c = 4700\sqrt{f'_c} = 23,500 \text{ MPa (approx.)}$

### **Reinforcing Steel**

Type: Deformed bar

Grade:  $f_y = 60 \text{ ksi}$

Modulus of Elasticity,  $E_s = 200,000 \text{ MPa}$

## **Other Materials**

Brickwork:  $10.0 \text{ kN/m}^3$  (non-structural)

Plaster and finishes:  $0.3 \text{ kN/m}^2$

Floor finish and screed:  $0.6 \text{ kN/m}^2$

These strengths ensure adequate ductility, durability, and safety under both static and dynamic loading.

## **2.5 Load Assumptions**

Load considerations play a vital role in ensuring the structure's safety and stability. The design loads have been selected according to BNBC 2020 guidelines.

### **2.5.1 Dead Load (DL)**

Dead load includes the self-weight of all permanent structural components such as slabs, beams, columns, and walls.

Slab (6 in thick):  $0.15 \text{ m} \times 24 \text{ kN/m}^3 = 3.6 \text{ kN/m}^2$

Floor finish:  $0.6 \text{ kN/m}^2$

Ceiling plaster:  $0.3 \text{ kN/m}^2$

Wall load (230 mm thick, 3 m height):  $0.23 \times 3 \times 20 = 13.8 \text{ kN/m}$  (on beams)

### **2.5.2 Live Load (LL)**

According to BNBC (Table 2.4.1),

Classrooms:  $3 \text{ kN/m}^2$

Offices (Headmaster/Teachers' Room):  $2.0 \text{ kN/m}^2$

Corridors and Staircases:  $4.0 \text{ kN/m}^2$

Roof (accessible for maintenance only):  $1.5 \text{ kN/m}^2$

### **2.5.3 Roof Load**

Roof slab self-weight + finishes + live load

$$= 3.5 \text{ kN/m}^2$$

### **2.5.4 Wind Load**

The wind load has been considered according to BNBC 2020 Part 6, assuming a basic wind speed of 210 km/h (typical for Bangladesh rural regions).

### **2.5.5 Seismic Load**

Seismic analysis has been carried out using ETABS based on BNBC 2020 (Part 6: Structural Design Section 2 – Earthquake Load).

Seismic Zone: Zone 2 ( $Z = 0.20$ )

Importance Factor (I): 1.5

Response Reduction Factor (R): 5 (RC Moment Resisting Frame)

### **2.5.6 Load Combinations**

As per ACI 318 and BNBC 2020, the following load combinations were used:

1. 1.4D
2. 1.2D + 1.6L
3. 1.2D + 1.0E + 1.0L
4. 0.9D + 1.0E
5. 1.2D + 1.0W + 1.0L

## **2.6 Structural System Description**

The two-storied school building has been modeled as a reinforced concrete frame structure with isolated footings. The vertical load is carried by columns and transmitted to the foundation, while lateral loads (wind and earthquake) are resisted by the frame action of beams and columns.

Table 2. 1 Structural System Description

<b>Element</b>	<b>Type and Dimensions</b>	<b>Function</b>
<b>Slab</b>	6-inch-thick RCC slab	Transfers live and dead loads to supporting beams
<b>Beams</b>	Rectangular RC beams (as per ETABS output)	Distribute floor loads to columns
<b>Columns</b>	12 in × 12, 12 in × 15 in & 15 in × 15 in RC columns	Carry vertical and lateral loads to foundation
<b>Footings</b>	Isolated footings (reinforced)	Transfer column loads safely to soil
<b>Foundation Depth</b>	6 ft below ground	Ensures stability and frost protection

## 2.7 Design Software Used

- AutoCAD 2024: For preparing architectural and structural drawings.
- ETABS 2023: For 3D modeling, load application, and structural analysis under gravity and seismic loads.
- MS Excel: For design verification, bar schedule preparation, and quantity estimation.
- MS Word: For report and documentation preparation.

## 2.8 Design Requirements and Criteria

- Safety: The structure must remain stable and strong under ultimate load conditions.
- Serviceability: Deflections, cracks, and vibrations must be within acceptable limits.
- Durability: Proper concrete cover and material quality ensure long service life.
- Economy: Efficient use of materials without compromising safety.
- Constructability: Member sizes, reinforcement details, and layout are practical for site construction.

## 2.9 Summary of this chapter

This chapter outlined the design principles, codes, material properties, and load assumptions used in the analysis and design of the two-storied primary school building. These parameters ensure that the structure fulfills both safety and serviceability requirements while maintaining economic feasibility and compliance with national standards.

The next chapter will focus on Detailed Structural Analysis and Design, where each structural element slab, beam, column, and footing will be analyzed and designed following the criteria set in this chapter.

# CHAPTER-III

## Structural Analysis and Design

### 3.1 General

Structural analysis and design are some of the most important steps in any civil engineering work. The structural analysis for the Primary School Building aimed at ensuring that under all imposed loads—vertical and lateral—the structure would be safe against failure while maintaining its functional performance and economy. The design was carried out using ETABS 2023, which is famous for the analysis and design of multistory as well as low-rise reinforced concrete buildings. Manual checking for some of the main parts has also been carried out to confirm the validity of results generated by the software.

In this project, the building is a single-storied reinforced concrete framed structure, designed with simplicity and durability in mind. Given that the building is located in a rural area within Seismic Zone 2 of Bangladesh, special attention was given to structural stability under moderate seismic effects. The overall design also considered local construction practices, availability of materials, and cost-effectiveness, ensuring the building remains feasible for government-funded primary education infrastructure.

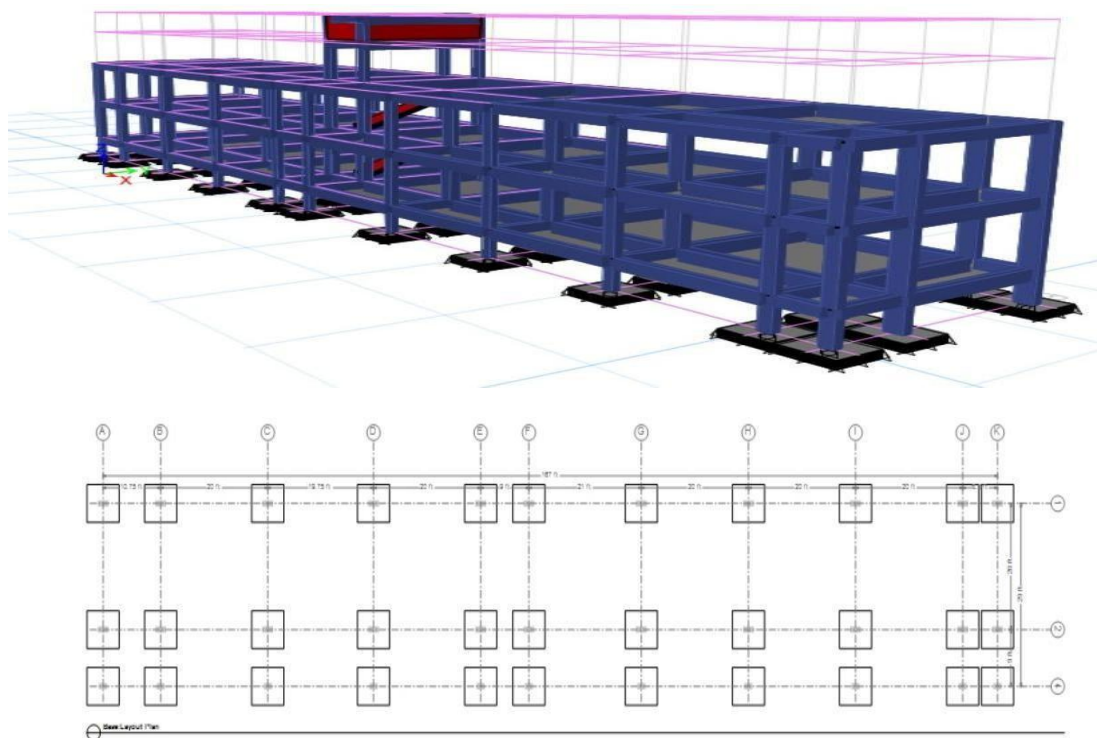


Figure 3. 1 Perspective view of the full 3D ETABS model showing beams, columns, and slabs

### 3.2 Modeling Approach in ETABS

A detailed analytical model of the school building was developed in ETABS to simulate the structural behavior accurately under different loading conditions. The story height was set to 12 feet, and the foundation depth was considered 8 feet below natural ground level.

The model included all primary structural elements:

- **Slab:** 6-inch-thick reinforced concrete slab acting as a rigid diaphragm.
- **Beams:** Reinforced concrete beams of uniform cross-section according to design drawing.
- **Columns:** Rectangular 12" × 15", 12 in × 12 in & 15 in × 15 in sections.
- **Footings:** Isolated type, designed for individual column supports.

The materials were defined with the following design properties:

- Concrete compressive strength:  $f' = 4 \text{ ksi}$
- Reinforcing steel yield strength:  $f_y = 60 \text{ ksi}$
- Unit weight of concrete:  $24 \text{ kN/m}^3$

The model was carefully meshed and connected to ensure proper load transfer among members. Columns were assigned fixed supports at the base to simulate isolated footings, and rigid diaphragm action was defined for the roof level to represent realistic behavior of slabs under horizontal forces.

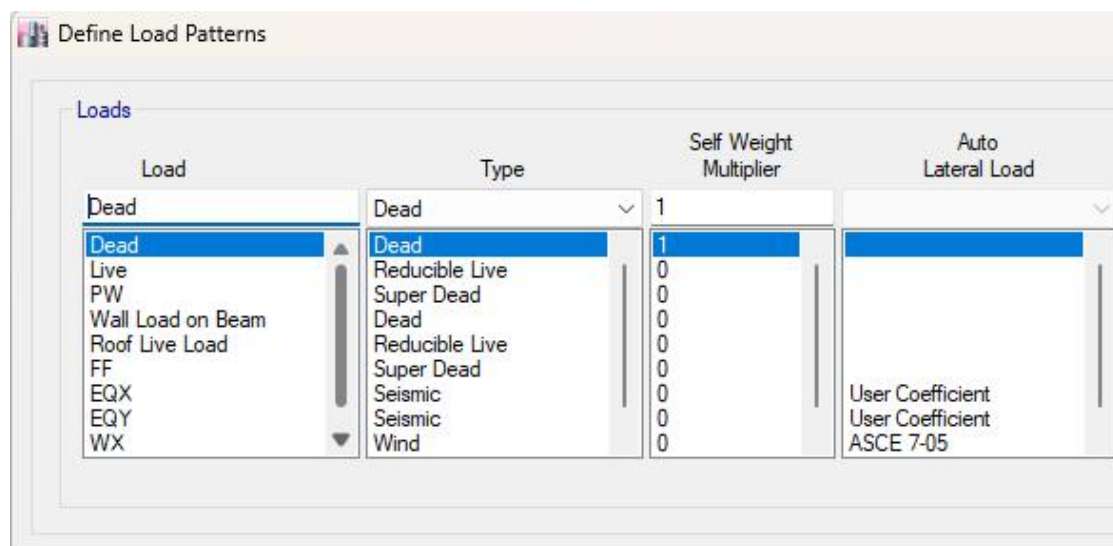


Figure 3. 2 ETABS model showing load assignment

Type	Schematic Representation	Boundary Conditions in Abaqus	Abaqus Graphical Representation
Fixed			
Pinned			
Roller			

Figure 3. 3 support conditions and fixed base representation.

### 3.3 Load Considerations and Combinations

The structure was subjected to several types of loads in accordance with **BNBC 2020**. These include:

1. **Dead Load (DL):** Self-weight of the structure, including slabs, beams, columns, plaster finishes, and floor finishes.
2. **Live Load (LL):** Load due to human occupancy and movable furniture. For classrooms, a live load of 3 kN/m<sup>2</sup> was applied.
3. **Seismic Load (EQ):** Generated automatically by ETABS based on BNBC seismic parameters for Zone 2.
4. **Roof Load and Finishes:** Additional load due to roof treatment and minor utilities.

Table 3. 1 Load pattern

Load	Type	Self-weight multiplier
Dead	Dead	1
Live	Live	0
Roof live	Live	0
PW	Super dead	0
FF	Super dead	0
Ex	Seismic	0
Ey	Seismic	0
W <sub>x</sub>	Wind	0
W <sub>y</sub>	Wind	0
<b>N.B.</b> PW= Partition Wall, FF= Floor Finish, Ex= Earthquake load X direction, Ey= Earthquake load Y direction, W <sub>x</sub> =Wind load X direction, W <sub>y</sub> = Wind load Y direction		

Load combinations were automatically generated by ETABS using BNBC 2020 load combination rules, including:

Table 3. 2 Load Combinations

$0.9D - 1.6W_x$	$1.2D - 0.8W_x$	$1.29D + L + Ex + 0.3Ey$
$0.9D + 1.6W_x$	$1.2D + 0.8W_x$	$1.29D + L + Ey - 0.3Ex$
$0.9D - 1.6W_y$	$1.2D - 0.8W_y$	$1.29D + L + Ey + 0.3Ex$
$0.9D + 1.6W_y$	$1.2D + 0.8W_y$	$1.29D + L - Ex - 0.3 Ey$
$0.81D + Ex - 0.3Ey$	$1.2D + 1.6L$	$1.29D + L - Ex + 0.3 Ey$
$0.81D + Ex + 0.3Ey$	$1.2D + L$	$1.29D + L - Ey - 0.3Ex$
$0.81D - Ex - 0.3Ey$	$1.4D$	$1.29D + L - Ey + 0.3Ex$
$0.81D - Ex + 0.3Ey$	$1.2D + L - 1.6W_x$	$D + 0.5L - 0.7W_x$
$0.81D + Ey - 0.3Ex$	$1.2D + L + 1.6W_x$	$D + 0.5L + 0.7W_x$
$0.81D + Ey + 0.3Ex$	$1.2D + L - 1.6W_y$	$D + 0.5L - 0.7W_y$
$0.81D - Ey - 0.3Ex$	$1.2D + L + 1.6W_y$	$D + 0.5L + 0.7W_x$
$0.81D - Ey + 0.3Ex$	$1.29D + L + Ex - 0.3Ey$	–
<b>N.B.</b> D= Dead load, L= Live load, Ex= Earthquake load X direction, Ey= Earthquake load Y direction, W <sub>x</sub> = Wind load X direction, W <sub>y</sub> = Wind load Y direction		

These combinations ensure that the most critical load conditions are checked for both strength and serviceability.

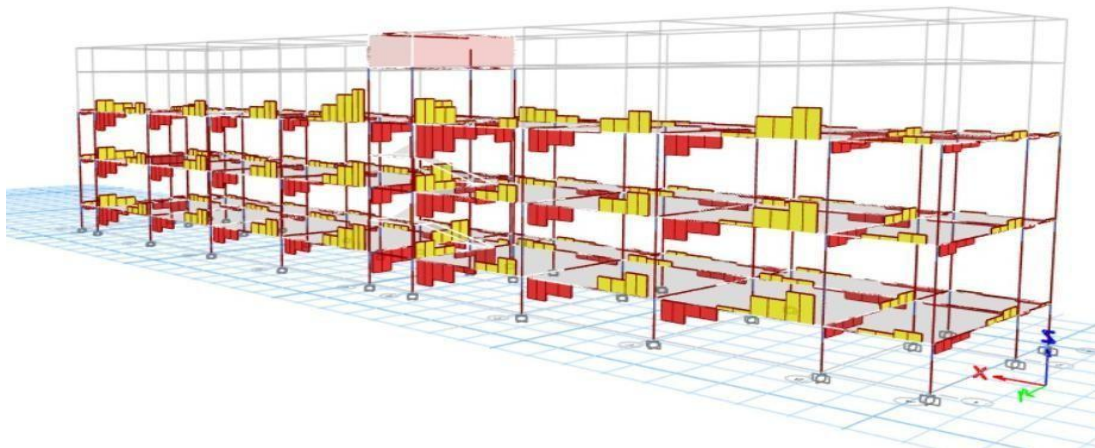


Figure 3. 4 showing applied load directions

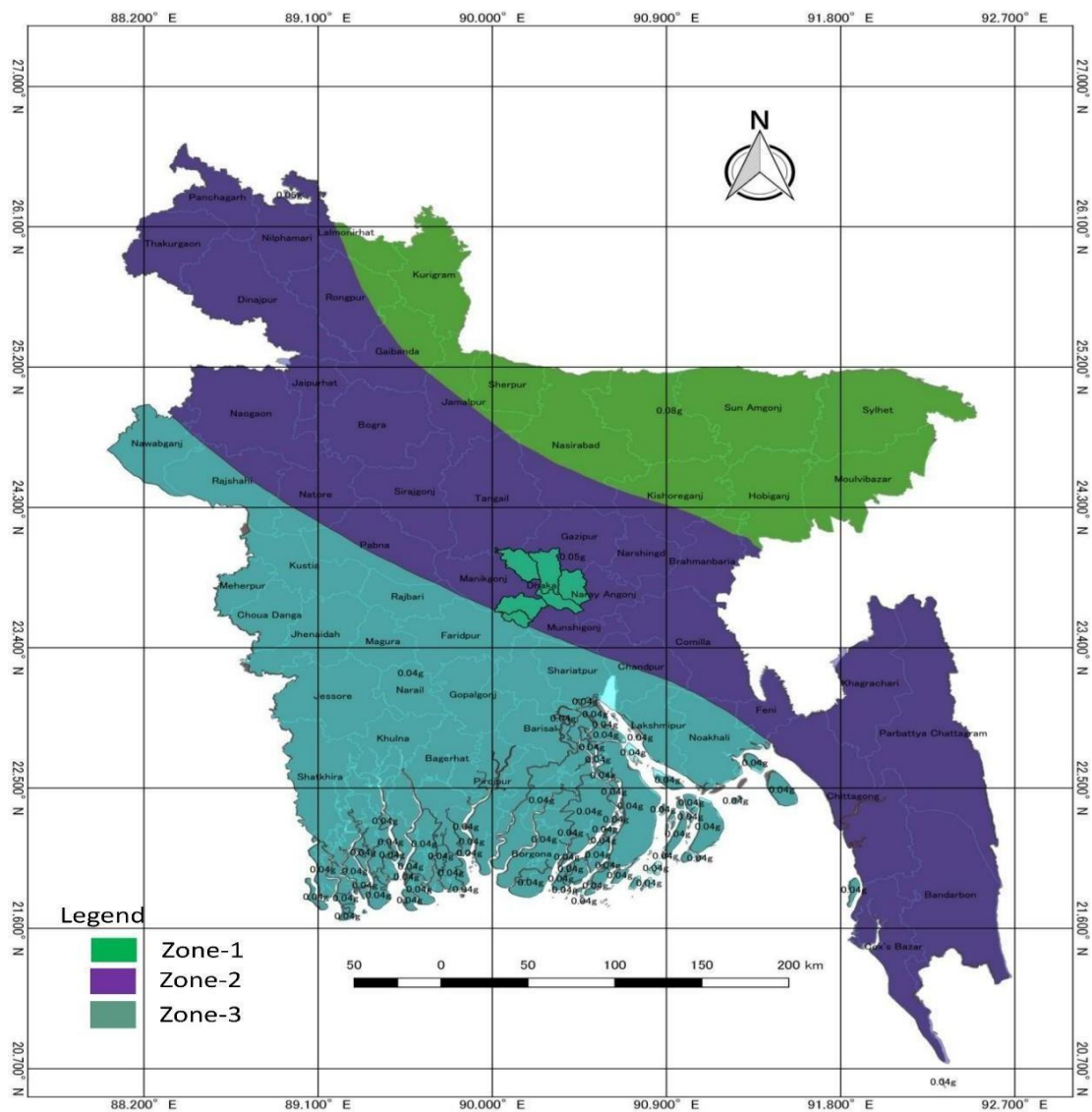


Figure 3. 5 Seismic zone map of Bangladesh

### 3.4 Analysis Procedure

After the loads and load combinations were assigned, a three-dimensional static and dynamic analysis was performed. The analysis yielded results such as bending moments, shear forces, deflections, and axial loads in different structural members.

The overall stiffness matrix of the building was generated internally by ETABS, and the equilibrium equations were solved to determine the deformations and internal forces.

The following major observations were made from the analysis:

- Maximum bending moments occurred at mid-span of beams under gravity load combinations.
- Columns primarily carried compressive loads with minor bending due to beam eccentricities.
- The roof slab exhibited adequate stiffness to distribute loads uniformly to supporting beams.
- The maximum story drift under seismic load was within BNBC limits for low-rise buildings, confirming lateral stability.

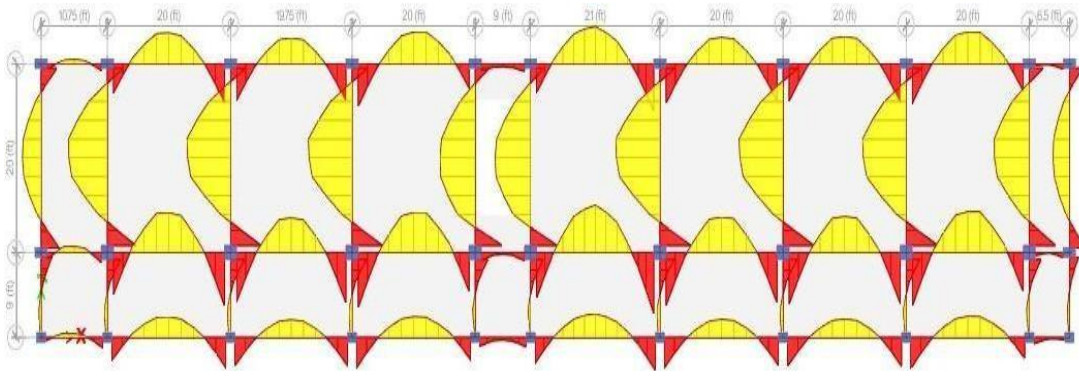


Figure 3. 6 Bending moment and shear force diagrams for a typical beam



Figure 3. 7 Axial load contour diagram for columns.

### 3.5 Slab Design

The roof slab of the school building is 6 inches thick and functions as a **two-way slab** supported by beams on all sides. ETABS automatically calculates the design moments in both directions, based on load distribution patterns.

- **Load Calculation:** Dead load of slab =  $0.15 \text{ m} \times 24 \text{ kN/m}^3 = 3.6 \text{ kN/m}^2$   
Live load =  $3 \text{ kN/m}^2$  Total load =  $6.6 \text{ kN/m}^2$
- **Moment Distribution:** Maximum positive and negative moments were obtained from ETABS, and the reinforcement was designed accordingly in both directions.
- **Deflection Check:** The span-to-depth ratio satisfied the limit specified in BNBC 2020, confirming that no excessive deflection would occur.

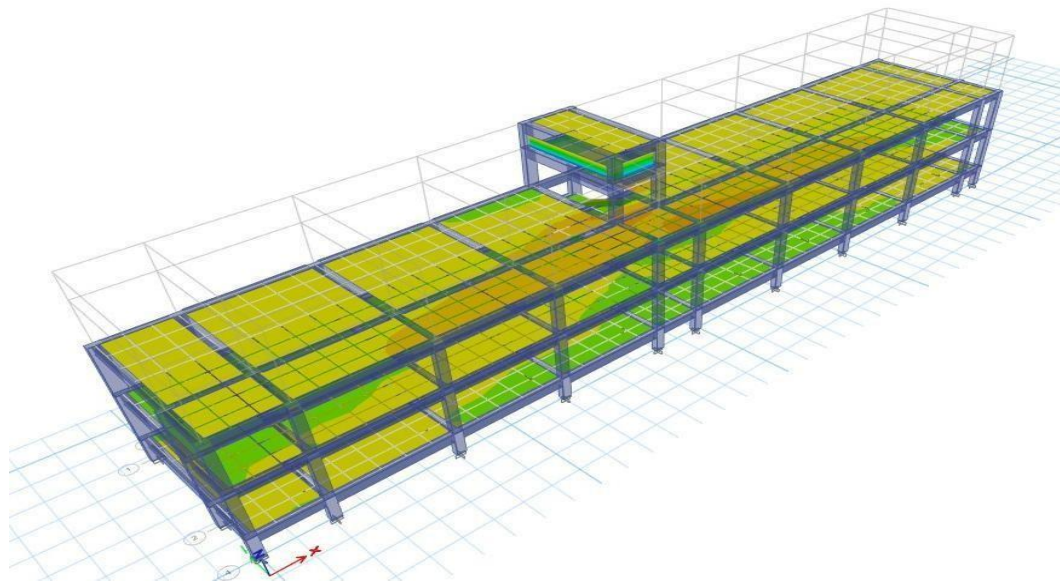


Figure 3. 8 ETABS slab meshing and contour of bending moments

The slab is designed using ETABS considering dead load, live load, and seismic load as per BNBC 2020.

Table 3. 3 Slab Reinforcement Summary

Slab No	Thickness	Main Bar	Distribution Bar	Support Condition
S1	6 in	10 mm @ 150 mm c/c	8 mm @ 200 mm c/c	Two-way slab
S2	6 in	10 mm @ 150 mm c/c	8 mm @ 200 mm c/c	Two-way slab
S3	6 in	12 mm @ 150 mm c/c	8 mm @ 200 mm c/c	Two-way slab

### 3.6 Beam Design

All beams were designed as reinforced concrete rectangular sections to resist flexure, shear, and torsion. The analysis results were directly used by ETABS to determine the required steel reinforcement area.

- Flexural Design:** Maximum bending moment was considered at mid-span for simply supported beams. The area of steel was provided to ensure that the Moment-capacity=  $M_u \geq M_{required}$   
 Reinforcement details were extracted and verified manually for critical beams.
- Shear Design:** The shear capacity of beams was checked along the span. Stirrups were designed to resist diagonal tension, and their spacing was adjusted accordingly.
- Serviceability:** Crack control and deflection checks were performed under service loads. The beams satisfied all code-specified limits.

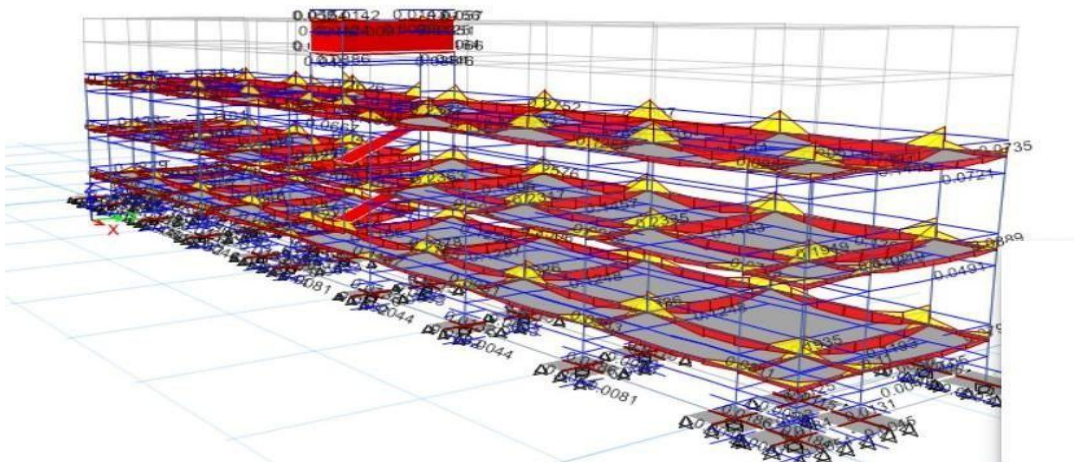


Figure 3. 9 Beam bending moment diagram (ETABS output)

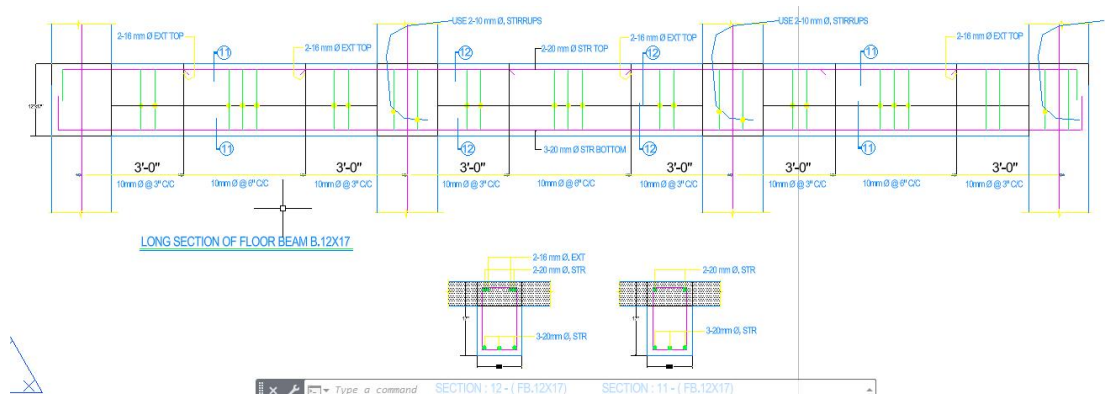


Figure 3. 10 Typical beam reinforcement detailing sketch.

The key members of the horizontal type are beams, which carry the loads of the slabs to the columns. Beam design, flexural and shear capacity were put into consideration in this project under ETABS. The reinforcing was to withstand maximum bending moments and shear forces which were obtained by analysis using the software. The table presented below indicates the standard reinforcement information of the main beams in the structure.

Table 3. 4 Beam Reinforcement Summary

Beam No	Dimension (in.)	Bottom Rebar	Top Rebar	Stirrups
B1	12 × 18	2 #5 (16 mm)	2 #5 (16 mm)	#3 @ 8 in c/c
B2	12 × 18	2 #5	2 #5	#3 @ 8 in c/c
B3	12 × 18	3 #5	2 #5	#3 @ 8 in c/c
B4	12 × 18	3 #5	2 #5	#3 @ 6 in c/c
B5	12 × 18	2 #5	2 #5	#3 @ 8 in c/c

### 3.7 Column Design

The columns act as the primary load-carrying elements, transferring both vertical and lateral forces to the foundation. Each column was designed in ETABS using interaction formulas based on axial load and biaxial bending.

- Cross-section: 12" × 15"
- Material Strengths:  $f' = 4 \text{ ksi}$ ,  $f = 60 \text{ ksi}$
- Design Checks:
  - Axial load ratio within BNBC limits
  - Slenderness ratio checked (not critical due to single story)
  - Adequate reinforcement provided as per interaction diagram results

All columns passed the ETABS design checks, confirming adequate strength and stability.

The building consists largely of columns which bear the vertical loads. They were made to withstand load and bending combinations of axial loads. The analysis of ETABS gave the optimum combination of loads, and the reinforcement was selected based on this. Column designs are in line with the requirements of BNBC regarding minimum reinforcement ratio, minimum spacing, and minimum slenderness requirements.

Table 3. 5 Column Reinforcement Summary

Column No	Size (in.)	Longitudinal Bars	Stirrups / Ties
C1	12 × 12	4 #6 (20 mm)	#3 @ 6 in c/c
C2	12 × 15	6 #5 (16 mm)	#3 @ 6 in c/c
C3	15 × 15	8 #5 (16 mm)	#3 @ 6 in c/c

### 3.8 Foundation Design

The structure applies isolated footings below every column. Manual design was carried out with the help of reactions from ETABS.

- Foundation Depth: 6 ft
- Type: Isolated footing
- Soil Bearing Capacity (SBC): 3500 psf

#### Design Steps:

1. Compute total load on each footing (from column reactions).
2. Required area of footing = Load/SBC.
3. Check bearing pressure distribution under service load.
4. Check one-way and two-way shear around column faces. Provide adequate thickness and reinforcement at the bottom.

All the footings were safe in bearing pressure, shear as well as bending.

Table 3. 6 Footing Reinforcement Summary

Footing No	Supported Column	Footing Size (ft)	Thickness (in.)	Reinforcement (Main)	Reinforcement (Distribution)
F1	C2	5 × 5	14	#5 @ 6 in c/c	#5 @ 8 in c/c
F2	C1	6 × 6	12	#5 @ 6 in c/c	#5 @ 8 in c/c
F3	C3	6.5 × 6.5	16	#5 @ 5 in c/c	#5 @ 6 in c/c

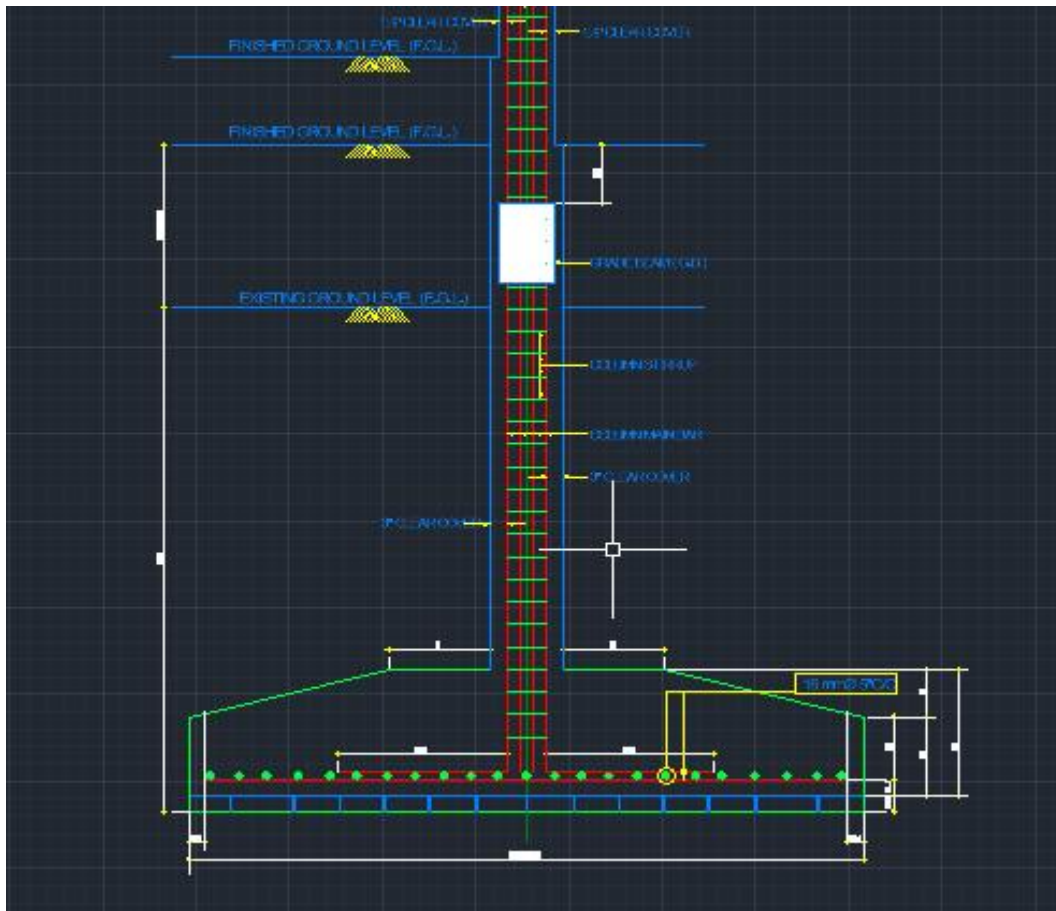


Figure 3. 11 Plan of footing layout

### 3.9 Design of Staircase and Detailing

Staircase is an important structural and functional element of any multi-storied building. It provides for vertical circulation from floor to floor with safety, comfort, and aesthetic components added to it. In this project work, the staircase has been designed and analyzed in ETABS considering all required structural as well as architectural parameters to fulfill stability & serviceability.

In the modeling stage, the geometric configuration of the staircase was first described in line with the building layout. The rise, tread, and number of steps were based on standard ergonomic dimensions for a school environment- such dimension ensures comfortability of stairs by children as well as teachers. The inclination angle of the staircase set to balance gives a slope that does not become steep yet consumes space efficiently.

After the final geometry, it was included in the ETABS model as a reinforced concrete slab element supported on beams or landings based on the configuration chosen. The model considered that load path mechanism wherein self-weight, finishing load, and

imposed loads due to human movement are transferred through the waist slab and steps to the supporting beams and columns.

Dead and live loads have been given as recommended by BNBC 2020. The dead load comprises the weight of the waist slab, steps, and finishes whereas the live load comprises the movement and weight of occupants using the stairs. Bending moments, shear forces, and support reactions for different combinations of load conditions that may be considered to determine the most critical condition are computed automatically by the software.

Material properties are those described in the structural specifications of the project using reinforced concrete with a compressive strength of 4 ksi and reinforcing bars with a yield strength of 60 ksi. This design used the limit state method of design, which requires that an element be safe at ultimate loading conditions and satisfactory under normal, service loading conditions.

In ETABS, support conditions of the staircase were input just as it is supported in reality. For this project, stairs have supports at both ends resting on reinforced concrete beams, which are also assumed for comfort of usage and strength provision. It enables the load to be transferred efficiently hence making the deflection under service condition minimized.

The bending moment envelope was derived from the software-generated results, and thus it gave way to detailing of reinforcement. Longitudinal reinforcement will be provided along the waist slab with extra bars in distribution placed transversely to help in resistance of shrinkage and temperature effects. Adequate cover and anchorage length have been ensured as per BNBC guidelines.

A drawing of the staircase was at last done in detail, covering aspects of reinforcement layout, landing connections as well as support conditions. The design brings into play that particular state where the staircase fulfills conditions relating to structural safety standards on one hand and offers a comfortable plus user-friendly transition between floors. This effectively means that it complies with functional and architectural objectives of the primary school building.

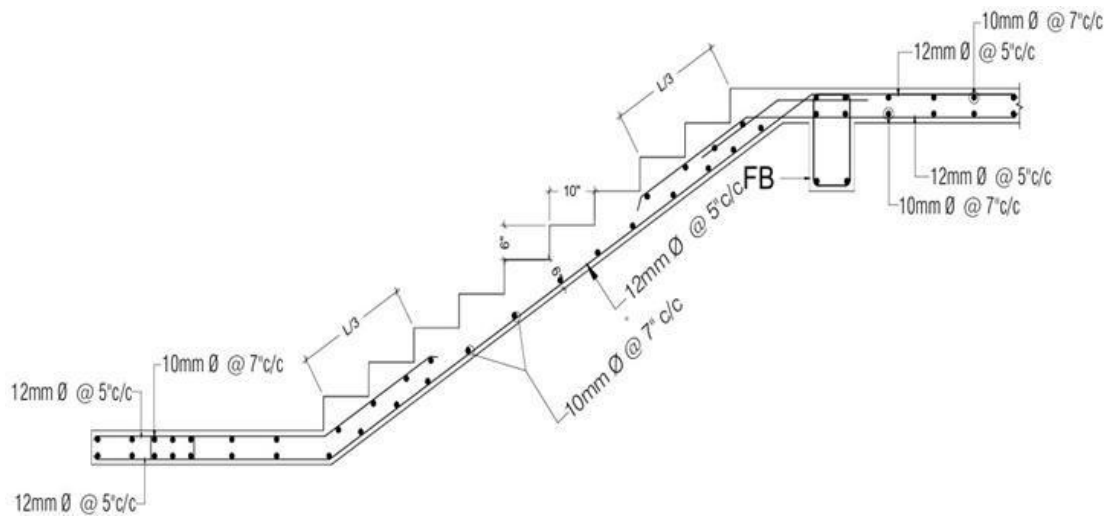


Figure 3. 12 Stair Reinforcement Details

### 3.10 Conclusion

The analysis and design of the structure of the Primary School Building prove that safety and stability requirements have been fulfilled by the proposed structure as per BNBC 2020. In ETABS, proper capturing of behavior for various load combinations has been done, and it is ensured that members are within allowable stress limits. Manual checking further ensures reliability and proves that the structure is not only sound from a structural point of view but also economical and practical for construction in such a rural setting. The detailed drawing and implementation phase can be conducted with complete confidence because the design has already been completed.

## CHAPTER-IV

### Cost Estimation and Scheduling

#### 4.1 General

One of the significant deliverables in any civil construction work is a proper cost and schedule. The BOQ of G +1 rural primary school building will identify, list, and measure all materials, labor, and resources against each of the structural elements which will comprise of slabs, beams, columns and footings which is all combined in one detailed document. This record will ensure the budgets are transparent and proper cost controls and procurement will be managed in construction.

The project has been calculated at the current ongoing rates of the material and labor that are normally used in the rural parts of Bangladesh taking into consideration the strength and safety factors into account concerning the cost factor. Findings have been outlined based on a Gantt chart which gives a time schedule of the construction activities to be undertaken to ensure that they are in the proper order and completed on time. The Overview of the Bill of Quantities (BOQ) is in 4.2.

It is the Bill of Quantities that provides the framework on which any cost determination with regard to this project can be based. It lists all the amounts of materials which pertain to every structural component as well as binding them together with unit costs to come up with the overall project cost. The BOQ will involve concrete, reinforcement, form work as well as labor of the principal structural elements of this school building.

All major structural elements have been constructed using M25 grade reinforced concrete (1:1.5:3 mix) to ensure quality of the construction process coupled with its durability. Steel reinforcement bars were taken into consideration (deformed bars, Fe 500 grade). The cost of steel bars has been taken to be BDT 91,000 per ton which is rather close to the domestic market rates of rural project.

#### 4.2 Bill of Quantities (BOQ) Overview

The Bill of Quantities is what lays down the basis for any cost decision relating to this project. It enumerates all the quantities of materials related to each structural component and ties them up with unit costs to derive at the total project cost. The BOQ will include concrete, reinforcement, formwork, and labor for the main structural components of this school building.

M25 grade reinforced concrete (1:1.5:3 mix) has been used for all major structural elements to maintain construction quality as well as durability. Steel reinforcement bars (deformed bars, Fe 500 grade) were considered. The price of steel bars has been assumed at BDT 91,000 per ton which is quite similar to the local market prices for rural projects.

### 4.3 Estimation Assumptions

To ensure realistic costing, the following assumptions were made:

Foundation type: Isolated Footing

Structural Frame: RCC (Reinforced Concrete Cement)

Floor height: 12 feet

Foundation depth: 6 feet

Slab thickness: 6 inches

Column size: , 12" × 12", 12" × 15", 15" × 15"

Beam sizes: As per ETABS design (average 12" × 18")

Material Source: Locally available from nearby suppliers

Currency: All costs in BDT (Bangladeshi Taka)

### 4.4 Material and Construction Cost Estimation

All structural and non-structural components were estimated using standard unit rates based on field experience and PWD reference data.

Table 4.1 Construction Cost Estimation Calculations

Sl. No.	Description of Item	Unit	Quantity	Unit Rate (BDT)	Total Cost (BDT)	Remarks
1	Site Clearing and Earthwork Excavation	cft	1,200	18	21,600	Including disposal
2	Plain Cement Concrete (PCC 1:3:6)	cft	250	190	47,500	Under foundation

3	Reinforced Cement Concrete (RCC 1:1.5:3)	cft	8,780	350	3,073,000	Slab, beam, column
4	Reinforcement (Deformed Bars, 60 Grade)	ton	61.02	91,000	5,593,200	From ETABS design
5	Brickwork (1st class, 1:5 mortar)	cft	5,600	65	364,000	Superstructure walls
6	Plaster (1:4 cement sand mix)	sft	6,500	20	130,000	Both sides of wall
7	Flooring (Cement concrete finish)	sft	4,735	95	449,825	Including finishing
8	Door and Window (Wood/Steel)	sft	420	450	189,000	Including fitting
9	Roof Finishing & Water Proofing	sft	4,735	55	260,425	Including bitumen layer
10	Painting (Interior & Exterior)	sft	6,800	25	170,000	Plastic paint finish
11	Electrical Fittings (Basic)	LS	1	120,000	120,000	Rural standard
12	Sanitary & Plumbing Works	LS	1	85,000	85,000	For toilet facilities
13	Boundary Wall and Gate	LS	1	250,000	250,000	RCC column with grill gate
14	Site Development & Landscaping	LS	1	100,000	100,000	Levelling and greenery
15	Contingency (5%) + Overhead (2%)	-	-	-	490,000	On total project cost

## 4.5 Cost Comparison and Practical Implications

Estimated cost of construction 10,002,260 BDT is an optimistic response to a rural two-storied school building. The budget will cover the structural works, but will not cover the external utilities, electrical works, and finishing materials such as tiles and joinery.

This level of estimation of the construction cost is highly significant in upholding transparency both in the project and also in ensuring that the acquisition of material is not only structurally safe but also cost effective.

### 4.6 Construction Planning and Scheduling (Gantt chart)

Gantt chart graphically illustrates the plan of works, including the beginning and the termination of building works. This facilitates correct coordination of the engineers, supervisors and labour teams. In the case of this specific Primary school building, it has therefore been divided into key stages of construction which involves excavation until plastering and painting.

### 4.6 Construction Planning and Scheduling (Gantt Chart)

Gantt chart is a visual representation of the running of works, it shows when the construction works commence and when they end. This allows the engineers, supervisors, and labor teams to be coordinated properly. In this case of the building of a primary school, it has been subdivided into the key stages of work which incorporates the excavation up to the plastering and finishing.

Table 4.2 Project Schedule

Task No.	Task Description	Duration	Start Date	End Date
1	Foundation Excavation	2 weeks	Day 1	Day 14
2	Footing Construction	3 weeks	Day 15	Day 35
3	Ground Floor Column Casting	2 weeks	Day 36	Day 50
4	Ground Floor Beams	3 weeks	Day 51	Day 71
5	Ground Floor Slab Casting	2 weeks	Day 72	Day 86
6	Staircase Construction	1 week	Day 87	Day 93
7	1st Floor Columns	2 weeks	Day 94	Day 108
8	1st Floor Beams	3 weeks	Day 109	Day 129
9	1st Floor Slab Casting	2 weeks	Day 130	Day 144
10	Septic Tank & Drainage	2 weeks	Day 145	Day 159
11	Plastering & Masonry	4 weeks	Day 160	Day 188
12	Final Staircase Work & Finishing	1 week	Day 189	Day 195

## **4.7 Summary and Discussion**

The cost is mainly concentrated on the RCC structural frame (approximately 65 percent), which is because of the need to require reinforced concrete and rebar, then the brickwork (10 percent) and finishing (15 percent). The contingency is much smaller, which means there is flexibility in funds during implementation.

This estimation can serve as an indicator in the budget preparations, tendering, and performance of works on like rural primary school structures under any governmental or non-governmental development project.

## CHAPTER-V

### Design of Septic Tank and Overhead Tank

#### 5.1 General

Septic tank refers to a sewage collection and treatment system that is an underground tank which is utilized in locations where sewage network is not centralized. It is applied as one of the primary treatment systems in which solid waste material is distanced, and liquid effluent is distanced permitting organic degradation by an anaerobic bacterial process.

In a rural school, e.g. the proposed two storied principal school building, a well-designed septic tank will serve as a way of facilitating a hygienic disposal of waste materials and does not contaminate soil and underground water surrounding the school building. The septic system functions with the assistance of the toilets and wash rooms emptying into a closed compartment, the heavy solids will be accumulated at the bottom of the tank in the form of sludge, the light stuff will begin to ascend to the top in the form of scum, and the middle, which is clarified, will also discharge through a soak pit or leach field.

To attain sustainable performance, the septic tank is to be constructed based on the recommendation of the Bangladesh National Building Code (BNBC 2020) and Public Health Engineering Department (DPHE). This design must be taken into account keeping in view the design of user capacity, retention time, material strength, ventilation and accessibility in maintenance. Septic system that is well engineered will serve the purpose of enhancing health of people and environmental protection in the rural school environment.

#### 5.2 Components of a Septic Tank

There are many significant structural and hydraulic components of a septic tank that have particular functions in the wastewater treatment process.

1. Inlet Pipe: This is the pipe whereby the sewage of toilets, washrooms enters, drains into the tank. Normally, it has been mounted 50-75 mm above the outlet pipe so that it can allow flow using gravity in addition to retaining the hydraulic gradient.

2. Division of the tank into two or three chambers is done with the help of Chambers-Inside baffle walls. The former chamber is to be used to sediment and to digest, the latter (and third, should there be any) to give more explanation.
3. Baffle Walls/Tees-They cause the flow to go one way, nothing to leave the scum, and little turbulence. They reach a depth of 300-400 mm above and below the liquid surface.
4. The highest layer of floating fats oils and grease is referred to as the scum layer. The sludge layer is referred to as bottom settled solids and they are subject to anaerobic digestion. The clarified effluent rests in the middle zone before it is discharged.
5. Outlet Pipe: Dumps partially treated effluent into soak pit or leaching field. The outlet will be positioned lower than the inlet such that a continuous flow will be obtained.
6. Manholes / Access Risers: Inspection, de-sludging, and maintenance provision shall be made, concrete slabs or any heavy cover shall be provided to prevent rainwater entry within the tank as well as odor emission.
7. Vent pipe: Serves to make sure that all the gases produced in the process of digestion like methane, carbon dioxide, and hydrogen sulfide, among others, are released, as well as make sure that no pressure accumulates within the chamber.
8. Drain Field / Soak Pit: It is the final step in the treatment process that is completed with the percolation through the layers of soil till it reaches the ground water table. The overall approximate cost of the construction of the Primary School Building is approximately 8.12 million BDT (81.2 lakh taka) of all structural, architectural, electrical, plumbing, and finishing works.

### **5.3 Design Considerations**

The design of the proposed rural school septic tank should be able to cover both technical and environmental parameters to make it efficient and lasting.

### 5.3.1 Design Data and Assumptions

Table 5. 1 Septic Tank Design Data Assumptions

Parameter	Symbol	Assumed/Calculated Value	Remarks
Number of users	N	350 persons	For school building (students + staff)
Sewage generation per person per day	q	30 liters/day	For institutional buildings (BNBC/CPHEEO)
Daily sewage flow	$Q = N \times q$	10.5 m <sup>3</sup> /day	$350 \times 30 = 10,500\text{L/day}$
Detention period	t	24 hours	For large systems (1-day detention)
Liquid depth	h	3.5 m	Usually more than 1
Freeboard	f	0.3 m	To prevent overflow
Sludge storage period	—	1 year	For institutional setup
Sludge accumulation rate	s	0.04 m <sup>3</sup> /person/year	As per CPHEEO

### 5.3.2 Volume

Total Volume Required = 99.3 m<sup>3</sup> (Calculation given in appendix)

### 5.3.3 Tank Dimensions

To achieve the required capacity, a rectangular-shaped tank was adopted for ease of construction and maintenance. The proportions were chosen as Length:Breadth:Depth= 3:1:1.2–1.8.

Let breadth (B) = 3.25m

Then, length (L) =  $3 \times 3.25 = 9.75$  m

Liquid depth (H) = 3.5 m

Now calculate:

$$\text{Volume} = L \times B \times h = 9.75 \times 3.25 \times 3.5 = 110.91 \text{ m}^3$$

Table 5. 2 Final Septic Tank Dimensions and Specifications

Component	Details / Dimension	Remarks
Number of Tanks	1	Placed in parallel
Chambers per tank	2	With baffle walls
Internal Length	9.75 m	—
Internal Breadth	3.25m	—
Liquid Depth	3.2 m	—
Freeboard	0.3 m	Total height 3.5 m
Partition wall	150 mm thick	With 150 × 200 mm openings
Inlet / Outlet pipes	100 mm dia PVC	Gravity flow
Manholes	2 per chamber	For cleaning access
Cover slab	100 mm RCC	With 450 mm dia openings

### 5.3.5 Soak Pit Design

For effluent disposal (if no municipal sewer line):

Table 5. 3 Soak pit Design calculations

Parameter	Value	Remarks
Daily discharge	33.6 m <sup>3</sup> /day	From septic tank outlet
Infiltration rate	30 L/m <sup>2</sup> /day (moderate soil)	—
Required infiltration area	$33,600 / 30 = 1,120 \text{ m}^2$	Hence, several soak pits or leach trenches needed
Adopt	4 pits of 1.5 m dia × 3 m deep	Equivalent area ≈ 1,060 m <sup>2</sup> (safe)

### 5.3.6 Final Septic Tank Summary Table

Table 5. 4 Septic Tank Design Summary

Item	Unit	Calculation/Description	Value
Population served	persons	—	350
Sewage generation	L/person/day	30	
Total sewage flow	m <sup>3</sup> /day	10.5	
Detention time	Hr	24	
Sludge storage	Yr	1	
Total volume required	m <sup>3</sup>	99.3	

No. of tanks	—	2	
Size of each tank	M	$9.75 \times 3.25 \times 3.5$	
Total volume provided	$m^3$	110.91	
No. of chambers per tank	—	2	
Inlet & Outlet pipe dia	Mm	100	
Soak pit	—	4 Nos., 1.5 m dia $\times$ 3 m deep	

## 5.4 Design of Overhead Water Tank

The same institutional building must have overhead water tank, which will be used as a constant supply of water to carry out daily tasks like drinking, washing, and sanitation. In the case of the proposed school building, the capacity of the overhead tank is to fulfill the daily demand of water of the targeted population of about 350 people so that it can be able to serve the population at least one full working day. The structure is in accordance with the recommendations of BNBC 2020 and IS 3370 on reinforced concrete water retaining structures.

Table 5. 5 Design Data and Assumptions

Parameter	Value / Description
Total Population	350 persons (students + staff)
Per Capita Demand	45 liters/person/day
Total Water Demand	$175 \times 45 = 7875$ liters/day ( $\approx 8 m^3$ /day)
Required Storage (1-day capacity + 20% reserve)	$8 \times 1.2 = 9.6 m^3$
Adopted Tank Capacity	<b><math>9.6 m^3</math> (9600 liters)</b>
Type of Tank	Elevated RCC tank on separate supporting structure
Shape	Rectangular
Water Depth (excluding freeboard)	1.5 m
Freeboard	0.25 m
Concrete Grade	M25 ( $f_c = 25$ MPa)
Steel Grade	60 ksi
Unit Weight of Water	$9.81 kN/m^3$

### 5.4.1 Dimensioning of the Tank

To achieve the required capacity of  $9.6 m^3$ , the tank dimensions were chosen based on a rectangular plan:

$$\text{Volume} = L \times B \times H$$

Assuming  $H = 1.75$  m, and adopting a practical proportion of  $L : B = 1.5 : 1$ , we have:

$$L \times B = \frac{9.6}{1.75} = 5.5$$

$$1.5B \times B = 5.5 \Rightarrow B = 2 \text{ m}, L = 3 \text{ m}$$

So, The Dimensions,

Length (L)	Width (B)	Depth (H)	Freeboard	Total Depth
3.0 m	2.0 m	1.5 m	0.25 m	1.75 m

#### 5.4.4 Structural Design Considerations

- Wall and Base Slab Thickness: 150 mm minimum (increased to 200 mm at base for durability).
- Top Slab Thickness: 125 mm with light reinforcement.
- Reinforcement:
  - Main bars: 10–12 mm  $\varnothing$  @ 150 mm c/c both ways.
  - Distribution bars: 8 mm  $\varnothing$  @ 200 mm c/c.
- Waterproofing:
  - Internal surfaces plastered with 1:3 cement mortar mixed with waterproofing compound.
  - External faces coated with cementitious waterproof slurry.

#### 5.5 Cost Estimation for Septic and Overhead Tank

Sl. No.	Item Description	Unit	Quantity	Rate (BDT)	Amount (BDT)	Remarks
<b>A. Septic Tank (for 350 users)</b>						
1	Earth excavation for tank pit	m <sup>3</sup>	18	250	4,500	Up to foundation level
2	Plain Cement Concrete (1:4:8)	m <sup>3</sup>	2.0	8,500	17,000	Base layer
3	RCC work (M20) for walls, slab & base	m <sup>3</sup>	8.0	10,000	80,000	150 mm thick walls

4	Reinforcement steel	Kg	650	115	74,750	10–12 mm bars
5	Brickwork in partition & top cover	m <sup>3</sup>	1.5	9,000	13,500	Internal baffle wall
6	Plastering (1:3) internal & external	m <sup>2</sup>	40	250	10,000	With waterproof additive
7	Vent pipe & fittings	Set	1	3,500	3,500	100 mm GI pipe
8	Inlet & outlet PVC pipes	M	10	400	4,000	100 mm dia
<b>Subtotal (A)</b>					<b>2,07,250 BDT</b>	
<b>B. Overhead Water Tank (9.6 m<sup>3</sup> capacity)</b>						
1	RCC work (M25) for tank walls, slab, and base	m <sup>3</sup>	6.0	10,500	63,000	150–200 mm thick
2	Reinforcement steel	Kg	500	115	57,500	Fe 415 steel
3	Formwork & centering	m <sup>2</sup>	60	450	27,000	For tank body
4	Waterproof plaster (1:3) with compound	m <sup>2</sup>	30	250	7,500	Internal coating
5	Supporting RCC frame (columns, beams, footings)	m <sup>3</sup>	4.0	10,500	42,000	Height 3.0 m
<b>Subtotal (B)</b>					<b>1,97,000 BDT</b>	

<b>C. Grand Total (A + B)</b>	<b>4,04,250 BDT (Approx.)</b>
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Notes:

The rates are calculated in accordance with the present local construction market rates (2025) of medium-size institutional projects.

These include costs on labor, material and transport.

At the last budgeting stage, contingency and supervision charges (approximately 510 percent) can be imposed.

All the works are planned and carried out according to the BNBC 2020 and the engineering standards of public health.

## CHAPTER-VI

### CONCLUSION

#### 6.1 Conclusion

The current capstone project that is named Design and Estimation of a Two-Story primary school building, a rural area in Bangladesh illustrates an in-depth approach of the planning, analysis, design and estimated costs of a small sized primary institutional building.

The engineering field of structural, architectural and environment design is united in the study to come up with a design that is technically sound or contextual in a rural community.

The software used in structuring analysis and design was the ETABS, and all of the structural components, including beams, slabs, columns, and footings, meet the requirements of the strength serviceability and stability of the relevant structures as per the BNBC 2020 and other global standards. The identified analysis ensured that the required sizes of the sections and the information on reinforcement addressed the validity of the considered load combinations and that all the concerned members met the design requirements.

In order to produce exquisite architectural drawings, such as floor plans, elevation and sectional drawing, AutoCAD was used, yet Revit was used in creating a 3 dimensional representation in order to understand more on how to organize space and the bulk form of the building. The drawings were very explicit in relation to the architectural planning and the structural viability upon the fact that they ensured that they had well-structured spaces to accommodate the students and the staff and yet kept construction very simple as that it could be used in the rural application.

Microsoft Excel was used in the preparation of the cost estimation and bill of quantities (BOQ) with all the key materials used in this category comprising of concrete, reinforcement, brickwork, plastering, finishing, plumbing and sanitation. The estimation process was realistic and cost effective at a cost of the cost and quality. With such financial analysis, the stakeholders will be able to plan the resources effectively and will help in making decisions in taking up the projects.

With regards to the hygienic and environmental factor, reinforced concrete septic tank was to be installed that would accommodate 410 users based on the BNBC 2020 requirements and the safety precautions of the environment. It was purposefully designed in a manner that took into consideration the retention time, the building up and discharge efficiency to increase the hygiene and sustainability of the school premises. This is what will make certain that the building project will not be merely a

talk of physical infrastructure, but also play a role in improving the environment and health by sanitizing the rural setting.

This project has presented the team with an opportunity to put into practice the theoretical knowledge of the civil engineering field on the real issue, which comprises the structural design, cost analysis and even the environment issues under an umbrella. It not only enhanced the design process and planning and engineering decisions of construction but also reassessed the repetition of software, teamwork, and standard adherence in engineering product production to professional level.

In general the project can show how the research conducted within the academic design exercise can be indicative of the real world construction practice. The proposed building is secure, strong, eco-friendly, and affordable, and it also can be exemplified in other similar educational construction projects in the rural areas of Bangladesh.

## **6.2 Closing Remarks**

The current project gives the proposal of how an organized civil engineering design activity using modern software and national building codes can result in a safe, sustainable and cost-effective infrastructure that can be used in the learning institutions within the rural Bangladesh. The analyses and the methodologies and results in this case can serve as a model guide in the future studies, which will be carried out by the students and other rural development programs to make the academic knowledge relevant to the national development goals.

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## Appendix

### DESIGN OF SEPTIC TANK

Design of a septic tank to serve a primary school of 350 persons who produce 30 lpcd of wastewater, and the tank is to be dislodged every two years.

Solution:

$$P = 350 \text{ persons}$$

$$N = 1 \text{ years (L:3W, Part VIII, Chapter 6, 6.9.12.8, BNBC 2020)}$$

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

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

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

Volume calculation ( $\text{m}^3$ )

Sedimentation Zone  $V_h$

$$\begin{aligned} T_h &= 1.5 - 0.3 \log (Pq) \\ &= 1.5 - 0.3 \log (350 \times 30) \\ &= 1.5 - 0.3 \log (9600) \\ &= 1.5 - 0.3 \times 3.982 \\ &= 1.5 - 1.1946 \\ &= 0.3054 \text{ days} \end{aligned}$$

The volume required by the Sedimentation Zone:

$$\begin{aligned} V_h &= 10^{-3} (Pq) \times T_h \\ &= 10^{-3} \times (350 \times 30) \times 0.3054 \\ &= 2.932 \text{ m}^3 \end{aligned}$$

Sludge Digestion Zone  $V_d$

Assuming a design temperature of  $25^\circ\text{C}$

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

$$\begin{aligned} V_d &= 0.5 \times 10^{-3} \times P \times T_d \\ &= 0.5 \times 10^{-3} \times 350 \times 42.3 = 6.768 \text{ m}^3 \end{aligned}$$

Sludge Zone  $V_{sl}$

$$V_{sl} = C \times P \times N \quad C = \text{Sludge accumulation constant (0.04 m}^3\text{/person/year)}$$

$$= 0.04 \times 320 \times 5$$

$$= 64 \text{ m}^3$$

Scum Zone ( $V_{sc}$ )

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

$$= 0.4 \times 64$$

$$= 25.6 \text{ m}^3$$

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

$$V = 2.932 + 6.768 + 64 + 25.6 = 99.3 \text{ m}^3$$

Depth Calculation

Cross-sectional area  $A = 23.4 \text{ m}^2$

The maximum depth of sludge:

$$d_{sl} = V_{sl} / A = 64 / 23.4 = 1.75 \text{ m}$$

The maximum submerged scum

$$d_{ss} = 0.4 \times V_{sl} / A = 0.4 \times 64 / 23.4 = 1.094 \text{ m}$$

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

$$d_d = V_d / A = 6.768 / 23.4 = 0.289 \text{ m} < 0.375$$

Depth required for sedimentation

$$d_h = V_h / A = 2.932 / 23.4 = 0.125 \text{ m}$$

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

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

Total effective depth

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

$$= 1.75 + 1.094 + 0.289 + 0.375$$

$$= 3.5 \text{ m (Including Freeboard)}$$

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

$$9.75 \text{ m} \times 3.25 \text{ m} \times 3.5 \text{ m}$$

## OVERHEAD TANK CALCULATION

Roof top water reservoir (Overhead water reservoir)

Assumptions and considerations

$$f_c = 4 \text{ ksi}$$

$$f_y = 60 \text{ ksi}$$

Total Floor 1

Units 1

$$P = 175$$

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 175 Persons

Total Capita Consuming = 7875 Liter per day

$$= 7.875 \text{ m}^3$$

$$= 277.89 \text{ ft}^3$$

Inner length & width of Reservoir are,

Length = 10 ft

Width = 7 ft

so, Height of the Reservoir = 5 ft (Including 1 ft Freeboard)

Height = 5 ft

c) Vertical Reinforcement of wall

Let wall Thickness = 6 inch

Effective Depth = 5 inch

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

$$\epsilon_u = 0.005$$

$$= 0.2032$$

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

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

$$D = 1.92 < \text{provided } 5 \text{ (Ok)}$$

$$A_{s \text{ min}} = 0.13 \text{ in}^2/\text{ft} \quad \rho_i = 3.1416$$

USE  $A_s = 5$  cross

$$A_s = M_u / (\phi f_y (d - a/2)) = 0.24 \text{ in}^2/\text{ft}$$

$$a = M_u / (0.85 f_c b) = 0.034 \text{ in}^2/\text{ft}$$

Bar No	Cross Sectional area in <sup>2</sup>	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

Large  $A_s = 0.24$ , Spacing = 15.5 in

Use 16 mm @ 15 in c/c

d) Horizontal reinforcement of wall

$$\text{Force} = \gamma \times h \times (14.52 + 14.52)$$

e) Design of Bottom slab

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

Here, l is the clear span

Multiplying factor=  $0.4+(f_y)/100$        $f_y$  in ksi

If,

Element	Simply Supported	One end continuous	Both ends continuous	Cantilever
One way solid slabs	1/20	1/24	1/28	1/10

Thickness < 6 inch then upper rounding to nearest 0.2

Thickness > 6 inch then upper rounding to nearest 0.50

Thickness 8.4 in

Self-weight of slab= 105 psf

Floor finish = 15 psf

WB= 68.19 psf      Total load, w= 0.693 ksf

WA= 36.81 psf

As min = 0.18 in<sup>2</sup>/ft

$$As = \frac{w}{\phi f_y (d - \frac{2}{2})} = 0.24 \text{ in}^2/\text{ft}$$

$$a = \frac{w}{0.85} = 0.649 \text{ in}^2/\text{ft}$$

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 in

Use 3 mm @ 2 in c/c

Top slab supported on all four tank walls (two-way slab)

Top slab supported on all four tank walls (two-way slab)

Clear span of slab: 11 ft (wall-to-wall clear)

L= 14 ft

Concrete strength: 3000 psi (fc')

W= 12 ft

Steel yield strength: 60,000 psi (fy)

Slab is exposed to pedestrian live load: 40 psf

Cover: 1 inch

Assume: 6 inch thickness slab initially

unit weight of concrete 150 psf

Durability class per BNBC: water tank, exposure moderate

Top slab is cast in place and monolithic with walls

load calculation:

live load 40 psf

dead load 75 psf

Total service load: 115 psf

Step 2:

(Use 1.4DL + 1.7LL as per BNBC load combinations)

=173 psf

Step 4: Design Moments (two-way slab)

Use simplified coefficients from BNBC (similar to ACI Table 9.5(c)):

For a square slab with four edges continuous:

Positive  $=\alpha_w u L^2$   $\alpha=0.041$

$$M = 2298.132 \text{ ft-lb/ft} = 27577.584 \text{ in-lb/ft}$$

Step 5: Steel Area

$$d = 4.5 < \text{provided, } 3.666667 \text{ not ok}$$

$$A_{s_{\min}} = 0.08 \text{ in}^2/\text{ft} \quad p_i = 3.1416$$

Spacing : 11.5 c/c

Step: 6 Shrinkage/ Temperature Steel

BNBC recommends minimum 0.0012

Bar No	Cross Sectional area	Bar mm
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

Spacing: 25.1 in c/c

Use # 10 mm @ 12 c/c.

Use # 10 mm @ 25 c/c.

## DESIGN OF STAIR CASE 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/m<sup>2</sup>

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

Beam width (B)= 304.8 mm

Unit wt. of concrete (Y)= 23.58 KN/m<sup>3</sup>

Grade of steel (f<sub>y</sub>)= 500 N/mm<sup>2</sup>

Grade of concrete (f<sub>c</sub>)= 20 N/mm<sup>2</sup>

Step 1: Calculation of effective span

Effective span (L<sub>eff</sub>)

$$= \{(N-1) \times T\} + L_1 + L_2 + (B/2) + (B/2)$$

$$= \{(12-1) \times 250\} + 1000 + 1000 + 304.8$$

$$= 5054.8 \text{ mm}$$

Step2: Calculation of effective depth

clear cover (c)= 15 mm

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

(assuming constant 30-40)

Effective depth (d)= (L<sub>eff</sub>/30) = 168.493 mm

Overall Depth (D)= d+(Ø/2)+c = 168.493+(12/2)+15

$$= 189.493 \text{ mm} \approx 190 \text{ mm}$$

Provided eff. depth= 169 mm

Step 3: Calculation of load

(i) Load on going on the projected plan area

Live load = 3 × 1

$$= 3 \text{ KN / m}$$

Floor finish = 1.25 × 1

$$= 1.25 \text{KN / m}$$

$$\text{wt. of waist slab} = \text{Upsilon} \times D \times \sqrt{R^2 + T^2} / T$$

$$= 5.5394 \text{KN / m}$$

$$\text{wt. of steps} = \text{Upsilon} \times 0.5 \times R$$

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

$$\text{Total load } l = 11.66 \text{KN / m}$$

$$\text{Factored load} = 1.5 \times 11.66$$

$$= 17.497 \text{KN / m}$$

$$\text{Live load} = 3 \times 1$$

(i) Load on landing

$$\text{Floor finish} = 1.25 \times 1$$

$$= 3 \text{KN / m}$$

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

$$= 1.25 \text{KN / m}$$

$$= 4.75 \text{KN / m}$$

$$\text{Total Load} = 9 \text{KN / m}$$

$$\text{Factored load} = 1.5 \times 9 = 13.5 \text{KN / m}$$

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

Taking the moment of all forces about point B

$$R_a \times 5.0548 = \left[ (13.5 \times 1.1524 \times (1.1524/2 + 2.75 + 1.1524)) + (17.5 \times 2.75 \times (2.75/2 + 1.1524)) + (13.5 \times 1.1524 \times 1.1524/2) \right]$$

$$R_a \times 5.0548 = 200.247 \quad R_a = 39.62 \text{KN}$$

$$R_a + R_b (13.5 \times 1.1524) + (17.5 \times 2.75) + (13.5 \times 1.1524)$$

$$39.62 + R_b = 79.23 \quad R_b = 39.62 \text{KN}$$

$$V_{\text{max}} = \left[ 13.5 \times (1.1524 + 1.1524) + (17.5 \times 2.75) \right] / 2 = 39.62 \text{KN}$$

$$M_{max} = [13.5^2 \times 1.1524 \times \{(1.1524/2) + (2.75/2)\}] - [17.5^2 \times (2.75/2) \times (2.75/2 \times 2)] + [39.62 \times \{1.1524 + (2.75/2)\}]$$

$$= 53.23 \text{ KN-m}$$

Step 5: Check for depth against bending moment

$$M_{max} = 0.133 \times f_{ck} \times b \times d_{req}^2 \quad 53.23 \times 10^6 = 0.133 \times 20 \times 1000 \times d_{req}^2$$

$$d_{req} = 141.46 \text{ mm}$$

( $d_{req} < d_{prov}$ ).

Hence OK

Step 6: Designing the reinforcement

$$53.23 \times 10^6 = 0.87 \times 500 \times A_{st} \times 169 \times [1 - \{(500 \times A_{st}) / (20 \times 1000 \times 169)\}]$$

$$A_{st} = 824.642 \text{ mm}^2$$

( $A_{st}$ )<sub>min.</sub> = 0.12% of bD

$$= (0.12/100) \times 1000 \times 190 = 228 \text{ mm}^2$$

$$\text{Spacing} = [1000 / (824.64 / (3.142 \times 12^2 / 4))] = 137.147 \text{ mm} \approx 150 \text{ mm}$$

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

$$(A_{st})_{prov.} = [1000 / 150 / (3.142 \times 12^2 / 4)] = 753.982 \text{ mm}^2 \quad \% \text{ of steel prov.} = 0.45\%$$

Step 7: Check for shear force

For M20 concrete

$$\text{Shear strength } (T_c) = 0.280 \text{ N/mm}^2$$

IS 456:2000, Table-19

$$\tau_{max} = (39.62 \times 10^3) / (1000 \times 169) = 0.234 \text{ N/mm}^2 \text{ OK}$$

Step 8: Check for deflection

$$(L_{eff}/d)_{prov.} = 5054.8 / 169 = 29.91$$

Basic values

$$\text{Basic value: } (\alpha) = 20$$

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 factor  $\gamma$

Steel Stress of service load ( $t_s$ ) =  $0.58f_y$

$$= 0.58 \times 500 \times [(A_{st,reg.}) / (A_{st,provided})] = 317.177$$

$$(A_s / bd) \% = [753.982 / (1000 \times 169)] \times 100 \times 0.446$$

$$(\gamma) = 1.5$$

$$\text{Now, } \alpha \times \beta \times \gamma \times \delta \times \lambda = 20^{\wedge} \times 1^{\wedge} \times 1.5^{\wedge} \times 1^{\wedge} \times 1 = 30$$

$$(I / (d)) \leq \alpha \times \beta \times \chi \times \delta \times \lambda \text{ OK}$$

Step 9: Development length

$$L_d = \frac{\sigma_{s,eq}}{4 \times \sigma_{t,eq}} \times 0.87 \times d$$

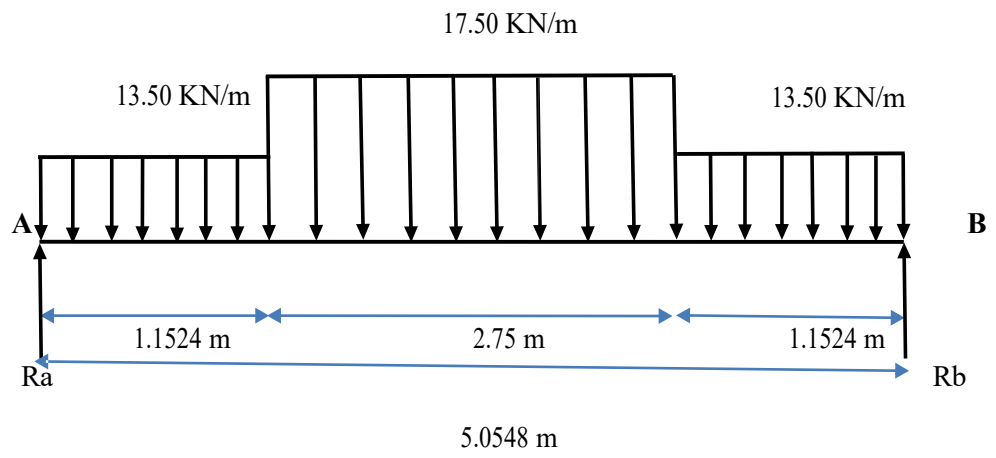
$$= (12^{\wedge} \times 0.87 \times 500) / (4^{\wedge} \times 1.2^{\wedge} \times 1.6) = 679.688 \text{ mm}$$

Step 10: Distribution bar reinforcement detailing

$$\text{Spacing} = \frac{1000^{\wedge} 228}{(3.142 / 4^{\wedge} \times 12^{\wedge} 2)}$$

$$= 496.041 \text{ mm} \leq 450 \text{ mm} \leq 845 \text{ mm} \text{ Spacing provided} = 250 \text{ mm}$$

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 AutoCAD for design and ETABS for structural analysis
CO2 (K7)	Work on a Team	Attendance	Collaborated effectively through regular meetings and task integration. Name: Zubaer Ahmed Zidan Student ID: 213-47-458 Name: Md. Faisal Siddik Piash Student ID: 213-47-462
CO3 (K7, P2, A2)	Alternative analysis presented	Economic and safety considered	Conducted alternative analysis, balancing cost and ethics.
CO4 (K7)	Benefit evaluation	Ethical obligation considered	Incorporated eco-friendly materials.
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
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	Manage project timelines and ensure timely completion
COs	Description	Criteria	Justification

CO8 (K7)	Communication	Drawing	Created precise technical drawings in A3 paper for clear demonstration of detailing.
		Presentation	Presented the visibility of the project by showcasing its innovative design and functionality.
		Report	<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 Septic tank</li> <li>vii Design of Overhead Tank</li> </ul>

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