Design and Analysis of a Two-storey Primary School Building Located at Changaon, LJN (Rural Area)

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A thesis submitted to the Department of Civil Engineering, Daffodil International University in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Civil Engineering

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November 2025

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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 head this humble attempt by bowing our head in submission to the Almighty Allah, the Most Gracious and the Most Merciful, whose bountiful blessings and mercy, and guidance, have helped us to carry out this capstone project successfully. This was all done only through His grace, which was a stage after stage of this work, beginning with the original idea and leading up to the final preparation.

We would also like to wish to thank our families. They have been our greatest strength because of their uncompromising support and motivation as well as constant encouragement. Their tolerance when we spend so much time studying, belief in our abilities, and prayers have kept us moving and positive whenever we are going through this academic process.

Another area that we wish to say a great thank you to the department of civil engineering, Daffodil International University, is the fact that it offers a vibrant academic atmosphere that keeps stimulating creativity and practical learning. This experience is very valuable as the department endeavors to give the students real-life design projects to help them relate the classroom theory to the engineering practice.

We would like to extend our warmest gratitude to **Mr. Kazi Obaidur Rahman,** Lecturer, Department of Civil Engineering for his guidance and insightful feedback on a regular basis and taking us through effective discussions. His mentorship has not been merely a technical management that he instructed us to do but a kind of systematic way of solving problems and be able to present our ideas in a positive manner. He showed such keen interest in our progress that we also worked with great diligence and accuracy.

We would also like to offer our gratefulness to all teachers of the Department of Civil Engineering who taught us the knowledge in many specific spheres of civil engineering that were the basis of this project. We would also like to acknowledge our classmates, friends, and laboratory assistants who helped us throughout the analysis and drafting processes by collaborating, making constructive ideas and suggestions, and cooperating with each other.

Lastly, we want to express our profound respect to the management and employees of Daffodil International University who were always willing to support us in terms of academic and technical facilities so that we were able to prepare this report in a successful manner.

ABSTRACT

This capstone project involves the comprehensive structural design and analysis of a two-storey reinforced concrete (RCC) primary school building located in the rural village of Changaon, LJN, Bangladesh. The project will incorporate the concepts of structural safety, architectural functionality and environmental sustainability as a single design solution. The main aim of this work is to come up with a safe, economical and environmental friendly educational building that can serve rural population in the site under climatic and geotechnical environments.

The building has ten classrooms with the capacity to seat forty students and other necessary functional spaces such as teachers room, headmasters office, common room and separate sanitary facilities to the male, female and teaching staff. Subsoil on the site has got a safe bearing capacity of 3500 psi hence suitable with shallow foundations. Because the location is in the Seismic Zone 2, which is established by Bangladesh National Building Code (BNBC 2020), the structural system has been designed with earthquake resilient characteristics.

The design process involves architectural and structural nature. AutoCAD has been employed in completing the architectural layout and dimensional planning but the detailed analysis of the structural analysis of beams, slabs, columns, and footings will be performed by using ETABS software. Microsoft Excel will be used in the cost estimation and construction planning, which will be accurate when it comes to resources management and budgeting.

In order to meet the environmental demands, the project will entail the designing of a septic tank system which is appropriate in rural waste management hence proper sanitation without the reliance of a central sewer system.

This project shows that the engineering principles can be successfully used to develop an infrastructure that is safe, economical and sustainable, which is the part of the work of civil engineers in the rural development. It also enhances our perception of the practical uses of BNBC 2020, structural modeling by means of ETABS, and detailed drawing with the help of AutoCAD which gives us a full bridge between theory and practice.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER-I

INTRODUCTION

1.1 Background and Project Overview

The project was developed to address the existing challenges and issues within the country of Oman, particularly within the city of Oman.

The need of quality education in rural Bangladesh is ever on the rise and demand of modern and safe school facilities that offer comfortable learning environment to children. Schools in most rural regions are either not properly designed or built without paying much concern to the building structure and sanitation. The current project adopts this gap by suggesting the design of a two storey primary school building in Changaon, LJN, which is a rural settlement with minimal education infrastructure.

The proposed building will strive to achieve not just the structural integrity, but also the functionality and sustainability. The proposed school will contain ten classrooms with each having forty students; the overall number of students will be four hundred. The plan will also provide the office of the headmaster, teachers room, common room and washrooms which will be separated as male, female and staff washrooms.

1.2 Basic Information of the Project

Table 1. 1 Basic Information about the project

Parameter	Description
Building Type	Educational (Primary School)
Structural System	RCC Beam-Column Frame (Intermediate Moment Resisting Frame)
No. of Storeys	Two
Location	Changaon, LJN – Rural Bangladesh
Seismic Zone	Zone 2 (as per BNBC 2020)
Soil Bearing Capacity	3500 psi
Foundation Type	Isolated Footings
Classroom Capacity	40 students per classroom
Total Number of Classrooms	10
Additional Facilities	Headmaster’s Room, Teachers’ Room, Common Room, Separate Wash Blocks

The building will be a reinforced concrete (RCC) frame building that will be supported on their own footing and will bear both the weight and lateral forces. The dimensions and height of the plan in totality have been drawn up with the help of AutoCAD with the basic concern of the proper use of space, natural lights, and ventilation as the necessary factors in the development of the healthy learning environment under the rural conditions.

Its structural design will be carried out based on the live load, dead load and seismic load combination as stipulated by BNBC 2020. The local construction practices and rural environment have also been put into consideration so as to make sure that the design is practical, affordable, and easily implemented using locally available materials.

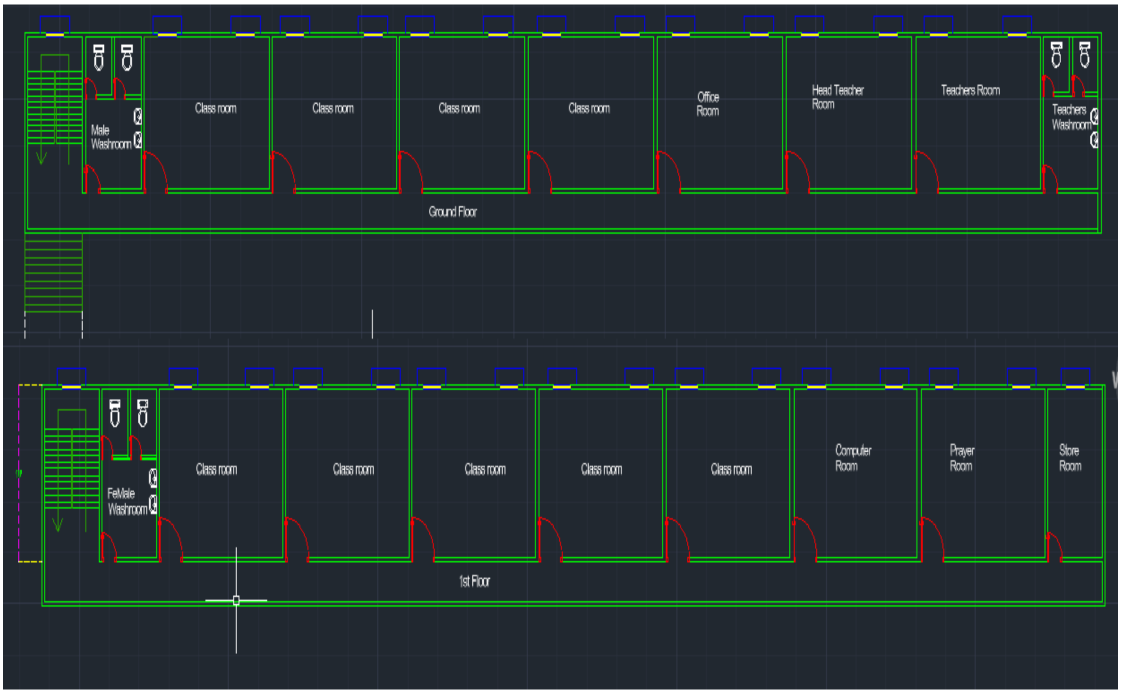

Figure 1. 1 The layout of Ground and first floor of the building

1.3 Design Objectives

The main objectives of this project are:

- To develop a structurally safe and functionally efficient primary school building that is appropriate for rural community needs.
- To conduct comprehensive structural analysis and design in accordance with BNBC 2020 and ACI 318-14 provisions.
- To incorporate environmental considerations into the design process, including sanitation infrastructure and the selection of sustainable construction materials..

1.4 Planning Guidelines and Design Considerations

To plan the system design, the following guidelines and design considerations will be employed.

1. The design is based on the Infrastructure Planning Guidelines on Primary Schools (DPE, 2018) and other applicable provisions in BNBC 2020. The main factors to be considered are:
2. At least half of the total area of the site will remain open to act as a playground and playing area.
3. The minimum internal size of each of the classrooms is 16 ft x 19 ft which is adequate to provide enough space on the floor, day light, and ventilation.
4. The building design will be in such a way that it can be expanded vertically in future in case the student population goes up.
5. Washrooms are separated to ensure hygiene and privacy among the students and the staff.
6. The stair width and corridor space are adequately provided to have ease of movement and because of emergency evacuations.
7. The system is to have a foundation system that has the 3500 psi bearing capacity of the site, and the superstructure is to have the Seismic Zone 2 loads, according to BNBC.
8. The building orientation is chosen in a way that it makes the building to be as much as possible natural-ventilated and day-lit to reduce the amount of energy consumed.

1.5 Scope and Limitations

The report currently submitted includes the architectural planning, principles of structural design and the cost estimation of the school building proposed. The sanitation layout and the design of the septic tank are the environmental element. This research is only up to the design phase, no physical construction or field test is involved.

Nevertheless, the results of the project can be utilized as a model of reference to other similar educational facilities that are located in the rural areas with similar geotechnical and climatic conditions.

1.6 Outline of the Report

Chapter 1: It gives the introduction, project background, objectives and design considerations.

Chapter 2: The chapter deals with the design codes, the material properties, and the general assumptions to be applied in the analysis.

Chapter 3: Contains the structural modeling, analysis and result of ETABS (to be filled later).

Chapter 4: Explains the cost estimation, bill of quantities and construction scheduling.

Chapter 5: Concentrates on the environmental issues like designing of septic tanks and sanitation planning.

Chapter 6: Concludes and gives recommendations on how to improve in future.

CHAPTER-II

DESIGN CODES AND STRUCTURAL REQUIREMENTS

2.1 Importance of Following Design Codes

Design codes in civil engineering are the basis of safe, durable and standard construction. In this project, the provisions presented in the Bangladesh National Building Code (BNBC 2020) are the required ones to provide structural integrity, the safety of people, and reliability. Adherence to standardized codes will give the building the capability to perform well, even in all the loads that are expected such as the gravity, wind, and seismic forces.

BNBC does not only specify the design loads and material strengths but also provides advice to the engineers in areas like detailing, minimum reinforcement, concrete cover and ductility requirements. Additionally, standards like ACI 318-14 and ASTM material standards are used to postulate design of concrete and material testing respectively which are international standards.

2.2 Applicable Codes and References

- BNBC 2020 - to design the structure in general, and to calculate load and seismic zoning.
- ACI 318-14 - design and detailing of reinforced concrete members.
- ASTM Standards - to test such materials as concrete and reinforcing steel.
- DPE Infrastructure Guidelines (2018) - in planning dimensions, layout and space requirements in primary schools.
- ACI Detailing Manual - to reinforcement anchorage details and lap splicing details.
- The qualities of the foundation and soil are described here.

2.3 Foundation and Soil Characteristics

The location of LJN site at Changaon is made up of moderately dense sandy soil with a safe bearing capacity of 3500 psi. This is what qualifies it to be used in a shallow foundation, like isolated footings. The depth of foundation and the reinforcement will be determined according to the output of the ETABS load and soil parameters.

Key assumptions include:

- Type of foundation: Isolated footings between isolated columns.
- Clear cover at least: 3 inches to reinforcement bars.

- Concrete Strength Foundation (f'c): 5000 psi.
- Settlement Criteria: Within BNBC limits in order to prevent differential settlement.
- Soil Bearing Safety Factor: According to BNBC, it is 2.5 to 3.0.

2.4 Material Strengths

Table 2. 1 Table for Materials Strengths

Structural Member	Concrete Compressive Strength (f′c)	Reinforcing Steel Yield Strength (fy)
Footing	5000 psi	60,000 psi
Columns	5000 psi	60,000 psi
Beams	5000 psi	60,000 psi
Slabs	4000 psi	60,000 psi
Staircase	4000 psi	60,000 psi

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

2.5 Lap Length and Development Length

Lap splices and development lengths are essential for maintaining the continuity of reinforcing steel. According to BNBC 2020:

Lap Length (Tension Zone): 40 × bar diameter (40D).

Lap Length (Compression Zone): 30 × D.

Development Length (Ld): $L_d = \frac{\phi f_y}{4\tau_b}$, where ϕ is the bar diameter, fy is the yield stress, and τ_b is the design bond stress.

All column laps are located within tension zones to ensure proper stress transfer.

2.6 Concrete Cover

Concrete cover provides protection to steel reinforcement from corrosion, fire, and environmental effects.

Table 2. 2 Concrete Cover

Member	Exposure Condition	Required Clear Cover
Column	In soil contact – 2.5 in; Elsewhere – 1.5 in	
Beam	Top, side, and bottom faces – 1.5 in	
Slab	Bottom – 1.0 in; Top – 0.75 in	
Staircase	Uniform cover – 0.75 in	

2.7 Design Approach

The structure will be analyzed using ETABS through a 3D finite element model representing all structural components — columns, beams, slabs, and footings. Loads will include:

- Dead load (self-weight of structural and non-structural components)
- Live load (occupancy and movable loads)
- Floor finish load
- Wind load (if applicable)
- Seismic load based on Zone 2 parameters from BNBC 2020

Load combinations will follow BNBC provisions to ensure both strength and serviceability requirements are satisfied.

2.6 Summary of the Chapter

This chapter came up with the basic parameters and assumptions that will be used in the detailed design process. The structures of the project will be based on the BNBC 2020 compliance; the material strengths will include f'c = 4000-5000 psi and fy = 60000 psi. The bearing capacity of soil of 3500 psi proves that isolated footings provide sufficient bearing capacity of the foundation system. Further chapters will elaborate on analysis findings, dimensions of design, cost estimation and environmental facilities, and make up a total engineering report of the Changaon LJN Primary School Building.

CHAPTER-III

Structural Analysis and Output

3.1 General

Structural analysis of a building has become one of the most important aspects of the building design process, as it provides safety, stability, and durability of the structure at different loads. Primary School Building at Changaon, LJN is a two-storied (G +1) building and was analyzed and designed in ETABS software according to the Bangladesh National Building Code (BNBC 2020).

This analysis was done to ensure that the sufficient strength of each structural component such as beams, columns, slabs, footings, and staircases was checked with gravity and lateral loads. ETABS was selected due to the combination of modeling features, accurate work with load combinations, and production of reinforcement information based on codes.

The height of the ground floor was taken to be 12 feet and the first floor height was taken to be 10 feet in the case of this project. Both Grade-3000 psi concrete and reinforcement steel Grade-60 were used to model the building. The building is situated in a rural setting of moderate seismicity (BNBC Seismic Zone 2) and the buildings soil bearing capacity at the site was approximated as 3500 psi with regards to the local soil conditions. The seismic importance factor (I) was considered 1.0, response reduction factor (R) 5, and soil type (S3) according to the classification of BNBC 2020.

Fig. 3.1 represents the frame configuration, member sizes and geometry of the building in the ETABS model. Bay spacing was based on the architectural layout in AutoCAD and this was used to develop the model. The model was then meshed and an analysis carried out at each combination of loads of interest after defining material properties and section dimensions.

3.2 Model Configuration in ETABS

The building model is a two-story (G +1) building with an overall height of 22 ft -12 ft at the ground level and 10 ft on the first level. The structural system comprises of reinforced-concrete moment-resisting frames laid on the two major axes.

Fig. 3.1 indicates that the plan has eight longitudinal bays with an average length of 22.2 ft and three transverse longitudinal bays with an approximate length of 16 ft. The distribution of columns is even, to guarantee uniform transfer of loads and to reduce the eccentricity.

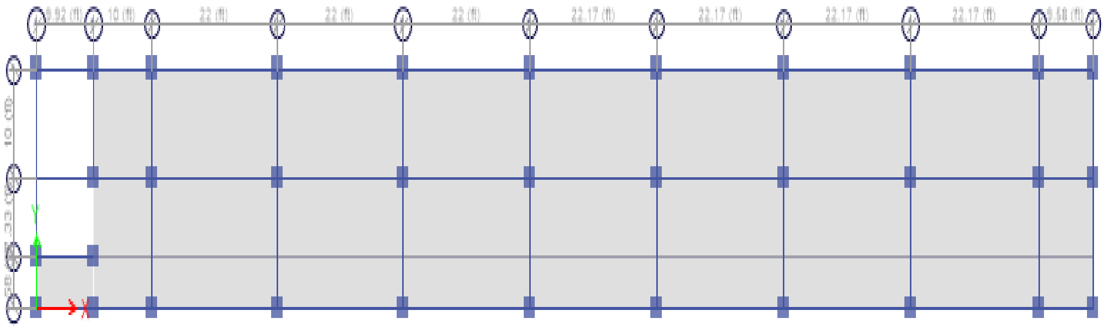

Figure 3. 1 ETABS Plan View Showing Structural Grid and Bay Spacing

Material Properties

- Concrete compressive strength (f′c): 3000 psi
- Reinforcing-steel yield strength (fy): Grade 60 = 60,000 psi
- Modulus of elasticity (Ec): 57,000 √(f′c) ≈ 3.1 × 10^6 psi
- Steel modulus (Es): 29 × 10^6 psi
- High-strength Grade 60 bars were selected for their superior ductility and corrosion resistance, making them suitable for humid rural environments.

Member Sizes

- Beams: 12 in × 18 in
- Columns: 18 in × 18 in
- Slabs: 6 in thick
- Stair waist slab: 6 in thick
- Isolated footings: square type, dimensions varying per column load (typically 5 ft × 5 ft to 9 ft × 9 ft)

Soil and Foundation

The calculated local data of the sub-soil bearing capacity is about 3500 psi, which is sufficient to use in shallow isolated footings. The building is built on medium-dense silty clay (BNBC soil type S3).

3.2.1 Load Consideration

The load definition in a building is critical in determining the structural performance of a building. The overall load on a building is generally as dead load, live load and lateral load (wind and earthquake).

All the loads in this work were distributed based on the recommendations of BNBC 2020 of educational buildings with minor modifications to reflect the real life circumstances in a rural primary school.

a) Dead Load

Dead load is the weight of structural elements including slabs, beams, columns and walls together with permanent finishes such as plaster and floor topping. When there are density values, ETABS automatically calculates the self-weight of the structural members.

Other fixed loads like floor finishing and ceiling plaster were added manually at 1.2 kN/m2 ≈ 25 psf). There was an application of brick wall loads which were 4.5 kN/m (≈300 plf) along beam lines.

b) Live Load

Live loads should be considered as the weight of people, furniture and portable items. According to BNBC 2020, the typical live load in classrooms of educational buildings is 3.0 kN/m 2 ([?] 62 psf), and the live load in corridors and staircases is 4.0 kN/m 2 (≈ 84 psf) because of higher occupancy. Roof live load was decreased to 1.0 kN/m2 (≈ 21 psf), with a restricted access.

c) Seismic Load

The position of the building in the Seismic Zone 2 is a medium-risk in terms of earthquakes. The following parameters of seismic were defined in ETABS:

Zone coefficient (Z): 0.15

Importance factor (I): 1.0

Response reduction factor (R): 5.0

Soil type: S3 (medium stiff)

ETABS automatically developed lateral loads both on the X and Y directions using the equivalent static method.

The load patterns within this model have been developed as follows-

Table 3. 1 Load pattern

Load	Type
Dead	Dead
Live	Live
Roof live	Live
PW	Super dead
FF	Super dead
Ex	Seismic
Ey	Seismic
Wx	Wind
Wy	Wind
N.B. PW= Partition Wall, FF= Floor Finish, Ex= Earthquake load X direction, Ey= Earthquake load Y direction, Wx=Wind load X direction, Wy= Wind load Y direction	

d) Load Combinations

The load combinations were developed based on BNBC 2020 to be safe under various loading conditions. Some of these combinations are as follows:In this model, the following vertical loads are to be applied by the BNBC 2020 standards (BNBC, 2020): Live Load (LL) of 42 psf, Roof Live Load of 61 psf, Balcony Live Load of 61 psf, Floor Finish (FF) of 35 psf, and Partition Wall (PW) of 50 psf.

The following load combination has been developed in this model-

Table 3. 2 Load combination

0.9D – 1.6Wx	1.2D – 0.8Wx	1.29D + L + Ex + 0.3Ey
0.9D + 1.6Wx	1.2D + 0.8Wx	1.29D + L + Ey – 0.3Ex
0.9D – 1.6Wy	1.2D – 0.8Wy	1.29D + L + Ey + 0.3Ex
0.9D + 1.6Wy	1.2D + 0.8Wy	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 – 1.6Wx	D + 0.5L – 0.7Wx
0.81D + Ey – 0.3Ex	1.2D + L + 1.6Wx	D + 0.5L + 0.7Wx
0.81D + Ey + 0.3Ex	1.2D + L – 1.6Wy	D + 0.5L – 0.7Wy
0.81D – Ey – 0.3Ex	1.2D + L + 1.6Wy	D + 0.5L + 0.7Wx
0.81D – Ey + 0.3Ex	1.29D + L + Ex – 0.3Ey	–
N.B. D= Dead load, L= Live load, Ex= Earthquake load X direction, Ey= Earthquake load Y direction, Wx= Wind load X direction, Wy= Wind load Y direction		

3.3 Design of Slab and Detailing

It was assumed that the floor slabs were membrane elements with the same thickness of 6 inches (150 mm). Grade 3000 psi was utilized as the concrete and Grade 60 was used as steel reinforcement which was modeled.

Bending moments, shear forces and deflection of the slabs were studied. ETABS is based on finite element analysis (FEA) to calculate the internal stress distribution which is a more precise measurement as compared to manual approach.

The maximum slab deflection read in the analysis was less than L/240 which is more than what is needed in the BNBC serviceability requirement. The best and worst reinforcement details were taken to AutoCAD to prepare the drawing.

The slab was normally reinforced as follows:

- Top reinforcement: #4 bars @ 8 in c/c both directions
- Bottom reinforcement: #4 bars @ 8 in c/c both directions

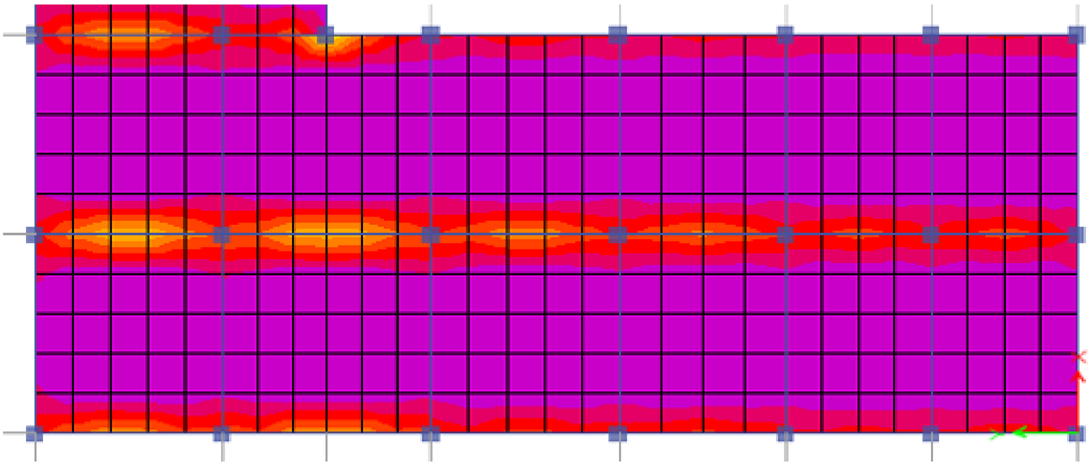

Figure 3. 2 Finite Element Mesh of Slab in ETABS

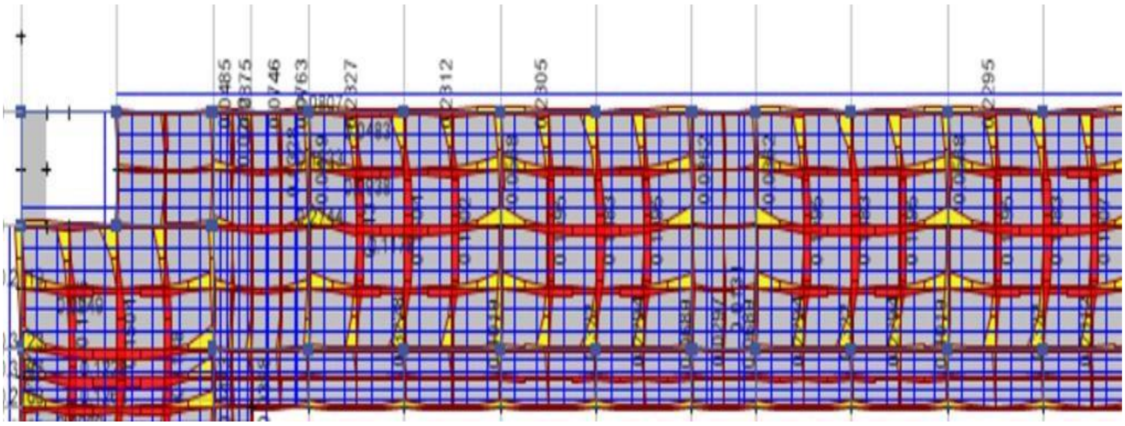

Figure 3. 3 Slab Top and Bottom Reinforcement Layout

3.4 Design of Beams and Detailing

The section size of all the beams in the model was set to 12 in x 18 in. The slab loads are transferred to the beams, which in turn transfer the weight to the columns. ETABS automatically calculates the bending moment, shear and torsional forces of every beam element in the specified combinations of loads.

The analysis resulted in a peak bending moment in the beams of 49 kip-ft and the limit of shear was not exceeded. These results were used to determine the reinforcement necessary in the program, and the design was made to meet the requirements of the both strength and serviceability.

Typical reinforcement provided:

Table 3. 3 Beam Reinforcement Details

Beam ID	Size (in)	Bottom Bars	Top Bars	Stirrups
B1	12″×18″	3# 16mm	2# 20mm	10mm @ 6″ c/c
B2	12″×18″	3# 20mm	3# 16mm	10mm @ 8″ c/c
B3	12″×18″	2# 20mm	2# 16mm	10mm @ 8″ c/c
B4	12″×18″	3# 20mm	2# 16mm	10mm @ 6″ c/c

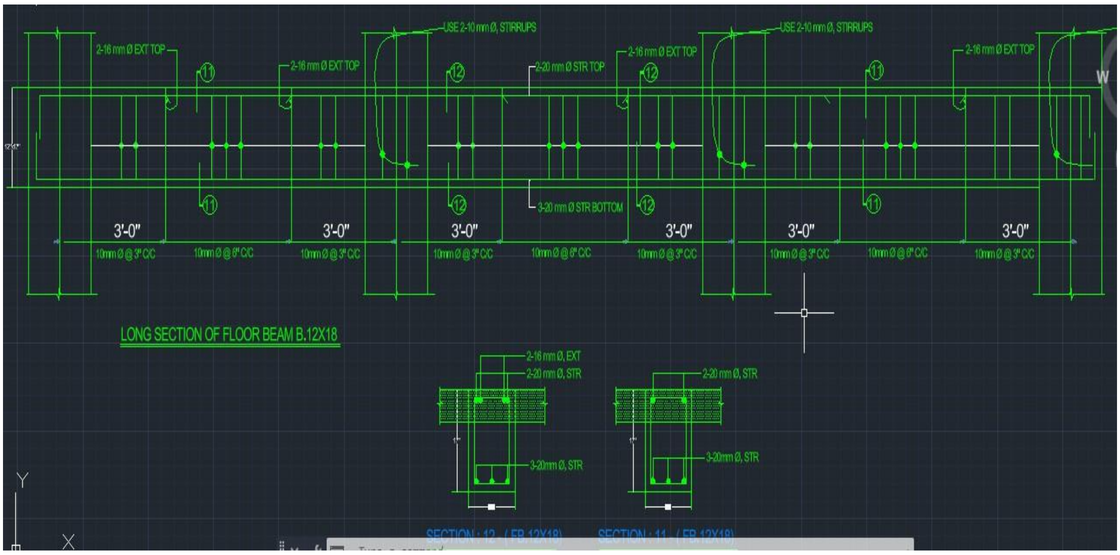

Figure 3. 4 Longitudinal Reinforcement of Beam

3.5 Design of Columns and Detailing

Columns were to be made 18 in x 18 in square, and reinforced by combined bending moment and axial load. The peak axial load in ETABS was 321kip, which falls within the safe load bearing capacity of the chosen column size and reinforcement.

All columns had an interaction ratio of below 1.0 which verified that they are structurally acceptable.
The designed columns all meet the BNBC 2020 requirements regarding strength and slenderness. The reinforcement ratio was kept to 1-3, which gave good ductility.

Typical Column Reinforcement:

Table 3. 4 Column Reinforcement Details

Column ID	Size (in)	Main Bars	Lateral Ties
C1–C8	18″×18″	8# 20mm dia	10mm @ 5″/10″ c/c
C9–C16	18″×18″	8# 16mm dia	10mm @ 6″ c/c
C17–C24	18″×18″	8# 20mm dia	10mm @ 6″ c/c

All designed columns satisfy BNBC 2020 requirements for strength and slenderness. The reinforcement ratio remained within 1–3%, ensuring good ductility.

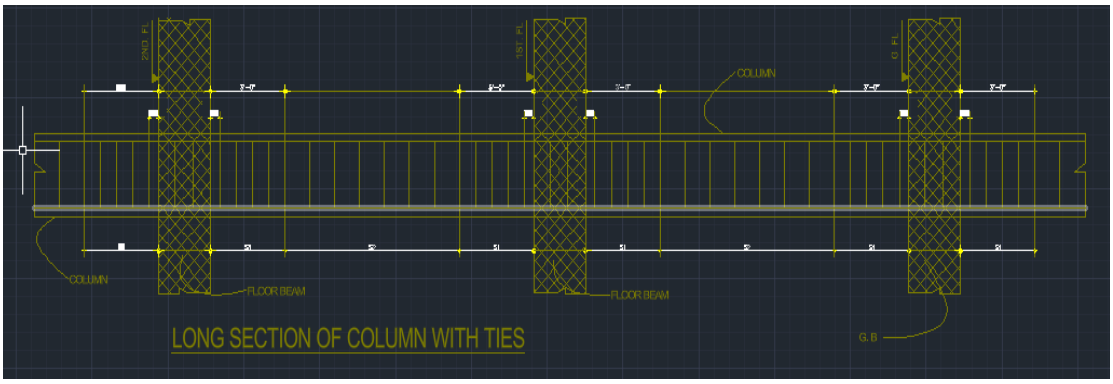

Figure 3. 5 Column Reinforcement Detailing

Figure 3. 6 Column Layout

3.6 Design of Foundation and Detailing

The supporting structure was isolated footing which was planned on column load and acceptable soil bearing capacity of 3500 psi. ETABS also determined the sizes needed in the footings to be used to make sure the soil pressure beneath each footing was not too high.

hear and punched shear check ensured that all footings are structurally sound with settlement within authorised limits.

Typical Footing Details:

Footing size: 7 ft × 7 ft × 1.5 ft thick

Concrete grade: 3000 psi

Reinforcement: #6 bars @ 8 in c/c both ways

Table 3. 5 Footing Summary

Footing ID	Column Load (kips)	Footing Size (ft)	Thickness (in)	Reinforcement (Top & Bottom)
F1	189	10′×10′	15″	#8 @ 10″ c/c
F2	150	8′×8′	13″	#8 @ 11″ c/c
F3	120	7′×7′	13″	#8 @ 12″ c/c
F4	95	6′×6′	11.5″	#8 @ 13″ c/c

Shear and punching shear checks confirmed that all footings are structurally adequate and settlement remains within permissible limits.

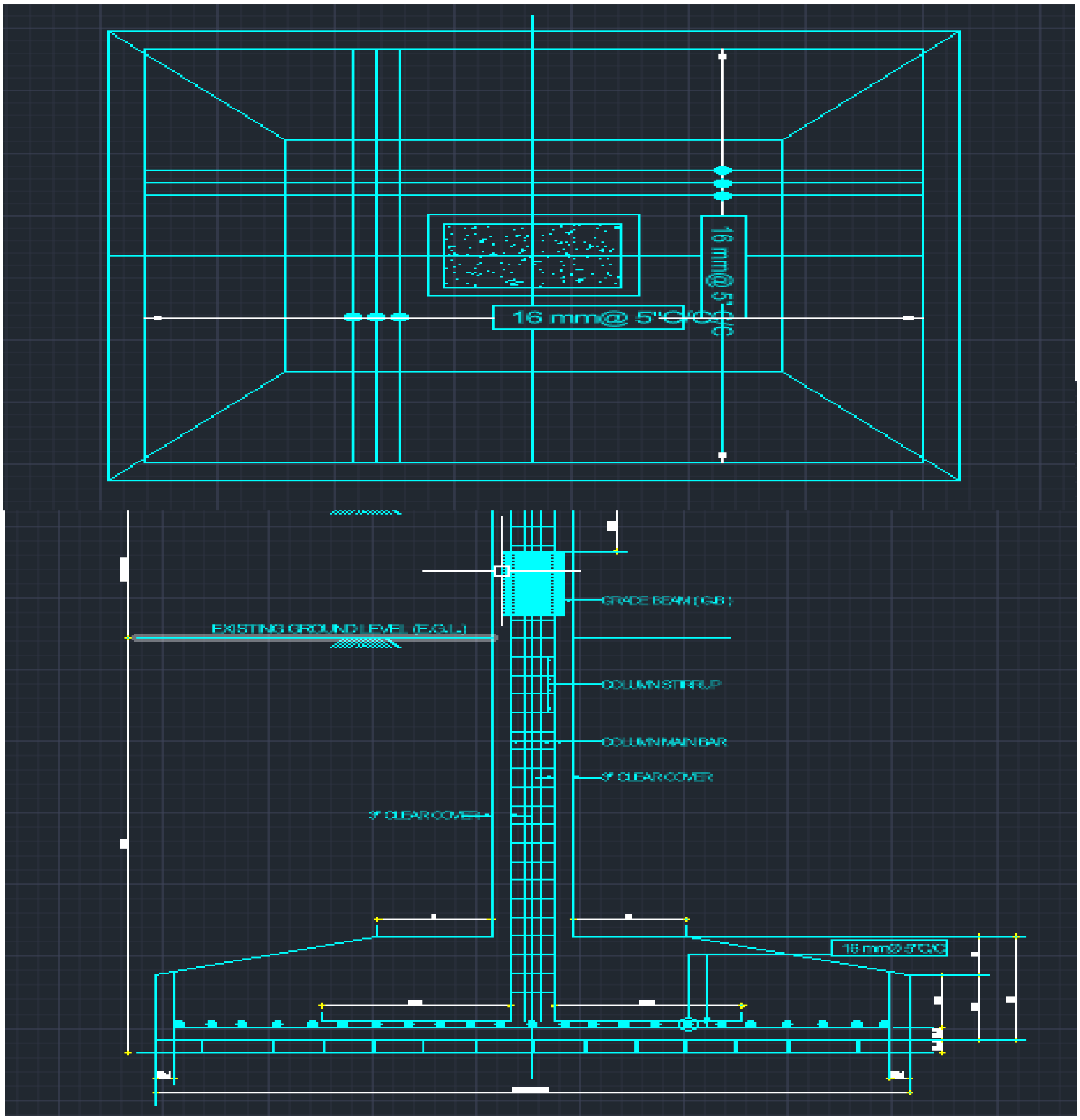

Figure 3. 7 Footing Layout and Reinforcement

3.7 Design of Staircase

The staircase was to be the model which is composed of the combination of slab and beam elements, the dead as well as the live weights. The takeoffs and crests were calculated at 6.5 in and 11 in respectively which made it a comfortable slope.

The analysis by ETABS established that the stair slab thickness of 6 inches is sufficient to meet the deflection and the strength requirement.

The reinforcement design has been made sure that it is easy to maintain and comfortable to the user as well as satisfying the geometry proportions that are suggested as applicable to the public buildings.

Reinforcement Details:

Main bars: #4 @ 6 in c/c (longitudinal)

Distribution bars: #3 @ 8 in c/c (transverse)

The reinforcement layout ensures serviceability and comfort for users, while meeting the geometric proportions recommended for public buildings.

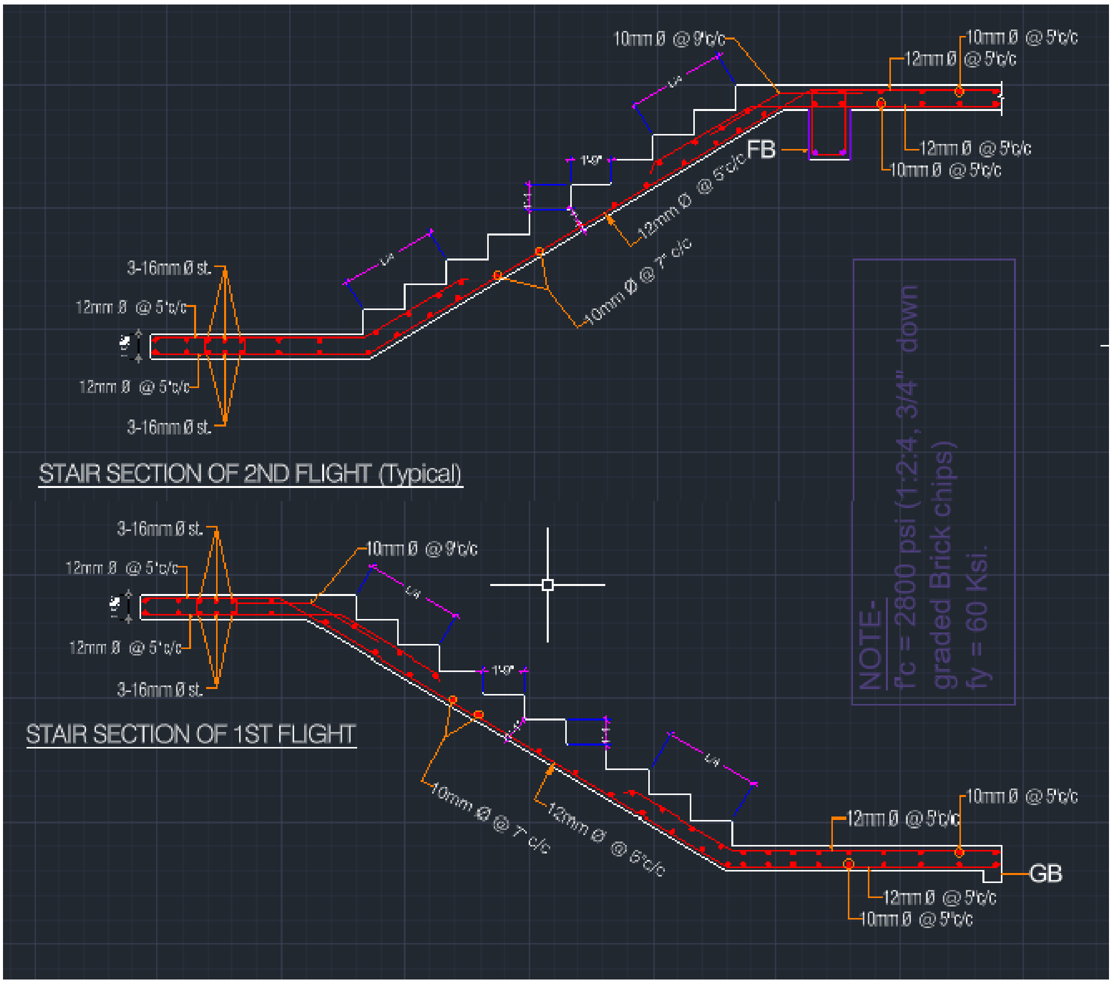

Figure 3. 8 Staircase Reinforcement Detailing

3.8 Structural Output Summary

The obtained results of ETABS were verified against permissible code limits and were satisfactory.

Maximum Storey Displacement: 0.48 in (in limit of H/500 [?] 0.7 in)

Highest Storey Drift Ratio 0.0024 (below a figure of 0.004 defined in BNBC)

Base Shear: X 277 kips, Y 220 kips (adequate lateral stability)

Maximum Bending Moment in Beam: -49 kip-ft.

Columnaxeial Maximum Load: 321 kips

The strength and serviceability of the structural members are all met. There was no observed excessive deflection or drift and this implies that the structure was stable and ductile thus able to sustain the design loads safely.

3.9 Discussion

The analysis of the ETABS confirmed that the selected member sizes, ratios of reinforcements, and the material will give a structurally efficient design. The gravity and lateral loads behaviour of the building was within the acceptable range.

Using the combination of ETABS analysis and AutoCAD detailing, all the processes became systematic and reliable. The detailing drawings also give the clear representation of each part slab of the beam, column, footing and will be connected with each other and hence a practical and constructable design.

3.10 Conclusion

As shown in the structural analysis of the two-storied main school building at Changaon, it is revealed that the design meets all the safety and serviceability requirements as requested by BNBC 2020. These three factors create a realistic material behavior, adequate sizing of the members, and effective reinforcement pattern that leads to a balanced design that is stable and economical at the same time.

The results of the ETABS proved that the maximum displacement, the ratio of drifts and the base shear of the structure was in an acceptable range revealing the resilience of the structure in face of gravity and seismic loads.

All in all, the analysis provides a good basis of the subsequent project implementation processes, such as cost estimation details and construction schedule.

CHAPTER-IV

DESIGN AND CONSIDERATION OF SEPTIC TANK AND OVERHEAD TANK

4.1 General

Any educational building must have the right sanitation systems as well as water storage that will guarantee hygiene, health and easy running. In the case of Two-Storied (G+1) Primary School Building at Changaon, LJN, two utility elements of significance were developed a septic tank that would treat the waste water and an overhead water tank that would provide water on a constant basis.

Both systems have been designed on the basis of the Bangladesh National Building Code (BNBC 2020) and practical design criteria applicable to the Dhaka area, which are the population density, groundwater table, and the general environmental conditions. The septic tank supplies onsite treatment of the wastewater where no sewer network is provided and the overhead tank ensures that water is available to use daily.

The two buildings are suggested in Reinforced Cement Concrete (RCC) so as to provide durability and strength. The overhead tank will be installed on another height elevation outside the roofline, such that the weight of the tank does not exert any direct pressure to the main building frame.

4.2 Design of Septic Tank

4.2.1 Design Considerations

According to BNBC 2020 (Part 9, Section 9.3.7.1) and related environmental guidelines, septic tank design depends on:

- Number of users,
- Average wastewater generation per capita,
- Retention time,
- Sludge accumulation rate, and
- Cleaning interval (usually once every 2 years).

For schools and educational institutions, the wastewater generation is assumed as 45 liters per person per day (BNBC Table 9.3.2).

Since the septic tank should store 3-day retention volume, this factor is multiplied accordingly.

4.2.2 Basic Data

Table 4. 1 Basic Data for septic tank

Parameter	Symbol	Value
Number of students	N_1	400
Number of staff	N_2	25
Total users	N	425 persons
Wastewater generation	q	45 L/person/day
Retention period	t	3 days
Sludge storage (2 years)	S	0.04 m^3/person/year

4.2.3 Total Sewage Volume

$$V_s = N \times q \times t$$
$$V_s = 425 \times 45 \times 3 = 57{,}375 \text{ liters} = 57.38 \text{ m}^3$$

4.2.4 Sludge Storage Volume

$$V_{sludge} = N \times 0.04 \times 2 = 425 \times 0.08 = 34 \text{ m}^3$$

4.2.5 Total Tank Capacity

$$V_{total} = V_s + V_{sludge} = 57.38 + 34 = 91.38 \text{ m}^3$$

4.2.6 Dimensions of Septic Tank

The septic tank is designed as a two-chamber rectangular RCC tank with length:width:depth = 3:1:1.2 (BNBC recommended proportion).

Let width = 2.0 m
Then,

$$Length = 3 \times 2.0 = 6.0 \text{ m}$$
$$Depth = 1.2 \times 2.0 = 2.4 \text{ m}$$

Gross capacity:

$$V = L \times B \times D = 6 \times 2 \times 2.4 = 28.8 \text{ m}^3$$

This single tank serves about 130–140 users, so for 425 users:

$$\frac{425}{140} \approx 3.0$$

Hence, three identical septic tanks (each 6 m × 2 m × 2.4 m) are required in parallel connection.

Each tank will include:

- Inlet chamber with baffle wall,
- Two compartments separated by partition wall,
- Inspection manholes (450 mm × 450 mm),
- Vent pipe (minimum 100 mm diameter, 2.5 m high above ground).

4.2.7 Structural and Construction Details

- Material: Reinforced Cement Concrete (RCC), M20 (fc′ = 3000 psi).
- Slab thickness: 150 mm bottom and 120 mm top.
- Reinforcement:
  - Bottom slab: #4 @ 6" c/c both ways,
  - Side walls: #4 @ 8" c/c vertically and horizontally,
  - Top slab: #4 @ 8" c/c both ways.
- Waterproofing: One coat of bituminous paint on both inside and outside surfaces.
- Access: RCC cover slab with cast iron manhole lids for maintenance.

4.2.8 Hydraulic Features

- Inlet and outlet difference: 75 mm
- Freeboard: 300 mm
- Ventilation: 100 mm PVC vent pipe with fly mesh cover
- Retention period achieved: ≈ 3 days

- Desludging interval: ≈ every 2 years

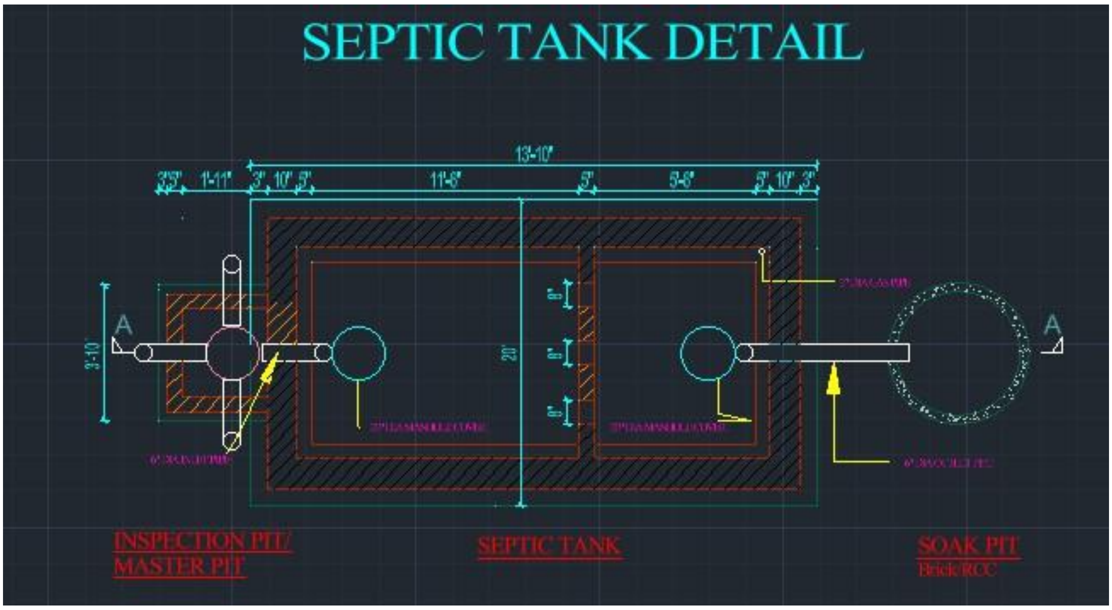

Figure 4. 1 Septic Tank Details

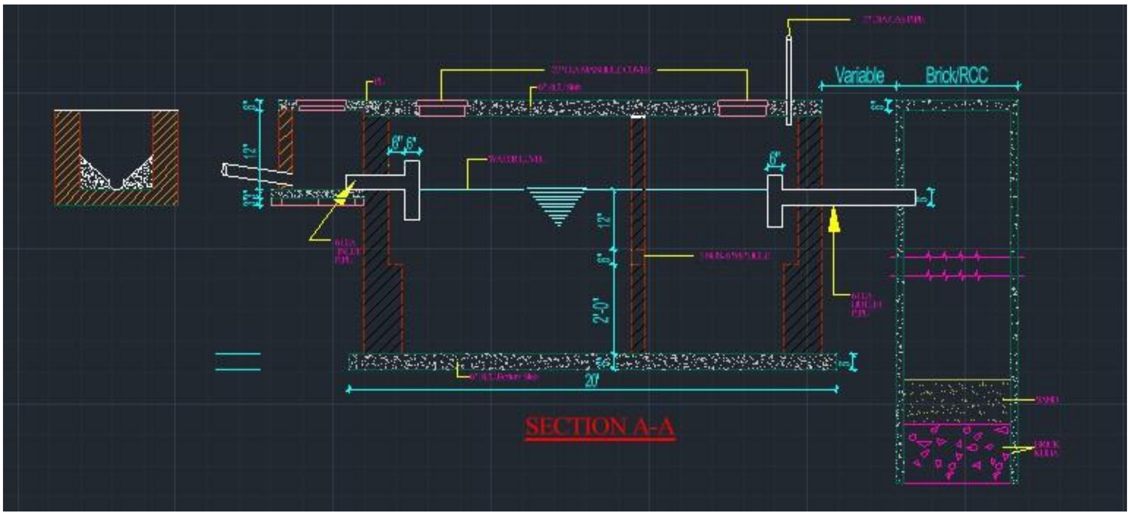

Figure 4. 2 Septic Tank Design Section View

4.3 Design of Overhead Tank

4.3.1 Design Considerations

The overhead tank is designed to store sufficient water for domestic use, flushing, cleaning, and other operational requirements of the school. The design follows BNBC 2020 water demand standards for schools:

Table 4. 2 Design Considerations for Overhead Tank

Type of Use	**Water Demand (L/person/day)**
Students and Staff	45
Cleaning and Miscellaneous	10% additional

Hence, $q_{total} = 45 + 0.10 \times 45 = 49.5$ L/person/day

4.3.2 Daily Water Requirement

$$Q = N \times q_{total} = 425 \times 49.5 = 21{,}037.5 \text{ L/day} \approx 21.04 \text{ m}^3\text{/day}$$

To ensure 1.5 days' reserve capacity: $V = 21.04 \times 1.5 = 31.56$ m³

Thus, Overhead tank capacity = 32 m³ (≈ 32,000 liters)

4.3.3 Tank Configuration

- Shape: Circular RCC tank (economical and durable)
- Tank capacity: 32 m³
- Height of staging: 25 ft (7.5 m) from roof level
- Support type: Four RCC columns with circular ring beam and bracing
- Tank diameter: 4.5 m
- Tank wall height: 2.0 m

$$V = \pi r^2 h = 3.1416 \times (2.25)^2 \times 2.0 = 31.8 \text{ m}^3$$

which satisfies design capacity.

4.3.4 Structural Design Parameters

Table 4. 3 Structural Design Parameters for overhead tank

Component	Design Details
Material	RCC (fc′ = 3000 psi), Reinforcement fy = 60,000 psi
Wall thickness	150 mm
Base slab thickness	200 mm
Top slab thickness	125 mm
Ring beam size	12 in × 18 in
Support columns	12 in × 12 in (4 nos.)
Bracings	9 in × 12 in @ 6 ft spacing
Ladder and railing	MS steel, painted anti-corrosive coating
Foundation	Isolated footings 6 ft × 6 ft × 1.5 ft

4.3.5 Water Load and Total Weight

Total water weight:

$$W_{water} = 32 \text{ m}^3 \times 9.81 \text{ kN/m}^3 = 314 \text{ kN}$$

Self-weight of RCC tank:

$$W_{tank} \approx 0.25 \times 314 = 78.5 \text{ kN}$$

Total = 314 + 78.5 = 392.5 kN (≈ 88,200 lb)

This load is distributed through columns to foundations, and load combinations are verified in ETABS to ensure that the main building remains unaffected since the tank rests on an independent support frame.

4.3.6 Reinforcement Details

- Tank wall: #4 @ 6 in c/c vertically and horizontally
- Base slab: #5 @ 8 in c/c both ways
- Top slab: #4 @ 8 in c/c both ways
- Column reinforcement: 4#16 mm bars with 10 mm ties @ 8 in c/c

4.4 Maintenance and Operational Considerations

Both tanks are designed not only for structural safety but also for long-term functionality.

- Septic tank must be desludged every 18–24 months.
- Overhead tank should be cleaned once every six months to prevent algae growth.
- The RCC surfaces must be coated with non-toxic waterproofing to prevent seepage.
- Valves and vent pipes should be checked periodically for proper operation.

4.5 Summary

The Changaon LJN Primary School has the septic and overhead tanks that offer effective waste water treatment systems as well as water storage.

- The septic system, divided into three interconnected RCC chambers, safely manages 425 users' wastewater with adequate retention and sludge storage.
- The overhead tank ensures uninterrupted water supply for sanitation, cleaning, and other uses.

The designs of both systems comply with the BNBC 2020 requirements and structurally fit the main building.

These designs strike a balance between functionality, cost efficiency and sustainability through careful attention to materials, capacity and layout that mean that the facility will be operational and hygienic over many years.

CHAPTER-V

COST ESTIMATION AND GANTT CHART

5.1 General

One of the most critical phases in any construction project is having a proper cost estimation since it defines the financial viability, the material that is required as well as the strategy of planning the project. In the proposed two-storied (G+1) primary school building at Changaon, LJN, the estimation has been done using a detailed Bill of Quantities (BOQ). This BOQ gives a full detail of all the major structural and finishing elements such as footings, columns, beams, slabs, staircases, brickwork and surface finishing.

Effective estimation will provide a guarantee that there will be enough money to cover every stage of the construction, as well as reduce wastage of materials and assist in keeping the timeline. All the construction activities had been considered individually to identify the quantity of the materials required including cement, sand, coarse aggregates, reinforcement steel, and bricks. The rates that were considered in this estimation were the contemporary prices of local markets of high quality materials in the year 2025.

The labor cost has been computed based on the mason rate of 800 BDT per day and the general laborer rate of 600 BDT per day rate, which is in accordance with the local rates of labor in rural projects. As this is a permanent institutional building, which is going to be used over a long period of time, only the best grade materials were chosen to make it structurally sound and durable.

The project covers about 8,080 sq.ft (4,040 sq.ft per floor) of floor area. All cost items were calculated with realistic data on material consumption and checked with the common rates of production.

5.2 Cost Estimation of Structural Elements

5.2.1 Reinforced Concrete Columns

Columns are the primary vertical load-bearing members of the structure. Their cost includes concrete, reinforcement, and formwork. The BOQ for all RC columns was prepared based on design dimensions and reinforcement details from ETABS analysis.

Table 5. 1 RC Columns – Material Summary

Item	Quantity	Unit	Rate (BDT)	Total Cost (BDT)
Cement	520 bags	550/bag	286,000	
Sand	920 cft	55/cft	50,600	
Stone Chips	1,840 cft	230/cft	423,200	
Reinforcement	22,500 kg	95,000/ton	2,137,500	
Total				**2,897,300**

5.2.2 Reinforced Concrete Beams

The beams carry loads from slabs and transfer them to the columns. For this project, the beam section size is 12 in × 18 in with Grade 60 steel. The following table summarizes beam quantities and costs.

Table 5. 2 RC Beams – Material Summary

Item	Quantity	Unit	Rate (BDT)	Total Cost (BDT)
Cement	1,900 bags	550/bag	1,045,000	
Sand	3,580 cft	55/cft	196,900	
Stone Chips	7,160 cft	230/cft	1,646,000	
Reinforcement	48,500 kg	95,000/ton	4,607,500	
Total				**7,495,400**

5.2.3 Slab

Slabs are designed as 6-inch thick RC members spanning between beams. The following cost includes concrete, steel reinforcement, and shuttering.

Table 5. 3 Slab – Material Summary

Item	Quantity	Unit	Rate (BDT)	Total Cost (BDT)
Cement	510 bags	550/bag	280,500	
Sand	940 cft	55/cft	51,700	
Stone Chips	1,880 cft	230/cft	432,400	
Reinforcement	6,400 kg	95,000/ton	608,000	
Total				**1,372,600**

5.2.4 Footing

The building uses isolated footings with a soil bearing capacity of 3,500 psi. The following estimation is based on footing design output from ETABS.

Table 5. 4 Footing – Material Summary

Item	Quantity	Unit	Rate (BDT)	Total Cost (BDT)
Cement	680 bags	550/bag	374,000	
Sand	1,300 cft	55/cft	71,500	
Stone Chips	2,600 cft	230/cft	598,000	
Brick Soling	24,000 pcs	14/piece	336,000	
Reinforcement	6,000 kg	95,000/ton	570,000	
Total				**1,949,500**

5.2.5 Staircase

The staircase connects the two floors and is designed as an RC structure with moderate reinforcement.

Table 5. 5 Staircase – Material Summary

Item	Quantity	Unit	Rate (BDT)	Total Cost (BDT)
Cement	28 bags	550/bag	15,400	
Sand	60 cft	55/cft	3,300	
Stone Chips	120 cft	230/cft	27,600	
Reinforcement	320 kg	95,000/ton	30,400	
Total				**76,700**

5.2.6 Brickwork

All external and internal walls are made of first-class bricks with cement-sand mortar (1:6).

Table 5. 6 Brickwork – Material Summary

Item	Quantity	Unit	Rate (BDT)	Total Cost (BDT)
Brick	50,000 pcs	14/piece	700,000	
Cement	230 bags	550/bag	126,500	
Sand	1,150 cft	55/cft	63,250	
Total				**889,750**

5.2.7 Finishing Works

This section includes plastering, flooring, painting, door-window installation, and electrical & plumbing fixtures.

Table 5. 7 Finishing Works – Material & Labor Cost

Item	Quantity	Unit	Rate (BDT)	Total Cost (BDT)
Plastering Materials	2,000 sq.ft	70/sq.ft	140,000	
Flooring (tiles + skirting)	2,000 sq.ft	150/sq.ft	300,000	
Painting (interior + exterior)	8,000 sq.ft	30/sq.ft	240,000	
Door & Window Installation	Lump Sum	—	220,000	
Electrical & Plumbing	Lump Sum	—	280,000	
Total				**1,180,000**

5.3 Cost Estimation for Septic and Overhead Water Tanks

A rough estimation of the cost was obtained in order to assess the financial side of the building of the septic tank as well as the overhead tank of water.

All the materials that are required like the concrete, reinforcement, bricks and formwork are taken into account in this estimation as well as a reasonable amount of labor allowance.

The prices have been based on the average market price of high grade RCC construction in Dhaka in 2025 that will take place using the locally available materials.

The calculation assumes:

- Concrete grade: 3000 psi (M20)
- Steel: Grade 60 reinforcement
- Labor rate Mason 800 BDT/day, Laborer 600 BDT/day
- Cost includes; work excavation, formwork, RCC works, plastering, waterproofing and fittings.

These are provisional values, but it is realistic to assume that these values give a picture of how much it would cost to construct the two systems in an efficient manner.

Table 5. 8 Combined Cost Estimation of Septic Tank and Overhead Water Tank

Item No.	**Description of Work / Materials**	**Unit**	**Estimated Quantity**	**Rate (BDT/unit)**	**Amount (BDT)**
A. Septic Tank (3 units)					
1	RCC Works (bottom slab, walls, top slab, partition)	m³	12.5	9,200	115,000
2	Reinforcement Steel	kg	1,250	95	118,750
3	Brick Soling and Plastering	m²	40	380	15,200
4	Excavation and Backfilling	m³	20	400	8,000
5	Vent Pipe, Manhole Covers, and Fittings	LS	—	—	10,000
Subtotal (A)					**266,950**
B. Overhead Water Tank (32,000 L)					
1	RCC Works (base, wall, top slab, ring beam, staging)	m³	18.0	9,500	171,000
2	Reinforcement Steel	kg	1,800	95	171,000
3	Scaffolding, Formwork, and Finishing	LS	—	—	35,000
4	Ladder, Railings, and MS Accessories	LS	—	—	20,000
5	Plumbing Connection and Valves	LS	—	—	15,000
Subtotal (B)					**412,000**
C. Labor and Miscellaneous Charges (≈ 10%)					**67,000**
Grand Total Estimated Cost (A + B + C)					**≈ 745,950 BDT**

5.4 Remarks on Cost and Feasibility

The approximate cost of building the two tanks is estimated to be BDT 7.46 lakh (Tk 745,950) which is fair given the quality of constructing an RCC installation that serves a medium sized learning institution.

This cost is inclusive of all the necessary works and materials but the contingency like electrical pumps or long-distance extension of pipeline which might differ according to the conditions of the site is excluded.

On the whole, the developed design will provide durability, working capacity, and adherence to the BNBC 2020 and be economically viable.

5.5 Summary of Total Project Cost

Table 5. 9 Summary table of total project cost

Item	Cost (BDT)
Columns	2,897,300
Beams	7,495,400
Slabs	1,372,600
Footings	1,949,500
Staircase	76,700
Brickwork	889,750
Finishing Works	1,180,000
Septic tank	266,950
Overhead Tank	412,000
Total Estimated Construction Cost	**16,540,200 BDT**

Hence, the approximate total construction cost for the G+1 school building is BDT 15.86 million (around 16 lakh per 1,000 sq.ft), which is reasonable for high-grade materials in a rural environment with skilled labor.

5.6 Construction Schedule (Gantt Chart)

The Gantt Chart is an easy but effective method of visualizing the course of the project, in time. It also sets start and end dates of each significant task, which serves to provide a smooth flow of coordination of the construction team. It had been estimated that the project will take a total of 225 days (7.5 months) to procure materials, cure and inspect the work.

Table 5. 10 Project Schedule

Sl. No.	Activity	Duration (Days)	Start	End	Remarks
1	Site Preparation & Layout	10	Day 1	Day 10	Leveling, fencing
2	Excavation & Earthwork	14	Day 11	Day 24	Footing & septic pit
3	Foundation & Footing Casting	20	Day 25	Day 44	PCC + rebar work
4	Ground Floor Columns & Beams	25	Day 45	Day 69	Reinforcement & curing
5	Ground Floor Slab Casting	18	Day 70	Day 87	Slab reinforcement & shuttering
6	Brickwork (Ground Floor)	20	Day 88	Day 107	Partition walls
7	First Floor Columns & Beams	22	Day 108	Day 129	Concrete & curing
8	First Floor Slab	18	Day 130	Day 147	Slab work
9	Brickwork (First Floor)	20	Day 148	Day 167	Masonry work
10	Staircase Construction	12	Day 150	Day 162	Finishing and handrail
11	Plastering (All floors)	20	Day 163	Day 182	Internal and external
12	Flooring Works	14	Day 183	Day 196	Tiles and skirting
13	Electrical & Plumbing	15	Day 190	Day 204	Concealed wiring, pipes
14	Painting	15	Day 205	Day 219	Primer + 2 coats
15	Door, Window & Fixture Installation	10	Day 220	Day 229	Joinery and fittings
16	Final Cleaning & Handover	6	Day 230	Day 235	Site cleanup & inspection

Total Duration: 225 days (≈ 7.5 months).

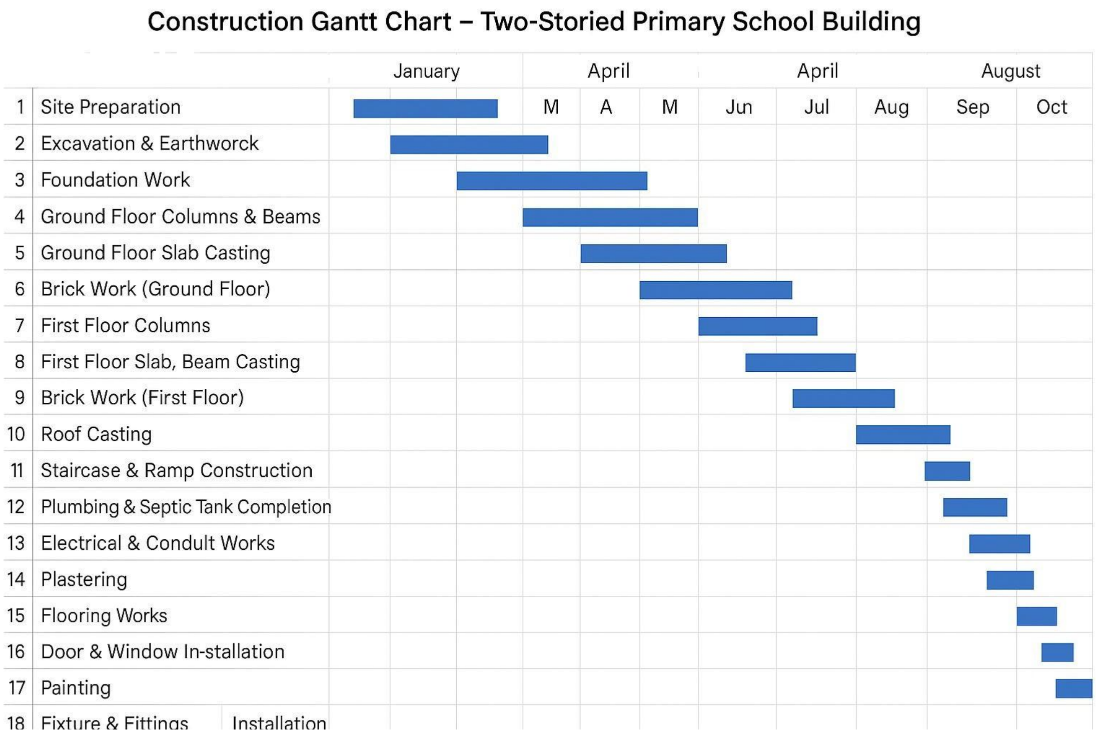

Figure 5. 1 Construction Gantt Chart Two-Storied Primary School Building

5.7 Discussion

As per the estimations, most of the project cost is concentrated in reinforced concrete works (columns,beams and slabs) which constitute approximately 70 percent of the entire project cost. Approximately, labor consumes about 15 percent and finishing works use about 10 percent. The amount of time spent on construction is viable and realistic at the rural location in relation to weather conditions, curing time, and delivery of the materials. An effective Gantt chart is determined by proper planning to make sure that there is no delay in critical path activity, which allows the project to be efficient and cost-controlled.

5.8 Conclusion

In this chapter, a detailed plan of the cost estimation and construction plan of the two-storied primary school building at Changaon was made. The BOQ presented the detailed material and labor breakdown of pricing of each structural part, which is transparent and accountable. The final project cost is around 15.86 million BDT, which is reasonable to be a high-quality educational building of this size. The Gantt chart illustrates the realistic and effective schedule that is achieved within a reasonable cost and quality assurance. The combination of these estimations can be used as a practical guide in the future construction of similar scope and assist junior engineers to realize the connection between the structural design, cost, and time management.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The aim of this project was to design and analyze a two-storied (G+1) primary school building at Changaon, LJN, with regard to architecture, structure, and the environment to provide a safe, functional, and a sustainable educational facility. The structural analysis, reinforcement detailing, and drawing preparation were done using modern design software which included ETABS and AutoCAD following Bangladesh National Building Code (BNBC 2020).

The analysis revealed that all the important structural members such as slabs, beams, columns, footing, and stairs meet the prescription of the code of the strength and serviceability requirements. The outcomes indicated that maximum storey displacement was (0.48 in) and drift ratio (0.0024) which are far below the maximum permissible values, meaning that it is stable both when subjected to gravity and seismic loading. On the same note, the base shear rates (277 kips in X and 220 kips in Y) show that the building has sufficient lateral resistance to the seismic zone it is situated in.

During the design, special consideration was taken on the choice of the material, the reinforcement arrangement and detailing to make it constructable and economical. The beam and column size was optimized both in regard to safety and cost whereas the footing design took into account the bearing capacity of the soil which was 3500 psi and this guaranteed uniform settlement control. The staircase and slab systems have been developed with an appropriate distribution of reinforcement, which increases structural integrity.

The other types of complementary systems included RCC septic tank and overhead water tank designed to supply the sanitation and water needs of the building. These auxiliary buildings were estimated on the basis of BNBC standards and environmental regulations applicable to the conditions of Dhaka region. The integrated utility design allows making sure that the school building may work independently and provide adequate hygiene and water supply even in the localities where there are no centralized facilities.

The Gantt chart and cost estimation generated in this project gave a realistic view of the plan and outlook of construction planning and budgeting. Using the amounts of materials and their own market prices, a financial picture was made out. The Gantt chart also illustrated how the project can be implemented effectively in an estimated period of about 7.5 months in a manner that balances the quality control and time management of the project.

In general, this project gave a full workflow of a conceptual planning and detailed design and estimation that presented the real process undertaken in real world practice of structural engineering. In addition to the technical outcomes, it also increased the skills in analytical thinking, problem solving, and the knowledge of building codes and design software. The practice acquired during this project will prove useful in the future structural design and fieldwork, especially in projects which involve sustainable and community-oriented practices.

6.2 Recommendations

Resting on the results and the experience of design in this work, the following recommendations can be offered to enhance the further designing works and the overall level of construction activities of buildings of such kind:

1. Site Investigation and Soil Testing: Prior to the commencement of any construction, it is best to carry out an elaborate geotechnical investigation. Though the assumed parameter of soil bearing capacity of 3500 psi was utilized in the given design, the real field (Standard Penetration Test or Plate Load Test) gives more precise parameters, which minimizes the chance of settlement problems in the future.
2. Quality Materials Used: Quality production of concrete, reinforcement and other materials should be utilized. In the case of rural school works, local materials may be taken, although the batches must comply with the necessary criteria of strength and durability set in BNBC 2020.
3. Earthquake and Wind:Although the building is located in Seismic Zone 2, moderate seismic resistant measures should be provided at all times. The nonstructural component anchorage and ductile detailing can be used in future projects to enhance the seismic performance.
4. Sustainable and Green Practices: Environmentally friendly ways of construction e.g. rain water harvesting, natural lighting, and adequate ventilation are suggested to minimize the use of energy and encourage sustainability in educational institutions.
5. Regular Maintenance Plan: The overhead tank as well as the septic tank must be cleaned and inspected on a regular basis to keep them functional. Maintenance record must be maintained and the tanks must be inspected on whether they have any leakage, corrosion or blockages at least once in every six months.

6. Supervising and Safety on the Construction: The proper site supervision and follow-up of safety protocols is also important. The reinforcement placement, concrete mixing, and curing operations should also be managed by skilled workers and proper qualified engineers to ensure that the structural integrity will not be impaired.
7. Use of Digital Tools: Digital software (Revit, ETABS and STAAD Pro) should be incorporated together with Auto CAD to generate 3D integrated models. This will reduce design mistakes and enhance integration of architecture and structure.
8. Post-Construction Evaluation: Once the completion is done, then it is recommended to conduct post-construction inspection to ascertain whether the real performance is as per the design assumptions. Minor deflection/crack readings can form useful information that can be used in the future.
9. Future Expansion Consideration: With the growth in the educational demand, future vertical or horizontal expansion should be provided at the design level. The present structural planning must have sufficient reserve strength in the foundation and columns with regard to any future stories.

6.3 Summary

To sum up, the given project can be considered an empirical implementation of theoretical knowledge in the field of structural and environmental engineering. Changaan LJN Primary School Building is one of the bright examples of how the properly designed, economically viable, technically reasonable design can help in the development of community and educational facilities.

The combination of analytical tools, the followership of the BNBC standards, and the environmental system are all that contributes to the comprehensiveness of the project and makes the project sustainable. The experience gained during this study, both in technical design and professional practice, will be critical in the process of improving future civil engineering projects, particularly those ones directed towards the provision of rural education and the common good.

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