DESIGN OF A SUSTAINABLE TWO-STORY PRIMARY SCHOOL BUILDING IN SAVER, DHAKA.

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

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November 15, 2025

The Capstone project titled **"DESIGN OF A SUSTAINABLE TWO-STORY PRIMARY SCHOOL BUILDING IN SAVAR, DHAKA".** Submitted by Md. Motiur Rahaman (221-47-623) & Fariha Aktar Khan (221-47-566), Department of Civil Engineering, Daffodil International University, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Civil Engineering and approved as in its style and content presentation which has been held on November 15, 2025.

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DECLARATION

We hereby declare that, the work presented in this project has been performed by us and the project report has not yet been submitted anywhere for the award of any degree.

We declare that, the study does not contain any material previously published or written by other persons except where specific references are used.

We further under take to indemnify the University against any loss or damage arising from breach of the fore going obligations.

Fariha

Md. Motiur Rahaman **Fariha Aktar Khan**

ACKNOWLEDGEMENTS

I would like to wish to state my heart-felt appreciation to the Almighty Allah who gave me the power, patience and endurance to complete this capstone project successfully, which is known as Design and Implementation of a two-story primary school building with green building concept at Savar, Dhaka.

I wish to inspect my deep-felt gratitude to my respected supervisor, Ms. Mardia Mumtaz, Lecturer, Department of Civil Engineering, Daffodil International University, who immensely guided, encouraged and thoughtfully supervised me in the entire development of this project. Her professional guidance and positive criticism have played a central role in developing the technical and conceptual side of this piece of work.

I also appreciate all the faculty members of the department of civil engineering at Daffodil Intenational University, who were helpful with my academic support and offered me a good ground in civil and environmental engineering that enabled me to undertake this project. Their paternal and maternalistic support in teaching and mentorship has immensely added to my knowledge in the field.

The cooperation and shared learning experiences with my classmates and friends have to be mentioned as special merits of this project as well as of my support through the course of the project. I also get to recognize the support provided by the laboratory technicians, the library staff and administration of resources and facilities that were a necessity to undertake the works of the analysis, design and documentation.

Lastly, I wish to express the sincere gratitude to my parents and family members who always supported me despite any circumstance and always inspired me. They have always inspired me along my academic life as they believed in me.

It is the culmination of a joint effort and scholarly work and pure commitment. I would like to dedicate this work to everyone who contributed to my accomplishment of this milestone and guided me.

ABSTRACT

This capstone project focuses on the design and analysis of a sustainable two-story primary school building in Savar, Dhaka, which was developed based on the concept of green building. Eight classrooms, two teachers rooms, a library, and two washroom will be a proposed facility, which will be planned in a way that will be functional, safe, and environmentally efficient (Bangladesh National Building Code 2020).

Structural modification and optimization of space was done in AutoCAD and structural analysis and modeling were conducted in ETABS according to the ACI and ASTM criteria. A balance between the cost, function and sustainability is exhibited by the total gross floor area of about 11,952 ft^2.

The project incorporates the use of energy-efficient materials, natural ventilation, solar lighting, and rainwater harvesting so as to minimise on resources use. Extensive Bill of Quantities (BOQ), methodology of construction, and risk management system had been prepared so that the project was technically, economically and operationally viable.

Moreover, the Quality Assurance/Quality Control (QA/QC) processes, Health, Safety and Environmental plans and sustainability tests were developed to increase the durability, safety, and long-term performance.

This capstone project is an example of how sustainability in design and contemporary engineer tools may bring a child-friendly, cost-saving and ecologically friendly educational facility, a model to be applied in school infrastructural projects in the future in Bangladesh.

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1.1 Background of the study

Education is widely accepted as a primary driver of social and economic development. On the elementary level, children are introduced to general literacy, numeracy, elementary level of science, socialness, and habits, which determine their future learning. Physical quality of school infrastructure has a strong influence on the attendance levels, retention level, health and learning levels in developing countries. The size of a classroom, day lighting, ventilation, thermal comfort, acoustics, and sanitations all have quantifiable contributions to the level of concentration duration of students, their frequency of attendance at school and their safety in school.

The high population growth rate coupled with rapid urbanization in Bangladesh has imposed strong strains on the educational facilities in the peri urban and semi urban regions. Such localities as Savar, within the outskirts of Dhaka and being subject to higher demand in school places and reduced supply of well-designed, and sturdy school structures, have a two-fold problem: the demand rises and supply decreasing. Most of the current schools were built using simple resources, little consideration to climate response, and unsufficient resources on water, sanitation as well as building resilience. Both short-term issues (if the operations become congested, the indoor air quality compromised, the more general sanitation problem), and long-term defenses (the buildings not capable of enduring the windstorms, the heavy rains, the seismic activity) can be provided by these deficits.

In line with these challenges, an increased awareness of the need to cut down on the environmental footprint of the buildings is increasing. By use of buildings, the buildings use high proportions of energy and water and produce huge amounts of waste and embodied carbon. This idea of green building, design and construction that minimizes environmental impact and maximizes indoor environmental quality has become a mature concept that comes in the form of useful strategies, which are viable even in the resource-limited setting. In the case of the primary school, the advantages of green building strategies in this case are both short-term (improvement in the quality of indoor air, enhanced daylighting, thermal comfort, etc.) and long-term (reduced operating expenses, decreased requirements in terms of consumption of water, and educational impact as a live demonstration of sustainability).

Design of a sustainable Two-Story Primary School Building in Savar, Dhaka with Green Building Concept is a project that answers the needs that overlap. It seeks to provide a design that is functional and regulatory to a primary school (classrooms, teachers rooms, library, wash rooms) with practical green designs suitable to particular climate of the region and financial limitations. The project is a combination of architectural planning, structural design (by use of ETABS), and sustainability requirements which resulted in the creation of a total design package that can be examined through academic analysis and implemented in practice.

1.2 Problem Statement

Although there is a significant rise in the enrollment of primary education in Bangladesh over the past number of decades, the quality of the school buildings is not continuous. There are problems that normally erode the learning environment, and these are:

- **A space shortage and congestion:** Smaller sized classroom constructions have been strained to hold more students as compared to the actual size of the classroom construction making it uncomfortable and less effective in learning.
- **Poor thermal and air conditioning:** Poor natural ventilation and a bad sense of solar orientation causes overheating, high humidity and poor indoor air quality of the same which damages concentration and is significant to the health.
- **Lack of sufficient sanitation and supply of water:** Most of the schools do not have safe drinking water and provisions of sanitation that are friendly to the children and this is a health issue, attendance (particularly amongst girls) and dignity.
- **Weak structural building resilience:** The constructions that are built without the adequate attention to seismic or wind loads can be damaged in case of extreme events occurring, and this is a major threat to school occupants.
- **Expensive operation cost and environmental cost:** This leads to high consumption of energy and water usage and construction waste and embodied carbon due to conventional practices of construction and operation.

The problems are acute in case of an area such as Savar, where the local context is still evolving due to the increase of population and the activity of industry. Two story school design would be more efficient in land use and offer the necessary amount of teaching spaces in a small area, however, this would only occur when the architectural and structural design takes into consideration, daylighting, ventilation, sanitation, safety, and resiliency.

Thus, the main issue that the given project deals with is:

What is proposed is how to design a small, two-storey primary school at Savar, which offers comfortable, safe, and functionally efficient learning environments, without impacting the environment excessively, and yet meets the local building standards.

This issue demands a solution with tradeoffs (e.g. footprint and daylighting) and regulatory requirements and integration of green strategies that offer quantifiable returns at reasonable costs.

1.3 Objectives of the Project

1.3.1 Primary Objective

Design a sustainable two-story primary school building in Savar, Dhaka, that provides eight classrooms, one teacher's rooms, a library, and two washroom, integrating green building concepts and complying with applicable structural and safety standards.

1.3.2 Specific Objectives

1. **Site and Context Analysis:** The site analysis (including climate, solar direction, winds) should be performed in order to define the best building area orientation and location.
2. **Architectural Programming/Design:** Set up operational programs and detailed architectural plans (plans, sections, elevations, 3-D visualizations) that facilitate learning processes in front of facilitating passive environmental control techniques.
3. **Structural Analysis and Design:** Model analysis the ETABS structural system, conduct the load analysis (dead, live, wind, seismic), design the main structural

elements (slabs, beams, columns, footings) and prepare the reinforcement detailing based on the position of current guidelines of the BNBC.

4. **Sustainability Integration:** Choose practical green implementations - daylighting, natural ventilation, solar PV, rainwater harvesting, low-embodied materials, and measure the performance benefits they are expected to have.
5. **Costing and Economic Assessment:** Estimate the costs of construction and operations and the lifecycle analysis of the costs is performed in order to compare them between green and conventional options, consequently producing a detailed Bill of Quantities (BOQ).
6. **Environmental and Social Assessment:** Critically assess the environmental effects (energy, water, waste, and embodied carbon) and socials (accessibility, community benefits, health).
7. **Documentation and Recommendations:** Prepare a finished project book (narrative, drawings, appendices with ETABS outputs and BOQ) that can be submitted to the academic and is able to be used practically in practice.

All of the concrete objectives can be quantified within the scope of the project: the designs will contain clear dimensions, calculations, software results, and cost tables that would enable one to check that everything is according to plan and predict results in terms of compliance and performance.

1.4 Scope of the Project

Project scope provides an understanding of what will be covered and that which will not be covered deliberately. There are no mistaking contours in design or analysis where they are needed the most.

1.4.1 Included in the Scope

- **Geographic span:** The geographical location is the site of Savar, Dhaka. The design takes into account the local climatic concerns that are characteristic of the area (tropical monsoon patterns).
- **Building program:** Eight classes, one teacher room, one library, 2 washrooms, circulation and small auxiliary (store, service area).
- **Structural design:** Modeling, analysis and design of a framed structure (two stories) reinforced with concrete with the help of ETABS and creation of structural drawings and schedules of reinforcements.
- **Sustainability aspects:** Passive (orientation, shading, natural ventilation, day lighting), and active (in practise) (solar PV to provide lighting, rain water harvested to flush toilets, use of efficient fixtures).
- **Estimating costs**: BOQ-level quantities and cost estimation upon unit rates characteristic of the area; lifecycle cost comparison of core green measures.
- **Documentation:** Comprehensive written report (chapters and appendices), architectural illustrations (AutoCAD), ETABS reports, the spreadsheet of the BoQ and an overview of the environmental and social effects.

1.4.2 Excluded from the Scope

- **Tendering or construction supervision at the contractor level Construction -** Prepares drawings and BOQ, but not responsible for the procurement (the study).

- **Juris Mechanical HVAC design** - the emphasis is put on passive and minimum mechanical provisions (fans, small solar-assisted systems) instead of complete air-conditioning systems.
- **Comprehensive energy modeling with specific software** (e.g., full building energy simulation) - the project will involve simplified engineering level estimates that are appropriate in a feasibility study and comparing with other ones.
- **Extensive geotechnical field campaign**- the form of design will be based on typical site conditions used in initial design; the final construction will have a complete site-specific geotechnical investigation.
- **Well-established environmental permitting process as the study will involve high**-level EIA and mitigation recommendations, but not the actual permitting process.

Clearly delimiting them ensures that the work is within reach and can be completed using the resources and time available during a capstone project but also comes up with outputs that can be implemented through standard follow-up procedures.

1.5 Methodology

An inflexible, repeatable research approach is necessary to produce design products that are defensible and verifiable. This project is based on the combination of the desk research, the graphical design, the numerical modeling and the cost analysis. The methodology is developed in separate, yet combined steps:

Phase 1 - Literature Review and Standards.

- **Purpose:** Establish regulatory and best-practice points of reference in designing decisions.
- **Activities:** BNBC (and other guidelines) structural, fire and occupancy loads Reviewing: Review UNICEF and education facility guidelines space and sanitation standards Survey: green building guidance (LEED, EDGE, GRIHA concepts) applicable measures.
- **Deliverable:** Integrated system of design requirements (space per student, lowest exit provisions, the selection of load value, guidelines on what will be green measure).

Phase 2 - Site and Context Analysis

- **Purpose:** Know the physical context in order to form decisions and information about siting.
- **Activities:** Gather climate information (the common temperatures, rainfall, wind patterns, the sun path), analyze the site plan (access, features of other land use), note constraints and opportunities (trees present, slope, utilities). To this end, common regional climate parameters are exercised and described, actual construction stage must employ local weather and surveying data.
- **Outcome:** Proposed building orientation, massing and landscape strategies, and site first layout.

Phase 3 - Architectural Programming and Conceptual Design.

- **Purpose:** Commentation of the functional requirements into the space layouts and architectural ideas.

- **Activities:** Determine room sizes and capacities on accepted metrics (area per student), prepare bubble diagrams and adjacency matrices (classrooms in groups, library quiet core, washrooms centrally located), develop schematic floor plans, and develop an idea of elevation and section that would focus on the idea of shading and ventilation.
- **Digital instruments:** AutoCAD to make 2-D patterns and sections, simple 3-D image visualization instruments (or crude rendering) as necessary.
- **Product:** Passive strategies Comprehensive architectural drafting (plans, elevations, and section) and design narrative.

Phase 4 - Structural Modeling and Analysis.

- **Purpose:** Provide structural safety and serviceability in the case of applicable loading.
- **Activities:** Construct the structural model in ETABS using grid sizes related to the architectural plan; allocate materials (concrete grade, steel grade), cross-section, and slab panel; specify loads (dead loads (self weight + finishes), live loads (occupancy), wind load (according to code maps), and seismic load (response spectrum or equivalent static (as per BNBC)) loads. Carry out modal analysis and check natural periods, member design checks (bending, shear, axial) and develop schedules of reinforcement.
- **Product:** There are the results of ETABS model (reaction forces, moment diagrams, modal shapes), the reports on member design and the drawings of reinforcement.

The outstanding features of Etabs workflow include creating a grid - floor levels - shell elements (slab panels) - frame assignments (beams and columns) - load patterns - load combinations - run analysis - review load-path and modal results - design members - iterate (as needed).

Phase 5 - Sustainability Evaluation and Green Measures.

- **Purpose:** Choose an appropriate combination of green measures based on the maximum contribution to the performance and minimization of the unit cost and on the maintenance capabilities of the school.
- **Actions:** Consider first passively the organization, cross ventilation, the shading, the daylighting; secondly, with regard to low operational costs (LED loading, the efficient fan); and lastly, with the modest renewable investment (solar PV on a rooftop within lighting capacity and fans). In the case of water, a rainwater harvesting system should be created to satisfy non-potable water requirements (toilet flushing, irrigation). Critically do some basic performance calculations: estimations of solar yield (Panel capacity and insolation estimate) and estimates of reduction of lighting energy (LED vs. baseline) and related water harvest (roof area x rainfall depth x runoff coefficient).
- **Deliverable:** Prioritized list of Green measures, proxy size of PV and storage, and estimated savings of energy and water.

Phase 6 Costing and Lifecycle Economic Analysis.

- **Purpose:** Find out the capital and operating costs and evaluate the economy.
- **Activities:** Prepare a BOQ of all the structural, architectural, and services. Get indicative unit rates of regional sources of cost or standard rate books. Estimate first and second costs (capital and annual like operation cost such as energy,

water). Compare the standard conventional design with the green-enhanced design using a simple lifecycle cost model (i.e. calculation of net present value or payback period) across a period of analysis of interest (e.g. 20 years). Add sensitivity test of price hikes of energy and maintenance expenses.

- **Deliverable:** See outcome, BOQ spread sheets, cost summary on the capital and the results of lifecycle comparisons.

Phase 7 Environmental and Social Appraisal.

- **Goal:** Determine impacts on the environment and social good.
- **Activities:** Complete a high-level EIA with the identification of the important construction and operating effects (dust, noise, waste, risks of water pollution) and mitigation is suggested. Overview social benefits (better health, higher attendance, neighborhood use). Match the project contributions with SDGs.
- **Product:** Health and safety plan, mitigation plan, and narrative of social benefits.

Phase 8 - Documentation and Recommendations.

- **Purpose:** create an integrated project book in which all the analyses, decisions, drawings, and recommendations are registered.
- **Activities**: Chaptered report preparation, architectural and structural drawings assembly, ETABS output appendix, BOQs and costing spreadsheets, and executive summary and recommendations to implementation.
- **Deliverable:** An end project paper fit to be assessed academically and a working design, as reference

1.6 Expected Outcomes and Deliverables

The overall output of the project will include a complete list of outputs that will fulfill the academic needs and give a viable package of design of implementation. Deliverables include:

1. **Narrative Report (Project Book):** Full chapter likewise recording background, literature review, methodology of studies, analyses, findings, and recommendations. The end product is a project book, with full project content, all very detailed with figures, tables and just about references.
2. **Architectural Drawings (AutoCAD):** Scaled plans (site, ground, first floor), sections and elevation plan and typical details. Drawings will reveal the sizes of rooms, door/window schedule, stairs and site layout.
3. **Structural Drawings and Schedules:** Foundation plan, beam layout, slab reinforcement plans, column schedules and major sections indicating reinforcement and cover.
4. **ETABS Model and Results:** ETABS model file, modal analysis output, load case reports, design checks on every member, and display of significant output materials (modal shapes, reaction charts, and screen shots of results).
5. **Bill of Quantities (BOQ):** for conventional and green conditions, spreadsheets with itemized quantities with unit rates, material and labor cost summary and life cycle cost comparison.
6. **Sustainability Analysis:** The following are important organized list of green interventions, the rough sizing of PV and rainwater systems, energy and water savings approximations, and narrative of the positive impact on the environment.

7. **Environmental and Social Appraisal:** High level EIA, study of mitigation of construction effects and statements of social benefits.
8. **Recommendations and Implementation Roadmap:** Practical implementation steps to design, procurement issues and recommendations on how to monitor performance (e.g. energy/water metering, occupant comfort survey).

All deliverables will contain a description of assumptions and computations resulting in the creation of some results so that the project team or contractor of the future may track the methodology and replicate the procedures.

1.7 Significance of the Study

The project is relevant on various levels, including Pedagogical, technical, environment, and social. The key contributions are:

1.7.1 Educational and Pedagogical Significance

- **Enhancing the learning environment:** Well planned classrooms that are well-lit, can be well ventilated and acoustically treated can help in enhancing concentration, fatigue levels, and attendance. With primary students, both physical comfort and safety are directly related to the learning efficacy of the student.
- **Demonstration effect:** A green school is both an educational instrument per se. Children who are exposed to rainwater harvesting, recycling and solar energy become conversant with sustainable practice, which may influence their future practices.

1.7.2 Technical and Professional Significance

- **Demonstration on integrated design:** Project illustrates how an architectural, structural and sustainability consideration can be integrated in a workable design package, which works as an of example to other student projects and minor scale designs of the constructed facilities.
- **Code-compliant structural design:** The project cuts across theoretical course work and generation of practical actions towards structural design that is applicable in Bangladeshi practice through: ETABS analysis and creation of reinforcement detailing.

1.7.3 Environmental and Economic Significance

- **Less physical presence and lower occurrence and reduction of costs:** Operational green measures can be practiced to lower costs of energy and water use, which lowers operation cost in schools with limited budgets which frequently have.
- **Scalability to scalable solutions**: The methods used are scalable and applicable to other school-based projects in Bangladesh giving a cheap but practical route to more sustainable public infrastructure.

1.7.4 Social and Community Significance

- **Community resilience:** A structurally healthy and climate-sensitive school building raises community resilience to hazards (storms, moderate earthquakes) and a secure space to gather in case of emergencies and offer education, in case of the building being multi-use designed.

- **Social inclusion:** The school promotes equity and dignity in education by being explicitly child friendly in its design; by making sanitary facilities friendly to staff and visitors; and by being community friendly.

Then all these effects can lead to justify the attention paid to the project and give the design several opportunities to enrich the physical building more than the immediate physical building.

1.8 Definitions and Key Terms

To be clearer, some of these terms are outlined as are employed in this project:

- **Green Building:** The building is an effective structure based on efficiency in its lifecycle i.e., in siting, design, construction, operation and maintenance, renovated, as well as demolition thereby with minimal impact on the environment and enhanced occupant health and productive life.
- **BNBC:** Bangladesh National Building Code the main regulation code that applies to building design and construction in Bangladesh (used as a reference in loadings, fire safety, and even structural requirements).
- **ETABS:** It is a building modeling software commonly used to model the structural analysis and design of frames and slabs that has the capability to complete modal analysis, response spectrum analysis, and member design.
- **BOQ :** Bill of Quantities- a detailed list of components, material and labor quantities used to determine the estimated cost of construction.
- **GFA:** Gross Floor Area This is the covered floor area of the building including circulation and service space.
- **Passive Design:** Architectural and landscape designs aims to employ the natural energy movement (sun, wind, thermal mass) to achieve comfortable interior environmental conditions without the use of a mechanical system.
- **PV:** Photovoltaic -solar electric panels, which transform sunlight into electricity.
- **Life-Cycle Costing (LCC):** This is an operation that involves addition of all the expenses that befall a building during a given analysis period such as initial capital costs, operation and maintenance costs, replacement costs and disposal costs.

1.9 Assumptions and Limitations.

Any design study is bound to make assumptions in the event of data incompleteness. Putting these assumptions out there makes the limitations of the conclusions clear and specifies the directions that should be pursued in the future.

1.9.1 Key Assumptions

- **Site conditions:** Project presupposes a comparatively flat and well-drained site which is characteristic of peri-urban Savar. There are no assumed geotechnical features on site. Construction final design to be done with the help of specific geotechnical report.
- **Occupancy:** The classrooms have the capacity of 40 students (as is in line with most primary schools). Differences in the number in the classes will necessitate changes in layouts.
- **Materials:** It will assume that typical construction material in the market place (this includes reinforced concrete, a masonry of brick, standard steel reinforcement, etc.) will have nominal properties typical of local use.

- **Code values:** Load pattern Load combination rules are subject to BNBC-type guidance. The load coefficients applying to specific numeric loads are implemented according to the standards of BNBC; where the code is not prescriptive in nature, a conservative approach to engineering is implemented.
- **Maintenance capacity:** The design presupposes a low-level maintenance in the school (routine cleaning, small repairs). Very sophisticated systems that are specialized to maintain (complex HVAC) are not used.

1.9.2 Limitations

- **No complete geotechnical campaign:** Foundation designs are initial and illustrative with no borehole information and lab tests. Actual construction involves investigation in site.
- **No simulation at the full dynamic energy scale:** Energy performance balanced-scorecard: Engineering (rather than detailed Building Energy Modeling (BEM)) runs.
- **Cost data:** Unit rates are pro forma and have an idea of the general rates in the region and precise budgeting requires detailed tendering and market quote.
- **As-built variability:** The end result as-built would be pegged on the quality of the construction, the materials acquired and patterns of the use.

Identifying these assumptions and constraints makes it clear how the design will be utilized: as a strong academic and conceptual design, which would be developed further in the implementation phase.

1.10 Organization of the Report

The structure of this project is designed in such a way that it follows a logical arrangement of the background and requirements up to the design, analysis, and recommendations. The organization of the chapters is the following:

- **Chapter 1 (this chapter) -** Introduction, background, objectives, scope, methodology and definitions.
- **Chapter 2:** Literature Review - review of standards, precedents and green building concepts that are used to base on the design decisions.
- **Chapter 3:** Project Overview - site analysis, program requirements as well as initial planning constraints.
- **Chapter 4:** Architectural Design -floor plans, elevations, sections, practical way and spatial layouts discussed.
- **Chapter 5:** Structural Design and Analysis etablissement Etablissement, expluvation, tolérance choosing and layout.
- **Chapter 6:** Green Building Features - description of choice, size, and performance estimates of sustainability features.
- **Chapter 7:** Building Services and Utilities - lighting, some basic electrical systems, plumbing, sanitation and provisions of fire safety.
- **Chapter 8:** Cost Estimation and Economic Analysis BOQ, costing and lifecycle economic comparison.
- **Chapter 9:** Project Management- schedule, quality control, procurement and Risk management proposals.
- **Chapter 10:** Results and Discussion - synthesis of the findings, performance indexes and contrastive assessment.

- **Chapter 11:** Conclusion and Recommendations - summary of the study, recommendations on what to do next to implement and investigate further.
- **Appendices:** Architectural drawings in full, ETABS output, spreadsheets of the BOQ files and additional data.

This planned development guarantees that every design move can be tracked to examination and norms, and the ultimate recommendations are workable.

1.11 Concluding Remarks

The chapter has defined the rationale and procedural basis of designing a sustainable two story primary school in Savar that is safe, useful and greener than the common practice. The project lies adjacent to providing a complete design package - architectural and structural, with some form of practical green solution and economical analysis. The approach puts an emphasis on the transparency (implicit arithmetic, written assumptions), regulatory flow and practical implementability. Embracing the opportunity to have academic rigor and practical use of design decisions based on the measurable criteria and established methods, this capstone aims to be academically sound and practically useful at the same time.

The following chapters of the research head into the library that informed the design, and thereafter uses the approaches and test standards outlined and explained here in building architectural and structural solutions, evaluating sustainability actions, and value costs and effects. The final goal is a design that enhances learning environments of primary learners in Savar and reveals how small green interventions can provide significant improvements in the environment of the Bangladesh state school infrastructure.

Chapter 2 — Literature Review

2.1 Introduction

An intense literature review provides a technical background, standards, precedent, and evidence base to support design choices to be made in favour of the two-story primary school in Savar. This project has four key functions of the literature review:

1. Gather and compile codes and general instructions or guidance on structural safety and building services that directly govern them (primarily the Bangladesh National Building Code BNBC 2020).
2. Resume the international, regional and sectoral best practice in school design including: spatial standards, WASH (water, sanitation, hygiene), indoor environmental quality (lighting, acoustics, ventilation) and child friendly design.
3. Discuss green building principles, rating scales and real-world green strategies (passive as well as low-cost active measures) that are the most applicable in small public school in tropical monsoon setting.
4. Current case studies and precedents (domestic and abroad) that show how schools can be feasibly, cheaply, climactically, and scaleably resolved - and induce a lesson that can be projected to Savar.

Those tasks are structured where this chapter is concerned. In each section, there is concept to be used, reference standards, technical background, evidence of efficiency (where applicable) and implications of the design to be used in the project. It focuses on operationally relevant content what the codes and standards demand, why some of the green strategies are effective in humid tropical climates, such as Savar, and what materials and low-tech interventions provide the most effective results per unit of cost to school projects.

The sources that are critical to this review work comprise the Bangladesh National Building Code (BNBC 2020) referring to regulatory requirements, UNICEF/WHO information relating to the WASH and school facilities, IES/DOE/ASHRAE standard relating to lighting and thermal comfort, and global established green building rating systems (LEED, EDGE, GRIHA), to the principle of sustainability and quantifiable goals. Case studies and examples are based on better recorded projects in Bangladesh and such climate (ex: METI Handmade School, Dinajpur; recent sustainable campuses of Dhaka). Primary sources are used where particular numeric design values have been mentioned.

2.2 Primary school building design: Educational, spatial and functional requirements

2.2.1 The relationship between physical space and learning outcomes

Studies in a wide range of settings evidenced that school building physical attributes adversely (and materially) affect school attendance, well-being, and achievement. The size of the classroom, daylight, thermal comfort, acoustic, indoor air quality and sanitation have an impact on the attention span, respiratory health, and attendance (most especially among the girls and the younger children). The design is then approached in a manner that actualizes a secure, adjustable space that is convenient to the students to accommodate various ways and models of teaching (lecturing, a group work, and play-based activities) without being flimsy or difficult to maintain.

An overview of studies in education and environment indicates:

- Daylighting enhances the rate of reading, minimizes eye-strain, and shows positive relationships with academic achievement when constructed in such a way that it eliminates glare. Proper daylighting also saves on the use of electric lighting which is a direct operation expense.
- There is a relationship between thermial comfort and ventilation and cognitive performance: high temperatures and ineffective ventilation (high levels of CO_2) hurts reflection and secure recollection.
- Acoustics are important in primary classes since verbal instructions are the most important kinds of instructions that young children get; poor acoustics reduce the level of understanding particularly of the children with hearing impairments.
- Sanitation and WASH amenities influence the rate of attendance (particularly during menstrual seasons amongst adolescent girls), minimizes absenteeism due to illnesses, and basic dignity and school attendance.

Based on this, the conclusions serve as foundations of the spatial decisions (sufficiency of space per student, window/shading plan, location and size of washrooms), and service options (ventilation plans, lighting, maintenance priorities). The prescriptive recommendations on the following aspects are practical and provided by various international organisations and guides (UNICEF, WHO, UNESCO, IES) which are utilised in the design.

2.2.2 Area standards and space planning for primary schools

School area is a subject of country and local differences; international standards (UNESCO, UNICEF, country manuals) can give such details as gross and net area per pupil, recommended classroom sizes, circulation allowance and special use space (library, teacher room, store). There are two conceptual measures which are useful:

- **Net teaching area per pupil** - space that can be used to teach an actual (desk space, teacher movement). The recommended size is usually between 4 -6 ft^2 divided between the number of pupils each, pedagogy and local conventions.
- **Gross floor area (GFA) per pupil** - excluding cafeteria, gymnasium. GFA seldom meets the standard of 1.5 to 2.5 times net teaching area based on school type and standards of countries.

Field theory applies a mixture of national expectations and pedagogical goals. In this project we used 10 ft^2 per pupil as a starting point in Chapter 1 (like compact primary schools designs found in much the same situations), giving us classroom spaces of 780 ft^2 in 40-pupil classes. But the designer should not violate local statutory requirements (BNBC concerning the width of egress, allowances of a corridor, number of sanitary fittings per pupil, etc.) and not to be less than minimums set by local educational authority where such do exist. Sanitation and water supply: UNICEF/WHO WinS (WASH in Schools) advice gives unambiguous information on the adequate number of toilets, hand washing facilities as well as supply of drinking water, per cohort of pupils. WinS recommendations that are modified to local norms should be implemented.

2.2.3 Functional adjacencies and supervision

The classes in primary schools have Teacher circulation and natural surveillance which is not possible in high schools due to its compact layout. Best practice indicates that it is better to group the classrooms to allow teachers to move easily between them, to place library in an area with good daylight and air, to place WASH facilities at a central and low profile position to facilitate supervision and privacy. Circulation made to a minimum possible to give as much useable learning space as possible, but corridors should be adequate in meeting the width requirements of egress and have transitional shaded areas in hot climates.

2.2.4 Child-friendly details (furnishings and fixtures)

The use of child-friendly design is also included in the height of fixtures, door latches and design of toilets: fewer heights of basin, child-sized door grip, and no-step entry as much as possible can make most regular activities of daily use by young children. Sanitary fixtures must be sturdy, as well as low-maintenance and need to utilize less water (dual-flush cisterns or waterless where necessary). These are practically economical decisions that lessen the maintenance expenses and enhance comfort and dignity in the daily lives.

2.3 National and international building codes and standards (structural & non-structural)

The design of any school should be according to code and other requirements of regulation, to ensure safety, durability and legality. As to Bangladesh, the Bangladesh National Building Code forms its main regulatory anchor (BNBC 2020). Islowly a number of national and global criteria supplement BNBC on sections of the designer who requires extra advice (e.g., ACI with the detailing of concrete, ASCE with comparative comprehension, ASHRAE/IES with thermal comfort and lighting).

2.3.1 Bangladesh National Building Code (BNBC 2020) — overview and implications

The latest national code is BNBC 2020 and sets the minimum requirements of the structural design (dead, live, wind, seismic loads), materials, fire safety, exit, and building services. It released updated previous provisions and gave new seismic zoning and wind speed maps in addition to load combination that relate to current seismic and climatic knowledge to Bangladesh. The BNBC must be adhered by the designers of school building:

- Load definitions, load combinations (dead, live, wind, seismic) and instructions on the way to incorporate appropriate sections of live load in seismic mass.
- Seismic zoning, seismic design coefficient, which vary throughout the country; that assigns to base shear calculations, and to member design (BNBC breaks down Bangladesh into seismic zones with varying design coefficient).
- Provisions of wind design, such as basic wind speed map, categorization of terrain/ exposure type to specify the pressure coefficients used in designing the cladding, roofs, and frames.
- Minimum live loads and concentration loads of various occupancy types; BNBC gives occupancy/use tabulated loads.
- Structural detailing requirements of reinforced concrete such as the development lengths, lap splices, minimum reinforcement, and confinement details of seismic performance.

Since BNBC is the legal reference, any structural analysis (e.g. ETABS modeling, loads application, and member checks) will have to be carried out in compliance with BNBC provisions. In practice, BNBC is often used in conjunction with ACI

318 (concrete design detail), and ASCE/Euro-code sources (conceptual checks), although BNBC is the governing one.

Design Implication to the current project: The ETABS model and design of the members will be configured with the BNBC load definition and load combinations and the seismic loading will be implemented in accordance with BNBC seismic zone which covers the Savar/ Dhaka. Checks will ensure BNBC wind pressures in roof and cladding. Chosen coefficients, as well as the corresponding clauses, will be documented in the project where the BNBC table values or maps are consulted.

2.3.2 Live load and seismic mass considerations

BNBC (and structural design practice in general) dictates that the mass of seismic must have appropriate parts of live load. A percentage rule (e.g., a quarter or half of the live load) is used to estimate mass in many codes based on the overall scale of live loads; in BNBC there is a guideline on the proportion of live loads that should be incorporated in seismic weight calculations (the historical usage and interpretation of the BNBC reflects with a smaller proportion of live loads) kN/m^2 being used in the derivation of a fraction of the applied load). Seismic base shear is sensitive to the seismic mass and a designer needs to make a proper draft of the fraction used in the model.

2.3.3 Wind design in BNBC and practice

BNBC 2020 contains simpler wind speed maps and processes of transducing basic wind speed into design pressures with exposure, topography, and structure geometry factoring. In the case of a single-storey or low-rise school structure, simplified BNBC procedures or tools are usually sufficient, however, care should be taken in the exposure classification (open, suburban, urban) since this would have an impact on velocity pressure and subsequent cladding and frame deflections. The BNBC update has modified the basic wind speeds in some division capitals against earlier versions and thus; the 2020 map is necessary to be utilized.

2.3.4 Seismic zoning and ductility design

BNBC 2020 splits the nation into seismic regions, with each having a documented design coefficient of the map; the structural detailing (e.g. confinement in column ties, shear in beam, lap splice lengths etc.) should detail the design principles of the required ductility and capacity. In the case of Dhaka/Savar which is located in moderate seismic intensity region in most BNBC maps, designers need to consider seismic detailing to guarantee dissipation of energy and prevent brittle failure mode. Comparative research papers that have been conducted on the subject between BNBC zoning and seismic parameters demonstrate the significance of BNBC-2020 zonation to be applied in modern designs.

2.3.5 Complementary standards (ACI, IS, ASHRAE, IES)

To achieve thorough calculation of reinforcement anchorage and length of development, the reference of ACI 318 is often trusted, along with BNBC clauses; numerous designers consult the two to make sure that they have the right details. Engineering Thermal comfort ASHRAE Standard 55 (thermal comfort) and ASHRAE 62.1 (ventilation) have the benefit of well-researched engineering criteria, whereas IES (or national lighting guides) give recommended illumination levels in the classroom (at the work plane) of between 300 and 500 lux to ensure satisfactory visual conditions.

Lighting and ASHRAE comfort criteria DOE/IES guidelines are usually cited when designing of school services.

2.4 Green building principles and frameworks

2.4.1 What "green building" means for a primary school

Green building, a generalized term, refers to design and construction, which minimizes environmental impact, uses resources cooperatively (energy, water, materials), and makes the occupants well. In the case of a primary school in resource-constrained environment, the environment should be green: should emphasize passive measures and undemanding, but well-built and low-maintenance, systems that bring instant occupancy and operation utility to the environment:

- **Passive:** first, orientation, shading, natural ventilation, daylighting - cheap, high value.
- **Low-energy services:** low-energy light bulbs, energy saving fans and least of the mechanical cooling.
- **Water efficiency and WASH:** use of rainwater by harvesting it and using it without consuming it, water efficient fittings and proper drainages.
- **Sustainable materials:** use resources that are locally made; have little overall carbon in their embodiment, i.e., fly-ash bricks or earth blocks that are stabilized or bamboo sustainably where possible.
- **Maintenance conscious:** systems selected must reflect local maintenance facilities (do not have very technical systems that need specialist service provisioned).

External support of this pragmatic approach is provided with green building rating and assessment tools allowing to balance between ambition and feasibility and estimate benefit (energy reduction, water savings, embodied carbon reduction).

2.4.2 Major rating systems and their relevance to schools

Some of the most well-known rating systems on the international and regional levels include both strengths and focus:

- **LEED (USGBC):** all-inclusive and the most popular of them; has a special group of ratings (LEED for Schools), in which acoustics, indoor air quality, daylighting and comfort of occupants play one of the central roles, which are of utmost importance in primary schools. LEED offers a wide list of credits in a checklist which helps in improving the building performance.
- **EDGE (IFC/World Bank):** oriented to the emerging markets and aimed at the efficiency of resources; at least 20% water, energy, and embodied carbon reduction is required to obtain the certification - appealing to the project aiming at an inexpensive sustainability award. The EDGE tool can be applied to early screening since it measures cost-efficiency savings of resources.
- **GRIHA (India) and GRIHA-Prakriti to schools:** GRIHA has designed a variant, the Prakriti, specifically to apply to existing schools, and the standards are adapted to the Indian climates and contexts and thus many of the principles apply in Bangladesh as well (similar climatic zoning, construction). GRIHA focuses on design on responding to climate, site planning, and interventions which are low cost in schools.

Design implication: LEED certification can be an expensive undertaking but best practices such as LEED oriented acoustics, ventilation, and daylighting can be adopted. Only EDGE offers an effective means of determining high impact, low cost actions (e.g. attaching waste to LED light), the school-focused tools of GRIHA can propose culturally sensitive and climate-related ones. In case of a government or NGO school project, the most viable course of action is usually a hybrid between EDGE and LEED/GRIHA as balanced between resource screening by EDGE criteria but indoor quality with the LEED/GRIHA standards.

2.4.3 Green strategies with proven benefits for schools

A literature review and case evidence suggests a limited set of strategies of primary schools in tropical monsoon climates with high impact:

1. **Orientation and shading:** orient the west sides of classrooms (i.e. to reduce direct solar penetration of long facades) (do not use large west glazing), use extended overhangs, loggia, and shading: limit direct heat gains by opening up to daylight and diffuse light (Raesoul 2007).
2. **Cross-ventilation/stack effects:** cross flows (openable opening on opposite facades) and high-level openings (which were used to allow high-level ventilation) in the designs provide thermal comfort most of the year without mechanical cooling.
3. **Day lighting controls:** Daylight is provided to the building through high windows, clerestories, light shelves and well constructed interior partitions to deliver low-glare, non-directional daylight, minimizing electricity lighting consumption and enhancing the status of occupants.
4. **There are also efficient electrical systems**: LED-lights, occupancy sensors (whenever possible), and efficient fans provide instant savings on energy and reduce service costs.
5. **Rooftop PV on critical loads:** such a scenario can be cost-effective when using PV to drive lights and fans, and the size is designed to meet important daily loads, when procuring PV resources enhance local maintenance.
6. **Harvesting rain water and water-efficient appliances:** Toilet flushing roof collection and irrigation of garden will save the municipal consumption and enhance resilience in case of shortages.
7. **Low-carbon materials:** where possible fly- ash-made bricks, compressed stabilized earth blocks (CSEB), responsibly treated bamboo are less embodied carbon and can frequently save on the prices of materials.
8. **Acoustic and indoor-air quality strategies:** ceiling panels with high absorption rates, buffers in corridors and openings in the high level ventilation eliminate noise and improve the intelligibility of the speech in classrooms.

One of the most appreciated aspects of the numerous measures is the fact that they are particularly useful in areas where there are constrained operating energy and water budgets - the measures save the operating expenditure, and have co-benefits (sustainability education, community resilience). EDGE/LEED/GRIHA case are often based on quantified outcomes in terms of savings and lifecycle and indicate measurable drops in energy and water consumption in schools and other institutional buildings.

2.5 Indoor environmental quality: daylighting, thermal comfort, ventilation, acoustics, and IAQ

2.5.1 Daylighting: principles and classroom targets

Why daylighting matters: Daylight has some contribution to visual comfort, circadian well-being, and learning results. Application of good daylighting can minimize electric lighting loads and give the pleasant stimulating environment.

Targets and metrics: The standards of lighting design provide illumination on classroom working surfaces of 300-500 lux in a standard primary school activity; higher limits in visual more demanding activity or evening classes. Mean illuminance is also equal to uniformity and glare control. Modern lighting recommendations (IES and DOE/IES school lighting specifications) give workable target ranges and recommend daylighting and electric lighting combination to achieve such level, with glare and overheating reduced to a minimum.

Architectural techniques: To have good heat gain with low day lighting in a tropical climate that has the monsoon winds:

- The best light is diffuse north light (in the northern hemisphere) and having north facing clerestory windows and light shelves brings in the diffuse daylight without taking in direct sun.
- East and west facades shall be treated through care: east lighting in the morning is of lower intensity and can be dealt with; west lighting in the late afternoon is abundant and adds heat to the building - employ deep shading, brise-solil or less high west windows.
- Top of the line openings and clerestories admit daylight to the interior of rooms without hitting work planes directly.
- Top lights and light wells have the ability to provide daylight to the interior rooms; they should be designed appropriately with right shading and being waterproof.
- The distribution of daylight is enhanced through the use of reflective interior finishes (moderate reflectance on ceilings and walls).

Design suggestion to Savar school: building orientation will be a mixture of shaded verandah, north-facing, clerestory (where east direction will permit) and regulated east glazing by means of fixed shading apparatus. Specification of electric lighting should be in terms of efficient LEDs with sizes that are to be used in addition to the day time lighting in a manner that they become dim or turn-off during sun-shine.

2.5.2 Thermal comfort and ventilation

Basic principals of thermal comfort: In the schools with natural ventilation, the architects engage in passive solutions and adaptive models of comfort. The ASHRAE Standard 55 offers the approaches to the assessment of thermal comfort (standard and adaptive approaches). Adaptive model In natural ventilated buildings in tropical environments, occupants acclimatize and the usefulness of air movement (fans) in raising acceptable operative temperatures is recognised. There is some support in Bangladesh that students in naturally ventilated classrooms can be comfortable at a higher range (i.e. 27-33degC) than a strictly conditioned standard is or implies but still performance and concentration decrease with an increase in temperatures.

Ventilation rates and IAQ: Ventilation lessens CO 2 concentration and dissipates pollutants. Minimal fresh air rates per occupant are in place internationally (ASHRAE 62.1) as firm positions of acceptability of IAQ; in schools, designers usually target the achievement of lowering CO_2 levels under the 1000-1200 ppm level when occupied through a combination of natural air movement and localized mechanical support (fans). Practical IAQ tools to schools are given by EPA and WHO that stress on the constant ventilation of the building together with low-cost monitoring (CO_2 monitors).

Passive strategies of ventilation: There are two major mechanisms of passive ventilation:

- Cross-ventilation: the air would pass through openings in one side to other; works well with small rooms or when the wind people are favorable. General layouts like opening ratios, window location and free flow paths will be important.
- Stack effect (buoyancy ventilation): the warm air ascends and cannot be expelled except by means of high vents or chimneys; at low like openings, an upwardgging air inflow is drawn in at low level. Stack ventilation works well in case of the diurnal temperature difference and can be utilized with the cross flow to achieve an encouraging performance.

Implication on design of Savar school: integrate cross ventilation (open windows on opposing walls) with high level openings (vents or clerestories) to leverage on the stack effect in still air condition. Mechanical augmentation can be in the form of ceiling fans that are cost efficient and enhance the perceived comfort (without providing full air conditioning) by adjusting the speed of air at the occupant level.

2.5.3 Acoustics and speech intelligibility

The acoustic design plays a key role in classrooms. Background noise and reverberation time (RT60) should be kept in check in order to ensure that the voices of the teachers can be heard and students are able to concentrate. There are acoustic strategies that consist of:

- absorptive ceilings to lessen reverberation or wall panels,
- area separating noisy (play areas, mechanical rooms) and classrooms,
- Flooring and furniture which minimises impact sound.

The LEED schools (among others) acoustic requirements take the form of targets and prescriptive guidance. The hearing-impaired or language-learning students are also assisted with good acoustic design.

2.5.4 Indoor air quality (IAQ) and health

IAQ is an aspect of controlling biological (mold), chemical (VOCs), and particulate contaminants (PM2.5). School design must include:

- **Control of the sources:** low-VOC material, storage of cleaning chemicals.
- **Adequate ventilation:** as has been mentioned.
- **On-demand filtration:** during extreme contamination of outdoors air, temporary filtration systems or designs that allow engineering filtration is possible.

- **Hygiene and cleaning:** create cleanable surfaces (particularly washable surfaces), proper drainage habits necessary to reduce the transmission of pathogens.

Balancing the ventilation and pollutant infiltration in high-pollution situations is not an easy task: ventilation will decrease the CO_2 and infection risk; however, outside PM can penetrate. There is evidence that the universal gains made by ventilation (less risk of infections, better attention) tend to outweigh the put up increase in PM ingress, although active filtration can be an effective supplement, when budgets and maintenance are reasonably provided. According to the recent field work, it is not a blanket solution to close all windows to protect IAQ, but the combination of methods (ventilation, filtration in the event of high pollution, anti-idling policy) is necessary to ensure both ventilation and the IAQ.

2.6 Water, sanitation and hygiene (WASH) in schools

2.6.1 Global guidance and local importance

WASH in schools is strengthened with guidelines in place by the UNICEF and WHO, which are field tested. Some of the core principles consist of adequate supply of drinking water, male and female and child-friendly toilets, open handwashing stations with soap, facilities to regulate menstrual hygiene in older students and weekly maintenance facilities (operation and maintenance plans). The measures cut down cases of diarrhoeal disease, absence and gender dropout.

2.6.2 Sizing and design of WASH facilities for primary schools

WASH guidelines are often used to spells out minimum ratios of toilets and handwashing points to students and advise separate facilities especially to boys and girls with privacy and lockable doors. They also propose convenient paths and fittings to individuals with disabilities. Design has to take into account the reliability of the water supply at the local level; in case of the intermittence of the municipal supply, it is also reasonable to use rainwater harvesting and storage tanks as the resilience strategies.

One of the strategies that have been broadly used in developing school resilience is rainwater harvesting (RWH). RWH potential = 1.4(absorption of nitrogen oxide) = 0.085.

Vol. harvested = Roof catchment area x Mean rainfall (depth) x Runoff coefficient.

The coefficient of runoff is determined by the material of the roof (corrugated metal = -0.8-0.95, tiled roofs = less). Detailed instructions and calculators are extensively accessible when it comes to preliminary sizing and UNICEF initiatives have successfully installed RWH in schools to toilet flushing, handwashing and garden irrigation. Basic decision-making with regard to storage size can be made on vital needs that are not potable and anticipated dry periods.

2.6.3 Maintenance, hygiene education and sustainability

Maintenance is critical towards the success of WASH. The schools should have cleaning, repair and consumable (soap, toilet paper) budgets and operational plans. Behavioral interventions (hygiene education, handwashing behavior) enhance the health outcome of infrastructure in multi. This according to the literature emphasizes that investment in infrastructure that is not maintained and maintenance programs that are not sustained in the programs tend not to sustain the health benefits

2.7 Sustainable construction and materials: local and sustainable.

Balancing between embodied carbon, thermal performance, cost, availability and local skills are all make or buy decisions in selection of construction materials to build a green school. A number of strategies in material pertain to Bangladesh

2.7.1 Bricks made of fly ash and other masonry units.

The coal combustion by-products are employed in fly-ash bricks (compressed or moulded), and less dependence on the fired clay-based bricks which extract topsoil is achieved. Their manufacture may be less carbon-intensive and be manufactured locally; a study in Bangladesh shows that fly-ash bricks with reasonable compressive strength and a reduced absorption of water can be produced to BDS requirements. Organisations (e.g. World Bank) have advanced fly-ash bricks as a substitute of lower carbon construction within South Asian regions. In the case of load carrying masonry, it is necessary to adhere to the local requirements and control quality; fly-ash bricks and AAC blocks are feasible in the non-load bearing partitions.

2.7.2 Stabilized earth blocks, CSEB and low-carbon concrete

Embodied energy in fired bricks is less when compared to Compressed Stabilized Earth Blocks (CSEB) and stabilized soils. Interlocked compressed blocks and Autoclaved Aerated Concrete (AAC) also need less mortar and may increase the speed of construction. Blast-furnace slag (ground granulatedblast-furnace slag (GGBS)) can be used as low-carbon concrete mixes which are less important in necessitating cement. Availability of materials locally, and manufacturing control should be identified as a determinant of feasibility and should be considered during the procurement process.

2.7.3 Finishes, paints and indoor environmental quality

There should also be the use of low-VOC paints, finishes, and adhesives to serve the interests of child occupants. Durable and washable interior wall finishes save on the maintenance costs that occur in the long term and ensure hygiene. The potential flooring material used should be cost-effective, sound absorbing as well as cleanable; polished concrete with suitable sealing can be cheap and low-maintenance.

2.8 Energy and renewable integration: sizing, expectations and procurement

2.8.1 Lighting and fans as primary electrical loads

Lighting and fans during the day used in schools with a small population typically are the key consumers of electricity; hence, efficient LEDs and efficient ceiling fans are low-hanging fruit in saving energy. The use of LED would cut lighting energy by half or three quarters of fluorescent or incandescent lighting.

Rooftop PV sizes: in most cases, the combination of rooftop PV is the most cost-effective one when daytime loads (lights, fans, few power outlets) are considered and when either there is a net-metering system or a backup battery. Simple sizing uses:

PV capacity (kW) = daydaily energy requirement (kWh/day) ÷ average peak hours of the sun.

Mean insolation at the Dhaka region is approximately 4-5kWh/m2/day (high seasonality caused by monsoon), thus an initial feasibility analysis would be low and contain a valley on the area of rainy seasons. In the case of many primary schools, a small PV array, say 1-3 kW is sufficient to support some lighting and fan loads during school time, although one will need a battery backup in case lights need to be used at night, or the grid is unavailable. The EDGE tools offer an effective avenue towards the retailing of the savings and yields of PV investments.

2.8.2 Economic payback and lifecycle perspective

Green investments cannot be taken in isolation; the need to spend more now in order to have better PV or more greta glazing payback will be reduced by years spent avoiding energy bills and maintaining equipment and glazing work instead of treating occupants to better occupant results. The accepted method of measuring economic feasibility is lifecycle costing (NPV, payback analysis sensitive to increase in energy prices). EDGE and others are generally a fast screening process that determines the measures with the most optimal cost-benefit result.

2.9 Design guidance and best practice synthesis (applied to Savar context)

This paragraph summarises the literature as easy to implement instructions towards designing the two-storey primary school in Savar.

2.9.1 Site and orientation

- Direct to the north-south put on orient long facades wherever possible so as to minimize direct sun gain; put north windows on the north and smaller shaded windows on the east and west.
- Classrooms should be practiced with shallow depths of plan (26-30 ft) to allow daylight to enter through the facades in cases when deeper plans are required, fall back to in-glass or light wells.

2.9.2 Form and massing

- Small-scale massing decreases the amount of construction exterior envelope area relative to unit floor area, decreasing heat gain and decreasing cost of construction.
- Verandah and shaded circulation give the thermal buffer to the classrooms and enhance comfort in movement during rains during monsoon seasons.

2.9.3 Envelope and fenestration

- Vertical fins and deep east and west sides overhangs minimize heat gain into the building in the late afternoons.
- Cross-ventilating windows in opposite walls; should have insect screens and closing latches.
- High level vents/clerestories to allow day lighting and stack ventilation.

2.9.4 Structure and materials

- A structure made of RCC framed construction is the best in a two-storey school structure when it has to withstand the earthquake and any additional modifications in the future, the detailing must be in accordance with BNBC.

- In compliant areas, use low -carbon infill material (CSEB, fly- ash bricks) when it is necessary and available on location.
- Take into account modularity and expansion in grids so that the expansion involves adding to the grid in future easily.

2.9.5 Services

- **Lighting:** daylighting controls and effective LED lighting with pre-determined sizes of lighting to suit the work plane with an approximate of 300 lux.
- **Ventilation:** passive cross ventilated design and ceiling fans to enhance the feeling of comfort.
- **Sanitation and water:** install RHW with the size to accommodate part of the non-portable demand, and have correctly advocated WASH amenities as recommended by UNICEF.
- **Electricity:** design roof to be developed later: PV installation in future; look into smaller short term PV to cover necessary day time load with battery backup in case of budget constraint.

2.9.6 Maintenance, training and lifecycle thinking

- **Design to be maintainable:** select materials and details which are easy to be repaired by local contractors; have good maintenance information and provide training in school.
- **Lifecycle costing:** analyse investments (e.g. PV, efficient glazing) based on NPV/payback accounting of local tariff on energy usage, and maintenance facts.

These direction points render literature to distinct design options to be applied in subsequent chapters. They are based on the BNBC regulatory foundation and guided by health and education guidelines of UNICEF/WHO, lighting and comfort guidelines of IES/ASHRAE and sustainability guidelines of EDGE/LEED/GRIHA.

2.10 Case study analysis - what was good, what was not

An analysis of school and institutional case studies comes up with repeating successful ingredients and pitfalls:

2.10.1 Success factors

1. Context-sensitive passive design: designs that reacted to the sun direction, local winds and rainfall worked successfully disregarding the use of heavy machinery.
2. Appropriateness of materials: locally available materials (bamboo, earth, fly-ash bricks) increased environmental friendliness, as well as benefited local economies.
3. Engagement of community: with community participation, the project maintenance was better and had greater local acceptance.
4. Operational simplicity: systems which the school personnel were able to upkeep (low-technology PV and replaceable battery simply, low-tech plumbing) continued even after commissioning.

2.10.2 Common pitfalls

Lack of maintenance: proper designed systems fail when consumables and maintenance funds are not scheduled (i.e. broken handwashing stations, clogged gutters to RWH).

1. **Too technical:** technical systems that need expert maintenance (complicated HVAC) tend to fail in small schools since the local technicians would not have experience in their maintenance.
2. **Poor specification in not relating moisture:** in wet climates poor moisture protection and thermal bridging leads to mould and decay.
3. **varying scale:** In some cases, local stakeholders could not afford large scale green strategies due to their large cost of upfront cost and a long payback period.

2.11 Gaps in the existing research and practice (justification for this capstone)

Despite the variety of resources, there are still aspects that the project fills:

1. BNBC-compliant school designs, where it is pragmatic to enforce the incidence of green measures, are relatively rare in the literature that is publicly available on Bangladesh specifically; most project reports either concentrate on architecture, or on engineering, but those that combine BNBC-level structural evidence with green measures at the BOQ level are few.
2. Passive + low-cost packages which have been tested operationally and scaled to primary schools in peri-urban Bangladesh are undocumented in regards to lifecycle costs and real-life maintenance aspects - a capstone of ETABS-constrained structural design, AutoCAD architectural models, and a comprehensive BOQ and lifecycle costing fits the bill.
3. Minor and poorly documented local material adaptation Local documentation (fly- ash brick mixes, treated bamboo detailing in RC hybrid structures) is available in a research but not in integrated project drawings and construction details that can be used directly in the contractor work.
4. There is a gap in the documented best practice in the practical advice on the implementation of the IAQ versus outdoor pollution at the city fringe of high-pollution urban areas, e.g.: a combination of natural ventilation and targeted filtration of high-pollution events.

This capstone is a design package (BNBC complexes) that incorporates all these usually disaggregated concepts: architectural program, structural design that has been validated through ETABS, green strategies that are sized and priced, and a realistic implementation plan on all stores of a two-storey primary school in Savar.

2.12 Summary and implications for design

The literature review provides a good basis on the Savar school design by incorporating the requirements of regulation, education, and sustainability. The design should be in full conformity to BNBC 2020 both in terms of structural, seismic and wind load requirements. It promotes a low-cost and maintenance-focused sustainability approach that focuses on natural ventilation, day lighting, LED-lights, low-speed fans, small-scale solar PV, and rain water capture. Where there is quality control, the use of locally available materials like fly-ash bricks, stabilized earth blocks, and treated bamboo should be used. The design must be straightforward, robust and maintainable with a well-documented design, the design must include ETABS reports, BOQs and life cycle cost analysis to ensure that design decisions made are transparent and verifiable.

Chapter 3: Project Overview

3.1 Introduction

The architecture of a school building can never be a simple affair in terms of architectural or engineering. It is a shaping of the future, since the building becomes the cradle where children and young generations get to learn, social and moral values. In the developing countries like Bangladesh where provision of education is still a key social and developmental objective, it is of national significance to construct safe, functional and sustainable primary schools.

This chapter gives an elaborate summary of the proposed project by the name, Design of a Sustainable Two-Story Primary School in Savar, Dhaka with Green Building Concept. The chapter sets the location, conditions of the sites, the nature of the soil used, climate and project requirements that determine the overall architectural and structural design. It also gives reasons as to why Savar was chosen as the location, the design assumptions and it also gives an outline of the scope of work that shall be used in the subsequent chapters.

3.2 Location of the Project (Savar, Dhaka)

3.2.1 Geographic Setting

The location of the proposed project is in Savar Upazila, which is about 24 kilometers northwestern to the Dhaka capital of the Bangladesh country. Savar is situated in Dhaka Division as well as in Dhaka District.

Savar is a strategic region due to a number of reasons:

- **Proximity to Dhaka:** This is relevant as one would be close to the capital and therefore would have access to an education, teachers and the government.
- **Rapid Urbanization:** Savar has been characterized by rapid industrial, commercial and residential development which has created the need to have new schools to accommodate the rising communities.
- **Educational Demand:** It has been caused by the large factories and industrial estates that have resulted to high influx of workers and their families and as such, the accessibility of primary schools to feed the children.

3.2.2 Social and Economic Context

The social economic analysis of the Savar suggests that it represents a mixed community comprising of industrial workers, employees of the service section, small traders, and farmers. Even though the literacy is increasing, it is still behind urban Dhaka. A large number of the children are first generation and as a result, having a fully functioning and well constructed primary school can change the lives of the children in terms of education.

The proposal will thus aim to:

- Offer learning in an inclusive and safe environment.
- Promote the primary education purposes of the government.
- Bring in the concept of green building to minimize the operation costs and make sure it is environmental friendly.

3.3 Site Selection Criteria

The location should be the main component of the success of every educational infrastructure project. This primary school was located inside a site in Savar, which was qualified based on the following criteria:

1. **Accessibility:** It should be easy to access it either on foot, bicycle, rickshaw, and small vehicles. In primary schools, the children are aged between 6-12 year and this means that accessible and safe availability is very important.
2. **Necity to Community:** The location should be close to residential clusters to reduce the travelling distance of the students.
3. **Topography:** It would prefer flat topography with very low slope in regard to building cost.
4. **Soil Condition:** Soil bearing capacity There must be sufficient soil bearing capacity to allow foundation design. Building sites consisting of excessively soft clay or prone to flooding are not that favorable.
5. **Flood and Drainage:** Since Bangladesh is the location prone to floods, the location must be slightly raised or should be drained adequately.
6. **Environmental Quality:** There should be no heavy noise or dust or any form of pollution in the area due to industries close to the site.
7. **Possibility of future expansion:** Accessibility to land in case the company wants to expanding vertically or horizontally in the future.

The site that has been chosen in Savar fits these requirements thus making it a site that can be used in this proposed project.

3.4 Site Analysis

3.4.1 Climate Analysis

Savar climatic is in line with the overall climate tendencies of the imprecise Bangladesh which is that of tropical monsoon. There are two important climatic parameters such as:

- Temperature: 12 ^{o}C in winter (December-January) to 40 ^{o}C in summer (April-May).
- Rainfall: Rainfall ranges are approximately 2,000-2,200mm annually but 80% of them occur during the months of June through September.
- Humidity: It is usually high with an averaging of 70-90 percent per year.
- Sunlight: The average day light period is 11-12 hours although cloud cover during the monsoon season diminishes the solar gains.
- Wind: Summer south/south east, and in winter north/west. Some cyclonic winds also hit the area.

Design Implications:

- It should allow maximum of natural ventilation inside buildings as monitored to counter heat and humidity.
- Shading devices (louvers, overhangs) must be fitted in order to minimize the heat gain produced by the sun.
- Wall and roofs of a home must be selected to reduce the amount of heat absorption.

- With the effect of high rainfall, harvesting of rainwater is possible.

3.4.2 Topography

Savar has a fairly low topography that is 26-40 feet above mean sea level. This height will limit direct flood threat, whereas, in time of heavy precipitation, local waterlogging will be possible.

Design Implications:

- Floor elevation on the groundmust be raised not less than 2.5 ft above ground surrounding.
- Proper drainage systems and site grading on the site must be done in order to avoid stagnant water.

3.4.3 Soil Condition and Geotechnical Investigation

The soil in Savar is generally an alluvial depositional which is composed of silty clay, sandy silt and some fine sand grains in some instances. The carrying capacity is different in relation to depth and location.

Past geotechnical researches of Savar considered:

- Shallow soils have allowable bearing capacity that is within the range of 2.5-3.5 ksf.
- Groundwater table also changes seasonally to range between 8-15ft.

Design Implications:

- It is possible to use shallow strip footings or isolated footings when dealing with a two-story building.
- The bearing capacity and settlement behavior has to be ascertained by soil research.
- There is a need to take waterproofing and damp-proofing measures because of high groundwater.

3.4.4 Environmental Considerations

The town is full of clothes factories and tanneries that are some of the sources of polluting air and water. The location of the site will not be in close proximity to industrialized areas. The place selected is situated in a semi-residential area that has quite clean environment.

There are also environmental considerations which are:

- Sustainable green open space of the building.
- Making good use of that which is already in existence.
- Setting the building to utilise natural light and wind.

3.5 Project Requirements

The spatial and functional requirements of the proposed school building shall include the following:

- **Classrooms:** 8-classrooms with 40-students each. Area per classroom: 780 ft^2.
- **Teachers' Rooms:** 1 rooms: 780 ft^2.

- **Library:** 1 library: 720 ft^2, with the capacity of accommodating 32 students simultaneously.
- **Washrooms:** 2 different washroom block (boys, girls, and teachers).
- **Circulation:** Circulation Cirdulation Circulation corridors and staircases, as specified in BNBC.
- **Green aspects:** Day lighting, cross ventilation, rainwater harvesting, and even solar power supply.

3.6 Design Assumptions

As far as structural and architectural design is concerned, the assumptions are as follows:

1. **Population:** 320 students, 8 teachers and 2 staff workers.
2. **Construction:** 100 years (design life).
3. **Construction Material:** Frame work made of Reinforced Cement Concrete (RCC), Infills made of brick.
4. **Dead Load:** According to BNBC 2020 - 145 psf on self weight, 25 psf on floor finish, 0.45 ksf on wall load on frame.
5. **Live Loads:** According to BNBC 2020 -60 psf on classrooms, 100 psf on corridors as well as library shelves and roof.
6. **Seismic Design:** Zone 2 in the case of adequate response reduction factor (R).
7. **Wind Design:** Dhaka region has 147 miles/h wind speed.
8. **Energy Efficiency:** Natural ventilation and use of solar panels to lower the operation costs.

3.7 Summary

This chapter has given a broad perspective of the overall project, its location, location analysis, soils, climatic and environmental concerns along with the project requirements. The justified reasons in choosing Savar as the location site of the project are based on the factors of accessibility, community need and suitability of the land.

Chapter 4 - Architectural Design

In this chapter, introduces the project of the practical architectural design of the two-story primary school in Savar. It has been authored in the form of practical design guide, evident room-by-room space plan, declared dimensions, furniture placement, door and window schedules, circulation and exiting planning, stair and ramp details, shading and daylighting designs, finishes and material, and particular green-building actions that can be executed with neighborhood craftsmen. Whichever arithmetic you use it is presented in steps so you can check that all your calculations.

4.1 Design philosophy - practical objectives

The design ideology is influenced by five pragmatical goals:

1. **Child centric:** spaces that are safe and secure and which are child scaled (doors, fixtures, furniture) and facilitate major pedagogy (group work, reading corners, play).
2. **Simplicity and strength:** simple plan geometry and construction details to reduce the cost and risk in the construction and maintenance.
3. **Passive comfort**: maximize the amount of natural ventilation and daylighting as that would minimize the operational costs and enhance the learning environment.
4. **Code-aware safety**: this is to ensure access to excellent egress, regularity, and compliance with stairs/ramps such that the building can be designed in ETABS and detailed in accordance with BNBC.
5. **Permanent green provisions:** opt PV, rainwater harvesting provisions, materials which are low maintenance and have identifiable clean lifecycle provisions.

Practical consequence: the plan will be rectilinear (easy to construct), with compaction of mass, repetitive classroom blocks, two stair cores, a simple load bearing grid to be clear of structural, and specific space to green infrastructure (roof PV, tank).

4.2 Overall planning strategy & module

Layout approach taken:

- simplify structure and services Use a repetitive classroom module: classroom footprint = 30 ft x 26 ft = 780 ft^2 (described and calculated below).
- Classrooms to be in pairs and on a passage of circulation with shaded walks/verandahs on the sunny sides.
- Install stairs at each end of the block, which are to provide safe two-direction escape.
- It is advisable to have the library and teacher rooms in less noisy areas (first floor) that have better daylight and lower external noise.
- Make at plan depth minimal ($\leq$ 26 ft) to allow day and natural ventilation deep into occupied space.

4.3 Space program & room dimensions (room-by-room)

The practical space program will be given hereunder. Having named all the spaces we need, we provide the recommended size of the space, furniture placement, finishes/spacing and door/windowing.

4.3.1 Analysis of the program (final design values)

We take an orthodox, comfortable one that compromises teaching requirements and constructions:

- 8 Classrooms - each 780 ft^2 (26 ft x 30 ft)
- 1 Teachers' rooms - 780 ft^2 (26 ft x 30 ft)
- 1 Library - 720 ft^2 (24 ft x 30 ft)
- 1 Store - 780 ft^2 (26 ft x 30 ft)
- Stair - 360 ft^2 (12 ft x 30 ft)
- washroom block 720 ft^2 (went in 2 parts, 1 each to the boys and girls and the teachers).
- Corridors, services, including allowance as 20 per cent., of core area (calculation of allowance in circulation allowance below)
- Gross floor Area (GFA) two floors Calculated sum of two floors- done after arithmetic step by step.

So that the numbers can be checked, we display all arithmetic digits by digits beneath it.

4.3.2 Classroom - detailed design

Capacity: the capacity is 40 students in the classroom.

Chosen room size: 26 ft x 30 ft = 780 ft^2.

Rationale: 30 ft provides 5 column & 4 row of desks, 26 ft depth to keep the plan shallow to enable natural ventilation and day lighting.

Furniture layout (practical):

- Use paired benches. The standard pragmatic desk bench, having two children: 4 ft by 1.5 ft long and deep. In case of simplicity we are dealing with mixed configuration with 20 benches on both the rows and each bench has 2 students.
  - length of benches (m) x length of bench (x) = length needed by bench.
  - When we take out 4 rows of 5 benches we must have certain that 5 benches x 4 ft = 20 ft bench bank across; we have to give a clearance in the middle of the aisle and at the sides.

  The following rules/standards should be followed for furniture layout in the classrooms:

  i) Maximum vertical viewing angle at the first row shall be less than 35° to the top of the board.

  ii) Minimum horizontal viewing angle at the first row shall be greater than 30°(from the side of the first row to the rear end of the writing board/chalkboard)

  iii) The distance from the first row of benches to the writing board should be at least 2 meters

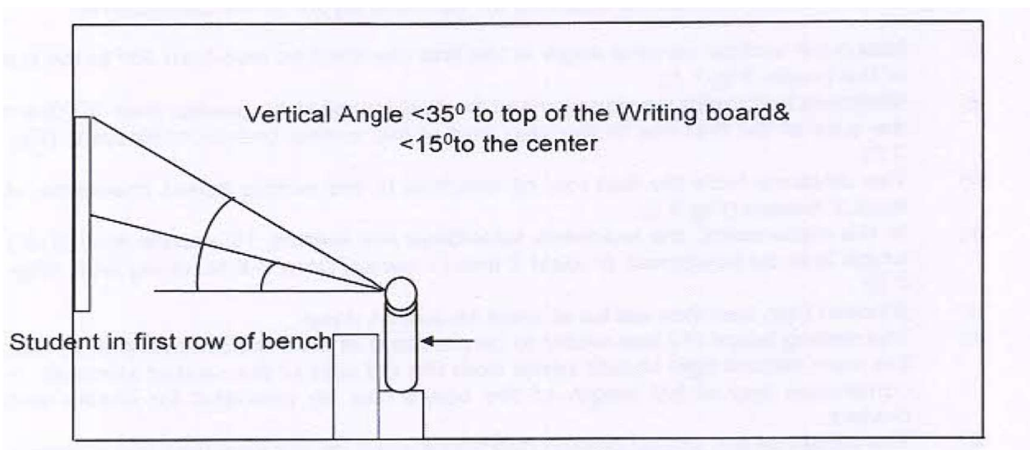
  iv) In the classrooms, the teacher's table/desk will require 10 square feet (5'x2') which is to be positioned at least 3 feet (1 meter) from the teaching wall.

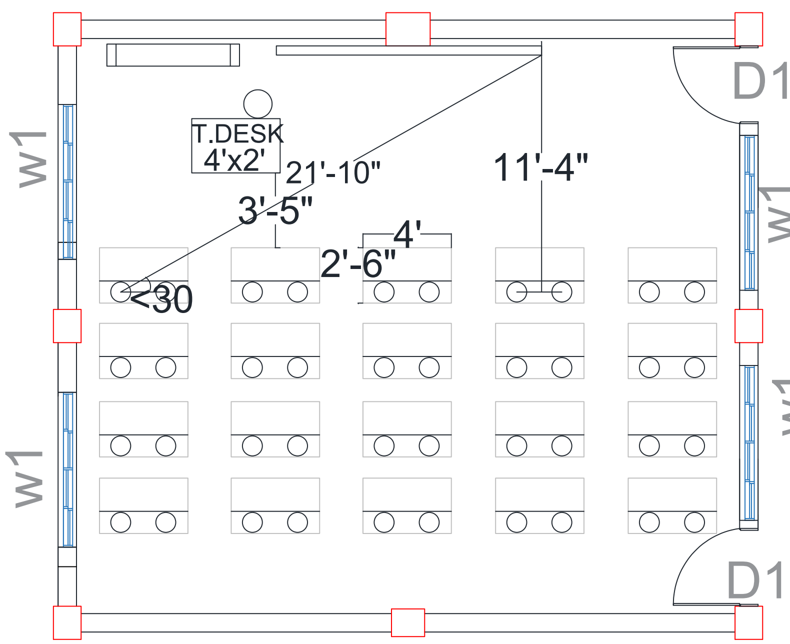
v) Student high benches will be at least 18 inches deep.

vi) The writing board (12 feet width) to be provided at the front or back wall so that the main natural light should come from the left side of the seated students. A continuous tray of full length of the board can be provided for chalks and dusters.

vii) The height of the writing board/chalkboard shall be not less than the distance from the center of the board to the furthest student/back row divided by 5.3

viii) The board could be 4 feet in height and in no case the bottom of the board is lower than 3 feet above the floor





CLASS ROOM
30'x26'

Example layout (one practical option):

- 4 rows (front to back), each row with 5 benches side-by-side: width needed = 5 benches × 4 ft = 20 ft.
- Suppose bench has 2 students in it - 4 rows x 5 benches x 2 = 40 students.
- Space (spacing between row of bench backs) = 2 ft circulation recommend.
- The table of teacher (4 ft x 2 ft) in front left or on center, and circulation space.

Ceiling: floor to floor we maintain at 12ft (floor to ceiling = 11.5ft after slab thickness) providing reasonable daylighting and stack ventilation opportunity.

Doors and windows:

- **Main door:** single leaf 3.5ft wide and 7 ft high.
- **Windows:** It is advised that there are 4 operable windows that are 6 ft (w) x 5 ft (h) in size and are constantly placed on the short facade, as much as possible, and cross ventilation provided. Each window area: 6 x 5 = 30 ft^2. In 4 windows: 30 + 4 = 120 ft^2 total window space per classroom.

Ventilation implication: operable area 120 ft^2/floor area 780 ft^2 =120 /780 =15.4=16%.

Window area is 16% of floor area.

This is a practical value that facilitates daylighting and cross-ventilation in association with the clerestory /vent openings, and is a reasonable practical range (10-25%) in tropical climates where natural ventilated classrooms are concerned.

Lighting design (artificial):

- Lighting on learning surface = 300 lux (standard).
- Luminous flux required = lux × area in m^2 = 300 x 72= 21600 lumens. [Room area, 780 ft2]

Selection of LED luminaire B = 5800 lumens luminaire (standard 45 W LED panel).

Division of number of luminaires by number of luminaires per tower = 13, 500/5800=3.72 = round up to 4 luminaires per tower.

Layout 4 ceiling mounted luminaires in 2x 2 -grid and linear 4-in-line on aspect-ratio of classroom. Daylight harvesting and energy savings Use dimmable drivers to have daylight harvesting functionality.

Acoustics & finishes (classroom):

- **Ceiling:** acoustic panels / perforated gypsum in order to reduce reverberation (target RT 60 = 0.6- 0.8 s).
- **Flooring:** sealed terrazzo, polished concrete and sealer or easy to clean and reduce impact resilient vinyl.
- **Walls:** daylight distribution by use of washable paint of medium reflectance (ceiling 70-80% reflectance, and walls 50-60% reflectance).

4.3.3 Teachers room - detailed design.

- **Room size chosen:** (30 x 26) ft = 780 ft^2
- **Useage & design:** 8 teacher room, meeting table, storage/lockers and notification board. Introduction of natural daylight and natural air. Door size 3.5 ft x 7 ft

- **Furniture:** 8 desks (4 x 2) ft, one common table (10 x 6) to hold meetings, 1 low book shelf.

4.3.4 Library - detailed design

Chosen size: (24 x 30) ft = 720 ft^2

Design logic behind seating capacity: the seating capacity of the library is to accommodate 15-20 concurrent students at the same time, reading shelves, school collection shelves with a small teacher librarian desk.

Assuming that the library has a desired number of 32 seats and the amount of 32/5=160 ft2 so far, assuming that the area per student in a library = 5 ft2: 32/5=160ft 2. As a practical operation, it is possible to refer to such a seating as flexible in which not all seats are occupied at the same time.

Shelving: 4 by-passers 2 ft deep, 10 ft long and 6 ft high.

Lighting design (artificial):

- Lighting on learning surface [?] 300 lux (industrial standard).
- The area (lumens) necessary = 300 x 72 -2 = 21600 lumens. [Room area, 780 ft^2 =72 m^2]

Selection of LED luminaire B = 5800 lumens luminaire (standard 45 W LED panel).

Division of number of luminaires by 5800 = 13,500/ 5800 =3.72 =4 luminaires.

Windows: more north and west -facing windows, and clerestory (where feasible by the orientation) to minimize glare and to help bring in diffuse day light.

4.3.5 Washroom block - detailed design

Size selected:(24 x 30) ft =720 ft^2 [divided in the middle].

Arithematic (design split example):

Typically, spend: boys Only: 4 pans/urinals to student and 1 pan to Teacher's + 7 basins and facility accessible. Approximate area split:

- Boys area = 360 ft^2
- Girls area = 360 ft^2

Note:

- nearly all physical vacation centers must work toward operational clarity.Outside remarks and recommendations (practical):
- Easy construction (alue use a partitioning) (brick with tile / washable finish).
- Enteries should be separate, boys and girls, well ventilated and have natural light (clerestory windows).
- Remodel the available stall with wheelchair by providing an accessible stall with a door swing of 3.42 ft (where possible) and clear turning circle of 4 ft x 4ft).
- Install handwashing points out of cubicles (to minimize queues within the cubicle).

4.3.6 Circulation, corridors and net/gross floor area

The calculation of the area of the classroom program is shown here in digits so as to represent the rigorous arithmetic aspect followed in the project:

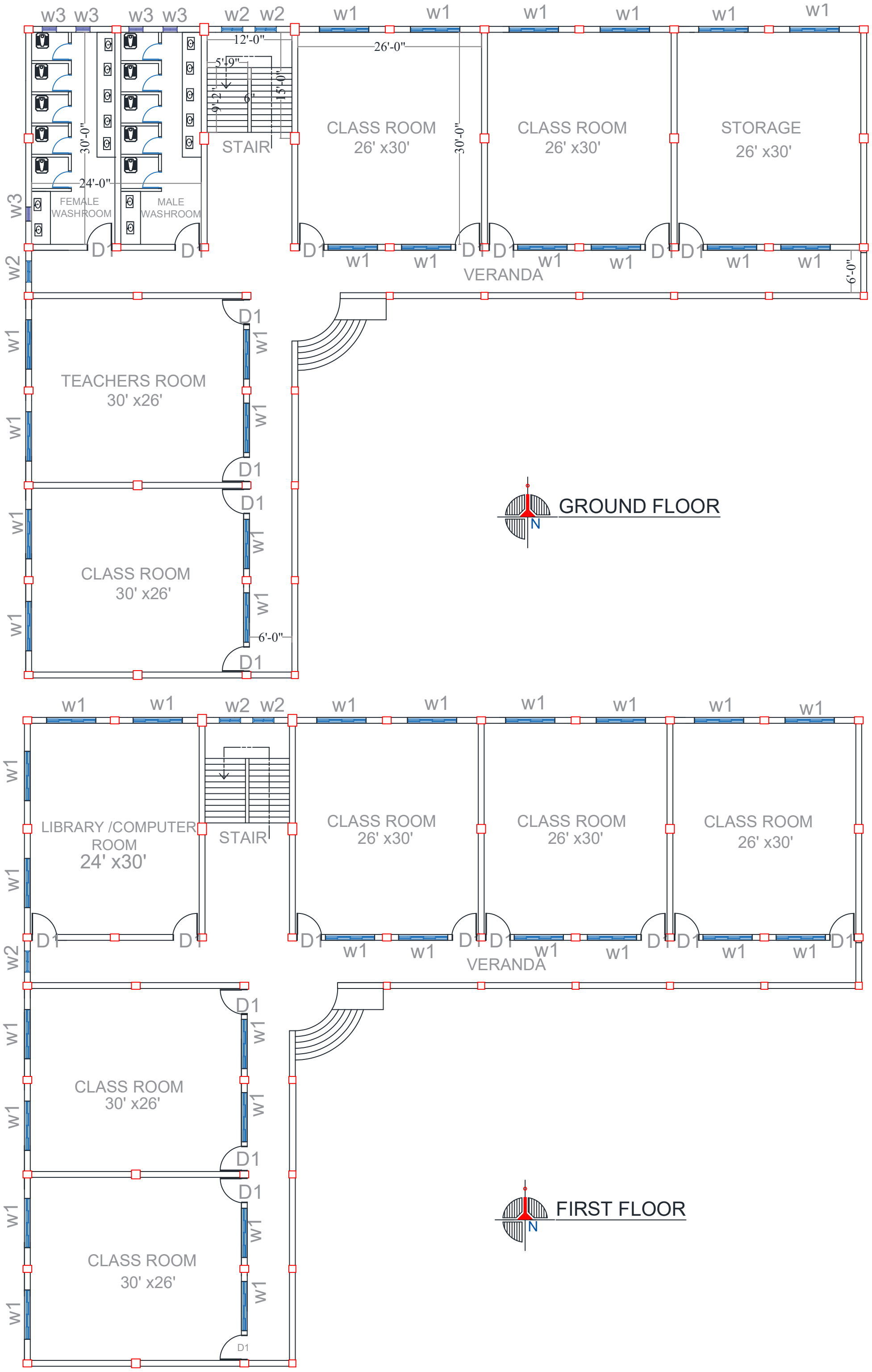
Assuming: The classrooms will accommodate 40 students. Standard area per student = 10 ft^2. Number of classrooms = 8.

1. **Compute area per classroom:**
   Average number of students per class = 40 Area / student = 400 ft^2.
   The area of the per class room is assumed to be 780 ft^2 including the area of a circulation.
   Total classroom area:
   classroom x number of classrooms = 780x8 = 6240ft^2.
2. **Total number of students:**
   Number of students in each class(x) by the number of classes(n) = 40x8 =320.
3. **Capacity of the library (10% of the total population):**
   10% of 320 = 320 x 0.10 = 32
4. **Library area :**
   24 x 30 = 720 ft^2
5. **Teachers' rooms area :**
   30 x 26 = 780 ft^2
6. **Store room area :**
   30x 26 = 780 ft^2
7. **Washroom area :**
   estimated 720 ft^2 (rough initial approximation).
8. **Stair Room**
   2x12 x 30 = 720 ft^2
9. **Core program area:**
   Sum = Sum of classroom area + library area + Teachers rooms + store room + Washroom + Stair room
   Sum = 6240+ 720 + 780 + 780 + 720 + 720= 9960 ft^2
10. **Allowance of circulation/ services (suppose 20% of core program):**
    20% of 9960= 1992 ft^2
11. **Total gross floor area (GFA):**
    9960 + 1992 = 11952 ft^2.
12. **Per floor area:**
    11952 / 2 = 5976 ft^2.
    We take per floor area 6647 ft^2

This arithmetic clearly shows openness in the program calculations applied in guiding architectural plans.

4.4 Floor plan layout Ground floor and first floor (practical plans)

Under the following, a realistic plan and circulation is outlined. Each floor will have room placement, circulation, door/entry, and furniture / services recommendations.



4.4.1 Ground floor general plan (working description)

Examples of a program that runs on the ground floor would look like the center line below:

- Primary access on corner point of the L shape.
- Two east facing and three south facing classrooms.
- Stair at north end
- Washroom block near Stair
- On ground floor- store/ teacher room.

Circulation width:

- Corridor width suggested 6 feet to move in both directions and where children move around.

Rationale One adult and a child can pass through a 6 ft corridor, and it is also easy to get out practically.

4.4.2 First floor characteristic plan (working description)

Program for first floor:

- 5 classrooms
- Library (quiet zone)
- The circulation has stair landing to the classrooms.
- Rooftop access hatching routing of PV and rainwater down pipe.

Placing of the library: the library should be located in the quieter side (north or courtyard side) so that infiltration of noise by the library can be minimized. Large clerestory and possibly small reading terrace wherever the structure plan will permit it.

4.5 Stair & ramp design - detailed practical calculations

The stairs and ramps become essential especially in terms of safety and access. The following are real world, constructible stair and ramp models having step by step arithmetic.

4.5.1 Stair design -flight geometry (per floor)

Design assumptions:

- Floor to floor height/ Clear vertical = 12 ft. The stair calculations are done using 11.58 ft.
- Select riser height = 6 in (comfortable riser practical school stair riser).
- Available tread (going) = 10 in (complete tread depth).

Arithmetic - number of risers:

1. Total vertical rise = 144 in
2. Riser height chosen = 6 in

Divide number of risers = total rise/ riser height:

$144 / 6 = 24$

Number of risers = 24 risers.

Number of treads: In the case of a normal takeoff and landing, the number of treads = number of risers in a flight. Assuming that we divide the stair into 2 flights that have a landing between, then we may have 12 risers per flight.

- Number of treads = 12-1= 11 treads per flight.

Horizontal length (flight run) in one flight = tread Multiy number of treads.

Compute flight run: 10 x 11 = 110 = 9.17 ft

Total stair horizontal footprint = 9.17+ 5.83 (intermediate landing) = 15 ft.

Railing and safety: On one side, 2.5ft handrails (For children per height)

4.5.2 Ramp design - accessibility

Purpose: Have available access to 2 ramps to ground floor in case ground floor elevated above exterior grade due to flood considerations.

Ramp length of the slope 1:12 (slope suggested to be used):

- Vertical rise = 2.5 ft
- Slope of 1:12 maximum implies rising = horizontal run X 12.

Compute: 2.5 x 12 = 30 ft

Ramp length required = 30 ft

Ramp width: minimum 4ft; suggest that 5ft is needed in movement in both directions as well as in turning wheelchairs about.

Edge protection and handrails: Handrails either side, edge kerbs minimum 2 inches to keep off rolling of wheelchairs.

4.6 Doors and windows — schedules & practical dimensions

4.6.1 Door schedule

- Main door Classroom (D 1): One solid core timber / Clear opening = 3.5 ft X 7 ft.
- Doors, Teacher Room (D1): 2 leaf, 3.5ft and 7ft.
- Main door to the library (D1): Leaf timber or steel frame with solid core is usual and both with the clear opening, 3.5 ft x 7 ft.
- Toilet cubicle door (D1): One leaf, 3.5 x 7 ft (swings to the right(safe) side is preferable).
- Utility / store door (D1): 3.5 ft x 7 ft

4.6.2 Window schedule

- Profile of windows in classrooms (W1): piveots that operate 7 ftx 5 ft (w x h)
- Clerestory vents (WV1) Mounted high vents (which are fixed or operable) 7 ft x 2 ft at top of wall used to ventilate stacks.
- Library (W1): Bigger openings 7 ftx 5 ft.
- Stair Windows (W2): 3 ft x 5 ft
- Toilet ventilation windows (W3): There are high vents 4 ft x 1 ft with louvers.

Glazing/shading: Glasswork Fixed parts Glazing -optional Operable mullions Glazing -optional Multiple mullions: use clear tempered glass. Install external shading equipment (depth of overhang suggested as being less than).

4.7 Shading, overhangs & solar control - practical dimensions

The size of shading should be that which will help keep out the high summer sun, and admit the low winter sun where advantageous. In a tropical place such as Savar, the most important thing is ensuring that direct sun can be shunned on the east/west facades and such solar gain on the north-south facade as much as possible.

Rule of thumb Practical rule Deep overhangs depth should be about 0.5 times the height of the window in cases of fixed horizontal shading of vertical glazing at intermediate sun angles.

In the case of classroom window height = 5 ft, and overhang depth =0.5x 5= 2.5 ft.

The size above window of classrooms in form of overhangs (horizontal eaves): 2.5 ft above window; a vertical injunction on the west facade mixes with vertical fins to control sun in the late afternoon.

4.8 Natural ventilation & passive cooling - practical detailing

The idea of natural ventilation strategy incorporates the combination of cross-ventilation and high-level stack vents and ceiling fans. Distributing leaflets in clinics with psychologist consulting rooms, where the psychological services may be performed:

1. **At least two operable openings** (one to each side of the classroom) (minimum operable area) 10-20% floor area). We have already offered 20 percent operational space (16 percent of the floor). Include high level vents (clerestory) 14 ft^2 in order to increase stack effect.
2. **High-level vents / clerestory:** Customer vents (W2) with area = 14 ft^2 =7 ft x 2ft. All classrooms will have one such vent, which will increase the effective ventilation.
3. **Ceiling fans:** roof fans should be one ceiling fan per every 8-10 ft width. In case of a 30 ft x 26 ft classroom, provision is 6 ceiling fans.
4. **Vent path system:** Internal partitions should be low or high louvered openings should be employed to maintain cross flow between classroom and circulation in case windows are open.

4.9 Daylighting strategy - targets and practical devices

Designing daylighting must eliminate the dependence on the electric lighting at the time of school and avoid glare and overheating.

Goal: Needs uniformity (>0.5) of student work plane of 300 lux, daytime.

The important devices and useful sizes are:

- Clerestory windows: there should be equal distribution of top light the height of which is 8-10 ft above the floor. Use clerestory area = 14 ft^2.
- Light shelves Light shelves on exterior or interior light shelves on north facades in order to bounce daylight deeper into the plan.

- Reflective ceilings: reflectance ceilings that are considered white have a reflectance of 70-80 percent and are used to disperse day light.

4.10 Acoustic design - practical measures

Target: acoustics and intelligibility of speech, and low level background noises.

Targets & design items:

- Background noise (external): in classroom preferably less than 40 dBA. Site next to Road or Industry, offer some form of acoustic shield (plant, masonry).
- Reverberation time (RT 60): 0.6- 0.8s in unregulated speech in classrooms. with acoustic ceiling tiles (mineral fibre or perforated gypsum) NRC 0.6 is achieved.
- Segregation of intense areas to the classroom: eliminate toilets, plant rooms, and stairs close to the library and silent classroom. Apply two door vestibules in areas with high level of noise.

4.11 Finishes, materials & sustainable choices (practical specs)

Wall & partition

- **External walls:** All-fly-ash bricks masonry on the walls and Brick masonry on loadbearing walls on non-RC walls only; desirable: fly-ash bricks because they embody less carbon. Outside facing: plastering made of cement with weatherproof paint.
- **Internal partitions:** 5 in hollow or lightweight block to be used as a non-structural partition; plastered blockwork to be used to install in library and teacher rooms.

Floors

- **Classrooms/ corridors:** polished concrete with built-in colour / epoxy sealer / or ceramic tiles in more used areas (porch/ wet areas). Durability and low cost- Polished concrete is cheap.
- **Toilets:** anti-skid ceramic tiles 24 in × 24 in for hygiene and maintenance.

Roof

- Slab roof which is waterproofed and insulated or has a reflective coating over the roof. Assuming finances, a green roof test patch should be offered in order to increase insulation and biodiversity.

Windows & doors

- **Frames:** aluminium or steel type can have powder-coated marks to ensure durability. Timber frames will be satisfactory provided that they are treated well.
- **Glazing:** harden glass where necessary; west facades, where there is a budget, glazing with low-E glazing, but this is an expensive option.

Paint & coatings

- All interiors are to be used with low-VOC paints. The exterior paint must be weather resistant.

Sustainable materials

- The alternatives to fired clay bricks are subsequently fly-ash bricks or CSEB (compressed stabilized earth blocks).
- Other non-structural concrete Recycled aggregates where quality in management has been allowed.

4.12 Toilet & WASH design - practical layout & fixtures

An effective WASH should be strong, maintainable and water- con-saving.

Fixture recommendations:

- Dual flush (water efficient cisterns) or low flow urinals.
- provide child-friendly pan.
- External hand-washing disinfection posts with soap alters and drainage.

SIZING EXAMPLE for 320 students:

Our offer is to make a conservatory working arrangement:

- Allocate boys: 4 pans/urinals/student and 1 pan/ Teacher + 7 basins and girls: same 4 pans / student and 1 pan / Teacher as above and accessible facility. Approximate area split:
  - Boys area = 360 ft^2
  - Girls area = 360 ft^2

Handling of wastewater: Installing of septic tank and soak pit of local required size, or include the municipal sewer (where possible). Toilet flushing can be done by toilet flushing rain water tanks which will lower the demand of potable water.

4.13 Roof plan & green infrastructure (PV & rainwater harvesting)

4.13.1 Roof available for PV

On roof 1000 ft^2 use for PV. Assume 70% usable for PV panels.

Compute usable PV area:

Roof area = 1000 ft^2.

Usable fraction = 70% = 0.70.

Usable PV area = 1000x0.7 = 700 ft^2.

4.13.2 PV sizing (practical rule of thumb)

Rough practical sizing: 1 kW average crystalline PV needs the area of 25-30 ft^2 based on panel efficiency. Take 28 ft^2/ kW as reasonable average.

calculate possible PV KW:

Usable area / area per kW = 700 / 28 = 25 KW

Not increasing cost: Due to the daytime loads of the school, full 50 kW can be inappropriate and costly. An initial more realistic home system would be 3-5 kW dedicated to school day lighting and fans with the possibility of increased later additions. The area of the roof is adequate however in case the project plans a bigger PV installation.

4.13.3 Rainwater harvesting (RWH)

Simple formula of RWH: Volume = weathered area (roof area) x rainfall depth x runoff coefficient.

Assume:

- Roof catchment = 6650 ft^2=617.8 m^2 (full roof).

- Mean rain/year in Savar 2100mm =2.1m(use locally obtained rainfall data, to be precise). In order to design to accommodate dry spells we need to consider monthly distribution, we would present basic annual yield to size feasibility.
- Co coefficient of runoff metal roof that is corrugated = 0.85 (0.80-0.95 average); runoff on tiled roof slightly lower.

Calculate volume of annual harvests:

1. Roof area x 2.1 x Rainfall depth = 617.8 x 2.1 x 0.85=1100 m^3.

Practical application: even a fraction of water flushed down the toilet, and the water used in irrigating gardens, will significantly decrease the reliance on the municipal water. In designing it, storage must have enough capacity to hold impetus in wet season in order to cover dry days: store size must be selected to achieve X days of non-portable demand.

Example tank size: in case non-portable daily demand (toilet flush combined with irrigation and cleaning) = 0.5 L per student/day x 240 students = 120 L/day and add staff - however this is too little. The non-portable realistically demanded demand at school may be a few hundreds and up to 1,000 L/day. It should be studied in terms of usage. However, the quantity of rainwater is a feasible source as demonstrated by the amount of rain per year.

4.14 Security, boundary & site layout

Boundary design (practical):

- Board wall 4-5 ft in height, secure gate, and planting buffer (to minimize dust and noise) should be furnished.
- There should be a safe primary entrance with a gatehouse or reception desk to check the visitors.

Play area & landscaping:

- Install soft play area 4000 ft^2 in location with trees used to provide shading and microclimate, or otherwise in staggered use with play courts and hard courts.

Drainage:

- Perimeter surface drains on buildings in perimeter of the building, with slope away the base (1% slope) to keep the water stagnant.
- RWH RWH cisterns collect down pipes; overflow to drainage/ no-surgery solution.

4.15 Fire safety & egress - practical layout

Basic practical measures:

Basic practical measures:

- **Corridor width:** 6 ft and stair width 5.75 ft offer working egress of normal school population.
- **Fire extinguishers:** portable extinguishers (2kg ABC) in corridors and in the vicinity of kitchen/technical rooms in case of any.
- **Emergency signage and emergency lighting:** the exit signs and emergency lights are lit on either the PV + battery system or UPS.

Idle location: designating external assembly space of least 1000ft^2 admitting no obstructions.

4.16 Maintenance & operational practicality

Design for low maintenance:

- Select strong finishes (sealed concrete floors, ceramic tiles in the damp places).
- Install standardised connectors and valves Make use of modular plumbing fixtures easily replaced.
- Equipment Provide maintenance closet with storage of spare parts, cleaning supplies, and rudimentary tools.
- Offer a straight forward manual of maintenance with monthly, quarterly and annual work and budget.

4.17 Practical construction sequencing notes

To retain the process of construction effective and cost-efficient:

1. **Site preparation and boundary:** initial perimeter works and set up Temporary site office set up.
2. **Foundations & groundworks:** excavate footings, soakaway and septic tank to be excavated together.
3. **Roof and waterproofing:** Put waterproofing over roof slab to secure the building.
4. **Masonry and internal walls Masonry:** brickwork.
5. **Windows and doors:** installing the frames early on minimizes possibilities of its damage following the finishes.
6. **Finishes and services:** electrical first with plaster then painting then final fixtures and furniture.
7. **External works:** when building envelope is secure play area, boundary wall and landscaping.

4.18 Summary

The chapter is the total architectural design of the two-storey primary school which offers design solutions that are practical and in-depth. It covers the plan of a typical classroom unit (26 x 30 ft), as well as, furniture, light and ventilation specifications. The gross floor area (GFA) and floor footprint was properly defined as 11,952 ft^2 and 5,976 ft^2, respectively, making sure that there was no unproductive use of space. The stair and ramp designs including the correct riser-tread geometry and spatial footprints are also described in the chapter. It also incorporates day lighting, acoustic, comprehensive door, window schedules, glazing and shading schedules. The design of the roof tops incorporates the feasibility of solar PV systems and rain water harvesting that would focus on sustainability. In general, the chapter encourages the consumption of materials and finish that is low in maintenance and is cost effective which is a way of identifying practicality and durability in the long run as well as their performance to the environment.

Chapter 5: Structural Design

5.1 Introduction

Any building project is largely dependent on structural design that will guarantee safety, stability, durability, and serviceability during the life of the building. Structural design is a crucial factor in the case of a two-story primary school building in Savar in Dhaka due to the fact that:

- The school will take in children between the ages of 6-12 years, whose safety will be the main concern.
- It is constructed in an area that is prone to seismic activities (BNBC Seismic Zone 2) and once such building should be able to survive a wind and earthquake.
- The weather conditions of Dhaka, with the presence of a high humidity rate, lots of rain, and high amount of ground water, demand the special attention to durability and construction of the foundation.
- The construction uses the principles of green design, however, the sustainability does not affect the building strength.

This chapter gives the detailed process of the structural design and includes the system selection process, load analysis, ETABS modeling, member design, seismic/wind checks as well as drawing outputs.

5.2 Selection of Structural System

The structure system that will be chosen in this project is a reinforced cement concrete (RCC) frame structure with:

- **Load-taking components:** Columns, beams and foundations.
- **Load distribution components:** Staircases and slabs.
- **Lateral load-resisting system:** The frame is rigid with proper detailing as per BNBC seismic requirements.
- **Nonstructural structures:** Infills Brick masonry infills (not designed as load-bearing).

Justification:

1. **Durability:** RCC is hard-wearing in the humid climatic condition of Bangladesh provided that there is a cover and mix mix design.
2. **Flexibility:** RCC frame gives flexibility of classrooms and flexibility of layout.
3. **Economy:** There have to be readily available materials (cement, steel, sand, aggregates) which save on cost.
4. **Seismic Performance:** When ductile detailed, the RCC frames are able to withstand the seismic forces effectively.
5. **Construction Feasibility:** The construction in the Savar locality among the contractors is proficient in RCC frame construction.

5.3 Structurel Requirments

1. General notes:

a) Design method usd for superstructure and sub-structrue according to bangladesh national building code (BNBC) 2020, ACI 318-08
b) 3d analysis for wind and earthquake analysis etabs-22.0.0 version was used
c) Any details not shown in the drawing should be done according to

aci detailing manual 2018.

d) For this structure basic wind speed-65.7 m/sec

e) Seismic zone-2

f) Others dead and live loads are as bnbc 2020

g) All the structural drawing shall be read in conjunction with relevant architectural drawing

2. Foundation

a) The building has been designed for g-05 storied kitchen (survice) building.

b) Foundation type-footing foundation

3. Concrete:

Concrete mix. proportions, materials and design strength at 28 day shall be as follows:

Sl no.	Reinforced concrete member.	Materials	Mix proportions	Specified design strength (fc)
01	Column, footing, floor beam, floor slab, grade beam & stair.	cement, 60% sylhet sand, (f.m. minium -2.5),33% local sand (f.m minimum=1.5) and ¼" down graded crushed stone chips dust free.	1:1.5:3	2900 psi.
02	lintel, sunshade, 03 drop wall, fins, false slab, septic tank.	cement, 100% local sand (f.m. minimum 1.50) and " down graded picked brick chips dust free.	1:2:4	2500 psi

4. Minimum cylinder strength:

I) 28th day strength-specified in above table.

Ii) 7th day strength-70% of specified fc.

5. Curing of r.c.c work:

1) curing time minimum 20 days

Ii) method of curing:

*horizontal surface by ponding of water

*other surfaces by wrapping moist jute fabri and sprinkling water by hose pipe frequently.

6. Water

Potable water to be used in concrete mix.

7. Rebar:

A) yield strength of steel fy= 500w deform bar (billet) for all 16mm to cligler bar.

B) yield strength of steel fy= 400w deform bar (billet) for all 10mmø and 12mmø bar

C) lap length = 40 times bar diameter (30db) but not less than 15" (for column).

D) lap length = 50 times diameter in all others structural member but not less than 15".

E) no bar shall be lapped in the zone of maximum tension stress.

F) use 10 mm diameter @ 9" c/c binder where necessary.

G) the following tests for reinforcing bars from random samples shall be Conducted at buet as per bds 1313: 1991 and test result shall be submitted

To the engineer for cheecking and record: 1) tensile strength test ii) percentage elongation test iii) bend/rebend test
Lap joint must be provided at the middle height of column in a staggered manner.
Lap joint for beam (l/3-l/4) distance from support.

8. Lap length

Unless otherwise mentioned in the drawings, lap length of bars shall be:

Concrete strength (psi)								
	2500	3000	3500	4000	4500	5000	5500	6000
Dia(mm)	Tension lap length(inch) for 60							
10	19	18	16	15	14	14	13	13
12	23	21	19	18	17	16	16	15
16	30	28	26	24	23	22	21	20
20	47	43	32	37	35	33	32	25

Column laps shall be tension laps

9. Hooks of rebar:

A) for all re-bar: provide 90° standard hooks (l-bent) if not shown in the drawings.

10. Spacer bars

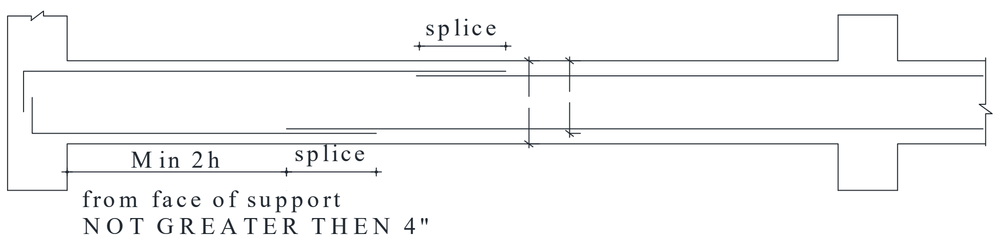
To support second layer bars in beams use 250 spacer bars @ 3'-0" c/c where required.

11. Chairs

Use chairs of necessary dimension made of 100/120 bar to support top bars of slab @ 3'-0" c/c.

12. Lap location:

A) for beam bottom bar, lap not to be provided at middle third zone of the span
B) for beam top bar, lap may be provided at middle third zone of the span
C) not more than 50% of the bars shall be spliced at one place
D) lap splices are to be confined by hoops with maximum spacing or pitch of d/4 or 4" where & is the effective depth of the beam.



13. Development length

All beam and slab rebars should be extended into the support upto development length.

14. Admixture

Approval by the engineer.

15. Water stopper

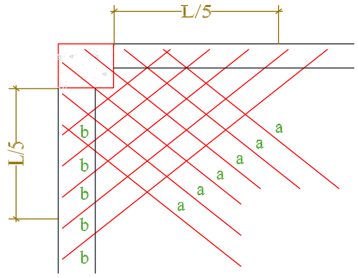
9" wide pvc water stopper to be used at all construction joints below ground in water tank wall.

Note

The dimension of column size, slab thickness, drop wall, etc. Excluding plaster thickness.

16. Corner Reinforcement ('CR')

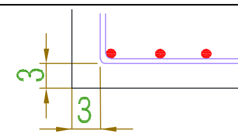
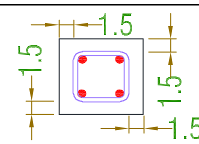
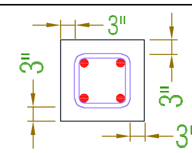
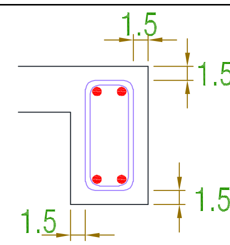
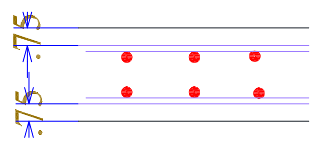
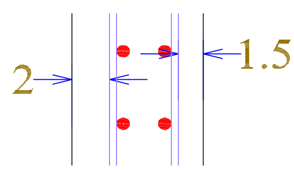
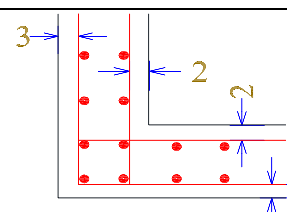
corner reinforcement for beam supported 2-way slabs



L-longer clear span

a-top bars-10 mm @ 6" c/c

17. Concrete clear cover for reinforcing bars

Member	Location/condition	Clear cover	Figure
Footing	Side	3"	
	Bottom	3"	
Column	Above f.g.l.	1.5"	
	Below f.g.l.	3"	
Beam	Top, side	1.5"	
	Bottom	1.5"	
Slab and stair	Top and bottom	0.75"	
Wall	Exterior	2"	
	Interior	1.5"	
U.g.w.r.	Water face	2"	
	Other face	2"	
3" or less thickness concrete element		1½"	

from tie & stirrups

18. Maximum bars in beams in single layer

Maximum number of bars as a single layer in beam stem shall be as per aci detailing manual 1994.

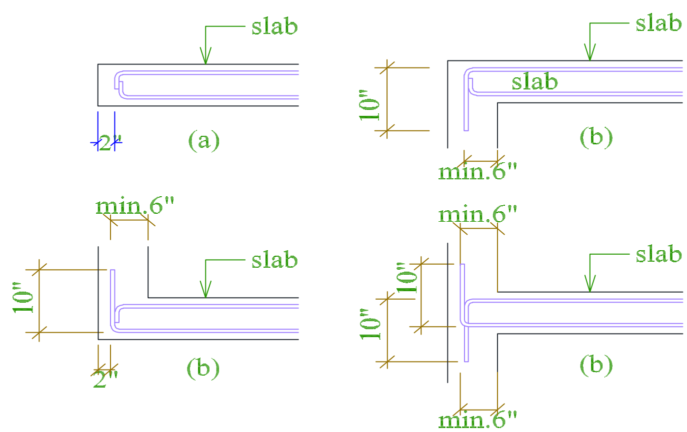
19. Minimum bar spacing of column longitudinal bars

Clear distance between longitudinal bars shall not be
Less than 1.5 times bar diameter, 1.5 times of the maximum size of coarse aggregate nor 1.5".

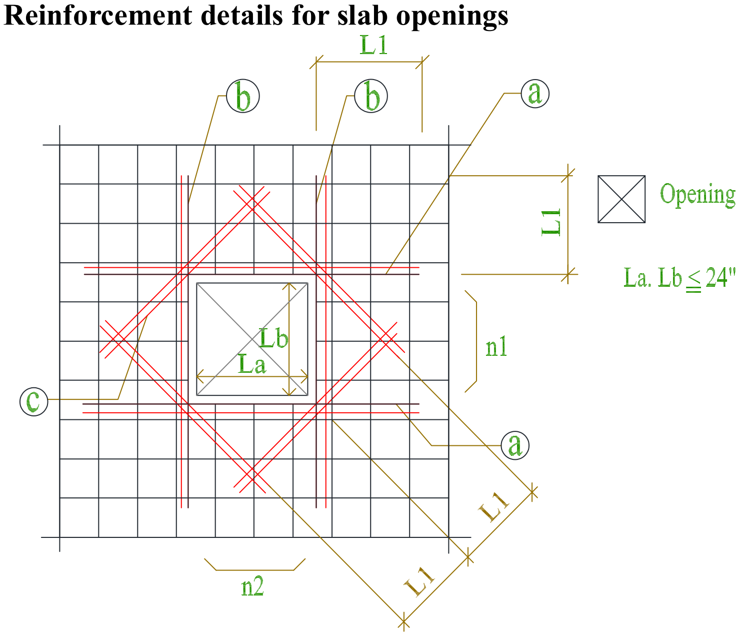
20. Slab and reinforcing details

A) free end of slab incapable of embedding of steel
Bar in beam/wall

B) others



21. Reinforcement details for slab openings



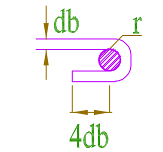
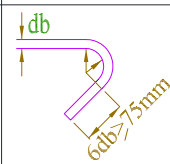
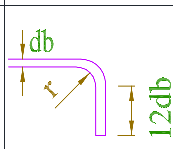
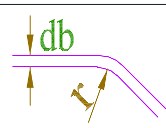
n1, n2 : THE NUMBER OF BARS WHICH ARE CUT OFF FOR OPENING

a) THE NUMBER OF EXTRA BARS > n1/2 (TOP AND BOTTOM BARS)

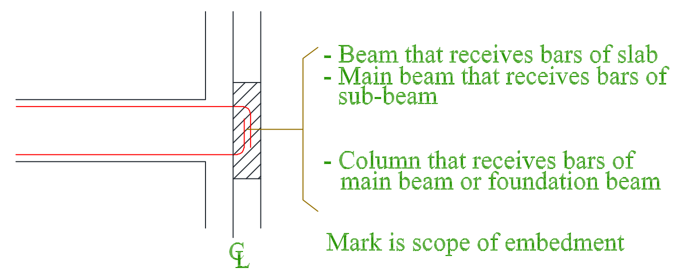
b) THE NUMBER OF EXTRA BARS > n2/2 (TOP AND BOTTOM BARS)

c) THE NUMBER OF EXTRA BARS = 2-D12(TOP AND BOTTOM BARS)

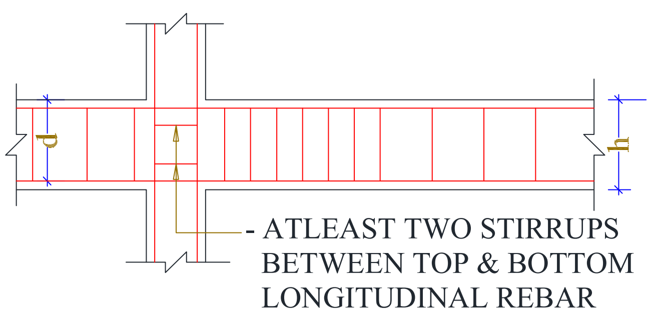
22. Recommended end hooks

BAR HOOK	FORM AND EXTENTION	BEND ANGLE (DEGREE)	BEND RADIUS (r)	USED BAR	LOCATION
PRIMARY REINF.		180°	r=2db	6 to 25	LAP SPLICE END OF ANCHORAGE
TIE/STIRRUPS		135°	r=1.25db	6 to 12	STIRRUPS FASTENING BAR DIAGONAL HOOP
PRIMARY REINF.		90°	r=2.5db	6 to 32	BEND-UP FOR EMBEDMENT
SLAB		45°	r=5db	8 to 20	BEND BAR IN SLAB

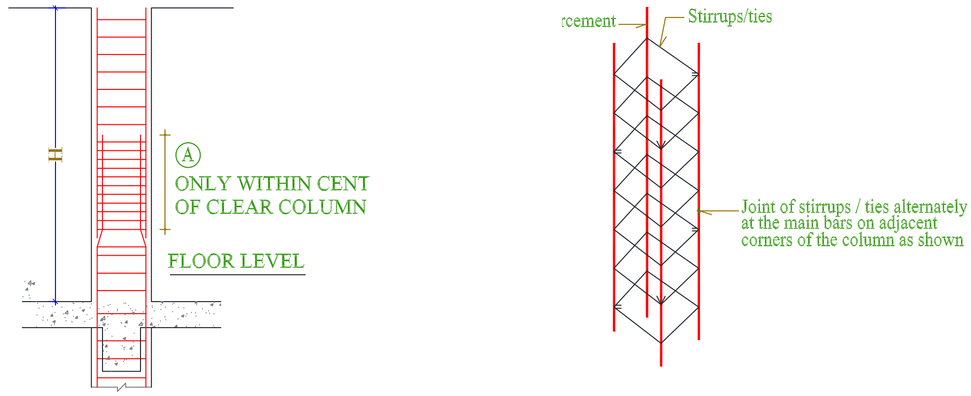
23. Scope of embedment



24. Requirments of column to beam joints for earthquake loading

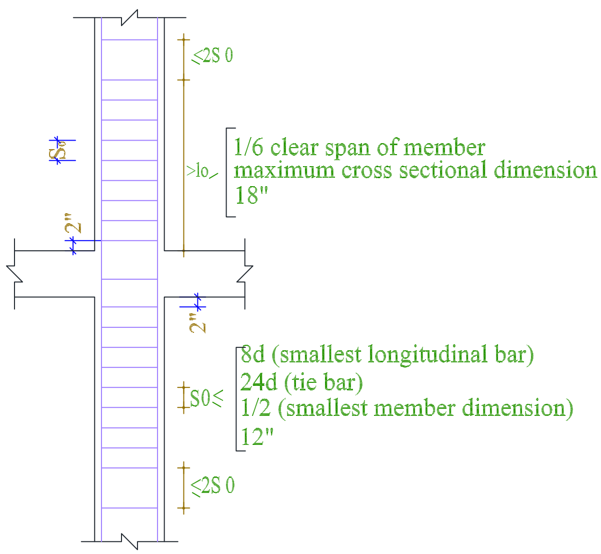


25. Column splice location

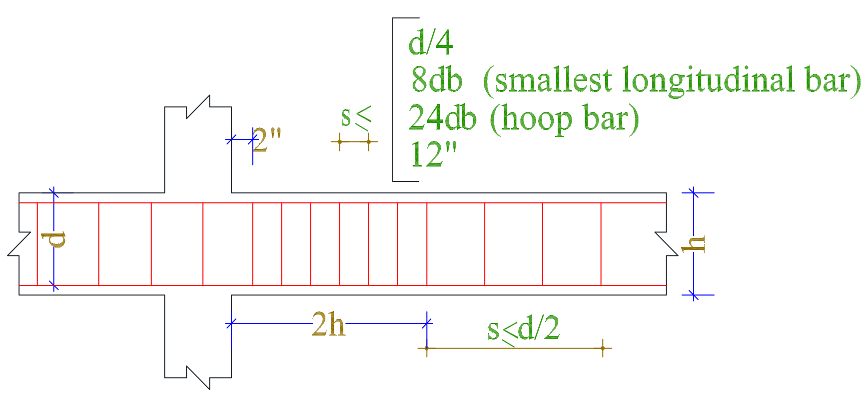


a) is area for splice of column reinforcement.
   maximum 50% of total bar is spiced at one level
   h = clear column height

26. Confinement requirement of column at joint for earthquake loading



27. Confinement requirement of beam at joint for earthquake loading



5.4 Load Considerations

Design loads are taken as per BNBC 2020.

5.4.1 Dead Load (DL)

Dead loads are fixed and they comprise self-weight of structural and non-structural components.

1. **Slab (5 in thick RCC):**
   - Density of RCC = 150 Ib/ft^3
   - Thickness = 5 in
   - Load = 150 x 5/12 = 62.5 Ib/ft^2
2. **Flooring: (tiles, screed, plaster):**
   - Average = 25 Ib/ft^2
3. **Brick Wall (5 in thick, 10.75 ft height):**
   - Brick masonry density = 120 Ib/ft^3.
   - Volume per ft^2 wall = 5/12 x 10.75 = 4.48 ft^3
   - Load = 130 x 4.48 = 582.4 Ib/ft^2 wall area [No door,window assume area = 400 Ib/ft^2]
4. **It will be treated with roof (screed + waterproofing+green concept):**
   - Average = 42 Ib/ft^2

5.4.2 Live Load (LL)

As per BNBC 2020, Table 6.2.3:

- **Classrooms:** 60 Ib/ft^2
- **Library (stack + reading):** 150 Ib/ft^2
- **Corridors & staircases:** 100 Ib/ft^2
- **Washrooms:** 60 Ib/ft^2
- **Roof (accessible to maintenance):** 100 Ib/ft^2

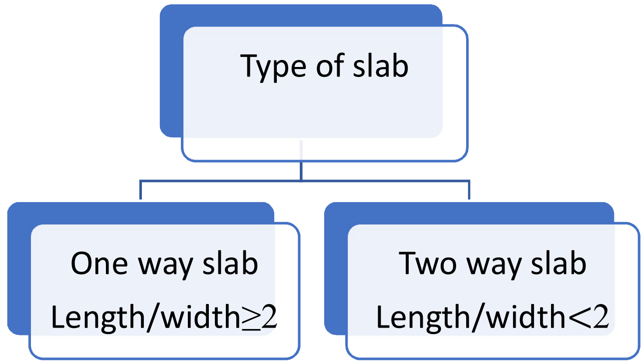
5.4.3 Environmental Loads

1. **Wind Load (BNBC 2020, Part 6):**
   - Saver Design wind speed = 147mile/h (65.7m/s)
   - Pressure, p = 0.6 x V2 = 0.6 x (65.72) = 2590 N/m^2 = 54 Ib/ft^2
   - Applied on exposed parts of the walls and roof.
2. **Earthquake Load (BNBC 2020, Part 2):**
   - Risk Range in Seismic Zone at Dhaka = Zone 2 (Z = 0.20)
   - The Importance factor (I) of schools = 1.25.
   - Response reduction factor (R) = -5 (of RCC moment resisting frame)
   - Site soil type = Medium stiff clay (SC)(Assume)
   - Computed in later stages in ETABS modeling.

5.5 Design of Structural Components

5.5.1 Slab Design

Slab type check:



Length = 15 ft
Width = 13 ft
Ratio : 15/13 = 1.15 [Two way slab]

Assume minimum thickness of slab : $h = \frac{\ln(0.8+\frac{fy(ksi)}{200})}{36+9\beta}$ $[\beta = \frac{ln\rightarrow in}{ls\rightarrow in}]$

$h = \frac{15\times12(0.8+\frac{60}{200})}{36+9\times1.15} = 4.27 \approx 5\ in$

d = 5 – 0.055 – 0.75 = 4.2 in

Dead Load:

Self weight of slab = $\frac{5}{12} \times 150 = 62.5\ psf$
Floor Finish = 35 psf [for roof slab]
Total Dead Load = 62.5+ 35 = 97.5 psf = 0.0975 ksf

Live Load:

Live load = 100 psf [for roof slab]
= 0.1 ksf
Load calculation:
Wu = 1.4×97.5+1.6×100 = 296.5 psf = 0.2965 ksf

Moment calculation:

Ratio : M = $\frac{13}{15}$ = 0.87

Table 6.6.8: Coefficients for Negative Moments in Slabs †

$M_{a,neg} = C_{a,neg} w l_a^2$

$M_{b,neg} = C_{b,neg} w l_b^2$

Where, w = total uniform dead plus live load per unit area

Span Ratio, $m = \frac{l_a}{l_b}$	Moment Coefficient	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
										
1.00	$C_{a,neg}$		0.045		0.050	0.075	0.071		0.033	0.061
	$C_{b,neg}$		0.045	0.076	0.050			0.071	0.061	0.033
0.95	$C_{a,neg}$		0.050		0.055	0.079	0.075		0.038	0.065
	$C_{b,neg}$		0.041	0.072	0.045			0.067	0.056	0.029
0.90	$C_{a,neg}$		0.055		0.060	0.080	0.079		0.043	0.068
	$C_{b,neg}$		0.037	0.070	0.040			0.062	0.052	0.025
0.85	$C_{a,neg}$		0.060		0.066	0.082	0.083		0.049	0.072
	$C_{b,neg}$		0.031	0.065	0.034			0.057	0.046	0.021
0.80	$C_{a,neg}$		0.065		0.071	0.083	0.086		0.055	0.075
	$C_{b,neg}$		0.027	0.061	0.029			0.051	0.041	0.017

Table 6.6.9: Coefficients for Dead Load Positive Moments in Slabs †

$M_{a,pos,dl} = C_{a,dl} w l_a^2$

$M_{b,pos,dl} = C_{b,dl} w l_b^2$

Where, w = uniform dead load per unit area

Span Ratio, $m = \frac{l_a}{l_b}$	Moment Coefficient	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
										
1.00	$C_{a,dl}$	0.036	0.018	0.018	0.027	0.027	0.033	0.027	0.020	0.023
	$C_{b,dl}$	0.036	0.018	0.027	0.027	0.018	0.027	0.033	0.023	0.020

Span Ratio, $m = \frac{l_a}{l_b}$	Moment Coefficient	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
0.95	$C_{a,dl}$	0.040	0.020	0.021	0.030	0.028	0.036	0.031	0.022	0.024
	$C_{b,dl}$	0.033	0.016	0.025	0.024	0.015	0.024	0.031	0.021	0.017
0.90	$C_{a,dl}$	0.045	0.022	0.025	0.033	0.029	0.039	0.035	0.025	0.026
	$C_{b,dl}$	0.029	0.014	0.024	0.022	0.013	0.021	0.028	0.019	0.015
0.85	$C_{a,dl}$	0.050	0.024	0.029	0.036	0.031	0.042	0.040	0.029	0.028
	$C_{b,dl}$	0.026	0.012	0.022	0.019	0.011	0.017	0.025	0.017	0.013
0.80	$C_{a,dl}$	0.056	0.026	0.034	0.039	0.032	0.045	0.045	0.032	0.029
	$C_{b,dl}$	0.023	0.011	0.020	0.016	0.009	0.015	0.022	0.015	0.010

Table 6.6.10: Coefficients for Live Load Positive Moments in Slabs †

$M_{a,pos,ll} = C_{a,ll} w l_a^2$

$M_{b,pos,ll} = C_{b,ll} w l_b^2$ Where, w = uniform live load per unit area

Span Ratio, $m = \frac{l_a}{l_b}$	Moment Coefficient	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,ll}$	0.036	0.027	0.027	0.032	0.032	0.035	0.032	0.028	0.030
	$C_{b,ll}$	0.036	0.027	0.032	0.032	0.027	0.032	0.035	0.030	0.028
0.95	$C_{a,ll}$	0.040	0.030	0.031	0.035	0.034	0.038	0.036	0.031	0.032
	$C_{b,ll}$	0.033	0.025	0.029	0.029	0.024	0.029	0.032	0.027	0.025
0.90	$C_{a,ll}$	0.045	0.034	0.035	0.039	0.037	0.042	0.040	0.035	0.036
	$C_{b,ll}$	0.029	0.022	0.027	0.026	0.021	0.025	0.029	0.024	0.022
0.85	$C_{a,ll}$	0.050	0.037	0.040	0.043	0.041	0.046	0.045	0.040	0.039
	$C_{b,ll}$	0.026	0.019	0.024	0.023	0.019	0.022	0.026	0.022	0.020
0.80	$C_{a,ll}$	0.056	0.041	0.045	0.048	0.044	0.051	0.051	0.044	0.042
	$C_{b,ll}$	0.023	0.017	0.022	0.020	0.016	0.019	0.023	0.019	0.017

FOR CASE 9:

C_a .nag = 0.0704

C_b .neg = 0.0226

[$C_{(unknown)} = C1 + \frac{C2-C1}{m2-m1} \times (m[unlisted] - m1)$]

C_a .dl = 0.0272

C_b .dl = 0.0138

C_a .ll = 0.0378

C_b .ll = 0.0208

Positive moment:

Ma(+ve) = $C_a .dlW_dL_a^2 + C_a .llW_lL_a^2 = 0.0272 \times 0.0975 \times 13^2 + 0.0378 \times 0.01 \times 13^2 = 0.512$ kip-ft/ft = 6.145 kip-in/ft
Mb(+ve) = $C_b.dlW_dL_b^2 + C_b .llW_lL_b^2 = 0.0138 \times 0.0975 \times 15^2 + 0.0208 \times 0.01 \times 15^2 = 0.349$ kip-ft/ft = 4.188 kip-in/ft

Negative moment:

Ma(-ve) = $C_a .nagW_uL_a^2 = 0.0704 \times 0.2965 \times 13^2 = 3.528$ kip-ft/ft = 42.336 kip-in/ft
Mb(-ve) = $C_b.nagW_uL_b^2 = 0.0226 \times 0.2965 \times 15^2 = 1.51$ kip-ft/ft = 18.12 kip-in/ft

Balanced steel ratio, $P_b = \alpha\beta \frac{f'c}{fy} \frac{\varepsilon u}{\varepsilon u + \varepsilon y} = 0.85 \times 0.85 \times \frac{2.9}{60} \times \frac{0.003}{0.003+0.005} = 0.0131$

$P_{max} = 0.75 \times 0.0131 = 0.01$

Check slab thickness:

$$d = \sqrt{\frac{42.336}{0.9 \times 0.01 \times 60 \times 12 \times (1 - 0.59 \times 0.01 \times \frac{60}{2.9})}} = 2.73 \leq d \text{ (ok)}$$

Reinforcement calculation:

Moment	Trial	Assume a (in)	b (in)	d (in)	M (kips-in/ft)	As= $\frac{M}{\emptyset fy\left(d-\frac{a}{2}\right)}$ (in²/ft)	a= $\frac{Asfy}{0.85f'cb}$ (in)	Comment
Ma(+ve)	01	0.5	12	4.2	6.145	0.029	0.059	Next Trial
	02	0.059				0.027	0.055	Next Trial
	03	0.055				0.027	0.055	Ok
Mb(+ve)	01	0.038			4.188	0.019	0.038	Ok
Ma(-ve)	01	0.43			42.336	0.21	0.43	Ok
Mb(-ve)	01	0.17			18.12	0.083	0.17	Ok

$As_{(minimum)} = 0.0018bt = 0.0018 \times 12 \times 5 = 0.11$ in²/ft

Now, $As_{a(+ve)} = 0.11$ in²/ft [For positive: Straight & Cranked bar]
$As_{b(+ve)} = 0.11$ in²/ft
$As_{a(-ve)} = 0.21$ in²/ft [For nagetive: Extra top(max 3 nos)]
$As_{b(-ve)} = 0.11$ in²/ft

Short Direction Specing :

1. Specing = $\frac{steel\ area \times 12}{Asa(+ve)} = \frac{0.11 \times 12}{0.11} = 12$ in
2. $S_{max} = 2t = 2 \times 5 = 10$ in
3. $S_{max} = 18$ in

Use 10 mm bar @8 in c/c alt ckd.

Extra Top = $\frac{Specing \times 2}{12} \times Asa(-ve) - steel\ area = \frac{8 \times 2}{12} \times 0.21 - 0.11 = 0.17$ in²

Use 2 - 10 mm bar between ckd.

5.5.2 Beam Design

Load area 55.25×2 = 110.5 ft^2
Beam length 15 ft
Height of Beam = 15 in
Clear cover = 1.5 in^2
d = 15 - 1.5 = 13.5 in

Dead Load:

Self weight of slab = $\frac{5}{12} \times 150 = 62.5\ psf$
Floor Finish = 35 psf [for roof slab]
Wall load = 50 psf
Total Dead Load = 62.5+35+50 = 147.5 psf × 110.5 ft^2 = 1629.75 Ib = 16.299 kip
Dead load of Beam(self) = $\frac{15}{12} \times \frac{12}{12} \times 15 \times 150 = 2812.5\ Ib = 2.813\ kip$
Total dead load = 146.299+2.813 = 19.112 kip

Live Load:

Live load = 100 psf [for roof slab]
= 0.1 ksf

Factor Load:

Wu = 1.4×19.112+1.6×11.05 = 44.44 kip

$Wu_{(udl)} = \frac{44.44}{15} = 2.96\ kip/ft$

Moment:

Ma(+ve) = $\frac{1}{14} Wu_u L^2 = \frac{1}{14} \times 2.96 \times 15^2$ = 47.57 kip- ft × 12 = 570.86 kip-in
Ma(-ve) = $\frac{1}{12} Wu_u L^2 = \frac{1}{12} \times 2.96 \times 15^2$ = 55.5 kip- ft × 12 = 666 kip-in
Balanced steel ratio, $P_b = \alpha\beta \frac{f'c}{fy} \frac{\varepsilon u}{\varepsilon u + \varepsilon y} = 0.85 \times 0.85 \times \frac{2.9}{60} \times \frac{0.003}{0.003+0.005} = 0.0131$
P_{max} = 0.75×0.0131 = 0.01
Check slab thickness:
d = $\sqrt{\frac{666}{0.9 \times 0.0131 \times 60 \times 12 \times (1 - 0.59 \times 0.0131 \times \frac{60}{2.9})}}$ = 9.66 ≤ d (ok)

Reinforcement calculation:

Moment	Trial	Assume a (in)	b (in)	d (in)	M (kips-in/ft)	As=$\frac{M}{\emptyset fy\left(d-\frac{a}{2}\right)}$ (in^2/ft)	a=$\frac{Asfy}{0.85f'cb}$ (in)	Comment
M(+ve)	01	0.5	12	13.5	570.86	0.79	1.6	Next Trial
	02	1.6				0.83	1.68	Next Trial
	03	1.68				0.84	1.7	Ok
M(-ve)	01	0.5			666	0.93	1.87	Next Trial
	02	1.87				0.98	1.98	Next Trial
	03	1.98				0.99	2	Ok

$As_{(minimum)} = \frac{3\sqrt{2900}}{60000} \times 12 \times 13.5 \geq \frac{200 \times 12 \times 13.5}{60000} = 0.436 \geq 0.54\ in^2$
$As_{(minimum)}$ = 0.54 in^2
As(+ve) = 0.84 in^2
As(-ve) = 0.99 in^2

Use 2-16mm + 1- 16 mm ext. [Bottom]
Use 2 – 16 mm + 2 – 16 mm ext. [Top]

5.5.3 Column Design

L_1 = 7.5+7.5 = 15 ft
L_2 = 6.5+6.5 = 13 ft
Beam length = 15+13 = 28 ft
Area of supported slab = 15×13 = 195 ft^2

From slab load:

Self weight of slab = $\frac{5}{12} \times 150 = 62.5\, psf$
Floor Finish = 35 psf [for roof slab]
Wall load = 50 psf
Total Dead Load = 62.5+35+50 = 147.5 psf × 195 ft^2 = 28762.5 = 28.76 kip
Live load = 100× 195 = 19500 = 19.5 kip
Dead load of Beam(self) = $\frac{12}{12} \times \frac{10}{12} \times 28 \times 150 = 3500\, psf = 3.5\, kip$
Self weight of column = 10% of (DL+LL) = 0.1×(28.76+3.5+19.5) = 5.176 kip
Total dead load = 28.76+3.5+5.176 = 37.436 kip

Factor load:

Pu = 1.4 ×37.436 + 1.6 × 19.5 = 83.61 kip [Multiply the story number]
For two story building (we use 2.5)
Pu = 83.61 × 2.5 = 209 ≈ 210 kip
DL = 37.436 × 2.5 = 93.59
LL = 19.5 × 2.5 = 48.75 kip

Tied Column Design:

	α	ϕ
Tied	0.8	0.65
Spiral	0.85	0.7
Pg	1% - 8%	

$\frac{Pu}{\alpha\phi} = Ag[0.85 \times f'c(1 - Pg) + Pg \times fy]$
$\frac{210}{0.8 \times 0.65} = Ag[0.85 \times 2.9(1 - 0.02) + 0.02 \times 60]$
Ag = 111.69 in^2
Use 12 × 12 in column [144in^2]
$\frac{Pu}{\alpha\phi} = 0.85 \times f'c(Ag - As) + As \times fy]$
$\frac{210}{0.8 \times 0.65} = 0.85 \times 2.9(144 - As) + As \times 60]$
As = 0.849 in^2
As_{min} = 1% of Ag = 0.01 × 144 = 1.44 in^2
Use 6 – 16 mm bar

5.5.4 Footing Design

Column load Pu = 210 kip
Self weight of footing = 10% of load = 0.1 × 210 = 21 kip
Avarage unit weight of live load = $\frac{150+1}{2} = 125\, psf$
Effective soil pressure q_a = 4000 – 125 × 6 = 3.25 ksf
Allowable bearing area, A_b = $\frac{210+21}{3.25} = 8.43 \approx 8.50$ ft^2 [8.5^2 = 72.25 ft^2]
P_{net} = $\frac{Pu}{Ab} = \frac{210}{72.25}$ = 2.91 ksf

Punching shear check:

Allowable punching shear stress, $V_{pu(all)} = 4\phi\sqrt{f'c} = 4\times0.75\sqrt{2900} = 161.55$ psi

$V_{pu} = P_u$ – Punching area × $P_{net} = 210 - \frac{30\times30}{12\times12} \times 2.91 = 191.81\ kip$

Acctual punching shear stress, $V_{pu(ac)} = \frac{Vpu}{punching\ area\times dept} = \frac{191.81\times 1000}{2\times(30+30)\times18}$

$= 59.2$ psi $< V_{pu(all)}$

(ok)

Critical shear check:

$V_{f(all)} = 2\phi\sqrt{f'c} = 2\times0.75\sqrt{2900} = 80.78$ psi

$V_f = 1\times \frac{33}{12} \times 2.91 = 8$ kip

$V_{f(ac)} = \frac{8\times1000}{12\times18} = 37.04 < V_{f(all)}$ (ok)

Moment:

$M = \frac{WL^2}{2} = \frac{PnetL^2}{2} = \frac{2.91\times\frac{39^2}{12}}{2} = 15.37$ k-$\frac{ft}{ft}$ = 184.42 k-$\frac{in}{ft}$

Balanced steel ratio, $P_b = \alpha\beta\frac{f'c}{fy}\frac{\varepsilon u}{\varepsilon u+\varepsilon y} = 0.85 \times 0.85 \times \frac{2.9}{60} \times \frac{0.003}{0.003+0.005} = 0.0131$

$P_{max} = 0.75\times0.0131 = 0.01$

Check slab thickness:

$d = \sqrt{\frac{184.42}{0.9\times0.01\times60\times12\times(1-0.59\times0.01\times\frac{60}{2.9})}} = 5.69 \leq d$ (ok)

Reinforcement calculation:

Moment	Trial	Assume a (in)	b (in)	d (in)	M (kips-in/ft)	As=$\frac{M}{\emptyset fy\left(d-\frac{a}{2}\right)}$ (in²/ft)	a=$\frac{Asfy}{0.85f'cb}$ (in)	Comment
M(+ve)	01	0.5	12	18	184.42	0.192	0.39	ok

$As = \frac{200bd}{fy} = \frac{200\times12\times18}{60000} = 0.72\ in^2$

Specing = $\frac{use\ steel\ area\times12}{req.\ steel\ area} = \frac{0.31\times12}{0.72} = 5.17 \approx 5$ in c/c

5.5.5 Stair Design

Assumptions and considerations :

fy= 60000 psi *f'c*= 2900 psi

Thickness of waist and landing slab = 6"

Live Load=0.1 ksf (BNBC 2020)

Floor Finish= 25 psf = 0.025 ksf

Load calculation:

Rises & Steps= $\left(\frac{\frac{1}{2}\times\frac{6}{12}\times\frac{10}{12}\times5.83\times11\times150}{1000}\right)$= 2 ksf

Waist slab =$\left(\frac{\sqrt{9.17^2+5.5^2}\times\frac{6}{12}\times5.83\times150}{1000}\right)$=4.68 ksf

Total Dead Load = Landing slab + (Rises & Steps+ Waist)

$= \frac{\left(\frac{\frac{6}{12}\times150}{1000}\right)+\left(\frac{2+4.68}{9.17\times5.83}\right)}{2}$ =0.1 ksf

Total load, W= (0.1*1.6) + [1.2*(0.1 +0.025)] =0.31 ksf

Moment :

M+= $\frac{WL^2}{14}$ = $\frac{0.31\times(5.83+9.17)^2}{14}$= 4.98 k-ft/ft

M−=$\frac{WL^2}{9}$ = $\frac{0.31\times(5.83+\ .17)^2}{9}$=7.75 k-ft/ft

d = (t-1) = (6-1) = 5"

Balanced steel ratio, $P_b = \alpha\beta\frac{f'c}{fy}\frac{\varepsilon u}{\varepsilon u+\varepsilon y}$ = 0.85 × 0.85 × $\frac{2.9}{60}$ × $\frac{0.003}{0.003\quad .005}$ = 0.0131

Check slab thickness:

d = $\sqrt{\frac{7.75\times12}{0.9\times0.0131\times60\times12\times(1-0.59\times0.0131\times\frac{60}{2.9})}}$ = 3.61 ≤ d (ok)

reinforcement calculation :

Moment	Trial	Assume a (in)	b (in)	d (in)	M (kips-in/ft)	As= $\frac{M}{\emptyset fy\left(d-\frac{a}{2}\right)}$ (in²/ft)	a= $\frac{Asfy}{0.85f'cb}$ (in)	Comment
M(+ve)	01	0.5	12	5	4.98	0.23	0.47	ok
M(-ve)	01	0.7			7.75	0.37	0.75	ok

$As_{(minimum)}$ = 0.0018bt = 0.0018×12×6 = 0.129 in²/ft

As(+ve) = 0.23 in²/ft

Specing = $\frac{steel\ area\times12}{Asa(+ve)}$ = $\frac{0.19\times12}{0.23}$ = 9.91 ≈ 8 in c/c

Use Ø12mm@8 in c/c

As(-ve) = 0.37 in²/ft

Extra Top = $\frac{Specing\times2}{12}\times Asa(-ve) - steel\ area$ = $\frac{8\times2}{12}\times 0.37 - 0.19$ = 0.30 in²

Use 2 - Ø12 mm bar between ckd.

5.6 ETABS Modeling

5.6.1 Model Setup

- Grids: Presentation of grid Data Spacing.
- Levels Ground floor (0 ft), ladder floor (12 ft), roof (24 ft).
- Frame Elements RCC columns, beams, and slabs.

5.6.2 Material Properties

- Concrete grade: fck = 2900 Psi (M25)
- Steel grade: fy = 60 ksi
- Unit weight of RCC = 145 Ib/ft3
- Mass of mortar weighing 1ft 3 walls, unit weight = 130 Ib/ft3.

5.6.3 Section Properties

- Slab thickness: 5 in
- Beams: B1 = (12 x 12) in, B2 = (12 x 15) in
- Columns: C1 = (12 x 12) in, C2 = (12 x 15) in, C3 = (15 x 15) in, C1 = (15 x 20) in

- Foundation: The foundation is isolated with the following dimensions: F1 = (4 x 4) ft, F 2 = (5 x 5) ft, F 3 = (6 x 6) ft, F 4 = (6.5 x 6.5) ft, F 5 = (7 x 7) ft, F 6 = (9 x 9) ft with 7 ft normal depth.

5.6.4 Load Combinations (BNBC 2020)

1. 1.4 DL
2. 1.2DL + 1.6 LL
3. 1.2 DL + 1.0 WL + 1.0 LL
4. 1.2 DL + 1.0 EQ + 1.0 LL
5. 0.9 DL ± 1.0 WL
6. 0.9 DL ± 1.0 EQ

5.7 Analysis Results

5.7.1 Structural Stability

- When laterally displacing Max (ETABS): < 25 mm (BNBC limit = H/500 =14.4 mm).

5.7.2 Member Forces

- Typical beam moment: 105 kip-ft
- Average column load axial: 45kip-ft.
- Shear forces in the domain of design.

5.7.3 Foundation Reactions

- Max soil pressure: 233 kip-ft

5.8 Seismic and Wind Analysis

- **Seismic checks:** ETABS Response Spectrum method indicates T = 0.35 s building period, and floor wise distribution of the shear at the base.
- **Wind checks:** wind, preventable change due to wind.

5.9 Safety and Serviceability Checks

- Deflection Max slab deflection = L/300 < L/250 limit.
- Crack control: Distance between bars should not exceed more than 300 mm in accordance with BNBC.
- Durability Concrete cover 1.5 – 2 in, water cement ratio less than 0.45 in exposure conditions.

5.10 Summary

This chapter outlined the process of structural design of the 2 story primary school, which consisted of system selection, determination of loads, ETABS modeling, and design of the members. The building is in accordance with the BNBC 2020 requirements of strength, stability, and servicing.

The RCC frame construction is a safe construction even to seismic and wind loads, and cost-effective and feasible in Savar. Its design is set to be countered with drawings and schedules.

Chapter 6: Materials & Sustainability

6.1 Introduction

Any building has skeleton and skin constituted by materials. The choice of materials is critical in the design of a sustainable two-story Primary School in Savar that is located in Dhaka, not only in the structural performance but also to make the building sustainable, affordable, and long lasting.

The masonry on bricks, RCC (Reinforced Cement Concrete), and sheets of corrugated iron, are regarded as traditional techniques in the construction activity in Bangladesh. These materials can be considered as functional but extremely costly to the environment: very high carbon levels during the burning of kilns, excessive sand utilization in rivers, and inability to recycle CI sheets.

Building practices around the world in the 21 st century are changing towards using green materials and eco-friendly construction systems which are based on low carbon, recyclable materials and locally sourced materials. In this chapter the materials used, green building, and sustainability measures that were adopted in the school project are discussed.

6.2 Principles of Sustainable Material Selection

Regarding the selection of materials in the case of this project, the selection is determined using the following principles:

1. **Local Availability:** Yet, Energy and cost lack of transportation.
2. **Low Embodied Energy:** It is preferring those of lower production energy.
3. **Recyclability & reuse:** Prejudice to the recyclable or reusable materials (steel, bamboo, fly ash).
4. **Durability:** The material must have the capacity to withstand the humid weather, rains and earthquakes.
5. **Affordability:** Must meet the budget constraints of the state schools.
6. **Health and Safety:** Toxic free presentations, poor indoor air quality, water-resistance.

6.3 Structural Materials

6.3.1 Concrete

- **Type:** The beams, columns, slabs, and foundations are made of reinforced Cement Concrete (RCC).
- **Grade:** M25 (fck = 2900 psi), and was designed according to BNBC 2020.
- **Mix Proportions:**
    - Cement: OPC cement or fly ash (PPC) cement.
    - Fine aggregate: local sand approved of quality of sand.
    - Coarse aggregate Crushed stone (20 mm down).
    - Water- cement ratio: 0.45 to be durable.

Sustainability Measures:

- Old 15-20% of cement with fly ash (thermal power plant byproduct).
- Transport energy is reduced by use of locally sourced aggregates.
- Make sure to batch ready-mix concrete control in order to minimize waste.

6.3.2 Steel Reinforcement

- Type: High Yield Strength Deformed Fy = 60 ksi
- Source: Made by re-rolling mills in Bangladesh (BSRM, Abul Khair Steel).

Sustainability Measures:

- Favoritism on recycled steel (reduced embodied energy).
- Provide sufficient cover as a measure of corrosion protection (40 mm in humid climate).
- Choose cutting optimization of bar bending schedules in the attempt to reduce scrap.

6.3.3 Masonry

- **Conventional:** 1 no. bricks Burnt clay bricks.
- **Sustainability Alternative:**
    - Concrete hollow blocks (need less cement and aggregates, would thermal insulate).
    - Fly ash bricks (less carbon footprint at clay kiln bricks).
    - Stabilized soil blocks (can be found in rural extensions, but are lower-established in urban Savar).

Comparison:

- Clay brick: Clay bricks consumed a lot of energy and killed topsoil.
- Fly ash bricks: Environmentally friendly, strong and lightweight.
- Concrete blocks: Greener building involving concrete blocks will be better in terms of thermal insulation.

In this project fly ash bricks are suggested.

6.4 Finishing Materials

6.4.1 Flooring

- Alternatives: frozen a tile, terrazzo, polished concrete.
- Rationale: Vitrified ceramic tiles in the classrooms, Corridors, library and staircases (durable and easy to clean).
- Washrooms: Ceramics on an anti-slip waterproof grout.

6.4.2 Wall Finishes

- Internet walls: Cement-sand plaster + low-VOC emulsion paint.
- Veneer walls: Weatherproofing paint + water-proof coating.
- Sustainability: Do not use oil based paints; use the low and volatile oil paints on the inside environment.

6.4.3 Roofing

- RCC flat slab with:
    - 3 in waterproof screed
    - Reflective white paint or cool roof coating to lower the heat gain.
    - Solar panel (3-5 kW) provision.

6.5 Sustainable Construction Practices

6.5.1 Energy Efficiency

- Solar PV panels to produce electricity to supply between 20 and 25 percent of the school demand.
- Lighting fixtures made of LED instead of CFL.
- Cross-ventilation so as to reduce the use of fans.

6.5.2 Water Efficiency

- Washrooms Low-flow tap and toilet dual-flush.
- The system of collecting rainwater: tank: 20,000 L of storage space, which feeds on flushing and gardening.
- Beneath ground recharge pits in rape of water.

6.5.3 Waste Reduction

- Revenue shuttering plywood, Scaffolding.
- Separated bins of construction waste.
- Recycling of concrete wastes as road base.

6.6 Green Materials Integration

6.6.1 Bamboo (Optional Elements)

- May be applied in to provisional site construction works, shading equipment or furniture.
- Renewable and low-carbon.

6.6.2 Recycled Aggregates

- Out of waste concrete and brick, which has been demolished.
- It can be used in non-structural (pavements, landscaping).

6.6.3 Local Timber

- Seldom used (library furniture, doors).
- Timber which has been certified/reclaimed in order to avoid deforestation.

6.7 Life-Cycle Cost Analysis (LCCA)

Traditional Building:

- Lower initial cost.
- Increased operating expenses (electricity, maintenance, repaint), in the long run.

Green Building (this project):

- Minor increase in initial cost (+10-15).
- Lower lifecycle cost due to:
    - 30-40% electricity savings
    - 50% water savings
    - Long lasting material that decreases repair time.

6.8 Durability in Bangladesh Climate

- **Hydraulic Resistance:** Concrete that has waterproofing admixtures.
- **Termite resistance:** Foundation termite treatment.
- **Corrosion Control:** Sufficient concrete cover, quality reinforcements.

- **Heat Protection:** Classrooms which have been ventilated and occupied by paints of light colors.

6.9 Alignment with Green Building Standards

1. **LEED leadership in Energy and Environmental Design:**
    - Site Sustainability: Flood prone areas to be avoided.
    - Water Efficiency: Rain collection.
    - Energy: Solar PV, lighting LED.
    - Materials Fly ash bricks, recycled steel.
    - IAQ: Low VOC paints, air conditioning.

1. **EDGE (Excellence in Design for Greater Efficiencies):**

    - 20% reduction in energy use.
    - 30% reduction in water use.
    - 30% cut in materials of embodied energy.

2. **BNBC & Local Green Guidelines:**

    - Adhere to structural + material compliance of BNBC 2020.
    - Adopt government programs on green schools

6.10 Summary

The selection of materials and sustainability will guarantee that the two-story primary school in Savar is not merely a structure that could withstand; however, it would be eco-friendly. The project achieves by incorporation of fly ash bricks, recycled steel, low VOC paints, water saving fixtures, and solar power, it has reduced carbon footprint, lower lifecycle cost, improved indoor air quality, the climate is flood prone and humid leading to better resilience.

This leaves a precedence of the future sustainable school projects with green concept in Bangladesh such that it relates to SDG 4 (Quality Education) and SDG 13 (Climate Action).

Chapter 7: Services & Utilities

7.1 Introduction

The structural and architectural design give the structure and use to any building, but services and utilities make the buildings habitable, safe and efficient in their operations. Services and utilities play an even larger part in case of a primary school because:

1. Children will be more susceptible to the risks of safety (fire, electricity, water contamination), and will be using the building.
2. Electricity, water availability, and sanitation are needed in the schools since they are open 6-8 hours a day.
3. The promotion of green schools in Bangladesh by the government is based on green energy, water conservation and sustainable management of waste.

In this chapter, a detailed design of services and utilities of the two stories primary school at Savar is offered including both the traditional engineering design specifics and the green building concepts.

7.2 Electrical System Design

7.2.1 Design Principles

- Safe, reliable and efficient electrical distribution.
- Install power backup on the essential loads.
- Minimize electricity use through low-energy consumption lamps and low-energy consuming equipment.
- Incorporate renewable power (solar PV) so that it can compensate grid power.

7.2.2 Load Estimation

Table 7.2.2.1: Under typical calculation of the School loading.

Space	Component Load	Qty	Wattage Each	Total Load (W)
Classroom (8)	LED lights, fans	8×	380w avg.	3040w
Library	LED lights, fans, computers	1×	980w	980w
Teachers Rooms	Lights,fans,PC, printer	1×	1040w	1040w
Washroom (2)	Lights, exhaust fan	2×	200w	400w
Circulation Areas	Corridor lights, Staircase	-	600w	600w
Outdoor Lighting	Floodlights, gate light	-	500w	500w
Miscellaneous	Office equipment	-	400w	400w

Total Connected Load = 6,960 =7,000 W (7 kW)

Taking diversity factor = 0.8

Maximum Demand = 7 x 0.8 = 5.6 kW = 6 kW

7.2.3 Distribution System

- **As of Incoming Power:** 11 kV line (DESCO/REB)-11/0.4 kV transformer (50 kVA).

- **Main Distribution Board (MDB):**Being on the ground floor and is bordering the stair room.
- **Sub Distribution Boards (SDB):**
    - One Ground floor, one first floor.
    - Circuit Design:
    - Lighting circuits: 10-15 A MCB.
    - Power sockets: 16-20 A MCB.
    - Air conditioning (future supply): 32 A MCB.
- **Earthing:** Resistance less than 1 O Copper plate earthing.

7.2.4 Lighting Design

- **Classrooms:** 300 lux (BNBC recommendation of teaching buildings).
- **Library:** 500 lux.
- **Circulation/Stairs:** 150 lux.
- **Washrooms:** 200 lux.
- **Outdoor:** 100 lux.

Energy efficiency is taken care of by using LED lights.

Daylighting Strategy

- North and western facade windows with shades.
- Install light shelves that will help in diffusing more daylight in classrooms.
- Lighting Reduce artificial daytime lighting by approximately forty percent.

7.2.5 Backup Power

- **Solar PV system:** 3-5 kW roof system with battery storage.
- **Diesel Generator (additional):** 10 kVA in case of emergency backup (it is hardly needed in case of the solar optimization of batteries).

7.3 Plumbing & Sanitation

7.3.1 Water Supply

- Landscape master planning: DESCO municipal water + Rainwater Harvesting.
- Storage:
    - Underground tank: 20,000 liters.
    - Overhead tank: 5,000 liters.

7.3.2 Demand Estimation

According to **BNBC & WHO school guidelines**:

- Water demand = 20 L/day/student.
- Students: 320.
- Teachers + Staff: 10.
- Total = 330 x 20 = 6,600 = 7,000 L/day.

Tank capacity 2-3 days backup.

7.3.3 Sanitation Facilities

- BNBC rule Boys 1toilet/75 and Girls 1toilet/50.
- Needed: 10 toilets, 8 student and 2 teacher.
- Design:
    - Combined Washroom Block: Male and female separate.
    - Handwashing basins: 1 in every 40 students - 8 minimum basins.

- Provision of disabled access.

7.3.4 Rainwater Harvesting

- Roof area: 5470 ft^2.
- Rainfall (Savar): 2,200 mm/year.
- Annual collection = 5470 ft^2 x 7.22 ft = 394934 = 39500 ft^3 = 11.18 million liters.
- Caught into down pipes- filters- underground tank.
- Use: Flushing + Gardening.

7.3.5 Drainage System

- Wastewater:
  - Blackwater (toilets)- septic- soak pit.
  - Greywater (wash basins) - treatment of greywater - reuse to irrigate gardens.
- Stormwater: Drains off roofs and drains off the ground - recharge pits.

7.4 Fire Safety System

7.4.1 Fire Risk in Schools

- Electricity malfunctions, shortcircuits.
- laboratory fires (were it to grow bigger).
- Incendiary instructional resources (books, furniture).

7.4.2 Fire Protection Measures

Table 7.4.2.1: Fire Safety Measures

Category	Provision
Fire Detection	Smoke detectors in classrooms, library, corridors
Fire Alarm	Central fire alarm with siren + visual strobe
Fire Extinguishers	1 unit (ABC type, 6 kg) per 200 m^2
Fire Hydrants	External hydrant connected to UG tank
Signage	Illuminated exit signs, emergency lights

7.4.3 Firefighting Water Demand

According to BNBC hydrants should have 10 L/sec.

- tank UG Tank (20,000 L) partly devoted to the storage of fire.
- Fire pump: 10 L/s, 2 bar pressure.

7.5 ICT Infrastructure

7.5.1 Need for ICT in Schools

- Projector based smart classrooms.
- Internet accessible library.
- Teachers' room with PCs.

7.5.2 Network Design

- LAN: Building cabling in cat-6.
- Wi-Fi: There are access points in every floor.
- Server Room: Brass mega,a small rack at the near afar library.

7.5.3 Safety

- exceptional conduits process ICT cabling.
- Surge protection on all IT equipment.

7.6 Renewable Energy Integration

7.6.1 Solar PV System

- Load: ~6 kW.
- PV capacity: 5 kW.
- Roof area required: 550 ft2 (110 ft2/kW).
- Batteries Lithium-ion, 2 days of autonomy.
- Hybrid inverter -grid tied and battery.

7.7 Sustainability of Services

- Energy: LED + Solar - 40% lessening the grid requirement.
- Water: Rain water harvesting - 30-40 percent saving.
- Sanitation: Reuse of greywater - 20% reduced usage of fresh water.
- ICT: online education - saves on paper.

7.8 Summary

The combined design of electrical, plumbing, fire safety and ICT and renewable energy provision facilities is such that the two-story primary school in Savar is safe for children, efficient in operation and sustainable in the long run.

The project brings about a model of sustainable schools in Bangladesh in the future by integrating the BNBC standards, WHO guidelines, the NFPA codes, and the concept of green building.

Chapter 8: Cost Estimation & Bill of Quantities (BOQ)

8.1 Introduction

In the execution of any civil engineering project, cost estimation and preparation of a Bill of Quantities (BOQ) is important in the process. In the case of this 2-story primary school building, Savar, Dhaka has its cost estimation that:

- Financial feasibility
- Budget allocation with regard to various trades.
- Sustainability vs. conventional construction comparative analysis.
- Openness in tender and procurement.
- Follow up of construction progress.

The BOQ is written and ready in compliance with:

- Public works department (PWD)sizeof rate bangladesh (2020).
- BNBC 2020 guidelines
- Local material prices (Savar, 2024-25) market survey.

8.2 Methodology of Cost Estimation

1. AutoCAD + ETABS drawings To drawup quantity.
2. local market + PWD Schedule testing Rate Analysis.
3. BOQ Preparation - Items, in CSI format.
4. Overhead added (in most cases 5-10%).
5. Cost Estimate of the final project completed.

8.3 Cost Heads of the Project

1. Site Development Excavation of Earths.
2. Foundation & Substructure
3. Superstructure (RCC Frame)
4. Masonry & Partition Works
5. Flooring & Finishes
6. Doors, Windows & Glazing
7. Plumbing & Sanitation
8. Electrical Works
9. Fire Safety System
10. ICT & Networking
11. Renewable Energy (Solar PV)
12. Green Building Features
13. External Development & Landscaping.
14. Contingency and Miscellany.

8.4. Detailed Bill of Quantities (BOQ)

Table 8.4.3: Site Development and Earthworks

Item	Quantity	Unit	Rate(TK)	Amount(TK)
Site clearance and excavation – foundation depth 6 ft	12906	ft^3	12	1,54,872
Sand filling back and compaction	8604	ft^3	10	86,040
Total				2,40,912

Table 8.4.4: Foundation and Substructure

Item	Quantity	Unit	Rate(TK)	Amount(TK)
PCC – 1:3:6	807	ft^3	300	2,42,100
RCC Footing – 1:2:4	4335	ft^3	400	10,68,800
Reinforcement – 1%	4,480	kg	125	5,60,000
Total				18,70,900

Table 8.4.5: Frame, superstructure (RCC Frame)

Item	Quantity	Unit	Rate(TK)	Amount(TK)
RCC column - 1:1.5:3	1740	ft^3	450	7,83,000
RCC Beam – 1:2:4	4335	ft^3	425	18,42,375
RCC Slab – 1:21:4	4568	ft^3	425	19,41,400
Reinforcement – 1%	23740	kg	125	29,67,500
Shuttering - 25mm ply	6778	ft^2	70	4,74,460
Total				80,08,735

Table 8.4.6: Masonry & Partition Works

Product	quantity	Unit	Rate (Tk)	amount (Tk)
Fly ash Bricks/1 st class Bricks	11000	ft^3	100	11,00,000
External & Internal plastering	13840	ft^2	30	4,15,200
Total				15,15,200

Table 8.4.7: Flooring & Finishes

Item	Quantity	Unit	Rate(TK)	Amount(TK)
Vitrified tiles	13394	ft^2	100	13,39,400
Washroom ceramic tiles	720	ft^2	85	61,200
Painting	1384	ft^2	30	41,510
Total				14,42,120

Table 8.4.8: Doors, Windows and Glazing

Item	Quantity	Unit	Rate(TK)	Amount(TK)
Wooden doors	21	each	7,000	1,47,000
Windows with grills	49	each	5,000	2,45,000
Glass panels	650	ft^2	75	48,750
Total				4,40,750

Table 8.4.9: Plumbing and Sanitation

Item	Quantity	Unit	Rate(TK)	Amount(TK)
UG water tank(20,000 L)	1	each	1,50,000	1,50,000
OH tank (5,000 L)	1	each	50,000	50,000
Pump (5 L/s)	1	each	50,000	50,000
Sanitary fixtures	-	Lump sum	1,00,000	1,00,000
Plumbing lines	-	Lump sum	50,000	50,000
Total				4,00,000

Table 8.4.10: Electrical Works

Item	Quantity	Unit Cost(TK)	Total Cost (TK)
Transformer 50 KVA	1	1,00,000	1,00,000
MDB + SDB Panels	3	30,000	90,000
Wiring ans Cables	-	-	1,00,000
Lighting Fixtures - LED	80	3,000	1,95,000
Fan - ceiling	65	3,000	1,95,000
Miscellaneous	-	-	50,000
Total			5,75,000

Table 8.4.11: Fire safety system

Item	Quantity	Unit Cost(TK)	Total Cost (TK)
Smoke Detectors	25	1,500	37,500
Fire alarm panel	1	20,000	20,000
Extinguishers – 6kg	12	4,000	48,000
Fire pump – 10 l/s	1	1,00,000	1,00,000
Hydrant system	65	3,000	1,95,000
Miscellaneous	-	-	50,000
Total			2,55,500

Table 8.4.12: ICT and Networking

Item	Quantity	Unit Cost(TK)	Total Cost (TK)
Server rack + Router	1	50,000	50,000
Switches – 24 port	2	10,000	20,000
Cabling – Cat 6	-	-	20,000
Wi-Fi access points	2	5,000	10,000
PC and Peripherals	10	40,000	4,00,000
Total			5,30,000

Table 8.4.13: Renewable Energy

Item	Quantity	Unit Cost(TK)	Total Cost (TK)
Solar panel 330 Wp	10	10,000	1,00,000
Inverter – 5 KW	1	60,000	60,000
Battery bank – 36 KWh	1	1,50,000	1,00,000
Mounting structure	-	-	50,000
Total			3,60,000

Table 8.4.14: Green Building Features

Item	Quantity	Unit	Rate(TK)	Amount(TK)
Rainwater harvesting system	1	-	1,00,000	1,00,000
Energy efficint lighting	80	each	500	40,000
Natural ventilation features	-	-	50,000	50,000
Land scaping and plantation	5,000	ft^2	40	2,00,000
Total				3,90,000

Table 8.4.15: External Developmen and Miscellaneous

Item	Quantity	Unit	Rate(TK)	Amount(TK)
Boundary wall – 6ft hight	2724	ft^2	100	2,72,400
Gate and Security post	1	Lump sum	1,00,000	1,00,000
Playground and Pavement	-	Lump sum	1,00,000	1,00,000
Total				4,72,400

Table 8.4.16: Summary of Project Cost

Head	Amount(TK)
Site development	2,40,912
Foundation and Substructure	18,70,900
Superstructure	80,08,735
Masonary and Partitions	15,15,200
Floooring and Finishes	14,42,120
Doors, Windows, Glazing	4,40,750
Plumbing and Sanitation	4,00,000
Electrical Works	5,75,000
Fire Safety	2,55,500
ICT and Networking	5,30,000
Renewable Energy	3,60,000
Green Features	3,90,000
Extrernal Works	4,72,400
Sub Total	**1,65,01,517**
Contingency – 5%	8,25,075
Grand Total	**1,73,26,592**

8.5 Conclusion

The 2-storey sustainable school building in Savar can be realized using the budget amounting to approximately 1.74 crore BDT, all the civil, architectural, MEP, ICT, fire, solar, and green building provisions are included in the budget of the building.

The sustainability aspects include solar, rainwater harvesting and insulating, which increase the cost of a regular school building by a factor of 12-15 percent, but within 6-8 years is predicted to be compensated by lifecycle energy, water and maintenance savings.

Chapter 9 — Project Management

9.1 Project Planning and Scheduling (Gantt Chart)

9.1.1 The Purpose and Scope of Planning

Project planning It is the process through which the project objectives are converted into an action plan in form of daily (or weekly) set of activities that are executable and have well-defined responsibilities, durations, resources requirements, milestones and contingencies. Planning will provide effective scope alignment, time and cost, as well as offer a control and decision-making mechanism.

In the case of the school project, the timeline of planning would comprise: pre-construction (surveys, permits), design and approvals, procurement and tender process, all the construction at work package (foundations, superstructure, finishes, services) level, commissioning, and handover. Green building features (solar PV, rainwater collecting, passive ventilation structures) are incorporated into the schedule and need to be procured and installed by the specialists at an early stage.

9.1.2 Work Breakdown Structure (WBS) — detailed decomposition

A WBS subdivides the project to progressively smaller parts until work packages become small enough to determine, allocate, and quantify. Strong WBS will reduce those objectives that are forgotten and enable proper timetable and budget management. The school project would have a Level 3 WBS that is recommended below:

1. Project Mobilization & Preliminaries
    - Project preparation, provisional office, the place of business.
    - Topographical & boundary marking Site survey.
    - Geotechnical survey (boreholes/ trial pits).
    - Authorization and legalization.
    - Temporary amenities (water, power) access roads.
2. Design & Approvals
    - Finishing (plans, elevations, sections) in architecture.
    - Construction design and computations (base conditions, seismic examination)
    - MEP base (capitalization planning, sanitary, Ligt design, and solar PV plan)
    - Green building strategy plan (energy/water supply)
    - Shop drawings and procurement drawings.
3. Procurement & Contracting
    - Preparation and tender documents of BOQ.
    - Tendering, assessment and awarding.
    - Order long time goods (windows, doors, solar PV)
    - Yes mobilization of sub contractor (electrical/plumbing/specialist installers)
4. Earthworks & Substructure
    - clearing of the site, safeguarding of trees, dewatering.
    - Excavation and leveling.4.2 Bulk excavation and leveling.
    - Foundation (Strip and raft/piles geotech based)
    - Substructure backfill, treatment of termites, damp proofing.
5. Superstructure
    - Ground floor columns
    - Ground floor slab (formwork, reinforcement, pour) Beams.

- First floor columns
- Beams and slab of floor and roof slab on the first floor.

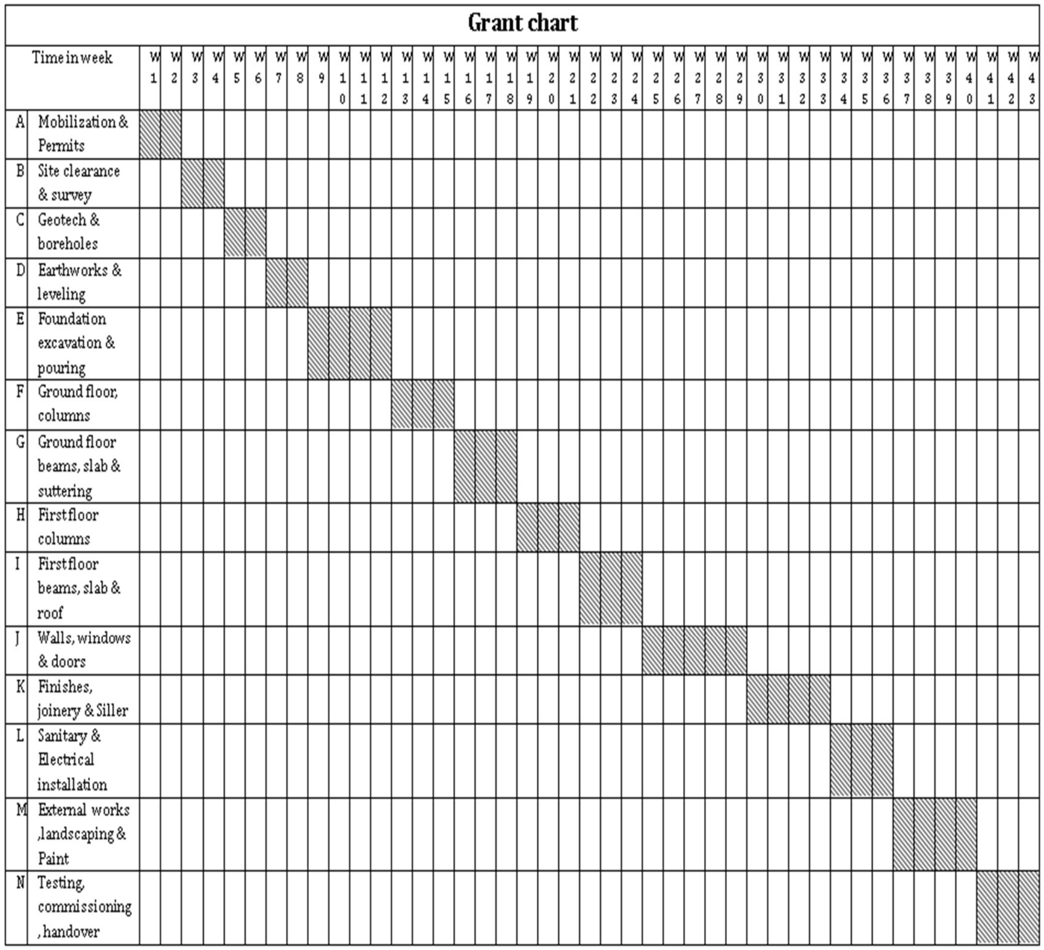
6. Building Envelope (External Works)
   - Wall of the building External, Insulation (where applicable).
   - Windows, door and frame (swing and encasing)
   - Roofing, waterproofing and guttering.
   - External finishes, paint work, rain collectors.
7. Interior Works & Finishes
   - Plastering, screed and partitioning.
   - Flooring (tile/terrazzo)
   - Protection and coating of paintings.
   - Joinery works (cupboards, library shelving)
8. Services (Sanitary, Plumbing, Electrical)
   - Plumbing and drainage rough-ins.
   - Water supply and water storage tanks.
   - Electrical conduits and lighting fixtures 8.3.
   - Solar PV mounting and wiring (with electrical co-ordination)
   - MEP systems testing and commissioning.
9. External Works & Landscaping
   - Foot paths, cycle stands, minor pavements
   - Landscape works, surfacing play area, and tree planting.
   - Safety walls, security gates.

10.0 Commissioning & Handover
- The final checks and snagging will be conducted.
- Staffgreen systems testing, commissioning and training.
- As-built, O&M and warranties.
- Management of the period of handover and defects liability.

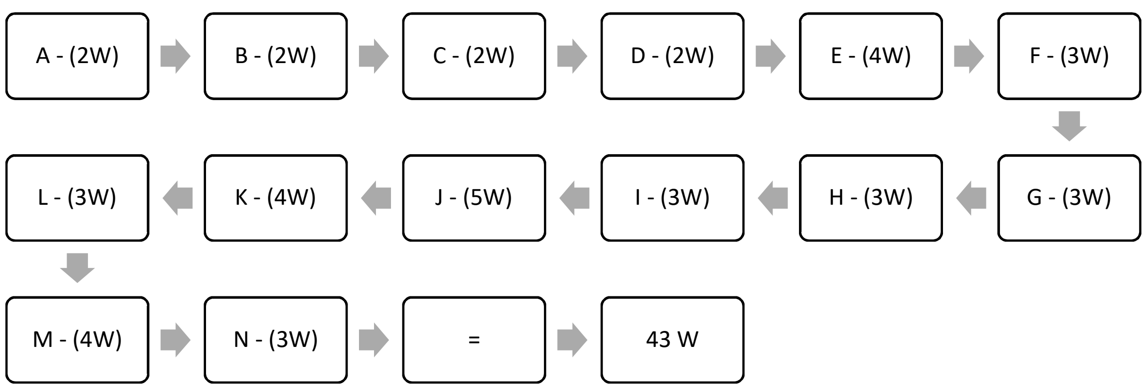
9.1.3 Gantt Chart — practical creation and content

The main visual tool of the schedule communication is a Gantt chart. In the case of the thesis and site-level application:

- Ready the baseline Gantt in MS project (or Primavera). contain WBS codes, activity id, predecessors, durations and resources allocations, start/ finish dates and a baseline date.
- Export views export key project Gantt (report), phase Gantts (site teams), milestone-only Gantt(stakeholders).



9.1.4 Critical Path Method (CPM) :



9.1.5 Change Control and Baseline Management

Formal change control process maintains consistency of the baseline, and has the property of traceability:

- Change Request: any of the stakeholders submit change requests with description, reason and anticipated impact.

- Impact Analysis: PM evaluates the time, cost, quality, risk and offers alternatives.
- Approval: Client and /or steering committee approval with revised baseline introduced in MS project.

Communication & Implementation: update the contracts in case of necessity, notify the site teams and to the suppliers.

9.2 Allocation of resources (material, labor, and machinery)

9.2.1 Resource Planning Overview

Resource planning is a method that ensures that whenever required they have the materials, personnel and equipments in the right amounts and at the right quality. In the case of the school project, resource planning should also be able to accept specialist and elements (solar PV panels, rainwater harvesting tanks) which require longer lead times and handling time.

Key objectives:

- Reduce waiting time and inventory.
- Make sure that it is good by pre-qualifying the supplier and delivering it through audit.
- Reduce costs incurred in control by means of buy-in-bulk purchasing and efficient inventory control.
- Be safe and environmental friendly in storing and handling.

9.2.2 Materials - estimation, procurement, and storage

Project materials:

- Cement, coarse and fine aggregates, sand, ready-mix concrete (in case it is used).
- Reinforcement (bars and fabric mesh) steel.
- Mortar/ Bricks/Blocks and masonry.
- Timber/formwork Quadrupolar shuttering system.
- Doors, windows and glazing
- Roofing/waterproofing membranes
- Fine finishes, tiles, skirtings, and decorations.
- Sanitary ware and plumbing suppliers.
- Lighting fixtures, electrical wiring, conduit and switches.
- Solar PV panels, inverters, mounting rails, batteries (unless operating on-grid) or off-grid exit batteries (Sawyer, 2012).
- Filtration and pumps, tank of rainwater collector.

Procurement strategy

1. **Bill of Quantities (BOQ):** Prepare a refined BOQ based on final drawings in order to do good procurement planning.
2. **Long-lead item identification:** Items with the lead time of 4+ weeks (solar PV, windows, specialized doors, etc.) are identified and ordered in advance.
3. **Supplier prequalification:** The suppliers are judged based on delivery reliability, quality, price and warranty.
4. **Contracts:** Purchase orders should have definite delivery dates, purchase terms of payment and clauses of nonconformity.

5. **Just-in-time vs bulk purchases:** Just-in-time (JIT) decreases the amount of storage required, although it demands consistent supplier and available schedules, whereas bulk purchases decrease the unit cost, but demand secure storage.

Storage and handling

- Cement should be raised, covered, and kept dry, it should have a date of delivery and foods first out first in uses.
- Aggregates: keep separate, keep dry (small stuff immixed with gravel).
- Steel: store off-ground, is covered and elevated; put out the inventory and take precautions to prevent rust, in case of long storage.
- Solar PV: install in safe, in dry and well-ventilated structures and do not place higher than recommended by the manufacturer.

9.2.3 Labor - forecasting, crew composition, training

Labor planning translates work packages into labor-hours and crew compositions. Define roles: supervisors/site engineers, masons, steel-fixers, carpenters, plumbers, electricians, laborers, equipment operators.

Benchmarks on productivity (adjust to local circumstances; add assumptions to the report):

- Masonry (blockwork): 500- 750 ft^2 per mason/per week (two reserves plaster omitted)
- Plastering: 450-650 ft^2 per plasterer per day (2 coats, which depends on ability)
- Reinforcement fixing: 150 -300 ft^2 slab equivalent per steel fixer per day.
- Concreting (setting up, pouring and finishing): 1500-3000ft^3 per day per crew (again depending on the mix and access)
- Sample of crew composition in case of concrete works (small slab 30 m^3).

Crew composition example for concrete works (small slab 1000 ft^3)

- 1 site engineer/supervisor
- 1 foreman
- 1 concrete pump operator (if pump used)
- 2 machine operators (truck mixer + pump)
- 6 labourers for placing, finishing and curing operations

Training and upskilling

- give first induction and training relating to the job (positioning of moisture barrier correctly, installing solar mounting rails and lightning protection correctly).
- Focus on green building installations: e.g. to have window sealing to help control the thermal, proper installation of rainwater filters so as to minimize contamination.

Rewards and human resource.

- Think about productivity based bonuses of key crews (masonry, concreting) but provide a countermeasure with quality checks that may force crews to go very fast but put poor masonry and poor concreting.
- Keep a balance of fair working hours and breaks and meet the local labor laws.

9.3 The QA/QC entails quality verification of the product or service delivered to the customer.

9.3.1 Principles of QA and QC

- **Quality Assurance (QA) is proactive:** strategies, process and protocols to avoid defects.
- **Quality Control (QC) Quality Control is reactive:** inspection and testing in order to identify nonconformances and rectify them.

They both are necessary to provide safe, durable and comfortable school building and to ensure the functioning of the green building features as it should.

Quality Management Framework of the Project.

Policy and goals of quality.

- Written quality policy by project leadership with an obligation to comply, and to continuously improve and achieve green performance targets (e.g. stated daylight factors or projected PV output).

Responsibilities and organization.

- **Project Manager:** ultimate quality accountability.
- **QA/QC Engineer:** prepares the QA Plan, records, organizes the testing and reports non-conformance.
- **Site Supervisor:** checks the compliance daily and provides corrective measures.
- **Third Party Test Lab:** A third party test of soil, concrete and materials.

Documentation

- Quality Plan, Inspection & Test Plans (ITPs), checklists, certification of calibration,certification of material, NCR logs, records of as-built.

9.3.2 Inspection and Test Plans (ITPs) Samples and templates.

A detailed plan ITP is a plan that stipulates what is to be inspected or tested, and at which stage, it should be of acceptable quality, the sample size, and the person in charge. Shortened ITP templates are represented below. In the case of the canvas we take the entire formal ITP tables; for example here we describe important entries.

Concrete ITP (key items)

- Approval of mix design: - Check laboratory mix design and target strength.
- Pre-pour checklist Pre-pour checklist formwork, reinforcement, embedded objects, before the pouring concrete.
- Slump test One test per pour or volume threshold.
- Cube sampling: 150 mm -1 cube based on 10 m^3 or 150 mm -1 cube based on code according to 7 and 28 days testing.
- Curing check: make sure there is continual curing with maximum required time.
- Acceptance: Acceptance by day 28 strength ≥ specified f'c.

Reinforcement ITP

- Enclosure: material certificates, grade of steel mill certificates.
- Bending and cutting of bars: lengths of check, lap and hook.

- Cover check: measure clear cover where several points to each of the bays.
- Faitting procedure: ties, chairs along with spacers according to the specification.

Masonry and Plaster ITP

- Mortar mix test: check the ratios of the mix.
- Alignment check Masonry Masonry: Level and plumbness checks periodically.
- Wall ties and reinforcement (in case of masonry reinforced): the verification of the placement.
- Plaster bonding tests and plaster its thickness.

Waterproofing ITP

- Preparation of substrates: native.
- Application of membranes: continuity & thickness of layer.
- Ponding test: 72 hours in the case of roofs and the balconies (where applicable).

Solar PV ITP (Commissioning)

- Visual inspection Visual inspection of modules, mounting structures and cable routing.
- Resistance to insulation test: according to the manufacturer.
- Power output testing Measure PV string output either at Standard Test Conditions (STC) equivalent or site adjusted conditions.
- Test of commissioning and isolation/inverter test.

9.3.3 Acceptance Criteria and sampling procedures.

Establish acceptance standards by project standards related to codes (BNBC, natural or manufacturer standards), and project specific targets. For sampling:

- Make resonably large sample sizes statistically: e.g. 1 cube/10 m^3 concrete or per pour; whichever is smaller.
- Random sampling by different batches should be used to make sure that it is representative.

Record sampling protocol and store sample labels, chains of custody form and laboratory certificates.

9.3.4 Calibration and Competency

- Make sure that equipment to be used in measurement slump cones, compression testing machines, tape measures, megger) are calibrated and the certificates are included to the QA file.
- Establish the qualification of expert installers (solar pv certified electricians) and keep the records of the certificates and training.

9.3.5 QA/QC for Green Building Elements

Ecofriendly characteristics may comprise fine interfaces:

- **Windows and Glazing-wrighting:** day light, thermal performance influenced by the need to seal the windows and ensure that they are aligned with the frames. World do the air leakage and water penetrating tests where feasible.
- **Rainwater Harvesting:** first-flush diverting, filter integrity, and pump reliability: require the commissioning and microbiological examination provided that non-portable material is of use.

- **Solar PV:** test mechanical mounting, torque, test azimuth and tilt (must be fixed) DC insulation tests DC, string level power tests.
- **Natural Ventilation:** smoke test, daylight factor test and occupant comfort test should be performed during commissioning.

Establish document baseline requirements of each Green measure and create a commissioning checklist with target metrics (the expected yearly PV production, the amount of rainwater that should be harvested in a day).

9.3.6 Documentation, Traceability and Handover.

Maintain a detailed QA file which will be included in the hand over pack: QA Plan, ITPs, Inspection record, material certs, cube test reports, calibration record, as-built drawings, warranties and O&M manual.

An in-depth handover and training (such as operating solar inverters and rainwater systems) minimises the initial failures in operation and develops confidence in the clients.

9.3.7 Quality review and incessant enhancement.

- Carry out internal audits on a regular basis.
- Strengths- Invite third party audit of both relevant milestones (e.g. after the structure has been constructed and is not enclosed) to gain the benefit of independent assurance.
- Improve procedures by using audit findings and using specific training.
- Regulations should cover health and safety in the workplace when doing construction.

9.4 Health and Safety in Construction

9.4.1 Structure and Legal conformity.

Health and safety covers the workers and the general people, decreases the project delays and is a moral and legal duty. In this project, the project would align the safety practices with local regulatory requirements and international good practice.

Safety governance elements:

- Stated Health and Safety Policy, which is approved by the project leadership.
- Emergency procedures and Safety Plan at the site.
- Site Safety Officer, first responders (First Aiders).
- Hazardous hazard permit- permit to work systems.

9.4.2 Site Safety - components

- Roles and responsibilities Roles and responsibility Determine who does what to encourage safety (PM, site engineer, safety officer, supervisors).
- High-risk activity risk-based assessments working at height, working in confined spaces, making excavations.
- PPE needs of every activity and monitoring system.
- Local hospital, ambulance, fire brigade emergency and contact information.
- Traffic and logistics strategy: regulate entrance/exit, routes of deliveries and speed of vehicle.

- Amenities: toilets, drinking water, washing space, restrooms and shaded rest space.

9.4.3 Safety Processes of Major operations.

Pouring of concrete: be sure there are supports of rebar in the formwork, exclusion of unnecessary personnel during the pour, and wear PPE against silica dust when cutting.

Roof Operations and Heights: There should be guardrails on the perimeter, anchorage of harnesses, trained roofers and or safety nets where necessary.

Constrained areas (where themed to be used): permit-to-work, atmospheric tests, stand-by staff with rescue strategy, ideal breathing gears.

9.4.4 Training and Competence

- Induction of all people working on site prior to commencement of working - includes hazards, emergency procedures and PPE.
- Task training: the scaffolders, crane operators, and electricians should be certified and registered.
- Toolbox talks mini-talks on daily/weekly safety briefs: briefing the workers about current risks (the case of weather-related issues such as the monsoons, heat stress) and safety tips.

9.4.5 Occupational health- climate and sanitation.

- **Heat stress (of relevance to Dhaka climate):** hydration initiative, Shaded rest init-iatives, moving heavy work to early morning or late afternoon, acclimatization initiative to new employees.
- **Sanitation- hygiene:** use segregated toilets, stations of handwashing with soap, clean drinking water, separate places of eating without contamination.
- **Vector control:** control standing water and site housekeeping in order to lessen breeding locations of the mosquitos.

9.4.6 Emergency Preparedness and First Aid

- Have a full stock of first aid equipment and first aiders.
- Post emergency toilet signs and evacuation routes in front.
- Develop evacuation/fire operations at least one time in the early mobilization and every quarter thereafter.
- Have documented processes of major incidents such as reporting of the incidence to the authorities and client.

9.4.7 Safety Surveillance, Reporting and Key Performance Indicators.

- **Everyday:** inspection of the field work site and toolbox talks; create notes about the day and activity which include notes about observation and action.
- **Weekly:** the safety officer presents a weekly safety report which contains the incidents, near misss, training provided and corrective measures.

9.4.8 partially occupied School Sites Safety

In the event of construction being graded and part occupation likely, adopt severe measures of separation:

- Reserved storing and pedestrian paths.

- Prefer out of school time to schedule any high-noise/dust-related activity.
- Placing supervision of the location of access and designated alternative routes deviated by the students.

9.5 Risk Assessment and Management.

9.5.1 Process Overview

Risk management is a continuous process that is incorporated in the process of planning, procurement, execution and handover. It will minimize the unexpected situations and will equip project team to act on an occasion of risks.

Steps:

- Risk identification (workshops, WBS review, lessons on past)
- Probability/impact matrix qualitative analysis.
- The quantitative analysis (EMV, schedule Monte Carlo where necessary, etc.)
- Risk response planning and designation of owners.
- Monitoring and reporting

9.5.2 Risk Identification : Categories and examples.

Categories

- Technical & Design: drawing mistakes, insufficiency of providing information concerning green systems.
- Geotechnical/Site: poor soil conditions, elevated ground water.
- Compliance: lack of speed in approvals, compliance requirements.
- Procurement: supplier breakdown, increase in material price.
- Weather, and Environmental: flooding, cyclone winds, monsoon winds.
- Health & Safety: large scale road accident suspension.
- Stakeholder: community antagonism, territory wrangles.
- Financial: shortages of cashflow, inflation.

Sample risks

- There is less geotechnical information and the design needed redesign.
- Solar pv modules broken during transportation.
- Extended monsoons of 4- 6 week postponement to external works.
- Contractor insolvency

9.5.3 Monitoring, Reporting and Escalation.

- Incorrect Risk status to be included in weekly site meeting and monthly progress report.
- In case of red risks, report to client or steering committee with action plan proposed and the impacts of cost-time.
- Record update register after reviewing, and any risk events and then record lessons learned.

9.5.4 Insurance and contractual risk allocation.

- Embark on proper insurances: all risk contractor insurances, third party, liability contractor insurances, employer insurances.

- Make risk in contract documents better understood (who bears the risk of weather delay, who insures, the amount of retention and the conditions of release of retention).

9.6 Summary

In the provision of a sustainable two-storey primary school, the Integrated Project Controls framework will provide the coordination of planning, resources, quality, safety and risk management of the project. It highlights a hierarchical Work Breakdown Structure (WBS), Critical Path Method (CPM) scheduling and an available tool of baseline monitoring such as MS Project or Primavera tool and providing a four-week rolling lookahead on site operations.

Resource allocation aims at transforming amounts into manpower and material plans, discovering long lead items (such as solar PV and windows) early on, and ensuring adequate storage and equipment reliability. In QA/QC QA Plan, Inspection and Test plans (ITPS) and non-conformance management are used to guarantee the quality construction and performance of the systems (green features, in particular).

Health and safety are internalized all over, through a hierarchy of controls, health and safety induction and heat stress precaution measures in Dhaka. Risk management comprises of a live risk register, qualitative analysis and quantitative analysis and the set contingencies is done through Expected Monetary Value (EMV). In sum this integrated approach brings the integration of all the project elements to have safe, sustainable and timely delivery.

Chapter 10: Results & Discussion

10.1 Results

10.1.1 Architectural Outcomes

The architectural framework of the two storey primary school led to the achievement of a functional, friendly and sustainable building that matches educational requirement of kids in Bangladesh. The structure will be built to include eight classrooms, two teacher rooms, one library, and one united wash room block, which will be well dispersed in the two levels in order to provide an optimal accessibility, natural light and ventilation. The classrooms are oriented on the east-west axis and this allows it to reduce heat gain as well as maximize on the use of daylight hence minimizing the artificial lighting.

The most important architectural deliverables are:

- **Streamlined Floor Plans:** The square area occupied by the classrooms is about 780 square feet with the comfort capacity at 40 students. The circulation areas like corridors and staircases are used effectively to ensure that children are not vulnerable and to minimise accidents, the facilities are fitted with handrails, anti-slip pavements and also made wide enough to allow children to get out safely.
- **Green Design Integration:** There will be operable windows, skylights, and cross-ventilation as a strategy to minimise dependence on mechanical ventilation. Verandas and shading devices are included to help in reducing solar glare and leaving the house comfortable.
- **Accessibility:** The design has ramps accommodating the disabled learners thus including them. The wash room block is also central and the distance covered by the students is minimized.

10.1.2 Structural Outcomes

The structural design was done based on BNBC 2020, the ACI 318, and ASCE 7-16. The structure system was analyzed by E tabs software.

- **Foundation:** A shallow spread footing foundation was adopted due to soil tests that were done which could safely support the loads with the required safety margins.
- **Columns and Beams:** The reinforcement concrete columns and beams were planned to have the capacity of supporting dead, live and subsequent load.
- **Slabs:** The design of the slabs consisted of two way reinforced concrete of 5 in thickness which was incorporated to the classrooms and corridors where they would be used to make sure they are serviceable and strong.
- **Seismic Consideration:** The building has met the seismic regulation of Zone II (Dhaka region), which requires the buildings to be resilient and laterally withstand load.
- **Safety Factors:** The load combinations were used as per the design codes and the structural members had more than the applicable minimum safety margin.

10.1.3 Environmental Outcomes

The sustainability priorities of the project are ensured by the means of the usage of green building technologies:

- **Energy efficiency:** The building design is made in the most efficient style; it has natural day lighting, ventilation and this reduces the consumption of energy by about a quarter compared to the traditional school construction design.
- **Solar panels:** Photovoltaic panels that can be attached on the roof are capable of generating 10-15 kW of renewable energy which would meet the requirements of lighting and fans.
- **Water Management:** Toilet flushing and landscape irrigation: 5,000 litres water harvesting system will be employed to sustain the two.
- **CO 2 Emission Reduction:** It is estimated that the school will reduce the emission of CO_2 because of the reduction in the use of grid electricity; the school is expected to bring down the emissions of CO 2 to a range of 8-10 tons annually.

10.1.4 Cost Outcomes

The cost estimation and the Life cycle cost analysis have shown that:

- **Initial Cost:** The green school design is about 10-12 percent pricier than the size of an ordinary school down to the addition of the solar panels, rain water harvesting and the use of green materials.
- **Savings in Operations:** The result of energy saving, lower water bills, and minimal maintenance costs amount to the 20-25 percent decrease in the operational costs.
- **Life Cycle Cost:** A total of 15-18 percent of money is saved by the school over the 20 years period of time as compared to the conventional design.

10.1.5 Construction Outcomes

Project management tools, such as a Gantt chart and resource planning, were used that led to an increase in efficiency in scheduling.

- Planned Duration: 10 months.
- Critical Path Activities: Foundation, superstructure, finishes, and roof slab No. MEP installations.
- Delays Reduced: Buffering and leveling of resources minimized the chances of delays.

10.2 Discussion

10.2.1 Comparison with Similar School Projects in Bangladesh

Traditional primary schools in Bangladesh are usually not green in nature, they are not well ventilated and use of materials in a sustainable manner. Compared to this, this design focuses on:

- Day lighting and natural ventilation.
- Renewable energy use.
- Rainwater harvesting.
- Inclusive facilities.

It is projected that this project will perform better energy, comfort of the inside and long-term sustainability than conventional schools.

10.2.2 Determining the Green Features Performance.

- Solar Power: It is expected to save 40-50 percent of the electricity payments.

- Rainwater Harvesting: Able to conserve as an average of 1,200 liters/day on average peak desert monsoon.
- Daylighting: 80% of the daily lighting needs are met with natural day light.
- Ventilation: Cross-ventilation makes a 3-4o C lower in-door temperature than the outside.

10.2.3 Effect on the student and teacher.

- Learning Environment: The daylight is sufficient to enhance the level of concentration and also alleviate the strain on the eyes.
- Indoor Air Quality: Natural ventilation increases comfort and diminishes the respiratory problems.
- Design of libraries: Will give a quiet and comfortable working environment that facilitates academic enrichment.
- Teachers Rooms: Provide a working room in which the tutors can prepare their lessons and advise the students.

10.2.4 Discussion Structural Performance.

- Reinforced concrete can be used to reduce costs of maintenance and make the structure enduring.
- The constitution of the building is in compliance with seismic as well as wind load requirements.
- The two story building has the benefit that in future the building can be extended vertically without compromising the structuring of the building.

10.2.5 Economic Feasibility

Initial investments would not pay back as compared to operational savings in 20 years despite the increased upfront cost. The payback duration of the solar panels is estimated to be 7-8 years where the net benefits are energy savings.

10.2.6 Challenges Faced

- Space Limitations: Space was limited hence economy and functionality in designs.
- Material Availability: Availability of green materials is not necessarily locally available.
- Regulatory Barriers: The unavailability of economical guidelines toward green buildings in Bangladesh.

10.5 Summary of Findings

Sustainable primary school is a two-story construction of the proposed project that is set to be environmentally friendly, technically sound, and cost-effective. It is concerned with the use of efficient energy and other water saving practices that greatly lead to minimizing the operating expenses and ensuring long-term sustainability. The design is also student-focused in terms of its concern toward indoor environmental quality since it directly affects learning outcomes in students and teacher satisfaction. The cost of green construction is more expensive at the beginning, but the cost sustainability model can prove this approach by benefits in the environment and economy in the long term. Additionally, green schools in Bangladesh can only be successfully adopted in large scale though policy support and quality training workforce as the measures of success in the implementation of the sustainable building practices nationwide.

Chapter 11: References, Appendices and Final Reflection

11.1 References

1. Directorate of Primary Education – Infrastructure plan and planning guidelines
2. Bangladesh National Building Code (BNBC), 2020
3. US Green Building Council (USGBC) – LEED Guidlines
4. ACI 318 – Building Code Requirments for Structural Concrete
5. UNICEF – Guidelines for School Infrastructure
6. World Bank – EDGE Certification Guidelines
7. Design of Reinforced Concrete Structures – arthur H. Nilson
8. Design of Reinforced Concrete Structures by N. Subramanian
9. Design of Reinforced Concrete – authored by Jack C. McCormac & Russell H. Brown
10. Structural Concrete: Theory and Design authored by M. Nadim Hassoun and Akthem Al-Manasee.

11.2 Appendices

Appendix A – Architectural Drawings

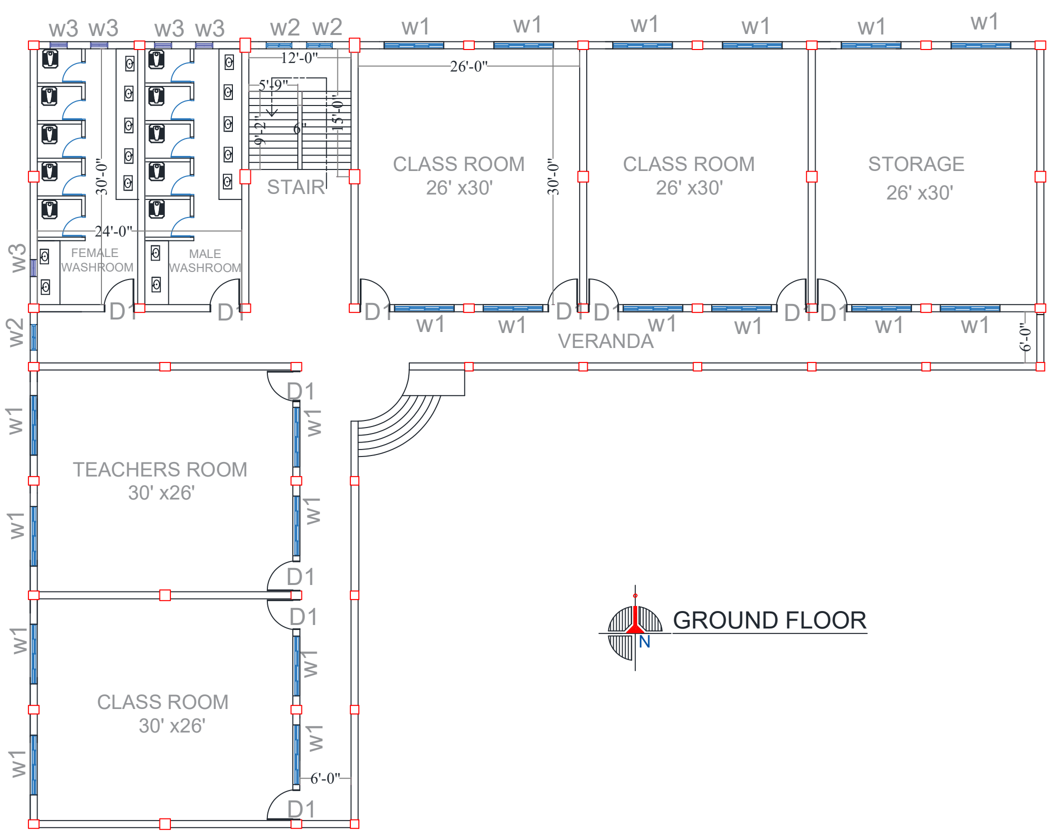


Figure 11.1: Ground floor layout.

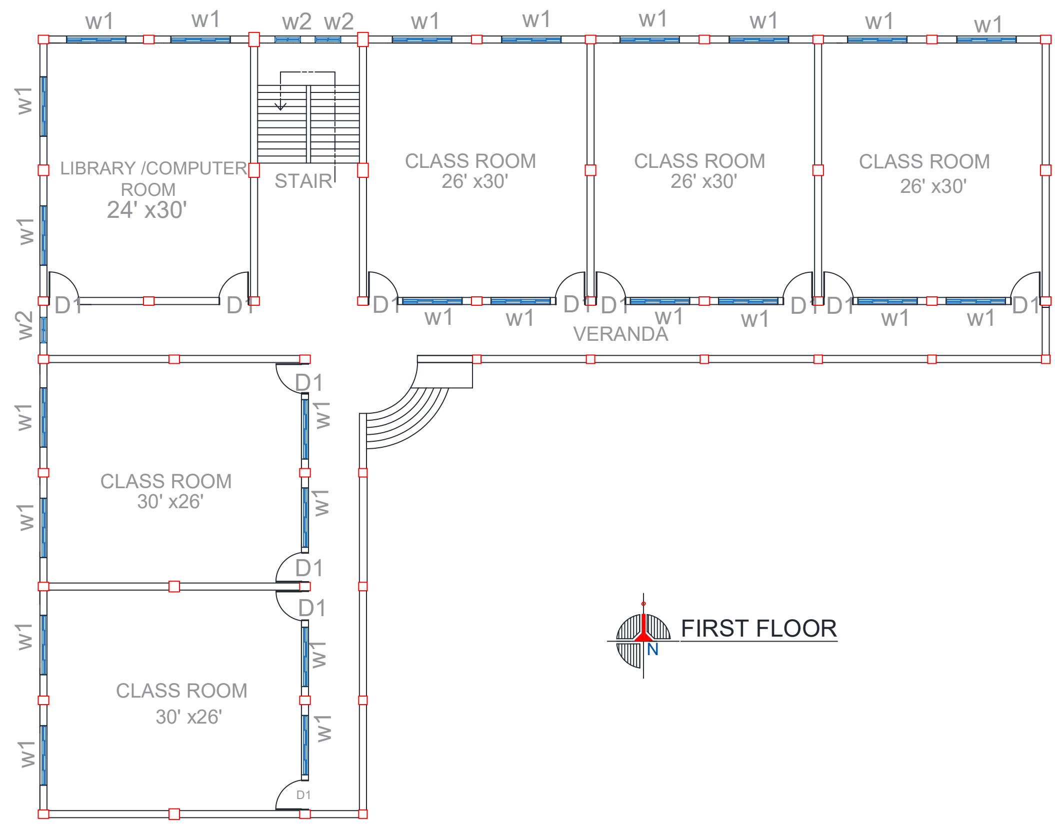


Figure 11.2: First floor layout.

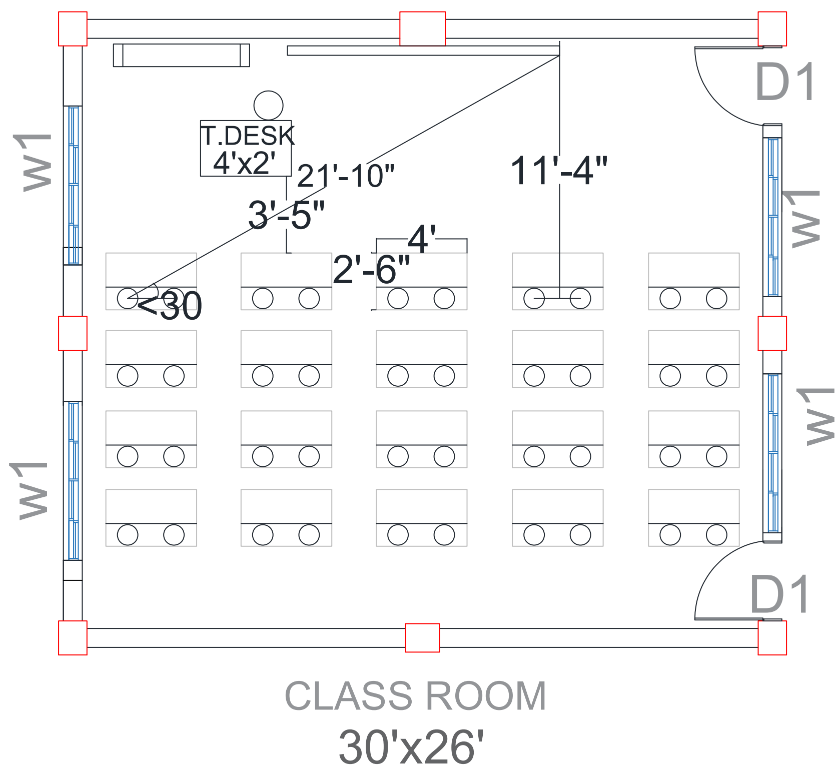


Figure 11.3: Class room layout.

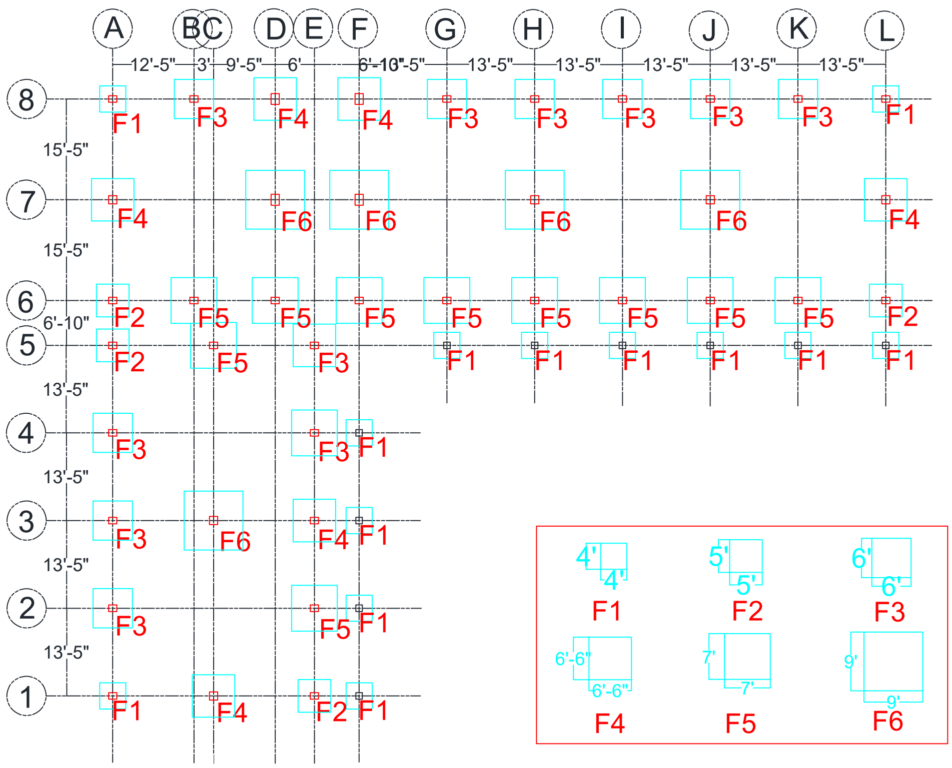
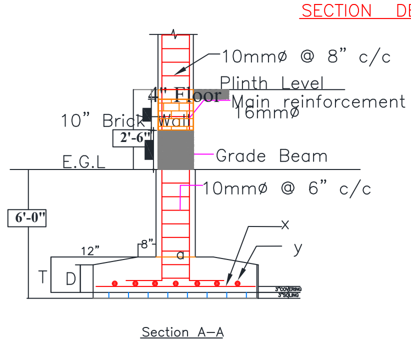


Figure 11.4: Footing Layout.

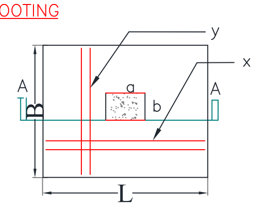
FOOTING SCHEDULE

Footing Index	Footing Size		Depth		Reinforcement	
	Length L	Breadth B	T	D	x	y
F1	4'–0"	4'–0"	12"	10"	16mmø @6"c/c	16mmø @6"c/c
F2	5'–0"	5'–0"	12"	10"	16mmø @6"c/c	16mmø @6"c/c
F3	6'–0"	6'–0"	12"	15"	16mmø @6"c/c	16mmø @6"c/c
F4	6'–6"	6'–6"	12"	15"	16mmø @6"c/c	16mmø @6"c/c
F5	7'–0"	7'–0"	15"	18"	16mmø @6"c/c	16mmø @6"c/c
F6	9'–0"	9'–0"	15"	18"	16mmø @6"c/c	16mmø @6"c/c

SECTION DETAILS OF FOOTING



Section A–A



NOTE :– L = B

fy = 60,000 psi (60 grade Deformed bar)

Concrete mix ratio = 1: 1.5 : 3
(Cement : Local Coarse Sand : Brick Chips)
(50 % Sylhet Sand & 50 % Local Sand)

Clear cover : Footing (all side)= 3"
Column (below GB) = 2.5"
Column (above GB) = 1.5"

Figure 11.5: Footing Details.

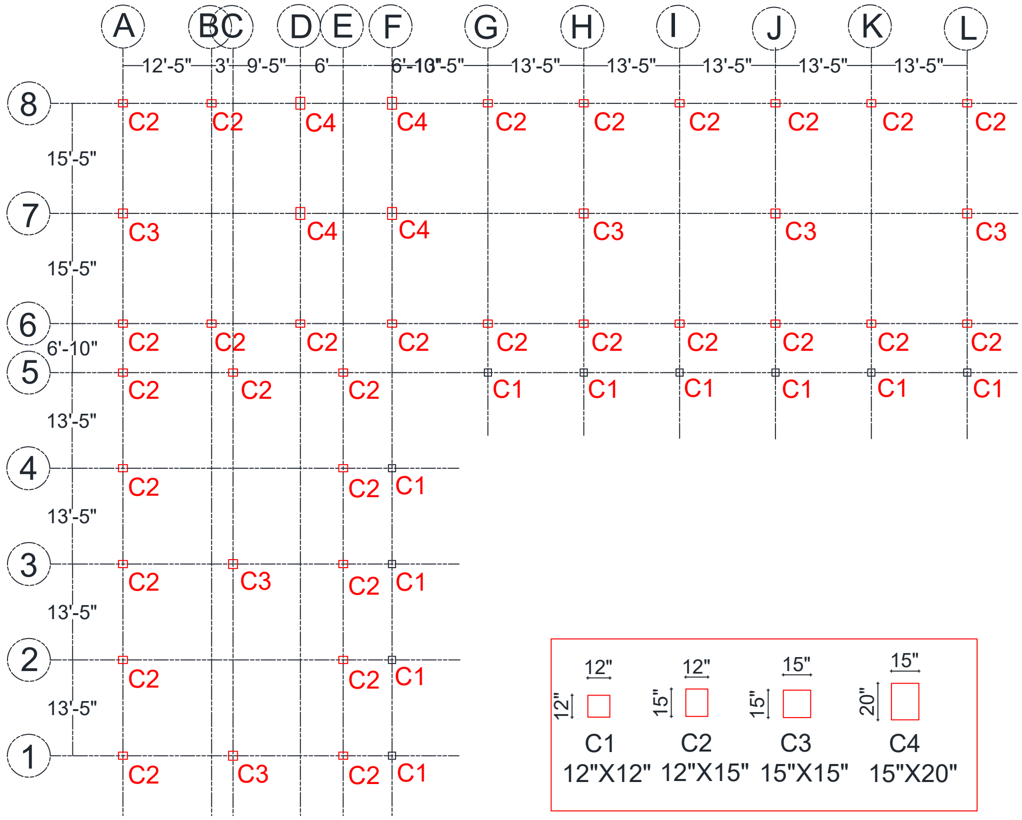


Figure 11.6: Column Layout.

COLUMN SCHEDULE

Column Index	Below G. Beam	Gr Floor-2nd Floor
C1	14" × 14" 4 - 16 mm Ø	12" × 12" 4 - 16 mm Ø
C2	17" × 14" 8 - 16 mm Ø	15" × 12" 8 - 16 mm Ø
C3	17" × 17" 12 - 16 mm Ø	15" × 15" 12 - 16 mm Ø
C4	22" × 17" 16 - 16 mm Ø	20" × 15" 16 - 16 mm Ø

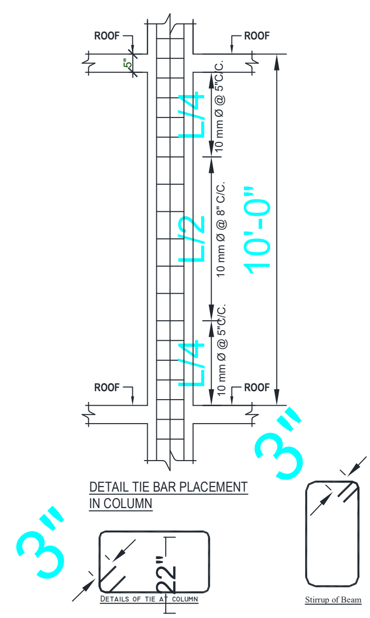


Figure 11.7: Column Details.

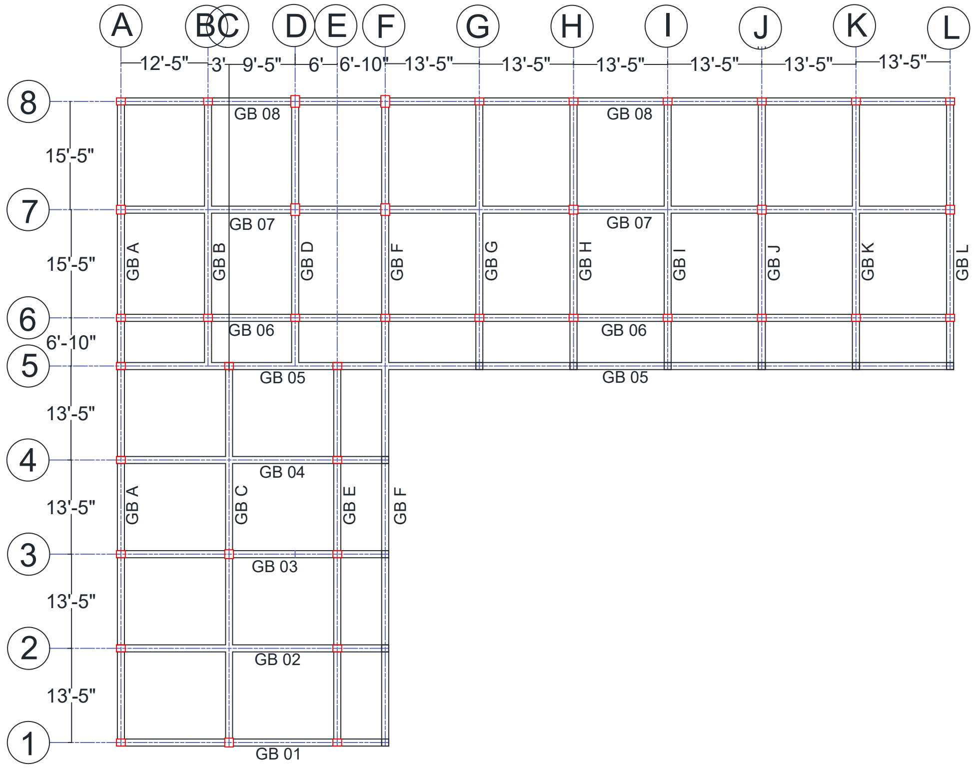


Figure 11.8: Ground Floor Beam layout.

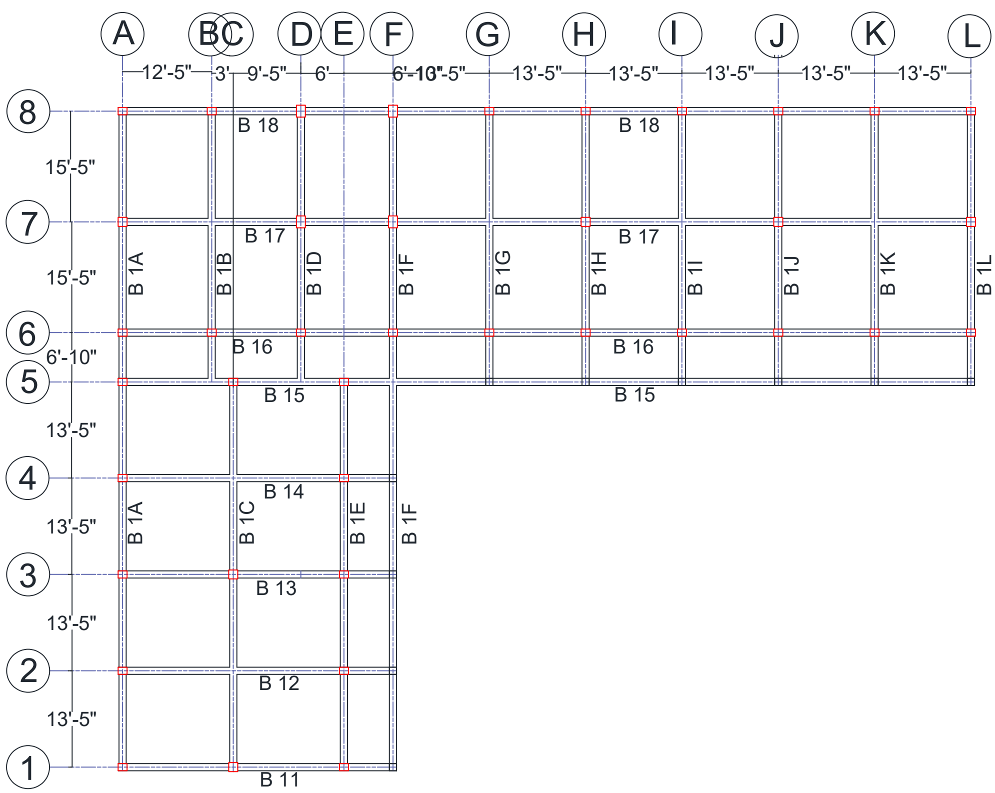


Figure 11.9: First Floor Beam Layout.

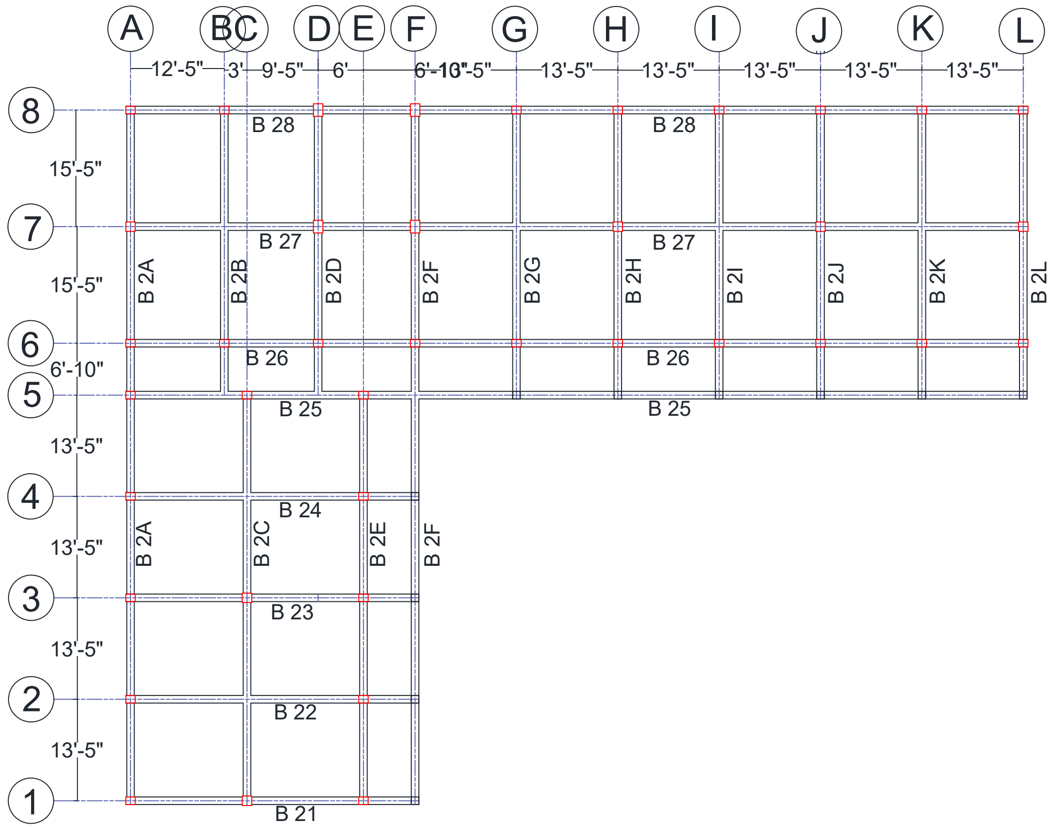
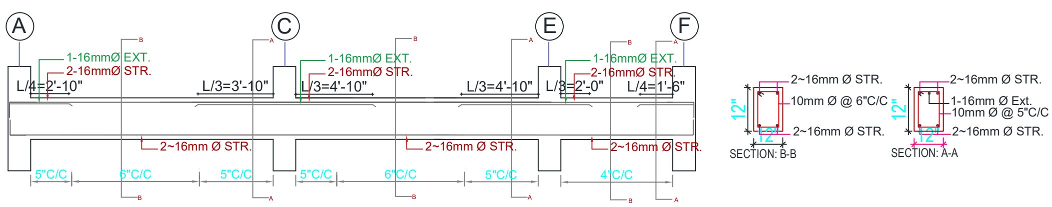
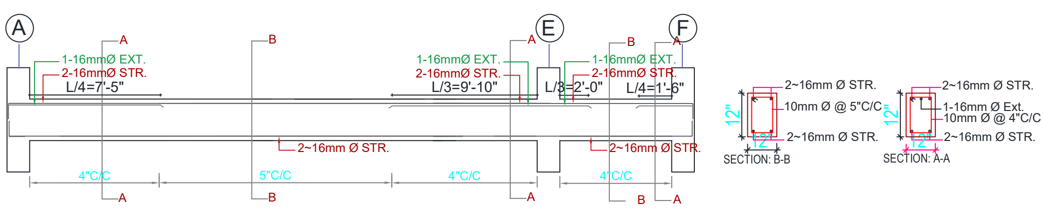


Figure 11.10: Second Floor Beam layout.



LONG SECTION OF BEAM GB 01 GB 04 FOR GB FLOOR = 12" X12"



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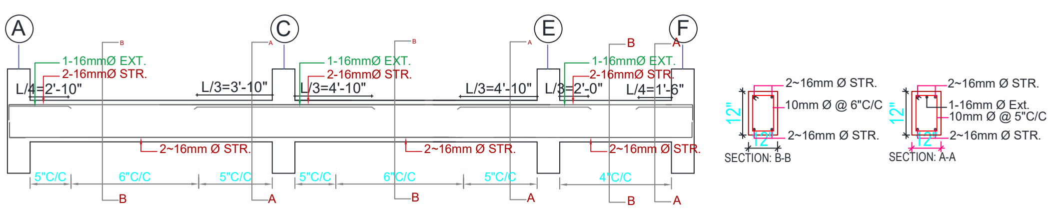

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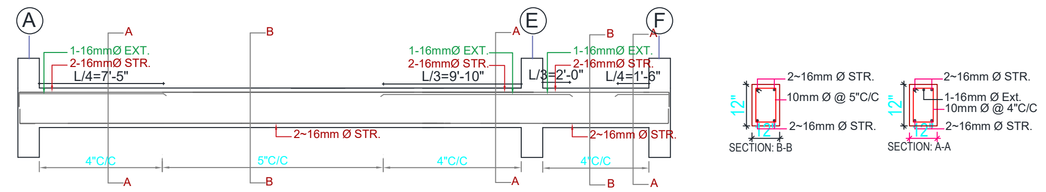

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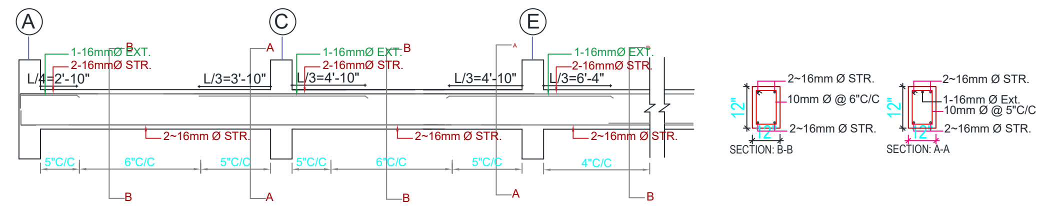

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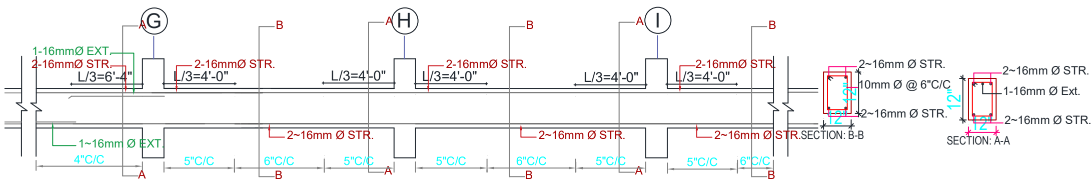

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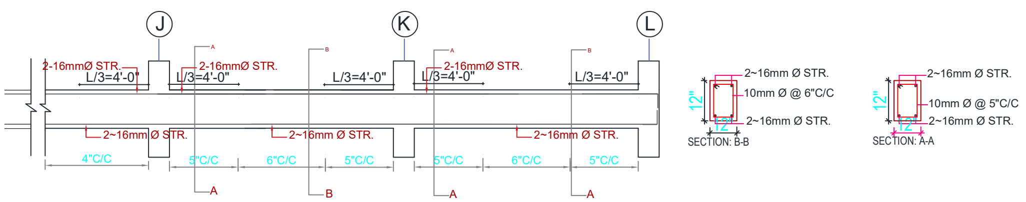

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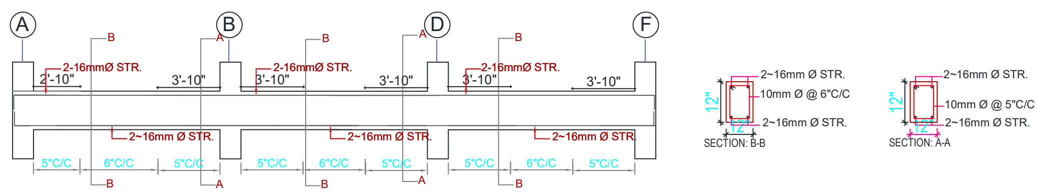

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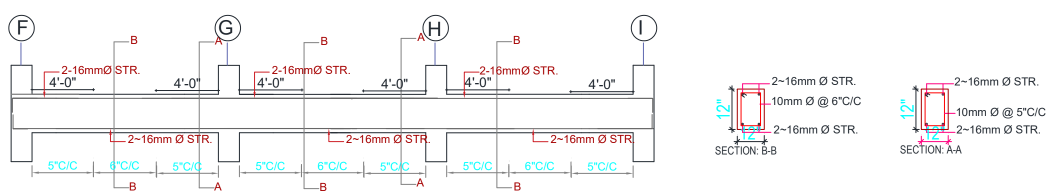

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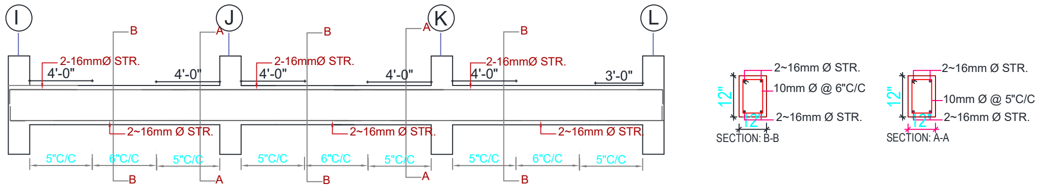

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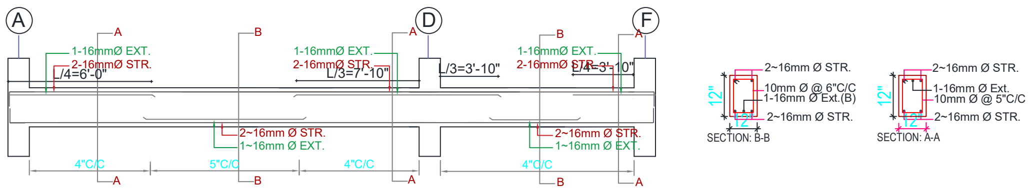

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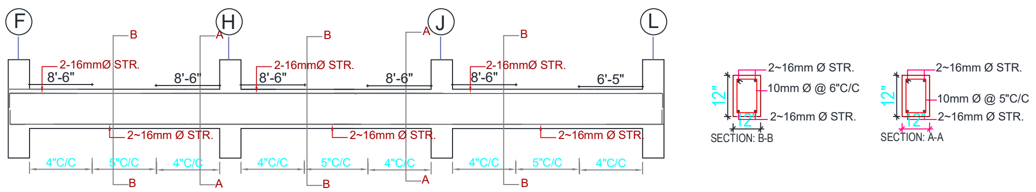

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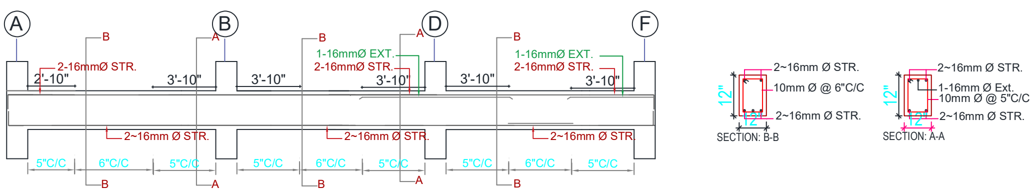

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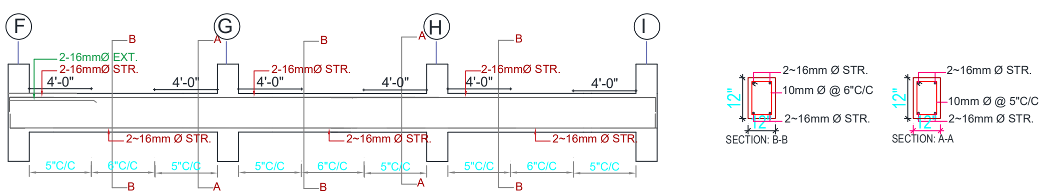

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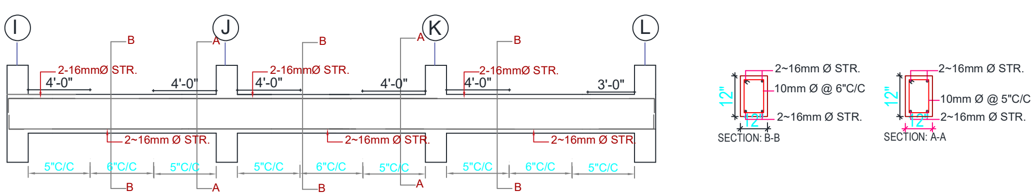

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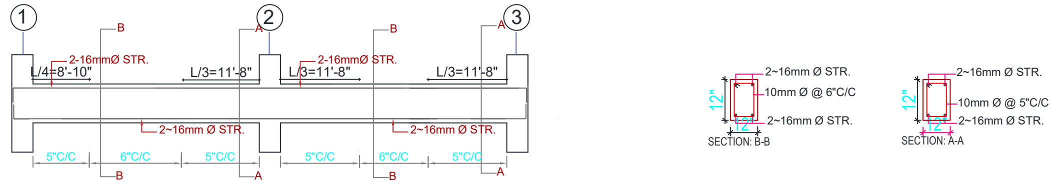

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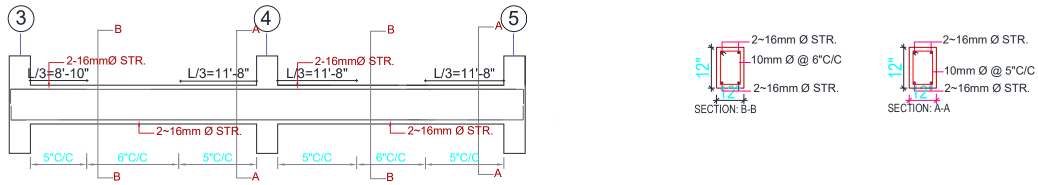

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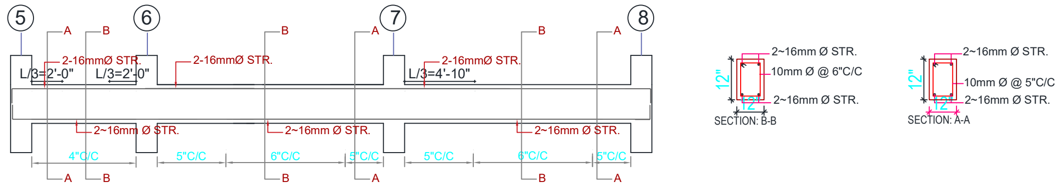

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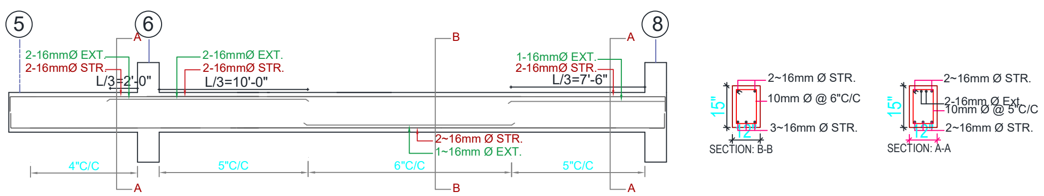

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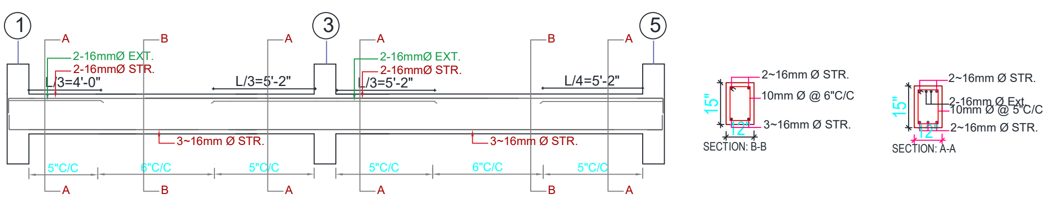

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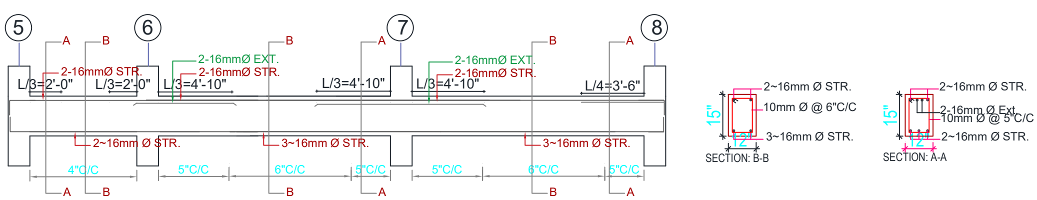

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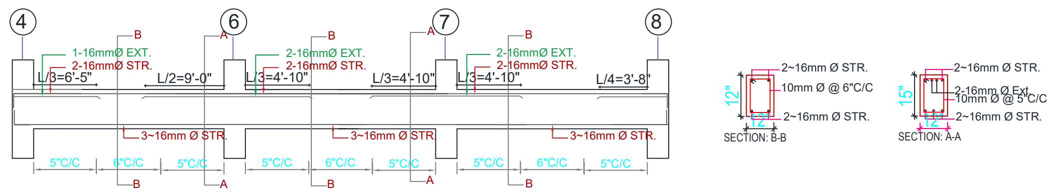

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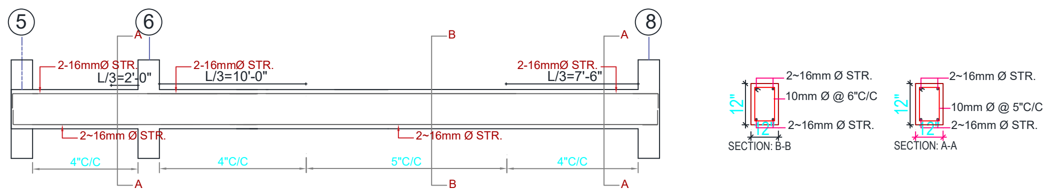

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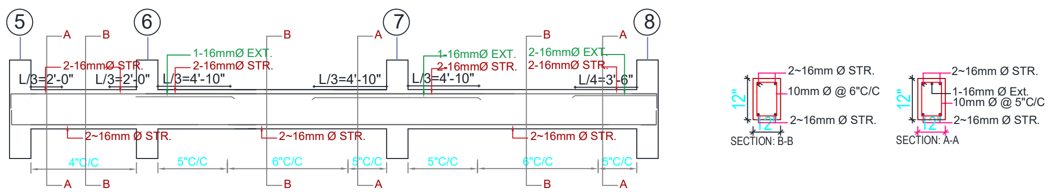

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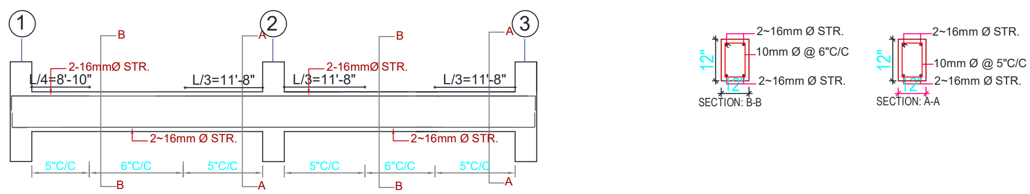

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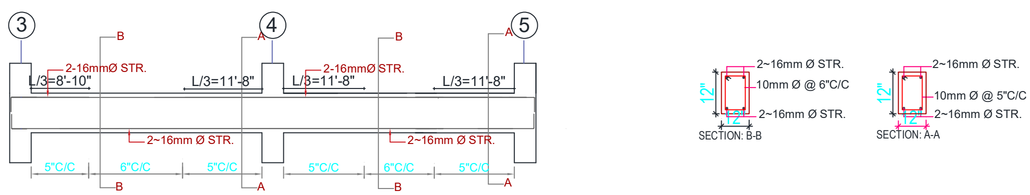
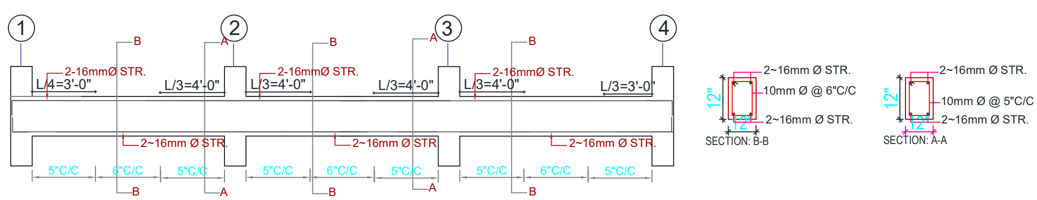
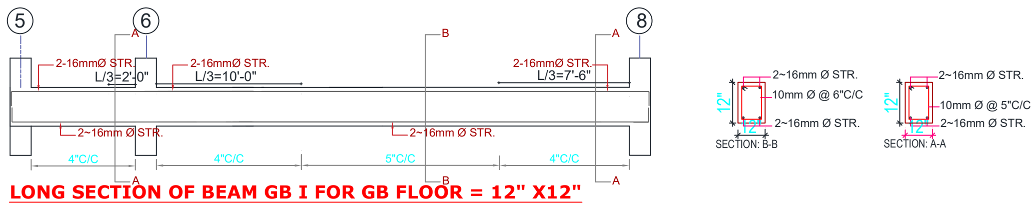


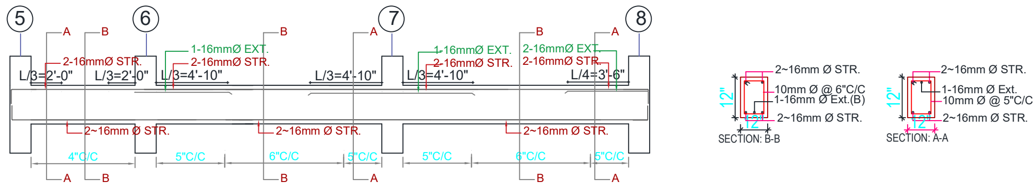
LONG SECTION OF BEAM GB E(PART-02) FOR GB FLOOR = 12" X12"



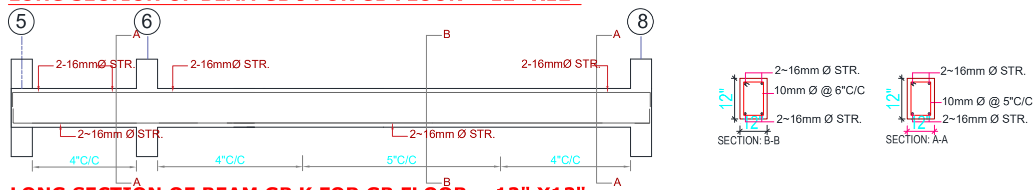
LONG SECTION OF BEAM GB F(PART-01) FOR GB FLOOR = 10" X12"



LONG SECTION OF BEAM GB I FOR GB FLOOR = 12" X12"



LONG SECTION OF BEAM GB J FOR GB FLOOR = 12" X12"



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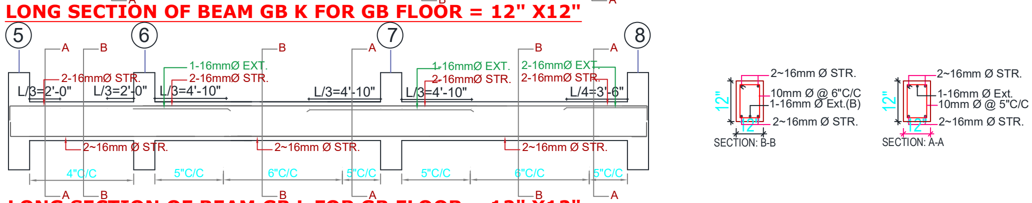
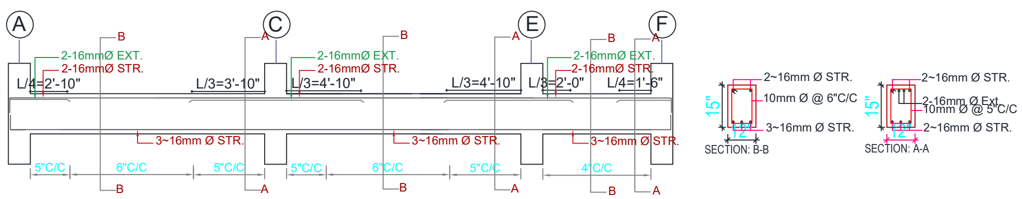
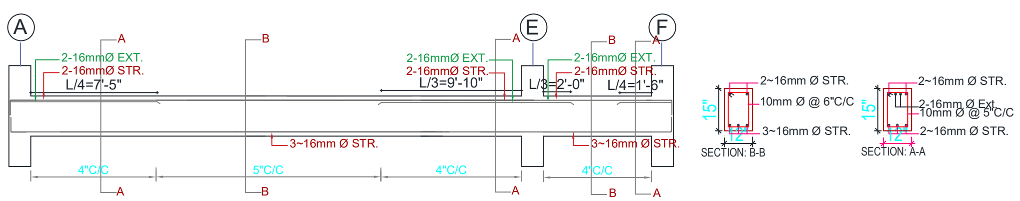


LONG SECTION OF BEAM GB L FOR GB FLOOR = 12" X12"



LONG SECTION OF BEAM B 11 FOR 1ST FLOOR = 12" X15"



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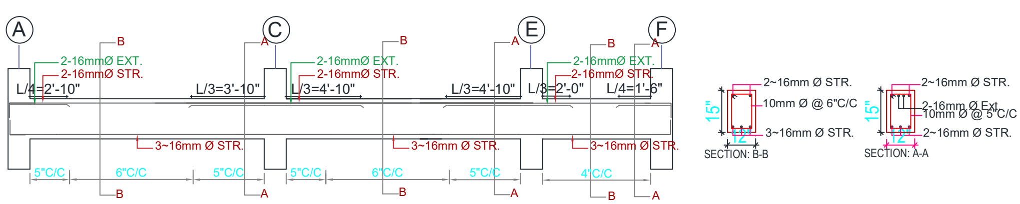

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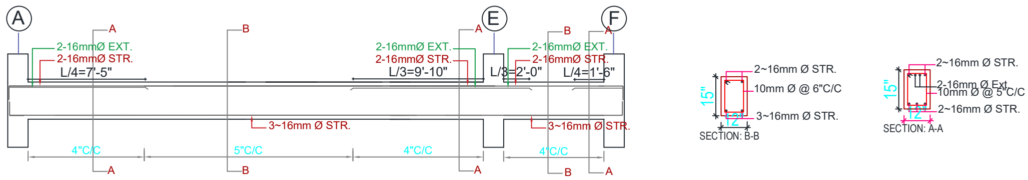
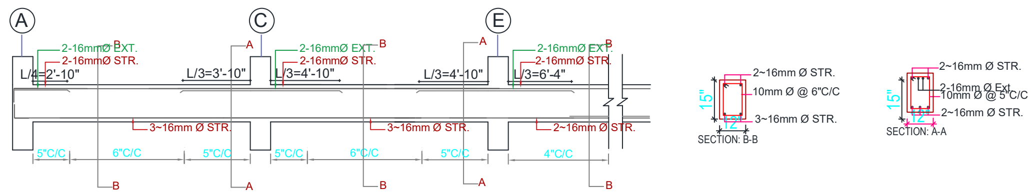
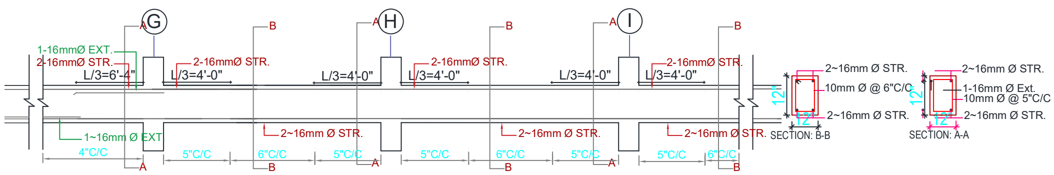


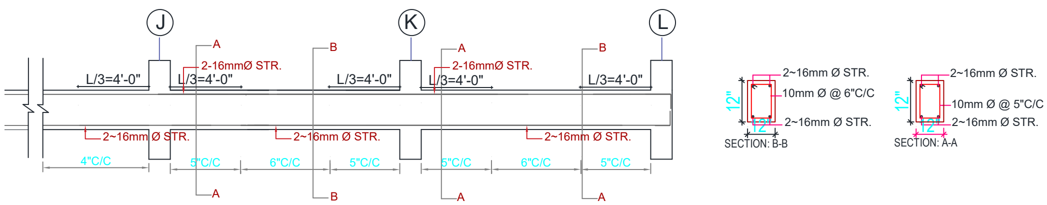
LONG SECTION OF BEAM B 14 FOR 1ST FLOOR = 12" X15"



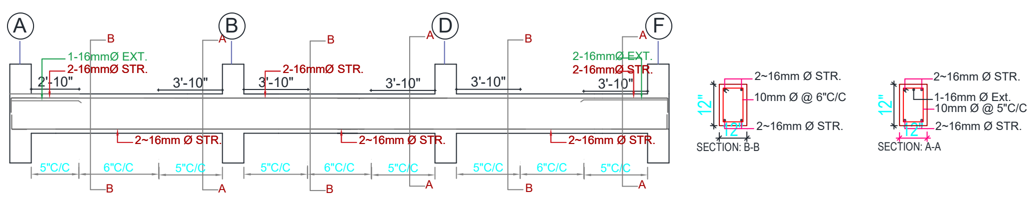
LONG SECTION OF BEAM B 15(PART-01) FOR 1ST FLOOR = 12" X15"



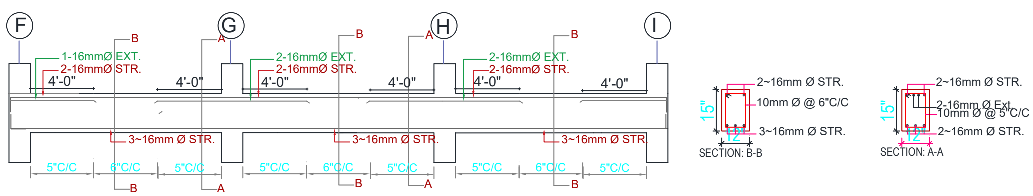
LONG SECTION OF BEAM B 15(PART-02) FOR 1ST FLOOR = 12" X12"



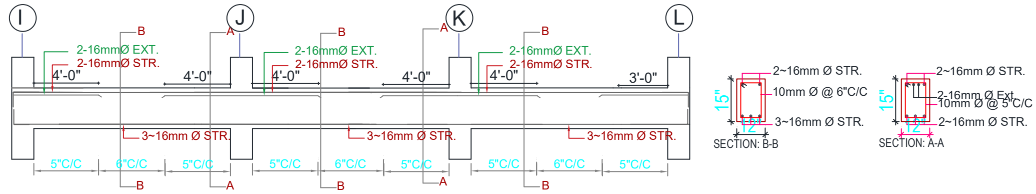
LONG SECTION OF BEAM B 15(PART-03) FOR 1ST FLOOR = 12" X12"



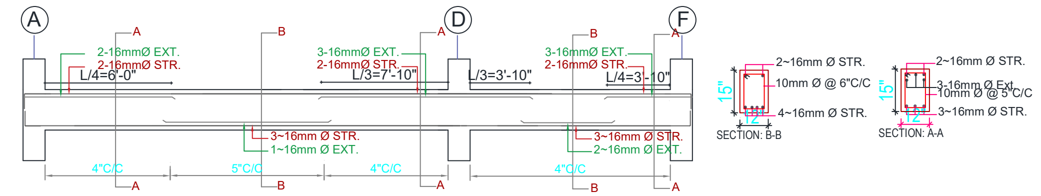
LONG SECTION OF BEAM B 16(PART-01) FOR 1ST FLOOR = 12" X15"



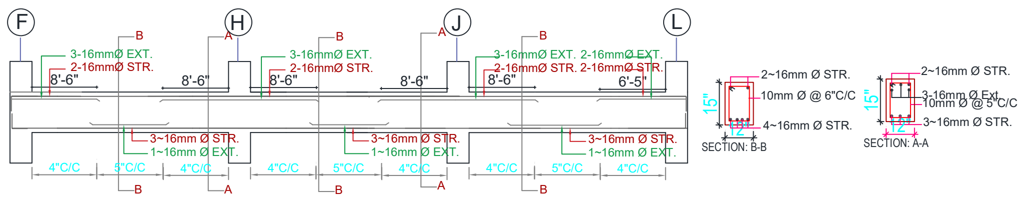
LONG SECTION OF BEAM B 16(PART-02) FOR GB FLOOR = 12"X15"



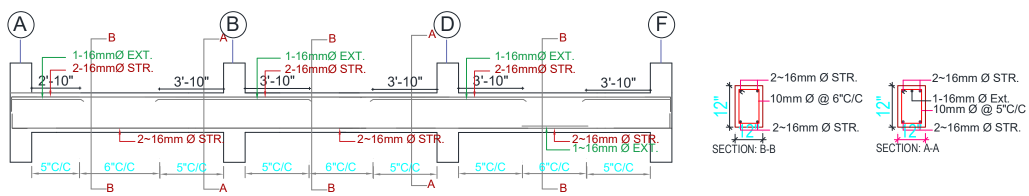
LONG SECTION OF BEAM B 16(PART-03) FOR 1ST FLOOR = 12" X15"



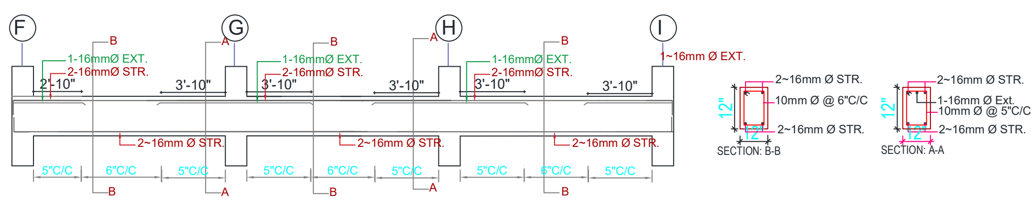
LONG SECTION OF BEAM B 17(PART-01) FOR 1ST FLOOR = 12" X15"



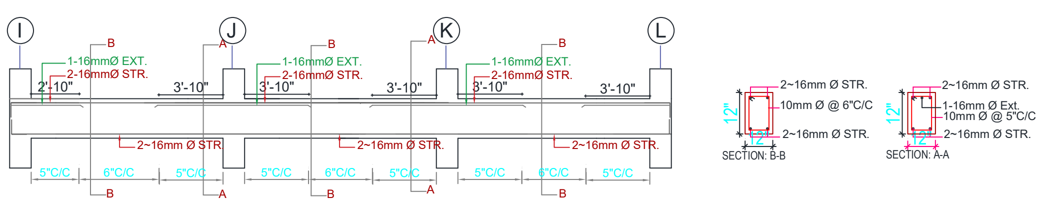
LONG SECTION OF BEAM B 17(PART-02) FOR 1ST FLOOR = 12" X15"



LONG SECTION OF BEAM B 18(PART-01) FOR 1ST FLOOR = 12" X15"



LONG SECTION OF BEAM B 18(PART-02) FOR 1ST FLOOR = 12" X15"



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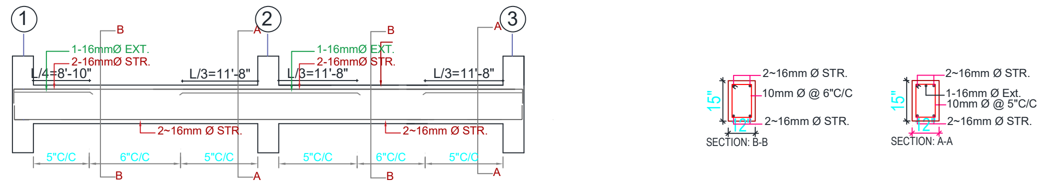
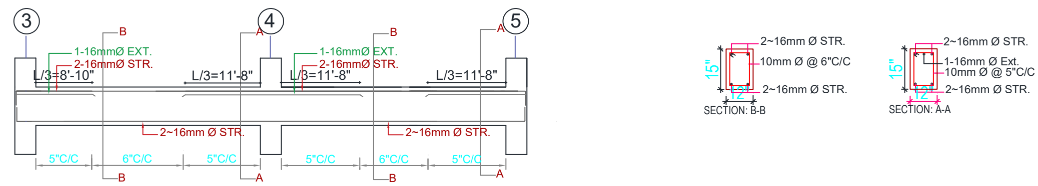
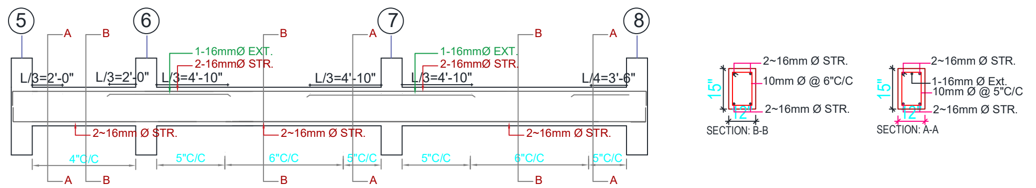


LONG SECTION OF BEAM B A1(PART-01) FOR 1ST FLOOR = 12" X15"



LONG SECTION OF BEAM B A1(PART-02) FOR 1ST FLOOR = 12" X15"



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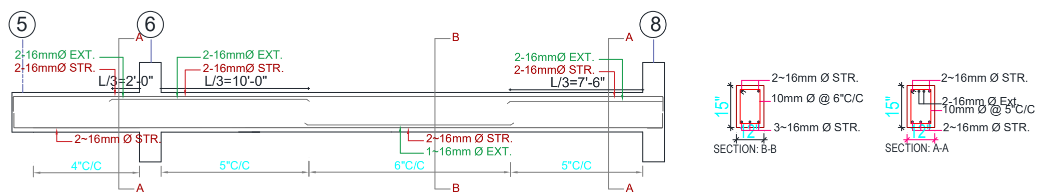
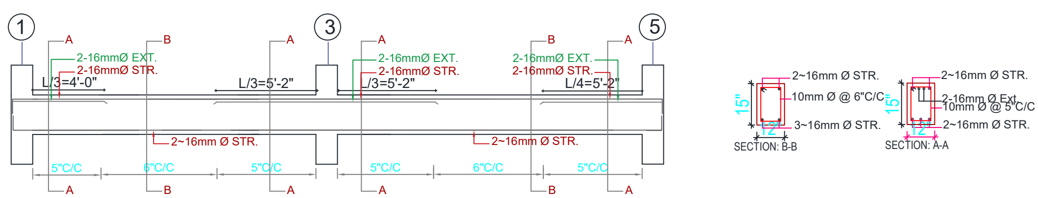
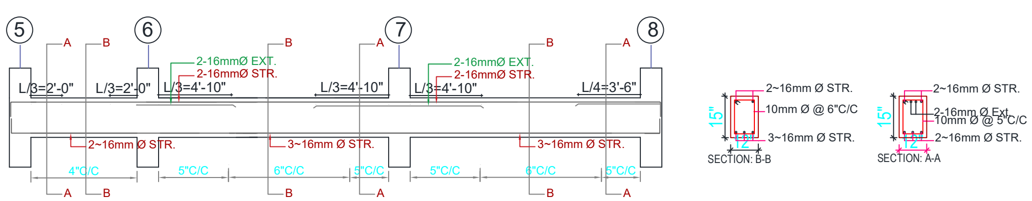


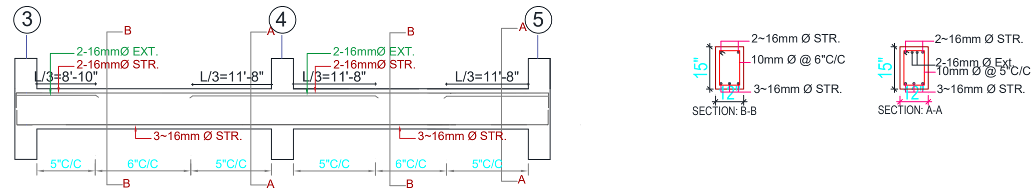
LONG SECTION OF BEAM B B1 FOR 1ST FLOOR = 12" X12"



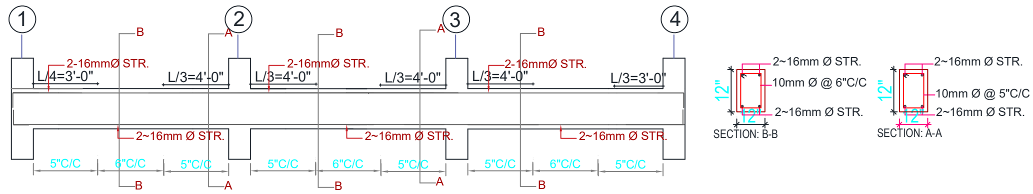
LONG SECTION OF BEAM B C1 FOR 1ST FLOOR = 12" X15"



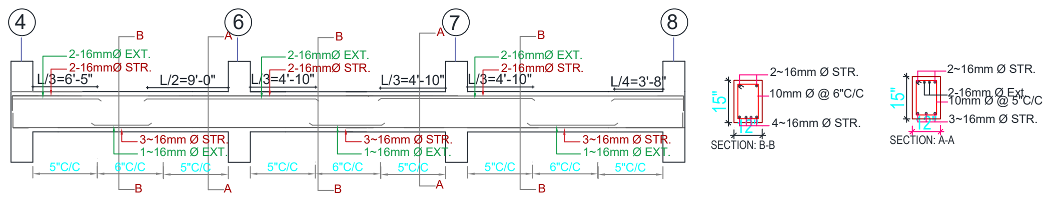
LONG SECTION OF BEAM B D1 FOR 1ST FLOOR = 12" X15"



LONG SECTION OF BEAM B E(PART-02) FOR 1ST FLOOR = 12" X15"



LONG SECTION OF BEAM B F(PART-01) FOR 1ST FLOOR = 12" X12"



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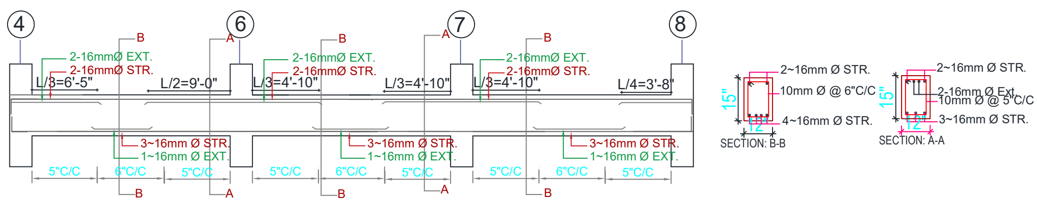
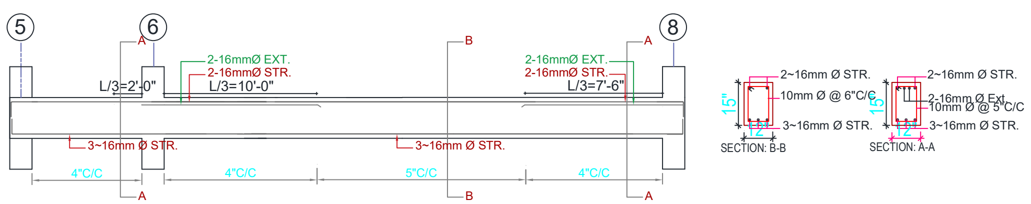
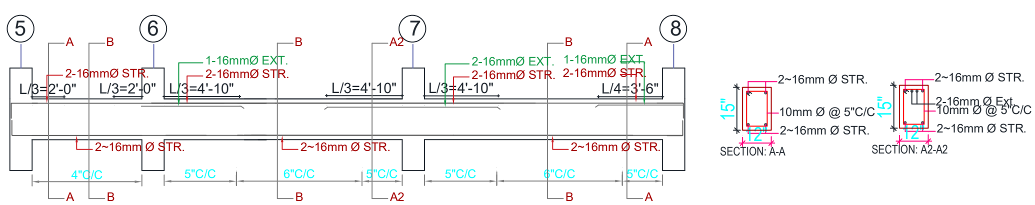


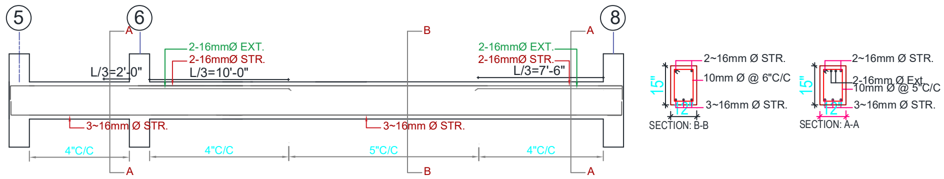
LONG SECTION OF BEAM B F(PART-02) FOR 1ST FLOOR = 12" X15"



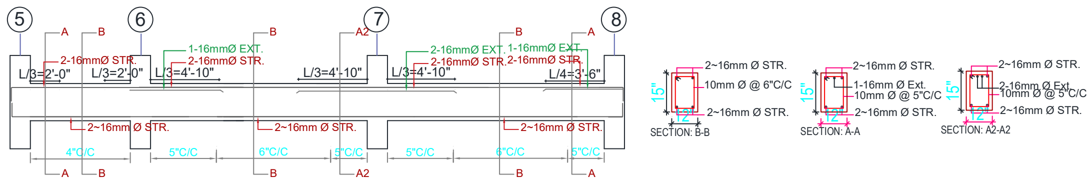
LONG SECTION OF BEAM B G1 FOR 1ST FLOOR = 12" X15"



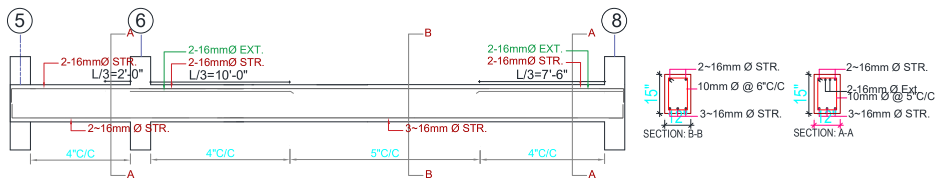
LONG SECTION OF BEAM B H1 FOR 1ST FLOOR = 12" X15"



LONG SECTION OF BEAM B I1 FOR 1ST FLOOR = 12" X15"



LONG SECTION OF BEAM B J1 FOR 1ST FLOOR = 12" X15"



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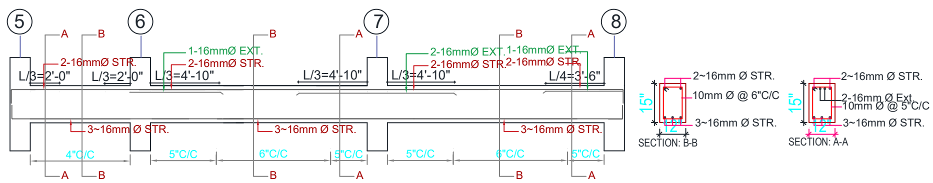
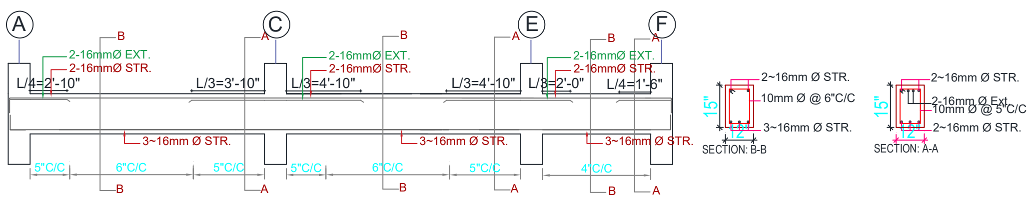
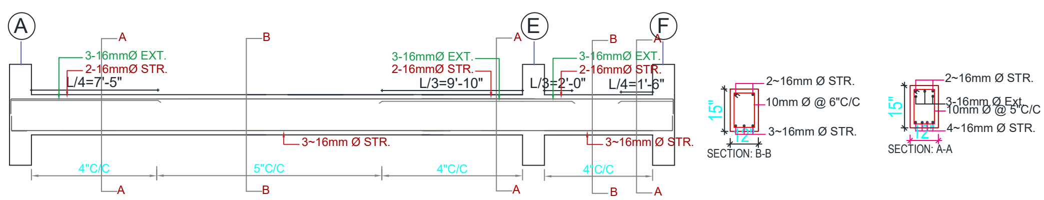


LONG SECTION OF BEAM B L1 FOR 1ST FLOOR = 12" X15"



LONG SECTION OF BEAM B 21 FOR 2ND FLOOR = 12" X15"



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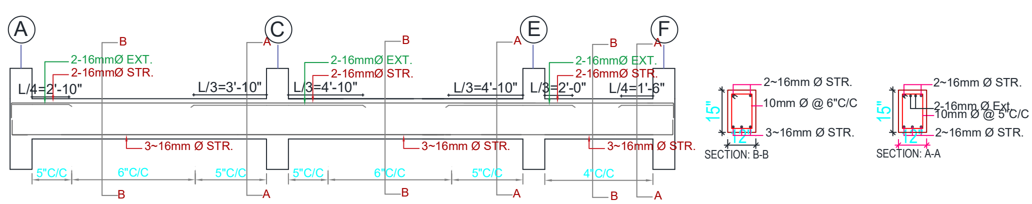

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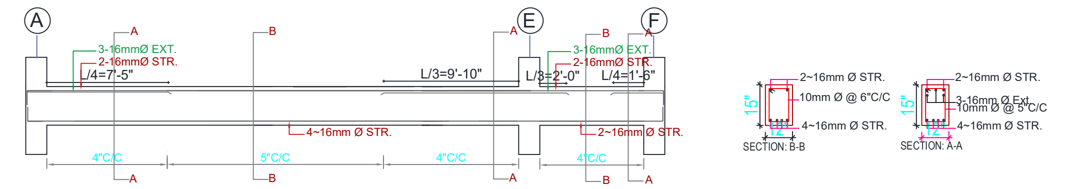
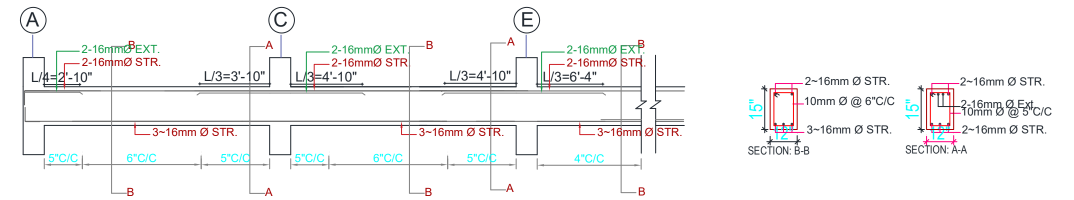
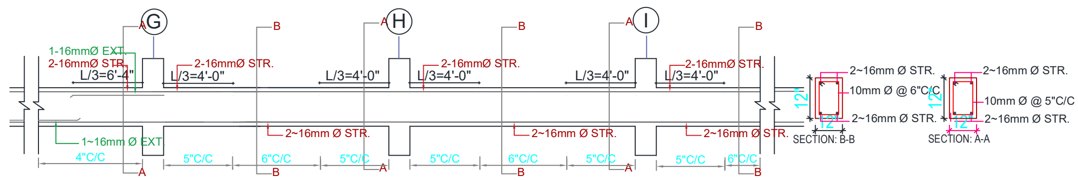


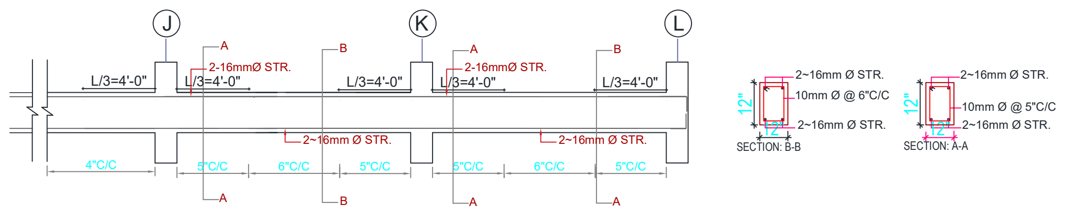
LONG SECTION OF BEAM B 24 FOR 2ND FLOOR = 12" X15"



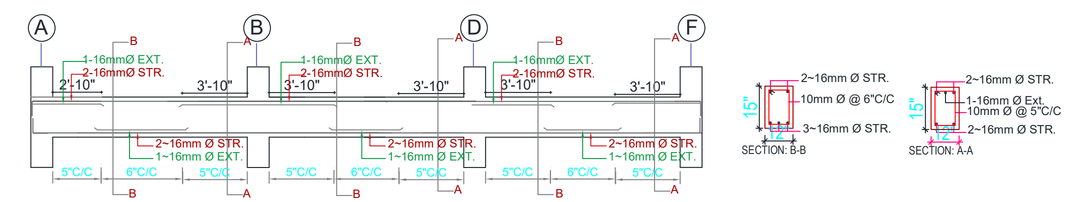
LONG SECTION OF BEAM B 25(PART-01) FOR 2ND FLOOR = 12" X15"



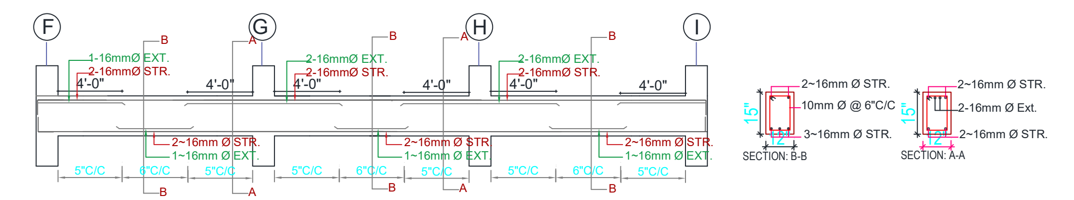
LONG SECTION OF BEAM B 25(PART-02) FOR 2ND FLOOR = 12" X12"



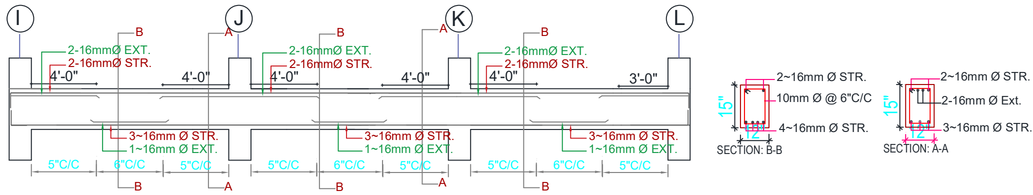
LONG SECTION OF BEAM B 25(PART-03) FOR 2ND FLOOR = 12" X12"



LONG SECTION OF BEAM B 26(PART-01) FOR 2ND FLOOR = 12" X15"



LONG SECTION OF BEAM B 26(PART-02) FOR 2ND FLOOR = 12"X15"



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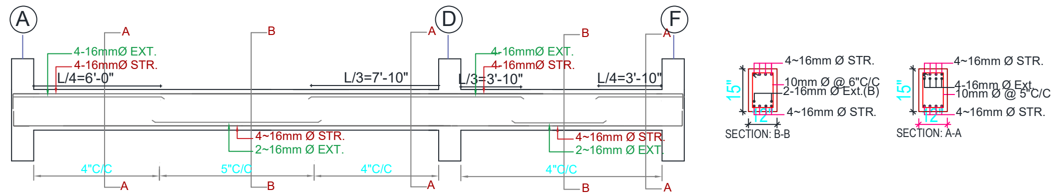
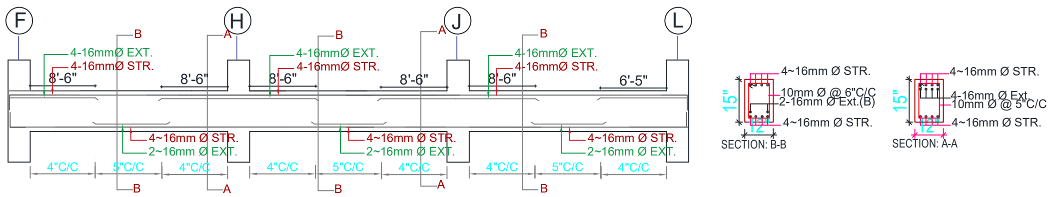
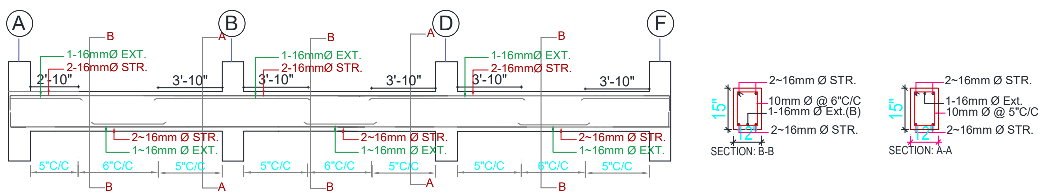


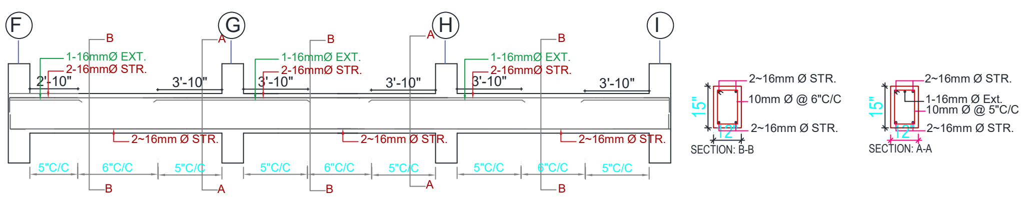
LONG SECTION OF BEAM B 27(PART-01) FOR 2ND FLOOR = 12" X15"



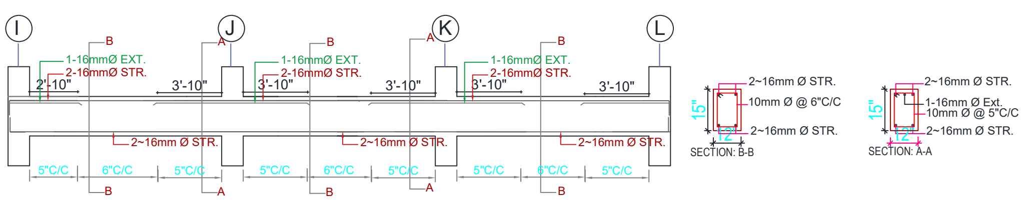
LONG SECTION OF BEAM B 27(PART-02) FOR 2ND FLOOR = 12" X15"



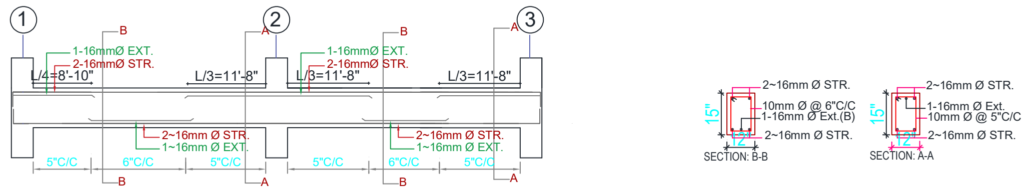
LONG SECTION OF BEAM B 28(PART-01) FOR 2ND FLOOR = 12" X15"



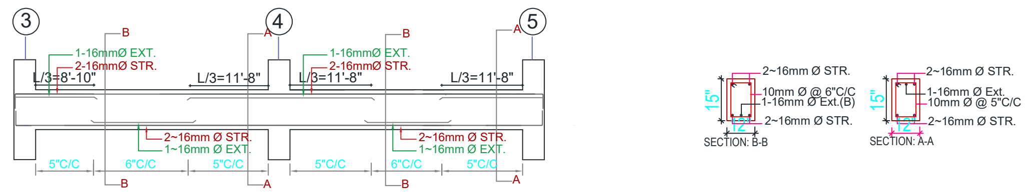
LONG SECTION OF BEAM B 28(PART-02) FOR 2ND FLOOR = 12" X15"



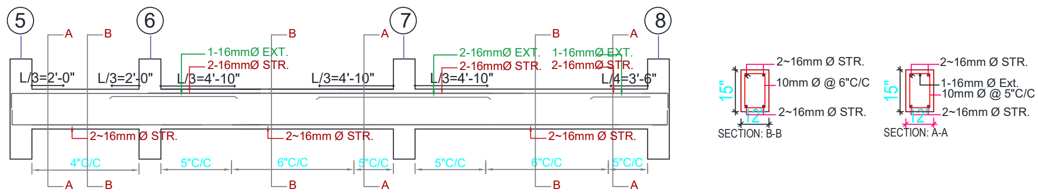
LONG SECTION OF BEAM B 28(PART-03) FOR 2ND FLOOR = 12" X15"



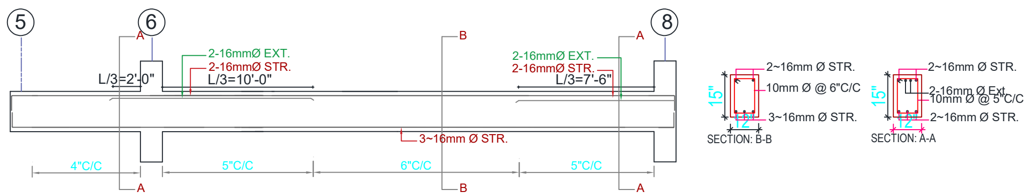
LONG SECTION OF BEAM B 2A(PART-01) FOR 2ND FLOOR = 12" X15"



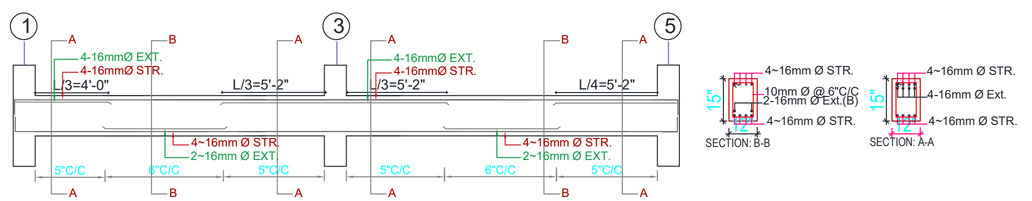
LONG SECTION OF BEAM B 2A(PART-02) FOR 1ST FLOOR = 12" X15"



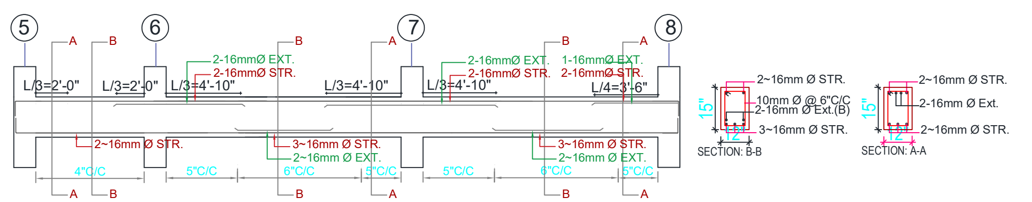
LONG SECTION OF BEAM B A1(PART-03) FOR 1ST FLOOR = 12" X15"



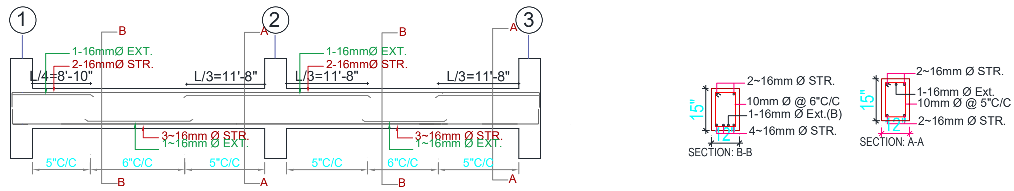
LONG SECTION OF BEAM B 2B FOR 2ND FLOOR = 12"X15"



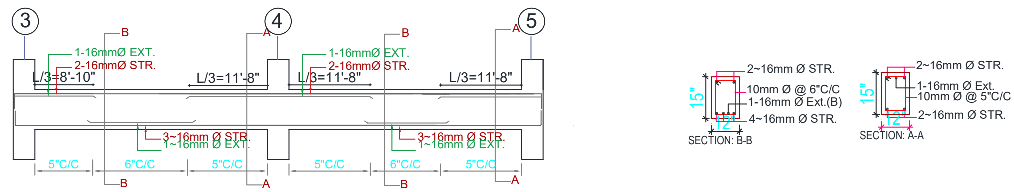
LONG SECTION OF BEAM B C1 FOR 1ST FLOOR = 12" X15"



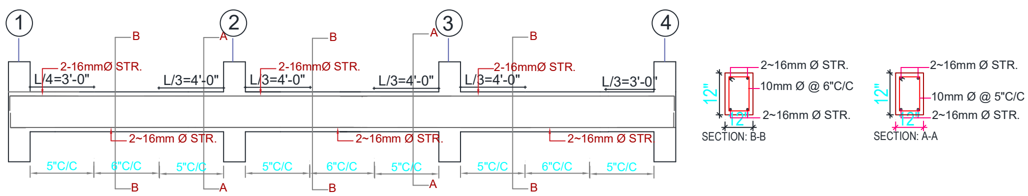
LONG SECTION OF BEAM B 2D FOR 2ND FLOOR = 12" X15"



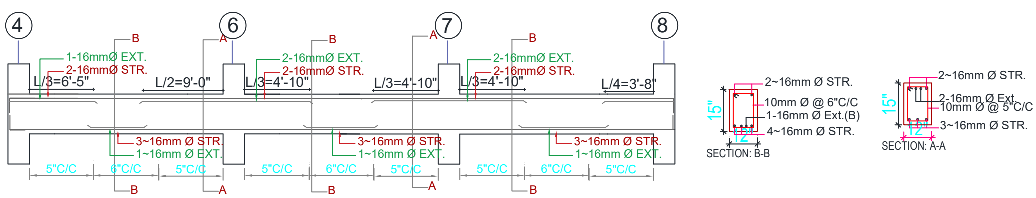
LONG SECTION OF BEAM B 2E(PART-01) FOR 2ND FLOOR = 12" X15"



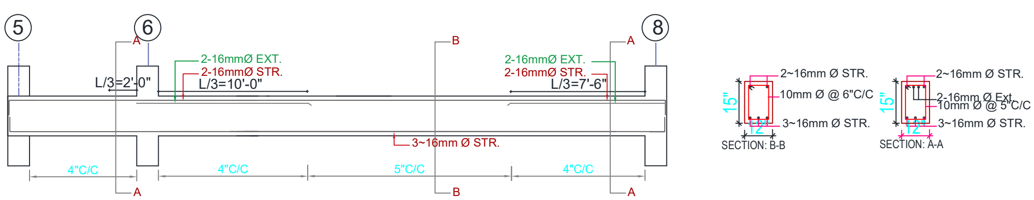
LONG SECTION OF BEAM B E(PART-02) FOR 1ST FLOOR = 12" X15"



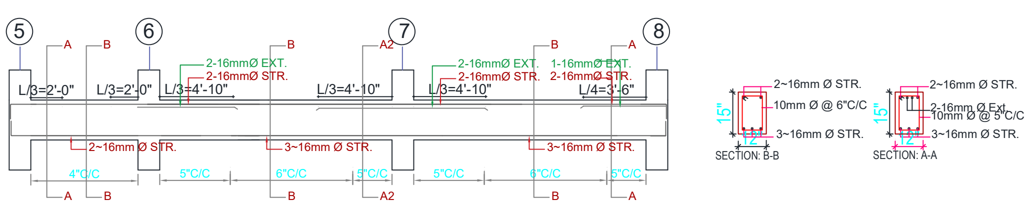
LONG SECTION OF BEAM B 2F(PART-01) FOR 2ND FLOOR = 12" X12"



LONG SECTION OF BEAM B 2F(PART-02) FOR 2ND FLOOR = 12" X15"



LONG SECTION OF BEAM B 2G FOR 2ND FLOOR = 12" X15"



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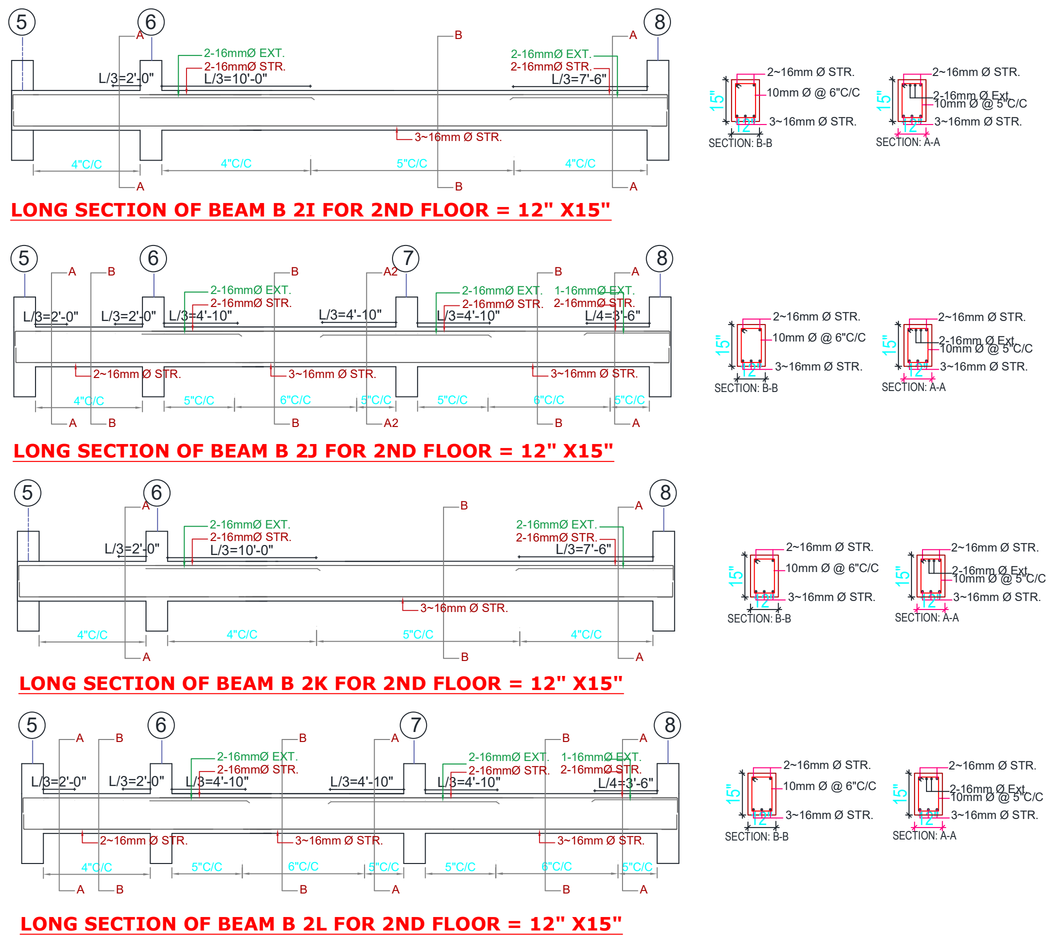

Figure 11.11: Beam Detailing.

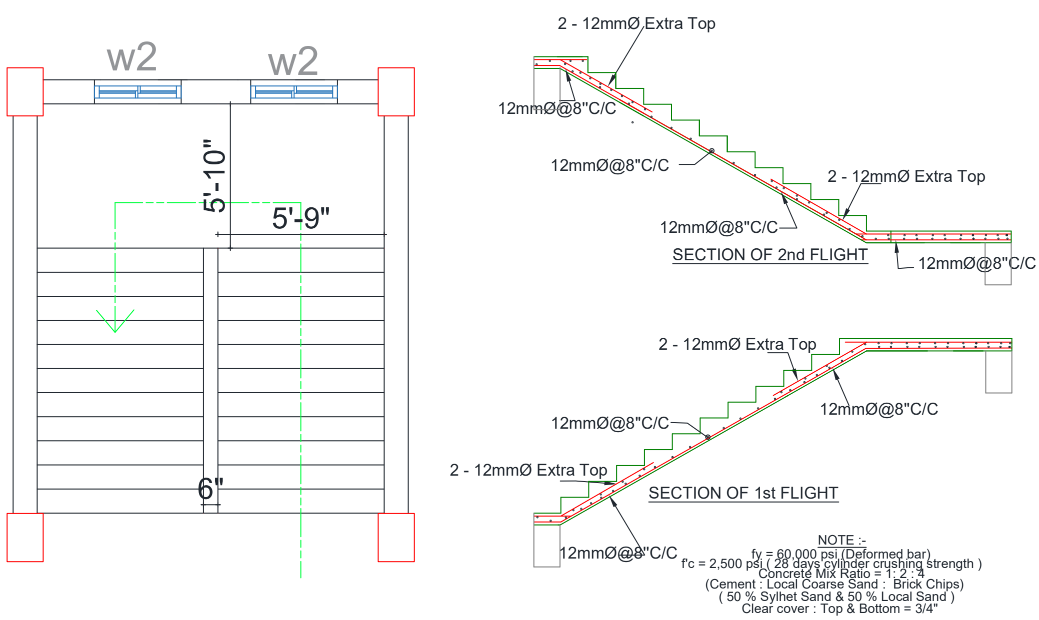

Figure 11.12: Stair Detailing.

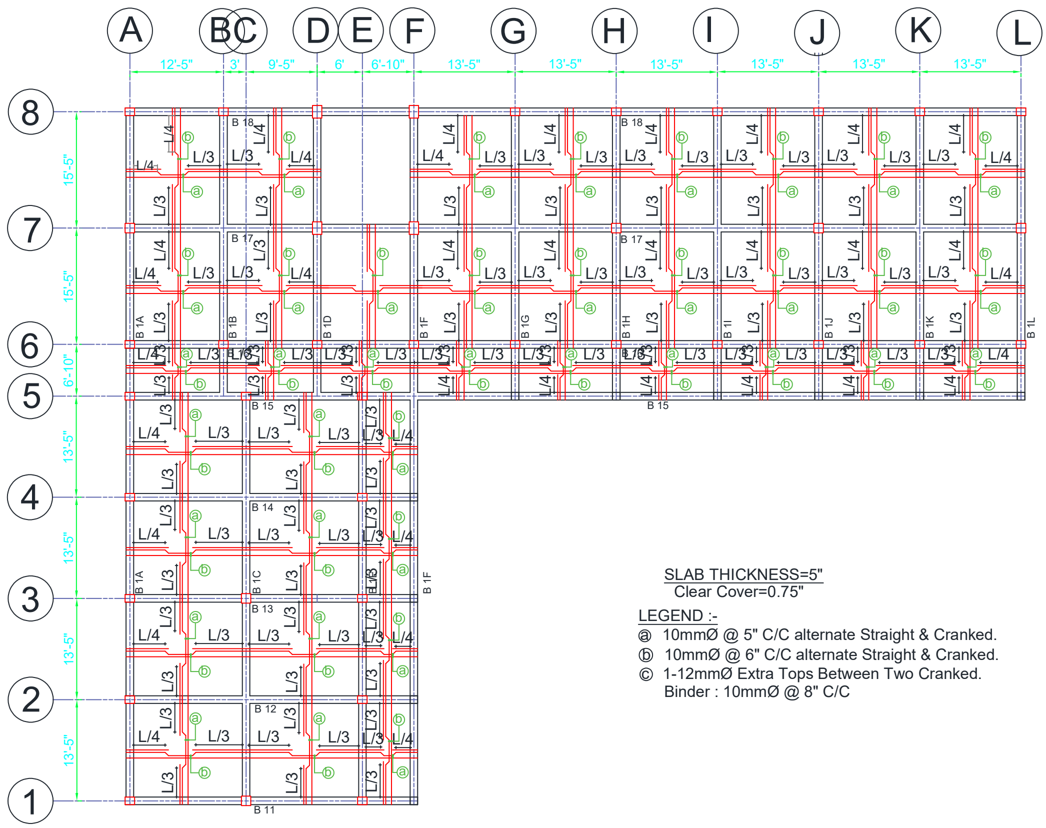

Figure 11.13: Slab Detailing.

Appendix B – Structural Analysis Sheets

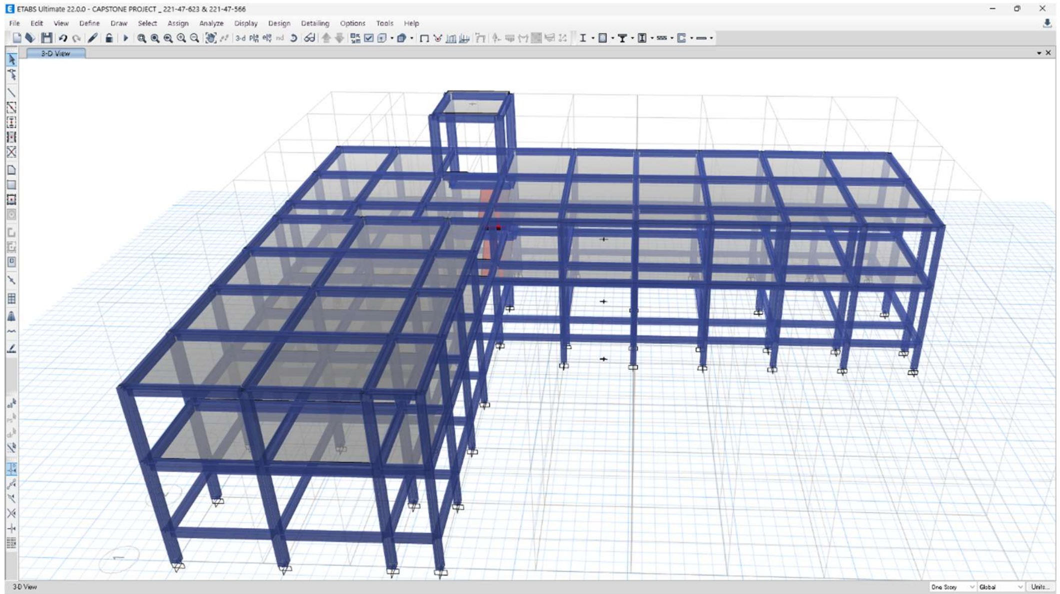

Figure (Etabs) 11.14: Model 3D view

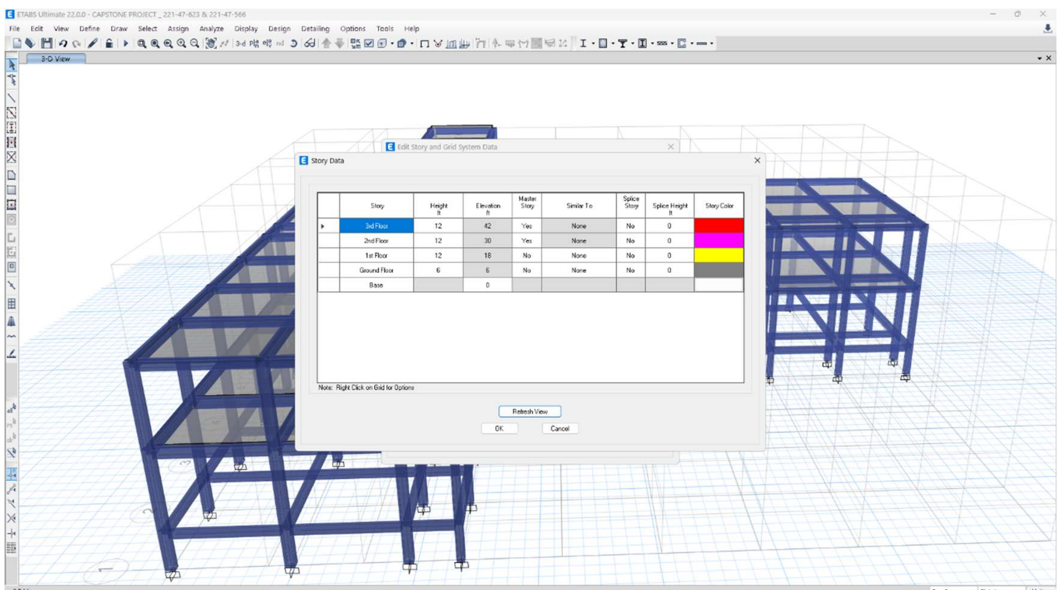

Figure (Etabs) 11.15: Story Data

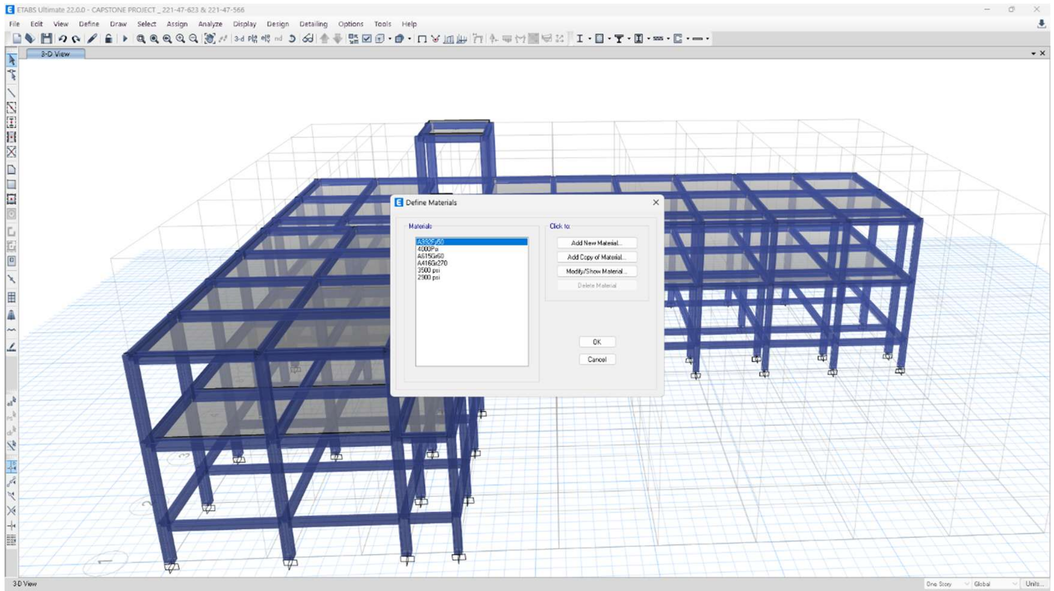

Figure (Etabs) 11.16: Define Materials.

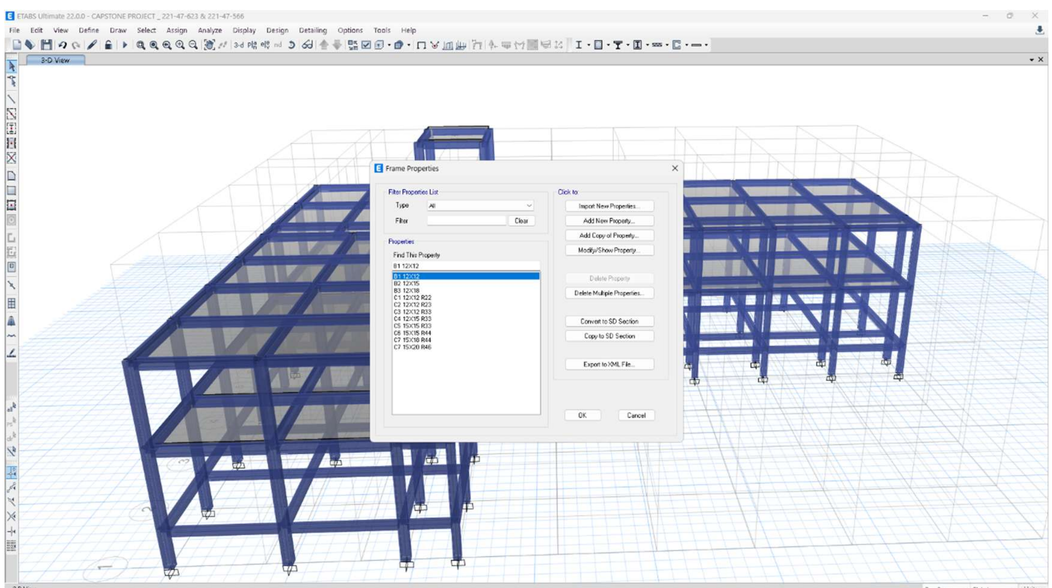

Figure (Etabs) 11.17: Frame Properties.

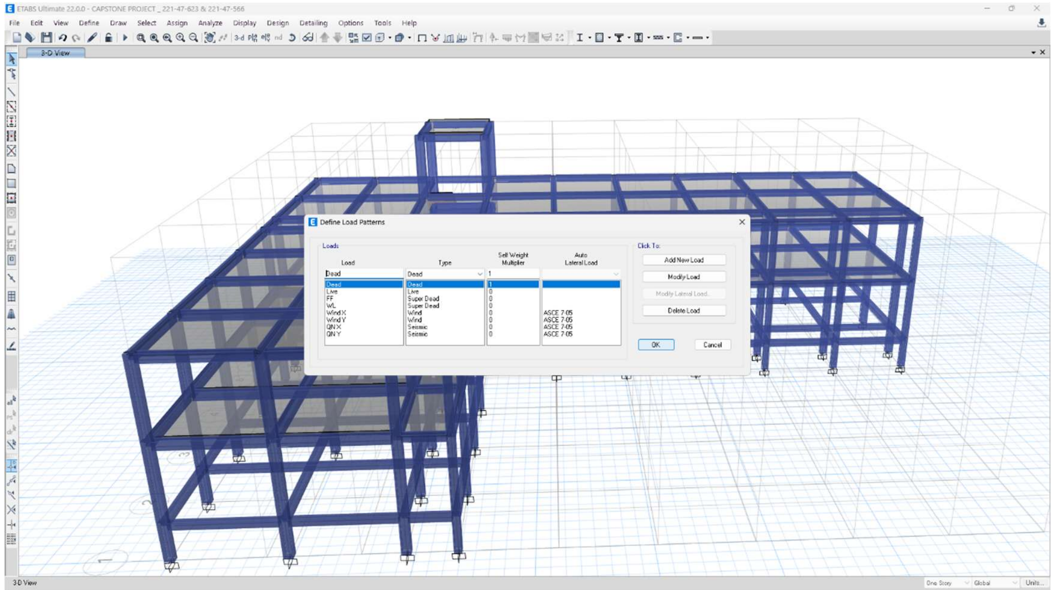

Figure (Etabs) 11.18: Load Patterns.

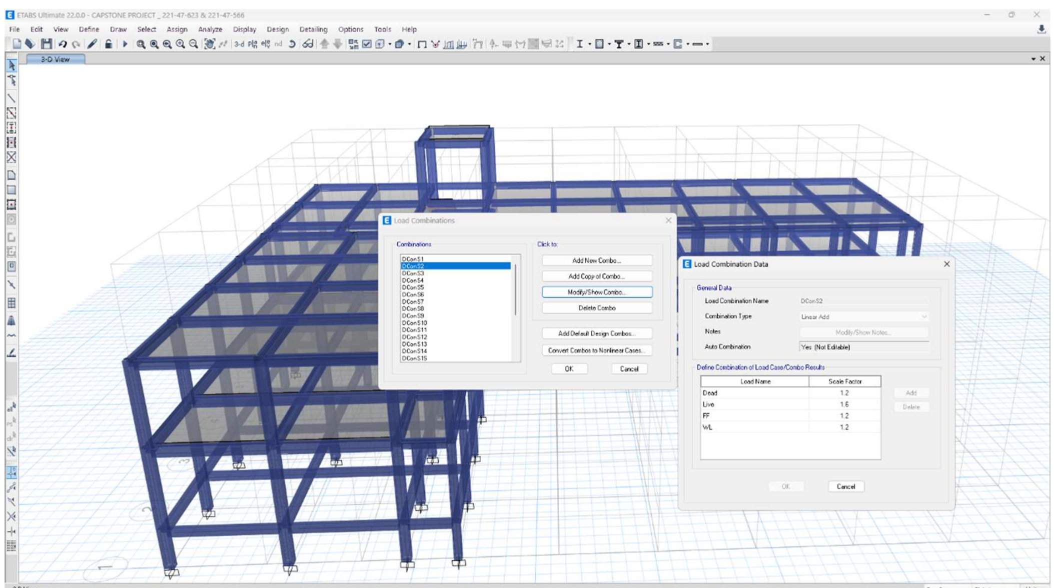

Figure (Etabs) 11.19: Load Combination.

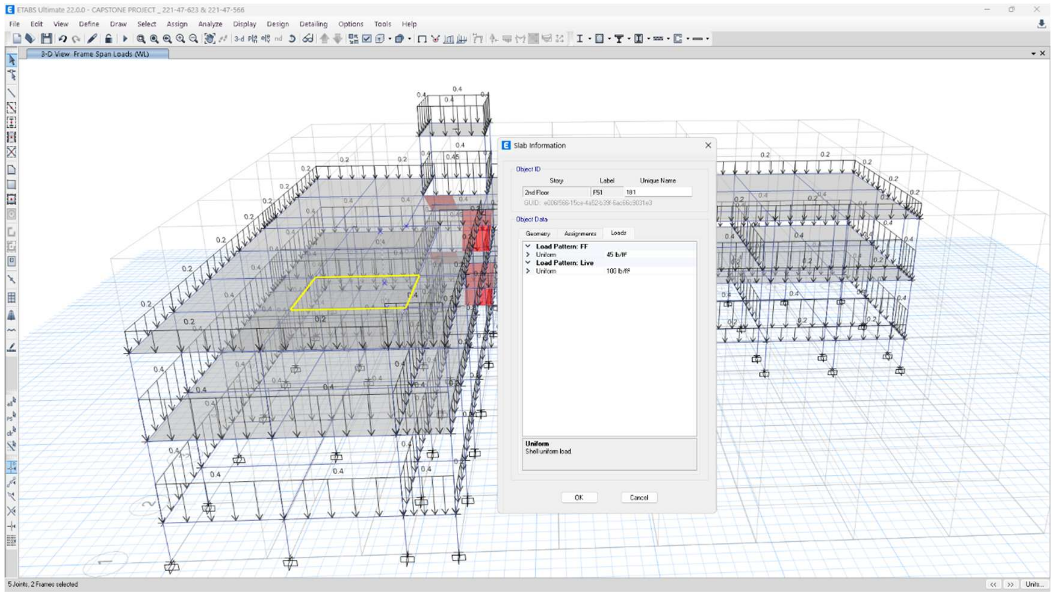

Figure (Etabs) 11.20: Imposed Load

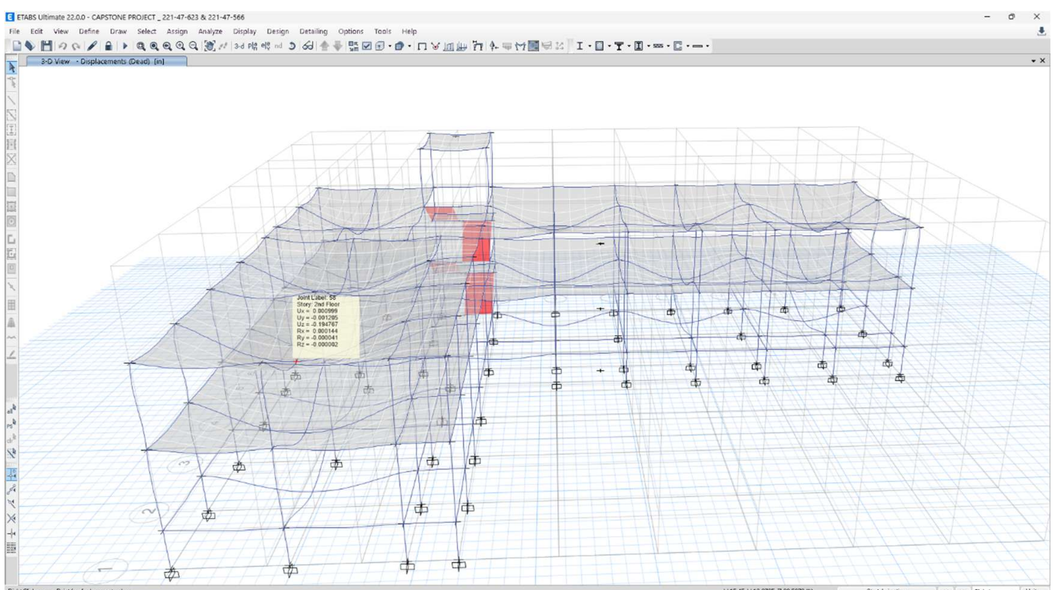

Figure (Etabs) 11.21: Displecment.

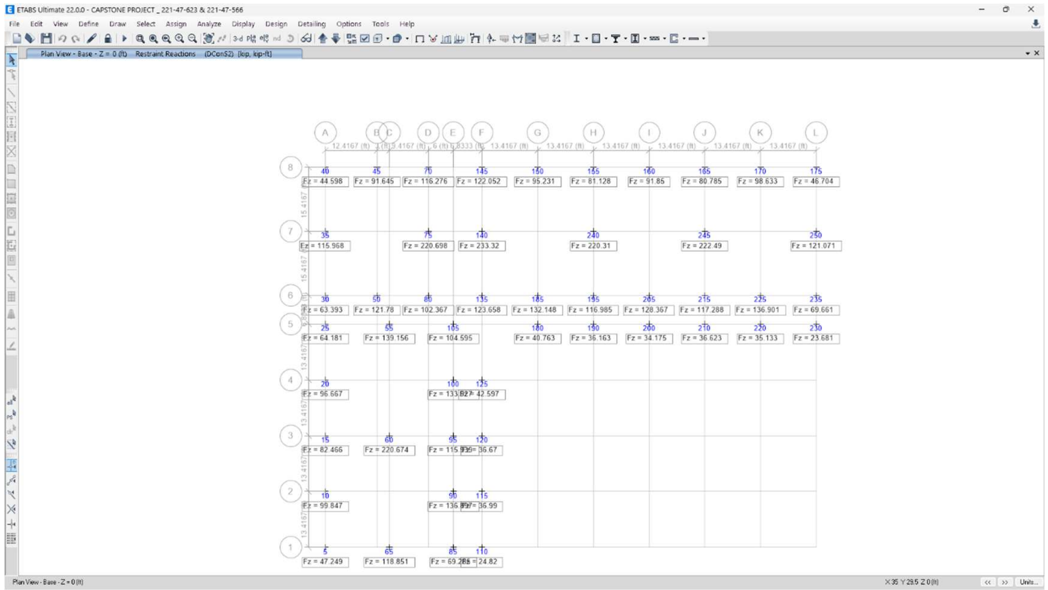

Figure (Etabs) 11.22: Resultant Rection.

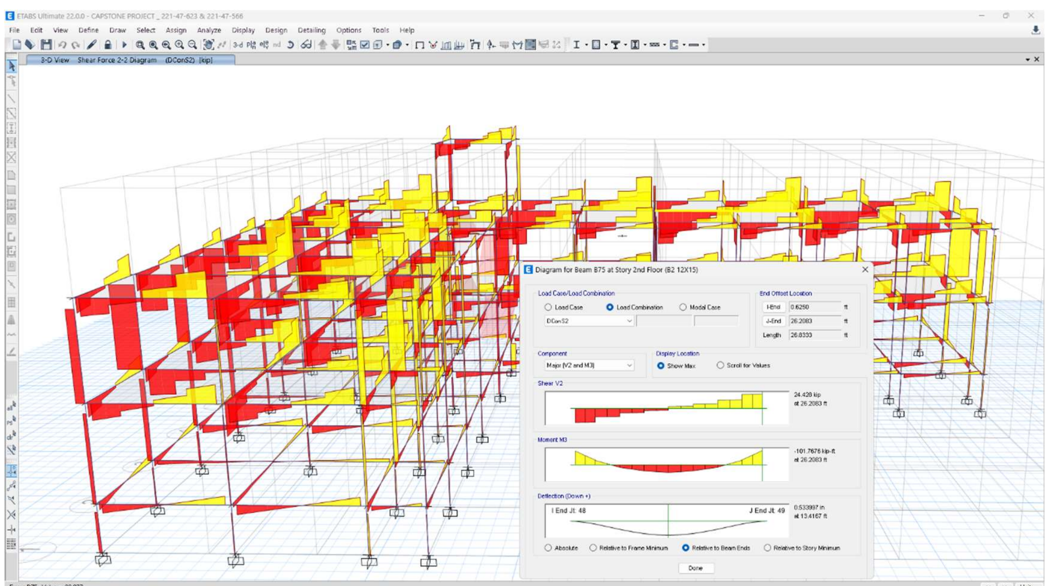

Figure (Etabs) 11.23: Shear Diagram.

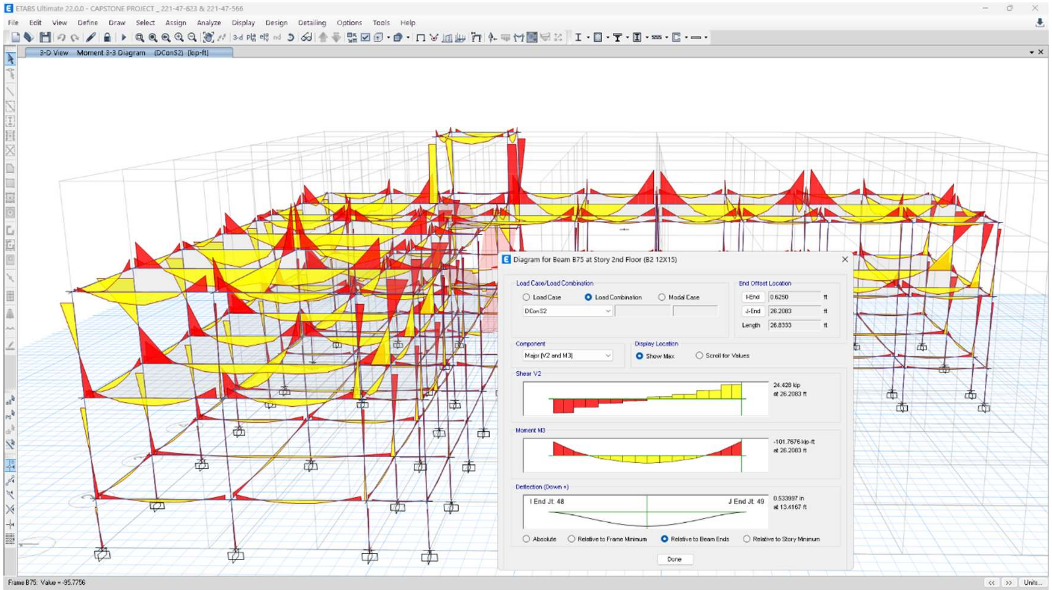

Figure (Etabs) 11.24: Moment Diagram.

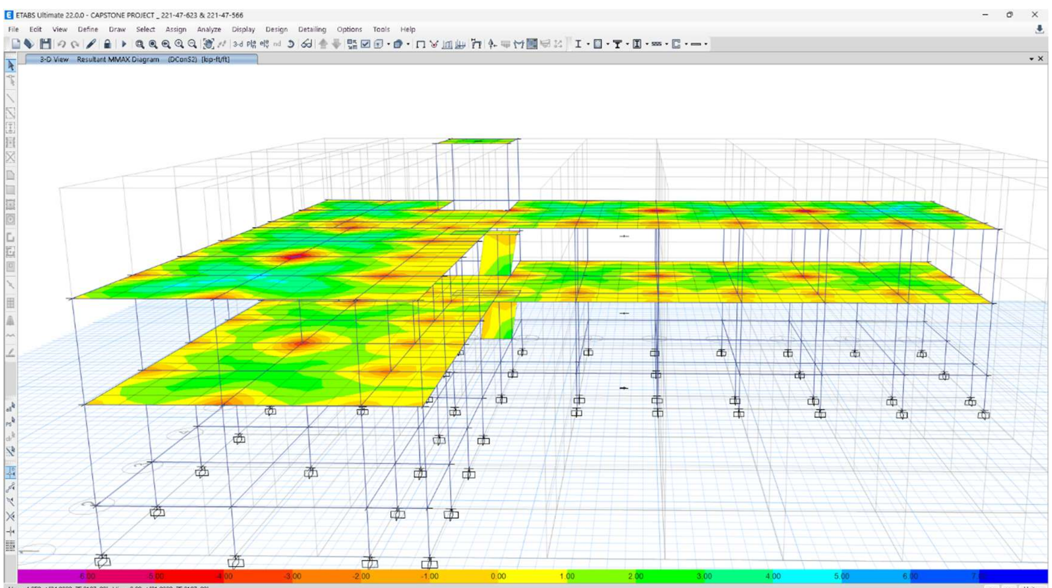

Figure (Etabs) 11.25: Slab Resultent

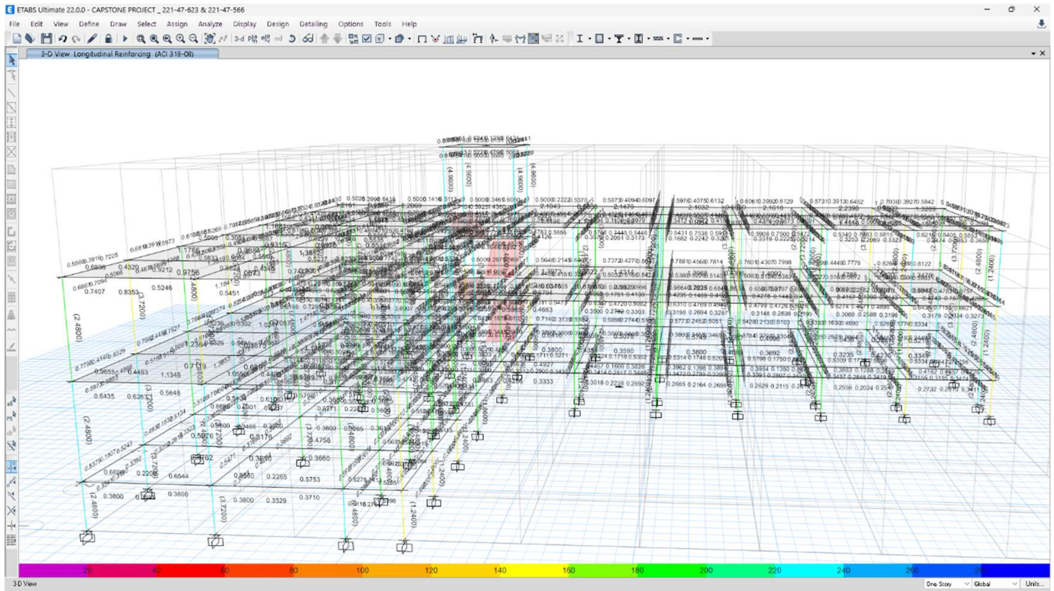

Figure (Etabs) 11.26: Longitudinal Reinforcement.

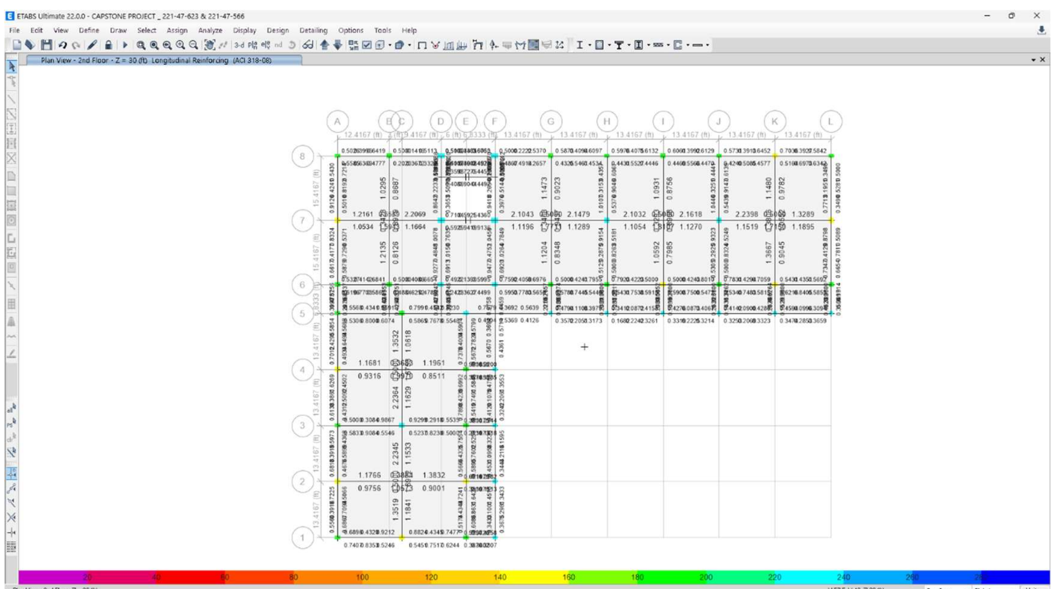

Figure (Etabs) 11.27: Beam Longitudinal Reinforcement.

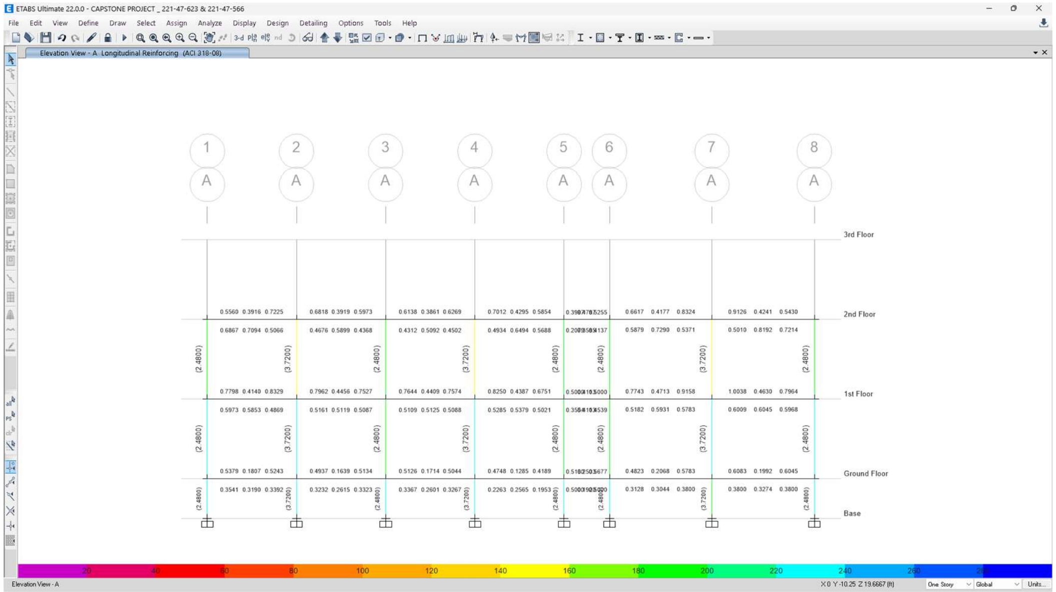

Figure (Etabs) 11.28: Elevetion section Column Longitudinal Reinforcement.

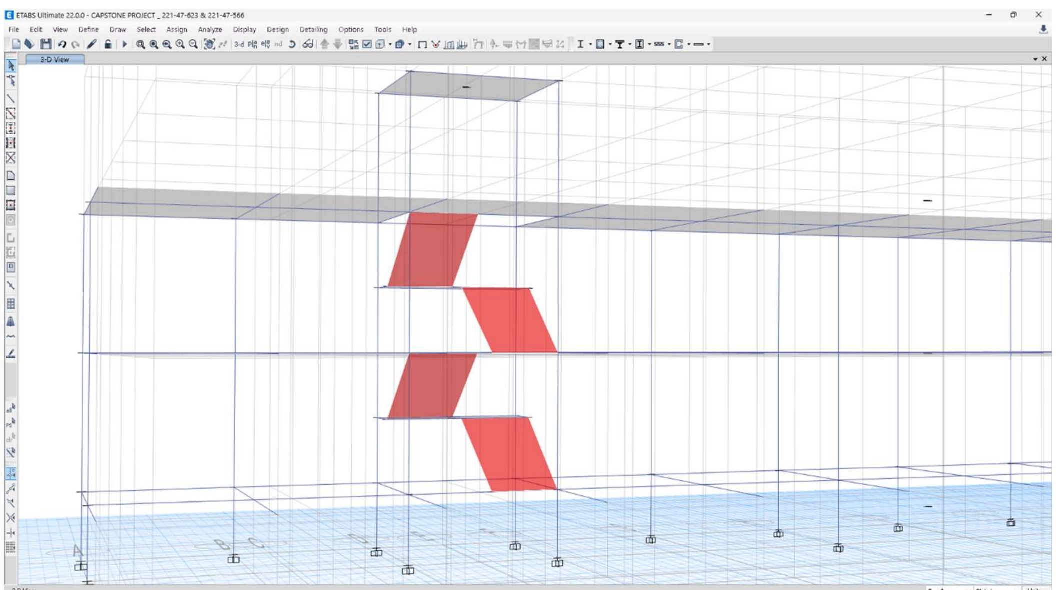

Figure (Etabs) 11.29: Stair Case.

Appendix C – Construction Schedule (Gantt Chart)

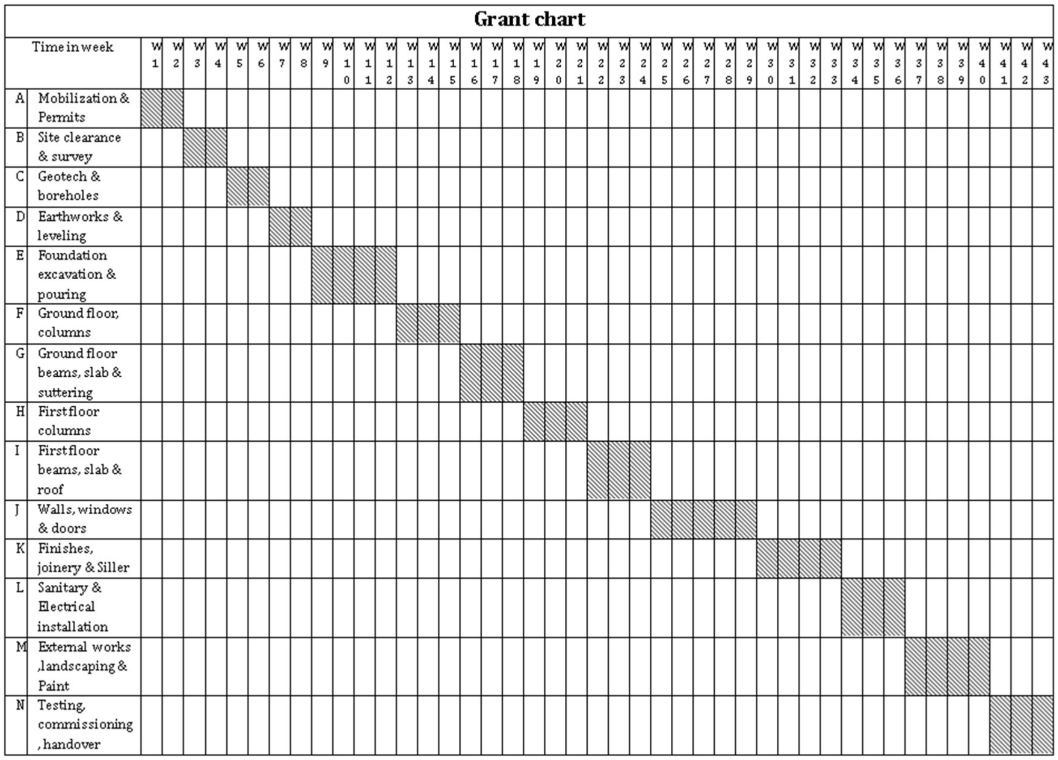

Figure 11.30: Grant Chart.

11.3 Final Reflection on the Project

Academic Reflection

This final project of the course offered the possibility to combine the theoretical experience of the structural design, architecture, environmental engineering, and project management into the entire design of a building. A combination of the ETABS, AutoCAD and MS Project technology enabled the practice of the industry standard software.

Personal Reflection

The project required a large amount of time management, coordination of different aspects in engineering, and addressing of limitations, as manifested in availability of materials and restriction in data. Endowed these tougher problem solving and critical thinking skills.

Professional Development

This project has led to the increase of the ability to take real life construction projects in a sustainable manner. The process of compromising between cost, safety and sustainability as a future civil engineer will be invaluable to practice.

Sustainability Vision

The school design suits the sustainable development of infrastructures in Bangladesh. Sustainable schools are healthier schools, which use less energy and can serve as the role models on future educational buildings.

Closing Statement

Not only does this capstone project meet an academic mandate, but it will also help in preparing a sustainable development in the long run in Bangladesh. The combination of structural engineering, that entails the incorporation of architecture and environmental issues and consideration and management proving that sustainable schools are feasible and needed. The lessons acquired in this case will be a good foundation in the future career in civil engineering discipline.

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