



# ETABS-Based Structural Analysis and Architectural Design of a 21-Story Multifunctional Building in Dhaka: Insights from Shanghai-Inspired Designs on Soft Soil

Asif Ahmed Sourov<sup>1</sup>, Fahmida Naznin<sup>2</sup>, Md. Rakibul Islam<sup>1</sup>, Md. Sagar Akon<sup>1</sup>, Idlachgar Rkia<sup>3</sup>

<sup>1</sup>College of Civil Engineering, Tongji University, Shanghai, China

<sup>2</sup>School of Architecture, Chang'an University, Xi'an, China

<sup>3</sup>School of Civil Engineering, Architecture and Environment, Hubei University of Technology, Wuhan, China

Email: asifahmedsourov@icloud.com, fahmidanaznin13@icloud.com, rakibce01@gmail.com, sagarakon.tongji.ce@gmail.com, rekia2001idlachgar@gmail.com

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## Abstract

The present research paper is a detailed study of the architectural design and structural analysis of a 21-story multifunctional tall building that is proposed to be constructed in Dhaka, Bangladesh. The architecture of the building is based on the high-rise buildings of Shanghai, which combine modern architectural design and functionality. The building has a mixed-use design where the ground floor to the 4th floor are commercial retail space and the 5th to the 21st floor are residential units, which are studio apartments and larger multi-bedroom units. This design combines the principles of vertical zoning, in which various functional areas are arranged effectively in the same building, and land use in the fast-growing urban city of Dhaka is maximized. The main aim of the study is to assess the viability of the proposed building design by performing structural analysis with the help of ETABS software, and it should be in accordance with the Bangladesh National Building Code (BNBC 2020). The architectural design focuses on energy efficiency, comfort, and aesthetic value, and includes such elements as the use of natural light, ventilation, and noise reduction measures to improve the well-being of occupants. The paper provides the main results of structural stability, displacement patterns, inter-story drifts, and reinforcement details, which provide a detailed insight into the issues and solutions of the design of tall buildings on soft soil.

## Subject Areas

Civil Engineering and Architecture

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## Keywords

ETABS Structural Analysis, Architectural Design, Bangladesh National Building Code (BNBC), Residential Building, Commercial Building, Urban Development

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## 1. Introduction

The capital city of Bangladesh, Dhaka, is one of the fastest urbanizing cities in the world, with a rapidly increasing population and an ever-increasing economic activity [1]. Dhaka is one of the most populated cities in the world and this has posed a great challenge in terms of urban planning, infrastructure and housing [2]. The need to maximize the available urban space has led to an increased demand of multifunctional buildings that can effectively combine commercial and residential uses [3]. To address these issues, the suggested 21-story multifunctional building in Dhaka will combine commercial and residential areas in one building. This will be the best way to utilize the land and it has the potential to develop a dynamic and sustainable urban environment. This building will create a lively community by integrating various functions into a single building to meet the increasing demands of the city. The major goals of this project are:

**Dual Functionality:** The building will provide a large amount of commercial space (ground floor to 4th floor) and high-quality residential living space (5th to 21st floor) to provide a balanced combination of business and living space.

**Sustainability:** The project focuses on the environmentally friendly design features that comply with the international environmental standards [4]. The green building techniques such as energy efficient systems and sustainable materials are also included to minimize the environmental impact of the building and to make it viable in the long run [5].

**Seismic Resilience:** An important objective of this project is to make sure that the building meets the seismic requirements of Bangladesh and surpasses the local seismic safety requirements [6]. The architecture uses modern engineering methods to protect the building against earthquake hazards that are characteristic of the geography of Dhaka [7].

**Community Enhancement:** The building is not only a physical building but also a community center, where accessible facilities, public space, and social space are provided and they have a positive impact on the urban fabric of Dhaka.

## 2. Project Scope and Methodology

### 2.1. Project Scope

The project is a complex of architectural and structural design of a 21-story multifunctional building in Dhaka. The scope encompasses the whole lifecycle of the project starting with conceptualization to its economic viability considering different design criteria, load calculations, material selection and sustainability [8].

Particular topics are:

**Architectural and Structural Design:** An in-depth discussion of the architectural design features that emphasize on the aesthetic value and functionality [9]. The structural design makes the building safe and fits well in the urban environment.

**Compliance and Standards:** A detailed analysis of how the design is in accordance with the local and international building codes and especially structural safety, seismic resilience, and sustainability.

**Technological Integration:** The integration of the latest technologies, such as structural modeling and simulation software (ETABS and SAP2000) to increase the efficiency of operations and make the building more comfortable to occupants [10].

**Financial Overview:** Cost estimates of the construction and maintenance of the project and an economic analysis of the project, so that the building is financially viable throughout its life.

## 2.2. Methodology

The approach taken in the current project is a combination of theoretical research, empirical studies, and computational modeling in order to make the design innovative and practical. The main stages of the methodology are the following:

**Literature Review:** The study of the current trends and technologies in the design of high-rise buildings, paying attention to mixed-use buildings. This stage examines international best practices and benchmarks of cities that have similar urban issues such as Shanghai, which has been used to design this building.

**Site Analysis:** The site analysis is done in terms of environmental and geotechnical analysis to determine the site conditions in Dhaka in terms of soil properties, seismic activity, and climatic considerations [7]. This is important information in the determination of design parameters particularly in foundation design and load bearing capacity (Figure 1).

**Design Simulation:** The structural modeling is done in ETABS and SAP2000 to simulate the behavior of the building under different loading conditions, e.g. seismic loads, wind loads, and live loads [11]. This assists in identifying the most effective and safe design alternatives of the structural system of the building.

**Stakeholder Consultations:** Consultation with the local authorities, potential investors and future occupants will help to make sure that the building design will be in line with the practical needs and expectations of all stakeholders. This teamwork will assist in perfecting the design and making it practical and workable.

**Evaluation and Revision:** There are constant feedback loops with design team and stakeholders so that the design of the building can be revised to reflect the goals of the project and the compliance needs. Refinement and optimization of the design is done through iterative revisions (Table 13).

## 2.3. ETABS Modelling Assumptions

The 3D structural model was built in ETABS (version X.X) using shell elements

as floor slabs and frame elements as beams/columns. Slabs of rigid diaphragms were assigned at each floor level to provide in-plane load distribution. Material models: concrete was modelled as linear elastic with M25 properties and HYSD415 reinforcement (E, rho and nu as shown in **Table 10**). According to BNBC load combinations, gravity loads and lateral loads (wind and BNBC 2020 seismic cases) were applied (see **Table 8**). To conduct dynamic analysis, we extracted eigenvalues (modal analysis) and Response Spectrum Analysis (RSA) with BNBC 2020 spectral parameters; P-Delta (geometric second-order) effects were considered in the analysis. A consistent meshing approach was used with element sizes selected so that the largest panel dimensions of the slab were not more than 4 m × 4 m (refinement around openings and irregular plan elements) (**Table 4**). Boundary conditions: piles/foundations and soil properties were modelled as fully fixed (zero displacement/rotation) at the base level in the ETABS model (no explicit soil-structure interaction) (**Table 2**). Damping of fundamental modes was 5% (**Table 3**). Spectral scaling was done using the modal period of the model unless otherwise stated; where empirical code period estimates were used to compare, the formula  $T = C_{tH} m$  (BNBC Table 6.2.20 parameters) was used and differences are discussed. Edit element size, foundation modelling and ETABS version to suit our precise model (if not the same).

### 3. Design Codes, Structural Design and Requirements

The proposed 21-story multifunctional building in Dhaka will be designed structurally in accordance with the Bangladesh National Building Code (BNBC) 2020 (**Table 1**) which is a complete set of guidelines specifically designed to provide structural safety, material specifications, load calculations, and design methodologies of high-rise buildings in Bangladesh. The BNBC 2020 has the necessary requirements of constructing structures that can resist seismic forces, wind loads, and other environmental stresses (**Table 1**) that are common in the area given the fact that Dhaka is prone to seismic activity and high wind velocity [7] [12].

**Table 1.** Design code standard.

Category	Code/Standard	Details
General Settings	BNBC 2020	Bangladesh National Building Code
Display Units	Metric SI	International System of Units
Region for Materials	User-Defined	Based on project specifications
Steel Database Section	AISC14	American Institute of Steel Constructure (14 <sup>th</sup> Edition)
Steel Design Code	AISC 360-10	Specification for Structural Steel Buildings
Concrete Design Code	ACI 318-08	Building Code Requirements for Structural Concrete
Seismic Design	BNBC 2020	Seismic provisions of BNBC

**Continued**

Wind Load Design	BNBC 2020	Wind load provisions of BNBC
Load Combinations	BNBC 2020	Load combination rules as per BNBC

**Table 2.** Foundation and soil properties.

Parameter	Value
Soil Bearing Capacity	250 kPa
Soil Type	In Between Loose to Medium Dense
Foundation Type	Pile Foundation
Soil Factor (S)	1.35
Time Period (T)	4.000 s
Seismic Zone (Z)	2
Short Period Site Coefficient ( $F_a$ )	1.35
Long Period Site Coefficient ( $F_v$ )	2.70

**Table 3.** Seismic load parameters determination.

Parameter	Value
Building Height Above Base (H)	66.5 m
Length Along X Direction	69.0 m
Length Along Y Direction	50.0 m
Structure Type	Concrete Moment Resisting Frame
Building Period Coefficient ( $C_t$ )	0.0466
x or m	0.90
Damping Ratio ( $\xi$ )	5%
Damping Correction Factor ( $\eta$ )	1.0
Response Modification/Reduction Factor (R)	6.5
Occupancy Category	II
Importance Factor (I)	1.0
Location of the Building	Dhaka
Seismic Zone (Z)	2
Soil Factor (S)	1.35
Long-Period TL	2.04 s
Normalized Acceleration Response Spectrum ( $C_s$ )	0.338
Coefficient used to calculate lower bound for $S_a$ ( $\beta$ )	0.11
Short Period Site Coefficient ( $F_a$ )	1.35
Long Period Site Coefficient ( $F_v$ )	2.70
Design Spectral Acceleration ( $S_d$ )	0.0199

Continued

Distribution exponent for Building Height (K)	2.000
Seismic Design Category (SDC)	D
Expected Horizontal Peak Ground Acceleration ( $a_h$ )	0.18
The vertical seismic load effect ( $E_v$ )	0.09 D
Concrete Unit Weight	24 kN/m <sup>3</sup>

Table 4. Various load condition.

Element	Level/Story	Width (mm)	Depth (mm)
Beam	1 - 5	350	700
Beam	6 - 21	300	600
Column	1 - 5	1200	1200
Column	1 - 5	100	1000
Column	6 - 21	600	800
Slab	All	190	N/A
Share Wall	All	350	N/A

### 4. Architectural Design

The architectural design of the multi-purpose high-rise building in Shanghai is a perfect combination of modern beauty and functionality (Figure 1). This is informed by the concept of vertical zoning whereby different functions are well planned on various levels to maximize land use and improve the overall functionality of the building (Figures 2-5).

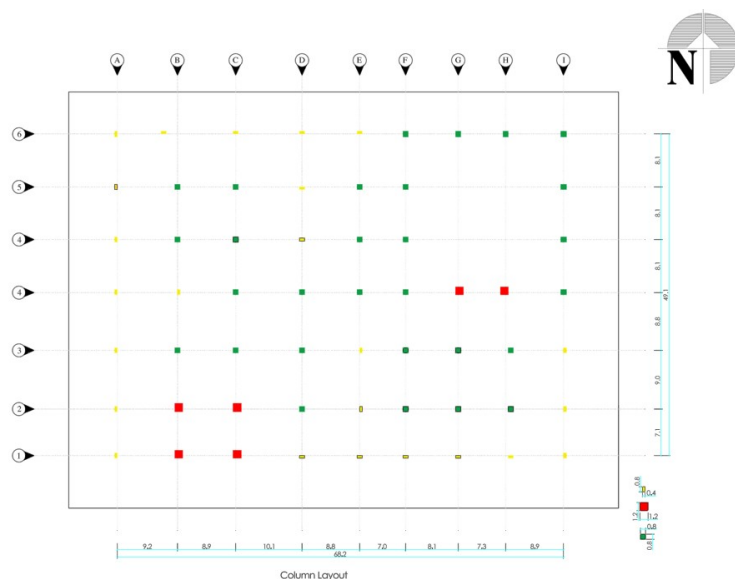


Figure 1. Column layout.

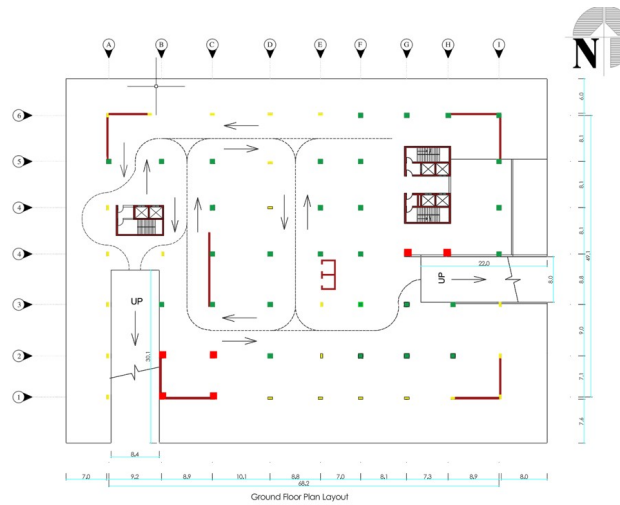


Figure 2. Ground floor layout.

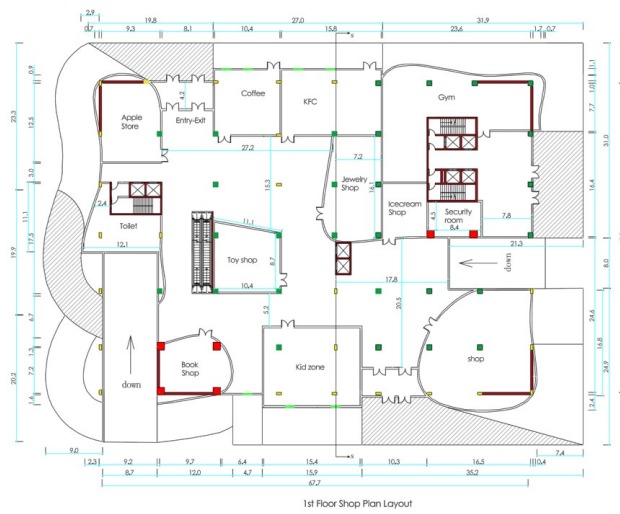


Figure 3. First floor shop layout.

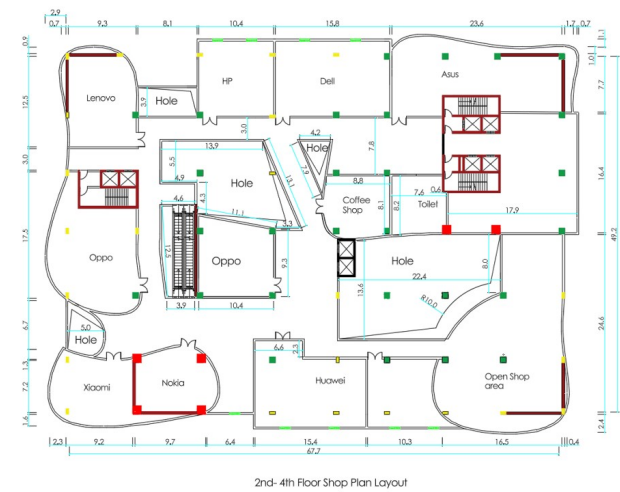


Figure 4. 2nd-4th floor shop layout.

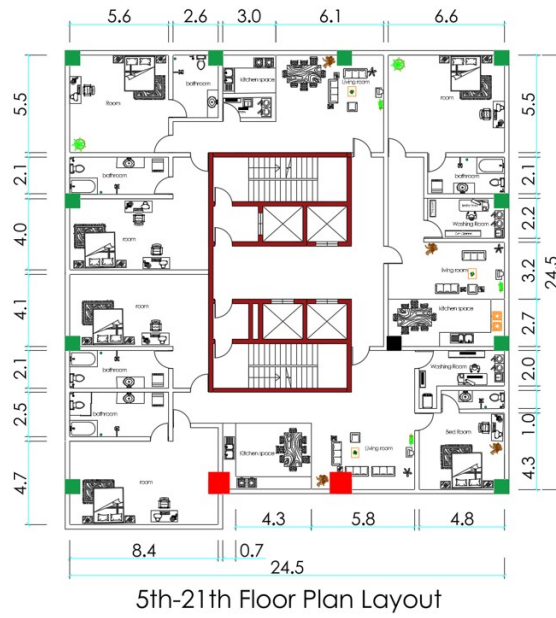


Figure 5. Residential floor (5th to 21st floor).

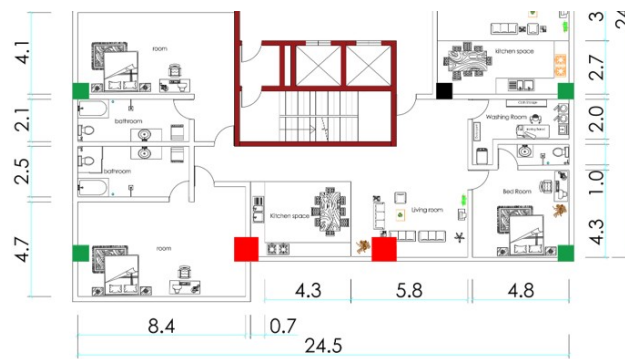


Figure 6. Details living space.

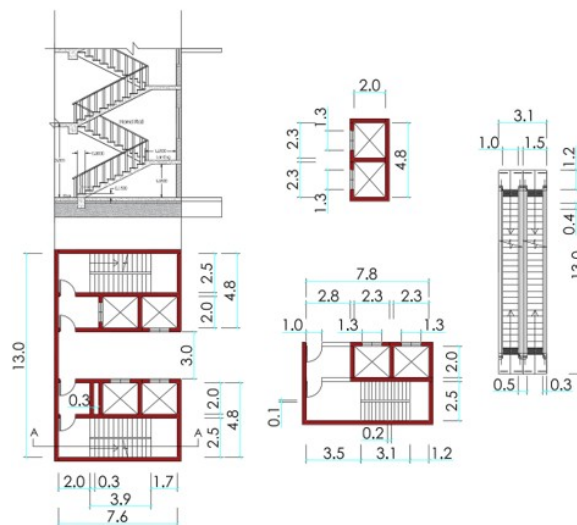


Figure 7. Stair, elevator and escalator details.

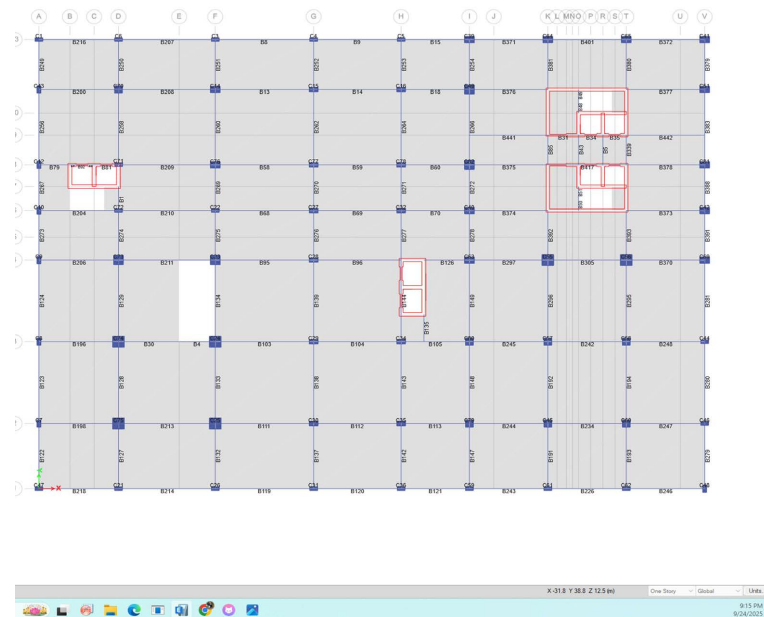


tion (EnergyPlus/IES/Green Building Studio) with precise program areas, internal gains and HVAC system specifications is suggested to substitute these estimates.

## 5. Structural Design, Load Analysis & Material Properties

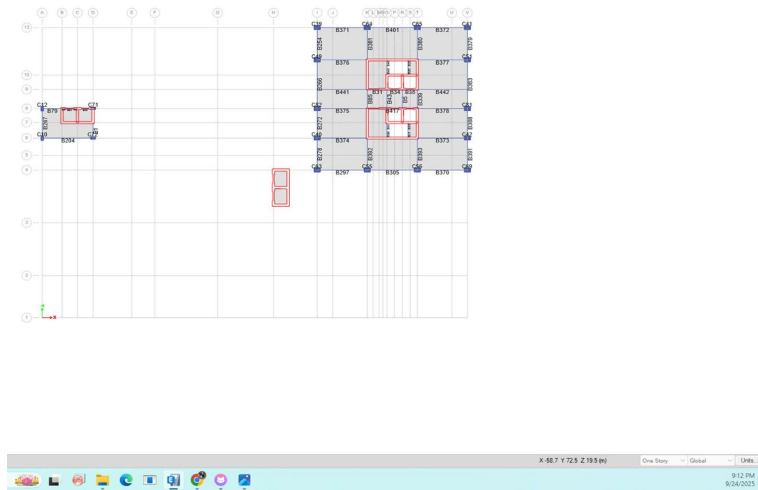
### 5.1. Design Analysis

**Column:** To design a column according to BNBC, start by calculating all applicable loads (dead, live, wind, seismic) and determine the factored load combinations. Select a preliminary column size and check the slenderness ratio to ensure it is not too slender. Calculate the axial load capacity using the formula  $\phi P_n = 0.65f_c'Ag + 0.75fyAs$ , where  $\phi$  is the strength reduction factor,  $f_c'$  is the compressive strength of concrete,  $Ag$  is the gross area,  $fy$  is the yield strength of steel, and  $As$  is the area of steel reinforcement (**Figure 10**). Verify the moment capacity using interaction diagrams to ensure  $\phi Mn \geq Mu$ . Calculate the required steel reinforcement and ensure it falls within the minimum and maximum reinforcement ratios (**Figure 10**). Design the transverse reinforcement (stirrups) to resist the shear force using  $V_s = V_u - V_c$ , where  $V_c$  is the shear capacity of concrete. Detail the longitudinal and transverse reinforcement according to BNBC requirements, ensuring proper cover, anchorage, and lap splices. Finally, verify the column design against BNBC requirements for stability and serviceability.



**Figure 10.** Beam selection commercial.

**Beam:** For the beam design according to BNBC, start by calculating the loads including dead loads, live loads, and any additional loads such as wind or seismic forces. Determine the factored load combinations as per BNBC. Select a preliminary beam size based on span, load, and deflection criteria (**Figure 11**).



**Figure 11.** Beam selection residential.

Compute the bending moments, shear forces, and deflections for the beam under these load combinations using structural analysis methods. Ensure the reinforcement ratio is within the allowable limits. Determine the shear reinforcement by calculating the shear capacity of the concrete  $V_c$  and the required shear reinforcement  $V_s$  using  $V_u = \phi(V_c + V_s)$ , where  $V_u$  is the factored shear force. Check for deflection control to ensure the beam meets serviceability requirements. Finally, detail the reinforcement, ensuring proper spacing, cover, anchorage, and lap splices according to BNBC requirements (**Figure 12**). Verify the design for compliance with all BNBC provisions, ensuring safety and performance.

**Slab:** For the slab design according to BNBC, start by determining the loads, including dead loads, live loads, and any additional loads such as wind or seismic forces. Use these loads to calculate the factored load combinations as per BNBC.

a) Load Calculation: Determine the total load per unit area including the self-weight of the slab, live loads, and any superimposed dead loads (**Tables 4-7**).

b) Thickness Selection: Select a preliminary slab thickness based on span-to-depth ratios specified by BNBC to control deflection (**Table 8**).

c) Moment and Shear Calculation: Calculate the bending moments and shear forces for the slab. For one-way slabs, use the formulas for simply supported or continuous slabs. For two-way slabs, use methods like the direct design method or equivalent frame method.

d) Flexural Reinforcement: Calculate the required reinforcement for flexure. Use the moment capacity equation  $M_u = \phi M_n$  where  $M_u$  is the factored moment,  $\phi$  is the strength reduction factor, and  $M_n$  is the nominal moment capacity. Ensure the reinforcement ratio is within allowable limits.

e) Shear Reinforcement: Check for shear strength. For slabs, shear reinforce-

ment is typically, not required unless the slab is very thick or carries high loads, as the concrete itself usually provides sufficient shear strength. Calculate the shear capacity of the slab and provide reinforcement if necessary (**Table 9**).

f) Deflection Check: Ensure that the slab meets deflection criteria. This can be done by verifying that the selected slab thickness and reinforcement comply with the serviceability requirements for deflection.

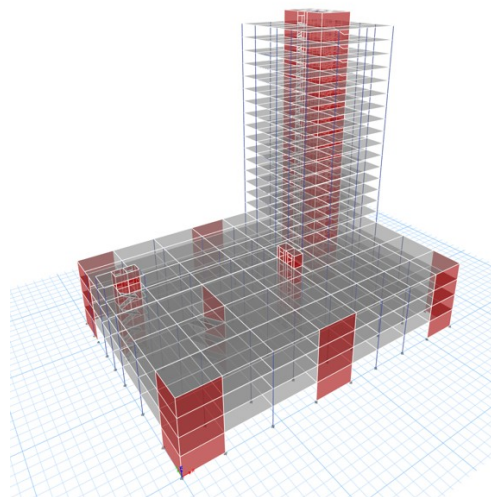
g) Detailing: Detail the reinforcement, ensuring proper spacing, cover, and anchorage. Follow BNBC guidelines for reinforcement detailing, including minimum and maximum reinforcement spacing, cover requirements, and lap splice lengths (**Table 13**).

h) Punching Shear Check: For flat slabs and slabs without beams, check for punching shear around columns. Calculate the punching shear stress and ensure it is within the limits specified by BNBC (**Table 1**).

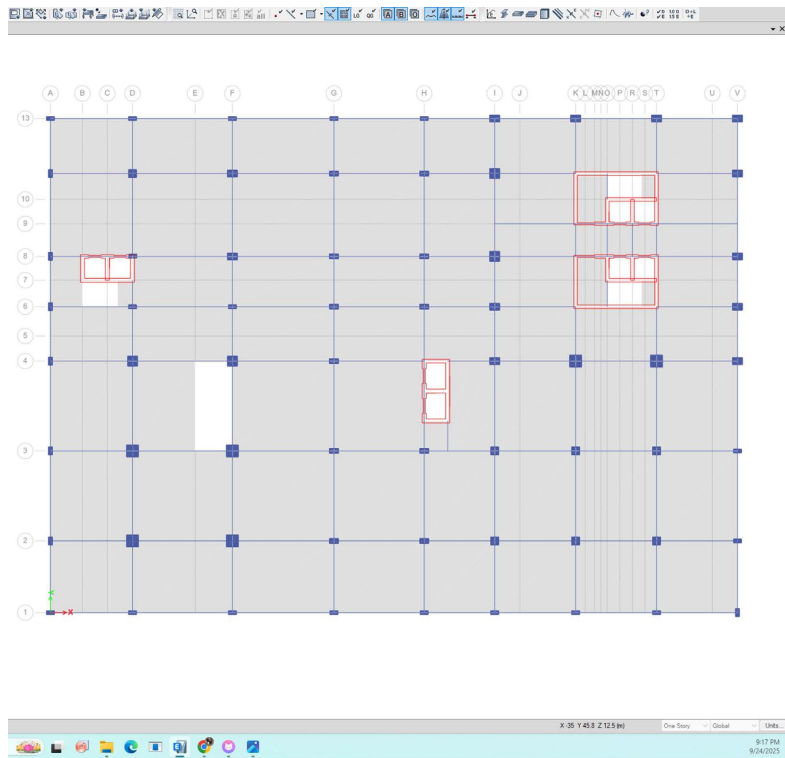
i) Serviceability Checks: Finally, check for serviceability criteria such as crack control and deflection limits to ensure the slab performs well under service conditions.

The structural plan of the first four stories, which are to be used as commercial, consists of a grid structure with regularly spaced columns and beams to hold the commercial spaces (**Figure 12**). The plan makes the distribution of the load uniform and has a lot of open space to be used commercially activities (**Figure 13**). The design combines permanent service equipment and partitions where required, making sure that they are in line with the load bearing elements to ensure structural integrity.

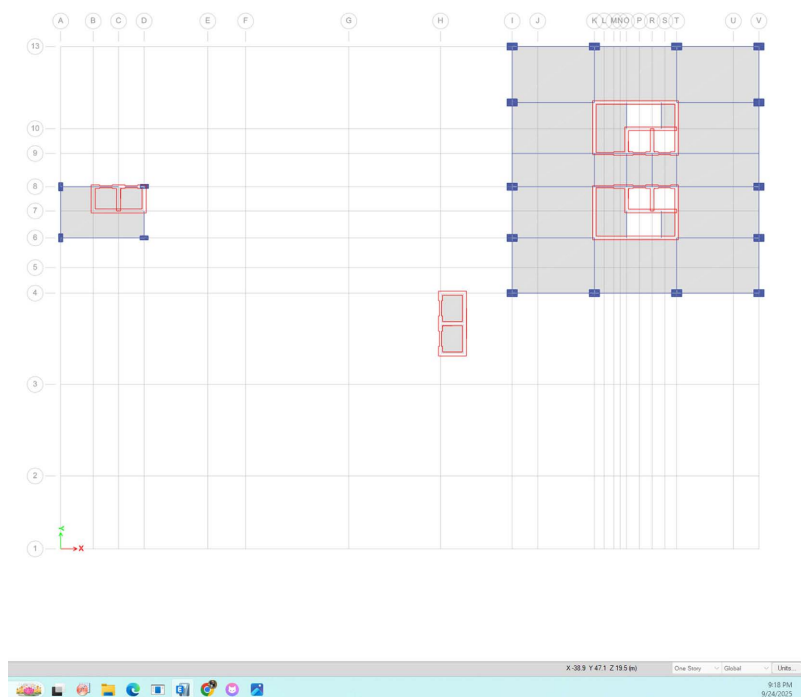
The structural layout changes to suit residential purposes starting with the fifth story. This plan is an extension of the grid system and can have more load-bearing walls and partition walls to hold the residential units (**Figure 14**). The plan guarantees the vertical and lateral load paths are in line with the lower commercial floors, which gives structural continuity in general and stability (**Figure 14**).



**Figure 12.** From first floor to top floor.



**Figure 13.** Commercial floor grid.



**Figure 14.** Residential floors grid.

The ETABS software was used to analyze and design the 21-story building in terms of its structure employed. ETABS is a powerful, easy to use and flexible

software that is popular in the building industry in structural analysis and design. It combines different calculation design codes, such as those of the Bangladesh National Building Code (BNBC).

## 5.2. Load Analysis

The Bangladesh National Building Code (BNBC) provides the following procedure of determining loads in building structures (Table 8). First, enumerate all the loads that are connected in each room, flat or office per floor and the whole building, including the equipment like lifts, water pumps and ventilation systems (Table 7). Use suitable diversity factors to cover the differences in the use of loads (Table 8). Based on these diversity factors, determine the maximum demand using the guidelines of BNBC on commonly used equipment. Design loads should be estimated in watts or kilowatts and track load growth with time. Compute current to select breakers, fuses and cables based on kVA and power factor.

Specific loads considerations are designing roofs to support loads of accumulated rainwater in case drainage systems are undersized or blocked, and calculating loads caused by hydrostatic and hydrodynamic effects on structures in flood-prone regions (Table 6 & Table 7). Loads that are miscellaneous should be followed as per BNBC procedures or consult an expert where not specified. Exceptions to load reduction are roof uniform dead and live loads, and the reduction is permitted on the basis of the tributary area (Table 5). Live loads greater than 4.80 kN/m<sup>2</sup> are not to be reduced, and there are particular restrictions on the reduction of loads in some occupancies such as public assembly areas and cyclone shelters (Table 6).

The site class definitions categorize the type of soil at a construction site based on its properties, significantly influencing the seismic design parameters. The BNBC 2020 references similar categories to those in ASCE 7-16 (Table 8). Below are the site class definitions and their corresponding parameters (Table 9). The seismic load calculations are based on the BNBC seismic zoning map of Bangladesh, which divides the country into four seismic zones with different spectral response acceleration parameters ( $S_s$  and  $S_1$ ). The design response spectrum is used to determine the maximum seismic response of structures at different periods (Table 13). This ensures that the structural design adheres to the seismic performance criteria specified by the BNBC, providing safety and resilience against earthquakes.

**Table 5.** Dead loads.

Component	Dead Load (kN/m <sup>2</sup> )	Details
Concrete Floor Slabs	5.0	Assuming 200 mm thickness
Partition Walls	2.4	120 mm thick brick walls
Fixed Equipment	0.5	HVAC systems, plumbing

**Table 6.** Live loads.

Area	Live Load (kN/m <sup>2</sup> )	Details
Residential Floors	2.0	Per Square Meter
Office Floors	2.5	Per Square Meter
Shops	4.0	Per Square Meter
Roof	1.5	Per Square Meter

**Table 7.** Special loads.

Load Type	Description	Load (kN/m <sup>2</sup> or kN/m)
Lift Load	Loads due to lift equipment and operation	Varies
Equipment Load	Loads due to heavy equipment	Varies
Light Shop	Loads due to light shop equipment	3.5
Heavy Shop	Loads due to heavy shop equipment	7.5
Storage Load	Loads due to storage materials	5.0
Vehicle Load	Loads due to vehicles in parking garages	2.5
Wind Load	Loads due to wind pressure	Varies
Seismic Load	Loads due to seismic activity	Varies

**Table 8.** Load table for ETABS according to BNBC 2020.

Load Case	Load Type	Occupancy /Category	Load Description	Value (kN/m <sup>2</sup> )
Dead Load	Self-Weight	Structural	--	--
Dead Load	Floor Finish	All	Floor finishes like tiles, marble	1.5
Dead Load	Partition Wall	All	Non-structural walls	1.0
Dead Load	Ceiling	All	Suspended ceilings	0.5
Dead Load	Roofing	Roof	Roofing materials	1.0
Live Load	Residential	Residential	Residential occupancy	2.0
Live Load	Office	Office	Office occupancy	2.5
Live Load	Classroom	Educational	Educational occupancy	3.0
Live Load	Corridor/Stairs	High Traffic	High foot traffic areas	4.0
Live Load	Storage	Storage	Storage areas	5.0
Live Load	Retail/Shop	Commercial	Retail spaces	4.0

**Continued**

Live Load	Assembly Areas	Assembly	Assembly spaces	4.5
Live Load	Industrial	Industrial	Machinery and equipment	7.5
Live Load	Roof Live	Roof	Typical roof live load	1.5
Live Load	Roof Garden	Roof	Landscaping and gardens	3.0
Special Load	Lift Load	All	Lift equipment and operation	Varies
Special Load	Equipment Load	All	Heavy equipment	Varies
Special Load	Light Shop	Commercial	Light shop equipment	3.5
Special Load	Heavy Shop	Industrial	Heavy shop equipment	7.5
Special Load	Storage Load	Storage	Storage materials	5.0
Special Load	Vehicle Load	Parking	Parking garages	2.5
Special Load	Wind Load	All	Wind pressure	Varies
Special Load	Seismic Load	All	Seismic activity	Varies

**Table 9.** Site class definitions (Earthquake).

Site Class	Shear Wave Velocity $V_s$ (ft/s)	Standard Penetration Resistance N (blows/ft)	Undrained Shear Strength $S_u$ (psf)
A. Hard rock	>5000	NA	NA
B. Rock	2500 to 5000	NA	NA
C. Very dense soil and soft rock	1200 to 2500	>50	>2000
D. Stiff soil	600 to 1200	15 to 50	1000 to 2000
E. Soft clay soil	<600	<15	<1000
F. Soils requiring site response analysis	BNBC Section 21.1	BNBC Section 21.1	BNBC Section 21.1

**5.3. Material Properties and Parameters**

Materials and their properties are very important in the structural integrity and performance of the building. The material properties and parameters applied in the ETABS model were specified and determined based on the specifications and guidelines of the BNBC. The structural performance requirements of the 21-story building are established to provide safety, serviceability, and durability of the building under different loading conditions as per the Bangladesh National Building Code (BNBC) (Table 10).

The material properties defined for the building include M25 grade concrete and

HYSD415 steel reinforcement (**Table 10**). For M25 concrete, the specified compressive strength is 25 MPa with a modulus of elasticity of 25,000 MPa. HYSD415 steel reinforcement is defined with a minimum yield strength of 415 MPa and a tensile strength up to 533.5 MPa. This material accurate lateral load application for seismic analysis (**Table 10**). These load definitions cover all essential load types acting on the structure, ensuring comprehensive analysis and design.

**Table 10.** Material properties and parameters.

Material	Property	Value
Concrete (M25)	Grade	M25 ( $f_c' = 25$ MPa)
	Density	24 kN/m <sup>3</sup>
	Young's Modulus ( $E$ )	25,000 MPa
	Poisson's Ratio ( $\nu$ )	0.2
Steel	Grade	Fe500 ( $f_y = 500$ MPa)
	Density	78.5 kN/m <sup>3</sup>
	Young's Modulus ( $E$ )	200,000 MPa
	Poisson's Ratio ( $\nu$ )	0.3
Reinforcement Bars	Yield Strength ( $f_y$ )	500 MPa
	Ultimate Strength ( $f_u$ )	600 MPa
Other Parameters	Live Load Reduction Factor	As per BNBC
	Damping Ratio	5%
	Seismic Zone Factors	As per BNBC
	Site Class	As per BNBC

#### 5.4. Story Drift

The story drift results for seismic effects along the X direction show that all levels of the structure are within the allowable drift limits as per BNBC 2020. The maximum calculated story drift ( $\Delta x$ ) at each level is compared against the allowable drift ( $\Delta_a$ ), **Table 11** which is 0.06 for most stories and 0.08 for the lower levels. All drift values fall within the permissible limits, ensuring the building's compliance with the code requirements for seismic safety and structural stability.

**Table 11.** For seismic effect along X direction.

Level ID	Floor Height Below the X $h_{ix}$ (m)	Elastic Displacement = Diaphragm Center of Mass Disp (For EQx)		Story Drift Analysis $\Delta = \delta_x - \delta_{x-1}$	Allowable Drift $\Delta_a$	Condition
		$\delta_{se}$ (or $U_x$ ) (m)	$\delta_x = \frac{C_d \delta_{se}}{1}$			
Story21	3	0.096341	0.431705	0.02864	0.06	Without Limit
Story20	3	0.080613	0.403065	0.028495	0.06	Without Limit
Story19	3	0.074916	0.374570	0.029165	0.06	Without Limit

## Continued

Story18	3	0.069081	0.345405	0.029605	0.06	Without Limit
Story17	3	0.063160	0.315800	0.030005	0.06	Without Limit
Story16	3	0.057159	0.285795	0.030285	0.06	Without Limit
Story15	3	0.051102	0.255510	0.030375	0.06	Without Limit
Story14	3	0.045027	0.225135	0.030250	0.06	Without Limit
Story13	3	0.038977	0.194885	0.029485	0.06	Without Limit
Story12	3	0.033008	0.165040	0.029120	0.06	Without Limit
Story11	3	0.027184	0.135920	0.028040	0.06	Without Limit
Story10	3	0.021576	0.107880	0.026645	0.06	Without Limit
Story09	3	0.016265	0.081325	0.024620	0.06	Without Limit
Story08	3	0.011341	0.056705	0.022175	0.06	Without Limit
Story07	3	0.006906	0.034530	0.019250	0.06	Without Limit
Story06	3	0.003056	0.015280	0.015280	0.06	Without Limit
Story05	3	0.000000	0.000000	0.004425	0.06	Without Limit
Story04	4	-0.000850	-0.004425	0.001565	0.08	Without Limit
Story03	4	-0.001197	-0.005985	-0.000860	0.08	Without Limit
Story02	4	-0.001025	-0.005125	-0.002430	0.08	Without Limit
Story01	4.5	-0.000539	-0.002695			Without Limit

The story drift results for seismic effects along the Y direction indicate that all levels of the structure are within the allowable drift limits as specified by BNBC 2020. The maximum story drift ( $\Delta y$ ) at each level is compared with the allowable drift ( $\Delta a$ ), **Table 12** which is 0.06 for most stories and 0.08 for the lower levels. All calculated drift values are within the permissible limits, ensuring the building's compliance with seismic safety and structural stability requirements.

**Table 12.** For seismic effect along Y direction.

Level ID	Floor Height Below the X $h_{sx}$ (m)	Elastic Displacement = Diaphragm Center of Mass Disp (For EQx)		Story Drift Analysis $\Delta = \delta_y - \delta_{y-1}$	Allowable Drift $\Delta_a$	Condition
		$\delta_{ye}$ (or $U_y$ ) (m)	$\delta_y = \frac{C_d \delta_{ye}}{1}$			
Story21	3	0.076800	0.384000	0.020550	0.06	Within Limit
Story20	3	0.072789	0.363945	0.020300	0.06	Within Limit
Story19	3	0.068729	0.343645	0.021555	0.06	Within Limit
Story18	3	0.064418	0.322090	0.022755	0.06	Within Limit
Story17	3	0.059867	0.299335	0.024015	0.06	Within Limit
Story16	3	0.055064	0.275320	0.025210	0.06	Within Limit
Story15	3	0.050022	0.250110	0.026265	0.06	Within Limit

## Continued

Story14	3	0.044769	0.223845	0.027155	0.06	Within Limit
Story13	3	0.039338	0.196690	0.027685	0.06	Within Limit
Story12	3	0.033801	0.169005	0.027910	0.06	Within Limit
Story11	3	0.028219	0.141095	0.027715	0.06	Within Limit
Story10	3	0.022676	0.113380	0.027030	0.06	Within Limit
Story09	3	0.017270	0.086350	0.025725	0.06	Within Limit
Story08	3	0.012125	0.060625	0.023685	0.06	Within Limit
Story07	3	0.007388	0.036940	0.020720	0.06	Within Limit
Story06	3	0.003244	0.016220	0.016220	0.06	Within Limit
Story05	3	0.000000	0.000000	0.002730	0.06	Within Limit
Story04	4	-0.000546	-0.002730	0.000880	0.08	Within Limit
Story03	4	-0.000722	-0.003610	-0.000680	0.08	Within Limit
Story02	4	-0.000586	-0.002930	-0.001440	0.08	Within Limit
Story01	4.5	-0.000298	-0.001490			Within Limit

## 6. Design Results (Vibration Periods & Mode Shapes)

The dynamic analysis of the building indicates the vibration of the building during an earthquake. The first mode is the most significant vibration, which occurs with the period of approximately 1.301 seconds (Table 13). This implies that it vibrates once in slightly more than one second. The frequency for this mode is 0.768 cycles per second. The higher the mode the shorter the period and the higher the frequency (Table 13). This implies that the building shakes more quickly in these higher modes. As an example, the second mode has a period of 1.252 seconds and the third mode has a period of 0.91 seconds (Table 13). The significance of these results is that they will enable us to know how the building will move in case of an earthquake. With the knowledge of the vibration periods and frequencies, engineers will be able to design the building in a way that it will be able to resist seismic forces more effectively and minimize the chances of damage (Table 13). The analysis assists in making the building safe and effective in case of an earthquake.

**Table 13.** Modal periods and frequencies.

Case	Mode	Period	Frequency	CircFreq	Eigenvalue
		sec	Cyc/sec	Rad/sec	Rad <sup>2</sup> /sec <sup>2</sup>
ModalH	1	1.301	0.768	4.8278	23.3077
ModalH	2	1.252	0.799	5.0186	25.1865
ModalH	3	0.91	1.099	6.9081	47.7215
ModalH	4	0.31	3.224	20.2601	410.4703
ModalH	5	0.271	3.696	23.2253	539.4158

## Continued

ModalH	6	0.268	3.735	23.4663	550.6679
ModalH	7	0.26	3.851	24.1942	585.3608
ModalH	8	0.166	6.016	37.7979	1425.6803
ModalH	9	0.144	6.959	43.7227	1911.6704
ModalH	10	0.139	73174	45.0783	2032.0521
ModalH	11	0.132	7.595	47.718	3060.2062
ModalH	12	0.114	8.804	55.3191	3247.8102
ModalH	13	0.11	9.07	56.9896	3247.8102
ModalH	14	0.094	10.593	66.5547	4429.5226
ModalH	15	0.092	10.86	68.2363	4656.1955
ModalH	16	0.086	11.63	73.0757	5340.0569
ModalH	17	0.074	13.439	84.4424	7130.514
ModalH	18	0.071	14.123	88.74	7874.792
ModalH	19	0.07	14.252	89.5487	8018.9723
ModalH	20	0.068	14.667	92.1544	8492.4248
ModalH	21	0.062	16.072	100.9814	10197.2333
ModalH	22	0.06	16.663	104.6985	10961.7668
ModalH	23	0.054	18.466	116.0282	13462.5526
ModalH	24	0.054	18.685	117.3994	13782.618
ModalH	25	0.051	19.775	124.2479	15437.5438
ModalH	26	0.049	20.276	127.3995	16230.6397
ModalH	27	0.048	20.829	130.8753	17128.3318
ModalH	28	0.046	21.661	136.0998	18523.1684
ModalH	29	0.045	22.272	22.272	19582.293
ModalH	30	0.041	24.235	152.2733	23187.169
ModalH	31	0.04	24.807	155.869	24295.1341
ModalH	32	0.04	25.212	158.4118	25094.2948
ModalH	33	0.038	26.049	163.6699	26787.8265
ModalH	34	0.037	26.711	167.8323	28167.6684
ModalH	35	0.034	29.201	183.4731	33662.3624
ModalH	36	0.034	29.809	187.295	35079.429
ModalH	37	0.033	30.374	190.8454	36421.9622
ModalH	38	0.032	31.583	198.4417	39379.0993
ModalH	39	0.03	33.49	210.4211	44277.0232
ModalH	40	0.028	35.263	221.5655	49091.2681
ModalH	41	0.028	36.183	227.3451	51685.8055
ModalH	42	0.027	37.04	232.7277	54162.1925

**Continued**

ModalH	43	0.025	39.857	250.4301	62715.2126
ModalH	44	0.025	40.307	253.2592	64140.2099
ModalH	45	0.025	40.442	254.1058	64569.7642
ModalH	46	0.023	43.193	271.3893	73652.1523
ModalH	47	0.023	44.105	277.1199	76795.4362
ModalH	48	0.023	44.262	278.1055	77342.6839
ModalH	49	0.022	45.433	285.4611	81488.0234
ModalH	50	0.021	46.887	294.5967	86787.2126
ModalH	51	0.021	47.544	298.7253	89236.7979
ModalH	52	0.021	47.953	301.2953	90778.8493
ModalH	53	0.02	50.23	315.606	99607.1474
ModalH	54	0.02	51.24	321.9497	103651.6293
ModalH	55	0.019	52.292	328.5625	107953.3074
ModalH	56	0.019	53.799	338.026	114261.6086
ModalH	57	0.019	53.811	338.1062	114315.7835
ModalH	58	0.018	54.805	344.347	118574.8309
ModalH	59	0.018	55.756	350.3259	122728.2054
ModalH	60	0.017	57.457	361.0148	130331.6931

**7. Discussion**

The 21-story multifunctional building proposed in Dhaka is a modern solution to the development of the city, as it is a solution to the architectural and structural problems of high-rise construction in a densely populated city. The combination of commercial and residential areas in one building is a sign of the current trends in urban planning to make the best use of the land, particularly in such cities as Dhaka, where space is a luxury [13]. The paper identifies some of the major aspects that make the building viable in general, including the architectural design and the structural analysis with the help of the advanced software such as ETABS.

The design of the building employs vertical zoning to divide the commercial and residential activities so that each area has its own space and the interference between the two areas is minimal. This segregation enables effective circulation and utility systems, which is essential in smooth running of mixed-use buildings. Also, the architecture emphasis on sustainability, including the employment of energy-efficient materials, renewable energy, and the maximization of natural light, is consistent with the worldwide trend toward greener and more sustainable architecture. The emphasis on seismic resilience, which is a critical factor considering that Dhaka is located in a seismic zone, will make the building comply with the structural safety standards and be effective in case of an earthquake [14].

Structural analysis of the building using ETABS software gives useful information on how the building will perform under various loading conditions [15].

The major results of the analysis such as the displacement patterns, inter-story drifts and reinforcement details show that the building can resist the high loads and environmental forces that Dhaka is likely to experience including wind and seismic forces. The robustness of the design is further increased by the detailed analysis of the load combinations, material properties and soil conditions, which makes the design efficient and durable [7].

Although the outcomes of the structural analysis and architectural design are encouraging, there are a number of aspects that should be investigated in future projects. Among them is the incorporation of high-tech sustainable solutions such as smart building systems, which may further increase energy efficiency, lower operational expenses, and the overall experience of building occupants [16]. Also, with the growing urbanization in Dhaka, it is necessary to explore the adaptive reuse approach in future projects, so that the buildings can be adaptable to the changing needs in the future. More advanced seismic resilience methods could also be studied in the future, given the growing number of seismic events in the area and the introduction of new technologies such as base isolators or energy dissipative devices to reduce the risks of earthquakes even further.

Regarding the architectural aspects, additional focus on the green roofs, rain-water harvesting systems, and larger landscaping elements may help to make the building more sustainable [17]. These characteristics do not only enhance the environmental performance of the building but also the quality of life of the occupants of the building by offering green spaces within an urban setting. Finally, the integration of the building into a smart city, in which the systems of the building are linked to a larger urban infrastructure network, may also optimize the use of resources, so that the building becomes not only a sustainable object, but also a component of a smarter, more connected city [18].

## 8. Conclusions

The structural analysis and design of the 21-story multifunctional building that is proposed to be constructed in Dhaka shows that it can become a new standard of urban development in the rapidly growing cities. The building combines commercial and residential areas in one building, which makes the best use of the land and provides a dynamic and sustainable environment that responds to the issues of urbanization. The project is in line with the Bangladesh National Building Code (BNBC 2020) [19] and best practices in architectural design, structural engineering, and sustainability, which will make the building last long and offer a safe and comfortable environment to its occupants.

The structural analysis, which is carried out with the help of ETABS, confirms the capacity of the building to resist seismic forces, wind loads, and other environmental stresses, which proves its resilience and safety once again [20]. The project is also environmentally sustainable, as the energy-efficient materials and systems and the emphasis on green building practices are used [6] [21]. As technology and construction methods continue to evolve, the building can be used as

a prototype of future high-rise buildings in Dhaka and other cities with such urban settings.

To sum up, the project does not only solve the existing problems of urban development in Dhaka but also opens the door to future innovations in building design, sustainability, and resilience. It establishes a standard in the combination of mixed-use areas, structural security, and environmental awareness, which can be of great use to architects, engineers, and urban planners.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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