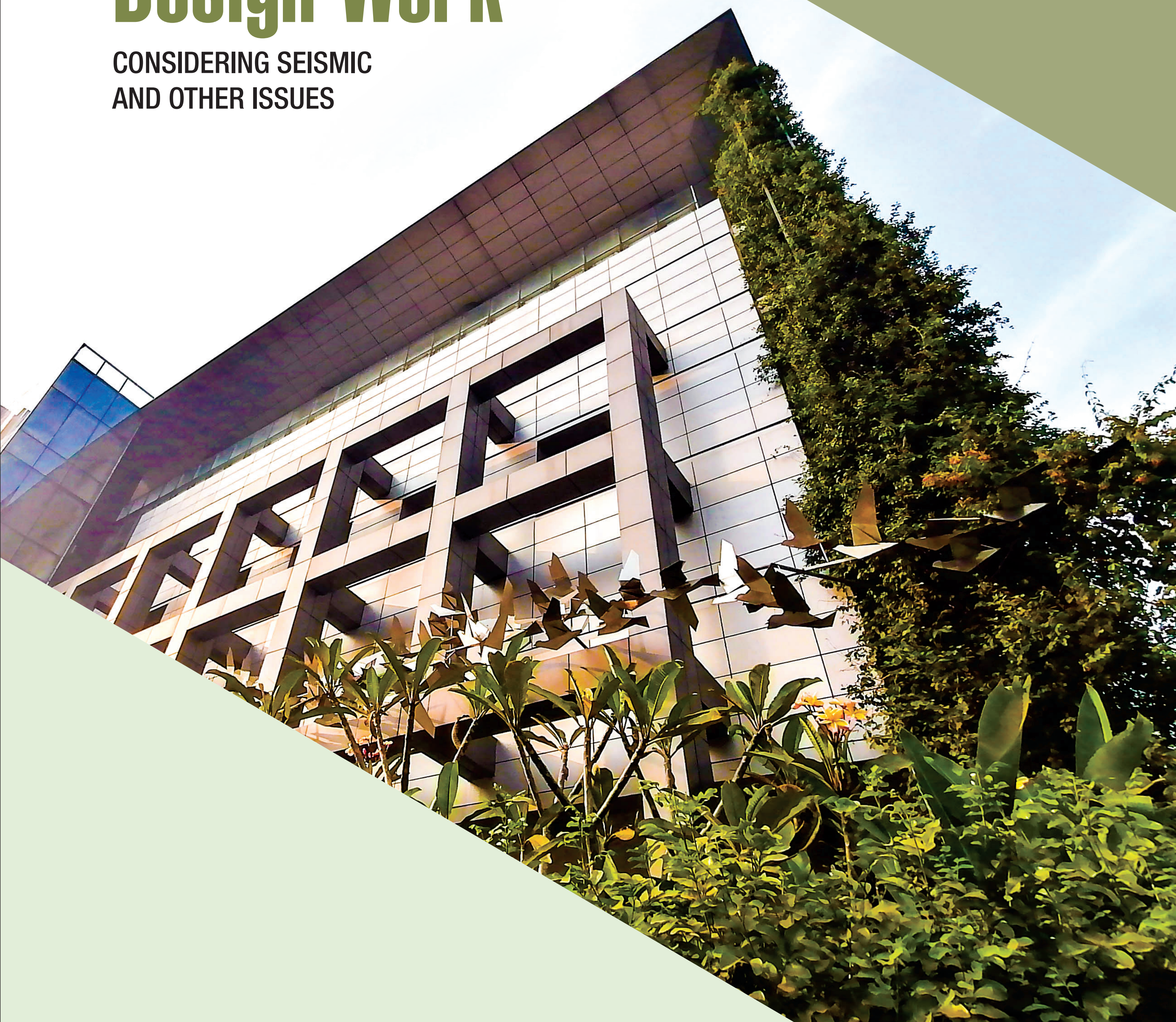
HANDBOOK FOR

Architectural Design Work

CONSIDERING SEISMIC AND OTHER ISSUES



Public Works Department

Bangladesh

HANDBOOK for Architectural Design Work

Considering Seismic and Other Issues

Prepared under the Project

Promoting Building Safety for Disaster Risk Reduction

in The People's Republic of Bangladesh (BSPP)

A Technical Cooperation Project between PWD and JICA

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Foreword from Chief Engineer

Bangladesh is situated in one of the most tectonically active regions of the world where three tectonic plates, namely: the Indian plate, the Eurasian plate and the Burmese plate, met. Over the last two hundred and fifty years, Bangladesh has experienced eight major earthquakes of a magnitude over 7.0 on the Richter scale. Due to its proximity to the plate boundaries, active faults and impact of past earthquakes in and around Bangladesh, the probability of occurrence of strong earthquakes is considered high.

The risks of loss of life and damage to properties by an earthquake are almost entirely attributed to man-made structures. The process of rapid urbanization and expansion of several cities, especially Dhaka, Chattogram and Sylhet, during the last 30 years, with most of the buildings being poorly designed and constructed, has been a big concern.

The first edition of the Bangladesh National Building Code (BNBC) was published in 1993 and was enacted in 2006. PWD (Public Works Department) has been following the Code of the American Concrete Institute (ACI) to design reinforced concrete buildings. But its strict adherence to the latest codes, especially the seismic design provisions, have come into effect very recently. As a result, many existing buildings do not meet the seismic requirements of the current BNBC 2020. This necessitates retrofitting of the vulnerable buildings.

PWD has been facing difficulties in taking up projects to retrofit existing vulnerable public buildings due to a lack of technical know-how. To overcome the deficiencies, PWD had taken up two projects with technical cooperation from JICA titled, 1. "Project for Capacity Development on Natural Disaster Resistant Techniques of Construction and Retrofitting for Public Buildings in Bangladesh (CNCRP, 2013-2017)", and 2. "Project on Promoting Building Safety for Disaster Risk Reduction (BSPP, 2017-2021)". This has significantly enhanced the capacity of the engineers of PWD for seismic assessment and retrofitting of existing vulnerable buildings.

One of the important outputs of those two projects were the following eight manuals and guidebooks:

1. Manual for Seismic Evaluation of Existing Reinforced Concrete Buildings (First Edition: CNCRP, 2015. Second Edition: BSPP, 2021).
2. Manual for Seismic Retrofit Design of Existing Reinforced Concrete Buildings (First Edition: CNCRP, 2015. Second Edition: BSPP, 2021).
3. Manual for Retrofit Construction and Supervision of Reinforced Concrete Buildings (First Edition: CNCRP, 2015. Second Edition: BSPP, 2021).

4. Manual for Seismic Design of Reinforced Concrete Buildings (First Edition: CNCRP, 2015. Second Edition: BSPP, 2021).
5. Manual for Vulnerability Assessment and Damage Prediction of Reinforced Concrete Buildings against Non-Seismic Hazards (First Edition: CNCRP, 2015).
6. Fire Safety Design Guidebook (First Edition: BSPP, 2021).
7. Handbook for Architectural Design Work Considering Seismic and Other Issues (First Edition: BSPP, 2021).
8. Handbook of Geotechnical Engineering: Assessment of Bearing Capacity, Liquefaction Potential and Slope Stability (First Edition: BSPP, 2021).

It is evident from the above list that the manuals or guidebooks covered a range of technical issues and subjects. Apart from assessment and retrofitting of buildings, they also covered design of new buildings, construction & quality control, fire safety design, geotechnical issues for foundation design, and architectural design works taking into consideration seismic and other safety issues. All of these manuals/ guidebooks have been helpful to the engineers and architects in their design and construction work and making safe and disaster-resilient buildings, particularly against earthquakes and different natural and man-made hazards.

These manuals and guidebooks will not only help the engineers of PWD and architects of the Department of Architecture (DoA) but also the professionals of other organizations, including those in the private sector. These are going to be useful in designing and constructing new buildings, assessing and retrofitting existing vulnerable buildings, ensuring safety and resilience against disasters related to earthquakes and other hazards.

I deeply appreciate the members of the Editorial Advisory Board consisting of respected members from Japan and Bangladesh for their valuable contribution to the eight manuals prepared under CNCRP and BSPP. I also thank both Japanese and Bangladeshi team members of CNCRP and BSPP for their assistance in writing the manuals and guidebooks.

Finally, I want to thank the Government of Japan, JICA and the Government of Bangladesh for their whole-hearted support and cooperation throughout the project phases.

(Mohammad Shamim Akhter)
Chief Engineer, PWD
November, 2021

Foreword from Chief Architect

The public buildings in Bangladesh are designed and constructed mainly by the two representing governmental organizations, DOA (Department of Architecture) is responsible for providing Architectural designs and PWD (Public Works Department) is responsible for providing structural, electrical, mechanical and plumbing designs as well as construction management.

Established in 1981, DOA is the only comprehensive Architectural design office of the Government of Bangladesh. This department is responsible for providing Architectural designs, in the formulation of program of any project, for providing master plans of various projects & detailed working drawings and supervising the site during the construction period of any project. PWD (Public Works Department) is responsible for providing structural, electrical and related support services for various development projects of government and semi-governmental organizations. DOA's scope of work is not limited to general construction plans but also includes rules and regulations regarding land use and human settlement and providing advisory services to the government regarding effective use of land and building code.

On the other hand, PWD has a long history of providing structural design, building service design and construction management for public buildings as collaborator PWD is working in close collaboration with DOA, especially with abundant experience and knowledge on seismic design and structural design issues of buildings.

Intensive training courses organized by BSPP for Architects and Engineers have enriched their knowledge on various technical aspects and created intelligent experts within these bodies. I hope, this Handbook will help the Architects of DOA to acquire and apply the knowledge and ideas for designing disaster resilient public buildings.

I wish to thank both the Japanese and Bangladeshi members of BSPP project, including the Architects of DOA and the Engineers of PWD, for undertaking the initiative to prepare the Handbook.

Finally, I want to take this opportunity to thank JICA and GOB for their continuous support to the BSPP project.

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Preface

In Bangladesh, architectural designs and construction works for the public buildings have been organized by the two representing government organizations, Department of Architecture (DOA) which is responsible for architectural design, and the Public Works Department (PWD) which provides structural, electrical, mechanical and plumbing design, and construction management.

The design and construction of buildings by these departments have been carried out in compliance with the Bangladesh National Building Code (BNBC).

One of the purposes of BNBC 2020 is "to establish minimum standards for design, construction, quality of materials, use and occupancy, location and maintenance of all buildings within Bangladesh in order to safeguard, within achievable limits, life, limb, health, property and public welfare."

To meet the objective of design, construction and maintenance of buildings that will be functional, safe, sustainable and aesthetically pleasing, a well-coordinated and concerted team effort by the architects, structural engineers, civil engineers, building services engineers are essential.

It is essential for the stakeholders of building construction to develop an appropriate design through discussions and communications among the parties concerned, based on the knowledge and experience of safety issues by the respective parties. By acquiring knowledge about the structure, electrical, mechanical, plumbing, and fire protection, will be enable the architect to develop a building design which will be architecturally beautiful and structurally safe against disasters caused by natural or man-made hazards.

Based on these considerations, this handbook has been developed to provide useful and important ideas for designing disaster-resilient buildings that could be useful for the architects, structural engineers, and building service engineers.

This handbook has five Chapters and an Annexure.

In the first chapter, the purpose and outline of this handbook has been presented.

In Chapter 2, the points to keep in mind at each stage and the points and timing that should be discussed among the parties concerned as mentioned has been discussed. As mentioned above, these are described in accordance with the flow of the design activities divided into three stages (Stage I: Initial Stage / Basic Design, Stage II: Intermediate Stage / Preliminary Design, and Stage III: Finalizing Stage / Detail Design). In addition, the classification of buildings in BNBC 2020 is presented in also presented in this Chapter, while its reference data for design is provided in the Annexure.

In Chapters 3 to Chapter 5, discussed the points to be considered along with relevant solutions, and examples mainly focusing to ensure safety of the buildings against disasters. Accordingly, the safety aspects in the fields of structural design, building service design consisting of electrical, mechanical, plumbing, and fire protection design issues has been provided.

We sincerely hope that this Handbook will help the architects, structural engineers, electrical, mechanical and plumbing engineers in their design practice and to build safer and more comfortable buildings in Bangladesh.

Ms. Fahmida Sultana: Team Leader, Superintending Architect, Department of Architecture
Ms. Izumi Kasai: Architect, JICA Expert of BSPP

Acknowledgement

Special thanks are due to the members of the steering group for this Handbook for their expert guidance and advice throughout the planning and development stages.

A Note of appreciation also goes to all the people associated with the process, i.e., the reviewers and advisers who contributed to producing the Chapters of this Handbook.

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CHAPTER 1 General

1-1 Introduction - Design for the Safer Buildings

This handbook is published as a part of the "Project on Promoting Building Safety for Disaster Risk Reduction in The People's Republic of Bangladesh (herein after "BSPP")". The project of BSPP aims to "Enhance capacity for promoting seismic safety in public buildings in urban areas of Bangladesh".

One of the key objectives of the BSPP was to provide capacity development support for constructing safer public buildings in different stages of architectural design. The need for capacity building support was identified at the initial phase of architectural design, as well as in its different stages to the final output Therefore, the handbook has focus on architectural design, taking disaster resilience into consideration. An Architect sometimes gets carried away by artistic forms and geometry and doesn't take into consideration such serious issues as seismic, structural, electrical, mechanical, plumbing, and fire safety. That is why, during the time of providing working drawings, plans to specify the safety measures to be adopted. As a result, the Architects need to do repetitive work, which can sometimes make them frustrated. Therefore, this handbook with an overview of basic information required by the Architects, was prepared to help them execute their architectural designs by taking disaster resilience and safety concepts into consideration right at the start of the process.

1-2 Importance of Communication for Design

A building design starts with an Architect who provides spatial design. After that, comes the role of a structural Engineer who provides an effective structure to embody it. To make the building functional, a building service Engineer designs the services and equipment required for the purpose. Therefore, in depth discussions with all the designers involved in the design process is necessary for the architect to finalize the trajectory among themselves.

However, if communication between the parties concerned is insufficient, problems may occur not only in the design phase but also during the construction process.

For this reason, general descriptions related to design are left to the main textbooks that have been distributed among all concerned people. Instead, items to be confirmed among related parties are listed along the stream of architectural design work.

1-3 How to use this Handbook

Architects need to manage and coordinate not only the architectural design issues, but also undertake collaborative work with other design parties. Therefore, it is indispensable for an Architect to grasp the entire design work as a series of action points. In this context, Chapter 2 of the handbook shows the work procedures in line with their three main design stages. In addition, the items and the timings are indicated that should be discussed with the concerned parties. Thereby, not only the Architect but also the parties involved in the project will be able to identify what type of intervention is needed when and at which stage of the architectural design.

Chapter 3 provides some essential knowledge and information to address the problems related to structural and seismic risks that is deemed most critical for an Architect. The chapter also gives suggestions for coordination between structural and architectural design units to satisfy the safety recommendations regarding dynamic building response or behavior during earthquakes.

Chapter 4 prepares the adjustment items with the building service Engineer necessary to realize the architectural design for the Architect. Basic information on electrical, mechanical and plumbing equipment for architectural design are provided in this chapter.

And Chapter 5 presents the basic items on fire safety that are required to be considered in architectural design process. Regarding fire safety, BSPP has separately prepared a detailed fire safety design guidebook which could also be used by the engineers and architects.

Finally, this handbook can be helpful for the Architects and building service Engineers to safely embody the shape and spatial composition of a plan with adequate safety measures.

CHAPTER 2 Basic Consideration for Architectural Design

2-1 Introduction

Architectural designs are initiated by the spatial data of the physical space and the requirements of the client. Later on, the idea becomes more functional with the input of Structural and Building Service Designs, including Electrical, Plumbing and Fire safety considerations.

Chapter 2 mainly describes the workflow an Architect needs to follow at different stages of the design process. This chapter will also provide details about the roles of the concerned people with whom effective communication and coordination need to be established.

2-2 Responsibility and Liability of Design Works

Architectural design work guides the other sectors on their engineering design. A proper engineering design that complements the architectural work will ensure an appropriate functional space. Simultaneously, an architectural design also needs to complement the engineering design to ensure structural safety and backup services.

The main items of design work and responsible organizations are shown in the figure 2-1.

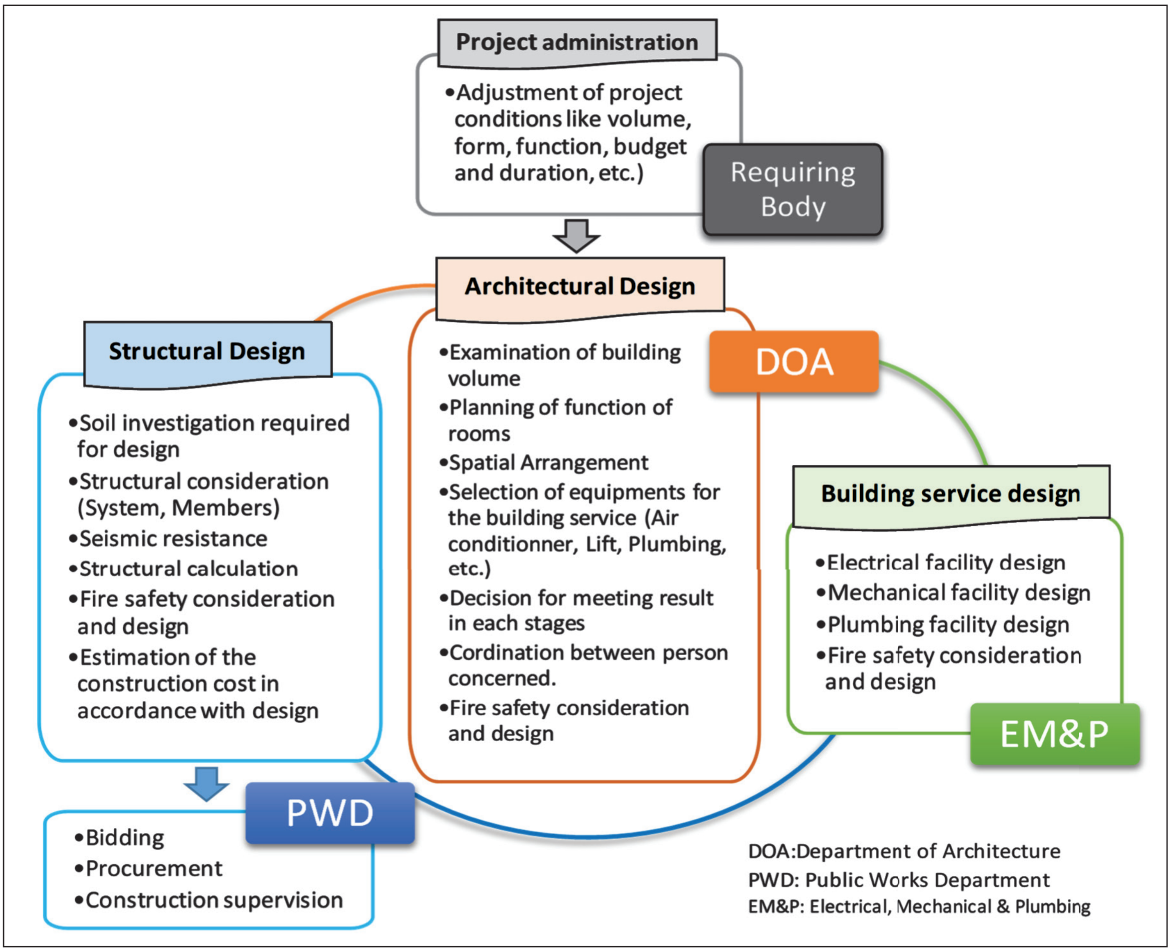


Figure 2-1 Responsibility and Liability Diagram

An Architect's work is complex because she/he normally stays involved from the beginning of a project to its end. He/she has to present the design and negotiate the requirements and allocated space with the requiring body and at these stages the involvement is nil for the other design engineers because of their specific job nature.

Later, as noted before, it sometimes becomes difficult to accommodate the engineering requirements in the preliminary architectural drawing. It is therefore, necessary to go through it and conduct a detailed examination by each specialized Engineers to confirm that the design of the structure can withstand various loads safely. The same is required with regard to the facilities to be provided in a building. Through this Handbook, it's the intension to help an Architects to refine their work from the initial steps.

2-3 Description of Various Design Works

In this section, the workflow of architectural design has been detailed out in relationship with the stages of design.

In those stages of design, the procedural steps that an architect needs to follow in consultation with other offices/persons have been pointed out.

- In the **Initial Stage**, the Architect at first makes sole communication with the requiring body. He/she visits the site, studies the requirements and learn about the site-specific rules and regulations provided by the requiring body The Architect then checks if the information received are sufficient or not. He/she also assesses the proposed site of construction and based on the complexity of the site makes a decision if other relevant technical persons are needed to be involved or not.

- In the **Intermediate Stage**, the design Architect starts the Preliminary design. He/she envisions the form of the structure, visualizes it, and discusses with the responsible officer of the controlling organization. He/she takes structure and EM&P related opinion and with these makes a preliminary drawing that reflects the requirements of the concerning parties to a logical extent. He/she then takes approval of the design from the requiring body and places the approved papers to the concerned office for preparing estimation and other project related issues.

- In the **Finalizing Stage**, detailed design for construction will be prepared by incorporating the calculation and detailed feedback from Structure design engineers and EM&P divisions as a general practice. Necessary adjustment to the design will be made after consultation with all concerned people at this stage. The Architect will now summarize the design reflecting the received feedback provided and deliver the drawing to the concerned party to proceed with construction.

As noted above, the Architects will lead the discussions among different designers to produce a synchronized version of the design and obtain approval of the owner or the organization. Thus, this kind of efficient management work should act like a driving force for an appropriate design.

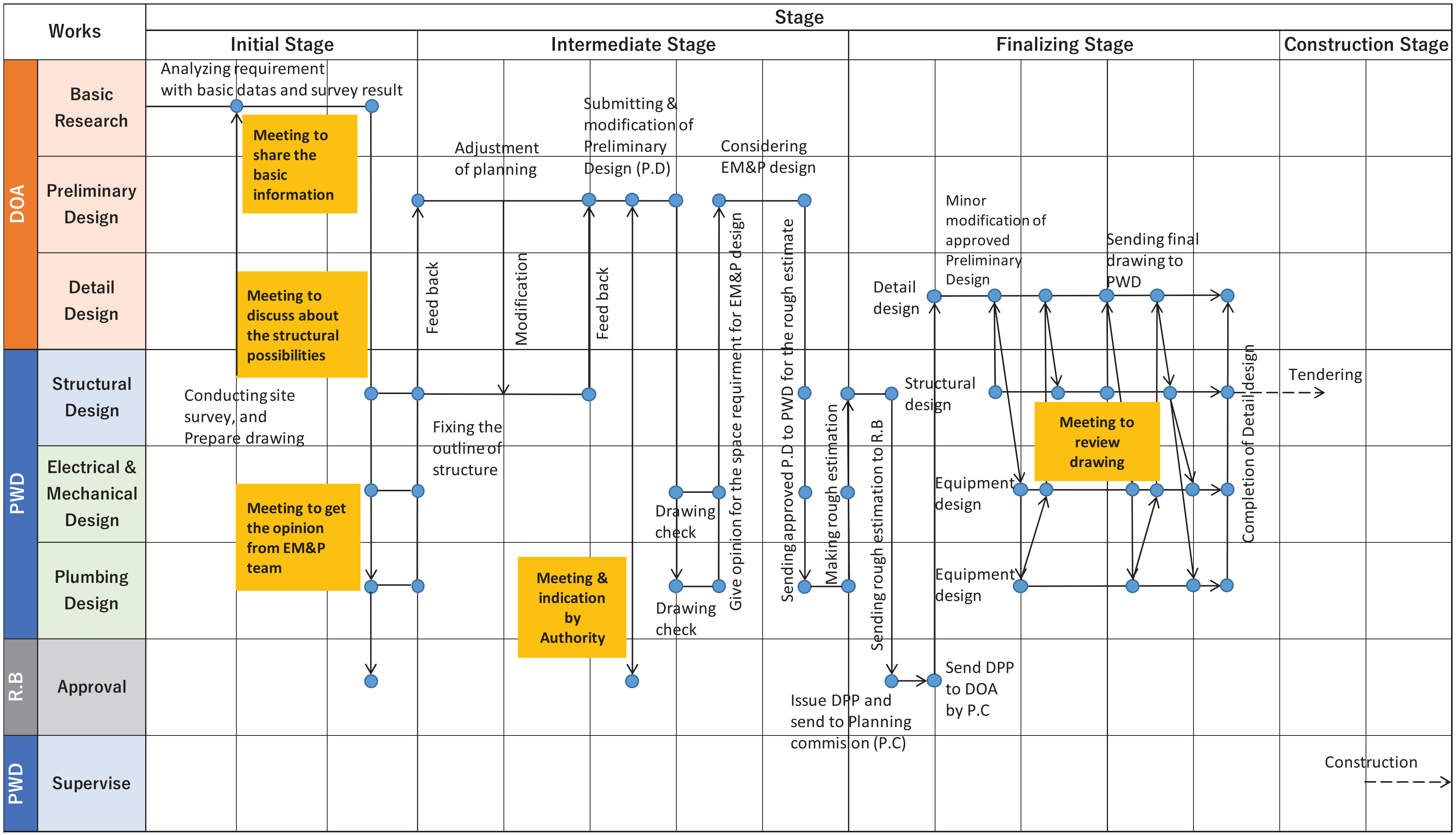


Figure 2-2 Time Schedule of Building Design Works

2-4 Work Flow Process of Design Works

As previously mentioned, the design and construction of public buildings in Bangladesh are carried out by DOA and PWD. DOA is responsible for architectural designs, PWD is responsible for structural & building service design (i.e. electrical, mechanical and plumbing). Supervision for the construction is conducted by the working divisions and sub-divisional offices of PWD, and DOA is also responsible for supervision from the top.

In this chapter, we will briefly discuss the “Work Flow Chart of Architectural Design Work” for public buildings in Bangladesh. In parallel, the process to be considered in each stage of the plan is also chalked out to create an ideal working arrangement.

2-4-1 Work Flow Process of Architectural Design Work - Explanation of Work Flow

The process for architectural work flow process in the government sector mainly consists of three broader stages, I : Initial stage for information gathering, II : Intermediate stage for preliminary design preparation and approval and III : Finalizing stage for creating detailed design (see below Figure 2-3).

In the Initial stage, some basic information for analysis is required; such as “Detail digital survey”, “Prevailing site situation”, “Site specific regulatory requirements”, “Space requirements and organizational aspiration”. These information are to be provided by the "Requiring Body (denoted as R.B)" (Main responsible section) and PWD. This initial information helps the architect to determine the scope, extent and volume of the design work.

The Intermediate stage is to establish a design concept, along with the preparation of a preliminary functional plan. The functional plan is site-specific, and is governed by the prevailing rules and regulations. It should also satisfy the requirements of the R.B. The preliminary plan also addresses the structural and EMP issues to the extent possible.

Furthermore, the functional relation and volume of the required spaces and other criteria of the preliminary drawings are examined internally in DOA before sending to the R.B for approval. After the approval, DOA prepares a finished schedule and sends the approved drawing and finish schedule to PWD for an estimate. DOA also needs to go through the rough DPP to ensure if all the required items are included or not.

Before initiating the detailed design in the Finalizing stage, it is necessary for the R.B to take the approval of the Development Project Proposal (denoted as DPP) from the Executive Committee of the National Economic Council (known as ECNEC). ECNEC operated by "Bangladesh Planning Commission" evaluates the DPP and after rationalizing gives administrative approval. The finalizing work at DOA starts only after the approval of the DPP is received so that the drawings can be translated into a physical structure. Based on the detailed design and drawings prepared in the Finalizing stage, the process of “tendering” work is carried out by PWD, and the construction phase starts after a contractor is selected.

In the Figure 2-3, the building owners as government and semi-government organization are abbreviated as "Requiring Body (denoted as R.B)", and the relationships during the design work between DOA and PWD are explained. Detailed work by the stakeholders are listed up in order to easily observe the features of the works.

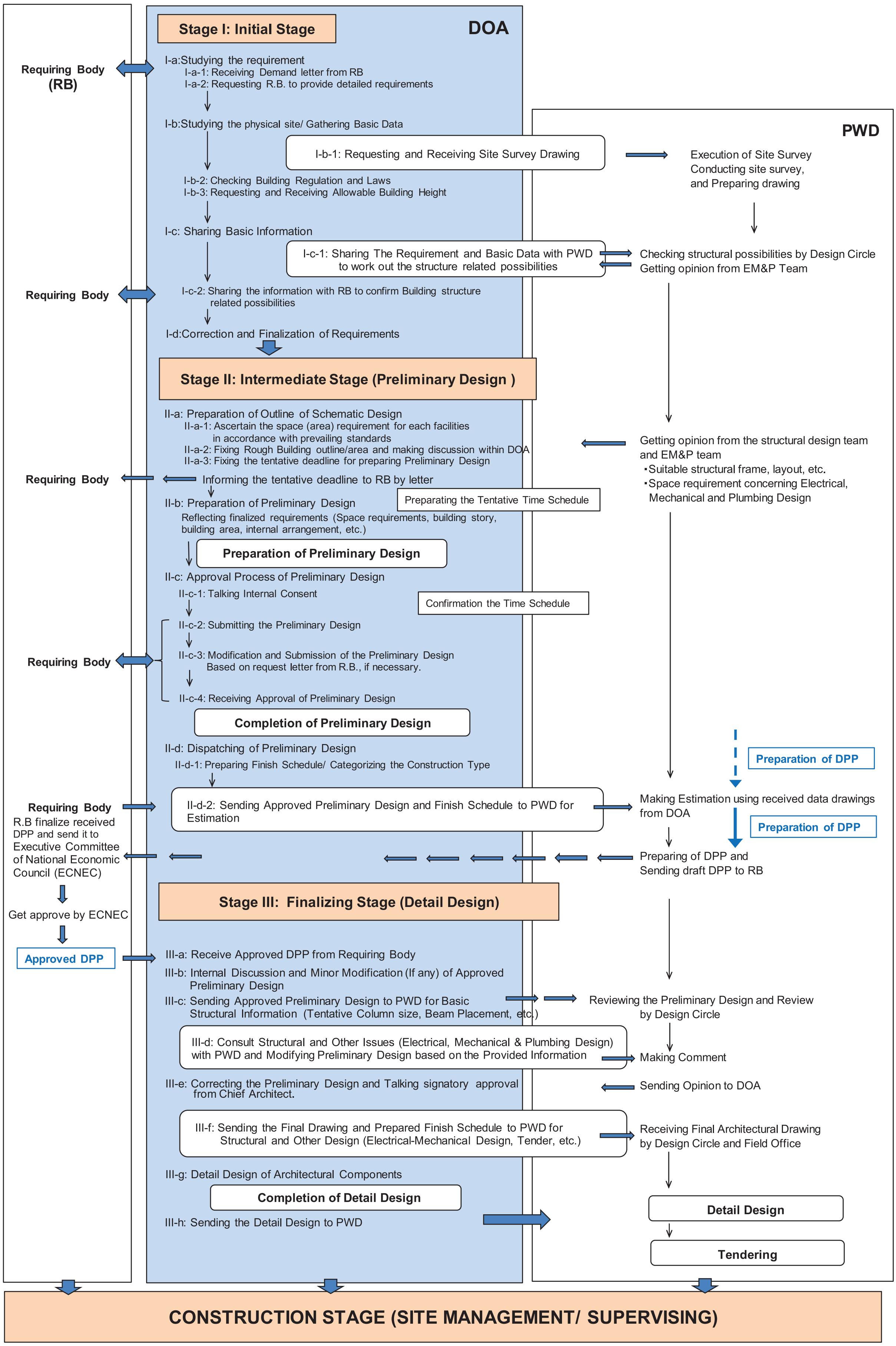


Figure 2-3 Flow Chart of Architectural Design Work

2-4-2 Issues to be Addressed during the Three Stages

The architectural design process that DOA follows, broadly consists of three stages as described below. In each stage, there are important factors that should be confirmed and to be discussed with the concerned parties.

Therefore, the Architect should keep ***a close communication*** with the requiring body as Owner of the project and the Public Works Department as the design implementing agency. This is necessary to prepare a sound architectural design that can accommodate structural and other service-related issues only, with minor modification at the finalizing stage. Furthermore, ***an internal communication*** within the DOA is also very important to finalize the design work.

The issues to be confirmed and the matters to be discussed for the three stages are described in the following tables.

(i) During Stage I: Initial Stage / Basic Design

Table 2-1 Issues to be Confirmed during Stage I

Period	Issue to be confirmed	Matters to be discussed
I-a: Studying the Requirements		
I-a-1: Receiving demand letter from Requiring Body (R.B).	1. Evaluating the demand letter, checking for all the required information (i.e. present organogram, proposed organogram if any, pay scale, Rooms/spaces regarding organizational activity, special room/ space requirements, vehicle, equipment, etc.). 2. Listing of missing data. 3. Project specific guidance/ NOC from Key Point installation defense committee (KPIDC), Special Security Force (SSF), etc. if required.	Between R.B and DOA. ● Verifying if the provided demand for space allocation by the R.B. complies with the existing rules and regulations and if the requirements are logical or not. Later based upon this evaluation having discussion with the R.B. and keeping all these correspondences in meeting records.
I-a-2 Requesting R.B to provide detailed requirements	1. Requesting for providing missing data and documents for the detailed requirement.	● Regarding the discussion clarified in 1-a-1, other missing requirements will be discussed and be reconfirmed with R.B.
I-b: Studying the Physical Site/ Gathering Basic Data		
I-b-1 Requesting and receiving site survey data.	1. The digital survey should be very informative with providing detail data on Topographical contour, geophysical features, vegetation, location, existing structures, roads, etc. 2. The digital survey should be provided by PWD or R.B. 3. Checking if the site falls under any special kind of constraint (Proximity with KPI structures, proximity with natural water-body, proximity with mound or hill, etc.). 4. Identifying the site-specific structural constraints and possibilities. 5. Listing of missing data.	● Informing PWD or R.B. for missing data and having a full-fledged functional survey from them.
I-b-2 Checking building regulation and laws	1. Identifying the jurisdiction authority that the specific physical site falls into. 2. Checking whether the target site can be utilized to construct according to building regulations 3. Identifying the section that needs to follow the regal provisions for the specific building type.	● The applicable rule/laws regarding the specific site and the scope of work should be discussed with R.B. ● DOA have to obtain consent from R.B. to proceed further.

Period	Issue to be confirmed	Matters to be discussed
I-b-3 Requesting and receiving allowable building height	1. Confirmation about the allowable building height should be taken from Civil Aviation Authority.	● DOA should request PWD to provide NOC from Civil Aviation Authority.
I-c: Sharing Basic Information		
I-c-1 Sharing the requirement and basic data with PWD to work out the structure related possibilities	1. Conducting an onsite or offsite meeting with PWD (Civil, electrical, mechanical and plumbing engineers (EM&P)) depending upon the complexity of the structure. 2. Sharing information that has been gathered and discussing the rule that needs to be followed and the type of structure the Architect is visioning. 3. The opinions that PWD (Civil and EM&P) provides on their respective discipline need to be addressed. 4. The decision should be concretized after negotiation.	● Discussing the planned type of structure, number of stories depending on basic site data with PWD.
I-c-2 Sharing the information with RB to confirm building structure related possibilities	1. Conducting an onsite or offsite meeting with RB & PWD (Civil and EM&P) describing the limitation or possibility depending upon the complexity of the structure.	● Sharing the information with R.B that has been confirmed with PWD during previous discussion and later finalizing it on a tri-party discussion.
I-d: Correction and Finalization of Requirements		
I-d Correction and finalization of requirements	1. Based upon previous discussions a corrected and finalized requirement has to be fixed. 2. The information then formally has to be sent to the concerned parties.	● Explain to R.B about the corrected requirement and take an approval. ● Sharing the finalized requirement and the information with PWD.

(ii) During Stage II: Intermediate Stage / Preliminary Design

Table 2-2 Issues to be Confirmed during Stage II

Period	Issue to be confirmed	Matters to be discussed
II-a: Preparation of Outline of Schematic Design		
II-a-1 Ascertain the space (area) requirement for each facility in accordance with the prevailing standard	1. Assigning the project generally to an Assistant Architect. 2. Preparation of schematic design (in sketchy form with zoning) by the Assistant Architect. 3. Taking verbal approval from Executive Architect if the approach is appropriate or not. 4. Inputting provided suggestions in design.	● Discussion within DOA internally about other issues, i.e. Fire Safety, Universal Accessibility, Gender equity, etc. ● Discussion with EM&P team about the space requirement for the building service. ● Discussion with PWD structural team about the structural frame for the building.

Period	Issue to be confirmed	Matters to be discussed
II-a-2 Fixing Rough Building outline/area and making discussion within DOA	1. Determine the basic design concept. 2. Internal discussion with senior Architects for better output. 3. Clarifying points of confusion through discussion to develop the drawing.	● Examine whether the estimated area and circulation flow meets the need of the R.B. ● Examine the space requirement concerning electrical, mechanical and plumbing design.
II-a-3 Fixing the tentative deadline for preparing preliminary design	1. Estimating the tentative time needed to develop preliminary design. 2. Informing R.B about the needed time.	● Discuss the operational time schedule of the design to take an agreement among the parties involved.
II-b: Preparation of Preliminary Design		
II-b Reflecting finalized requirements (Space requirements, Building storey, Building area, Internal arrangement, etc.)	1. Preparation of preliminary design. 2. Determination of the layout of structural frames and structural members, and building service spaces. 3. Examine the space requirement concerning the requirement finalized previously with R.B and PWD. 4. Having verbal discussion with executive architect and incorporating his suggestions. 5. To examine whether the designed spaces meets the requirement of Fire Safety, Universal Accessibility, Gender equity, etc.	● Discussion with the structural and EM&P team is essential at this stage. (See Chapter 3 and Chapter 4 for important points)
II-c: Approval Process of Preliminary Design		
II-c-1 Taking Internal Consent	1. Sending the drawing formally to the Executive Architect to start the internal approval process. 2. The Executive Architect takes verbal/ written approval from his/her senior officers	● Logical explanation and argument to senior officers on the concept, the form, the process of design development and reasons behind the space allocation.
II-c-2 Submitting the Preliminary Design	1. The executive architect sends it to the R.B for formal approval.	
II-c-3 Modification and Submission of the Preliminary Design based on request letter from R.B. if necessary.	1. The R.B checks if the preliminary design fulfills their need or not. 2. If not, they resend it for modification.	● In consultation with R. B, confirm in detail the correction points, their reasons behind, and points of improvement.
II-c-4 Receiving Approval of Preliminary Design	1. If the preliminary design/modified preliminary design fulfills their requirement then the R.B. gives approval formally and provides signed copy.	● Inform and share the final design approved by R.B to the parties involved.

Period	Issue to be confirmed	Matters to be discussed
II-d: Dispatching of Preliminary Design		
II-d-1 Preparing finish schedule/ categorizing the construction type	1. Preparation of detailed finish schedule based on the category of building (Standard, Super and Superior). 2. Incorporating special items if variation from standard practice is needed.	● Sufficient consultation within DOA to propose a proper finish schedule that suits the purpose and character of the building.
II-d-2 Sending approved preliminary design and finishing schedule to PWD for estimation	1. Sending copy of approved preliminary design and finish schedule to PWD (Working division) for estimate and informing requiring body by letter. 2. Corresponding to the questions from R.B that is required at the time of creation of the DPP	● Based on the Approved Drawing and Finish Schedule from DOA, PWD and R.B. prepare an estimation of the project. At this stage, PWD /R.B. should show the rough DPP and take confirmation from DOA for final submission. ● Similarly, DOA should be consistent about the design concept to describe the contents clearly to PWD for preparing the DPP. ● Consultation between PWD and DOA about the estimation provided by PWD before submission to R.B.

(iii) During Stage III: Finalizing Stage / Detailed Design

Table 2-3 Issues to be confirmed during Stage III

Issue to be confirmed	Matters to be discussed
III-a: Receive Approved DPP from Requiring Body	
1. Receiving approved DPP from R.B. 2. Estimating the tentative time needed to provide the working drawing.	● Confirming necessary time for providing working drawing with other parties involved.
III-b: Internal Discussion and Minor Modification (if any) of Approved Preliminary Design	
1. Internal discussion on assessing the nature of preliminary design, etc. 2. Incorporating discussed issues (minor modification) and memo no. to the preliminary design.	● Confirm whether the design concept and the building design are consistent.
III-c: Sending Approved Preliminary Design to PWD (Civil and EM&P) for Basic Structural Information	
1. Sending the preliminary design with memo number to PWD to get the information about the tentative column size, beam placement, beam size, location of cable duct, MDB, DB, SDB, fire hydrant, lift shaft, escalator, positive pressure, chiller, AHU, outdoor unit of AC, sub-station, generator room size, fire compartment, control room of Closed-Circuit Television (CCTV), medical gas plant room etc.	● It should be the nearly final version after internal discussion within DOA. Therefore, DOA should be informative about their architectural intention to the engineers of PWD.
III-d: **Consult Structural and other Issues with PWD and Modifying Preliminary Design based on the Provided Information**	
1. Receiving information from PWD by letter. 2. Incorporating the information provided by PWD in the preliminary drawing. 3. Checking if any conflict arises. 4. Discussing the problematic issues with PWD and coming up with a joint solution.	● PWD at this stage should provide feedback to DOA of structural and other issues (Electrical, Mechanical & Plumbing Design) to modify the preliminary design. ● After examination and tallying the information provided by PWD, DOA should make comments in the case of any discrepancy or change that occurs from the original plan. In that case both parties after consultation should come up with a final version of design. After this final version, no changes should be done by either party without properly informing and accepting.

Issue to be confirmed	Matters to be discussed
III-e: Correcting the Preliminary Design and Taking Signatory Approval from Chief Architect (C.A) of DOA	
1. Finalizing the preliminary design on the basis of joint solution. 2. Taking signatory approval from the department head through proper channel. 3. Preparing a detail finish schedule and taking signatory approval.	● Internal discussion within DOA to finalize the preliminary design. ● The Architect in charge of the project needs to explain concisely the design plan to the approver. It should confirm adequately to the relevant parties for the questions from the approver.
III-f: : Sending the Final Drawing and Prepared Finish Schedule to PWD for Structural and Other Design (Electrical-Mechanical Design, Tender, etc.)	
1. Sending the final signed drawing and finish schedule to PWD for structural, other design (electro-mechanical design, etc.) and works (tender, etc.).	• When handing over the final drawing and finish schedule from DOA to PWD, make sure that the drawing and documents are enough informative to proceed.
III-g: Detailed design of Architectural Components	
1. Completion of detailed design by DOA based on the Tender Document.	• Internal discussion within DOA to decide the details and interior design components. The designer Architect should make sure that the items used should be mentioned in the tender document.
III-h: Sending the Detailed Design to PWD	
1. Sending the detailed design to PWD	• Precisely explain the specifications of finishing, etc. in the drawing to avoid contradiction and to be easily understood by PWD.

2-5 Design by Architect

2-5-1 Category of Building

Here, examples of the functional classification of buildings used in Bangladesh and the existing rules, standards and references to be followed in designing building are indicated.

In architectural design, it is necessary to propose a form that adapts to the function of the building and satisfies the client's requirements. Therefore, the Architect will proceed with the design while understanding the characteristics of the building in accordance with the category of each building and complying with the laws and regulations. The categories classified according to their use or character of occupancy as shown in the [Table 3.1.1, Sec 1.4, Chapter-2, Part III, BNBC 2020] and DMINB 2008 [“Dhaka Mahanagar Imarat (Nirman, Unnayan, Songrokkhon O Aposaran) Bidhimala , 2008”] (Table 2-4).

Table 2-4 Summary of Occupancy Classification

Occupancy type	Sub-division	Nature of use or occupancy	Fire Index*
A-Residential	**A-1**	Single family dwelling	1
	A-2	Two families dwelling	1
	A-3	Flats or apartments	1
	A-4	Mess, boarding houses, dormitories and hostels	1
	A-5	Hotels and lodging houses	1
B-Educational Facilities	**B-1**	Educational facilities up to higher secondary levels	1
	B-2	Facilities for training and above higher secondary education	1
	B-3	Pre-school facilities	1
C-Institution for Care	**C-1**	Institution for care of children	1
	C-2	Custodial institution for physically capable adults	1
	C-3	Custodial institution for the incapable adults	1
	C-4	Penal and mental institutions for children	1
	C-5	Penal and mental institutions for adults	1
D-Health Care Facilities	**D-1**	Normal medical facilities	2
	D-2	Emergency medical facilities	2
E-Business	**E-1**	Offices	2
	E-2	Research and testing laboratories	2
	E-3	Essential services	2
F-Mercantile	**F-1**	Small shops and market	2
	F-2	Large shops and market	2
	F-3	Refueling station	2
G-Industrial Buildings	**G-1**	Low hazard industries	3
	G-2	Moderate hazard industries	3
H-Storage Buildings	**H-1**	Low fire risk storage	3
	H-2	Moderate fire risk storage	3
I-Assembly	**I-1**	Large assembly with fixed seats	1
	I-2	Small assembly with fixed seats	1
	I-3	Large assembly without fixed seats	1
	I-4	Small assembly without fixed seats	1
	I-5	Sports facilities	1
J-Hazardous Building	**J-1**	Explosion hazard building	4
	J-2	Chemical hazard building	4
	J-3	Biological hazard building	4
	J-4	Radiation hazard building	4
K-Garage	**K-1**	Parking garage	2
	K-2	Private garage	1
	K-3	Repair garage	3
L-Utility	**L**	Utility	2
M-Miscellaneous	**M-1**	Special structures	2
	M-2	Fences, tanks and towers	1

* Fire Index: fire index is an absolute number, Occupancy group having same fire index may be permitted as mixed occupancy and different fire index shall be separated or detached as per provisions of this Code.

2-5-2 Standards for Each Category of Building

Once the type and function of the buildings are decided, design work is started based on prevailing rules. "Front side and rear separation distance / Open spaces", "Means of access", "Open spaces within the plot and the permitted construction area" should require to be followed by the existing rules and regulations.

The characteristics of each building is defined by the allocation of space (this may change depending on the number of people staying in the building) and for what purpose it has been constructed. Therefore, it is necessary to make an appropriate plan according to the regulations based on more detailed conditions in the actual design.

On the other hand, the measures against natural disasters (earthquakes, floods, tsunamis, wind and rain, etc.) and human-created disasters (fires, explosions, building collapses, etc.) must also be considered during the design phase.

Therefore, Architects are required to have a comprehensive knowledge on these different fields to ensure safety and law abidance of the law.

The standard space (area) required for each building category presented in Annex 1 are based on the following references.

Table 2-5 List of Regulations and Useful Standards

No.		Name of reference	Publication
Act , Rules, Amendments and Circulars cases	1	Building Construction Act 1952 (BCA'52) http://doe.portal.gov.bd/sites/default/files/files/doe.portal.gov.bd/policies/96e31494_610d_4295_801d_9a4e0d8a241b/Building%20Construction%20Acts-1952.pdf	1952
	2	Town Improvement Act 1953 http://rajuk.portal.gov.bd/sites/default/files/files/rajuk.portal.gov.bd/page/20b761b8_ab9c_4ec7_8692_0877fe834afd/town_improvement_act_1953.pdf	1953
	3	Bangladesh Allocation Rules, 1982 http://doga.portal.gov.bd/sites/default/files/files/doga.portal.gov.bd/policies/7a576196_fe19_4f8e_8cf3_663658a63bef/381-Law-1982%20(1).pdf	1982
	4	Bangladesh National Building Code 1993 (BNBC'93) http://bnbc93.blogspot.com/p/BNBC_1993.html	1993
	5	Dhaka Shena Nibash (Imarat Nirman) Upo Ain 1994 http://www.iab.com.bd/Resources/Miscs/Cantonment_Board%20Bidhimal_213473408480315169.pdf	1994
	6	The Building Construction Rules 1996 (BCR'96) http://www.clcbd.org/document/132.html	1996
	7	Natural Water Body Protection and Preservation of Open space and Playground Act 2000 http://rajuk.portal.gov.bd/sites/default/files/files/rajuk.portal.gov.bd/page/20b761b8_ab9c_4ec7_8692_0877fe834afd/PondOpenSpace.pdf	2000
	8	Fire Protection and Fire-fighting Act 03 http://www.fireservice.manikganj.gov.bd/site/law_policy/6fe02b6c-2015-11e7-8f57-286ed488c766/Fire-Prevention-Act-2003-Pdf	2003

No.		Name of reference	Publication
Act , Rules, Amendments and Circulars	9	Bangladesh National Building Code 2006 (BNBC 2006) https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.01.pdf https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.02.pdf https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.03.pdf https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.04.pdf https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.05.pdf https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.06.pdf https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.07.pdf https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.08.pdf https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.09.pdf https://law.resource.org/pub/bd/bnbc.2006/gov.bd.bnbc.2006.10.pdf	2006
	10	Bangladesh National Building Code 2020 (BNBC 2020) https://drive.google.com/file/d/1yTU6Y5JOx21YY1rrzN21-dE0bIHbHGFi/view?fbclid=IwAR3zCF4uurwrAGcfqhB9luojEpyqyNgx2WFL0_qpwaIeixFWARzVIShYvrM	2020
	11	Memo No: Sha-2/2M-26/2007/542 Dated 15 Nov 2007 (Office circular regarding space allocation for Government offices) http://doga.portal.gov.bd/sites/default/files/files/doga.portal.gov.bd/law/397fa283_e54e_4dc2_9bad_76c5c6203180/Regarding%20Office%20Space.pdf	2007
	12	Dhaka Mahanagar Imarat (Nirman, Unnayan, Songrokkhon O Aposaran) Bidhimala 2008 (DMINB'08) https://www.rehab-bd.org/img/home_attach/Dhaka%20Imarat%20Nirman%20Bidhimala-2008.pdf	2008
	13	Chattogram Mahanagar Building (Construction, Development, Protection and Removal) Rule 2008 https://pdfslide.net/documents/chittagong-imarotnirman-bidhimala-2008.html	2008
	14	Preservation of Historical Buildings / Infrastructures/Important Locations 2009 http://rajuk.portal.gov.bd/sites/default/files/files/rajuk.portal.gov.bd/page/20b761b8_ab9c_4ec7_8692_0877fe834afd/HaritazeGazette.pdf	2009
	15	Key point installation Nirapotta Nitimala 2013 https://ssd.portal.gov.bd/sites/default/files/files/ssd.portal.gov.bd/page/908aa2bc_85d4_4d2e_9545_1cb406844f07/%e0%a6%a8%e0%a6%bf%e0%a6%b0%e0%a6%be%e0%a6%aa%e0%a6%a4%e0%a7%8d%e0%a6%a4%e0%a6%be%20%e0%a6%a8%e0%a7%80%e0%a6%a4%e0%a6%ae%e0%a6%be%e0%a6%b2%e0%a6%be,%e0%a7%a8%e0%a7%a6%e0%a7%a7%e0%a7%a9.pdf	2013
	16	Memo No: Pro Sha-6 / Bibdh (Shadharon-5) /2013/136 Dated 25 March 2014 (Office circular regarding approval of building drawing by Local Government Bodies)	2014
	17	Fire Prevention and Extinguishing Rules Agni Pratirodh o Nirbapaṇ Bidhimala 2014 (APNB'2014) http://fireservice.portal.gov.bd/sites/default/files/files/fireservice.portal.gov.bd/notices/ca3b3540_efde_493b_98c2_15b816e51c93/ও%20নির্বাপণ%20বিধিমালা%20(২০১৪).pdf	2014
	18	Amendment of Bangladesh Allocation Rule S.R.O. No: 90 Ain/2019, Dated:07-04-2019 http://doga.portal.gov.bd/sites/default/files/files/doga.portal.gov.bd/law/e0600327_ebec_4bba_a69a_707c1bab75f5/31542_30643.pdf	2019
Reference Cases	19	Time-saver Standards for Building Types Edited/ Author: Joseph de Chiara & John Hankock Callender	1982 (6th edition)
	20	Time-saver Standards for Architectural Design Data Edited/ Author: Donald Watson	1997 (7th edition)
	21	National Fire Protection Association (NFPA)101 Life safety Code Handbook 2015 13th edition, Edited/ Author: NFPA	2015

CHAPTER 3 Basic Considerations in Architectural Design for Seismic Loads

3-1 Introduction

While the provision of earthquake resistance is accomplished through structural means, the architectural design plays a major role in determining the building's seismic performance. The building architecture must permit as effective a seismic design as much as possible. At the same time, the structure must permit the functional and aesthetic objectives of the building to be constructed. In addition to how the earthquake forces are carried to the ground, the architectural features that critically influence the seismic resistance capacity of structures include the overall shape, size, and geometry of the building.

Each of these architectural features has a significant bearing on the performance of the building during earthquakes. Regarding the importance of building configuration, Henry J. Degenkolb, a noted earthquake Engineer of USA, said. ***"If we have a poor configuration to start with, all the Engineer can do is to provide a band-aid – improve a basically poor solution as best as he can. Conversely, if we start-off with a good configuration and reasonable framing system, even a poor Engineer cannot harm its ultimate performance too much."***

Therefore, at the planning stage itself, Architects and structural Engineers must work together in order to avoid undesired architectural features and come up with the good configuration for the building. When irregular features are included in buildings, a considerably higher level of engineering effort is required in the structural design, and yet, the building may not be as good as one with simple architectural features.

This chapter discusses the issues related to architectural decisions that affect seismic performance, This in turn, will promote a better understanding of the Architects regarding earthquake resistant design. Hence, this will reduce the time for coordination between the Architects and Engineers as well as to speed up the project implementation process.

Regarding the details for the structural design, the following documents have been referred:

- BNBC 2020 [Bangladesh National Building Code]
- Designing for Earthquakes: A Manual for Architects. [FEMA 454 / December 2006]
- Seismic Design for Architects: Outwitting the Quake [Andrew Charleson, July 2008, Elsevier]
- The Seismic Design Handbook, Second Edition [Edited By Farzad Naiem, 2001]
- Structure as Architecture, a source book for Architects and Structural Engineers [Andrew W. Charleson, 2006, Elsevier]

3-2 Seismic Zoning in Bangladesh

The seismic zoning map is intended to give an indication of the Maximum Considered Earthquake (MCE) motion at different parts of the country. In probabilistic terms, the MCE motion may be considered to correspond to having a 2% probability of exceedance within a period of 50 years. Bangladesh has been divided into four seismic zones with different levels of ground motion. Table 3-1 includes a description of the four seismic zones. The Figure 3-1 presents a map of Bangladesh showing the boundaries of the four zones. Each zone has a Seismic Zone Coefficient (Z), which represents the maximum considered Peak Ground Acceleration (PGA) on very stiff soil/rock (site class SA) in units of g (acceleration due to gravity). The Zone Coefficients (Z) of the four zones are: Z=0.12 (Zone 1), Z=0.20 (Zone 2), Z=0.28 (Zone 3) and Z=0.36 (Zone 4). Table 3-2 lists zone coefficients for some important towns of Bangladesh. The most severe Earthquake Prone Zone, Zone 4 is in the northeast which includes Sylhet. It has a maximum PGA value of 0.36g. Dhaka city falls in the moderate seismic intensity zone with Z=0.2, while Chittagong city falls in a severe intensity zone with Z=0.28.

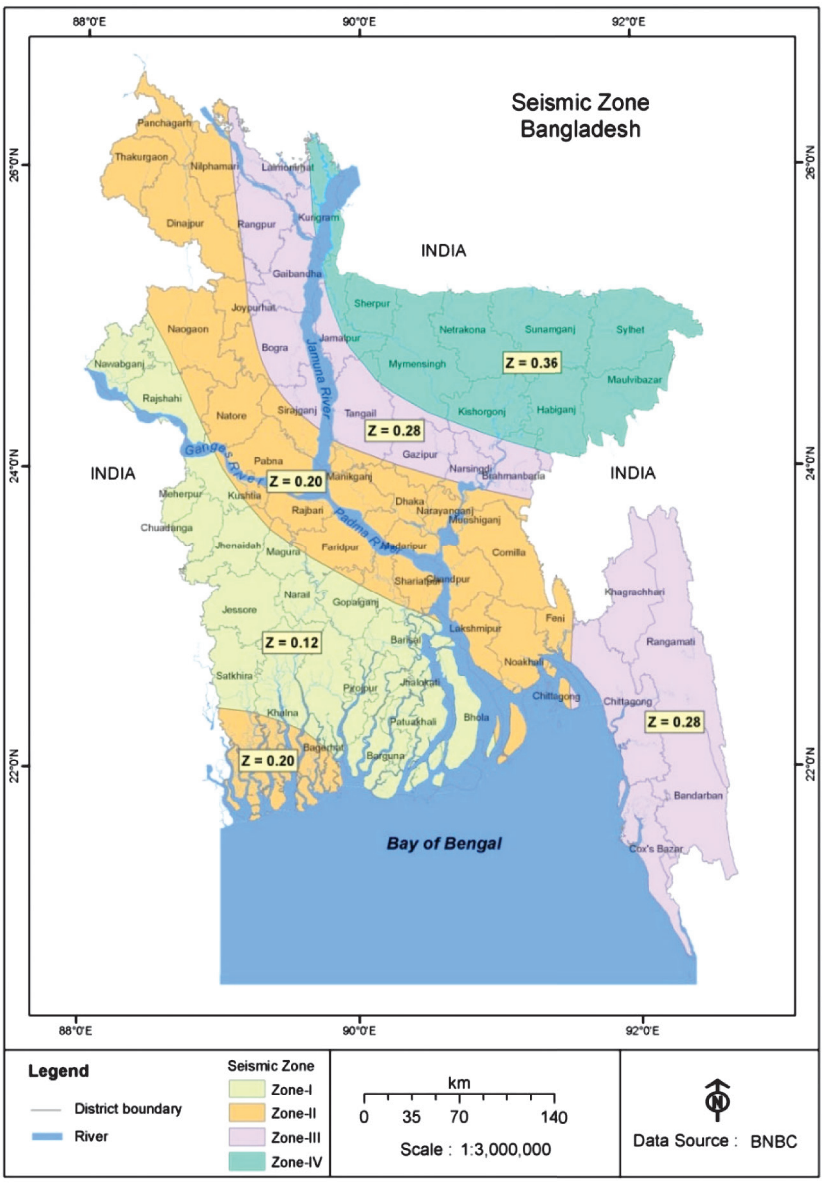


Figure 3-1 Seismic Zoning Map of Bangladesh

Reference: [Table 6.2.24, Chapter 2, Part VI, BNBC 2020]

Table 3-1 Description of Seismic Zones

Seismic Zone	Location	Seismic Intensity	Seismic Zone Coefficient, Z
1	Southwestern part including Barisal, Khulna, Jessore, Rajshahi	Low	0.12
2	Lower Central and Northwestern part including Noakhali, Dhaka, Pabna, Dinajpur, as well as Southwestern corner including Sundarbans	Moderate	0.20
3	Upper Central and Northwestern part including Brahmanbaria, Sirajganj, Rangpur	Severe	0.28
4	Northeastern part including Sylhet, Mymensingh, Kurigram	Very Severe	0.36

Reference: [Table 6.2.14 (b), Chapter 2, Part VI, BNBC 2020]

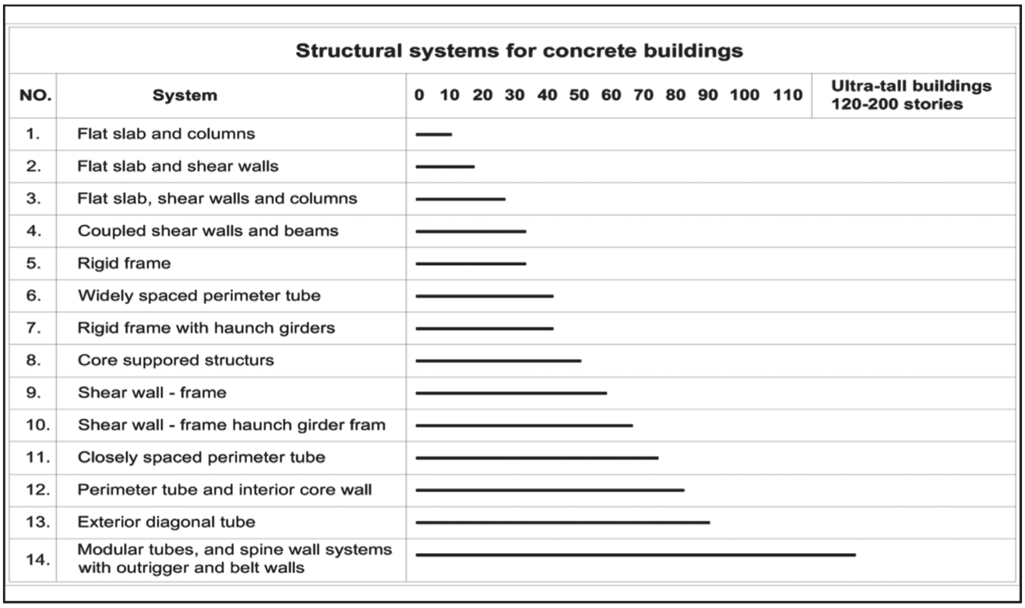
Table 3-2 Seismic Zone Coefficient *Z* for Some Important Towns of Bangladesh

Town	*Z*	Town	*Z*	Town	*Z*	Town	*Z*
Bagerhat	0.12	Gaibandha	0.28	Magura	0.12	Patuakhali	0.12
Bandarban	0.28	Gazipur	0.20	Manikganj	0.20	Pirojpur	0.12
Barguna	0.12	Gopalganj	0.12	Maulvibazar	0.36	Rajbari	0.20
Barisal	0.12	Habiganj	0.36	Meherpur	0.12	Rajshahi	0.12
Bhola	0.12	Jaipurhat	0.20	Mongla	0.12	Rangamati	0.28
Bogra	0.28	Jamalpur	0.36	Munshiganj	0.20	Rangpur	0.28
Brahmanbaria	0.28	Jessore	0.12	Mymensingh	0.36	Satkhira	0.12
Chandpur	0.20	Jhalokati	0.12	Narail	0.12	Shariatpur	0.20
Chapainababganj	0.12	Jhenaidah	0.12	Narayanganj	0.20	Sherpur	0.36
Chittagong	0.28	Khagrachari	0.28	Narsingdi	0.28	Sirajganj	0.28
Chuadanga	0.12	Khulna	0.12	Natore	0.20	Srimangal	0.36
Comilla	0.20	Kishoreganj	0.36	Naogaon	0.20	Sunamganj	0.36
Cox's Bazar	0.28	Kurigram	0.36	Netrakona	0.36	Sylhet	0.36
Dhaka	0.20	Kushtia	0.20	Nilphamari	0.12	Tangail	0.28
Dinajpur	0.20	Lakshmipur	0.20	Noakhali	0.20	Thakurgaon	0.20
Faridpur	0.20	Lalmanirhat	0.28	Pabna	0.20		
Feni	0.20	Madaripur	0.20	Panchagarh	0.20		

Reference: [Table 6.2.15, Chapter 2, Part VI, BNBC 2020]

3-3 Basic Structural Forms

Reinforced concrete, known to humans since the nineteenth century, offers a wide range of structural systems that may be grouped into distinct categories, each with an applicable height range, as shown in Figure 3-2 (Reinforced Concrete Design of Tall Buildings by Bungale S. Taranath).



Structural systems for concrete buildings		
NO.	System	0 10 20 30 40 50 60 70 80 90 100 110 / Ultra-tall buildings 120-200 stories
1.	Flat slab and columns	
2.	Flat slab and shear walls	
3.	Flat slab, shear walls and columns	
4.	Coupled shear walls and beams	
5.	Rigid frame	
6.	Widely spaced perimeter tube	
7.	Rigid frame with haunch girders	
8.	Core suppored structurs	
9.	Shear wall - frame	
10.	Shear wall - frame haunch girder fram	
11.	Closely spaced perimeter tube	
12.	Perimeter tube and interior core wall	
13.	Exterior diagonal tube	
14.	Modular tubes, and spine wall systems with outrigger and belt walls	

Figure 3-2 Applicable Height Range of Buildings

Besides reinforced concrete, structual steel shapes and combinations of the two, known as composite, are widely used as basic construction material for building construction. A typical Structural framing system using the materials, mentioned above can be grouped as shown in Figure 3-3.

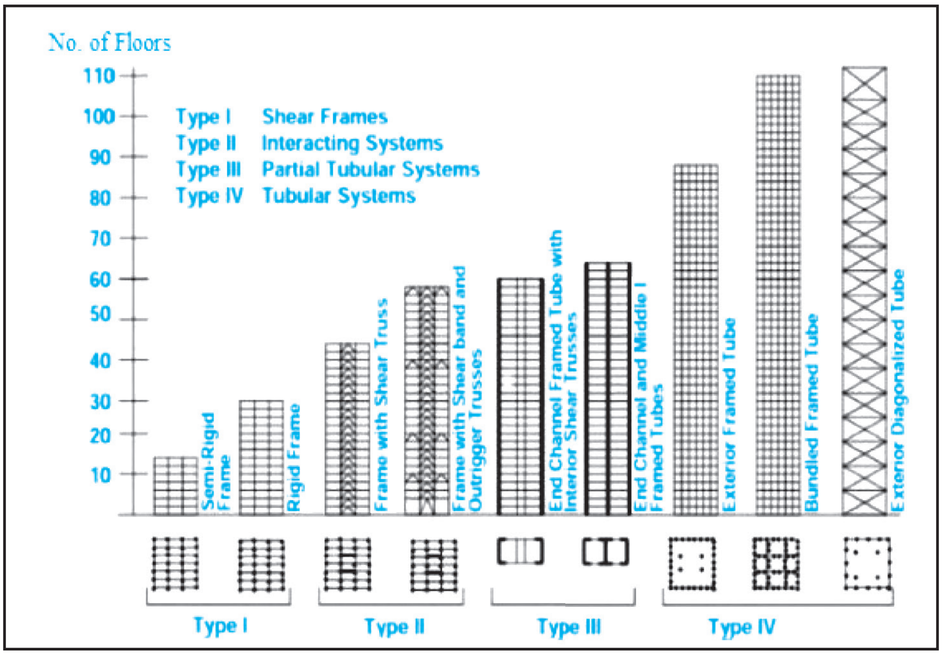


Figure 3-3 Typical Structural Framing System

Reference: [SSRG International Journal of Civil Engineering (SSRG-IJCE)]

3-4 Optimizing the Structural Configuration by Architectural Design

The characteristics of the seismic resistant structure considering only architectural configuration and disposition of the seismic resisting elements can be described by the following building attributes.

- **Continuous load path.**
  Uniform loading of structural elements and no stress concentrations.
- **Low height-to base ratio**
  Minimizes tendency to overturn.
- **Equal floor heights**
  Equalizes column or wall stiffness, no stress concentrations.
- **Symmetrical plan shape**
  Minimizes torsion.
- **Identical resistance on both axes**
  Eliminates eccentricity between the centers of mass and resistance and provides balanced resistance in all directions, thus minimizing torsion.
- **Identical vertical resistance**
  No concentrations of strength or weakness.
- **Uniform section and elevations**
  Minimize stress concentrations.
- **Seismic resisting elements at perimeter**
  Maximum torsional resistance.
- **Short spans**
  Low unit stress in members, multiple columns provide redundancy-loads can be redistributed if some columns are lost.
- **No or Small cantilevers**
  Reduced vulnerability to vertical accelerations.
- **No openings in diaphragms (floors and roof)**
  Ensures direct transfer of lateral forces to the resistant elements.

Buildings with irregularity in plan or elevation suffer much more damage in earthquakes than buildings with regular configuration. According to BNBC 2020, a building may be considered as irregular, if at least one of the conditions given below are applicable:

3-4-1 Horizontal Irregularity

Following are the different types of irregularities that may exist in the plan of a building.

(i) Torsion Irregularity

To be considered for rigid floor diaphragms, when the maximum storey drift (Δ_{max}) as shown in Figure 3-3, computed including accidental torsion, at one end of the structure is more than 1.2 times the average$\left(\Delta_{avg}=\frac{\Delta_{max}+\Delta_{min}}{2}\right)$ of the storey drifts at the two ends of the structure. If $\Delta_{max} > 1.4\Delta_{avg}$ then the irregularity is termed as extreme torsional irregularity. [Sec 2.5.5.3.1 (i), Chapter 2, Part VI, BNBC 2020]

Typically, the torsional irregularities are induced due to the irregular plan configuration or the eccentricity between the center of mass and the center of resistance/rigidity. Torsional irregularities contribute a significant element of uncertainty to an analysis of building resistance, and are probably the most frequent cause of structural failure. Common building floor plans where torsional irregularity may be present are L-shape, T-shape, too long, different building width at parallel ends etc.

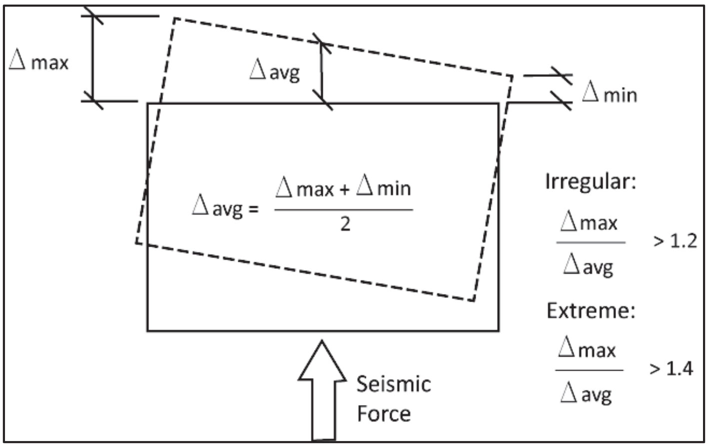


Figure 3-4 Torsional Irregularity

Reference: [Figure 6.2.27 (a), Chapter 2, Part VI, BNBC 2020]

<Way of Improvement of the Torsional Irregularity Condition>

Considering the land constraint or functional requirements, the Architect should try to configure a building plan keeping in mind all the irregularities enumerated in [Sec 2.5.5.3, Chapter 2, Part VI, BNBC 2020].

In many cases, that may not be possible and in that situation, Architects can improve the torsional irregularity condition by (1) separating the regular parts of the building with a seismic separation (see Sec 3-6 of this Chapter) for L and T-shape plan as shown in Figure 3-9 and (2) Placing shear wall/bracing in such a way that they avoid the eccentricity due to center of mass and center of rigidity, (iii) Placing shear wall/bracing to balance the resistance around the perimeter, that configures a frame structure of approximately equal strength and stiffness for the entire perimeter as shown in Figure 3-8.

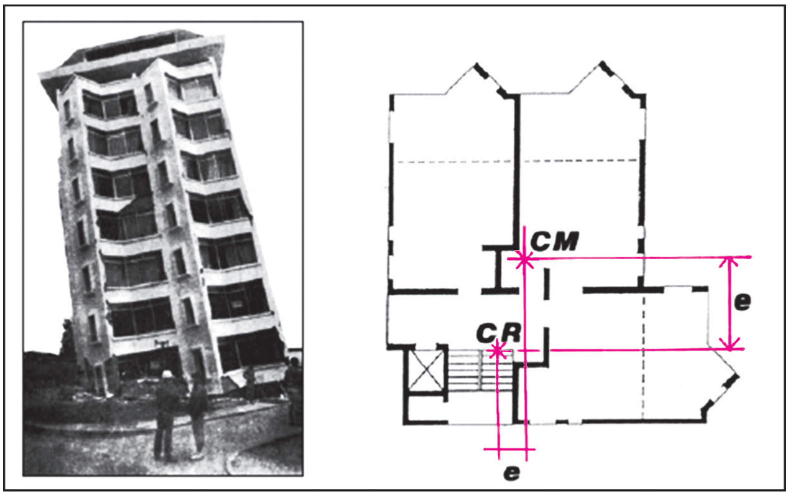


Figure 3-5 Left-the Building after the Earthquake, Right-Typical Floor Plan showing the Center of Mass (CM), Center of Resistance (CR) and Eccentricity (e) along the Two Axes. Reference: EERI

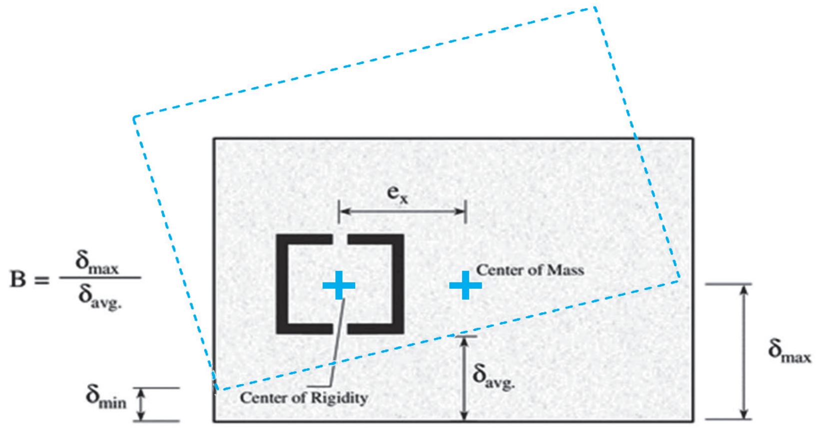


Figure 3-6 Eccentricity due to the Different Center of Mass and the Center of Rigidity caused by Asymmetric Placement of Shear Wall / Core Wall.
Reference: [Figure 6.2.27 (a), Chapter 2, Part VI, BNBC 2020]

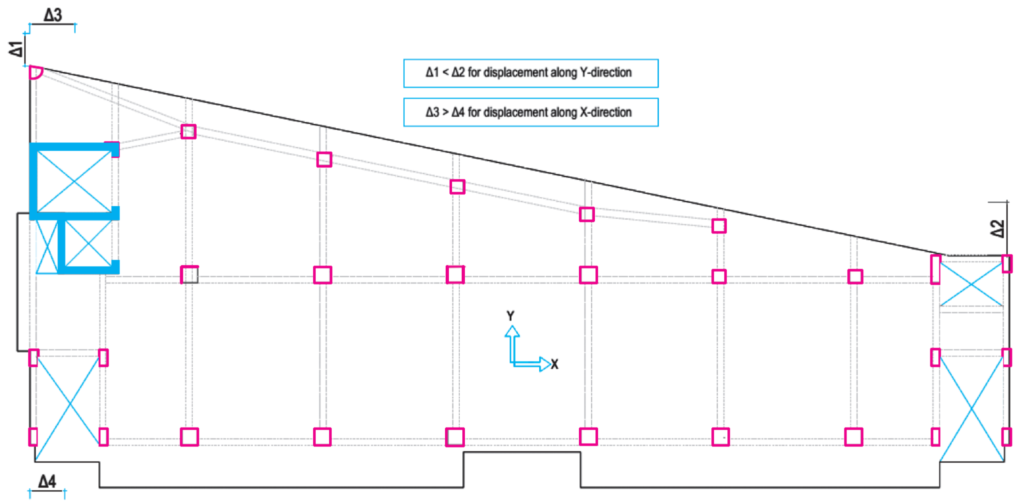


Figure 3-7-(a) Typical Floor Plan of a 12-storied Building
- with torsional irregularity due to its shape and asymmetric distribution of shear wall

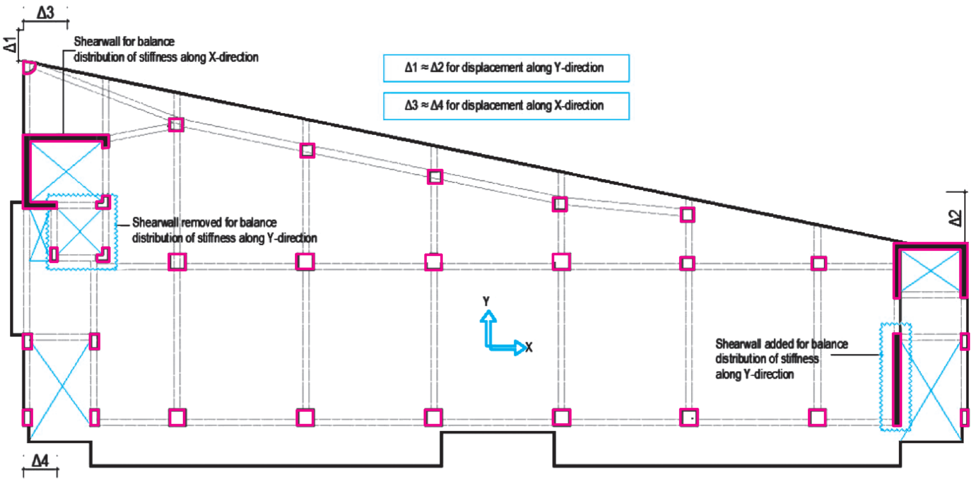


Figure 3-7-(b) Modified Shearwall Layout

- to balance stiffness distribution hence minimizes the torsional irregularity

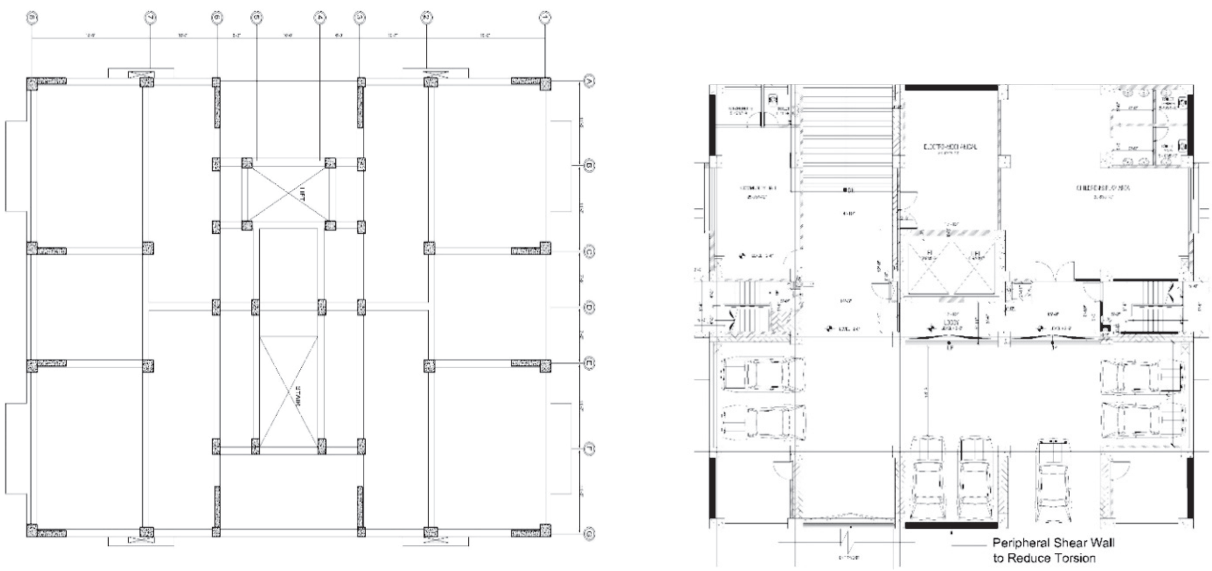


Figure 3-8 Symmetric and Peripheral Distribution of Shear Wall to Reduce Torsion

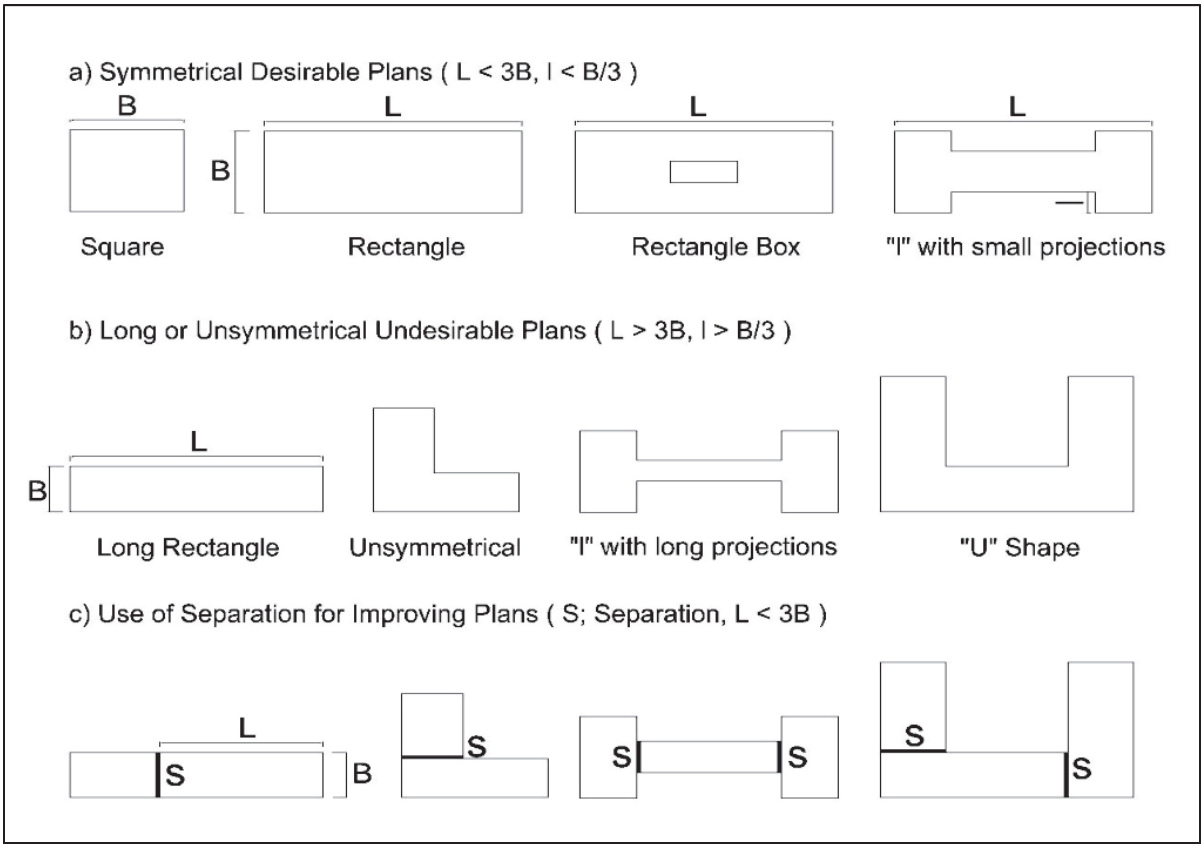


Figure 3-9 Common undesirable and Improved Plans

(ii) Re-entrant Corners

As per [Sec 2.5.5.3.1 (ii), Chapter 2, Part VI, BNBC 2020], Re-entrant corner exists when "Both projections of the structure beyond a re-entrant corner (see Figure 3-10 as follow) are greater than 15 percent of its plan dimension in the given direction".

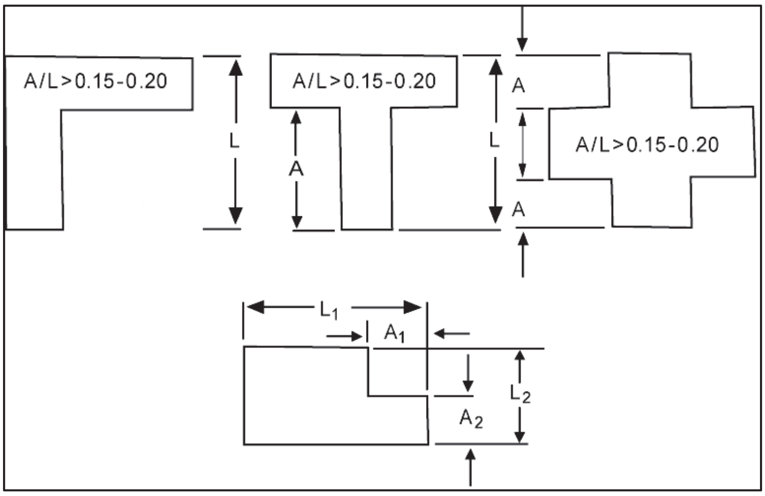


Figure 3-10 Re-entrant Corners
Reference: [Figure 6.2.27 (b), Chapter 2, Part VI, BNBC 2020]

The re-entrant corner is the common characteristic of building forms that, in plan, assume the shape of an L, T, H, etc., or a combination of these shapes. These shapes are create two problems.

The first is that they tend to produce differential motions between different wings of the building that, because of stiff elements that tend to be located in this region, result in local stress concentrations at the re-entrant corner, or "notch". The second problem of this form is torsion which is discussed in Sec 3-4-1 (i). Figure 3-11 shows the problems with the re-entrant-corner form. The stress concentration at the "notch" and the torsional effects are interrelated.

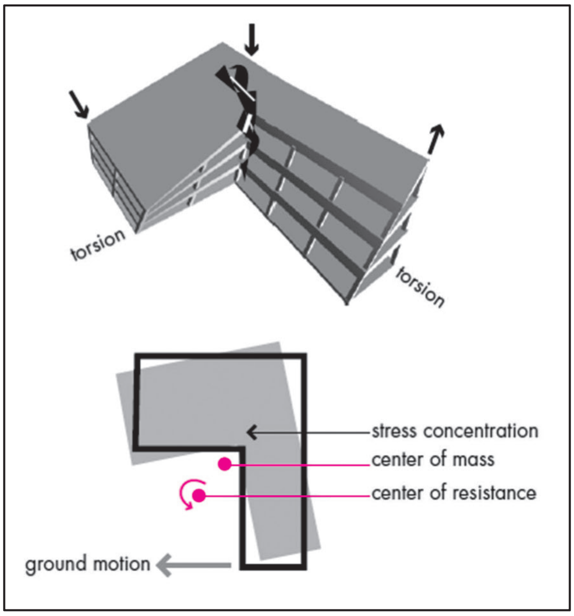


Figure 3-11 Re-entrant Corner Plan Form
Reference: [Designing for Earthquakes, FEMA, p. 5-25]

<Way of Improvement of Re-entrant Corner Condition>

There are two basic alternative approaches to the problem of re-entrant-corner forms: structurally to separate the building into simpler shapes or to tie the building together more strongly with elements positioned to provide a more balanced resistance (Figure 3-13). The latter solution applies only to smaller buildings.

Once the decision is made to use separation joints, they must be designed and constructed correctly to achieve the original intent. Structurally separated entities of a building must be fully capable of resisting vertical and lateral forces on their own, and their individual configurations must be balanced horizontally and vertically.

To design a separation joint, the maximum drift of the two units must be calculated by the structural consultant. The worst case is, when the two individual structures lean toward each other simultaneously.

Thus, the sum of the dimensions of the separation spaces must allow for the sum of the building deflections. Several considerations would arise if it is decided to dispense with the separation joint and tie the building together. Collectors at the intersection can transfer forces across the intersection area, but only if the design allows for these beam-like members to extend straight across without interruption. If they can be accommodated, full-height continuous walls in the same locations are even more effective. Since the portion of the wing which typically distorts the most is the free end, it is desirable to place stiffening elements at that location.

Figure 3-12 West Anchorage High School, Alaska Earthquake, 1964
Stress concentration at the notch of this shallow L-shaped building damaged the concrete roof diaphragm
[Reference: National Information Service for Earthquake Engineering, University of California, Berkeley]

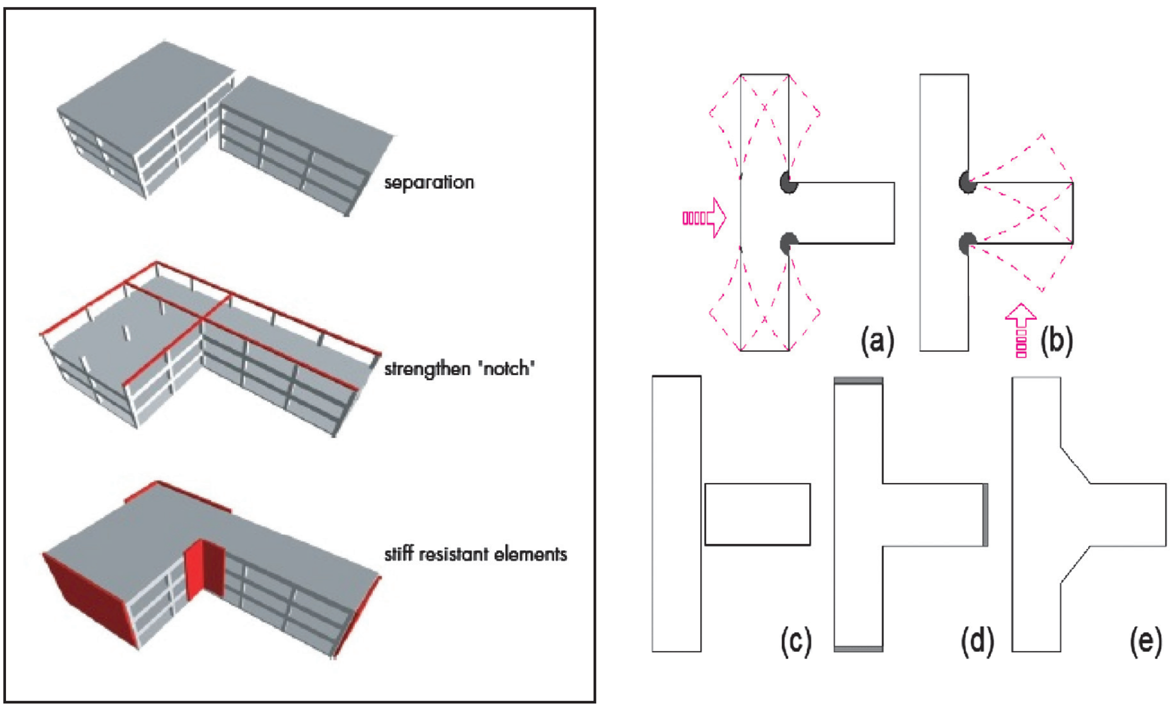
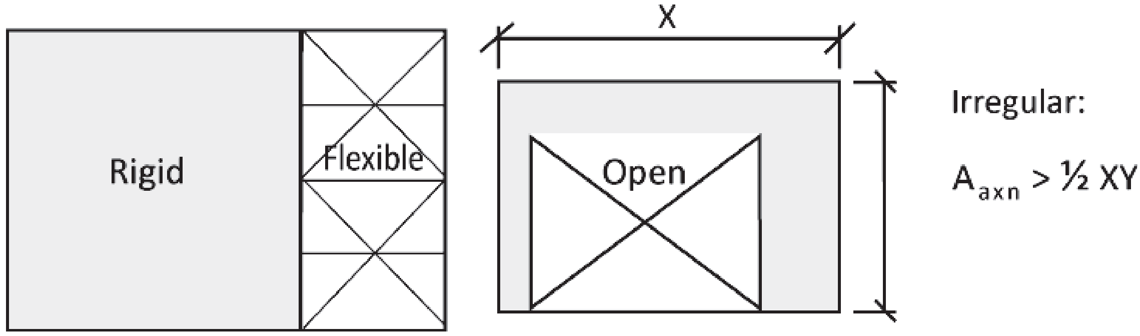


Figure 3-13 Improvement of Re-entrant Corners

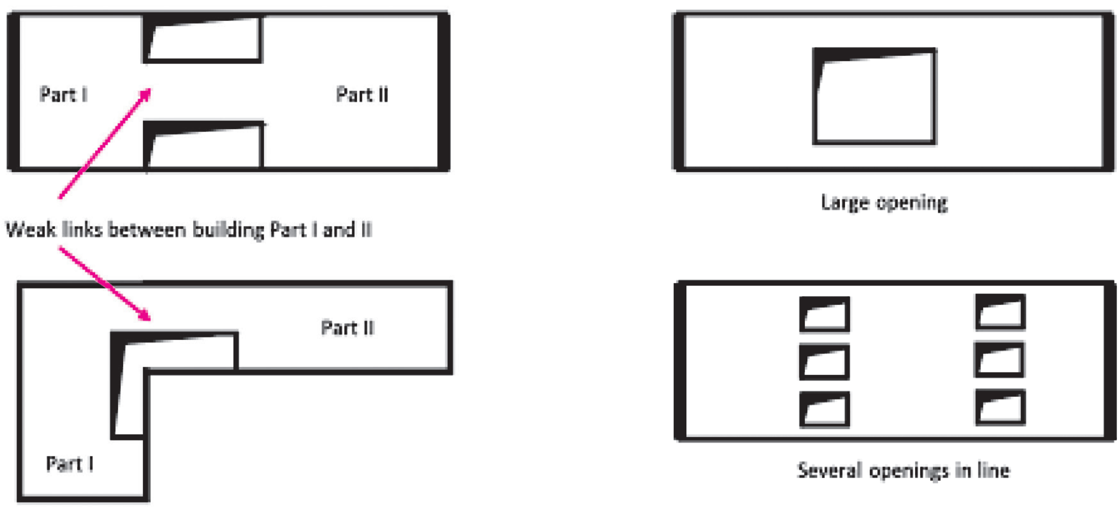
(iii) Diaphragm Discontinuity

Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out (Figure 3-14(a)) or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next. [Sec 2.5.5.3.1 (iii), Chapter 2, Part VI, BNBC 2020]



(a)

Reference: [Figure 6.2.27 (c), Chapter 2, Part VI, BNBC 2020]



(b)

Figure 3-14 Diaphragm Discontinuity

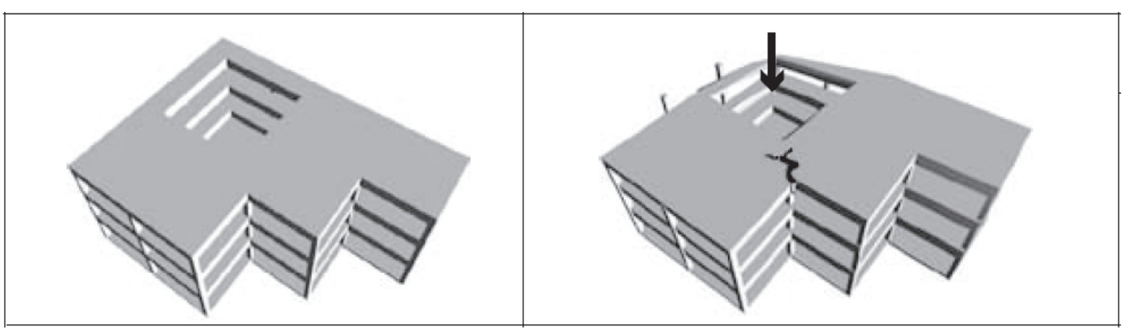


Figure 3-15 Diaphragm Discontinuity and Resulting Failure in Weak Links

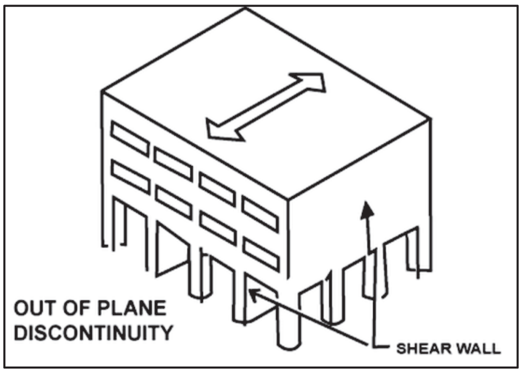
Reference: [Designing for Earthquakes, FEMA, p. 5-12]

<Way of Improvement of Diaphragm Discontinuity>

Damage to the structure due to diaphragm discontinuity effect can be reduced by allowing continuity of beam or cord element capable of withstanding probable stress concentration.

(iv) Out-of-Plane Offset

Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements, as shown in Figure 3-16. [Sec 2.5.5.3.1 (iv), Chapter 2, Part VI, BNBC 2020]



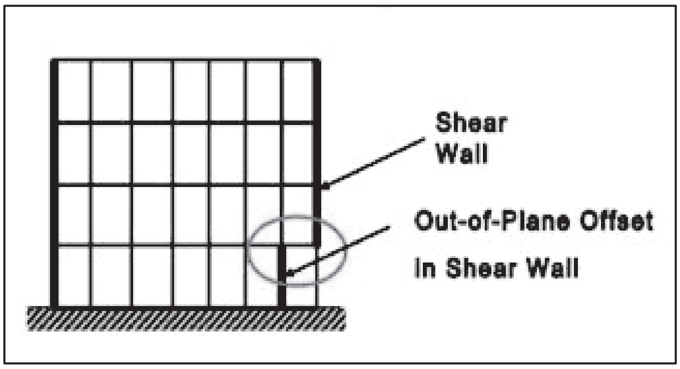


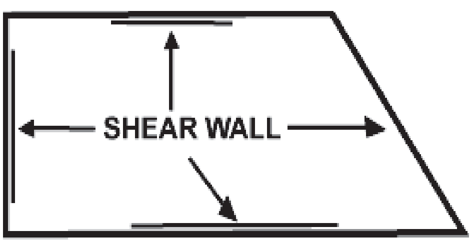
Figure 3-16 Out- of-Plane Offsets of Shear Wall

<Way of Improvement of Diaphragm Discontinuity>

An architect should try by all means to avoid out of plane offset configuration to avoid a significant increase in cost as well as low reliability of the structural performance.

(v) Non-Parallel Systems

The vertical elements resisting the lateral force are not parallel to or symmetric (Figure 3-17) about the major orthogonal axes of the lateral force-resisting elements [Sec 2.5.5.3.1 (v), Chapter 2, Part VI, BNBC 2020].



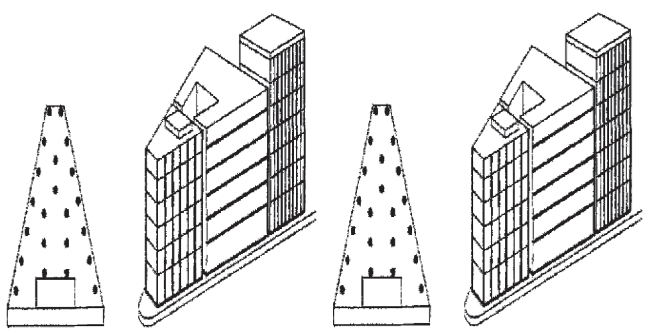


Figure 3-17 Non-Parallel Systems: Invitation to Torsion

Figure 3-18 Distortion in Wedge Shaped Building, Mexico City, 1985

<Way of Improvement of Non-Parallel Systems >

To improve the performance of the non-parallel system, it is recommended to place the lateral load resistance elements in such way as avoid the eccentricity from the center of mass and center of gravity along with measures specified in the code for force increment and rigorous analysis.

3-4-2 Vertical Irregularity

Following are the different types of irregularities that may exist along vertical elevations of a building.

(i) Stiffness Irregularity - Soft Storey

As per [Sec 2.5.5.3.2 (i), Chapter 2, Part VI, BNBC 2020], the soft storey is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storeys above irregularity (Figure 3-19). An extreme soft storey is defined where its lateral stiffness is less than 60% of that in the storey above or less than 70% of the average lateral stiffness of the three storeys above.

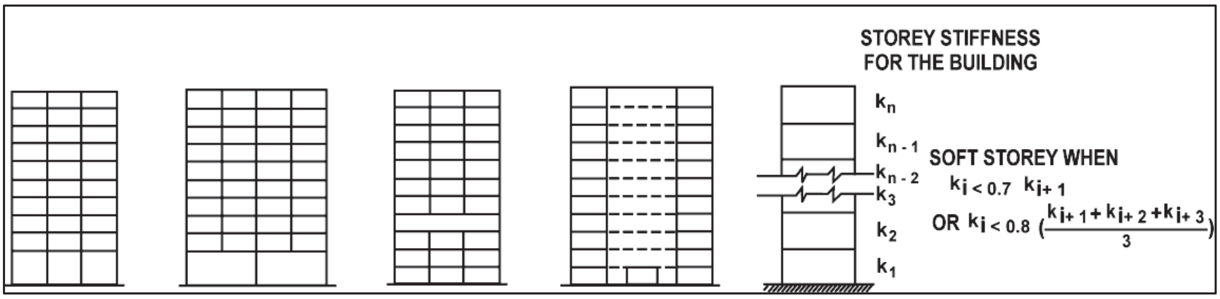


Figure 3-19 Soft Storey

Reference: [Figure 6.2.28 (a), Chapter 2, Part VI, BNBC 2020]

Soft-storey buildings so-called for having the first storey much less rigid than the storey above, are particularly susceptible to earthquake damage because of large, unreinforced openings on their ground floors. These openings often accommodate parking spaces, large windows and expansive lobbies in residential and office buildings. Without proper design, such structures are much less able to withstand the lateral forces. Once the first-floor folds, the upper floors pancake down on top of it, crushing anything underneath.

The most prominent of the problems caused by severe stress concentration is that of the "soft" storey. The term has commonly been applied to buildings whose ground-level storey is less stiff than those above. The building code distinguishes between "soft" and "weak" storey. Soft storey is less rigid, or more flexible, than the storey above; the weak storey has less strength. A soft or weak storey at any height creates a problem, but since the cumulative loads are greatest towards the base of the building, a discontinuity between the first and second floor tends to result in the most serious condition.

The way in which severe stress concentration is caused at the top of the first floor is shown in the diagram sequence in Figure 3-20. Normal drift under earthquake forces that is distributed equally among the upper floors is shown in Figure 3-20 A. With a soft storey, almost all the drift occurs in the first floor, and stress concentrates at the second-floor connections (Figure 3-20 B). This concentration overstresses the joints along the second-floor line, leading to distortion or collapse (Figure 3-20 C).

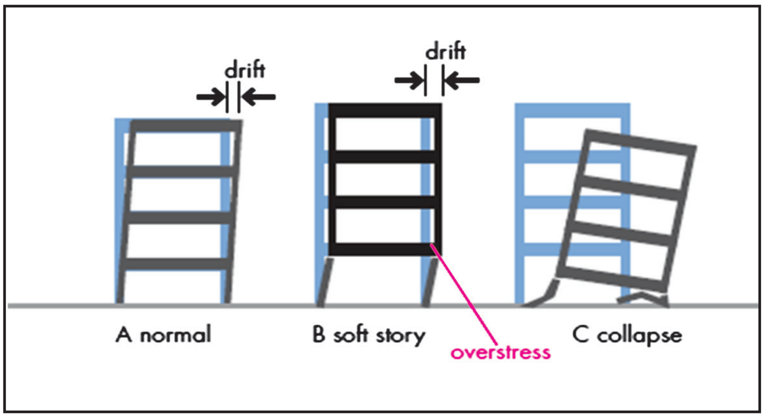


Figure 3-20 The Soft First Storey Failure Mechanism

Reference: [Designing for Earthquakes, FEMA, p. 5-14]

Figure 3-21 Olive View Hospital, San Fernando Earthquake, 1971, showing the extreme deformation of the columns above the plaza level.
Reference: [Designing for Earthquakes, FEMA, p. 5-19]

Basic principles for the seismic design of buildings

Avoid soft-storey ground floors!

Many building collapses during earthquakes may be attributed to the fact that the bracing elements, e.g. walls, which are available in the upper floors, are omitted in the ground floor and substituted by columns. Thus a ground floor that is soft in the horizontal direction is developed (soft storey). Often the columns are damaged by the cyclic displacements between the moving soil and the upper part of the building. The plastic deformations (plastic hinges) at the top and bottom end of the columns lead to a dangerous sway mechanism (storey mechanism) with a large concentration of the plastic deformations at the column ends.
A collapse is often inevitable.

4/1 This sway mechanism in the ground floor of a building under construction almost provoked a collapse (Friaul, Italy 1976).

4/2 Sway mechanisms are often inevitable with soft storey ground floors (Izmit, Turkey 1999).

4/3 Here the front columns are inclined in their weaker direction, the rear columns have failed completely (Izmit, Turkey 1999).

Figure 3-22 Soft Storey Failure

<Way of Improving the for Soft Storey Condition>

When the soft storey is the ground floor for providing car parking, the following measures can be taken to improve the performance of the structural system;

- Providing confined masonry walls as much as possible to provide stiffness to columns.
- Providing shear walls/bracings, placed symmetrically in both directions of the buildings as far as feasible and away from the center of the buildings, and
- In another solution is to provide L, T, + shaped columns at ground floor as shown in Figure 3-23.

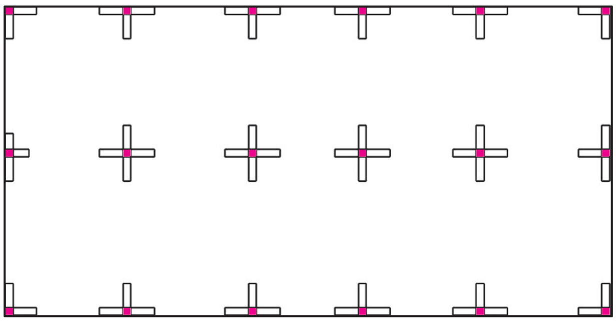


Figure 3-23 Soft Storey Improvement by using L, T, + shape columns at ground floor

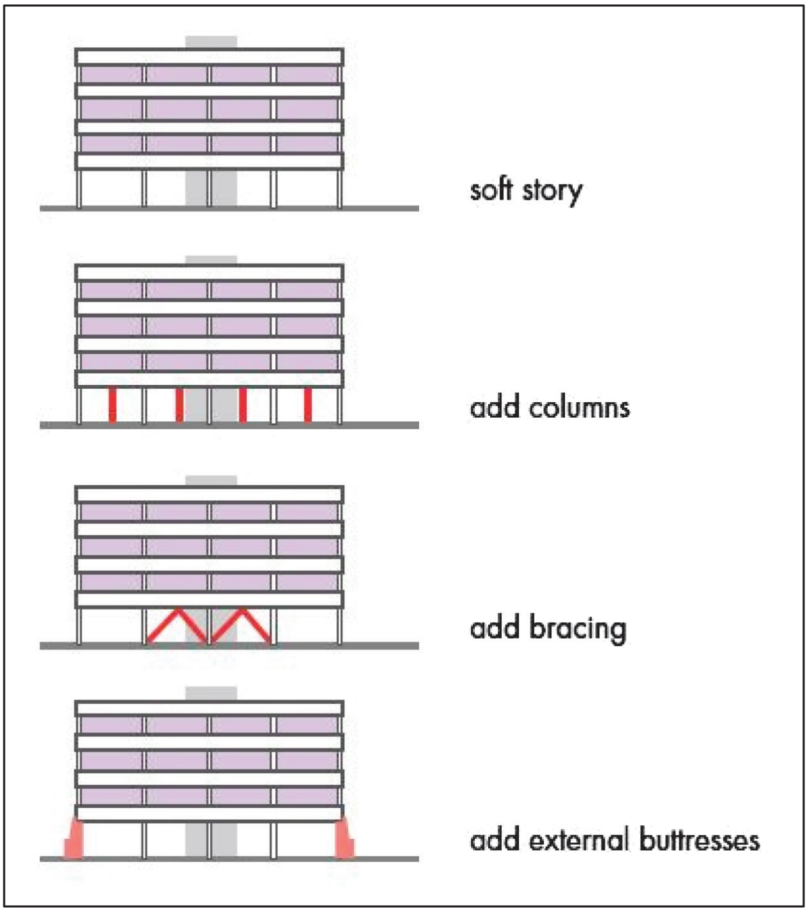


Figure 3-24 Some Conceptual Solution to Soft First Storey

Reference: [Designing for Earthquakes, FEMA, p. 5-17]

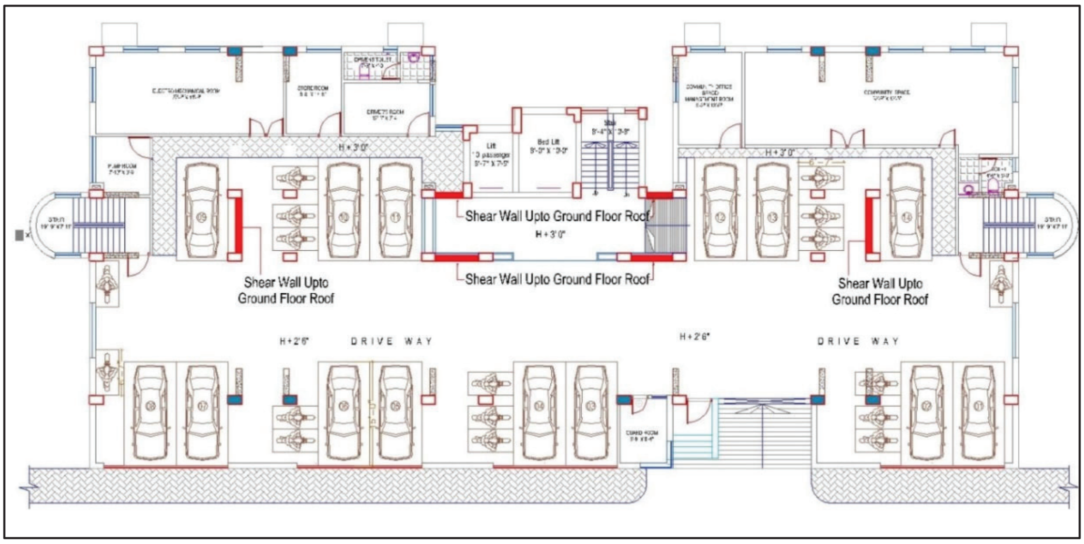


Figure 3-25 Provision for Column Connecting Shear Wall up-to Ground Floor Roof for Soft Storey Improvement

(ii) Mass Irregularity

The seismic weight of any storey is more than twice of that of its adjacent storeys (Figure 3-26). This irregularity need not be considered in the case of roofs. [Sec 2.5.5.3.2 (ii), Chapter 2, Part VI, BNBC 2020]

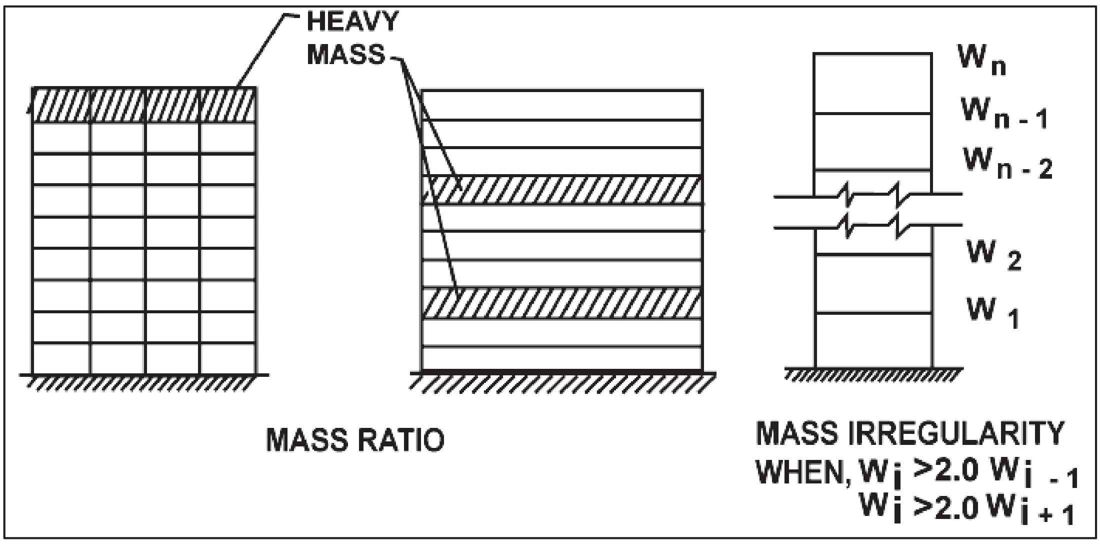


Figure 3-26 Mass irregularity

Reference: [Figure 6.2.28 (b), Chapter 2, Part VI, BNBC 2020]

(iii) Vertical Geometric Irregularity

This irregularity exists for buildings with setbacks with dimensions given in Figure 3-27. [Sec 2.5.5.3.2 (iii), Chapter 2, Part VI, BNBC 2020]

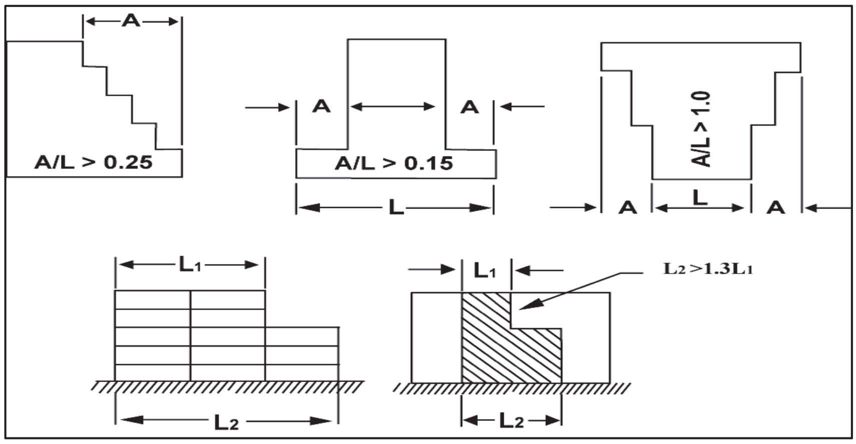


Figure 3-27 Vertical Geometric Irregularity (setback structures)
[Reference: Figure 6.2.28 (c), Chapter 2, Part VI, BNBC 2020]

(iv) Vertical In-Plane Discontinuity in Vertical Elements Resisting Lateral Force

An in-plane offset of the lateral force-resisting elements greater than the length of those elements. (Figure 3-28) [Sec 2.5.5.3.1 (iv), Chapter 2, Part VI, BNBC 2020]

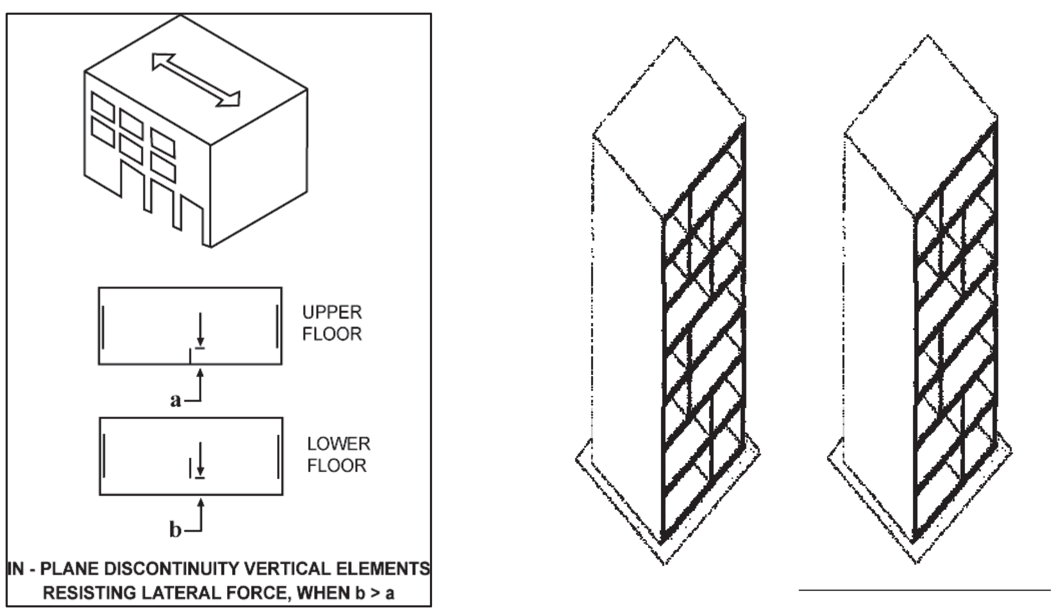


Figure 3-28 Vertical In-Plane Discontinuity in Vertical Elements Resisting Lateral Force
[Reference: Figure 6.2.28 (d), Chapter 2, Part VI, BNBC 2020]

(v) Discontinuity in Capacity - Weak Storey

A weak storey is one in which the storey's lateral strength is less than 80% of that in the storey above. The storey's lateral strength is the total strength of all seismic force-resisting elements sharing the storey shear in the considered direction (Figure 3-29 (a)). An extreme weak storey is one where the storey's lateral strength is less than 65% of that in the storey above. [Sec 2.5.5.3.2 (v), Chapter 2, Part VI, BNBC 2020]

(a) (b)

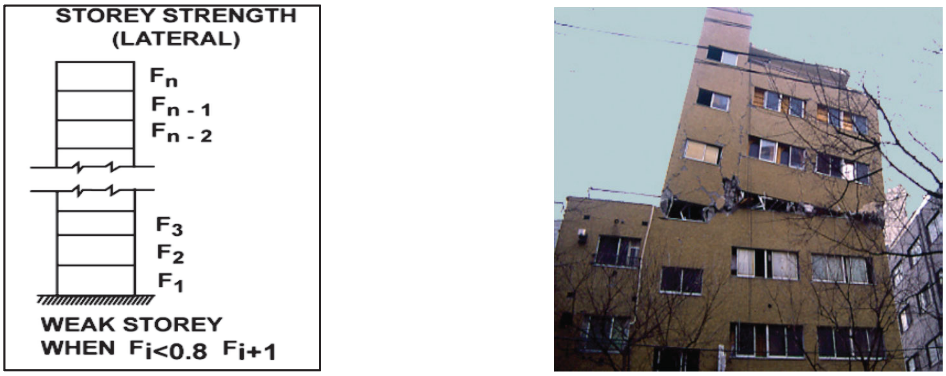
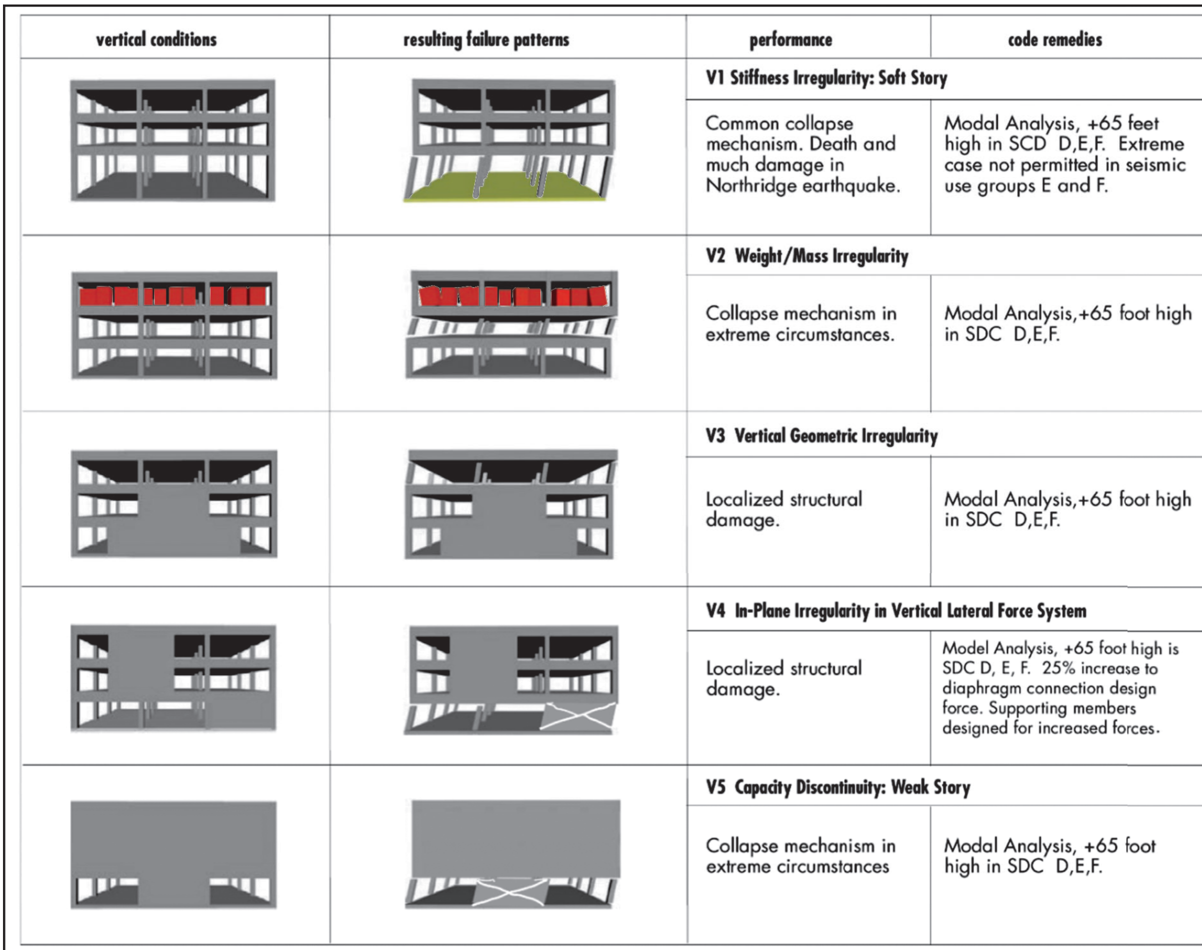


Figure 3-29 (a) Weak Storey [Reference: Figure 6.2.28 (e), Chapter 2, Part VI, BNBC 2020]
(b) Damaged Weak Storey during Hanshin Awaji Earthquake, 1995
[Reference: Designing for Earthquakes, FEMA p.5-32]



vertical conditions	resulting failure patterns	performance	code remedies
		V1 Stiffness Irregularity: Soft Story	
		Common collapse mechanism. Death and much damage in Northridge earthquake.	Modal Analysis, +65 feet high in SCD D,E,F. Extreme case not permitted in seismic use groups E and F.
		V2 Weight/Mass Irregularity	
		Collapse mechanism in extreme circumstances.	Modal Analysis,+65 foot high in SDC D,E,F.
		V3 Vertical Geometric Irregularity	
		Localized structural damage.	Modal Analysis,+65 foot high in SDC D,E,F.
		V4 In-Plane Irregularity in Vertical Lateral Force System	
		Localized structural damage.	Model Analysis, +65 foot high is SDC D, E, F. 25% increase to diaphragm connection design force. Supporting members designed for increased forces.
		V5 Capacity Discontinuity: Weak Story	
		Collapse mechanism in extreme circumstances	Modal Analysis, +65 foot high in SDC D,E,F.

Figure 3-30 Resulting Failure Pattern of Vertical Irregularity
[Reference: Designing for Earthquakes, FEMA, p.5-13]

3-4-3 Some Referential Information on Different Irregularities and Layouts of Buildings

Earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path. Any deviation or discontinuity in this load transfer path results in poor performance of the building. Buildings with vertical setbacks cause a sudden jump in earthquake forces at the level of discontinuity.

Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse, which is initiated in that storey. Buildings on the sloppy ground have unequal height columns along the slope, which causes twisting and damage in shorter columns that hang or float on beams have discontinuity in load transfer. Buildings in which RC walls do not go all the way to the ground but stop at upper levels get severely damaged.

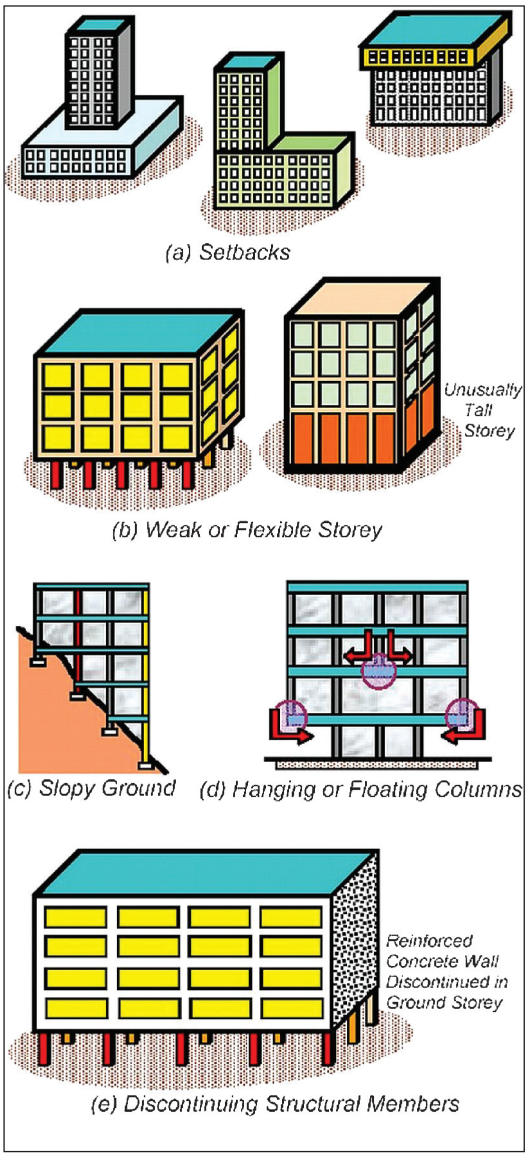


Figure 3-31 Vertical Layout of Buildings: Sudden Deviation in Load Transfer Path Along the Height Lead to Poor Performance of Building

Reference [Earthquake Tips- learning earthquake design and construction, Murty, C.V.R, 2005, IITK]

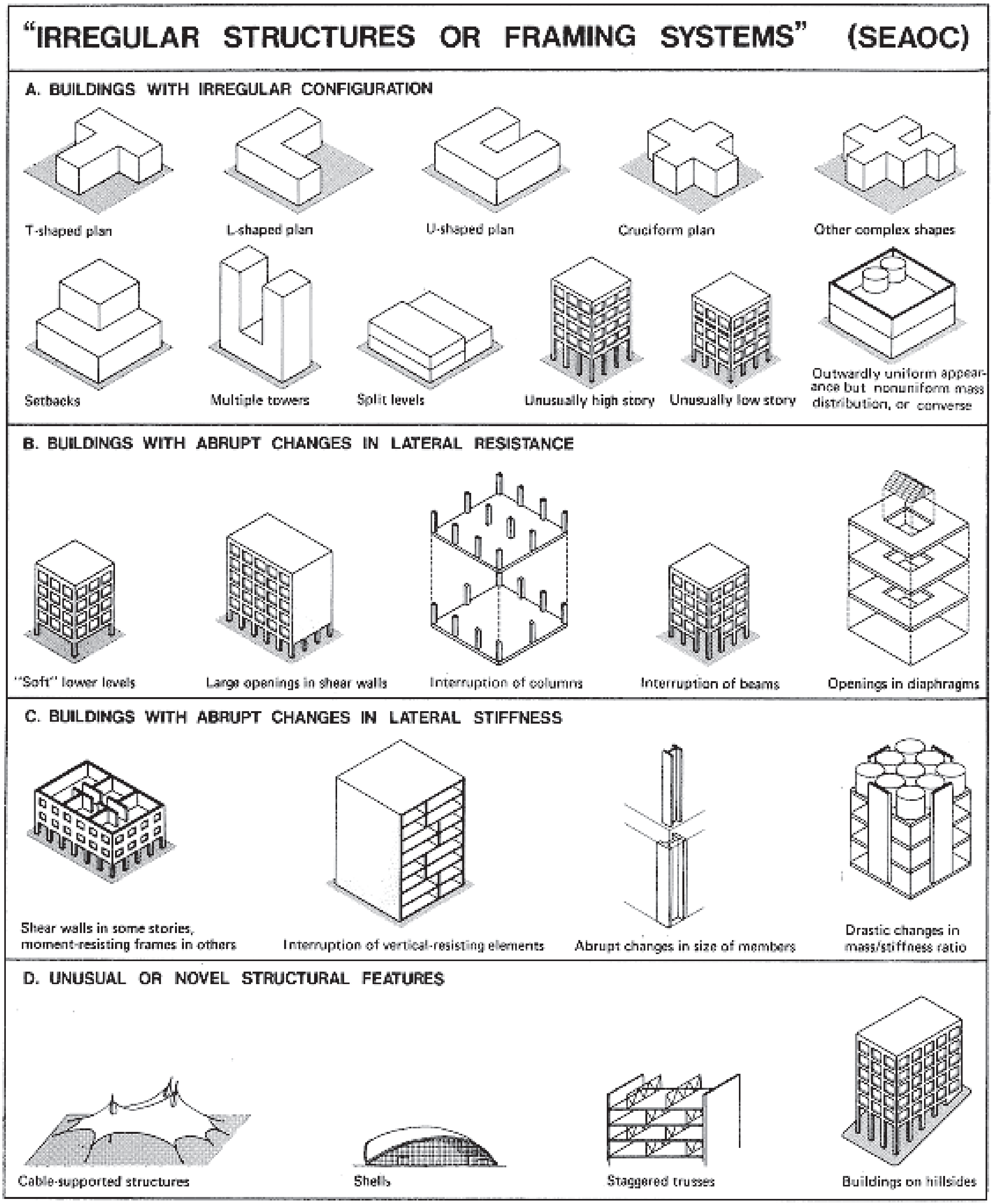


Figure 3.32: Irregular Framing Patterns

[Reference: "Recommended Lateral Force Requirements and Commentary" by Structural Engineers Association of California (SEAOC))]

3-5 Non-Structural Walls: Those Likely to Cause Structural Damage

Against the shaking of an earthquake, there are cases where the column itself does not collapse as it sways and bends. In the case of a structure with only one column without a wall. However, when the walls are joined to the column, the walls interfere with the curvature of the column, so horizontal forces concentrate on the column and the column may be destroyed. In order to prevent the failure of the column against such horizontal force, it is effective to make a slit between the columns (seismic slit reinforcement). The longer the columns are, the higher the toughness (tenacity), but the shorter the column, the lower the toughness and the larger the shear force.

Therefore, by taking such measures against seismic force, the toughness of the column can be improved and secured. Also, even if the building is damaged, the pillars can prevent the building from collapsing and save lives.

(i) Captive Columns / Short Column

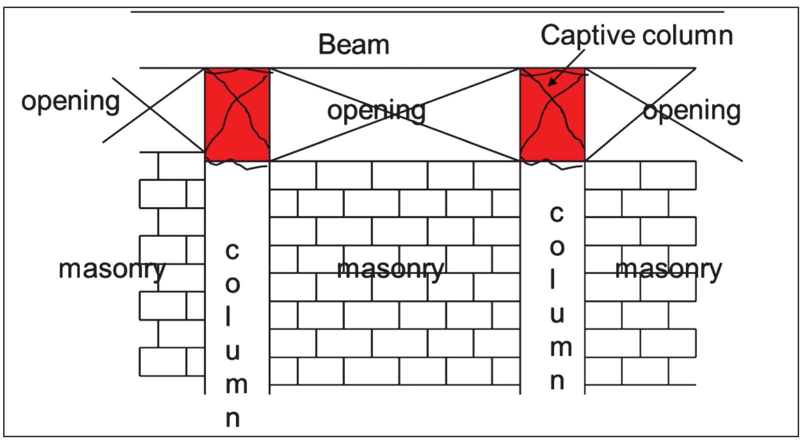


Figure 3-33 Captive Column Condition

<Solution for the Captive Column>

Provide masonry walls on either side equal to twice the opening sizes by reducing the openings but less than 0.6 meter. (See Figure 3-34)

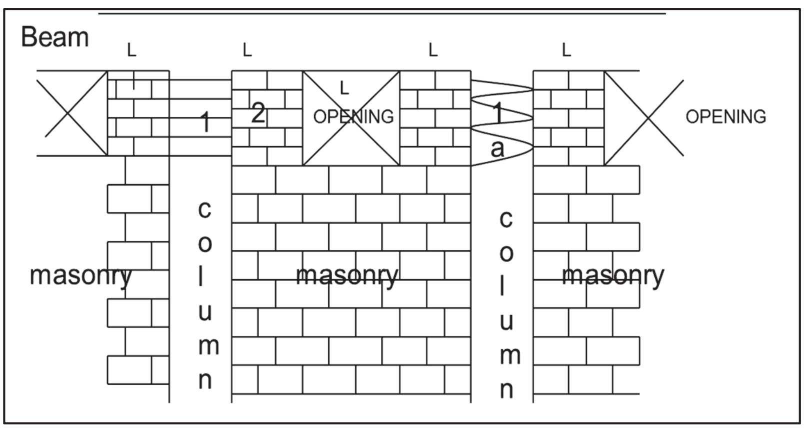


Figure 3-34 Captive Column Solution

Figure 3-35 Captive Column Failure, Japan, Miyagi-ken-oki, 1978

(ii) Improved Column Performance with Slit

To prevent a shear fracture, slit or a joint can be provided between the pillars, beams and the non-structural walls of reinforced concrete buildings. After providing slit or joint the wall which don't have the window will function as a load-bearing wall and that wall must be designed for lateral stability against wind and earthquake loads.

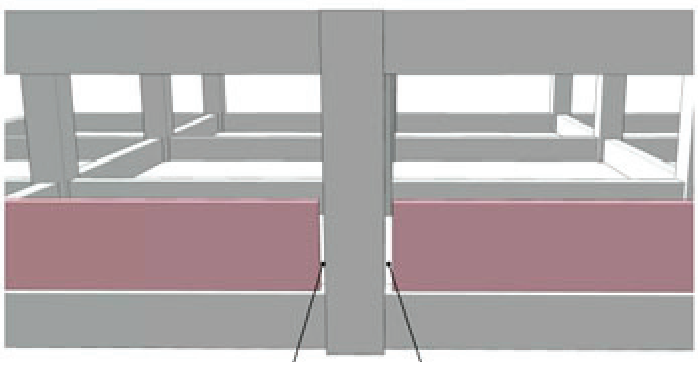


Figure 3-36 Slit for the Prevention of Shear

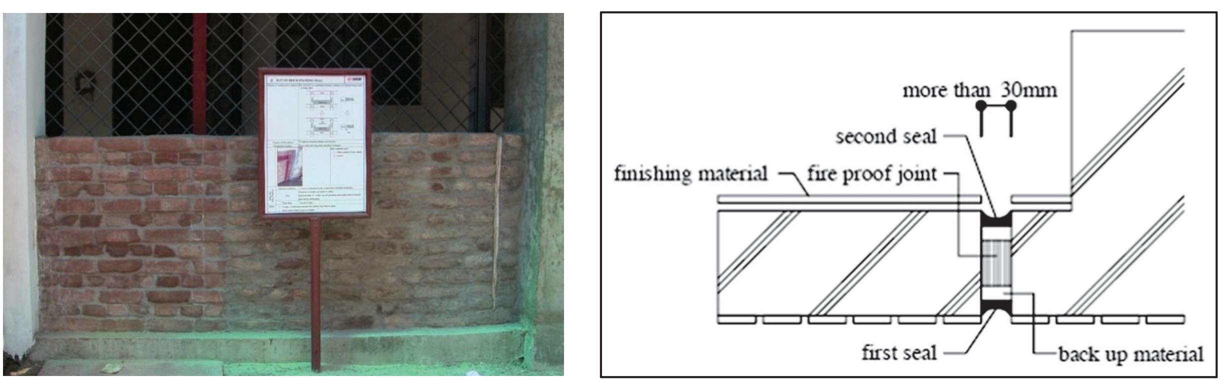


Figure 3-37 Slit for the Prevention of Shear Fracture

3-6 Need for Building Separation

The objectives of building separation are (i): To minimize the force and hence the damage probability due to temperature variation and (ii): To minimize the plan irregularity. Exact details of dimensions and efficient details of expansion joint are important for damage prevention, function, and appearance.

(i) Separation Gap for Temperature Variation

Although there is no clear guideline in BNBC 2020 regarding the requirement of temperature gap, according to IS-456:2000, structures exceeding **45m** in length are to be designed with one or more expansion joints. As per IS-3414, which is a specific code for joints, it is mentioned as **30m**. It may be noted that as per BNBC 2020, all land area of Bangladesh has some level of seismicity [Appendix B, Part VI, BNBC 2020]. Hence the temperature gap in a buildings need to follow the seismic separation requirement.

(ii) Seismic Separation

According to [Sec 2.5.14.3, Chapter 2, Part VI, BNBC 2020], Buildings shall be protected from earthquake - induced pounding from adjacent structures or between structurally independent units of the same building, maintaining a safe distance between such structures as follows,

a) For buildings, or structurally independent units, that do not belong to the same property, the distance from the property line to the potential points of impact shall not be less than the computed maximum horizontal displacement of the building at the corresponding level.

b) For buildings, or structurally independent units belonging to the same property, if the distance between them is not less than the square root of the sum - of the squares (SRSS) of the computed maximum horizontal displacements of the two buildings or units at the corresponding level.

c) If the floor elevations of the building or independent unit under design are the same as those of the adjacent building or unit, the above-referred minimum distance may be reduced by a factor of 0.7.

It is to be noted that the seismic separation requirement depends on the location of the building with respect to the seismic zone as defined in [Sec 2.5.4, Chapter 2, Part VI, BNBC 2020] as well as the building occupancy category. For better understanding of the Architects, the above requirements can be simplified as below,

a)' The minimum distance of any part of the building from the property line shall not be less than 0.01H, where H is the total height of the building.

b)' The minimum seismic separation for buildings within the same property shall not be less than 0.014 H, where H is the height of the lower height building.

c)' If the floor height of the adjacent buildings is the same, the above separations can be reduced by a factor of 0.7.

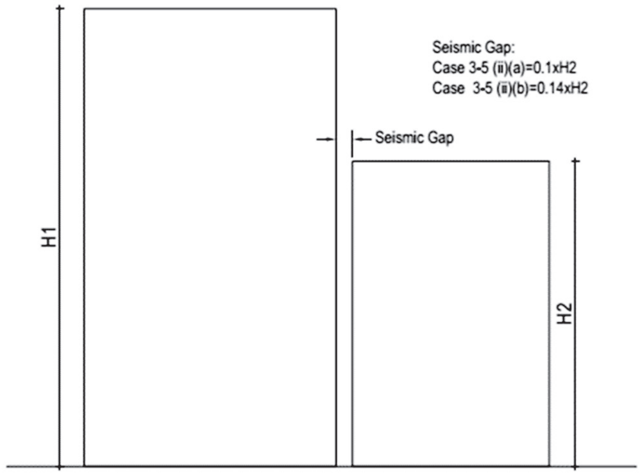


Figure 3-38 Building Separation requirement

Figure 3-39 Damage caused by Hammering of Adjacent Buildings due to Inadequate Separation in 1985 Mexico Earthquake

[Reference: Design of Concrete Structure, 14th Edition by Arthur H. Nilson]

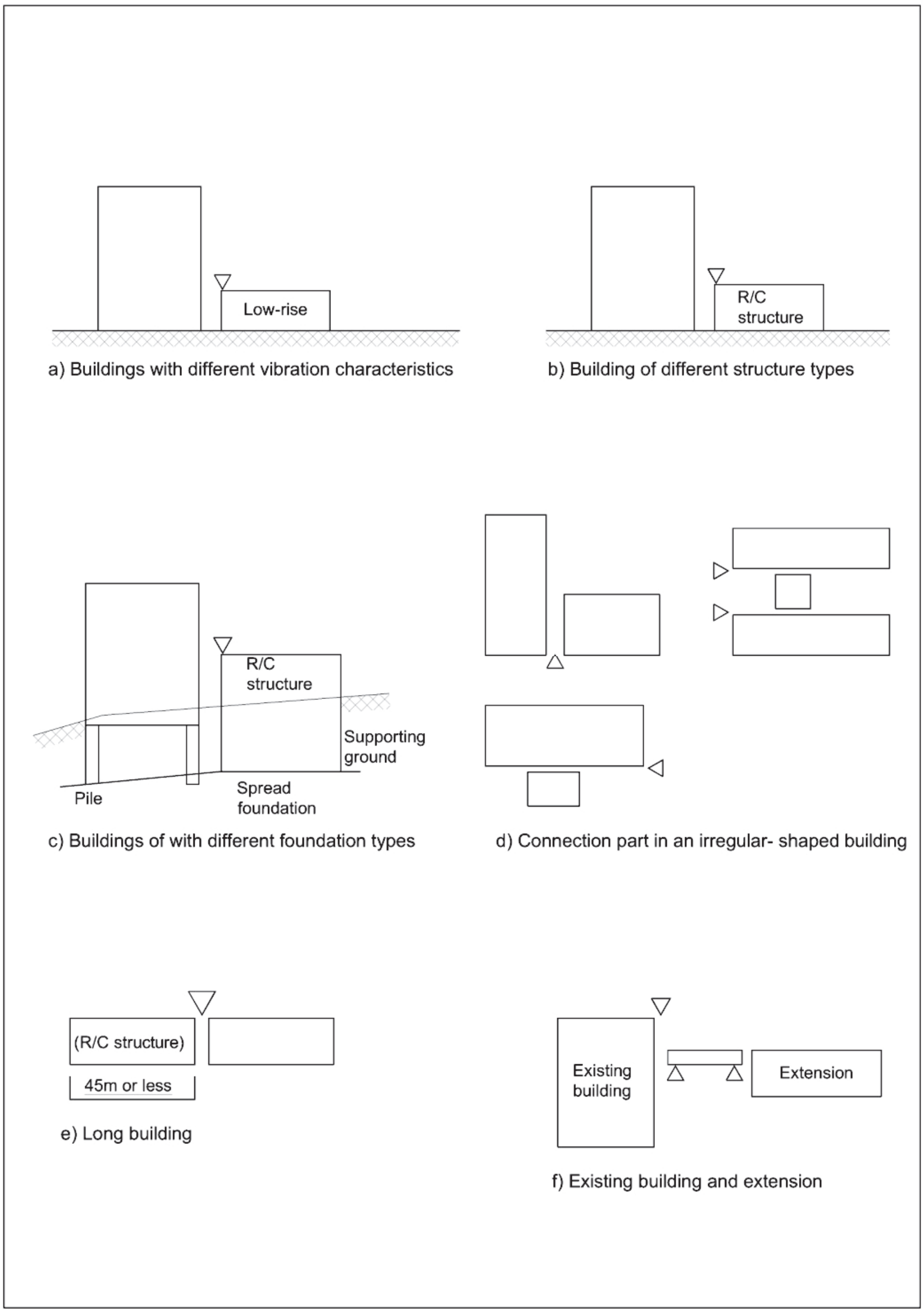


Figure 3-40 Separation of Buildings

3-7 Structural Members Sizing and some Relevant Issues

(i) Minimum Dimension of Flexural Members (Beam)

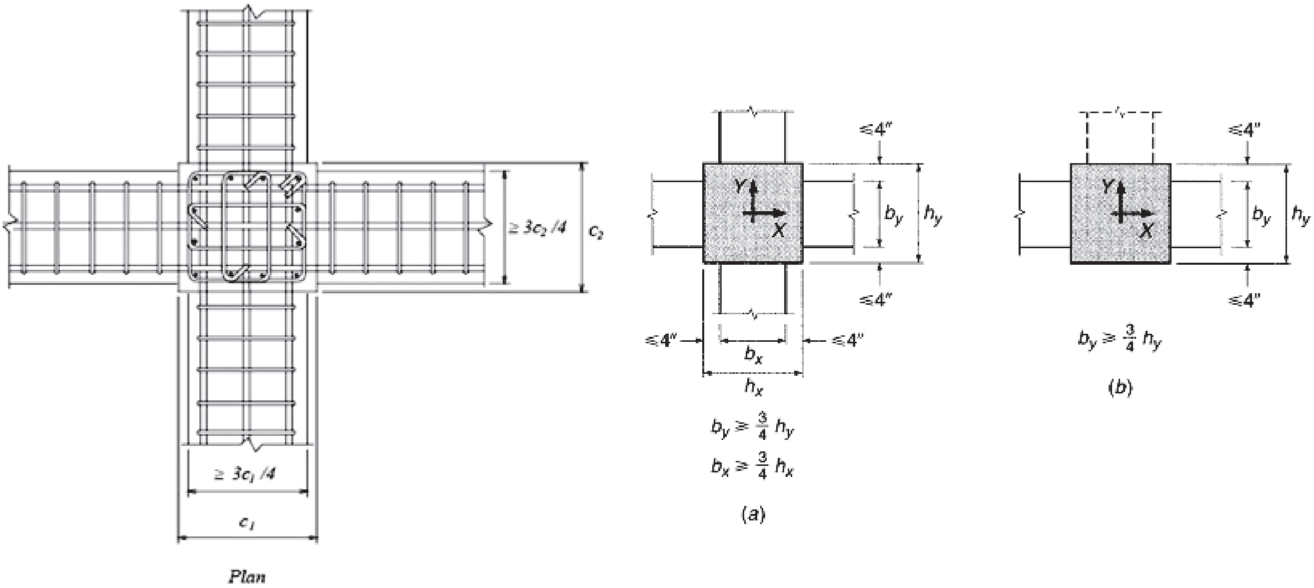


Figure 3-41 Minimum Beam Width with respect to Column Width to reduce Rebar Congestion and to improve Joint Performance

[Reference: Figure 6.8.16, Chapter 8, Part VI, BNBC 2020]

Requirements of this section shall apply to special moment frame members; (i) resisting earthquake-induced forces, and (ii) proportioned primarily to resist flexure. These frame members shall also satisfy the following conditions. The requirements are also shown in Figure 3-41.

a) Clear span for the member, l_n shall not be less than four times its effective depth.

b) The width to depth ratio shall be at least 0.3.

c) The width shall not be (i) less than 250 mm and (ii) more than the width of the supporting member (measured on a plane perpendicular to the longitudinal axis of the flexural member) plus distances on each side of the supporting member neither exceeding three-fourths of the depth of the flexural member C_1 nor width of supporting member C_2 as shown in Figure 3-41.

(ii) Minimum Dimension of Flexural and Axial Members (Column)

a) The shortest cross-sectional dimension shall not be less than 300 mm.

b) The ratio of the shortest cross-sectional dimension to the perpendicular dimension shall not be less than 0.4.

However, for end and corner columns, to provide the required development length for beam re-bars minimum column dimension shall not be less than as mentioned in figure 3-42 (a) and for interior columns the minimum column dimension shall not be less than 20 times the largest diameter of main bars used for the flexural member (Beam) as shown in Figure 3-42 (b).

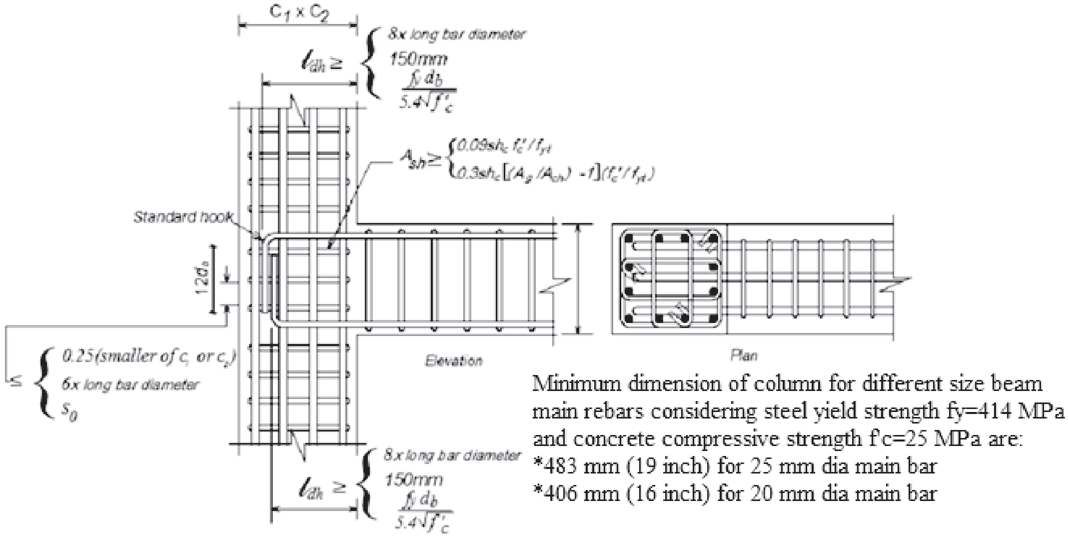


Figure 3-42 (a) Minimum Column Size Requirement for Exterior and Corner Column

[Reference: Figure 6.8.15, Chapter 8, Part VI, BNBC 2020]

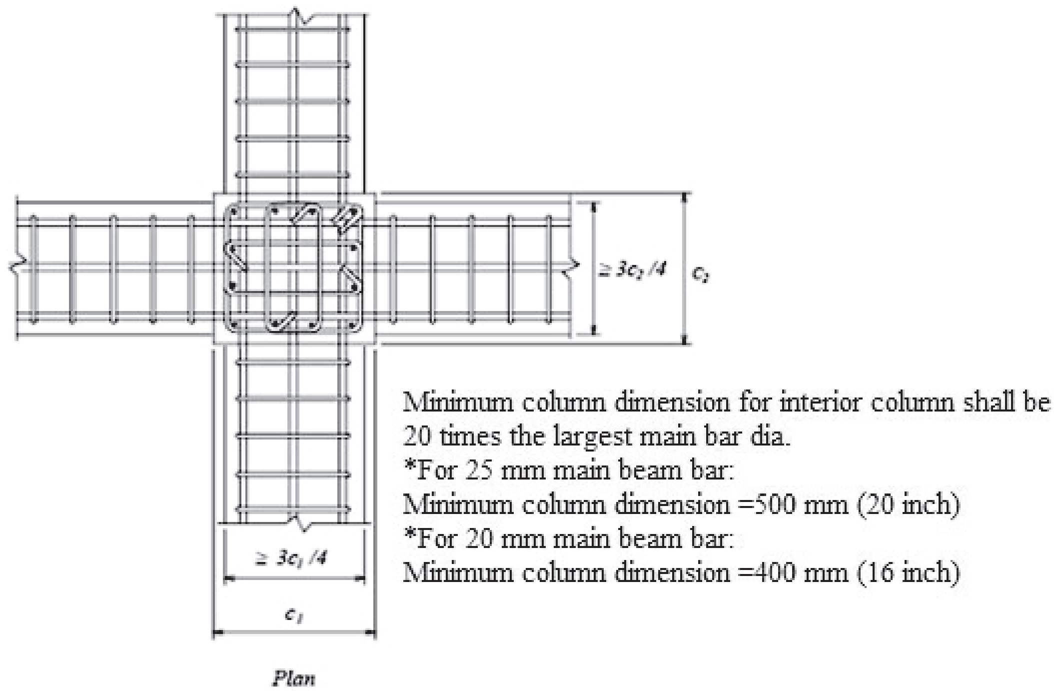


Figure 3-42 (b) Minimum Column size requirement for interior column

[Reference: Figure 6.8.16, Chapter 8, Part VI, BNBC 2020]

(iii) Need for Continuity of Beams

Discontinuous beams tend to create abrupt changes in strength or stiffness that may concentrate forces in an undesirable way. Sudden changes in alignment of beam alignment for reasons like adequate punch width, infill/ partition wall layout etc. are undesirable. Such changes in alignment causes rebar congestion at the beam-column joint hence poor concreting.

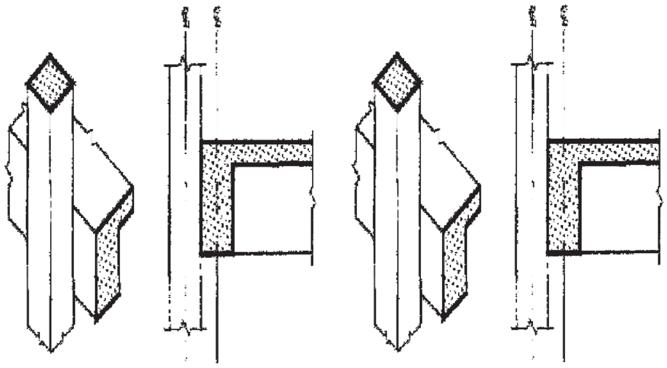


Figure 3-43 Eccentric Load Paths Created by Architectural Detailing of Structural Connection

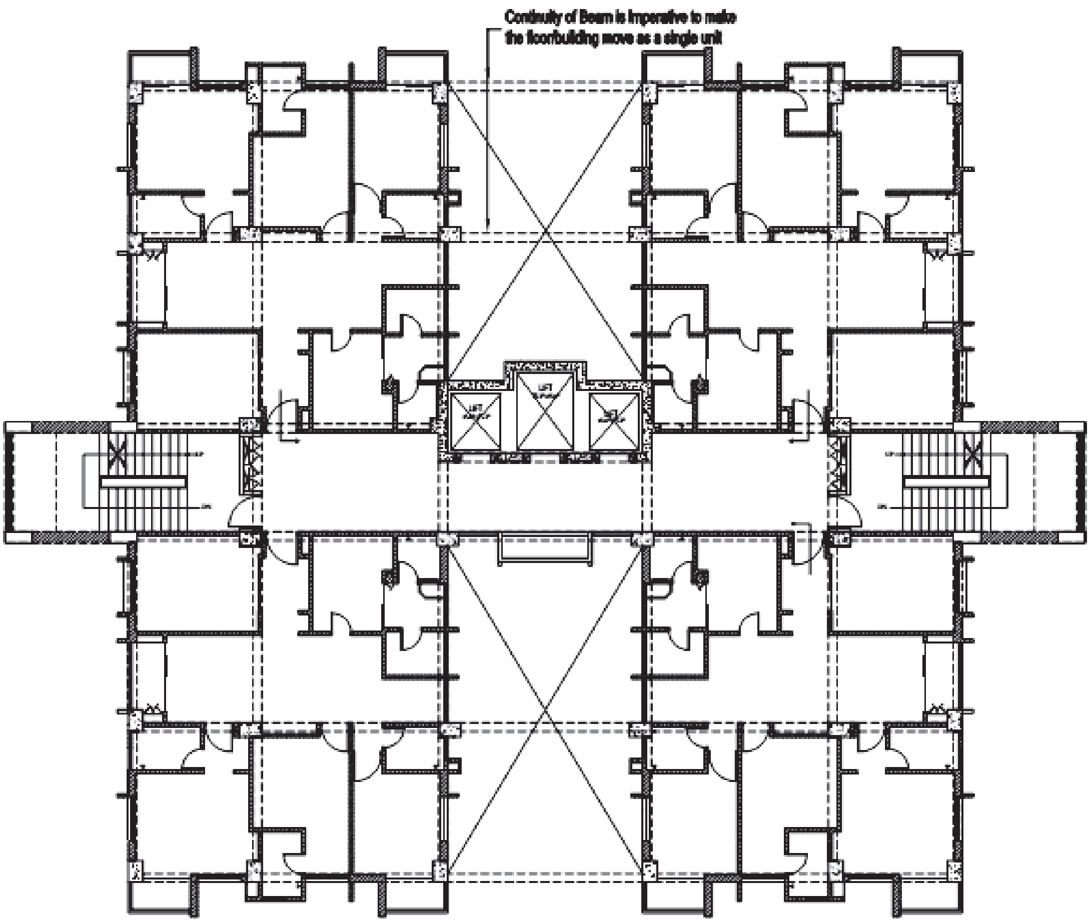


Figure 3-44 Beam Continuity Requirement when Diaphragm Discontinues

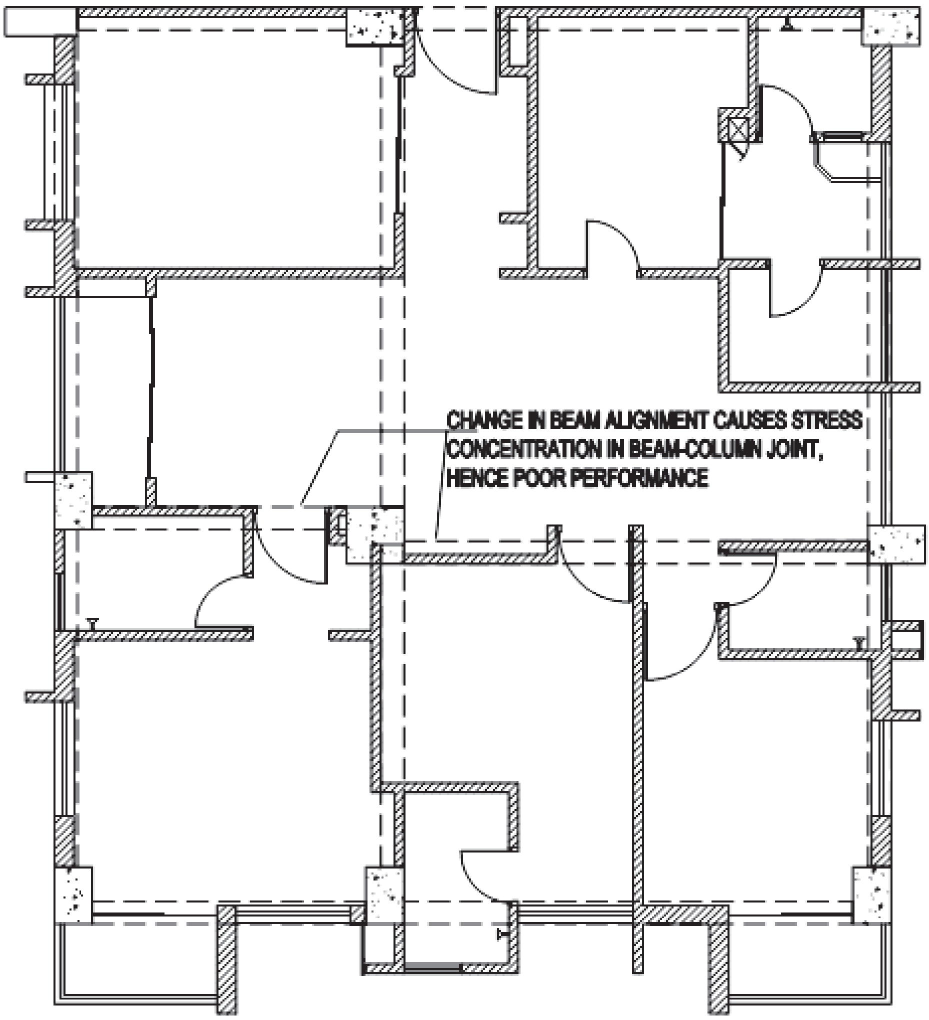


Figure 3-45 Beam Continuity Requirement through the Column

(iv) Location and Size of Slab Opening

Opening in slab should be as minimum as feasible and should not be located adjacent to lateral load resisting elements like shear wall/core wall or bracing.

(v) Interval of Columns

In general, columns spacing at 6.0~ 7.0 m provides optimum cost for concrete structure and 8.0~9.0 m span for steel multi-storied building (Structural Analysis and Design of Tall Building Structures by B.S Taranath). Short spans of columns provide low unit stress in members. Multiple columns providing redundancy loads can be redistributed if some columns are lost.

(vi) Seismic Resisting Element along Perimeter

Since ground motion is essentially random in direction, the resistance system must protect against shaking in all directions. In a rectilinear plan building, the resistance elements are most effective when placed along the perimeter of the building in a symmetrical arrangement as shown in Figure 3-46, which provides balanced resistance.

(vii) Perforated Shear Wall

Another undesirable condition is when a shear wall is perforated by aligned openings for doors, windows and the like, so that its integrity may be compromised. Careful analysis is necessary to ensure that a continuous load path remains without a significant loss of horizontal shear capacity.

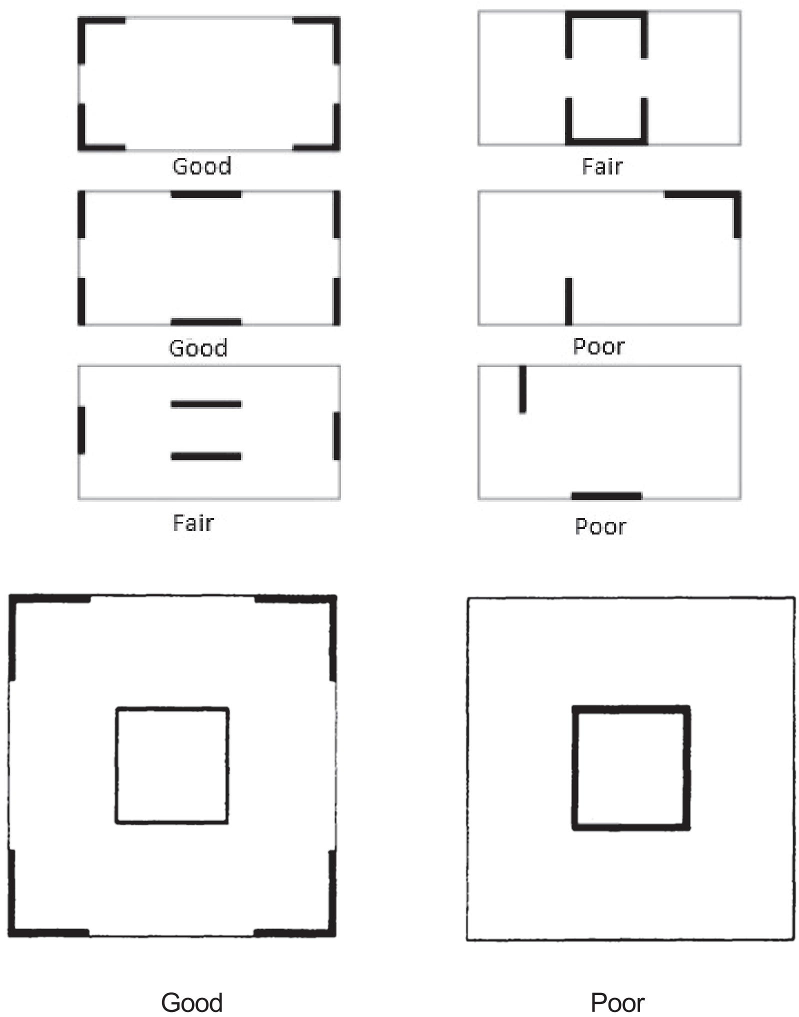


Figure 3-46 Shear Wall Layout
Reference [The Seismic Design Handbook, Second Edition, Edited By Farzad Naiem]

CHAPTER 4 Building Services Design Considering the Safety Issues

4-1 Introduction- Consideration for Design of Building Services Related to Safety

In design for building services, we optimize the environment and energy in buildings and structures to design a comfortable indoor environment. Basically, design for the building services such as electrical, mechanical and plumbing are carried out by separate specialist Engineers.

However, in consideration with the overall plan, it is necessary that the Architect is knowledgeable about the building services. He/she should coordinate with the engineers (both Civil Engineers and EM & P Engineers) during the architectural design phase and should also consider the future maintenance issues of the equipment to be installed in the building.

In Chapter 4, discusses the points to be considered when designing a building services and to consider the seismic and the fire safety issues.

4-2 Electrical Design for Safety

Proper design of an electrical system can reduce the risk associated with the use of electricity and electrical equipment at an acceptable level. Electric current flowing through the cabling systems is partially converted to heat. Since the amount of heat generated evolves quadratically to the current intensity, the resulting temperature rise will be more significant during circuit overload, and can be very dramatic and hazardous in short circuit conditions. Depending on the environmental conditions and the materials in contact with the cabling system, such elevated temperatures can act as an ignition source, causing a fire.

4-2-1 Electrical Control Design

- During the architectural planning, it is important to secure the space for the Main Distribution Board (MDB) and the Sub Distribution Board (SDB) and to think about their placement.
- The Location of distribution boards (MDB / DB / SDB) should be as near as possible to the center of the load.
- An electrical control room which has the size of 8ft x 6ft should be provided adjacent to electrical duct on each floor of those buildings for the electrical control panel and electricians/attendants.
- The following places are not suitable for the installation of the distribution board,
  - ✓ Exterior wall
  - ✓ Shear wall
  - ✓ Place where the maintenance is difficult
  - ✓ Kitchen, Bathroom
  - ✓ A room using fire or gas
  - ✓ Stair room, Staircase landing

For details, please see [Sec1.3.29, Chapter 1, Part VIII, BNBC 2020].

Figure 4-1 Electrical control room

4-2-2 Electrical Duct and Cabling Route

One of the most common causes of fire is the occurrence of the electrical disorder. It should therefore, be designed incorporating Engineer's advice as follows.

- The electrical duct should be separated from the sanitary duct.
- Separate duct may be installed for PABX, Fire, Signal cable etc.
- For High rise buildings (exceeding 20 m height), there should be minimum of one electrical duct (200mm x400mm) for every 1500 m2 floor area. It is required for lifting the electrical cables at different floors, communication cables, fire alarm and signal cables etc.
- The cabling route shall be designed so that it remains visible and easy to maintain.
- A Considerable size for cabling space.
- Installation of protective tubes (Plastic Flexible Conduit tube or metal tube) to protect the wiring.

Figure 4-2
Exposed Cable Lines and Pipe Lines

4-2-3 Sub-station and Generator Room as Emergency Power Supply

The capacity of sub-station can be worked out from the type of occupancy of building, floor area, % of AC area, lift, pump, compound load & other load etc. (Table 4-1)

Table 4-1 Minimum Load Densities

Type of Occupancy	Unit load (Watts / m2 Covered Area	
	Non Air Conditioner	Air Conditioner
Residence / Dwelling: Single family	20	75
Residence / Dwelling: Multi-family (other than Hotels)	20	75
Hospitals	32	80
Hotels, including apartment house (excluding any provisions for electric cooking)	24	75
Office and commercial multistoried buildings	28	75
Industrial buildings (excluding the loads for machines)	16	-
Departmental stores	28	75
Banks	20	75
Restaurants (excluding any provisions for electric cooking)	16	75
Barber shops and beauty parlors	32	75
Schools and colleges	12	70
Parking area in commercial buildings	4	-
Warehouses, large storage areas	2	-

Reference: [Table 8.1.17, Chapter 1, Part VIII, BNBC 2020]

- If the building load exceeds 50KW, then a sub-station will be required.
- A separate sub-station building is preferred for any project. The location of sub- station shall be at the load center of the complex.
- In case of a building complex or a group of buildings belonging to the same organization, the sub-station should preferably be located in a separate building and should be adjacent to the generator room, if any.
- If the sub-station is to be located in the main building, it must not be placed on the basement floor or lower floors, considering the case of flood damage. The same thing applies to the generator.
- The room size of the sub-station shall be sufficient enough, to accommodate the equipment of the sub-station as well as for the maintenance work, according to sub-station capacity. The same applies to the generator room. The areas required for "transformer Room" and "sub-station" for different capacities are mentioned in [Sec 1.3.18, Chapter 1, Part VIII, BNBC 2020]. (Table 4-3)
- The height of the sub-station room and generator room must not be less than 14 feet.
- It is important to maintain the generator on a regular basis so that it can be used immediately as a standby power supply in case of emergency.

Table 4-2 Area Requirement for Stand by Generator Room

Capacity (K watt)	Area (m^2)
1 x 25	20
1 x 48	24
1 x 100	30
1 x 150	36
1 x 300	48
1 x 500	56

Reference: [Table 8.1.24, Chapter 2, Part VIII, BNBC 2020]

Figure 4-3 Generator Room

Table 4-3 Area Required for Transformer Room and Substation for Different Capacities

Capacity of Transformer (KVA)	Transformer Room Area (m^2)	Total Sub-station Area With H.T , LT panels & transformer room but without Generator (m^2)
1 x 150	12	45
1 x 250	13	48
2 x 250	26	100
1 x 400	13	48
2 x 400	30	100
3 x 400	40	135
2 x 630	26	100
3 x 630	40	190
2 x 1000	40	180
3 x 1000	45	220

Reference: [Table 8.1.23, Chapter 1, Part VIII, BNBC 2020]

4-2-4 Emergency Light

If the generator cannot be operated due to fire or flood, the emergency lighting for evacuation guidance should function properly. Emergency lighting will be provided in living rooms and evacuation passages to ensure safe and smooth evacuation. The figure below shows an emergency light integrated battery and its installation example. Emergency lighting circuits should be isolated from all other cables.

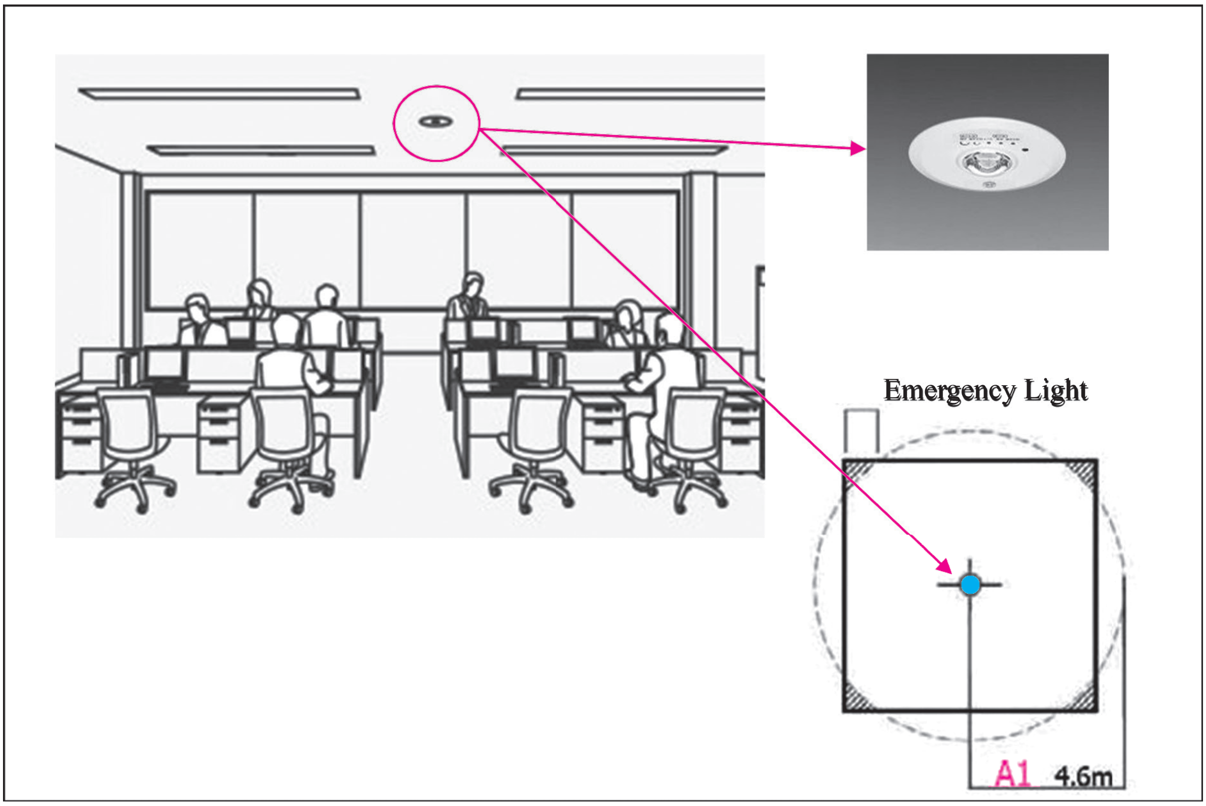


Figure 4-4 Layout of Emergency Lights

4-2-5 Referential Information

(iii) Light fitting

During design, an appropriate type of light fitting shall be selected to match the requirement of desired distribution of light. Light fittings may be classified into five categories according to the proportion of the total light output.

- Direct fittings, giving 90-100 percent light downwards
- Semi-direct fittings, giving 60-90 percent downwards
- General diffusing fittings, giving 40-60 percent light downwards
- Semi-indirect fittings, giving 10-40 percent light downwards
- Indirect fittings, giving 0-10 percent light downwards.

For more detail, please see [Sec 1.2.6.2, Chapter 1, Part VIII, BNBC 2020].

Before 2000, normal fluorescent light was used in every building but nowadays LED (Light Emitting Diode) lights are common. Due to its polycarbonate properties, it is energy efficient, flame-retardant and will not be damaged during a disaster.

Energy cost will be 1/7 (14.23%) and save maintenance jobs such as exchange of light, glow lamp and stabilizer.

Figure 4-5 Layout of LED

Recommended Values of Illumination for various types of buildings depends on its occupancy type and use.

For more detail, see [Table 8.1.5 to 8.1.13, Chapter 1, Part VIII, BNBC 2020].

(iv) Illumination of Exit Signs and Means of Escape

- All required exit signs should be illuminated at night or during dark periods within the area served.
- The intensity of illumination at floor level of means of escape shall not be less than 10 lux.
- The illumination of exit signs and the lighting of the means of escape and exit access shall be powered by an alternate or emergency electrical system to ensure continuous illumination for a duration of not less than 30 minutes after the failure of the primary power supply. For more information, please see [Sec 1.2.7, Chapter 1, Part VIII, BNBC 2020].

(v) Electrical Wiring in the Interior of Buildings

The electrical wiring system runs over in various ways in the interior of the building, such as

- Surface wiring or exposed wiring
- Concealed wiring
- Wiring inside suspended ceilings (false ceilings)
- Wiring through cable tray.

For more detail, please see [Sec 1.3.6, Chapter 1, Part VIII, BNBC 2020].

4-3 Mechanical Design for Safety

4-3-1 Ventilation, Air Intake and Exhaust: Natural, Mechanical Ventilation

Ventilation systems are roughly divided into "Natural ventilation" that uses wind power and the density difference (temperature difference) and "Mechanical ventilation" that uses a blowing machine.

(i) Type A: Natural Ventilation

By utilizing natural forces such as the difference of pressures, temperature difference and wind pressure, fresh air taken from the air inlet port placed at a low level, is circulated in the room and finally the stale air from the roof is discharged to ventilate the entire building. The air intake of these vents can be adjusted manually. - For the variations on "Natural ventilation", see the "Time Saver Standard for Architectural Design Data (Part I: Article 6: Natural ventilation)".

Natural (Passive) air supply + Natural (Passive) exhaust
Indoor air: Normal
Application: Residence (excluding toilet, bathroom), Office, etc.
Benefits: Low cost/ easy to install, Low maintenance
Disadvantages: Least energy-efficient, Limited control, Difficult to insulate acoustically
Considerations: Make the height difference between the air inlet port and the exhaust port.

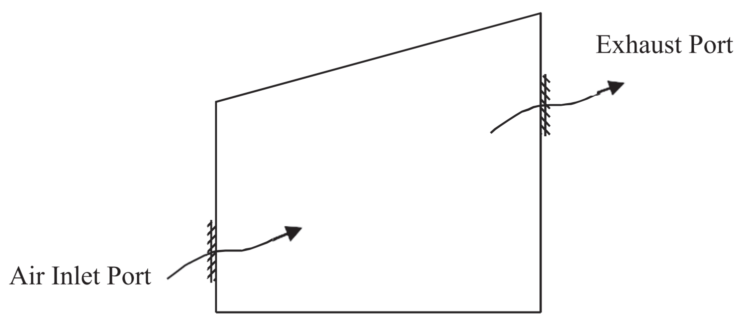


Figure 4-6 Passive Ventilation System Type A

(ii) Type B: Mechanical Ventilation

- **Type B-1: Intake and Exhaust by Mechanical Ventilation**

This system uses blowers and exhausts to automatically control ventilation. The air is supplied and exhausted by the fans. There is an advantage in this case that the pressure inside the room can be kept positive or negative relative to the external pressure.

By properly installing the ducts in the building, different air flows do not cross each other. Because of this, the same air is supplied to the vents in each room. [Sec 2.11.3, Chapter 2, Part VIII, BNBC 2020]

<u>Mechanical</u> supply + <u>Mechanical</u> exhaust
Indoor air: Positive or Negative pressure
Application: Office, Kitchen, Theater, Laboratory, etc.
Benefits: The level of ventilation can be controlled, Air flows are balanced, Possible to recover heat from exhaust air (using a heat exchanger)
Disadvantages: Difficult to clean up the dust accumulated in the duct,
Cost is high (Energy consumption of the fans),
May produce noise,
Requires more maintenance than other systems

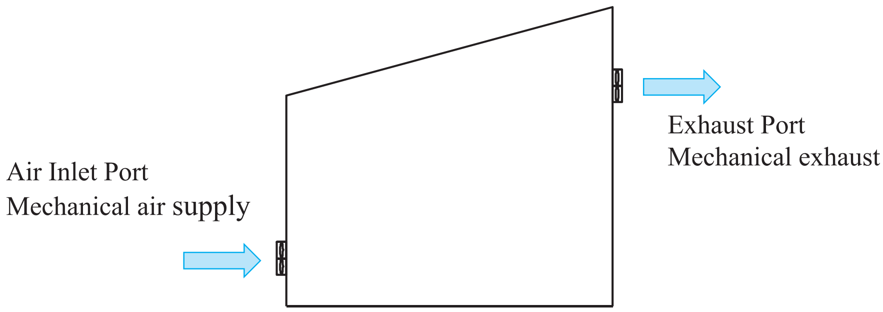


Figure 4-7 Mechanical Ventilation System Type B-1

- **Type B-2: Intake by Mechanical Ventilation and Exhaust by Natural Ventilation**

This type refers to a ventilation system in which outdoor air is taken into the room using mechanical equipment. The difference of pressure is used to discard air from the natural exhaust port installed indoors to the outside.

<u>Mechanical</u> air supply + <u>Natural (Passive)</u> exhaust
Indoor air: Positive pressure
Application: Boiler room, clean room (sterile room, operating room)
Benefits: Controlled supply of fresh air, Interesting solution for noisy environments, Location of the air supply can be chosen.
Disadvantages: Cost is high (Energy consumption of the fans)
Considerations: The indoor temperature and humidity environment is 100% affected by the outdoor environment.

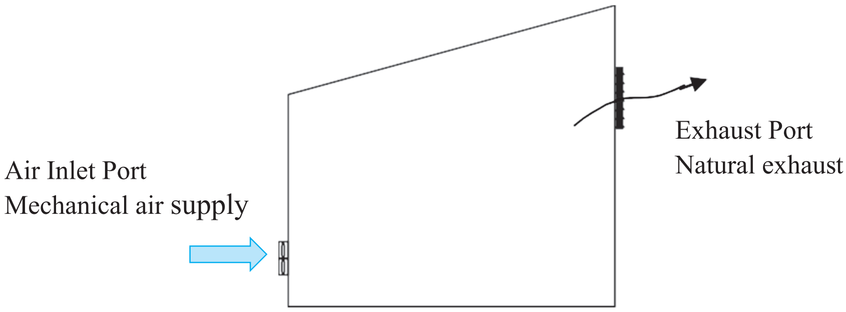


Figure 4-8 Mechanical Ventilation System Type B-2

- **Type B-3: Intake by Natural Ventilation and Exhaust by Mechanical Ventilation**

This type refers to a ventilation method in which indoor air is blown out using a ventilating device to the outside, and the differential pressure is used to take in outdoor air from a natural vent installed in the room. The room air is under negative pressure, and room air does not flow out even if the door of the entrance is opened.

Natural (Passive) exhaust + Mechanical air supply Indoor air: Negative pressure Application: Toilet, Bath room, Kitchen etc. Benefits: Better ventilation than type A, Location of the air exhaust can be chosen. More cheap than system type B-1 Disadvantages: Susceptible to outside temperature, Energy consumption of the fan Considerations: The indoor temperature and humidity environment is 100% affected by the outdoor environment.

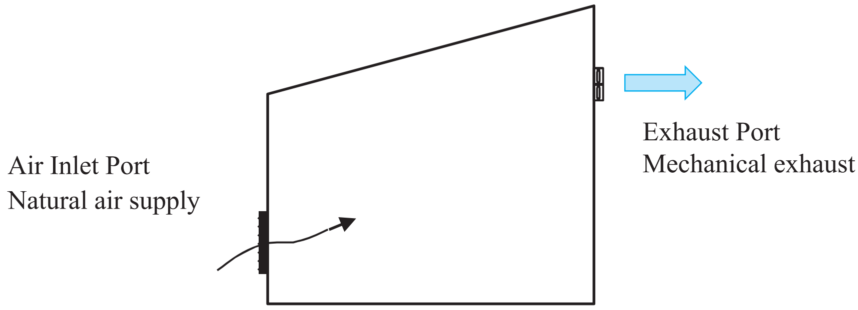


Figure 4-9 Mechanical Ventilation System Type B-3

4-3-2 Smoke Exhaust Window

Once a fire occurs, a large amount of smoke is emitted along with the flame. In that case, it is effective to install a smoke exhaust system to emit smoke for evacuation.

(i) Natural Smoke Exhaust

Figure 4-10 Smoke Flow in Case of Fire

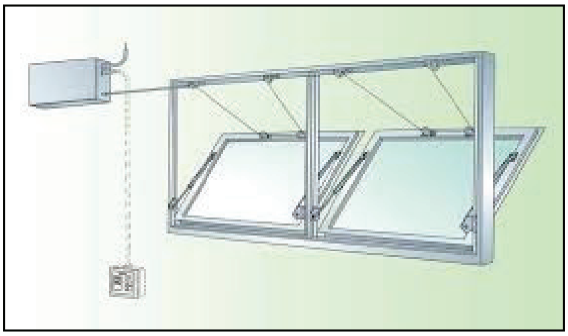


Figure 4-11 Smoke Exhaust Window

(ii) Mechanical Smoke Exhaust

In a mechanical smoke exhaust system, a large amount of smoke is forcibly released outdoors by mechanical power.
In the figure on the right, an air intake is provided on the ceiling surface, and smoke is emitted to the outside through a duct.

Figure 4-12 Smoke Exhaust

4-3-3 Air Conditioning

It is necessary to observe certain standards for the air environment in the building. For this object, the equipment related to air conditioning is designed to maintain the indoor environment, such as temperature and humidity, properly and to stay healthy and comfortable. The main points to be considered during the design phase are shown below:

- If central AC is required, then location/room for installing the chiller plant, cooling tower etc. must be selected first. For each chiller (more than 100 RT) minimum 500 sq feet area is required for chiller including VFD, control panel, chilled water pump and condensing water pump etc.
- The height of the central AC plant room must not be less than 16 feet. In the case of water-cooled chiller, separate space will be required for the cooling tower.
- In the case of central AC or ducted type AC, floor height should be minimum 13feet.
- Required arrangements should be provided for laying the ducts.
- The location of punches for central or ducted type air coolers should be marked in the architectural drawing.
- Location of outdoor units of air conditioning system must be selected so that the aesthetic view of the building is not hampered.
- Height for HVAC (Heating Ventilation and Air Conditioning) - Floor to bottom height of the suspended beam is as follows,
    - ✓ Minimum height should be 10 ft.
    - ✓ Minimum 2 ft. for duct run
    - ✓ Total Minimunm10’ + 2’=12 ft.

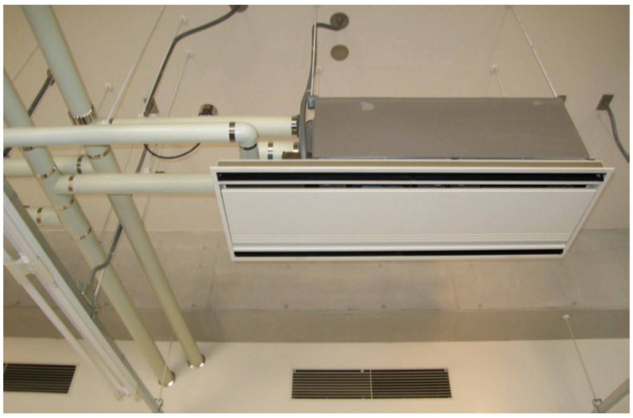


Figure 4-13 Air Duct

4-3-4 Equipment Space Planning for Central Air Conditioning

Space requirements for assembly and fixing of air-conditioning, heating and ventilation system equipment (ducting, cooling, heating and air-conditioning equipment; refrigerating machinery, boiler etc.) should be determined during the planning stage of the building. The most important points for space planning are:

- In case of large capacity water-cooled chiller installations (500 TR and above), the clear headroom below soffit of beam should be minimum 4.5 m for centrifugal chillers and minimum 3.6 m for reciprocating and screw type chillers.
- Equipment rooms, wherever necessary, shall have provision for mechanical ventilation
- The plant room shall be placed on a plain/reinforced cement concrete foundation and provided with anti-vibration supports.
- The equipment room should preferably be located adjacent to an external wall.
- Acoustic treatment should be provided in plant room space to prevent noise.
- The air conditioning plant room should preferably be located close to the main electrical panel of the building in order to avoid large cable lengths.
- Air cooled chiller should be installed where adequate open space is available.
- The roof of the building is a suitable location for the installation of an air-cooled chiller.
- Vibration from the machine should not be transmitted to the roof structure.
- Supply/return air duct should not be taken through the emergency fire staircase.
- Cooling towers shall be installed at least 3 m above the bases of the chillers. Any obstruction to the free flow of air to the cooling tower shall be avoided.

For more information, please see [Sec 2.6.2 and Sec 2.11.4.8, Chapter 2, Part VIII, BNBC2020].

4-3-5 Elevator System (Lift)

To consider an elevator system for a building, and before designing the core / shaft size of a lift, it is essential to calculate the traffic load of the building. The capacity and the number of lift depends on traffic analysis. After determining the capacity and number of lifts, the core/shaft size should be determined according to the chart mentioned below.

Lifts shall be provided in buildings more than six storeys or 20 m in height. Installation of lifts shall be carried out in conformity with the "Lift Act" and rules there under, wherever they are in force. [Sec 4.2.1, Chapter 4, Part VIII, BNBC 2020] The shaft size is shown in Table 4-4.

Table 4-4 Measurement Chart for Passenger Lift

Passenger (No)	Capacity (Kg)	Shaft Size (W^D) (mm)	Car Size (W^D) (mm)	Door Size(mm) (Centre Opening)	Pit Depth (mm)	Over head Height (mm)	Power (KW)	Slab Load (Tons)
6	450/500	1700x1800	1000x1300	750	1500	5000	4.04	8
8	600/630	1800x2000	1100x1400	800	1500	5000	5.5	10
10	750/800	2000x2000	1350x1400	900	1500	5000	8	12
13	1000	2200x2200	1500x1600	1000	1500	5000	11	16
17	1250	2400x2600	1500x2000	1100	1500	5000	15	20
19	1350/1400	2400x2600	1600x2000	1100	1600	5000	18	25
21	1600	2600x2750	1700x2100	1200	1600	5000	20	30
24	2100	2800x3000	1800x2400	1300	1600	5000	22/24	35

Reference: "Study of Electro-Mechanical Works" 2020, Mr.Ashraful Haque, Additional Chief Engineer E/M-P&D Zone, PWD

If the height of the building exceeds 32m or more than ten storeys, then at least one bed-lift must be provided with stretcher facility.

Also, in any multistoried hospital and health care building, there shall be at least one hospital lift having stretcher facility.

The shaft size is shown in Table 4-5.

Figure 4-14 Bed Lift

Table 4-5 Measurement Chart for Passenger Cum Bed Lift

Capacity (Kg)	Shaft Size (W^D) (mm)	Car Size (W^D)(mm)	Door Size (mm) (Centre Opening)	Pit Depth (mm)	Overhead Height (mm)	Machine Room Plan (mm)
1000	2200X2900	1100X2200	1000	1800	5000	2900x4200
1250	2400X2900	1300X2300	1100	1800	5000	3000x4200
1350/1400	2400X2950	1400X2300	1100	1800	5000	3200x4300
1600	2600X2950	1600X2300	1200	1800	5000	3300x4300
2100	2800X3000	1800X2400	1300	1800	5000	3500x4300

Reference: "Study of Electro-Mechanical Works" 2020, Mr.Ashraful Haque, Additional Chief Engineer E/M- P&D Zone, PWD

Table 4-6 Measurement Chart for Cargo Lift

Load (Kg)	Shaft Size (W^D) (mm)	Car Size (W^D)(mm)	Pit Depth (mm)	Overhead Height (mm)	Machine Room Plan(mm)
2000	2800x2750	2000x2400	1400/1500	4500	4500
3000	3550x2950	2500x2600	1400/1501	4800	4300x4700
5000	4400x3750	3000x3400	1400/1600	5000	5500x5500

Reference: "Study of Electro-Mechanical Works" 2020, Mr.Ashraful Haque, Additional Chief Engineer E/M-P&D Zone, PWD

(i) The above chart is based on lift speed of 1 m/sec to 1.5 m/sec
(ii) The dimension of pit & overhead will increase with increase of the elevator speed.
(iii) The door opening can be increased in case of side opening

Table 4-7 Minimum Pit Depths for Lifts

	Depth (m)							
Speed (m / sec)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
(i) With restrained rope compensation	-	-	-	1.6	2.6	2.8	3.0	3.2
(ii) With chain, free rope or travelling cable compensation	1.5	1.5	1.6	2.4	2.5	-	-	-
(iii) With reduced stroke buffer and either restrained rope chain travelling cable or free	-	-	1.5	1.6	2.4	2.6	2.6	2.8

Reference for Table 4-4 ~ 4-7: Schedule of Rate-E/M PWD 2018, "Study of Electro-Mechanical Works" 2020, Mr. Ashraful Haque, Additional Chief Engineer E/M-P&D Zone, PWD

- Overhead height and pit depth should be selected on lift speed as shown in [Table 8.4.3, Chapter 4, Part VIII, BNBC 2020].
- Positive pressure should be maintained in the lift lobby.
- Lift shaft width will be compatible with door width.
- Goods Lift should be placed in a separate space. The basement should have provision for goods lift.
- For Buildings of more than 32 m height, at least one lift core with stretcher facility should be provided.
- One/more fire lift should be provided for buildings more than 20m in height.
- When RCC Wall is provided as Lift Core Wall, Columns and Beams are not required to provide. But when Brick Wall is provided as Lift Core Wall, Load Bearing RCC Columns and Beams are required.
- Recommended dimensions of the lift-well and its entrances are provided in [Tables 8.4.3 to 8.4.6, Chapter 4, Part VIII, BNBC 2020].

4-3-6 Emergency Elevator System

- One/more fire lift should be provided for buildings more than 20m in height. Also, an emergency elevator needs a spare power supply. A generator for the emergency elevator shall have a power supply independent of the main source supplying the building.
- When RCC Wall is provided as Lift Core Wall, Columns and Beams are not required to provide. But when Brick Wall is provided as Lift Core Wall, Load Bearing RCC Columns and Beams are required.

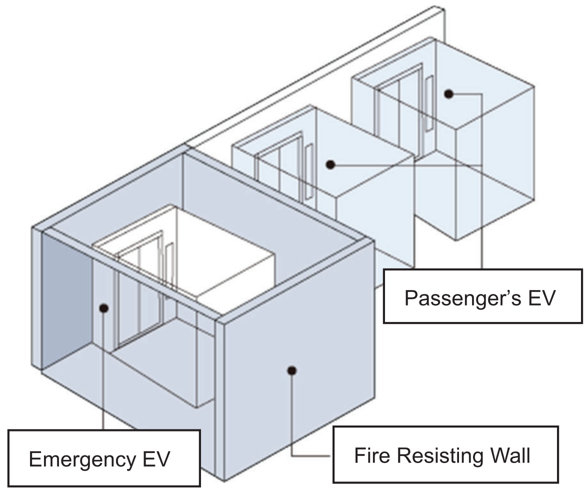


Figure 4-15 Emergency Elevator

- Emergency and general elevators should be divided by fire-resistant walls.
- The doors of EV lobby and the shutters of EV needs to be fire-resistant.
- Elevator Safety Gear System shall conform to the safety requirement for human life during big earthquakes.

(i) Fireman's lift

For buildings having a height of 15 m or more, at least one lift should meet the requirements of fireman's lift as designated below:

(a) Lift car should have floor area of not less than 1.44 m2.

(b) It should also have a loading capacity of not less than 544 kg (8 persons).

(c) Lift landing doors should have a minimum fire resistance of two hours. [Sec 4.2.2.3, Chapter 4, Part VIII, BNBC 2020]

(ii) Lift Cars

- Height of the entrance to the lift car shall not be less than 2 m.
- The inside surfaces of the lift with enclosures facing any car entrance shall form a smooth continuous flush surface devoid of projections or recesses. Where projections or recesses cannot be avoided, the underside of these projections/recesses shall be beveled to an angle of 60 degrees from the horizontal by means of metal plates or other fire- resistive materials as shown in Table 4.9

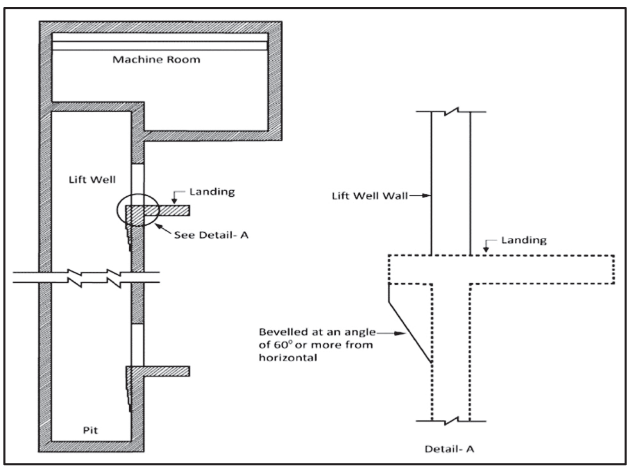


Figure 4-16 Beveled projections/ recesses

Reference:[Figure 8.4.1, Chapter 4, Part VIII, BNBC 2020]

For more information, see [Sec 4.2.3, Chapter 4, Part VIII, BNBC 2020.]

Table 4-9 Maximum Inside Area for Different Loading Capacities

Rated Load (mass) (kg)	Maximum Available Car Area (see note) (m^2)	Maximum Number of Passengers	Rated Load (mass) (kg)	Maximum Available Car Area (see note) (m^2)	Maximum Number of Passengers
100	0.40	1	975	2.35	14
180	0.50	2	1000	2.40	14
225	0.70	3	1050	2.50	15
300	0.90	4	1125	2.65	16
375	1.10	5	1200	2.80	17
400	1.17	5	1250	2.90	18
450	1.30	6	1275	2.95	18
525	1.45	7	1350	3.10	19
600	1.60	8	1425	3.25	20
630	1.66	9	1500	3.40	22
675	1.75	10	1600	3.56	23
750	1.90	11	1800	3.88	26
800	2.00	11	2100	4.36	30
825	2.05	12	2500	5.00	36
900	2.20	13			

Note: (i) Beyond 2500 kg, add 0.16 m^2 for each 100 kg extra

(ii) Maximum available car area = (W x D) + Available area near the car door(s) inside the car.

Where, W = Car inside width in metre; D = Car inside depth in metre

Reference: [Table 8.4.1, Chapter 4, Part VIII, BNBC 2020]

4-3-7 Any Other Mechanical System

- Arrangements for MGPLS

  For Hospitals, separate arrangements should be made for lifting the medical gas pipeline system. Separate rooms should be provided for installation of "Manifold control system" and "Vacuum plants" and "Medical air plant/compressor".

- Fire Control Room

  For fire protection system, when a hydrant system is required, a room for installing the fire pumps, fire control panel will be necessary.

- Control Room for PABX, PA System, CCTV, Conference System etc.

  These should be separated from the fire control room.

- Fire Pump Room

  There should be a fire pump room and preferably located near the underground reservoir.

- Forced Ventilation System at Basement

  Architectural drawing should include the locations of punches in consultation with the MEP consultant for the ducts of forced ventilation system in basement slabs.

4-4 Plumbing for Safer Design

Plumbing work shall be explained as a system of potable water supply and distribution pipes, plumbing fixtures and traps, soil waste and vent pipes, and sanitary and storm sewers and building drains, including their respective connections, devices and appurtenances within a building or premises.

4-4-1 Site Plan

In this clause, the requirements of the necessary plumbing issues of the site plan are described. The location of the main water main/source, underground water reservoir, existing drainage system, existing roads, water bodies, flood level, road levels, effluent disposing area, etc. shall be described in the plan. The mandatory issues are mentioned below.

(i) Existing Situation of Water Supply

According to BNBC 2020, the existing water main and supply line should be marked in the site plan. The existing source of water supply should be presented in the site plan, not only the water main but also any kind of water bodies (e.g. pond/canals/well/ditches). In that case, it is necessary to consider the water level during the monsoon.

(ii) Existing Drainage

For the drainage purpose, especially for surface water, the existing location of open drain / canal / box drain should be located in the site plan. Also, for the disposal of surface drain water / waste water / effluent, a dedicated dumping area should be designated. The location of the septic tank and soak well should also be marked in the site plan.

(iii) Existing Gas Connection

In site plan, the gas connection or source should be located. If a new connection is needed, then it should also be marked in the site plan.

(iv) Flood Level

For avoiding hydrostatic and hydrodynamic loads and stresses or the effects of buoyancy during the occurrence of flooding, the structure should be constructed by taking into account the flood elevation profile of the location.

(v) Existing Ground Level and Road Level

In the site plan, the existing ground level and the nearest road levels should be marked clearly.

4-4-2 Typical Plan

This section describes the requirement of all the plumbing fittings and fixtures, duct size and location, planter locations, and the details of toilets. The standard sizes and minimum requirements for plumbing purposes as well as the issues, are mentioned below.

(i) Duct Space

During architectural design, the position of piping facilities and pipe shafts should be specified in the planning stage of the basic design. Also, the duct space shall be arranged considering beam and pillar positions. For example, while the proper design and positioning of the duct on the roof to supply water can use a roof effectively, the architect should confirm the exact position and dimensions by discussing with the plumbing engineer during detailed design.

Duct size and its positioning are very important for sanitary and plumbing design. A duct should have adequate space for the installation of pipes and maintenance. Duct size can be determined based on the number of pipes passing through it and adequate space between them for the maintenance. Generally, there are soil pipes (4” minimum), waste pipes (4” minimum), vent pipes (2”-4”), water distribution pipes (1” minimum), rain pipes (4” minimum) in a duct.

The number of pipes and size of pipes can be changed based on load. The duct size should be 8”-10” in width and 3’-0” in length for pipes running in one side and 3’-0” x 3’-0” for pipes running in both sides.

Figure 4-17 A Sample of Pipe Space

Figure 4-18 A Sample of Pipe Space

(ii) Drainage System

A drainage system (drainage piping) includes all the piping within public or private premises, which carry sewage, rain water, or other liquid wastes to a legal point of disposal, but does not include the mains of a public sewer system or a private or public sewage treatment or disposal plant.

- **Design Route of Roof Drainage System**

For the roof drainage design, adequate rain water pipes shall be provided. Based on rainfall intensity and roof area, rain stack should be provided uniformly so that the slope can be maintained smoothly. The place where the roof garden exists, drainage of the garden area and water proofing should be planned earlier for smooth operation and leak proofing.

Step-1: Select roof drain size/ down spout size
(50 Φ, 75 Φ, 100 Φ, 125 Φ, 150 Φ, etc.)
Step-2: Select down spout material
(PVC, steel, stainless, etc.)
Step-3: Calculate the capacity of discharging rain-water
Step-4: Fixing of number of the setting position
The number of the setting position of roof drain shall be decided by capacity of roof drain (down spout).
Number of roof drain = Roof area/ Covered area of roof drain (See Figure 4-19)

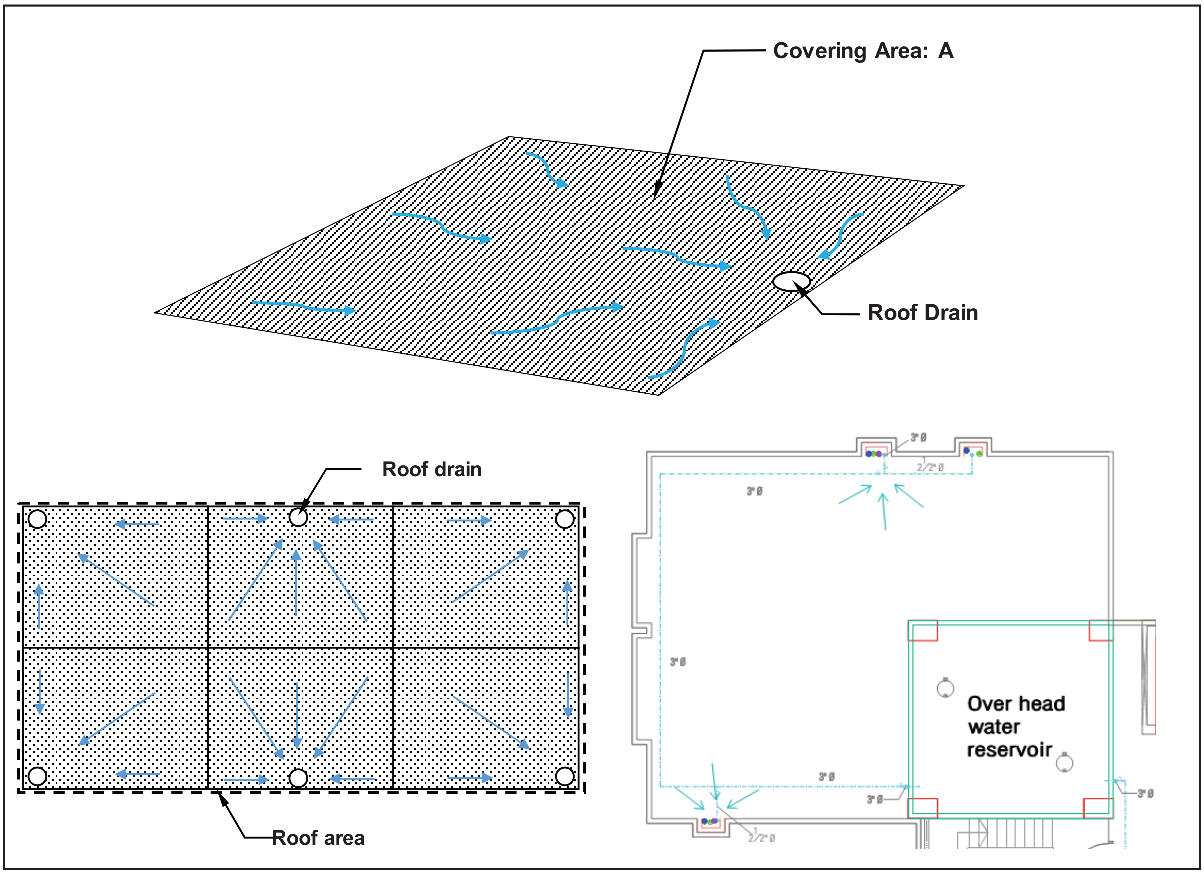


Figure 4-19 Position of Roof Drain

- **Size and slope of drainage pipe**

The size and slope of the waste drainage pipe to keep the piping space should be considered. The chart below shall be referred to for the purpose.

Table 4-11 Size and Slope of Drainage Pipe

Drainage Population (P)	Pipe Size (mm)	Piping Slope (S)
P<150	$\phi \geqq 100$	S≧2/100
150≦P<300	$\phi \geqq 125$	S≧1.7/100
300≦P<500	$\phi \geqq 150$	S≧1.5/102
500≦P	$\phi \geqq 200$	S≧1.2/103

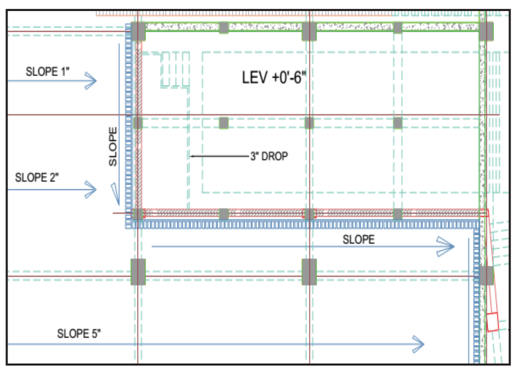


Figure 4-20 Slope and Gutter

- **Drainage for basement water**

For the regular drainage of basement water, it is important to have a drainage plan. The basement water can be collected by gutter/peripheral drain or by the connection of sump pits and then drained out by a submersible pump. All buildings having a basement floor below the surrounding sewer system and an area of more than 1000 m^2 shall have one sump pit for every 1000 m^2. The minimum diameter of sump pit connection drain shall be 75mm.

- **Surface drainage**

Drain or pipe size can be determined on the basis of the surface area, rainfall intensity, percentage of paved/covered area etc. Planning of the drainage layout should be considered for the aesthetics of the project. The locations of planters, open terrace garden and rooftop garden should be provided with proper legends and sections to avoid drainage problems.

The rooftop garden plans in architectural design needs careful consideration for ducts or water gradients. A technical meeting with the building service engineer at an early design stage is necessary.

Figure 4-21 Gutter

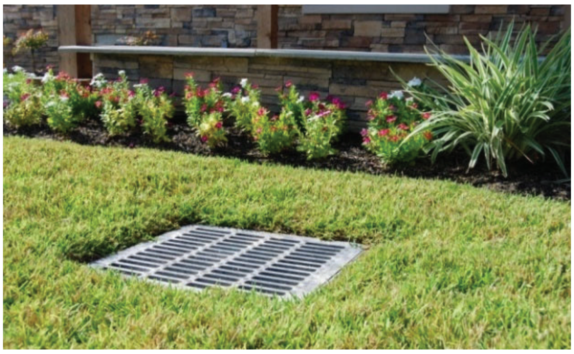


Figure 4-22 Drain in the Garden

(iii) Location of Underground Water Reservoir

In the floor plan, the location of the underground water reservoir should be precisely shown. The capacity of the underground reservoir should be '1 x Total daily demand of water (m3) + Amount of water that can be used for firefighting for 1 hour (for tall building)' [Sec 5.9.1.2, Chapter 5, Part VIII, BNBC 2020]. For emergency requirements, 2-3 days daily demand of water is sometimes stored.

(iv) Roof Tank Capacity

The capacity of the Roof Tank should be '½ x Total daily demand of water (m^3) + 1 hr. reserve (m^3) for firefighting requirement (for tall building)' [Sec 5.9.1.2, Chapter 5, Part VIII, BNBC 2020]. Therefore, two times filling of roof tank will meet the daily requirement.

(v) Water Requirement for Fire Fighting

It is important to note that the water stored in the storage tank for firefighting operations shall not be used for other purposes. Accordingly, separate water connections should be provided.

According to APNB 2014 [Agni Pratirodh o Nirbapaṇ Bidhimala, 2014], a reservoir for underground water shall be required for a minimum 50,000 US gallons (189,270 litres) as a minimum capacity. And the overhead water reservoir capacity should be 25,000 US gallon. In the case of high-rise buildings, that means if it is more than 15 storied, an intermediate reservoir should be provided in every 26-meter height. If the occupancy group is A5 (Hotel and lodging house), the capacity of underground water reservoir should be 100,000 US gallon and capacity of overhead water reservoir should be 40,000 US gallons. In typical floor plans, the underground and overhead water reservoirs with capacity and legends should be indicated.

For more information, please also see [Sec 4.2, Chapter 4, Part IV, BNBC 2020].

(vi) Location of Septic Tank and Soak Well

In the typical plan, the position of a septic tank and soak well (if required) should be carefully chosen and located. It shall be located by keeping adequate horizontal distance with various elements. For details, please see [Sec 6.9.14, Chapter 6, Part VIII, BNBC 2020].

(vii) Location of Pump House

For the domestic water, a pump house should be located and a dedicated firefighting pump is to be arranged. The fire pump shall be housed in a readily accessible position in a building of non-combustible construction. The pump shall be adequately protected against mechanical damage [Sec 4.2.2.5, Chapter 4, Part IV, BNBC 2020].

(viii) Location of Air Conditioner and its Outdoor Unit

If the outdoor unit is surrounded by obstacles, it causes a "short cycle" (the outdoor unit sucks in the heat radiated). As a result, the cooling capacity may decrease or cause overheating, resulting in its failure. Therefore, the outdoor unit of air cooler/conditioner should be located considering the environment around the building.

(ix) Hot water Supply

For a residential building, hot water may be supplied to all plumbing fixtures and equipment used for bathing, washing, cleansing, laundry and culinary purposes. All hospitals shall be equipped to supply hot water as required by different fixtures and equipment. For more information, please see [Sec 5.12 and 5.19, Chapter 5, Part VIII, BNBC 2020].

(x) Health Care Water Supply

All hospitals shall have at least two service pipes from the individual water supply source or from the water main for supplying water without any interruption. The hospital shall have at least two storage tanks connected internally so that each of them is capable of serving the water distribution system in the absence of the other.

(xi) Hangers and Support

The piping system shall be installed with proper hangers and support to minimize undue strains and stresses. Pipes running below the GF (ground floor) slab or GF roof needs adequate space and gradient, which may affect the clear floor height.

Figure 4-23: Example of Breakage of Suspension by Earthquake
"Report for the damage of equipment and seismic countermeasures due to the Great East Japan Earthquake, 2012, Japan"

(xii) Toilet Booth

A toilet shall be located against an exterior wall or wall on the interior open space, except where they are ventilated through the ventilation shaft. Such ventilation shafts shall have the minimum dimensions for different heights of buildings. [Table 3.1.11, Sec 1.14.4.5, Chapter 1, Part III, BNBC 2020] In addition, shafts for buildings exceeding 6 storeys or a height of 20 m shall be mechanically ventilated. All shafts must be accessible at the ground floor level for cleaning and servicing.

(xiii) Water Distribution in Tall Buildings

In tall buildings some of the fixtures at the lower level may be subject to excessive pressure. The sanitary appliances and fittings in tall buildings shall not be subject to a pressure of greater than 350 kPa (approx 35m height). This shall be achieved by one or a combination of the following methods:

- Zoning Floors by Intermediate Tank
- System Incorporating Pressure Reducing Valves
- Hydro-Pneumatic System

4-4-3 Rain Water Harvesting

According to BNBC 2020, every building having 300 sqm and above shall have facilities for conserving and harvesting rain water. [Sec 7.4, Chapter 7, Part VIII, BNBC 2020] In addition to rainwater harvesting and drainage plan, a separate site plan of the building shall be submitted with the following particulars:

(a) Adjoining plots and streets with their identification;
(b) The position and invert level of the storm sewers, (if any), surface drain water and the direction of flow in it;
(c) The level of the proposed drainage pipe connecting to the storm sewers (if any);
(d) The position and layout of private storm drainage system (in the absence of public storm sewers); and
(e) The alignment, size and gradients of all harvesting and drainage piping.

- **Rooftop Rain Water Harvesting**

Water can be collected through roof gutters and rainwater downpipes. Provision shall be made to divert the first rainfall after the dry season to avoid dust, soot, and leaves etc. in the water to be collected into the water tank. The capacity of the water tank should be enough for storing water required for consumption between two dry seasons. [Sec 7.8, Chapter 7, Part VIII, BNBC 2020]

- **Catchments Area for a Flat Surface**

Figure 4-23 shows a building having flat roofs at different levels. In level 3 the area ABCD is the catchment area contributing to the rainwater down pipe RDP1.

In level 2 horizontal area EFGH and 50% of the vertical wall surface area AFHM, projecting above is the catchment area of rainwater downpipe RDP2.

For the rainwater downpipe RDP3 the catchment area will be the terrace at level 2, 3 and fifty percent of the adjacent contributory wall AFHM, GHIJ and MJLC. [Appendix U, Part VIII, BNBC 2020]

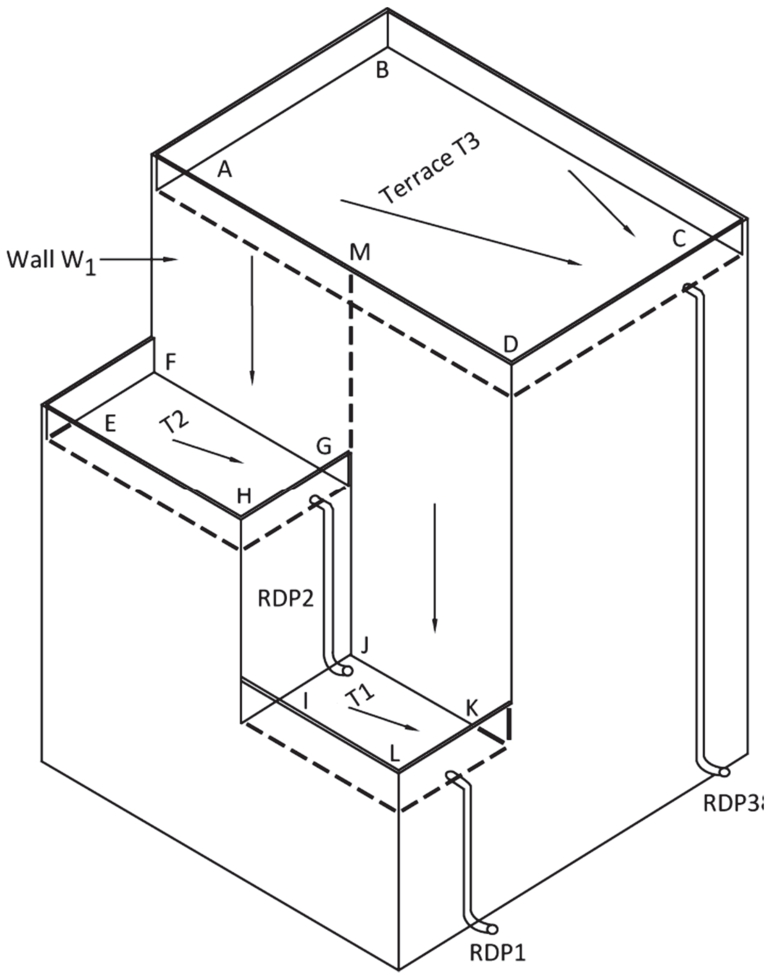


Figure 4-23 Catchment area of flat roof and wall surface
Reference: [Appendix U, Part VIII, BNBC 2020]

CHAPTER 5 Fire Safety Design

5-1 Introduction for the Fire Safety Design

In recent times, the fire incidents in the country have increased, in Dhaka city area. From the building safety point of view, fire safety design is of utmost importance.

During the planning and basic design stages of a building, the space configuration of each component such as room, hallway, stair, elevator (lift), etc. are usually taken into consideration. Additionally, the functional aspects, such as usage, scale, flow-line and of the building are regarded as very important. Fire prevention and evacuation are also to be incorporated into the overall plan at the early stage of the architectural design.

Chapter 5 gives a brief description of the points connected to design procedure, equipment, materials, and evacuation process in relation to fire safety concerns.

Regarding details for the fire safety design, the following documents have been referred to:

- Fire Safety Design Guidebook [“Fire Safety Design Guidebook” by BSPP, 2021]
- BNBC 2020 [Bangladesh National Building Code 2020]
- DMINB 2008 [Dhaka Mahanagar Imrat (Nirman, Unnayan, Songrokkhn Aposaran) Bidhimala, 2008]
- APNB 2014 [Agni Pratirodh o Nirbapaṇ Bidhimala, 2014"]

5-2 Arrangement of Space Planning for the Fire Safety

5-2-1 Zoning and Classification

Considering fire hazards inherent in the buildings, and the degree of safety desired for the occupancy therein, zooning is regarded important. Zoning is based on the possible fire hazard characteristics of the building and the degree of safety desired for the occupancy accommodated therein. It is divided into three main fire zone areas [Sec 3.1.5, Chapter 3, Part III, BNBC 2020].

Again, all buildings must be classified according to their use, or by considering the characteristics of their occupancy and type of construction. [Sec 3.1.1, Table 3.3.1 (a), (b), Chapter 3, Part III, BNBC 2020] and [Sec 2.1, Chapter 2, Part IV, BNBC 2020]

5-2-2 Drawings of Fire Protection Plan

Most buildings need to have a fire protection plan. A fire protection plan shall be signed by the same Architect who signed drawings for approval of the building and any person responsible for the Fire protection design.

The fire protection plan consists of the information where applicable: address of the building address, height in meter, occupancy classification, and detailed occupant load. The key Plan shows all floors, exits, corridors, partitions serving as fire separations or compartments, locations and ratings of required enclosures, windowless stair with pressurization, exit discharge, locations of frontage space, including street width of the abutting plot. [Sec 5.1.6 (i), (f) and (g), Chapter 5, Part IV, BNBC 2020].

5-2-3 Building and the Site (Evacuation and Entrance route)

It is required to show an evacuation route in the layout plan of a building through which occupants, during a fire incident, can easily reach to a safe vacant land or road from the building. An entrance route must also be indicated so that personnel from the fire department can have easy access to the building.

Sufficient open space (setbacks) around the buildings, as defined in [Table 2, Chapter 5, DMINB 2008] for Dhaka city and [Sec 1.7 and 1.8, Table 3.1.5, 3.1.7 and 3.1.8, Chapter 1 Part III, BNBC 2020] for other cities along with "APNB 2014", shall ensure access of the users and operation of fire services.

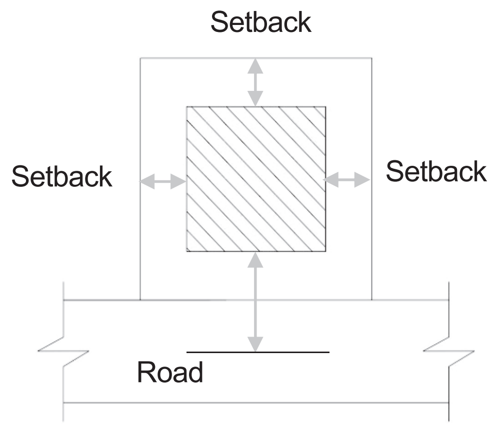


Figure 5-1 A Concept of Setback

According to [Table 2, Chapter 5, DMINB 2008], for any amount of site area, the setback between the building and the surroundings must have a minimum gap of 1.50m at the front, 3.00m at the rear, and 3.00m at the sides, when the height of the building is 33 meters or above 10 stories. However, because of the difference of conditions and difference in the characteristics of each site, the setback of the building will change.

On the other hand, according to APNB, [Sec ka) (1), Fire Extinguishing provisions for multistoried "A" Occupancy Type Buildings, Thirteenth Schedule, Regulation 19 (3), APNB 2014], the minimum width of the front main road of a residential multistoried building shall be 9 meters. If there is more than one building in the same plot, the minimum height of the gate of the main entrance shall be 5 meters and the minimum width of the internal roads with turning circles shall be 4.5 meters for the convenient access of the fire fighting vehicles to the plot or building.

Provision for the required refuge area or assembly point positions should be created for easy evacuation to a nearby front road.

5-2-4 Prevention of Fire Spread

In order to prevent the spread of fire between existing buildings, it is required to ensure appropriate distances and use fire resistant material for the exterior wall.

(i) Fire Resistance Rating for Occupancy Separation

For fire-resistance rating requirements of separating walls and floor/ceiling assemblies between mixed occupancies, we need to follow the instruction given in [Table 3.2.1, Chapter 2, Part III, BNBC 2020].

(ii) Fire Resistance Rating According to Fire Separation Distance for Different Occupancy Groups

For avoiding any fire incident, it is necessary to maintain and the suggestions in Figure 5-2 and Table 5-1 below. Regarding fire resistance ratings of exterior walls (in hours) according to various occupancy groups and fire separation distance, the following are to be maintained.

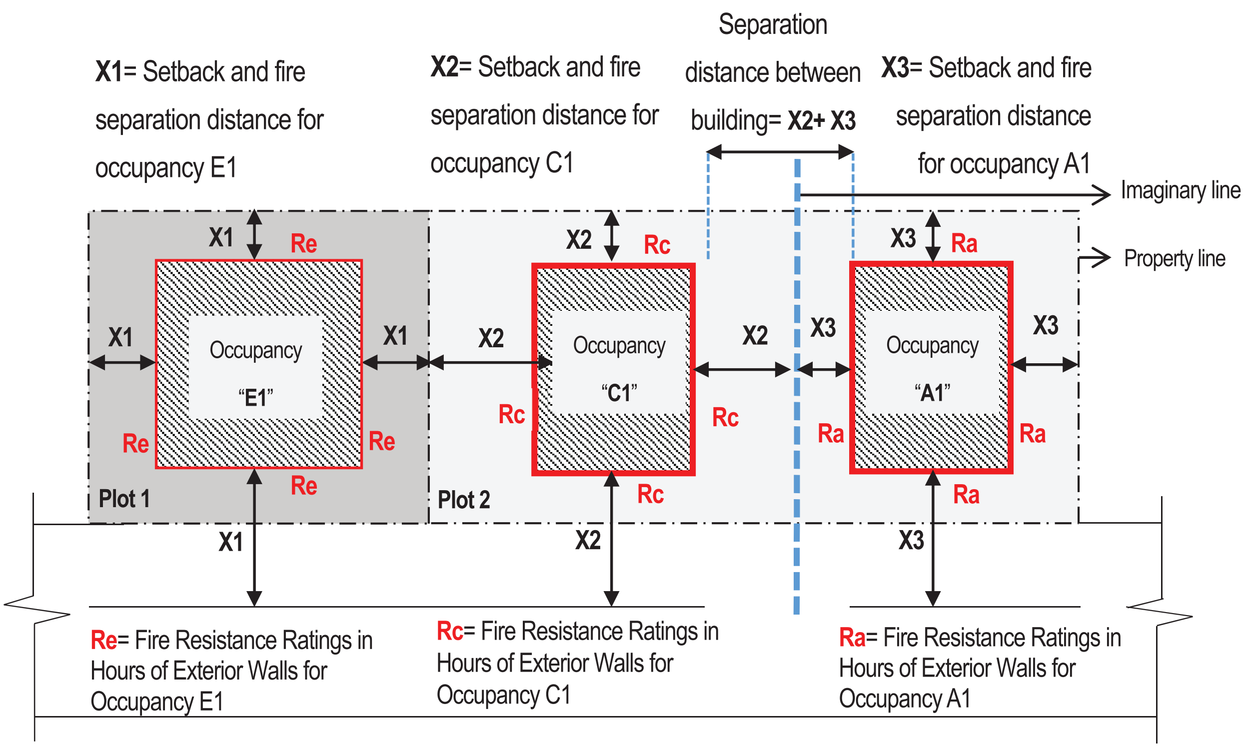


Figure 5-2 A Concept of Setback, Fire Separation Distance, Separation Distance & Fire Resistance Ratings in Hours of Exterior Wall

Table 5-1 Fire Resistance Ratings in Hours of Exterior Walls for Various Occupancy Groups

Fire Separation Distance	Occupancy			
	A1,A2,K2,M2	A3,A4,A5,B,C,D,E1,F1,F2,G1,I	E2,F3,F4,E3,G2,H1	H2,J
Up to 1.5m	1	2	3	4
Greater than 1.5m and up to 3m	N*	1	2	3
Greater than 3m and up to 4.5m	N	N	1	2
Greater than 4.5m and up to 9m	N	N	N	1
Greater than 9m	N	N	N	N

*N=No requirement,
Reference: [Table 3.2.2, Chapter 2, Part III, BNBC 2020]

Table 5-2 Requirements for Opening Protection Assembly Based on Fire Resistance Rating of Exterior Walls

Fire Resistance Rating of Exterior Walls (in hours)	Fire Resistance Rating for Opening Assembly (in hours)
4	Not permitted
3	3.0
2	1.5
1	0.5
N	No requirements

Reference: [Table 3.2.3, Chapter 2, Part III, BNBC 2020]

5-2-5 Fire Compartment

According to [Sec 1.2 (Terminology); Chapter 1, Part IV, BNBC 2020], the definition of "fire compartment" is "a space within a building that is enclosed by fire barriers on all sides, including the top and the bottom to limit the transfer of fire". Considering the space plan for fire prevention, the design of the fire compartment is one of the first priorities, together with the space for equipment related to detection, warning, and extinguishing. The main purpose of the fire compartment can be two as follows:

- ✓ "Securing safe evacuation route in case of fire"
- ✓ "Prevention of fire spread"

In order to secure an evacuation route, we need to have a continuous path from inside to a safe place outside. This will determine the most important part of fire compartment.

On the other hand, the main purpose of preventing fire spread is to prevent the dispersion of flames and smoke.

Design details are mentioned in [Chapters 3 and 4 of the Fire Safety Design Guidebook]. Also please see [Sec 3.13, Chapter 3, Part IV, BNBC 2020].

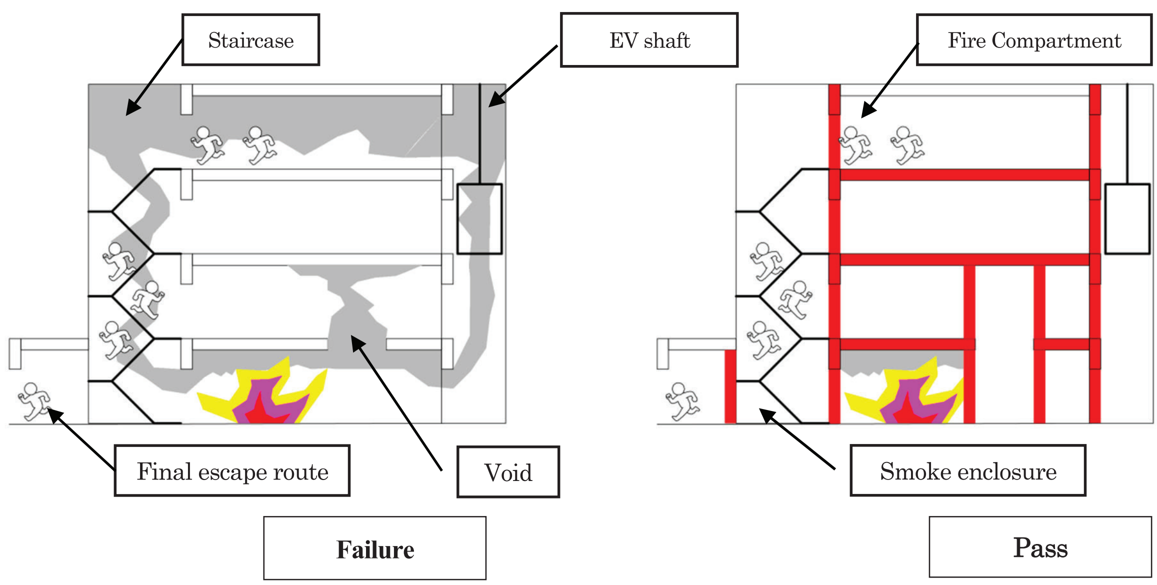


Figure 5-3 Where Smoke Enclosures are Needed

Reference: [Figure 4.2, Chapter 4, Fire Safety Design Guidebook]

5-2-6 Arrangement of Lift and Services Core

Reinforced concrete cores in a building includes stairs, elevators, equipment space, toilets, hot water supply rooms, etc. It is necessary to consider the direction of evacuation during a fire (single and multi-directional), and the simplification in the arrangement of cores for the floor plan.

The types of cores and the directions of exit for evacuation are as follow.

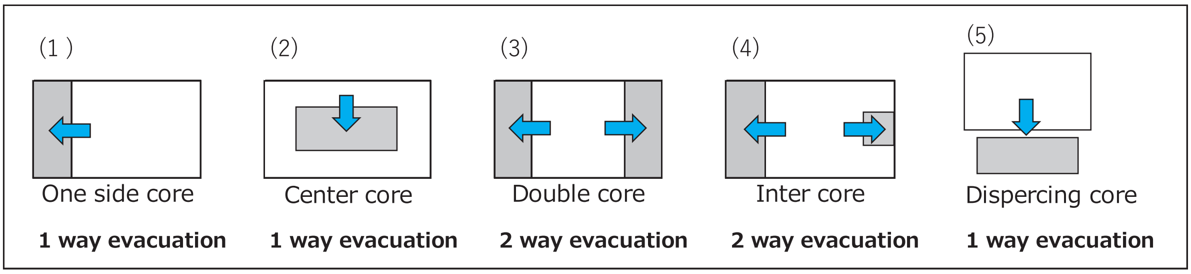


Figure 5-4 Types of Cores and Directions of Exit for Evacuation

5-2-7 Interior Planning

In the rooms of a building where there is a provisions of using fire, non-combustible materials should be used for interior decoration. It is important to delay the spread of fire combustion by the selection of materials for walls and ceiling, taking into consideration the spatial form and the arrangement of openings, ceiling height, window position, door position, and duct location.

5-2-8 Service Duct

(i) Duct or vent

A building requires proper planning to run its services, like electrical, plumbing and air conditioning lines etc. Air-conditioning and ventilation systems shall be installed and maintained so that the fire, fumes, or smoke do not spread from one area of fire to another area of a building through the ducts or vents. Properly designed fire dampers shall be installed within the air-conditioning and ventilation ducts, which shall automatically close the flow of air in case of fire. In large assembly areas, where fuses of fire dampers may not function during the early state of a fire due to insufficient heat, smoke sensing control devices to operate the fire dampers should be used . [Sec 2.7, Chapter 2, Part IV, BNBC 2020].

Openings of service lines like cables, electrical wirings, telephone cables, plumbing fixture etc. shall be protected by enclosures having an approved fire-resistance rating. Medium or low voltage electrical wire running through shaft or ducts shall be either armored or cased within metal conduits [Sec 2.5 (e), 2.6, Chapter 2, Part IV, BNBC 2020]. All the service duct walls of the building shall be 4-hour fire rated and all the opening doors shall be 2-hour fire-rated, which is free from heat and smoke. [Sec ka) (16), Fire extinguishing provisions for multi-storied “A” occupancy type buildings A-1 (Single dwelling home), A-2 (Flat or Apartment), A-3 (Mess, Boarding house, dormitory or hostel) and A-5 (Hotel, Motel, Guest house, Restaurant and Club), please refer to the Thirteenth schedule, Regulation 19(3), APNB 2014]

(ii) Shaft

Elevator shafts, vent shafts and other vertical openings shall be enclosed conforming to the provisions of [Table 3.3.1 (a) and (b), Chapter 3, Part III, BNBC 2020]. Exit requirements shall comply with [Chapter 3, Part IV, BNBC 2020].

Rubbish and linen chute shall terminate in rooms separate from the remaining of the building having the same fire resistance as required for shafts in [Tables 3.3.1 (a) and (b), Chapter 3, Part III, BNBC 2020] but not less than one hour. [Sec 3.1.11.5, Chapter 3, Part IV, BNBC 2020]

5-3 Equipment and Material for Fire Prevention

5-3-1 Fire and Smoke Prevention Section

In order to limit the fire and smoke generated during a fire to a narrow range and to minimize loss of life and property, provisions for fire prevention should be incorporated in the design. For details, please see [Chapter 3 and 4, Fire Safety Design Guidebook], [Sec 3.1.9 & 3.1.10, Table 3.3.2, Chapter 3, Part III, BNBC 2020] and [Sec 2.6, Chapter 2, Part IV, BNBC 2020].

5-3-2 Equipment and Material

(i) Fire Protection Equipment

At the stage of architectural design, an architect should have discussions with the person in charge of building services design. And a safer fire protection plan needs to be developed by effective arrangement of fire prevention equipment in space design by considering the following points:

- Fire extinguisher position
- Riser location
- Sprinkler position
- Gas riser location etc.

(ii) Equipment in Vulnerable Space

Rooms with fire-generating equipment, such as kitchen, mechanical room, pump room, control room etc. requires considerations for fire prevention and exhaust facilities.

The space where the equipment is installed should be clean and properly ventilated. Before cleaning, the equipment, they should be switched off and disconnected from power. For internal cleaning, a suction cleaner should be used. If the equipment is ventilated, then it should be ensured that the airflow is smooth and not restricted. If filters are provided, they should be cleaned or replaced, as necessary. [Sec A.4 & A.11, Appendix A, Part VII, BNBC 2020]. The proscenium curtain used in a theatre hall shall be made of approved fire-retardant material and shall protect against the passage of flame and smoke for at least 30 minutes. [Sec 2.13.6.7, Chapter 2, Part III, BNBC 2020].

(iii) Elevator (Lift)

Elevators (lifts) are basically considered as an enclosure where smoke can easily invade. To prevent fire and smoke from intruding lift cores, fire and smoke-proof elevator lobbies should be provided in the architectural design of the building. The minimum value of the lift, cabin space, according to "Sec 6 (Ga); Regulation 64, Appendix 2; DMINB 2008" shall be 1500mm x 1200mm and the minimum width of the door shall be 800mm. Also please see [Sec D.22, Appendix D, Part III, BNBC 2020] and [Sec 2.11, Chapter 2, Part IV, BNBC 2020] for further details.

(iv) Material Selection

Material selection is a crucial issue for design as well as fire safety. Fire-rated elements should be used to make the buildings fire-safe. In an accessible route, apart from the general requirement of [Sec D.5, Appendix D, Part III, BNBC 2020], floor surfaces with tactile indicators shall be required. In such cases, dot type surface texture on the floor shall indicate a warning, while line type surface texture on the floor shall indicate the intended path of travel. [Sec D.5.4, Appendix D, Part III, BNBC 2020]. Measurement of the fire safety value of various types of combustible material is very significant for warehouses and factories.

For more detail, please see [First schedule, Regulation 4, 8 and 14, APNB 2014], [Sec 2.8 and 2.9, Chapter 2, Part IV, BNBC 2020], [Sec 3.1.10 (d) {(i), (ii)}, (f) and (g), Chapter 3, Part III, BNBC 2020].

5-3-3 Water Supply for Fire Extinguishing Provision

A certain amount of water shall always be preserved for an emergency case of fire in underground or roof top water reservoir. [Sec ka) (1); Fire provisions for "F" occupancy type buildings, Thirteenth schedule, Regulation 19 (3); APNB 2014].

In case of emergency, there are some important components identified for water supply:

- Storage tank
- Roof gravity tanks
- Fire pump.

For more detail, please see [Sec 4.2, Chapter 4, Part IV, BNBC 2020]

5-4 Means of Egress

A means of egress is an evacuation system with the provisions of reentry for rescuers, and fire fighters where a continuous and unobstructed way of exit travel shall be provided from any point within a building to a designated area of refuge. For allowable delayed evacuation, it should end up with the exit termination by reaching a street, abutting building or plot or a safe area which is open to air can be designated for assemblies for evacuees. [Sec 3.2, Chapter 3, Part IV, BNBC 2020]

The way of exit travel within a building from any point thereof, or along a means of egress, shall consist of three parts;

- The Exit Access
- The Exit
- The Exit Discharge

5-4-1 The Exit Access

A way or path of evacuation from any point of an area affected due to a fire incident leads to a protected entry to another separated area of a building shall be termed as exit access.

(i) Corridor

The safety corridor refers to a passage that provides an evacuation route from rooms to stairways safely. The following points should be noted.

- It should not be the dead end. If the dead-end is unavoidable, install a balcony and a ladder at the end of that dead-end corridor. And the length of dead-end corridor should not be more than 10m.
- Easy visibility - No obstacle, avoid dead ends, proper travel distance.
- Well protective - Using non-combustible material, fire rating door
- The minimum width of the corridor and passage shall be determined according to the number of users of each floor.

For details, please see [Sec 3.7, Chapter 3, Part IV, BNBC 2020] and [Sec 06, Fire safety, Appendix 1, Regulation 59 (CHA), DMINB 2008]. For more information regarding safety corridor, please see [Sec 1.4.3. & 1.4.4 of Chapter 1 and chapter 3; Fire Safety Design Guidebook published by PWD]

Figure 5-5 Evacuation Passage

Reference: Web page of Medical Corporation SOUJUKAI, Japan

(ii) Travel Distance

According to [Sec 1.2 (Terminology), Chapter 1 and Sec 3.9.2, Chapter 3, Part IV, BNBC 2020], the definition of "Travel Distance" is "Straight line distance between the remotest point of a space of a floor and the exit access door placed thereof". Where either the occupant load or the travel distance exceeds the values specified in the table 5-2 shall have multiple exit doors.

Table 5-2 Maximum Occupant Load and Travel Distance for Spaces with One Exit Door

Occupancy		Maximum Design Occupant Load	Maximum Travel Distance (m)
A C D	Residential Institutional Health Care	12	23
B I E F G	Educational Assembly Business Mercantile Industrial	50	23
H	Storage	30	30
J	Hazardous	5	8

Reference: [Table 4.3.4, Part IV, BNBC2020]

According to [Sec 13, Fire safety, Appendix 1, Regulation 59 (CHA), DMINB 2008], for more than one exits in the same building, the exit (evacuation path) shall be arranged in such a manner that the travel distance from any point in the area served shall not exceed the following values:

- Occupancy: A, B, C, D, E, J: 25 meters
- Occupancy: F, H: 30 meters
- Occupancy: G: 45 meters

For buildings with a single exit (evacuation path) [Table 5, Fire safety, Appendix 1, Regulation 59 (CHA), DMINB 2008] needs to be followed.

(iii) Travel Path

According to [Sec 2 (Terminology), Chapter 1 and Sec 3.15, Chapter 3, Part IV, BNBC 2020], the definition of "Travel Path" is "length of a passage from the remotest point of a space up to the exit access door placed thereof". Travel path shall be measured along the center line of a natural and unobstructed path up to the center of an exit access door opening. In case of a stairway in the travel path, it shall be measured along an inclined straight line through the center of outer edge of each tread of a stairway.

Occupant load and components of exits shall be arranged in such a manner that the travel path from any point in the area served shall not be exceeded as listed in [Table 4.3.10, Chapter 3, Part IV, BNBC 2020].

5-4-2 The Exit

The exit is a component or a group of components to evacuate an area of fire incidence, which is a component of means of egress and subsequently leads to the exit discharge.

The required minimum number of exits in a space is specified below;

- Occupant load less than 50 1 exit
- Occupant load 50 to 500 2 exits
- Occupant load 501 to 1000 3 exits
- Occupant load more than 1000 4 exits

(i) Exit Stairways, Horizontal Exits, Exit Ramp

A stairway within an envelope shall be termed as interior stairway or staircase. High rise buildings having a floor area larger than 500 m² on each floor used as educational, institutional, assembly, industrial, storage or a mixed occupancy involving any of these or hazardous occupancy shall have a minimum of two staircases.

Where two accessible means of egress are required, the exits shall be located at a distance from one another not less than one-half the length of the maximum overall diagonal dimension of the building. An exit stairway shall not be built around a lift shaft unless both are located in a smoke proof enclosure.

However, all exit stairways mentioned above shall be protected by a smoke proof enclosure. There shall be provision for access stairways through a vestibule or an open balcony.

In stairway arrangement, a safe escape route shall be ensured, following the principle of two-way evacuation and the stairs shall be dispersed as much as possible in the same plane surface.

The following points should be noted for the staircase design.

- Occupant load
- Number of stairways
- Stairway position
- Width of stairways

The connection between two separated areas of a building at the same level which the horizontal exit serves shall be provided with at least 2-hour fire-resistance-rated walls, or by an open-air balcony or a bridge having protected openings.

A ramp is a sloping surface and the minimum width of exit ramps shall not be less than the width required for corridors or passages. The slope of an exit ramp shall not exceed 1 in 8, but for slopes steeper than 1 in 10, the ramp shall be surfaced with approved non-slip material or finished in such way as to prevent slipping effectively.

For details, please see [Chapter 3, Fire Safety Design Guidebook], [Sec 3.11, 3.10 and 3.12, Chapter 3, Part IV, BNBC 2020] and [Sec 9 &10; Fire safety, Appendix 1, Regulation 59 (CHA); DMINB 2008].

(ii) Fire Lift

Both firefighting lifts and evacuation lifts should be installed for the high-rise buildings. They can be used as passenger or cargo lifts during normal times. These lifts have a structure that fire fighters can use immediately once a fire disaster occurs.

- One lift out of more than one, and at least 2 lifts out of four (4) or more lifts shall be constructed as fire lifts and shall be shown in the plan.
- All the lifts of the building shall be installed according to the concept of fire lift if the height of the building is more than 15 stories and all the lifts shall be marked in the plan as fire lifts. Lift core walls shall be of minimum 2 hours' fire rated and not more than 4 lifts shall be installed within one lift core.

For details, please see [Sec ka). (10), Fire extinguishing provisions for multistoried "A" occupancy type buildings, Thirteenth schedule, Regulation 19(3), APNB 2014] and [Sec 2.11, Chapter 2, Part IV, BNBC 2020].

5-4-3 The Exit Discharge

The outer edges or peripheral points of a building from where occupants shall evacuate the building envelope is termed as Exit Discharges. This will lead evacuees to the terminal points at a safe distance from thereof [Sec 3.2.1, Chapter 3, Part IV, BNBC 2020].

(i) Refuge Area

According to [Sec ka). (17), fire extinguishing provisions for multi storied occupancy 'A' type buildings, please refer to the "Thirteenth schedule, Regulation 19(3), APNB 2014]". A fire, heat and smoke-free safe area adjacent to the proposed building shall be marked, where the exit discharge landing of the emergency exit stair has been placed. There shall be one refuse area if the height of the building ranges from 20 meters to 26 meters and there shall be one refuse area at the interval of every five stories if the height of the building is more than 26 meters.

- A balcony is effective in the evacuation by climbing the fire escape ladder that leads to the refuge floor. Refugees can wait at the balcony to be rescued by firefighters.
- The capacity of the refuge area shall be computed on the basis of net floor area excluding stairways, shafts and spaces allotted to occupants of the receiving end. The required capacity of a refuge area shall be equivalent to a passage or a corridor having a width to comply with the capacity of evacuees and connected with the components of exits up to exit discharge [Sec 3.12.6, Chapter 3, Part IV, BNBC 2020].
- Wherever more than one exit is required in a room or on any floor, they shall be placed as remotely as possible from each other. As far as practicable, exits shall be arranged in such a manner to provide a refuge area or an exit discharge to the occupants, irrespective of the direction of travel from any point in an area served. [Sec 3.15.5, Chapter 3, Part IV, BNBC 2020]
- A Roof, an open-air space used as an assembly or refuge area, educational or other types of human occupancy shall be provided with exit facilities as per provisions of this Code. [Sec 3.5.5, Chapter 3, Part IV, BNBC 2020]
- When occupants are relocated at the flat roof of a building which is not connected with any means of exit shall be treated as an isolated refuge area and must have provisions for placing of ladders of fire department vehicles. [Sec 1.2 (Terminology), Chapter 1, Part IV, BNBC 2020]
- Exterior stairways used as fire stair shall not be considered as a component of means of egress, unless they lead directly to the ground or a refuge area, and separated from the building interior by fire-resistive assemblies or walls and are constructed by noncombustible materials and free from smoke accumulation. [Sec 3.10.11, Chapter 3, Part IV, BNBC 2020]

5-4-4 Means of Access

All buildings within such area or a plot shall have access facilities that shall be connected with the national road transportation system. The access facilities shall meet the requirements of fire service vehicles and engines movement for rescue and fire extinguishing operations. The width and vertical clearance of access roads may be increased as per the requirement of the fire service authority, if the clearances are not adequate to provide access to fire apparatus. [Sec 1.7, Chapter 1, Part III, BNBC 2020]

(i) Access and Exit Facilities and Egress System

Facilities for access and exit and egress or escape shall comply with the provisions of [Part IV, BNBC 2020]. According to [Sec 2.5.3, Chapter 2, Part III, BNBC 2020], every sleeping room in the ground, first and second floors shall have at least one operable window or door for emergency escape which shall open directly into the exterior or an interior courtyard. The units shall be operable from the inside without needing any tool and provide a minimum clear opening of 500 mm width by 600 mm height with a maximum sill height of 1 m above the floor.

(ii) Street Side Hydrant Points

For areas fully covered by private hydrant system with street-side hydrant points or hydrants within the building of equivalent standard to that of the Fire Service and Civil Defense department's specification and the buildings-having fire stairs as per the requirements of [Sec 1.7 (a), (b) and (c), Chapter 1, Part III, BNBC 2020], may be exempted from installing hydrant points. However this provision shall not be applicable for planning new developments. The minimum width of access roads for plot divisions in new developments shall follow the guidelines of [Table 3. F.1 of Appendix F, Part III, BNBC 2020]. [Sec 1.7 (g), Chapter 1, Part III, BNBC 2020]

5-5 Planning of the Emergency Sign Design

In an emergency situation, the people should be notified at first by an alarm system and then guided to evacuate quickly by an audio-visual device.

5-5-1 Fire Alarm System

To ensure safe evacuation, the early detection and announcement of fires by the alarm system is necessary and effective. Receiving a fire signal from a detector devices or transmitter installed in the building, the occurrence of a fire should immediately be notified with sounds alarms bell and display boards. The fire signals should also be notified to the person in charge of the nearest fire station.

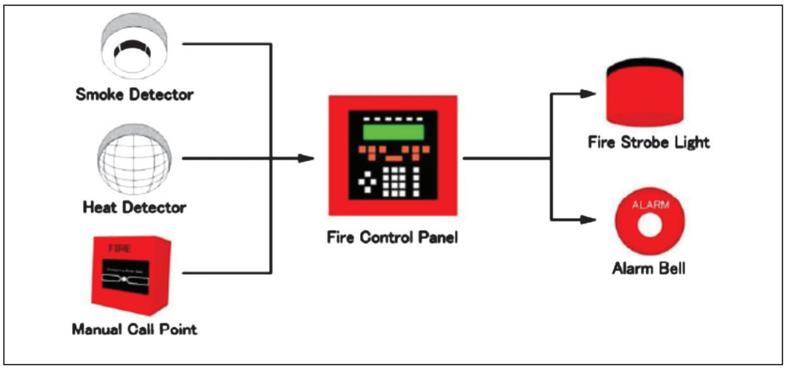


Figure 5-6 A Scheme of Components of Fire Alarm System

Reference: [Figure 9.1, Chapter-9, Fire Safety Design Guidebook]

Manual call points shall be installed in the corridor or in the stairs or at outside the corridor of each floor, including the basement of the building. Connection of alarm bell & strobe shall be established with manual call-points. The numbers of manual call-points, alarm bells and strobes on each floor shall be determined in such ways that the sound of the bells and flashing lights of the strobes shall be able to draw everyone's attention.

Locations of the manual call-points, alarm bells and strobes shall be marked with legends in the floor plan. Cables of call-point alarm bells and strobes shall be connected to the main panel board. [Sec ka) (6), Fire extinguishing provisions for multi-storied "A" occupancy type buildings should be installed according to the thirteenth schedule, Regulation 19 (3), APNB 2014]

Detailed information about the devices of fire alarm system is explained in [Chapter 9; Fire Safety Guidebook] and the requirement for a fire alarm system for various occupancies are specified in [Sec 4.6.2, Chapter 4, Part IV, BNBC 2020].

5-3-2 Fire Detection System

Fire detection systems are important to identify quickly a fire incidence, which could reduce the risk of disaster due to fire. No single detector can meet the need of all types of fires and all types of occupancies. There are various types of detectors, such as Heat Detectors, Flame Detectors, Smoke Detectors etc.

For more information, please see [Sec 4.6.1, Chapter 4, Part IV and Sec C.2, Appendix C, Part IV, BNBC 2020].

5-3-3 Emergency Sign Design

Considering the safety of people, the design of emergency sign is to be planned as follows;

- Emergency signs should be simple but conspicuous and visible in case of normal power failure.
- Exits should be lighted with the evacuation guidance sign at any time when building fire alarm system of the building is activated.
- The purpose of the evacuation guidance sign is to show an emergency exit (evacuation exit) and an evacuation route. Easily communicative Symbols and words used for the purpose should be simple and easily comprehensible to all.
- The directional sign of the emergency exit must be displayed in all the buildings.
- The distance between the two signs should be maintained appropriately.

For details, please see [Sec 3.16, Chapter 3, Part IV, BNBC 2020] and NFPA 170.

Figure 5-7 Evacuation Guidance Sign Samples (http://www.freepik.com)

5-6 Useful Reference _ Fire Safety Design Guidebook of PWD

For details of Fire Safety Design issues including the Checklist for Fire Safety Design, it is preferable to refer to the Fire Safety Design Guidebook by BSPP 2021.

ANNEXURE Standard Space (Area) Requirement for the Categories of Building

Standard Space (Area) Requirement for the Categories of Building

In DOA, the function of each space and the building as the aggregate is designed according to the client's request, using the national regulation and useful standard textbook as mentioned before and the standard obtained from the past experience of DOA. The basic data for some building types (in accordance with the Occupancy Classification of BNBC-2020) mentioned here are based on buildings designed by DOA.

(A) Residential

A-1: Single-family dwelling (an example for single-family row housing)

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Bed Room	Min	2.00	5.00	For A/C=2.44 For Non A/C =2.75 From Beam Bottom = 2.13	12	The room should be naturally ventilated and lighted. Should be located according to wind flow and sun's direction.
Kitchen	Min	1.50	4.00	2.75	12	The room should be properly ventilated and lighted.
Toilet (3 fixture)	Min	1.00	2.75	2.13	12	Basin, W/C & Bath
Toilet (2 fixture)	Min	1.00	1.20	2.13	12	Basin & W/C
Toilet (2 fixture)	Min	1.00	1.50	2.13	12	Basin & Bath
Toilet (2 fixture)	Min	1.00	2.50	2.13	12	W/C & Bath
Staircase	Normal (Min)	1.00 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.00 (Width)			16, 17	Fire safety measures should be taken.
Window Opening (Bedroom)	Min	-	15% of floor space		12	Should be located according to wind flow and sun's direction.
Window Opening (Kitchen)	Min	-	-	-	12	Should be located in an external wall or within a verandah not more than 2m in depth or a courtyard of approved size.
Window Opening (Toilet)	Min	-	0.37	-	12	Should be located in an external wall or within a shaft of approved size.

*Parking shall be in accordance with the concerned building regulation.

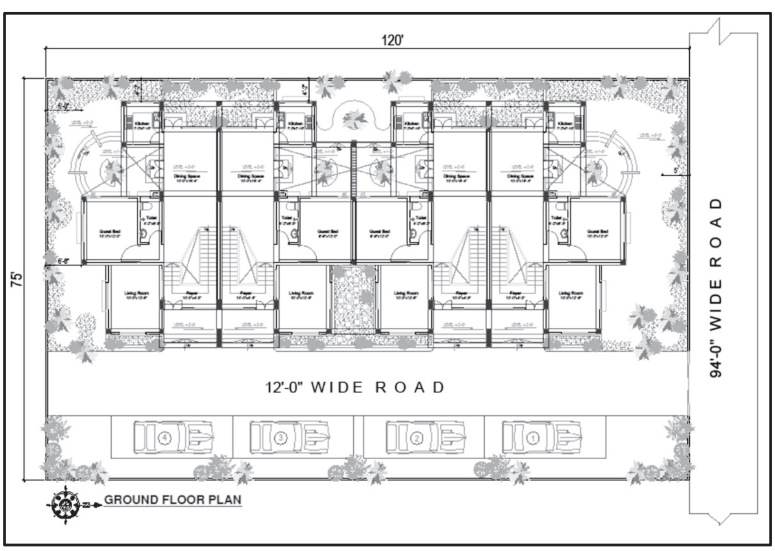


Figure A-1 Single family row housing plan

A-1: Single family dwelling (an example for low-income residence)

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Bed room	Min	2.00	5.00	3	DOA's Standard	The room should be naturally ventilated and lighted. Should be located according to wind flow and sun's direction.
Kitchen	Min	1.50	4.00	-	19	The room should be properly ventilated and lighted.
Living room	Min	2.00	5.00	-	19	-
Toilet (2 fixture)	Min	1.00	2.75	-	19	W/C & Bath
Staircase	Normal (Min)	1.25 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.50 (Width)	-	-	16, 17	Fire safety measures should be taken.

*Parking shall be in accordance with the concerned building regulation.

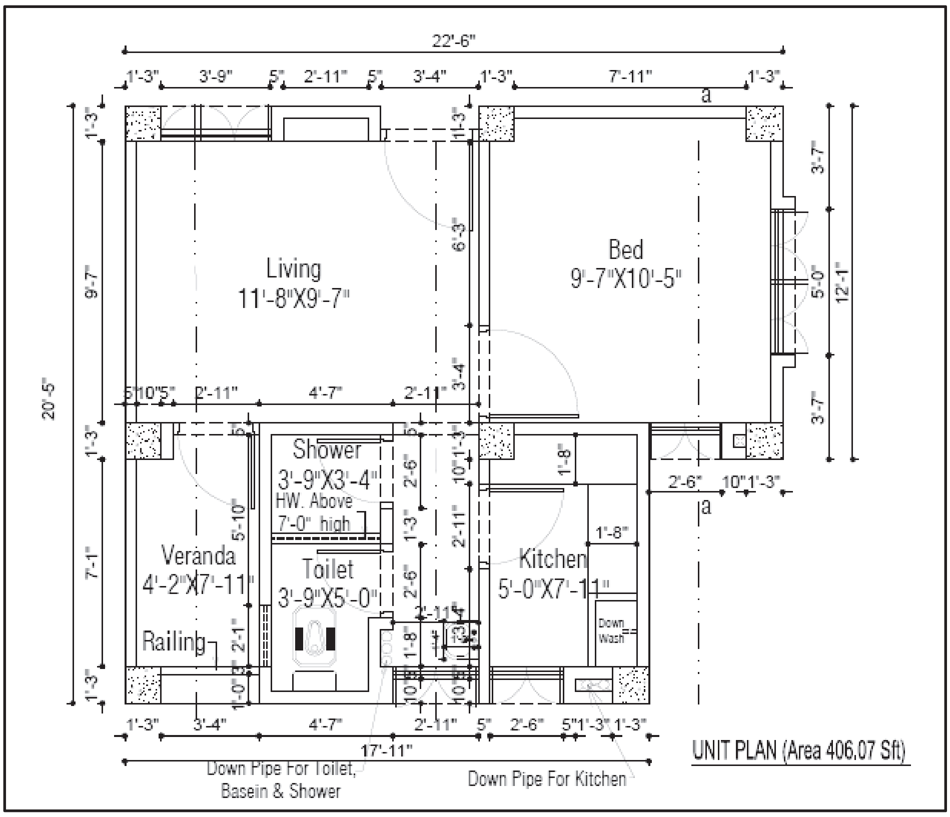


Figure A-2 Low-income residence _ Unit plan

The above plan presents the result as follows.

1) The areas of the bedroom and the living room are sufficient compared to standard.

2) The kitchen area is slightly less than standard.

3) The area of the toilet is only half than standard.

To ensure a more comfortable space, it is necessary to secure an area according to the standard.

A-3: Flats or apartments (an example for Apartment)

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Bed room	Min	2.00	5.00	For A/C=2.44 For Non A/C =2.75 From Beam Bottom = 2.13	19	The room should be naturally ventilated and lighted. Should be located according to wind flow and sun's direction.
Kitchen	Min	1.50	4.00	2.75	19	The room should be properly ventilated and lighted.
Toilet (3 fixture)	Min	1.00	2.75	2.13	-	Basin, W/C & Bath
Toilet (2 fixture)	Min	1.00	1.20	2.13	12	Basin & W/C
Toilet (2 fixture)	Min	1.00	1.50	2.13	12	Basin & Bath
Toilet (2 fixture)	Min	1.00	2.50	2.13	12	W/C & Bath
Staircase	Normal (Min)	1.15 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1 .00 (Width)			16, 17	Fire safety measures should be taken.
Window Opening (Bedroom)	Min	-	15% of floor space		12	Should be located according to wind flow and sun's direction.
Window Opening (Kitchen)	Min	-	-	-	12	Should be located in an external wall or within a verandah not more than 2m in depth or a courtyard of approved size.
Window Opening (Toilet)	Min	-	0.37	-	12	Should be located in an external wall or within a shaft of approved size.

*Parking shall be in accordance with the concerned building regulation.

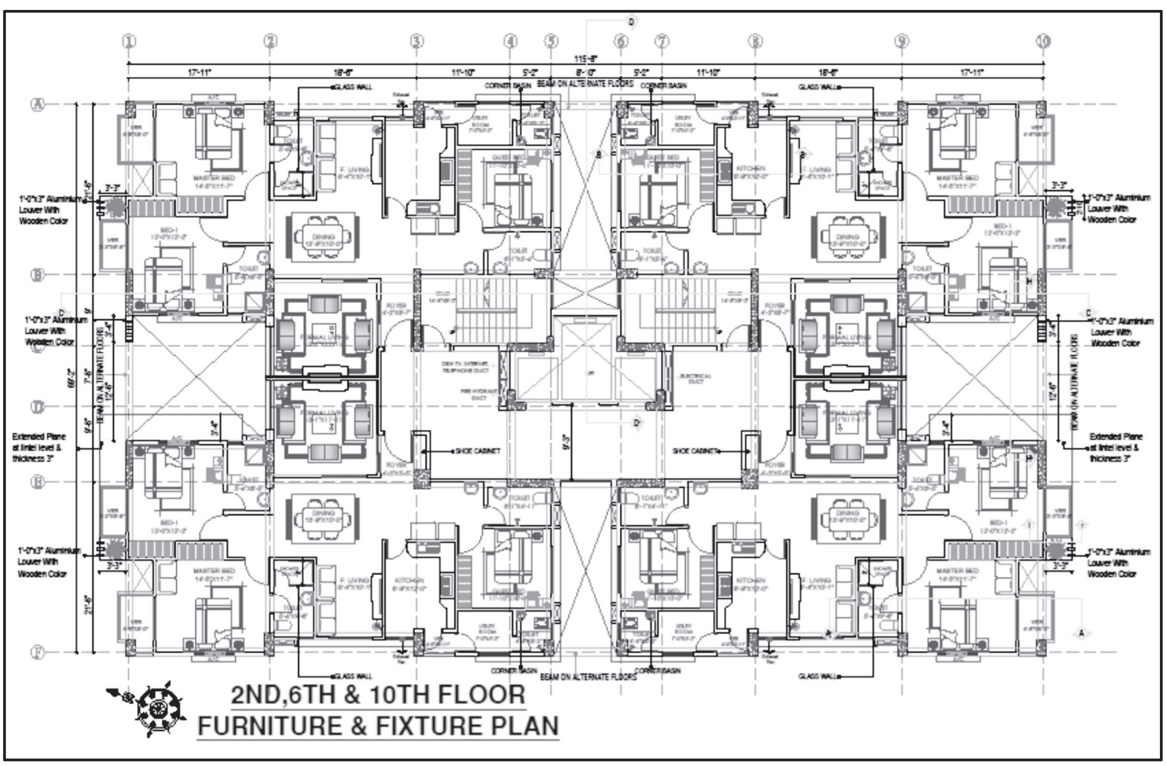


Figure A-3 Apartment typical floor plan

A-4: Mess, boarding houses, dormitories and hostels (an example for Dormitory)

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Bed room	Min	-	24.00	3	DOA's Standard	Area for 4 persons. The room should be naturally ventilated and lighted. Should be located according to wind flow and sun's direction.
Common Room	Min	-	1.40	-	19	Area per person
Dining	Min	-	1.10	-	19	Area per person
Kitchen	Min	-	15.00	-	19	Typical kitchen area (Feeds about 30 people)
Toilet	Min	-	14.00	-	19	Area for 16 boys (2 W.C, 1 Urinal, 2 Sinks, 2 Showers)
	Min	-	14.00	-		Area for 16 girls (2 W.C, 2 Sinks, 2 Showers)
Staircase	Normal (Min)	1.25 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.50 (Width)	-	-	16, 17	Fire safety measures should be taken.

*Parking shall be in accordance with the concerned building regulation.

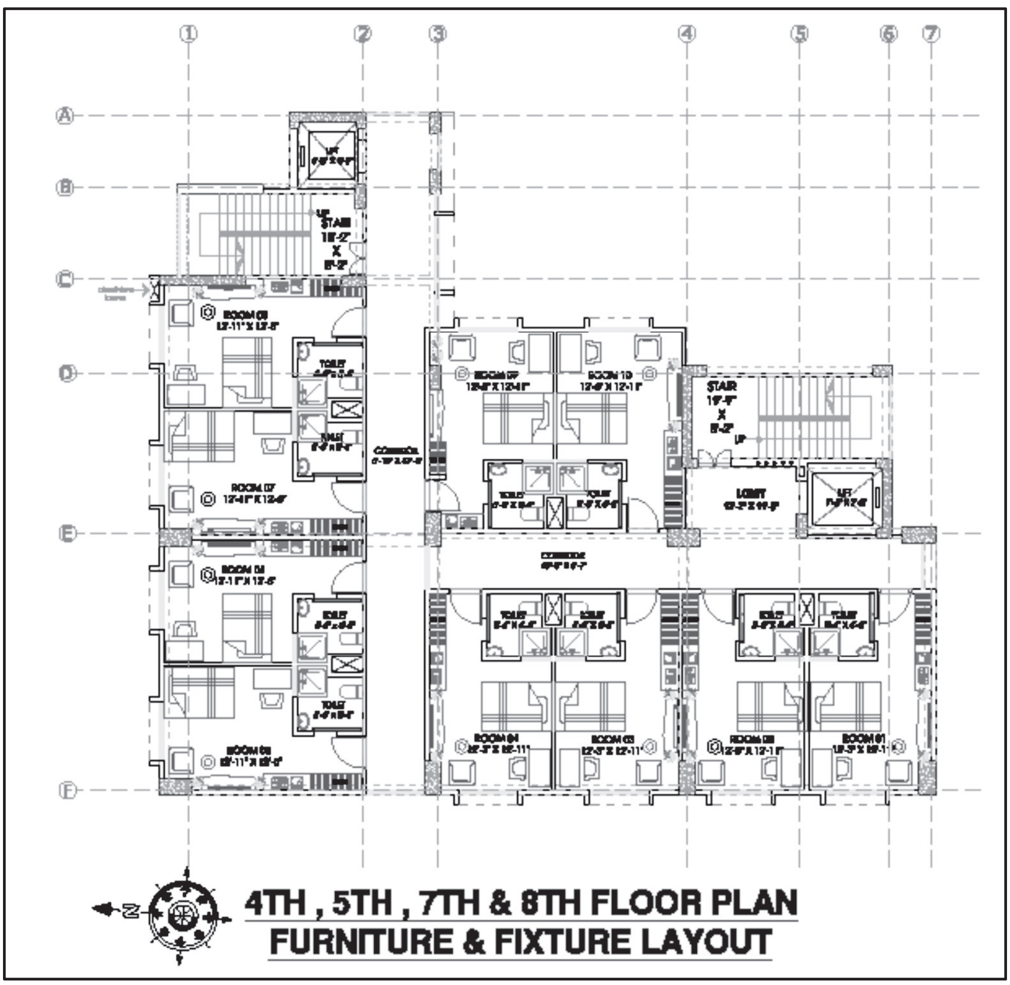


Figure A-4 Dormitory typical floor plan

(B) Educational Facilities

B-2: Facilities for training and above higher secondary (an example for Nurse's training college)

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Conference Room	Min	-	46.50	-	19	Decide a size that can be maintained assuming the maximum capacity of persons.
Top Executive room	-	-	37.00 - 75.00	3.00	19	-
Office room (Junior Executive)	-	-	9.00 - 18.50	3.00	19	-
Workstation	-	-	4.00 - 5.00	-	19	-
Staircase	Normal (Min)	1.50 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.50 (Width)	-	-	16, 17	Fire safety measures should be taken.

*Parking shall be in accordance with the concerned building regulation.

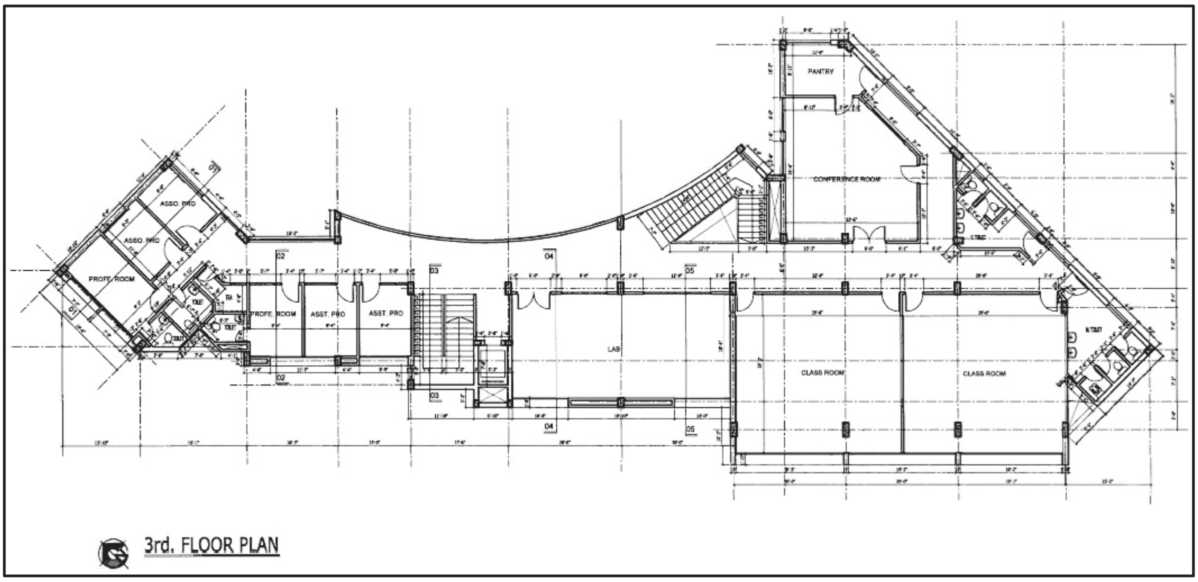


Figure A-5 Nurse's Training College (Dhaka medical College Hospital)

(C) Institution for Care

C-2: Custodial institution for physically capable adults (an example for Prison of 1000 capacity

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Bed room	Min	2.00	5.00	3	DOA's Standard	The room should be naturally ventilated and lighted. Should be located according to wind flow and sun's direction.
Kitchen	Min	1.50	4.00	-	19	The room should be properly ventilated and lighted.
Living room	Min	2.00	5.00	-	19	-
Toilet (2 fixture)	Min	1.00	2.75	-	19	W/C & Bath
Staircase	Normal (Min)	1.25 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.50 (Width)	-	-	16, 17	Fire safety measures should be taken.

*Parking shall be in accordance with the concerned building regulation.

(D) Health Care Facilities

D-1: Normal medical facilities (an example for the Hospital considering with 250 beds)

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Emergency unit	Min	-	190.00	-	DOA's Standard	Included with Minor OT, EMO,Nurse station, Casualty ward, Observation ward, Plaster room, Stomach wash facility room etc.
O.P.D	-	-	146.00	-	DOA's Standard	Included with Sr. Consultant room, Consultant room, Vaccination room, IMC, NCD, ANC & PNC, RP room, RS room.
Diagnostic	-	-	458.00	-	DOA's Standard	Blood sample collection room, Pathologist room, Laboratory, CT scan room, MRI, USG, ECG, X-ray, Mammography, Radio diagnostic.
In-patient facilities	-	-	249.00	-	DOA's Standard	Normal child delivery unit, Scabu, Duty doctor's room, Ward, Cabin room, ICU, CCU, Anesthetist room, Scrub room, Sterile store, O.T, Dirty room, Clean room, Post O.T., Patient holding, Doctor's meeting room.
Administrative	-	-	1135.00	-	DOA's Standard	Canteen, Admin, Conference, Toilet.
Service	-	-	446.00	-	DOA's Standard	Including with generator, laundry, lilen store, store MSR room etc.
Staircase	Normal (Min)	2.00 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.50 (Width)	-	-	16, 17	Fire safety measures should be taken.

*Parking shall be in accordance with the concerned building regulation.

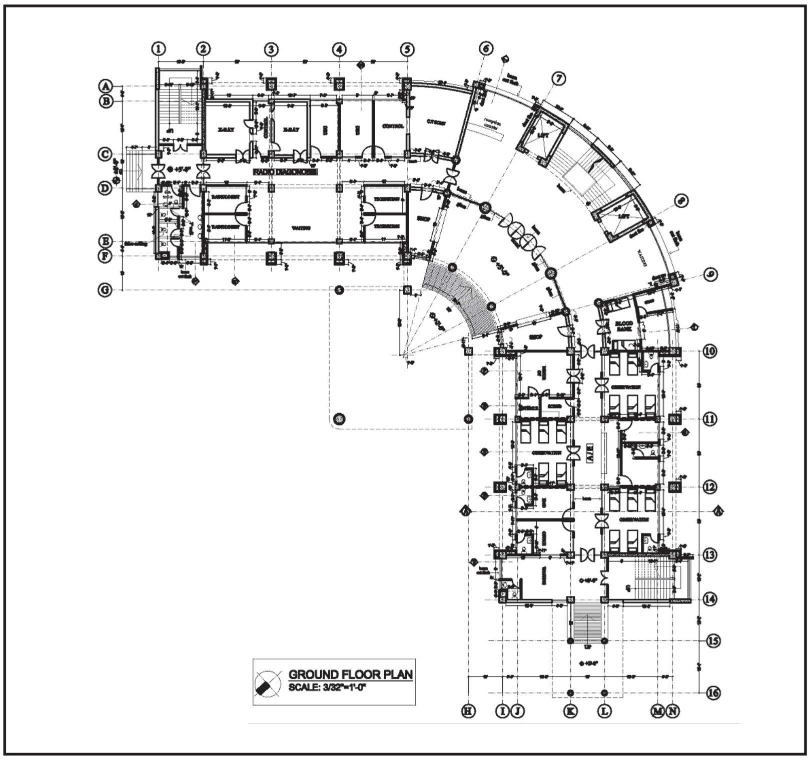


Figure A-6 Ground Floor Plan of a Hospital

D-2: Emergency medical facilities (an example for the Emergency treatment center (Trauma Center))

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Emergency facilities	-	-	340.00	-	DOA's Standard	Emergency Bed, Diagnostic, Treatment Room, Observation, Examination, Nurse Station Etc.
In-patient facilities	-	-	680.00	-	DOA's Standard	Post-operative, C.C.U, Resuscitation, O.T, Scrub, Dock/surgeon anesthetist, Duty doctor, Nurse station, ward, Doctor's room etc.
Service & circulatio	-	-	420.00	-	DOA's Standard	-
Staircase	Normal (Min)	2.00 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.50 (Width)	-	-	16, 17	Fire safety measures should be taken.

*Parking shall be in accordance with the concerned building regulation.

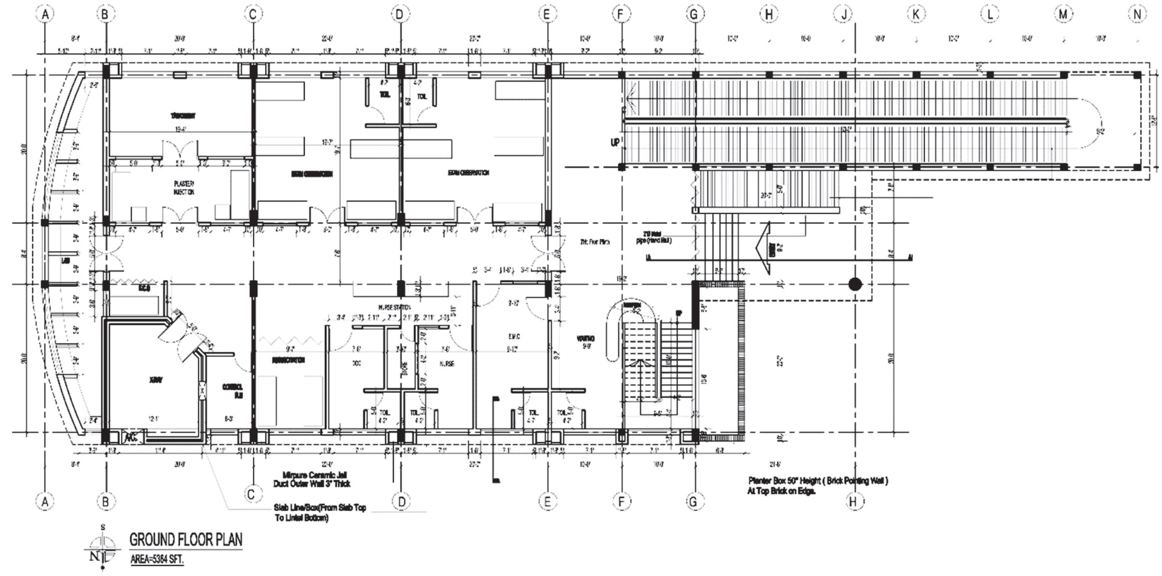


Figure A-7 Ground Floor Plan of a Trauma Center

(E) Business

E-1: Office

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Minister/ State Minister/ Deputy Minister	Min	-	34.00	-	MOHPW & DOA's Standard	With attached toilet.
Secretary/ Additional Secretary/ Equivalent	-	-	30.00	-	MOHPW & DOA's Standard	With attached toilet.
Joint Secretary & Equivalent	-	-	21.00	-	MOHPW & DOA's Standard	With attached toilet.
Deputy Secretary & Equivalent	-	-	15.00	-	MOHPW & DOA's Standard	MOHPW & DOA's Standard Individual room with common toilet.
I class & II class officers	-	-	9.50	-	MOHPW & DOA's Standard	Common toilet
Class III employee	-	-	5.60	-	MOHPW & DOA's Standard	Including with generator, laundry, lilen store, store MSR room etc.
Staircase	Normal (Min)	1.50 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.50 (Width)	-	-	16, 17	Fire safety measures should be taken.

* Parking shall be in accordance with the concerned building regulation.

* MOHPW= Ministry of Housing & Public Works.

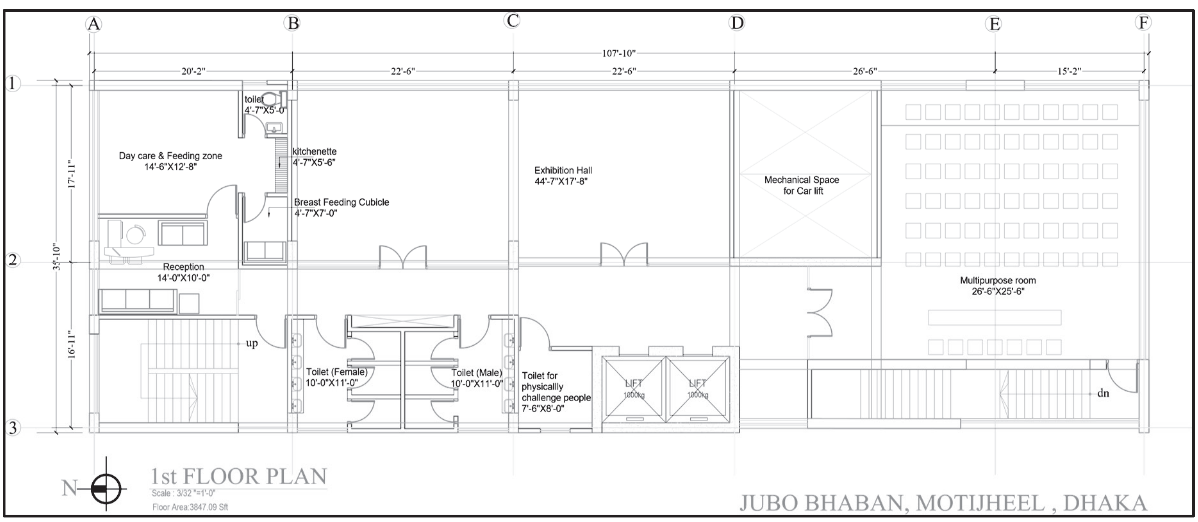


Figure A-8 Office Jubo Bhaban

(I) Assembly

I-1: Large assembly with fixed seats (an example for Auditorium)

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Seating area	-	-	325.00	6	DOA's Standard	-
Lobby	-	-	325.00	4	DOA's Standard	-
Stage with back stage & others	-	-	325.00	-	DOA's Standard	-
Staircase	Normal (Min)	2.00 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.50 (Width)	-	-	16, 17	Fire safety measures should be taken.

*Parking shall be in accordance with the concerned building regulation

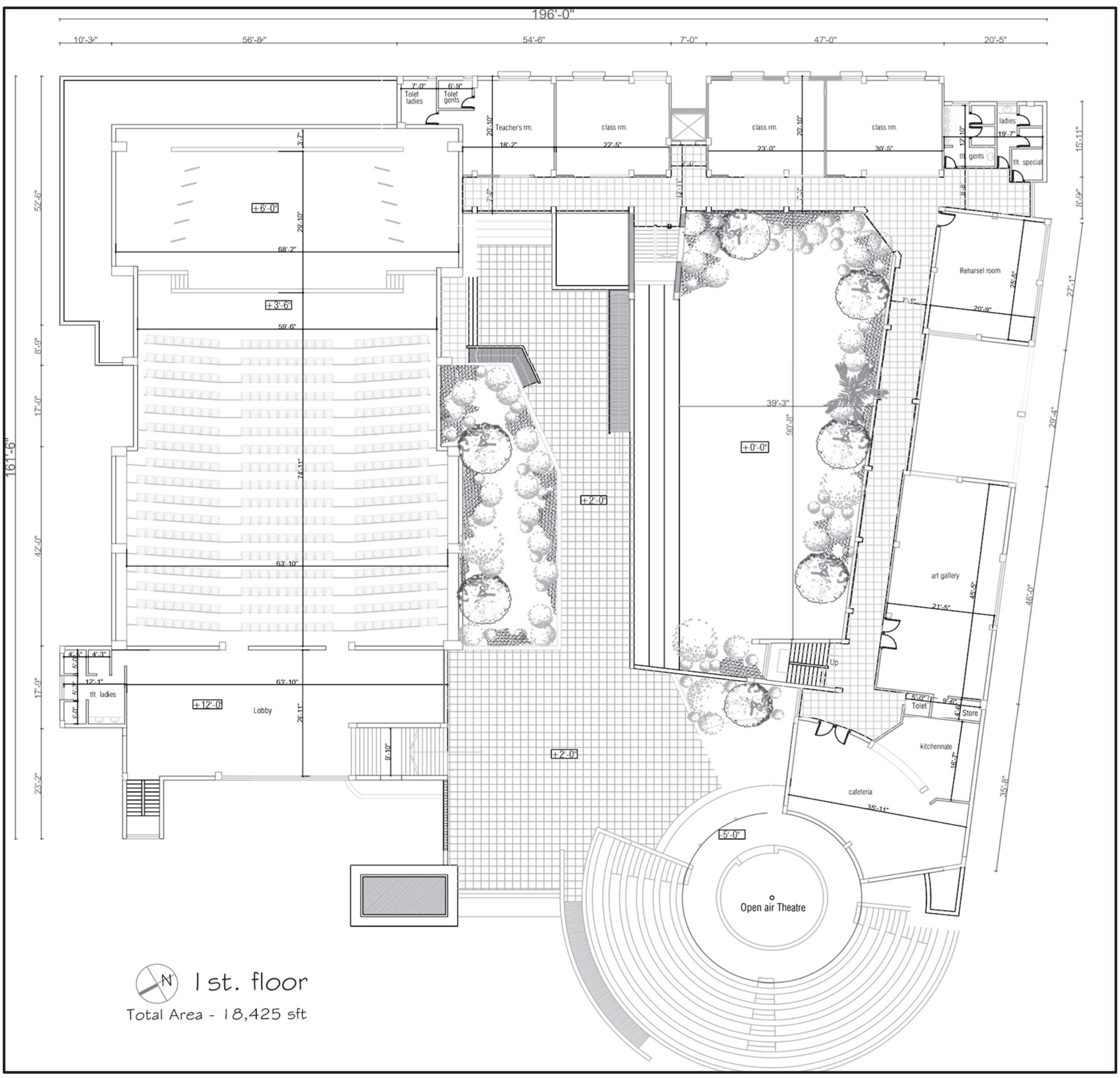


Figure A-9 Shilpakala Academi, Barishal Auditorium

(M) Miscellaneous

M-1: Special structures (Religious buildings considering a Mosque for 500 people)

Space	Space Type	Length/ Dimension (m)	Area (Sqm)	Clear Height (m)	Reference No. of Table 2-5	Remark
Prayer room	-	-	0.75/ Person	-	DOA's Standard	-
Priest's room	-	-	50.00		DOA's Standard	Included with kitchen & toilet
Office room	-	-	50.00		DOA's Standard	-
Toilet & ablution	-	-	50.00	-	DOA's Standard	Shall increase with the increasing number of purson
Staircase	Normal (Min)	2.00 (Width)	-	-	12	Stair railing height should be followed according to Refernce No.7.
	Fire exit Stairway (Min)	1.50 (Width)	-	-	16, 17	Fire safety measures should be taken.

*Parking shall be in accordance with the concerned building regulation.

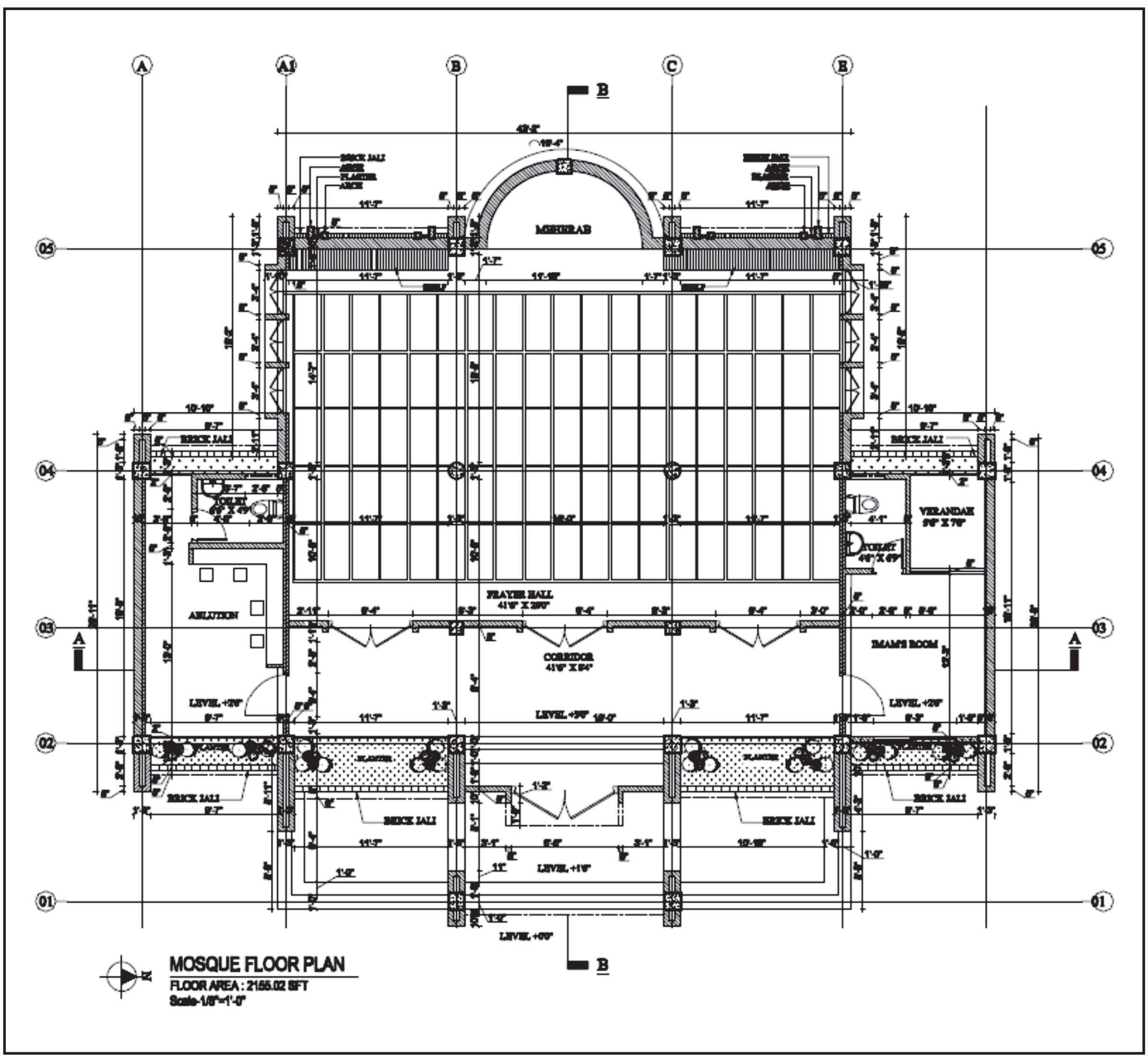


Figure A-10 Plan of a Mosque

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