

MIXED USE DEVELOPMENT

A THESIS

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Architecture degree

By

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
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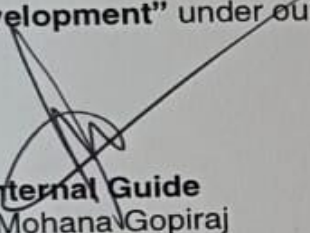
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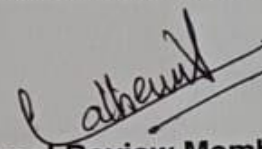
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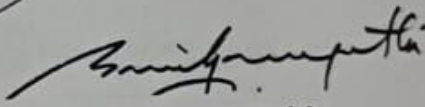
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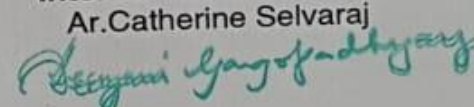
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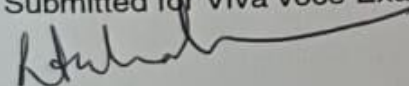

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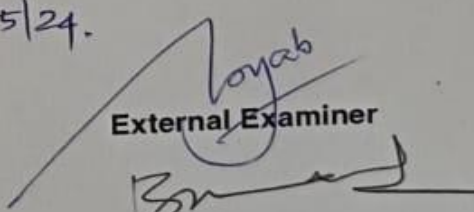

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I, **SHANJAY M** hereby declare that the Thesis Report entitled "**MIXED USE DEVELOPMENT**" done by me under the guidance of **Ar. Mohana Gopiraj** (Internal Guide), **Ar. Catherine Selvaraj** (Internal Review Member) and **Ar. Sriram Ganapathy** (External Guide) Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Bachelor of Architecture Degree.

DATE: MAY 25, 2024

PLACE: CHENNAI



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SHANJAY M

THESIS SYNOPSIS

Mixed-use development has emerged as a pivotal solution in urban planning, catering to the evolving needs of communities and addressing the challenges of sustainability, economic vitality, and social cohesion. This paper explores the evolution of mixed-use development, tracing its historical roots, analyzing contemporary trends, and envisioning its future trajectory.

The historical narrative reveals how mixed-use developments have transitioned from traditional town centers and market squares to modern-day urban districts, characterized by a blend of residential, commercial, and recreational spaces. This evolution has been shaped by shifts in societal preferences, economic dynamics, and urban planning paradigms, reflecting a growing recognition of the interconnectedness between built environments and quality of life.

Contemporary mixed-use developments are characterized by their emphasis on walkability, accessibility, and diversity. By integrating various land uses within close proximity, these developments promote vibrant street life, foster social interaction, and reduce reliance on automobile transportation. Moreover, the analysis evaluates how mixed-use buildings impact sustainability, urban planning and community wellbeing. It assesses their contribution towards reducing commute times improving energy efficiency and fostering interactions. Ultimately this promotes a livable urban landscape.

In conclusion this thesis provides insights into the realm of mixed use development . It offers an understanding of their significance in urban development. Its goal is to help optimize the delivery of mixed use development fostering vibrant and thriving environments.

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Chapter 1 Introduction

In today's fast-paced urban environment, mixed-use developments have emerged as dynamic hubs that embody the essence of contemporary living with first-class ease and seamless blending of living, working and recreational spaces. A mixed-use building is a type of urban development that integrates several uses such as residential, commercial, cultural, institutional and entertainment uses, into a single building with the desire to provide multiple functionalities and build a sustainable urban environment that creates a mindful community with enhanced social and economic interactions. These buildings are real ecosystems that encourage the sense of surroundings with increased convenience that transform the fundamental essence of urban living.

In this analysis of services for mixed-use buildings, we investigate the wide variety of options that tend to the diverse demands and requirements of residents and businesses coexisting under a single roof. From collaborative amenities that upgrade livelihood to integrated solutions that simplify operations, this architectural wonder represents the evolution of spaces that transcend from the conventional single-use buildings. The purpose of studying and analyzing the services in mixed-use buildings is to understand how these buildings can be designed to provide the best possible services to their occupants. This includes analyzing the different types of services that are provided in mixed-use buildings and how they can be optimized to meet the needs of the residents.

Difficulties faced by current urban development:

- Rapid growth of population in urban communities.
- Expensive land prices.
- Restriction of random expansion in major cities adjacent to agricultural land.
- The high cost of setting up infrastructure for new cities.
- Expression of progress and civilization.
- Increasing demand for residential and business space.
- Innovation in structural system.
- Land scarcity.

Mixed-use buildings address the above challenges by providing varied solutions that promote sustainability and a productive community.

Services play a crucial role in any building irrespective of its size along with careful design and planning of building components like ventilation, HVAC systems, lift, staircase, water supply system, firefighting system, drainage system. The right design of services promotes circulation and good ventilation. Building services play a key role in contributing to the design of a building, not only in terms of overall strategies and standards to be achieved, but also in facade, weights, sizes and location of major plant and equipment, the position of vertical service risers, routes for the distribution of horizontal services, drainage, energy sources, sustainability, and so on. This means that building services design must be integrated into the overall building design from a very early stage, particularly on complex building projects such as mixed-use building. Building related directly to the services. Without services, a building is of no use.

1.1 Aim

An Analysis of Mixed-Use Buildings

1.2 Objective

- To study the functionality of services of mixed-use building to date.
- To define the complex challenges of determining the services of a mixed-use building.
- To represent the benefits and drawbacks of a mixed-use building and how automation and digitalization helps in improving the functionality of the building.
- To provide the knowledge of functionality of spaces in a mixed-use building.

1.3 Research Questions

- To study the different type of services used in Mixed-use buildings.
- Investigate how different services are integrated within the building considering spatial, accessibility and ease of use.
- How are the design considerations being followed in the mixed use building for each services.
- Analysis of the latest technological advancements in building services.

Research Papers

1.Mixed-use development in a high-rise context

Elena M. Generalova^{1,*} , Viktor P. Generalov¹ , Anna A. Kuznetsova¹ , and Oksana N. Bobkova¹
<https://doi.org/10.1051/e3sconf/20183301021>

About the paper:

The article deals with an actual problem of finding techniques and methods to create a comfortable urban environment. The authors emphasize that in the existing conditions of intensive urban development greater attention should be given to spatial concentration based on and more compact

distribution of population in urban space. It is stressed that including mixed-use facilities into urban realm results in a significant improvement of living environment qualitative characteristics.

2. Integration of Building Services in Intelligent Buildings

Journal of Civil Engineering and Environmental Technology p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 6, Issue 5; July-September, 2019, pp. 358-362 © Krishi Sanskriti Publications <http://www.krishisanskriti.org/Publication.html>

About the paper:

This paper explains about the central unit that monitor the services. This tells about the relationship between two systems. this paper explain about Building automation system, network intelligence in the building and automatic alarm system and fire system. This focus on integration aspects of various building services in Intelligent Buildings.

3. Mechanical supply and exhaust ventilation in high rise residential buildings in russia

Author: Elena Zolotareva

About this paper:

This paper explain about the natural ventilation system and mechanical ventilation system types of mechanical ventilation system. This paper detail it about the system explain with pictorial graphic. This paper also explain about the balanced ventilation system

4. Building services handbook

Author: Fred Hall & Roger Greeno

About the book:

It overviews of the role and importance of building services in modern construction. Discusses various heating systems, their components, and energy-efficient methods. Provides insights into electrical system design, power distribution, and lighting design. Highlights the importance of sustainable building practices and energy-efficient technologies. Regulations and Standards Discusses relevant building codes, regulations, and industry standards.

5. Mixed use super tall and hybridization of program

Author: Forth Bagley

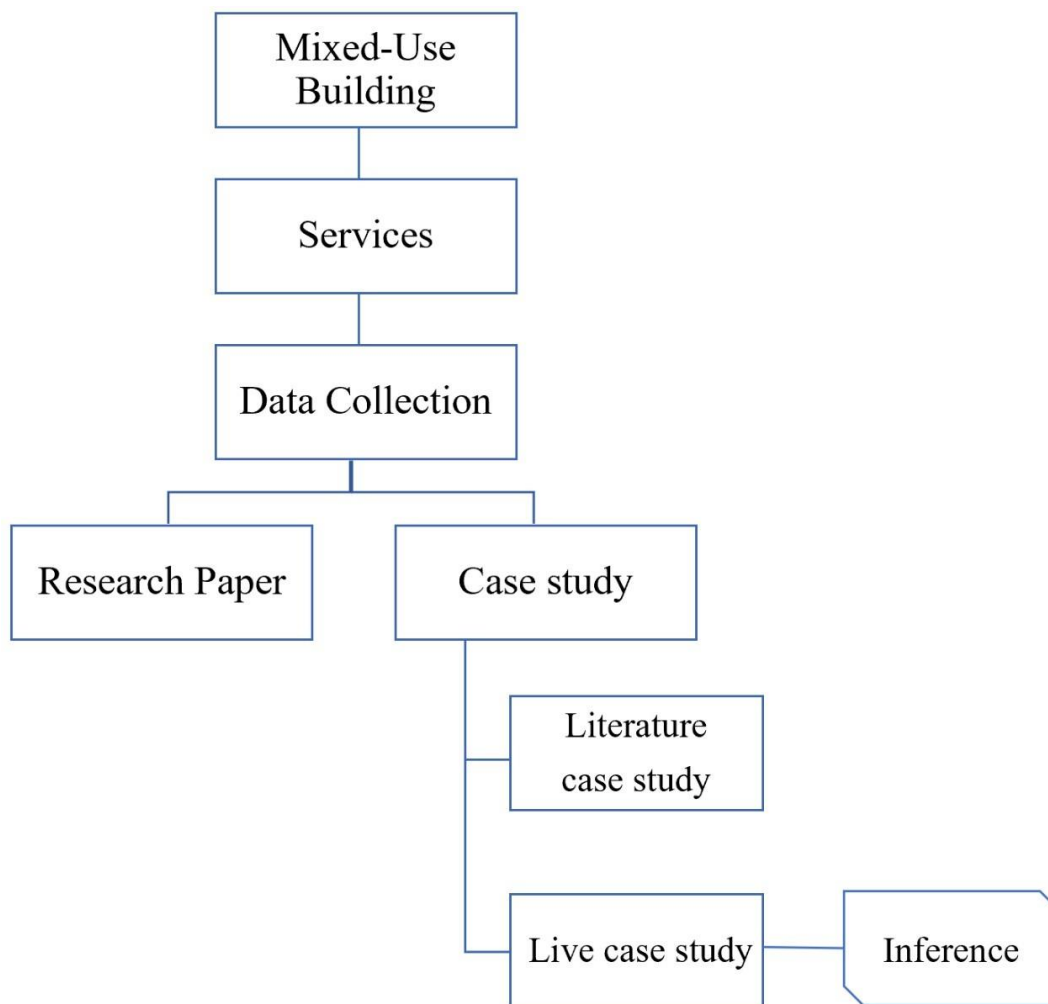
About the paper:

Programmatic advancements in supertall design outlined here are each incremental. Taken together, however, they represent a sea change in the way developers and their designers are approaching the functional planning of these iconic structures. In years we will see supertall towers that more completely integrate and blend user needs. Existing towers will be repositioned. new

towers will be built. The dream of the supertall as a "city within a building" will be closer to its full realization.

1.4 Methodology

The process begins by identifying aims and objectives, followed by the literature study and reviews. Then, various services required in a mixed-use building are analyzed and determined. Later, live and research studies have been done for better understanding of services in mixed use buildings.



Chapter 2 Introduction to Building Services

This Chapter provides a brief introduction about the building services and the mixed-use buildings considered for the case study.

Building services comprises of multiple systems and components installed in the buildings which provide comfort, functionality, efficiency, and safety. Some of the building services include:

- HVAC
- Lifts and escalators
- Water supply and disposal
- Electrical system
- Fire safety, detection, and protection
- Acoustics

In simple terms, a building can be described as a structure and the building services can be described as the components within the structure that provide functionality to a building which meets with the requirements of the occupants. Electricity, water, and telecommunication are basic requirements in the domestic houses for day-to-day usage. But the mixed-use buildings which are designed for multifunctionality, and versatility consist of various other services as well.

2.1 Types of Building Services

2.1.1 HVAC

HVAC stands for Heating, Ventilation and Air Conditioning

1. Ventilation:

Ventilation is the process of interchanging air in a space to ensure good indoor air quality including temperature management along with removal of excess moisture, heat and odor. The ventilation can be divided into two types as follows:

- **Natural ventilation:** Natural ventilation refers to the entry of fresh air and exit of used air from a room or a building under the influence of natural factors. The most common sources for natural ventilation are wind pressure and stack effect.
- **Mechanical ventilation:** Mechanical ventilation refers to the use of mechanically engineered systems for the exchange of air to keep the indoors cooler.

2. Air Conditioning:

Air conditioning is the process of removing heat and moisture from the interior space. It is used in commercial and domestic environments to achieve thermal comfort and to control humidity, temperature, sound, cleanliness, and heat. The different types of air conditioning systems are as follows:

- Window AC: As the name suggests, this type of air conditioning is installed on the windows which comprises of a compressor, an evaporator with fans and air-cooled condenser. Suitable for bedrooms, office cabins, etc.
- Split AC: Split AC consists of an indoor unit comprising of a filter, evaporator, and a fan and an outdoor unit with compressor and air-cooled condenser with fan.
- Packed AC: This type of air conditioners are primarily mounted outdoors or in rooftops and they consist of multiple components such as compressor, condenser, and evaporator, which are interconnected with copper refrigerant piping and refrigerant controls housed in a single packaged unit.
- Centralized AC: This air conditioning system involves cooling the air in a centralized location and supplying the cooled air throughout the building through vents and duct work.

2.1.2 Lifts and Escalators

A lift or an elevator represents a car that moves in a vertical shaft to carry people and goods between the levels of a multistoried building. While an escalator is a moving stairway that has a capacity to transport a considerable quantity of people effectively that requires little to no waiting time. There is another lift/escalator referred as travelator that carries people and goods in horizontal manner usually seen in airports.

2.1.3 Water Supply and Disposal

Water supply and disposal systems are basic requirements of any building that ensures proper supply of clean water for multiple purposes from source to the point the usage and removal of used water through drains and pipes. The basic components of water supply system include water source, storage, treatment, and distribution, while disposal systems contain drainage, septic tanks, etc.

2.1.4 Electrical System:

Electrical system is a network of circuits, wires, conductor, and equipment designed to securely transport, distribute, and convert electrical power from the generation units to the various other units that consume the electrical energy throughout the building. These systems are crucial as various other services rely on electricity for lighting, heating, air conditioning and so on. The components of an electrical system are as follows:

- Wires and cables

- Switches
- Fixtures
- Main panel
- Grounding system

2.1.5 Fire Safety System:

A fire safety system is a collection of protocols, equipment and safety measures required for the detection, protection, and prevention of damage to public and property in the event of fire. The components of a fire safety system involve,

- Fire alarm systems
- Smoke and flame detectors
- Fire extinguishers
- Sprinkler systems
- Fire escape exits.

2.1.6 Acoustics

Acoustic system consists of set of components for recording, transmitting and processing the sound to manage the sound quality, reduce noise and ensuring better audio experiences.

2.2 Case Studies:

This section represents the various mixed-use buildings taken as a part of case study.

2.2.1 Live Study:

1. Marina Mall:

Located: OMR, Chennai

Building type: mixed-use development

Total area: 5,32,680 sq ft

Floors: 3B+ G +Four floors offering spaces for shopping, dining, sports and entertainment purposes.

Project Completed in -2019



Fig 2.1 Marina Mall

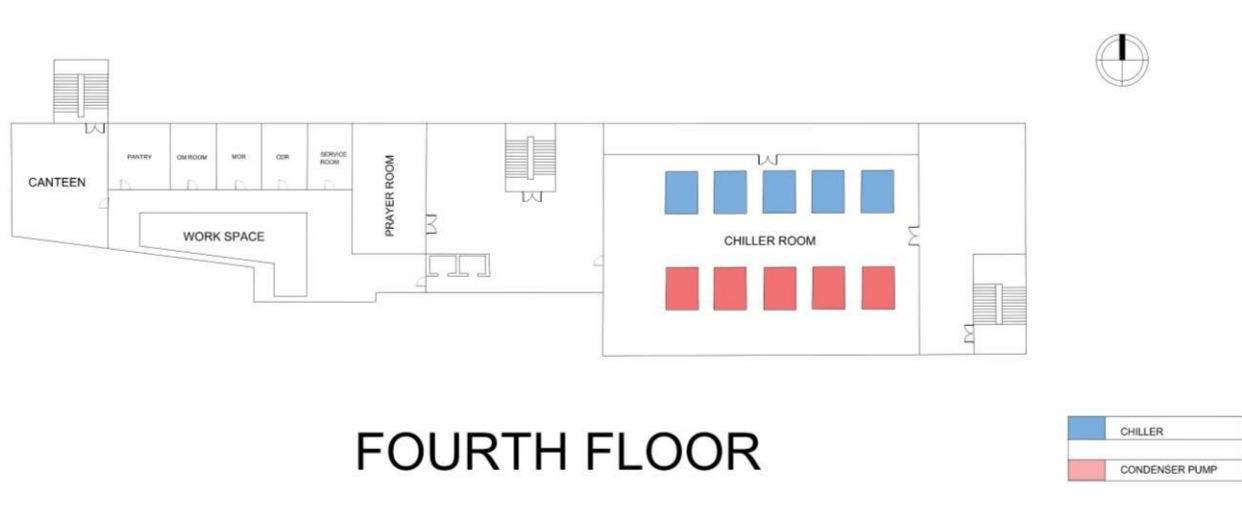


Fig 2.2 chiller plant



Fig 2.3 Vertical transportation



Fig 2.4 water supply and disposal

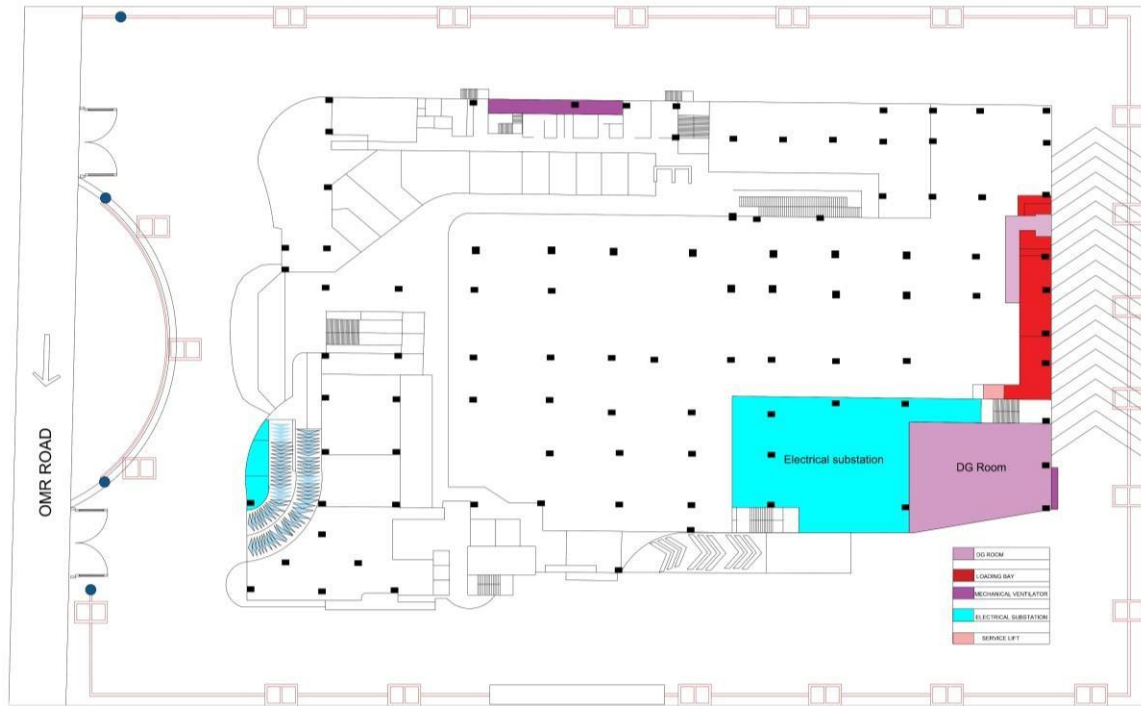


Fig 2.5 Electrical substation & DG



BASEMENT 2

Fig 2.6 Firefighting water system

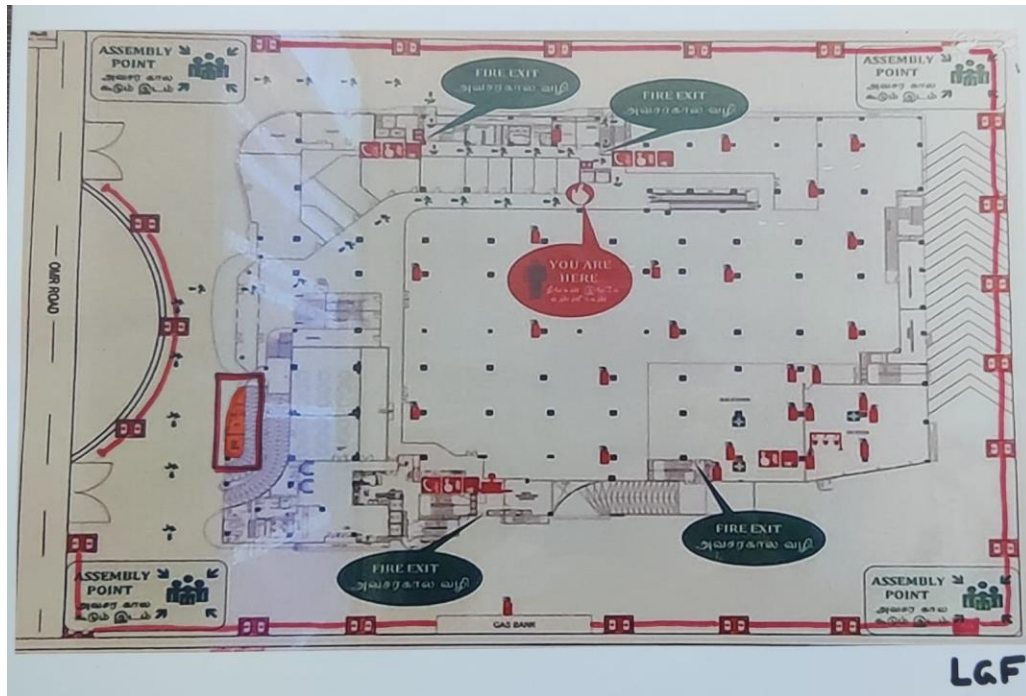


Fig 2.7 Fire water pipe line



Fig 2.8 Cooling tower

Thamarai tech park

Typology: commercial

Address: Thiru Vi Ka Industrial Estate, SIDCO Industrial Estate, Guindy

Total area: 6,30,000 sq.ft

Total no of parking:

720 parking, 520 basement parking

Block	Typical floor area	Total area	Floor
North Block	40500 sqft	243000 sqft	2B+G+5
South Block	38000 sqft	266000 sqft	2B+G+6

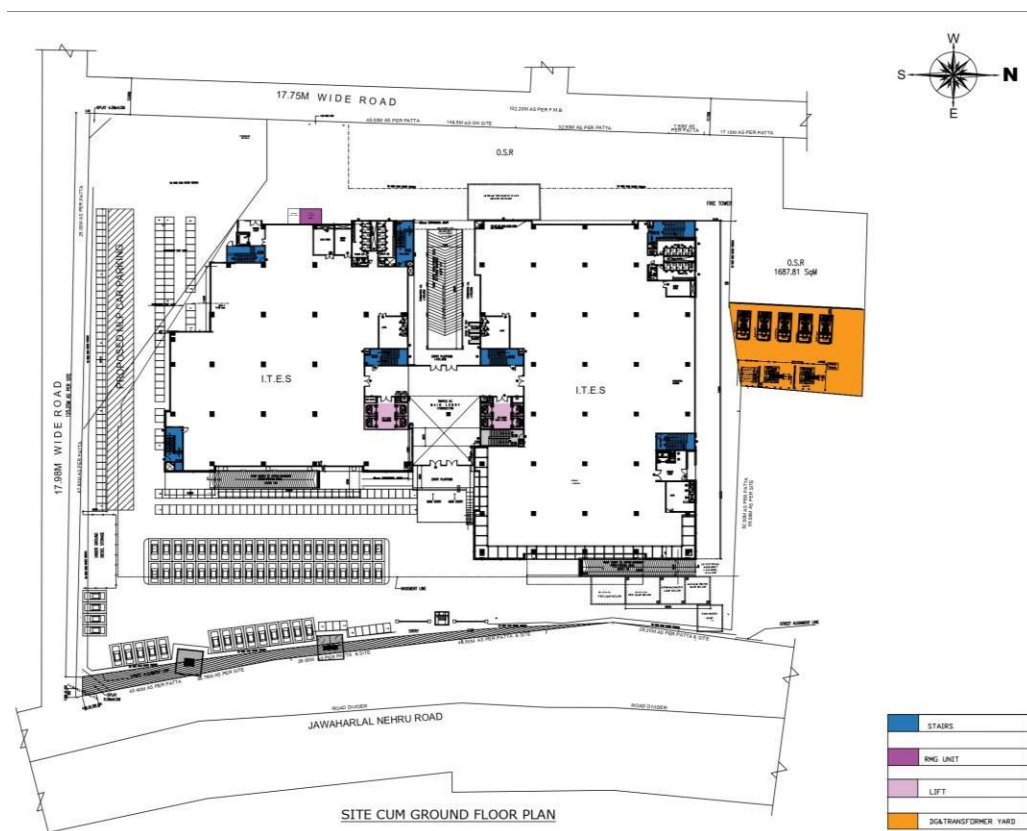


Fig 2.9 vertical transportation

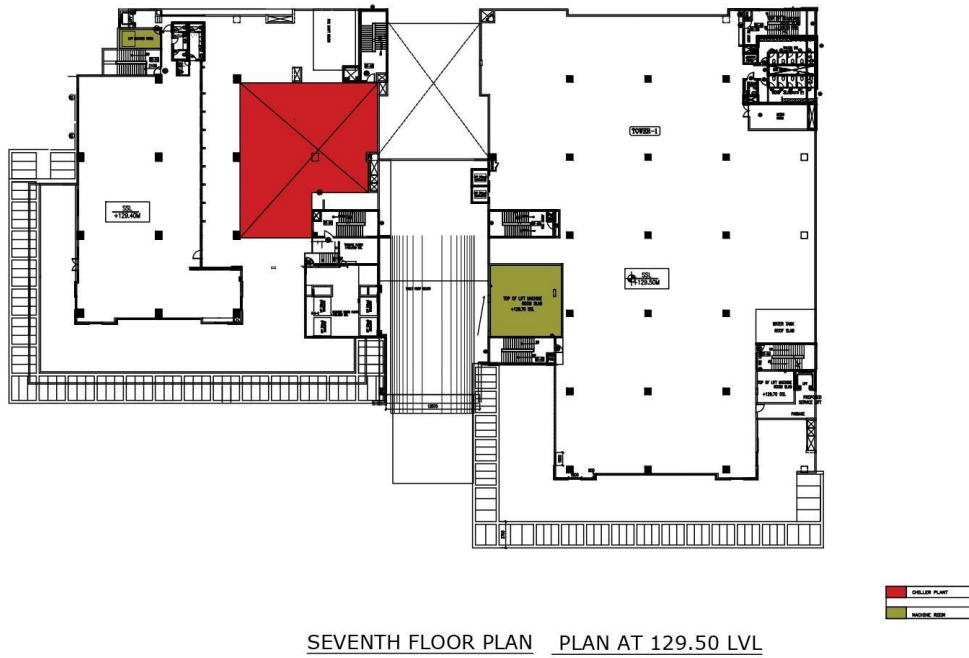


Fig 2.10 chiller plant & lift machine room

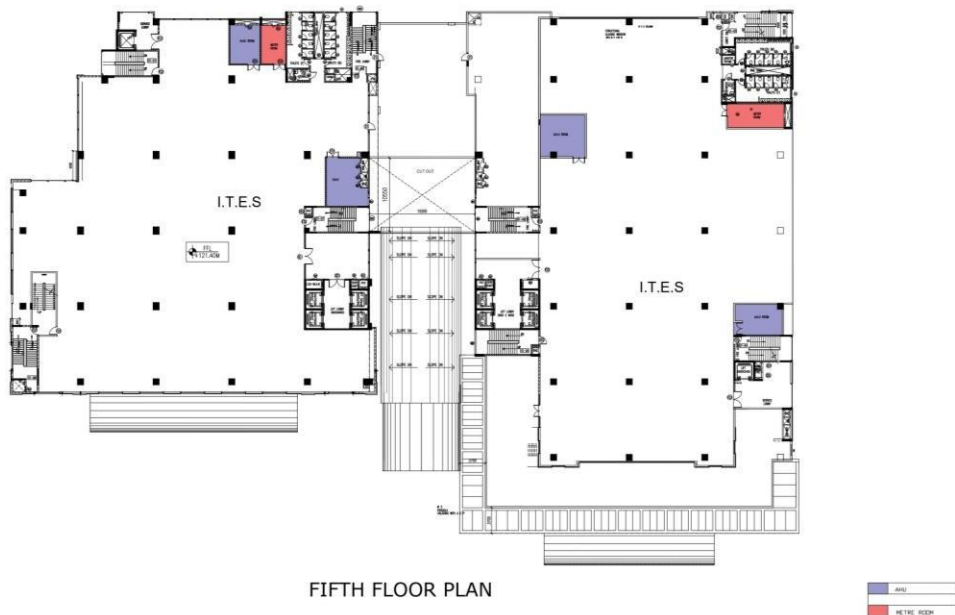


Fig 2.11 AHU & Meter Room

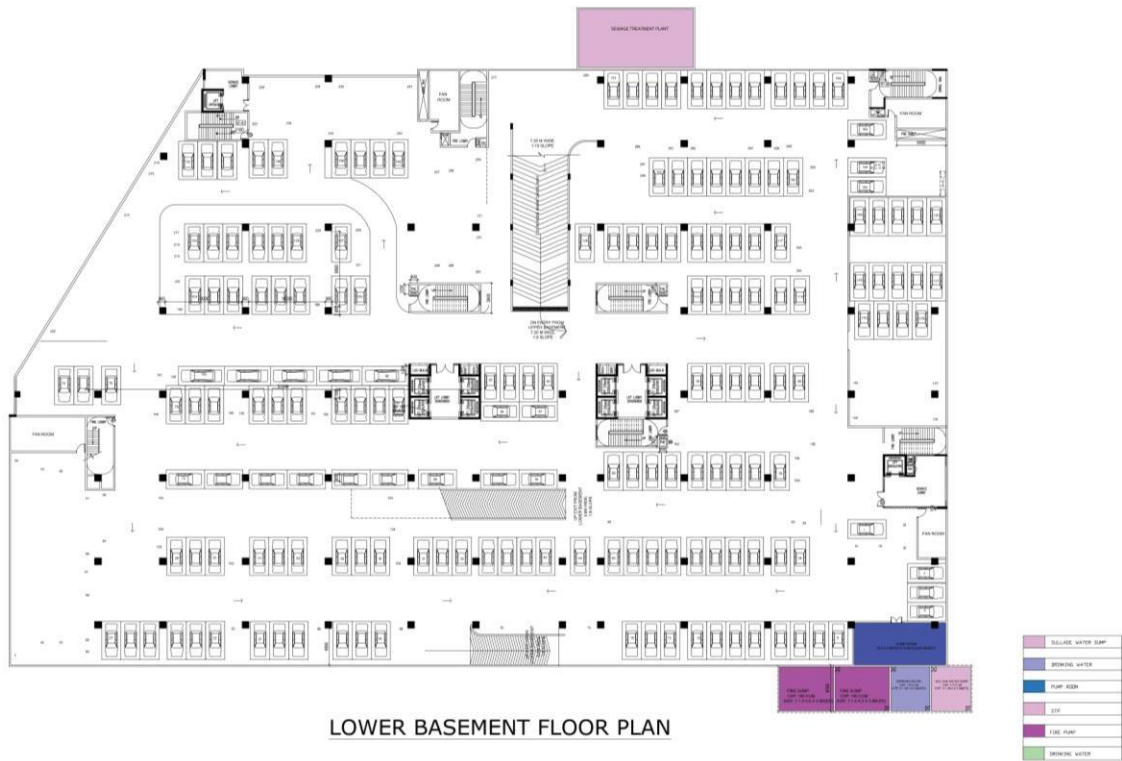


Fig 2.12 WTP & STP

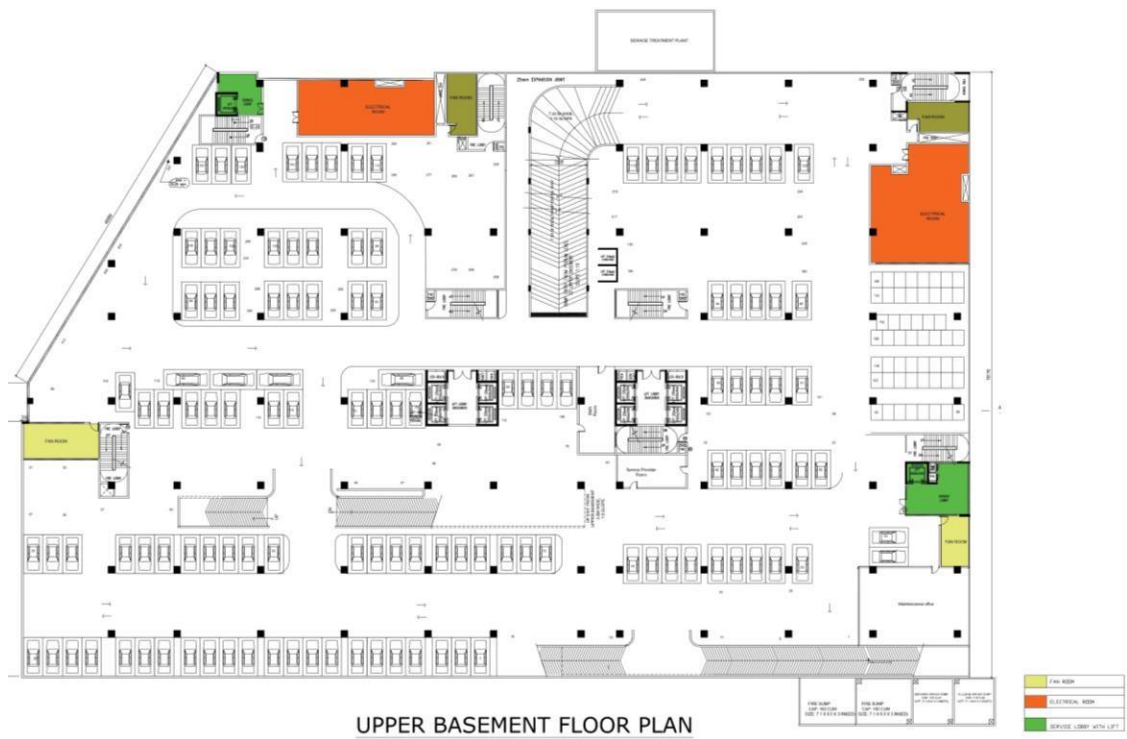
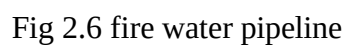


Fig 2.13 Electrical room & fan room



2.3.2 Literature Study:

1. Burj Khalifa - Dubai

Burj Khalifa is the world's tallest building of mixed-use type developed by architect Adrian Smith situated at an area of 454,249 sq m and a height of 2,717 ft. This structure expands over 163 floors containing residential, dining, official, mechanical and communication spaces.



FLOORS	USAGE
160 – 163	Mechanical
156 – 159	Communication and
111 – 154	Corporate Suites
19 – 108	Residential
Concourse – 16	Armani hotel and Residences
B1 – B2	Parking

Table 2.1 Burj Khalifa floor plan

2. Taipei 101 – Taipei

Taipei 101 tower is a mixed-use skyscraper of an area of about 412,500 sq m and height of 1,667 sq ft. The floor plan of the tower is as follows:



FLOORS	USAGE
101 st	Private VIP Club
92 nd – 100 th	Communication
91 st	Observatory Deck
88 th – 89 th	Indoor Observatory Deck
85 th – 86 th	Observatory Restaurant
59 th – 84 th	High Zone Lobbies
59 th – 60 th	Sky Lobbies
36 th – 58 th	Mid Zone Lobbies
35 th – 36 th	Sky Lobbies
9 th – 34 th	Amenities
B1 – 5 th	Taipei Mall
B5 – B2	Parking Levels

Table 2.2 Taipei tower floor plan

2. Shanghai Tower – Shanghai

Shanghai tower is a 2073 ft mega tall mixed-use skyscraper located in Shanghai, China which expands over an area of 380,000 sq m with 128 floors. The floor plan is represented in fig 2.3.

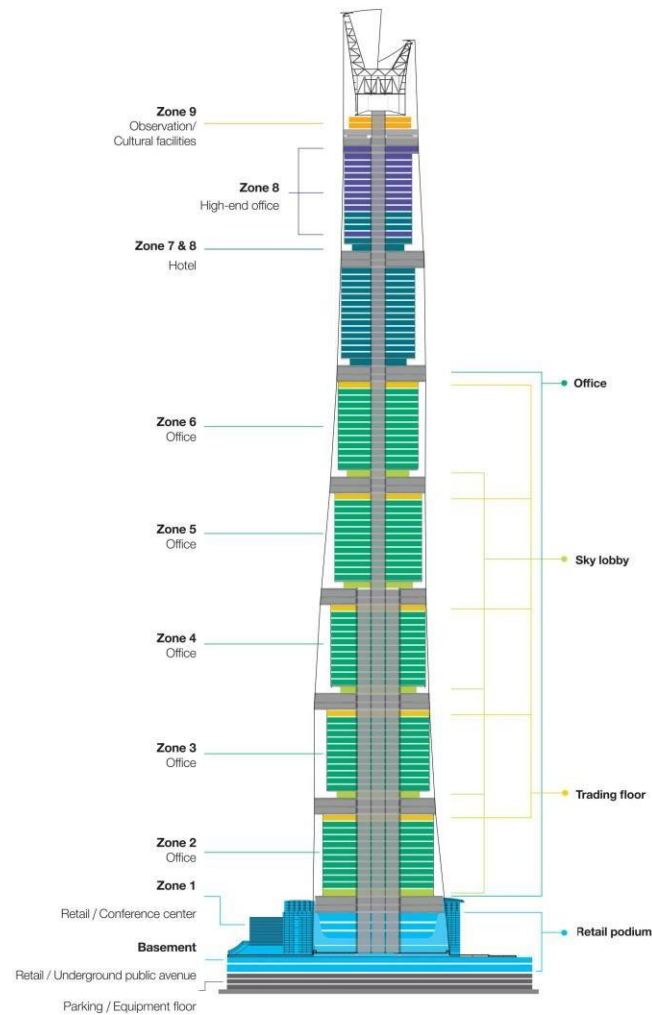


Fig 2.15 Shanghai tower floor plan

Chapter 3 Ventilation

Ventilation plays an important role in any building, especially in the case of mixed-use development involving multiple services used by a large group of people. Building a mixed use environment that has open space and provisions for air flow may not be the best ventilation strategy as the amount of heat, moisture and dust levels can't be controlled. Hence, in this case mechanical ventilation is a more suitable option.

3.1 Mechanical Ventilation

Mechanical ventilation refers to the use of mechanically engineered systems for the exchange of air to keep the indoors cooler. There are three types of mechanical ventilation systems with each having distinct functions. Mechanical ventilation is used where natural ventilation is not suitable. Without mechanical ventilation which brings in fresh air, factors such as impurity, heat, moisture, and odors may remain in the building which will cause health related problems and sometimes even cause fire. Mechanical ventilation circulates fresh air by using fans and ductwork rather than relying on openings or windows.

Types of mechanical ventilation system

- Supply ventilation system
- Exhaust ventilation system
- Balanced ventilation system

3.1.1 Supply Ventilation System

Supply ventilation system supplies fresh outdoor air with the help of mechanical inlet and natural outlet. The function of the system is to provide outside air through mechanical means and to maintain positive pressure within the enclosed space. This system ensures constant circulation of indoor and outdoor air through a controlled supply of fresh outdoor air. This system is commonly found in factories or boiler plants. The supply ventilation system is shown in fig 3.1.

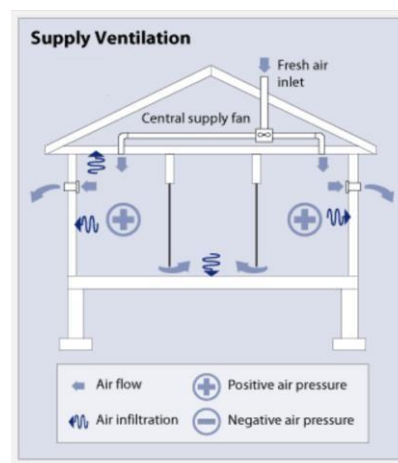


Fig 3.1 Supply ventilation system

3.1.2 Exhaust Ventilation System

The exhaust ventilation system consists of a natural inlet and a mechanical outlet. The function of this ventilation system is to remove stale indoor air through mechanical means by creating a negative pressure in the space and replace it with outdoor air incoming through a natural inlet. This maintains a flow of outdoor air into the enclosed space. This system is commonly used in kitchens, bathrooms, basements, and attics. The working of exhaust ventilation system is represented in fig 3.2.

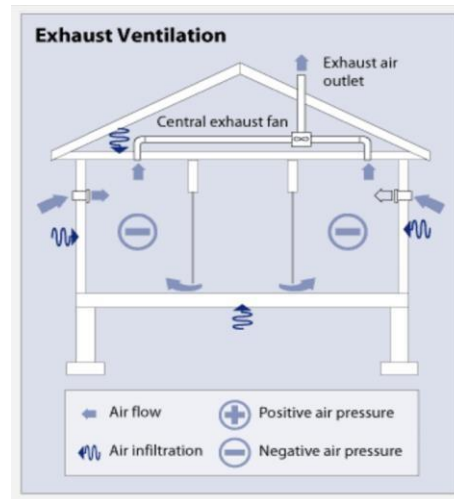


Fig 3.2 Exhaust ventilation system

3.1.3 Balanced Ventilation System

Balanced ventilation system comprises of both mechanical inlet and outlet as represented in fig 3.3. This ventilation system provides a balanced supply of fresh outdoor air at the same rate as the exhausted stale indoor air. A balanced ventilation system with proper design and installation pressurizes or depressurizes the space. This allows to control the flow of air within space, without relying on natural ventilation to move air and pollutants. This system is commonly used in basements, theatres, sport centers, cinemas.

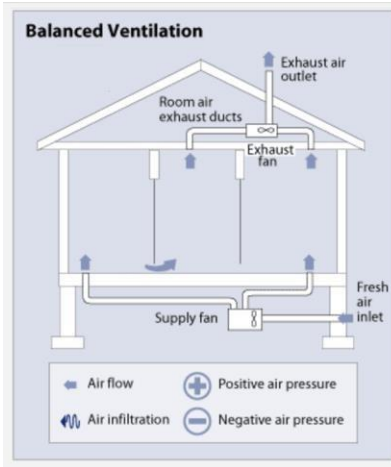


Fig 3.3 Balanced ventilation system

3.2 Design considerations of a Ventilation System:

- As per NBC norms 20% to 30% floor area to be adopted for natural ventilation.
- Recommended value for air changes for shops and supermarket is 8 to 15 m² per hour per square meter of floor area.
- Air change requirement as per NBC for Basement Car Parking is 9 to 12 ACPH under normal conditions. (For Design purpose 10 ACPH is used)
- 30 air change per hour in case of fire.

3.3 Ventilation Systems in the Case Studies:

Marina mall

4 Inlet – 4 exhaust ventilators provided in all the basement.
Jet fan toward exhaust vent is provided.

Tamarai tech park

4 Nos for inhale of air - 4 Nos for exit of air in each basement.
Jet fan towards exhaust fan.

Chapter 4 Air Conditioning

Air conditioning systems are responsible for maintaining the temperature, air quality and humidity of a building. The most common type of air conditioning system used in mixed-use buildings is centralized air conditioning system.

4.1 Centralized Air Conditioning System

In central air conditioning systems, compressor, condenser, thermostatic expansion valve, and evaporator are all located in a separate plant room. They carry out all the duties of a standard refrigeration system, but they are bigger and more powerful. While the compressor and the condenser are of the shell and tube type, the compressor is of the open reciprocating type with several cylinders cooled by water. While thermostatic expansion valves are utilized in central air conditioning systems, capillary expansion valves are employed in compact air conditioning systems.

The chilled air is passed via the ducts to all spaces that need to be air conditioned. Since, there are no individual cooling coils and other parts of the refrigeration system required in each space, this system keeps the spaces silent and the air conditioned. The amount of cool air required can be controlled by the openings depending on the total heat load inside the room.

There are two types of central air conditioning systems:

- (a) Direct expansion central air conditioning system
- (b) Chilled water central air conditioning plant

4.1.1 Direct Expansion Central Air Conditioning System

DX central air conditioning system comprises three parts: the plant room, the air handling unit room and the air-conditioned room as represented fig 4.1. The plant room comprises of the important parts of the refrigeration system, the compressor, and the condenser. The refrigerant leaving the condenser in the plant room enters the thermostatic expansion valve and then the air handling unit, which is kept in the separate rooms. The air handling unit is a large box type of unit that comprises of the evaporator or the cooling coil, air filter and the large blower which sucks the hot air from the room through ducts and blows it over the cooling coil. The cooled air is then supplied through ducts from the air handling room to all the rooms that are to be cooled. The ducts are connected to the grilles or diffusers that supply the chilled air to the rooms. This type of system is useful for small buildings.

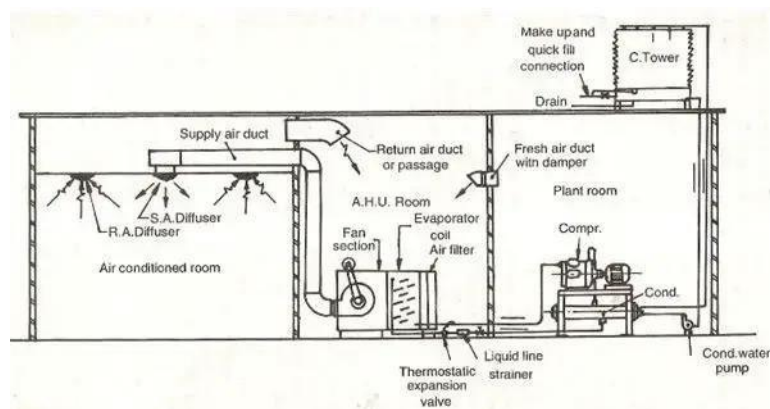


Fig 4.1 DX central air conditioning system

4.1.2 Chilled water Central Air Conditioning

This type of air conditioning system is more useful for large buildings comprising multiple floors. It has the plant room where all the important units like the compressor, condenser, throttling valve, and the evaporator are housed. This system used chilled water as a cooling to distribute cooler air to the building. The working of chilled water central air conditioning plant represented in fig 4.2 is as follows. This system consists of a chiller which comprises of compressor, condenser, evaporator and expansion valve for cooling the water to a desired temperature depending on the requirements. The cooled water is distributed to the air handling units situated throughout the building. Warm air from the building is drawn through the ducts and blown over the chilled water coils causing the air to cool down. The chilled air is then distributed throughout the building via vents and duct works.

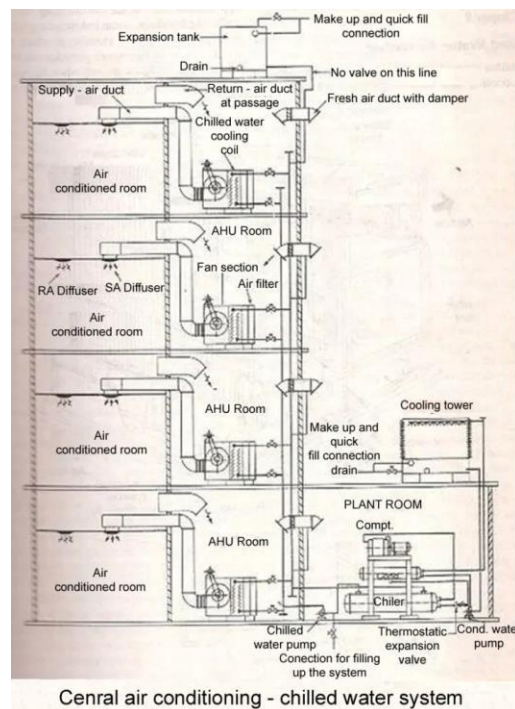


Fig 4.2 Chilled Water Central Air Conditioning Plant

4.2 Advanced Air Conditioning Methods

Advancements in technology have revolutionized the air conditioning systems as well, leading to innovations like smart thermostats, variable refrigerant flow (VRF) systems, and heat pump technologies. These innovations offer great control, efficiency, and adaptability to changing environmental conditions.

4.2.1 Variable Refrigerant Flow (VRF)

Variable Refrigerant Flow is an advanced, large scale, ductless air conditioning system that uses the refrigerant for both heating and cooling. VRF uses inverter-based compressors to increase or decrease the capacity depending upon the requirements of each space making it an effective air conditioning system to be used in a high-rise mixed-use building. This system consists of an outdoor unit and multiple indoor units connected through refrigerant pipes. The outdoor unit consists of a compressor that modulates the refrigerant flow based on demand. This system also consists of a smart central controller that allows the residents and users to adjust the temperature settings and air flow. The working of the VRF is represented in fig.4.3.



Fig 4.3 Variable refrigerant flow

Types of VRF:

There are three types of VRF as follows:

- Heat pump VRF: This VRF consists of two pipes for providing both heating and cooling but not at the same time. This has less chances of creating leaks and allows easy maintenance.
- Air cooled VRF: This uses natural outside air.
- Three pipe VRF: This type of VRF is highly efficient as it can provide heating and cooling at the same time.

4.2.2 District Cooling Systems (DCS)

A district cooling system (DCS) distributes the cooling capacity in the form of chilled water or other medium from a central source to multiple buildings through a network of underground

pipes for use in space and process cooling. Individual users purchase chilled water for their building from the district cooling system operator and do not need to install their own chiller plants. For this system, a central chiller plant, a pump house and a distribution pipeline network are required. The DCS is an energy-efficient air-conditioning system as it consumes 35% and 20% less electricity as compared with traditional air-cooled air-conditioning systems and individual water-cooled air-conditioning systems using cooling towers respectively. In some countries that have substantial heating demand, the plant can also be designed to supply hot water to form a District Heating and Cooling System (DHCS).

A typical DCS comprises the following components:

- Central Chiller Plant - generate chilled water for cooling purposes.
- Distribution Network - distribute chilled water to buildings
- Consumer Substation - interface with buildings' own air-conditioning circuits.

4.3 Design Considerations for Air Conditioning

4.3.1 Equipment room for central air conditioning system

- The equipment room should be located within the air-conditioned building closer to the external wall for facilitating ventilation and equipment movement. The equipment may also be installed in a separate service block which should also be located as close as possible to the building.
- The clear headroom should be a minimum of 4.5 m for larger capacity chillers with 500 TR and above and minimum 3.6 m for smaller plants.
- For the air conditioning plant located in basement, equipment movement route shall be planned to facilitate maintenance and future replacement. Service ramps or hatch in ground floor slab should be provided.
- Floor drain channels in slope shall be provided within plant room space for effective disposal of wastewater.

4.3.2 Equipment room for AHU and packaged air conditioning

- This room shall be located as centrally as possible to the conditioned area and adjacent to the corridors or other service areas for carrying air ducts in ceiling spaces.
- Provision shall be made for the entry of outdoor ventilation air into air handling unit room.
- Exterior openings for outdoor air intake and exhaust outlets shall have louvers having rain protection profile, with volume control damper, pre-filter and bird screen.
- In all cases, outdoor air intakes shall be located as to avoid contamination from exhaust outlets and from the sources in concentration greater than normal in the locality in which the building is located. It is recommended to maintain a minimum of 8m separation between outdoor air intake points and exhaust outlets.
- All air handling rooms should have floor drains and if possible, a water supply connection.

- Access door to air handling unit room shall be single/double leaf type, airtight, opening outwards and should have a sill to prevent flooding of adjacent occupied areas.
- It is desirable that individual air handling units should be installed for each fire compartment.

4.3.3 Pipe shaft and air duct

- The shafts carrying chilled water pipes should be located adjacent to air handling unit room or within the room
- Shaft carrying condensing water pipes to cooling towers located on terrace should be vertically aligned,
- Access to shaft shall be provided at every level, if there is any serviceable component in the shaft.
- If a false ceiling is provided, the supports for the duct and the false ceiling, shall be independent.

4.3.4 Cooling tower

- Cooling towers shall be installed at a place where free flow of atmospheric air is available
- Evaporation: About 1% of the rate of water circulation
- The drift loss shall be below 0.1 % of rate of water circulation
- The amount of blow down shall be below 0.8% of the total water circulation (for removing suspension particles to prevent corrosion)
- Floor area requirement for various types of cooling tower
 - Mechanical draft: 0.07 to 0.10 sq.m./TR cooling tower
 - Minimum cooling tower efficiency 350 litres per min/hp for 24/7

4.3.5 Installation of AHU and Air Washer Unit

- Floor mounted air handling unit is generally installed on a set of precast PCC blocks to raise it off the mounting surface to permit easy drainage of the AHU drain pan and cleaning of the mounting surface.
- A set of 4 or 6 numbers of 200 mm x 200 mm x 200mm blocks are generally used for AHUs up to capacity of 10 000 m³/h air-flow, 6 or more 300 mm x 300 mm x 300 mm blocks for higher capacity AHU.
- Air washer unit (AWU) components are similar to those of AHU, except for water spray section with in-line recirculation pump, which replaces the cooling coil. Installation of AWU shall follow the same steps as described above for AHU. Ceiling suspended AWU is not recommended.

4.4 Air Conditioning systems in Case Studies

4.4.1 Marina Mall

- Marina mall uses chilled water air conditioning system
- The air handling units (AHUs) are in every floor of the mall. They are located in North, south and East side of the mall. Each having capacity of 32000 cfm 80 TR.
- Ducts are mounted in the ceiling for the supply cooler air throughout the mall.
- 5 Nos of chiller plant 510 TR. 6 Nos of condenser pump with 40 hp power and within this one standby pump.

4.4.2 Tamarai tech park

- Tamarai tech park uses Air-cooled air-conditioning system for whole building.
- 3 Nos of chiller plant with capacity of 400 TR with 4 primary pump 10 hp and 4 secondary pump 15 hp.
- 2 Nos of Air handling units are situated on every floor.
- North block has 12 AHUs with capacity of each 45 TR.
- South block has 14 AHUs with capacity of each 40 TR.
- It consists of about 4 cooling towers.

4.4.3 Burj Khalifa

- Burj Khalifa uses 946,000 litres of water through flow pipes that extend over 34 km for chilled water air conditioning system.
- Desalination and cooling water are done by means of contrite and partially melted ice. By this solution, the building receives water with temperature 3.3 °C. This chilled water and the fan system serves in cooling the air during the hot months when the temperature reaches up to 50°C.
- Due to the high humidity and difference in temperature between the inside and outside of the Burj Khalifa, causes subsidence of water vapor which can be dangerous for electrical equipment. Hence, a unique system is developed whose main task is to collect the water vapor and drain it into underground reservoirs. more than 150,000 L of water is recovered from the vapor, which annually produces 50 million litres of water (volume of 20 Olympic swimming pools). Water, that arises on the walls of the building due to temperature differences is also collected and is sufficient to maintain the park around the building.

4.4.4 Taipei 101

- Taipei 101 tower uses Variable Air Volume System (VAV) for air conditioning.
- The mechanical floors of the tower have air handling units (AHU) to provide air conditioning to different sections.
- Siemens Energy Monitoring and Control System Environmental Compliance Management Software (EMCS) facilitated the streamlining of the operation and control of the HVAC

equipment throughout the complex, optimizing the entire energy usage. Applying improved algorithms for the chiller plant and changing the sequence of operation also considerably increased the efficiency of the cooling system.

4.4.5 Shanghai tower:

Shanghai tower contains the following:

- Nine YK water-cooled centrifugal chillers
- Three YK dual-operation water-cooled centrifugal chillers
- One YEWS screw geothermal heat pump to provide heating
- A overhead variable air volume air conditioning systems with demand-control ventilation.

Chapter 5 Lift

Lifts are categorized according to their driving system. There are two common types of lift, namely the electric lift and the hydraulic lift. The electric lift powers the electric motors by driving traction cables. They can be subdivided into the traction lift with machine room, and the machine-room-less (MRL) traction lift. The traction lifts are represented in fig 5.1.

5.1 Traction Lift

Traction lifts function with the help of a rope which passes over a wheel. This wheel is attached to an electric motor, that is in a machine room above the lift shaft. When the motor is powered, the wheel is set in motion, pulling the rope and in turn lifting the lift car to the desired floors. A counterweight is used to reduce the motor load, increasing the efficiency of the lift.

This type is commonly used in mid and high-rise buildings, as it can reach higher travel speeds than most other types of lift. Traction lifts are further divided into three types, namely geared traction lift, gearless traction lift and machine-room-less (MRL) lift.

5.1.1 Geared and Gearless Traction Lifts

In geared traction lifts, a gearbox attached to the motor for driving the wheels causing movement of the ropes. A geared traction lift can travel at distance of 76m, with a maximum travel speed of around 1 to 2.5 m/s thus providing maintenance and energy conservation. In a gearless traction lift, the wheels are attached to the motor directly without the need for gearbox. The gearless traction lift can travel a speed of 1 to 4m/s making them a better choice for high-rise buildings. Fig 5.1 represents the geared and gearless traction lifts.

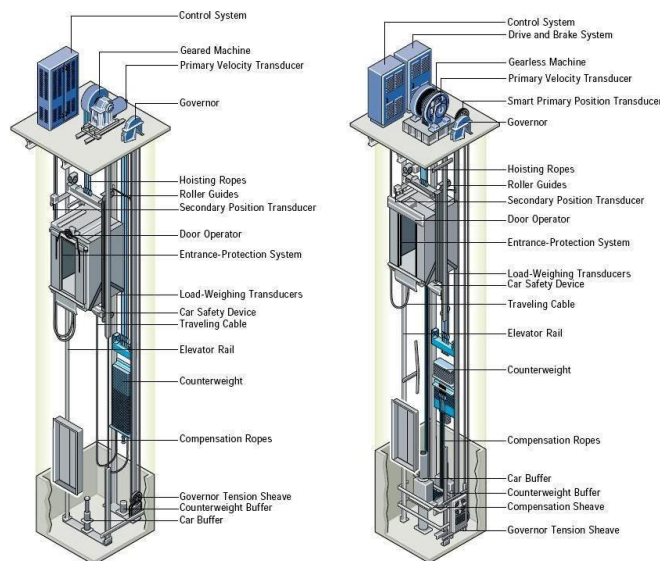


Fig 5.1 Gearless traction lift

5.1.2 Machine Room Less (MRL) Lift

Machine room less (MRL) lifts do not require a machine room above the lift shaft like the other traction lifts as represented in fig 5.3. Their traction machines, controllers and other components are tightly packed along the elevator shaft. The machine sits in the override space and is accessed from the top of the lift cab when maintenance or repairs are required. The control boxes are located in a control room that is adjacent to the lift shaft on the highest landing and within around 45m of the machine. MRL lifts can travel a maximum distance of around 76m and travel at speeds up to 2.5m/s. They are mostly seen in low to mid-rise applications. Additionally, they have low energy consumption compared to other traction lifts.

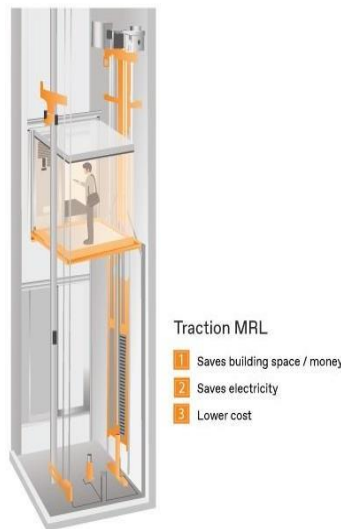


Fig 5.2 Machine room less lift

5.2 Express lift:

Express lifts are swift moving elevator systems that transport people and cargo between the floors of especially tall buildings and skyscrapers. The main features of express lifts include high speed, multiple elevator cars, safety, and efficiency. This type of elevator does not serve all the floors of the building in order to maintain speed and efficiency. The express lift consists of

- High speed motors
- Traction systems
- Control systems
- Elevator car
- Hoist way
- Safety and emergency components

5.3 Requirements for Passenger and Goods Lifts:

- Bottom car clearance: a minimum clearance of 600 mm is available over a horizontal area of 800 mm x 500 mm.
- The car platform is level with the top landing, shall be not less than the sum of the following:
 - a) The bottom counterweight run by.
 - b) The stroke of the counterweight buffer used.
 - c) One-half of the gravity stopping distance based on 115 percent of the rated speed where oil buffers are used and no provision is made to prevent the jump of the car at counterweight buffer engagement; and Governor tripping speed where spring buffers are used.
 - d) The bottom run by of cars and counter weights shall be not less than 150 mm where oil buffers are used. Where spring-buffers are used.

Rated speed	Run by in/s mm
75	Up to .125
150	.125 to .25
225	.25 to .50
300	.50 to 1

Table 5.1 Speed of the lift

Maximum bottom run by 600 mm for cars and 900 mm for counterweight.

5.4 Escalator

An escalator is a moving stairway that moves people between levels in a building is known as an escalator. Escalators have the capacity to move lots of people. With the exception of when it's busy, they are quick and effective, requiring no waiting. Additionally, they may be reversible to accommodate a high volume of travel. Escalators that aren't working can be used as regular staircases. They might also be weatherproofed for outdoor use.

Escalators ought to be placed in areas where they may be seen. An escalator's carrying capacity is determined by its speed, which ranges from 0.45 m/s to 0.7 m/s. In addition, the carrying capacity of escalators is impacted by the tread width, which ranges from 600mm to 1200mm.

5.4.1 Arrangement of Escalator

Single Unit: The single unit used to link 2 levels. It is suitable for buildings with passenger traffic flowing mainly in one direction. Flexible adjustment to traffic flow is possible.

- Continuous Arrangement (One-way Traffic): This arrangement is used mainly in small commercial spaces with a maximum of 3 levels. It requires more space than the interrupted arrangement.
- Parallel or Interrupted Arrangement (One-Way Traffic): This configuration causes some inconvenience as the users are required to take a brief diversion to the following unit. This arrangement provides a spatial divide between up and down traffic directing customers to strategically positioned advertising displays. This type of arrangement is mainly used in malls to catch the attention of the shoppers.
- Scissor arrangement (Two-way traffic): This arrangement allows a continuous flow of the passengers avoiding congestion and crowding near the landing. This requires more space than the previous arrangements.
- Crisscross, Continuous layout (Two-way Traffic): Whereas travel time between various levels should be kept to a minimum, this layout is typically utilized in large department shops, public buildings, and public transportation buildings.

5.5 Design Considerations of Lift and Escalator:

- Traffic Analysis is calculated based on the number of occupants and the peak usage time. Based on the number of elevators required, speed and capacity of the lift will be finalized.
- Based on the entry and exit point of the building, the zoning of the lift and escalator will be planned.
- Consider the accessibility to people with disabilities, including features like wheelchair ramps, audible announcements and tactile buttons.
- Lift will be provided close the staircase.
- If the building has retail, restaurants or other commercial spaces separate freight and service lift should be provided.
- For supermarket, traveller will be provided for easy transportation of goods within the building.
- Speed of lift varies from 0.5 to 1.5 m/s based on the height of the building.
- Speed of the escalator 0.3-0.6 m (1-2 ft) per second.
- Speed of goods lift is represented in the table below:

No.of. Floors	Recommended Speed
Up to 6 Floors	0.5 MPS
Above 6 Floors	0.75 MPS

Table 5.2 Speed of Goods Lift

5.6 vertical transportation Used in the Case Study

5.6.1 Marina mall:

Type of vertical transportation	Number	Specification
Lift	4	- Carries 14 persons with the capacity of 1050 kg and 1300mm wide - Located on both sides of the building
Escalator	22	0.9 m wide
Travelator	4	Installed in the basements and lower ground floor
Stairways	29	Including Fire staircase

Table 5.3 Lift Systems in Marina Mall

- Two lifts are provided on the north nearby stairs & lobby.
- Two lifts are provided on the South side nearby stairs.

5.6.2 Tamarai tech park:

Type of vertical transportation	Number	Specification
Lift	8	- Carries 20 persons with the capacity of 1350 kg and 1.2m wide. - Machine room lift is used.
Service lift	2	Installed in all the floors separate for both the block
Stairways	8	4 Nos for south block 4 Nos for north block

Table 5.4 Lift Systems in

5.6.3 Burj Khalifa

Burj Khalifa has the following types of lift systems:

Lift:

Total number - 57

Specification:

Travels at a speed of 600m/min

Contains double-decker elevator with 12 to 14 persons capacity

Contains fire safety elevator

2909 stairs are provided in Burj Khalifa

Escalators - 8**5.6.4 Taipei 101****Types of elevators:****1. Passenger elevators**

- Double deck elevators:
 - 10 double deck elevators 2040 kg (31 persons) per deck
 - 24 double deck elevators, 1350 kg (20 person) per deck, for access within 6 sub-zones (4 in each sub-zone) at 210 metres per minute
- Shuttle elevator serving the transfer Floors at 460 metres per minute
- Single-deck elevators (various capacities) – 3
- Communication floors elevators – 2

2. Observation elevators - 2 pressurised single-deck elevators, 1350 kg 120 persons) serving the observation decks at 1010 metres per minute and running a distance of 3822 metres in 37 seconds

3. Service elevators

- Single deck elevators, 2x 2040 kg 1x4800 kg Car park elevations

Single deck elevators, 1600 kg to tower lobby. 2046 steps are there in Taipei 101.

5.6.5 Shanghai Tower

Elevators:

Ultra-high-speed elevators is used.

Speed-10 m/s .21 persons capacity 1600 kg lift is provided.

Number of elevators – 114 Double decker type

Total 3398 stairs till 119 floor and escalator are provided till retail only lvl 7.

The elevator tend to vibrate travelling at high speed in order to overcome it Toshiba active damper is used.

Chapter 6 Water supply and disposal

Water supply and disposal systems are crucial for the supply of clean water and disposal of the used water. The water distribution system commonly used in mixed-use buildings are as follows:

1. Gravity distribution
2. Hydro-Pneumatic System
3. Combined Distribution system

6.1 Water Supply Systems

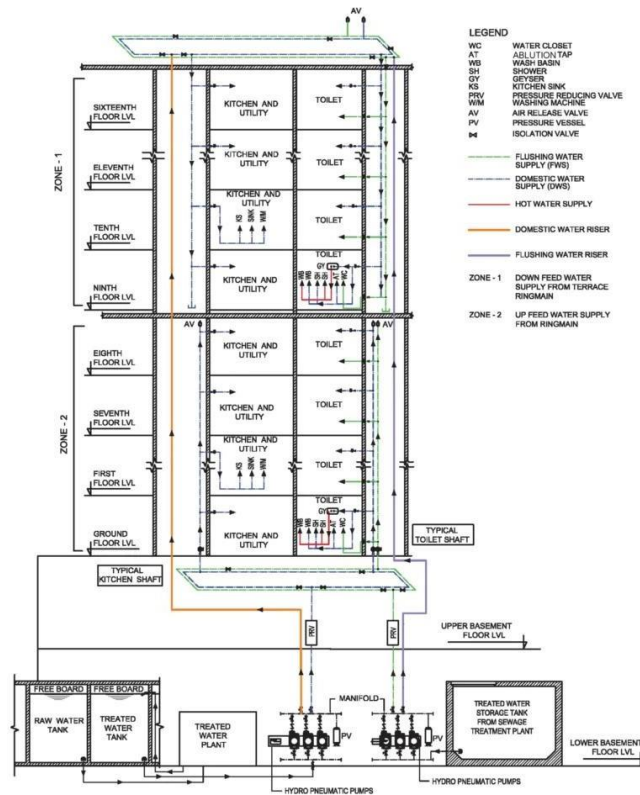
6.1.1 Gravity distribution

Gravity distribution system is widely used in buildings. It involves pumping water into one or more tanks, which then use gravity to distribute the water through a network of pipes, to areas of the building.

6.1.2 Hydro pneumatic system

Hydro-pneumatic system is a variation of direct pumping system represented in fig 6.1. It is made up of multiple-stage centrifugal pumps that can withstand high pressure. In addition, it features high-resistance valves and a control panel to regulate the number of pumps that will run in accordance with the rate of pressure and the system discharge. Pressure tanks are used to lessen the frequency of starts and stops caused by centrifugal motors and pumps. In addition, a pressure transmitter and switches designed to detect high and low pressure are included. Since water is a non-compressible liquid, pressure tanks made of rubber bladders are surrounded by compressed air. The pressure in the tank decreases as soon as you open a tap since the water level is dropping. As soon as the pressure level drops to a certain level, the pressure switch senses it and turns on the pumps and turns it off when the desired level of pressure is achieved. These are majorly used by large commercial sectors like malls, airports, metros, hospitals based on the need of the specific sector.

Hydro-pneumatic systems are available with variable frequency drive, where the pump is efficiently used to deliver water at rates of flow as required by the system, by varying its speed with the assistance of an electronic device, thereby meeting the demand flow through variation in speed of the motor from 960 rpm to 3 000 rpm. With this arrangement, the same pump is able to deliver water at required pressure and flow as required at different times of the day. The system consumes energy in proportion to the work done and helps in controlling the water surge in the distribution line. Hydro-pneumatic systems generally eliminate the need of an overhead tank.



SCHEMATIC DIAGRAM SHOWING THE DISTRIBUTION SYSTEM IN RESPECT OF HYDRO-PNEUMATIC SYSTEM FOR A MULTI-STOREYED BUILDING

Fig 6.1 Hydro-Pneumatic distribution system

6.1.3 Combined Distribution system

This system is a combination of gravity and pressurized distribution. A few upper floors are provided with a pressure booster pumping system to reach the desired residual pressure, while the lower floors are provided by gravity supply. Water collected in the overhead tank is supplied to the various parts of the building. To achieve required residual pressure for top 2 to 4 floors for proper functioning of the fixtures, pressure booster pumping system is installed on the dedicated outlet from overhead tank with its distribution piping serving the top 2 to 4 floors. For lower floors, water is distributed by gravity system.

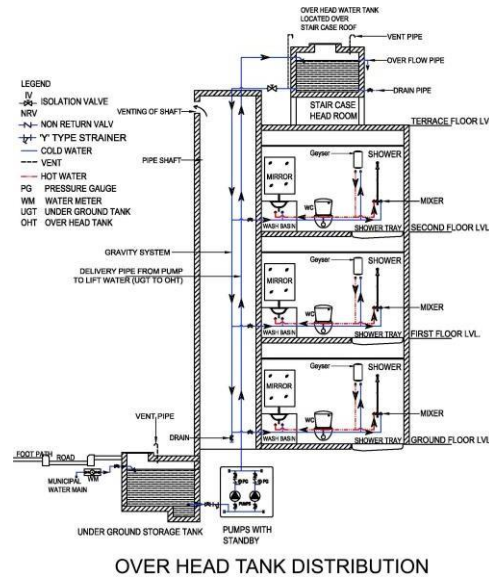


Fig 6.2 Combined distribution system

Pressure-boosting systems can be of several different types:

- Pumping from a ground level or basement gravity tank to a gravity roof tank.
- Pumping from a gravity storage tank or public water main into a hydro-pneumatic pressure tank that uses captive air pressure to provide adequate drinking-water supply pressure.
- Installation of booster pump sets consisting of multiple staged pumps or variable speed pumps that draw water directly from a gravity storage tank or the public water main. Multistage booster pump sets typically include discharge pressure regulating valves to maintain a constant drinking-water supply pressure.

6.2 Water Disposal System

- Conventional (gravity) drainage system
- Conventional (pumped) drainage system
- Vacuum drainage system

The following are the piping systems adopted in drainage of the high-rise structures:

- Two-Pipe System
- One-Pipe System
- Single Stack System
- Single Stack System (Partially Ventilated)

6.2.1 Two-Pipe System

Ideal for irregular or recurrent placement of restrooms, toilet stacks, and waste fittings. The sullage water from the waste system can be employed for gardening and agriculture in large

buildings and homes with gardens and open space. Sullage from high-rise buildings is treated inside the structure so it can be used as makeup water for cooling towers and water closet flushing. Make sure it is not connected to any tank, supply line, or system utilized for domestic or drinking water supply.

6.2.2 One-Pipe System

- Suitable where toilet layouts and shafts are repetitive. Requires less space, and is economical.
- The continuous flow of water from waste appliances in the pipe reduces the risk of blockage.
- The system eliminates the need for a gully trap which requires constant cleaning.
- Prevents pipe crossing problems and saves space
- It May not suitable if the flow is heavy.

6.2.3 Single Stack System (Without Vent Pipe)

Suitable where toilet layouts and shafts are repetitive and there is less space for pipes on the walls.

6.2.4 Single Stack System (Partially Ventilated)

- Is the same but the only modification is that it is partially ventilated.
- Also, you can connect the waste appliances such as washbasin, bathtub, sink or sink to a floor trap.

6.3 Design Considerations for Water Supply and Disposal Systems

6.3.1 Water supply

- Demand for water requirement for commercial buildings ranges up to 45 litres per head per day.
- Flushing storage capacity 900 litres per w.c and 350 litres per urinal.

6.3.2 Sewage treatment plant

- A maximum of 3 batches of sewage treatment should be considered per day.
- Waste from food courts should be collected separately in a waste collection sump and neutralized with hypo-chlorite solution within 6-8 hrs. After neutralization the waste will be pumped to STP for further treatment process.
- Sewage treatment plant is of “Sequence Batch Reactor - Technology” which collects all the sewage water and takes it into equalization tank through a bar screen chamber. The equalization tank will have a retention capacity of approximately 6 – 8 hrs . Sewage from this tank is pumped to SBR tank using effluent transfer pump.

- The air blower is placed on the Decanting / SBR tank slab (vary as per the final equipment layout) which will suck the oxygen from the atmosphere and dispersed into the liquid through the micron holes of the EPDM membranes installed at the bottom.
- The Biological oxygen demand in the sewage is degraded by the bacteria, which in turn utilize the dissolved oxygen to degrade the organic pollutants in the sewage. The BOD shall be brought down to the prescribed level by the bacteria, which is growing and multiplying from the biological mass (also called sludge).
 - The SBR tank will have a detention time of 8 hours for aeration. Aerated waste will be allowed to settle down in the SBR tank, and overflow is let in to semi treated effluent sump/ decant water tank. The sludge will be pumping to the sludge holding tank and pass through sludge handling system consisting of automatic / manual filter press, dry cake handling equipment for disposal. Dried cake will be removed and used as manure for plants. From Decanter water Tank, water will be pumped through pressure sand filter, activated carbon filter through pumping and stored in a treated water tank after the online chlorination & it will be used for Flushing, cooling tower makeup & landscaping / Gardening purpose etc.

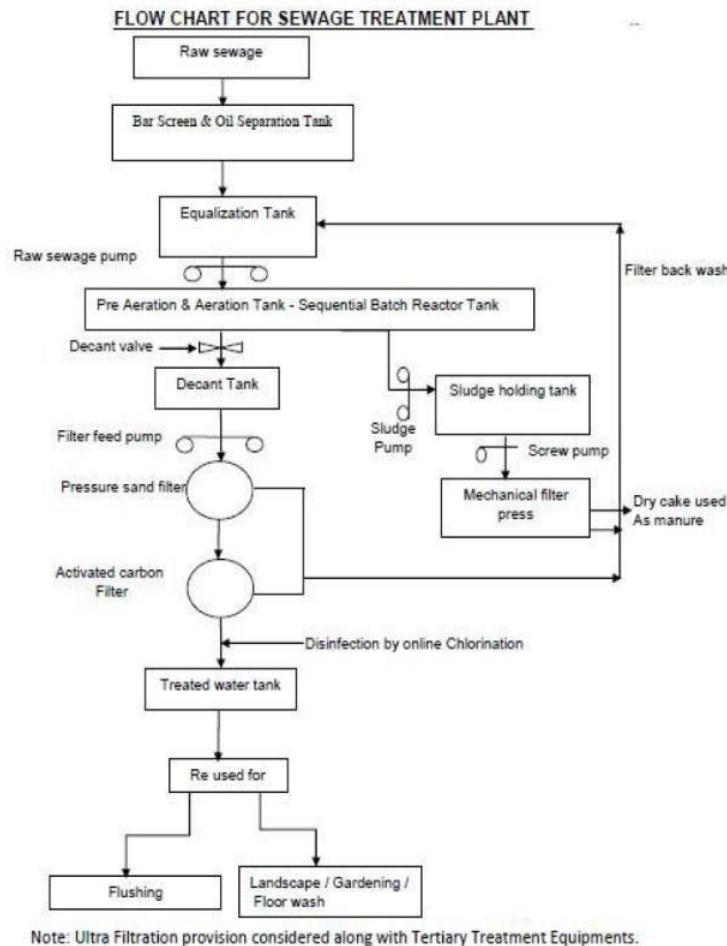


Fig 6.3 Sewage treatment flow chart

6.4 Case study for water supply and disposal

Marina mall

- Water demand is 45 litres per day per person considered and the total demand for water supply of 150 cubic meter per day is required.
- 100 KLD water is stored for fire safety.
- Water treatment plant 150 KLD 80 KLD Fire supply 70 KLD domestic purpose.
- Sewage treatment plant treats 270 KLD .7.5 kw motor is used in the STP.

Tamarai tech park

- Water demand is 45 litres per day per person and the total demand supply of water is 500 cubic meter per day.
- 110 KL capacity from raw water treatment at WTP and sent to treatment water tank and pumped to overhead tank.
- Pneumatic pump 75 kw
- Collection tank 120 KLD, Aeration tank 120 KLD, Clarifier tank 120 KLD
- 2 Nos Lamella air blower used at clarifier to treat the water.
- Sewage treatment plant for capacity of 80 % of water supply generated and provided.

Burj Khalifa

- Water supply is equipped with six water transfer sets and seven pressure booster sets from Xylem's product. The water booster sets, which are used to boost water pressure, are fitted with Hydrovar variable speed that drives 1,000 cubic meters every day. The water system supplies on an average 946,000 litres of water per day along with the water that is gathered from condensation from the cooling system.
- The average daily supply of water is 249,908 gallons throughout the Burj Khalifa with pipes extending over 62 miles. An additional 132 miles of piping supplies the fire emergency system and another 21 miles supplies chilled water for the air conditioning system. The water available on-site is desalinated sea water from the Persian Gulf.
- The drainage pipes are nearly 2 feet in diameter.
- The pumps have the pressure of 30 bar.
- A single-stack drainage system doesn't separate wastewater. About 15 million gallons of water is produced yearly from condensation. Pre-cooling of the water is required in the summer.
- This water is collected and drained in a separate piping system to a holding tank in the basement parking garage.

Taipei 101

Water management systems work with low-flow water fixtures to reduce total water usage. rainwater harvested by the building is used for circulation. Motion-sensors save the building about 28,000 litres of potable water annually by managing all toilets, sinks, and urinal. This is a saving of at least 30% when compared to the water consumed by an average building of a similar size.

Shanghai tower

The rain collection system recycles 25 percent of rainwater and supplies 245,000 cubic meters of water to the tower every year, reducing the tower's water consumption by 53 percent.

Chapter 7 Electrical System

The electrical demand of a large building requires three phase system and a neutral to operate and satisfy a wide distribution of electricity to machinery, lift, lighting. Large buildings generally have their own sub-station and transformers to meet their electrical requirements.

The common electrical distribution systems used in mixed-use developments are as follows:

- Main-tie-main system
- Busbar trunking system
- Sub distribution system
- Emergency power distribution system

7.1 Types of Electrical Distribution System

7.1.1 Main-tie-Main System

Main-tie-main system is used for its capability to produce uninterrupted power supply in case of mixed-use buildings where multiple services require electricity to carry out their tasks. This system contains multiple power sources coming from the substations. The load is evenly distributed between the sources, thereby providing continuous power supply even in the event of failure of one the sources. The redundancy of this system provides flexibility, scalability and reduced downtime.

7.1.2 Busbar Trunking System (BTS)

This system consists of a continuous series of conductors made up of aluminum and copper encased in a protective covering. The main component of this system is busbars that carry the current from the source to the load points continuously for seamless power transfer. Insulators are used to combine the busbars together. This system is usually installed in the ceiling of the building consists of tap-off boxes that are typically used to divide the power load into different areas. The main advantages of BTS system are high power transmission and easy installation.

7.1.3 Sub-Distribution System

The Sub-Distribution System is a part of main substation that supplies electrical power to specific regions of the building. This system consists of a main distribution panel which receives the power supply from the main substation. Then, the power supply is broken down into multiple circuits, which are then redirected to the sub panel. The sub panel protects the circuits from damage with circuit breakers and distributes them to different parts of the building without overwhelming the main system.

7.1.4 Emergency Power Distribution System

As the name suggests, an emergency power distribution system is used at times of emergency like power outage or shortage. This system consists of an emergency generator usually powered by diesel or other fuel source, a transfer switch, distribution panel and load circuits.

7.2 Components of an Electrical System in Mixed-Use Building

7.2.1 Generator

Generators produce electrical energy from mechanical energy. Generators are used in mixed use buildings for power backup. Different types of generators used are as follows:

- Standby generators: Used as a power backup for HVAC systems, security systems, emergency lighting, and so on.
- Distributed generators: Used as a power backup for certain parts of the mixed-use building.
- Hybrid power systems: An eco-friendly power backup option
- Portable generators: Some mixed-use buildings may contain portable generators provide power backup to a certain region of the building for emergency purposes.

7.2.2 Transformer

A power transformer a transformer that operates at high voltages in the power system network. It is mainly used to increase or decrease the voltage level between the generator and the distribution circuits. A power transformer has two or more windings that are magnetically coupled through a core. A varying current in one winding creates a varying magnetic flux in the core, which induces a varying voltage in the other windings. The ratio of the voltages in the primary and secondary windings depends on the number of turns in each winding.

7.2.3 Panel board

Alternatively referred to as a distribution board, a panel board is an element of a system used to supply electricity. Its primary function is to divide an electrical feed into supplementary circuits while providing a shielding or protective fuse for each circuit in an enclosed space. Panel and distribution boards tend to be made up of fuse links, bus bars, switches and automated protective equipment, sometimes called bypass equipment—these protect electrical distribution systems and electrical connections from overloading, short-circuiting and other problems.

7.2.4 Distribution Circuits

In most of the building's electricity supply is divided into two types of sub circuit:

- Lighting Load sub-circuit
- Power load Sub Circuit and finally for operation purpose into three phases circuit-lighting, socket outlets and fixed apparatus.

- The sub circuit which gives supply to lighting load points is called lighting load sub circuit. This circuit includes lamps, fans, tubes etc. As per Indian Electricity Rules. The following rating should be assumed.

Filament lamp	60W
Ceiling fan	60W
Socket for radio, table fan	60W
Fluorescent tube	40W
Mercury Vapor lamp	80W

7.2.5 Substation

Electrical substations are the interface between parts of the distribution grid and transmission systems. These fenced off areas step down the voltage in the transmission lines to one that is suitable for the distribution grid. They are also equipped with circuit breakers to protect the distribution system, and can be used to control the flow of current in various directions. They also smooth and filter voltage fluctuations caused by, for example, an increased load. Step up substation is used in mixed use building.

Sl No.	Purpose of Final Circuit Fed from Conductors or Switchgear to which Diversity Applies	Typical Allowances for Diversity Based on: Type of Building							
		Individual House Hold Installations, Including Individual Dwelling of a Block (3)	Small Shops, Stores, Offices and Business Premises (4)	Small Hotels, Boarding Houses, etc (5)					
(1)	(2)								
i)	Lighting	66 percent of total current demand	90 percent of total current demand	75 percent of total current demand	v)	Water heater [instantaneous type ¹⁷]	100 percent of full load of largest appliance + 100 percent of full load of second largest appliance + 25 percent of full load of remaining appliances	+ 60 percent of full load of remaining motors	100 percent of full load of largest appliance + 100 percent of full load of second largest appliance + 25 percent of full load of remaining appliances
ii)	Heating and power [see also Sl No. (iii) to (iv)]	100 percent of total current demand up to 10 A + 50 percent of any current demand in excess of 10 A	100 percent of full load of largest appliance + 75 percent of remaining appliances	100 percent of full load of largest appliance + 80 percent of second largest appliance + 60 percent of remaining appliances	vi)	Water heater (thermostatically controlled)	No diversity allowable ²¹		
					vii)	Floor warming installations	No diversity allowable ²¹		
					viii)	Water heaters thermal storage space heating installations	No diversity allowable ²¹		
iii)	Cooking appliances	10 A + 30 percent full load of connected cooking appliances in excess of 10 A + 6 A if socket-outlet incorporated in the unit	100 percent of full load of largest appliance + 80 percent of full load of second largest appliance + 60 percent of full load of remaining appliances	100 percent of full load of largest appliance + 80 percent of full load of second largest appliance + 60 percent of full load of remaining appliances	ix)	Standard arrangements of final circuits in accordance with good practice [8-2(11)]	100 percent of the current demand of the largest circuit + 40 percent of the current demand of every other circuit	100 percent of the current demand of the largest circuit + 50 percent of the current demand of every other circuit	
iv)	Motors (other than lift motors which are subject to special consideration)		100 percent of full load of largest motor + 80 percent of full load of second largest motor	100 percent of full load of largest motor + 50 percent of full load of remaining motors	x)	Socket outlets other than those included in Sl No. (ix) and stationary equipment other than those listed above	100 percent of the current demand of the largest point + 40 percent of the current demand of every other point	100 percent of the current demand of the largest point + 75 percent of the current demand of every other point	100 percent of the current demand of the largest point + 75 percent of the current demand of every point in main rooms (dining rooms, etc) + 40 percent of the current demand of every other point

Fig 7.1 Substation Requirements

7.3 Design Considerations for an Electrical Systems

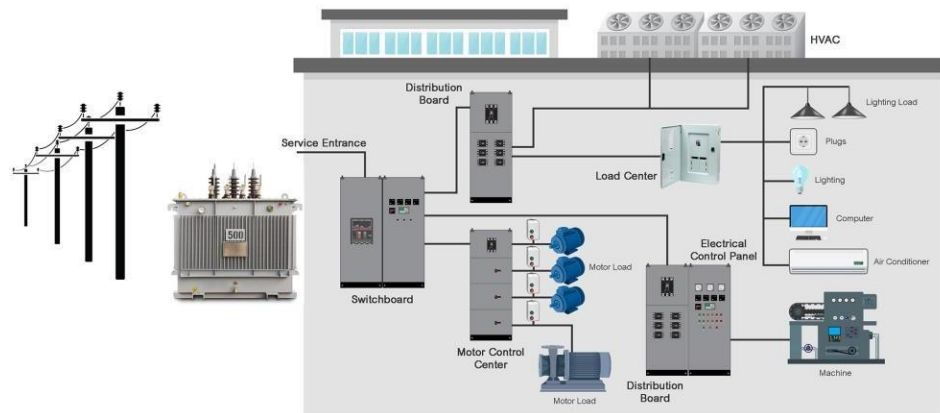


Fig 7.2 Power Supply

- Indoor Substations and Underground Cable power distribution.
- Substation with diesel generator backup.
- Voltage stabilization with Transformers with OLTC.
- Each Distribution substation to have its DG Back up.
- It is not recommended to have a centralized DG Backup to supply 11 KV DG Power to the distribution substations.
- Provision of SCADA PANEL in Substation.
- Provision of Main LT PANEL.
- Provision of APFC PANEL.
- Integrated substation to include transformers, DG Sets, UPS, AC Plant It is also advisable to adopt integrated substation to reduce interconnection cost, space and operation/maintenance cost. Basic facilities like washroom and toilets for personnel are to be provided.
- Space for future expansion of substation should be provided.
- Each substation should have provision of addition for at least one transformer and extension of LT Panel to take care of future growth of load.
- There may be substantial variation in load estimate prepared by individual designers.
- The best practical guide is to get actual loading of similar working buildings as watt per sq meter.
- For electrical loading to include all loads except air-conditioning, based on actual power demand of major CPWD buildings in metropolitan cities, it is practical to assume 40 watt per sq meter of built up area, for high load intensity buildings and 25-30 watt per sq meter for medium load intensity buildings.

- Load demand should include demand for Air-conditioning. For energy efficient central AC, 40 watts per sq meter of air-conditioned area can be added. If inefficient AC like window/ Split AC/ VRV are adopted about 25 % extra load can be considered.
- In the case of special equipment's like medical equipment's for hospitals and laboratory equipment's for IITs/NITs etc., as a thumb rule 10-15 % may be added to electrical load.
- Modern buildings are centrally air-conditioned for ensuring working efficiency, human comfort and better inside air quality.
- About 50 % of power is spent on AC. Therefore, for most efficient Air-conditioning backed by appropriate architecture like envelope insulation to reduce heat load of the building should be adopted.
- Also back up arrangement with solar power backup to reduce the Substation KVA and also to reduce electricity bill expenditure are recommended.
- For calculation, if the load comes to 10 MVA based on conventional technology, this load may be reduced to 7 MVA by going for energy efficient lighting, fans, appliances, energy efficient AC backed by VFD, BMS, building orientation, insulation etc. This saving of 3 MVA amounts to saving of capital outlay and energy cost saving. If we have about 1 to 2 MVA solar backup, the substation MVA is further reduced to 6MVA/5MVA.

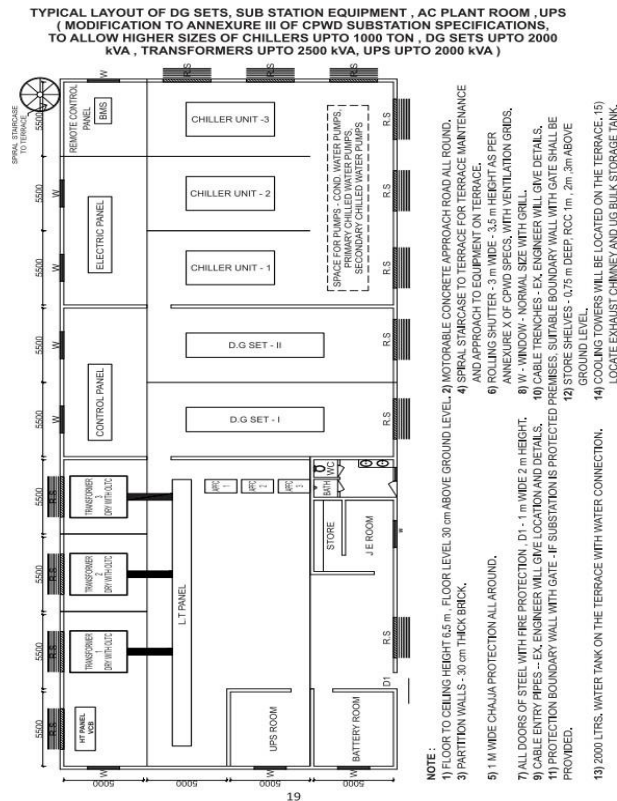


Fig 7.3 substation

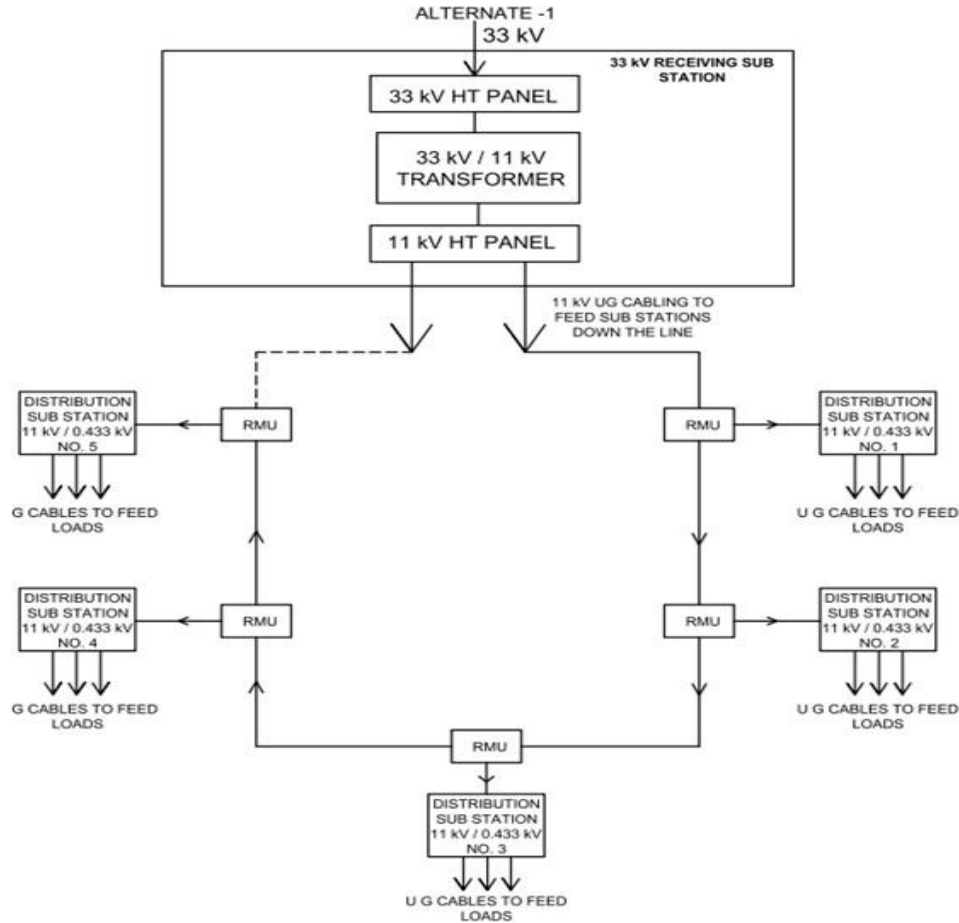


Fig 7.4

7.4 Electrical Systems used in Case Studies

Marina mall:

- 33kv 4 VCB HTB. 3 Nos Transformer 33kv 2000kVA.
- 5 Nos Koel DG Capacity of 3 Nos of 1500 kVA & 2 Nos of 1010 kVA.
- Total electrical demand for the mall 3300 KVA.

Tamarai tech park:

- Transformers are provided in safe area away from the building.
- Transformer is 2000 kVA.
- During summer 2700 kVA Per month & other season 2400 kVA Per month.
- 6 Nos of 725 kVA diesel generator. DG smoke chimney exhaust provided.
- 2 Nos of transformers available (2000 kVA/11kv/433 v)

Burj Khalifa:

- Burj Khalifa has its own substation of 11kV capacity incoming DEWA from the ground floor.
- A 11 kV distribution substation is located on the 150th floor which provides service for the top floors.
- Multiple 11KV/400Y/230V transformers located at mechanical floors.
- 400Y/230V Local zone vertical bus and switch boards.
- Electricity consumption is expected at 50 MVA.

Taipei 101:

Dual feed from two sub stations, two risers for internal distribution transformer redundancy

General office use design load of 65 VA/sq m (excluding air conditioning and lighting)

Taiwan Electric Company, via Hulin and Shimao Second Substation, feed 22.8 KV high-voltage power.

The building's electrical system applies the concept of dual-source, dual-backup, and dual-feeder to lay cables for internal power supply.

Shanghai tower:

- Contains 270 wind turbines at the top of the building which provides power for exterior lighting.
- 2,130 kW natural gas-fired cogeneration system provides electricity and heat energy to the low-zone areas.
- The total energy consumption of Shanghai tower is around 12 million kWh.

Chapter 8 FIRE SAFETY, DETECTION & PROTECTION

Active Fire Protection is a series of fire systems-operated either manually or automatically that require the action to function correctly in an event of fire. The active fire protection system is a mandatory requirement that should be fulfilled when designing a building.

8.1 Types of fire Suppression Systems

The fire safety system can broadly be classified as water-based and non-water based systems.

8.1.1 Water Based System

Water-based fire suppression systems utilize water as a means of extinguishing fire, through a fixed pressurized piping network. These systems are commonly used in both commercial and industrial buildings as a means of suppressing building fires. These systems include the following:

1. External Fire Hydrant

External fire hydrant is an exposed water outlet valve found in strategic locations of a building connected by a series of pipes. It is connected to the municipal water service network and provides emergency water supply for firefighters to manage building fires. The water pressure supplied through the hydrant is equivalent to the pressure within the underground water line. The Fire hydrants are placed not more than 30 meters away from the breeching inlet of a building. It is spaced not more than 90 meters apart along an access road and should be accessed easily by firefighters.

2. Hose Reel System

The hose reel system is designed to be used by occupants and firefighters during the early stages of fire. The system comprises of an on-site water tank, pumps (duty pump and standby pump), pipework, valves and hose reels which are located near fire escape staircases and beside exit doors on each floor to be easily accessed by users.

3. Dry Riser System

A dry riser system consists of a series of vertical pipes installed within a building whose topmost floor exceeds 18.3m and is less than 30.5m above the fire appliance access level. As the name suggests, a dry riser is always dry until an event of fire occurs during which, water is charged through the pipes via the fire engine pump. Like the wet riser system, it features a landing valve on each floor which serves as an internal hydrant for firefighters to use. The top of the riser features an air release valve which serves to discharge any trapped air as water is pumped into the system.

A dry riser breeching inlet is installed at the bottom of the riser and is usually enclosed safely within a metal cabinet. Water is pumped through the inlet from a fire engine during an event of fire. Therefore, these inlets are placed not more than 18 meters from the fire appliance access road and not more than 30 meters from the nearest fire hydrant. A drain is provided at the bottom

of the breeching inlet to drain the system after use. Landing valves are installed on every floor and are usually located within fire access lobbies, protected staircase. These valves are installed not more than 0.75m above floor level. Along with the valves, is a 30m fire hose provided for firefighters to use during fire hazards.

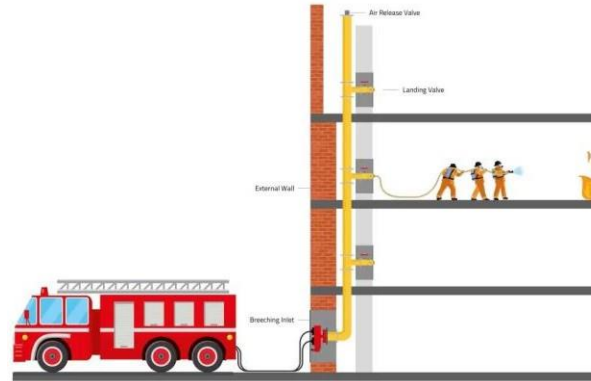


Fig 8.1 Dry riser system

4. Wet Riser System

A wet riser system is similar to that of a dry riser, with the difference where the vertical pipes are permanently charged with water from a pressurized source and fitted with landing valves on each floor. A wet riser system is utilized when the building height exceeds 30.5 m, above the fire appliance access level. The riser pipe is made of galvanized iron measuring 150 mm in diameter.

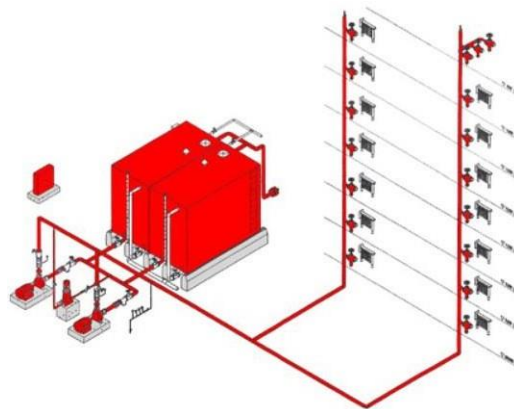


Fig 8.2 Wet riser system

Water is pumped from the storage tank to the pipes through a duty pump. In the case of a duty pump failure, the standby pump will be activated and powered by an emergency generator or driven by a diesel engine to prevent the cessation of its function. The jockey pump functions to maintain the system pressure and operates during initial minor pressure loss. It also prevents larger duty pumps to cut-in intermittently.

5. Automatic Fire Sprinkler System

An automatic fire sprinkler system is designed to alert the occupants of a building and suppress fire damage during an event of fire. It comprises of a series of water pipes, water supply from a water tank and pumps (duty pump, standby pump and jockey pump) which pressurize the water and provide an adequate flow rate.

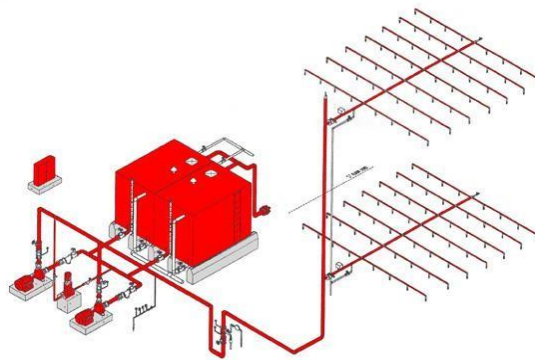


Fig 8.3 Fire sprinkler system

Sprinklers are fitted with a temperature sensitive liquid which breaks the glass casing it. This subsequently causes the water to discharge from the pipes and onto the deflector, which disperses water over a defined fire hazard area. Common sprinkler sensing element typically breaks at 68.3°C. The sprinkler heads are often categorized according to the head design and temperature sensitivity and are color coded which indicates its temperature rating.

8.1.2 Non-Water-based System

Although water is an effective component in controlling the spread of fire, it may cause more damage depending on the type of fire hazard such as an electrical outburst or a hazmat fire. During such cases, non-water-based systems are utilized to control and extinguish fire safely and efficiently.

1. Fire Extinguisher

Portable fire extinguishers are designed to be used during initial stages of a small fire outbreak with an intend to control and extinguish fires and prevent further escalation into full scale fire. They are positioned in strategic areas which are prone to fire hazards and bare a minimal gross weight such that it can be carried by a person. There are several types of fire extinguishers designed to control and extinguish different types of fire hazards as represented in the fig 8.4.

Type Extinguisher	Fire	CLASS A	CLASS B	CLASS C	CLASS D	Electrical	CLASS F	Comments
		Combustible materials (e.g. paper & wood)	Flammable liquids (e.g. paint & petrol)	Flammable gases (e.g. butane and methane)	Flammable metals (e.g. lithium & potassium)	Electrical equipment (e.g. computers & generators)	Deep fat fryers (e.g. chip pans)	
Water		✓	✗	✗	✗	✗	✗	Do not use on liquid or electric fires
Foam		✓	✓	✗	✗	✗	✗	Not suited to domestic use
Dry Powder		✓	✓	✓	✓	✓	✗	Can be used safely up to 1000 volts
CO ₂		✗	✓	✗	✗	✓	✗	Safe on both high and low voltage
Wet Chemical		✓	✗	✗	✗	✗	✓	Use on extremely high temperatures

Fig 8.4 Types of fire extinguishers

8.2 Fire Detection & Alarm System

Fire detection during the early stages usually reduces the damage caused to the people and property and it is especially crucial in a mixed-use building as it can be dangerous due to its usage by people of different walks of life.

8.2.1 Fire Detector

Fire detectors are designed as an early detection for fire hazards and alert the building's occupants of a fire emergency. They are designed to detect smoke, heat or flames.

1. Smoke Detectors: As the name suggests, used in the detection of smoke. It can be categorized into two main types, namely the photoelectric smoke detector and the ionization smoke detector,

- Photoelectric smoke detectors: When the smoke enters the detector, the smoke particles reflect the light into the sensor triggering the detector and subsequently sounding the alarm.
- An ionization smoke detector detects fires when the smoke enters the chamber and disrupting the electrically charged plates in the detector.

2. Heat Detector: A heat detector features a heat sensing circuit that can sense rapid increases in temperature. If the temperature of a room increases too quickly or crosses a certain threshold, the detector will send a signal to the fire alarm control panel.

3. Flame Detector: A flame detector is utilized in areas where a possible fire hazard could potentially cause massive amounts of damage and losses. A flame detector has a quicker response and more accurate detection compare to smoke or heat detectors.

8.2.2 Fire Alarm System

Fire alarm systems consists of fire detection equipment and fire alarm control panels. During an event of fire, these components serve to detect and issue visual and audio warnings such that necessary firefighting procedures can be taken.

Types of Fire Alarm System

1. Fire Alarm Control Panel: It is usually utilized in large buildings and is the main controlling device which receives information and signals from alarms or detectors and subsequently relays the signal to suppression systems and other firefighting systems. The control panel is usually located in a fire control room.

2. Fire Alarm Bell: A fire alarm bell is an equipment which issue an audible siren during fire emergency. It is designed to produce a minimum sound lever of 65dB that drown out any background noise and shall persist for at least 30 seconds.

3. Pull Station: A manual call point or pull station is a device that can be operated by occupants of a building to warn other occupants and send a signal to the fire alarm control panel when a fire event occurs. It is installed 45 meters apart and can be found in easily accessible areas and exit routes to floor landing and exits to open air.

4. Fire Intercom System: It is a two-way emergency voice communication system. It provides direct communication between the remote telephone handsets located in the fire control room with the master telephone handset of the local fire department.

5. Fireman's Switch: It is a specialized switch intended for firemen use only during an event of fire. They function to disconnect all electrical or power supply of a particular floor which prevents overheated equipment's from exploding. They are usually found on the walls outside shops, industries, commercial buildings or near fire escape staircases. The handle has a unique design such that a fireman's axe or hook can be used to activate it and to prevent other accidental triggers.

8.3 Smoke Control System

Smoke control systems are mechanical systems designed to control the movement of smoke through a building during fire. They serve to protect the building's occupants as they evacuate to safety.

8.3.1 Smoke Exhaust System

The most common smoke control system is the atrium smoke exhaust system and the stair-pressurized system. The former serves to alleviate and limit the accumulation of smoke in a building greater than or equal to the rate at which it is generated with the use of exhaust inlets installed at the ceiling.

8.3.2 Stairway Pressurized System

This system prevents toxic gas and smoke from spreading through stairwells, elevator shafts and other vertical openings. The accumulation of smoke in stairwells will greatly complicate fire evacuation processes and firefighting operations. To prevent such an event from occurring, these crucial spaces are constantly driven with outside air with mechanical fans in order to produce a positive pressure within it. This prevents toxic fumes and smoke from entering as they can only flow from a higher pressure to a lower pressure.

8.4 Passive Fire Protection (PFP)

System allows fire to act upon the system itself which only active when fire breaks out. It is an important component of the components of structural fire protection and fire safety in a building. PFP begins at the planning design stage of any construction as it is built into the buildings to ensure protection of occupants and structure even when failure of active fire protection occurs.

Objectives of Passive Fire Protection

- Helps to slow down the spread of fire within buildings and to another adjacent buildings.
- To protect building occupants from fire by providing sufficient time and safe evacuation routes.
- To protect building structure from severe total damage within a specific time, to ensure safe firefighting access.
- To minimize building properties total damage.

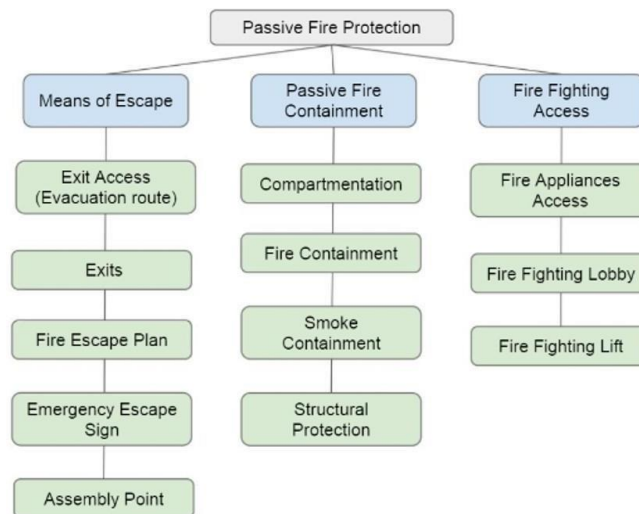


Fig 8.5 Passive fire protection

8.4.1 Exit Requirement for Fire Escapes and Stairs

- Fire escape shall not be taken into account while calculating the number of staircases for a building.

- All fire escapes shall be directly connected to the ground.
- Entrance to the fire escape shall be separate and remote from the internal staircase.
- The route to fire escape shall be always free of obstructions except the doorway leading to the fire escape which shall have the required fire resistance.
- Fire escape shall be constructed of non-combustible materials.
- Fire escape stairs shall have straight flight not less than 125 cm wide with 25 cm treads and risers not more than 19 cm.
- Handrails shall be at a height not less than 100 cm.
- Fire escape staircase in the mercantile, business, assembly, hotel buildings above 24 m. height shall be a fire tower and in such a case width of the same shall not be less than the width of the main staircase. No combustible material shall be allowed in the fire tower.

8.5 Design Considerations for a Fire Safety System:

- The number and size of the exit is based on the number of occupants.
- Exits should be located within the travel distance of 30m.
- Capacity of exits – no of occupants

	Stairways	Ramp	Doors
Business	50	60	75
Mercantile	50	60	75

- Open area around buildings: Up to 18 m – 6m
Up to 21 m - 7m
- Ventilation shafts up to 24 m height – 5.4 sqm required shaft size 1.80 m.
- Above 24 m height smoke fire check door is required.
- Provision for lifts shall be made for MSB having a height of 15 m above with accessible for 24 hrs.
- A wet riser system is used. At the basement, a pump room 5x5 m to be provided.
- Fire water sump for the capacity of 4 L per square feet
- Minimum 10 L to be provided for fire water sump during the need of firefighting arrangement.
- Four types of pumps namely diesel pump, main pump, jockey pump and sprinkler pump to be provided.
- For each 30 m running distance fire hydrant with hose reel to be provided
- For all the floor area sprinkler system should be provided at ceiling.
- For every 3-meter fire alarm system 1 point should be provided.

8.6 Fire Safety Systems used in Case Study:

Marina mall:

Fire water sump of 2 L is provided for 4 hrs. of fire rating. A wet riser system is provided. 20 hose reels within the boundary of the site. Fire water sump is located in B2.

Tamarai tech park:

- Fire water sump of 2.5 L is provided for 4 hrs. of fire rating.
- The types of extinguishers available are as follows:
ABC 6kg extinguisher, Co2 4.5kg extinguisher, DCP 75 kg extinguisher
Co2 22.5 kg fire extinguisher.
- Diesel fire pump 68 kw, Hydrant pump 55kw, Jockey pump 10 hp
Sprinkler pump 55 kw
Fire pumping wet riser system.
- five Fire hydrant shaft
- smoke detector & Fire sprinkler for every 10 ft dist.

Burj Khalifa:

- Fire and life safety plan system common path egress 22m travel distance 40m refuge area exit stair & exit passageways common path of egress 20m.
- Consists of 13 shuttle elevators used during fire emergency.
- Contains functions like fire protection, smoke prevention and water proofing.
- Evacuation time - 138 minutes to 108 minutes.
- Contains separate power supply, turbocharging and waterproofing along with functions of fire prevention, smoke prevention and waterproofing.
- Primary fire water supply: basement tank with secondary tanks distributed vertically throughout tower with pumps.
- Fire water supply duration: 2 hours internal and 4 hours total
- Fireman's elevator: 2 elevators that travel up to level 111 and 1 for level 112 through 160
- Smoke protected exit stairs: pressurized
- Floor smoke control is provided.
- Pressurized air-conditioned refuge areas, approximately every 20 floors where they could wait safely or rest on the way down.

Taipei 101

- The company is equipped with 8 diesel-fuel emergency generators, capable of supplying power for 46 hours continuously without additional fuel.
- Emergency generator grows about 70 percent of the tower tenants power consumption needs. An Uninterruptible Power Supply (UPS) ensures that the building's control and security systems remain in operation before the emergency generators start.

Shanghai tower

- Contains cesium potassium fireproof glass in the inner curtain wall along with special fireproof adhesive strip.
- Fireproof performance of the inner wall is crucial as it is closely related to the "temperature-time relationship curve" after the fire. Each area of Shanghai Tower has 12 to 15 layers.
- Fireproof and armored glass, together with special drencher spray header, which can conduct an automatic sprinkler in the event of fire to protect the glass curtain wall. In this way, nearly 80,000 m² interior curtain wall has been placed on a special fireproof coat. The technical research and development serve the safety realizing the best protection for people.

Chapter 9 Acoustics

Acoustics planning and design is required to achieve proper acoustical conditions inside and outside the mixed-use building. It is also provided for correcting the defects in building units and components of the structure and is mainly the absorption and dissipation of exterior and interior noise and their insulation against sound.

9.1 Role of Acoustics in a mixed-use Development

- Noise Control: Since mixed-use development involves multiple usage like residential, commercial, and so on, the noise from one space should not affect the other. Therefore, soundproofing should be installed.
- Acoustic planning is required to provide speech privacy and noise reduction.
- Acoustics helps in optimizing the sound in various spaces depending on its needs.
- Acoustics planning is also crucial in reducing noise pollution.

9.2 Design Considerations for Acoustics

The management of noise is important for a mixed-use building. The following concepts can be applied to minimize the need for applying detailed acoustic treatments:

1. Keeping noisy areas of the mixed-use building away from quiet areas. This is the most basic and yet most effective principle in managing the noise.

- Do not locate air conditioning units near residential or official spaces.
- Do not locate nightclubs and residential areas in the same floor.

2. Avoid high speed equipment like pumps, fans, lifts, etc. Generally, it is much better acoustically to select equipment at lower speeds and larger physical dimensions like larger fans running at slower speeds.

3. Run equipment wherever possible at a lower speed for nighttime operation.

4. Design low velocity and pressure duct and piping systems as it reduces the potential for these ducts to be a source of unwanted noise.

5. Design heavier systems: Greater the mass the greater potential to isolate noise and vibration.

6. Decouple where possible.

- Party walls with separated leaves provide considerably higher levels of acoustic isolation than solid walls of the same and even greater mass.
- Floating floors can be used for roof top chiller and cooling tower plant rooms to significantly reduce the levels of sound transmission to lower areas.
- Sound locks can be used for the doors of plant rooms and noisy places to minimize sound breakout through the entrance doors.

7. Minimize the transfer of vibration as noise into the building. Such treatments range from rubber pads under AHU cases to high deflection springs under chillers. All major plant such as chillers, pumps, fans, etc., will need to include spring mounts with spring hangers for the associated pipe work. In sensitive locations consideration should also be given to vibration isolating vertical pipe work risers. Cooling towers can either be supported on neoprene pads or springs depending upon the tower and the location.

8. Use carpet where possible instead of hard floor surfaces. Where hard floor surfaces are used, consideration should be given to floor impact isolation and also in busy active areas the levels of reverberant sound.

9. Keep waste pipes above floor level. Where possible do not allow waste pipes to penetrate the floor slab to lower sensitive areas.

10. Acoustically lag waste pipes in ceiling voids of sensitive areas and/or place them inside acoustically rated bulkheads.

11. Acoustic design is based on dissipation of Noises and external and internal, insulation of sound. Two aspects to control the remedy of acoustical defects in buildings and sound insulation.

- Selection of location and orientation
- Lining of wall and ceiling by means of air-filled materials, like felts, straw boards, etc.
- Rigid wall, floor, partitions can prevent transmission of noise
- Structure borne noise can be prevented by introducing discontinuities in the path of vibrating waves or expansion joint.

Acoustics used in Case Study:

Marina mall:

mineral wool, rock wool, and fiberglass, designed to fit in between the studs of walls.

acoustic panel board

natural frequency down to 6hz

acoustic gap between 20 to 200mm.

Live case study -Comparative Analysis

	Marina mall	Tamarai tech park
Total area	5,32,680 sqft	6,30,000 sqft
HVAC	chilled water air conditioning system VRF (Varied refrigerant flow). 5 cooling tower	Air-cooled air-conditioning system 3 cooling tower
Lifts and escalators	MRL is used in marina mall total of 4 passenger lift 1050 kg 14 persons and 3 service lift. 29 Staircase & 22 escalator.	8 No's Carries 20 persons with the capacity of 1350 kg and 1.2m wide. 8 Nos of staircase
Water supply and disposal	45 litres per day per person - Water treatment plant capacity is 180 KLD. 270 KLD sewage treatment	45 litres per day per person - total demand for water supply of 110 KLD cubic meter per day is required. 120 KLD Sewage treatment
Electrical system	3 Nos of Transformer Diesel generator 3 Nos of 1500 kVA 2 Nos of 1010 kVA	Transformer 2Nos of 2000kVA Diesel generator 6 Nos of 725 kVA. Separate Smoke chimney.
Fire safety, detection, and protection	Fire water sump of 2 L is provided for 4 hrs. of fire rating wet riser system	Fire water sump of 2.5 L is provided for 4 hrs. of fire rating. ABC 6kg extinguisher Co2 4.5kg extinguisher DCP 75 kg extinguisher Co2 22.5 kg fire extinguisher
Acoustics	Noise lock are used in AHUs,chiller room. Noise insulation is provided for the theatre of marina mall.	Noise lock are used in AHUs.

Inference

Marina mall

In marina mall it is evident that the efficient provision and management of building services, HVAC systems, lighting, security, and maintenance, have played a major role in enhancing the overall operational performance of the mall. Implementation of energy-efficient AC systems solutions resulted in cost savings.

In marina mall there is an enormous amount natural lighting in lobby area. The air supply of the lobby is insufficient because of heat produced by natural lighting.

Tamarai tech park

Tamarai tech park is efficient and accessibility to each floor with elevator it is easy.

Efficiency of the air conditioning system is less. Sufficient parking is provided. there were no much issues faced by user of this building.

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Design consideration on Live Case Study

	Design consideration	Marina mall	Tamarai tech park
HVAC	Air change requirement as per NBC for Basement Car Parking is 9 to 12 ACPH under normal conditions. Equipment room for central air conditioning system clear headroom should be min 4.5 m for 500 TR Capacity. Equipment room for AHU should have natural ventilation	Marina mall has a clear headroom of 4.5 m it chiller capacity is 500 TR. Water cooled air condition system is used and has high efficiency	Mechanical ventilation is provided for AHUs as per norms 20 to 30 % fresh air is provided. Air cooled air condition system is used and less efficient
Lifts and escalators	Based on the number of occupants and the peak usage time. The number of elevators, speed and capacity of the lift will be finalized.	On an average 12000 ppl visit marina mall per day & on weekend 20000 ppl. vertical transportation are provided as per the standards. It has adequate amount of lifts, elevators & travelator.	On an average 8000 -10000 ppl work per day. vertical transportation are provided as per the standards. It has adequate amount of lifts, elevators & travelator.
Water supply and disposal	Demand for water requirement for commercial buildings ranges up to 45 litres per head per day. Flushing storage capacity 900 litres per wc and 350 litres per urinal. A maximum of 3 batches of sewage treatment should be considered per day	raw water sump and water treatment is located in north side of the building. Sewage treatment plant located in backside of the building in basement 1 it extend to basement 2 capacity of 270 KLD. Treated water pumped up and then distributed to each floor of the building	water treatment is located in front east end of the building capacity of 110 KLD. Sewage treatment plant located in backside of the building in upper basement it extend to lower basement capacity of 120 KLD. Treated water pumped up and then distributed to each floor of the building
Electrical system	Each substation should have provision of addition for at least one transformer and extension of LT Panel to take care of future growth of load back up arrangement with solar power backup to reduce the Substation KVA and also to reduce electricity bill expenditure are recommended.	Transformers is located in lower ground floor of the mall with electrical room. There is no additional space for future expansion. DG is also provided in LGF. Solar panel are used to generate power for the mall located in terrace floor.	Transformers is located separate outside the building . There is additional space for future expansion is provided. DG is located close to the transformer in transformer yard. Tamarai tech park has LEED zero rating .

	Design consideration	Marina mall	Tamarai tech park
Fire safety	No of fire exit is calculated based on no of occupants. Exits should be located within the travel distance of 30m. For each 30 m running distance fire hydrant with hose reel to be provided For all the floor area fire Sprinkler ,fire Alarm , Smoke detector system should be provided at ceiling.	Marina mall has 5-6 fire exit on each floor. All the fire exit are within 30 m distance it has followed the rules. Hose reel are provided in each floor near AHUs, electrical room and around the building.	Tamarai tech park has fire exit on each floor. All the fire exit are within 30 m distance it has followed the rules. Hose reel are provided in each floor near AHUs, meter room and around the building.
Acoustics	Design low velocity and pressure duct and piping systems as it reduces the potential for these ducts to be a source of unwanted noise Sound locks can be used for the doors of plant rooms and noisy places to minimize sound breakout through the entrance doors. hard floor surfaces are used, consideration should be given to floor impact isolation and also in busy active areas the levels of reverberant sound.	Noise lock are used in equipment room Chiller room, AHUs. Theatre use carpet flooring to damp noise . wall panel are used to reflect the noise .	Noise lock are used in AHUs.

Literature case study -Comparative Analysis

	Burj Khalifa	Shanghai tower	Taipei 101
Total build up area	4,54,249 sq m	3,80,000 sqm	4,12,500 sqm
HVAC	chilled water air conditioning system DCS	chilled water air conditioning system	chilled water air conditioning system 9water-cooled centrifugal chillers 3 dual-operation water-cooled centrifugal chillers 1 screw geothermal heat pump to provide heating variable air volume air
Lifts and escalators	57 Lift carries 12 -14 people speed 600 m/m 8 Escalator for shopping complex 2909 staircases including fire staircase	Ultra-high-speed elevators is used. Speed-10 m/s . 21 persons capacity 1600 kg lift is provided. Number of elevators – 114 Double decker Total 3398 stairs till 119 floor and escalator are provided till retail only lvl 7. The elevator tend to vibrate travelling at high speed in order to overcome it Toshiba active damper is used.	10 double deck elevators 2040 kg (31 persons) 24 double deck elevators, 1350 kg (20 person) Shuttle elevator serving the transfer Floors at 460 metres per minute Single-deck elevators (various capacities) – 3 Communication floors elevators – 2 2 pressurised single-deck elevators, 1350 kg 120 persons) Single deck elevators, 2x 2040 kg 1x4800 kg Car park elevations Single deck elevators, 1600 kg to tower lobby. 2046 steps are there.

Water supply & disposal	six water transfer sets and seven pressure booster sets 1,000 cubic meters every day average 946,000 litres of water per day The pumps have the pressure of 30 bar. About 15 million gallons of water is produced yearly from condensation	Shanghai tower The rain collection system recycles 25 percent of rainwater and supplies 245,000 cubic meters of water to the tower every year, reducing the tower's water consumption by 53 percent.	Water management systems work with low-flow water fixtures to reduce total water usage . rainwater harvested by the building is used for circulation. Motion-sensors save the building about 28,000 litres of potable water annually by managing all toilets, sinks, and urinal. This is a saving of at least 30% when compared to the water consumed by an average building of a similar size.
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Electrical	Burj Khalifa has its own substation of 11kV capacity incoming DEWA from the ground floor. A 11 kV distribution substation is located on the 150th floor which provides service for the top floors. Multiple 11KV/400Y/230V transformers located at mechanical floors. 400Y/230V Local zone vertical bus and switch boards. Electricity consumption is expected at 50 MVA.	Dual feed from two sub stations, two risers for internal distribution transformer redundancy General office use design load of 65 VA/sq m (excluding air conditioning and lighting) Taiwan Electric Company, via Hulin and Shimao Second Substation, feed 22.8 KV high-voltage power. The building's electrical system applies the concept of dual-source, dual-backup, and dual-feeder to lay cables for internal power supply.	Contains 270 wind turbines at the top of the building which provides power for exterior lighting. 2,130 kW natural gas-fired cogeneration system provides electricity and heat energy to the low-zone areas. The total energy consumption of Shanghai tower is around 12 million kWh.
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Fire safety detection & protection	Fire and life safety plan system common path egress 22m travel distance 40m refuge area exit stair & exit passageways common path of egress 20m. Consists of 13 shuttle elevators used during fire emergency. Contains functions like fire protection, smoke prevention and water proofing. Evacuation time - 138 minutes to 108 minutes. Contains separate power supply, turbocharging and waterproofing along with functions of fire prevention, smoke prevention and waterproofing. Primary fire water supply: basement tank with secondary tanks distributed vertically throughout tower with pumps. Fire water supply duration: 2 hours internal and 4 hours total Fireman's elevator: 2 elevators that travel up to level 111 and 1 for level 112 through 160	Contains cesium potassium fireproof glass in the inner curtain wall along with special fireproof adhesive strip. Fireproof performance of the inner wall is crucial as it is closely related to the "temperature-time relationship curve" after the fire. Each area of Shanghai Tower has 12 to 15 layers. Fireproof and armored glass, together with special drencher spray header, which can conduct an automatic sprinkler in the event of fire to protect the glass curtain wall. In this way, nearly 80,000 m² interior curtain wall has been placed on a special fireproof coat The technical research and development serve the safety realizing the best protection for people.	8 diesel-fuel emergency generators, capable of supplying power for 46 hours continuously without additional fuel. Emergency generator grows about 70 percent of the tower tenants power consumption needs. An Uninterruptible Power Supply (UPS) ensures that the building's control and security systems remain in operation before the emergency generators start.
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	Smoke protected exit stairs: pressurized Floor smoke control is provided. Pressurized air-conditioned refuge areas, approximately every 20 floors where they could wait safely or rest on the way down.		
Acoustics	Double-Glazed Windows Damping systems, which can include vibration dampers and tuned mass dampers, are used to reduce vibrations	Double-Glazed Windows or triple glazing are used Damping systems, which can include vibration dampers and tuned mass dampers, are used to reduce vibrations	Double-Glazed Windows Damping systems for lift . vibration dampers are used to reduce vibrations

Chapter 10 Technological Advancement in Building Management System

BMS systems are “Intelligent” microprocessor-based controller networks installed to monitor and control a buildings technical systems and services such as air conditioning, ventilation, lighting and hydraulics. More specifically they link the functionality of individual pieces of building equipment so that they operate as one complete integrated system. Now installed in every major building or facility with the availability of direct integration into all other building services such as security, access control, CCTV, fire, Lifts and other life and safety systems.

1. Integrated BMS

IBMS in high rise buildings is the new advancement.in large commercial complexes, provide “single window” access, for:

- Monitoring & control of firefighting systems.
- Security module for access control.
- Elevator control.
- Module for management of energy in the complex.
- Module for preventive maintenance of equipment’s etc.

Lifesaving module provide primary monitoring & full control of smoke detection. Fire detection through hundreds of smart smoke detectors installed assist in providing information of the Floor affected by fire as well as for safe evacuation of persons.

2. IoT-based BMS

Instead of being accessed locally, an IoT-based BMS is housed on a distant server and accessed online. It can be used to manage a single structure, a group of structures, or a whole campus. The most cutting-edge & adaptable building management system, IoT-based BMS is suited for all types of structures & infrastructure, including retail establishments, hotels, industrial facilities, offices, warehouses, and data centers.

3.Artificial Intelligence (AI) and Machine Learning:

To improve building operations, BMS are progressively integrating AI and ML technologies. These systems can forecast equipment failures, minimize energy use, and enhance occupant comfort by analyzing enormous volumes of data from sensors and previous performance. BMS powered by AI can change in real-time and continually learn to improve building performance.

4. Edge Computing:

In BMS automation, edge computing has grown in importance. BMS can lower latency, enhance responsiveness, and ensure that crucial services continue to run even if there is a loss of connectivity to the cloud or central servers by processing data locally at the edge (inside the building).

5. Cloud-Based BMS:

Remote analytics, management, and monitoring are made possible via cloud-based BMS technologies. When connected to the internet, building operators and managers can access and operate building systems from any location. Additionally, scalability, adaptability, and data storage are made possible via cloud-based BMS.

6. Advancements in HVAC

- **Energy Recovery Ventilation (ERV) Systems:** Energy Recovery Ventilation Systems work using two fans, which in turn create two airstreams. The first pulls fresh outside air into a building, while the second draws stale, polluted air out. Heat and moisture are transferred from the outgoing air to the incoming airstream in the summer and vice versa in the winter as the airstreams pass through the ERV.
- **Carbon Dioxide (CO2) Sensors:** Indoor air quality is tracked using CO2 sensors, and ventilation rates are changed in response to occupancy levels. This saves electricity while preserving a healthy and cozy environment.
- **High-Efficiency Heat Pumps:** Modern heat pump technology has produced systems that are more effective and environmentally benign. Heat pumps are an effective alternative for heating in colder climates because some versions are made to function effectively even in extreme temperatures.

7. Advancements in Vertical transportation

- **Maglev Elevators:** It is being investigated if magnetic fields, rather than the more conventional cables and pulleys, may be used to propel magnetic levitation (Maglev) elevator technology, which has the potential to offer faster, quieter, and smoother journeys.
- **Ultra-High-Rise Elevators:** Manufacturers of elevators are working on systems that can support ultra-high-rise structures that can reach heights of more than 500 meters. These elevators are built to resist high pressures, cover large distances, and move people fast and safely.

8. Advancements in Fire safety

- **Air Sampling Smoke Detection:** Even in difficult conditions with little airflow, these devices constantly sample the air for the presence of smoke particles and offer early detection.
- **Video-Based Fire Detection:** Intelligent video analytics-enabled cameras can detect smoke, flames, or strange heat patterns, setting off alarms and giving first responders a visual confirmation.
- **Addressable Systems:** In order to streamline the response and lower false alerts, addressable fire alarm systems can detect the precise location of a fire or issue.

9. Advancements in Acoustics

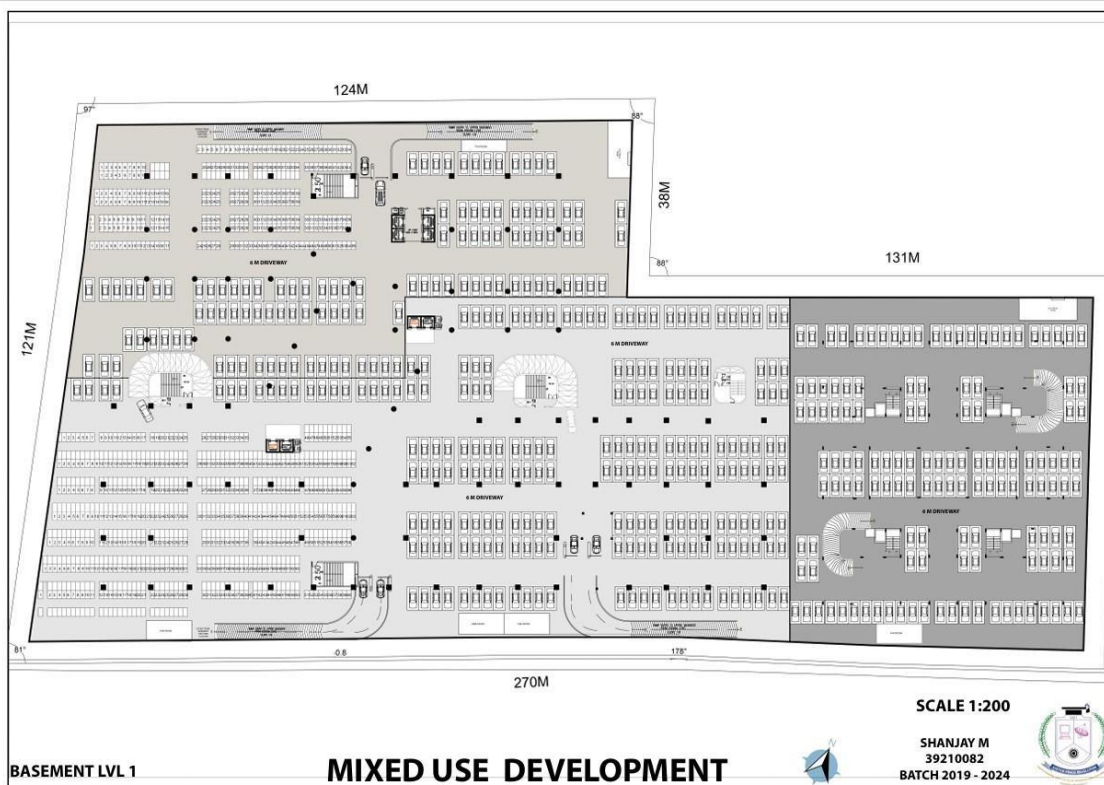
- **Vibration isolators:** Advanced vibration isolation systems are used in high-rise buildings to mitigate structural vibrations, especially in areas near heavy machinery or transportation hubs.
- **Floating Floors:** Floating floors, constructed with resilient materials, absorb and isolate vibrations from sources like elevators or mechanical equipment.

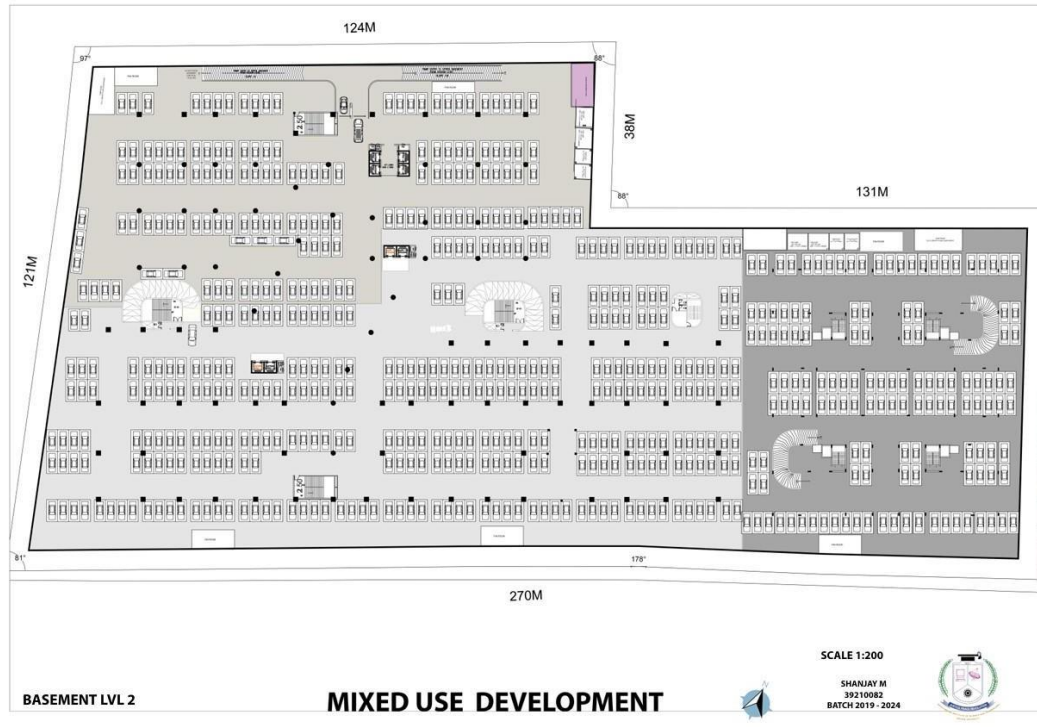
5.3 DETAILED DRAWINGS

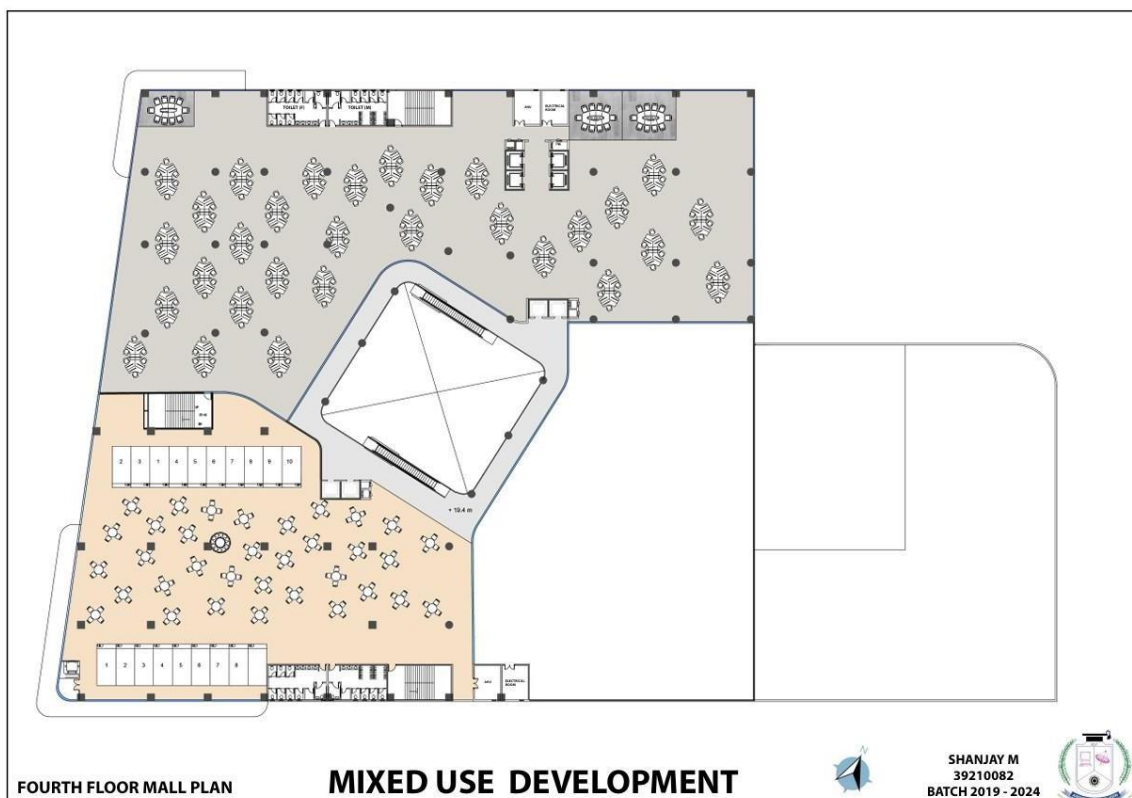
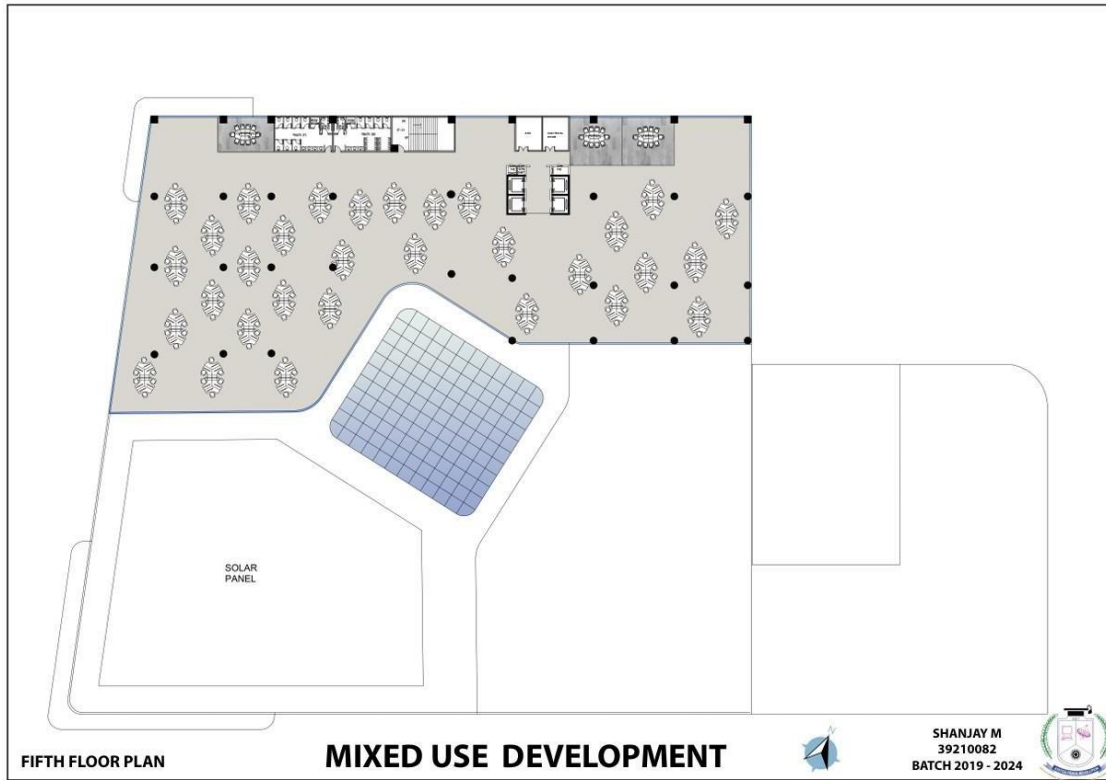
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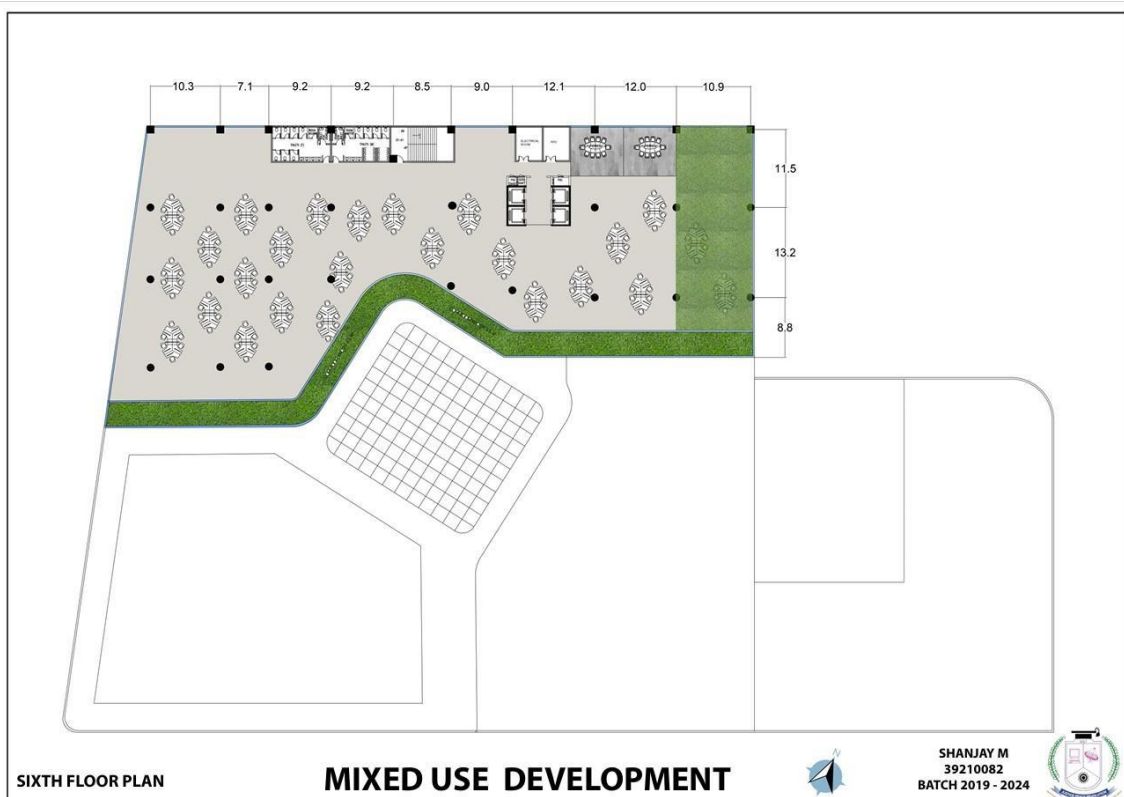




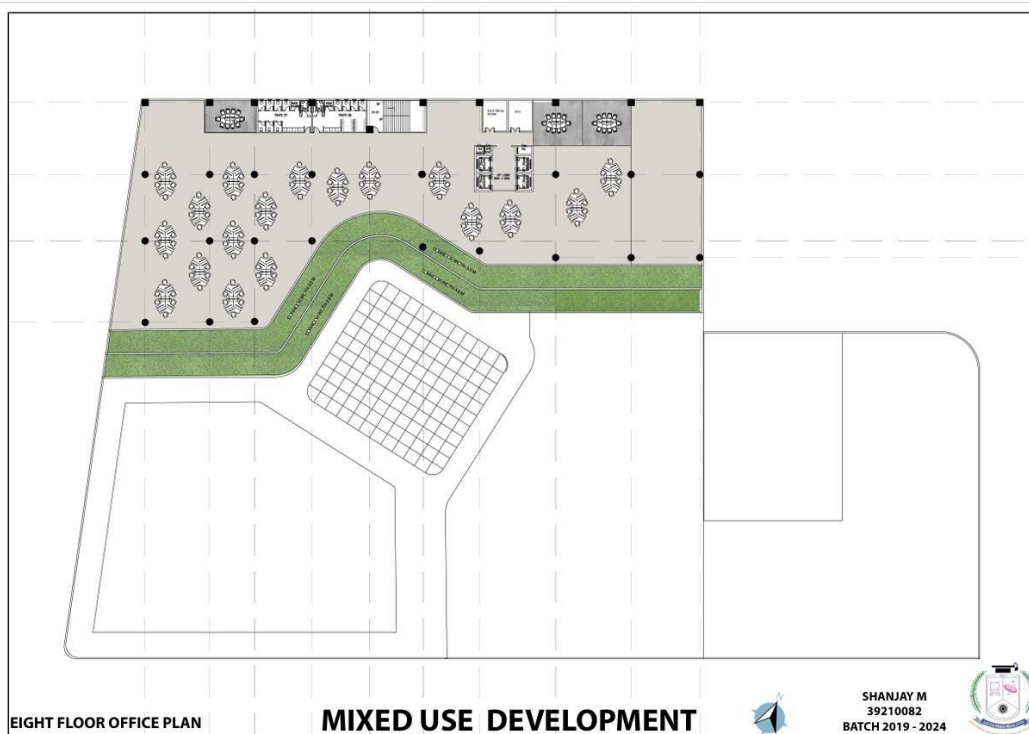
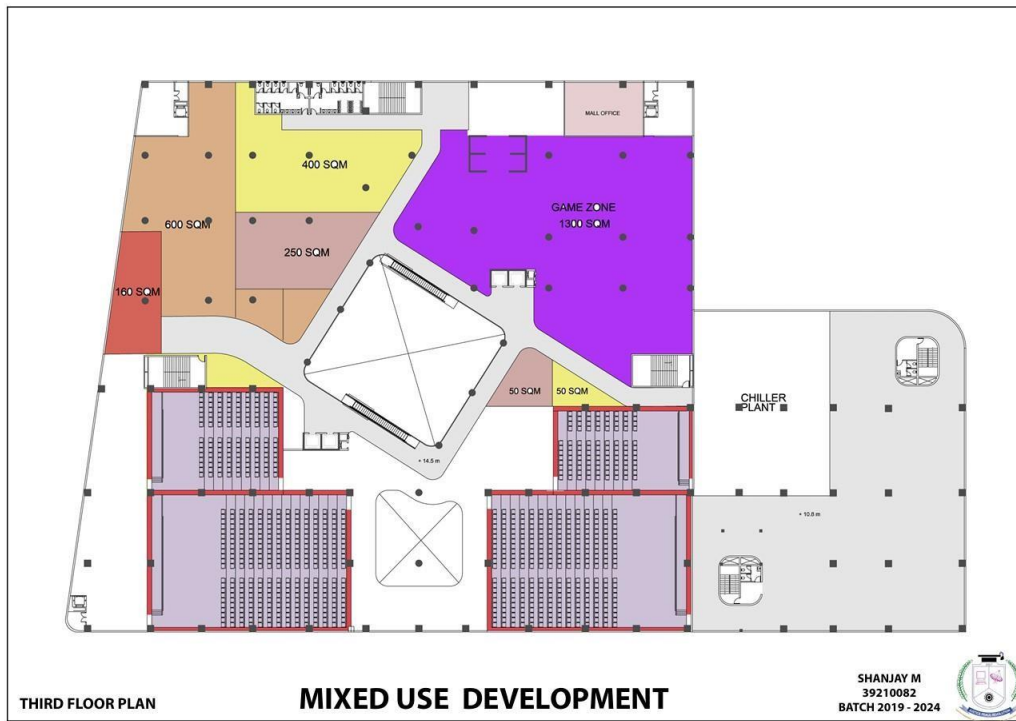


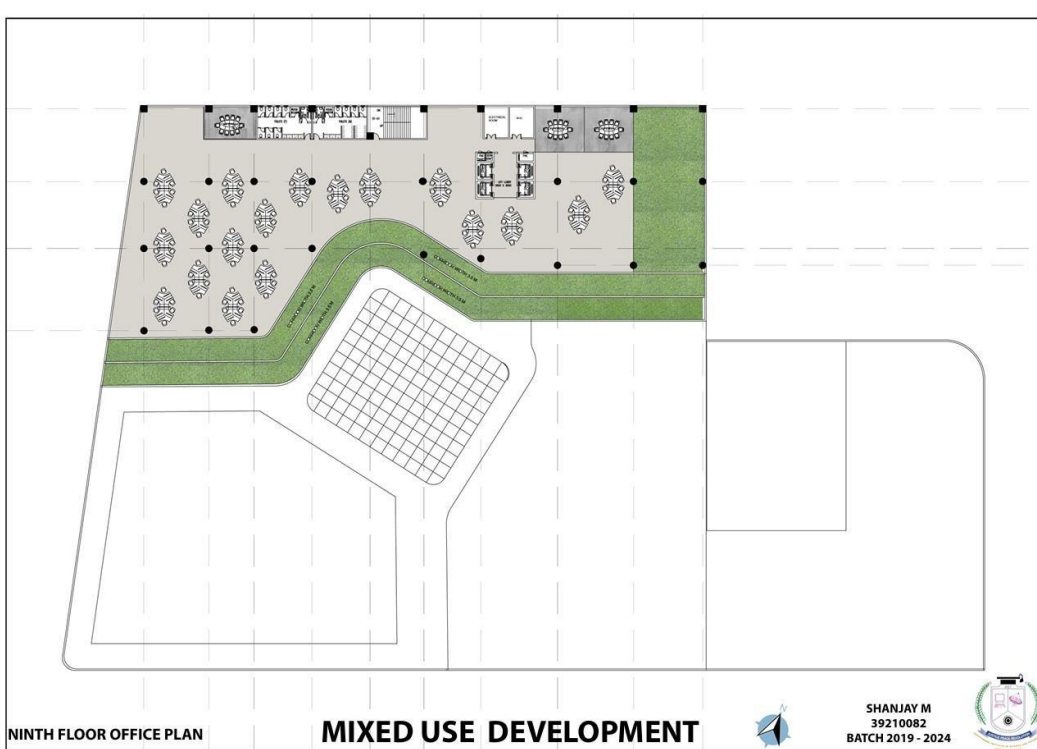












Reference

1. NBC National building code
2. Zolotareva E. Mechanical supply and exhaust ventilation in high rise residential buildings in Russia.
3. Hall F, Greeno R. Building services handbook. Routledge; 2017 Apr 28.
4. <https://hnhub.in/types-of-air-conditioning-plants/#:~:text=Centralized%20Air%20Conditioning%20Plant,essentially%20in%20a%20closed%20cycle.>
5. <https://www.architecturaldigest.com/story/types-of-stairs-explained>
6. <https://smartacsolutions.com/which-air-conditioner-is-used-in-burj-khalifa/>
7. https://www.emsd.gov.hk/energyland/en/building/district_cooling_sys/dcs.html#:~:text=What%20is%20District%20Cooling%3F,in%20space%20and%20process%20cooling.
8. <https://www.studocu.com/in/document/dr-b-r-ambedkar-open-university/electronic-maadhyamaala-rachana-padhathulu/airconditioning-library-notes/43800779>
9. <https://archi-monarch.com/water-supply-system-in-tall-building/>
10. <https://www.vemc.co.in/blogs/fundamentals-of-hydro-pneumatic-pumps/>
12. <https://us5fanstation.de/fire-suppression-gas-types>
13. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8776175/#:~:text=All%20decision%20making%20parameters%20for,HVAC%20systems%20to%20achieve%20sustainability.>