Addis Ababa University

Addis Ababa Institute of Technology (AAiT)

School of Civil and Environmental Engineering

Water Supply and Environmental Engineering M.Sc. Program

Assessment of Ethiopian Plumbing Code and its Compliance for High-rise Buildings in Addis Ababa, Ethiopia

A thesis submitted to school of graduate studies of Addis Ababa University in partial fulfillment of the Degree of Master of Science in Civil Engineering.

(Major in Water Supply and Environmental Engineering)

By: Teshager Gebeyehu

Advisor: Agzew Nigussie (Dr)

October, 2024

Addis Ababa, Ethiopia

Approval letter

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By

Teshager Gebeyehu Ali

Approved by

AgzewNigussie (Dr).	[signature]	02/12/24
Advisor	Signature	Date
Johnny Girma (phD)	[signature]	02/12/2024
Internal Examiner	Signature	Date
Geremew Sahilu (PhD)	[signature]	02/12/2024
External Examiner	Signature	Date
School dean	Signature	Date

PG Program Coordinator
School of Civil &
Environmental Engineering

Declaration

I, Teshager Gebeyehu Ali, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics and all other outside contributions have been acknowledged properly.

Declared by

Name: Teshager Gebeyehu

Signature: ____________

Date: 02/12/2024

Confirmed by

Name: Agizew Nigussie (Dr.)

Signature: ____________

Date: 02/12/24

Abstract

The thesis examines the compliance of Ethiopian plumbing code for high rise buildings in Addis Ababa city. The adequacy of Ethiopian plumbing code with other international plumbing codes and its effectiveness of the design and installations of water supply systems of a building, the design and installation of internal waste water drainage systems of a building, the design and installation of external waste water drainage systems of a building (septic tank), the code compliance of installed sanitary fixtures and appliances and the design and installation of roof storm water drainage systems using both the international and local plumbing codes. New technology PEX-AL-PEX pipe material, grease interceptor for kitchen sink and vent piping system were used for over viewing of Ethiopian plumping codes to the other international plumbing code. Hazzen William equation, plumber's chart, flow rate and loading units of fixture units were used the analysis of the design of water supply system.

The traps and loading units of sanitary appliance, slope and horizontal pipe size, fixture units and vertical pipe size of stack, total loading unit of fixtures and pipe size for both common and combined vent were used the analysis of internal wastewater drainage systems of a building.

The rate of flow method, discharge versus total loading unit chart, standard area covered for storage septic tank, volume of sediment, volume of sludge were used the analysis of external waste water drainage systems of a building. Discharge of roof storm water by rational formula. Pipe size capacity of down pipe, intensity of rain fall and specifications of roof gutter were used the analysis of roof storm water drainage system of a building.

The local Ethiopian plumbing code was used for analysis of internal waste water drainage systems and the roof storm - water drainage. The international plumbing code and Indian plumbing code is good for analysis of water supply pipe lines and external waste water drainage system. The study focused on assessing whether the installed plumbing components of selected buildings meets the established design requirements, standards and regulations of plumbing codes.

Recommendations were also provided to ensure optimal plumbing system designs, functionality and compliance with relevant plumbing codes and standard requirements.

Keywords: plumbing code; plumbing system design and installations; water supply system, waste - water drainage system; roof storm -water drainage system.

Acknowledgment

First of all, I would like to thank the Almighty God for all the blessings and guidance's throughout my study.

Secondly, I would like to express my genuine acknowledgement to the Addis Ababa University for giving me an opportunity to attend my favorite field of study through the scholarship program which is sponsored by Ministry of education.

I am privileged to thank my advisor, Dr. Agzew Nigussie for his efforts, useful suggestions, and encouragements, which provided valuable guidance for me starting from proposal up to the whole thesis work. I want to express my thanks, Mr. Getu Merdasa (plumber) for their assistance in a data collection and analysis.

Finally, I wish to thank my paramount gratitude goes to my family and all those who have helped me by one way or another during this research

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List of abbreviation

AAU	Addis Ababa University
AAiT	Addis Ababa Institute of Technology
EBPCS	Ethiopian building plumbing code standard
IBPCSs	Indian building plumbing code standard
IPCS	International plumbing code standard
HWB	Hand wash basin
Ks	Kitchen sinks
WC	Water closet
Lau	Laundry
Sh	Shower head
Ur	Urinal
Tub	Bath tub
MBR	Master Bed room
CBR	Common bed room
KBR	Kids bed room
WWD	Waste water drainage
WSS	Water supply system
BWD	Black water drain
BrWD	Brown water drain
GWD	Gray water drain

BD	Below design
AD	Above design
MR	Main riser

Chapter one

1. Introduction

1.1 Background

The Ethiopian Plumbing Code (EPC) is a building code that regulates the design and installation of plumbing systems including the plumbing fixtures in all types of buildings except for detached one- and two-family dwellings and townhouses that are not more than three stories above grade in height (Construction, 2013).

The comprehensive plumbing code establishes minimum regulations for plumbing systems using prescriptive and performance related provisions (Ilemobade, 2006). It is founded on broad-based principles that make possible the use of new materials and new plumbing designs and installation systems of a building.

Internationally code officials recognize the need for a modern, up-to-date plumbing code addressing the design and installation of plumbing systems through requirements emphasizing performance (Woodson R. D., 2009).

In Ethiopia the design and installation of building plumbing systems of water supply system ,Waste water drainage system , storm water drainage system have been written in EBCS-9 2013 the National Building Code of India ,Uniform Plumbing Code and British Plumbing Standards were used as model.

To ensure public and environmental health, buildings should be provided with technical aspects of the design meet the installation of plumbing systems water supply system, waste water drainage systems and storm water. This requires a standard code of practice that governs their planning, design, installation, use and maintenance. The code have reflects the state-of-the-art in material science, technology and approach as much as practical. Plumbing code is designed to meet these needs through model code regulations that safeguard the public health and safety in all communities, large and small.

1.2 Statement of the Problem

Plumbing code compliance is a pivotal or crucial aspect of erecting construction. Still, it is not uncommon for structures to face challenges in meeting these conditions. One of the main issues is the lack of understanding and mindfulness of the plumbing codes regulations. This can affect in non-compliant installations, which may lead to safety hazards and expensive repairs in the future. Another problem is the complexity of the plumbing law itself. The regulations can be intricate and difficult to interpret, especially for those without a background in plumbing or construction. This can make it challenging for structure possessors, contractors, and indeed inspectors to insure compliance with the plumbing law. In conclusion, the statement of problems in plumbing law compliance demand of structures revolves around a lack of understanding, complexity, and the need to stay updated. Addressing these issues is important to insure the safety and functionality of plumbing systems in building structures and the occupants.

1.3 Study Objectives

1.3.1General objective

The general objective of this research is to assess the plumbing code requirements of Water Distribution Network, Waste water drainage and storm water drainage of the high raised building of Addis Ababa University and condominium. To address any improvements required in existing network and the mode of operation, in order to improve the quantity of water distributed to the consumers and to ensure the safety and functionality of plumbing systems in buildings.

1.3.2 Specific objective

- To review the Ethiopian plumbing code requirements
- To assess building water supply system design and installation
- To assess the internal and external wastewater drainage systems designs and installations of buildings

- To verify the code compliance of installed sanitary fixtures and appliances
- To assess the storm water drainage designs and installations of buildings.

1.4 Research Questions

1. How adequate is the Ethiopian Plumbing Code when compared to other International Plumbing codes?
2. Are the installed plumbing systems in compliance with the relevant local state and international code?
3. Does the building have adequate and properly sized plumbing fixtures to meet the occupant load and usage requirements?
4. Have water supply system been properly designed and installed as per plumbing code requirements?
5. Are the wastewater drainage systems properly designed and installed based on the applicable code requirements
6. Does the design and installation of the roof and storm water drainage system meet applicable code requirements?

1.5 Significance of the study

The study of plumbing code compliance requirements is significant for public safety, legal compliance, quality assurance, building sustainability, cost reduction, and establishing the standards. It plays a crucial role in ensuring that plumbing systems meet the necessary standards and regulations, ultimately contributing to the overall functionality and safety of buildings.

Chapter Two

2 Literature Review

2.1 Water Supply Distribution Systems

Water supply distribution systems play a pivotal part in delivering clean and safe water to civic communities, ensuring their health and well- being. These systems correspond of colorful factors similar as pipe lines or channels, storage tanks, pumps, faucets, valves and control systems, all working together to distribute water from the source to the consumers or users (SHONE, 2017).

Water supply distribution systems consist of various components that are responsible for effectively delivering treated water to households, businesses, and other public or private entities. Some of the key components include **(Anore, 2020)**.

1. **Water Sources**, These comprise man-made sources like dams and water treatment facilities that gather, clean, and store water in addition to natural sources including rivers, lakes, wells, and subterranean reservoirs.
2. **Treatment Plants**, In order to make raw water safe for human consumption, water treatment plants clean and purify it. Usually, they use procedures like sedimentation, filtration, disinfection, flocculation, coagulation, and occasionally more sophisticated methods like reverse osmosis.
3. **Transmission Lines**, after being treated, water is sent via a vast network of transmission lines, which are mainly large-diameter pipes composed of steel, ductile iron, or concrete. Water is transported via these lines from treatment facilities to distribution terminals or distribution reservoirs.
4. **Distribution Reservoirs**, The treated water in these enormous storage tanks is kept close to the distribution region. They assist in keeping the distribution system's pressure at an appropriate level and provide a consistent supply of water during times of high demand.

5. **Pumping Stations**, Pumping stations are used to overcome changes in geographic elevation, increase the water pressure in the distribution system, and provide continuous water flow. Pumps that run on electricity or gasoline are frequently used to transfer water through pipes.
6. **Distribution Mains**, The main pipes for distributing water carry water from the distribution reservoir or pumping station to smaller distribution networks. Typically, these pipes are made of materials such as cast iron, UPVC, or HDPE and are laid underground to safeguard them from damage and preserve water quality.
7. **Distribution Networks**, The distribution networks are comprised of intricate arrangements of smaller pipes that extend from the main distribution system to deliver water to individual properties, homes, buildings and structures. Typically, they are equipped with valves, hydrants, and control mechanisms to manage the flow and pressure of water.
8. **Service Lines**, Individual properties are connected to the distribution network by service lines. Water is delivered to residential, commercial, or industrial buildings through these smaller pipes, which are typically constructed from copper or plastic.
9. **Water Meters**, Individual properties have water meters installed to measure and track water usage, aiding in billing and water conservation initiatives.
10. **Hydrants and Valves**, Hydrants, which are equipped with valves, can be found along the distribution network for the purpose of firefighting. The valves are utilized for regulating and managing water flow and pressure within the system, enabling maintenance and repairs.

For customers to receive a dependable and secure water supply, these parts must be properly designed, maintained, and inspected on a regular basis.

2.2 System Components

Pipe sections or links are the most abundant elements in the network. These may contain fittings and other appurtenances, such as valves, storage facilities, and pumps

(BHADBHADE, 2004).Pipes come in a variety of sizes and are made of a variety of materials, including fiberglass, asbestos cement, polyvinyl chloride, and fiberglass, reinforced or pre-stressed concrete, and cast or ductile iron. The World Water Works Association releases performance, installation, and construction standards for pipes. The largest capital expenditure in a distribution system is made up of pipes. To guarantee that customers receive a dependable and secure water supply, these components must be designed, maintained, and inspected on a regular basis.

Water distribution systems' flow and pressure are managed through control valves. The valve will close and no flow will pass if the circumstances are met for flow reversal. The most popular kind of control valve is the pressure-reducing (also known as pressure-regulating) valve (PRV), which lowers pressure by being positioned at the boundaries of pressure zones. For all flows with a pressure lower than the upstream head, the PRV keeps the pressure at the downstream side of the valve constant. The PRV allows flow from the high-pressure system when connecting low-pressure and high-pressure water distribution systems as long as the low-side pressure is not too high.

A number of additional kinds of valves exist as well, such as isolation valves, which are used to stop a section of a distribution system; direction-control (check) valves, which accept water flow in only one direction and include swing, rubber-flapper, slanting check disk, and double-door check valves; and air-release/vacuum-breaker valves, which regulate flow in the main.

Distribution-system storage is required to maintain an effective operating point for the pump discharge despite fluctuating demands, to maintain supply in the event that individual components fail, and to supply water for fighting fires. In a water distribution network, the water tank and distribution storage are closely related. Steel is the most common material for tanks, which can be constructed at ground level or elevated above it. When pumps are unable to sufficiently meet the pressure requirements at the demand nodes, either in an emergency or during periods of high system demand, the water tank is utilized to supply water to meet requirements.

A water distribution system's energy can be increased by using pumps. Positive-displacement pumps, kinetic pumps, turbine pumps, centrifugal pumps, vertical pumps, and horizontal pumps are a few of the numerous varieties of pumps. Centrifugal pumps are the most widely utilized kind of pumps in water distribution systems. Numerous of metering devices are used in the metering (flow measurement) of water mains, these consist of displacement meters, multi-jet meters, compound meters, propeller or turbine meters, electromagnetic meters, and ultrasonic meters. A magnetic field created around an insulated pipe segment is used by electromagnetic meters to measure flow. Ultrasonic meters make use of transducers, which are sound-generating and sound-receiving sensors that are fastened to the pipe's sidewalls. The water flow in turbine meters rotates a measuring chamber. A multiplied rotor situated on a vertical spindle inside a cylindrical measuring chamber is the feature of multi-jet meters. By using a restriction in the water line, proportional meters can direct a portion of the flow into a loop that houses a displacement meter or turbine, with the amount of water diverted being proportionate to the flow in the main line. Compound meters join various sized meters together in parallel.

2.3 water supply system design of a building

Design of water supply system of a building involves several critical steps to ensure the efficiency and its reliability (B.CPunmia, 1995). The assessment of water demand by calculating the peak usage based on the number of occupants and the fixture units of a building using per capital demand calculation and storage requirmentes of fixture units (MuhammedAnisH.AL-Layala, 2007).

A. Domestic water demand

Domestic water demand is the amount of water needed of customer's for daily activity which includes Drinking, Food preparation (cooking), Washing, Cleaning, Bathing and other miscellaneous domestic purpose. The amount of water used for domestic purpose is generally depends on the life style, living standard, climatic condition of the services and affordability of the users. The main purpose of each of the housing development projects are for Residential purposes with exceptions of shops and other commercial purposes. Therefor we can conclude that the majority of water demand in any housing is domestic demand.

The total domestic average water requirement for each housing development projects according to Addis Ababa Water and Sewerage Authority (AAWSA) target average per capital water consumption is 110 L/cap/day.

Per capital demand

Q = C*P

Where

Q is Average demand in l/day

C is per capital demand in l/cap/day

P is total number of populations

B. Non-Domestic Water Demand

The non-domestic water demand consists of school, shops; health centers community centers market places and the like. If the building consists thus institution the non-domestic demand is estimated as 20% of domestic demands.

C. Fire Fighting Demand

Choosing the water supply demand for firefighting by the water supply service due to very difficult in developing country due to economical consideration. The annual volume required of water by the firefighting is small. Though during the period of fire happening in a building the demand requirements may extremely large and in many situations the design of distribution, storage and pump requirements. This demand is taken by increasing the volume of storage tank of a building by 10%.

Firefighting demand =0.1 * the total storage

D. Non-Revenue Water demand

The non -revenue water demand is the water losses due to illegal connections, over flow in the reservoir (storage) and improper metering. The amount of non-revenue water demands during a design of water demand requirement's in a building is estimated as the percentage of the domestic water demand. The water loss in a building mainly depends on age of pipe, condition of existing pipe networks and complexity of the system.

Water loses in a system is minimum at the beginning of the design and installation and it increase gradually with time in expected service life of the distribution system in a building.so that Addis Ababa water distribution network project estimated as on average non-revenue water loss is 15% of the total domestic demands in a building.

Non-revenue water demand = 0.15*total domestic demand

2.4 waste water drainage system of a building.

Wastewater drainage is a crucial aspect of building design and infrastructure, as it involves the safe and efficient removal of used water from various sources within a building((NELSON L. NEMEROW, 2009).

This includes water from sinks, toilets, showers, baths, and other sanitary fixtures. The background of wastewater drainage in a building can be traced back to ancient civilizations. However, widespread implementation of comprehensive wastewater drainage systems did not occur until much later in history. Modern wastewater drainage systems are designed to ensure the proper disposal and treatment of wastewater to safeguard public health and the environment.

The component of drainage structures are

A .Drainage System, Buildings and structures are generally have a network of drain pipes or rain spouts, frequently made of durable materials such as PVC or cast iron, which collect wastewater from different sources and carry it down. These pipes are generally installed beneath the structure or building, connecting to the municipal sewer system or an on-site (on-point) septic tank.

B. Ventilation: Acceptable ventilation is essential to maintain a proper inflow of wastewater within the drainage system. Vent pipes, generally extending above the roofline, allow for the release of sewer gases, precluding the buildup of pressure and foul odors.

C. Traps and Siphons, Helps to prevent sewer feasts from entering living or workspaces, traps are installed in drain lines. These are twisted sections of the pipe that retain enough water to produce a hedge between the inside of the structure and the sewer system. Siphons are also integrated into the system to insure a constant inflow of wastewater. This system helps to prevent the backflow of odors, feasts, and sewage.

D. Grease Interceptors and Sand Traps, in marketable structures similar as cafés, grease interceptors are installed to trap greases and oils from kitchen sink wastewater drainage system, precluding them from congesting or clogging the drainage pipe system. Also, beach or sand traps are used to capture beach, clay, and other deposition from wastewater to avoid blockages.

E. Backflow Prevention, to help wastewater from flowing back into the structure in the event of a blockage or flooding in the main sewer line, backflow prevention bias may be installed. These bias or devices insure one- way inflow by blocking the reveres movement or flow of wastewater drainage systems.

F. Maintenance and Inspections, Regular Conservation or maintenance and inspections of the wastewater drainage system are necessary to identify and address implicit issues, similar as leaks, blockages, or degraded factors.

This helps maintain the system's efficiency and prevents costly repairs. Building codes and regulations dictate the requirements and standards for wastewater drainage systems, ensuring they meet the necessary safety and environmental standards. Plumbing professionals, such as engineers and licensed plumbers, are involved in the design, installation, and maintenance of these systems to ensure their proper functioning.

In recent years, there has been a growing interest in sustainable wastewater management practices. Some buildings incorporate water conservation measures, such as rainwater harvesting and gray water recycling systems, which recycle and reuse wastewater for non-potable purposes, reducing strain on both freshwater supplies and drainage systems.

2.5 waste water drainage system design of a building

To ensure efficient and effective removal of waste water drainage system the proper design and installation should involve in considerations. The outlines of the process for waste water drainage system designs are understanding the local plumbing codes ,standards and regulations, identifying all sources of waste water in the building including (Toilets, Sinks, Showers and bath tubs, Dish washers and washing machines, Hand wash basins and floor drains),estimate the flow rates for each fixture units based on plumbing codes expressed in gallon per minute or liters per second considering peak usage times to ensure the system can handle maximum flow, design horizontal pipes to carry waste water from fixtures to the main drain with in proper relevant slope, the vertical pipe size to carry the waste water and dispose from the higher floor level to the required disposal points, proper design of vent pipe sizes with in the total fixture loading units (Joanne, 1976). A well-designed and properly maintained wastewater drainage system is essential for the safe and efficient removal of wastewater, contributing to the overall hygiene, health, and functionality of a building.

2.6 Roof storm water drainage system design

The design of a roof storm water drainage system involves several key steps to ensure effective management of rain water run-off (w.Mays, 2005).

1. Assessment of roof area, calculating the roof area of a building measures the total area of the roof that can contribute the storm water run-off by identifying weather the roof is flat, sloped or has multiple levels which affects drainage design.
2. Rain fall data collection, local rain fall intensity, gathering historical rain fall for the area including average rainfall rates and peak intensity during storms. Design storms by selecting design storm event (10-years, 25-years or 100 –year storm with in the expected rain fall duration time in minutes) based on local regulations and risk management practices.

3. Determining run off, determination of the run-off coefficient based on the roof materials and the levels of roof. Using rational method or other hydrological methods to calculate the expected run-of

$$Q = \frac{CIA}{60x60x1000}$$

Where

Q = Rainfall flow or runoff in m^3/s

A= Area of roof in m^2

C= Impermeability factor constant

I= Intensity of rainfall mm/hour

2.7 Building plumbing system components

Designing and building a plumbing system involves various components to ensure proper water supply, drainage, and waste removal. Here are some essential components of plumbing system components (prabhatak.Swamee, 2008)

Pipes

Water Supply Pipes: Common materials include copper, PEX (cross-linked polyethylene), PVC (polyvinyl chloride), and CPVC (chlorinated polyvinyl chloride).

- Drainage Pipes: Materials may include PVC, or cast iron.

Fittings

- Elbows, Tees, and Couplings: Connect pipes at various angles and junctions.
- Reducers: Change pipe size to accommodate different flow rates.
- Adapters: Connect different types of pipes.
- Valves: Control the flow of water, including ball valves, gate valves, and check valves.

Fixtures:

- Sinks, Faucets, and Bathtubs: Provide points of use for water.
- Toilets and Bidets: Collect and remove waste.
- Showers: Combine hot and cold water for bathing.

Water Heater

- Thankless (instant boiler) or Storage Tank: Heats water for domestic use.

Traps:

- P-traps and S-traps: Prevent sewer gases from entering the building while allowing water to drain.

Ventilation System

- Vent Pipes: Allow air to enter the plumbing system, preventing vacuum and ensuring proper drainage.

Backflow Prevention Devices

- Backflow preventers: Ensure that water flows in one direction to prevent contamination of the water supply check valve

Pumps:

- Sump Pumps: Remove water from basements or lower levels.
- Booster Pumps: Increase water pressure.

Water Meters:

- Measure and Monitor: Record water consumption for billing purposes.

Shut-off Valves:

- Isolation Valves: Enable the shut-off of water to specific areas or fixtures for maintenance or repairs.

Pressure Regulators:

- Maintain Consistent Pressure: Ensure water pressure within a safe range to prevent damage to the plumbing system.

. **Insulation:**

- Pipe Insulation: Protect pipes from freezing in colder climates.

Pipe Hangers and Supports:

- Secure Pipes: Prevent sagging and ensure proper alignment.

Pipe Sealants and Tapes:

- Thread Sealant and Teflon Tape: Seal pipe joints to prevent leaks.

Plumbing Tools:

- Wrenches, Pipe Cutters, and bender, rimers. Essential tools for installation and maintenance.

When designing and installing a plumbing system, it's crucial to adhere to local building codes and regulations. Professional guidance and assistance may be necessary, especially for complex systems or larger projects.

2.8 Importance of plumbing code compliance

Plumbing code compliance is crucial for several reasons, as it ensures the safety, health, and well-being of individuals, as well as the proper functioning of buildings and infrastructure. Here are some key reasons of the importance of plumbing code compliance:

1. **Health and Safety**. Plumbing codes are intended, designed to safeguard the public's health by guaranteeing the cleanliness and safety of water supply systems. Adherence to plumbing codes serves as a preventive measure against the introduction of hazardous substances, chemicals, or other contaminants into potable water. The risk of waterborne illnesses is also decreased by properly built plumbing systems.
2. **Prevention of Water Damage**. Plumbing code compliance aids in preventing building from damage and water leaks. Leaks, which can result in structural damage, the growth of mold, and other problems, are less likely to occur in plumbing systems that are installed correctly using the right materials and techniques.
3. **Environmental Protection**. Regulations to reduce the environmental effect of plumbing systems are frequently included in plumbing codes. This can involve taking

precautions to avoid dangerous materials seeping into the water supply and disposing of wastewater properly.

4. **Energy Efficiency**. Plumbing codes may include requirements for water heaters, plumbing insulation, or other components to improve energy efficiency and reduce environmental impact. These are just a few examples of the provisions that codes may include to encourage the use of energy-efficient plumbing systems.

5. **Consistency and Standardization**. In order to prevent poor workmanship and guarantee that plumbing systems are installed in a standardized and safe manner, plumbing codes offer a set of standards and guidelines that help ensure consistency in construction practices.

6. **Building Inspections and Permits**. A building's ability to be used safely and habitably is ensured by building inspections, which confirm that plumbing installations comply with code requirements. Getting a building permit frequently requires compliance with plumbing codes.

7. **Liability Reduction**. If a plumbing system fails as a result of non-compliance with plumbing codes, property owners, contractors, or plumbers may be subject to fines, lawsuits, or the need to make the necessary corrections. Non-compliance with plumbing codes can also result in financial liabilities.

8. **Insurance Requirements**: Building code compliance may be a requirement set by insurance companies for coverage; noncompliance may result in claims being rejected or in higher insurance costs.

9. **Resale Value**. Plumbing systems that comply with building codes enhance the overall quality and safety of a property. Adherence to building codes can have a positive effect on the resale value of a property when it is being bought or sold.

2.9 System Operation

The most fundamental decision that must be made in the operation of water distribution systems is which pumps should be operated at any given time ((Mays, 2000).

The three competing goals for water distribution system operations are:

1. Maximize reliability, which is achieved by keeping the maximum amount of water in storage in case of emergencies, such as pipe breaks and fires.
2. Minimize energy costs, which is achieved by operating pumps against as low a head as possible (minimize water in storage) near the best efficiency point for the pump.
3. Meet water-quality standards, which involve minimizing the time the water is in the distribution system and storage tanks and is achieved by having storage-tank levels fluctuate as much as possible.

Chapter Three

3. Material and methodology

3.1 Description of the Study Area

Addis Ababa is located between 972000N to 1000500N and 462000E to 488000E UTM coordinates. It is situated in central highland of Ethiopia surrounded by the Blue Nile catchments in the north and the Wachacha Mountain which forms separation belt of the city from the Awash River catchments in the west (AdaneBekele, 1999). Fig. 3-1 shows the location of Addis Ababa with respect to the map of Ethiopia. The city descends from Entoto ridge which is at an altitude of 2,975m a.s.l. at Entoto to Akaki area to an elevation of about 2,050m a.s.l around Kality. Addis Ababa has subtropical highland climate. According to National Meteorological Agency of Ethiopia, Mean minimum temperature varies from 7°C to 11°C and mean maximum varies from 21°C to 25°C. From June to mid-September is main rainy season for city of Addis Ababa. Mid-November to January is a season for occasional rain. Based on the last population and housing census report of 2007, which was prepared by Ethiopian Central Statistical Agency (CSA) in December 2008, the population of Addis Ababa was estimated to be 2,739,551 in May 2007. The population of Addis Ababa is also estimated to be growing at 3.26% rate ((mola, 2018).

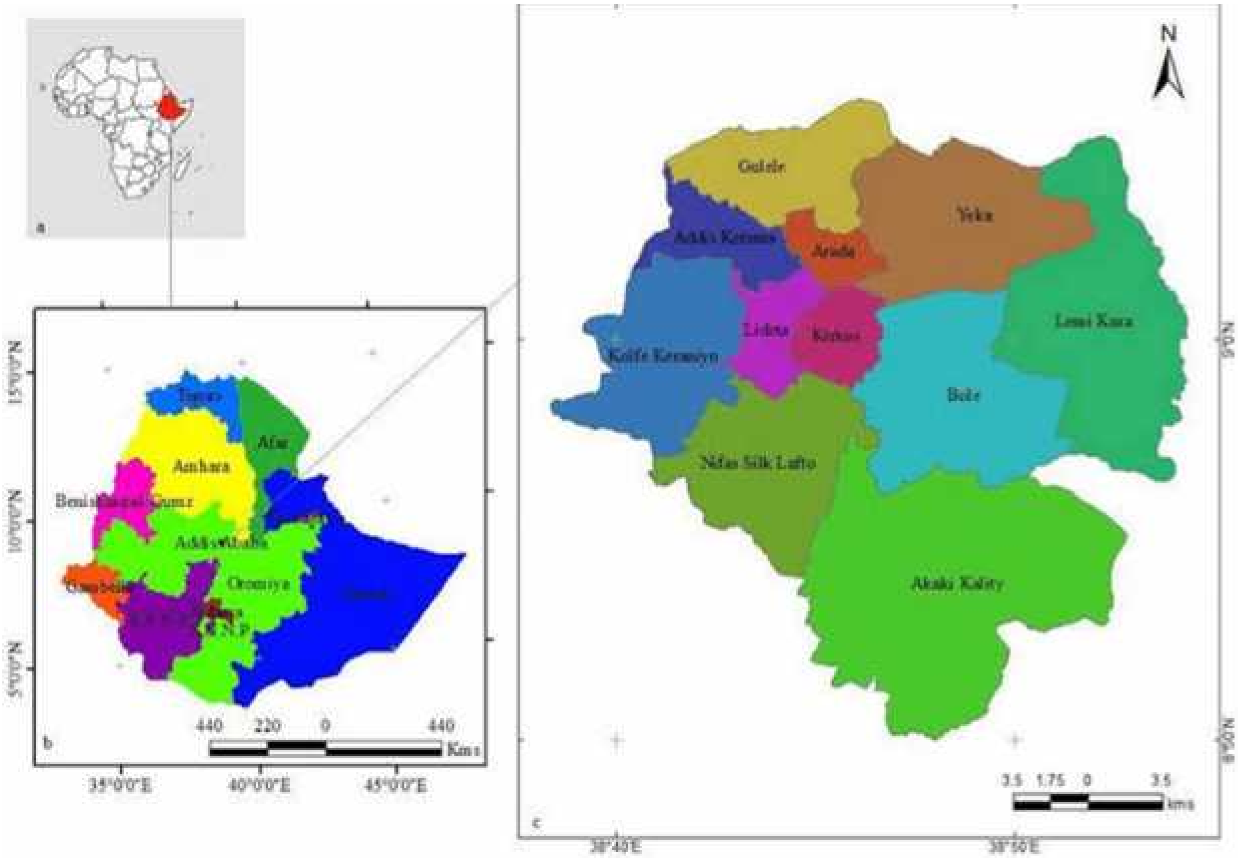


Figure 1Addis Ababa city Map

3.1 A Mickey apartments and real estate (building A)

This building is located in the capital city of Addis Ababa, bole –sub city, woreda 03 and is being built and constructed by the private company and constructed on the 450 square meter area. The building has a total of 1basmentand 9th floor level including the ground level. The basement is serviced for setting of ground reservoir, septic tank and car parking to the building customers. all other remaining floors are to be used for living the ground floor has service for 1 house hold of two bed rooms, from 1st -4thfloor has serviced for 3 house hold of each has one bed rooms, 5th – 6th floor gives service for 2 households having two bed rooms of each and the last two floors 7th and 8th floor have 1 house hold but three bed rooms for each .the roof top center of a building have constructed wall to carry the elevated tanker.

The building has the access of plumbing systems and electric system .in the plumbing system the water supply lines are installed by PEX-AL-PEX composite pipe material whereas the internal waste water drainage and roof waste water drainages are installed by PVC pipe.in general the building gives services for above 105 people.

The water is lifted by pump from the ground reservoir to roof reservoir the pipe size of water supply system of pumping is 11/2 inch (40 mm) which is supplied by PPR pipe.

The water is distributed to the customers' from elevated tanker to each bed rooms by PEX-AL-PEX pipe materials by using the riser pipe installations of reducing the pipe sizes from the elevated tanker to all the fixtures. The pipe diameter of the out let of the tanker is 21/2 inch(63mm) which supply's the water to the 1st floor risers and in each floor it connects by reducer to supply water to each floors and it reduces to 2 inch (50mm) diameter pipes and this pipe supply to another diameter of the feed water in to each hose hold of the floors by connecting the reducer of 11/4 inch (33mm) diameter pipes to supply water up to water meter after water meter of each floor the pipe is reduced to1 inch (25mm) diameter pipes of PEX-AL-PEX pipes and these pipe is installed up to the manifold .

The manifold is used to distribute the coming of water from the tanker risers to all the fixture units.

All the fixture units have get water by using manifolds having the pipe diameter of ½ inch (15mm) of PEX-AL-PEX of five layer composite pipe lines. The manifold has its own controller valve in nature which is fabricated as one in two branches and one in three branches.

Data collected

The Primary data was collected from the site to analyses all the plumbing systems of the building.

Table 1 collected data for building A

No	Number Floor	Number House hold	Number bed	Number WC	Number HWB	Number Shower	Number Kitchen	Number bathtub	Number laundry
1	Ground	1	2	3	3	2	1		1
2	1st floor	3	6	6	6	3	3	----	3
3	2nd floor	3	6	6	6	3	3	----	3
4	3rd floor	3	6	6	6	3	3	----	3
5	4th floor	3	6	6	6	3	3	----	3
6	5th floor	2	4	6	6	4	2	----	2
7	6th floor	2	4	6	6	4	2	----	2
8	7th floor	1	3	4	4	4	2	1	1
9	8th floor	1	3	4	4	4	2	1	1

3.1. B AAU main campus (building B)

The building is governmental building which is located in Addis Ababa city,Gulele sub-city ,Wereda 02 ,Addis Ababa university main campus near to the main road of shiro-meda it is being built and constructed by Etete construction level 1 contractors. The building has 2 basement and 16 floors including the ground level and which is built to give service for the university staff offices. The infrastructures of plumbing systems and electric systems are installed and they are in functionality. From 1st -15th floors there are 7 offices and 2 bathrooms which are named as male bath rooms and female bath room. The male bath room has sanitary appliances of one water closet, one hand wash basin, one urinal for normal customers and one water closet.one hand wash basin for disabled users. Similarly the female bath room has the sanitary appliances like male bath rooms and in all floor common double hand washbasin is installed.in addition to this sanitary appliance the 10 floors from 6th floor up to 15th floor the kitchen sink and 50 litter water heaters are installed.

The water supply systems are installed by ppr materials and the fire hydrant hose water supply lines are installed by Gs material whereas the internal waste water drainage systems of a fixtures and roof storm waste water drainage down pipe are installed by UPVC materials.

Roof tanker receives water from ground tanker using pump the diameter of water supply line from ground reservoir to the roof reservoir is 11/2 inch (40mm) diameter of PPR lines all water supply installation of a building is installed by PPR lines. The water distributes from the roof tanker to the fixtures. The diameter of the pipe lines which feeds the fixture from the tanker is 21/2 inch (63mm) of pipe sizes of a riser this line is connected by reducer sockets(joints) to reduce the water supply line in to 11/4 inch (32mm) diameter of PPR pipes .

All fixtures can receive water in each floor by reducing of 1 inch water supply line into ¾ inch of PPR lines and all of the fixture supply water in the diameter of 3/4inch (20mm) diameter pipe lines by connecting in each fixture points by tee line up to the end and the end fixture only connected by elbow at the final.

The entire purpose of the building is to give office services for the staff mainly the university president offices and large meeting hall.

Data collected

The Primary data was collected from the site to analyses all the plumbing systems of the building.

Table 2 collected data for building B

Item Num ber	Number Floor	Numb er office	Numb er WC	Number HWB	Numb er kitche n	Numbe r floor drain	urina l	Numbe r fixtures
2	1st floor	7	4	6	----	4	1	11
3	2ndfloor	7	4	6	----	4	1	11
4	3rd floor	7	4	6	----	4	1	11

5	4th floor	7	4	6	----	4	1	11
6	5th floor	7	4	6	----	4	1	11
7	6th floor	7	4	6	1	5	1	13
8	7th floor	7	4	6	1	5	1	13
9	8th floor	7	4	6	1	5	1	13
10	9th floor	7	4	6	1	5	1	13
11	10th floor	7	4	6	1	5	1	13
12	11th floor	7	4	6	1	5	1	13
13	12th floor	7	4	6	1	5	1	13
14	13th floor	7	4	6	1	5	1	13
15	14th floor	7	4	6	1	5	1	13
16	15th floor	7	4	6	1	5	1	13

3.1.C Hayat 49 condominium block 34 (building C)

This building is located in the capital city of Addis Ababa, lemi-kura –sub city, woreda 02 and is being built and constructed by the Addis Ababa housing corporation and constructed on the 800 square meter area which is twins building. The building has a total of 1basment and 13th floor level including the ground level. The basement is serviced for setting of ground reservoir and car parking to the building customers. Ground floor, 1stfloor and 2nd floor are used for renting of shop having five shop per floor and all other remaining floors are to be used for living the floor has service for the total of 5 house hold of which the one house hold have two bed rooms but the other 4 households has serviced for one bed rooms.

The building has the access of plumbing systems and electric system .in the plumbing system the water supply lines are installed by PPR pipe material whereas the internal waste water drainage and roof waste water drainages are installed by UPVC pipe.in general the building gives services for above 700 people.

Number	House	Number of bed	shop	WC	HWB	Sh	Ks	FD

floor	Hold	rooms								
		1 BR	2 BR	3 BR						
Ground	-	-	-	-	5	-	-	-	-	-
1st	-	-	-	-	5	-	-	-	-	-
2nd	-	-	-	-	5	-	-	-	-	-
3rd	5	2	2	1	-	6	6	6	5	3
4th	5	2	2	1	-	6	6	6	5	3
5th	5	2	2	1	-	6	6	6	5	3
6th	5	2	2	1	-	6	6	6	5	3
7th	5	2	2	1	-	6	6	6	5	3
8th	5	2	2	1	-	6	6	6	5	3
9th	5	2	2	1	-	6	6	6	5	3
10th	5	2	2	1	-	6	6	6	5	3
11th	5	2	2	1	-	6	6	6	5	3
12th	5	2	2	1	-	6	6	6	5	3
13th	5	2	2		-	6	6	6	5	3

3.1.1 Data collection

Primary data was collected from each site of the building.

The parameters of analysis includes the storage capacity of ground reservoir and elevated tank, pump head, water supply pipe diameter of a building, pipe size for internal waste water drainage, slope of horizontal pipe size for internal waste water drainage, vertical pipe size requirements of internal waste water drainage, vent pipe size requirements of internal waste water drainage, design and installation of septic tank of a building and roof storm waste water drainage pipe size requirements.

Field measurements and collected data

a. Volume capacity storage of each building

b. All sanitary appliances

c. Water supply pipe size diameter

d. Waste water drainage pipe size

e. Size of septic tank

f. Roof area of a building

Water supply and roof storm water data collection from field of each building

3.2 Method of analysis

3.2. A. The local plumbing code as compared to other international plumbing code

The parameters which are used to compare the local plumbing code of Ethiopia with other international plumbing codes of buildings are.

- The detailed specification and requirements of new technology plumbing pipe materials like PEX-AL-PEX material.
- The detailed specification and requirements of water supply pipe size.
- Waste water drainage system of kitchen sink.
- Vent pipe requirements of internal waste water drainage system of a building.

3.2.1 Water supply distribution of a building

3.2.1.1 Storage capacity of tank

General guidelines for calculation of the minimum recommended capacity of storage tanks is (EBCS-9 , augest 2013)

a. In case only elevated water tank is provided, it will be taken as 33 to 50 percent of one day's requirement;

b. In case only underground water tanks is provided, it may be taken as 50 to150 percent of one day's requirement; and

c. In case combined storage is provided, it may be taken as 67 percent underground tank and 33 percent elevated water tank of one day's requirement.

Filling time for roof tank is taken as

a. 2 to 3 hours for small tanker of storage capacity less than 5000liter

b. 3 to 6 hour for big tankers of storage capacity greater than or equal to 5000liters

The storage capacity of tank is designed satisfy the demand requirements per capital demand according to AWWSA manual is 110l/c/day and the cold water storage for one day storage based on sanitary appliance is given by the following table (C.R.Mohan, Design of septic tank, 2008)

Table 3 storage capacity of sanitary appliance

Description	Storage capacity lit/day
Water closet	180
Sink	200
Wash basin	180
Shower	200
Urinal	200

3.2.1.2 Design of pump head in a building

Whenever water is pumped through out a pipe friction of pipe and acceleration due to gravity are acting against the direction of flow so additional force is required to against this factor (C.R.Mohan, pump set and pump main, 2003).

Power of pump = discharge x acceleration due to gravity x total head / efficiency

1 horse power = 0.746 kilowatts

Acceleration due to gravity = 9.81m/s^2

Efficiency of pump = 65%

As Hazen Williams equation head loss due to friction,

H_f1000m= 0.029049*$Q_k^{1.851851}$ ……………………………….Equation 1

Where, H_f is friction loss in meter

$Q_k$is discharge in kilo litter/day

Pump set head = (H_1+H_2+H_3+H_4+H_5),

Where,

H_1 =pipe friction loss in m

H_2 = loss in fitting and valves 0.5m per each fitting

H_3 = total height in m to where water is lifted

H_4 = discharge head (2m)

H_5 = pump loss (2m)

According to the plumbers chart for international plumbing code, head loss due to fitting given as the table

Item number	Name of fitting	Unit Rate of loss m
1	Gate valve	0.5
2	Check valve	0.5
3	Union	1.5
4	Adapter	0.5
5	Socket	0.5
6	Elbow	0.5

3.2.1.3 Design and installation of water supply pipe size

a. Plumber's chart

Plumbers chart is used to assess the approximate estimation of size of water supply pipes in a building.

If sufficient capacity of water is stored in roof tank .the chart can safely use for single and double story buildings ((C.R.Mohan, Design and practical hand book on plumbing, 2008).

Table 4 fixture unit and pipe size based on plumber's chart

		Number of fixtures						
	Sanitary fixtures	1	2	4	8	12	16	≥24
		Pipe size diameter in mm						
No								
1	Water closets	15	20	25	32	40	40	50
2	Urinals	15	20	25	32	32	32	40
3	Wash basin	15	15	20	25	25	32	32
4	Bath tab	20	25	32	40	50	50	65
5	Shower	15	20	32	40	50	50	65
6	Sink	20	25	32	40	40	50	50
7	Washing machine	15	20	25	32	32	32	40

b. box formula

The box formula is used to determine the equivalent pipe size of water supply distribution lines ((Mohan, equivalent pipe size for water upply lines, 2003).

$N=\sqrt{\left(\frac{D}{d}\right)}^{\wedge}\mathbf{5}$……………………………………….Equation 2

Where N is number of branch pipes in short length

D diameter of main pipes in mm

d diameter of branched pipe in mm

Based on this box formula method there are the possible recommended pipe diameters of branched in shorter length of smaller diameter pipe lines.

Table 5equivalent pipe size based on box formula

Size of pipe in mm	15	20	25	32	40	50	≥ 60
No of equivalent 15mm pipe size	1	1.8	3.7	5.9	12	23	42

c. Flow rate and loading unit

Probability equation of loading rate of fixtures and flow rate

$Q = 0.25\sqrt{(\mathbf{Z1} + \mathbf{Z2} + \mathbf{Z3} + \cdots + \mathbf{Zn})}$… …………………....Equation3

Where

Q is flow rate in liter per second

Z1, Z2, Z3…Zn = Z value * number of sanitary appliance (Mohan, water pipe size in building, 2003).

Table 6 loading unit and sanitary appliance

S .no	Sanitary appliance	Loading unit (Z)
1	Hand wash basin	0.5
2	Urinal	0.5
3	Shower	1
4	Bath tub	1.96
5	WC flash	4.32
6	Sink	1
7	Laundry	1

3.2.2 Internal waste water drainage system of a building

3.2.2.1 Loading unit of sanitary appliance for waste water drainage

The waste water drainage system of a building is installed to meet the loading rate of all sanitary appliances and minimum discharge pipe requirement's (construction m. o., Ethiopian Building Code standard plumbing service of buildings, 2013).

Table 7 trap of sanitary appliance and loading rate

Fixtures	Discharge pipe diameter mm	Fixture loading rate
Hand wash basin	50	1
Water closet	100	8
Sink	75	1-3
Bath	50	3
Shower	40/50	2
Floor drain	65	1
Urinal	50	4
Laundry	65	2

3.2.2.2 Horizontal pipe size and slope requirements of waste water drainage

a. slope and horizontal pipe size

Horizontal drainage piping is installed in uniform alignment at uniform slopes. The minimum slope of a horizontal drainage pipe is given in the table below ((construction m. o., slope of horizontal drainage pipe, 2013).

Table 8 horizontal pipe size and slope

Horizontal Pipe size inch	Slope inch/foot
≤ 2 ½	¼

3 to 7	1/8
≥ 8	1/16

3.2.2.3 Design and installation of vertical pipe size and horizontal branch for internal waste water drainage system

Table 9 vertical drain and horizontal brunch pipe size

Diameter of Pipe (Inches)	Maximum Number of Drainage Fixture Units(dfu)			
	Total for horizontal branch	Total discharge into one branch interval	Total for stack of three branch intervals or less	Total for stack greater than three branch intervals
1 ½	3	2	4	8
2	6	6	10	24
2 ½	12	9	20	42
3	20	20	48	72
4	160	90	240	500
5	360	200	540	1100
6	620	350	960	1900
8	1400	600	2,200	3600
10	2500	1000	3,800	5600
12	2900	1500	6000	8400
15	7000	Note c	Note c	Note c

For SI: 1 inch = 25.4 mm

a. Does not include branches of the building drain. Refer to Table 5.25
b. Stacks shall be sized based on the total accumulated connected load at each story or branch interval. As the total accumulated connected load decreases, stacks are permitted to be reduced in size. Stack diameters shall not be reduced to less than one –half of the diameters of the largest stack size required.

3.2.2.4 Design and installation of vent pipe for internal waste water drainage system

A. common vent (construction M. o., 2013)

Table 10 common vent pipe size

Maximum discharge of fixture drain	Pipe size inch
1	1 ½
4	2
≥ 6	2 ½ to 3

b. combined vent (council, 2009)

Table 11 combination vent pipe size

Connecting to a building drain	Connecting to stack	Pipe diameter inch
4	3	2
26	6	2 ½
31	12	3
50	20	4
250	160	5
≥ 575	≥ 360	6

3.2.3 External waste water drainage systems of a building

3.2.3.1 Design and installation of septic tank

Disposing domestic sewage of a building is by septic tank.

The recommended distance of septic tank in any drinking water source should have a spacing of up to 20m.

The ground water table is minimum of 2m below the bottom of soak away pit to prevent direct contamination of ground water table.

The detention time of aseptic tank is in between 1day to 3 days.

De-slugging of septic tank is 2 -5 years.

Septic tank is constructed either R.C.C or brick.

- ✓ The length greater than 4m two chambers are used if less than 4m single chamber is provided.
- ✓ The 1st chamber is the inlet chamber which covers 2/3 the length of the septic tank.
- ✓ The 2nd camper of aseptic tank is 1/3 of the length of septic tank .in the inlet chamber baffle wall is provided at distance of 1/5 length to prevent the entry of foams in to the sedimentation zone. Free board of 30cm up to 50 cm is provided. The floor is sloped 2.5 % towards the manhole opening to facilitate de-slugging wastes.
- ✓ 50 mm diameter pipe of an air vent is provided for escape of gases and the height should be minimums of 2.5 m to avoid smell noises.
- ✓ The out let of septic tank is minimums of 5 cm up to 7 cm below the inlet to avoid the flooding of inlet.

3.2.3.2 Design of septic tank

Septic tank is designed by using rate of flow method of using loading units and flow rate

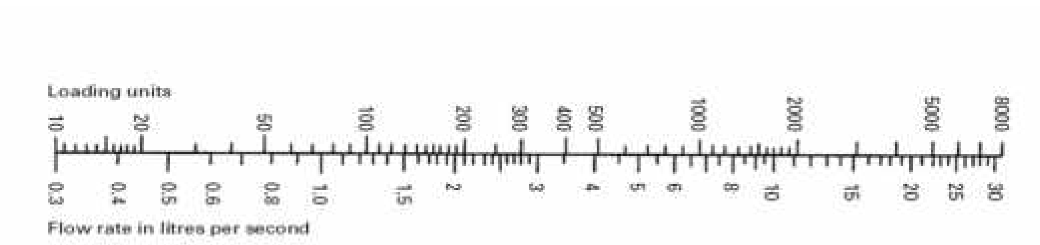


Figure 2 loading unit rate and fixture units

From this chart read the flow rate using the total loading units of a building and convert the flow rate in to surface area coverage of septic tank by using the conversion factors of areal rate (C.R.Mohan, Design of septic tank, 2008)

10 Lpm covers 0.92 m^2 of surface area.

Total capacity of septic tank = Volume sediments + Volume of sludge

Volume of sediment = $\frac{t*p*q}{1000}m^3$ ……………….. ……………….Equation 4

Volume of sludge = $\frac{s*p*d}{1000}m^3$ ………………………………….Equation 5

Where,

t= hydraulic detention time is taken 1- 3 day

p = population served

q = water consumption in liter/capital/day

s = sludge production in liter/cap/day usually 0.15 l/c/d

d = number of days b/n de-sledging is 1-5 year

Effective depth

Effective depth (d) =$\frac{volume}{surface\,area}$ ……………………………Equation 6

3.2.4 Roof storm waste water drainage of a building

3.2.4.1 Design and installation of roof storm water drainage

The intensity of rain fall for a specific duration is to be known for designing the rain fall flow run off of roof storm water drainage. The intensity of rain fall varies according to duration and return period. For short duration and long return period intensity of rain fall is more whereas foe long duration and less return period the intensity of rain fall is low.

For all rain water design purpose the return period and duration is assumed for 2 years and 15 minutes respectively. Some times to avoid flooding of rain water over the roof the return period for design purpose is taken as 10 years. The recommended slope of roof is 1/60 and the flat roof is used for high rise building.

A. design discharge of roof storm water

Based on Ethiopian Building Standard we use 5minute duration and 10 year return period for design of roof storm water drainage pipe lines.

Rational formula (Subramanya, 2008).

$$Q = \frac{CIA}{60x60x1000}$$ ……………………………………………Equation 7

Where

Q = Rainfall flow or runoff in m^3/s

A= Area of roof in m^2

C= Impermeability factor constant

I= Intensity of rainfall mm/hour

Table 12 impermeability factor C

Area of roof	Impermeability factor, C
Paved and flat roof	1
Unpaved and sloped roof	0.75-0.95

Source EBCS-9

B. pipe size determination of roof storm water

The down pipe size of roof storm water is determined by using the roof area coverage and the intensity of rain fall table ((Woodson R. , 2009).

Table 13horizontal projected roof area, down pipe and intensity of rainfall

DIAMETER OF LEADER (inches)[a]	HORIZONTALLY PROJECTED ROOF AREA (square feet)											
	Rainfall rate (inches per hour)											
	1	2	3	4	5	6	7	8	9	10	11	12
2	2,880	1,440	960	720	575	480	410	360	320	290	260	240
3	8,800	4,400	2,930	2,200	1,760	1,470	1,260	1,100	980	880	800	730
4	18,400	9,200	6,130	4,600	3,680	3,070	2,630	2,300	2,045	1,840	1,675	1,530
5	34,600	17,300	11,530	8,650	6,920	5,765	4,945	4,325	3,845	3,460	3,145	2,880
6	54,000	27,000	17,995	13,500	10,800	9,000	7,715	6,750	6,000	5,400	4,910	4,500
8	116,000	58,000	38,660	29,000	23,200	19,315	16,570	14,500	12,890	11,600	10,545	9,600

For SI: 1 inch = 25.4 mm, 1 square foot = 0.0929 m^2.

C. intensity of rain fall

The intensity of rain fall is determined by using the IDF curves based on the return period and the duration of rain fall from the chart below (construction M. o., 2013).

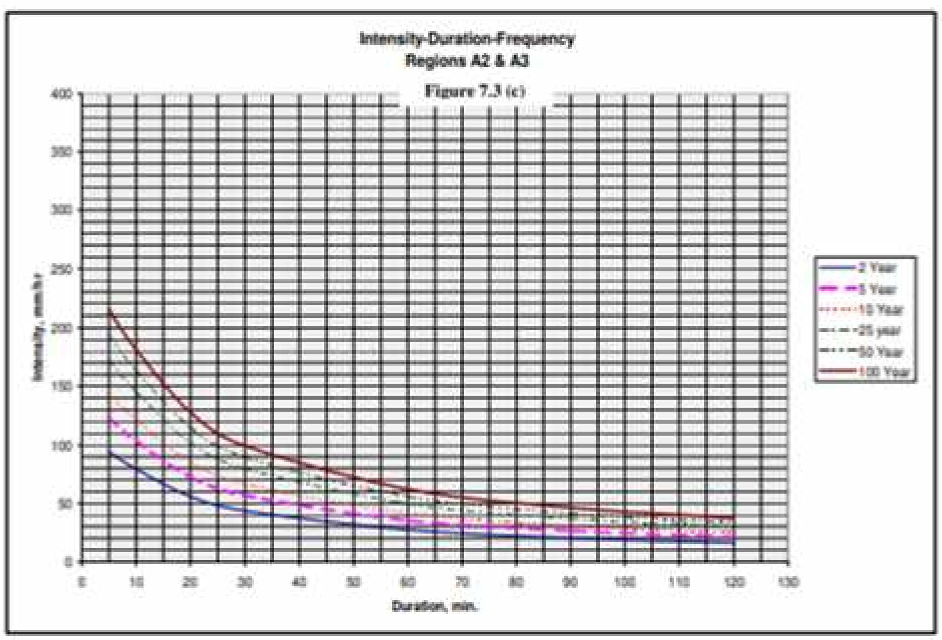


Figure 3 duration and return period

D. capacity of down pipe diameter

Based on Indian international plumbing code the capacity of down pipe in roof storm water drainage is given as the table below.

Table 14 capacity of diameter down pipe

Diameter of down pipe mm	Capacity of discharge in liter/sec
50	0.4
65	0.8
75	1.5
100	2.3

E. Gutter design

For roof rectangular gutter is recommended and the gutter provide in the building is rectangular.

The gutter in a building is design as the out let function is the absence of swirl and vortex.

Using the governing equation of discharge capacity of out let rectangular gutter channel for the absence of swirl (C.R.Mohan, Design of septic tank, 2008).

1. For h/d up to 1/3

$q = \frac{l*\sqrt{h3}}{5000}$ Littre /sec

2. For h/d greater than 1/3

$q = \frac{d2*\sqrt{h}}{15000}$ Littre /sec

D = 2/3d

where,

q = discharge capacity of outlet lit/sec

h = head of water over out let mm

d = diameter of out let mm

D =down pipe diameter mm

Chapter four

4 Result and discussion

4.1 The adequacy of local plumbing code as compared to the international plumbing code of a building.

Both the international and local plumbing codes have been widely used for the design and installation of various aspects of plumbing and sanitary systems such as internal wastewater drainage, water supply system, external wastewater drainage system, storage capacity of water tank, storm water drainage system.

The international plumbing code is a widely recognized and respected code that is used in many countries around the world it is regularly updated to reflect the latest advances in plumbing technology and best practices to ensure the functionality, safety and health of building occupants.

The local plumbing code is specific to a particular jurisdiction and the typically developed and enforced by local government authority. The code is generated based on the international plumbing code or other model codes. They may also include additional requirements that are tailored to the local conditions, climate and topography.

The plumbing code of Ethiopia has deficiencies when compared to the international plumbing code as illustrated by the following.

- It does not include new pipe and fitting materials like PEX
- It does not cover important sanitary fixtures like dishwashing machine, laundry tray, drinking fountain, floor sink, accessible sanitary fixtures, etc.
- It does not specify maximum flow rates and flush volumes of plumbing fixtures to ensure water conservation
- It does not have code on health care plumbing systems
- It does not have provisions for indirect waste piping which is important to prevent contamination of potable water supply. For instance, indirect waste piping is often

required for sinks and equipment that handle food to minimize the risk of cross-contamination.

- It lacks provisos for the design and installation of subsurface drainage system
- It includes a section on solid waste management which is uncommon in many plumbing codes including the international plumbing code

The Ethiopian local plumbing code of building provides detailed design and specification for the wastewater drainage systems by classifying it in to internal and external wastewater drainage system understanding this drainage system of a building can offer several advantages of the readers and its construction worker of plumber and designers. By classifying the wastewater drainage system of a building in to internal and external components the Ethiopian plumbing code provides a clear and structured over view of how the system should be designed and implemented in a building. Understanding the destination between internal and external waste water drainage system of a building can helps in designing an efficient and effective systems that minimize the risk of blockages, leakage, and other related issues leading to improve performance and longitivity of drainage systems in a building. The proper implementation of the waste water drainage system of a building based on the local plumbing code of Ethiopia can contribute to the safety of occupants and the surrounding environment by reducing the potential for health hazards and environmental contamination.

The requirement for detailed information on the storage capacity of both ground reservoir and elevated water tanker in the Ethiopia local plumbing code suggests specific focus on addressing local water supply and distribution issues. This emphasizes on storage capacity may be indicative of challenges or considerations to Ethiopia such as water scarcity, intermittent supply or the need to store water for longer period for the building occupants. By comparing the Ethiopian local plumbing code of a building to the international plumbing code, which might not emphasize storage capacity of water to the same extents, the designer or contractor could infer that the local code is tailored to address the unique water infrastructure needs and conditions in Ethiopia. The designer's approaches likely takes in to account factors such as climate, geography, water source and other local building practices. The presence of detailed storage capacity requirements in the

Ethiopian local plumbing code highlights a commitment to ensuring reliable water supply and efficient distribution systems that are specifically suited to local conditions and challenges.

The Ethiopia local plumbing code describes more detailed design and specification of gutter and down pipe installations for storm water drainage in a building. the proper gutter and down pipe design is a crucial for effective storm water drainage without a well-designed system water can accumulate near the foundation of the building that can leads to water damage ,erosion and potential structural issues overtime. Understanding the design requirements ensures that the system functions as intended. Correctly design gutter and down pipe helps to prevent water from entering the buildings, which can cause damage to the interior including mold growth ,rot, and structural deterioration ,designers and contractors should need to review the Ethiopian plumbing codes and understand the design principles to ensure the building remains protected. Improperly managed storm water can create safety hazards such as slippery surfaces, ice buildup in cold climate and potential flooding understanding the design and installations requirement for gutters and down pipe helps to mitigate these risks and ensures safe environment for occupants and workers.

In general, the Ethiopian plumbing code governs the design, installation and maintenance of plumbing systems in buildings within the country. While the code provides general guidelines for the design and installation of water supply system and drainage systems, it lacks details specifications found in international plumbing codes. The Ethiopian plumbing code focuses more on basic requirements and not delves deeply in to the technical aspects of the different plumbing systems.

Overall, the international plumbing code provides comprehensive and detailed provisions for the design and installation of plumbing systems of buildings. The international plumbing code includes the specific requirements and best practices for water supply pipe size system and common venting systems, covering aspects such as sizing, material, placement and connections. The international plumbing code aims to ensure the proper functioning and safety of water supply pipe size and common venting systems.

When comparing the local and international plumbing codes regarding the water supply pipe sizing and venting systems, the international plumbing code provides in depth and detailed explanations with practical examples. The Ethiopian plumbing code offers more generalized approach to water supply pipe sizing and venting system design. Generally, both the international plumbing code and the local plumbing code play crucial roles in regulating the design, installation and uses of plumbing system to ensure the safety and health of the public.

4.2 The design and installation of plumbing systems in high rise selected building

4.2.1 Design and installation of water supply system for building A

4.2.1.1Design and installation of storage capacity of tank for building A

Based on this information the domestic water requirement of the mickey real estate and apartment is calculated as follows and summarized below the table.

From the governing equation of per capital demand (PROJECTOFFICE, March, 2013).

Per capital demand

Q = C*P ………………………………………….Equation 8

Where

Q is Average demand in l/day

C is per capital demand in l/cap/day

P is total number of populations

Table 15 average daily water demand for building A

Name of building (1)	Number of floors (2)	Number of population (3)	Per capital demand l/cap/day (4)	Average daily demand l/day (3x4)

Mickey Apartment and real-estate	9	105	110	11550

Table 16 average water demand requirement for building A

Item number	Description	Unit	Amount
1	Population	No	105
2	Per capital demand	l/cap/day	110
3	Domestic demand (Dd)	l/day	11550
4	Non Domestic demand (NDd) = 20% Dd	l/day	NO
5	Non- Revenue water demand = 15 % Dd	l/day	1732.5
6	Total Average demand	l/day	13282.5

Based on the information above the volume requirement of the tank is given by the general equation of.

Volume of storage tank

V=Q*T ………………………………....................Equation 9

Where,

V = volume of storage tank in liter

Q = discharge l/day

T = storage time in day

From the above table the water supply storage tank is design by average day demand

V = 13282.5 l/day * 3 day

Because for storage capacity of a tank is designed to store water minimum of

3 days.

V =39847.5 litter

Based on the design manual of AAWSA standard we have to considering the

Firefighting demand is 10% of the total storage.

Fire demand = 0.1 * 39847.5 litter = 3984.75 litter

Volume of total storage = 39847.5 + 3984.75 = 43832.25 =44000 litter

The storage of tank is combined storage of ground reservoir and elevated tank so sizing the diameter of main pipe is required to fill the elevated tank.

For combined storage use.

- Velocity in pumping main is between 0.6 m/s and 3m/s.
- Filling time for roof tank is 2 to 3 hours for small tanker less than or equal to 5000 liter
- 3 to 6 hour for big tank greater than 5000 liter
- 33% of storage is recommended elevated tank 67 % is underground tank.
  Volume of ground storage = 0.67 * 44000 = ~~ 29000 liter
  Volume elevated tank = 0.33*44000litter

= 14520 litter ~ 15m^3

For any flow the discharge Q of a pipe channel is expressed as (Bosch, 1992)

Continuity equation of hydraulic channel

Q = AV …………………………..Equation 10

Where,

Q = discharge m^3/s

V = velocity of flow in m/s

A = area in m^2

Assume a filling time of 5 hours and velocity in pumping main 1.5m/s.

Rate of filling = volume of elevated storage/filling time.

Q = $15m^3/5hour$

Q = $3m^3/hr$. Q = $3m^3/*60*60sec$ =0.00083 m^3/s

From Q = AV, A = Q/V, = (0.00083 m^3/s) / (1.5m/s), = 0.00055 m^2

$A = \pi r^2$, r =D/2

$A = \pi (D/2)^2$, 0.00055 m^2 = 3.14*D^2/4, D^2 = 0.00055 m^2/0.785 = 0.0007m^2

D =26.5m, adopt 32mm diameter of pipe as minimum

The installation of tanker total storage is 34000 liter among these the plumber said the ground reservoir will 2000 liter storage and the roof tank will install 14000 Littre storage but the design requirement storage capacity of a building according to local plumbing code is 44000 liter storage this indicates that the installed storage capacity of tank does not meet the design requirements. If the installed storage capacity of a tank is below the required capacity specified from local plumbing code there will be.

Inadequate water supply, one of the most immediate consequences would be shortage of water supply for the building water supply. This could lead to inconvenience; health concerns and safety.to satisfy the demand additional storage is required.

4.2.1.2 Pump design and installation for building A

Pump set head = $(H_1+H_2+H_3+H_4+H_5)$

Q_{k} = (0.00083 *1000littre/s)*(24*60*60 s/day)/1000 = 71.71kilo litter/day

H_f1000m = 0.029049 * $71.71^{1.851851}$ = 79.32m

Vertical length of pumping main = 4*9 +4 = 40meter

Ground + 8 floors having 4 m height of each floor

Horizontal length for connection of pump set 8m the total length of pumping main is 48m.

H_f1000m = 79.32m

H_f 48m = x xm = 70.72*48/1000, x=3.8m

Friction loss is 3.8 m

H_2 = Head loss due to fitting

First counting the total number of fittings used for the installation of pumping main riser pipe to supply water to the elevated tanks.

Table 17 : summary of head loss due to fitting for building A

Item number	Name of fitting	Quantity of fitting	Unit Rate of loss m	Total loss m
1	Gate valve	2	0.5	1
2	Check valve	2	0.5	1
3	Union	3	1.5	4.5
4	Adapter	4	0.5	2

5	Socket	11	0.5	5.5
6	Elbow	6	0.5	3
7	Total loss due to fitting			14

Total head loss due to fitting = 1m+1m+1.5m+2m+5.5m+3m =14m

H_3 , total height to which water is to be lifted

36+4 =40m

H_4 = discharge head =2m

H_5= pump loss = 2m

Total pump head is 3.4m+14m+40m+2m+2m =61.4m

Pump discharge = 0.83littre/sec

Total head = 61.4m

Power of pump set = discharge x acceleration due to gravity x total head/efficiency

0.83 x 9.81 x 61.4 x100/65 = 769.13 watt

Power =0.769 kilo watts

1 horse power = 0.746 kilo watt

Horse power of pump = 0.769/0.746 =1.03 Hp, use two pump sets of 1.03 Hp out of which one is standby to pump quantity of 0.83lit/sec against a head of 61.4m.

According to the design requirmentes of plumbing code, in order to provide sufficient water to the residents to this building without any problems and to push 61.4 meter head for 0.83 l/s the size of the pump requires 1.03 horse powers. Therefore, a pump with 10.3 horse power must be installed. And this means that the residents are exposed to disease due to in sufficient water entering to the fixture units.to prevent this from happening the pump installation must be meet with the plumbing codes.

4.2.1.3 Pipe size requirements for all fixture units of building A

The size of pipe is determined by using plumber's chart to supply water from the elevated tank to all the fixtures vertical riser or main supply line, horizontal riser sub main supply line and distribution line which connects to the fixture.

4.2.1.3.1. Pipe size for vertical main line riser for each floor

From point of roof tanker to 8th floor

Table 18: pipe size and its equivalent pipe for building A

Item number	Name of fixture	Quantity of fixture	Pipe size mm	Number of equivalent pipe size 15mm
1	Water closet	47	50	23
2	Hand wash basin	47	32	5.9
3	Shower head	30	65	42
4	Kitchen sink	21	50	23
5	Bath tub	2	25	3.7
6	Laundry	19	40	12
7	Total			109.6

Total = 109.6 ==110 for value ≥ 42 we use 60mm

Check for velocity of a should be pipe 0.6m/s to 3m/s

From continuity equation

$$Q = \pi \frac{D^2}{4} * V$$

$$V = \frac{4 * Q}{\pi \quad D^{\wedge}2}$$

Deter mine flow rate using probability equation of loading unit z value

Table 19 fixture loading rate based on probability equation for building A

Fixture (1)	Z value (2)	Number (3)	Product (4) 2x3
WC flash	4.32	47	203.04
Hand wash basin	0.5	47	23.5
Shower	1	30	30
Sink	1	21	21
Bath tub	1.96	2	3.92
Laundry	1	19	19
Urinal	0.5	0	0
Total sum	-	-	300.46

Q = $0.25\sqrt{(203.04} + 23.5 + 30 + 21 + 3.92 + 19 + 0)$

Q = $0.25\sqrt{300.46}$ = 0.25x17.33 = 4.33lit/sec

V = $\frac{4*Q}{\pi \quad D^{\wedge}2}$

Q = 4.33/1000 m^3/sec =0.00433 m^3/sec

D = 60/1000 m =0.06 m

V = 4x0.00433/3.14x0.06^2 m/s = 0.0172/0.0113 = 1.5 m/s it is safe use 60mm diameter pipe as raiser.

Following this step generalize all the pipe size requirements' of a building in as a table below.

Table 20 vertical riser pipe diameter for building A

Description	Diameter of pipe	Design	Design	Remarks

	mm		Rate of flow Q l/s	Velocity of flow V m/s	
	Installed	Designed			
Roof tank – 8th floor	50	65	4.33	1.5	Below deign
8th -7th floor	50	65	4.125	1.46	Below design
7th -6th floor	50	65	3.905	1.38	Below deign
6th -5th floor	50	65	3.598	1.27	Below design
5th -4th floor	50	65	3.36	1.19	Below deign
4th -3rd floor	32	65	2.875	1.02	Below design
3rd -2nd floor	32	65	2.43	0.86	Below deign
2nd-1st floor	25	65	1.88	0.67	Below design
1st-ground floor	25	50	5.144	2.62	Below design

As the table shows the installation of water supply pipe size of a building is not satisfy the minimum design requirements'. The under sized water supply riser leads to reduce the flow rate and restricts the flow rate of the pipe which has the potential for in sufficient water pressure at fixtures and the sanitary appliances located to the riser it also increases pressure drop.

The smaller pipe size experiences higher pressure loss due to friction and increases the risk of water hammer and the water hammer has an effect of higher potential for damaging the pipes and fixtures

After the installation of under sized pipe line for water supply system of a building up grading the required pipe size based on the minimum design requirements' will be challenging, requiring extensive and costly for modification.

4.2.1.3.2Horizontal transition pipe size for building A

The minimum pipe diameter of a building should satisfy the demand requirements' of each fixture the pipe requirements' of a building is determined by using the simplest way of plumber's chart.

- Floor 8th and 7th has similar number of fixtures so typical each other
- Floor 6th and 5th has similar number of fixture they are typical
- Floor 1st – 4th have similar house hold and number of fixture typical each other
- Ground floor is different from all other floors

Design and determination of horizontal main pipe size diameters for floor 8th.

Table 21 horizontal pipe diameter transmission main per floor of building A

Description	Diameter of pipe mm		Design flow Q l/s	Design Velocity of flow V m/s	Remarks
	Installed	Designed			
Ground floor	25	50	5.144	2.62	Below design
1st floor	25	50	1.54	0.785	Below design
2nd floor	25	50	1.54	0.785	Below design
3rd floor	25	50	1.54	0.785	Below design
4th floor	25	50	1.54	0.785	Below design
5th floor	25	50	1.519	0.77	Below design
6th floor	25	50	1.519	0.77	Below design
7th floor	25	50	1.328	0.7	Below design
8th floor	25	50	1.328	0.7	Below design

The installation of horizontal transmission water supply line of a building falls below the design and specification requirements' according to the local and international plumbing code requirements' of a building. The undersized pipe size leads

- Insufficient water pressure and flow, the water supply pipe line installation, pipe size reduction, or water flow capacity does not meet the building's minimum water demand and design specifications. This results in low water pressure and inadequate water flow to fixtures and sanitary appliances, which impairs plumbing system performance and reduces water flows to faucets, showers, and other fixtures.

- Uneven water distribution: An inadequately sized water supply line may not be able to distribute water evenly to all building customers, resulting in higher water pressure and flow in some areas of the building and lower water pressure and flow in other areas.
- Decreases water quality: A water supply line that is too small may not be able to maintain the right water velocity in a pipe, which can cause sediments, minerals, and other contaminants to accumulate in the pipe.
- Raises the risk of seepage, leaks, and pipe failures: Undersized water supply lines cause higher water velocity and pressure fluctuations, which put stress on the water supply pipe line and raise the possibility of leaks, bursts, and other pipe failures.
- Limited capacity for expansion: An undersized water supply line may not be able to handle the additional water requirements if the building's water demand rises in the future. This limits the capacity for expansion.

4.2.1.3.3 Horizontal transmission pipe size per room to manifold of building A

Table 22 horizontal transmission pipe size per room to manifold for building A

Description			Diameter of pipe mm		Design flow Q l/s	Design Velocity V m/s	Remarks
			Installed	Designed			
Ground Floor	A	MBR	25	32	0.721	0.897	Below design
		KBR	25	25	0.6	1.27	Ok
		GTR	25	25	0.55	1.12	Ok
1st floor Three house hold	A	MBR	25	32	0.7	0.87	Below design
		GTR	25	25	0.55	1.12	Ok
	B	MBR	25	32	0.7	0.87	Below design
		GTR	25	25	0.55	1.12	Ok
	C	MBR	25	32	0.7	0.87	Below design
		GTR	25	25	0.55	1.12	Ok

2^{nd} floor	A	MBR	25	32	0.7	0.87	Below design
Three		GTR	25	25	0.55	1.12	Ok
house hold	B	MBR	25	32	0.7	0.87	Below design
		GTR	25	25	0.55	1.12	Ok
	C	MBR	25	32	0.7	0.87	Below design
		GTR	25	25	0.55	1.12	Ok
3^{rd} floor	A	MBR	25	32	0.7	0.87	Below design
Three		GTR	25	25	0.55	1.12	Ok
house hold	B	MBR	25	32	0.7	0.87	Below design
		GTR	25	25	0.55	1.12	Ok
	C	MBR	25	32	0.7	0.87	Below design
		GTR	25	25	0.55	1.12	Ok
4^{th} floor	A	MBR	25	32	0.7	0.87	Below design
Three		GTR	25	25	0.55	1.12	Ok
house hold	B	MBR	25	32	0.7	0.87	Below design
		GTR	25	25	0.55	1.12	Ok
	C	MBR	25	32	0.7	0.87	Below design
		GTR	25	25	0.55	1.12	Ok
5^{th} floor	A	MBR	25	32	0.721	0.897	Below design
Two		KBR	25	25	0.6	1.27	Ok
house hold		GTR	25	25	0.55	1.12	Ok
	B	MBR	25	32	0.721	0.897	Below design
		KBR	25	25	0.6	1.27	Ok
		GTR	25	25	0.55	1.12	Ok
6^{th} floor	A	MBR	25	32	0.721	0.897	Below design
Two		KBR	25	25	0.6	1.27	Ok
house hold		GTR	25	25	0.55	1.12	Ok
	B	MBR	25	32	0.721	0.897	Below design
		KBR	25	25	0.6	1.27	Ok

		GTR	25	25	0.55	1.12	Ok
7th floor One house hold	A	MBR	25	40	0.84	0.7	Below design
		CBR	25	25	0.63	1.3	Ok
		KBR	25	25	0.6	1.23	Ok
		GTR	25	25	0.6	1.23	Ok
8th floor One house hold	A	MBR	25	40	0.84	0.7	Below design
		CBR	25	25	0.63	1.3	Ok
		KBR	25	25	0.6	1.23	Ok
		GTR	25	25	0.6	1.23	Ok

The installed horizontal transmission pipe size from the transmission line to the distribution of manifolds the water supply to the common bedroom, children's bedroom, guest toilet room, and maid's bathroom meets the minimum design requirements according to the local and international plumbing codes of a building.Installing a water supply line that meets the minimum design requirements for a pipe size ensures proper water flow and pressure throughout the building's plumbing systems.it helps for

- Adequate water pressure and flow. Correctly sized pipe lines maintain the necessary water pressure and flow rate, ensuring that all fixtures and appliances receive the necessary water supply. This is especially important in high-demand areas such as bathrooms, kitchens, and laundry rooms, where multiple fixtures are used at the same time.
- Effective water distribution. Properly sized pipes lessen the possibility of water pressure drops and flow limits, which can occur when the installed pipes are insufficient for the building's water demand.This helps to guarantee that the water is distributed equally and efficiently across the building's requirements, avoiding problems such as low water and uneven distribution.
- Reduce risk of water-related issues. Correctly sizing pipe lines based on design requirements helps to avoid problems like water hammer, high pressure, and flow imbalances, which can lead to leaks, pipe brusts, and other water-related

concerns. As a result, properly sized pipe lines extend the life of the plumbing system while reducing the need for costly repairs and replacement.

- Iproved over all system performance properly sized pipe contributes the over all efficiency and performance of the building water supply system.
- Compliance with plumbing codes of a building and regulations the minimum pipe size requirments are typically specified in building codes and plumbing regulations to ensure the saftey and functionality of the plumbing system meeting the instaaled and minimum requirment of design ensures that the buildings water supply system is compliant with the international and local standards.

In thise building's the water supply distribution pipe size from the transmission line to the manifold distribution line of CBD,KBD and GTR is reliable,efficient and compliant with the relevant codes and regulations correctley leads to a better functioning and more sustainable plumbing systems.

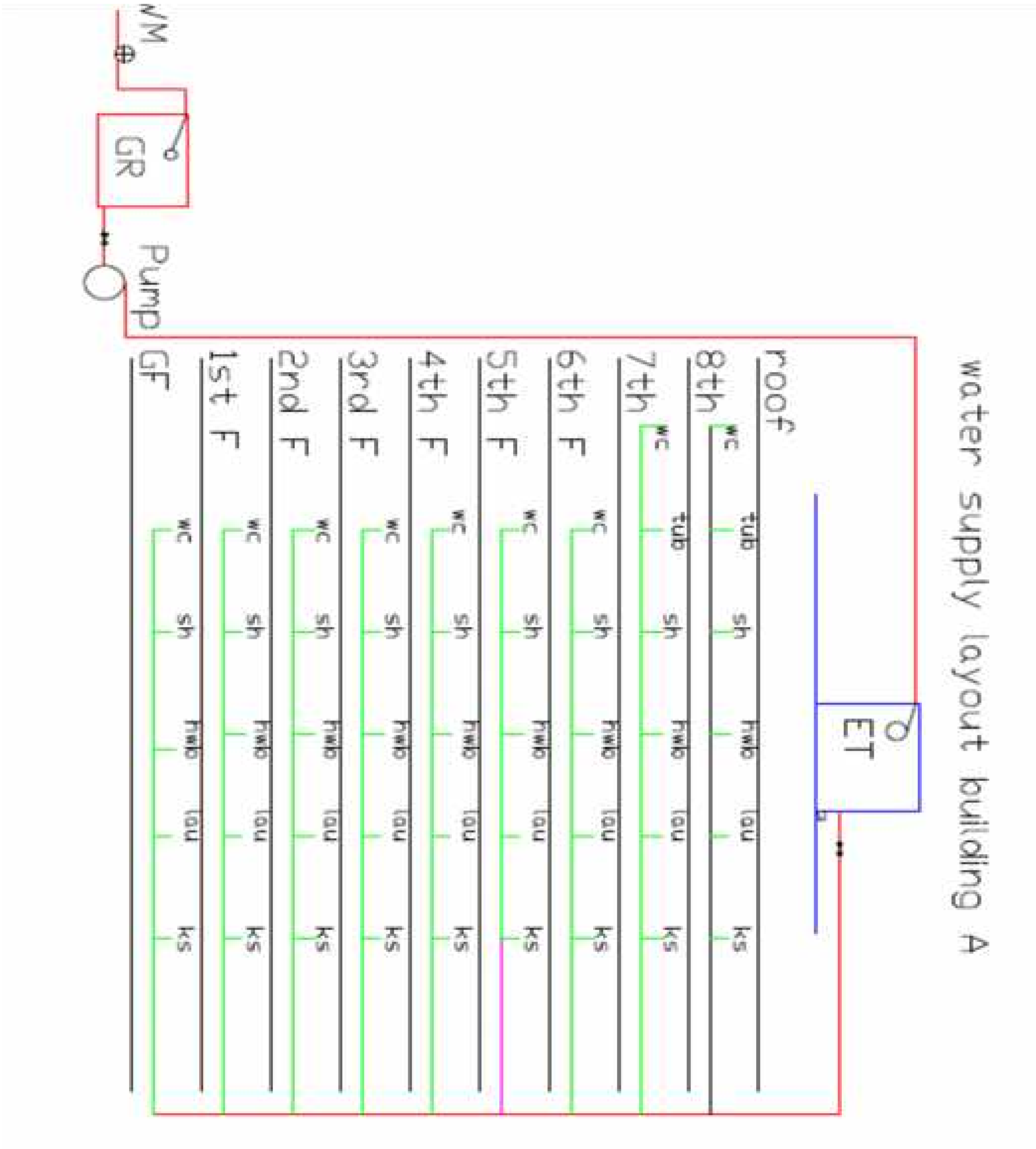


Figure 4 water supply line lay out for building A

4.2.3. Design and installation of internal waste water drainage of building A

Because of the installation of the waste water drainage stack is installed using two duct system of the riser.

DUCT A

- Master bath room and kids bed room for floor 7th and 8th
- Households A for floor 5th and 6th
- Households A and B for floor1st to 4th
- Ground floor

4.2.3.1Number of fixture in a floor that drain a horizontal drainage system per floor

Amount Horizontal drains in each floor can be determined by using fixture loading rate factor

The riser pipes in a building are expressed as black water drain, grey water drain and brown water drain to clear the idea of waste water drainage system of abuilding the Engineers classify the internal waste water drainages.

In this paper

Black water drain = waste water drain from water closet + urinal

Grey water drain = waste water drain from hand wash basin + shower + bath tub + floor drain

Brown water drain = waste water drain from kitchen sink and its floor drain

As per Ethiopian building plumbing code the amount of waste water drainage for floor 8th is given as follows.

For floor 8th

Table 23 : fixture units and loading rate per floor for building A

Item number	Name of fixture	quantity of fixture	Loading unit rate	Total loading rate
1	Water closet	2	8	16
2	Hand wash basin	3	1	3
3	Shower	2	2	4
4	Laundry	1	2	2
5	Bath tub	1	3	3

6	Kitchen sink	1	2	2
7	Floor drain	1	1	1

Black water drain = 16

Grey water drain = 3+4+2+3+0 = 12

Brown water drain = 2+1 =3

By following this step generalize the number of fixture of waste water drainage in one table

Table 24 waste water drainage of horizontal drain building A

Number of floor		BWD	GWD	BrWD
8	A	16	12	3
7	A	16	12	3
6	A	24	11	3
5	A	24	11	3
4	A	16	7	3
	B	16	6	3
3	A	16	7	3
	B	16	6	3
2	A	16	7	3
	B	16	6	3
1	A	16	7	3
	B	16	6	3
Ground		24	10	3

4.2.3.2 Pipe diameter and slope of horizontal waste water drainage for building A

a. slope for horizontal pipe

According to the Ethiopian building's construction code standards of plumbing services.

The recommended slope is expressed by inch per foot

Using conversion factor

1 inch = 25.4mm

1 foot = 304.8 mm

Slope

1 inch/foot = 83.3mm/m

0.125 inch/foot = 0.125* 83.3mm/m = 10.4mm/m

Use 1/100 or 1:100 or 1% slope

0.25 inch/foot = 83.3mm/m * 0.25 = 20.825mm/m

Slope H: V = 1:50 or 1/50 or use 2% slope for 65mm pipe diameter.

b. check the velocity of sewer

For Ethiopian building construction code standard of plumbing codes of a building the minimum and maximum velocity of flow is limited between 0.61m/s and 2.4m/s.

From Manning's governing equation of velocity of flow for sewer is given by

Manning equation of sewer

$$V = \frac{r^{2/3}\sqrt{S}}{n} \text{...Equation 11}$$

Where

V = velocity of sewer

r = hydraulic radius of the sewer pipe

S = hydraulic gradient or slope of

N = Manning's roughness' coefficient of materials constant

Note; - the risk of induced trap siphon age is minimized by ensuring adequate air movement in the drain but not exceeding a proportional depth of 0.75

Proportional depth of sewer

$\frac{d}{D} = 0.75$ …………………………………………….. Equation 12

For partially full flow the design of sewer line for horizontal drain is given by

$\frac{d}{D} = \frac{1}{2}(1 - \cos\theta/2)$ Where, d = mean depth of sewer hydraulic depth in m

$\frac{r}{R} = 1 - \frac{360 \sin\theta}{2\pi\theta}$ D = diameter of pipe in m

$\frac{a}{A} = \frac{\theta}{360} - \frac{\sin\theta}{2\pi}$ r = hydraulic radius of sewer line in m

R = radius of circular pipe in m

a = hydraulic area of sewer in m^2

A = correctional area of circular pipe in m^2

Using maximum depth ratio of partially half full sewer of d/D = 0.75 determine all parameters of sewer line and check for velocity of minimum flow using Manning's equation.

$\frac{d}{D} = \frac{1}{2}(1 - \cos\theta/2)$

$0.75 = \frac{1}{2}(1 - \cos\theta/2)$

$1 - \cos\theta/2 = 1.5$ and $\cos\theta/2 = -0.5$ then $\theta/2 = \cos^{-1} -0.5$ we get $\theta/2 = 120°$

The inflation angle of $\theta = 240°$

Next we can determine all the hydraulic parameters of a sewer line

$\frac{r}{R} = 1 - \frac{360 \sin\theta}{2\pi\theta}$ from this equation substitute $\theta = 240°$

$\frac{r}{R} = 1 - \frac{360 \sin 240°}{2\pi 240°}$ we get $\frac{r}{R} = 1.21$

$\frac{a}{A} = \frac{\theta}{360} - \frac{\sin\theta}{2\pi}$ substitute $\theta = 240°$

$\frac{a}{A} = \frac{240°}{360} - \frac{\sin 240°}{2\pi}$ we get $\frac{a}{A} = 0.81$

For D = 50 mm, r = 1.21*0.025 m = 0.03 m

For D = 65 mm, r = 1.21*0.0325 m = 0.038m

For D = 75 mm, r = 1.21*0.0375 m = 0.046 m

For D = 100 mm, r = 1.21*0.05 m = 0.06 m

For D = 150 mm, r = 1.21* 0.075 m = 0.09 m

The velocity of sewer is

N = 0.009 – 0.011 for PVC pipe use 0.011

For D 50 mm, V = $\frac{0.03^{2/3}\sqrt{1/50}}{0.011}$ = 1.24 m/s

For D 65 mm, V = $\frac{0.038^{2/3}\sqrt{1/50}}{0.011}$ = 1.45 m/s

For D = 75mm, V = $\frac{0.046^{2/3}\sqrt{1}/100}{0.011}$ = 1.17 m/s

For D = 100 mm, V = $\frac{0.06^{2/3}\sqrt{1}/100}{0.011}$ = 1.39 m/s

For D = 150 mm, V = $\frac{0.09^{2/3}\sqrt{1}/100}{0.011}$ = 1.33 m/s

Table 25 horizontal pipe size and slope for building A

Floor	Description of drain For house hold		Fixture unit es	Pipe diameter Mm		Slope %		Design velocity of sewer V in m/s	Remark	
				Installed	Design	Installed	Designed		Pipe size	Slope
8th Floor	BWD	A	16	100	100	1	1	1.39	Ok	Ok
	BrWD	A	3	75	75	1	1	1.17	Ok	Ok
	GWD	A	12	50	65	2	2	1.45	BD	Ok
7th Floor	BWD	A	16	100	100	1	1	1.39	Ok	Ok
	BrWD	A	3	75	75	1	1	1.17	Ok	Ok
	GWD	A	12	50	65	2	2	1.45	BD	Ok
6th Floor	BWD	A	24	100	100	1	1	1.39	Ok	Ok
	BrWD	A	3	75	75	1	2	1.17	Ok	Ok
	GWD	A	11	50	65	2	1	1.45	BD	Ok
5th Floor	BWD	A	24	100	100	1	1	2.21	Ok	Ok
	BrWD	A	3	75	75	1	2	1.39	Ok	Ok
	GWD	A	11	50	65	2	2	1.17	BD	Ok
4th Floor	BWD	A	16	100	100	1	1	1.39	Ok	Ok
		B	16	100	100	1	1	1.39	Ok	Ok
	BrWD	A	3	75	75	1	1	1.17	Ok	Ok
		B	3	75	75	1	1	1.17	Ok	Ok
	GWD	A	7	50	65	2	2	1.45	BD	Ok
		B	6	50	65	2	2	1.45	BD	Ok
3rd Floor	BWD	A	16	100	100	1	1	1.39	Ok	Ok
		B	16	100	100	1	1	1.39	Ok	Ok
	BrWD	A	3	75	75	1	1	1.17	Ok	Ok
		B	3	75	75	1	1	1.17	Ok	Ok

	GWD	A	7	50	65	2	2	1.45	BD	Ok
		B	6	50	65	2	2	1.45	BD	Ok
2nd Floor	BWD	A	16	100	100	1	1	1.39	Ok	Ok
		B	16	100	100	1	1	1.39	Ok	Ok
	BrWD	A	3	75	75	1	1	1.17	Ok	Ok
		B	3	75	75	1	1	1.17	Ok	Ok
	GWD	A	7	50	65	2	2	1.45	BD	Ok
		B	6	50	65	2	2	1.45	BD	Ok
1st Floor	BWD	A	16	100	100	1	1	1.39	Ok	Ok
		B	16	100	100	1	1	1.39	Ok	Ok
	BrWD	A	3	75	75	1	1	1.17	Ok	Ok
		B	3	75	75	1	1	1.17	Ok	Ok
	GWD	A	7	50	65	2	2	1.45	BD	Ok
		B	6	50	65	2	2	1.45	BD	Ok
Grd floor	BWD		24	100	100	1	1	1.39	Ok	Ok
	BrWD		3	75	75	1	1	1.17	Ok	Ok
	GWD		10	50	65	2	2	1.45	BD	Ok
Collector pipe			278	150	150	1	1	1.83	Ok	Ok

The table above shows that the result of the horizontal drainage of a building the slope of each pipe, the size of black water drain and brown water meets the design requirements of local plumbing code while the pipe size of grey water drain doesn't meet the design requirement which is installed below design it is under sized.

On this residential building the installation of horizontal waste water drainage has been discussed below.

1. Slope

The result of the table states that the horizontal pipe installation of a building meets the slope requirements of any horizontal pipe installation ,the proper slope installation of waste water drainage system could have better advantages of both the building and its occupants than improper sloped design and installation of horizontal drains, these are some important issues,

- Proper flow of waste water, meeting the slope requirements of horizontal pipe installation ensures and makes that the waste water flows smoothly and efficiently through the pipes this can reduces the likelihood of clogs and backups.
- Reduce pressures, a properly sloped pipe installation of a building reduces the pressure on the pipe walls, this could minimizes the risk of pipe damage and cracking.
- Less odor, smell and gas issues, with in well designed and correctly sloped of horizontal drainage the waste water drainage flows quickly this can reduce the time for odor and gases accumulation which makes the living environment more pleasant.

2. Grey water drain

The installation of grey water drain of a building with a horizontal pipe that meets the slope requirements but has undersized horizontal pipe to drain grey water wastes or disposes from shower,bathtub,laundry,hand wash and floor drain does not meet the minimum design requirements of local plumbing code in size. This can results in the building and its occupants.

- Increase pressure and risk of pipe rapture, an undersized pipe might causes an increase in pressure within the system. The excessive pressure can leads to pipe raptures.
- Inefficient drainage, with a smaller pipe size there might be reduced capacity for carrying waste water drains; this can cause blockages or slow drainage of fixtures which leads to an unhygienic environment and increased maintenance cost.

- Long term issue, an undersized grey water drainage system can causes ongoing problems such as unpleasant odors from slow drainage fixtures, potential health hazard due to standing water or structural damage to building components of floors and walls if leaks and seepages are not properly managed.

3. Black water and brown water drain

The black water drain and brown water drain of a residential building, black water drain wastes disposed from flashing toilet and the brown water drain waste water disposes from kitchen sink of a horizontal waste water drainage system installation meets the required adhesive sealant, slope and its pipe size of design requirements of local plumbing codes, this have several benefits of the building structures and the occupants among these,

- Enhance hygiene and sanitation, the installation of waste water drainage meeting the local plumbing code reduce the risk of harm full microorganisms from toilets to other area of a building.
- Increased longitivity of plumbing system, properly designed and installation of waste water drainage system and adherence of local plumbing code could extends the life of plumbing systems and reduce maintenance costs.
- Better overall performance, compliance with local plumbing code ensures that all components in the building, including the black water drain, brown water drain and associated fixtures are designed for optimal performance.

4.2.3.3 Stack or vertical riser of waste water drainage for building A

Stack is a vertical waste pipe passing through different floors of a building for collecting and conveying waste waters from brunch drain.

All brunch drains are directly connected to stack and the stack also acts as a ventilating pipe for air movement.

When waste water flows down ward to a stack due to the gravity .the friction of the pipe against the direction of flow .the flow finally attains balanced velocity and the wastewater flows down ward .the quantity of waste water flowing in stack not greater than one fourth of the diameter of the stack pipe if not the function of stack will be air disturbances. Due to this reason the diameter of stack is limited by the discharge unit methods on the sanitary fixtures.

- Collect all stack pipes of the black water drain by combining in to one horizontal pipe with minimum requirements of gradient and then recharge to septic tank.
- Collect and receive the vertical stack pipe of grey water drain by one horizontal pipe with in minimum slope requirements to recharge septic tank treat it and re use for irrigation purpose.
- Collect all the vertical stack pipe of brown water drain by one horizontal pipe with in minimum requirements of slope and pipe diameter recharge to grace interceptor.

Table 26 vertical stack pipe size for building A

Floor number	Description of drain for house hold		Fixture unites per floor	Fixture units per stack	Pipe Mm		Remarks
					Installed	Designed	
8^{th} Floor	BWD	A	16	16	100	100	Ok
	BrWD	A	3	3	75	75	Ok
	GWD	A	7	7	75	75	Ok
7^{th} Floor	BWD	A	16	32	100	100	Ok
	BrWD	A	3	6	75	75	Ok
	GWD	A	7	14	75	100	Below design
6^{th} Floor	BWD	B	24	56	100	100	Ok
	BrWD	B	3	9	75	75	Ok
	GWD	B	11	25	75	100	Below design
5^{th} Floor	BWD	B	24	80	100	100	Ok
	BrWD	B	3	12	75	75	Ok
	GWD	B	11	36	75	100	Below design
4^{th} Floor	BWD	C	16	96	100	160	Below design
	BrWD	C	3	15	75	75	Ok

	GWD	C	7	43	75	100	Below design
3rd Floor	BWD	C	16	128	100	160	Below design
	BrWD	C	3	18	75	75	Ok
	GWD	C	7	50	75	100	Below design
2nd Floor	BWD	C	16	160	100	160	Below design
	BrWD	C	3	21	75	75	Ok
	GWD	C	7	57	75	100	Below design
1st Floor	BWD	C	16	192	100	160	Below design
	BrWD	C	3	24	75	100	Below design
	GWD	C	7	64	75	150	Below design
Ground floor	BWD		0	192	100	150	Below design
	BrWD		0	24	75	100	Below design
	GWD		0	64	75	150	Below design

The table shows that the installation of waste water drainage is constant from the lower number of fixture units to the higher number of fixture units which means it doesn't meet the minimum requirements of the design based on the plumbing code due to this the installed pipe might have

The risk of blockages and clogs inside the pipe whenever the vertical drain does not meet the minimum design requirements of plumbing code there is a higher risk of blockage and clogs occurring in the system . This could leads backups, overflows and potential to damage the building structure.

Poor drainage efficiency the vertical installed drain is not meeting the design requirements it cannot effectively drain the wastes from the building. This can results in slow drainage, foul odors and unsanitary condition in the building.

The undersize of waste water drainage due to blockage and other problems it could be failed once it fails leads to higher costs in the long run due to maintenance and repairing issues.

4.2.3.4 Vent pipe size of waste water drainage for building A

- Combined vent is provided for black water drain and grey water drain in one stack by combining them.
- Common vent is provided for brown water drain.

Table 27vent pipe size for building A

Number of floor	Description	Number of fixture per floor	Discharged fixture in stake	discharge units in stack	Vent pipe mm		Remarks
					installed	designed	
Ground	BWD	24	24	34	75	100	Below design
	GWD	10	10				
	BrWD	3	3	3	75	50	Above design
1	BWD	32	56	79	75	100	Below design
	GWD	13	23				
	BrWD	6	3	9	75	75	Ok
2	BWD	32	88	124	75	100	Below Design
	GWD	13	36				
	BrWD	6	9	15	75	75	Ok
3	BWD	32	120	169	75	127	Below Design
	GWD	13	49				
	BrWD	6	15	21	75	75	Ok

4	BWD	32	152	214	75	127	Below Design
	GWD	13	62				
	BrWD	6	21	27	75	75	Ok
5	BWD	24	176	249	75	150	Below Design
	GWD	11	73				
	BrWD	3	27	30	75	75	Ok
6	BWD	24	200	284	75	150	Below Design
	GWD	11	84				
	BrWD	3	30	33	75	75	Ok
7	BWD	16	216	312	75	150	Below Design
	GWD	12	96				
	BrWD	3	33	36	75	75	Ok
8	BWD	16	232	340	75	150	Below design
	GWD	12	108				
	BrWD	3	36	39	75	75	Ok

1. Common vent

Based on the provided information of the table above the installation of common vent pipe system of the brown water drain of a building meets the minimum design requirements of plumbing codes. The installation of the common vent size for the waste water drainage system in the building complies the minimum design requirements specified in the applicable plumbing codes, this ensures that the drainage system is properly designed and installed to effectively handle the waste water drainage in the building.by meeting the design standard the common vent pipe size can effectively provide the necessary air circulation and pressure balance with in the drainage system ,preventing the potential issues like odor problems and inadequate drainage.

The installations of common vent pipe size have been carried out in accordance with the recognized industry standards and best practices. This provides that the waste water drainage system can operate reliably and efficiently, contributing to the overall functionality and safety of the building plumbing infrastructures.

2. Combined vent

As the table shows that the installation of combined vent of black water drain and grey water drain systems of waste water drainage is not meet the minimum design requirements plumbing code. Which is installed under sized or the installed pipe size is below the design requirements this leads to

Reduces air flow and pressure issues insufficient air in the vent pipe can create a vacuum in the drainage system and reduced air flow can also cause gurgling or bubbling noises in fixtures when water is being drained.

Health and safety insufficient venting pipe size allows the sewer gas to enter to the building carrying harmful bacteria and unpleasant odors which can pose health risks.

Plumbing issues improper venting can promote corrosion and rust with in the drainage system which reduces the life span of the plumbing fixtures and it increase plumbing maintenance cost due to undersized of venting system.

Unpleasant living conditions the smell and noise issues associated with undersized vent pipe system can significantly affect the quality of life.

The undersized combination vent system of a waste water drainage have plumbing problems of health concerns and over all discomfort of life quality.it is a critical to ensure proper venting for waste water drainage system in order to prevent these issues and maintain a safe and healthy living environment.

Duct B

Duct B waste water drainage design and installation system of a building based on loading factor units of a fixture.

- Common bed room and guest toilet room for floor 7th and 8th
- Households B for floor 5th and 6th
- Households C for floor1st to 4th

The design and installation of waste water drainage system for duct B is similar to duct A

Loading unit duct A = 340 + 39 = 379

Loading unit duct B = 340 + 39 =379

Total = 379+379 = 758

4.2.3 Design and installation of external waste water drainage for building A

4.2.3.1 Design and installation of septic tank

Disposing domestic sewage of a building is by septic tank. the recommended distance of soak away pit in any drinking water source should have a spacing of up to 20m.the ground water table is minimum of 2m below the bottom of septic tank to prevent direct contamination of ground water table.

The length greater than 4m double chamber is used if less than 4m single chamber provided.

The 1st chamber is the inlet chamber which covers 2/3 the length of the septic tank.

The 2nd camper of aseptic tank is 1/3 of the length of septic tank .in the inlet chamber baffle wall is provided at distance of 1/5 length to prevent the entry of foams in to the sedimentation zone. Free board of 30cm up to 50 cm is provided. The length is provided twice width of septic tank

1 .Rate of water supply method

Total capacity of septic tank = Volume sediments + Volume of sludge

Volume of sediment = $\frac{t*p*q}{1000} m^3$

Volume of sludge = $\frac{s*p*d}{1000} m^3$

Where,

t= hydraulic detention time is taken 3 day

p = population served

q = water consumption in liter/capital/day

s = sludge production in liter/cap/day usually 0.15 l/c/d

d = number of days b/n de-sledging is 5 year

For this building

Number of people = 105

Per capital demand = 110l/c/d

Total loading unit = 758

Volume of sediment = 3 x105x110/1000 = 35 m^3

Volume of sludge = 0.15x105x5x365/1000 = 29m^3

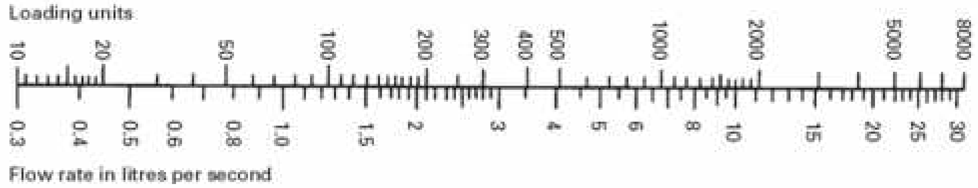
Total volume = 35 m^3+ 29 m^3

v = 64 m^3

Determine the depth of septic tank using simple mathematical equation of

Effective depth (d) $= \frac{volume}{surface\ area}$

Determine the surface area of septic tank using flow rate and loading unit chart.



Read the flow rate from the chart at 758 loading unit.

Using linear interpolation method

Loading unit	flow rate in liters/second
750	5.5
758	Q
800	5.75

$\frac{800-750}{758-750} = \frac{5.75-5.5}{Q-5.5}$ Q = 5.54 liter / sec which is 332.4lpm

10lpm of discharge requires 0.92m^2 surface area then 324.6lpm cover the surface area of

A = $\frac{332.4\ lpm\ x0.92m2}{10\ lpm} = 30.056m^2$

Effective depth = $\frac{64\ m3}{30.056\ m2} \approx 2.2$ m

Total depth of septic tank = effective depth +free board of 0.3m

= 2.2+0.3 =2.5m

Length Width ratio of septic tank is 2:1

A = L*W

$29.6\ m^2 = 2w*w$, $w^2 = 14.8\ m^2$ $w = \sqrt{14.8m^2}$

W = 3.8 m

L = 2w = 2*3.8 m = 7.6 m

Size of septic tank is 7.6 m x 3.8 m x 2.5m

Effective depth = 2.2 m and use freeboard = 0.3 m

Total in side depth = 2.5m

Since the length is more than 4m, the septic tank is to be divided in to two compartments

Inlet compartment length = 2/3 length

2/3*7.6 = 5 m

2nd compartment length = 7.6 m- 5 m = 2.6 m

Distance to baffle wall = length /5 = 7.6/5 = 1.52 m

Table 28 design and installation of septic tank for building A

Description septic tank	Dimensions in meter		Remarks
	Installed	Designed	
Length	4	7.6	Below design
Width	2	3.8	Below design
Depth	2	2.5	Below design
Length of 1st compartment	No	5	Impossible to decide
Length of 2nd compartment	No	2.6	Impossible to decide
Distance from baffle wall	No	1.52	Impossible to decide

As the table shows that all the dimension of septic tank installed is below the design requirements and the installation is instated without subdivision of compartment, the building does not satisfy the design requirements of septic tank at all

Based on the table above installed septic tank in a building does not meet the minimum design requirements of the plumbing codes these it might has the effects of the building ,its occupants and the whole environment.

- The improper design and installation of septic tank could lead to contamination of ground water and surface water, this can results in the spread of disease and infections among the occupants and the environment.
- Poor design and installation of septic tank system can cause damage to building structures and foundations due to flooding, sewage backups and leaks from the system component, this could leads costly repairs and potential legal issues related to code violation.
- Due to Inadequate design and installation of septic tank improper disposal of wastes can result foul odors emanating from septic tank and the surrounding area this can create a nuisance for the building occupants and passers.

To prevent such issues the contractor or the professional plumber should check the plumbing cods are they meet the design and installation before proceeding with the project work.

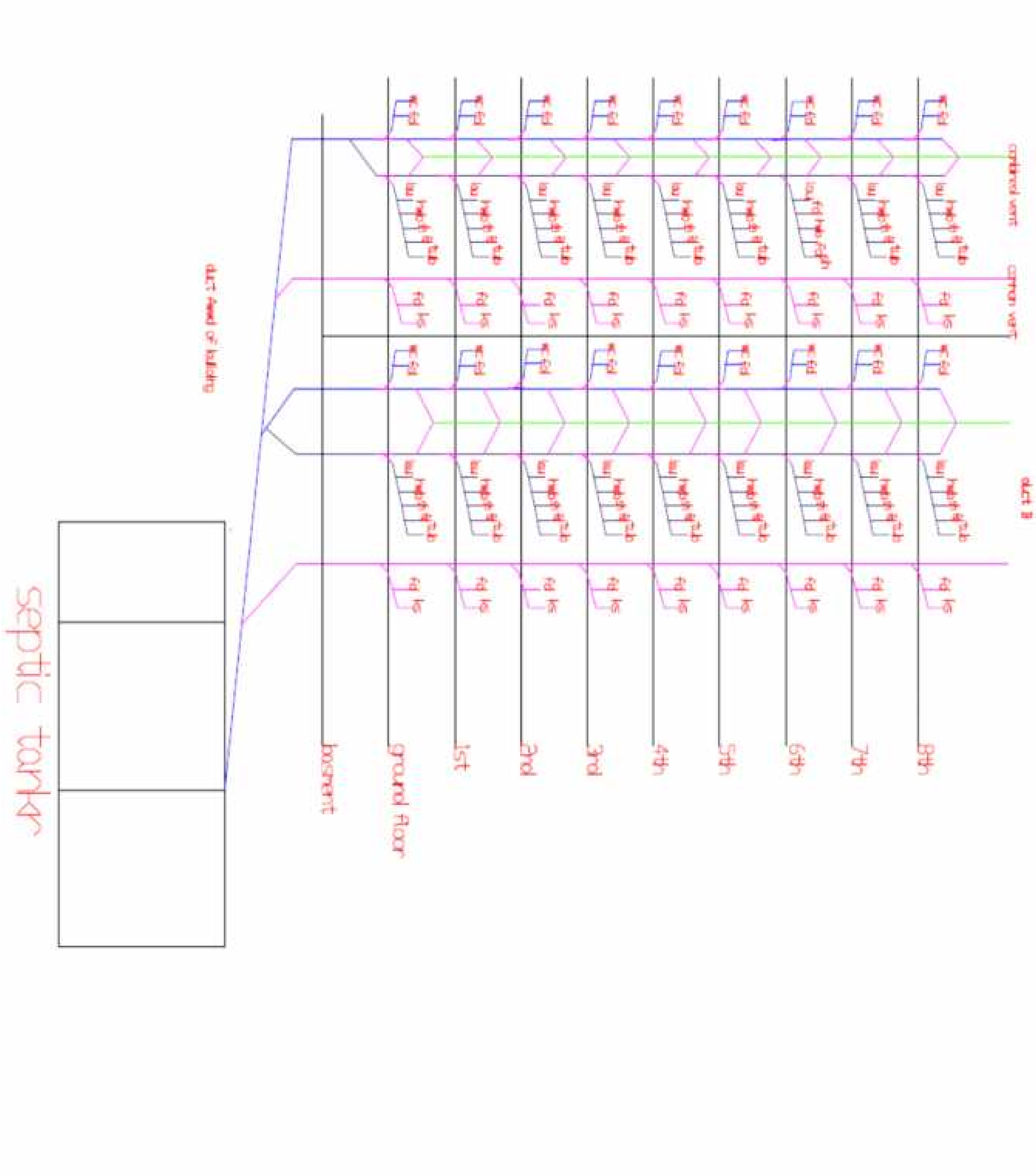


Figure 5 waste water drainage lay out building A

4.2.4. Design and installation of roof storm water drainage for building A

For all rain water design purpose the return period and duration is assumed for 2 years and 15 minutes respectively. Some times to avoid flooding of rain water over the roof the return period for design purpose is taken as 10 years.

Based on Ethiopian Building Standard we use 5minute duration and 10 year return period for design of roof storm water drainage pipe lines.

Rain fall flow is calculated by

Rational formula

Q =CIA/60x60x1000

Where

Q = Rainfall flow or runoff in m^3/s

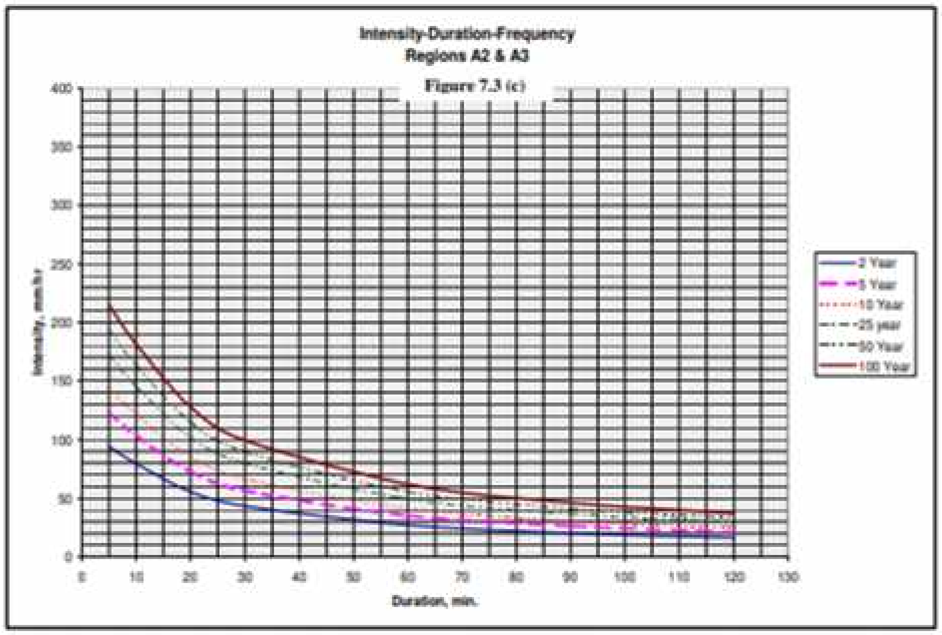
A= Area of roof in m^2

C= Impermeability factor constant

I= Intensity of rainfall mm/hour

Area of roof	Impermeability factor, C
Paved and flat roof	1
Unpaved and sloped roof	0.75-0.95

Source Federal highway administration



Addis Ababa City and nearest areas intensity of rain fall in mm/hour from the Intensity Duration Frequency curve (IDF). The curve is developed by Ethiopian Roads Authority (ERA).

Rainfall data used in the preparation of this figure have been collected from many Ministry of Water Resources meteorology stations.

From the IDF curve of 5minute duration and 10 year return period intensity of rain fall is read as

I = 145mm/hr.

C= 1 because the building roof is flat

A = it can measure the roof length and width then area is the product of length and width

Length of roof =25m

Width of roof = 15m

A = L*W = 25*10 = 250m^2

From international plumbing code hand book we can determine the pipe size of leader or down pipe size using applicable table standards of rain fall intensity, area of roof and pipe sizes.

From the IDF curve I = 145mm/hr. convert mm/hr.in to inch/hr. using the governing unit conversion of 1 inch = 25.4mm

I = 145/25.4 inch/hr. = 5.7 inch/hr. approximately intensity of rain fall is 6inch/hr.

The measured area is in m^2 to read the pipe size diameter from the table we convert the area from m^2 to square foot using the conversion factor of 1square foot = $0.0929m^2$

We get the total area of roof in square foot A =$250m^2/0.0929m^2$ *1square foot

A = 2691.0656 square foot approximately 2691.1 square foot

Simply we can find the pipe size of storm water using the area of roof 4036.6 square foot and intensity of rain fall 6inch/hr. in the above standard table but we can’t get directly the pipe diameter in the table simply we use interpolation method.

At 6inch/hr. intensity of rain fall

Area of roof in square foot	down pipe size (inch)
1470	3
2691.1	x =?
3070	4

From the general equation of linear interpolation we can get the down pipe diameter required for roof area of 2691.1

$$\frac{3070-1470}{2691.1-1470}=\frac{4-3}{x-3}$$

X = 3.79 inch use 4 inch diameter of down pipe for 2691.1 square foot area of roof

Number of down pipe installed in abuilding

4 inch diameter pipe have a capacity of discharge 2.3littre/sec the total discharge in a roof is calculated using the empirical formula written above.

Q =CIA/60x60x1000

Q = 1*145*250/60*60*1000

= 10.06944littre/sec

Number of down pipe in a floor= $\frac{10.06944\text{littre/sec}}{2.3\text{littre/sec}}$ = 4.39 use 5 number of down pipe drain of the long side of the floor.

The gutter lies on the longest side of the floor the length one down pipe coverage is

Q1 can discharge 2.3littre/sec from 10.06944littre/sec of the total and the length to which the down pipe can drain along the longest side of the roof is

Distance of drain = long length/number of down pipe drain

= 25m /5 = 5m

For each 5m along the longest one sloped side of the roof down pipe drain is provided.2.5m right side and 2.5m left side of the roof is drained to each down pipe drains.

The result shows that the installation of down pipe of storm waste water for building A meets the minimum design requirements of plumbing code so that the building and its occupants have,

- Meeting the local plumbing code for installation of down pipe ensures water is effectively drained from the roof which reduces the risk of storm water drainage inside the building such as leaks, mold growth and it helps to manage storm water runoff and prevent flooding in the surrounding area.
- Properly designed and installed of down pipes inside a building can manage storm water runoff contribute to the protection of local ecosystems by reducing erosion, sedimentation, pollution in the surrounding area ,this promote healthier environment for people and wild life it has environmental benefits .

Gutter design

For roof rectangular gutter is recommended and the gutter provide in the building is rectangular.

The gutter in a building is design as the out let function is the absence of swirl and vortex.

Using the governing equation of discharge capacity of out let rectangular gutter channel for the absence of swirl.

1. For h/d up to 1/3

$q = \frac{1*\sqrt{h3}}{5000}$ Littre /sec

2. For h/d greater than 1/3

$q = \frac{d2*\sqrt{h}}{15000}$ Littre /sec

d = 2/3D

where,

q = discharge capacity of outlet lit/sec

h = head of water over out let mm

d = diameter of out let mm

D =down pipe diameter mm

For design purpose we use one of the equation above and check h/d to avoid the over flow of the rain water drain on roof of rectangular gutter.

Trial 1, check the first equations

3d = 2D, d = 2*100/3 = 66.67mm use 7o mm diameter of out let for gutter

2.3litter/sec = ((70mm) *$\sqrt{h}$3)/5000

$\sqrt{h}3$ = 164.3, h^3 = 26994.49 mm

h = 29.99 mm, say 30 mm head of water over out let

Check h/d <1/3,

30/70 < 0.33

0.43 >0.33, since h/d is greater than 1/3 so don’t use this equation for design purpose of guter

Trial 2 check the second equation

$$2.3\text{litter/sec} = ((70\text{mm})^2 * \sqrt{h})/15000$$

$\sqrt{h}$ = 6.97, h = 48.6 mm, say 49 mm head of water over out let

Check h/d $>$1/3,

49/70 $>$ 1/3 which is 0.7 $>$ 0.33 it is always true

So use this equation for design of rectangular gutter.

Gutter depth is double the depth of out let + free board (60mm to 70mm) in this case free board is the average of the minimum limit to the maximum limit which is 65mm

Gutter depth = 2*49 mm + 65mm = 163 mm use 200 mm gutter depth for safety.

Gutter width

For best hydraulic section or economical efficient hydraulic section of rectangular channel

Width of rectangular channel for best hydraulic section

B = 2y ……………………………………………………………….Equation 13

Hydraulic radius of rectangular channel for best hydraulic section

R = y/2 … …………………………………………………………Equation 14

Where

B is channel bed width

Y is channel depth

R hydraulic radius

B = 2x200 = 400 mm

R = 200/2 = 100mm = 100/1000 = 0.1m

Check for velocity of flow is not higher than 3m/s and 0.6m/s using manning's equation

V = $\frac{r^{2/3}\sqrt{s}}{n}$ n = 0.012 for stainless steel

S = 1/60 for flat roof recommended IBCS

R = 0.05m hydraulic radius of channel

V= $0.1^{2/3}$ x $(1/60)^{1/2}$ /0.012 = 0.21x 0.13 = 0.0273/0.012 =2.3 m/s which is save so use depth of gutter 100mm and width of gutter 200 mm of rectangular channel.

Table 29: gutter design and installation for building A

Item number	Description	Size of gutter mm		Remarks
		Installed	Designed	
1	Depth	150	200	Under sized
2	Width	350	400	Under sized

Based on the observation that the installation of gutter depth and width of the building does not meet the minimum design requirmentes of the plumbing code, which means the current gutter installation is undersized, the size of the installation of both width and depth of gutter is less than the design requirement the under sizing gutter has in adequate storm water drainage potentially causing water accumulation in a roof which damages the building structures and walls. The building storm water drainage does not comply with the plumbing code based on gutter thus can results safety hazards, property damages.

4.3. Design and installation of plumbing systems for building B

4.3.1. Design and installation of water supply system for building B

4.3.1.1. Design of storage capacity of tank

Because of the building access for office it requires for design of storage capacity of tank the standard cold water storage per day per ahead in litter or cold water storage for one day on sanitary appliance Indian international plumbing code states that the design criteria of storage capacity for office per a head is 35lit/day/ahead if the number of population is known. If not use following.

Table 30 : storage capacity requirements of tank for building B

Item number	Name of fixtures	Quantity Per floor	Total fixture units	Discharge Lit/day	Total discharge Lit/day
1	Water closet	4	60	180	10800
2	Urinal	1	15	200	3000
3	Wash basin	6	90	180	16200
4	Kitchen sink	1	10	200	2000
5	**Total sum**				32000

Volume of storage= 32000 litter of water is required for one day

In our country Ethiopia working hour per day is 8hr since the building is used for office.

Volume of storage required in 8 hour is 32000/24 *8 = 10666.67 approximately 10700littre of storage tank is required.

Firefighting = 10% storage volume, 0.1*10700 litter. = 1070litter is required for Firefighting.

Total volume of storage =10700 litter+1070litter = 11770littre use 12000 litter of tank storage.

The storage capacity of the system is combined system which means the system of water supply line is pumping from the ground reservoir to the elevated tank.

The elevated tank storage is 33% of the total daily storage capacity and the ground reservoir is 67% of the total daily storage capacity of tanks.

Ground reservoir =67%*12000 litter =8040 ~ 8000 litter

Elevated tank = 33%*12000 litter = 3960 ~4000littre.

The installation of tanker for total storage of a building is 10000 liter among these the plumber said the ground reservoir will 5000 liter storage and the roof tank will install 5000 Littre storage but the design requirement storage capacity of a building according to local plumbing code is 12000 liter storage the ground reservoir could 8000 liter and the elevated tanker also 4000 liter this indicates that the installed storage capacity of tank does not meet the design requirments.if the installed storage capacity of a tank is below the required capacity specified from local plumbing code there will be

Inadequate water supply, one of the most immediate consequences would be shortage of water supply for the building water supply. This could lead to inconvenience; health concerns and safety.to satisfy the demand additional storage is required.

4.3.1.2 Design of pump main and pump set for building B

For 4000littrestorage the filling time required is assumed to be 1hrs because for small tank storage we use filling time of the roof tank 1hrs to 3hrs and the big tanks used 3hrs to 6hrs.

Volume of storage in many ways less than 5000littre it is small tank greater than 5000littre is big tank storage.

For pumping main the velocity of flow is 0.6 m/s to 3m/s in this case take 1.8m/s.

From governing formula of continuity equation

Discharge of (Q) = area of pipe (A) x velocity of flow (V) but

Q = Volume of storage/Time

$Q = 4m^3/1hr = 4m^3/hr$.

1hr = 3600sec

$Q = 4\ m^3/3600sec = 0.0011m^3/sec$

The rate of flow in a pumping main is $0.0011m^3/s$ to fill the elevated tanker in 1hr with in 1.8m/s velocity of flow.

Q = AV

$0.0011m^3/sec$ = A x 1.8m/s, A = $0.0006m^2$

Diameter of pumping main is $A = \pi D2/4$

$D^2 = 4A/3.14 = 4*0.00055m^2/3.14 = 0.0007m^2$

D =√0.0007m2 = 0.0265m =26.5mm

Use 32 mm diameter pipe lines to fill 12000 litter of elevated tank for 3hr pumping as raiser.

1.2.1 Design of pump sets

Pump set head = $(H_1+H_2+H_3+H_4+H_{5)}$

Head loos due to friction is calculated by using Hazen William's equation

$H_1 = 0.029049*Q_k^{1.851851}$

$Q_{k\,=}$ (0.0011*1000littre/s)*(24*60*60 s/day)/1000 = 95.04kilo litter/day

H_f1000m = $0.029049 * 95.04^{1.851851}$ = 133.64m

Vertical length of pumping main = 4*16 +6 = 70meter

Ground + 15 floors having 4 m height of each floor

Horizontal length for connection of pump set 7m the total length of pumping main is 77m.

H_f1000m = 133.64m

H_f 77m = x

Using simple mathematical cross multiplication we get head loos due to friction by substituting the values in the general equation of Hazen William formula x = 133.64*77/1000, x=10.3m

Friction loss is 10.3 m

H_2 = Head loss due to fitting

First counting the total number of fittings used for the installation of pumping main riser pipe to supply water to the elevated tanks.

Table 31: head loos due to fitting for building B

Item number	Name of fitting	Quantity of fitting	Unit Rate of loss m	Total loss m
1	Gate valve	2	0.5	1
2	Check valve	2	0.5	1
3	Union	3	1.5	4.5
4	Adapter	4	0.5	2
5	Socket	17	0.5	8.5
6	Elbow	9	0.5	4.5
7	Total loss due to fitting			18.5

Total head loss due to fitting = 1m+1m+1.5m+2m+8.5m+4.5m =18.5m

H_3 = total height to which water is to be lifted

64+6 =70m

H_4 = discharge head =2m

H_5= pump loss = 2m

Total pump head is 10.3m+18.5m+70+2+2 =102.8m

Pump discharge = 1.1littre/sec

Total head = 102.8m

Power of pump set = discharge x acceleration due to gravity x total head/efficiency

1.1 x 9.81 x 102.8 x100/65 = 1706.64 watt

Power =1.71 kilo watts

1 horse power = 0.746 kilo watt

Horse power of pump = 1.71/0.746 =2.29 Hp, use two pump sets of 2.29 Hp out of which one is standby to pump quantity of 1.1lit/sec against a head of 102.8m.

In order to make water distribution for this building accessible to office users in a proper manner, the size of the pump installed to push or lift water from the lower level (ground reservoir) water tank to the roof tanker at 1.11 lit/sec discharges should require 2.29 horse power of pump. If the installation pump is above 2.29HP it leads to high cost for pump purchase and operation. On the other hand, if the installation of pump is less than 2.29HP.eventhough, the purchase cost of pump will reduced, but it has lack of power or efficiency to lift the water and the water does not flow properly to the elevated tank ,shortage of water the bath room will cause the smell and the users to be exposed to diseases. Therefore, according to the design requirements of plumbing code two pumps of 2.29 horse power to 102.8 m head at 1.11lit/sec of water to lift and fill the roof tank should be installed one is standby.

4.3.1.3. Design and installation of vertical pipe size for building B

1 .For male bath room determination of vertical riser from out let of tank to 15th floor pipe diameters

Table 32: pipe size requirement based on plumber's chart for building B

Item number	Name of fixture	Quantity of fixture	Pipe size mm	Number of equivalent pipe size 15mm
1	Water closet	30	50	23
2	Hand wash basin	60	32	5.9
3	Urinal	15	32	5.9

7	Total	34.8

Total = 34.8 use 60mm diameter pipe for riser

Check the velocity of flow of pipe in a limited interval of 0.6m/s minimum and 3m/s maximum it should be between the intervals.

Using Probability equation loading rate of fixtures and flow rate check the velocity of flow in a pipe.

$Q = 0.25\sqrt{(Z1 + Z2 + Z3 + \cdots + Zn)}$

Z = (4.32x30) + (0.5x60) + (15x0.5) + = 167.1

$Q = 0.25\sqrt{167.1}$ = 3.23 litter/sec

Q = AV

$V = \frac{4*Q}{\pi \quad D^{\wedge}2} = \frac{4*3.23}{3.14*0.06^2*1000} = 1.143$ m/s it is safe use 60mm diameter pipe as the main riser.

Table 33 vertical water supply pipe size for building B male bath room

Description of floors	Diameter mm		Design flow rate l/s	Design Velocity m/s	Remarks
	installed	Designed			
Roof tank-15th	50	60	3.23	1.14	Below design
15th -14th	50	60	3.12	1.1	Below design
14th -13th	50	60	3	1.06	Below design
13th -12th	50	60	2.89	1.02	Below design
12th-11th	50	60	2.77	0.98	Below design
11th -10th	50	60	2.64	0.934	Below design
10th -9th	50	60	2.5	0.88	Below design
9th -8th	50	60	2.36	0.83	Below design

8^{th} -7^{th}	50	60	2.2	0.78	Below design
7^{th} -6^{th}	50	60	2.04	0.72	Below design
6^{th}-5^{th}	50	60	1.87	0.66	Below design
5^{th} -4^{th}	50	50	1.67	0.85	Below design
4^{th} -3^{rd}	40	50	1.445	0.74	Below design
3^{rd} -2^{nd}	40	40	1.4	1.11	Ok
2^{nd} -1^{st}	32	32	0.00082	1.04	Ok

The installation of water supply line of the riser does not meet the minimum design requirements of plumbing code as the table above shows that the installation pipe is undersized it does not adhering to the necessary codes and standards. Due to under sized water supply pipe lines the following problems could occur.

Safety concern problems in adequate or poor installation of the water supply line could poses safety risk for building occupants.

Functionality problems the under sized water supply system leads to insufficient water supply ,low pressure in critical areas and un equal distribution of water for the building customers.

4.3.1.5. Vertical riser pipe size for building B female bath room

A. vertical riser pipe diameter

Diameter vertical riser pipe from roof tank to 15^{th} floor

Determination of pipe size diameter for vertical riser Using plumber’s chart

Table 34: vertical riser determination of building B female bath room

Item number	Name of fixture	Quantity of fixture	Pipe size mm	Number of equivalent pipe size 15mm
1	Water closet	30	50	23
2	Hand wash basin	30	32	5.9

3	Kitchen sink	10	40	12
7	Total			40.9

Total = 40.9 use 60 mm diameter pipe

Z = (4.32x30) + (0.5x30) + (10x1) = 154.6

Q = $0.25\sqrt{154.6}$ = 3.11 litter/sec = 0.00311 m^3/s

Q = A V

V = $\frac{4*Q}{\pi \quad D^{\wedge}2} = \frac{4*3.11}{3.14*0.06^2*1000} = 1.1$ m/sit is safe use 60mm diameter pipe as the main riser

Following these entire step pipe diameter requirements of main riser for each floor is generalized as table below.

Table 35 water supply pipe size of female bath room for building B

Description of floors	Diameter mm		Design Flow rate l/s	Design Velocity of flow m/s	Remarks
	Installed	Designed			
Roof tank-15th	25	60	3.11	1.1	Below design
15th -14th	25	60	3.99	1.06	Below design
14th -13th	25	60	2.87	1.05	Below design
13th -12th	25	60	2.77	0.98	Below design
12th-11th	25	60	2.65	0.94	Below design
11th -10th	25	60	2.52	0.89	Below design
10th -9th	25	60	2.38	0.842	Below design
9th -8th	25	60	2.24	0.79	Below design
8th -7th	25	50	2.08	1.06	Below design

7th -6th	25	50	1.92	0.98	Below design
6th-5th	25	50	1.73	0.88	Below design
5th -4th	25	40	1.55	1.23	Below design
4th -3rd	25	40	1.34	1.067	Below design
3rd -2nd	25	32	1.1	1.37	Below design
2nd -1st	25	25	0.77	1.6	Ok

The horizontal transmission line of female bath room water supply system is installed below the design requirements of plumbing codes.

The undersized water supply line leads

Reduced water pressure the under sized pipe restricts the flow of water, lower water pressure in the tabs, shower heads or fixture units. Lower capacity the under sized pipe limits the amount of water that can be supplied to the bath room fixtures this might not meet the needs of multiple users simultaneously especially during peak usage times. In efficiency in water usage the under sized pipes is not designed to handle large amount of water.

4.3.1.6. Horizontal transmission pipe size per floor of building B

By following the entire steps from above calculation for the determination of pipe size diameter horizontal riser for all floors is expressed as the following table below.

Table 36 horizontal water supply pipe size of bath rooms for building B

Description of floors	Diameter mm		Design flow rate l/s	Design velocity m/s	Remarks
	Installed	Designed			
1st floor	20	25	0.77	1.6	Below design
2nd	20	25	0.77	1.6	Below design
3rd	20	25	0.77	1.6	Below design
4th	20	25	0.77	1.6	Below design

5th	20	25	0.77	1.6	Below design
6th	25	32	0.815	1.01	Below design
7th	25	32	0.815	1.01	Below design
8th	25	32	0.815	1.01	Below design
9th	25	32	0.815	1.01	Below design
10th	25	32	0.815	1.01	Below design
11th	25	32	0.815	1.01	Below design
12th	25	32	0.815	1.01	Below design
13th	25	32	0.815	1.01	Below design
14th	25	32	0.815	1.01	Below design
15th	25	32	0.815	1.01	Below design

The water supply system of distribution lines in each room installation of female bath rooms in a building does not meet the design requirments due to improper design the installation of water supply system might have under estimated the water demand or the flow rate required for the bath room fixtures ,this could be due to inaccurate calculations ,in correct fixture unit selections or lack of considerations for future needs.the under sizedwater supply distribution pipe size have the following effects.

Reduced water flow the under sized water supply distribution pipe size would results in a reduced water flow rate to the bath room fixtures like sinks,showers and toilets this can lead to poor water pressure and frustrating experiences for the users.

Longer fill time wth reduced water flow it will take longer to fill up sinks,bath tubs,flushing toilets and boilers.this could be time consuming for the occupants.

Un even water distribution when the water supply line are not properly balanced some of the fixtures receive more water than others .

Potential overloading when ever the bath room fixtures have higher water demand ,the under sized water supply line might not be able to meet the required flows.this leads to potencial over loading and issues with the over all plumbing system.

Deacreases the water efficiency the lower or reduced water flow has impcts on the efficiency of water using appliances and fitures. This leads to higher water consumption and potentially higher utility bills.

To address thes issuse it is recommonded to have a professional plumber or Enginners asses the desighn and installation of water supply system and make the necessarly adjestments to ensure the bath room fixtures are properly supplied wth the required water flow and pressure.

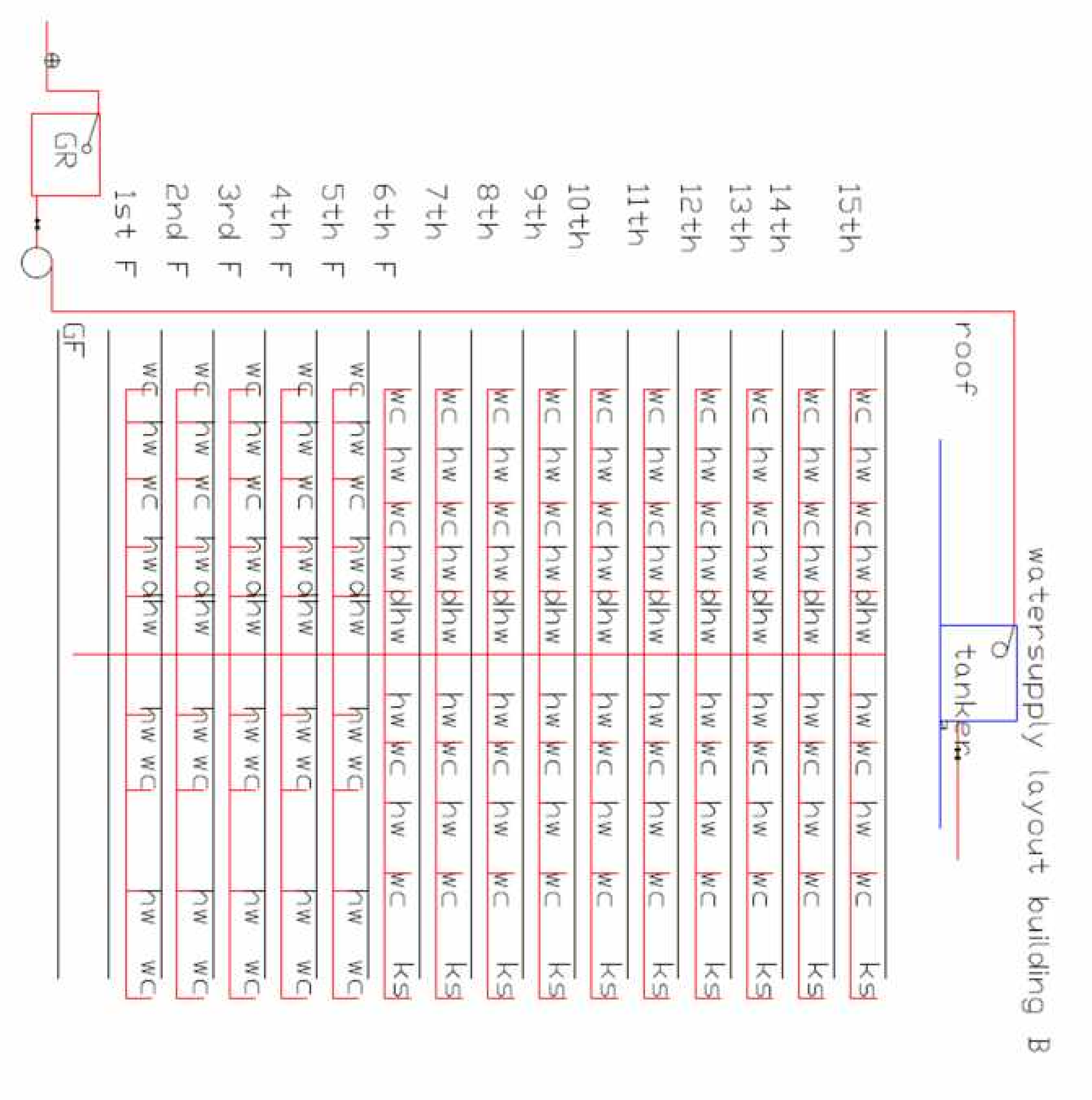


Figure 6 water supply line lay out for building B

4.3.2. Design and installation of internal waste water drainage system for building B

4.3.2.1 Number of fixtures per floor for male bath room of building B

A .For Male bath room

Wastewater drainage system can be designed by using recommended fixture unit loading system by adding all the amount of installed fixtures in each floor.

As per Ethiopian building plumbing code the amount of waste water drainage for 1stfloor amount of fixtures on the fixture unit loading rate.

Table 37 : fixture unit and loading rate for building B

Item number	Name of fixture	Quantity of fixture per floor	Loading unit rate	Total loading rate
1	Water closet	2	8	16
2	Hand wash basin	4	1	4
3	Urinal	1	4	4
4	Floor drain	4	1	4

Black water drain = 16 + 4 = 20

Grey water drain = 4+4= 8

By following this step and using the fixtures loading unit rate all amount of fixture drains for each floors are listed below the tabular form.

Table 38amount of fixture units per floor for male bath room in building B

Description of floors	BWD	GWD
1st floor	20	8
2nd	20	8

3rd	20	8
4th	20	8
5th	20	8
6th	20	8
7th	20	8
8th	20	8
9th	20	8
10th	20	8
11th	20	8
12th	20	8
13th	20	8
14th	20	8
15th	20	8

4.3.2.2. Slope and horizontal pipe diameter per floor of building B for male bath room

Proper diameter of waste water drainage pipe and slope is required to avoid the de-sludge of solid wastes or blockage of solid wastes inside the pipe.as per Ethiopian building plumbing code the pipe size and the required slope is listed as follows.

Table 39horizontal pipe size and slope of male bath room for building B

floor	Description	Fixture Units	Pipe size mm		slope %		velocity of sewer m/s	Remarks	
			Installed	Designed	Installed	Designed		Pipe size	Slope
1	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	8	50	65	2	2	1.45	BD	Ok
2	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	8	50	65	2	2	1.45	BD	Ok

3	BWD	8	100	100	1	1	1.39	Ok	Ok
	GWD	8	50	65	2	2	1.45	BD	Ok
4	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	8	50	65	2	2	1.45	BD	Ok
5	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	2	50	65	2	2	1.45	BD	Ok
6	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok
7	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok
8	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok
9	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok
10	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok
11	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok
12	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok
13	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok
14	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok
15	BWD	20	100	100	1	1	1.39	Ok	Ok
	GWD	9	50	65	2	2	1.45	BD	Ok

In this building the horizontal pipe installation of waste water drainage for each floor of the pipe system the slope of all pipe and waste water drainage pipe size for black water drain water drain meets the minimum design requirements of local plumbing while the grey water drain of horizontal drain per floor doesn't meet the design requirements, being undersized of grey water drain leads some issues of the building infrastructures and the occupants among this

1. **Design and installation of grey water drain**

As the table of the result shows the horizontal waste water drain of a building which drains the grey water drain does not meet the minimum design requirements of local plumbing code which means the required pipe size of grey water drain based on the plumbing code for this building is 65mm but the installation pipe size is 50mm PVC pipe which is undersized, this can leads the building infrastructure and its occupants have problems of

Blockage and clogs, a smaller pipe size for grey waste water drain might leads to more frequent blockages and clogs as the system might not be to handle the volume of grey water drain being discharged. This can results backups, overflows and foul odors.

Slow drainages system, the smaller pipe size could cause slow drainage of wastes from shower, floor drain, hand wash and other fixture. This can be inconvenient for occupants and leads to water pooling in areas such as shower.

Health and safety risks, drainage issue could create health and safety risks for occupants. The sanding water can harbor bacteria and mold growth. This can pose a risk to the health of those living or working in the building. Structural damage, if water overflows or leaks due to drainage problem which can cause damages to the building infrastructures of walls, floors and ceilings.

2. Slope and black water drain

From the table above result states that the horizontal pipe installation of the building in each floor slope of pipe and size of waste water drain of the system meets the design requirements of local plumbing code this gives both the building and the office workers.

For building

Reduce the risk of water damage, a well-designed and installation of drainage system helps to prevent water accumulation and reduce the risk of water damage, structural issues and costly repairs.

Expended life span of building components efficient wastewater drainage prevents water accumulation the building components such as walls, floors and ceilings are protected from water damage issues and can use longer time.

For office workers

Creates healthier working environment, a well-designed and installation of horizontal waste water drainage system helps prevent the spread of disease and unpleasant odors.

Increases productivity, a comfortable and healthy working environment can boost office workers productivity and overall job satisfaction.

Improve hygiene and sanitation, properly functioning flashing toilet and drainage system ensures that the waste water disposed of efficiently, maintaining a high level of hygiene and sanitation in the office.

4.3.2.3. Stack (vertical drain) of male bath room for building B

Stack is provided to drain the waste water systems from higher level of floor to the lower level of floor.

Table 40 vertical drain pipe size for male bath room of building B

Number of floor	Description	Number of fixture per floor	Discharge unit per stack	Pipe size mm		Remarks
				Installed	designed	
15	BWD	20	20	100	100	Ok
	GWD	9	9	75	65	Above design
14	BWD	20	40	100	100	Ok
	GWD	9	18	75	65	Above design

13	BWD	20	60	100	100	Ok
	GWD	9	27	75	75	Ok
12	BWD	20	80	100	100	Ok
	GWD	9	36	75	75	Ok
11	BWD	20	100	100	100	Ok
	GWD	9	45	75	75	Ok
10	BWD	20	120	100	100	Ok
	GWD	9	54	75	75	Ok
9	BWD	20	140	100	100	Ok
	GWD	9	63	75	75	Ok
8	BWD	20	160	100	100	Ok
	GWD	9	72	75	75	Ok
7	BWD	20	180	100	100	Ok
	GWD	9	81	75	100	Below design
6	BWD	20	200	100	150	Below design
	GWD	9	90	75	100	Below design
5	BWD	20	220	100	150	Below design
	GWD	8	98	75	100	Below design
4	BWD	20	240	100	150	Below design
	GWD	8	106	75	100	Below design
3	BWD	20	260	100	150	Below design
	GWD	8	114	75	100	Below design
2	BWD	20	280	100	150	Below design
	GWD	8	122	75	100	Below design
1	BWD	20	300	100	150	Below design
	GWD	8	130	75	100	Below design
Ground	BWD		300	100	150	Below design
	GWD		130	75	100	Below design

The table shows the waste water drainage system of vertical stack of a building have three results.

1. **From floor 7th up to 15th meets the design standard**

On this floor of a building the installation of wastewater drainage system of a vertical stack meets the minimum design requirements of plumbing codes. This means that the floors can ensure proper functionality and efficiency of the drainage system, adhering by the plumbing codes the installation is more likely to have adequate slope and pipe sizes to prevent issues of clogs and backup flows. Additionally compliance with plumbing codes promote safety and health standards by ensuring the waste water drain is properly contained and disposed of insanitary manner. This can helps to prevent contamination and the spread of harm full bacteria and diseases.

Meeting the minimum design requirements of plumbing codes helps with maintenance and future renovations. Following the plumbing codes when installing the vertical stack of waste water drain leads to more reliable and long lasting plumbing systems that give functions effectively and safely.

2. **from 6th floor up to ground floor and grey water drain of 7th floor**

On this floor of a building the vertical stack of waste water drain is installed below the minimum design requirements of plumbing code standards. Due to undersized of waste water drainage systems different issues could occur in the building.

- Insufficient flow capacity the undersized wastewater drainage pipe leads to inadequate flow capacity causing waste waters to back up to fixtures, appliances and floors which results in property damage and health risks.
- Increased pressure and velocity the smaller pipe size with higher number of fixture units can leads to increase pressure and velocity of flow that can cause pipes to vibrate, pipe damage, and potentially for pipe failure.

- Clogging and blockage the undersized waste water drainage of vertical stack pipes are more potential to clogging and blockage as debris, sediments, oils and other vegetable products can accumulate more easily.
- Health and safety risk inadequate waste water drainage could leads to higher risks of health and safety due to unpleasant odors, unsanitary conditions that increases the spread of diseases.
- Higher maintenance cost the under sized pipe can fails easily and could have require frequent maintenance, repairs and replacements resulting in higher costs over the systems life span.
- Reduce property values poorly designed and installation of wastewater drainage systems of a building can have negative impact on property values which makes less attractive to potential buyers or renters.

3. **For floor 14th and 15th the grey water drainage system**

On this floor of a building the grey water drains are installed above the design requirements of plumbing code means the pipe is over sized, even though the installation pipe is over sized it can have the following conditions,

- High drainage capacity the oversized of grey water drains can accommodate higher volumes of grey water drains, which can prevent the blockage, backup flow and clogging of the drainage systems.
- Reduces risk of blockage with in larger drain pipe and small number of fixture units there is less likelihood of blockage caused by debris, sediments, hairs and small soaps in the grey water drainage pipe leading to smoother and more efficient drainage.
- Better performance an oversized drain can provide better performance in handling peak flow rate especially during heavy water usage periods. Future - proofing the installation of larger drain above the required number of fixture units have no problems to increase the addition of new fixture in the future.

  But also the oversized wastewater drainage system installation has compliances of different issues such that

- Required higher costs the installation of larger pipe size drainage requires more materials, labor and equipment costs.
- Wastage resources an oversized drain might lead unnecessary water wastages when the volume of grey water discharge is lower than the drainage capacity.
- Potential for gurgling and odor whenever the drain is significantly oversized it might not efficiently self- clean or trap water, which can leads to gurgling sounds or unpleasant odors in the drainage systems. The oversized pipe requires more space for installation this can reduces the safety and beauty of the houses.

4.3.2.4. Vent pipe size of male bath room for building B

Table 41vent pipe size of male bath room in building B

Number of floor	Description	Fixture units per floor	Discharge per stake	Combined discharge per stake	Pipe size mm		Remarks
					Installed	Designed	
1	BWD	20	20	28	75	100	Below design
	GWD	8	8				
2	BWD	20	40	56	75	100	Below design
	GWD	8	16				
3	BWD	20	60	84	75	100	Below design
	GWD	8	24				
4	BWD	20	80	112	75	100	Below design
	GWD	8	32				

5	BWD	20	100	140	75	100	Below design
	GWD	8	40				
6	BWD	20	120	169	75	150	Below design
	GWD	9	49				
7	BWD	20	140	198	75	150	Below design
	GWD	9	58				
8	BWD	20	160	227	75	150	Below design
	GWD	9	67				
9	BWD	20	180	256	75	150	Below design
	GWD	9	76				
10	BWD	20	200	285	75	150	Below design
	GWD	9	85				
11	BWD	20	220	314	75	150	Below design
	GWD	9	94				
12	BWD	20	240	343	75	150	Below design
	GWD	9	103				
13	BWD	20	260	372	75	150	Below design
	GWD	9	112				
14	BWD	20	280	401	75	150	Below

	GWD	9	121				design
15	BWD	20	300	430	75	150	Below design
	GWD	9	130				

The installed combined vent system of waste water drainage for male bath rooms of a building does not meet the minimum design requirements of plumbing code. The combined vent is installed under sized. Due to undersized ventilation pipe the building might have critical problems based on the plumbing issues.

- The undersized combined vent pipe can leads to causes sewer gases to enter the bath rooms through the fixtures units like toilet, sink and showers which can results unpleasant odors and health hazards.
- Slow drainage a smaller vent pipe restricts the flow of waste water systems this again leads gurgling sounds, potential to backup flow in the bath room fixture units.
- Potential health risks in extreme case an undersized combined vent pipe can leads to sewage backups which can contaminate the bath rooms and pose health risks to occupants.

It is essential that the combined vent must be sized correctly based on the minimum design requirements of plumbing codes to avoid such problems and to ensure safe, functional. Hygienic bath room environment and protect the building structures from damage.

4.3.3. Design and installation of external waste water drainage for building B

4.3.3.1 Design and installation of septic tank

Table 42 design and installation of septic tank for building B

Description of dimensions for septic tank	Measured values in meter		Remarks
	Installed	Designed	Approximately

Length	7.78	7.8	Ok
Width	3.86	3.9	Ok
Depth	3.63	3.6	Ok
Length 1st compartment	5.18	5.2	Ok
Length 2nd compartment	2.6	2.6	Ok
Distance to baffle wall	No	1.56	Impossible to decide

As the table shows that installation and design of dimension of septic tank meets the design requirements of plumbing code but not properly design and install distance to baffle wall of septic tank, meeting the minimum design requirements for a septic tank installation in a correct dimensions have the following advantages.

- Proper capacity, meeting the design requirement ensures the septic tank has the appropriate capacity to handle wastes from the building, this prevents overflow and reduce the risk of contamination nearby water sources.
- Efficient decomposition, adequate size and dimensions ensure that solid wastes in the tank decomposes properly, which leads to fewer odors, less maintenance and longer lifespan for the system.
- Enhanced environmental protection, well- designed and installation septic tank system minimizes the potential for contamination of ground water and nearby water sources, which is essential to protect local ecosystem and public health.
- Reduce operational cost; a properly designed and installed dimension of septic tank requires less maintenance, repair and replacement, which can save money and time in the long run.
- Increase property value, meeting the design requirements of septic tank and ensuring proper function of a septic tank increases property values of a system.
- Improve occupant satisfaction, a proper design, install and functioning of septic tank minimizes odors, reduce risk of blockage or over flow and maintain an acceptable level of hygiene for building occupants.

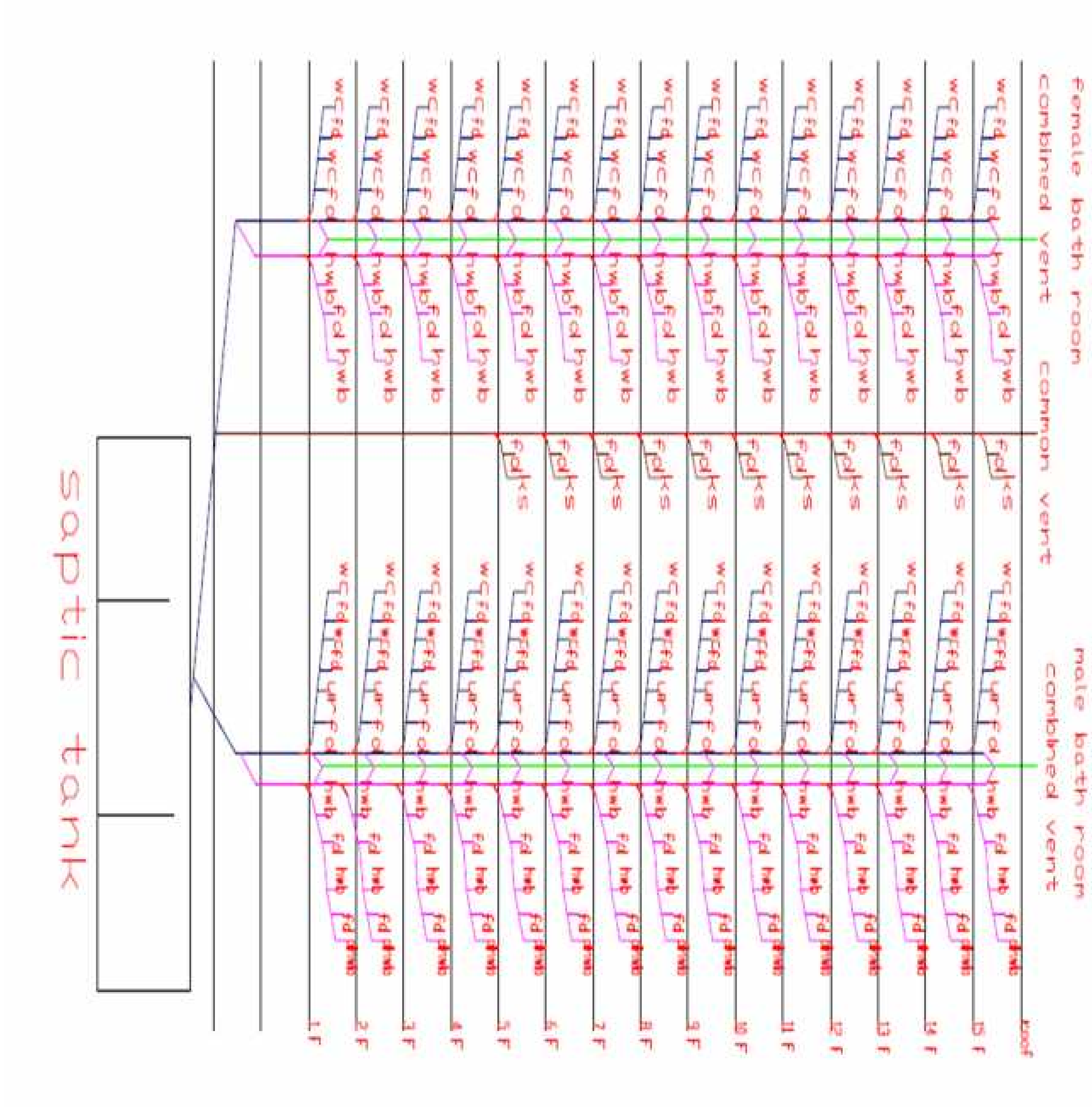


Figure 7 waste water drainage layout of building B

4.3.4. Design and installation of roof storm water drainage for building B

For all rain water design purpose the return period and duration is assumed for 10 years and 5 minutes respectively.

The top area of the building has no roof the roof is finished as slab with covered or lined in water proof chemical in a rectangular shape having the measured value of length and width

Length = 30m

Width = 15m

Area of surface = L x W

$30x15 = 450m^2$

I = 143mm/ hr. Use 6inch/hr. Area of roof $=450m^2$ one square foot = 0.0929 m^2

Area of roof = $\frac{450}{0.0929}$ = 4844inch/foot

From the table diameter verses intensity of rainfall determine the diameter of drainage pipe using roof area of 4844inch / foot for 6inch/hr. using linear interpolation.

At 6inch/foot of rain fall intensity

Roof area inch/foot	Pipe in inch
3070	4
4844	x
5765	5

$\frac{5765-3070}{4844-3070} = \frac{5-4}{x-4}$ x = 4.66 inch use 4 inch for roof storm water drainage for high rise building.

100 mm pipe can discharge 2.3 l/s recommended IBC

From rational formula

$Q = \frac{CIA}{3600}$ C = 1 for flat roof

I = 143mm/hr.

$A = 450\ m^2$

$Q = \frac{1x143x450}{3600} = 17.875\ l/s$

Number of down pipe = $\frac{17.875\ l/s}{2.3l/s}$ = 7.7 use 8 number of down pipe

The down pipe is installed in the longest side of both sides the length

4 down pipe should install in the 1st longest side of the building and the other remaining 4 also installed in the next longest side of a building.

Because the roof is sloped towards the longest side.

Length of down pipe installation = $\frac{30\ m}{4}$ = 7.5m so for each 7.5m on the longest side of the roof down pipe is installed.

The required number of down pipes for drainage roof storm water is 8 based on the minimum design requirements of local building plumbing codes but the installed number of down pipes are 6 it shows that the installed down pipe for roof storm water drainage does not meet the design requirements, the insufficient number of down pipes could have several problems of building infrastructure, building occupants and the environment among these,

1. **for building infrastructures**

- Insufficient drainage capacity, with in the fewer down pipes than the required number, the building roof storm water drainage system could not be able to handle the full volume of roof rain water runoff this can leads to water accumulation on the roof and potential to leakage or water intrusion in to the building.
- Over loading of the drainage system, the limited number of down pipes may causes the existing drainage system to become overwhelmed or over tension, leading to blockage, backups and potential to damage pipes or drainage infrastructures.

- Structural damage, excessive water buildup on the roof or around the building foundation can cause water damage, erosion and structural deterioration over time.

2. **Building occupants**

- Water intrusion and leaks, the insufficient drainage can results in water leaks or seepages in to the building potentially causing water damage to the interior infrastructures and furniture.
- Health and safety concern, the water accumulation can creates an environmental conductive to the growth of mold and mildew which can have adverse effects on the health and well-being of the building occupants.

3. **Environmental impact**

- Increased storm water runoff, with fewer down pipes the excesses storm water may not be properly channeled and could lead to increase runoff which can contribute to erosion, sedimentation and potential flooding in the surrounding area.
- Strain on municipal drainage, the in adequate building level drainage may put additional strain on the municipal storm water drainage infrastructures potentially causing issue for the wider community.

To address these problems, it is important to ensure that the building roof storm water drainage system is designed and installed in accordance with the relevant plumbing building codes and standards with the appropriate number of down pipes to handle the expected rain water load, regular maintenance and inspection of the drainage system which can also prevent issues and ensure proper functioning,

4.4 .Design and installation of plumbing system for building C

4.4.1. Design and installation of water supply system for building C

4.4.1.1. Design of storage capacity of tank or reservoir

Table 43 bed room quantity of building C code 1

Bed room from 3rd -13th typical Total bed rooms per floor						
Lay out	A	B	C	D	E	Total
1 Bedroom	-	-	1	1	-	2
2 Bed room	-	1	-	-	1	2
3 Bed room	1	-	-	-	-	1

The building is multi use it has shop from the ground to 2nd floor and residential from 3rd to 13th floor.

Table 44 number of shop in a building C code 1

Name	Ground floor	1st floor	2nd floor
Shop	5	5	5
Total			15

Estimation of number of people lived

One bed room = two bed room = three bed room = shop = 5 people

For one bed room = 2 x 11 x 5 =110

For two bedroom = 2 x 11 x5 = 110

For three bed room = 1 x 11 x 5 = 55

For shop = 5 x 3 x 5 = 75

Total population served = 110+110+55+75 = 350

Per capital demand according to AAWSA design manual = 110 l/c/d

Q = 350 x 110 = 38500 l/d

Table 45average water demand for building C code 1

Item number	Description	Unit	Amount
1	Population	No	350
2	Per capital demand	l/cap/day	110
3	Domestic demand (Dd)	l/day	38500
4	Non Domestic demand (NDd) = 20% Dd	l/day	7700
5	Non- Revenue water demand = 15 % Dd	l/day	5775
6	Total Average demand	l/day	51975

The building tanker should have store water for 3 days. The design is 3 day storage

V = Q * T

= 51975 l/day * 3 day = 155925 liter say 156000 liter

For fire fighting

= 10% V = 0.01*156000 = 15600 liter

The building use combined storage of firefighting and water demand

Total volume of water required is = 156000 liter +15600 liter = 171600 liter

Since it is combined storage it has ground reservoir and elevated tanker.

The ground reservoir is 67%V and the elevated tank is 33%V

Ground reservoir = 0.67 * 171600 liter = 114972 use 115000 liter reservoir

Elevated tanker = 0.33 * 171600 liter = 56628 use 57000 liter tanker for the roof.

As the plumber said installation of tanker total storage is 50000 liter among these the plumber said the ground reservoir will 30000 liter storage and the roof tank will install 20000 Littre storage but the design requirement storage capacity of a building according to local plumbing code is 171600 liter storage of this the ground reservoir 115000 liter and the elevated tank 57000 liter storage this indicates that the installed storage capacity of tank does not meet the design requirements .if the installed storage capacity of a tank is below the required capacity specified from local plumbing code there will be

Inadequate water supply, one of the most immediate consequences would be shortage of water supply for the building water supply. This could lead to inconvenience; health concerns and safety.to satisfy the demand additional storage is required.

Design of pipe diameter to fill the roof tanker from the ground reservoir to elevated tanker.

Assume filling time 3hrs and velocity of flow 1.8m/s

$Q = \frac{V}{T}$ V volume of elevated tanker in cumec

T filling time in second

$Q = 1.8 m/s = \frac{5700\ cumec}{1000x3x60x60\ sec} = 0.0053\ m^3/s$

From continuity equation

Q = A x V V is velocity of flow in m/s

A is cross-sectional area of pipe in m^2

$A = \frac{Q}{V} = \frac{0.0053m3/s}{1.8m/s} = 0.0029m^2$

$A = \frac{\pi D^2}{4} = D^2 = 4*0.0029m^2/3.14 = 0.0037m^2$

D =√0.0037m2 = 0.061m which is 61mm use 65mm diameter of pipe as riser to fill the elevated tank.

4.4.1.2. Design of pump main and pump set

As Hazen Williams equation head loss due to friction,

$H_f 1000m = 0.029049*Q_k^{1.851851}$ Where, H_f= friction loss in meter

Q_k = discharge in kilo litter/day

$Q_k =$ (0.0053 *1000littre/s)*(24*60*60 s/day)/1000 = 457.92 kilo litter/day

$H_f 1000m = 0.029049 * 457.92^{1.851851} = 2457.63$ m

3m Basement +Ground + 13 floors having 4 m height of each floor

Vertical length of pumping main = 4*14 +4 +3 = 63 meter

Horizontal length for connection of pump set 5m the total length of pumping main is 68m.

$H_f 1000m = 2457.63$ m

H_f 68m = x xm = 2457.63 *68/1000, x=167.1 m

H1 = Friction loss is 167.1 m

H_2 = loss in fitting and valves 0.5m per each fitting

Table 46: head loss due to fitting for building C1

Item number	Name of fitting	Quantity of fitting	Unit Rate of loss m	Total loss m
1	Gate valve	2	0.5	1
2	Check valve	2	0.5	1
3	Union	3	1.5	4.5
4	Adapter	4	0.5	2
5	Socket	17	0.5	8.5
6	Elbow	5	0.5	2.5
7	Total loss due to fitting			16.5

H_3 = total height in m to where water is lifted

H_3 = 63 m

H_4 = discharge head (2m)

H_5 = pump loss (2m)

Total head loos = 167.1 + 16.5 + 63 + 2 + 2 = 250.6 m

Power of pump set = discharge x acceleration due to gravity x total head/efficiency

$= 5.3 * 9.81m/s^2*250.6\ m/65\% = 20045.3$ watt

Power =20.045 kilo watts

1 horse power = 0.746 kilo watt

Horse power of pump = 20.045 /0.746 =26.87 Hp, use two pump sets of 26.87 Hp out of which one is standby to pump quantity of 5.3 lit/sec against a head of 250.6m.

In this twins or a two story building until I finished my data collection on site the installation of entire plumbing system had not been completed, so it was not equipped with a pump that pushes water from the ground reservoir to the elevated tank, but according to the minimum design requirements of plumbing code for this twins multi use building ,to make water distribution equally accessible to the users ,two pump sets of 26.87 horse power pump against 250.6 m head to fill the roof tanker by 5.3 lit/s should be installed. Although this condominium building is a twins building, the water line is different and it has different water tankers so that 4 pumps of 26.87horse power should be installed in the whole buildings separately. This means when two are on working the other two is stand by

4.4.1.3. Design and installation of vertical pipe size for building C

Using plumber's chart

Table 47 : vertical pipe size as per plumber's chart for building C1

Item number	Name of fixture	Quantity of fixture	Pipe size Mm	Number of equivalent pipe size 15mm
1	Water closet	66	50	23
2	Hand wash basin	66	32	5.9
3	Shower head	66	65	42
4	Kitchen sink	55	50	23
7	Total			93.9

Total = 93.9 use 60 mm diameter pipe

Check for velocity of flow using probability equation

Z = 66*4.32 + 66*0.5 + 66*1 + 55*1 = 439.12

Q = $0.25\sqrt{439.12} = 5.24$ lit/s or Q = 0.00524m^3/s

A = $\frac{\pi D^2}{4} = \frac{3.14*0.06^2}{4} = 0.0028m^2$

V = $\frac{Q}{A} = \frac{0.00524m3/s}{0.0028m2} = 1.87$m/s it is safe use 60mm diameter pipe

By following these entire steps all the pipe diameter requirements of vertical riser is listed the table below.

Table 48 water supply riser pipe size building C code 1

Description	Pipe diameter mm		Design Flow rate Q l/s	Design Velocity of flow V m/s	Remarks
	Installed	Designed			
Roof tank -13th	50	60	5.24	1.87	Below design
13th – 12th	50	60	4.99	1.78	Below design
12th -11th	50	60	4.75	1.69	Below design
11th – 10th	50	60	4.47	1.59	Below design
10th – 9th	50	60	4.18	1.49	Below design
9th – 8th	50	60	3.87	1.38	Below design
8th -7th	50	60	3.53	1.26	Below design
7th -6th	50	60	3.16	1.13	Below design
6th -5th	50	60	2.73	0.975	Below design
5th -4th	40	60	2.23	0.796	Below design
4th -3rd	32	50	1.58	0.81	Below design

The results of the table shows that the installation of water supply line of a condominium building main riser pipe does not meet the design standards of plumbing code. The undersized pipe installation on a building leads to have

- The strong reduction of water pressure the most immediate effects of undersized water supply line is reduce water pressure at a fixture units this happens especially at peak usage times when multiple units of fixtures are using water simultaneously.

- Slow fill time of fixture units the sanitary appliances like kitchen sink, bathtubs and flashing toilets could take longer time to fill due to undersized of pipe and the higher number of fixtures.
- Inefficient appliances the appliances such as dish washers, washing machines and other sanitary appliances could not operate efficiently at all due to in sufficient water pressure of undersized pipe installation.
- Strong discomfort and frustration of occupants the reduced water pressure and reduced water flow due to undersized pipe line installation makes everyday tasks like drinking, showering, dish–washing and flushing toilets inconvenient and frustrating of the building occupants.
- The safety concern having low pressure and low flow pipe could have impacts for fire suppressions systems the sprinkler system of water could not activate properly in the case of a fire.
- Insufficient water pressure due to undersized pipe installation leads to problems with water sanitation, bacteria and other contaminants might have longer residence time in a pipes and increases health risks.
- The undersized installation of water supply line in a building have strong impact of the occupants because the occupants may need to purchase additional water pressure boosters or other equipment's to compensate the under sized pipe flow of water and needs to buy water by hauling.
- Highly improves the property value reduction an undersized water supply pipe installation cab negatively affects the buildings overall value and make it more difficult to sell or rent.
- An undersized water riser pipe creates a cascading effects of problems the lack of adequate water flow directly affects the functionality of fixture units .the comfort and safety of building occupants.

All of the above problems happened due to the undersized of water supply pipe lines addressing the issues and to reduce these problems thy should involve as soon as possible

- Replacing the existing pipes the most effective solution is to replace the undersized pipe with a larger diameter one that meets the design standards.
- Installing pressure boosters adding pressure booster can increase water pressure throughout the building, but this is temporary fix and may not address the underlined issue.

4.4.1.4. Horizontal transmission pipe diameter for each floor of building C

1. For house hold A main horizontal pipe diameter typical (3rd -13th)

Following the step above all the house hold of a building pipe diameter is listed on the following table.

Table 49 horizontal pipe size for building C code 1

Description		House hold										
		A			B		C		D		E	
		MR	Sub-MR		MR	CBR	MR	CBR	MR	CBR	MR	CBR
			MBR	CBR								
Pipe size mm	Installed	25	20	20	25	20	25	20	25	20	25	20
	Designed	32	25	25	32	25	32	25	32	25	32	25
Flow rate l/s		0. 9	0. 6	0. 6	0.65	0. 6	0. 65	0. 6	0. 65	0. 6	0. 65	0. 6
Flow velocity m/s		1.125	1.22	1.22	0.8	1.22	0.8	1.22	0.8	1.22	0.8	1.22
Remarks		BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD

As the table above shows tha the result of the analysis horizontal tramsmission water supply pipe line of abuilding installation from water meter to hose hald is 25 mm and branched to each bed rooms is 20 mm as the distributon pipe size also 15 mm for all but the design reqirments of water upply pipe size for a building is sated as the table above and the distribution also not 15 mm for all fixture unites it is also stated counting fixture above the kitchen silk requres 20mm pipe size based on local plumbing codes.thes the horizontal transmission and distribution pipe size does not meet the design requirments of local plumbing code of a building this leads the buildings and its occupants have the problems of

The building problem

The undersized pipe installation might leads to reduced water pressure which causes with water supply to upper or higher floors or distant fixtures.in adequate pipe size could have exssesive water velocity which leads to pipe erossion and increases pipe brust.pumps may need to work harder to componsate for the undersized pipe which increases energy consumption and cost.

The customors problem

Low water pressure when the residents might have low water pressure making every day activity like showering,cooking and flushing toilet difficults.in adequate water supply pipe size could cause intermitent water supply issue leading to frustration and inconvenience.pipe noises,vibrations or brusts could disrupt daily life and cause distubance to residents.

In efficient water supply system can leads to increases water consumption with higher water bills for residents.in addequate water supply system could leads to issues with sanitation,hygine and even health problems if wateris not readly available for drinking,cooking and cleaning or dispose wastes.

To addres these issues it is essential reasses the buildings water supply system and ensure the installation meets the local plumbing ode reqirments.which might involves upgrading or replacing the existing pipes installing pumps or pressure boosting system.

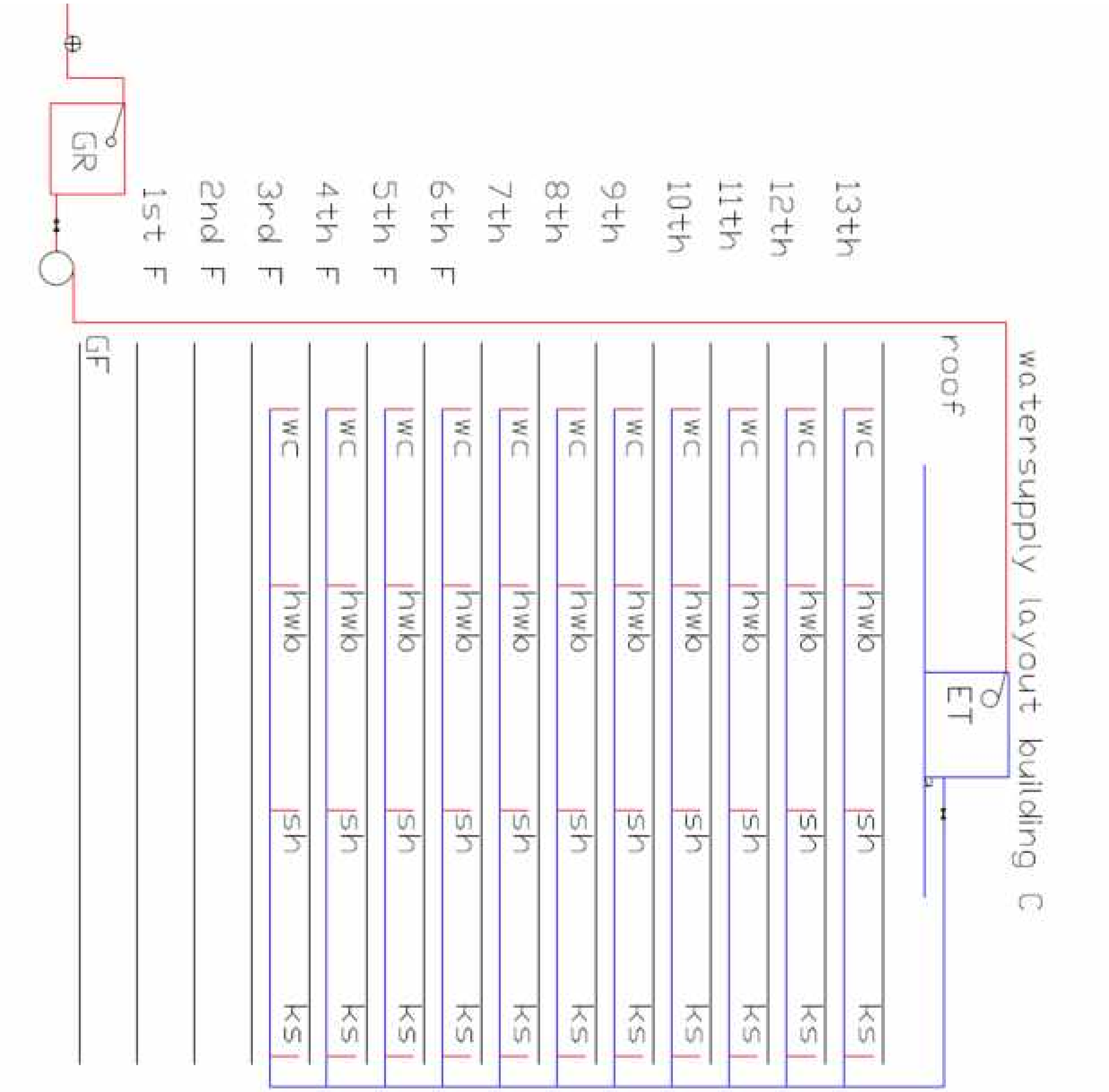


Figure 8 water supply line layout of building C

4.4.2.. Design and installation of internal waste water drainage of building C

4.4.2.1 .Number of fixture units per floor of house hold A

Table 50amount of fixture units per floor of house hold A building C code 1

Description		BWD	GWD	BrWD
3rd floor	MBR	8	4	3
	CBR	8	4	
4th Floor	MBR	8	4	3
	CBR	8	4	
5th Floor	MBR	8	4	3
	CBR	8	4	
6th Floor	MBR	8	4	3
	CBR	8	4	
7th Floor	MBR	8	4	3
	CBR	8	4	
8th Floor	MBR	8	4	3
	CBR	8	4	
9th Floor	MBR	8	4	3
	CBR	8	4	
10th floor	MBR	8	4	3
	CBR	8	4	
11th floor	MBR	8	4	3
	CBR	8	4	
12th floor	MBR	8	4	3
	CBR	8	4	
13th floor	MBR	8	4	3
	CBR	8	4	

4.4.2.2. Horizontal pipe size and slope of house hold A for building C

Table 51horizontal pipe and slope house hold A of building C code 1

Number of floor		Description	fixture units	pipe size mm		slope %		Velocity of sewer m/s	Remarks	
				Installed	Designed	installed	Designed		Pipe size	Slope
3	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
4	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
5	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok

		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
6	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
7	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
8	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
9	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok

		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
10	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
11	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
12	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
13	MBR	BWD	8	100	100	1	1	1.39	Ok	Ok
		GWD	4	50	50	2	2	1.24	Ok	Ok
	CBR	BWD	8	100	100	1	1	1.39	Ok	Ok

		GWD	4	50	50	2	2	1.24	Ok	Ok
	KR	BrWD	3	75	75	1	1	1.17	Ok	Ok
Basement		All drain	297	150	150	1	1	1.83	Ok	Ok

In this building as the table shows of results installation of horizontal waste water drainage system meets the design requirements' of local plumbing code by slope and pipe size which insure safe and functionality of the pipe systems but as I see in the installation system of UPVC pipe the plumber is not use adhesive to connect all the fitting systems. If the connection pipes with fittings in a waste water drainage system are not correctly sealed with adhesive or sealant several problems could arise in the building infrastructure, its occupants and environment. Some of the potential issues are

1. **Building related problem**

- Leaks and water damage, improperly sealed connections of pipe and its fitting could leads to leak which can cause water damage to the buildings infrastructure of walls and floors.
- Corrosion and pipe damage, leads can also leads corrosion of pipe and fitting which reduces their life spans and potentially causing catastrophic failure.
- Clogs and blockages, debris and sediments can enter to the system through unsealed connection of pipes and the clogs and blockages could leads backups and overflows.

2. Occupant related problem

- Health risk, leaks and backups can create unsanitary conditions exposing occupants to waste water borne pathogens and diseases.
- Unpleasant odors and noise, leaks and clogs can cause unpleasant odors and noise creating an uncomfortable living and living occupants.

- Disruption of services, backups and overflows could leads to disruptions in waste water service causing inconvenience and distress to occupants.

3. Environmental related problems

- Water pollution leaks and spills can contaminate soil, surface water and ground water, harming aquatic ecosystems and wild life.
- Air pollution, improperly functioning of sealant waste water drainage system pipe of a building can release methane and other greenhouse gases contributing to climate change.
- Soil erosion, leaks on pipe can cause soil erosion leading to over sedimentation in water way and damages to surrounding landscape.

To mitigate these risks, it is essential to ensure that all connections in the waste water drainage systems pipe lines of a building should properly sealed with adhesive or sealant.

4.4.2.3. Stack of household A for building C

Stack or vertical drain is provided to remove the waste water drain the fixture units to the required septic tank always provided from the higher elevation to the lower elevation of a building.

Table 52stack pipe size house hold A building C code 1

Number of floor		Description	fixture units	discharge per stack	Pipe size mm		Remarks
					Installed	Designed	
13	MBR	BWD	8	8	100	100	Ok
		GWD	4	4	75	50	Above design
	CBR	BWD	8	8	100	100	Ok
		GWD	4	4	75	50	Above design

	KR	BrWD	3	3	75	75	Ok
12	MBR	BWD	8	16	100	100	Ok
		GWD	4	8	75	50	Above design
	CBR	BWD	8	16	100	100	Ok
		GWD	4	8	75	50	Above design
	KR	BrWD	3	6	75	75	Ok
11	MBR	BWD	8	24	100	100	Ok
		GWD	4	12	75	65	Above design
	CBR	BWD	8	24	100	100	Ok
		GWD	4	12	75	65	Above design
	KR	BrWD	3	9	75	75	Ok
10	MBR	BWD	8	32	100	100	Ok
		GWD	4	16	75	65	Above design
	CBR	BWD	8	32	100	100	Ok
		GWD	4	16	75	65	Above design
	KR	BrWD	3	12	75	75	Ok
9	MBR	BWD	8	40	100	100	Ok
		GWD	4	20	75	75	Ok
	CBR	BWD	8	40	100	100	Ok

		GWD	4	20	75	75	Ok
	KR	BrWD	3	15	75	75	Ok
8	MBR	BWD	8	48	100	100	Ok
		GWD	4	24	75	75	Ok
	CBR	BWD	8	48	100	100	Ok
		GWD	4	24	75	75	Ok
	KR	BrWD	3	18	75	75	Ok
7	MBR	BWD	8	56	100	100	Ok
		GWD	4	28	75	75	Ok
	CBR	BWD	8	56	100	100	Ok
		GWD	4	28	75	75	Ok
	KR	BrWD	3	21	75	75	Ok
6	MBR	BWD	8	64	100	100	Ok
		GWD	4	32	75	75	Ok
	CBR	BWD	8	64	100	100	Ok
		GWD	4	32	75	75	Ok
	KR	BrWD	3	24	75	75	Ok
5	MBR	BWD	8	72	100	100	Ok
		GWD	4	36	75	75	Ok
	CBR	BWD	8	72	100	100	Ok
		GWD	4	36	75	75	Ok

	KR	BrWD	3	27	75	75	Ok
4	MBR	BWD	8	80	100	100	Ok
		GWD	4	40	75	75	Ok
	CBR	BWD	8	80	100	100	Ok
		GWD	4	40	75	75	Ok
	KR	BrWD	3	30	75	75	Ok
3	MBR	BWD	8	88	100	100	Ok
		GWD	4	44	75	75	Ok
	CBR	BWD	8	88	100	100	Ok
		GWD	4	44	75	75	Ok
	KR	BrWD	3	33	75	75	Ok
2	MBR	BWD		88	100	100	Ok
		GWD		44	75	75	Ok
	CBR	BWD		88	100	100	Ok
		GWD		44	75	75	Ok
	KR	BrWD		33	75	75	Ok
1	MBR	BWD		88	100	100	Ok
		GWD		44	75	75	Ok
	CBR	BWD		88	100	100	Ok
		GWD		44	75	75	Ok

	KR	BrWD		33	75	75	Ok
Basement				297	150	150	Ok

The result of the table shows that the waste water drainage system of a stack of a building has two result the 1st result states that the installation of waste water drainage of stack is meets the design requirements of plumbing codes while the 2nd result states that installation of grey water drain is above the design requirement which is oversized. All of the results have the following out comes.

1. **From floor 10th to 13th the grey water drains are oversized**

As the result shows that the contractor or plumber installed the pipe size typically without considering the number of fixtures and the design standard this leads to oversized the pipe line system .the oversized installed pipe systems of the grey water drain can have the effects of

- Wasted resources and expenses an oversized installation of grey waste water drain requires more resources such as materials, labor and equipment's which can leads the higher costs for the property and the building owners or managers.
- Unpleasant odor and sights inadequate and oversized installation of waste water drainage pipe can leads to unpleasant odor and sight creating unhealthy and uncomfortable environment for the building occupants.
- Unnecessary complexity the oversized systems might introduce unnecessarily complexity in to the plumbing system of the building potentially making to harder to maintain and damage.an oversized waste water drainage system might require more regular maintenance and could potentially be at great risk of failures or malfunctions due to the larger diameter and complexity of the system.
- It could have negative environmental impact if an oversized waste water drainage installation results in excessive use of water resources it can have a negative

impact on the environment especially if it leads to increase demand for water supply.

While an oversized wastewater drainage installation might initially seems advantageous in meeting the design requirements as compared to undersized pipe, it is important to consider these potential effects with such projects of a building, Proper planning and sizing can helps to ensure that the system meets its intended purpose without causing unnecessary issues or costs down the line.

2. The overall vertical drain and grey water drain from floor 9th to basement

In this building the waste water drainage installation of a vertical drain for each floors and grey water drains from the 9thfloor to the basement meets the minimum design requirements of plumbing code, meeting the minimum design requirements of the plumbing code for the installation of waste water drainage in a vertical pipe of a building offers several issues and advantages for both the buildings and its occupants.

- Safety and health ,proper drainage system helps to ensure the safe removal of waste water from the fixtures of a building, reducing the risk of water damages, mold growth and potential health hazard associated with standing water and sewage backups.
- Compliance, adhering to the plumbing code ensures that the building meets legal requirements and building codes of regulations.
- Durability and longevity, a well-designed drainage system is more durable and less prone to issues of clogs, leaks and corrosion which leading to reduced maintenance and repair cost over time.
- Functionality and efficiency, the adequate waste water drainage system prevents blockages and backup flows, ensuring that the waste water drain flows smoothly and efficiently away from the building.
- Comfort and convenience, the proper waste water drainage system contributes to a confortable indoor environment by reducing odors, moistures, and potential water damages enhancing the overall quality of life for the occupants.

In general , meeting the minimum design requirements of the plumbing code for waste water drainage in a building have the benefits of both the building structure and its occupants by ensuring safety ,compliance, durability, functionality and comfort.

4.4.2.4. Vent pipe size for house hold A of building C

Brown water drain vent is installed by common ventilation method where as both black water drain and grey water drains are installed by combination vent method.

Table 53 vent pipe for house hold A building C code 1

Number of floor		Description	Fixture Units	Discharge on stack	Total for stack	Pipe size mm		Remarks
						installed	Designed	
3	MBR	BWD	8	8	12	75	75	Ok
		GWD	4	4				
	CBR	BWD	8	8	12	75	75	Ok
		GWD	4	4				
	KR	BrWD	3	3	3	75	50	Above design
4	MBR	BWD	8	16	24	75	100	Below design
		GWD	4	8				
	CBR	BWD	8	16	24	75	100	Below design
		GWD	4	8				
	KR	BrWD	3	3	6	75	50	Above

								design
5	MBR	BWD	8	24	36	75	100	Below design
		GWD	4	12				
	CBR	BWD	8	24	36	75	100	Below design
		GWD	4	12				
	KR	BrWD	3	6	9	75	65	Above design
6	MBR	BWD	8	32	48	75	100	Below design
		GWD	4	16				
	CBR	BWD	8	32	48	75	100	Below design
		GWD	4	16				
	KR	BrWD	3	9	12	75	75	Ok
7	MBR	BWD	8	40	60	75	100	Below design
		GWD	4	20				
	CBR	BWD	8	40	60	75	100	Below design
		GWD	4	20				
	KR	BrWD	3	12	15	75	75	Ok
8	MBR	BWD	8	48	72	75	100	Below design
		GWD	4	24				
	CBR	BWD	8	48	72	75	100	Below

		GWD	4	24				design
	KR	BrWD	3	15	18	75	75	Ok
9	MBR	BWD	8	56	84	75	100	Below design
		GWD	4	28				
	CBR	BWD	8	56	84	75	100	Below design
		GWD	4	28				
	KR	BrWD	3	18	21	75	75	Ok
10	MBR	BWD	8	64	96	75	100	Below design
		GWD	4	32				
	CBR	BWD	8	64	96	75	100	Below design
		GWD	4	32				
	KR	BrWD	3	21	24	75	75	Ok
11	MBR	BWD	8	72	108	75	100	Below design
		GWD	4	36				
	CBR	BWD	8	72	108	75	100	Below design
		GWD	4	36				
	KR	BrWD	3	24	27	75	75	Ok
12	MBR	BWD	8	80	120	75	100	Below design
		GWD	4	40				

	CBR	BWD	8	80	120	75	100	Below design
		GWD	4	40				
	KR	BrWD	3	27	30	75	75	Ok
13	MBR	BWD	8	88	132	75	100	Below design
		GWD	4	44				
	CBR	BWD	8	88	132	75	100	Below design
		GWD	4	44				
	KR	BrWD	3	30	33	75	75	Ok

Under this building the contractors or plumbers tend to install the ventilation of waste water drainage system as common vent for brown water drains the drain from kitchen sink and the combination vent the pipe contains drains from black water drain flushing toilet and grey water drain which receives from bathtub, shower and hand wash basin, the results in the table above shows the installation of vent pipe system in the building have two results.

1. **The common ventilation system**

As the result shows that the installation of common vent pipe is meets the minimum design requirements of plumbing codes of a building this leads to have the effects of both the buildings and the occupants.

- A proper ventilation system prevents cross-contamination between clean and dirty waste water lines, by keeping these separation there is reduction risk of sewage backups and unpleasant odors entering to the buildings.
- A proper functioning of vent pipes of wastes from kitchen or brown water drainage system contributes to a cleaner and more hygienic environment for the

occupants of a building leads to increased satisfactions and well beings of the occupants .

- Following the design requirements of plumbing codes of a building ensures that the building meets all the necessary safety and health standards set by local authorities.

Adhering to the plumbing codes when installing common vent systems for brown waste water drainage provides a number of benefits for both the buildings infrastructures and its occupants to ensure safe, efficient and comfortable environment.

2. The combined ventilation system

On this building the result of the table shows that the installation of combined vent systems ofthe waste water drain from black water drain and grey water drains does not meet the minimum design requirements of plumbing code standards of a building, the installed vent pipe is undersized this can leads both the building structure and the occupants, these issues are

- Slow drainage systems in a pipe, when the combined vent system is undersized it can cause slow drainage in flushing toilet and showers as well as bad odors due to the buildup of waste waters in a pipe.
- Increases the risk of blockage in the pipe line, with in undersized vent system the potential for debris, soaps and other materials to accumulate in the pipes increases leading to clogging drains, this might results in costly repairs and increases maintenance requirements.
- Structural damage ,the undersized combined vent pipe prolonged moistures due to poor drainage of ventilation which can cause structural damage to a building materials such as flooring, walls and ceilings,
- Increased energy costs, insufficient ventilation pipe can causes increased demand on heating and cooling systems, leading to higher energy costs for the building occupants.

To avoid those the above listed issues it is essential to follow the local plumbing code and regulations when installing combined ventilation systems in a buildings because proper design and sized vents will ensure efficient waste removal, odor control, protection of building infrastructures and its occupants.

4.4.2.5. Number of fixture units per floor for household B, C, D, and E for building C

In this building installation of waste water drainage for all house hold House hold B,C,D and E are similar to house hold A the difference is in house hold A it has two bed rooms master bed room of waste water is included .so that the common bed room of waste water drainage system of pipe size and slope for horizontal drains per floor, vertical stack pipe size ,combined vent pipe size and common vent pipe size for all house hold installation and design is similar .the result is explained in house hold A above

The design and installations are listed below in the annex part

4.4.3. Design and installation of external waste water drainage for building C

4.4.3.1. Design of septic tank

Using similar procedure of building A above the septic tank is design using flow rate method and the installation and the design requirmentes of septic tank according to minimum plumping code requirement is given as the table below

Table 54 design and installation of septic tank for building C

Description of dimensions	Measured dimensions in meter		Remarks
	Installed	Designed	
Length	No	11	Impossible to decide
Width	No	5.5	Impossible to decide
Depth	No	4.2	Impossible to decide
Length 1st compartment	No	7.3	Impossible to decide
Length 2nd compartment	No	3.7	Impossible to decide
Distance of baffle wall	No	2.2	Impossible to decide

As the table shows above the multi-use building of the condominium has no installed septic tank to dispose the waste water drainage systems of a building.it means that there is no proper sewage system in place, means wastewater drains from flushing toilet, sinks, showers and other fixture units will flow directly in to the environment without undergoing any treatment. This can leads to several issues

- Environmental pollutions, the untreated wastewater can contaminate nearby lakes, rivers and the underground water sources the water source might be a source of water supply system.
- Health hazards, the presence of untreated sewage in the environment increases the risk of spreading disease to humans,
- Odor problems, without septic tank waste water drain unpleasant odors or bad smell can become a nuisance or problem for the building occupants, neighbors and the passers.
- Structural damage, the disposal of waste water drainage without septic tank can cause soil erosions, and flooding’s which can have structural damages in the building and infrastructures.

To address these issues the plumber or contractor should design and install appropriate septic tanks and connect the building sewages to public sewer system.

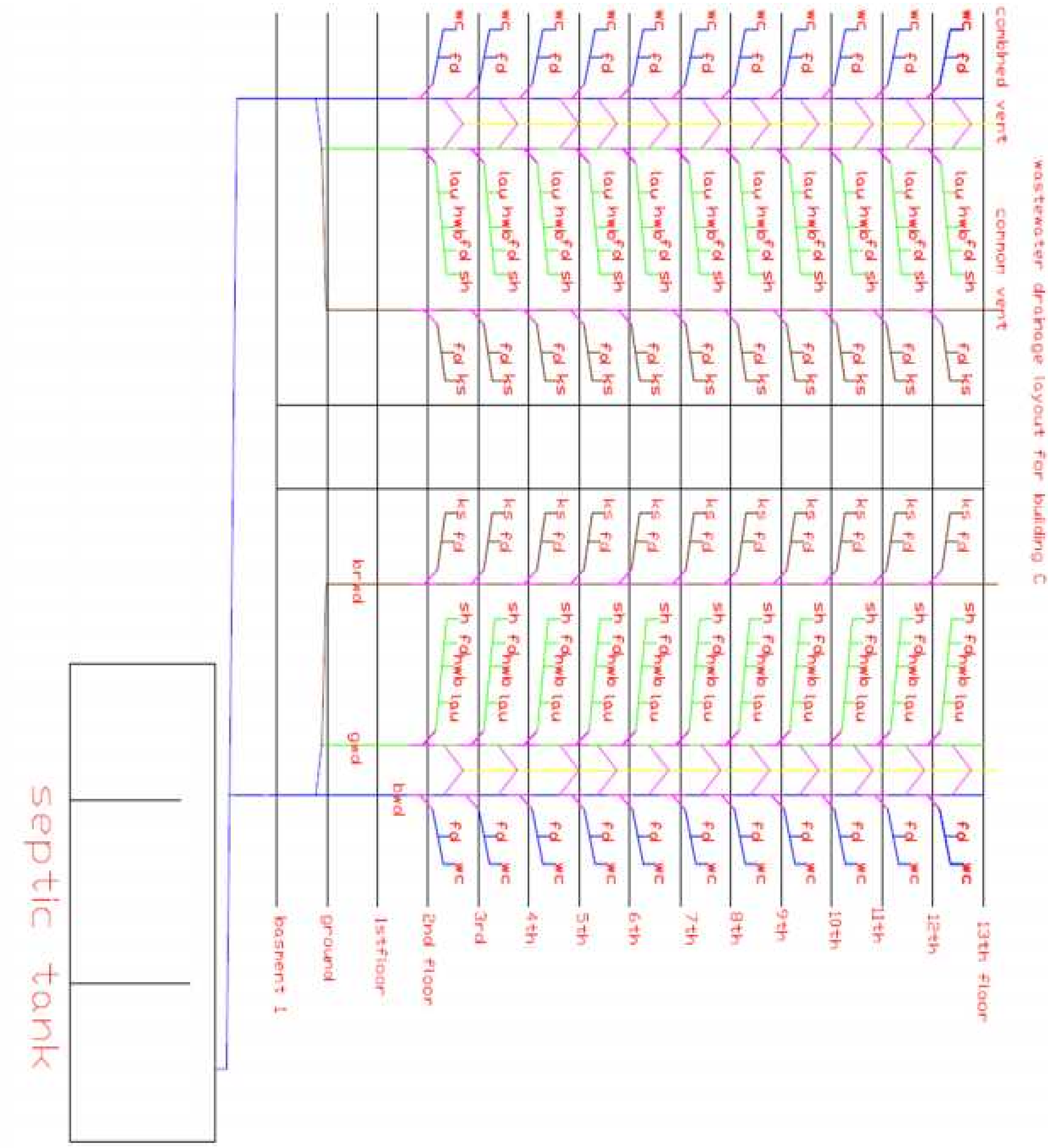


Figure 9 waste water drainage layout of building C

4.4.4. Design and installation of roof storm waste water drainage of building C

The required number of down pipe in a building is 7 in number but the installed is 5.which means the installation of roof storm waste water drainage does not meet the minimum design requirmentes of local plumbing codes of a building. The discrepancy between the required number of down pipe 7 and the actual installation of roof storm water drainage is 5in the condominium twins building .due to this several effects the buildings, its occupants and surrounding environment issues occurs.

- Drainage capacity issue, with in few number of down pipe than the required numbers of local plumbing code, the building plumbing code might not have sufficient capacity to handle heavy rainfall events. This could leads to localized flooding or water pooling on the building which can pose safety hazards for occupants and damage the building foundation and other structural elements.
- Water accumulation and potential damages, insufficient roof storm water drainage can cause water to accumulate on the roof or around the building ,this leads to potential leaks, structural damage, potential mold or mildew growth and spreading of mosquito, which could have negatively impact on the building integrity, compromising the safety and well-being of the occupants.
- Environmental impact, in adequate roof storm water drainage can contribute to increase runoff and potential flooding in the surrounding area, this can impact on local ecosystem, disrupt natural drainage patterns and potentially causes erosion or damage to nearby properties or infrastructures.
- Compliance and legal issues, the installation of fewer number of down pipes than the required number by the local plumbing code might not comply with local building regulations and standards; this could results in fines or penalties, legal challenges or even the requirmentes to retrofit the buildings with the appropriate number of down pipe.
- Maintenance and operational challenge, the lower number of down pipe the limited drainage capacity might require more frequent maintenance and cleaning of the existing downpipes and drainage systems to ensure proper functioning. This

could increase the operational costs and burden for the building management and maintenance staff.

To mitigate these potential issues it should be consult with local authorities, building professionals and plumbing experts to assess the situation and determine the best course of action, this may involve upgrading the drainage system to meet the required standards, implementing additional water management strategies or addressing any underlying structural or design issues that contributed to the discrepancy.

Design of Gutter for roof storm water drainage

The design of getter in a building is crucial for dispose roof storm water drainage system for this building the design of gutter both depth and width are similar manner in a building A above for more detail design it holds on the annex calculation part. The design and installation of gutter for building C condominium is given as the table below

Table 55 :gutter design and installation of building C

Item number	Description	Size of gutter mm		Remarks
		Installed	Designed	
1	Depth	200	200	Ok
2	Width	400	400	Ok

Based on the analysis of the design and the installation of gutter listed above the table, the installation of gutter in both width and depth of gutter meets the plumbing code requirement for roof storm water drainage of a building. The gutter depth and width are sufficient to effectively collect and drain storm water from the roof which ensures the buildings structure and surrounding area protected from water damage.

The gutters depth is adequate to handle the maximum expected rainfall intensity, ensures that the water does not over flow and cause damages to the buildings or surrounding areas.

The gutter width is sufficient to collect and drain storm water from the entire roof area, preventing water from accumulating and causing structural damage.

Chapter five

5 .Conclusion and Recommendation

5.1. Conclusion

- As compared to other international plumbing codes, the local plumbing codes of Ethiopia building plumbing code has lack of detailed descriptions and specification's for various plumbing components and systems like:-
  1. PEX-AL-PEX (cross-linked poly ethylene) piping material.
  2. Detailed sizing of water supply pipe size based on their equivalent pipe size and the number of fixture unites.
  3. The combination venting size requirmentes for waste water drainage systems of a building.
  4. Grease interceptor for kitchen sink waste water drainage.
  5. Detailed design consideration of septic tank**.**
- The installation of the plumbing systems of a building doesn't meet the design standards of a building so there are potentials of risk and inefficiencies in the systems this can leads to water leakage, contaminations and drainage problems in the building.
- Compromises the health and well-being of the customers and it also results in long term damage to the building structures.
- The buildings do not have the drawings of plumbing fixtures so it creates challenges during construction and maintenances. The absence of drawing of plumbing fixture

  Leads:

  1. Lack of detail: - without plumbing fixture drawing it is difficult to plan and install plumbing systems in a building accurately.

  2. Compliance issues: - a building codes and regulations require detailed drawings of plumbing fixtures the absence of these drawings may hinder compliance with legal requirmentes.

3. Maintenance challenge: - in the absence of plumbing fixture drawings identifying and repairing plumbing issues is more time consuming and costly.

- The down pipe installation system in the building is not effectively managing the roof rain water run off this leads damaging of the building, leakage, and high potential of flooding in the building due to the non-compliance of the design specification requirmentes.
- The government condominium building has no proper design and installation of septic tank the internal waste water drainage of a building is directly connected to the municipal sewer systems this leads to have potential ground water pollution when un treated water seeps to the ground and surface water pollution when untreated wastewater runs into the surface water bodies like streams, rivers and lakes which affects the source of drinking water, the local ecosystems and aquatic life’s.

5.2. Recommendation

- The construction authority should review and update the Ethiopian local plumbing code and include detailed descriptions, specifications and guide lines for the plumbing components and systems mentioned from the above conclusion.
- Assessment of the existing systems by qualified professional could be in order to identify the specific deficiencies and non-compliances with the design standards and the remedial action should be taken.
- As Ethiopia continue to develop and modernize its infrastructure, aligning local plumbing code with international standards such as other international plumbing codes could have help enhance the quality and reliability of plumbing systems in the country. it is recommended that Ethiopian construction authorities considering adopting certain provision of international plumbing code to improve the regulation of plumbing systems of a building and ensure compliance with other global best practices.
- Experienced contractor's or plumber's must carry out the necessary repairs or upgrades to bring the systems up to the standard of regular maintenance and monitoring of the system must be implemented to prevent future issue and ensure the long term performance of the buildings water supply and waste water drainage systems of high rise building.
- Addressing the non-compliance of the design and installation of sanitary appliances in a building is essential for maintaining safe and functional for living and working of the environments. By taking immediate actions following the recommended ideas the building can brought up to the required standards to ensure the safety and well- being of the customer.
- Advice the building owner or the responsible party to engage qualified contractor or plumber to rectify the issues and bring the down pipe installations up to the required standard.
- The sewerage authority and construction authority gives permission of construction for contractors by addressing all the required septic tank design and installation systems obtaining from the local and international plumbing codes before the contractor or plumber is proceeding to the work.

- Because of the budget and time constraint I can't asses the design and installation of all the plumbing systems of a building like fire hydrants and external waste water drainage systems the researcher will do more about it and should be set the proper solutions.

Chapter six

6.1 Reference

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Annexes

Calculations

Calculations of all building plumbing system

1. Building A

Pipe size for vertical main line riser for each floor for building A

From floor 8^{th} to 7^{th} vertical riser pipe diameter vertical

Counting fixtures	Diameter of pipes as per plumber's chart
Water closet = 43	50mm, number of equivalent 15mm = 23
Hand wash = 43	40mm, equivalent 15mm =12
Shower head = 26	65mm, equivalent 15mm = 42
Kitchen sink= 19	50mm, equivalent of 15mm =23
Wash machine = 18	40mm, equivalent 15mm = 12
Bath tub =1	20mm, equivalent 15mm = 1.8

Total =113.8 greater than 42 we use 60mm diameter pipe.

Deter mine flow rate using probability equation of loading unit z value

$Q = 0.25\sqrt{272.22} = 0.25x16.499= 4.125$ lit/sec

$V = \frac{4 \cdot Q}{\pi \; D^{\wedge}2}$

Q = 4.125 /1000 m^3/sec =0.004125 m^3/sec

D = 60/1000 m =0.06 m

$V = 4x0.004125/3.14x0.06^2$ m/s = 0.0165/0.0113 = 1.46 m/s it is safe use 60mm diameter pipe as raiser.

4.2.1.3.2Horizontal transition pipe size for building A

For floor 8th and 7th the diameter of the pipe horizontal main line

Counting of fixture	Diameter of pipes as per plumber's chart
Water closet = 4	25mm, number of equivalent 15mm =3.7
Hand wash =4	20mm, number of equivalent 15mm =1.8
Shower head = 4	32mm, number of equivalent 15mm =5.9
Kitchen sink = 2	25mm, number of equivalent 15mm =3.7
Wash machine = 1	15mm, number of equivalent 15mm =1
Bath tub = 1	20mm, number of equivalent 15mm =1.8
	Total = 17.9 it is b/n 12 and 23 we use 50mm diameter pipe

Deter mine flow rate using probability equation of loading unit z value

$Q = 0.25\sqrt{(17.28 + 2 + 4 + 2 + 1.96 + 1 + 0)}$= 0.25x5.314= 1.328 lit/sec

$V = \frac{4*Q}{\pi \quad D^2}$

Q = 1.328/1000 m^3/sec =0.001328 m^3/sec

D = 50/1000 m =0.05 m

$V = 4x0.001328 /3.14x0.05^2$ m/s = 0.005312/0.00785 = 0.68 m/s ~ 0.7 m/s it is safe use 50mm diameter pipe as horizontal sub main raiser.

For floor 6th and 5th the diameter of the pipe horizontal main line

Counting fixtures Diameter of pipes as per plumber's chart

Water closet =6 32mm, equivalent pipe 15mm= 5.9

Hand wash =6 25mm, equivalent pipe 15mm= 3.7

Shower head =4 32mm, equivalent 15mm pipe =5.9

Kitchen sink =2 25mm, equivalent pipe 15mm= 3.7

Wash machine =2 20mm, equivalent pipe 15mm=1.8

Total =21 use 50mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z values

$Q = 0.25\sqrt{(25.92 + 3 + 4 + 2 + 0 + 2 + 0)}$= 0.25x6.076= 1.519 lit/sec

$V = \frac{4 \cdot Q}{\pi \cdot D^2}$

Q = 1.519 /1000 m^3/sec =0.001519 m^3/sec

D = 50/1000 m =0.05 m

V = 4x0.001519 /3.14x0.05^2 m/s = 0.006076/0.00785 = 0.77 m/s it is safe use 50mm diameter pipe as raiser.

For 1st floor – 4th floors the diameter of the pipe horizontal main line

Counting fixture units Diameter of pipes as per plumber's chart

Water closet =6 32mm, equivalent pipe15mm =5.9

Hand wash =6 25mm, equivalent pipe 15mm =3.7

Shower head =3 32mm, equivalent pipe 15mm =5.9

Kitchen sink =3 32mm, equivalent pipe 15mm =5.9

Wash machine =3 25mm, equivalent pipe 15mm =3.7

Total =25.1 use 60mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = 0.25√(25.92 + 3 + 3 + 3 + 0 + 3 + 0)= 0.25x6.16= 1.54 lit/sec

$V = \frac{4 \cdot Q}{\pi \quad D^2}$

Q = 1.54 /1000 m^3/sec =0.00154 m^3/sec

D = 60/1000 m =0.06 m

V = 4x0.00154 /3.14x0.06^2 m/s = 0.00616/0.0113 = 0.545 m/s it is not safe because the diameter of the pipe can't attain the minimum flow of self-cleansing velocity so the diameter of the riser pipe should be decrease and check the minimum attaining velocity flow.

Use 50 mm pipe size

D = 50/1000 = 0.05m

V = 4x0.00154 /3.14x0.05^2 m/s = 0.00616/0.00785 = 0.785 m/s now it is safe which attain the minimum velocity of a pipe and use 50 mm diameter of pipe as riser sub-main or horizontal main.

4.2.1.3.3 Horizontal transmission pipe size per room to manifold of building A

Floor 7th and 8th water distribution pipe size diameter for sub-main to fixture house hold A

A .for master bed room

Water closet = 1 15mm, number of equivalent 15mm =1

Hand wash =2 15mm, number of equivalent 15mm =1

Shower head = 1 15mm, number of equivalent 15mm =1

Kitchen sink = 2 25mm, number of equivalent 15mm =3.7

Wash machine = 1 15mm, number of equivalent 15mm =1

Bath tub = 1 20mm, number of equivalent 15mm =1.8

Total = 9.5 use 40mm diameter pipe sizes

Deter mine flow rate using probability equation of loading unit z value

Q = $0.25\sqrt{(4.31 + 1 + 1 + 2 + 1.96 + 1)}$ = 0.25x3.36= 0.84 lit/sec

V = $\frac{4 * Q}{\pi \quad D^{\wedge}2}$

Q = 0.84/1000 m^3/sec =0.00084 m^3/sec

D = 40/1000 m =0.04 m

V = 4x0.00084 /3.14x0.04^2 m/s = 0.00336/0.005 = 0.672 m/s ~0.7m/s it is safe use 40mm diameter pipe as distribution of fixtures.

B .common bed room

Water closet = 1 15mm, number of equivalent 15mm =1

Hand wash =2 15mm, number of equivalent 15mm =1

Shower head = 1 15mm, number of equivalent 15mm =1

Total = 3 use 25 mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = $0.25\sqrt{(4.32 + 1 + 1)}$ = 0.25x 2.514= 0.6285lit/sec

V = $\frac{4 * Q}{\pi \quad D^{\wedge}2}$

Q = 0.6285/1000 m^3/sec =0.0006285 m^3/sec

D = 25/1000 m =0.025 m

V = 4x0.0006285 /3.14x0.025^2 m/s = 0.002514/0.00196 = 1.28 m/s ~1.3$/s$ it is safe use 25mm diameter pipe as distribution of fixtures.

C .kids bed room

Water closet = 1 15mm, number of equivalent 15mm =1

Hand wash =1 15mm, number of equivalent 15mm =1

Shower head = 1 15mm, number of equivalent 15mm =1

Total = 3 use 25 mm diameter pipe sizes

Deter mine flow rate using probability equation of loading unit z value

Q = $0.25\sqrt{(4.32 + 0.5 + 1)}$ = 0.25x 2.41= 0.6025lit/sec

V = $\frac{4*Q}{\pi \quad D^2}$

Q = 0.6025/1000 m^3/sec =0.0006025 m^3/sec

D = 25/1000 m =0.025 m

V = 4x0.0006025 /3.14x0.025^2 m/s = 0.00241/0.00196 = 1.229 m/s ~1.23 m/s it is safe use 25mm diameter pipe as distribution of fixtures.

D .guest toilet room

Water closet = 1 15mm, number of equivalent 15mm =1

Hand wash =1 15mm, number of equivalent 15mm =1

Shower head = 1 15mm, number of equivalent 15mm =1

Total = 3 use 25 mm diameter pipe sizes

Deter mine flow rate using probability equation of loading unit z value

Q = 0.25√(4.32 + 0.5 + 1) = 0.25x 2.41= 0.6025lit/sec

V = $\frac{4*Q}{\pi \quad D^2}$

Q = 0.6025/1000 m^3/sec =0.0006025 m^3/sec

D = 25/1000 m =0.025 m

V = 4x0.0006025 /3.14x0.025^2 m/s = 0.00241/0.00196 = 1.229 m/s ~1.23 m/s it is safe use 25mm diameter pipe as distribution of fixtures.

Horizontal pipe lines for fixture units sub main pipe for both house hold A and B 5th and 6th floor.

A .master bed room

Counting fixtures	Diameter of pipes as per plumber's chart
Water closet =1	15mm, equivalent pipe 15mm= 1
Hand wash =2	15mm, equivalent pipe 15mm= 1
Shower head =1	15mm, equivalent 15mm pipe =1
Kitchen sink =1	20mm, equivalent pipe 15mm= 1.8
Wash machine =1	15mm, equivalent pipe 15mm=1

Total =5.8 use 32mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = 0.25√(4.32 + 1 + 1 + 1 + 1)= 0.25x2.884= 0.721 lit/sec

V = $\frac{4*Q}{\pi \quad D^2}$

Q = 0.721 /1000 m^3/sec =0.000721 m^3/sec

D = 32/1000 m =0.032 m

V = 4x0.000721.001519 /3.14x0.032^2 m/s = 0.002884/0.003215 = 0.897m/s it is safe use 32mm diameter pipe as a distribution pipe of fixtures

B .kids bed room

Counting fixtures Diameter of pipes as per plumber's chart

Water closet =1 15mm, equivalent pipe 15mm= 1

Hand wash =1 15mm, equivalent pipe 15mm= 1

Shower head =1 15mm, equivalent 15mm pipe =1

Total =3 use 25mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = $0.25\sqrt{(4.32 + 0.5 + 1)}$= 0.25x2.41= 0.6025 lit/sec

V = $\frac{4 \cdot Q}{\pi \quad D^{\wedge}2}$

Q = 0.6025 /1000 m^3/sec =0.0006025 m^3/sec

D = 25/1000 m =0.025 m

V = 4x0.0006025 /3.14x0.025^2 m/s = 0.00241/0.00196 = 1.23 m/s it is safe use 25mm diameter pipe as distribution of fixture.

C .Guest toilet room

Counting fixtures Diameter of pipes as per plumber's chart

Water closet =1 15mm, equivalent pipe 15mm= 1

Hand wash =1 15mm, equivalent pipe 15mm= 1

Total =2 use 25mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = $0.25\sqrt{(4.32 + 0.5)}$= 0.25x2.195= 0.54875 lit/sec

V = $\frac{4*Q}{\pi \quad D^2}$

Q = 0.54875 /1000 m^3/sec =0.00054875 m^3/sec

D = 25/1000 m =0.025 m

V = 4x0.00054875 /3.14x0.025^2 m/s = 0.002195/0.00196 = 1.12 m/s it is safe use 25mm diameter pipe as distribution of fixture.

Note: -Horizontal pipe lines for fixture units sub main pipe for both houses hold A, B and C 4^{th}, 3rd, 2nd and 1^{st} floor typical from 1^{st} to 4^{th} floor.

A .master bed room

Counting fixtures	Diameter of pipes as per plumber's chart
Water closet =1	15mm, equivalent pipe 15mm= 1
Hand wash =1	15mm, equivalent pipe 15mm= 1
Shower head =1	15mm, equivalent 15mm pipe =1
Kitchen sink =1	20mm, equivalent pipe 15mm= 1.8
Wash machine =1	15mm, equivalent pipe 15mm=1

Total =5.8 use 32mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = $0.25\sqrt{(4.32 + 0.5 + 1 + 1 + 1)}$= 0.25x2.796= 0.699 lit/sec

V = $\frac{4*Q}{\pi \quad D^2}$

Q = 0.699 /1000 m^3/sec =0.000699 m^3/sec

D = 32/1000 m =0.032 m

V = 4x0.000699/3.14x0.032^2 m/s = 0.002796/0.003215 = 0.87m/s it is safe use 32mm diameter pipe as a distribution pipe of fixtures

B .guest toilet room

Counting fixtures Diameter of pipes as per plumber's chart

Water closet =1 15mm, equivalent pipe 15mm= 1

Hand wash =1 15mm, equivalent pipe 15mm= 1

Total =2 use 25mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = $0.25\sqrt{(4.32 + 0.5)}$= 0.25x2.195= 0.54875 lit/sec

V = $\frac{4 \cdot Q}{\pi \quad D^2}$

Q = 0.54875 /1000 m^3/sec =0.00054875 m^3/sec

D = 25/1000 m =0.025 m

V = 4x0.00054875 /3.14x0.025^2 m/s = 0.002195/0.00196 = 1.12 m/s it is safe use 25mm diameter pipe as distribution of fixture.

For ground floor diameter of pipe sizes to distribution main

Horizontal pipe lines for fixture units sub main pipe for house hold A ground floor.

A .master bed room

Counting fixtures Diameter of pipes as per plumber's chart

Water closet =1 15mm, equivalent pipe 15mm= 1

Hand wash =2 15mm, equivalent pipe 15mm= 1

Shower head =1 15mm, equivalent 15mm pipe =1

Kitchen sink =1 20mm, equivalent pipe 15mm= 1.8

Wash machine =1 15mm, equivalent pipe 15mm=1

Total =5.8 use 32mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = 0.25$\sqrt{}$(4.32 + 1 + 1 + 1 + 1)= 0.25x2.884= 0.721 lit/sec

V = $\frac{4 \cdot Q}{\pi \quad D^{\wedge}2}$

Q = 0.721 /1000 m^3/sec =0.000721 m^3/sec

D = 32/1000 m =0.032 m

V = 4x0.000721.001519 /3.14x0.032^2 m/s = 0.002884/0.003215 = 0.897m/s it is safe use 32mm diameter pipe as a distribution pipe of fixtures

B .kids bed room

Counting fixtures Diameter of pipes as per plumber's chart

Water closet =1 15mm, equivalent pipe 15mm= 1

Hand wash =1 15mm, equivalent pipe 15mm= 1

Shower head =1 15mm, equivalent 15mm pipe =1

Total =3 use 25mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = 0.25$\sqrt{}$(4.32 + 0.5 + 1)= 0.25x2.41= 0.6025 lit/sec

$V = \frac{4*Q}{\pi \quad D^2}$

Q = 0.6025 /1000 m^3/sec =0.0006025 m^3/sec

D = 25/1000 m =0.025 m

V = 4x0.0006025 /3.14x0.025^2 m/s = 0.00241/0.00196 = 1.23 m/s it is safe use 25mm diameter pipe as distribution of fixture.

C .Guest toilet room

Counting fixtures Diameter of pipes as per plumber's chart

Water closet =1 15mm, equivalent pipe 15mm= 1

Hand wash =1 15mm, equivalent pipe 15mm= 1

Total =2 use 25mm diameter pipe size

Deter mine flow rate using probability equation of loading unit z value

Q = $0.25\sqrt{(4.32 + 0.5)}$= 0.25x2.195= 0.54875 lit/sec

$V = \frac{4*Q}{\pi \quad D^2}$

Q = 0.54875 /1000 m^3/sec =0.00054875 m^3/sec

D = 25/1000 m =0.025 m

V = 4x0.00054875 /3.14x0.025^2 m/s = 0.002195/0.00196 = 1.12 m/s it is safe use 25mm diameter pipe as distribution of fixture.

2. Building B

4.3.1.6. Horizontal transmission pipe size per floor of building B

1. Horizontal pipe diameter of sub- main riser for 6^{th} - 15^{th}floor are typical similar to each other.

Using plumber's chart pipe size can be designed as follows.

Counting fixture units Diameter of pipes as per plumber's chart

Water closet = 2 20mm, equivalent pipe 15mm =1.8

Hand wash = 2 15mm, equivalent pipe 15mm=1

Kitchen sink = 1 20mm, equivalent pipe 15mm =1.8

Total = 4.6 use 32 mm diameter pipe

Z = (4.32x2) + (0.5x2) + (1x1) = 10.64

Q = $0.25\sqrt{10.64}$ = 0.815 litter/sec = 0.000815 m^3/s

Q = AV

V = $\frac{4*Q}{\pi \ D^{\wedge}2} = \frac{4*0.815}{3.14*0.032^2*1000}$ = 1.01 m/s it is safe use 32 mm diameter pipe as the main riser of horizontal pipe lines to supply all fixtures.

2. Horizontal pipe diameter of sub- main riser for 1st - 5th floor are typical similar to each other

Counting fixture units Diameter of pipes as per plumber's chart

Water closet = 2 20mm, equivalent pipe 15mm =1.8

Hand wash = 2 15mm, equivalent pipe 15mm=1

Total = 2.8 use 25mm diameter pipe

Z = (4.32x2) + (0.5x2) = 9.64

Q = $0.25\sqrt{9.64}$ = 0.776litter/sec

Q = AV

$V = \frac{4*Q}{\pi \; D^{\wedge}2} = \frac{4*0.776}{3.14*0.025^2*1000} = 1.6$ m/s it is safe use 25mm diameter pipe as the main riser of horizontal pipe lines to supply all fixtures.

4.3.3.1 Design and installation of septic tank for building B

1 .Using flow rate method

First of all determine number of people lives in the office the water supply and waste water drainage is designed to satisfy 8hrs requirement for office.

Per capital demand C = 35l/c/d

Flow rate Q = 10700 l/d

From Q = C*P,

P = Q/C = 10700 l/d/35l/c/d = 305.7 say 306

P population served in the office is 306

Total capacity of septic tank = Volume sediments + Volume of sludge

Volume of sediment $= \frac{t*p*q}{1000} m^3 = \frac{1.5*306*35}{1000} m^3 = 16\ m^3$

Volume of sludge $= \frac{s*p*d}{1000} m^3 = \frac{0.15*306*5*365}{1000} m^3 = 66.7\ m^3$

Total volume = 16 m^3+ 66.7 m^3 = 99.7 say 100 m^3

Determine the surface area of septic tank using fixture unit - discharge chart calculate the flow rate.

Total fixture in a building is 765 read the discharge from table at 765 fixture unit

Interpret the discharge by using linear interpolation methods.

Loading unit flow rate (litter/sec)

750 5.5

765 Q

850 6

$$\frac{850-750}{765-750} = \frac{6-5.5}{Q-5.5}$$

Q = 5.57 liter/sec = 334.2lpm

Determine the surface area of septic tank

10lpm = 0.92m^2

271.2lpm = A

A = $\frac{334.2x0.92}{10}$ = 30.7 m^2

Effective depth = $\frac{100\,m3}{30.7m2}$ = 3.3 m

Total depth of septic tank = effective depth +free board of 0.3m

= 3.3+0.3 = 3.6 m

Length Width ratio of septic tank is 2:1

A = L*W

30.7 m^2 = 2w*w, w^2 = 15.35 m^2 w =$\sqrt{15.35}\ m\text{^}2$

W = 3.9 m

L = 2w = 2*3.9 m = 7.8 m

Size of septic tank is 7.8 m x 3.9 m x 3.6 m

Effective depth = 3.3 m and use freeboard = 0.3 m

Total in side depth = 3.6 m

Since the length is more than 4m, the septic tank is to be divided in to two compartments

Inlet compartment length = 2/3 length

2/3*7.8 = 5.2 m

2nd compartment length = 7.8 m- 5.2 m = 2.6 m

Distance to baffle wall = length /5 = 7.8/5 = 1.56 m

3. Building C

4.4.1.4. Horizontal transmission pipe diameter for each floor of building C

1. For house hold A main horizontal pipe diameter typical (3rd -13th)

Counting of fixture	Diameter of pipes as per plumber's chart
Water closet = 2	20mm, equivalent pipe 15mm =1.8
Hand wash basin = 2	15mm, equivalent pipe 15mm =1
Shower = 2	20mm, equivalent pipe 15mm =1.8
Kitchen sink = 1	20mm, equivalent pipe 15mm =1.8

Total = 6.4 use 40 mm diameter pipe

Z = 2*4.32 + 2*0.5 + 2*1 + 1*1 = 12.64

Q = $0.25\sqrt{12.64} = 0.9$ lit/s or Q = $0.0009 m^3/s$

A = $\frac{\pi D^2}{4} = \frac{3.14*0.04^2}{4} = 0.005 m^2$

V = $\frac{Q}{A} = \frac{0.0009 m3/s}{0.005 m2} = 0.18$m/s it is not safe decrease the diameter of pipe

Use 32mm

$A = \frac{\pi D^2}{4} = \frac{3.14*0.032^2}{4} = 0.0008m^2$

$V = \frac{Q}{A} = \frac{0.0009m3/s}{0.0008m2} = 1.125$ m/s it is safe

For master bed room house hold A horizontal branched pipe size

Counting of fixture	Diameter of pipes as per plumber's chart
Water closet = 1	15mm, equivalent pipe 15mm =1
Hand wash basin = 1	15mm, equivalent pipe 15mm =1
Shower = 1	15mm, equivalent pipe 15mm =1

Total = 3 use 25 mm diameter pipe

Z = 1*4.32 + 1*0.5 + *1 + = 5.82

Q = $0.25\sqrt{5.82}$= 0.6 lit/s or Q = $0.0006m^3/s$

$A = \frac{\pi D^2}{4} = \frac{3.14*0.025^2}{4} = 0.00049m^2$

$V = \frac{Q}{A} = \frac{0.0006m3/s}{0.00049m2} = 1.22$ m/s it is safe

For common bed room house hold A horizontal branched pipe size

Counting of fixture	Diameter of pipes as per plumber's chart
Water closet = 1	15mm, equivalent pipe 15mm =1
Hand wash basin = 1	15mm, equivalent pipe 15mm =1
Shower = 1	15mm, equivalent pipe 15mm =1

Total = 3 use 25 mm diameter pipe

Z = 1*4.32 + 1*0.5 + *1 + = 5.82

Q = $0.25\sqrt{5.82}$= 0.6 lit/s or Q = 0.0006m^3/s

A = $\frac{\pi D^2}{4}$ = $\frac{3.14*0.025^2}{4}$ = 0.00049m^2

V = $\frac{Q}{A}$ = $\frac{0.0006m3/s}{0.00049m2}$ = 1.22 m/s it is safe

2. For house hold B, C, D and E main horizontal pipe diameter typical (3rd -13th)

Counting of fixture	Diameter of pipes as per plumber's chart
Water closet = 1	15mm, equivalent pipe 15mm =1
Hand wash basin = 1	15mm, equivalent pipe 15mm =1
Shower = 1	15mm, equivalent pipe 15mm =1
Kitchen sink = 1	20mm, equivalent pipe 15mm =1.8

Total = 4.8 use 32 mm diameter pipe

Z = 1*4.32 + 1*0.5 + 1*1 + 1*1= 6.82

Q = $0.25\sqrt{6.82}$= 0.65 lit/s or Q = 0.00065m^3/s

A = $\frac{\pi D^2}{4}$ = $\frac{3.14*0.032^2}{4}$ = 0.0008m^2

V = $\frac{Q}{A}$ = $\frac{0.00065m3/s}{0.0008m2}$ = 0.8 m/s it is safe

For common bed room house hold B.C.D and E horizontal branched pipe size

Counting of fixture	Diameter of pipes as per plumber's chart
Water closet = 1	15mm, equivalent pipe 15mm =1
Hand wash basin = 1	15mm, equivalent pipe 15mm =1
Shower = 1	15mm, equivalent pipe 15mm =1

Total = 3 use 25 mm diameter pipe

Z = 1*4.32 + 1*0.5 + *1 + = 5.82

Q = $0.25\sqrt{5.82}$ = 0.6 lit/s or Q = 0.0006m^3/s

A = $\frac{\pi D^2}{4} = \frac{3.14*0.025^2}{4}$ = 0.00049m^2

V = $\frac{Q}{A} = \frac{0.0006m3/s}{0.00049m2}$ = 1.22 m/s it is safe

4.4.2.. Design and installation of internal waste water drainage of building C

4.4.2.1 .Number of fixture units per floor of house hold A

1. Household A total fixture loading per floor typical for all (3^{rd} -13^{th})

Counting of fixtures	Unite rate	Amount
Water closet = 1	8	8
Hand wash basin = 1	1	1
Shower =1	2	2
Floor drain = 1	1	1
Kitchen sink =1	2	2

Black water drain = 8

Grey water drain = 1+2+1 = 4

Brown water drain = 2 +1 =3

Following this sample calculation of determining the amount of fixture unit loading of drain is listed the table below.

4.4.3.1. Design of septic tank

Using flow rate method

Total capacity of septic tank = Volume sediments + Volume of sludge

One septic tank is provided in the building for 3 years of deluging period

Volume of sediment = $\frac{t*p*q}{1000}m^3$

Volume of sludge = $\frac{s*p*d}{1000}m^3$

Volume of sediment = 1.5x700x110/1000 = 115.5 m^3

Volume of sludge = 0.15x700x3x365/1000 = 115 m^3

Total volume = 115.5 m^3+ 38.3 m^3

v = 230.5 m^3

Determine the total discharge using the loading unit vs. Flow rate chart

Total sanitary loading unit of a building is the sum of all house hold fixture units

House hold A = 2x297 = 594

House hold B, C, D and E = 2x4x165 = 1320

Total loading unit = 1914

Loading unit	flow rate in liter/sec
1900	10.67
1914	Q

1950 11

$\frac{1950-1900}{1914-1900} = \frac{11-10.67}{Q-10.67}$ Q = 10.76 l/s

The flow rate in liter per minute is 647.6lpm

10lpm requires 0.92 m^2 surface area 647.6lpm of discharge is

A = $\frac{647.6X0.92}{10}$ = 59.4 m^2

Depth of septic tank = $\frac{230.5\ m3}{59.4\ m2}$ = 3.9 m

Length Width ratio of septic tank is 2:1

A = L*W

59.4 m^2 = 2w*w, w^2 = 29.7 m^2 w =$\sqrt{29.7m2}$

W = 5.45 say 5.5 m

L = 2w = 2*5.5 = 11 m

Size of septic tank is 11 m x 5.5 m x 4.2m

Effective depth = 3.9 m and use freeboard = 0.3 m

Total in side depth = 4.2 m

Since the length is more than 4m, the septic tank is to be divided in to two compartments

Inlet compartment length = 2/3 length

2/3*11 = 7.3 m

2^{nd} compartment length = 11 m- 7.3 m = 3.7 m

Distance to baffle wall = length /5 = 11/5 = 2.2 m

4.4.4. Design and installation of roof storm waste water drainage of building C

Rational formula

Q =CIA/60x60x1000 where

Q = Rainfall flow or runoff in m^3/s

A= Area of roof in m^2

C= Impermeability factor constant

I= Intensity of rainfall mm/hour

Area of roof	Impermeability factor, C
Paved and flat roof	1
Unpaved and sloped roof	0.75-0.95

Source Federal highway administration

Rainfall data used in the preparation of this figure have been collected from many Ministry of Water Resources meteorology stations.

From the IDF curve of 5minute duration and 10 year return period intensity of rain fall is read as

I = 145mm/hr.

C= 1 because the building roof is flat

A = it can measure the roof length and width then area is the product of length and width

Length of roof =20m

Width of roof = 15 m

A = L*W = 20*15 = 400m^2

From international plumbing code hand book we can determine the pipe size of leader or down pipe size using applicable table standards of rain fall intensity, area of roof and pipe sizes.

From the IDF curve I = 145mm/hr. convert mm/hr.in to inch/hr. using the governing unit conversion of 1 inch = 25.4mm

I = 145/25.4 inch/hr. = 5.7 inch/hr. approximately intensity of rain fall is 6inch/hr.

The measured area is in m^2 to read the pipe size diameter from the table we convert the area from m^2 to square foot using the conversion factor of 1square foot = $0.0929m^2$

We get the total area of roof in square foot A $=400m^2/0.0929m^2$ *1square foot

A = 4305.7 square foot

DIAMETER OF LEADER (inches)[a]	HORIZONTALLY PROJECTED ROOF AREA (square feet)											
	Rainfall rate (inches per hour)											
	1	2	3	4	5	6	7	8	9	10	11	12
2	2,880	1,440	960	720	575	480	410	360	320	290	260	240
3	8,800	4,400	2,930	2,200	1,760	1,470	1,260	1,100	980	880	800	730
4	18,400	9,200	6,130	4,600	3,680	3,070	2,630	2,300	2,045	1,840	1,675	1,530
5	34,600	17,300	11,530	8,650	6,920	5,765	4,945	4,325	3,845	3,460	3,145	2,880
6	54,000	27,000	17,995	13,500	10,800	9,000	7,715	6,750	6,000	5,400	4,910	4,500
8	116,000	58,000	38,660	29,000	23,200	19,315	16,570	14,500	12,890	11,600	10,545	9,600

For SI: 1 inch = 25.4 mm, 1 square foot = $0.0929 m^2$.

Simply we can find the pipe size of storm water using the area of roof 4036.6 square foot and intensity of rain fall 6inch/hr. in the above standard table but we can't get directly the pipe diameter in the table simply we use interpolation method.

At 6inch/hr. intensity of rain fall

Area of roof in square foot down pipe size (inch)

30704

4305.7 x =?

57675

From the general equation of linear interpolation we can get the down pipe diameter required for roof area of 2691.1

$$\frac{5767 - 3070}{4305.7 - 3070} = \frac{5 - 4}{x - 4}$$

X = 4.4 inch use 4 inch diameter of down pipe for 4305.7 square foot area of roof

Number of down pipe installed in abuilding

4 inch diameter pipe have a capacity of discharge 2.3littre/sec of the total discharge in a roof is calculated using the empirical formula written above.

Q =CIA/60x60x1000

Q = 1*145*400/60*60*1000 m^3/s =0.0161 m^3/s

=16.11 litter/sec

Number of down pipe in a floor= $\frac{16.11\ littre/sec}{2.3littre/sec}$ = 7 use 7 number of down pipe drain of the long side of the floor in both sides.

Number of down pipe for both sides = 7/2 = 3.5 use 4 number of down pipes for the longest two sides.

The gutter lies on the longest side of the floor the length one down pipe coverage is

Q1 can discharge 2.3littre/sec from 16.11 litter/sec of the total and the length to which the down pipe can drain along the longest side of the roof is

Distance of drain = long length/number of down pipe drain

20m /4 = 5m

For each 5m along the longest one sloped side of the roof down pipe drain is provided.2.5m right side and 2.5m left side of the roof is drained to each down pipe drains.