International Journal of Engineering Applied Sciences and Technology, 2023
Vol. 8, Issue 01, ISSN No. 2455-2143, Pages 355-369
Published Online May 2023 in IJEAST (http://www.ijeast.com)

MECHANICAL SERVICES DESIGN OF AN ESTATE WITH A SINGLE OVERHEAD WATER SUPPLY

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Abstract—**This work focused on mechanical services design of an estate with a single overhead water supply. The residential development has twenty dwelling units and consists of two housing prototype of a four unit five bedroom detached house with one room servant's quarter and sixteen units four bedroom semi-detached house with one room servant's quarters. The estate shall be provided with a swimming pool, a gymnasium room, store, shops, car park, and children playing ground. The total floor area of the estate is 8512m^2. The mechanical services covered in this work include, air-conditioning, ventilation and extraction system, hot and cold water distribution, water storage tanks, water transfer pump set, borehole and water treatment plant, sanitary plumbing, soil and waste disposal, sewage treatment plant and firefighting. The total cooling load estimated for the estate is 35.7kW and water storage requirement was 44928litres and the estimated BOD (Biochemical Oxygen Demand) and flow rate for the sewage treatment plants are 14.1kg/BOD/day and 112.3m^3/day.**

Keywords—**Mechanical Services, Design, Estate, housing prototype, four bedroom semi-detached, five bedroom detached.**

I. INTRODUCTION

The practice of engineering profession is dynamic, noteworthy and problem solving experience as it affects every facet of the society. Engineering practice involves both theoretical and practical aspects/experiences. Each of these aspects is equally important and goes hand in hand with the practice of engineering especially in these days of ever changing/dynamic technology. The primary function of buildings and some other structures is to make up an environment for man to live and work in. For the purpose of this work, we may distinguish residential buildings (such as apartment houses and hotels), public buildings (office, cinemas theatre, schools, hospital, canteens, commercial center, etc.), industrial buildings (factories, power plants, mine superstructures, various auxiliary buildings, etc.) and farm buildings (low houses, poultry houses, granaries, vegetable storage, etc.). In order for it to be habitable, these buildings require engineering services. Engineering services in buildings include; Structural design, Mechanical services, Electrical services, etc.It can be seen today that many home plumbing sanitary fixtures has problem of water supply due to low pressure of water, it is also observed that water supply from the roof to the ground floor or basement floor reduces in pressure before getting to the sanitary fixtures. At times, when a faucet is opened in a floor and another tap is opened in another floor, the tap in the upper floor tends to supply water faster than the tap below. Therefore, for this work, a PEX (cross-linked polyethylene) is used which has a supply manifolds that supply water at equal flow rateand at the same pressure.

Mechanical services in building systems involves the design and selection of equipment to render services in buildings [4]. It cut across many spheres of discipline ranging from industrial to buildings which include Plumbing (drainage and water supply), Air conditioning, Vertical transportation (elevators, escalators, lift, etc.), Firefighting (sprinkler system, fire hydrant, fire extinguishers), Gas supply, etc. and industrial mechanical services which include general plant and equipment maintenance [4].For the purpose of this work, attention is focused on Plumbing, Air conditioning and Firefighting using an estate as case study.The aim of this work is to design the mechanical services requirement in a modern estate on a parcel of land of about 8512m^2. The objective of the work includes:

1) The distribution of water supply to the twenty unit dwellings with a single overhead water tank.
2) To determine the flow rate and the pressure head at which the water will supply the entire roof tank in the estate at a particular given time.
3) To determine the invert level at which the soil drains and waste will be discharged to the sewage treatment plant.

The significance of this work is to aid the supply of water to all sanitary fixtures in the buildings at minimal pressure loss using a PEX manifold system.The design of all plumbing and drainage works required for the completion of the proposed estate is generally indicated on the tendered drawing and specification, and include other works, which may be inferred as necessary to ensure the proper and efficient operation of the entire installation even though some may not be specifically mentioned or indicated therein. All accessories, appliances, equipment shall include but not limited to the following:

1) Soil, Waste, Vent pipes and Fittings
2) Drain pipes and Fittings
3) Cold and Hot water pipes Fittings
4) Firefighting Systems
5) Water Tanks and Pumps
6) Air-conditioning and Ventilation Systems

II. REVIEW OF LITERATURE

A. Design Specification using British Standard

British standard provides a wide range of detailed information. The majority of the information is specific to installation requirement; i.e. BS 4504: Circular flanges for pipes, valves and fittings, 1989. However a number of the standards do provide design guidance that could impact on concept work[4].

Plumbing and Heat Ventilation Air-Conditioning (HVAC)

- BS 4660: Code of practice for UPVC pipes and fittings.
- BS 5572: Code of practice for sanitary pipe work, 1994
- BS 5720:Code of practice for mechanical ventilation, 1979
- BS 6700: Specification for the look, Installation, Testing and Maintenance of services supplying water for domestic use within buildings, 1997
- BS 8301: Code of practice for building drainage, 1991

Fire protection

- BS 5306: Fire Extinguisher Installations
  Part 1: Hydrant systems, Hose Reels and Foam inlets, 1976
  Part 2: Specification for sprinkler installations, 1990
- BS 5588: Fireplace precaution in the styles, construction and use of buildings.
  Part 1: Guide to fire safety codes of practice for particular premises, 1996
  Part 2: Code of practice for firefighting stairs and lifts, 1991

B. The Home Plumbing System

It can be seen that most of a plumbing system is hidden inside walls and floors, it may appear to be a posh maze of pipes and fittings. A typical home plumbing system includes three basic parts:

1) A water supply system
2) A fixture and appliance set
3) A drain system

These three parts can be seen clearly in the photograph of the cut-away house in Fig. 1. Fresh water enters the house through the main supply line (1). This fresh water source is provided by either a municipal water company or a private underground bore-hole. If the source is a municipal supplier, the water passes through a meter (2) that registers the amount of water used. A family of four uses about 400gallons of water each day.Immediately after the main supply enters the house, a branch line splits off (3) and is joined to a water heater (4). From the water heater, a hot water line runs parallel to the cold water line to bring the water supply to the fixtures and appliances throughout the house. The fixtures include sinks, bathtubs, showers, and laundry tubs. The appliances include water heaters, dishwashers, garment washers, and water softeners. Toilets and urinals are example of fixtures that require only a cold water line.The water supply to the fixtures and appliances is controlled with faucets and valves. Faucets and valves have moving parts and seals that eventually may wear out or break, but they are easily required or replaced.The waste water then enters the drain system. It first must flow past a drain trap (5), a U-shaped piece of pipe that holds standing water and prevents sewer gases from entering the home. Every fixture must have a drain trap.The drain system works entirely by gravity allowing waste to flow downhill through a series of large diameter pipes. These drain pipes are attached to a system of vent pipes, vent pipes (6) brings fresh air to the drain system, preventing suction that would slow drain water from flowing freely. Vent pipes usually exit the house at a roof vent (7).All waste water eventually reaches a main waste and vent stack (8). The main stack curves to become a sewer line (9) that exit the house near the foundation. In a municipal system, this sewer line joins a main sewer line located near the street. Where sewer services is not available, waste water empties into a septic tank [3].

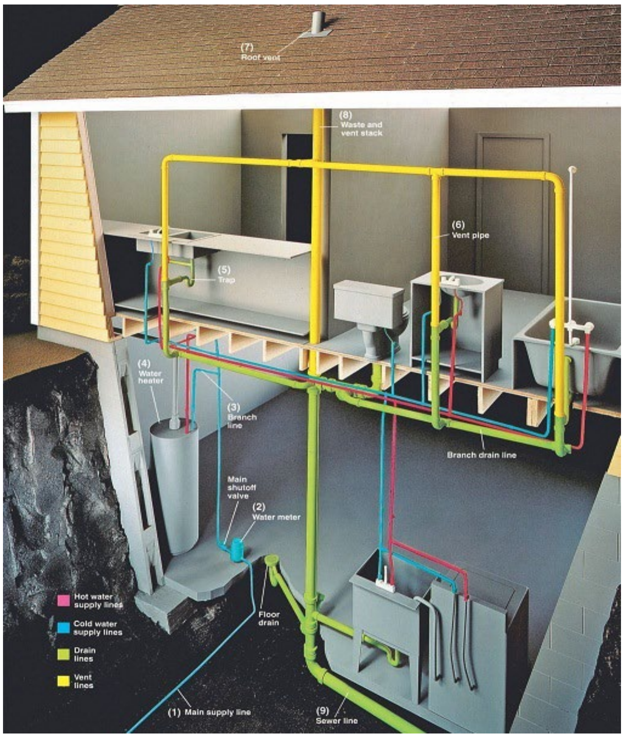

Fig. 1. Photograph of a home plumbing cut-away house [3]

Connections between drains and sewers must be obliquely in the direction of flow. Drains may be connected independently to the public sewer so that each building owner is responsible for the maintenance of the drainage system for that building. In situations where there would be long drain runs, it may be more economical to connect each drain to a private sewer. This requires only one sewer connection for several buildings. Maintenance of the private sewer is shared between the separate users.Connection of a drain or private sewer to the public sewer can be made with a manhole. If one of these is used at every connection, the road surface is unnecessarily disrupted. Therefore a saddle is preferred, but manhole access is still required at no more than 90m intervals. Saddles are bedded in cement mortar in a hole made in the top of the sewer.

C. Water Supply System

Water supply pipes caries hot and cold water throughout the house. In homes built before 1960, the original supply pipes were usually made of galvanized iron. Newer homes have supply pipes made of copper. In most areas of the countries, supply pipes made of rigid plastics or PEX are accepted by local plumbing codes.Water supply pipes are made to withstand the high pressure of the water system. They have small diameters, typically 1/2" (15mm) to 1" (25mm), joined with robust water tight fittings. The hot and cold lines runs in wheel to any or all elements of the house. Usually, the supply pipes run inside wall cavities or are strapped to the undersides of floor joists.Hot and cold water supply pipes are connected to the fixtures and appliances which include sinks, tubs, showers, dish washers, and clothes washers. Some fixtures, such as toilets or hose bibs, are supplied only by cold water. A refrigerator ice maker uses only cold water. Tradition says that hot water supply pipes and faucet handles are found on the left-hand side of a fixture, with cold water on the right [3]. Because it is pressurized, the water supply system is prone to leaks. This is especially true of galvanized iron pipe which has limited resistance to corrosion.Storage of cold water has traditionally been provided to give a safe guide against interruption of mains water supply and to meet peak draw off demands. The water supply regulations do not have specific requirements for water storage. Capacities of storage must therefore be decided based upon the risk and extent of any interruption to supply, the usage and occupancy of the building together with the size and pressure and of the available mains water supply. Consideration must also be given to the risk of over long periods of storage which could cause the quality of the water to be impaired and subject to bacterial contamination [11].

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Table 1. Provision of cold water storage to cover 24 hours interruption of supply.

TYPES OF BUILDING	STORAGE IN LITRES
Dwelling House and flats per resident	180
Hostels per resident	180
Hotels per resident	270
Offices without canteens per head	40
Offices with canteens per head	45
Restaurants per head per meal	14
Day schools per head	54
Boarding schools per resident	180
Nurses' homes and medical quarters per resident	220

D. Connections for Hot and Cold Water Pipework

Connections to showers

The hot and cold water supplies to the shower will need to be of equal pressure. Where the supply is directly from the service main, provision must be made to ensure no back-flow occurs. This is usually achieved by ensuring that the shower head cannot discharge below the over spill level of the appliance or by incorporating a double check-valve assembly into the pipeline.Connections via a storage cistern will need to be such that an adequate pressure is achieved. The pressure are often exaggerated by the utilization of a booster pump fitted into the pipeline during which a little contained unit, designed to grant a bigger head, is used

Connections to bidets

There are two types of bidet[13]:

1) Those with pillar taps to grant an over-the-rim type discharged, therefore maintaining an air gap and,
2) Those with a submerged nozzle which discharged a spray of water upwards from the base of the appliance.

E. Systems for Enhancing Water Pressure

Pressure boosting systems are often of many completely different types:

1) Pumping from a ground level gravity tank to a gravity roof tank.
2) Pumping from a gravity vessel or public water main into a hydro-pneumatic pressure tank that uses captive air pressure to provide adequate drinking water supply.

Nowadays, "packaged" pumping sets are installed consisting of twin pumps to overcome the problem of failure of (or the need to renew) one of the pump. The second pump also assists at times of high demand on the system, cutting in as necessary. To prevent pump seizure and stagnation of water, the pump should be designed to work alternately. The system used can either be those using pressure sensing devices, and those using float switches [10].

F. Types of Cold Water Supply System

The type of cold water supply system by which water is supplied to buildings depends on the local water authorities bylaws. These are categorized into two:

1) The indirect and
2) The direct supply systems.

The Indirect Supply System

In this system, the cold water to the sanitary fittings, i.e. the bath, basin and WC and hot water cylinder is supplied indirectly from the cold water storage tank, thus preventing back siphon of foul water from the sanitary fitting into the water company's main. This type of system is used in areas where the water pressure from the main is not high enough to supply all the fittings. It is also used in areas where the demand for water is very high. In this system, storage tanks used are usually large in capacity and size since they have to supply the fittings and hot water cylinder. The sink is supplied direct from the main and this is usually the only point where drinking water can be obtained.

The Direct Supply System

This system is used in Northern districts where large high level reservoirs provide a good mains supply and pressure. In this system the whole of the sanitary fittings are provided with water directly from the main supply. Only the hot water cylinder is supplied from the storage tank which is therefore small in capacity and size.

G. Accessing Water Efficiency in New Dwellings

Changes to part G of the building regulations, which came into force in (2010), identify that all new dwellings must have the water consumption of wholesome water limited so as not to exceed 125litres/person/day. In order to complete this calculations one need to know the specific flow rates and volumes of water used by the appliances within the new buildings.To find the average flow rate from the faucet that is required, you select the largest of the following:

1) Average flow rate
2) Proportional flow rate

The average flow rate is found by simply adding together the individual flow rates from all the individual taps and dividing by the number of taps.The proportional flow rate is found by taking the tap with the highest flow rate and multiplying this by 0.7.

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Table 2. Water calculation for new dwellings (Building Act 2010)

Installation type	**Flow rate 1**	**Factor 2**	**Fixed use 3**	**Litres/person/ day** $(1 \times 2) + 3$
Single WC(Flush)		4.42	0	
Single WC(Flush)		1.46	0	
Dual flush		2.96	0	
Several WC	6.00	4.42	0	26.52
Taps excluding the kitchen	8.40	1.58	1.58	14.85
Kitchen/utility room taps	12.00	0.44	10.36	15.64
Bath(shower present)	220.00	0.11	0	24.20
Shower(bath present)		4.37	0	
Bath only		0.50	0	
Shower only		5.60	0	
Washing machine	6.30	2.10	0	13.23
Dish washer	1.60	3.60	0	5.76
Waste disposal unit		3.08	0	
Water softener		1.00	0	

Total flow calculated from Table 1= 100.2
Multiplying by a normalization factor of 0.91= 91.182
Adding 5.0litres for external use = 96.182
Total water consumption (litres/person/day) = 96.182

Table 2 was completed based upon the following:
Kitchen

1) 1 hot and 1 cold tap providing a combined average flow of 12 litres/min
2) 1 washing machine using 6.3litres/kg dry load
3) 1 dish washer using 1.6 litres/place settings

Bathroom and additional cloakroom

1) 3 hot and 3 cold taps providing a combined average flow of 8.4litres/min
2) 2 WCs flushing a combined average of 6 litres/min
3) Bath volume 190litres with shower located above [13]

H. Drain Waste Vent System

Drain pipes use gravity to carry waste water away from fixture, appliances, and other drains. This waste water is carried out of the house to a municipal sewer system or septic tank. Drain pipes are usually plastic or cast iron. In some older homes, drain pipes may be made of copper or lead. Because they are not part of the supply system, lead drain pipes pose no health hazard. However, lead pipes are no longer manufacture for home plumbing systems.Drain pipes have diameters ranging from 2 "(50mm) to 4"(100mm). These large diameters allow waste to pass through easily.Traps are an important part of the drain system. The curved sections of drain pipe hold standing water, and they are usually found near any drain opening. The standing water of a trap prevents sewer gases from backing up into the home. Each time a drain is used, the standing trap water is flushed away and is replaced by new water. In order to work properly, the drain system require air. Air allows waste water to flow freely down drain pipes.To allow air into the drain system, drain pipes are connected to vent pipes. All drain systems must include vents, and the entire system is called the drain waste vent (DWV) systems. One or more vent stacks, located on the roof, provide the air needed for the DWV system to work [3].

I. Building Drainage System

The building drainage system includes all the piping within public or private premises which conveys sewage, rainwater or other liquid water to a legal point of disposal but does not include the mains of a public sewer or a private or public sewage treatment or disposal plant. The pipes which convey sewage, rainwater or other liquids are known as drains.The drainage system is required in buildings so as to provide a means by which all sewage, rainwater and other liquids wastes can be removed from the building thus providing a clean, neater and healthy environment in which people can live. By having drainage systems in buildings the possibility of outbreaks of diseases such as cholera, dysentery etc. is eradicated.

Types of Drainage System

There are two types of drainage systems these are:

1) The separated and,
2) The combined drainage systems.

The Separated Drainage System

In this system there are two separate drains. The first drain carries away the discharge from the soil and waste pipe into either inspection chambers or manholes from where it is conveyed to the septic tank or sewage plant. The second drain carries away rainwater from roofs and paved areas. The rainwater is either discharged into the environment or into an inspection chamber or manholes which in turn convey the water to soak away pits via building drains. Although the drainage cost is higher than with the combined system since more pipe and manholes are used, the volume of sewage to be treated at the septic tank or sewage work is considerably less. This system also prevents foul gasses escaping through an unseated rain water gully.

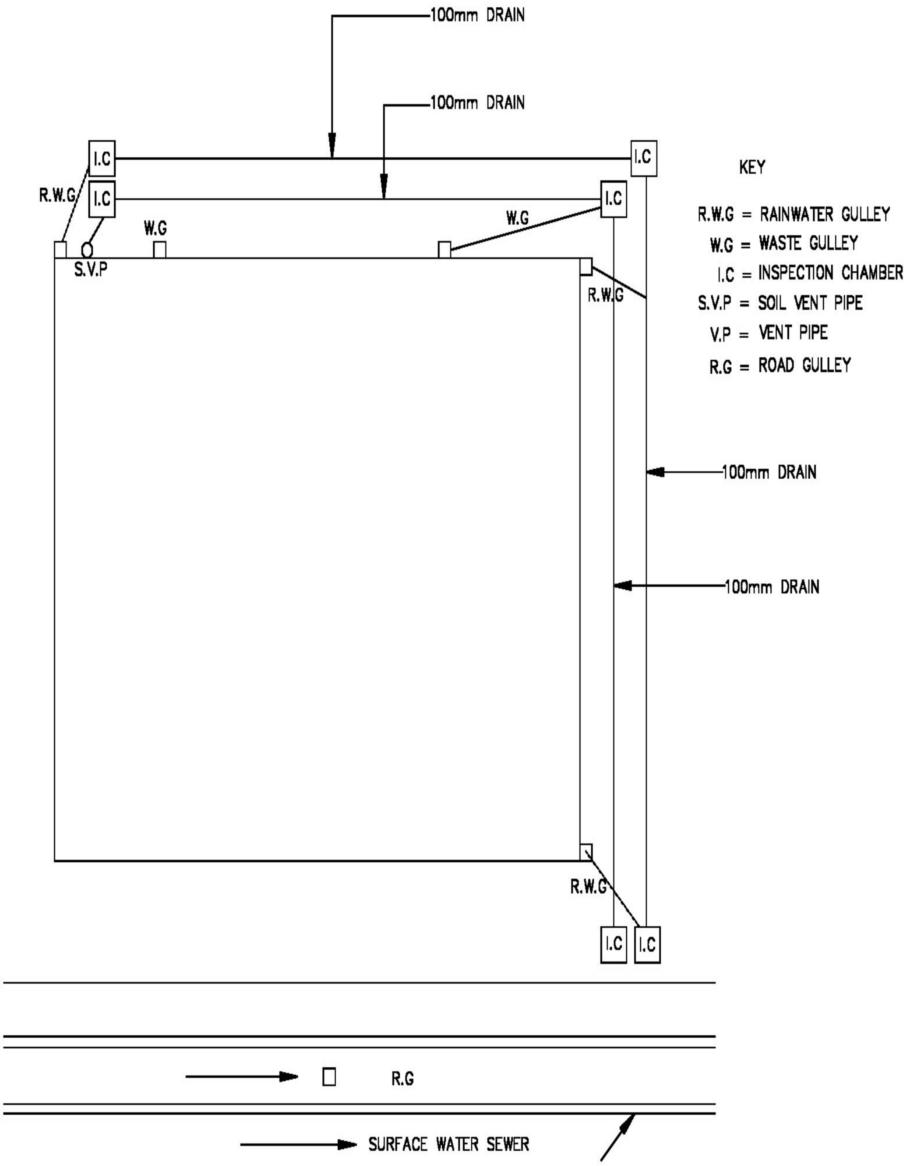

Fig. 2. The Separated Drainage System

The Combined Drainage System

In this system foul water from sanitary fittings and rainwater from roofs and paved areas is carried in a single drain. There is a saving in drainage cost, but treatment at the sewage costs more. This system is not frequently use in Nigeria since in the rainy season, the rainwater is usually very much so that the septic tanks and soak-away pits become over flooded and the contents in them overflow.

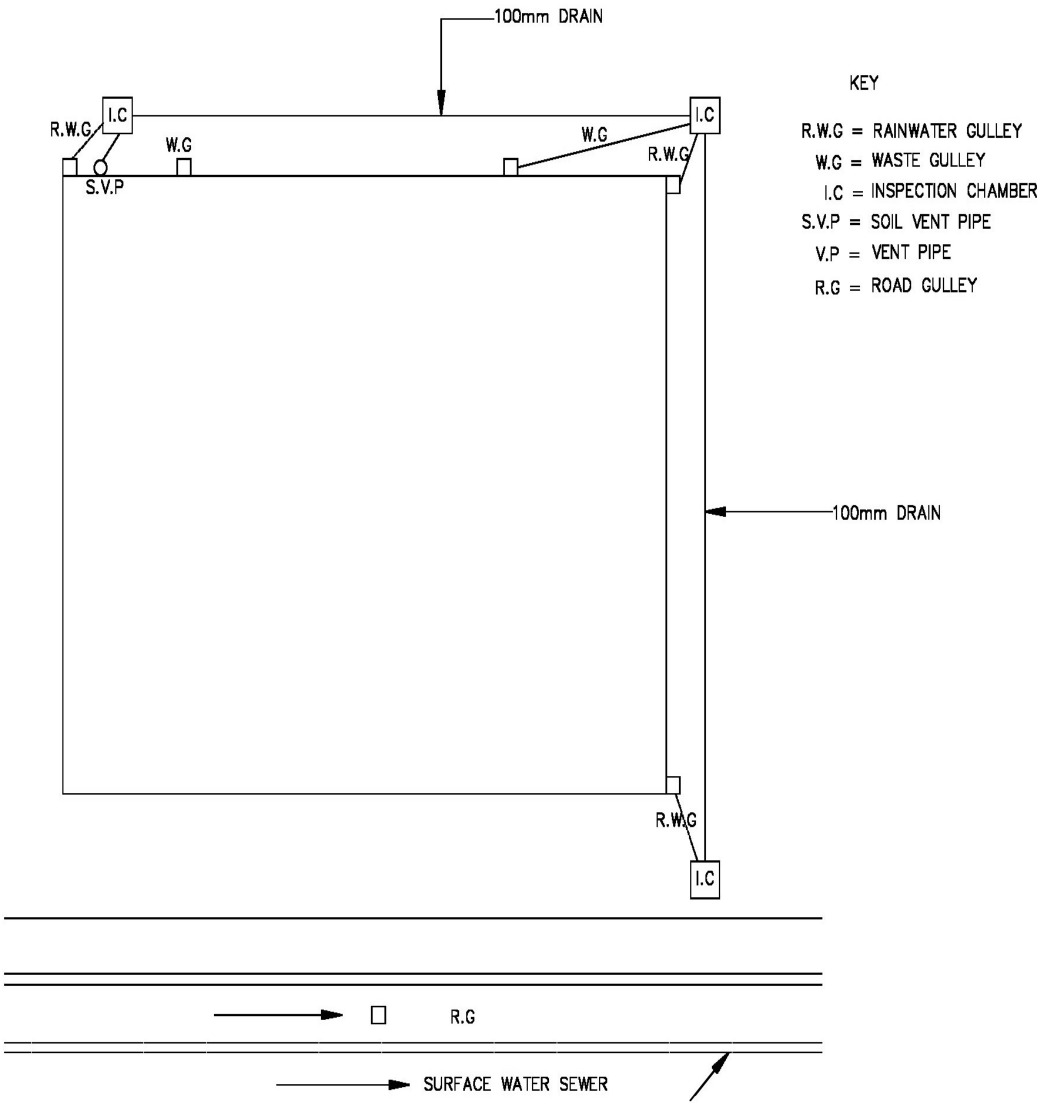

Fig. 3.The Combined Drainage System

J. **Air-Conditioning System**

This system is designed to provide comfortable conditions for the occupants [16]. It can also be defined as a system or process for controlling the temperature, 'humidity' and cleanliness of air.The primary function is to maintain conditions that are:

1) Conducive to human comfort or
2) Required by a product, or process within a space.

To perform this function, equipment of the proper capacity must be installed and controlled throughout the year. The equipment capacity is determined by the actual instantaneous peak load requirements.It is impossible to measure either the actual peak or the partial load in any given space, these load must be estimated [16].The following physical aspects must be considered when estimating the load:

1) Orientation of the building – location of the space to be air-conditioned with respect to:
2) Compass point – Sun and wind effect.
3) Nearby permanent structures – Shading effects.
4) Reflective surfaces – Water, sand, parking lots etc.
5) Use of spaces – office, hospitals, department store, specialty shop, machine shop, factory, assembly plant etc.
6) Physical dimensions of spaces – length width and height.

7) Ceiling height – floor to floor, floor to ceiling, clearance between suspended ceiling and beams.
8) Construction materials – materials and thickness of walls, roof, ceiling, floors and partitions, and their relative position in the structure
9) Columns and beams – size, depth, and also knee braces.
10) Surrounding conditions – exterior color of walls and roof shading by adjacent building or sunlit.
11) Attic spaces – unvented or vented, gravity or forced ventilation
12) Surrounding spaces conditioned or unconditioned – temperature of non-conditioned adjacent spaces, such as furnace of boiler room and kitchen.
13) Windows – size and location, wood or metal sash, single or double hung. Types of glass – single or multilane.
14) Doors – location, types, size and frequency of use.
15) People – number, duration of occupancy, nature of activity, any special concentration. At times, it is required to estimate the number of people on the basic of square feet per person, or an average traffic.
16) Lighting – wattage at peak. Types – incandescent, fluorescent, recessed, exposed. If the lights are recessed, the type of airflow over the lights, exhaust, return or supply should be anticipated. At times, it is required to estimate the wattage on a basis of watt per square feet, due to lack of exact information.
17) Appliances, business machine, electronic equipment – location, rated wattage, steam or gas consumption, hooded or unhooded, exhaust air quantity installed or required and usage.
18) Ventilation – cubic feet per meter per person (cfm/person), cubic feet per meter per square feet (cfm/ft^2), scheduled ventilation. Excessive smoking or odors, code requirements.
19) Exhaust fan – types, size, speed, cubic feet per meter delivery.
20) Continuous or intermittent operation: whether system be required to operate every business day during cooling season, or only occasionally, such as churches, and ball rooms. If intermittent operation, determine duration of time available for precooling or pull-down [6].

K. Firefighting Systems Protection

A fire is supported by three essential ingredients: fuel, heat and oxygen. The absence of any one of these causes an established fire to be extinguished. The firefighting system must be appropriate to the location of the fire and preferably limited to that area in order to minimize damage to materials, plants and building structure. Radiation from a fire may provoke damage or combustion of materials at a distance. Structural fire protection can include water sprays onto steel work to avoid collapse, as used in the Concorde aircraft production hanger [6, 15].

L. Fire Protection Systems

Fire protection systems are of many type. Selecting the appropriate type requires understanding the hazard to be protected, the type of protective systems that are appropriate for that hazard, and the level of protection each type of system can be expected to provide [8, 15]. Examples of different types of fire protection system include:

1) Detection systems with interlocks for door or damper closure, HVAC shutdown, or process shutdown.
2) Fire proofing for buildings, structures or processes.
3) Fire walls, fire barriers, fire doors and other fire resistant construction.
4) Smoke control system
5) Sprinkler system
6) Hydrant and hose reel systems.
7) Special extinguishing system, including those using wet or dry chemicals, foams, or “clean” agents [8].

III. MATERIALS AND METHOD

Materials

The following materials and software’s shall be used for this work:

1) Auto-CAD
2) HVAC-Equation, Data, and Rules of Thumb
3) LG-RAC-Catalogue
4) LOWARA Catalogue
5) GRUNDFOS
6) Hourly Analysis Program 4.41 (E20)
7) Eng. Tools Converter

Materials used for the Waste and Discharge Systems

The materials available for waste pipes and soil and vent stacks are listed in Table 3.A clearance of 30mm should be left between external pipes and the structure to allow free access and for painting. Secure bracketing to the structure is essential and allowance for thermal expansion should be made. Pipes passing through walls or floors should be sleeved with a layer of inert material to prevent the ingress of moisture into the building and provide the elasticity required for thermal movement. This is particularly important with plastics [6].

Table 3: Materials for waste and discharged pipework

Materials	Application	Jointing
Cast iron	50mm and above vent and discharge stacks	Lead caulking
Galvanized steel	Waste pipes	BSPT screwed
Copper	Waste pipes and traps	Push-fit ring seal
Lead	Waste pipes and discharged stacks	Lead welded
ABS	Up to 50mm waste and vent pipes	Solvent cement
Polypropylene	Up to 50mm waste and vent pipes and traps	Push-fit ring seal
Modified PVC	Up to 50mm waste and vent pipes	Push-fit ring seal
Plasticized PVC	Over 50mm soil and vent stacks	Solvent cement
Pitch fiber	Over 50mm discharged and vent stacks	Driven tapper

Note: ABS, acrylonitrile butadiene styrene, PVC, polyvinyl chloride

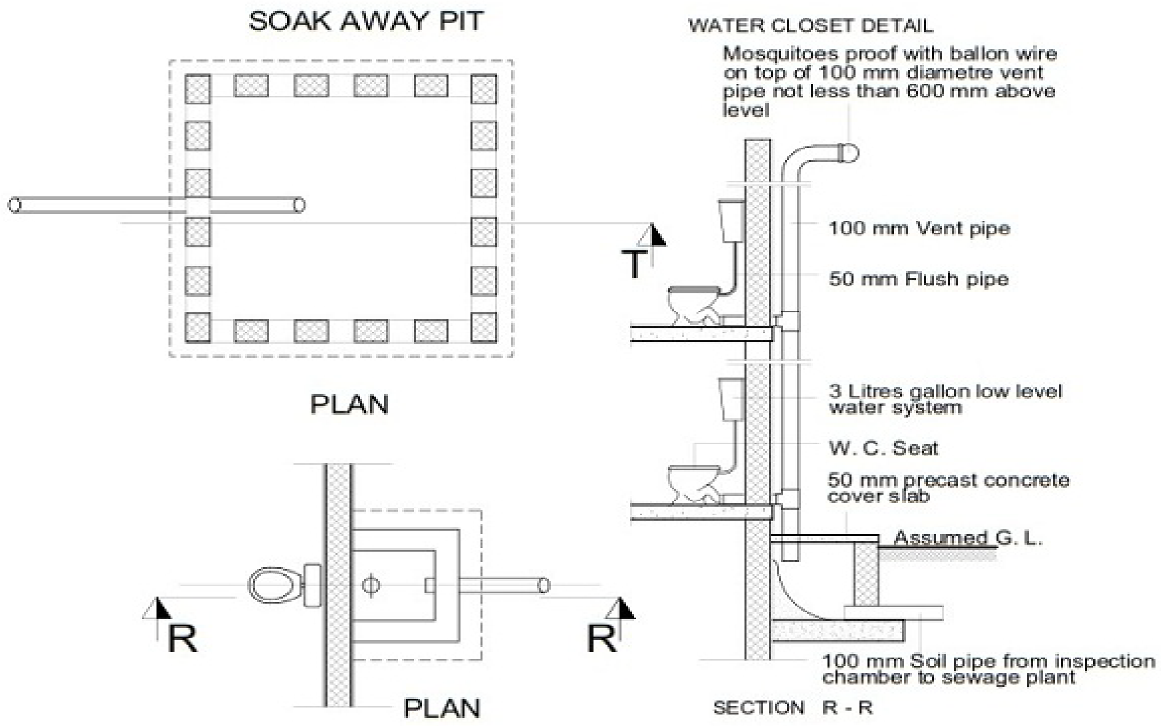

Fig. 4. Details and plan of a water closet (Auto-CAD)

Materials Used for Water Supply Pipework

For this work, the Cross-linked polyethylene (PEX) pipes were used for the distribution and supply of cold water. PEX is a flexible plastic tubing that's reinforced by a chemical reaction that creates long fibers to increase the strength of the material. It is frequently used in manufactured housing and recreational vehicles and in radiant heating systems. Because it is so flexible, PEX can easily be bent to follow corners and make other changes in direction from the water main and heater, it is connected into manifold fittings that redistribute the water in much the same manner as a lawn irrigation system.

Plumbing Manifold Structure

Separated manifold chambers or separate manifold plumbing systems can serve hot and cold water lines. The cold water manifold is fed from the main water supply line, and the hot water manifold is fed from the water heater. Water pressure in manifolds is maintained by the incoming service line. A water line dedicated to each fixture originates from a port in the manifold. Manifold plumbing systems can be centrally located at the water service line entry point, or in larger homes or apartment buildings, mini-manifolds can service remote

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fixture groups. Plumbing manifolds are mounted in a convenient, accessible location, such as a basement wall or a service closet, to allow access for shut off to individual fixtures. Minimum clearances of 36-inches (vertical) and 18-inches (horizontal) are needed between a thermoplastic manifold and a water heater. Opposing port manifolds can be mounted conveniently between stud framing [9].For standard residential installation, PEX can be joined with very simple fittings and tools. Unions are generally made with a crimping tool and a crimping ring. You simply insert the ends of the pipe you are joining into the ring, then clamp down on the ring with the crimping tool. Coils of PEX are sold in several diameters from 1/2" (15mm) to 1" (25mm). PEX tubing and fittings from different manufacturers are not interchangeable [3].

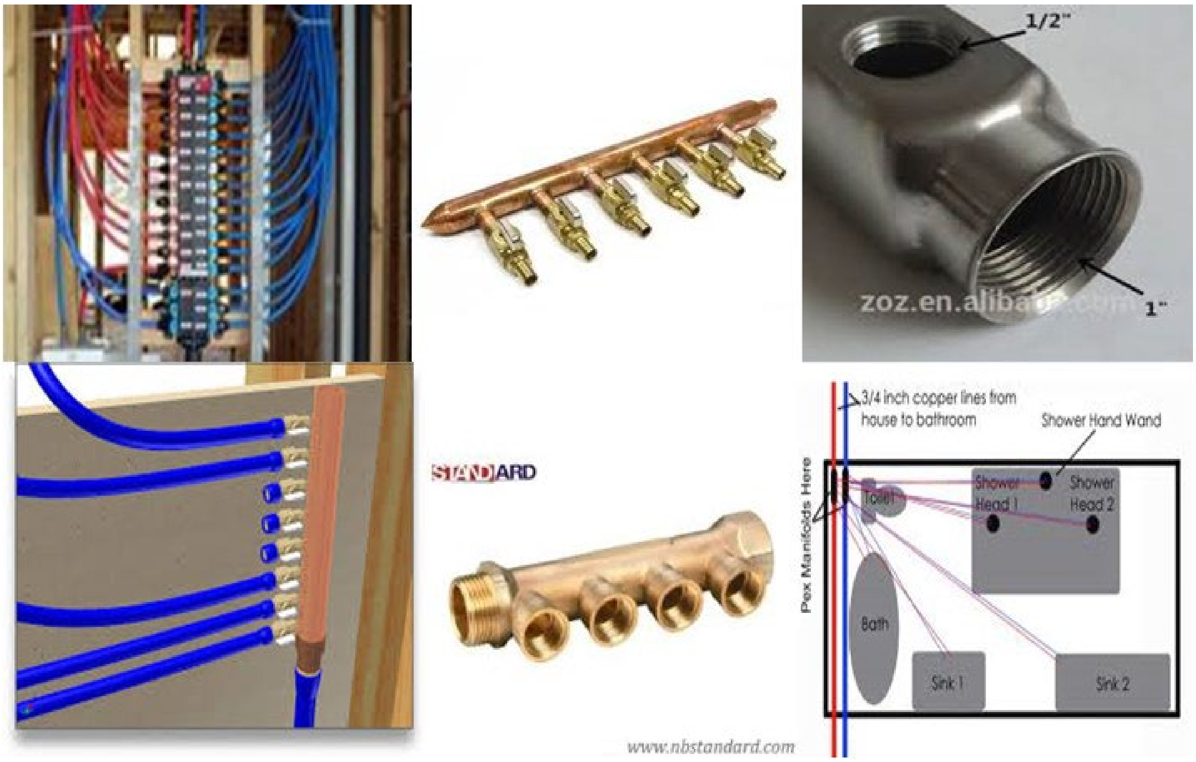

Fig. 5: PEX Plumbing Manifold System

Design Calculations
Plumbing

For the water consumption and storage for the twenty units dwellings which comprises of the four (4) bedroom semi-detached and the five (5) bedroom detached buildings in the estate was calculated as follows:

Four (4) Bedroom Semi-Detached House
Total occupancy= 10 persons
Since the building is a semi-detached house
Total occupancy= $10 \times 2 = 20$ persons

From Table 1, it is seen that the water requirement for dwelling house and flat per head is 180litres
Water requirement = $20 \times 180 = 3600$litres

For three (3) days water storage requirement
Total water tank storage capacity = $3600 \times 3 = 10800$litres

Capacity of the water tanks

The ratio of the capacity of ground to roof water tank is 3:2 of the total water tank storage capacity
The ground water tank capacity= $10800 \times \frac{3}{5} = 6480$litres
The roof water tank capacity = $10800 \times \frac{2}{5} = 4320$litres
Since the building is a semi-detached house therefore, each roof tank will have a capacity of about 2160litres. Gee-pee tank of 2500litres is used for the roof tank.

Five (5) Bedroom Detached House
Since the building is a detached house
Total occupancy = 12 person

From Table 1, it is seen that the water requirement for dwelling house and flat per head is 180litres
Water requirement = $12 \times 180 = 2160$litres

For three (3) days water storage requirement

Total water tank storage capacity= $2160 \times 3 = 6480$litres

Capacity of the water tanks
The ratio of the capacity of ground to roof water tank is 3:2 of total storage capacity
The ground water tank capacity = $6480 \times \frac{3}{5} = 3888$litres
The roof water tank capacity= $6480 \times \frac{2}{5} = 2592$litres

Since the building is a detached house therefore, the roof tank will have a capacity of about 2592litres. Gee-pee tank of 3000 liters is used for the roof tank.

Site plan water requirement
Total occupancy for water consumption for the whole twenty units' dwelling house in the estate is:
4-Bedroom semi-detached house = 160 persons
5-Bedroom detached house= 48 persons
Total occupancy= 208 persons

From Table 1, it is seen that the water requirement for dwelling house and flat per head is 180litres
Water requirement = $208 \times 180 = 37440$litres

For three (3) days water storage requirement
Total water storage capacity = $37440 \times 3 = 112320$litres

Capacity of water tanks
The ratio of the capacity of ground to roof water tank is 3:2 of total water storage capacity
The ground water tank capacity= $112320 \times \frac{3}{5} = 67392$litres
The elevated water tank capacity = $112320 \times \frac{2}{5} = 44928$litres

Overhead Water Tank Size:
The overhead water tank was sized using the nominal capacity chart from the balmoral tanks group [2].

Elevated water tank size
Elevated water tank capacity = 44928litres
Tank size = $(4 \times 4 \times 3)$m deep
Tank weight = 48746kg

Ground water tank and fire-hydrant requirement
Since fire-hydrant is used in the estate, 45000litres was added to the ground water tank capacity, which becomes:
$67392 + 45000 = 112392$litres
Tank size = $(6 \times 5 \times 4)$ m deep
Weight = 122020kg

Table 4.Balmoralfiber glass tanks size chart [2]

1m module tanks
Tank capacities in litres
To convert to gallons divide by 4.546

Length x breadth (m)	1m deep capacity (litres)	2m deep capacity (litres)	3m deep capacity (litres)	4m deep capacity (litres)	5m deep capacity (litres)
2 x 1	2000	4000	6000	8000	10000
3 x 1	3000	6000	9000	12000	15000
2 x 2	4000	8000	12000	16000	20000
3 x 2	6000	12000	18000	24000	30000
4 x 2	8000	16000	24000	32000	40000
3 x 3	9000	18000	27000	36000	45000
4 x 3	12000	24000	36000	48000	60000
4 x 4	16000	32000	48000	64000	80000
5 x 4	20000	40000	60000	80000	100000
5 x 5	25000	50000	75000	100000	125000
6 x 5	30000	60000	90000	120000	150000
6 x 6	36000	72000	108000	144000	180000
7 x 6	42000	84000	126000	168000	210000
7 x 7	49000	98000	147000	196000	245000
8 x 8	64000	128000	192000	256000	320000
10 x 8	80000	160000	240000	320000	400000
9 x 9	81000	162000	243000	324000	405000
10 x 10	100000	200000	300000	400000	500000
11 x 11	121000	242000	363000	484000	605000
12 x 12	144000	288000	432000	576000	720000
13 x 12	156000	312000	468000	624000	780000
13 x 13	169000	338000	507000	676000	845000

Transfer Pump Calculation
The flow rate and the available pressure head at which water will be pumped from the ground water tank to the elevated tank is calculated as follow:

Flow rate (litres/sec) = Elevated water tank capacity (litres) /time (seconds)
44,928litres/7200s = 6.24litres/s

Total height of building = 10.6m (from building section)
Available pressure head (Height of elevated water tank) $=1.4 \times 10.6 = 14.8\text{m}$

Pump sizing [7]
Pump type: FH Series 40-125/15*
Power input: 1.5kW, 2hp (1 duty, I standby)
Power supply: 3-phase at 50Hz

The power input of the pump is 1.5 kW or 2hp, it will be able to pump water from the ground tank to the elevated tank at a time frame of 2hours at a flow rate of 6.24litres/s at a head of 15m high.

Borehole calculation
From water requirement storage for a day which is 37440litres or $37.4m^3$.
Running for 8hour, therefore the flow rate or yield of borehole is:
$37.4m^3$/8hour = $4.68m^3$/hour (calculated)
Expected yield required = $5m^3$/hr.
Minimum head suspension of submersible pump is 60m.
Depth of elevated tank = 3m high
Total head (60 + 3) = 63m
Static head = 40%
Actual head (63 x 1.4) = 88.2m

Table 5. FH Series Hydraulic Performance at 50 Hz, 2 Poles [7]

PUMP TYPE	RATED POWER		Q = DELIVERY																		
			l/min 0	100	150	250	300	400	450	600	700	800	900	1200	1400	1500	1800	2000	2300	3000	3500
			m³/h 0	6	9	15	18	24	27	36	42	48	54	72	84	90	108	120	138	180	210
	kW	HP	H = TOTAL HEAD IN COLUMN OF WATER (METRES)																		
32-125/07*	0,75	1	16,9		14,6	11	8,7														
32-125/11*	1,1	1,5	21,9		19,6	16,3	14,2	9													
32-160/15*	1,5	2	27,3		24,5	20,5	17,8	11													
32-160/22*	2,2	3	34,7		32	28	25,3	18,8	15												
32-200/30	3	4	44,2		39,8	35,2	32,2	24,6	19,8												
32-200/40	4	5,5	54,4		50	45	41,9	34,6	30,3												
32-250/55	5,5	7,5	79	74,7	71	62	56	37													
32-250/75	7,5	10	99	95,3	92	83	76	58													
40-125/11*	1,1	1,5	14,5				13	11,3	10,1	5,8											
40-125/15*	1,5	2	18,1				16,7	15	13,9	9,6	6										
40-125/22*	2,2	3	24,5				23	21	20,1	15,8	12,3	8,2									
40-160/30	3	4	31,5				29,4	27,5	26,1	21,5	17,4										
40-160/40	4	5,5	38				36,2	34	33	28,5	24,5	20,1									
40-200/55	5,5	7,5	46,5				44	41,5	40,2	34,5	29,5										
40-200/75	7,5	10	57				54	52	50	45,5	41	36,1									
40-250/**	**	**	64				59	56	55	49	45	39,5									
40-250/110	11	15	72				67,5	65	63	57	52	47									
40-250/150	15	20	85				80	77	75	70	65	60									

Pump sizing [7]:
Pump type: 8GS Series 8GS30 [at 2900rpm]
Power input: 3kW, 4hp (1 duty, I standby)
Power supply: 3-phase at 50Hz

The power input of the pump is 3kW or 4hp, it will be able to pump water from the borehole to the ground tank at a time frame of 8hours at a yield /flow rate of 5m^3/hr. at a head of 88.2m high.

Fig. 6. GS 4" Series Hydraulic Performance at 50 Hz, 2 Poles [7]

Sewage Treatment Plant Calculation
From water requirement calculation
Population = 208 persons
Hydraulic loading/day = 180litres

Total hydraulic loading = 208 x 180 = 37440litres
Peak flow rate at 3 Average Dry weather flow (DWF) = (37440 x 3) = 112320litres/day = 112.3m^3/day
Organic loading/head/day = 68g = 208 x 68g = 14,144g/BOD/day = 14.1kg/BOD/day

Table 6. GS 4" Series Hydraulic Performance at 50 Hz, 2 Poles [7]

PUMP TYPE	NUMBER OF STAGES	RATED POWER		Q = DELIVERY					
				l/min 0	67	100	120	140	183
				m^3/h 0	4	6	7,2	8,4	11
		kW	HP	H = TOTAL HEAD IN COLUMN OF WATER (METRES)					
8GS07	4	0,75	1	26	23	22	20	18	11
8GS11	6	1,1	1,5	39	35	33	31	28	17
8GS15	8	1,5	2	52	46	44	41	37	22
8GS22	13	2,2	3	85	75	71	67	60	36
8GS30	17	3	4	111	98	93	87	78	47
8GS40	23	4	5,5	150	133	126	118	106	63
8GS55	32	5,5	7,5	208	185	175	164	147	88
8GS75	43	7,5	10	280	249	235	220	198	118

Plant size:
Hydraulic loading = 112.3m^3/day
Organic loading = 14.1kgs/BOD/day
Model: 45-MD-1563 (SATEC)
Dimension: (6.7 x 4.5 x 2.7) m
Air-conditioning design consideration (Split Unit Air Conditioning System)
The system operates using one single indoor unit connected via refrigerant pipes of a corresponding outdoor unit. The capacities specified for each space is selected using the calculated cooling load estimate. The cooling estimation has been obtained by calculations which considered factors and conditions such as:

1) Size of Space
2) Usage of Space
3) Occupancy
4) Orientation of Building and Spaces
5) Sources of Heat: Glass, Appliances Lighting.
6) Outdoor Condition Max: Dry bulb 35°C Wet Bulb 28°C
7) Indoor Design Condition Dry Bulb 22°CRH50%

IV. RESULTS AND DISCUSSION

General
The provision for external plumbing design was done such that each unit is connected to form a network, which is being fed by

International Journal of Engineering Applied Sciences and Technology, 2023
Vol. 8, Issue 01, ISSN No. 2455-2143, Pages 355-369
Published Online May 2023 in IJEAST (http://www.ijeast.com)

a central elevated water tank. Soil and waste water generated from each unit are collected at a central point (Sewage Treatment Plant) where they are treated and discharge as effluent to the municipal outlet.

Water Requirement and Storage

The water supply has been designed to cater for each unit from elevated water tank that takes care of all the buildings with a roof water storage tank located on the roof of each block. The water storage for the estates has been estimated based on 180litres per head/day. It is expected that when the buildings are fully occupied, the population would be about 208 person, including daily visitors. The 5-bedroom detached will have an estimated population of about 48 people, while the 4-bedroom semi-detached would also be about 160 people. Water storage for the entire complex would be 37440litres. Considering three days storage, this gives a total of about 112320litres. Adding 45000litres storage for firefighting the total water storage would be about 112392litres. Using a ratio of 3:2 for ground to elevated storage, the ground would be 67,392litres, while the elevated storage tank would be 44928litres. The selected tank shall be 5m x 6m x 4m deep for 112392litres capacity (122020 kg) for the ground storage, while a fibre glass of size: 4m x 4m x 3m deep for 44928litres capacity (48746kg) is selected for the elevated storage tank. The additional 45000litres storage for firefighting takes care of the estate capacity.

Water Borehole

Water from two boreholes is connected through a header to the treatment plant of the estates. The boreholes shall be drilled to a depth of not less than 250m and lined with Rigid UPVC pipe of 200mm-250mm and shall be complete with suitable casings, sand screen, submersible pump set and PPR rising pipes.

Water Distribution System

The treated water from each of the ground water tanks located in the service area shall be pumped to the respective elevated storage tanks. The water from the elevated storage tanks shall feed the roof tanks of each block, from which each roof storage tank water are distributed through a system of the pipes, valves and fitting under gravity within the building.

Hot Water System

An instantaneous hot water heater shall be utilized for the work. This shall be selected to meet the hot water demands in each block.
Type: Golf thermo cool Heater
Model: FCD-JTHC-40
Power rating: 1.5kW
Product type: Mechanical
Installation: Horizontal
Net dimension: (702 x 380 x 350) mm
Capacity: 30litres

Internal Plumbing

The internal plumbing installation consist of soil, waste, vent pipes and fittings, rain water pipes and fittings, water supply pipes, water pumps, water storage tanks and sanitary appliances. All soil waste vent pipes are recommended to be in UPVC pipes to British standard. All rain water pipes and drain pipes shall be UPVC pipes with fittings to BS4660. Kitchen sinks are to be stainless steel. Toilet mirror, toilet roll holder and other accessories associated with sanitary wares shall be specified appropriately. Cold and hot water are to be of PEX piping system with fittings to BS standard. Water requirements for each block have been estimated and tabulated in Table 7 and 8 for a four (4) bedroom semi-detached house and a five (5) bedroom detached house respectively.

Table 7. Water Requirement for a Four (4) Bedroom Semi-Detached House

Parameter	Value
Estimated population	10 people
Water required per person per day	180litres
Consumption per day	1800litres
3 days storage	5400litres
Ratio of ground to roof storage tank	3:2
Roof water storage tank capacity	2160litres
Selected Gee Pee water tank capacity	2500litres

Table 8. Water Requirement for a Five (5) Bedroom Detached House

Parameter	Value
Estimated population	12 people
Water required per person per day	180litres
Consumption per day	2160litres
3 days water storage requirement	6480litres
Ratio of ground to roof storage tank	3:2
Roof water storage tank capacity	2592litres
Selected Gee Pee water tank capacity	3000litres

Sewage Disposal System

All foul and waste discharge from the various blocks has been collected using network of drainage pipes and circular manholes to the sewage treatment plant. The effluent from the sewage treatment plant shall be connected to public storm water drain.

Fire Protection

The mechanical protections proposed for the work are as follows:

1) Fire extinguisher shall be provided in the 4/5 bedroom block.
2) Five blankets shall be provided for each kitchen.
3) Twin pillar fire hydrant valve shall be provided within the estate.

Fire Hydrant System

The fire hydrant firefighting system consist of a fire pack pump set having duplicate pumps, diaphragm air vessel, complete with an electronic control panel incorporating pressure switches already regulated to pre-determined on and off pressure levels. The fire pack pump set shall be located at the service area in the pump room to feed the hydrant at the 4/5-bedroom block of flats, each pump is connected to a pipeline pressure unit rated 25litres/seconds with minimum cut of pressure of 2.1bar and maximum cut off pressure of 3bar. In addition, fire extinguishers are located at appropriate positions in each flat.

V. CONCLUSION

This work considered the mechanical services design for an estate. The design included plumbing, air-conditioning as well as firefighting system. The total floor area is 8512m^2 and the total cooling load is 35.7kW, the assumed population for the building is 208 person. Also the water tank size was calculated, the ground tank has a capacity of 112392litres while the capacity of the elevated tank is 44928litres.The power rating of a suitable pump for pumping the water is calculated to be 1.5kW or 2HP with a head of 15m high and a flow rate of 6.24litres/s, which is able to pump water from the ground tank to the elevated tank at a time frame of 2hours. The invert level at which the soil drains and waste is being discharged to the sewage treatment plant is calculated to be 2.3m deep at ground level.

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