ENERGY EXTRACTION FROM WASTES IN HIGH RISE BUILDINGS

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

WATER RESOURCES DEVELOPMENT

By

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MAY, 2015

DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled "***Energy Extraction from Wastes in High Rise Buildings***" in partial fulfilment of the requirements for the award of the degree of ***Master of Technology in Water Resources Development and Management***, submitted to Water Resources Development and Management Department, Indian Institute of Technology, is an authentic record of my own work, carried out during the period July 2014 till the date of submission under the supervision of ***Dr. M.L. Kansal***, Professor, WRD&M Department, Indian Institute of Technology Roorkee.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Date: May 2015

Place: Roorkee

(***Mannan Umar***)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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(***Mannan Umar***)

ABSTRACT

"Energy Extraction from Wastes in High Rise Buildings"

Conserving energy and finding alternate sources of energy has always been a favorite subject among research scholars and the industrialists alike. Converting mechanical energy from falling liquids is a well known field with huge developments in hydro-mechanical equipments like turbines that convert potential energy of fluids to rotational mechanical energy that can be used for generating electricity.

In today's world a lot of energy is supplied to a modern city to meet the ever increasing energy requirements and a lot of energy is wasted out of the total energy supplied. In a high rise building a lot of energy is used to pump water for domestic requirements. The waste water is simply dumped to ground level wasting its potential energy. Turbines and pump as turbines (PAT) have been used in some places around the world to harness the energy of waste water but they face a great maintenance challenge for the system is choked, get rusted and further the inconsistent water flow makes their use quite difficult. In the present study, effort has been made to find out a suitable solution that could help east out the difficulties faced in extracting energy from wastes in a high rise building. Also, effort has been made to orient the system in a way that enables to extract energy from rain water as well. The solution is designed and developed using a 3D Modeling platform, which enables to find the material and space requirements helping in studying the cost involved and cost of power generated. A couple of case studies are taken up to simulate different scenarios of annual rainfall and different apartment sizes. It has been found that the effect of rainfall is very small in the total energy extracted. Though the system is able to address the two main challenges of choking and inconsistent water flow, but the cost of energy is found to be on the higher side. The system thus needs to be further refined to bring down the cost of energy. The various results thus obtained and the case studies made are discussed to identify various aspects that need to be addressed.

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CHAPTER 1

INTRODUCTION

1.1 General

Energy is a prominent enabler. Advanced economies of the world have required secured access of modern sources of energy to mark their growing prosperity and development. In countries that are developing, access of affordable and energy services that are reliable is fundamental for reducing poverty and health improvement, productivity increase, competitiveness enhancement and promoting economic growth. This is generally because it is important for the provision of clean water, healthcare and sanitation, and great benefits are provided to development through the availability of reliable and efficient lighting, cooking, heating, mechanical power, telecommunication and transport services.

Political implications with regard to the security of supplies, global warming related environmental concerns and sustainability are expected to move the world's energy consumption away from fossil fuels. Figure of the peak oil shows half of the world's available petroleum resources have been already produced, and thus would lead to a decrease of production. A government move away from fossil fuels would create most likely economic pressure through green taxation and carbon emissions. Few countries are taking action as a result of the Kyoto Protocol, and steps are further proposed in this direction, for example, the European Commission has suggested that the energy policy of the European Union should set a binding target of increasing the level of renewable energy in the EU's overall mix from less than 7% in 2007 to 20% by 2020

The turn of the 21st century has seen an unprecedented growth of the human kind and put enormous pressure on the resources of the mother earth, to fuel the ever increasing development race. With the development cycle came the need for energy to an extent that the available resources too started falling short and thus human kind set for finding alternate sources of energy, making systems more and more efficient and finding ways to extract energy from resources which till date were either wasted or were found to be economically non-feasible.

In today's world a lot of energy is supplied to a modern city to meet the ever increasing energy requirements and a lot of energy is wasted out of the total energy supplied. In a high rise building a lot of energy is used to pump water for domestic requirements. The waste water is simply dumped to ground level wasting its potential energy. Turbines and pump as turbines (PAT) have been used in some places around the world to harness the energy of waste water, but most of the systems remain confined to single homes. There is a need to study and understand how the energy in high rise buildings can be extracted for useful purpose of generating electricity or pumping back water from ground to the building.

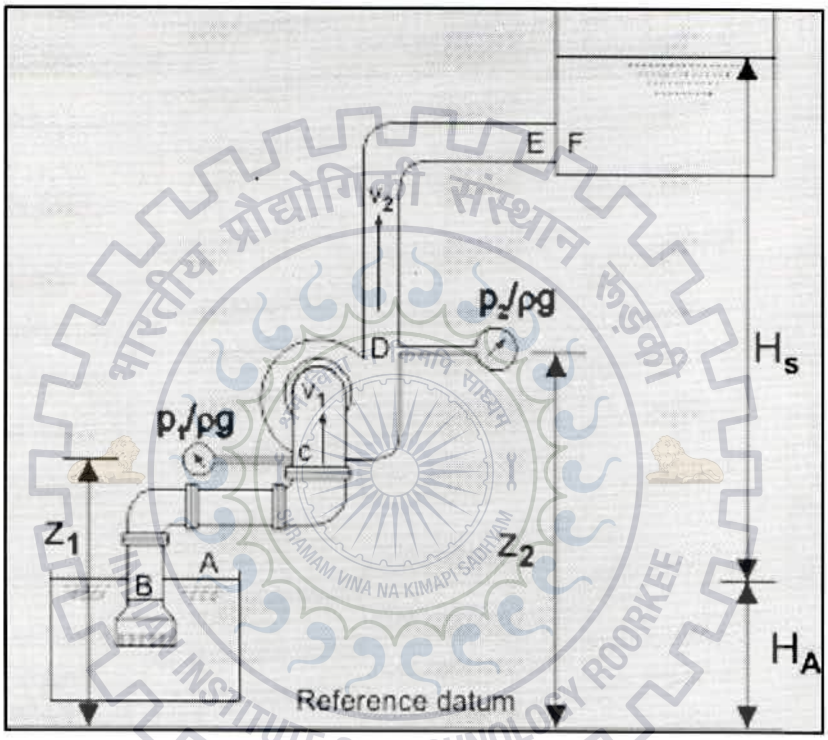

Fig. 1.1 *A general pumping system*

Although the technology of extracting the energy from sewer system needs to be further refined, it is interesting that in the future we may be recycling energy from our own waste stream to generate electricity. Future work could include evaluating present hydro-mechanical technology and researching methods of how to extract energy from contaminated and uncontaminated sewage flows. The final goal would be designing and building a suitable apparatus for waste water energy capture. Although such an alternative source of energy may be a future reality, it is a discipline being studied carefully by many. Who knows, what may be possible?

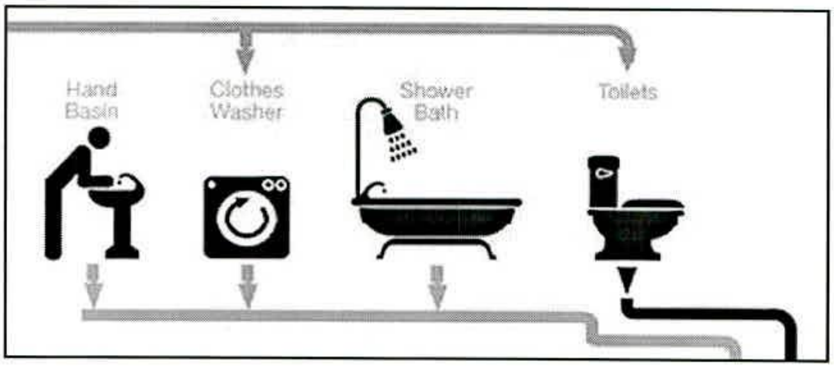

Fig. 1.2 *Domestic water use*

1.2 OBJECTIVES AND METHODODLOGY OF THE CURRENT STUDY

The study aims at finding a solution to extract energy from wastes in a high rise building which is capable of keeping grey water and black water separate as well as able to use solid wastes. The aim is generally related to methods of generating electrical power, and specially to systems which capture otherwise wasted energy. Methods and systems for generating energy from falling water are known in several forms, the most common being hydroelectric dams which seek to capture energy from rivers as the water they carry responds to the downward pull of gravity.

There are a couple of concerns with the known solutions for generating electrical power from the stored energy of elevated liquids in tall buildings:

1) Clogs/Solids—in the known solutions the wastewater comes in contact with the turbine. Depending on the amount and type of solids in the wastewater this can lead to maintenance issues with the turbines getting clogged and needing to be cleaned out to resume generating power.

2) Frequency of waste-water flow—in many cases depending on the occupancy of the building and the time of day the wastewater might not be a constant flow. Known solutions only generate power while (or immediately after) wastewater flows. Additionally a minimum flow rate is required to engage the turbine.

The objectives of the current study "Energy extraction from wastes in a High Rise Building" are:

1) The study aims at finding a solution to extract energy from wastes in a tall rise building.
2) The proposed solution has to be capable of keeping grey and black water separate, as well as use solid wastes and rain water also in extracting energy.
3) To study the space and cost requirements of building the proposed solution.
4) To study the effect of different building sizes and occupancy on the total energy extracted and the cost.
5) To study the effect of different rainfall scenarios on the total energy extracted and its cost.

The approach has been to find an innovative solution to build an apparatus that can convert the potential energy of the falling liquids into useful rotational kinetic energy. The solution has to be such that there is no choking within the system due to solid wastes being drained together with waste water. There is also a concern of inconsistent water flow through the drainage system that has to be addressed. A diligent effort is made in finding an effective solution that helps in solving the concerned issues faced in extracting energy in a high rise building using a turbine in the drainage system. The solution is found out by conceptualizing different ideas and working on them to find the most optimum solution. The finalized design is then developed using 3d platform and analyzed further.

Taking into consideration a 20 storey building of average floor height of 3.5m with 4 flats on each floor with a 5 member family having a daily consumption of 250 litres per person, the total energy wasted per day would be approximately 38 MJ.

Making a system that is even 70% efficient would be able to light up a bulb of 30 W on each floor for 10 hrs.

The amount of work can be broadly divided into four parts which makes the overall methodology of approach towards the dissertation.

1) In the first part, water requirements and its supply is studied in detail so as to find out the total amount of energy used in supplying water to a high rise building.
2) In the second part domestic water use is explored so as to understand the daily use of water for domestic purposes.

3) Conceptualization, design and development of the system is done so as to meet the objectives of the study.
4) In the fourth part the system or apparatus thus developed is analysed for its efficiency, space and cost requirements.

In order to follow the proposed methodology as stated above, the first part is done doing a literature review from different sources like the internet, journals, periodicals, text books and published papers. The second part is also based on literature review of through the above said items. Further work is taken up by thinking out various methods by which falling objects can be made to turn a wheel so as to convert potential energy into rotational kinetic energy. There are a few methods that have been previously explored and they help in finding newer ways of converting mechanical energy of falling liquids and other solid wastes into rotational kinetic energy. Out of the many designs that are thought of, a design that suits the requirements well is chosen and is worked upon to give a final shape. The finalized design is then modeled using SolidWorks, to give shape to the concept. The apparatus is worked upon to make it workable for a suitable building of 20 floors with 4 flats on each floor. The family size is taken as 5 which make a total of 400 occupants in the entire building.

1.3 ORGANIZATION OF THESIS

The current study is organized in the following chapters : Introduction, Water Supply in a High Rise Building, Domestic water use and wastes from a high rise building, 3D modeling using SolidWorks, Development of Energy Extracting System from Wastes, and Results & Conclusions.

Introduction (Chapter 1) emphasizes the importance of rising need of renewable sources of energy, making systems energy efficient and finding ways of extracting energy from otherwise wasted resources of energy, followed by the objectives and methodology and is concluded by the scope of study presented in this dissertation.

Water Supply in a High Rise Building (Chapter 2) describes the components of water distribution system in general, followed by a discussion of pump fundamentals, their types, application, selection of pumps, difference between various pumps and the relevant theory on their energy requirements which help to build an understanding on the energy requirements for pumping a building. Flow of a fluid a pipe is briefly touched upon to understand the waste water flow in the sewage system.

Domestic water use and wastes from a high rise building (Chapter 3) is a dedicated discourse on the domestic water requirements in general while that of an urban city with high rise buildings in particular. The water requirements worldwide is studied which is followed by the per capita requirements in different countries. The per capita requirements set the basic logical understanding of studying the energy requirements and waste water production. Water requirements for daily use for various activities that makes the overall composition of grey and black water from human use is taken up. The grey water and black water study is followed by hourly variation of human water use. It is a variable factor and is a critical factor for designing even the water distribution system as it is the peak demand and not the total demand of water use.

Water use resulting in mix of the grey and black water is followed by the solidwastes that is produced in an urban city. Municipal Solid waste as it is named , is a key component for the design of the system for extraction from wastes.

3D modeling using SolidWorks (Chapter 5) Solid Modeling or 3D modeling is one of the key ingredients of the current study. Using 3D modeling technique the entire apparatus is build up. The application makes the designing process very easy and helps in avoiding making a scaled model. In the chapter dedicated to 3D modeling, fundamentals of solid modeling are taken up.

Various features of the solid modeling technique are studied with regards to the overall development of the system to be build up for the current study. Solidworks features are looked into for an understanding of how to build a solid model. Features like volume and mass properties are also explored, which eventually helps in getting the required details of the system developed later.

Development of the Energy Extracting System(Chapter 6) is a chapter dedicated entirely to the study made in detail. The discourse beginning from understanding the objectives in their entirety with pertinence to the study, leads to the final details and results through the entire design process, the various factors and parameters acting as the constraints that shape the design.

The system or the apparatus being developed has mechanical constraints that needs to be overcome, further the shape and its design has to be a kind of perfect movement of various components which enable smooth transmission of fluid from the building to the ground floor.

The overall design approach has be studied in detail, and so has been the modeling of the design.

The various features of the design are highlighted followed by an analytical approach towards the space and cost requirements. The results are summed up, so as to make a clear understanding of the work done, which helps further to derive accurate conclusions and make statements for the scope of further study.

Conclusions (Chapter 7)The results of the dissertation are analyzed so as to give conclusions regarding the system for extraction of energy from wastes in a high rise building. The conclusions given are followed by recommended suggestions for further study.

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Chapter 2

WATER SUPPLY IN A HIGH RISE BUILDING

2.1 Introduction

Water distribution systems or a Water Distribution Network is a system of interconnected pipes, tanks, and other components through which drinking water is supplied and fire protection needs are met for schools, homes, industries etc.The Public water systems will depend on the distribution systems to provide an uninterrupted supply of required pressurized safe drinking water to all the connected consumers. It is this distribution system of mains that will carry water from the treatment plant (or from the source directly in the absence of a treatment facility) to the consumers.A water supply network or a water supply system is a system of engineered hydrologic and hydraulic components which provide water supply. A Water Supply Scheme can be sub-divided into two basic systems such as:

1) Source, treatment and clear-water storage system.
2) Pumping, distribution storage and distribution system.

Generally a water supply system consistsof:

1. Drainage basin.
2. Collection point for raw water which can be above or below ground where water collects such as a river, lake etc. The water then can be transported by uncovered acqueducts of ground, tunnels which are covered, pipes to water purifications facilities.
3. Facilities for water purification. Treated water is transferred using water pipes (usually underground).
4. Facilities for storing water such as tanks, reservoirs, water towers etc. Cisterns or pressure vessels may be used in case of small water systems. High rise buildings would also need to store water locally under pressure to be able to reach high floors.
5. Pressurizing components such as pumping stations may be required in case where gravity flow is impractical.

6. A network of interconnected pipes to distribute the water to various establishments like private houses, apartments, commercial buildings, industrial requirements and other uses like fire fighting.
7. Connections to the sewers (underground pipes, or aboveground ditches in some developing countries) are generally found downstream of the water consumers, but the sewer system is considered to be a separate system, rather than part of the water supply system.

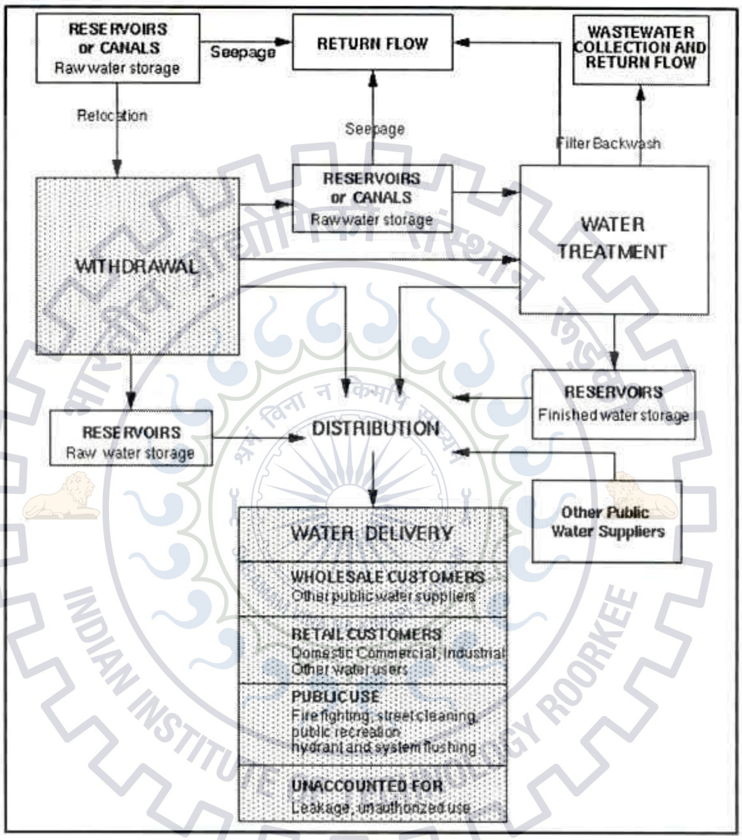

Fig. 2.1 *Water Distribution System*

*

2.2 Water distribution systems have three main parts namely

1) Pumping stations,

2) Distribution storage and

3) Distribution piping.

These components may be further divided into subcomponents, which subsequently can be divided into sub-subcomponents. For instance, the pumping station components consist of structural, electrical, piping and pumping subcomponents. The pumping unit can then be divided further into sub-components such as : pump, driver, controls, and power transmission.

A municipal water supplies system cannot provide its customers till there is a continuous supply of water to meet consumption needs in the broadest sense and water needs for structural fire protection. Water sources need to be selected carefully to make sure that this fundamental requirement is met. Two main factors that affect water supply selection are

1) Quality of water: Water must be treated or purified to meet Regulatory Requirements
2) Quantity of water: The quantity of water must be adequate to meet consumer consumption and fireflow demands at any time of the day, day of week, and week of the year.

Maintaining a continuous or uninterrupted supply of water for municipal demands is a major challenge to many municipalities because of the following conditions:

1) droughts;

2) growing demands that cannot be met by the treatment plant;

3) lack of adequate storage capacity;

4) other communities drawing water from the same supply sources such as a lake or a river;

5) undetected underground leakage on the pipe distribution system.

A municipality must recognize that the quantity of available water needs to be such that maximum daily consumption demands are satisfied at all times, even during periods of drought or after years of community growth. The water delivery system needs to expand as the municipality expands.

2.2.1 Pumps

A hydraulic pump is a hydro-mechanical device that converts mechanical energy into hydraulic energy. It generates flow having enough power to overcome pressure induced by the load.

When a hydraulic pump operates, it does a couple of functions. First, the mechanical action would create a vacuum at inlet of the pump which forces the atmospheric pressure to force liquid from the reservoir to the inlet line of the pump. Secondly, its mechanical motion delivers this liquid to the pump's outlet and forces it into the hydraulic system.

A pump will produce liquid movement or flow but **it does not generate pressure**. It creates the flow necessary for the development of pressure which is a function of resistance to fluid flow in the system. For example, the pressure of the fluid at the pump outlet is *zero* for a pump not connected to a system (load). Further, for a pump delivering into a system, the pressure will rise only to the level necessary to overcome the resistance of the load.

2.2.2 Classification of pumps

All pumps may be divided as either positive-displacement and centrifugal or roto-dynamic pumps.

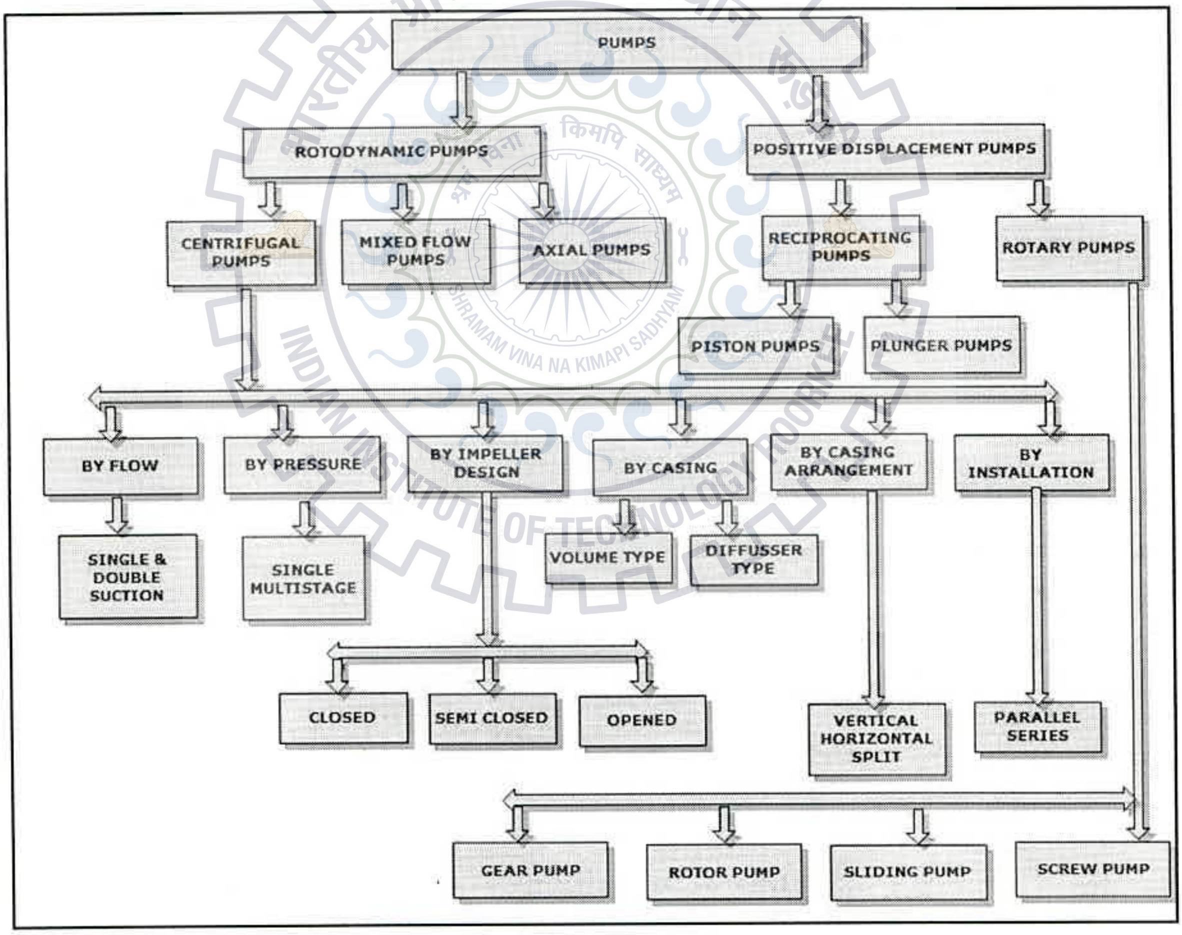

Fig. 2.2 Classification of pumps

Most of the pumps used generally in hydraulic systems are positive-displacement. A **roto-dynamic pump** would produce a continuous flow. However, because it does not provide a positive internal seal against the slippage, its output will vary considerably as pressure varies. Centrifugal and propeller pumps are examples of roto-dynamic pumps. If the output port of a roto-dynamic pump were blocked off, the pressure would rise, and output would decrease to zero. Still the pumping element would continue moving, flow would stop because of the slippage within the pump. In a **positive-displacement pump**, slippage is negligible compared to the pump's volumetric output flow. If the output port were plugged, pressure would increase instantaneously to the point that the pump's pumping element or even its case would fail (probably would explode, if the drive shaft din't break first), or the pump's prime mover would stall.A centrifugal or roto-dynamic pump produces a head and a flow by increasing the velocity of the liquid through the machine with the help of a rotating vane impeller. Centrifugal pumps include radial, axial and mixed flow units.

Centrifugal pumps can further be classified as

- end suction pumps
- in-line pumps
- double suction pumps
- vertical multistage pumps
- horizontal multistage pumps
- submersible pumps
- self-priming pumps
- axial-flow pumps
- regenerative pumps

The **positive displacement pump** operates by alternating of filling a cavity and then displacing a given volume of liquid. The positive displacement pump delivers a constant volume of liquid for each cycle against varying discharge pressure or head.

The positive displacement pump can be classified as:

- Reciprocating pumps - piston, plunger and diaphragm
- Power pumps

- Steam pumps
- Rotary pumps - gear, lobe, screw, vane, regenerative (peripheral)

2.2.3 Selecting between Centrifugal or Positive Displacement Pumps

Selecting between a Centrifugal Pump or a Positive Displacement Pump is not always straight forward. A lot of understanding is required in finding a best match for the requirements. With time, guidelines and processes have been developed that ease the process of finding the perfect solution. The various factors that need to be taken care of while making a decision are discussed.

2.2.3.1 *Flow Rate and Pressure Head*

The two types of pumps behave very differently regarding pressure head and flow rate:

- The Centrifugal Pump has varying flow depending on the system pressure or head
- The Positive Displacement Pump has more or less a constant flow regardless of the system pressure or head. Positive Displacement pumps generally gives more pressure than Centrifugal Pump's.

2.2.3.2 *Capacity and Viscosity*

Another major difference between the pump types is the effect of viscosity on the capacity:

- In the Centrifugal Pump the flow is reduced when the viscosity is increased
- In the Positive Displacement Pump the flow is increased when viscosity is increased

Liquids that have high viscosity would fill the clearance of a Positive Displacement Pump causing a larger volumetric efficiency and a Positive Displacement Pump is more suited for high viscosity applications. A Centrifugal Pump becomes would be very inefficient at even modest viscosity.

2.2.3.3 *Mechanical Efficiency*

The pumps ought to behave different considering mechanical efficiency as well.

- Changing the system pressure or head has little or no effect on the flow rate in the Positive Displacement Pump

- Changing the system pressure or head has a dramatic effect on the flow rate in the Centrifugal Pump

2.2.3.4 *Net Positive Suction Head - NPSH*

Another consideration is the Net Positive Suction Head NPSH.

- In a Centrifugal Pump, NPSH varies as a function of flow determined by pressure
- In a Positive Displacement Pump, NPSH varies as a function of flow determined by speed. Reducing the speed of the Positive Displacement Pump pump, reduces the NPSH

2.2.4 Pumps Characteristics

The fluid quantities that are involved in all hydraulic machines are the flow rate (Q) and the head (H), whereas the mechanical quantities associated with the machine itself are the power (P), speed (N), size (D) and efficiency (h). Although they are of equal importance, the emphasis placed on certain of these quantities is different for different pumps. The output of a pump running at a given speed is the flow rate delivered by it and the head developed. Thus, a plot of head and flow rate at a given speed forms the fundamental performance characteristic of a pump. In order to achieve this performance, a power input is required which involves efficiency of energy transfer. Thus, it is useful to plot also the power P and the efficiency h against Q.

Overall efficiency of a pump (h) = Fluid power output / Power input to the shaft = rgHQ / P

Type number or Specific speed of pump, $n_S = NQ^{1/2} / (gH)^{3/4}$ (it is a dimensionless number)

2.2.4.1 Centrifugal Pump Performance

In the volute of the centrifugal pump, the cross section of the liquid path is greater than in the impeller, and in an ideal frictionless pump the drop from the velocity V to the lower velocity is converted according to Bernoulli's equation, to an increased pressure. This is the source of the discharge pressure of a centrifugal pump.

If the speed of the impeller is increased from N_1 to N_2 rpm, the flow rate will increase from Q_1 to Q_2 as per the given formula:

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$$

The head developed(H) will be proportional to the square of the quantity discharged, so that

$$\frac{H_1}{H_2} = \frac{Q_1^2}{Q_2^2} = \frac{N_1^2}{N_2^2}$$

The power consumed(W) will be the product of H and Q, and, therefore

$$\frac{W_1}{W_2} = \frac{Q_1^3}{Q_2^3} = \frac{N_1^3}{N_2^3}$$

These relationships, however, form only the roughest guide to the performance of centrifugal pumps.

2.2.4.2 Characteristic Curves:

Pump action and the performance of a pump are defined interms of their *characteristic curves*. These curves correlate the capacity of the pump in unit volume per unit time versus discharge or differential pressures. These curves usually supplied by pump manufacturers are for water only.

The curves usually depict the following relationships(for centrifugal pump).

a) A plot of capacity versus differential head. The differential head is the difference in pressure between the suction and discharge.
b) The pump efficiency as a percentage versus capacity.
c) The break horsepower of the pump versus capacity.
d) The net positive head required by the pump versus capacity. The required NPSH for the pump is a characteristic determined by the manufacturer.

Centrifugal pumps are usually rated on the basis of head andcapacity at the point of maximum efficiency.

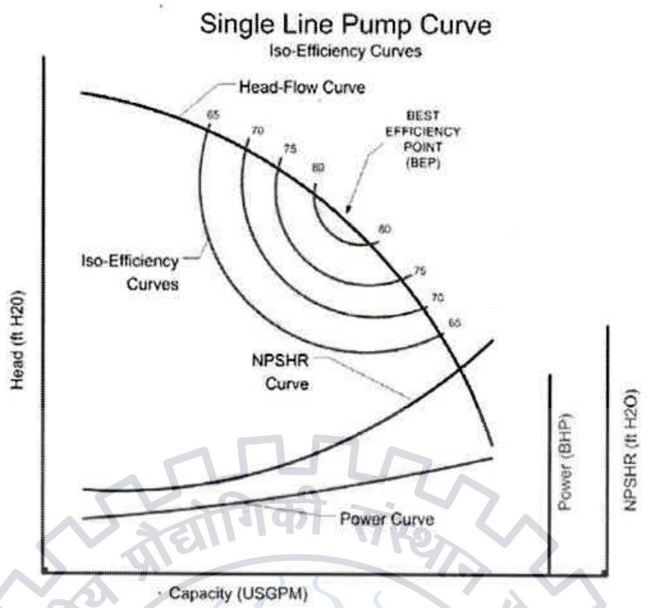

Fig. 2.2 Characteristic Curves of a Centrifugal Pump

2.2.5 Energy requirements of a pump

Hydraulic Pump Power

The ideal hydraulic power to drive a pump depends on

- the mass flow rate the
- liquid density
- the differential height

- either it is the static lift from one height to another, or the friction head loss component of the system - and can be calculated as

$P_{h(kW)} = q \rho g h / (3.6\ 10^6)$ *(1)*

Where

$P_{h(kW)}$ *= hydraulic power (kW)*

q *= flow capacity* (m^3/h)

ρ *= density of fluid* (kg/m^3)

g = gravity (9.81 m/s²)

h = differential head (m)

The hydraulic Horse Power can be calculated as:

$$P_{h(hp)} = P_{h(kW)} / 0.746 \qquad (2)$$

where

$P_{h(hp)}$ = **hydraulic** *horsepower (hp)*

Example - Power pumping Water

1 m³/h of water is pumped a head of ***10 m***. The theoretical pump power can be calculated as

$$P_{h(kW)} = (1\ m^3/h)\ (1000\ kg/m^3)\ (9.81\ m/s^2)\ (10\ m) / (3.6\ 10^6)$$

$$= \underline{0.027}\ kW$$

Shaft Pump Power

The shaft power - the power required transferred from the motor to the shaft of the pump - depends on the efficiency of the pump and can be calculated as

$$P_{s(kW)} = P_{h(kW)} / \eta \qquad (2)$$

Where

$P_{s(kW)}$ = *shaft power (kW)*

η = *pump efficiency*

2.3 Summary

The usual characteristics of the pumps used in water supply distribution are based on their low cost, simplicity and reliability in operation, which is the intrinsic quality of centrifugal pumps. Centrifugal pumps are classified on the direction of flow of liquid through impeller of which give different specific speed, pumping action, head ranges and capacity.

In pump selection power and efficiency are one of the most important factors. Selection of pump is essential task in design of water supply since conveying water often requires of pumping the water over the hills and mountains or into storage facilities. Pumps must be carefully selected in order to operate near peak efficiency at the design flow rate and to operate smoothly throughout the entire range of expected operation conditions.

Moreover, selection of pumps involves review in critical details of the considerations used in the screening process as well as detailed discussions with the pump manufacturers and owners. Detailed evaluation of system hydraulics and consideration of performance of prospective pumps at all operating conditions must be performed. Layout of pumping station must also be taken into consideration in selection of pumps specially the floor area of the pumping station.

Chapter 3

DOMESTIC WATER USE AND WASTE FROM A HIGH RISE BUILDING

3.1 Introduction

With the population growth, urbanization and huge economic development, the demand for freshwater is constantly on the increase throughout the world .At the same time, climate changes and increasing pollution levels are also affecting the availability of fresh water for city residents.Having a continuous supply of clean water to the public is a great task. The water system developed needs to consider many factors such as including population and household sizes, change in the overall physical characteristic of land surfaces, consumer behavior pattern, demands of economic sector (like tourist activities), the water's chemical makeup and the logistics of water storage and its transport. It also has to bring in the challenges faced from climate change that can include unexpected flooding, heat waves and water scarce periods.

To prevent the urban water crises, we would need to manage our water resources effectively at almost every stage: from the likes of supply of clean water to its different uses by the respective consumers. This could largely involve reducing consumption also as well as finding newer ways of collection and using the water. Water management should also be need to better integrated within wider urban management while taking into account characteristics of the available local environment.

Of course of the most important uses for water are at our homes. Domestic water use is the water that is used for indoor and outdoor purposes— all the things that are done at home: drinking, washing clothes, brushing teeths, food preparation, preparing food, bathing, and dishes, brushing your teeth, watering the yard and garden, and even bathing the dog.

Water is generally gets to our homes in one of two ways. Either it is supplied by a city/municipalwater department (or maybe from a private company), or people have their supply their own water, normally from well. Water delivered to homes is called "public-supplied deliveries" and water that people supply themselves is called "self supplied", and is almost is generally always from the groundwater.

3.2 Water Quantity Required for Various Activities

Humans require water for various activities in domestic use that varies from drinking to gardening. The water use differs with communities across the world, with the developed nations using the maximum while the water starved developing nations lie at the bottom. The availability of water resources is a huge factor that drives the water use pattern across the world. Further, not only the developed state of a country is factor, awareness of water scarcity and government role plays a major role.

The amount of water used by any human varies as an average and also it varies on hourly basis. The two factors take us to peak demand and average demand. These two factors are critical in designing any water distribution network or any system whose working depends on the water consumption pattern of humans.

3.2.1 Domestic Uses of Water

It is very important to note here, and this will be make clear later, that the quantity of water consumed generally in Indian cities is not determined by the demand but the supply. People attempt to adjust to the quantity (as well as quality) of water supplied. Having said that, it is apparent that the more water we have, more do we use it and the lesser we have, we adjust accordingly. This is indeed human nature to adapt to the available resources. The following pie chart shows a typical domestic water consumption pattern. It shows that out of the total water consumed, one third is essentially used in flushing and another third is utilized in gardening, which leaves us with the last third part, that is used for the remaining activities of human, that ranges from drinking, cooking food, taking bath, showering, washing clothes, washing utensils, brushing teeth etc.

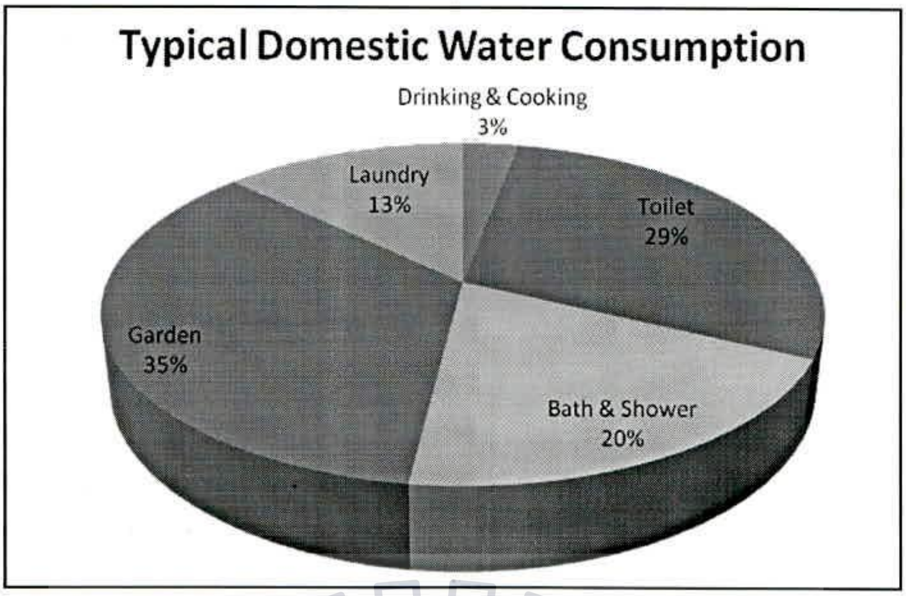

Table 3.1 *Typical Domestic Water Consumption*

White et al. (1972) suggested that three types of use could be defined in relation to normal domestic supply:

a) Consumption (drinking and cooking)
b) Hygiene (including basic needs for personal and domestic cleanliness)
c) Amenity use (for instance car washing, lawn watering).

3.2.2 Per Capita Domestic Water Usage

The per capita water consumption varies worldwide and is indeed an indicator the economic development, urbanization and hygiene conditions prevalent in the country. It is a worldwide perception that water supply will decrease in times to come. It is estimated that global water withdrawals will increase 35 per cent between 1995 and 2020. It has been estimated that in India per capita withdrawal of water is 585 m3 /year, out of which 8 per cent is for domestic 6 per cent for industrial use and 86 per cent for agriculture. Failure to balance the supply side and demand side of water resource management provides a number of negative links in our society, like links to public health problems, environmental degradation and economic loss that are associated with the resulting water shortages and / or water contamination (Serageldin, 1995). The supply of water in large cities of India is going to be a big challenge in future.

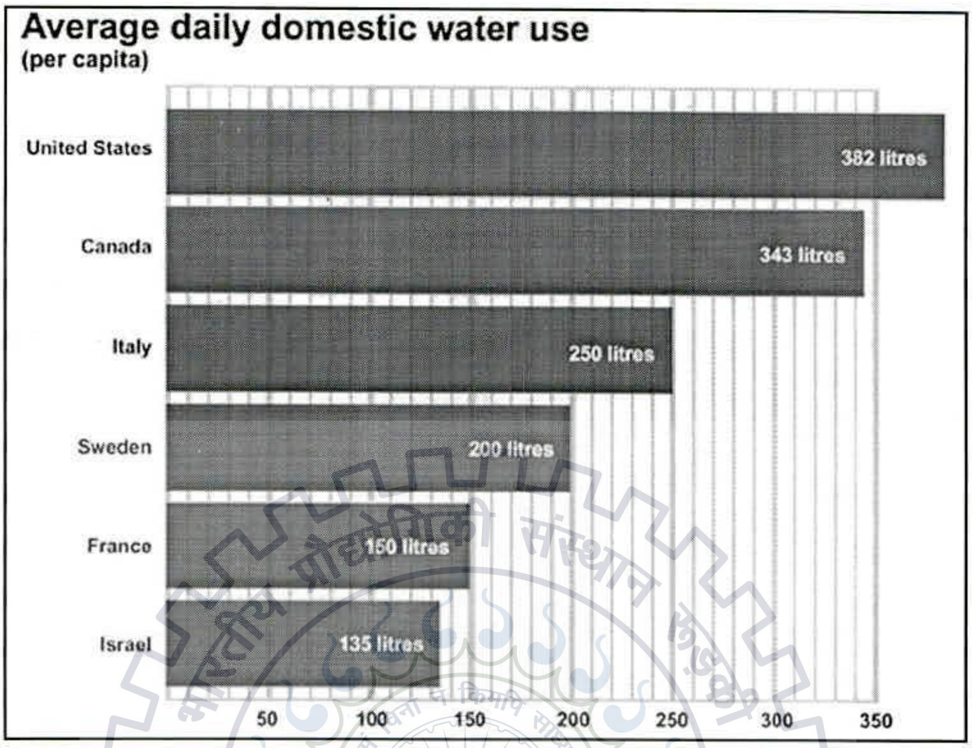

Table 3.2 *Average Daily Water Use*

The rapid increase in population in these cities, depleting water resources and enhanced consumer needs are going to create a difficult situation. The market oriented development is creating new needs in sectors like entertainment industry, tourism and building industry, adapted new technologies pushing up water needs, more supply in shopping malls, and so on. Simultaneously, the alarming rise in pollution levels in surface water needs a comprehensive water policy for cities which are suitable and satisfactory to growing needs of citizens.

3.2.3 Hourly Variation of Domestic Water Usage

3.2.3.1 Factors affecting per capita demand:

a. Size of the city: Per capita demand for big cities is generally large as compared to that for smaller towns as big cities have sewered houses.
b. Presence of industries.

c. Climatic conditions.
d. Habits of people and their economic status.
e. Quality of water: If water is aesthetically and medically safe, the consumption will increase as people will not resort to private wells, etc.
f. Pressure in the distribution system.
g. Efficiency of water works administration: Leaks in water mains and services; and unauthorised use of water can be kept to a minimum by surveys.
h. Cost of water.
i. Policy of metering and charging method: Water tax is charged in two different ways: on the basis of meter reading and on the basis of certain fixed monthly rate.

3.2.3.2 Fluctuations in Rate of Demand

The demand for water is not constant throughout the day or a month or throughout the year. It changes with season so much so that the variation is throughout the day and the peak demand is at time double the average demand. Thus it becomes very important to have a comprehensive understanding of water demand fluctuations before designing any system that serves human needs of water. Average Daily Per Capita Demand = Quantity Required in 12 Months/ (365 x Population)

If this average demand is supplied at all the times, it will not be sufficient to meet the fluctuations.

- ***Seasonal variation***: The demand peaks during summer. Firebreak outs are generally more in summer, increasing demand. So, there is seasonal variation .
- ***Daily variation*** depends on the activity. People draw out more water on Sundays and Festival days, thus increasing demand on these days.
- ***Hourly variations*** are very important as they have a wide range. During active household working hours i.e. from six to ten in the morning and four to eight in the evening, the bulk of the daily requirement is taken. During other hours the requirement is negligible. Moreover, if a fire breaks out, a huge quantity of water is required to be supplied during short duration, necessitating the need for a maximum rate of hourly supply.

So, an adequate quantity of water must be available to meet the peak demand. To meet all the fluctuations, the supply pipes, service reservoirs and distribution pipes must be properly proportioned. The water is supplied by pumping directly and the pumps and distribution system must be designed to meet the peak demand. The effect of monthly variation influences the design of storage reservoirs and the hourly variations influences the design of pumps and service reservoirs. As the population decreases, the fluctuation rate increases.

The changes in the demand can be easily found out by plotting the flow against time for various locations and then finding out an average.

<u>*Maximum daily demand*</u> = 1.8 x average daily demand

<u>*Maximum hourly demand of maximum day i.e. Peak demand*</u>

= 1.5 x average hourly demand

= 1.5 x Maximum daily demand/24

= 1.5 x (1.8 x average daily demand)/24

= 2.7 x average daily demand/24

= 2.7 x annual average hourly demand

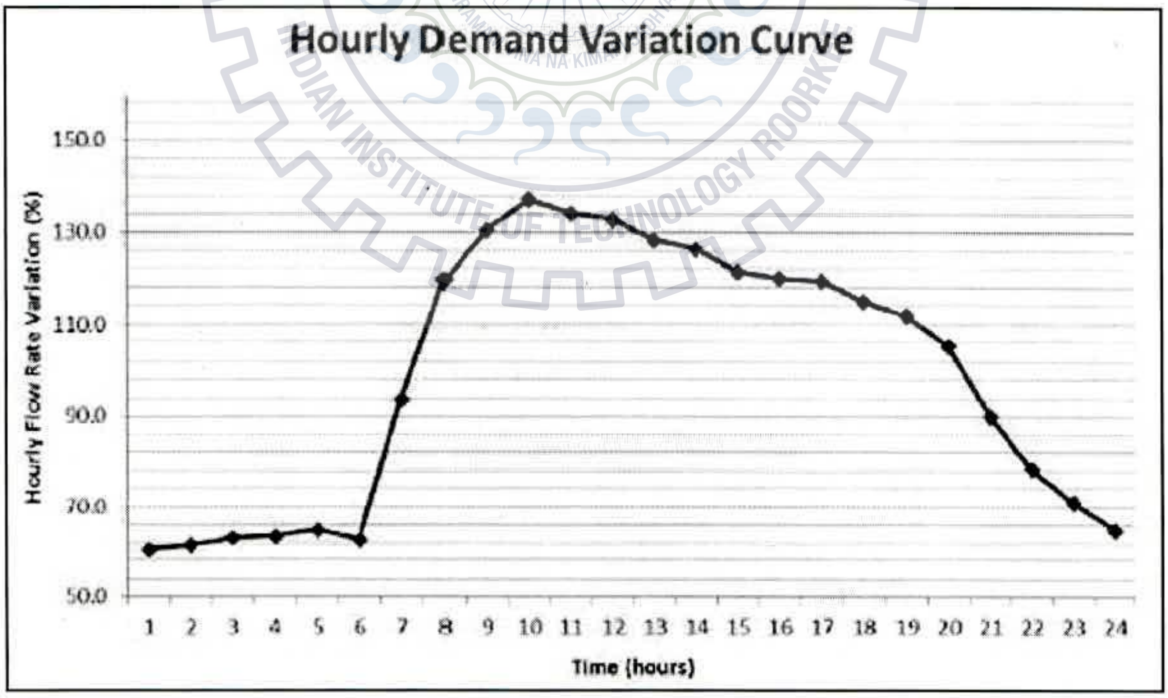

Fig 3.1 *Hourly Water Demand Variation Curve*

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3.2.3.3 Design Periods & Population Forecast

This quantity should be worked out with due provision for the estimated requirements of the future . The future period for which a provision is made in the water supply scheme is known as the **design period**.

Design period is estimated based on the following:

- Useful life of the component, considering obsolescence, wear, tear, etc.
- Expandability aspect.
- Anticipated rate of growth of population, including industrial, commercial developments & migration-immigration.
- Available resources.
- Performance of the system during initial period.

Population Forecasting Methods

The various methods adopted for estimating future populations are given below. The particular method to be adopted for a particular case or for a particular city will vary

a) Arithmetic Increase Method
b) Geometric Increase Method
c) Incremental Increase Method
d) Decreasing Rate of Growth Method
e) Simple Graphical Method
f) Comparative Graphical Method
g) Ratio Method
h) Logistic Curve Method

For the purposes of planning a water system, the total daily water use is less important than the peak daily water use or the *peak demand.* In reality, most of the water used in the home occurs over a very short time period, usually in the morning or evening. As a result, for planning purposes it is recommended that a water system be able to supply all of the days projected water use in a 2-hour peak demand period. If you estimate that your home water use will be 400 gallons per day, the water system should be sized to provide this much water in a 2-hour period.

So, how much water can be delivered from your well or spring in a given period of time? This is referred to as the well or spring *yield*. The yield from a spring can be easily measured by determining how many gallons of water flow from the outlet pipe every minute. This flow rate will likely vary considerably with weather conditions, but, for planning purposes, it would be best to measure flow during a dry time period. For a well, the yield is considered the maximum rate in gallons per minute (GPM) that a well can be pumped without lowering the water level in the borehole below the pump intake.

For most single-family homes, a minimum flow of 6 GPM is suggested from a well or spring. This flow would provide 360 gallons of water each hour, which would be sufficient to meet most home water peak demands. Higher flow rates may be necessary for larger homes with more fixtures, appliances, and residents that may all be using water at the same time. The

3.3 Solid Wastes from an Urban City

Cities now are at the turn of a great threat to the environment, which is the production of an increasingly quantity and the complexity of wastes. The estimated is a quantity of Municipal Solid Waste (MSW) a generated worldwide is a 1.8 – 2.0 billion metric tons. In many a cases, municipal wastes are not properly managed in developing countries, as cities and municipalities are unable to cope with the accelerated pace of waste production.

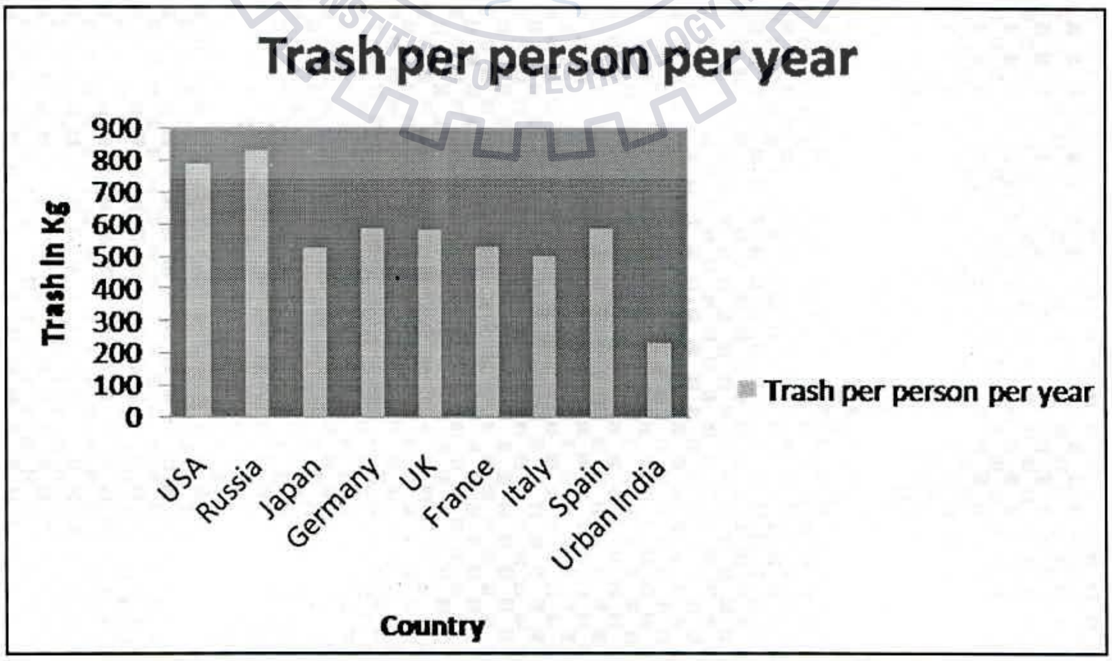

Table 3.3 *Waste produced per capita per annum*

The waste produces is a combination of bio-degradable and non-biodegradable wastes which comes together down the system. If need arises be, separate compartments can also be made for both the types, depending upon the relative proportion of the wastes produced. The urban waste in today's world carries a lot of non-biodegradable waste and most of it is in the form of plastic bags and electronic components or gadgets. There is a dire need to take stock of the alarming rate of these kind of wastes and necessary steps need to be taken, before the situation goes out of hand and nothing could be done. One method is to put the waste materials back into reuse which would save money as well as a lot of time. Thus it is of imminent importance that the required steps be taken at the earliest

3.4 Summary

The amount of wastes in the form of waste water and other solid wastes are constantly on the increase worldwide. The changing lifestyle puts extreme pressures on the available water resources as well as other resources. The per capita water consumption varies worldwide and is indeed an indicator the economic development, urbanization and hygiene conditions prevalent in the country. It is a worldwide perception that water supply will decrease in times to come.The supply of water in large cities of India is going to be a big challenge in future. The rapid increase in population in these cities, depleting water resources and enhanced consumer needs are going to create a difficult situation. The market oriented development is creating new needs in sectors like entertainment industry, tourism and building industry, adapted new technologies pushing up water needs, more supply in shopping malls, and so on. Simultaneously, the alarming rise in pollution levels in surface water needs a comprehensive water policy for cities which are suitable and satisfactory to growing needs of citizens.

Chapter 4

3D MODELING USING SOLIDWORKS

4.1 Introduction

Solid modelling or 3D modeling is one of the most important applications of the CAD software and it has been becoming increasingly popular of late. The solid modeling CAD software is of great help to a designer as it helps him see the concept in his mind as a virtual model and does away with the need to go for an actual physical model which otherwise would be required. Furthermore the model created in virtual world is just like a physical model but in virtual world and cannot be touched by hand as such. It can be seen from various angles and projections can be taken from any direction as well. Thus the designer has the concept of his mind or some else made into a virtual file that can be transported free of cost, seen from various angles, can be checked for interferences, can be used for physical testing in FEM applications, its volume, mass, dimensions can be easily found.The designer can also see for himself, what are the required changes that are to be made to the model to make it as the one that is intended to be developed. The amount of time in all these actions is small in comparison to the actual time that would have been spend had the model was to be developed as a physical model. Firstly wired models are made and then they are converted to solid models by applying surfaces. A lot of software packages are available in the market today to aid the process, prominent among them are the SolidWorks, SolidEdge, ProE, Catia etc.

Solid modelling in today's world is an interdisciplinary field involving a growing number of different areas. The objective evolves from an understanding of the various practices and needs of the domains of applications that are targeted. The formulation are based on mathematical foundations from general and algebraic topology to Euclidean , differential and algebraic geometry. Aspects related to computational side of solid modelling requires efficient date structures and algorithms and recent developments in the field of computational geometry has helped a lot in developing the field. Highly efficient processing is required to process huge data fields and the complexity of the data makes it more cumbersome. It could be sensed that the industrial models are fast growing and tend to outpace the performance of general workstations so high configurations are required.

Modeling and techniques of analysing surfaces are an important lot in 3D modelling. The area of research that serves the purpose sometimes called computer aided geometric design has strong relations with differential geometry and numerical analysis. Graphic user-interface (GUI) also has a very important part in 3d modelling as it tends to find the overall modelere usability and also user's productivity is affected.

Solid modeling interfaces are based on efficient three-dimensional (3D) graphics techniques, whereas research in 3D graphics focuses on fast or photo-realistic rendering of complex scenes, often composed of solid models, and on realistic or artistic animations of non-rigid objects. A similar symbiotic relation with computer vision is regaining popularity, as many research efforts in vision are model-based and attempt to extract 3D models from images or video sequences of existing parts or scenes. These efforts are particularly important for solid modeling, because the cost of manually designing solid models of existing objects or scenes far exceeds the other costs (hardware, software, maintenance, and training) associated with solid modeling. Finally, the growing complexity of solid models and the growing need for collaboration, reusability of design, and interoperability of software require expertise in distributed databases, constraint management systems, optimization techniques, object linking standards, and internet protocols.

4.2 Applications of Solid Modeling

Solid modeling is used not only for creating solid models of machine parts, but also the buildings, electric circuits and even of the human beings. The solid modeling software are being used for a large variety of applications, here are some of them:

4.2.1 Engineering: The engineering design professionals use solid modeling to see how the designed product will actually look like. The architects and civil engineers use it to use the layout of the designed building.

4.2.2 Entertainment industry: The animation industry has been using solid modeling to create various characters and the movies out of them.

4.2.3 Medical industry: Modern imaging scanners are being used to create the solid models of the internal parts of the body. This helps the doctors to visualize specific tissues of the body, designing various medical devices etc.

4.3 Solid Modeling in Mechanical engineering

In mechanical engineering a solid model is used for the following applications:

1) **Graphics:** generating drawings, surface and solid models.
2) **Design :** Mass property calculation, interference analysis, finite element modeling, kinematics and mechanism analysis, animation etc.
3) **Manufacturing:** Tool path generation and verification, process planning, dimension inspection, tolerance and surface finish. 4. Component Assembly: Application to robotics and flexible manufacturing: Assembly planning, vision algorithm, kinematics and dynamics driven by solid models.

4.4 Solid Model Representation

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There are three different forms in which a solid model can be represented in CAD:

1) **Wireframe Model**
2) **Surface Model**
3) **Solid Model**

4.4.1 Wireframe Models: Joining points and curves creates wireframe models. These models can be ambiguous and unable to provide mass property calculations, hidden surface removal, or generation of shaded images. Wireframe models are mainly used for a quick verification of design ideas.

4.4.2 Surface Models: Surface models are created using points, lines, and planes. A surface model is unable to identify points that do not lie on the surface, and therefore, the moment of inertia, volume, or sections of the model cannot be obtained. A surface model can be shaded for better visibility. Surface models are used for modeling surfaces of engineering components.

4.4.3 Solid models: Solid models are the most preferred form of CAD models. and represent unambiguous image of a component. A solid model can be used to analyze the moment of inertia, mass, volume, sections of the model, etc. Solid models are mathematical models of objects in the real world that satisfy specific properties, listed below.

1. Bounded: The boundary must limit and contain the interior of the solid.

2. Homogeneously Three-Dimensional: No dangling edges or faces be present so that the boundary is always in contact with the interior of the solid.

3. Finite: The solid must be finite in size.

4.5 Solid Model Creation Scheme

A solid model can be generated by the following schemes.

1. Constructive Solid Geometry (CSG)

2. Boundary Representation (B-Rep)

3. Sweeping

A brief description of these schemes follows.

4.5.1 Constructive Solid Geometry Scheme

This scheme is based on the principle that two primitives can be combined to produce a new solid model. This method is also known as 'Building Block' method. The scheme uses the Union, Intersection, and Subtraction techniques to create three-dimensional models, which are based on the Boolean operation. The steps involved in generating a solid model are:

1. Select the primitives from a library
2. Go through the scaling, dimension modification, and any other transformations.
3. Combine the primitives to create the desired solid model.

Since CSG method uses solid primitives, internal details of the object are automatically contained in the model. The model can be sectioned to reveal internal details and can be used for calculating mass, volume, moment of inertia, etc.

New solid models can be created from the primitives or other solid models by the following operations:

1. Union (U): Two solids are joined and the common volume of one of the primitives is neglected in the resulting solid.

2. Subtraction or Difference (-): One solid is subtracted from the other and the resultant solid retains only the uncut portion of the solid.

3. Intersection (Π): When two solids are combined, the resultant solid represents the common volume of the two solids.

The most common primitive solids found in a CAD program are: Block, Cylinder, Cone, Sphere, Wedge, and Torus.

4.5.2 Boundary Representation (B-Rep) Scheme

This scheme is based on the concept that a physical object is bounded by a set of faces. A solid model is created by combining faces and contains vertices, edges, loops, and bodies. Only the boundary surfaces of the model are stored and the volumetric properties are calculated by the Gauss Divergence theorem, which relates volume integral to surface integrals. This scheme can model a variety of solids depending on the primitive surfaces (planar, curved, or sculptured). There are two types of solid models in this scheme:

1. Polyhedral solids
2. Curved solids

4.5.2.1 Polyhedral Solids: Polyhedral models consist of straight edges, e.g., a non-cylindrical surface: box, wedge, combination of two or more non-cylindrical bodies, etc. Polyhedral solids can have blind or through holes, and two or three-dimensional faces, with no dangling edges.

A valid polyhedral abides by the Euler's equation: $F - E + V - L = 2(B - G)$

Where, F = Face

E = Edge

V = Vertices

L = Inner Loop

B = Bodies

G = Through holes

A simple polyhedral has no holes; each face is bounded by a single set of connected edges (bounded by one loop of edges).

Euler's equation for a simple polyhedral can be reduced to: F - E + V = 2

4.5.2.2 Curved Solids: A curved solid is similar to a polyhedral object but it has curved faces and edges. Spheres and cylinders are examples of curved solids.

4.5.3 Sweeping Scheme

Sweeping can create a solid model. The method is useful for creating 2 ½ – dimension models. The generated models are axisymmetric and have uniform thickness (i.e., extruded models). There are two types of sweeps: linear and rotational. In linear sweep, a closed 2-D sketch is extruded through the desired length, creating a homogeneous and axisymmetric model, as shown in the figure. Sweep direction Linear sweep – Creating a box by sweeping a rectangle In rotational sweep, a closed sketch is rotated around an axis. The generated model is always axisymmetric. In addition to the two sweeps described above, a model can also be created by a nonlinear sweep. In this type of sweep, a closed sketch is sweeped along a non-linear path

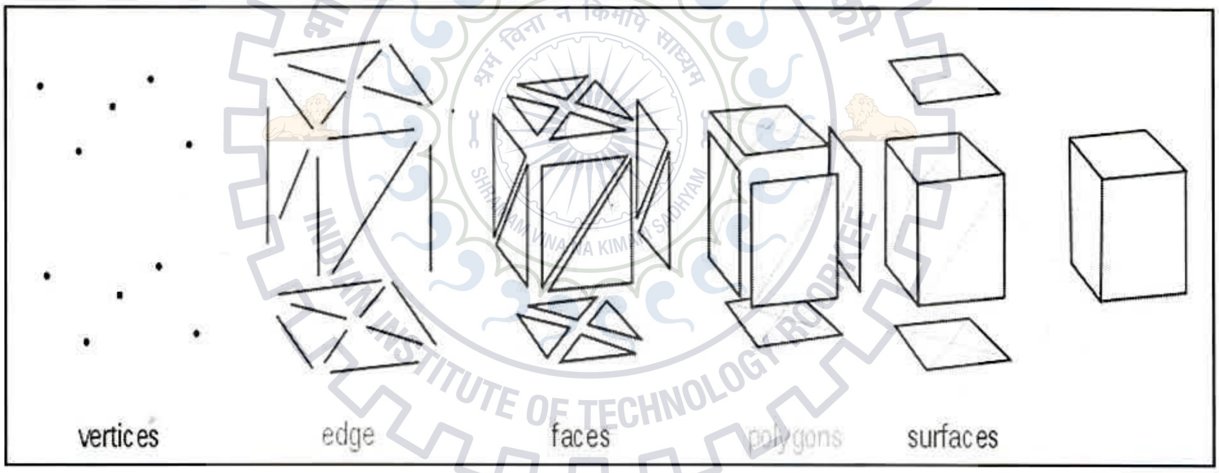

Fig. 4.1 *Entities of a Solid Model*

4.6 Summary

Just as s set of 2D lines and curves does not need to describe the boundary of a closed area, a collection of 3D planes and surfaces does not necessarily bound a closed volume. In many applications, however, it is important to distinguish between the inside, outside, and surface of a 3D object and to be able to compute properties of the object that depend on this distinction. In CAD/CAM, for example, if a solid object can be modeled in a way that adequately captures is manufactured. We may wish to determine whether two objects interfere with each other; for example, whether a robot arm will bump into objects in its environment, or whether a cutting tool will cut only the material it is intended to remove. In simulating physical mechanisms, such as a gear train, it may be important to compute properties such as volume and center of mass .Finite-element analysis is applied to solid models to determine response to factors such as stress and temperature through finite-element modeling. A satisfactory representation for a solid object may even make it possible to generate instructions automatically for computer-controlled machine tools to create that object. In addition, some graphical techniques, such as modeling refractive transparency, depend on being able to determine where a beam of light enters and exits a object. These applications are all examples of solid modeling. The need to model objects as solids has resulted in the development of a variety of specialized ways to represent them.

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Chapter 5
DEVELOPMENT OF THE ENERGY EXTRACTION SYSTEM

5.1 Introduction

In today's world where energy requirements are constantly on the rise, a lot of emphasis is being laid on using renewable sources of energy, making systems more efficient as well as extracting energy from resources which till recently were considered wasted, but are indeed resources of energy which are capable of providing key solutions to energy requirements of the modern world.

Putting waste energy to use from exhaust gases in a thermal power station or in an automobile is well known, but extracting energy from wastes in a high rise building is something that has not been explored very much. A lot of energy is used in pumping water to tall rise buildings in a modern city like Gurgaon, but the waste water is simply drained down thereby wasting its mechanical energy which could otherwise be harnessed to generate electricity.

Taking into consideration a 20 storey building of average floor height of 3.5m with 4 flats on each floor with a 5 member family having a daily consumption of 250 litres per person, the total energy wasted per day would be approximately 38 MJ. Making a system that is even 70% efficient would be able to light up a bulb of 30 W on each floor for 10 hrs.
Methods and systems for generating energy from falling Water are known in several forms, the most common being hydroelectric dams which seek to capture energy from rivers as the Water they carry responds to the downward pull of gravity. Another method known in the art is a "pump-back" lake, which is actually two lakes separated by a vertical distance. During times in Which electricity is in higher demand or When electricity is sold for a greater value, Water from the upper lake is released through a hydroelectric dam to the lower lake to generate electricity, Which is sold at the higher value or used to supplement the peak demand for energy. Then, When demand is lower or energy prices are lower, electricity is purchased to pump Water from the lower lake back up to the upper lake, thereby "reloading" the upper lake to generate electricity during the next peak demand or peak value period. The net value of this system is the difference between the higher value of electricity at the peak demand period and the lower value of electricity at the lower demand period. Most of the Water,

except for loss via evaporation and absorption, is conserved throughout the process. Several other methods and systems for generating power as Water falls through a building are also known or proposed. In one system, rain Water is collected from the top of tall buildings, and directed through downspouts through turbines which generate electricity, annally into the rain sewer system. Similarly, Water may be collected from gray sources, such as showers and clothes Washers, and optionally from black sources, such as toilets, and directed through turbines to generate power before it is ?nally disposed into a sanitary sewer. Each of these approaches uses turbines, Which essentially consist of impellers or fan blades over Which the falling liquid and contaminants it carries pass, thereby converting a portion of the kinetic energy of the falling liquid and solids into rotational energy Which can be directed to an electrical generator.

Generally speaking, the contaminants such as sewage solids, dirt, etc., may cling to the turbine blades (e.g. impeller) and over time add mass to the turbine blades. This can eventually lower the performance of the electrical generation to the point Where maintenance is required to clean the blades, Which is a costly and unclean As the population increases across a mostly mixed footprint of urban land mass, a common Way to address the increasing housing needs to expand upwards, especially In cities and land-locked areas. More and more tall buildings Will be constructed, and the need to optimize the energy usage Will be One of the systems that every building contains is a Waste Water system. Energy is used to move Water (and other materials) upwards in the building, and the potential energy of that wastewater as it moves down through the building can be harnessed to create energy.

5.2 Objective of the Study

The study aims at finding a solution to extract energy from wastes in a high rise building which is capable of keeping grey water and black water separate as well as able to use solid wastes. The aim is generally related to methods of generating electrical power, and especially to systems which capture otherwise wasted energy. Methods and systems for generating energy from falling water are known in several forms, the most common being hydroelectric dams which seek to capture energy from rivers as the water they carry responds to the downward pull of gravity.

There are two problems with the known solutions for generating electrical power from the potential energy of elevated liquids in tall buildings:

1) Clogs/Solids—in the known solutions the wastewater comes in contact with the turbine. Depending on the amount and type of solids in the wastewater this can lead to maintenance issues with the turbines getting clogged and needing to be cleaned out to resume generating power.

2) Frequency of waste-water flow—in many cases depending on the occupancy of the building and the time of day the wastewater might not be a constant flow. Known solutions only generate power while (or immediately after) wastewater flows. Additionally a minimum flow rate is required to engage the turbine.

5.3 System Proposed

1) Electrical power is generated from falling liquids such as captured rain water, gray water and black water in tall buildings using two reservoirs.
2) Movement of each of the reservoirs is controlled in a way such that the first reservoir while being lowered collects waste from each floor and the second reservoir is emptied in a lowered position.
3) The first reservoir is dropped to the lowered position while imparting mechanical energy to an electrical generator and while raising the second reservoir to the top position.
4) Now, the second reservoir is lowered from top to bottom collecting water from each floor, while the first one gets emptied at bottom.
5) The cycle thus completed is repeated.

To address these problems, embodiments of the present study uses reservoirs, a feed and control system, and a discharge control system to charge a kinetic storage device, which is then used to generate power. This solves the problem of clogs/solids as there are no moving pieces in-line with the wastewater to clog. This solves the frequency issue as the invention captures small amounts of wastewater until the minimum amount is gathered to put the power generation in motion. Additionally, it can continue to generate power for a short amount of time even after the wastewater has stopped working. Generally speaking, embodiments of the present study follow a process as such:

1) Wastewater enters the system continuously from each floor.

2) The system operates in a way as to send the wastewater to one of the empty reservoirs which is in a raised (elevated) position, while emptying one or more of the reservoirs which is in a lower position;

3) When the lower reservoir is empty and the raised reservoir is moving down, through a mechanical interaction, the reservoir is allowed to fall or drop, while the empty reservoir(s) is/are allowed to raise, meanwhile the falling action of the full reservoir imparts an impulse of energy to a kinetic storage device, While the how of water from above may be optionally directed around the system via a bypass;

4) Upon coming down of the raised reservoir and emptying of the lowered reservoir, they are again allowed to swap positions (upper falling, lower raising) while making a mechanical impulse of energy to the kinetic storage device and optionally while diverting additional water through a bypass.

This process cycle is repeated for two or more reservoirs in some embodiments, thereby allowing full raised reservoirs to fall and generate electricity, while also raising lowered emptied reservoirs. The kinetic storage device, such as a flywheel or raised weight, drives the input to an electrical generator, which produces electricity on a continuous basis due to the constant output of the kinetic storage device. In some embodiments, only one reservoir may be used which may be lower in cost to implement, but may, depending on design details, not capture as much energy. In such a one reservoir embodiment, the previously-described cycle for just the first reservoir would be implemented, for example. The mechanism for imparting mechanical energy into the kinetic storage device may be any of a range of mechanical, electro -mechanical, magnetic, hydraulic, and pneumatic options, such as but not limited to a chain and sprocket drive system, a shaft drive, a gear drive, a magnetic coupling, a hydraulic pump, and a pneumatic pump.

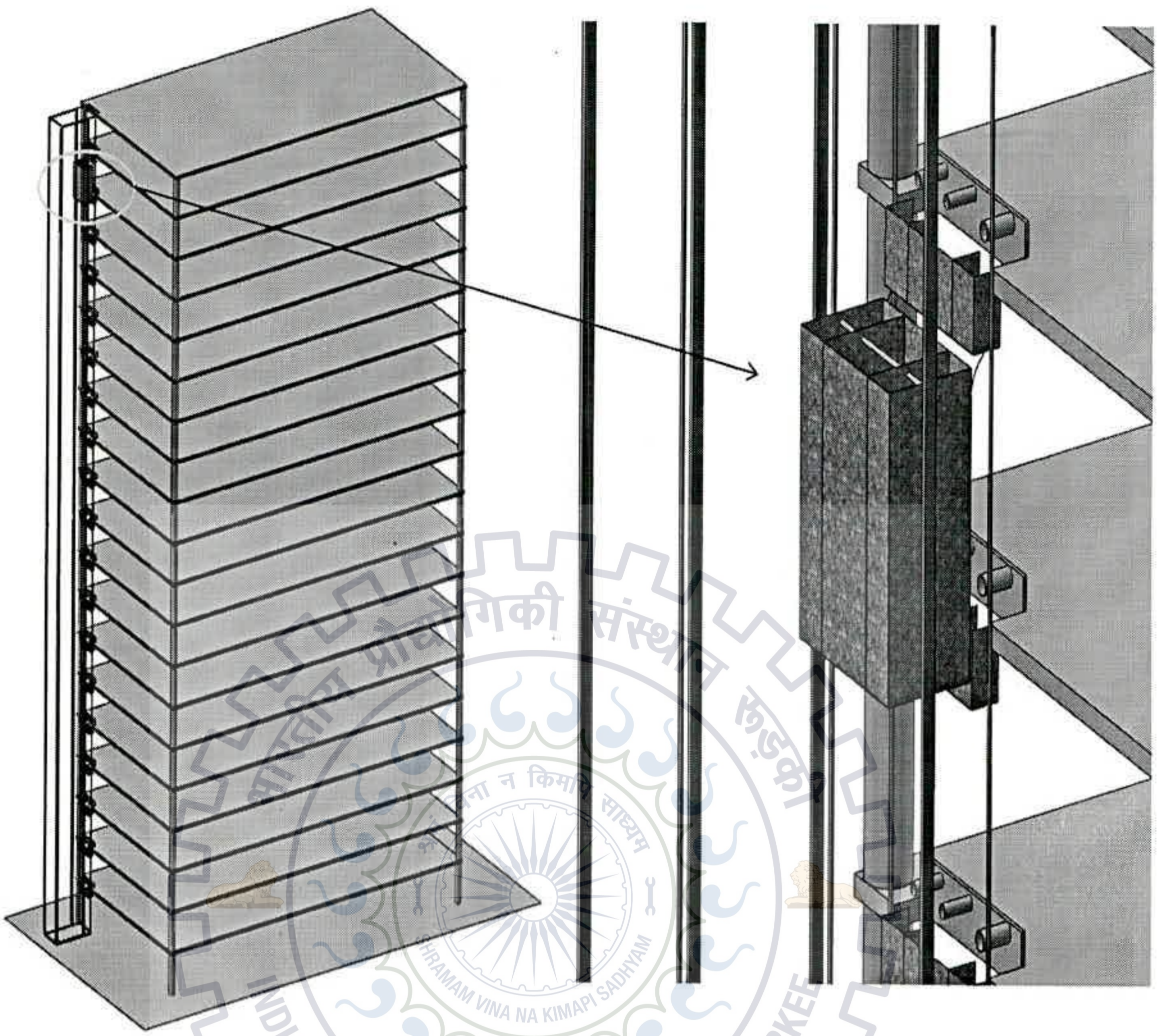

Fig. 5.1 *The waste water energy extracting system*

In today's world a lot of energy is supplied to a modern city to meet the ever increasing energy requirements and a lot of energy is wasted out of the total energy supplied. In a high rise building a lot of energy is used to pump water for domestic requirements. The waste water is simply dumped to ground level wasting its potential energy. Turbines and pump as turbines (PAT) have been used in some places around the world to harness the energy of waste water but they face a great maintenance challenge for the system is choked, get rusted and further the inconsistent water flow makes their use quite difficult. In the present study, effort has been made to find out a suitable solution that could help east out the difficulties faced in extracting energy from wastes in a high rise building. Also, effort has been made to orient the system in a way that enables to extract energy from rain water as well. The solution is designed and developed using a 3D Modeling platform, which enables to find the material and space requirements helping in studying the cost involved and cost of power generated. A couple of case studies are taken up to simulate different scenarios of annual rainfall and different apartment sizes. It has been found that the effect of rainfall is very small in the total energy extracted. Though the system is able to address the two main challenges of choking and inconsistent water flow, but the cost of energy is found to be on the higher side. The system thus needs to be further refined to bring down the cost of energy. The various results thus obtained and the case studies made are discussed to identify various aspects that need to be addressed.

5.4 Building Specifications

The building taken up for the study is a 20 floor building which has got 4 flats on each floor. Therefore the number of families on each floor is 4. The number of people in each family is assumed to be 5. The building specifications make a major criterion in designing the system. Also the total energy that can be reclaimed also would depend upon the size of the building and the number of occupants. The system proposed would also change with different building styles. Thus the system is a tailor made one and it would change with building. Once the entire design is developed and refined, guidelines can be drawn for the design of the system which would be of great help for anyone to design the system for any particular building.

It could be easily make out that with the increase of the building size, the total amount of energy would increase, and so would be the rainwater energy that can be successfully captured. But the amount of money that would go in designing the system could not be calculated that easily as the material requirements would change with the system. Thus it would become necessary either to go for a full working model of the system or use some alternative to find out the material requirement. Solid modelling gives a great platform to do jobs of these kind as it enables the user to go for actual physical model, rather a virtual model can be done in some time and the material properties, mass properties of the required material that would go into the system could be found out, which otherwise would be a very cumbersome task. The building specification of the system taken here are as follows

Area of each flat = 50 * 30 = 1500 Sq. Ft.

No. of flats on each floor = 4

Total covered Area including miscellaneous requirements = 1500 x 4 + 1000

= 7000 Sq. Ft. (650 m^2)

No. of floors = 20

Floor height = 3.5m

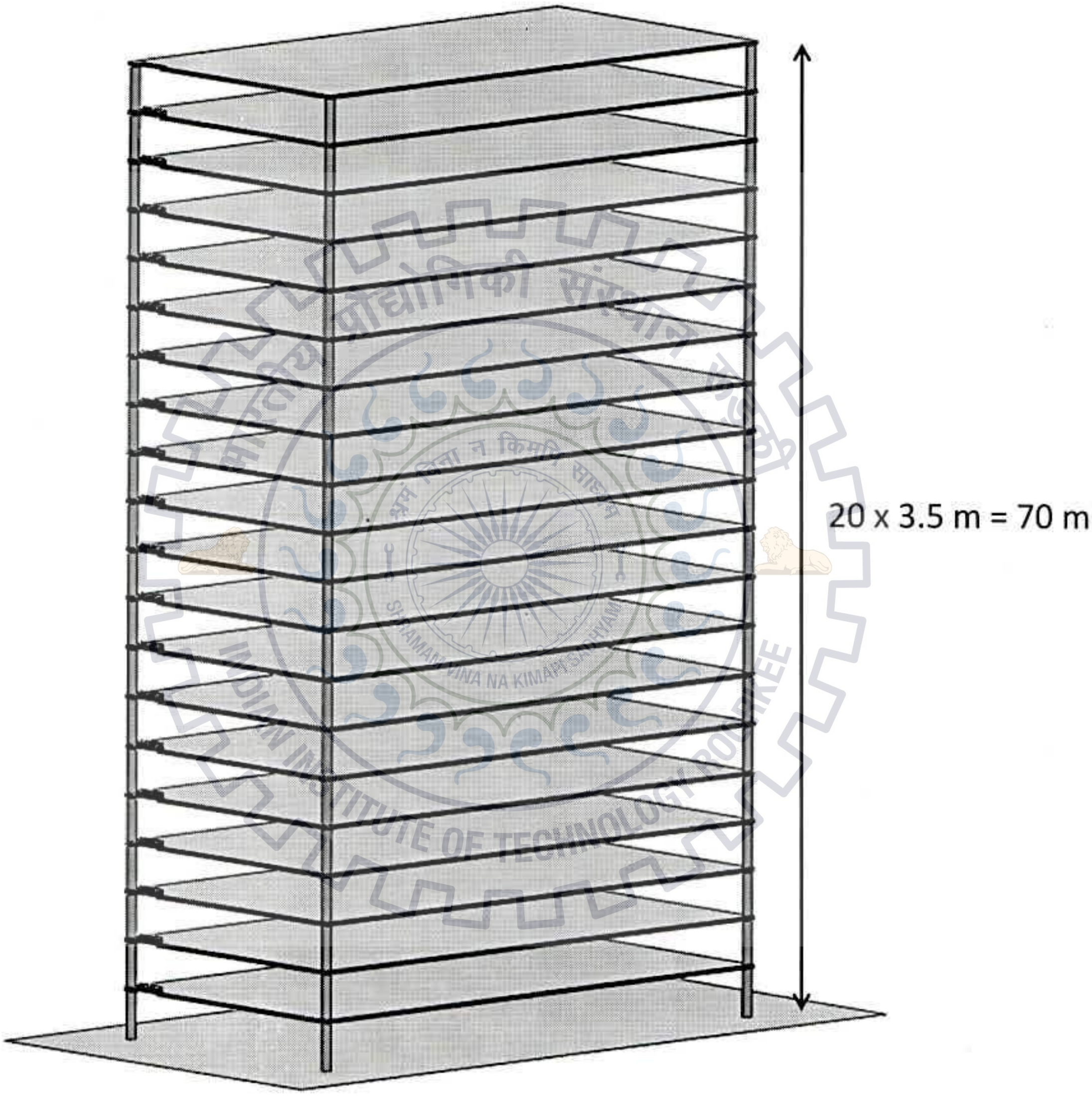

Fig. 5.2 *A solid model of the building*

5.5 Supply Water Calculations

The building taken up for the study is a 20 floor building which has got 4 flats on each floor. Therefore the number of families on each floor is 4. The number of people in each family is assumed to be 5. The total flow of water supplied to the building would get back to ground level after use in the building by the human population. The water depending upon its usage for various activities would be converted to either grey water or black water. The two compositions of the water would make up the total waste water produced. The designing of the entire system would be dependent upon various factors which would include the total water consumption of the building, percentage of grey and black water produced, amount of the solid waste produced by humans, site location as it would limit the space use. The various parameters need to be taken up carefully as it would affect the entire design and working of the system.

No. of floors = 20

Family members per family = 5

No. of families per floor = 4

No. of persons on each floor = Family members per family x Total families per floor = 5 x 4 = 20

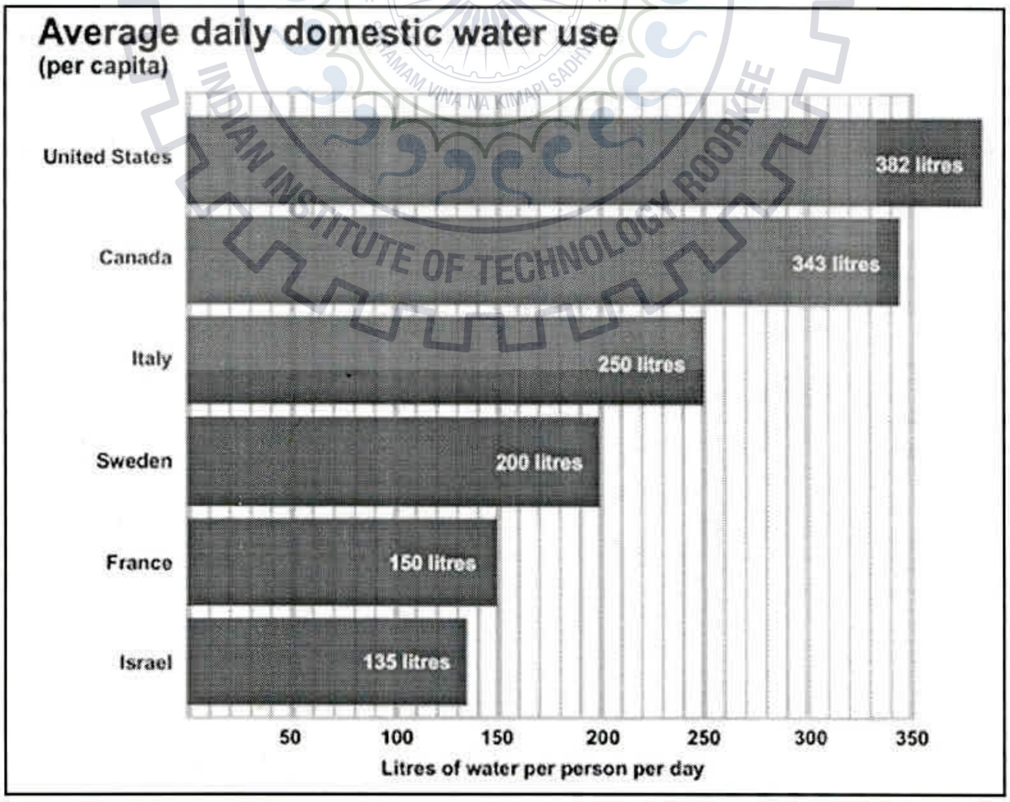

Fig. 5.3 *Average daily water consumption*

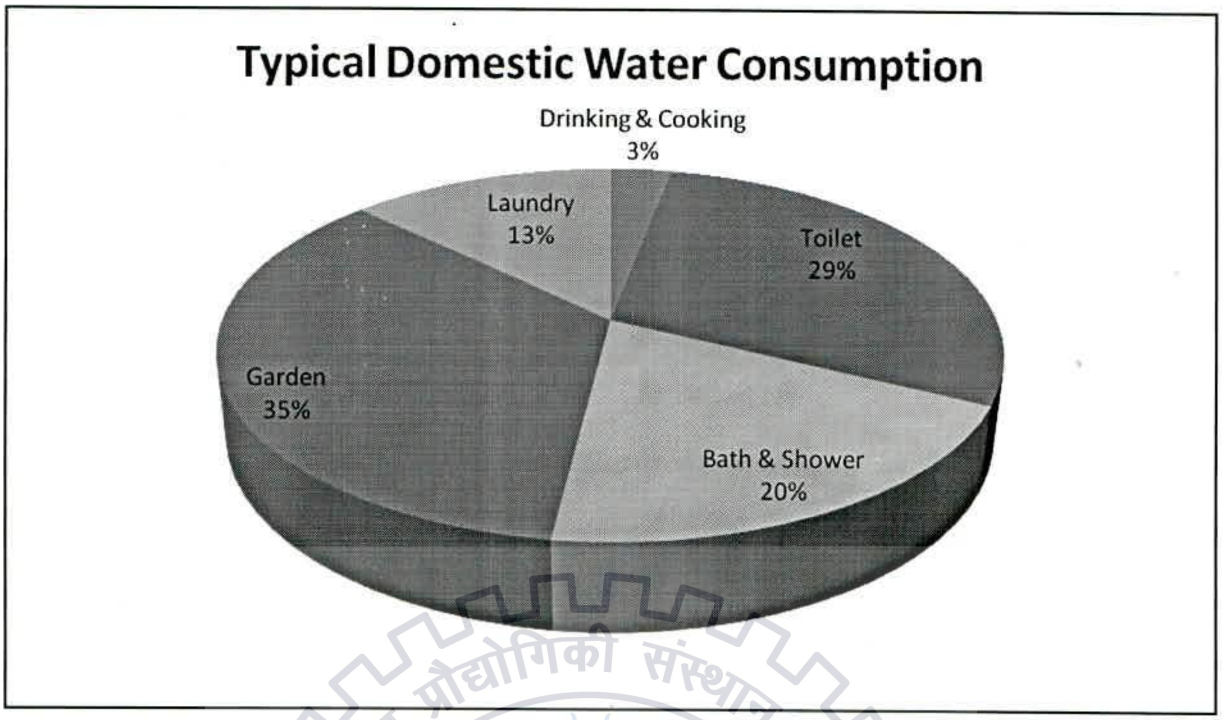

Fig. 5.4 *Domestic water consumption for various activities*

Average use of water per person per day = 250 L

Water usage per floor = 20 * 250 = 5000 L

Total water usage in the building per day = 5000 x 20 = 100,000 L

Miscellaneous water requirements = 10% of net requirement = 10000 L

Water pumped each day = 110,000 L

The water pumped is ultimately disposed off as waste after use in drinking, washing, bathing and other activities. Of the total waste water 30% of Black Water (33,000 L) and 70% of Grey Water (77,000 L) is produced.

5.6 Solid Waste Calculations

The proposed system is made in a way so to reclaim the potential energy of the solid waste as well. There would be a lot of waste produced from each floor, which can be utilised to add on the total energy from waste water.The building taken up for the study is a 20 floor building which has got 4 flats on each floor. Therefore the number of families on each floor is 4. The number of people in each family is assumed to be 5. The total flow of water supplied to the building would get back to ground level after use in the building by the human population. The water depending upon its usage for various activities would be converted to either grey water or black water. The two compositions of the water would make up the total waste water produced. The designing of the entire system would be dependent upon various factors which would include the total water consumption of the building, percentage of grey and black water produced, amount of the solid waste produced by humans, site location as it would limit the space use.

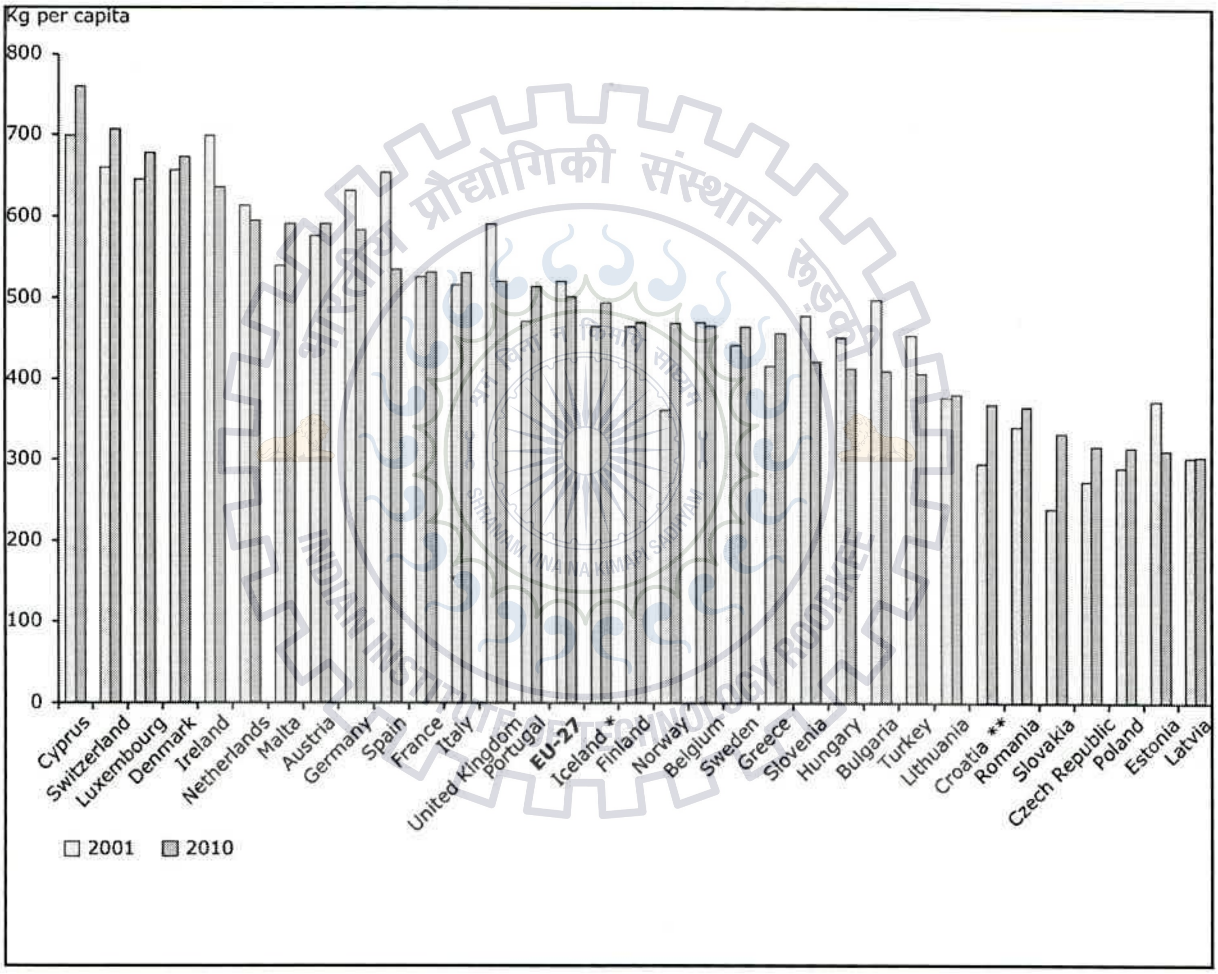

Table 5.1 *Average trash produced per capita per annum*

The amount of solid produced per annum per capita is shown here in a tabulated form. It can be seen that most of the countries produce around 600 kg of waste per capita per annum. The maximum amount of solid waste is 800 kg per capita per annum. For our calculations, we take the maximum limit as it makes our system more robust and for future expansions also. The waste produces is a combination of bio-degradable and non-biodegradable wastes which comes together down the system. If need arises be, separate compartments can also be made for both the types, depending upon the relative proportion of the wastes produced. The urban waste in today's world carries a lot of non-biodegradable waste and most of it is in the form of plastic bags and electronic components or gadgets. There is a dire need to take stock of the alarming rate of these kind of wastes and necessary steps need to be taken, before the situation goes out of hand and nothing could be done. One method is to put the waste materials back into reuse which would save money as well as a lot of time. Thus it is of imminent importance that the required steps be taken at the earliest.

Urban waste produced per capita per annum = 800 Kg

Urban Waste produced per capita per day = 2.2 Kg

Urban Waste per floor = 2.2 x 20 = 44 Kg

5.7 Design of the system

The proposed design is a tailor made solution that would fit a particular site location. Depending upon various parameters involved, the design would change accordingly for different locations. So, there has to be a comprehensive design procedure for the system design that would take shape with progress on the development and the challenges face in designing the system. Both these aspects would go on simultaneously and thus leading to a full discourse on the design procedure. Extreme care has been taken here, so as to not bring in unnecessary parameters and also not to leave the required parameters. The work has been done continuously on paper and solid modelling using SolidWorks so as to take up minimum time in coming up with a working solution for the objective.

It could be easily make out that with the increase of the building size, the total amount of energy would increase, and so would be the rainwater energy that can be successfully captured. But the amount of money that would go in designing the system could not be calculated that easily as the material requirements would change with the system. Thus it would become necessary either to go for a full working model of the system or use some alternative to find out the material requirement. Solid modelling gives a great platform to do jobs of these kind as it enables the user to go for actual physical model, rather a virtual model can be done in some time and the material properties, mass properties of the required material that would go into the system could be found out, which otherwise would be a very cumbersome task.

The foremost thing in designing the system would be the sizing of the two reservoirs and the bucket to be placed at each floor.

The floor bucket would be required to have 3 compartments for grey water, black water and solid wastes.

The floor bucket size and subsequently the reservoir size would depend on the following parameters

1) Water flow, which would further depend upon
   i) Hourly water usage
   ii) No. of flats on each floor
2) No. of cycles made by the reservoir per hour, which would depend on
   i) Speed of the reservoir
   ii) Height of the building (No. of flats in the building)

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5.7.1 Cycles made by reservoir per hour

The system could be made smaller or bigger in size depending upon the number of cycles made by the reservoir in an hour. So it is a variable that has to be carefully selected so as to enable a smooth and jerk free movement of the floor bucket and the reservoirs. Also, the wastes from the floor buckets should move easily to the reservoir, without any spilling on to the floor area. These two conditions make it quite necessary that utmost care is taken in finding the cycles made by the reservoir per hour. It can be easily pointed out here that the number of cycles made by the reservoir collecting wastes from each floor would depend upon the speed of the reservoir and the height of the building. These two factors are independent of each other. The speed of the reservoir would be limited by the inertia forces on the reservoir which would be transferred to the chain system and hence the capacity of the chain system to lift the reservoir would make the final call for the top speed of the reservoir. Secondly, the height of the building is an independent parameter which would be a function of the total number of floors in the building.

Number of cycles made by the reservoir per hour would depend on

i) Speed of the reservoir

ii) Height of the building (No. of flats in the building)

The speed of the reservoir has to be such that it enables

i) Easy movement without jerks.

ii) Smooth transfer of wastes from the floor buckets to reservoir without spilling.

iii) Low cost Moderate strength materials to work efficiently.

iv) Proper removal of wastes without overflowing from the floor buckets.

The speed of the reservoir would not be constant, as it would increase with decreasing height. The speed is to be controlled by using multiple (2 or more) flywheels, which would subsequently engage with increasing speeds.

Kinetic storages, also known as Flywheel Energy Storages (FES), are used in many technical fields. While using this technical approach, inertial mass is accelerating to a very high rotational speed and maintaining the energy in the system as rotational energy. The energy is converted back by slowing down the flywheel. Available performance comes from moment of inertia effect and operating rotational speed. In comparison with other conventional ways of storing electricity (batteries andcapacitors), electric FES systems combinedwith innovative concept offer essential advantages. Especially considering full-cycle lifetime, operating temperature range and steady voltage and power level, which is independent of load, temperature and state of charge. Thus FES provides minimally much higher power output and energy efficiency.

A flywheel is a device to store rotational kinetic energy and the formula for a flywheel can be written as

$$K.E = \frac{1}{2} I \omega^2$$

Maximum kinetic energy of flywheel

$$(K.E.)_{max} = \frac{1}{2} I \omega_1^2$$

Minimum kinetic energy of flywheel

$$(K.E.)_{min} = \frac{1}{2} I \omega_2^2$$

Change in K.E., i.e. $\Delta K.E. = \frac{1}{2} I (\omega_1^2 - \omega_2^2)$

$\Delta K.E.$ = fluctuation in energy, i.e. ΔE

$$\therefore \quad \Delta E = \frac{1}{2} I (\omega_1^2 - \omega_2^2)$$

or,

$$\Delta E = \frac{1}{2} I (\omega_1 - \omega_2)(\omega_1 + \omega_2)$$

$$= \frac{1}{2} I (\omega_1 - \omega_2) \times 2\omega$$

where 'ω' is average speed given by

$$\omega = \frac{(\omega_1 + \omega_2)}{2}$$

or,

$$\Delta E = \frac{1}{2} I \frac{(\omega_1 - \omega_2)}{w} \times \omega^2$$

or,

$$\Delta E = I k_s \omega^2$$

Here I is the moment of inertia, while ω is the angular velocity in rad/s

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Taking an average speed (u) of 0.20 m/sec (.75 Km/hr), the time taken by the reservoir in one cycle would be

Time taken, T = (Building height + miscellaneous distance) / u

Thus,

$$T = (70m \times 2 + 4m) / 0.2 \ S$$

$$Or, T = 720 \ S$$

Hence, the time period is 12 Min (720 Seconds), which means that the number of cycles made by the reservoir in an hour would be,

$$n = 5$$

5.7.2 Waste Water Flow Calculations

Water flow would further depend upon

i) Hourly water usage

ii) No. of flats on each floor

The building taken up for the study is a 20 floor building which has got 4 flats on each floor. Therefore the number of families on each floor is 4. The number of people in each family is assumed to be 5. The total flow of water supplied to the building would get back to ground level after use in the building by the human population. The water depending upon its usage for various activities would be converted to either grey water or black water. The two compositions of the water would make up the total waste water produced. The designing of the entire system would be dependent upon various factors which would include the total water consumption of the building, percentage of grey and black water produced, amount of the solid waste produced by humans, site location as it would limit the space use.

The hourly waste water production from each floor would be a function of hourly water usage and total number of families residing on each floor.

The usage of water varies during the day and so does the waste water. During morning, use of water is maximum while that after midnight to early morning water usage is minimum. As is evident from the hourly water usage graph, the maximum water usage per family (of 4 members) is around 7 am, and is around 200 Lt/hr per family or 50 Lt/hr per person.

In our case, the number of families per floor is 4, while the average number of people in each family is taken as 5, which makes a total of 20 persons per floor.

The total maximum flow per hour per floor would thus be

$$q = 20 \times 50 \text{ Lt/hr per floor}$$

$$\text{or,} \quad q = 1000 \text{ Lt/hr per floor}$$

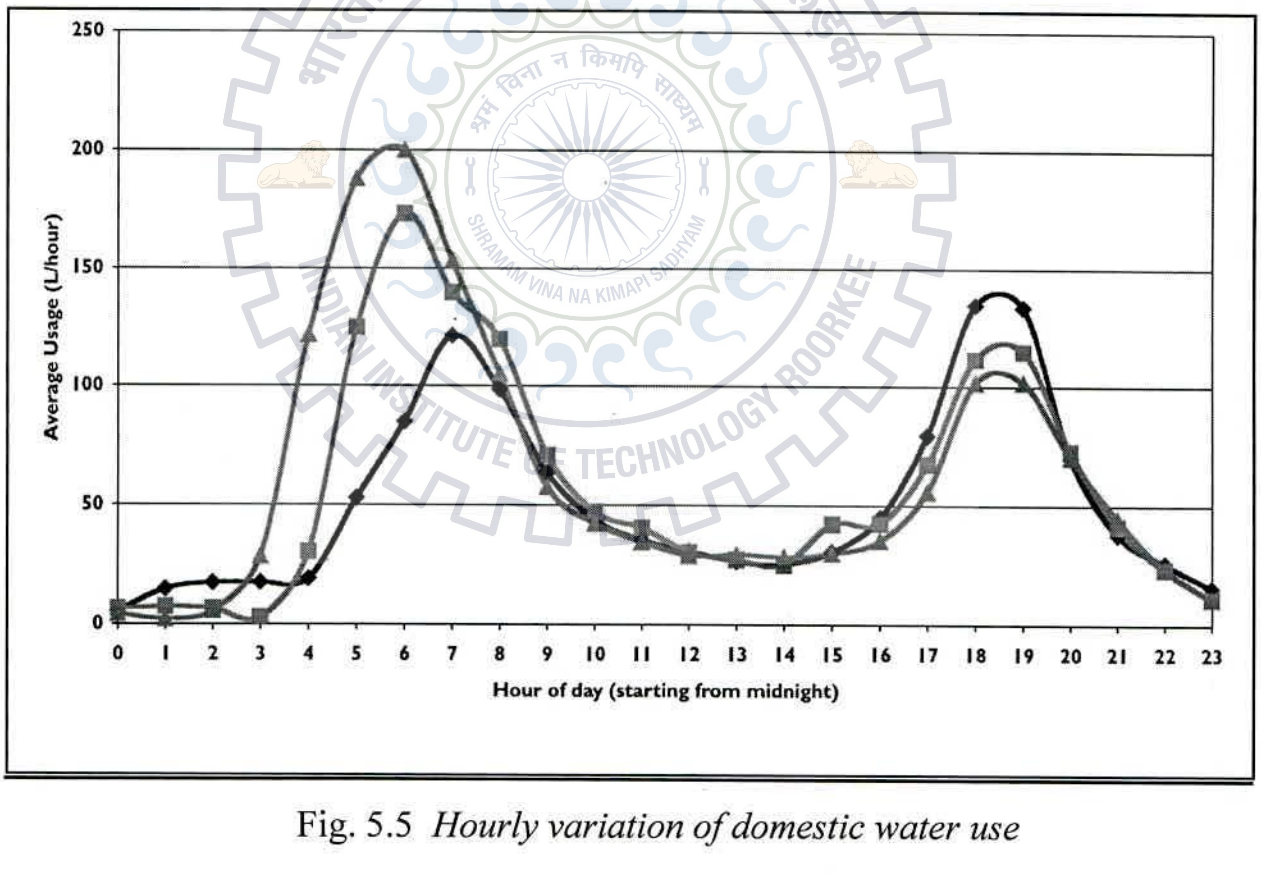

Fig. 5.5 *Hourly variation of domestic water use*

5.7.3 Sizing of the floor bucket

The size of the floor bucket is calculated on the basis of hourly waste water flow and the number of cycles made by the reservoir in an hour

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The number of cylces made by the reservoir is, n = 5

Thus the minimum size would be q/n

Or the size of the floor bucket would be 1000/5 = 200 Lt

The volume is divided in three compartments for 30% black water and 70% grey water

Also, the solid waste volume of 50 Lt is also added to it, thus making, v = 250 Lt

The size is made as 2000 mm x 400 mm x 400 mm (a surplus capacity of 70 Lt) = 320 Lt

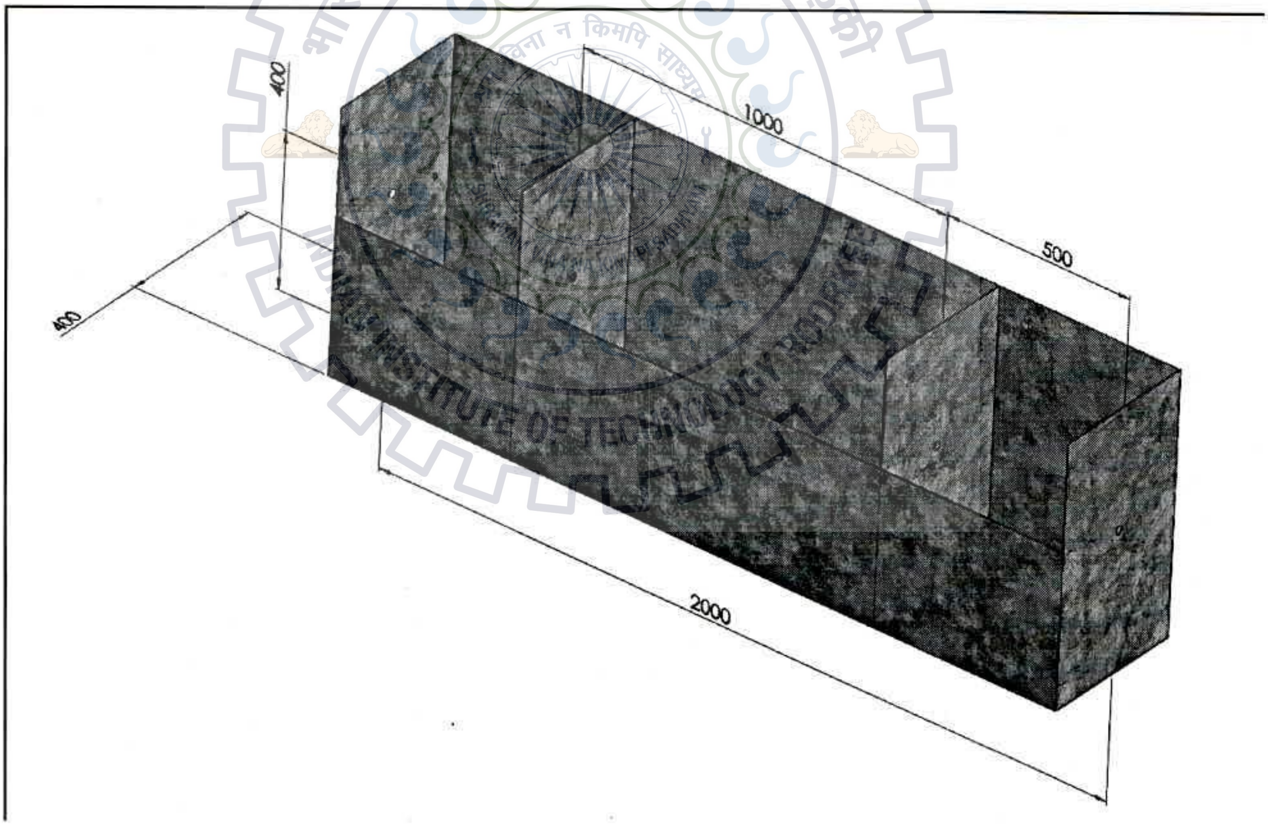

Fig. 5.6 *A solid model of the floor bucket*

5.7.4 Sizing of the Reservoir

The reservoir takes waste water from each floor as it moves down slowly. The floor bucket on each floor pour their contents into the reservoir as it moves along the side channel. The reservoir thus has to be big enough so that it takes the waste water from each floor and does not over spill or over flow. The reservoir can also not be made very big in size as it would make the system occupy a lot of space, thus increasing the total cost of the system as well as the space requirement.

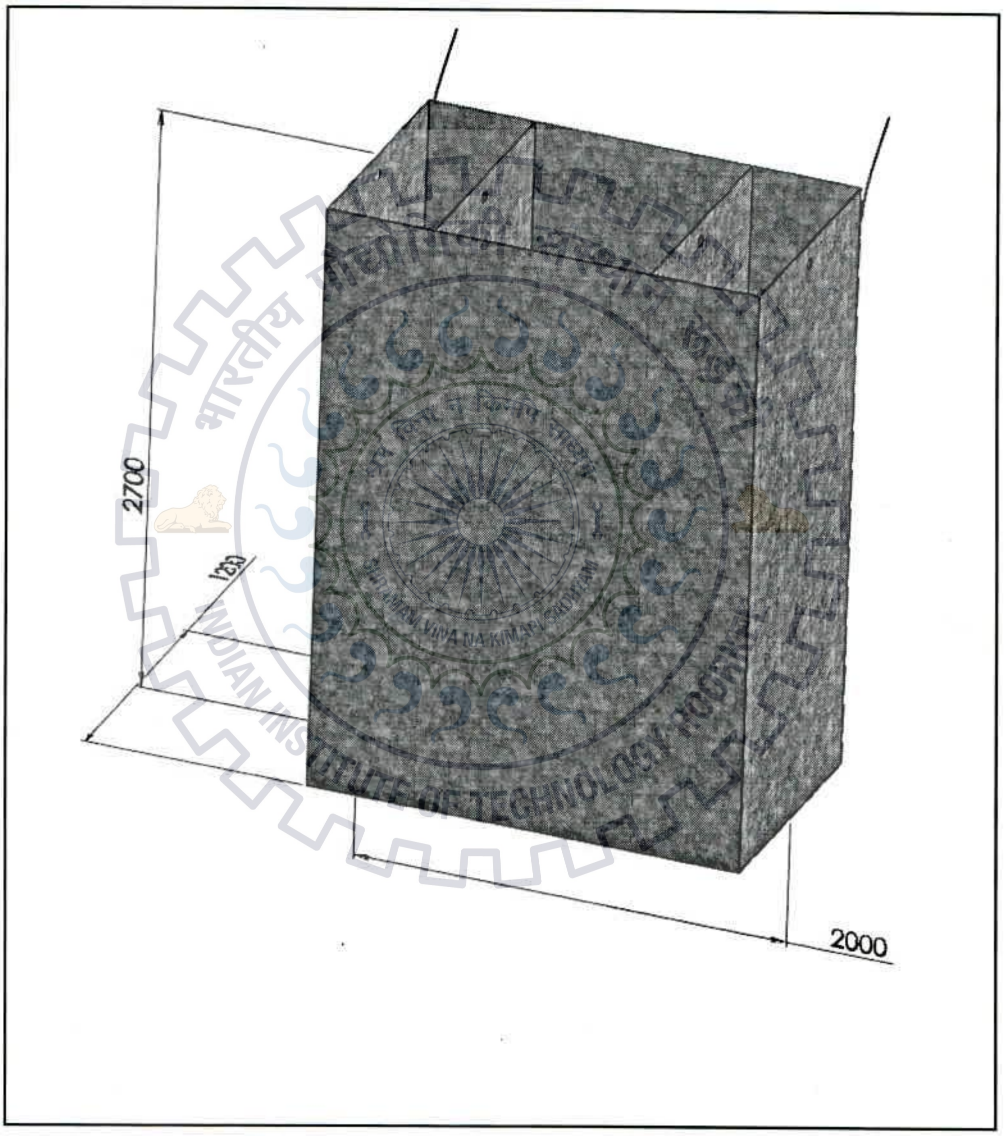

Fig. 5.7 *A solid model of the reservoir*

The design process is thus an iterative one where different combinations are to be checked so that the total space used up by the system does not go beyond a specified limit as well as the system is not to be small which makes the system inefficient or ineffective. Hence it takes efforts to find out that optimal solution that suits the bill perfectly. A lot of work can be done in this regards once the basic design is finalized and a baseline for seeing various perspectives of the design is laid. That being said and done would make the system very much easy to design and cost effective.

The reservoir is made 20 times the bucket capacity for collection from all 20 floors.

Thus V = 20v

Or V = 6400 Lt

It is made as 2000mm x 1200mm x 2700mm

The reservoir too has 3 different compartments for black water, grey water and solid wastes.

5.8 Extracting Energy from Rainwater

The system designed can also be used to extract energy from rainwater. A second reservoir can be engaged during monsoon to increase the overall capacity of the system.

The amount of rainfall that fall on the top of the building is drained off to the system via a drain specifically made for the rainwater. The water is made to fall into a separate compartment, specially made for collecting rainwater. The rainwater is thus made to do work in the system.

The system has a limited capacity to carry rainwater, beyond which it would start to overflow. Overflow from the system is highly undesirable as it would make the entire location quite messy and hard to maintain. But the overall cost of the system would increase with increasing the capacity of the system to carry off rainwater.

Taking one more reservoir, increases the capacity of the system to two times, and it would help in carrying off the rainwater to a large extent. The maximum amount of rainfall that the system can tackle has to be calculated. The calculation is done by taking into consideration the total area covered and the capacity dedicated to drain off rainwater.

By engaging the second reservoir the total capacity of the system is doubled, i.e from 6400 Lt/cycle to 12800 Lt/cycle

For 5 cycles/Hr the capacity to drain off rain water would be, 6400 x 5 = 32000 Lt/Hr (32 m^3/Hr)

The covered area of the building is 6000 Sq. Ft or 560 m^2

The maximum rainfall before the system starts to overflow would be

$$m_{max.} = 32/560 \text{ m/Hr}$$

$$m_{max.} = 57 \text{ mm/Hr}$$

5.9 Analysis of the system

5.9.1 Energy Extracted

The gross energy that can be extracted from the system equals the total energy of the falling liquid.

a) From waste water

110,000 Lt or 110 m^3 water energy per day falling through mean height of 35 m

Energy/day = 38 MJ/day

Taking a conservative approach towards the system and considering 70% efficiency, the net energy extracted would be 26.5 MJ/day or 9675 MJ/year

b) Further the energy that can be extracted from the rainwater, considering 90% capture

- 600 mm of annual rainfall (Gurgaon district)

Energy extracted with 70% efficient system is 161 MJ/year

The above results make it quite clear that the energy recovered from falling rainwater is under **2 %** of the waste water energy annually.

5.9.2 Space Requirements of the System

The space requirement as found from the 3d model of the complete system is 20 m^2approx.

This area is **3%** of the covered area of the flats it serves.

5.9.3 Cost of Material

The total amount of steel that would be used for building the system

Wt. of Steel structure = 14 Tonnes

Wt. of Reservoir = 0.6 Tonne

Wt. of one floor bucket = 50 kg, thus for 20 buckets Wt. = 1 Tonne

Taking into consideration the other requirements of steel, the total weight as approximated is 20 Tonnes

Assuming 400 Rs/Kg as the combined cost of fabrication and material the total cost comes out to be Rs 80 Lakhs

5.9.4 Cost per Unit of Energy

Considering a life expectancy of 20 yrs of the system, the total energy extracted would stand at 53750 Kw-hr.

Thus the cost of energy is 80,00,000/53750 = 150 Rs/Unit approx.

The energy from the system thus proposed can be either used to generate electricity or can be put to any other use.

The total energy extracted yearly by the system would be a function of

i) The total flow of waste water through the system, which would further depend on

   a) Water usage pattern, which is highly governed by lifestyle.

   b) Number of occupants in the building, which would be a function of family size, number of floors & flats on each floor.

ii) Total precipitation in an year.

To study the effects of the above parameters, two case studies have been taken up. The first case study takes into account the affect of size of the building and the total number of occupants. While in the second study, the affect of higher rainfall is studied. The results of the studies are tabulated and then discussed to draw conclusions regarding the effect of change in building size and the effect of higher rainfall.

5.10 Case Studies

5.10.1 Case Study 1

To analyse the effect of total number of occupants on the total energy extracted, a building with 30 floors and 10 flats with average number of family members 4 is taken up.

Total number of floors	30	
Flats per floor	10	
Members per family	4	
Total occupants	1200	
Average water use per day	250	Lt
Total waste water produced per day	300000	Lt
Height of the building (3.5 m floor height)	105	m
Mean heigt of the building	53	m
Energy extracted per day (70 % Efficiency)	108	MJ/Day
	39436	MJ/Year
	10955	KwHr/Year
Covered area accouting to rainwater energy	15000	Sq. Ft.
	1394	Sq. m
Annual rainfall	600	mm
Energy recovered from rain water	430	MJ/Year
	1.09	% of Waste water energy
Space requirement for the system	60	Sq. m
Space requirement of the system as percentage of covered area	4.31	%
Cost of the system	175	Lakhs
Expected life of the system	20	Years
Energy Produced in expected life	219091	KwHr
Cost of energy per Kilo Watt-Hour	80	Rs/Unit

Table 5.2 Results of Case Study 1

The results give an indication of reduction of cost of energy with increase in the size of building. This could be accounted to the increase of mean building height as well as to the increase in water flow from each floor due to increased number of flats per floor. The energy generated as a fraction of total energy is reduced due to higher increase in the wastewater energy.

5.10.2 Case Study 2

To study the effect of higher rainfall, the first example from the study is taken up but with average annual rainfall as double the initial case, i.e 1200 mm.

Total number of floors	20	
Flats per floor	4	
Members per family	5	
Total occupants	400	
Average water use per day	250	Lt
Total waste water produced per day	100000	Lt
Height of the building (3.5 m floor height)	70	m
Mean heigt of the building	35	m
Energy extracted per day (70 % Efficiency)	24	MJ/Day
	8764	MJ/Year
	2434	KwHr/Year
Covered area accouting to rainwater energy	6000	Sq. Ft.
	557	Sq. m
Annual rainfall	1200	mm
Energy recovered from rain water	229	MJ/Year
	2.62	% of Waste water energy
Space requirement for the system	20	Sq. m
Space requirement of the system as percentage of covered area	3.59	%
Cost of the system	80	Lakhs
Expected life of the system	20	Years
Energy Produced in expected life	48687	KwHr
Cost of energy per Kilo Watt-Hour	164	Rs/Unit

Table 5.2 Results of Case Study 2

The results shows very clearly that even though rainfall is doubled, still the amount of energy produced by it does not change significantly, so it is advisable not to overdesign the system for rainfall as it would unnecessary increase the cost of the system as well as the cost of energy per unit without having any major output change in total energy.

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5.11 Results and Discussion

The results from the studies taken up have been summarised in previous pages and it gives a good overall understanding of how the system proposed would respond to the changes in the critical parameters. The following observations can be made from the results obtained

Energy Extracted – The amount of energy extracted increases with the increase in the population of the building. The energy extracted bears a linear relationship with increasing height as well as the increasing number of families on each floor. The energy extracted increases from 24 MJ/Day to 108 MJ/Day when the population increase is 3 times from 40 to 1200. This increase is attributed to the increase in mean height of the building as well as the number of people staying on each floor.

Further the amount of energy generated by rain water is a fraction of the energy generated by waste water, it makes only 2% of the waste water energy.

Space requirements of the system – The space required by the system though would increase with the size of the building, it would vary with the design parameters. Like a 40 storey building can have a system similar to a system build for a 20 storey building if the number of cycles made by the reservoir is doubled or the number of reservoirs is doubled keeping the number or cycles constant. So it can be concluded that the space requirement of the system would vary with different designs and that would be largely governed by site conditions. From the studies taken up, the space requirement of the system is around 3% of the covered area of the building.

Cost of Material – The cost of material increases with the increase of the building size on account of larger material requirements for building the system. Cost of the system would change with change of material and change in over all material requirements which would change with design of the system. The cost of the system is 80,00,000 /- INR for a 20 storey building while for the 30 storey building the cost comes out to be 1,75,00,000/- INR.

Cost per Unit of Energy – The cost per unit of energy is a function of the total energy extracted by the system over its expected life and the cost of the system. Assuming the expected life of the system as 20 years, the cost of the energy per unit changes from 164

Rs/Unit approximately to 80 Rs/Unit when the size of the building is increases 1.5 times while the population is increased 3 times. Thus energy extracted would be cheaper for larger buildings than for smaller ones.

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Chapter 6
CONCLUSIONS

6.1 CONCLUSIONS

The amount of energy that goes in pumping water from ground level to high rise building goes waste down the drain when the water is simply dumped to ground water. Turbines have been used but they are not very effective due to maintenance problems. Further there use is limited to liquids only and not solid wastes. The current study gives an insight into the idea of using reservoirs instead of turbines to harness energy from waste water high rise buildings. The challenge was to develop a system that can keep grey water and black water separate as well as able to absorb energy from the solid wastes also.

Use of CAD has been of tremendous help as the system for extracting energy is designed and developed using SolidWorks, which reduces the amount of efforts to develop the design. The designing process of the system would have been otherwise very cumbersome, but for the sake of solid modelling. Further, tools like mass properties, helps to find out the total volume and the total amount of material that goes into making the system. Amount of mass helps in determining the cost of the system and understanding the cost of energy produced.

From the analysis of the results obtained, it can be broadly summed up that the cost of the energy produced in quite high and efforts have to be made to bring down the cost of energy per unit. The waste energy from a high rise building can help in saving the energy required for street lighting in the concerned locality once the energy produced is cost effective. Though the solution suggested overcomes the concerns faced by use of turbines, and also would do away with the drainage system required for the building, the cost parameter might be a big hurdle in taking up the project. Further work has to be done so the cost of the system is brought down and enables it to be installed as a pilot project initially.

6.2 SCOPE FOR FURTHER STUDY

As is quite evident, the amount of energy obtained from rain water is just a fraction of the total energy produced, thus ways can be explored that would increase the total energy produced by rainwater like increasing the surface area during monsoons. Further the cost of the system is major factor for costly energy, and work should be carried out to bring down the cost of the system. The overall cost of the system can be brought down either by working on its shape, material or its entire design. Only when the cost of the system is brought down to a level where it becomes economical to install the system, then only the possibility of using the system would become possible.

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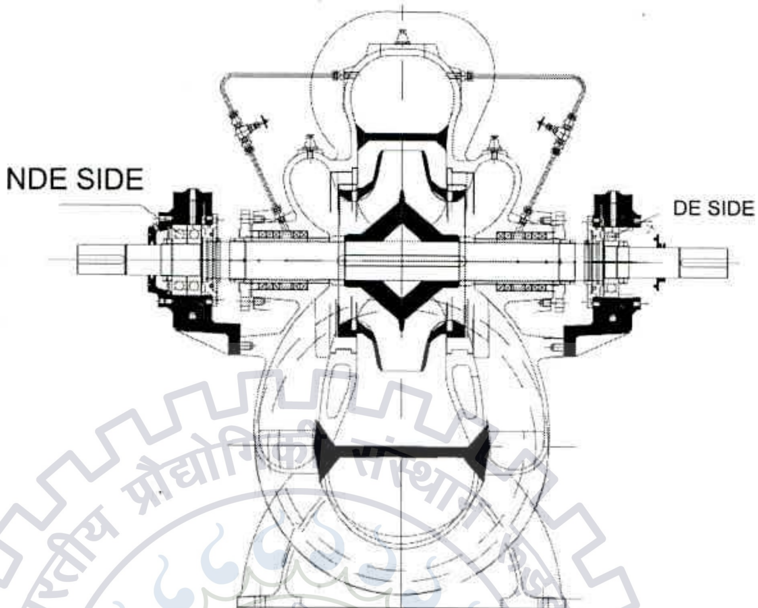
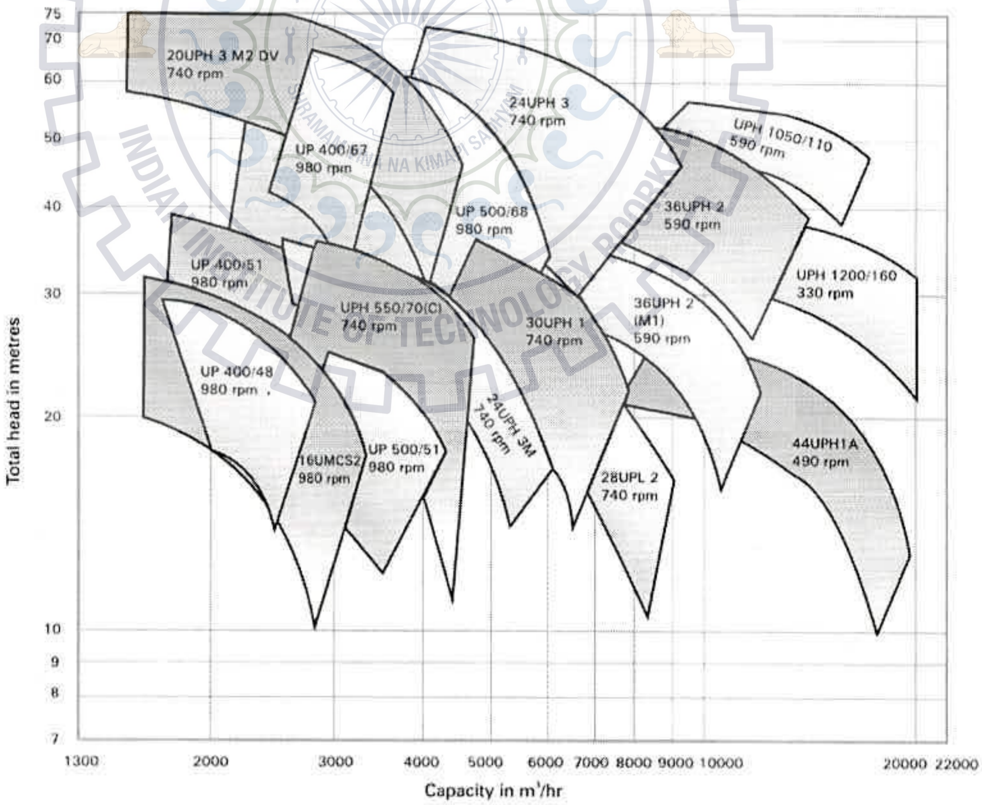
APPENDIX 1

Cross-Sectional View of a Kirloskar Double Suction Horizontal Split Case Pump and its Family Curves





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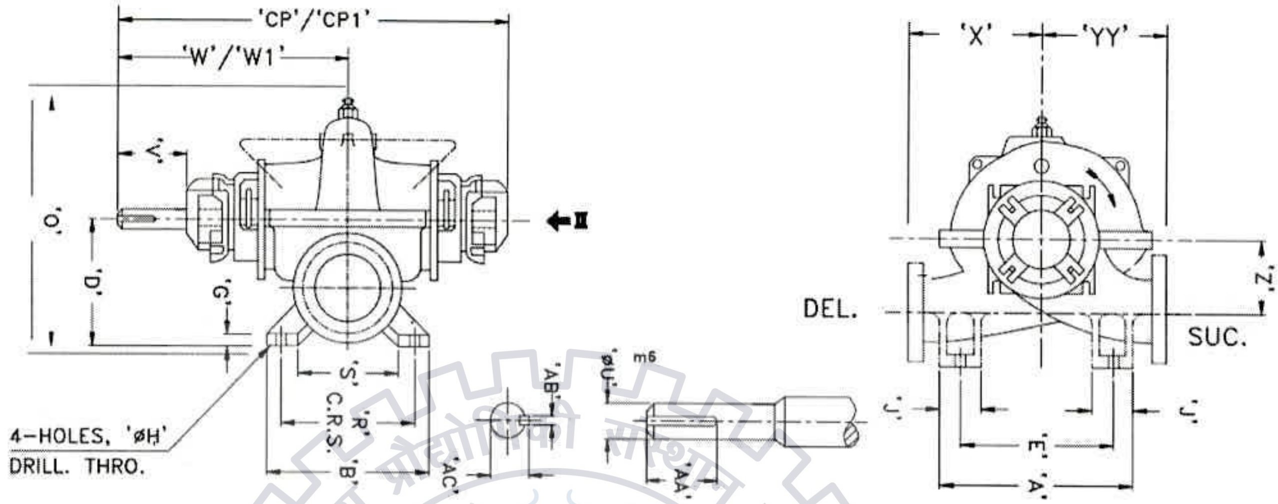
APPENDIX 2

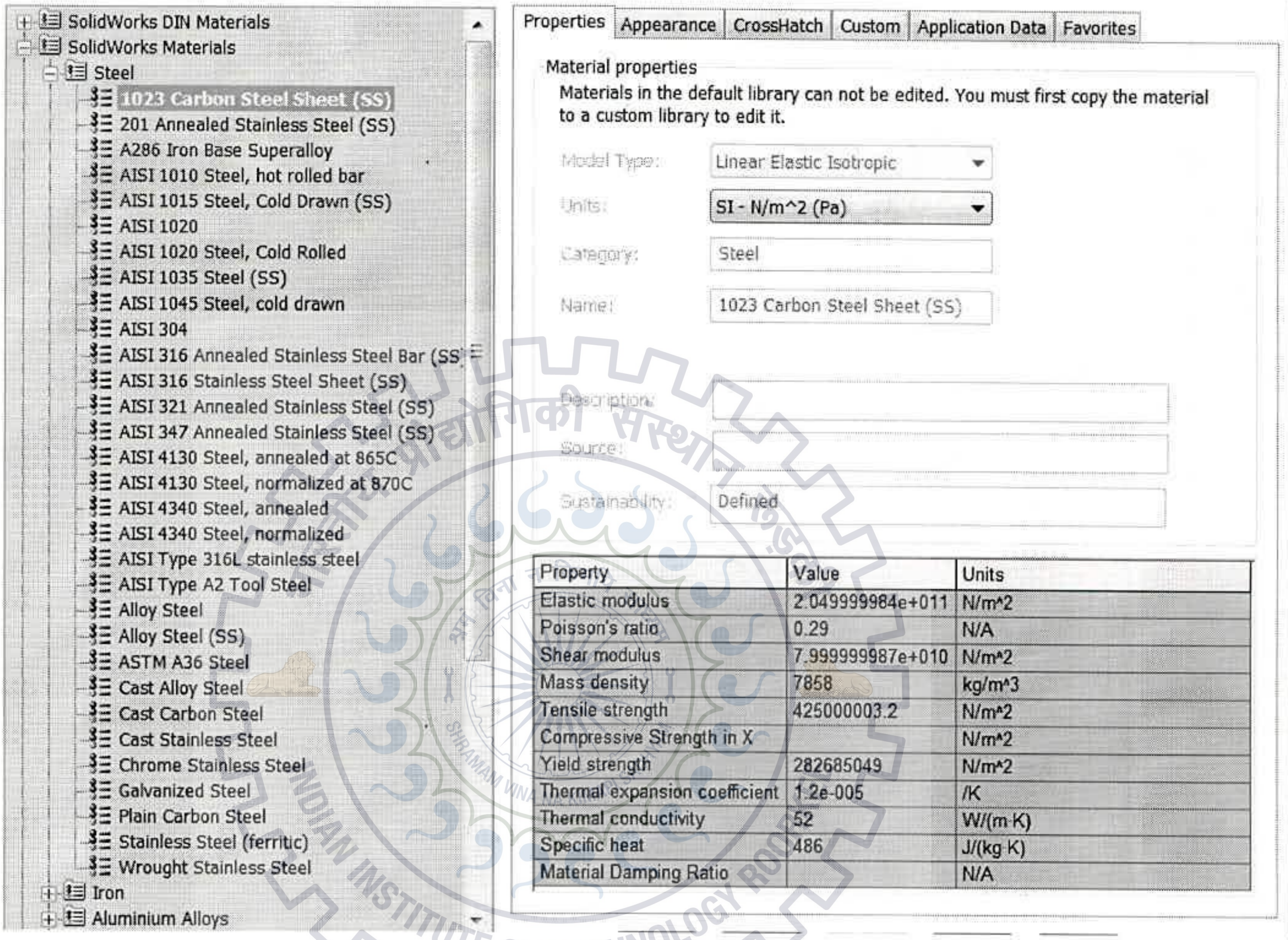
General Dimensions of a Kirloskar Double Suction Horizontal Split Case Pump



PUMP TYPE	MODULE NO.	SUC	DEL	'A'	'B'	'D'	'E'	'G'	'H'	'J'	'O'	'R'	'S'	'V'	'W'	'X'	'Z'	'CP'	'YY'	'L'	'Wt' Kg.	'W1'	'CP1'	'L1'	'Wt' Kg.
				For Soft Packed																		For Mechanical Seal			
UP 50/30A	0	65	50	300	210	240	230	15	14	70	442	170	90	48	304	225	140	548	275	219	80	276	506	191	72
UP 50/30B		65	50	300	210	240	230	15	14	70	442	170	90	48	304	225	140	548	275	219	80	276	506	191	72
UP 65/24		80	65	300	210	240	230	18	14	70	440	170	90	50	306.5	210	130	565	280	221.5	84	306.5	565	221.5	84
UP 80/24		100	80	300	210	260	230	18	14	70	450	170	90	50	306.5	230	130	565	270	221.5	95	306.5	565	221.5	95
UP 65/38	I	80	65	400	240	300	300	25	23	100	575	190	100	55	375	275	175	696	325	280	164	292	530	197	150
UP 65/38M		80	65	400	240	300	300	25	23	100	565	190	100	55	375	275	175	696	325	280	164	292	530	197	150
UP 80/30		125	80	330	280	310	230	25	23	100	550	220	130	56	375	240	170	696	320	265	130	292	530	182	120
UP 80/38		100	80	440	280	310	340	25	23	100	585	220	130	56	375	285	175	696	340	265	158	292	530	182	146
UP 100/24		150	100	260	280	330	160	20	23	100	553	220	130	56	375	210	170	696	310	265	158	292	530	182	146
UP 100/29		150	100	300	280	310	200	25	23	100	540	220	130	56	375	230	160	696	310	265	137	292	530	182	124
UP 125/24		150	125	310	330	330	210	25	23	100	560	270	180	56	394	235	180	734	350	259	180	316	578	181	170
UP 125/30A		150	125	370	330	330	270	25	23	100	580	270	180	56	394	245	175	734	335	259	182	316	578	181	172
UP 125/30B		150	125	370	330	330	270	25	23	100	580	270	180	56	394	245	175	734	335	259	182	316	578	181	172
UP 100-35	IE	150	100	400	300	360	300	20	23	100	630	240	140	75	413	260	205	753	340	293	177	413	753	293	177
UP 100/38	II	150	100	440	330	360	340	25	23	100	660	270	180	90	480	300	210	872	400	345	240	378	668	243	218
UP 150/26N		200	150	500	370	385	400	25	23	100	635	300	220	90	480	355	195	897	380	330	262	480	897	330	262
UP 150/30		200	150	370	370	415	270	25	23	100	695	310	220	90	480	270	235	872	365	325	253	378	668	223	236
UP 150/30AN		200	150	500	370	385	400	25	23	100	655	300	220	90	480	355	195	897	380	330	270	480	897	330	270

APPENDIX 3

Solidworks Material Library



APPENDIX 4

Coefficient of Fluctuation of Speed of Flywheel for various applications

Application	C_s
• Crushing machinery, Hammers	0.200
• Punching machines, Shearing machines, Presses	0.150
• Pumps, I.C. engines	0.030
• Machine tools, Textile machines	0.025
• D.C. Generators	0.010
• A.C. Generators	0.005

APPENDIX 5

Material Properties for a Flywheel

Material	Mass Density, kg/m^3
1. Gray cast iron :	
• FG 150	7000
• FG 200	7050
• FG 220	7100
• FG 260	7150
• FG 300	7200
2. Carbon steels :	7800

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