# ISSUES AND CHALLENGES IN THE DRAINAGE AND WATER SUPPLY SYSTEMS IN HIGH-RISE BUILDINGS: TWO CASE STUDIES

*A thesis submitted toward partial fulfillment of the requirements for the degree of*

**MASTER OF ENGINEERING**

*in* **Water Resources and Hydraulic Engineering**

*Course affiliated to Faculty of Engineering & Technology*

**Jadavpur University**

*submitted by*

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2019

# CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"ISSUES AND CHALLENGES IN THE DRAINAGE AND WATER SUPPLY SYSTEMS IN HIGH-RISE BUILDINGS: TWO CASE STUDIES"** is bonafide work carried out by **Subhas Chandra Pal** under our supervision and guidance for partial fulfillment of the requirement for Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academic session 2018-2019.

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of his Master of Water Recourses & Hydraulic Engineering studies during academic session 2018-2019.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have fully cited and referred all material and results that are not original to this work.

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Date:

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# ABSTRACT

A good plumbing system is as essential as the structural safety of the building. Today much emphasis has been given for the services of the building since, the comfort living is very much depending on the quality of services in the buildings and most importantly plumbing is one of them. If the plumbing system is not designed and implemented properly then everybody can imagine, how the life would be.

The National Building Code (NBC) - India has given guidelines for the design and installation of the plumbing system. However, during study, two of the high-rise buildings, **ATMOSPHERE (B+G+39 Storeyed Residential Building)** and **URBANA, TOWER 5 (G+45 Storeyed Residential Building)** in Kolkata, have been found that there are some problems even, it is designed and installed as per the guidelines of NBC-I. An effort is given to understand those problems and attempted to find out the probable solutions.

A very popular single stack drainage system used in Europe has been discussed including its technical aspects and possibility of use in India considering the economic, cultural and social aspects.

A case study for the Storm Water Management and Rain Water Harvesting as per the requirement of the Pollution Control Board has been discussed for obtaining the Environmental Clearance of the Project. These are relevant in understanding the importance of water conservation and how this can be achieved in a real-life Project delineated a case study.

# TABLE OF CONTENTS

# CHAPTER 1

## 1. INTRODUCTION:

Drainage system in high-rise building is an important issue in today's context. If, we look around the City of Kolkata, we see lots of buildings are damaged due to the plumbing leakage problem. Many of the Flat owners of the high-rise buildings are experiencing very tough situation to get sufficient water and proper drainage of the waste and soil waste water.

Lots of money is spending on this system but most of the time the technical issues are neglected due to the lack of awareness of the developers. There are some guidelines and technical details in the NBC and UIPC-I but those are very much based on theory and needs field study to know the real problems and find out the practical solution of the problems. The basic guidelines on the drainage and water supply system as per the NBC are discussed in short as follows:

### 1.1 TYPES OF DRAINAGE SYSTEMS AS PER NBC-2016:

**A). SINGLE STACK SYSTEM:**

The piping system in which there is no trap ventilation and obviously no additional vent pipe is provided. The stack itself act as a vent pipe through roof.

**B). ONE PIPE - PARTIALLY VENTILATED SYSTEM:**

Soil & waste pipes are connected in a single vertical pipe with an additional pipe that act as a vent pipe. This vent pipe vent and maintained the water seal.

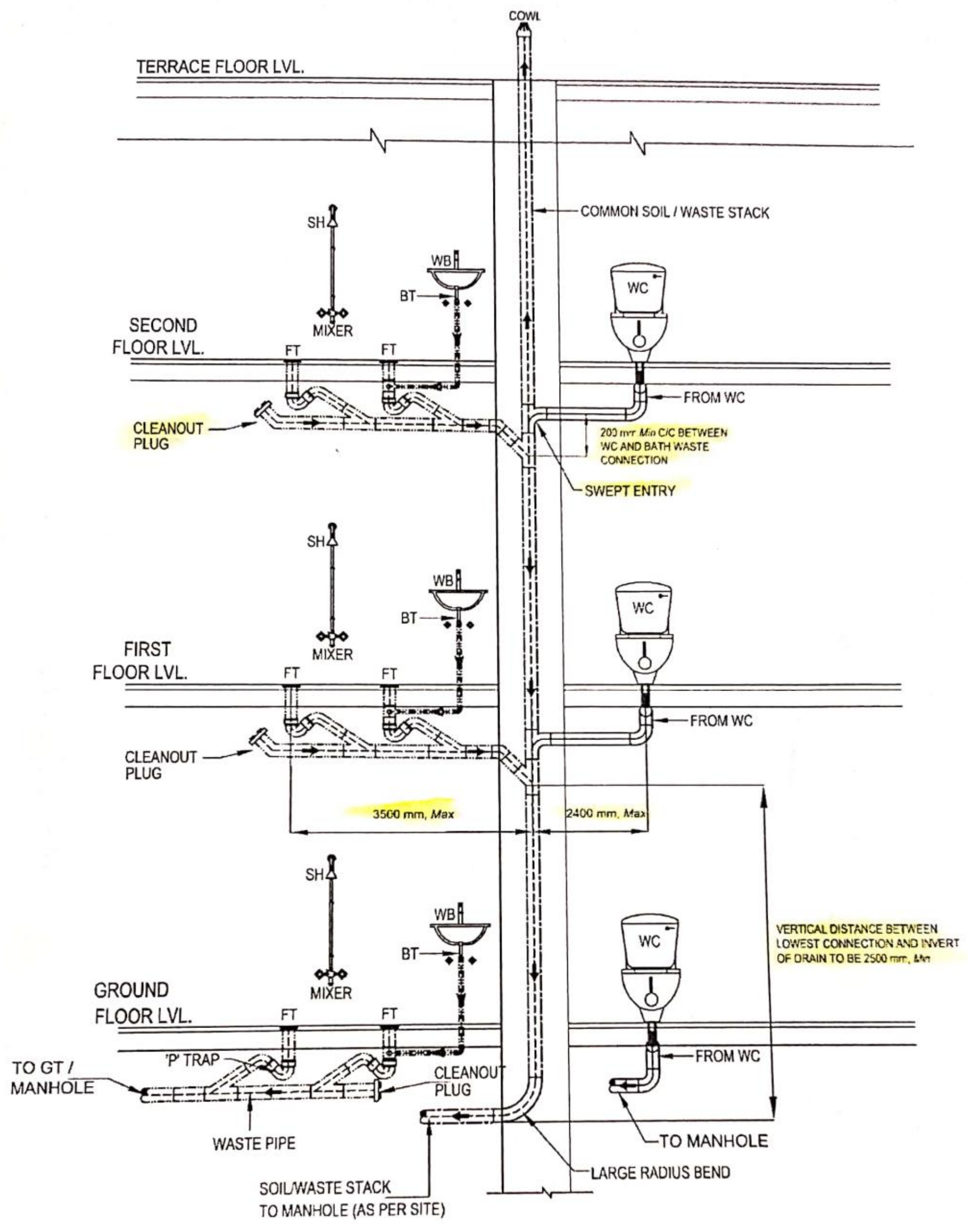
**C). ONE PIPE - FULLY VENTILATED SYSTEM:**

Same as sl. No. (b) except that the vent pipes vent the trap of water closet, urinals, bedpan sinks, bidet traps & all other waste appliances.

D). **TWO PIPES SYSTEM:**

i). With common vent: in this system one vent pipe vent the soil & waste stacks.

ii). With independent vent pipes, one for soil & one for waste stack.




LEGEND

| | |
|---|---|
| SH | SHOWER |
| WC | WATER CLOSET |
| WB | WASH BASIN |
| FT | FLOOR TRAP |
| BT | BOTTLE TRAP |
| GT | GULLY TRAP |

NOTES

1 Presentation of type of fixtures/drains, and pipe route/layout is typical in nature.

2 Kitchen waste piping shall also be planned in a similar manner as for other waste appliances.

**Fig. 1**

## ONE PIPE - FULLY VENTILATED SYSTEM

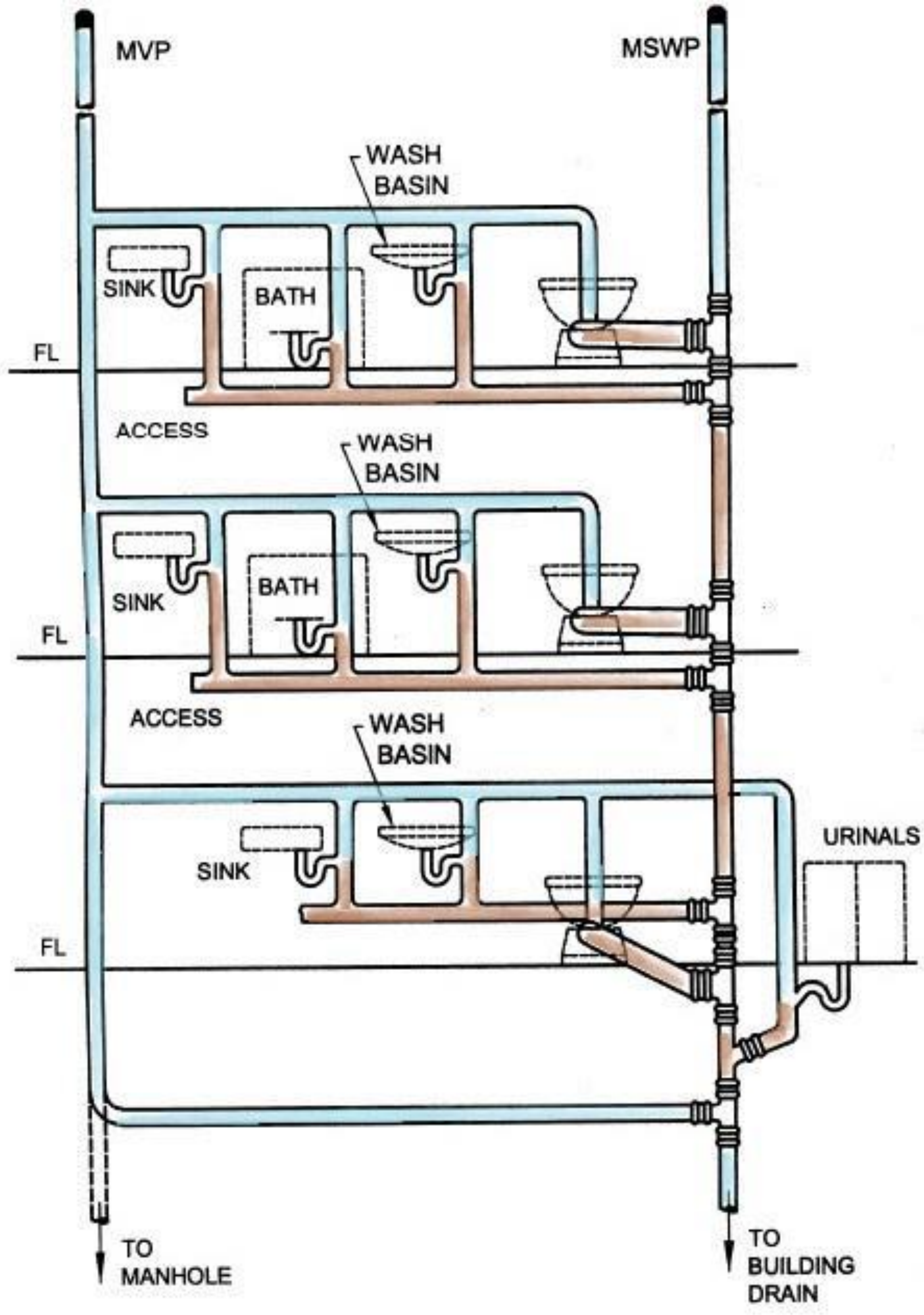



**Fig. 2**

## TWO PIPES WITH INDEPENDENT VENT PIPES

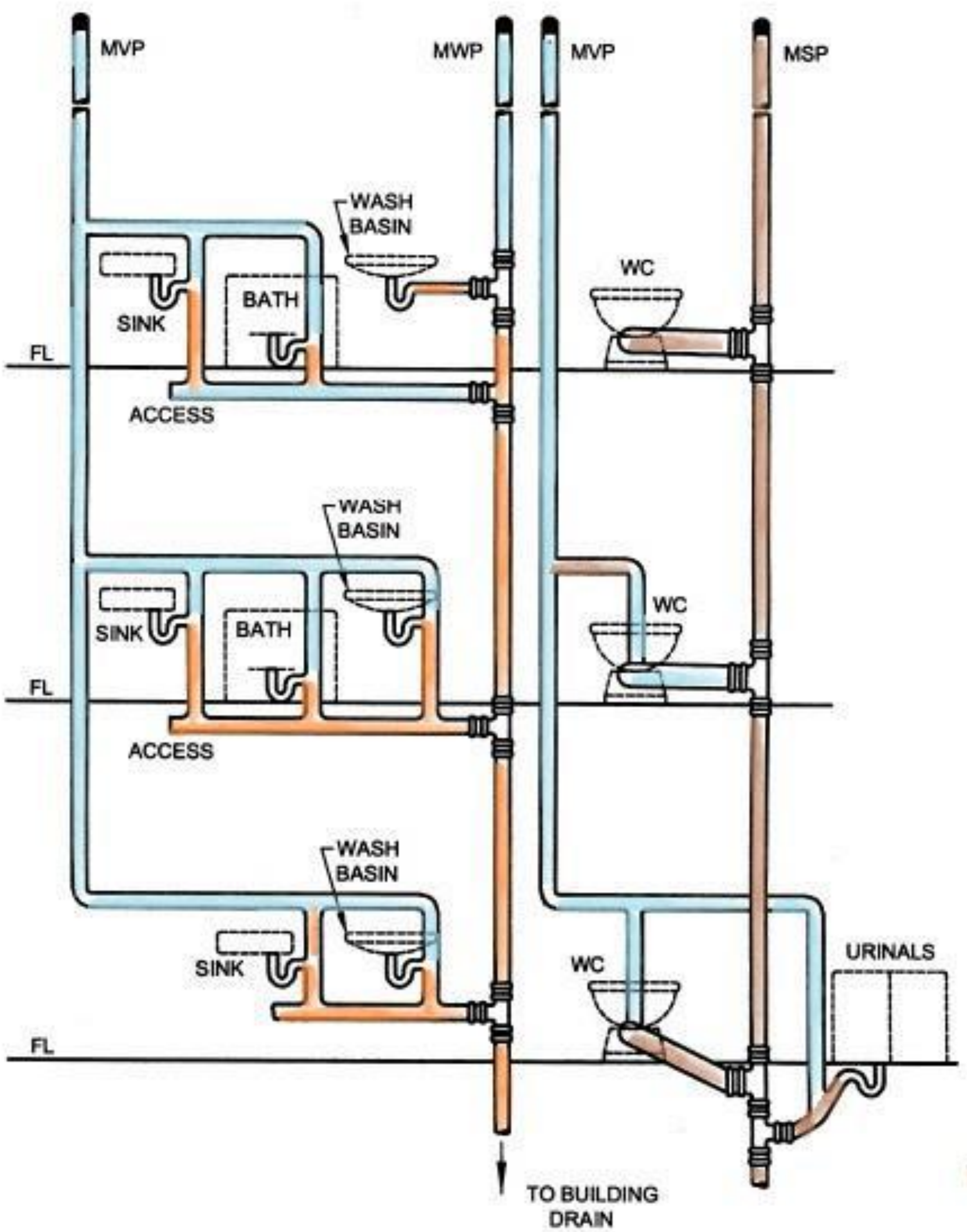



Fig. 3

## 1.2 TYPES OF WATER SUPPLY SYSTEMS AS PER NBC-2016[l]:

There are following four basic methods of distribution of water to a multistoried building:

**A. Direct supply system from mains—public or private.**

This system is adopted when adequate pressure is available in the mains to supply water at adequate pressure at the topmost floor. With limited pressure available in most city mains, water from direct supply is normally not available above two or three floors.

**B. Gravity distribution system:**

This is the most common water distribution system. The system comprises pumping water to one or more overhead water tanks. Water transferred to overhead tank(s) is distributed by gravity to various parts of the building by the system of piping network.

**C. Pressurized distribution system (hydro-pneumatic pumping system):**

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

Hydro-pneumatic system generally eliminates the need of an overhead tank. As a good engineering practice and to take care of emergencies, an overhead of smaller capacity should be provided which feeds by gravity to the system.

**D. Combined distribution system:**

In this system, a combination of gravity and pressurized distribution is adopted. A few upper floors are provided with a pressure booster pumping system to achieve the desired residual pressure, while the lower floors are fed by gravity supply.

water collected in the overhead tank is distributed to the various parts of the building. To achieve required residual pressure for top 2 to 4 floors for proper functioning of the fixtures, a pressure booster pumping system is installed on the dedicated outlet from overhead tank with its own distribution piping serving the top 2 to 4 floors. For lower floors, water is distributed by gravity system.

## 1.3 HISTORY OF DEVELOPMENT OF HIGH-RISE BUILDING / SKYSCRAPPER:

More than 150 years ago, cities looked very different from the way they look today. The buildings that housed people and their businesses were rarely over the height of a flag-pole. Urban landscapes tended to be flat and uniform in pattern, apart from monuments, temples, and town halls; and cathedrals (adorned with domes, spires, or towers) which "towered above everything else in a city or town; they were visible from miles away". Historically, the word tower usually designated the church and the town hall until the birth of the skyscraper. The main evolutionary change has been in function, from a Campanile watchtower of the Renaissance or minaret of Islamic architecture to the office building."

Two major developments led to the skyscrapers that dominate major city skylines throughout the modern world:

A. In 1853, an American, Elisha Graves Otis, invented the world's first safety lift or elevator. This new form of vertical movements, make possible people to travel safely upstairs at a much higher speed and with significantly less effort than by walking.

B. In the 1870s, steel frames became available, gradually replacing the weaker combination of cast iron and wood previously used in construction. Until then, the walls had to be very thick to carry the weight of each floor.

## 1.4 DEVELOPMENT OF MODERN PLUMBING SYSTEM:

Dr. Roy B. Hunter, who was appointed to head the plumbing division of the National Bureau of Standards, dedicated his talents to the research of plumbing systems in an effort to standardize regulations in the United States. Current plumbing codes are based on his research. (1930s to 1940s)

The first plumbing code was published (1928) and nicknamed the "Hoover Code," after Herbert Hoover's efforts to instigate the code.

Legislation was adopted as part of the Energy Efficiency Act in the 1980s and later amended with the Energy Policy Act of 1992 to restrict water flow rates in plumbing fixtures.

The Uniform Plumbing Code – India (UPC-I) is the first ever plumbing code developed by the Indian plumbing industry to achieve its mission – "Redefining Plumbing standard in India" was successfully launched in the year 2008. In the year 2014, UPC-I, updated and renamed Uniform Illustrated Plumbing Code – India (UIPC-I) is the combined version of the UPC-I and Illustrated Training Manual is published. However, the provisions in the 2017 UIPC-I, the latest version are not mandatory at present.

## 1.5 APPLICATION OF GREEN PLUMBING:

Green means environmentally friendly therefore, the selection of plumbing systems and materials shall be accordingly. For example, the pipe shall be reusable and during melting or remoulding, this should not produce toxic gases or waste that would harm the environment.

The low flow sanitary fixtures are also called green fixtures since, it saves the precious natural resource i.e. water.

A research work “Modification of Hunter’s Curve in the Perspective of Water Conservation” shows that the water demand can be reduced by 61% & 67% by minor reduction of Confidence Limit from 99% as taken by Hunter to 95% & 90% for 300 fixtures. This new concept may be considered for the design of present plumbing system that will make the system green plumbing by saving the considerable amount of water. A significant amount of cost reduction also can be possible since, the cost of systems and reservoir will be less.

There is another addition in the system of green plumbing, “Green Plumbers”. Green plumbers recycle all eligible materials used on a job site. Any items that can be repaired and reused can save customers money while promoting environmentally sound practices.

**Green Plumbing Code Supplement – India (GPCS-I), was** published in 2010 and revised in 2013 by IPA in partnership with IAPMO – India, is the most comprehensive document on sustainable plumbing systems. This code gives guidelines for the design, selection, installation and maintenance of water and energy saving products used for the plumbing systems

## 1.6 TECHNICAL DETAILS OF "SOVENT DRAINAGE SYSTEM" AND ITS APPLICATION POSSIBILITY IN KOLKATA'S PRESPECTIVE:

The Sovent Drainage system is new to Kolkata and it would be my pleasure to discuss about the system and find out the advantages of using this system in our design, considering the cultural, economic & environmental criteria.

- **HOW SOVENT DWV SYSTEM WORKS:**

Sovent single-stack sanitary drainage, waste & venting (DWV) systems transport sanitary wastes from plumbing fixtures to a legal point of disposal while protecting the trap-seal of each fixture. The Sovent system prevents pressure excursions from exceeding +/- one inch of water column, which is the standard for sanitary drainage systems.

A Sovent system consists of a vertical stack open to the atmosphere (Fig. 4), horizontal branches to each fixture (Fig. 5), Sovent Aerator fittings (Fig. 6), and Sovent De-aerator fittings (Fig. 7).

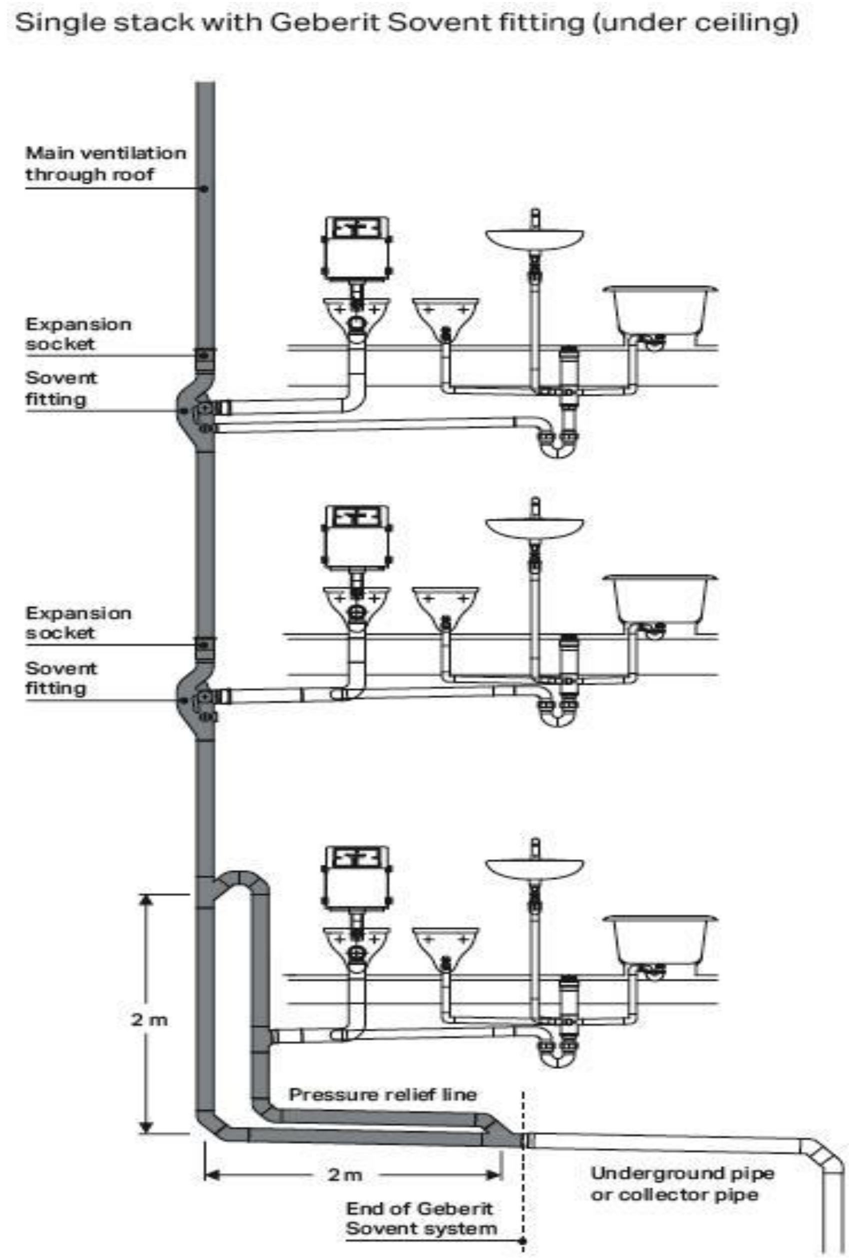

Single stack with Geberit Sovent fitting (under ceiling)
Main ventilation through roof
Expansion socket
Sovent fitting
Expansion socket
Sovent fitting
2 m
Pressure relief line
2 m
End of Geberit Sovent system
Underground pipe or collector pipe

**Fig. 4**

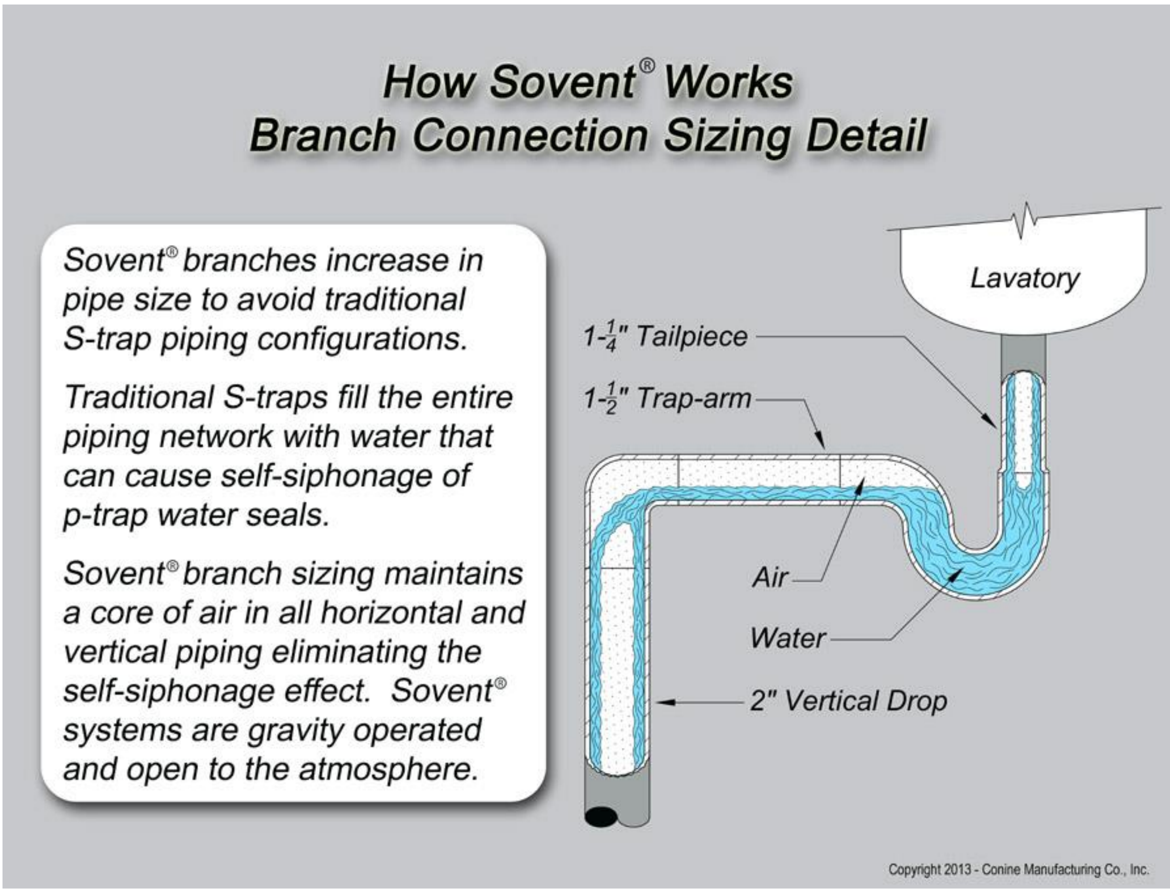

How Sovent® Works
Branch Connection Sizing Detail
Sovent® branches increase in pipe size to avoid traditional S-trap piping configurations.
Traditional S-traps fill the entire piping network with water that can cause self-siphonage of p-trap water seals.
Sovent® branch sizing maintains a core of air in all horizontal and vertical piping eliminating the self-siphonage effect. Sovent® systems are gravity operated and open to the atmosphere.
Lavatory
1-1/4" Tailpiece
1-1/2" Trap-arm
Air
Water
2" Vertical Drop
Copyright 2013 - Conine Manufacturing Co., Inc.

**Fig. 5**

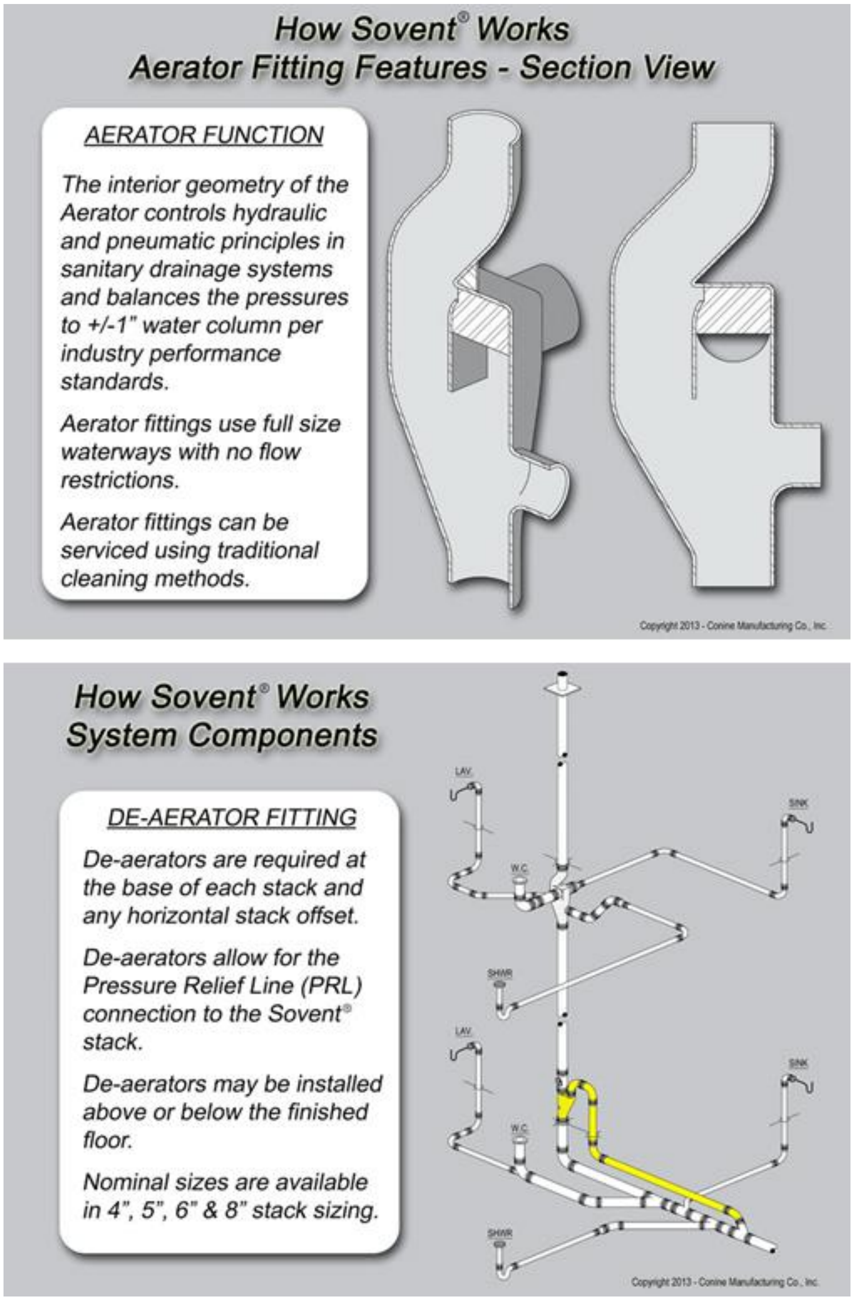



**Fig. 6**

A basic understanding of air and water movement in a sanitary system is required to illustrate how Sovent accomplishes the DWV function in a single tube. Waste flow in a vertical stack will cling to the interior wall surface, proceed downward in a swirling motion, and leave an open airway in the center (Fig. 7). As the velocity increases, the falling waste encounters air resistance, which reduces the airway size (Fig. 6). As long as this airway exists, the pressures are balanced within the stack.

Left uncontrolled, the flow velocity will increase to a point known as "terminal velocity" and may form a complete cross-sectional blockage of the tube. This results in positive and negative pressures that may cause trap seal failures through induced siphonage and/or blowback. The Sovent system design eliminates the formation of the "hydraulic plug" and maintains a core of air throughout the vertical stack.

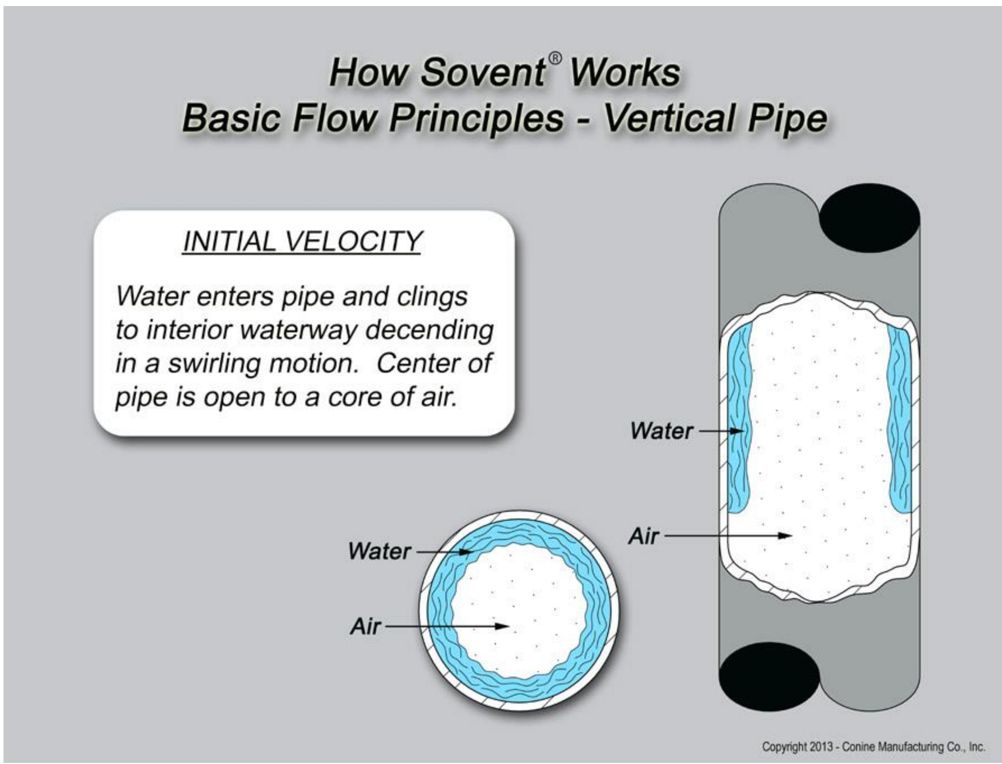
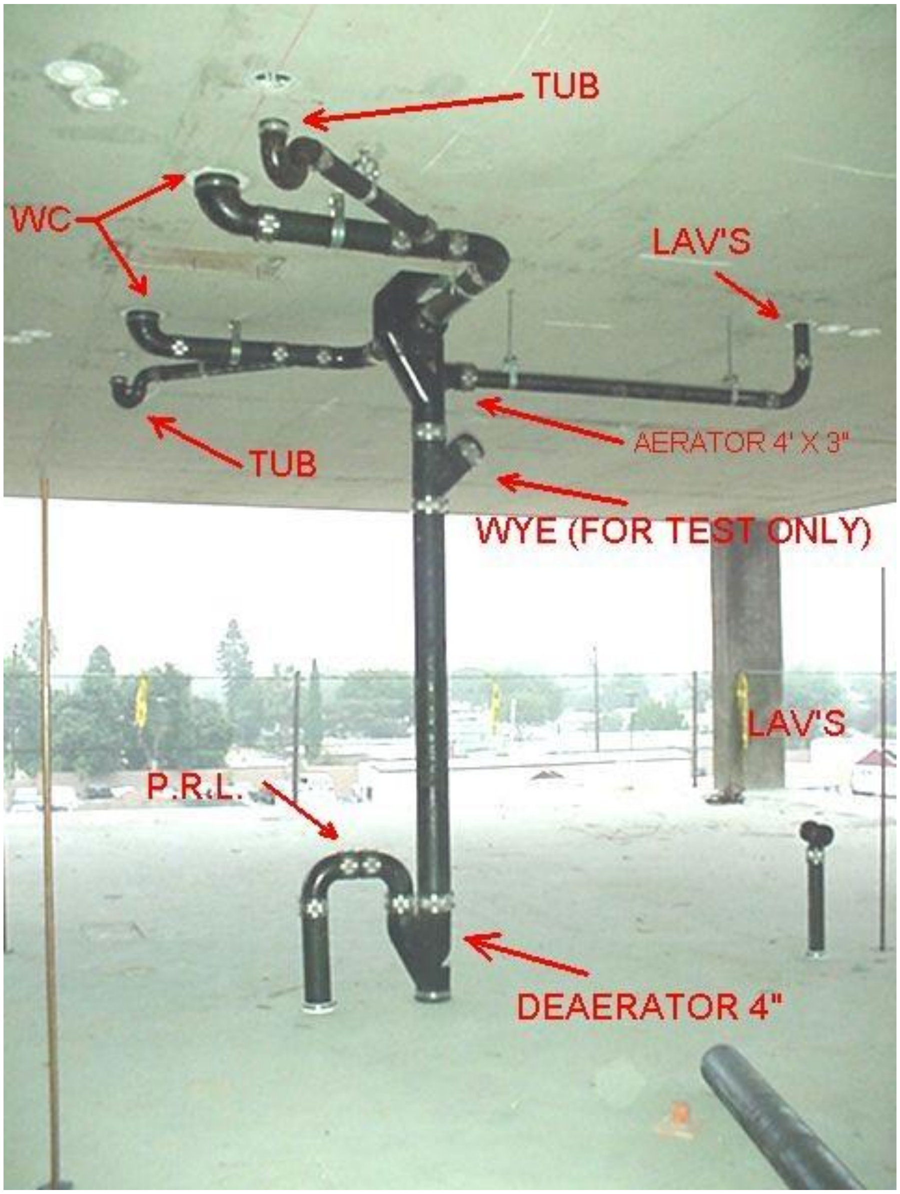



**Fig. 7**




**Overview of the Sovent Drainage connection**

**Fig. 8**

- **APPLICATION POSSIBILITY IN KOLKATA:**

It was discussed to few consultants, experts, Project Managers and Architects and understood that the awareness is the main problem of not using this system. Most of the professionals are afraid of adopting the new system because of difficulties to convince the developers. The more vital reason is the initial cost since, there is no market for this system in India as well as it is a foreign product.

In view of the above, the initiative should be taken by the Industrialist, Institution, Govt. funded R & D department and make a sample in Kolkata for the system that can be shown to the developers and do the awareness campaigning. There could be another option that Govt. projects start adopting this system initially then a confidence will build up among the developers knowing that the system is functioning properly and cost is not very high because, this system eliminates the many fittings, accessories etc. those are required in the conventional two pipes system with vent.

# CHAPTER 2

## 2 OBJECTIVE & SCOPE OF WORK:

### 2.1 OBJECTIVE:

The objectives of the study are:

- To understand the present trend of drainage and water supply systems in high-rise buildings.
- To understand the merits and demerits of the present system.
- Finding out the alternative measure to overcome the demerits of the present system.
- Technical possibility of single stack system even for the low height buildings.
- Possibility of using the Sovent Fittings in the India's Context.
- Understand the ideal algorithm for the design of the systems.
- Major criteria those are to be considered while designing systems.
- Future scope of the study on the basis of the challenges face in the present design of the systems.

### 2.2 SCOPE OF THE STUDY:

The scope of the studies is limited to the followings:

- Site investigation.
- Discussion with the users and maintenance staff to understand the problem they are facing.
- Determine the basic technical difference between the single pipe system and two pipes system.
- Introducing the green plumbing concept to the design.
- Discussion on different plumbing issues with the reputed plumbing Consultants in Kolkata.
- Refer different books, journals, research works etc.

# CHAPTER 3

## 3 STUDY AREA:

The present design trend of the Drainage and Water Supply Systems in the high-rise buildings and the issues and challenges faced by the users in their daily life. The difficulties faced during installation; maintenance also was in the scope of the study. Comparing the different systems used around the world and understand the advantages and disadvantages of the systems and see the possibility of the use of best system in our country.

There are few high-rise buildings in Kolkata are studied and the short description of the City of Kolkata is given below.

**Brief of Kolkata:**

Kolkata founded in the year 1690, is the capital of the state of West Bengal, located on the eastern shore of India. Kolkata at 880 30’ Eastern longitudes and 220 33’ northern latitude is 180 km from Bay of Bengal and stands on the eastern bank of river Hooghly. The elevation ranges from 1.5 to 9.0 m above sea level. The city can primarily be divided into two parts i.e. old historic city in northern portion which is heavily congested and the new city which is better planned in southern part.

The Kolkata Municipal Corporation (KMC) is the largest Municipal Corporation in West Bengal having an area of 205.77 square kilometers. As of 2011, the city had 4.5 million residents; the urban agglomeration, which comprises the city and its suburbs, was home to approximately 14.1 million, making it the third-most populous metropolitan area in India. As of 2008, its economic output as measured by gross domestic product ranked third among South Asian cities, behind Mumbai and Delhi.

# CHAPTER 4

## 4. PRESENT TREND OF PLUMBING SYSTEM:

### 4.1. PRESENT TREND IN KOLKATA

#### 4.1.1. THE FOLLOWING TABLE SHOWS THE PLUMBING SYSTEM OF FEW HIGH-RISE RESIDENTIAL BUILDINGS:

Table 1

| Name | Height (m) | Floor | Year | Drainage system | Water supply system |
|---|---|---|---|---|---|
| The 42 | 268 | 63 | 2018 | Two pipes with common vent | Gravity with break tank system |
| Urbana | 168 | 46 | 2014 | One pipe with partially ventilated | Gravity distribution + Booster pump for upper 4 floors |
| Forum Atmosphere T1 | 152 | 33 | 2016 | Two pipe systems with common vent | Gravity distribution + Booster pump for upper 5 floors |
| Forum Atmosphere T2 | 152 | 33 | 2016 | Two pipe systems with common vent | Gravity distribution + Booster pump for upper 5 floors |
| Fort Oasis | 80 | 26 | 2012 | Two pipe systems with common vent | Gravity distribution (Booster pump for upper 5 floors installed by the Flat owners) |

**4.1.2. THE FOLLOWING TABLE SHOWS THE FEW ASSEMBLY / OFFICE BUILDINGS:**

Table 2

| Name | Height (m) | Floor | Year | Drainage system | Water supply system |
|---|---|---|---|---|---|
| The Kolkata Museum of Modern Art (KMOMA) | 48 | 10 | Under construction | Two pipes system with common vent pipe | Hydro-pneumatic |
| Martin Burn Office Building | Multi-storied building | | 2018 | Single Stack | Gravity system only |

**4.1.3. THE FOLLOWING TABLE SHOWS THE FEW COMMERCIAL BUILDINGS:**

Table 3

| Name | Height (m) | Floor | Year | Drainage system | Water supply system |
|---|---|---|---|---|---|
| City Centre 2 Rajarhat | - | 4 | Completed few years back | Single Stack | Hydro-pneumatic |
| | | | | | |

## 4.2. PRESENT TREND OF DRAINAGE SYSTEM IN INDIA:

In India, this has been observed that two pipes system with common vent is the preferred system of the Architects, Engineers as well as the plumbing experts. Although, few experts having the idea that India is moving towards the Single Pipe with partially ventilated system but in very slow pace.

### 4.2. PRESENT TREND OF DRAINAGE SYSTEM IN WORLD:

From the research work done by the professor Cheng-Li Cheng, National Taiwan University of Science & Technology, Department of Architecture in 2014, it has been revealed that the **"TWO PIPES SYSTEM WITH INDEPENDENT VENTS"** is the most common drainage system for the high-rise buildings in Taiwan.

However, in central Europe and Switzerland, the **SINGLE STACK SYSTEM** is the commonest one and one more interesting point, they do not provide floor drain in bath or kitchen since, all the appliances have the individual trap. But in India, it is very common of having floor trap which aesthetically very ugly and basically has no use.

As per the opinion of Mr. Rene Machler, CEO of RMC Consulting ag, Switzerland, the most appropriate drainage system for the high-rise buildings shall be single stack with Sovent Fittings that is called "Sovent System".

The **"BHURJ KHALIFA",** the tallest building 828 Mtr. High (163 storied) in the world having single stack drainage system.

# CHAPTER 5

## 4 METHODOLOGY:

### 5.1. SYSTEM ADOPTED:

#### 5.1.1. SITE INVESTIGATION: CASE-I

**A. PROJECT DETAILS:**

- Name of the project: **Atmosphere (2-blocks connected with a bridge at ht. Of 96m)**
- Status: **Under Construction**
- Type: **Residential**
- Client: **Forum Group**
- Architect: **ARC Studio**
- Total Built-up Area: **6.5 lakhs sq. Ft**
- Height of the building: 152 mtr.
- No of storeyed: **B+G+39**
- No. of apartments (each tower):

**Simplex – 24 nos (4 Bed Rm + 4 Toilet & 1 WC + 1 Kit)**

**Duplex – 16 nos (5 Bed Rm + 5 Toilet & 1 WC + 1 Kit)**

- Location: **Kolkata (Near Science City)**
- MEP Consultant: **Tylin (Singapore)**

**B. DRAINAGE:**

The concept of the existing design is two pipes system with common vent pipe, one pipe will carry the soil waste and other will carry the waste water & vent pipe will serve both the pipes for ventilation.

**C. WATER SUPPLY SYSTEM:**

The concept of the existing design is Gravity system with booster pumps for upper five floors.

- **FLOW DIAGRAM OF WATER DISTRIBUTION:**

**RAW WATER → STORAGE (UGR) → TREATMENT → PUMPING → STORAGE (OHR)**

**DISTRIBUTION (Gravity supply with Booster Pumps for the upper four floors) → USE**

**Note:** Upper five floors having separate line with Booster Pumps since the gravity pressure is not enough for normal use.

## Pipes & Tank Sizes:

Size of inlet pipe: 150mm (D.I)

Size of outlet pipe: 150mm & 80mm (CPVC)

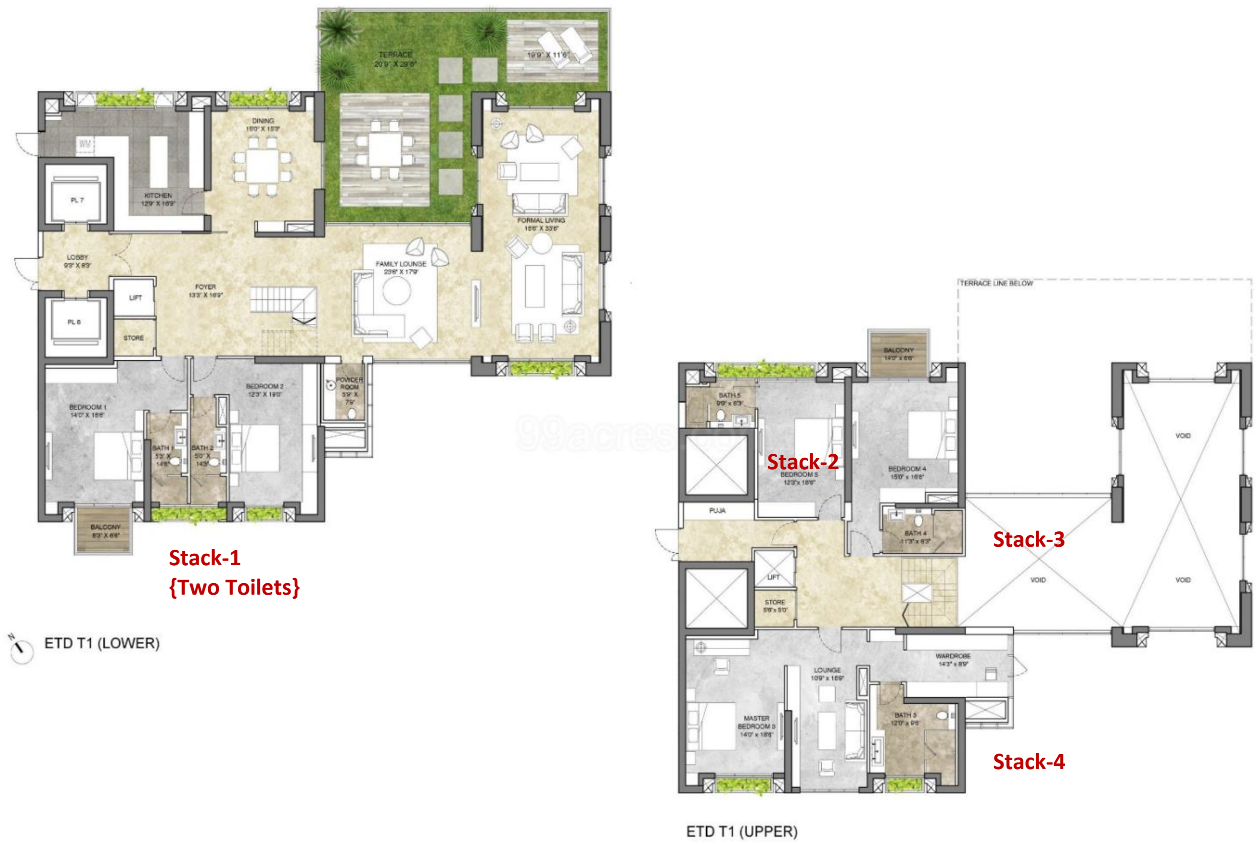
Pressure released valve: installed at every $5^{th}$ floor

Size of OHR = 70 cum

Size of UHR = 300 cum

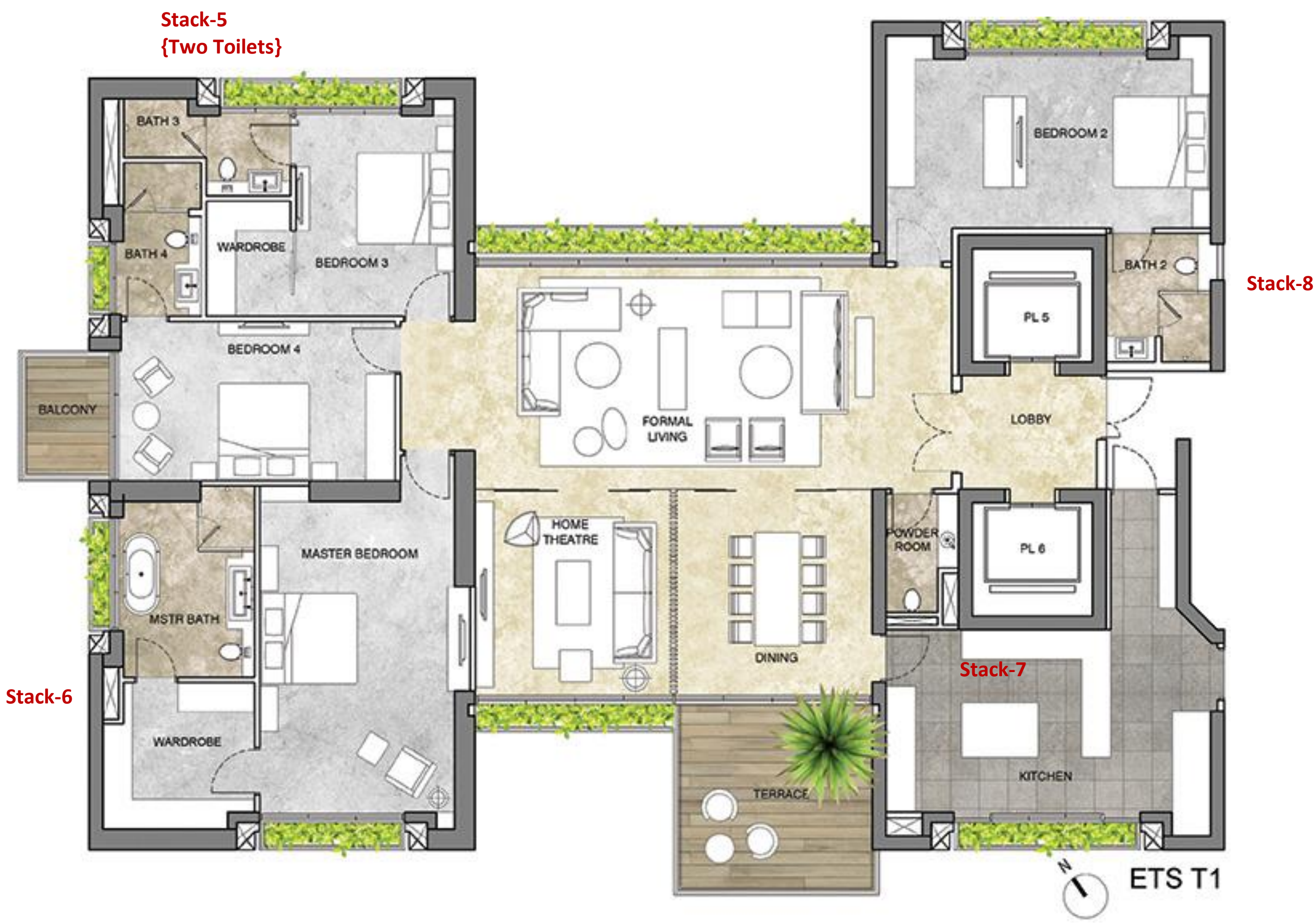
### 5.1.2. THE ABOVE DESIGN IS NOW COMPARAED BASED ON THE GUIDELINES OF THE NBC-2016 AND UPC-I:

## ATMOSPHERE
## B+G+39 Storeyed Residential Building




## FLOOR PLAN OF DUPLEX FLAT

**Fig. 9**




**PLAN OF SIMPLEX FLAT**

**Fig. 10**

- **FIXTURE DETAILS:**

Table 4

| **Details:** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Facilities in each floor** | | | | **Total** | | | | |
| **Flat Type** | **Nos** | **Master Toilet** | **Toilet** | **WC** | **Kitchen** | **Master Toilet** | **Toilet** | **WC** | **Kitchen** | |
| Simplex | 24 | 1 | 3 | 1 | 1 | 24 | 72 | 24 | 24 | |
| Duplex | 16 | 1 | 4 | 1 | 1 | 16 | 64 | 16 | 16 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| **Simplex Flat:** | **Fixtures** | | | | | | | | | |
| | WC | Wash Basin | Shower | Bath Tub | Health Faucet | Floor Drain | Abulation Tap | sink | Dish washer | Washing m/c |
| Area | | | | | | | | | | |
| MT | 1 | 1 | | 1 | 1 | 1 | 1 | | | |
| Toilet | 1 | 1 | 1 | | 1 | 1 | 1 | | | |
| WC | 1 | 1 | | | 1 | 1 | 1 | | | |
| | | | | | | | | | | |
| Kitchen | | | | | | | | 1 | 1 | |
| Washing Area | | | | | | | | | | 1 |
| **TOTAL:** | **120** | **120** | **72** | **24** | **120** | **120** | **120** | **24** | **24** | **24** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Duplex Flat:** | **Fixtures** | | | | | | | | | |
| | WC | Wash Basin | Shower | Bath Tub | Health Faucet | Floor Drain | Abulation Tap | sink | Dish washer | Washing m/c |
| **Area** | | | | | | | | | | |
| MT | 1 | 1 | | 1 | 1 | 1 | 1 | | | |
| Toilet | 1 | 1 | 1 | | 1 | 1 | 1 | | | |
| WC | 1 | 1 | | | 1 | 1 | 1 | | | |
| | | | | | | | | | | |
| Kitchen | | | | | | | | 1 | 1 | |
| Washing Area | | | | | | | | | | 1 |
| **TOTAL:** | **96** | **96** | **64** | **16** | **96** | **96** | **96** | **16** | **16** | **16** |
| | | | | | | | | | | |

- **DRAINAGE FIXTURE UNITS (DFU):**

Table 5

| | | | | |
|---|---|---|---|---|
| **Fixtures** | **DFU** | **Type of Flat** | | **Notes** |
| | | **Simplex** | **Duplex** | |
| WC with flush valves | 8 | 960 | 768 | |
| wash Basin | 1 | 120 | 96 | |
| Shower | 2 | 144 | 128 | |
| Bath Tub | 3 | 24 | 48 | |
| Abu. Tap /Heath Faucet | 1 | 120 | 96 | |
| Floor Drain | 1 | 120 | 96 | |
| Kit Sink | 2 | 48 | 32 | |
| Dish Washer | 2 | 48 | 32 | |
| washing m/c | 3 | 72 | 48 | |
| **For Security & Maintenance Staff:** | | | | |
| Urinal with flush tank | 2 | 12 | 12 | 6-Urinals |
| WC | 8 | 24 | 24 | 3-WC |
| Floor Drain | 1 | 1 | 1 | 1- Floor Drain |

- **REQUIRED PIPE SIZES:**

Table 6

| Simplex | | | Duplex | | |
|---|---|---|---|---|---|
| **1116** | **409** | **168** | **900** | **369** | **112** |
| **Sewer Line** | **Waste Line** | **Kit waste + w/m*** | **Sewer Line** | **Waste Line** | **Kit waste + w/m*** |
| **No. of stacks** | | | **No. of stacks** | | |
| **5** | 5 | 1 | **5** | 5 | 1 |
| **DFU per stack** | | | **DFU per stack** | | |
| **223** | 82 | | **180** | 74 | |
| **Design DFU (Two Toilets)** | | | **Design DFU (Two Toilets)** | | |
| **446** | **164** | **168** | **360** | **148** | **112** |
| **Simplex** | | | **Duplex** | | |
| **Required dia. of Pipe (mm), NBC** | | | **Required dia. of Pipe (mm), NBC** | | |
| **100** | **100** | **100** | **100** | **100** | **100** |
| **Required dia. of Pipe (mm), UPC - I** | | | **Required dia. of Pipe (mm), UPC - I** | | |
| **125** | **100** | **100** | **125** | **100** | **100** |
| **Provided** | | | **Provided** | | |
| **150** | **150** | **150** | **150** | **150** | **150** |
| ***Provided more*** | | | ***Provided more*** | | |

w/m*: Washing Machine.
dia.: Diameter

- **CALCULATION FOR WATER DEMAND:**

Table 7

| Apartment Type | Nos | Population per Apartment (NBC 2016, p-11, part 9) | Total Population | Water demand / head / day (NBC 2016) | Total Water demand (Litre.) | Total Water demand (cum) |
|---|---|---|---|---|---|---|
| | | | | | | |
| Simplex (4-bed room) | 24 | 7 | 168 | 135 | 22680 | 22.68 |
| | | | | | | |
| Duplex (5-bed room) | 16 | 7 | 112 | 135 | 15120 | 15.12 |
| | | | | | | |
| Security & Maintenance staff | | | 30 | 50 | 1500 | 1.5 |
| | | | | | | |
| | | TOTAL FOR ONE TOWER | | | = | 39.3 |
| | | | | | | |
| | **Therefore, requirements for two towers = 39.3 x 2** | | | | **=** | **78.6** |

***(Note: Detail calculations given in Annex. – I)***

Total storage = 1.5 times of the requirement of one day = 78.6 x 1.5 = 118 cum

Capacity of UGR= 66.67% of 118 = 78.67 cum

Capacity of OHR = 33.33% of 118 = 39 cum

Therefore,

- Required storage reservoir size as per NBC-2016 & UIPC-I = 200 + 78.67 = 279 cum
- *Underground storage reservoir size as per existing design = 300 cum*
- Required size for overhead water reservoir for one tower considering that the water will be lifted to OHR twice a day = (0.5 x 39.3 + 10 for fire requirement) = 29.65 say 30 cum
- *Overhead reservoir size as per existing design = 70 cum*

**Note:**

As per NBC-2016, part-4, table-7

Required capacity for UGR = 200000 liters = 200 cum

Required capacity for OHR = 10000 liters = 10 cum

- **OBSERVATIONS:**

(i) The calculated pipe sizes for all the lines as per UIPC-I (2017), table 703.2 are lower than the existing design done by a Singapore based company "TYLIN".

(ii) Both the water reservoirs, OHR & UGR are oversized. These could have been reduced as per NBC & UIPC-I guidelines.

(iii) The size of vent pipe is 100mm which is less than the guidelines of NBC. As per NBC, this should be same size as that of the size of drainage pipe i.e. 150mm.

(iv) **Bello joint** used for the connection of two blocks as well as when the pipes are crossing the expansion joints. These joints are compensating elements for thermal expansion and relative movement in pipelines, containers and machines. They consist of one or more metal bellows, connectors at both ends, and tie rods that depend on the application. They are differentiated according to the three basic types of movement: axial, angular and lateral expansion joints. Expansion joints have usage in various sectors, like energy productions, paper industry, chemical industry, water treatment, oil and gas. Everywhere where exist pipelines and occurs thermal movements or vibration, then expansion joints can be used.

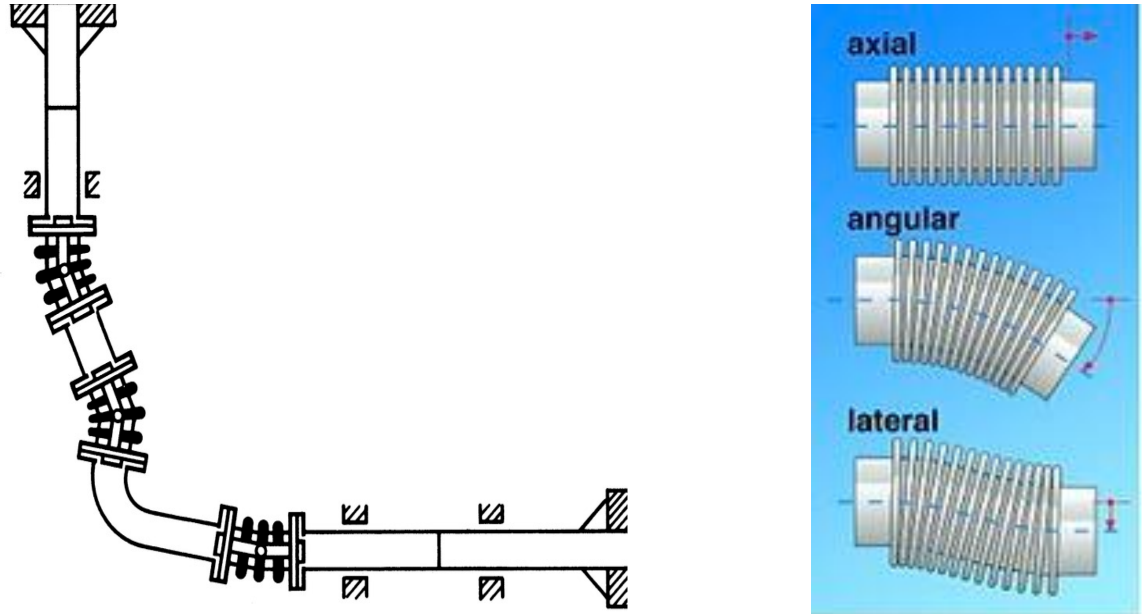



**Fig. 11**

(v) **Roof drain water:** Normal vertical roof drain pipe of dia. 150mm is used, since the roof area is small.

(vi) **Grease Traps** have been used for the waste from Kitchen & Garbage chute has been provided for the solid waste disposal.

- **ISSUES FOR THIS BUILDING:**

(i) Maintenance of booster pumps is a continuous & expensive process.

(ii) Too many pipes in a small duct:

This creates serious problem for the maintenance works. The tendency of the developer to make duct size as minimum as possible to get the more floor area, which ultimate gives more money. The statutory authority should be strict enough to control these types of irregularities by imposing the penalty etc.

(iii) **Provided oversized pipes:**

Since the NBC & UIPC-I are the basis for the design of the plumbing system in India then the size of the pipes could have been reduced.

(iv) **Pressure released valve** (PRV) installed at every 5$^{th}$ floor instead of at every 10$^{th}$ floor, it is not understood. Technically pressure released valve at every 7$^{th}$ floor is quite safe.

(v) Using Syphon roof drain could have been reduced the pipe size.

**5.1.3. CASE-II:**

**A. PROJECT DETAILS:**

- Name of the project: **URBANA (Tower-5)**
- Type: **Residential**
- Client: **Bengal NRI Complex Limited**
- Total BUA: **1,55,000 sq. ft (approx.)**
- Height of the building: 167.6 Metre
- No of storied: **G+45**
- No. of apartments at each floor:

**6-flats from 1$^{st}$ to 45$^{th}$ floor (each flat: 4 toilet + 1 kit)**

- Total nos. of flats = 270 flats
- Total no. of toilets = 1080
- Ground floor: 3-toilet + 1-kit

**B. DRAINAGE:**

The concept of design is one pipe partially ventilated system.

One vertical pipe for the connection of floor 45$^{th}$ to 4$^{th}$ & the remaining floors have another vertical pipe from the 3$^{rd}$ to gr. Floor.

**C. WATER SUPPLY:**

The concept of design is Gravity system with booster pumps for upper five floors.

- **FLOW DIAGRAM OF WATER DISTRIBUTION:**

**RAW WATER** → **STORAGE (UGR)** → **TREATMENT** → **PUMPING** → **STORAGE (OHR)**

**DISTRIBUTION (Gravity supply with Booster Pumps for the upper three floors)** → **USE**

**5.1.4. THE ABOVE DESIGN IS NOW CHECKED AS PER THE NORMS OF NBC-2016 AND UPC-I:**

**URBANA (Tower-5)**
**G+45 Storeyed Residential Building**


**TYPICAL FLOOR PLAN**

**Fig. 12**

- **FIXTURES DETAILS:**

Table 8

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Details:** | | | | | | | | | | | |
| Flat | | Facilities in each floor | | | | Total | | | | | |
| | Nos | Master Toilet | Toilet | Kitchen | | Master Toilet | Toilet | Kitchen | | | |
| | 270 | 1 | 3 | 1 | | 270 | 810 | 270 | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | **Fixtures** | | | | | | | | | | |
| **FLATS (Area)** | **WC** | **Wash Basin** | **Shower** | **Bath Tub** | **Health Faucet** | **Floor Drain** | **Abulation Tap** | **sink** | **Dish washer** | **Washing m/c** | |
| | | | | | | | | | | | |
| MT | 1 | 1 | | 1 | 1 | 1 | | | | | |
| Toilet | 1 | 1 | 1 | | 1 | 1 | | | | | |
| | | | | | | | | | | | |
| Kitchen | | | | | | | | 1 | 1 | | |
| Washing Area | | | | | | | | | | 1 | |
| **TOTAL:** | **2160** | **2160** | **810** | **270** | **2160** | **2160** | | **270** | **270** | **270** | |
| | | | | | | | | | | | Urinals |
| For Security & Maintenance Staff: | 3 | 3 | 3 | 0 | 3 | 3 | 3 | 1 | | | 8 |

- **DRAINAGE FIXTURE UNITS (DFU):**

Table 9

| Fixtures | DFU | Total | Total DFU |
|---|---|---|---|
| WC with Flush Valve | 8 | 2160 | 17280 |
| wash Basin | 1 | 2160 | 2160 |
| Shower | 2 | 810 | 1620 |
| Bath Tub | 3 | 270 | 810 |
| Abu. Tap /Heath Faucet | 1 | 2160 | 2160 |
| Floor Drain | 1 | 2160 | 2160 |
| Kit Sink | 2 | 270 | 540 |
| Dish Washer | 2 | 270 | 540 |
| washing m/c | 3 | 270 | 810 |
| For Security & Maintenance Staff: | | | |
| Urinal with flush tank | 2 | 16 | 32 |
| WC | 8 | 24 | 192 |
| Floor Drain | 1 | 3 | 3 |
| wash Basin | 1 | 3 | 3 |

- **STACK WISE DFU & PIPE SIZE:**

Table 10

| Sewer Line | Waste line | Kit & W/m |
|---|---|---|
| 19664 | 6756 | |
| Total DFU in combined line {Sewer + Waste} | | |
| 26420 | | 1890 |
| No. of stacks | 24 | 6 |
| DFU per stack | | |
| 1101 | | 315 |
| One stack carrying loads of two toilets (Max. DFU for design) | | |
| 2202 | | 315 |
| Required dia. of Pipe (mm) | | |
| 300 | | 200 |
| As per UIPC-I | | |
| 200 | | 125 |
| Provided | | |
| 150 | | 150 |

***(Note: Detail calculations given in Annex. – II)***

- **OBSERVATIONS:**

(a) The calculated pipe sizes are higher than the existing design.

(b) Size of vent pipe has been kept 100mm, which is not as per the norms.

(c) According to NBC the size of vent pipe (terminating to the outdoor) shall be same as the size of drainage stack in case of single stack system.

(d) Both the water reservoirs, OHR & UGR are oversized. These could have been reduced as per NBC & UIPC-I.

(e) The very interesting part of the system, they have separated the lower three floors from the rest of the line. This has great advantage of the distributing the positive pressure that develop at the base of the vertical line, where it takes turn and join to the public sewer / outside sewer line.

(f) **Stage wise pipe size:** this could have been beneficial for the high-rise buildings and this is in line with the NBC guidelines. It is very much possible of changing the pipe size at every 10 floors.

(g) Size of service duct is very small, so access to the pipe for the purpose of maintenance is the tough job.

(h) Few flat owners have the complaints about the foul gas / smell.

(i) Service duct is not well ventilated and at the same time numbers of exhaust fans are throwing air into the ducts from toilets / kitchens making the situation even worse.

(j) Noise is the problem while number of flushes are operating at the same time.

(k) The size of the receiving pipe outside the Building, the one which is receiving the discharge from the vertical pipe is of same size. This is creating stagnation of the discharge for few minutes which supposed to create back flow to the lower floors.

(l) Pressure released Valve: Installed at every 5th Floor.

(m) Strainer is used in the outlet pipe of water supply.

- **ISSUES FOR THIS BUILDING DESIGN:**

i). Maintenance of Booster Pumps for the upper floors in the high-rise buildings is problematic as well as expensive in long run.

ii). Use of low flow fixtures not used due to its high initial cost and this building is for Low income group (LIG).

iii). Sound insulated drainage pipe is not used due to the same reason as mentioned in the sl no. (ii).

iv). Duct size is inadequate in the view of the maintenance and safety.

v). Stagewise pipe size say at every 10th floor could have been done.

vi). Siphon roof drainage can reduce the size of the roof drain pipe and save the cost.

vii). Alternate technology for the replacement of Pressure Reducing Valves (PRV). It is basically the energy wasting valves and this violet the norms of the green plumbing.

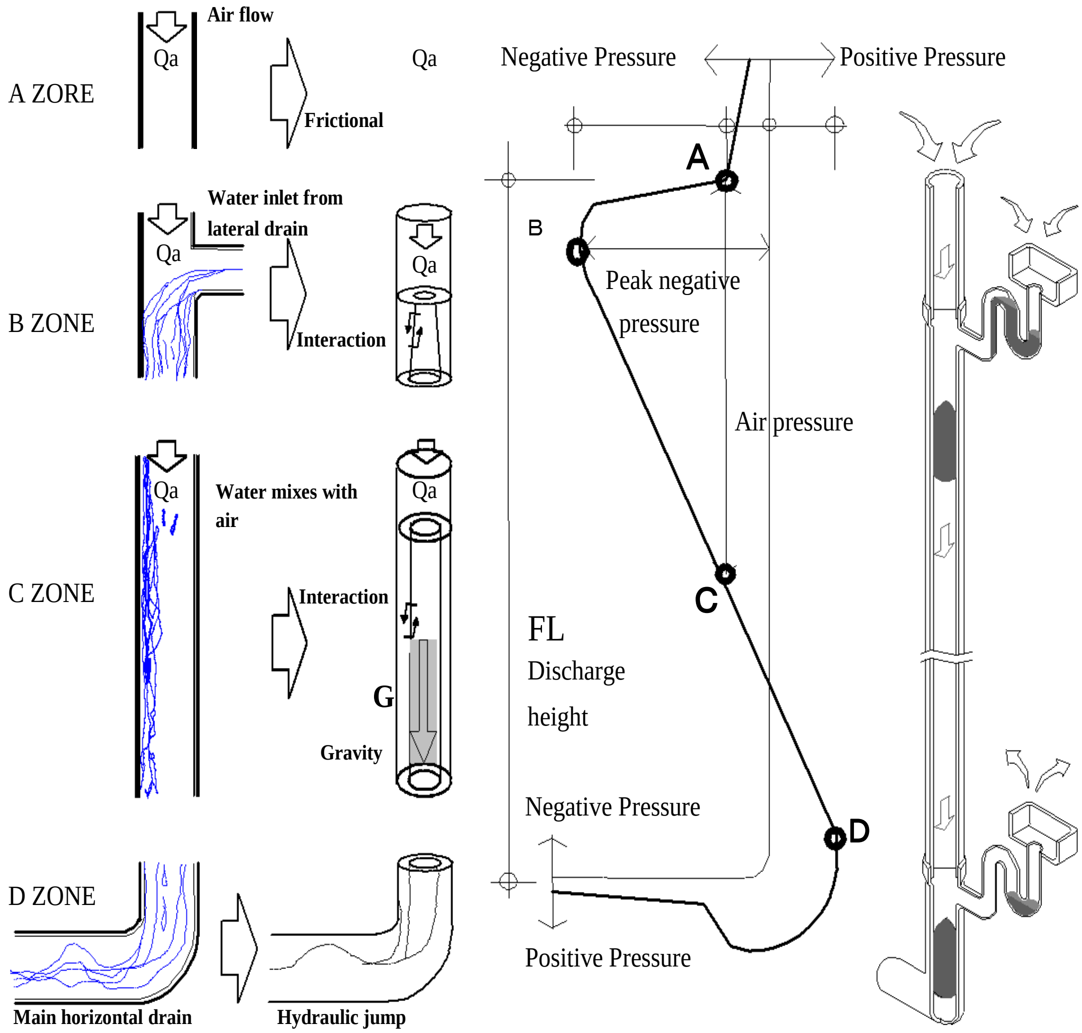
# CHAPTER 6

## 6.1 ESTIMATION OF PRESSURE VARIATION IN VERTICAL STACK:

Appliance discharges to a vertical stack of drain may be described as unsteady or time dependent flow. The actual discharge of vertical drainage stack has a complex phenomenon and may consist of triple phase flow feature with incorporated solid, liquid & air. This mechanism causes the (-) ve pressure on the upper floors and (+) ve pressure on the lower floors.

Air flow rate is the dominant factor in the vertical drainage stack, it plays a critical role in the subsequent operation of vertical drainage stack and the mechanism may be assumed to be quasi-fan machine, thus the law of fan can be introduced to link with the vertical drainage flow.

Air pressure in vertical drainage stack is caused by the series of interactions between downstream water and through-flow air in vertical pipe.



A ZORE
Air flow
Qa
Frictional
Qa
Negative Pressure
Positive Pressure
A
B ZONE
Water inlet from lateral drain
Qa
Interaction
Qa
B
Peak negative pressure
Air pressure
C ZONE
Qa
Water mixes with air
Qa
Interaction
G
Gravity
C
FL
Discharge height
Negative Pressure
D
D ZONE
Main horizontal drain
Hydraulic jump
Positive Pressure


**Fig. 13**

## 6.2 DESIGN STEPS OF DRAINAGE AND WATER SUPPLY SYSTEMS IN HIGH-RISE BUILDING:

- **FLOW DIAGRAM:**

**RAW WATER → STORAGE → TREATMENT → STORAGE → DISTRIBUTION → USE →**

**DISCHARGE (Drainage) → TREATMENT → REUSE OR DISPOSAL**

**Step-1:** **Study the floor plan thoroughly. Know the type of apartment such as LIG, MIG, HIG etc. It is important since the water demand depends on this criterion.**

**Step-2:** **Calculate the population per flat as per the norms of the NBC and then total water demand for the building.**

**Step-3:** **Find out the sizes of the Under-Ground Reservoir as well as Over Head Reservoir (required for gravity distribution) on the basis of step-2. The tank sizes shall be considering the water requirement for the fire protection as per norms.**

**Step-4:** **Choose the distribution system of the water supply:**

1. **Direct supply system from mains—public or private.**
2. **Gravity distribution system:**
3. **Pressurized distribution system (hydro-pneumatic pumping system):**
4. **Combined distribution system:**

**Step-5:** **Calculate the volume of waste water or water to be drained from the building. It is generally taken as 85% of the total demand.**

**Step-6:** **Calculate the size of the Sewage Treatment Plant (STP). Decide the disposal / reuse of the treated water.**

**Step-7: Choose the type of drainage system to be adopted on the basis of:**

- **Type of Building**
- **Height of Building**
- **Space available for the system**
- **Choice of developers**

**Step-8: Available drainage system as per the NBC-2016:**

- **Single stack system**
- **One pipe - partially ventilated system**
- **One pipe - fully ventilated system**
- **Two pipes system:**

  i). With common vent: in this system one vent pipe vent the soil & waste stacks.

  ii). With independent vent pipes, one for soil & one for waste stack.

**Step-9: Choose the materials of the systems keeping in mind:**

- **Availability**
- **Cost**
- **Concept of Green plumbing**
- **BIS approval**

**Step-10: Study the Sanitary and Water Supply Fixtures in each Toilet / Kitchen such as Water Closet (WC), Wash Basin (WB), Health Faucet, Shower, Bath Tub, Sink, Dishwasher, Washing Machine etc.**

**Step-11: Work out the item wise total fixtures per floor i.e. total WC, WB, etc.**

**Step-12: Now calculate the cumulative total of the fixtures at every 10$^{th}$ Floor starting from top i.e., Total of 10$^{th}$ Floor, Total of 20$^{th}$ floor, Total of 30$^{th}$ floor so on.**

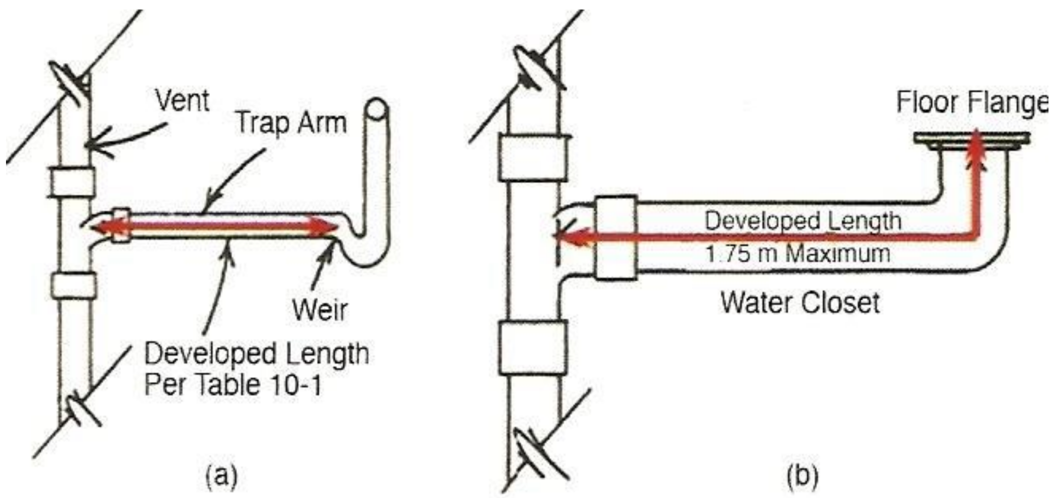
**Step-13: Take the value of Drainage Fixtures Unit (DFU) from the NBC and multiply with the number of fixtures and get the value of total stage wise as mentioned in the previous step.**

**Step-14: Get the pipe size from the NBC-2016 on the basis of the total DFU as calculated.**

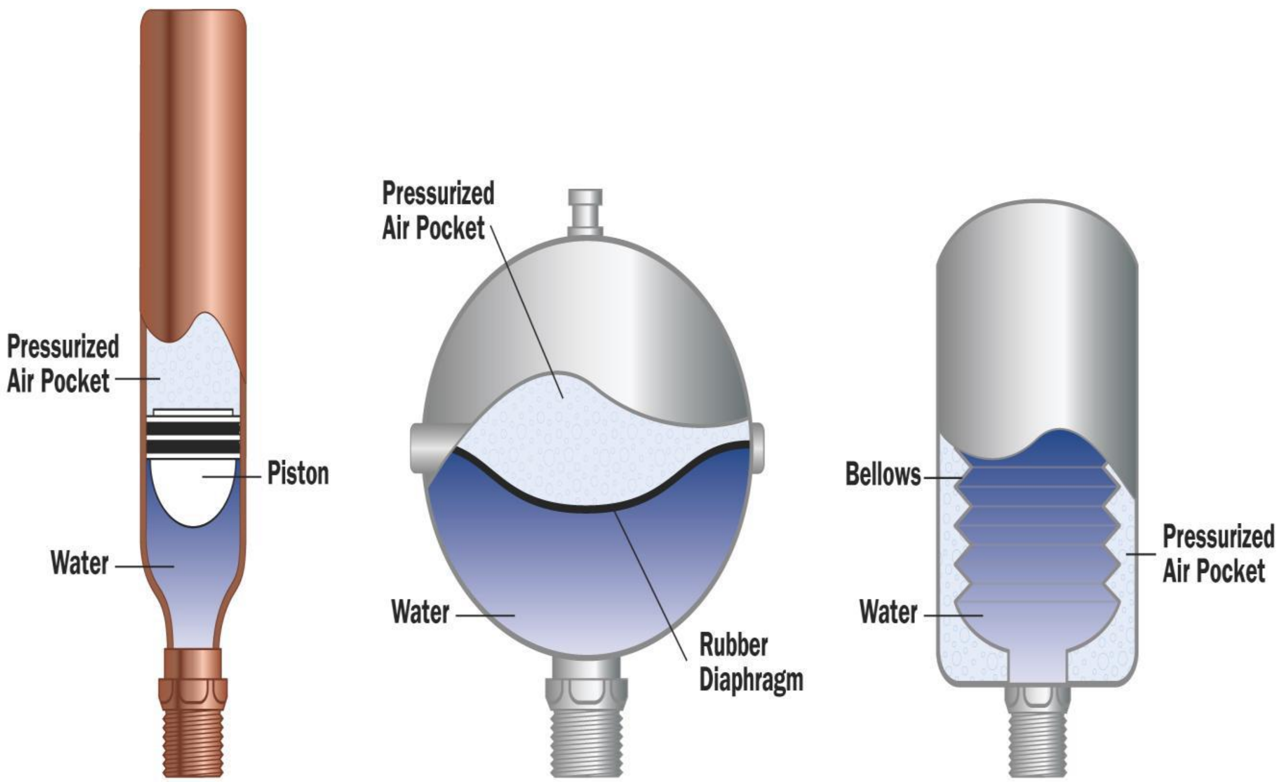
------*End of Design*-----

- **ADDITIONAL CARE SHALL BE TAKEN WHILE DESIGNING, DETAILING AND INSTALLING THE SYSTEM**

1. All the fixtures shall be 3-star marked conforming Green Plumbing Code / UIPC.
2. Care must be for the development length of the horizontal pipe.




3. All building systems with quick-acting valves shall be provided with pressure absorbing devices to negotiate the effect of water hammer.




**Some Typical Pressure absorbing devices available in the market**

4. Sound insulated drainage pipe shall be used for the high-rise buildings.

5. Water Supply System connected to hydro-pneumatic or direct pumping systems should be provided with suitable air chamber for protection against water hammer and noise problems.

# CHAPTER 7

## 7.1 STROM WATER MANAGEMENT AS PER THE NORMS OF POLLUTION CONTROL BOARD: A CASE STUDY

Project: **THE KOLKATA MUSEUM OF MODERN ART**

Location: **NEWTOWN, KOLKATA**

Sub: **STORM WATER MANAGEMENT**

### 7.1.1 DESCRIPTION OF AREA AND MANAGEMENT:

The surrounding area is mainly composed of residential and commercial area. The total land area of the proposed project is 40468.00 sqm i.e., 10 acres. Area covered by the buildings = 35%. The area to be considered for the rain water = (40468.00 – 0.35 x 40468.00) = 26304.20 sqm

Table 11

| | **DETAILS OF AREA STATEMENT** | | | |
|---|---|---|---|---|
| | | | | |
| **Sl. No.** | **Description** | | **Area** (sqm) | **%** |
| 1 | **LAND AREA** | | 40468.00 | 100 |
| | | | | |
| i. | Ground Coverage Area (Building Area) | | 14162.0 | 35.00 |
| ii. | Amphitheatre Area | | 1202.75 | 2.97 |
| iii. | Road/Paved Area | | 5424.28 | 13.40 |
| iv. | Tree Plantation Area | | 8159.48 | 20.16 |
| v. | Other Green Area | | 1534.62 | 3.79 |
| vi. | Service Area | | 791.83 | 1.96 |
| vii. | Semi Paved Area | | 4852.38 | 11.99 |
| viii. | Open Parking Area | | 4185.32 | 10.34 |
| ix. | Water Feature Area | | 155.34 | 0.39 |
| | | | | |
| | **TOTAL** | | **40468.00** | **100.00** |
| | | | | |

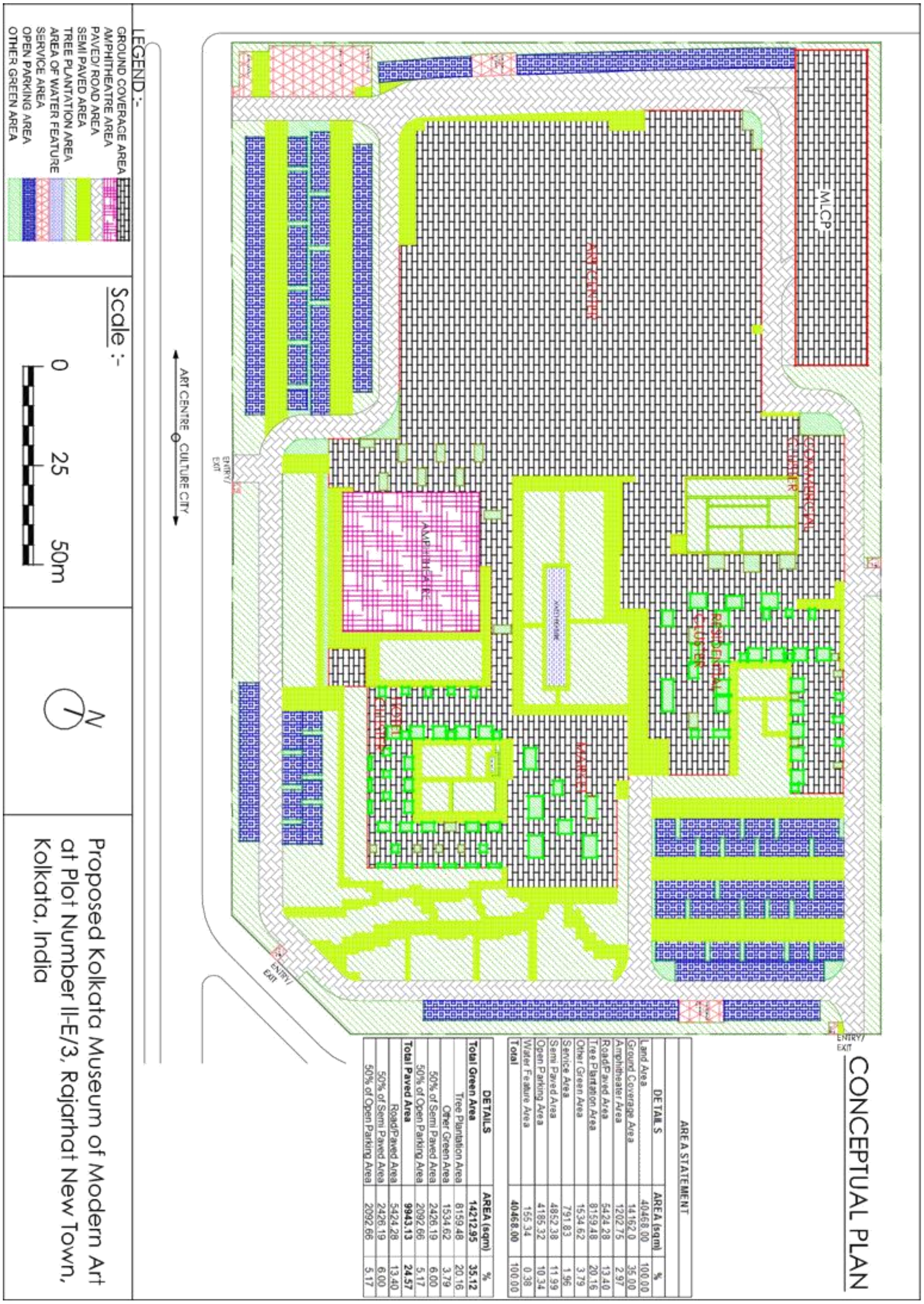

LEGEND :-
GROUND COVERAGE AREA
AMPHITHEATRE AREA
PAVED/ ROAD AREA
SEMI PAVED AREA
TREE PLANTATION AREA
AREA OF WATER FEATURE
SERVICE AREA
OPEN PARKING AREA
OTHER GREEN AREA
Scale :-
0
25
50m
N
Proposed Kolkata Museum of Modern Art at Plot Number II-E/3, Rajarhat New Town, Kolkata, India
ART CENTRE
CULTURE CITY
ENTRY/ EXIT
MLCP
ART CENTRE
AMPHITHEATRE
CONCEPTUAL PLAN
AREA STATEMENT
DETAILS | AREA (sqm) | %
Land Area | 40468.00 | 100.00
Ground Coverage Area | 14162.0 | 35.00
Amphitheater Area | 1202.75 | 2.97
Road/Paved Area | 5424.28 | 13.40
Tree Plantation Area | 8159.48 | 20.16
Other Green Area | 1534.62 | 3.79
Service Area | 791.83 | 1.96
Semi Paved Area | 4852.38 | 11.99
Open Parking Area | 4185.32 | 10.34
Water Feature Area | 155.34 | 0.38
Total | 40468.00 | 100.00
DETAILS | AREA (sqm) | %
Total Green Area | 14212.95 | 35.12
Tree Plantation Area | 8159.48 | 20.16
Other Green Area | 1534.62 | 3.79
50% of Semi Paved Area | 2426.19 | 6.00
50% of Open Parking Area | 2092.66 | 5.17
Total Paved Area | 9943.13 | 24.57
Road/Paved Area | 5424.28 | 13.40
50% of Semi Paved Area | 2426.19 | 6.00
50% of Open Parking Area | 2092.66 | 5.17

**Fig. 14**

The intensity of rainfall = 12mm/hr
By applying rational formula, the peak rate of storm runoff considering 12 mm/hr rainfall is given hereunder.

Total land area is = 26304.20 sqm = 2.64 ha.

By applying rational method, the peak rate of run-off = 10 x 0.60 x 12 x 2.64 cum./hr. = 191.00 cum./hr. = 0.053 cum/sec

Non-scouring and non-silting velocity is 1 m/sec.

Now, Q = A.V

A = Q/V = 0.053 / 1

(3.14/4) x $D^2$ = 0.053

D = 0.260 m

The required diameter of pipe is 260 mm.

The storm drains of the complex will collect and convey the rainwater into the adjacent drain. The internal drainage system will be designed considering the invert level of the master trap to avoid any flooding or water logging in the site.

### 7.1.2 CHALLENGES:

The invert of the Master Trap (MT) is higher than the invert of the inlet. The invert level of the MT cannot be changed because it has the relation with the Municipal Strom Water Drainage System.

### 7.1.3 PROPOSALS TO OVERCOME THE CHALLENGE:

We can make a separate chamber before connecting to MT with required level and a sensor operated pump can solve this problem. But it needs continuous supervision and servicing of the pump and that is expensive. In my view the following solution would be better:

We can make a separate chamber with required level and provide a non-returned valve in the inlet. The outlet should be at higher level as per the level of the MT (refer the fig……) but the following points shall have to be taken into consideration for the technically sound design:

a. The back pressure of the stored water inside the chamber must be less than the inflow pressure when there is one fourth full flow of the inlet pipe.

b. Substantial amount of silt to be carried by the inflow and will be deposited inside the chamber which may obstruct the inflow of the pipe, when the height of the deposit above the invert of the inlet. Therefore, the height of the inlet should be such that the water dropping / entering from the inlet would be able to create enough turbulence so that silt would be mixed up with the water and go out from the chamber through the outlet.

## 7.2 RAIN WATER HARVESTING AS PER STATE LEVEL ENVIRONMENT IMPACT ASSESSMENT COMMITTEE (SEIAA) - A CASE STUDY

The total roof area is about 14162.0 sqm. Rain water harvesting according to the SEIAA guidelines is as follows:

Table 12

| **Block Type** | **No. Of Story** | **Roof Area, Sqm** | **Total Rain Water Potential, Lakh Litre** | **Minimum Percentage Of Rain Water Which Should Harvested By** | | **Rain Water Harvesting Potential as Per SEIAA Guidelines** | |
|---|---|---|---|---|---|---|---|
| | | | | **Surface Storage (%)** | **Sub-Surface Recharge (%)** | **Surface Storage, Lakh Litre** | **Sub-Surface Recharge, Lakh Litre** |
| MLCP | G+3 | 1072 | 8.23 | 25 | 15 | 2.06 | 1.23 |
| Main Building Roof at First Floor Level | G+9 | 3445.28 | 26.46 | 10 | 10 | 2.65 | 2.65 |
| Main Building Roof At Fourth Floor Level | G+9 | 5463.63 | 41.96 | 25 | 15 | 10.49 | 6.29 |
| Main Building Roof At Ninth Floor Level | G+9 | 4181.090 | 32.11 | 35 | 45 | 11.24 | 14.45 |
| | | | | | | | |
| **TOTAL** | | **14162** | 108.76 | | | 26.44 | 24.62 |
| **TOTAL** | | | | | | **51.06** | |

As per SEIAA proposed guidelines, storage facilities and sub-surface recharging facilities required will be 26.44 lakh litres and 24.62 lakh litres respectively. Thus, the total rain water harvesting capacity is 51.06 lakh litres.

We are proposing 2 nos. of storage tank of 50 cum each for roof top rain water storage (total = 100 cum). Rest (50.06 lakh litre i.e. 5006 cum) will be recharged through 2 nos. of recharge tube well of 150 mm diameter each.

Considering 81 days rainfall in a year, per day average rain water available is 61.80 cum/day. Per day average rainwater available for each recharge structure = 61.80/2 = 30.90 cum/ day.

All rooftop rain water will be diverted to the rainwater storage tank of 100 cum capacity and overflow of the tank will be diverted to recharge structure and overflow of the recharge structure will be diverted to the storm water drain within the campus.

From the local survey/the agencies working for doing borewells, it is observed that there are prominent sand layers (confined aquifer) in the 70.0 to 122.0 meter zone. We are proposing to install our strainer in between 80 to 98-meter zone.

The quantity of Recharge, “Q” can be calculated through the following formula for confined Aquifer:

**Q = [2(22/7) * T *(H-h)] /[2.3 log 10(R/r)**

**Where,**

K= Permeability Coefficient is 5 cum/day/sqm,

(considering fine sand b = Average height of Confined Aquifer = 18-meter)

T= Transmissibility of the aquifer = K * b

H=Initial artesian pressure at the bottom of the aquifer h=Artesian pressure in the well, (H-h) = Drawdown =1.0 meter.

R = 200 metre

r =Radius of well = 150mm = 0.15 M

Therefore, Total recharging capacity from 1 no. 150 mm diameter tube well is given below –

Q= [2*(22/7) *5*18] / [{2.3 Log 10 (200/0.15)}]

= (565.7 / 7.2) Cum/Day

= 78.57 cum /Day

Per day average roof top rainwater available for recharging is 60.80 cum.

We are proposing 2 nos. of 150 mm diameter tube wells for recharging.

Average Capacity of recharging through 2 nos. of tube wells is = 78.57*2 = 157.14 cum/day and our average requirement is 60.80 cum/day

Average Capacity of recharging through 1 no. tube well is = 78.57 cum/day and our average requirement for each recharge tube well is 30.90 cum/day

<u>**Hence OK**</u>

## CHECK FOR RECHARGE STRUCTURE STORAGE

Table 13

| BLOCK TYPE | Roof Area, Sqm | Runoff Co-efficient | Annual Rainfall, meter | Total Potential of rainwater per Annum, cum | Total Potential of rainwater per Annum, lakh litre | Per day average rainwater available considering 81 rainy days in a year, cum/day |
|---|---|---|---|---|---|---|
| MLCP | 1072.00 | 0.95 | 1.5 | 1527.60 | 15.28 | 18.86 |
| Main Building Roof At First Floor Level | 3445.28 | 0.95 | 1.5 | 4909.52 | 49.10 | 60.61 |
| Main Building Roof At Fourth Floor Level | 5463.63 | 0.95 | 1.5 | 7785.67 | 77.86 | 96.12 |
| Main Building Roof At Ninth Floor Level | 4181.090 | 0.95 | 1.5 | 5958.05 | 59.58 | 73.56 |
| | | | | | | |
| **TOTAL** | **14162.000** | | | **20180.84** | **201.81** | **249.15** |

Table 14

| Block Type | No. Of Story | Roof Area, Sqm | Total Rain Water Potential, Lakh Litre | Minimum Percentage Of Rain Water Which Should Harvested By | | Rain Water Harvesting Potential As Per SEAC Guidelines | |
|---|---|---|---|---|---|---|---|
| | | | | Surface Storage (%) | Sub-Surface Recharge (%) | Surface Storage, Lakh Litre | Sub-Surface Recharge, Lakh Litre |
| MLCP | G+3 | 1072 | 15.28 | 25 | 15 | 3.82 | 2.29 |
| Main Building Roof At First Floor Level | G+9 | 3445.28 | 49.10 | 10 | 10 | 4.91 | 4.91 |
| Main Building Roof At Fourth Floor Level | G+9 | 5463.63 | 77.86 | 25 | 15 | 19.46 | 11.68 |
| Main Building Roof At Ninth Floor Level | G+9 | 4181.09 | 59.58 | 35 | 45 | 20.85 | 26.81 |
| | | | | | | | |
| **TOTAL** | | **14162.000** | **201.81** | | | **49.04** | **45.69** |
| **TOTAL** | | | | | | **94.73** | |

We are proposing 2 nos. of storage tank of 50 cum capacity each (total 100 cum) for roof top rain water storage. Rest (93.73 lakh litre i.e. 9373 cum) will be recharged through 2 nos. of recharge tube well of 150 mm diameter each.

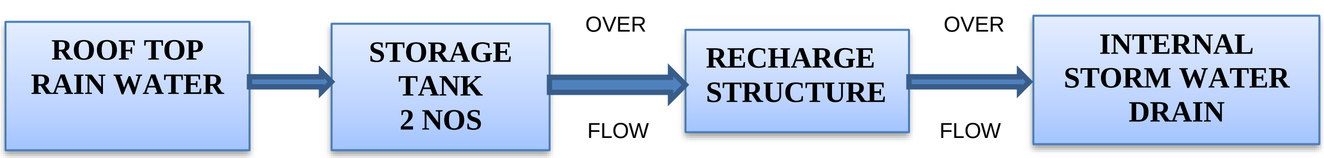
Considering 81 days rainfall in a year, per day average rain water available for recharge is = 115.72 cum/day.

Rainwater available for recharge for each recharge tube well per day = 115.72/2 = 57.86cum/day.

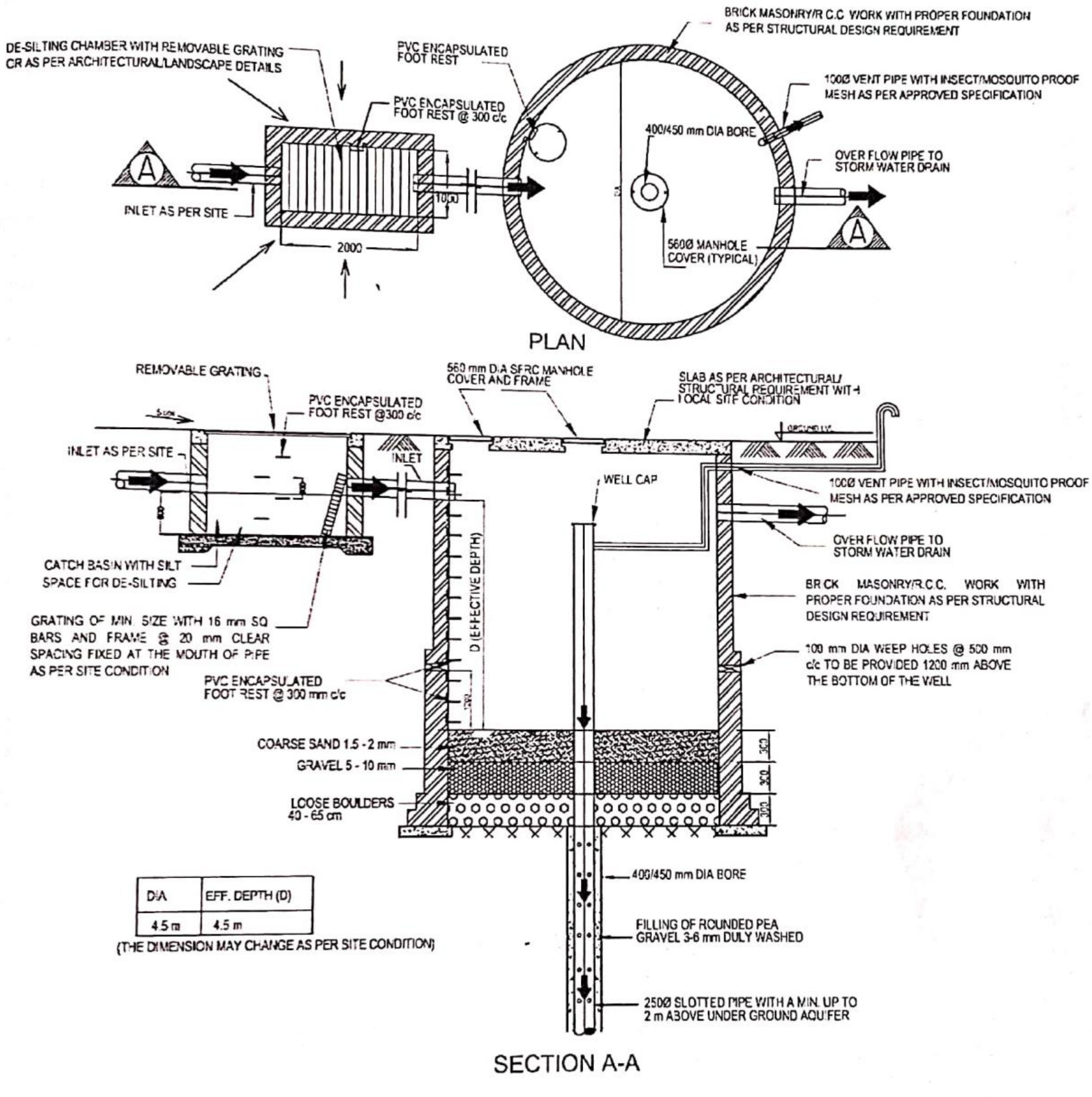
Each Tank volume required = 57.86 cum.

Overflow of the recharge structure will be diverted to the storm drain in the project area.

## RAIN WATER HARVESTING FLOW SHEET




***Note:*** As per NBC – I (2016), Rain Water Harvesting and Sullage recycle systems need to be implemented on all new constructions over 1 000 m2 in urban areas.




All dimensions in millimetres unless specified.

NOTE — Depending on site soil condition and keeping the above plumbing details and dimensions in view, the detailed structural/ shop drawing to be prepared, before executing the work.

**A TYPICAL ARTIFICIAL GROUND WATER RECHARGE STRUCTURE**

**Fig. 15**

# CHAPTER 8

## 8.1 CHALLENGES:

i). Avoidance of booster pump by the natural system. For example, increase of pressure by changing the dia. of pipe. It is a very new concept and need experiments for further development and use in daily life.

ii). Use of single stack without additional vent pipe and this can be developed by knowing the technical part of the Sovent Fittings which is specially made for the single stack system.

iii). A new idea has also been thought considering the following aspects that suits for the single stack system:

- It has been established that the suction developed in the vertical stack if, sufficient air is not entered during downward flow of the waste which creates a (-) ve pressure. The reverse situation experience at the end of the stack where it takes bend and join to the Master Trap
- In the building drainage system, the vertical stacks are connected with the floor outlet by the "T" joint or "Y" joint or with bend. Now if, we can provide an arrangement in the "T" or "Y" or in the bend so that air can enter in to the vertical stack whenever, there is a fall of air pressure then obviously the breakage of water seal can be avoided. The same arrangement will work when there is (+) ve pressure develops by allowing the air to escape. A conceptual sketch of the arrangement is given below which needs further investigation and experiments before come to a conclusion.

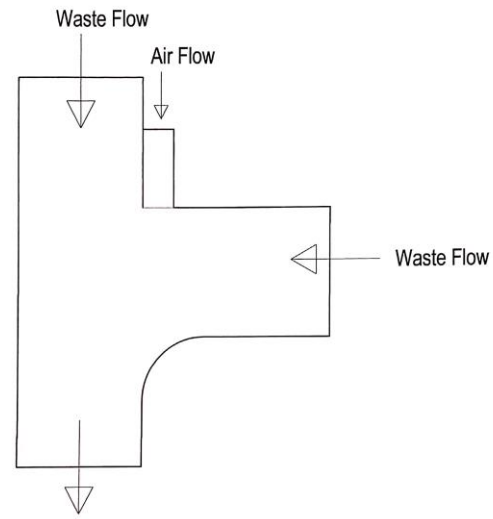



**Fig. 14**

iv). Duct size shall be maintained as per the norms of the statutory authority. Architect and the Project Manager should be strict enough about the size of the ducts keeping in mind that future maintenance is major issue for the smooth and d hazard free running of the system and we need adequate space in the duct.

v). **Avoidance of PRV and use of the Break-Tank concept**: It is extremely difficult to convince the developer since the commercially, the use of Break-Tank is not beneficial. But if, we consider all the factors i.e., future maintenance, functional reliability, simplicity of the system then it is obvious that Break-Tank system is far superior than the PRV.

## 8.2 CONCLUSION:

i. In the absence of the research and experiments, the Consultants are skeptical to move to the single pipe with partially ventilated system or single stack system which is popular in developed countries. They are still going for the two pipes with common vent pipe system for most of the high-rise buildings in Kolkata till date.

ii. The replacement of the Booster pumps as this is the common system adopted for the high-rise building to develop the required pressure at the top four to five floors is theoretically possible by creating a jet action. This can be done by changing pipe size. More investigation and experiment are required to establish this system.

iii. Break-tank system, a conventional method was in practice for high-rise buildings for the reduction of pressure in the water supply line before the development of Pressure Reducing Valve (PRV). The PRV, which is very much in practice at present, is not the satisfactory replacement of Break-tank system considering its maintenance cost, complicacy and low level of reliability. In the hot water system, it is even more problematic.

iv. Design of the Stage wise pipe size is not considered in general for most of the high-rise buildings in Kolkata for the drainage system. This is an option that could be adopted very easily and it is in line with the norms of NBC. This option will save cost, time and spa8ce.

v. There must be a guideline for the size of pipe duct and layout of the pipes in the duct considering the maintenance aspect as well as proper ventilation and accessibility.

vi. In view of the above, it is clear that govt., NGO, Institution should give the necessary support for the Research and Development of the systems and then only the improvement of the systems can be done.

## 8.2 FUTURE SCOPE OF THE STUDY:

i. More research and experiment work shall be carried out for finding out the alternative which is simple and sustainable technology in place of PRV.

ii. Finding out an alternative system in place of Booster Pumps.

iii. The advantages of using Single Stack Drainage System shall be publicized by arranging seminar, conference or any other way which may appropriate for the success.

iv. The advantages of using stage wise pipe size shall be conveyed to the concerned persons / executing authority.

v. A research work should be initiated for the modification of the technology of "Sovent Drainage System" as per the India's perspective.

# CHAPTER – 9

## 9.1 ANNEX. – I

**(ATMOSHPHERE)**
**B+G+39 Storeyed Residential Building**

**Sub: Comparison between the existing design & the norms of NBC: 2016 & UIPC-India, 2017**
**Design Concept: Two Pipes with common vent pipe.**

**<u>No of Flats per floor:</u>**
**Simplex Type = 24 nos (4 Bed Rm + 4 Toilet & 1 WC + 1 Kit)**
**Duplex Type = 16 nos (5 Bed Rm + 5 Toilet & 1 WC + 1 Kit)**

- **Details of Toilet & Kitchen in each floor:**

| **Flat Type** | **Total Flats** | **Master Toilet** | **Toilet** | **WC** | **Kitchen** |
|---|---|---|---|---|---|
| **Simplex** | **24** | **1** | **3** | **1** | **1** |
| **Duplex** | **16** | **1** | **4** | **1** | **1** |
| | | | | | |

- **Total Toilets & Kit. in building Flat Type-wise:**

| **Flat Type** | **Total Toilets & Kit. in building** | | | |
|---|---|---|---|---|
| | **Master Toilet** | **Toilet** | **WC** | **Kitchen** |
| Simplex | 24 | 72 | 24 | 24 |
| Duplex | 16 | 64 | 16 | 16 |
| | | | | |

- **Fixtures in Toilets & Kit Flat Type-wise: SIMPLEX FLAT**

| **Simplex Flats:** | **Fixtures** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **WC** | **Wash Basin** | **Shower** | **Bath Tub** | **Health Faucet** | **Floor Drain** | **Abu. Tap** | **sink** | **Dish washer** | **Washing m/c** |
| **Area** | | | | | | | | | | |
| MT | 1 | 1 | | 1 | 1 | 1 | 1 | | | |
| Toilet | 1 | 1 | 1 | | 1 | 1 | 1 | | | |
| WC | 1 | 1 | | | 1 | 1 | 1 | | | |
| | | | | | | | | | | |
| Kitchen | | | | | | | | 1 | 1 | |
| Washing Area | | | | | | | | | | 1 |
| **TOTAL:** | **120** | **120** | **72** | **24** | **120** | **120** | **120** | **24** | **24** | **24** |

- **Fixtures in Toilets & Kit Flat Type-wise: DUPLEX FLAT**

| **Duplex Flats:** | **Fixtures** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **WC** | **Wash Basin** | **Shower** | **Bath Tub** | **Health Faucet** | **Floor Drain** | **Abu. Tap** | **sink** | **Dish washer** | **Washing m/c** |
| **Area** | | | | | | | | | | |
| MT | 1 | 1 | | 1 | 1 | 1 | 1 | | | |
| Toilet | 1 | 1 | 1 | | 1 | 1 | 1 | | | |
| WC | 1 | 1 | | | 1 | 1 | 1 | | | |
| | | | | | | | | | | |
| Kitchen | | | | | | | | 1 | 1 | |
| Washing Area | | | | | | | | | | 1 |
| **TOTAL:** | **96** | **96** | **64** | **16** | **96** | **96** | **96** | **16** | **16** | **16** |

- **FIXTURS-WISE TOTAL DRAINAGE FIXTURE UNITS:**

| Drainage Fixture Units (DFU) as per NBC-2016, Table 18, Clause 4.5.3.5.1 | | | | |
|---|---|---|---|---|
| **Fixtures Type** | **DFU** | **Type of Flat** | | |
| | | **Simplex Flat** | **Duplex Flat** | **Notes** |
| 1. WC with flush valves | 8 | 960 | 768 | 8 x 120 (no of WC) = 960 And 8 x 96 (no of WC) = 768 |
| 2. wash Basin | 1 | 120 | 96 | 1 x 120 (no of WB) = 120 And 1 x 96 (no of WB) = 96 |
| 3. Shower | 2 | 144 | 128 | 2 x 72 (no of SH) = 144 And 2 x 64 (no of SH) = 128 |
| 4. Bath Tub | 3 | 24 | 48 | 3 x 24 (no of Bath tub) = 24 And 1 x 48 (no of Bath Tub) = 48 |
| 5. Abu. Tap /Heath Faucet | 1 | 120 | 96 | 1 x 120 (no of Abu. Tap) = 120 And 1 x 96 (no of Abu. Tap) = 96 |
| 6. Floor Drain | 1 | 120 | 96 | 1 x 120 (no of FD) = 120 And 1 x 96 (no of FD) = 96 |
| 7. Kit Sink | 2 | 48 | 32 | 2 x 24 (no of Kit sink) = 48 And 2 x 16 (no of Kit sink) = 32 |
| 8. Dish Washer | 2 | 48 | 32 | 2 x 24 (no of D. washer) = 48 And 2 x 16 (no of D. washer) = 32 |
| 9. washing m/c | 3 | 72 | 48 | 3 x 24 (no of W/M) = 72 And 3 x 16 (no of W/M) = 48 |
| **For Security & Maintenance Staff:** | | | | |
| 10. Urinal with flush tank | 2 | 12 | 12 | 6-Urinals |
| 11. WC | 8 | 24 | 24 | 3-WC |
| 12. Floor Drain | 1 | 1 | 1 | 1- Floor Drain |

**STACK-WISE TOTAL DFU:**

Sewer Line DFU = sl. no. (1+5+10+11) = 1116 Units for Simplex Flats & for Duplex Flats = 900 Units

Waste Line DFU = (sum of remaining sl nos.) = 409 Units for Simplex Flats & for Duplex Flats = 369 Units

Kit. Waste Line DFU = (Sink + W/M) =168 Units for Simplex Flats & for Duplex Flats = 112 Units

As per Floor Plan of two different types of the Flats, there are 5-stack for the each Flat. It has also been observed that one stack carrying load of two toilets at each floor and that is the max. load to be considered for the design of the vertical stack. The detail comparison with NBC-I & UPC-I of the existing design has been shown in the table below:

| | | | | | |
|---|---|---|---|---|---|
| **Simplex** | | | **Duplex** | | |
| **1116** | **409** | **112** | **900** | **369** | **112** |
| **Sewer Line** | **Waste Line** | **Kit waste + w/m** | **Sewer Line** | **Waste Line** | **Kit waste + w/m** |
| **No. of stacks** | | | **No. of stacks** | | |
| **5** | **5** | **1** | **5** | **5** | **1** |
| **DFU per stack** | | | **DFU per stack** | | |
| **223** | 82 | 112 | **180** | 74 | 112 |
| **Design DFU (Two Toilets)** | | | **Design DFU (Two Toilets)** | | |
| **446** | **164** | | **360** | **148** | |
| **Simplex** | | | **Duplex** | | |
| **Required dia of Pipe (mm), NBC** | | | **Required dia of Pipe (mm), NBC** | | |
| 100 | 100 | 100 | Sewer Line | Waste Line | Kit Line |
| | | | | | |
| **Required dia of Pipe (mm), UPC-I** | | | **Required dia of Pipe (mm), UPC-I** | | |
| **125** | **100** | **100** | **125** | **100** | **100** |
| **Provided** | | | **Provided** | | |
| **150** | **150** | **150** | **150** | **150** | **150** |
| ***Provided more*** | | | ***Provided more*** | | |

**Note: The pipes size provide in the design are higher than the requirement of the NBC-I (2016) and or UIPC-I (2017)**

| | | | | | | |
|---|---|---|---|---|---|---|
| **CALCULATION FOR WATER DEMAND:** | | | | | | |
| | | | | | | |
| **Apartment Type** | **No. of Flats** | **Population per Apartment (NBC 2016, p-11, part 9)** | **Total Population** | **Water demand / head / day (NBC 2016)** | **Total Water demand (Ltr.)** | **Total Water demand (cum)** |
| | | | | | | |
| **Simplex (4-bed room)** | **24** | **7** | **168** | **135** | **22680** | **22.68** |
| | | | | | | |
| **Duplex (5-bed room)** | **16** | **7** | **112** | **135** | **15120** | **15.12** |
| | | | | | | |
| **Security & Maintenance staff** | | | **30** | **50** | **1500** | **1.5** |
| | | | | | | |
| | | **TOTAL FOR ONE TOWER** | | | **=** | **39.3** |
| | | | | | | |
| | **Therefore, requirements for two towers = 39.3 x 2** | | | | **=** | **78.6** |
| | | | | | | |
| | | | | | | |
| **Firefighting requirement as per NBC for building ht > 68m** | | | | **200000** | **ltrs** | **200** |
| | | | **GRAND TOTAL** | | **=** | **278.6** |
| | | | | | | |

**Therefore, size of UGR should be > 279 cum**

**How to calculate the Pump Horse power:**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Selection of Pump:** | | | | | | |
| | | | | | | |
| **Capacity of OHR** | **=** | **70000** | **ltrs** | | | |
| **Filling time** | **=** | **0.5** | **hr** | | | |
| **Flow required'** | **=** | **140000** | **ltrs / hr** | **=** | **140** | **cum/hr** |
| **Head** | | | | **=** | **180** | **m** |

**The horse power of the pump can be worked out with help of Manufacture's catalogue.**

## 9.2 ANNEX. - II

### URBANA (TOWER-5): G+45 STOREYED RESIDENTIAL TOWER AT KOLKATA

**Sub: Comparison btn. the existing design & the norms of NBC / UIPC-I**

**Design concept: Single pipe with partially ventilated.**

This building is a residential building and having six flats in each floor. The numbers of toilets & kit given in the table below:

**TOTAL TOILETS AND KIT. IN THE ENTIRE BUILDING:**

| | | | |
|---|---|---|---|
| | | | |
| | **Total Toilets & Kit in the entire building** | | |
| | **Master Toilet** | **Toilet** | **Kitchen** |
| | 270 | 810 | 270 |
| | | | |

**FIXTURES IN EACH TOILETS AND KIT.:**

| **FLATS** | WC | Wash Basin | Shower | Bath Tub | Health Faucet / Abu. Tab | Floor Drain | sink | Dish washer | Washing m/c | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | | | | | | | | | | | |
| MT | 1 | 1 | | 1 | 1 | 1 | | | | | |
| Toilet | 1 | 1 | 1 | | 1 | 1 | | | | | |
| Kitchen | | | | | | | 1 | 1 | | | |
| Washing Area | | | | | | | | | 1 | | |
| **TOTAL:** | **2160** | **2160** | **810** | **270** | **2160** | **2160** | **270** | **270** | **270** | | |
| | | | | | | | | | | | Urinals |
| **For Security & Maintenance Staff:** | 3 | 3 | 3 | 0 | 3 | 3 | 3 | 1 | | | 8 |

**FIXTURS-WISE TOTAL DRAINAGE FIXTURE UNITS:**

| **DFU with Flush valve:** | | NBC-p-36 | | |
|---|---|---|---|---|
| | | | | |
| **Fixtures** | **DFU** | **Total** | **Total DFU** | |
| 1. WC | 8 | 2160 | 17280 | 8 x 2160 (no. of WC) = 17280 |
| 2. Wash Basin | 1 | 2160 | 2160 | 1 x 2160 (no. of WB) = 2160 |
| 3. Shower | 2 | 810 | 1620 | 2 x 810 (no. of SH) = 1620 |
| 4. Bath Tub | 3 | 270 | 810 | 3 x 810 (no. of BT) = 810 |
| 5. Abu. Tap /Heath Faucet | 1 | 2160 | 2160 | 1 x 2160 (no. of Health Faucet) = 2160 |
| 6. Floor Drain | 1 | 2160 | 2160 | 1 x 2160 (no. of FD) = 2160 |
| 7. Kit Sink | 2 | 270 | 540 | 2 x 270 (no. of kit sinks) = 540 |
| 8. Dish Washer | 2 | 270 | 540 | 2 x 270 (no. of Dish washers) = 540 |
| 9. washing m/c | 3 | 270 | 810 | 3 x 270 (no. of W/M) = 810 |
| **For Security & Maintenance Staff:** | | | | |
| 10. Urinal with flush tank | 2 | 16 | 32 | 2 x 16 (no. of urinals) = 32 |
| 11. WC | 8 | 24 | 192 | 8 x 24 (no. of WC) = 192 |
| 12. Floor Drain | 1 | 3 | 3 | 1 x 3 (no. of FD) = 3 |
| 13. wash Basin | 1 | 3 | 3 | 1 x 3 (no. of WB) = 3 |
| | | | | |
| | | | | |

**STACK-WISE TOTAL DFU:**

Sewer Line DFU = sl. no. (1+5+10+11) = 19664 Units

Waste Line DFU = (sum of remaining sl. nos.) = 6756 Units

Kit. Waste Line DFU = (Sink + W/M + Dish Washer) =1890 Units

As per Floor Plan the Flats, there are 24-stacks for the entire building. It has also been observed that one stack carrying load of two toilets at each floor and that is the max. load to be considered for the design of the vertical stack. The detail comparison with NBC-I & UPC-I of the existing design has been shown in the table below:

| STACK WISE DFU | | |
|---|---|---|
| **Sewer Line** | **Waste line** | **Kit & W/m** |
| **19664** | **6756** | **1890** |
| **Total DFU in combined line (sewer + waste)** | | |
| **26420** | | |
| | | |
| **No. of stacks** | **24** | **6** |
| **DFU per stack** | | |
| **1101** | | **315** |
| | | |
| **One stack carrying loads of two toilets (Max. DFU for design)** | | |
| **2202** | | **315** |
| | | |
| **Required dia of Pipe (mm) NBC2016, part 9, sec-2, p-32** | | |
| **300** | | **200** |
| | | |
| **As per UIPC-I** | | |
| **200** | | **125** |
| | | |
| **Provided** | | |
| **150** | | **150** |

Observation: The pipe sizes as per NBC-I are higher than the existing pipe sizes.

## 8.3 REFERENCES:

Bureau of Indian Standard. *National Building Code of India (NBC) 2016*, Chennai, Tamil Nadu, India, section 2, 7 – 12.

Bureau of Indian Standard. *National Building Code of India (NBC) 2016*, Chennai, Tamil Nadu, India, section 1, 19-24

Mazumdar, Asis., et al., (2013) "Modification of Hunter's Curve in the Perspective of Water Conservation", Journal of Pipeline Systems Engineering and Practice.

Indian Plumbing Association (IPA). "Indian Plumbing Today", official journal of the Indian plumbing association, vol.19 / issue 02 / feb 2019.

Bureau of Indian Standard. *National Building Code of India (NBC) 2016*, Chennai, Tamil Nadu, India, sec-2, table 18, table 20

Bureau of Indian Standard. *National Building Code of India (NBC) 2016*, Chennai, Tamil Nadu, India, part 9, sec-1, clause 4.

Bureau of Indian Standard. *National Building Code of India (NBC) 2016*, Chennai, Tamil Nadu, India, part 9, part 9, section 1, clause 4.4.10 / section 2, table 16, clause 4.5.2.4.2.1/ clause 4.5.2.4.2.2 / table 20

Cheng, C.L., Lu, W.H., Ho, K.C. "Current design of high-rise building drainage system in Taiwan", Symposium cib w62 2004, Cstb, France.

Indian Plumbing Association (IPA). (2017). *"Water Efficient Products – India (WEP – I)",* Indian Plumbing Association (IPA). International Association of Plumbing & Mechanical Officials (IAPMO), India. (2017). *"Uniform Illustrated Plumbing Code – India (UIPC – I)*", New Delhi, Bangalore, India.

Indian Plumbing Association (IPA). (2016). *"A Guide to Good Plumbing Practice",* New Delh, India.

Indian Plumbing Association (IPA). International Association of Plumbing & Mechanical Officials (IAPMO), India. (2017). *"Green Plumbing Code Supplement - India (GPCS – I)*", New Delhi, Bangalore, India.

Bureau of Indian Standard. IS:1172. (1993). *"Code of Basic Requirements for Water Supply, Drainage and Sanitary",* New Delhi.

Bureau of Indian Standard. IS:1742. (1983).*" Code of Practice for Building Drainage",* New Delhi.

Bureau of Indian Standard. IS:1950. (1962)." *Code of Practice for Sound Insulation of Non-Industrial Buildings",* New Delhi.

Bureau of Indian Standard. IS:2065. (1983)." *Code of Practice for Water Supply in Buildings",* New Delhi.

Bureau of Indian Standard. IS:12183 (Part 1). (2009)." *Code of Practice for Plumbing in Multi-storeyed Buildings, Water Supply",* New Delhi.

## 8.4 ABBRIVIATIONS:

NBC – I: National Building Code – India
UPC – I: Uniform Plumbing Code – India
UIPC – I: Uniform Illustrated Plumbing Code – India
DFU: Drainage Fixture Units
DWV: Drainage, Water and Vent
STP: Sewage Treatment Plant
WC: Water Closet
WB: Wash Basin
MVP: Main Vent Pipe
MWP: Main Waste Pipe
MSP: Main Sewer Pipe
MSWP: Main Sewer and Waste Pipe
FL: Floor Level
BT: Bottle Trap
SH: Shower
(+) ve: Positive
(-) ve: Negative
LIG: Low Income Group
MIG: Middle Income Group
HIG: High Income Group
UGR: Under Ground Reservoir
OHR: Over-Head Reservoir
DIA.: Diameter
GR.: Ground
PRV: Pressure Reducing Valve
FD: Floor Drain
W/M: Washing Machine