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DESIGN OF PLUMBING SYSTEM AT TUNJUNGAN PLAZA APARTMENT, SURABAYA

Sarah Meilani, Ariani Dwi Astuti, R. Ratnaningsih*

Department of Environmental Engineering, Faculty of Landscape Architecture and Environmental Engineering, Universitas Trisakti, Jakarta, Indonesia

*Corresponding author: ratnaningsih@trisakti.ac.id

ABSTRACT

Aim: This study of plumbing system plan is aimed at planning a plumbing system that is compatible with clean water, waste water and rain water management at Tunjungan Plaza apartment, Surabaya City, Indonesia according to SNI 8153-2015, and meet 5 aspects of safety, security, simplicity, beauty, and economy. It applies water supply system which commonly used for high rise buildings, namely Roof Tank system. **Methodology and Result**: Plumbing system planning methods are collecting and analyzing fluctuation in water use, planning clean water and recycled water systems by endorsing alternative piping for clean water and recycled water. In addition to water supply, recycled water system that utilizes waste water to be recycled for flushing closets and watering plants also required to be implemented. Average daily water consumption is 268 m^3/day for clean water and 44 m^3/day for recycled water with the capacity of ground water tank for clean water is 564.54 m^3 and recycled water is 62 m^3. **Conclusion, significance and impact study:** Clean water supply system will implement roof tank system and recycled water will reutilize wastewater for flushing on toilet tank and watering the plants. Waste water use separated system between grey water and black water and then distributed to STP to be treated and reused for flushing water closet and watering plants. Rain water goes to infiltration well by gravity through designed 1 well. Total amount of investment of plumbing equipment is Rp 2,157,697,501,- with cost of water supply per unit Rp 4,445,643,- meanwhile waste water piping cost per units is Rp 1,070,711,-.

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- Water supply
- Wastewater

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1. INTRODUCTION

The rapid growth of population in Surabaya as the second biggest city in Indonesia contributed the same problem as many cities in the world should deal with, which ishousing. Lands availability for housing is getting so limited that causes apartment to be the best option to resolve this problem.The most important thing in supporting daily activities living in an apartment is a feasible plumbing system that manages water flows throughout apartment building. Tunjungan Plaza Apartment Constructionrefers to Standard National Indonesia or SNI 8135:2015 that regulates piping network designing standard including the provision of drinking water, wastewater treatment, supporting building, distribution and drainage piping, altogether with all connections, tools, and equipment installed in the plot and building, as well as water heater and ventilation for the same purpose. This paper of Plumbing System Design aimstodesign a plumbing system that is compatible with clean water, wastewater and rainwater management at Tunjungan Plaza apartment, according to SNI 8153-2015, and meet 5 aspects of safety, security, simplicity, beauty, and economy.

2. RESEARCH METHODOLOGY

The stages of water plumbing system designing methods are: determining the location and time line of the design; gathering references, literature, and guidelines studies; collecting and analyzing primary data (fluctuation in water use) and secondary data (layout drawing of the apartment, maximum daily rainfall); designing clean water and recycled water systems by endorsing alternative piping for clean water and recycled water; determining and drawing lines and isometrics; calculating dimensions of horizontal branch pipes and vertical pipes; calculating critical points of the building and determining PRV placement; calculating upper and lower reservoir capacities; calculating reservoir capacity and heads of transfer pumps and booster pumps. While designing wastewater and vent systems stages are determining and drawing lines and isometrics; calculating dimensions of horizontal branch pipes and vertical pipes. Stages of designing rainwater system are determining rainfall intensity; calculating roof area; determining lines and area of open flat gutter; calculating the dimensions of horizontal pipes, vertical pipes, and roof gutter diameter, designing infiltration. All systems are ended by projecting investment budget plan as the last stage.

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3. RESULTS AND DISCUSSION

3.1 Floor Analysis

This apartment is a multi-function building that blends residential, commercial and officeutilizationinone tower with 36 floors. Floors UG (underground) to 3 are the sections of shopping mall providing a variety of needs, floors 8 to 16 are office buildings while floors 17 to 36 are for residence apartments with type of 1-3 Bedrooms. Floor 22 to 36 have typical architectural. Each floor has a different height. The height of typical floors (floors 22 to 36), floors 20 and 19 is 3.3 m, whlie floors 17 and 18 is 3.5 m, and floor 21 is 4 m.

3.2 Clean Water and Recycled Water Systems

Tunjungan Plaza apartment usesclean water from local state-owned water company of the City of Surabaya. This 24 hours water supply is collected in the ground water tank (GWT) or lower reservoir located on basement floor. A transfer pump then pushes the water up to the roof tank or upper reservoir and distribute it to each occupant with gravity system. Recycled water system using wastewater is also recommended. It is used for flushing water on the toilet tank.

3.3 Clean Water Piping System

Development of clean water piping network should considering the 5 aspects which mentioned before. Two alternatives plumbing system designs were compared to find the plumbing equipment designed workmosteffectively. To generate the chosen option, multi-criteria analysis was compared on the two alternatives including weighting as well as the scoring system to each criterion. Weighting for each aspect was divided by technical aspect 45% and for economic aspect 55%. The reason why Economic aspect has a weight of 55% because it plays an important role for investment, maintenance, and operational costs while technical aspect involves in running of plumbing equipment effectively.

The assessment result in Table 1 below indicates that the total score of alternative 1 is 132.4 which is considered as high category, while alternative 2 is 120.3 or lower than first alternative. Therefore, alternative 1 is recommended with 2 vertical pipes consisting of 1 vertical pipe without booster pump and 1 vertical pipe with booster pump. To obtain volume of reservoir, comparative water use fluctuation data was used. Benchmarking data used were from 2 other apartments in Surabaya, namely, Merr apartment and Manyar apartment. Recording

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was done every 1 hour for 7 days consisting of 5 weekdays and on the weekend. Data obtained is in unit of m^3/hour, the percentages of clean water usage in 1 day per hour was calculated as well as the average of percentages of water usage during weekdays and weekend. Data collection on weekdays and weekend, data from direct observation, and another supporting data such as water needs are shown in Table 2.

Table 1 The assessment of alternative clean water drainage system

Criteria	Percentage	Alternative I			Alternative II		
		Assessment	Value	Score	Assessment	Value	Score
Technical Aspects	**45%**						
Operation and maintenance of plumbing equipment (technical training and monitoring)	22.5%	**+**	75	16.9	-	-25	-5.6
Installation of plumbing materials and equipment	22.5%	**+**	75	16.9	**+/-**	50	11.3
Sub Total				**33.8**			**5.7**
Economic Aspects	**55%**						
Operating and maintenance costs	19%	**+**	75	14.3	-	-25	-4.8
Cost of pipe investment and accessories	19%	**+/-**	50	9.5	**+**	75	14.4
Cost of PRV investment	8.5%	**+/-**	50	4.3	**+**	75	6.4
Cost of pump investment	8.5%	**+**	75	6.4	**+/-**	50	4.3
Sub Total				**34.5**			**20.3**
Total Score	**100%**			**132.4**			**120.3**

Table 2 The details of results of water needs data retrieval

Apartement	**Merr**	**Manyar**
Location	Surabaya	Surabaya
Type of Occupant	Employee, Student, Family	Employee, Student
Peak Hour Use of Water	06.00 – 07.00 18.00 – 19.00	06.00 – 07.00 18.00 – 19.00
Percentage of Occupancy	92%	80%
Number of Occupants (people)	954	778
Average Water requirement (m^3/day)	253	118
Demand of Water (L/person/day)	283	161

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It can be concluded that the fluctuation of water use that is approaching the characteristic of designing apartment is Merr apartment. Fluctuation data in water usage was required to determine reservoir volume, as well as the amount of water needs in the apartment.

3.4 Calculation of the Size of Clean Water and Recycled Water Horizontal Branch Pipes

Clean Water demand has total Head Loss of 11,7482 m and recycled water has total Head Loss of 21,9766 m for residence with 1 BR type. Architectural, clean water and recycled isometry line of 1 BR type can be seen in Figure 1.

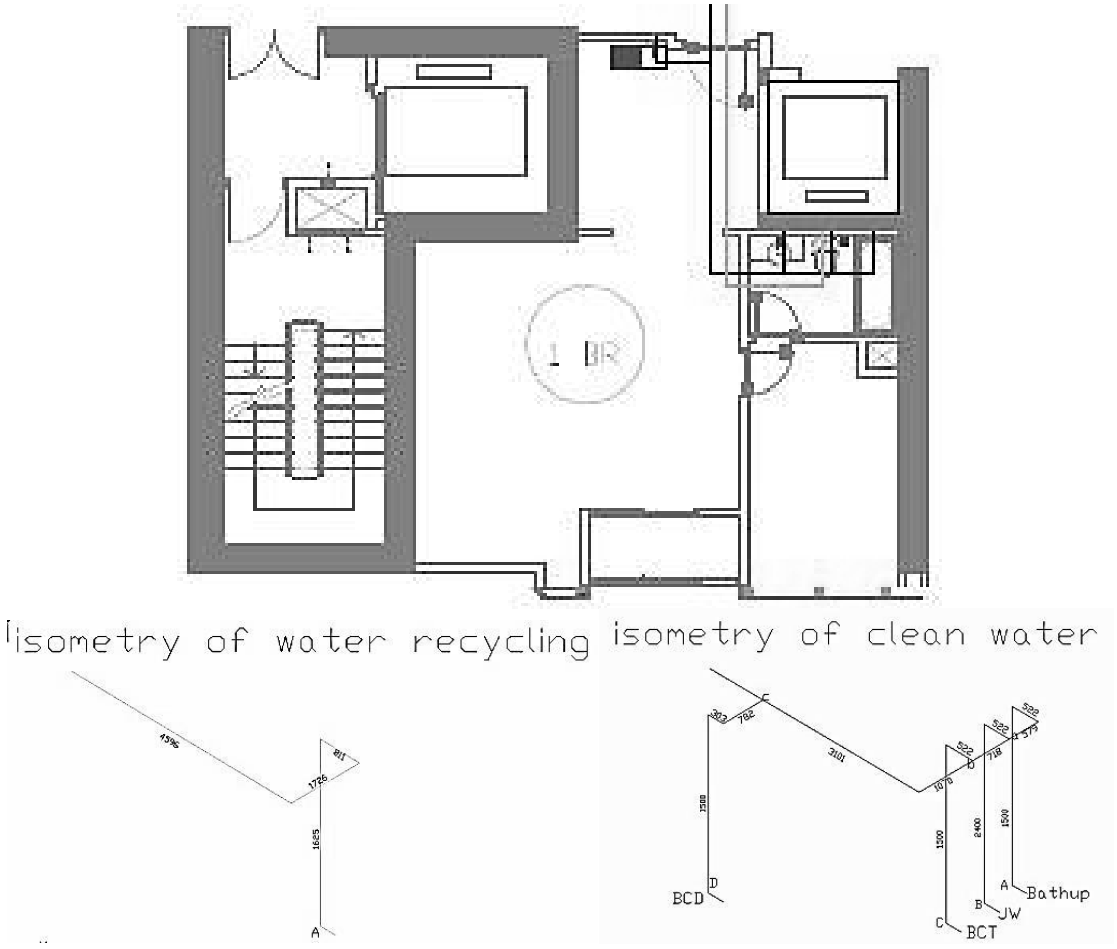

Figure 1 The lines and isometrics of clean water and recycled water of residence with 1BR-type

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3.5 Calculation of the Size of Clean Water and Recycled Water Vertical Pipes

Two vertical pipes for clean water and 2 vertical pipes for recycled water were also designed. Each usage pipes consist of a gravity vertical pipe and a booster vertical pipe.

3.6 Calculation of Building Critical Points for Determination of PRV and Booster Pumps

If the remaining pressure exceeds allowable pressure of 3.5 kg/cm^2, then it is necessary to install PRV (Japan International Cooperation Agency (JICA), 1978). Based on calculation, PRVsare installed on floors 26, 18, 10, and 3. If the standard pressure of 1 kg/cm^2 is not met, then it needs booster pumps. They will be installed to supply water for floors 30-36, according the calculation result.

3.7 Upper Reservoir

Capacity or volume of upper reservoir can determined based on fluctuation of water use within 24 hours. On the design of Plumbing system for Tunjungan Plaza apartment, water entering the upper reservoir was assumed by pumping for 12 hours as shown in Figure 2.

3.8 Lower Reservoir

Lower reservoir or ground water tank is located on the bottom floor, i.e., basement floor. A 24-hour supply is needed to determine the capacity of lower reservoir. The supply will be obtained from local water company of the City of Surabaya. The following Figure 3 is graph of lower reservoir.

3.9 Transfer Pumps

Transfer pump function is to pump water from the ground water tank to the roof tank. It should be adjusted in line with the designed clean water needs, the head required for water to pump up, and the characteristic of the pump that is available on the market. The transfer pumps will be operated for 12 hours. There are 2 transfer pumps to be recommended, which is 1 for clean water and 1 for recycled water. The calculation indicates the curves of transfer pump in Figure 4 for clean water and Figure 5 for recycled water.

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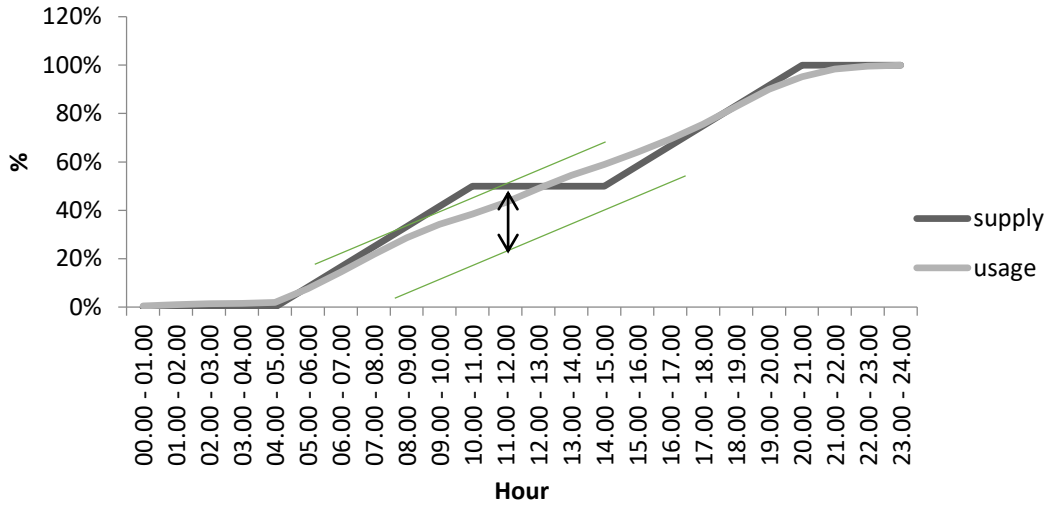

Figure 2 The graphs of cumulative supply and cumulative usage on holidays

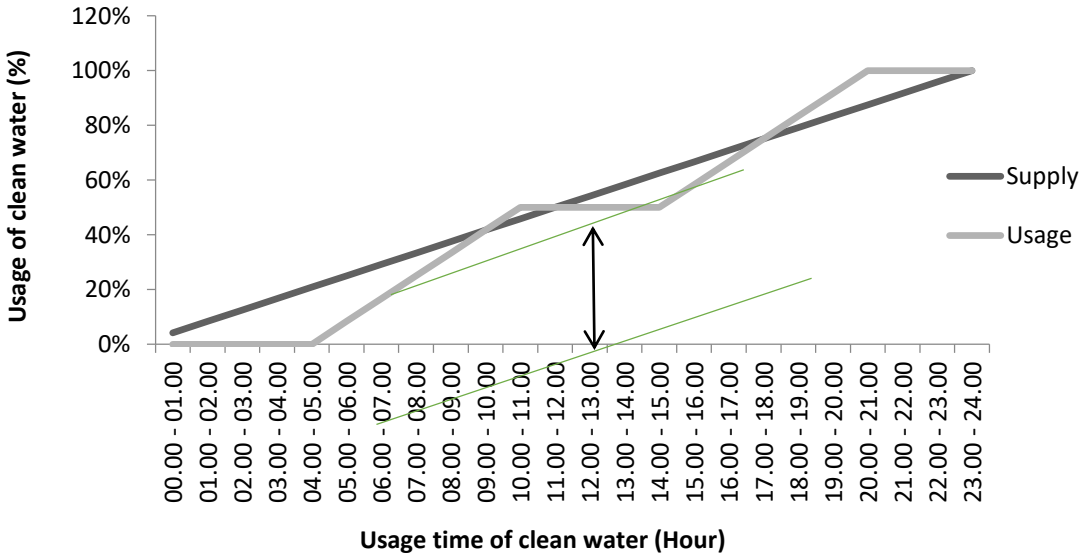

Figure 3 The graph of cumulative supply and cumulative usage of bottom reservoir

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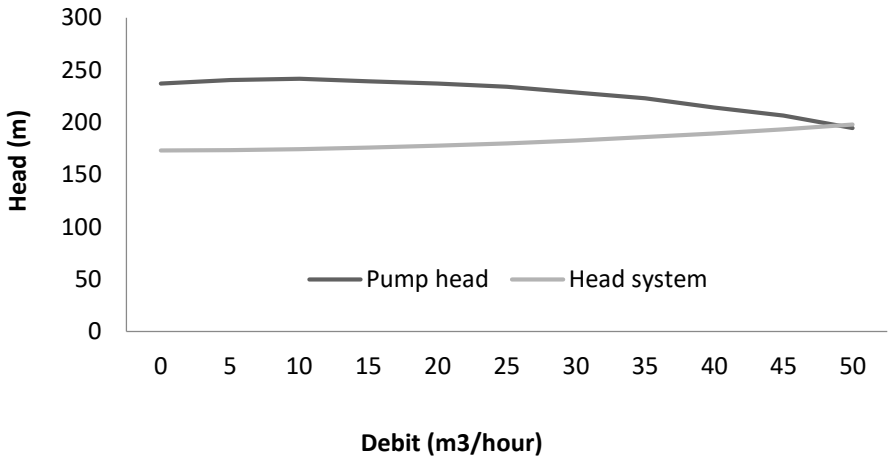

Figure 4 The curve of clean water transfer pump

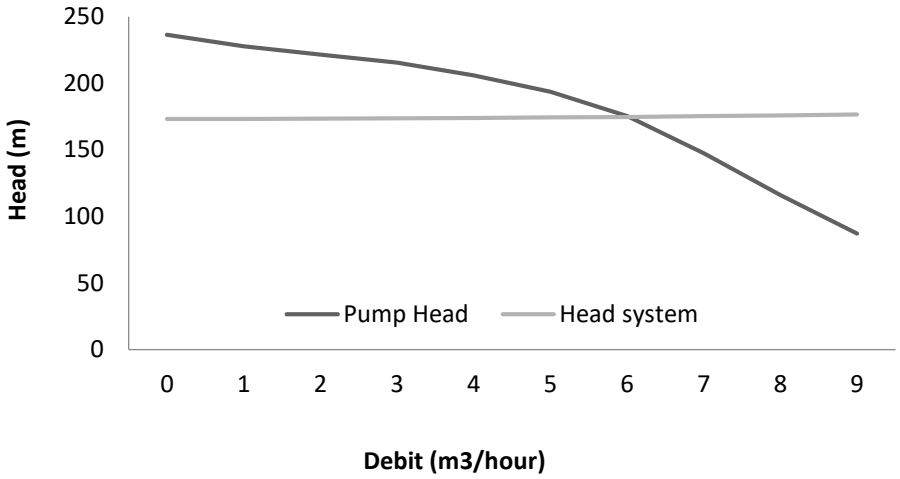

Figure 5 The curve of recycled water transfer pump

3.10 Booster Pumps

Booster pump is pump to serves particularly to meet the needs of clean water on the top floorssince there is enough remain pressure to comply the requirement. The standard minimum pressure in each floor is 1 kg/cm^2 (Noerbambang et al., 1988). Booster pumps will be installed on apartment to supply water for 7 top floors, which are floors 36-30. The calculation obtains the curves of booster pump as in Figure 6 for clean water and Figure 7 for recycled water.

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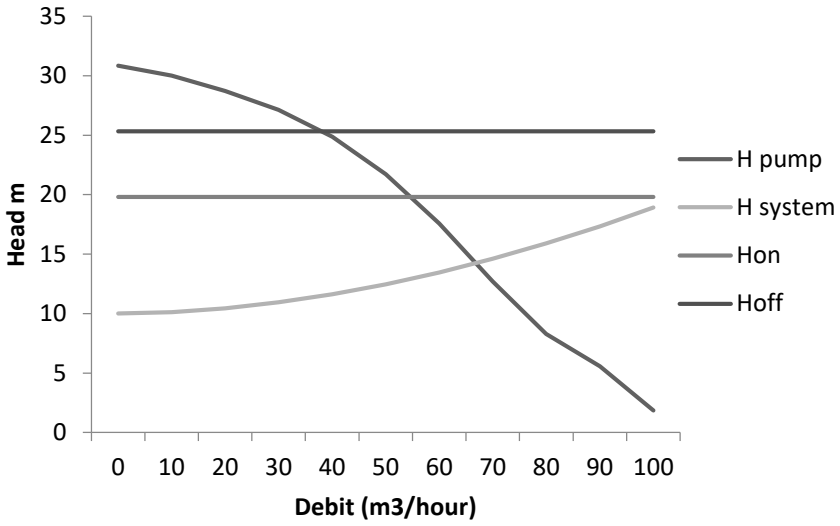

Figure 6 The graph of clean water booster pump

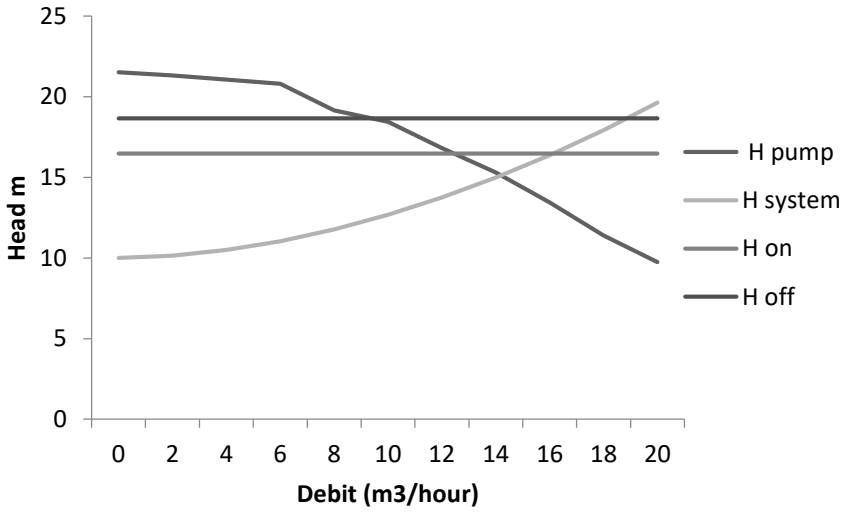

Figure 7 The graph of recycled water booster pump

3.11 Recycled Water Piping System

Recycled water piping system is also alternative 1 as for clean water system, which is using 2 vertical pipes and 1 main shaft. The first vertical pipe supplies water for floors 36-31 using booster pumps and the second vertical pipe floors 30-basement by gravity. Consideration to utilize wastewater was done by the calculation of water balance, between discharged

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wastewater and the needs of recycled water used for flushing on toilet tank and watering the plants. The amount of clean water consumption is 269 m^3/day. Wastewater generated from clean water ranges about 80-90% (Setiyono, 2009). The assumption of wastewater quantitygenerated from clean water usage is 80%, so the amount of wastewater in the apartment is 215 m^3/day. The assumption of wastewater recycled is 30%, so the recycled water production is 65 m3/day. The result of recycled water used for flushing on toilet tank is 44 m^3/day and for watering the plants is 21 m^3/day.

3.12 Sewerage and Vent Systems

The sewerage and vent systems designs are separate systems using gravity system by arranging the position and tilt of the wastewater pipes. Unit shaft or the shaft in each residence is functioned for wastewater and vent vertical pipes. The wastewater from each plumbing equipment is drained to the wastewater, dirty water, and vent vertical pipes. Vent vertical pipe will be installed in wastewater and dirty water vertical pipes directly connected using plumbing equipment. Wastewater at offices, public toilets, and malls are flowed to STP.

3.13 Calculation of the Size of Wastewater Horizontal Branch Pipes

Sewerage system design uses separate system between wastewater (from hand wash basin, kitchen sink, urinal bowl, and floor drain) and dirty water from toilet tank. Based on the calculation of wastewater and vent horizontal branch pipes of the residence with 2BR-1 type, the diameter of pipe for wastewater ranged between 42 mm to 60 mm, the diameter of pipe for dirty water was 89 mm, and the diameter of pipe for vent ranged between 45 mm to 65 mm.

3.14 Calculation of the Size of Wastewater and Vent Vertical Pipes

Determination of vertical pipesdiameter based on total number of plumbing fixture unit on horizontal branch pipes for wastewater, dirty water, and vent. The diameter of pipe for dirty water ranged between 89 mm to 140 mm, the diameter of pipe for wastewater ranged between 42 mm to 114 mm, and the diameter of pipe for vent ranged between 42 mm to 114 mm.

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3.15 Rainwater System

Rainfall data from Indonesian Agency for Meteorology, Climatology and Geophysics for the City of Surabaya, Station Perak 1, required for deciding the dimensions of the pipe to channel rainwater. The data are the average maximum daily rainfall data during the last 10 years. Rainwater falling on the roof and from the balcony of each residence is drained to infiltration well by gravity.

3.16 Rainwater Drainage System

Roof gutter is divided into 10 sections. The slope of the roof designed is 1%. The calculation resultis the diameter of rainwater vertical pipe ranged between 60 mm to 89 mm.

3.17 Infiltration Well

With a land area of 4,520 m^2, Tunjungan Plaza apartment will be equipped with 1 infiltration well to hold and infiltrate rainwater into the ground.

The calculation of total cost investment of all plumbing system can be seen on Table 3.

Table 3 The total Investment cost plan

Information	Cost (Rp)
Clean water supply	982,487,305
Reservoir	735,196,593.00
The distribution of wastewater and ven	236,627,087
distribution of rain water	165,007,920
Infiltration wells	38,378,601
Total	**2,157,697,507**

4. CONCLUSION

Based on the results of the analysis and calculations, the conclusions of this design are as follows: Clean water supply system will implement roof tank system and recycled water will reutilize wastewater for flushing on toilet tank and watering the plants. Clean water requirement at Tunjungan Plaza could reach to 269 m^3/day while recycled water need is 44 m^3/day. The clean water system chosen will use 2 vertical pipes: 1 vertical pipe for gravity pipe and 1 vertical pipe for booster pipe. The booster pumps will be installed to supply pressure for

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the 7 top floors. Clean water will be obtained from local water company of the City of Surabaya and wastewater treatment process will generate recycled water. It is recommended to have 1 upper reservoir for both clean water and recycled water. The capacity of upper reservoir for clean water is 112 m^3 and 23 m^3 for recycled water. 12 hours transfer pump will be operated for these reservoirs. The capacity of lower reservoir for clean water is 564.54 m^3 and 61.44 m^3 for recycled water. Sewerage system which will be applied is a separate system between wastewater and dirty water. Wastewater and dirty water will be processed in sewage treatment plant (STP). Recycled wastewater will be reused for flushing on toilet tank and watering the plants. Rainwater will be flowed through roof gutter with diameters of 114 mm and 89 mm and vertical pipes with diameters of 60 mm and 89 mm. The rainwater will then be drainaged into the infiltration well; A unit of infiltration well is designed with a diameter of 3 meters; and 3 meters high. The cost of the investment of plumbing equipmentand construction at Tunjungan Plaza apartment is Rp 2,135,213,315.00 while the price per unit for clean water is Rp 4,445,643.00 and wastewater is Rp 1,070,711.000.

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