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# DESIGN OF CLEAN WATER BOOSTER PUMP FOR HIGH-RISE BUILDINGS

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***Abstract.*** A sanitary system is a supporting component designed to meet the clean water requirements of a building, primarily for sanitation activities. The average sanitary equipment used typically requires a shower pressure of ±1 Bar. However, the shower pressure can be significantly affected by factors such as the distance from the top tank and the building's layout, considering only the pressure due to gravity. To address inadequate shower pressure, an auxiliary pump known as a booster pump is necessary. The need for a booster pump is determined by the cumulative demand from plumbing equipment, where the total capacity required is 6057 liters/hour. To address this demand, the system employs two pump units, each with a capacity of 3 $m^3$/hour. The distribution pipes utilized in the system adhere to established standards and are made of random polypropylene with a diameter of 2 inches and a flow rate of 0.005889 $m^3$/second. The overall head loss resulting from this installation amounts to 31.62 meters. To accommodate the booster system, a pressure tank with a capacity of 67 liters is employed. The minimum working pressure required for the pumps is 1.8 Bar

*Keywords: clean water, booster pump, high-rise building.*

## 1. INTRODUCTION

As the population grows, the pattern of building construction shifts, namely the pattern of horizontal development which slowly begins to shift with vertical development. This is due to the limited land available for residential areas, where population growth in recent years has continued to increase, so a solution to the problem of providing residential areas is needed without having to take up a lot of land, namely through the construction of high-rise buildings [1][2].

The impact of this shift in development patterns is on the use of clean water, where in the past the clean water supply system was very inefficient because it provided too much water. But at present there are limitations in the use of the amount of water, which is highly considered due to energy savings and limited water resources for the long term [3]. Supporting facilities, especially the factor of using clean water is very crucial, as clean water is a basic need that is needed by humans in carrying out their daily lives.

In a clean water distribution system, especially in a high-rise building, a method is needed to provide proper clean water. In the field of clean water plumbing installations, obstacles are often found, namely the lack of water pressure in each sanitary ware, which has an impact on the flow rate for sanitary equipment. So clean water plumbing installations must be designed so that they can provide a minimum pressure of 1 kg/$cm^2$ (±1 Bar) on each sanitary device when used during peak hours and be efficient and economical [4][5].

Planning a clean water plumbing installation system uses SNI references for calculating clean water needs and determining the dimensions of clean water pipes, as in previous [1][6][7][8][9].

To achieve this goal, clean water plumbing systems in high-rise buildings must be designed by the technical terms and conditions that have been legalized or stipulated in Indonesia. The results of designing a clean water booster pump for high-rise buildings will increase the convenience of using water in this building.
The novelty is the building is very large and the water flow is very small, so this building cannot apply the direct connection method or use a pressure tank, so water distribution is implemented using a roof tank.

## 2. METHODS

The design of a clean water booster pump for high-rise buildings, according to Nayono [10] can use two methods, i.e. basic plan and preliminary plan. The high-rise buildings have two floors where the area of the first floor is 1500 $m^2$, so the total area of this building is 3000 $m^2$. The occupant capacity of this building is 120 people and water usage activities here tend to be moderate. The problem faced is a large building with a small water supply, so this building cannot apply the direct connection method or use a pressure tank. A suitable method for this problem is implementing water distribution with a roof tank [11][12].

The basic plan method is a method of calculating water requirements based on sanitary estimates, main pipe networks, or plumbing system diagrams, determining the pump plan and other components used which refer to SNI standards which can be seen in Figure 1 [5]. After the basic planning method is carried out, it is followed by a preliminary plan, where this plan contains calculations to determine the specifications of the material to be used [13].

The booster pump is an auxiliary pump that functions as a pressure booster in the water distribution installation. This pump works to overcome water discharge due to insufficient static pressure in the installation if only utilizing gravity [5][7]. The use of highly fluctuating water is also the reason for choosing this booster pump so the determination of the capacity of this booster pump is based on the method of the type and number of plumbing equipment with several parameters as listed. The types of plumbing tools are shown in Table 1, and the number of plumbing tools is shown in Table 2. The pressure required for each sanitary ware is shown in Table 3.

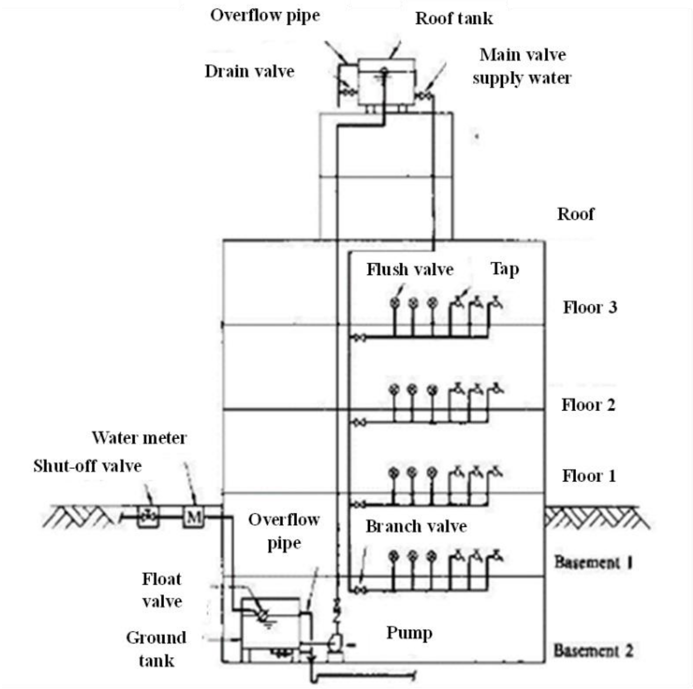


Figure 1. A system with a roof tank
Source: SNI 03-7065-2005F

The design of the booster pump needs to know the sanitary amount and the building's elevation. After the data has been obtained, the next step is to calculate the water needs by combining additional data from SNI standards. This water requirement is not only about the flow rate but also the head or pressure in the system. Where the minimum pressure at each point of the plumbing tool is on average 0.7 $kg/cm^2$ [13]. In general, it can be said that the standard pressure is 1 $kg/cm^2$. For static pressure, it is better to try between 4 $kg/cm^2$ to 5 $kg/cm^2$ [2]. The pressure on the pipe will affect the speed of the water flow, where the speed of the pipe in general in Indonesia is 0.9 to 2 m/secound [5][14]. The difference between the pipe diameter and the pump outlet diameter must be adjusted using a reducer.

Table 1. Water use in every sanitary

| Name of plumbing unit | One time use (Liters) | Water filling time (second) |
|---|---|---|
| Toilets with flush valves | 15 | 10 |
| Toilets, flush tanks | 14 | 60 |
| Peturasan, flush valve | 5 | 10 |
| Peturasan, flush tank | 14 | 300 |
| Small hand sink | 10 | 18 |
| Normal hand wash | 10 | 40 |
| Kitchen sink, with 13mm faucet | 15 | |
| Kitchen sink, with 20 mm faucet | 25 | 60 |
| *Bathtub* | 125 | 250 |
| *Shower* | 42 | 210 |

Source: SNI 03-7065-2005

Table 2. Percentage of usage on plumbing tools

| Number of plumbing tools | 1 | 2 | 4 | 8 | 12 | 16 | 24 | 32 | 40 | 50 | 70 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Toilet with flush valve | 1 | 50%<br>One | 50%<br>2 | 40%<br>3 | 30%<br>4 | 27%<br>5 | 23%<br>6 | 19%<br>7 | 17%<br>7 | 15%<br>8 | 12%<br>9 | 10%<br>10 |
| Ordinary plumbing tool | 1 | 100%<br>Two | 75%<br>3 | 55%<br>5 | 48%<br>6 | 45%<br>7 | 42%<br>10 | 40%<br>13 | 39%<br>16 | 38%<br>19 | 35%<br>25 | 33%<br>33 |

Source: Noerbambang & Morimura, 2005

Table 3. The pressure required for each sanitary

| Name of plumbing tool | Minimum pressure ($kg/cm^2$) |
|---|---|
| Toilet with flush valve | 0,7 |
| Interlocking flush valve | 0,4 |
| Automatic faucet | 0,7 |
| Shower | 0,7 |
| Faucet | 0,3 |
| Water heater | 0,3-0,7 |

Source: SNI 03-7065-2005

This preliminary plan determines the specifications of the booster pump and calculates the clean water required pipe, and pump sizes.

1) Capacity of booster pump ($Q_{pu}$)

Booster pump capacity can be calculated based on the unit load factor of the plumbing equipment [4][11]. Because this is a pressure pump system, the number of pumps must be more than 1 unit with installations arranged in parallel, this aims to meet the demand during peak hours and meet the needs for water discharge in fluctuating usage [5][15].

$$Q\_booster = L \times t \times a \times n \quad (1)$$

where :

$Q_{booster}$ = Capacity of booster pump ($m^3$/hour)
L = Water use capacity of sanitary (liters)
t = Estimates of sanitary usage (hour)
a = Presentase penggunaan saniter (%)
n = number of sanitary

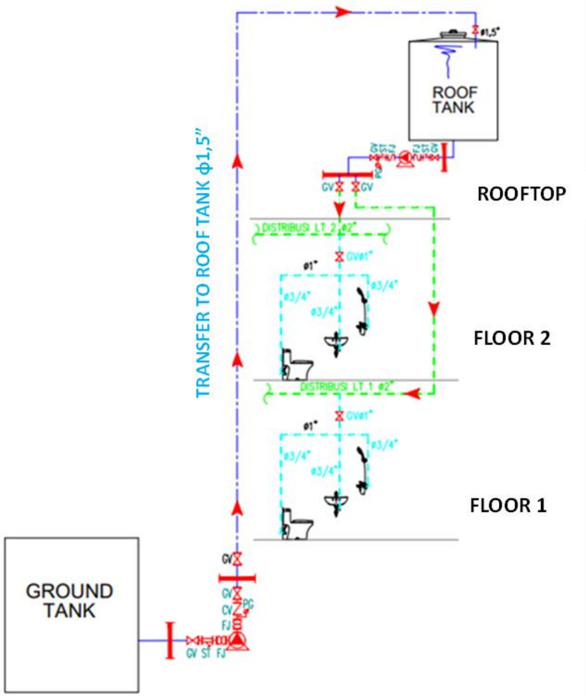


Figure 2. Schematic drawing for clean water installation in buildings

2) Pump discharge ($Q_{pu}$)

The flow rate of the pump is known based on the formula according to Sularso [11].

$$Q\_pu = \frac{Q_{booster}}{3600} \times 3{,}5 \quad (2)$$

where :

$Q_{pu}$ = Pump discharge ($m^3$/second)

3) Pipe distribution (D)

$$D = \sqrt{\frac{4 \times Q_{pu}}{v \times \pi}} \quad (3)$$

where :

D = Diameter of pipe (m)

v = Velocity of water (m/secound)

4) Pump head (H)

The total pump head can be determined based on the formula according to Sularso [11].

$$H = H_a + \Delta H_p + H_i + \frac{v^2}{2g} \quad (4)$$

where :

H = Head total of pump (m)

$H_a$ = Potential height (m)

$\Delta H_p$ = The difference in pressure head at the water surface (m)

$H_i$ = Total major losses and minor losses (m)

$\frac{v^2}{2g}$ = Head velocity of water in the pipeline (m)

g = Gravitation acceleration (9,8 $m/s^2$)

The total head is obtained by the parameters that cause losses to the system. The losses are called major losses, minor losses, and static heads, which determine losses using the following formulas[6].

Major losses caplosses (5)

$$H_f = \frac{10{,}66 \times Q_{pu}{}^{15}}{C^{1{,}85} \times D^{4{,}85}} \times L$$

where :

$H_f$ = Pipe losses (m)

C = Pipe coefficient
D = Diameter of pipe (m)
L = Distance of pipe (m)

a) Minor losses

Effect head losses of pipe bends

$$h_n = n \quad (6)$$

where :
$h_n$ = Friction loss in fittings (m)
n = Total fitting (unit)
v = Velocity of water (m/secound)
f = Friction loss each fittings unit

equal head losse f overlap $h_o = f \frac{(v^1 - v^2)^2}{2g}$ (7)

where :
$h_o$ = Friction loss in reducer (m)
f = Friction loss each overloop unit
$v_1$ = Velocity of water inlet (m/second)
$v_2$ = Velocity of water outlet (m/second)

Effect head losses of reducer $h_o = f \frac{v_2^2}{2g}$ (8)

where :
$h_o$ = Friction loss in overlook (m)
f = Friction loss of each reducer
$v_2$ = Velocity of water outlet (m/second)
g = Gravitation acceleration (9,8 m/s$^2$)

5) Minimum pump pressure (P) [16]

$$P_{booster} = (P]]_h + P\_min) \times 1.5 \quad (9)$$

$$P = \rho \times g \times h \quad (10)$$

where :
$P_{booster}$ = Minimum pressure of booster pump (Kg/cm$^2$)
P = Static pressure of booster pump (Kg/cm$^2$)
$P_{min}$ = Minimum pressure on sanitary unit (Kg/cm$^2$)
ρ = Density of water (998,2 Kg/m$^3$)
h = Potential height (m)

6) Capacity of pressure tank (V) [1]

$$V_{tank} = \frac{Q_{booster} \times n}{3} \quad (11)$$

where :
$V_{tank}$ = Capacity of pressure tank (liters)
n = Total pompa

## 3. RESULTS AND DISCUSSION

### 3.1. Basic plan results

With the calculation data that has been done, it is found that this building has 2 floors with a total of 71 rooms and a total occupant density in the building of 120 people. The number of sanitary equipment used in this building is shown in Table 4.:

Table 4. Total sanitary need

| Name of sanitary | Total |
|---|---|
| For cold water | |
| Shower | 36 |
| Toilet with flush valve | 46 |

| | |
|---|---|
| Sink | 47 |
| Faucet 20mm | 3 |
| Laundry sink | 3 |
| Faucet 13mm | 6 |
| For hot water | |
| Shower | 36 |
| Kitchen sink | 2 |
| Laundry sink | 3 |
| Total | 182 |

### 3.2. Preliminary plan results

1) Capacity of the booster pump

The results from the initial data using formula (1) and a combination of tables 1 and 2 are presented in Figure 3 and Table 5,

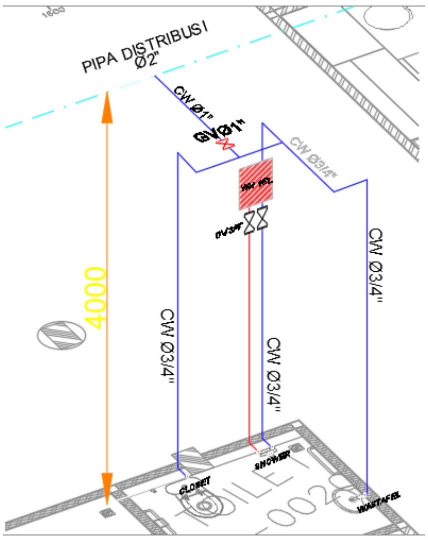


Figure 1. Isometric clean water installation in the bathroom

Table 5. The result of determining the pump capacity

| NO | Sanitary | Water usage in sanitary (liters) | Sanitary quantity (units) | Usage percentage (%) | Hourly usage (hours) | Water usage (liters/hours) |
|---|---|---|---|---|---|---|
| **COLD WATER** | | | | | | |
| 1 | Shower | 42 | 36 | 39% | 3 | 1769,04 |
| 2 | Toilet with flush valve | 14 | 46 | 16% | 6 | 618,24 |
| 3 | Sink | 10 | 47 | 38% | 6 | 1071,6 |
| 4 | Kitchen sink with faucet 20mm | 25 | 3 | 75% | 6 | 337,5 |
| 5 | Laundry sink | 15 | 3 | 75% | 5 | 168,75 |
| 6 | Faucet 13mm | 15 | 6 | 65% | 6 | 351 |
| **AIR PANAS** | | | | | | |
| 7 | Shower | 50 | 36 | 30% | 3 | 1620 |
| 8 | Kitchen sink | 15 | 2 | 30% | 6 | 54 |
| 9 | Laundry sink | 15 | 3 | 30% | 5 | 67,5 |
| | | | | | Total used water | 6057,63 |

The total capacity of the booster pump is a system with more than one pump, so the total capacity will be divided by 2 so that each pump is 3000 liters/hour or 3 $m^3$/hour. After the pump capacity is obtained, determine the irrigation capacity using formula (2) so that:

$$Q_{pu} = \frac{\left(6{,}05\frac{m^3}{hour}\right)}{3600} \times 3{,}5$$

$$Q_{pu} = 0{,}005889\frac{m^3}{second}$$

So the irrigation discharge for this booster pump is 0,005889 $m^3$/second.

2) The diameter of the pipe distribution
The diameter of pipe distribution for the first floor and second floor can use formula (3) and for water flow rates follow the standards specified in the planned method, so when:

$$the\ D = \sqrt{\frac{4 \times 0{,}005889}{2 \times 3{,}14}}$$

$$D = \sqrt{0{,}003749}$$

$$D = 0{,}06122\, m \times 1000 = 61{,}2mm$$

So that the diameter of the pipe used is 61.2 mm. To make it easier to select pipes, the diameter size is 63 mm. Because the selection of pipe material refers to PPR, rounding the pipe diameter is equivalent to 2 inches. This pipe has a Hazen-William coefficient (C) of 150 [11][17].

3) Pump head
In the installation drawings it is known that the elevation of the 1st floor distribution pipe to the pump discharge is 6 m and the 2nd floor distribution pipe elevation to the pump discharge is 1.5 m. So the head required for the booster pump is as follows:

*a) Major losses*
It is known that the length of the distribution pipe from the roof tank to serve water on the 1st floor is 97 m and for the 2nd floor is 105 m. So that the head due to the surface of the distribution pipe and the length of the pipe is obtained using formula (5) as follows:

- For distribution pipe floor 1

$$Hf\ = \frac{(10{,}666 \times 0{,}005889^{1{,}85})}{150^{1{,}85}\ 0{,}063^{4{,}85}} \times 97$$

$$Hf\ = 4{,}86\, m$$

- For distribution pipe floor 2

$$Hf\ = \frac{10{,}666 \times 0{,}005889^{1{,}85}}{150^{1{,}85}\ 0{,}063^{4{,}85}} \times 105$$

$$Hf\ = 5{,}26\, m$$

*b) Minor losses*
At the analysis stage using software to find out the basic plan drawings for this plumbing system, it was found that the distribution pipes for the 1st and 2nd floors obtained various types of fittings as shown in Table 6.

Table 6. Fittings needed on distribution pipes

| Materials | Total fitting | |
|---|---|---|
| | 1nd floor | 2nd floor |
| El-bow 2" | 10 | 9 |
| Tee reducer 2" x 1" | 19 | 30 |
| Reducer 2" x 1" | 0 | 1 |

For each fitting has a friction coefficient value (f) which refers to the determination of a source [11]. The results are given in Table 7.

Table 7. Minor loss calculation results

| Explanation | 1nd floor [m] | 2nd floor [m] |
|---|---|---|
| Friction loss due el-bow (hn) | 1,84 | 1,65 |
| Friction loss due tee (ht) | 3,88 | 6,12 |

| | | |
|---|---|---|
| Friction loss due to reducer (ho) | 0 | 0,10 |
| Total | 5,72 | 7,87 |

c) *Total losses*
The total of this head will be used as a reference to determine the booster pump head used. So that the total loss due to head on the distribution pipe for floors 1 and 2 can be found using formula (4):

- Distribution pipe in 1st floor
$$H = 6\ m + 0 + (4{,}86m + 5{,}72) + \frac{2^2 \frac{m}{second}}{2\times 9{,}8 \frac{m}{second}}$$
$$H = 16{,}784\ m$$
- Distribution pipe in 2nd floor
$$H = 1{,}5\ m + 0 + (5{,}26m + 7{,}87) + \frac{2^2 \frac{m}{detik}}{2\times 9{,}8 \frac{m}{detik}}$$
$$H = 14{,}844\ m$$

So the total head required to select a pump is 31,628 m

4) Minimum pump pressure
To determine the minimum pressure specs that must be provided for this booster pump, it is assumed to have the minimum pressure required in Table 3. So that the minimum pressure for using a booster pump for the distribution of clean water on floors 1 and 2 can be determined if gravity is not used using the formula (9) to get:

$$P_{booster} = \left(0{,}5 \frac{kg}{cm^2} + 0{,}7 \frac{kg}{cm}\rrbracket^{2}\right) \times 1.5$$
$$P_{booster} = 1{,}8 \frac{kg}{cm^2} \times 0{,}98 = 1{,}76\ Bar$$

So the minimum working pressure for this booster pump is 1,8 Bar.

5) Compressive capacity
The pressure tank is a component used to control the pump so that it does not run continuously. To determine the capacity of the pressure tank can use the formula (11). Judging from the previously known pump capacity, this booster pump is sufficient to only use 2 pumps. So obtained for the pressure tank capacity:

$$Q = \frac{6057 \frac{\ell}{hour}}{60\ minute} = 100{,}97 \frac{\ell}{minute}$$

Where :

$$V = \frac{100{,}97 \frac{\ell}{minute} \times 2\ unit}{3} = 67{,}3\ liter$$

Obtained for the pressure tank capacity is 67 liters. Because there is no pressure tank with this capacity in the market, we are looking for one with a capacity close to 80 liters.

## 4. CONCLUSION

Based on the results of the calculations that have been discussed, it can be concluded as follows:

1) The design of a clean water booster pump for high-rise buildings with a building area of 3000 $m^2$ and a capacity of 120 people has been carried out. There are two types of water used, namely cold water and hot water which will serve 142 units of sanitary equipment using a pump called a booster pump. To service all of these sanitary devices, two booster pump units are needed, each having a capacity of 3 $m^3$/hour. This pump must be able to meet the predetermined head of 31.62 m. This system uses a pressure tank with a capacity that must be met, namely 67.3 liters. This pressure tank will be set with a pump control (pressure switch) to regulate the work of pumps one and two. The minimum pressure for the booster pump is 1.76 Bar. The type of pipe used is PPR (Polypropylene Random) with a diameter of 2 inches.
2) From the specifications above, the pump that is suitable for use as a booster pump is a vertical multistage centrifugal pump. The placement of this booster pump will be designed with positive suction line conditions.

## 5. REFERENCES

[1] Suhardiyanto, “Perancangan Sistem Plambing Instalasi Air Bersih dan Air Buangan Pada Pembangunan Gedung Perkantoran Bertingkat Tujuh Lantai,” *J. Tek. Mesin*, vol. 05, pp. 2–9, 2016.
[2] F. Muhamad and E. Wardhani, “Studi Penghematan Air pada Sistem Plambing Air Bersih di Apartemen

Menara Cibinong Tower Mahoni," vol. VI, no. 4, pp. 2303–2309, 2021.
[3] K. C. B. Artayana and G. Indra, "Perencanaan Instalasi Air Bersih dan Air Kotor Pada Bangunan Gedung dengan Menggunakan Sistem Pompa," vol. 4, no. 1, pp. 51–56, 2010.
[4] I. P. Lilipaly, R. E. Badriani, U. Jember, and J. Timur, "Perencanaan Sistem Plambing Dan Hidran Kebakaran Pada Proyek Pembangunan Hotel Pesona Alam," vol. 10, pp. 266–279, 2021, doi: 10.22225/pd.10.2.2818.266-279.
[5] S. 03-7065-2005, "Tata cara perencanaan sistem plambing," 2005.
[6] P. Wirasakti and L. Apriyanti, "Perencanaan Sistem Instalasi Plambing Air Bersih Apartemen Royal Paradise Bandung," vol. 7, no. 1, pp. 1–12, 2019.
[7] Ubaedilah, "ANALISA KEBUTUHAN JENIS DAN SPESIFIKASI POMPA UNTUK SUPLAI AIR BERSIH DI GEDUNG KANTIN BERLANTAI 3 PT ASTRA DAIHATSU MOTOR," vol. 05, no. 3, pp. 119–127, 2016.
[8] A. Gofar, "Perancangan sistem plambing di gedung asrama 6 institut teknologi sumatera," pp. 1–10.
[9] R. D. Riyadi, "PERENCANAAN SISTEM PLAMBING PADA GEDUNG LABORATORIUM TEKNIK 5 INSTITUT TEKNOLOGI SUMATERA," vol. 3, no. 1, pp. 1–9, 2005.
[10] R. N. Syamsudin, "Pengembangan Modul Pembelajaran Mata Kuliah Praktik Kerja Plambing dan Sanitasi di Prodi Pendidikan Teknik Sipil dan Perencanaan FT UNY," pp. 83–93, 2020.
[11] Sularso, "Pompa dan Kompresor".
[12] A. S. of P. Engineers, "Plumbing Engineering Design Handbook Volume 1," vol. 1, 2004.
[13] E. S. Menon, "Piping Calculations Manual".
[14] D. W. Widihasta, "PERENCANAAN SISTEM AIR BERSIH PADA PEMBANGUNAN APARTEMEN SUNCITY SIDOARJO," *JOS MRK*, vol. 2, pp. 66–71, 2021.
[15] A. Agung, A. Suryawan, M. Suarda, and I. G. K. Sukadana, "Penentuan dimensi perpipaan sistem pompa paralel," vol. 9, no. 1, pp. 84–90, 2016.
[16] J. J. Susilo, "Studi Perencanaan Penyediaan Air Bersih Pada gedung Bertingkat Tunjungan Plasa VI Kota Surabaya.pdf." 2014.
[17] P. P. Association, "Handbook of PVC Pipe Design and Construction".