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Effect of Pipe Friction on Nodal Pressure of Water Distribution System

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Abstract: ***Water Distribution System, a hydraulic infrastructure that consists of elements such as Pipe, Node, Reservoir, Tank, Pump and valves. An effective Water Supply System is paramount to deliver good quality of water at a considerable pressure to the consumer's end. Using computation technique to Simulate the Water Distribution System has progressed to a mature stage of development. The EPANET Software is used to design and analyze the hydraulics and water quality parameter of Water Distribution Network. EPANET 2.2 monitors the flow of water in each pipe as well as Pressure at each node. The friction factor, which affects the head loss in pipe, has a direct effect on the nodal pressure. So, the effect of friction coefficient on nodal pressure is studied. It will help to select the proper pipe material and to optimize the network cost. This work highlights the study on effect of pipe friction on Nodal pressure of Pipe Network System. The analysis carried on the basis of varying friction factor and the critical nodes are identified for different size of pipe in network system. This Study is intended to give the information about minimum desired pressure at each node and to check the reliability.***

Keywords: EPANET 2.2, Pipe Network, Water Distribution System

1. Introduction

The water distribution system is a vital utility. Due to the urbanization people are shifting to the newly developed urbanized area hence a greater number of people need piped water supply. The water distribution system should be capable to supply water at appropriate pressure, quality and quantity to fulfil the requirements to each consumer. The water distribution network (WDN) is a system of hydraulic components that conveys the water fromsources to the consumers in a timely manner. It is a hydraulic infrastructure composed of elements such as pipes, tanks reservoirs pumps and valves among other things.Cast or ductile iron, mild steel, concrete and prestressed concrete, asbestos cement, polyvinyl chloride (PVC) and high-density polyethylene (HDPE) are some of the materials used in the distribution network. As Pressure at nodes is directly affected by friction coefficient of pipe. So, it is essential to study about the effect of pipe friction of different pipe material on the nodes of distribution network system. Software, EPANET 2.2 can perform the hydraulic analysis of water distribution network. EPANET is a computational program that simulates hydraulic and water quality behaviour within pressurized pipe networks over a long period of time (Rossman, 2000). It is open-source Software that makes creating a water network model, editing its properties, and running extended-period steady-state hydraulic simulation easier.

2. Background

A well-designed water distribution system should function adequately to provide users with portable water of appropriate pressure and quality in the least times. However, pressure drop, leakages and contamination occur during the operation of water supply systems and the fundamental difficulty is the lack of a simple tools to precisely forecast zones of low pressures and locations where quality is compromised (Bwire, 2015). Performance of Water Distribution system must be assessed to check the reliability and efficiency. Different types of performance evaluation methodologies have been used by many authors. Zhuang et al. (2011) conducted Monte Carlo simulation to generate the nodal demands and component failure, further hydraulic solver EPANET is utilized to estimate system pressure. Bwire C et al. (2015) modelled the entire Kimilili water reticulation network in the terms of demands, pressure variation from the treatment plant to users using EPANET. Considering the simulation's outcomes, 80% of nodes receives a pressure of more than 16m which is adequate to fill the tanks. A minimum pressure of 10m maintained. There are also a pressure reducing valves within the network to prevent hydraulic shocks within the taps.To kept in mind the pipe ageing due to frictional loss and variation of roughness coefficient of pipe, directly affects the pressure at nodes. So, it is required to provide the different kind of pipes as HDPE / Ductile iron / GI pipe that fulfil minimum pressure head at different node.

3. Methodology

In this paper, the study has been conducted for WDN under different value of frictional coefficient as changing the pipe material Roughness coefficient that effects the nodal pressure of network system. The simulation of looped WDN (Sayyed, 2014) was carried out using EPANET 2.2. Because the actual pressure head is less than required minimum pressure head (Sayyed, 2014), the analysis is carried out to check if the frictional coefficients minimum pressure head requirement is met. Figure 3.1 shows the methodology used in EPANET 2.2 Software for study of looped WDN.

Figure 3.2 shows looped water distribution network, obtained from the literature (Sayyed,2014). The head at both the RES1 and RES2reservoirs is 60.96 m. There are13 demand nodes and 21 pipes in the network. Table 3.1 illustrates the Node number, elevation, and nodal demands. The Required minimum pressure head at each node is 17 m. Table 3.2 shows number of pipes, their length, diameter and Hazen-William's roughness coefficient.

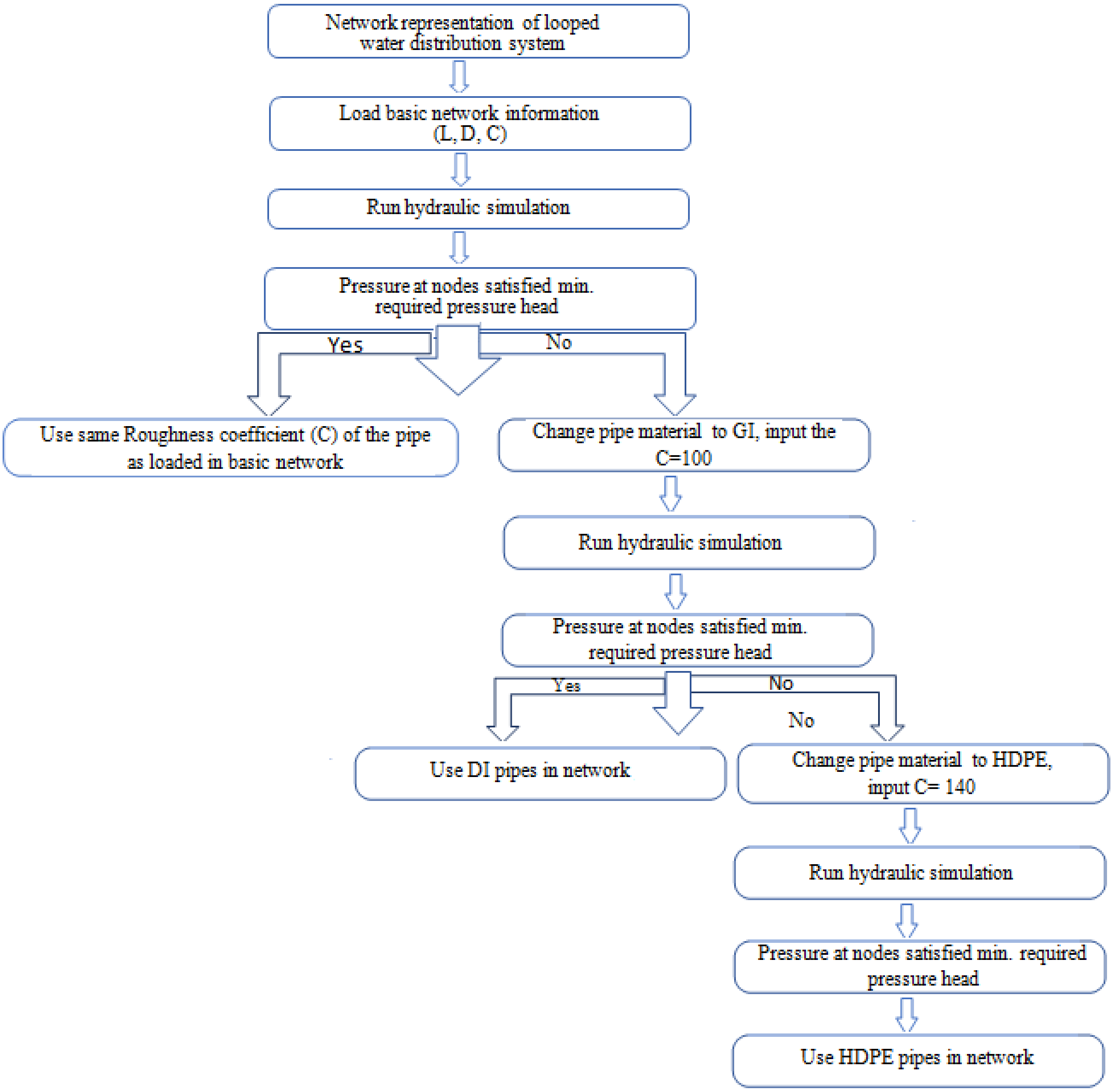

Figure 3.1: Flowchart of steps used in EPANET 2.2

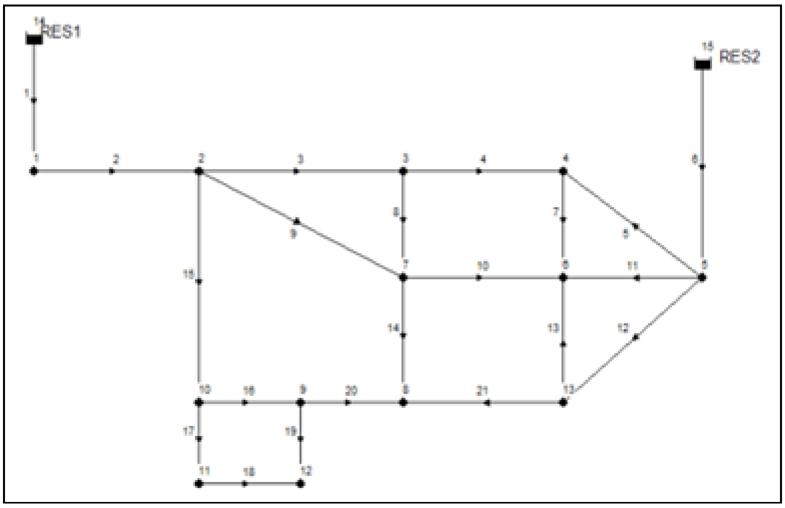

Figure 3.2: Water Distribution Network

Table 3.1: Node Data of Water Distribution Network

Node ID	Elevation (m)	Demand (CMH)
Junc 1	27.43	3.8100
Junc 2	33.53	215.79
Junc 3	28.96	215.88
Junc 4	32.00	644.01
Junc 5	30.48	215.72
Junc 6	31.39	686.87
Junc 7	29.56	643.82
Junc 8	31.39	330.39
Junc 9	32.61	2.9400
Junc 10	34.14	2.9300
Junc 11	35.05	110.46
Junc 12	36.58	110.30
Junc 13	33.53	2.8800

Table 3.2: Given Link Data of Looped WDN

Link ID	Length (m)	Diameter (mm)	Roughness
Pipe 1	609.60	762	130
Pipe 2	243.80	762	128
Pipe 3	1524.00	609	126
Pipe 4	1127.76	609	124
Pipe 5	1188.72	406	122
Pipe 6	640.08	406	120
Pipe 7	762.00	254	118
Pipe 8	944.88	254	116
Pipe 9	1676.40	381	114
Pipe 10	883.92	305	112
Pipe 11	883.92	305	110
Pipe 12	1371.6	381	108
Pipe 13	762.00	254	106
Pipe 14	822.96	254	104
Pipe 15	944.88	305	102
Pipe 16	579.00	305	100
Pipe 17	487.68	203	98
Pipe 18	457.20	152	96
Pipe 19	502.92	203	94
Pipe 20	883.92	203	92
Pipe 21	944.88	305	90

4. Result and Discussion

As the Table 4.2 shows the pressure at each node when the frictional coefficient varies in each pipe. At node 11 and 12 pressure head is 13.37 and 11.61 respectively, which is less than minimum required pressure 17 m. Further simulation is carried out for GI pipes that shows the actual pressure head at node 6, 7, 8, 11, 12, 13 have less than minimum desired Pressure. Simulation is carried out for DI pipes; it shows Node 12 as a critical node having 16.53m of pressure head. At last, we used HDPE pipes for the analysis of Water Distribution Network that satisfied minimum required pressure criteria in each node. For the analysis using different pipes, roughness coefficient and corresponding friction factor is given in Table 4.1

Table 4.1: Roughness and Friction coefficient of different pipe material

	Given Data		GI PIPES		DI PIPES		HDPE PIPES	
	C	F	C1	F1	C2	F2	C3	F3
Pipe 1	130	0.016	100	0.026	140	0.014	150	0.012
Pipe 2	128	0.017	100	0.026	140	0.014	150	0.012
Pipe 3	126	0.018	100	0.028	140	0.015	150	0.013
Pipe 4	124	0.02	100	0.03	140	0.016	150	0.014
Pipe 5	122	0.028	100	0.04	140	0.021	150	0.019
Pipe 6	120	0.02	100	0.028	140	0.015	150	0.013
Pipe 7	118	0.024	100	0.033	140	0.018	150	0.015
Pipe 8	116	0.025	100	0.033	140	0.018	150	0.015
Pipe 9	114	0.023	100	0.03	140	0.016	150	0.014
Pipe 10	112	0.035	100	0.041	140	0.022	150	0.019
Pipe 11	110	0.026	100	0.032	140	0.017	150	0.015
Pipe 12	108	0.028	100	0.032	140	0.017	150	0.015
Pipe 13	106	0.032	100	0.035	140	0.019	150	0.017
Pipe 14	104	0.035	100	0.04	140	0.021	150	0.019

Pipe 15	102	0.031	100	0.032	140	0.017	150	0.015
Pipe 16	100	0.034	100	0.034	140	0.018	150	0.016
Pipe 17	98	0.036	100	0.034	140	0.018	150	0.016
Pipe 18	96	0.051	100	0.047	140	0.025	150	0.022
Pipe 19	94	0.04	100	0.035	140	0.019	150	0.017
Pipe 20	92	0.044	100	0.036	140	0.019	150	0.017
Pipe 21	90	0.041	100	0.034	140	0.018	150	0.016

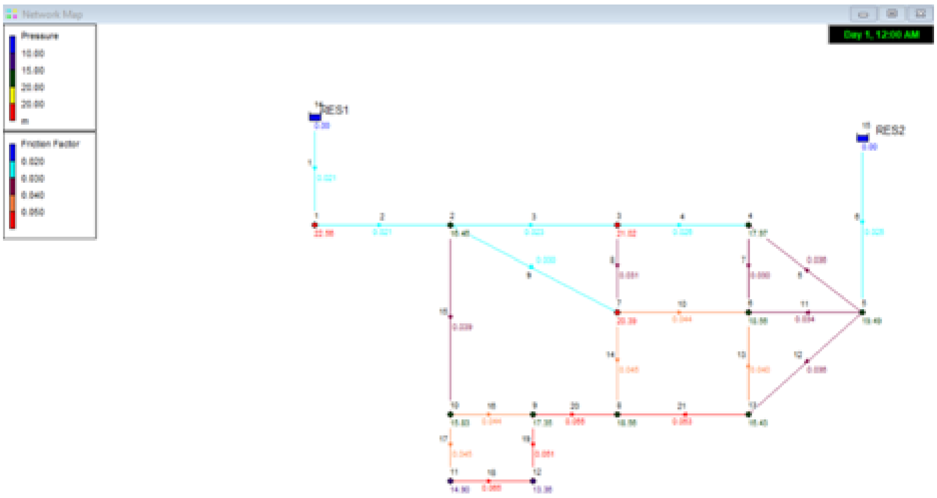

Figure 4.1: Friction coefficient at link and Pressure at each node for HDPE pipe

Table 4.2: Pressure at nodes in different pipe materials

Node ID	Given PIPES	GI PIPES	DI PIPES	HDPE PIPES
	Pressure head (m)	P at C=100 (m)	P at C=140 (m)	P at C=150 (m)
Junc 1	32.25	31.49	32.43	32.56
Junc 2	25.63	24.58	25.9	26.08
Junc 3	27.02	24.58	28.01	28.49
Junc 4	22.89	20.02	24.15	24.73
Junc 5	24.49	21.71	25.76	26.33
Junc 6	18.28	14.51	21.47	22.44
Junc 7	20.21	16.58	23.43	24.38
Junc 8	17.31	14.19	21.3	22.29
Junc 9	19.21	17.04	22.24	22.97
Junc 10	19.04	17.12	21.58	22.2
Junc 11	13.37	11.62	18.18	19.1
Junc 12	11.61	9.87	16.53	17.47
Junc 13	18.43	14.97	20.73	21.53

Nodal pressure in pipes having roughness factor 150 gives higher nodal pressure while pipes having roughness factor 140 and 100 give lower nodal pressure subsequently. As the pipe become rough, it tends to increase frictional head losses and due to this pressure deliver to the user decrease (Byzkika, 2017).

Some nodes highlighted with red colour in Table 4.2, that fails to fulfil minimum pressure head criteria and indicates reduction in hydraulic performance of the system. Study related to pipe roughness is useful to help identify critical pipes or joints needs to be rehabilitated in the water distribution system.

High density Polyethene pipes are rigid and tough, while also being resilient and conforming to the land topography. As lighter in weight, they are easy to carry and install. They can endure movement of heavy traffic. HDPE offers superior free flowing properties and have smooth inner surface, resulting in less friction and comparatively less pressure loss as compared to other material (CPHEEO, 2020).

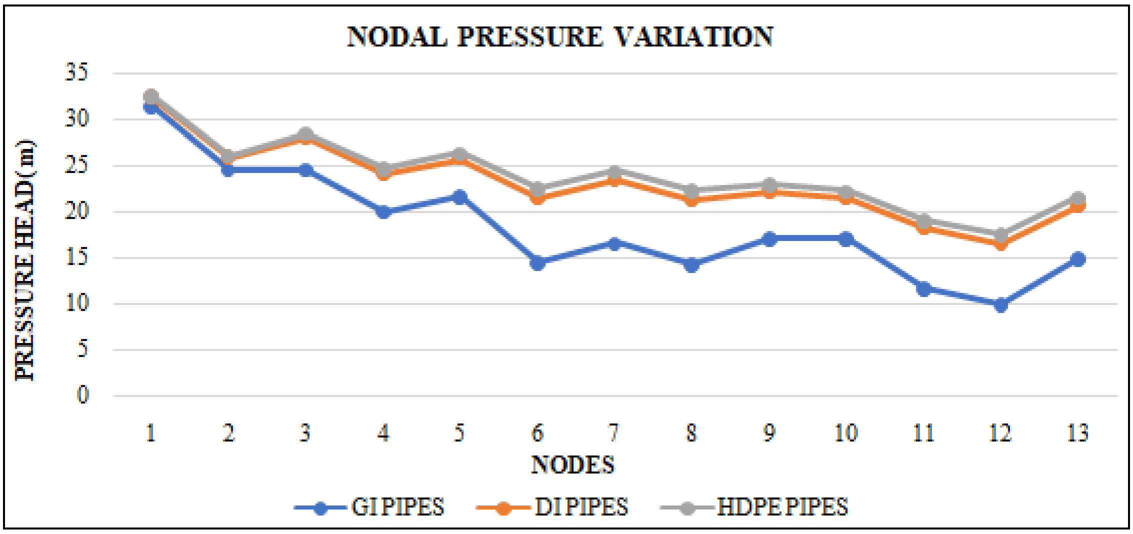

Figure 4.2: Nodal pressure variation at each node of GI, DI and HDPE pipe

This graphical representation is helpful to sort out those nodes which are not fulfilling minimum required pressure limit set by water supply authority. According to Central Public Health and Environmental Engineering Organization's manual on water supply and treatment, water should be deliveredat a minimum 17m pressure head at all nodes. DI and GI pipe were not able to fulfil the required pressure limit whereas the HDPE pipes fulfilled this pressure head criteria.

5. Conclusion

This paper presents the effect of pipe roughness on nodal pressure in a looped water distribution network using a variety of pipe materials. The key finding of this study is that, with increase in Hazen Williams Roughness coefficient, pipe friction decreases which directly affects the nodal pressure. HDPE pipe are the most suitable for the designing of Water Distribution Network.

References

[1] Advisory on pipe materials for transmission of water, Central Public Health and Environmental Engineering Organisation (CPHEEO), (2020), 27-80.
[2] Anisha G., Kumar A., et al. "Analysis and Design of Water Distribution Network Using EPANET for Chirala Municipality in Prakasam District of Andhra Pradesh", International Journal of Engineering and Applied Sciences (IJEAS), Vol. 3, (2016), 53-61.
[3] Bwire C., Onchiri R., and Mburu N. "Simulation of Pressure Variation within Kimilili Water Supply System using EPANET.", International Journal of Civil Engineering and Technology (IJCET), Vol. 6, (2015), 28-38.
[4] Halgalimath S. S., Kumar V. H., and Patil N. S. "Hydraulic modelling of water supply network using EPANET" International Research Journal of Engineering and Technology, Vol. 3, (2016), 1022-1027.
[5] Nallanathel M., Ramesh B., and Santhosh A. B. "Water distribution network design using EPANET A case study" International Journal of Pure and Applied Mathematics, Vol.119, (2018), 1165-1172.
[6] Pandya N., Popawal R., and Yadav S. (2019) "Performance Evaluation of water Distribution Network using hydraulic parameter" International Journal of Research and Analytical Reviews, Vol. 6, (2019), 289-295.
[7] RossmanL. A. "EPANET 2 user's manual", National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH, (2000).
[8] Ramana V., Sudheer V. S., and Rajashekhar b. "Network analysis of water distribution system in rural areas using EPANET", Elsevier, Vol. 119, (2015), 496-505.
[9] Sayyed M. A. H. A., Gupta R., and Tanyimboh T. "Modelling Pressure Deficient Water Distribution Networks in EPANET", Elsevier, Vol. 89, (2014), 626-631.
[10] Stephen Nyende-Byzkika "Impact of pipe roughness of a water distribution network: A case study of Westbury network, Johannesburg, South Africa", African journal Science, innovation and development, Vol. 9, (2017), 143-146.
[11] Zhuang B., Lansey K., and Kang D. "Reliability/availability analysis of water distribution systems considering adaptive pump operation" World Environmental and Water Resources Congress 2011(ASCE), (2011), 224-234.