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Experimental Study of Hydraulic Modeling of Water Distribution Network with Pressure Driven Approach

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ABSTRACT: Water distribution network design is being more complicated over the period. In India, network is designed on the basis of demand driven approach, demand is calculated according to the population forecasting and then certain per capita amount of water is allotted. In pressure driven approach, pressure plays key role in designing of network. It is very important to maintain required pressure value at each node. Use of pressure driven approach in practical network simulation is important so that in the proposed study analysis of double looped network is done using Newton Raphson method. The excel program was prepared for the same. Then the simulation for experimental setup was carried out by applying demand driven approach and pressure driven approach. The observations were made related to pressure and demand and are discussed in the respective chapter.

KEYWORDS: Water distribution simulation, pressure dependent demand, Newton Raphson method, double loop network, waterGEMS, EPANET

I. INTRODUCTION

Water distribution network design is essential for complicated pipeline networks. A water distribution system is a complicated combination of hydraulic control parameters connected together to convey of water from sources to consumers. Now days various algorithms and software programs are being installed for simulation of complex network. Pressure driven approach and demand driven approach are being main points in such network simulation scenarios. Newton Raphson method is the base of all hydraulic simulation algorithms. While allocating demand at a junction in software the pressure at that particular junction should be sufficient. Pressure driven approach gives an advantage when the system is having pressure deficient condition. Practical application of this approach is possible above mentioned case. PDD function in Bentley WaterGEMS is given for such calculation; effective use of it can create economical pipe diameters with revised demand values at each node.

II. OBJECTIVES OF PROJECT

- 1) To simulate water distribution network using pressure driven approach and demand driven approach.
- 2) To study application of pressure driven demand approach.

III. REVIEW OF LITERATURE

Various studies have been performed about simulation of water distribution network and on pressure dependent demand. Certain papers are related to the importance of Pressure dependent demand function in water network analysis and use of PDD function in software like waterGEMS, waterCAD, EPANET. In this report, literature review covers

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most of the papers regarding with design, analysis and research parameters of design of water distribution network and pressure dependent demand approach.

IV. METHODOLOGY

Methodology is developed in the following manner, Firstly topic is selected on the basis of current trend in water supply network design. Demand driven approach has got some drawbacks and those can be corrected in pressure driven approach. Literature review has covered major papers related to the pressure driven approach in hydraulic simulation. To go with the basics of hydraulic simulation, various methods of network analysis are studied. Case studies are selected in such a way that those will cover both theoretical and practical points of consideration. First case study is based on Newton Raphson method, second case study is based on actual site condition and third case study is based on the experiments carried out on actual physical pipe network. Third case study has covered scope of demand driven demand function and pressure driven function. Comparison between actual results generated from physical model and results generated from software simulation is done. Flow chart on the next page gives brief idea about the methodology

V. DESIGN AND MODEL CONSTRUCTION

To study the actual process of pressure driven demand function, practical double looped network was constructed with sufficient pipe diameters and measurable length. 2 Flow was measured by water meters and two nodes are set to open so that it will be easy to consider those nodes as a demand nodes and where outflow could be measured. As shown in this following figures actual pipeline network was constructed.



Fig 1: Physical network setup

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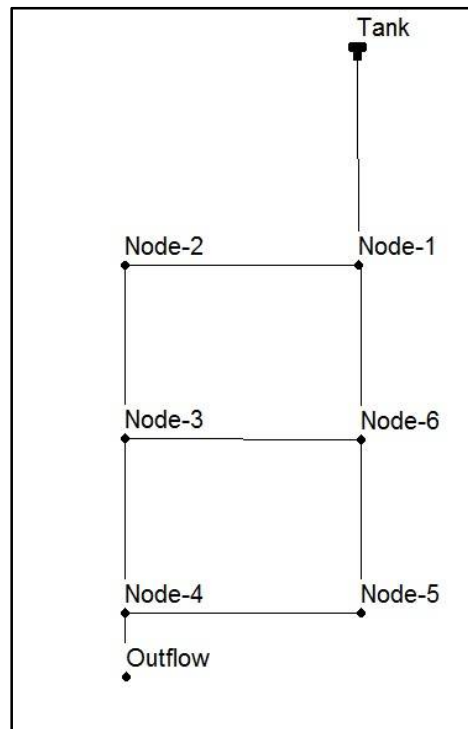


Fig 2: Typical diagram of network

To measure pressure, scaled wooden platforms were erected and piezometers were attached to it. To measure the inflow and outflow water meters were installed. Typical diagram of a network is shown, node 1 is directly attached to the tank through 25mm diameter pipe and node 4 has outlet for the system. Nodes 5 and 6 were open during the operation to determine the actual outflow through it so that those input values can be taken for hydraulicsimulation of the network. In other word node 5 and 6 will act as consumer demand nodes.

Source	Inflow (Node 1)	Outflow (Node 4)	Outflow at Node 5	Outflow at Node 6
Tank	Reading measured by flow meter	Reading measured by flow meter		
Head = (103 + 0.93m)	0.31 LPS	0.26 LPS	0.030 LPS	0.024 LPS

Table No 1: Input Data for network

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Above observation table gives basic details of data entered in during the experiments. In observation table 2 all network details are entered and pressure values generated from piezometers are also enlisted. Flow through node 5 and 6 are measured. Source was overhead tank with 900mm diameter. Temporary benchmark was considered as 100m and tank level was kept to 93cm. Elevation of each node is considered as 100 m as it is on the flat surface.

	Dia. Of pipe (mm)	Elevation (m)	Flow measured by water meter (LPS)	Pressure (m)
Tank	900	103.93	-	-
Node 5	25.000	100	0.030	0.640
Node 4	25.000	100	0.260	0.530
Node 3	25.000	100	0.000	0.590
Node 6	25.000	100	0.024	0.680
Node 2	25.000	100	0.000	0.670
Node 1	25.000	100	0.000	0.720

Table No 2: Calculation for Model

VI. HYDRAULIC SIMULATION

Hydraulic simulation is done in software waterGEMS series 5. While simulating it in the software two scenarios were created, one is simulation without PDD function and other is simulation with PDD function.

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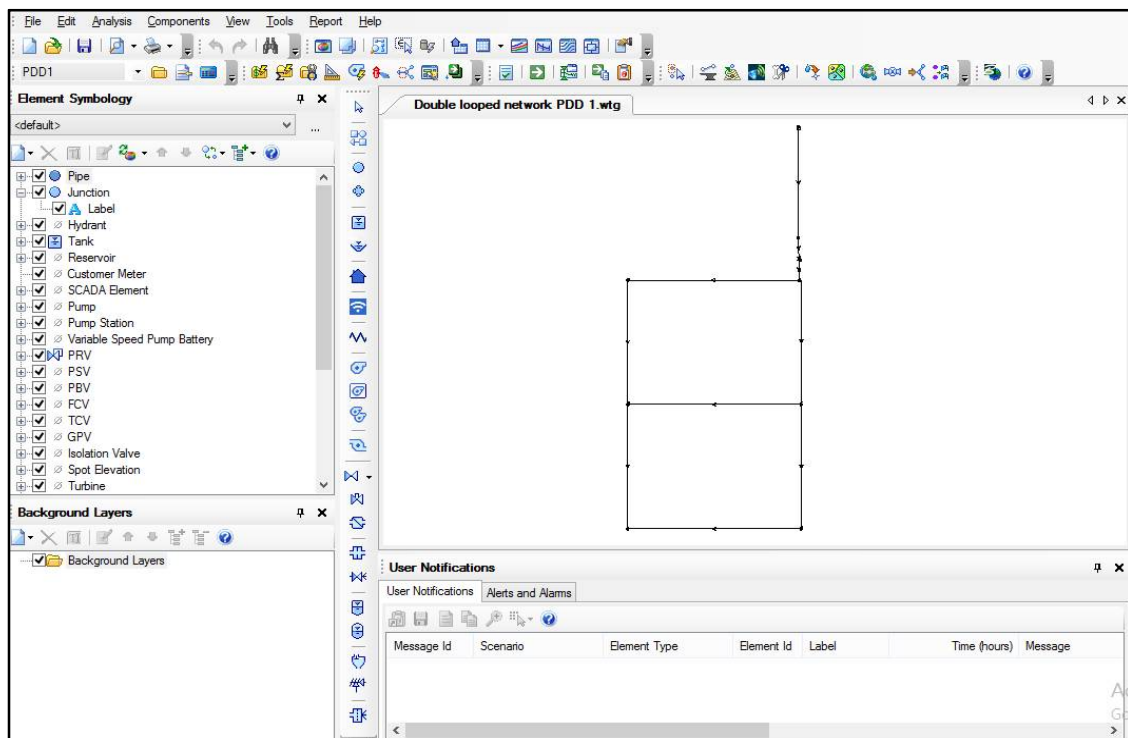


Fig 3: Simulation in waterGEMS

As shown here this is window of waterGEMS software which shows network and nodes.

While simulating the scenarios threshold pressure was kept varying such as for case one it was 0.6m, for case two it was 0.7m and so on. Results from all these scenarios are attached herewith.

VI. CONCLUSIONS

This section contains comparative results of experimental outcomes and software analysis outcomes. Percentage increase in pressure heads of each node is calculated and pressure prediction equation is generated from the results.

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Experimental Data (Double looped network)			Practical Results		waterGEMS Without pdd		With PDD (Threshold pressure 0.8m)		% Increase in Pressure
Node no	Dia. Of pipe (mm)	Elevation (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	Demand (L/s)	Pressure (m H2O)	
5	25.000	100	0.030	0.640	0.030	0.62891	0.027	0.645	2.519
4	25.000	100	0.260	0.530	0.260	0.5473	0.219	0.567	3.514
3	25.000	100	0.000	0.590	0.000	0.5788	0.000	0.590	1.876
6	25.000	100	0.024	0.680	0.024	0.6800	0.022	0.690	1.519
2	25.000	100	0.000	0.670	0.000	0.6505	0.000	0.656	0.813
1	25.000	100	0.000	0.720	0.000	0.7200	0.000	0.720	0.036
Experimental Data (Double looped network)			Practical Results		waterGEMS Without pdd		With PDD (Threshold pressure 1.2m)		% Increase in Pressure
Node no	Dia. Of pipe (mm)	Elevation (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	Demand (L/s)	Pressure (m H2O)	
5	25.000	100	0.030	0.640	0.030	0.62891	0.022	0.658	4.665
4	25.000	100	0.260	0.530	0.260	0.5473	0.182	0.583	6.432
3	25.000	100	0.000	0.590	0.000	0.5788	0.000	0.599	3.452
6	25.000	100	0.024	0.680	0.024	0.6800	0.018	0.699	2.825
2	25.000	100	0.000	0.670	0.000	0.6505	0.000	0.660	1.477
1	25.000	100	0.000	0.720	0.000	0.7200	0.000	0.720	0.036
Experimental Data (Double looped network)			Practical Results		waterGEMS Without pdd		With PDD (Threshold pressure 0.6m)		% Increase in Pressure
Node no	Dia. Of pipe (mm)	Elevation (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	
5	25.000	100	0.030	0.640	0.030	0.62891	0.030	0.6329	0.634
4	25.000	100	0.260	0.530	0.260	0.5473	0.250	0.5523	0.914
3	25.000	100	0.000	0.590	0.000	0.5788	0.000	0.5817	0.496
6	25.000	100	0.024	0.680	0.024	0.6800	0.024	0.6826	0.384
2	25.000	100	0.000	0.670	0.000	0.6505	0.000	0.6520	0.231
1	25.000	100	0.000	0.720	0.000	0.7200	0.000	0.7203	0.042
Experimental Data (Double looped network)			Practical Results		waterGEMS Without pdd		With PDD (Threshold pressure 0.9m)		% Increase in Pressure
Node no	Dia. Of pipe (mm)	Elevation (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	Demand (L/s)	Pressure (m H2O)	
5	25.000	100	0.030	0.640	0.030	0.62891	0.026	0.649	3.215
4	25.000	100	0.260	0.530	0.260	0.5473	0.208	0.572	4.460
3	25.000	100	0.000	0.590	0.000	0.5788	0.000	0.593	2.389
6	25.000	100	0.024	0.680	0.024	0.6800	0.021	0.693	1.943
2	25.000	100	0.000	0.670	0.000	0.6505	0.000	0.657	1.028
1	25.000	100	0.000	0.720	0.000	0.7200	0.000	0.720	0.036

Experimental Data (Double looped network)			Practical Results		waterGEMS Without pdd		With PDD (Threshold pressure 1.4m)		% Increase in Pressure
Node no	Dia. Of pipe (mm)	Elevation (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	Demand (L/s)	Pressure (m H2O)	
5	25.000	100	0.030	0.640	0.030	0.62891	0.021	0.662	5.312
4	25.000	100	0.260	0.530	0.260	0.5473	0.169	0.587	7.310
3	25.000	100	0.000	0.590	0.000	0.5788	0.000	0.602	3.927
6	25.000	100	0.024	0.680	0.024	0.6800	0.017	0.702	3.218
2	25.000	100	0.000	0.670	0.000	0.6505	0.000	0.661	1.677
1	25.000	100	0.000	0.720	0.000	0.7200	0.000	0.720	0.036
Experimental Data (Double looped network)			Practical Results		waterGEMS Without pdd		With PDD (Threshold pressure 1m)		% Increase in Pressure
Node no	Dia. Of pipe (mm)	Elevation (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	Demand (L/s)	Pressure (m H2O)	
5	25.000	100	0.030	0.640	0.030	0.62891	0.024	0.653	3.786
4	25.000	100	0.260	0.530	0.260	0.5473	0.198	0.576	5.237
3	25.000	100	0.000	0.590	0.000	0.5788	0.000	0.595	2.807
6	25.000	100	0.024	0.680	0.024	0.6800	0.020	0.696	2.291
2	25.000	100	0.000	0.670	0.000	0.6505	0.000	0.658	1.205
1	25.000	100	0.000	0.720	0.000	0.7200	0.000	0.720	0.036
Experimental Data (Double looped network)			Practical Results		waterGEMS Without pdd		With PDD (Threshold pressure 1.3m)		% Increase in Pressure
Node no	Dia. Of pipe (mm)	Elevation (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	Demand (L/s)	Pressure (m H2O)	
5	25.000	100	0.030	0.640	0.030	0.62891	0.021	0.660	5.010
4	25.000	100	0.260	0.530	0.260	0.5473	0.175	0.585	6.901
3	25.000	100	0.000	0.590	0.000	0.5788	0.000	0.600	3.707
6	25.000	100	0.024	0.680	0.024	0.6800	0.018	0.701	3.035
2	25.000	100	0.000	0.670	0.000	0.6505	0.000	0.661	1.583
1	25.000	100	0.000	0.720	0.000	0.7200	0.000	0.720	0.036
Experimental Data (Double looped network)			Practical Results		waterGEMS Without pdd		With PDD (Threshold pressure 0.7m)		% Increase in Pressure
Node no	Dia. Of pipe (mm)	Elevation (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	Demand (L/s)	Pressure (m H2O)	
5	25.000	100	0.030	0.640	0.030	0.62891	0.029	0.6393	1.647
4	25.000	100	0.260	0.530	0.260	0.5473	0.233	0.5601	2.330
3	25.000	100	0.000	0.590	0.000	0.5788	0.000	0.5860	1.237
6	25.000	100	0.024	0.680	0.024	0.6800	0.024	0.6867	0.988
2	25.000	100	0.000	0.670	0.000	0.6505	0.000	0.6540	0.544
1	25.000	100	0.000	0.720	0.000	0.7200	0.000	0.7203	0.036

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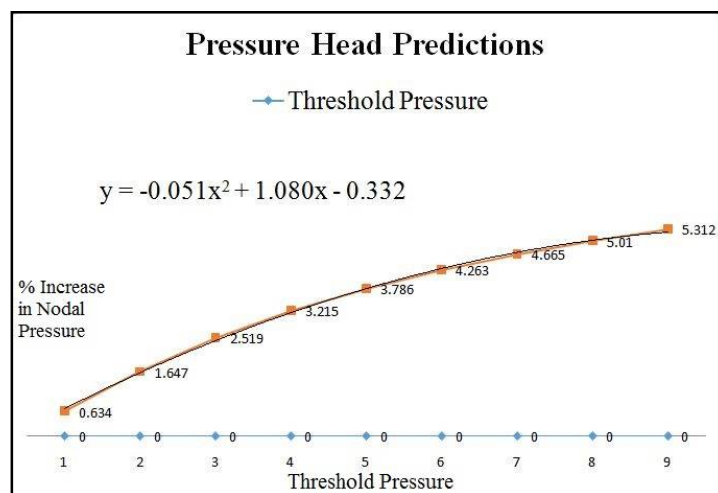
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Experimental Data (Double looped network)			Practical Results		waterGEMS Without pdd		With PDD (Threshold pressure 1.1m)		% Increase in Pressure
Nodeno	Dia. Of pipe (mm)	Elevation (m)	Demand (LPS)	Pressure (m)	Demand (LPS)	Pressure (m)	Demand (L/s)	Pressure (m H ₂ O)	
5	25.000	100	0.030	0.640	0.030	0.62891	0.023	0.656	4.263
4	25.000	100	0.260	0.530	0.260	0.5473	0.189	0.580	5.883
3	25.000	100	0.000	0.590	0.000	0.5788	0.000	0.597	3.156
6	25.000	100	0.024	0.680	0.024	0.6800	0.019	0.698	2.579
2	25.000	100	0.000	0.670	0.000	0.6505	0.000	0.659	1.353
1	25.000	100	0.000	0.720	0.000	0.7200	0.000	0.720	0.036

Threshold pressure	0.6m	0.7m	0.8m	0.9m	1m	1.1m	1.2m	1.3m	1.4m
Node5	0.634	1.647	2.519	3.215	3.786	4.263	4.665	5.010	5.312
Node4	0.914	2.330	3.514	4.460	5.237	5.883	6.432	6.901	7.310
Node3	0.496	1.237	1.876	2.389	2.807	3.156	3.452	3.707	3.927
Node6	0.384	0.988	1.519	1.943	2.291	2.579	2.825	3.035	3.218
Node2	0.231	0.544	0.813	1.028	1.205	1.353	1.477	1.583	1.677
Node1	0.042	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036

Table 3: % increase in nodal pressures



Above equation is generated from threshold pressure values at X axis vs. percentage increase in pressure heads at each node at Y axis. This equation will give us approximate value of pressure head (% increase) if threshold pressure is given.

Advantages of study: Study is related to practical work. All the experimental results are matching with software simulation. This will give benefits to workout simulation for larger and complicated networks.

Limitation of study: All the above data is generated on the basis of small network as compared to actual pipeline networks in which diameter varies from 50mm to 2100 mm.

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