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A Comparative Study on Hydraulic Properties of Different Pipe Material with Same Diameters in Buried Pipe Distribution System

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Abstract

A research work was conducted on buried pipe distribution systems in two different DTW irrigation schemes located in the villages of Alokdia and Chongacha in the sadar upazilla of Sirajganj district. The main objectives of the study were to determine and compare the hydraulic properties of flow through buried pipes made of different materials and having same diameters. Air vents of the buried pipe were used as piezometers for the calculation of hydraulic grade line along the pipe length. The flow rate was measured by a cutthroat flume, placed in the open channel several meters away from the outlet of the buried pipe. This work shows that hydraulic properties of buried pipe such as frictional, entrance and exit losses, as well as friction factor are nonlinearly related to velocity of flow. Frictional, entrance and exit losses, as well as friction factor are significantly smaller in a PVC pipe compared to a CC pipes for the same velocity of flow. This study suggests

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that, as the loss of head in a PVC pipe is significantly smaller than in CC pipe, the former is particularly suitable for long buried pipe lines.

Keywords: Buried pipe, head loss, open channel, velocity, entrance loss and exit loss.

INTRODUCTION

Agriculture is the largest user of water and covers about 70 percent of the worldwide consumption. Minor irrigation technologies namely deep tube well (DTW), shallow tube well (STW) and low lift pump (LLP) have been spreading rapidly in Bangladesh for the last four decades. Obviously, various types of studies are carried out for addressing the issues and problems associated with both the operation and management of irrigation systems. Amongst these, Improvement of performance of water distribution system is the prominent one. Proper water distribution system and its efficient management play a very important role in the command area development of any irrigation project.

In Bangladesh, use of earthen open channel for water distribution is common in the minor irrigation sector. These earthen open channel distribution systems generally have very low conveyance and distribution efficiencies, resulting in less irrigated area and high maintenance cost. It is fact that, these systems confront some physical obstructions and canals suffer from high seepage, leakage and evaporation losses.

1.1 Statement of problems

Field open channels in surface water distribution systems in Bangladesh generally originate from a DTW or a STW or even from a major canal outlet, run in a random manner with a little consideration of topographical features of the areas (BARI, 1988). Seepage and evaporation losses are high in such systems. Besides these, Michael (1978) reported that about 2 to 4 percent of the cultivable land area is taken up by open channels in these systems. Plausible economic solutions of some of these problems in the areas with plain topography and having heavy to medium textured soils, include construction of improved (compact) earth channel with necessary water control structures and strengthening operation and maintenance to improve performance of the system. However, the buried pipe distribution system (BPDS) may be the best solution to these problems, especially for uneven topography and light textured soils provided the users can afford it.

In a buried pipe distribution system, the pipelines are placed underground and cultivation can be done above the pipelines without interference to farming operations. If the pipelines are properly installed, they are very durable and the maintenance cost is low. Their placement below ground surface prevents any damage and eliminates water loss by evaporation. The systems are operated under pressure. Therefore, they can be laid uphill and downhill, thus permitting the delivery of water to areas not accessible when open channels are used. They do not become clogged by vegetation and windblown materials. With an underground pipeline system, the DTW need not be located at the highest point of the farm but may be at a location that provides the best water supply. No land needs to be reserved for right-of-way in the buried pipe distribution system (BPDS). This is not only an economic advantage but also a practical benefit when a large number of field plots belonging to different individuals are not required to be crossed to distribute water from a pumping well.

Despite the clear advantages and benefits of the buried pipe, some problems have been observed in the systems, for instance, unsatisfactory jointing methods and techniques, frequent leaks, faulty outlet valves, poor hydraulic design (using trial and error method) spillage from air vents, higher initial cost and so on.

Since BPDS uses low-pressure pipes, maximum pressure in the buried pipes should not exceed a limiting value; Therefore, the rate of head loss is an important parameter to be considered in the design of a BPDS. For a given pipe, the head loss per unit length of pipe again depends on discharge through the pipe.

1.2 Objectives

The main objective of this work was to determine major and minor losses in buried pipe distribution systems having same pipe diameters and different pipe materials. The specific objectives were:

a) to study the friction loss parameters of selected schemes for different flow rates,
b) to determine the head losses at the entrance and exit of a buried pipe system for different discharges, and
c) to compare the hydraulic properties of buried pipe distribution system (BPDS) of same pipe diameters and different pipe materials.

MATERIALS AND METHODS

3.1 The study schemes

To study the hydraulic properties of buried pipe with same pipe diameter and different pipe materials, two DTW irrigation schemes were selected. The study sites were located in the villages of Alokdia and Chongacha in the sadar upazilla of Sirajganj district. The sites were about 10 km west of the upazilla headquarter. The diameters of the buried pipes in the study schemes were 25 cm and made of CC and PVC respectively.

A schematic diagram showing the hydraulics of flow in a buried pipe system is presented in Fig. 3.2.

In this work, the buried pipe distribution systems were run to measure the head losses in the pipe, as well as at the inlet and outlet, for different discharges. The flow rate was measured by a cutthroat flume placed in the open channel several meters away from the outlet of the buried pipe.

3.2 Head loss in pipe

Loss of head in feet of fluid, meaning loss of energy expressed in foot-pounds per pound of fluid, occurs in any flow of fluid through a pipe. The loss is caused by: (1) “pipe friction” along the straight sections of pipe of uniform diameter and uniform roughness and (2) changes in velocity or direction of flow. Losses of these two types are ordinarily referred to respectively as major losses and minor losses.

Loss of head due to pipe friction

Frictional losses in a pipe are considered to be a major loss.
From Darcy-Weisbach formula, loss of head h_f is given by

$$h_f = f \frac{L}{D} \frac{V2}{2g}$$

Where,
f = coefficient of friction for pipe, dimensionless
L =length of pipe, m
g = acceleration due to gravity, m/s^2
V = velocity, m/s
D = diameter of pipe, m
h_f= head loss, m

This formula is of convenient form since it expresses the loss of head in terms of the velocity head in the pipe. Moreover, it is dimensionally correct since *f* is a numerical factor L/D is a ratio of lengths, and h_f and $V^2/2g$ are both expressed in units of length.

Value of *f* depends on pipe materials and velocity of flow. Value of *f* for different pipe materials and velocities are available in relevant textbooks.

3.3 Methodology

Before starting the experimental work, the buried pipelines, air vents, outlets, storage tank and open channels were properly checked to ensure that they are well in order. The best pipe line of the distribution systems of each study scheme was selected. Flow rate through the buried pipe under study was controlled by adjusting the cap plates of the inlets in the storage tank and the alfalfa valves. After starting the pump, sufficient time was allowed to elapse to stabilize the flow through the buried pipe. A cutthroat flume was placed in the open channel several meters away from the outlet for the measurement of discharge. The flume was installed with its floor horizontal, length wise and breadth wise.

Air vents of the buried pipe were used for the measurement of pressure head in the pipeline. When the flow through the pipe became steady, piezometric heads, h_1 and h_2 were measured with reference to an arbitrary datum as shown in Fig. 3.2. Total head in the storage tank, H_i causing flow through the pipe and the total head H_0 (Fig. 3.2) at the outlet were also measured.

Loss of head in the pipe between the two air vents was calculated by subtracting h_2 from h_1. From this, loss of head in meter per 100 m length of pipe was calculated. The hydraulic grade line passing through h_1 and h_2 was extended backward and forward. From this line, potential head h_i in the pipe, just outside the storage tank, was estimated in order to calculate the entrance loss. Similarly potential head h_0 in the pipe just before the outlet was estimated from this hydraulic grade line for the calculation of exit loss.

Entrance loss h_{fi} in meter at the inlet was calculated from,

$$h_{fi} = H_i - h_i - V2/2g$$

Exit loss at the outlet $h_{fo} = h_o - H_o + V^2/2g$

Where, V is the velocity in meter per second through the buried pipe, H_i, h_i, H_o and h_o are in meter. For the estimation of discharge, the upstream flow depth h_a and the downstream flow depth h_b were measured from the scales attached to the flume. The flow condition was determined from submergence ratio h_b/h_a and the flow rate was obtained.After taking these measurements, for a particular discharge, flow to the selected pipe line was changed by adjusting the alfalfa valves of other pipe lines. Some time was allowed to elapse in order to stabilize the flow in the buried pipe. When the flow in the pipe became steady, H_i, h_1 h_2 H_o were measured for calculation of head losses and h_a and h_b for discharge. The work was repeated for several variations of discharge.

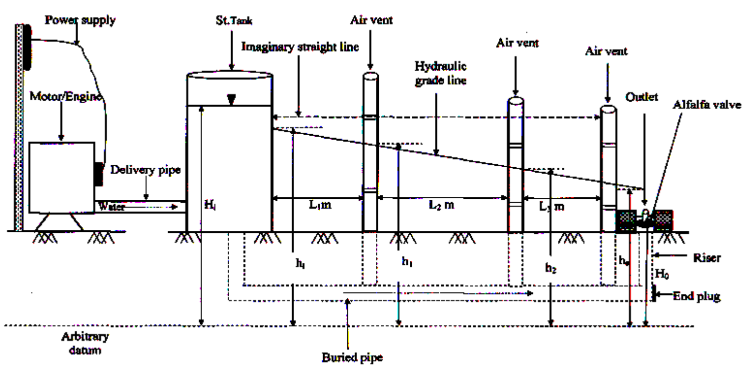

Fig.3.2: A schematic diagram of the hydraulics of flow in a buried pipe

RESULTS AND DISCUSSION

For each site, hydraulic properties of the buried pipe are calculated from measured data and summarized in tables. Results obtained in different sites are sequentially presented below in tables and graphs.

Table C-1: Measurement of discharge data by cutthroat flume and pressure head at different points of 25 CC buried pipe.

Test No.	h_a (cm)	h_b (cm)	S= h_b/ h_a	Flow condition	Q(m^3/s)	V^2/2g	H_i(m)	h_i(m)	h_1(m)	h_2(m)	h_0(m)	H_0(m)
1	20.80	6.17	0.30		0.0496	0.050	1.337	1.130	1.040	0.843	0.761	0.425
2	19.53	5.79	0.30	Free	0.0445	0.042	1.205	1.030	0.956	0.783	0.710	0.405
3	18.89	5.54	0.29	flow	0.042	0.038	1.130	0.970	0.896	0.734	0.667	0.396
4	17.30	5.11	0.29		0.037	0.029	0.925	0.786	0.728	0.602	0.548	0.346
5	17.10	5.05	0.29		0.035	0.026	0.865	0.747	0.693	0.574	0.524	0.337
6	15.87	4.57	0.29		0.03	0.020	0.763	0.678	0.634	0.537	0.497	0.325
7	15.28	4.4	0.29		0.027	0.05	0.640	0.575	0.537	0.453	0.418	0.272
8	13.34	3.87	0.29		0.023	0.011	0.516	0.505	0.473	0.403	0.373	0.255
9	12.07	3.32	0.27		0.09	0.008	0.474	0.393	0.365	0.304	0.278	0.215

Table C-2: Hydraulic properties for different discharges of 25cm CC buried pipe

Discharge Q (m^3/s)	Velocity V (m/s)	Frictional loss h_f (m/100m)	Friction factor, f	Entrance loss h_{fi}(m)	Exit loss h_{fo}(m)
0.0496	0.98	0.61	0.031	0.157	0.386
0.0445	0.91	0.54	0.032	0.133	0.347
0.042	0.86	0.51	0.034	0.122	0.309
0.037	0.75	0.40	0.034	0.110	0.232
0.035	0.71	0.37	0.036	0.092	0.213
0.031	0.63	0.30	0.037	0.065	0.192
0.027	0.55	0.26	0.042	0.050	0.161
0.023	0.47	0.22	0.049	0.058	0.129
0.019	0.39	0.19	0.061	0.073	0.071

Table P-1: Measurement of discharge data by cutthroat flume and pressure head at different points of 25 cm PVC buried pipe.

Test No.	h_a (cm)	h_b (cm)	S= h_b/ h_a	Flow condition	Q(m^3/s)	V^2/2g	H_i(m)	h_i(m)	h_1(m)	h_2(m)	h_0(m)	H_0(m)
1	21.27	6.52	0.31		0.0524	0.058	0.835	0.656	0.639	0.559	0.496	0.327
2	20.16	5.98	0.30	Free	0.0496	0.047	0.721	0.571	0.558	0.493	0.443	0.303
3	18.45	5.41	0.30	flow	0.0415	0.037	0.631	0.510	0.499	0.447	0.406	0.286
4	17.24	5.10	0.29		0.0363	0.028	0.548	0.453	0.450	0.407	0.374	0.264
5	16.94	4.88	0.29		0.0325	0.022	0.453	0.401	0.393	0.359	0.333	0.237
6	14.60	4.28	0.29		0.0260	0.014	0.385	0.348	0.323	0.323	0.307	0.228
7	13.34	3.85	0.29		0.0204	0.009	0.355	0.314	0.296	0.296	0.285	0.213
8	10.95	2.95			0.0153	0.005	0.322	0.271	0.260	0.260	0.253	0.19247/

Table P-2: Hydraulic properties for different discharges of 25 cm PVC buried pipe.

Discharge Q (m^3/s)	Velocity V (m/s)	Frictional loss h_f (m/100m)	Friction factor, f	Entrance loss h_{fi}(m)	Exit loss h_{fo}(m)
0.0524	1.07	0.292	0.0125	0.121	0.227
0.0496	0.96	0.235	0.0125	0.103	0.187
0.0415	0.85	0.190	0.0128	0.084	0.157
0.0363	0.74	0.155	0.0130	0.067	0.138
0.0325	0.66	0.123	0.0130	0.031	0.118
0.0260	0.53	0.075	0.0130	0.023	0.093
0.0204	0.42	0.053	0.014	0.032	0.081
0.0153	0.312	0.032	0.0160	0.046	0.067

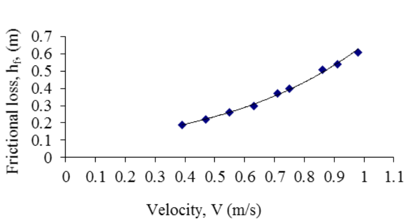

Fig.C-1: Relationship between velocity and frictional loss for 25 cm CC buried pipe

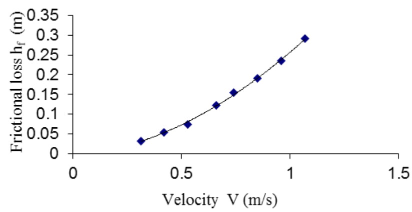

Fig.P-1: Relationship between velocity and frictional loss for 25 cm PVC buried pipe

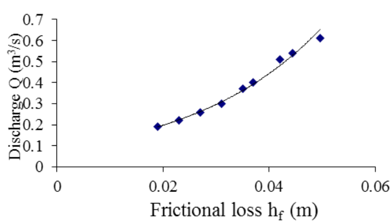

Fig.C-2: Relationship between discharge and frictional loss for 25 cm CC buried pipe

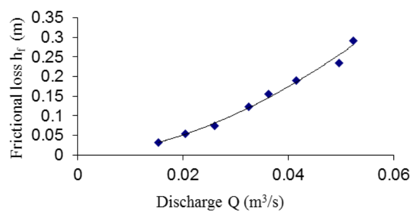

Fig.P-2: Relationship between discharge and frictional loss for 25 cm PVC buried pipe

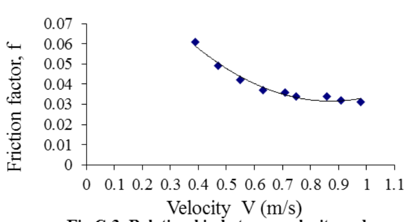

Fig.C-3: Relationship between velocity and friction factor for 25 cm CC buried pipe

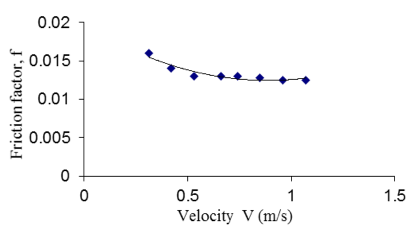

Fig.P-3: Relationship between velocity and friction factor for 25 cm PVC buried pipe

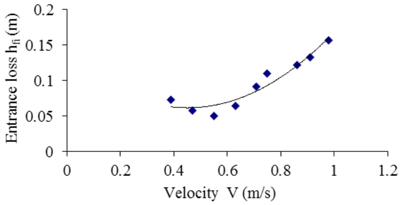

Fig.C-4: Relationship between velocity and Entrance loss for 25 cm CC buried pipe

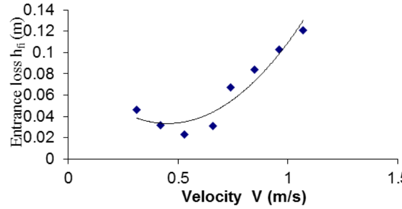

Fig.P-4: Relationship between velocity and Entrance loss loss for 25 cm PVC buried pipe

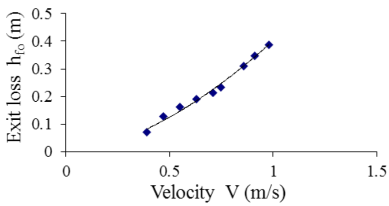

Fig.C-5: Relationship between velocity and Exit loss for 25 cm CC buried pipe

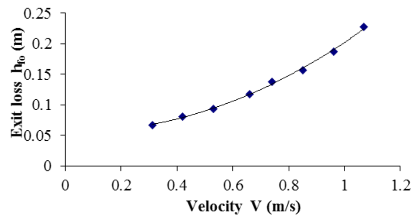

Fig.P-5: Relationship between velocity and Exit loss for 25 cm PVC buried pipe

4.4 Comparisons of hydraulic properties

The study shows that for the same velocity and same discharge, the frictional losses were different for different pipe materials and same diameter. As indicated in Figs.C-1 and Figs.P-1, the frictional loss for a velocity of 0.8 m/s is the lowest in PVC buried pipe compared to the CC buried pipe, for the same discharge of 0.03 m^3/s, frictional loss is the lowest in PVC pipe compared to the CC pope (Figs.C-2 and Figs.P-2).

For the same velocity of flow, friction factor varies for different pipe materials (Figs.C-3 and Figs.P-3). The friction factor for a velocity of 0.8 m/s is the lowest in the PVC buried pipe than CC buried pipes.

For the same velocity of flow, entrance and exit losses vary for different pipe materials and same diameter (Figs.C-4, Figs.P-4, Figs.C-5 and Figs.P-5). The entrance loss for a velocity of 0.8 m/s is the lowest in PVC buried pipe than that of CC buried pipe. The exit loss for a velocity of 0.8 m/s is the lowest in PVC buried pipe than the CC buried pipe.

From these results and discussion, it can be said that, the frictional loss nonlinearly related to both velocity and discharge. Frictional loss in PVC is observed to be significantly smaller than that in CC pipe.

The friction factor decreases nonlinearly with the increase of velocity of flow in a given buried pipe. Friction factor is significantly smaller in PVC buried pipe than in CC pipe for the same velocity of flow.

The entrance loss initially decreases up to a certain increase of velocity and then it increases with the increase of velocity. For the same velocity, entrance loss is smaller in PVC pipe than the CC pipe.

Exit loss varies nonlinearly with the velocity of flow. For the same velocity, exit loss is smaller in PVC pipe than in CC pipe. Exit loss is greater than the entrance loss except very low flow rates. All types of losses are smaller in PVC pipe compared to CC pipe for the velocity of flow.

CONCLUSIONS

From this study on cement concrete and PVC pipes of same diameter, the following conclusions could be made.

- Hydraulic properties of buried pipe, such as frictional, entrance and exit losses as well as friction factor are nonlinearly related to velocity of flow;
- Frictional, entrance and exit losses as well as friction faction factor are significantly smaller in a PVC pipe compared to a CC pipes for the same velocity of flow;
- Exit loss is greater than the entrance loss except very low flow rates;
- As the loss of head in a PVC pipe is significantly smaller than in CC pipe, the former is particularly suitable for long buried pipe lines.

RECOMMENDATIONS

- Similar study should be carried out in other buried pipe irrigation schemes where pipes of other materials are used;
- PVC pipe is found to be superior to CC pipe in terms of hydraulic properties. However, economic analyses need to be carried out to determine which of these is profitable to use in buried pipe distribution system.

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