EVALUATION OF FRICTION LOSSES DISSIPATE ENERGY AND ASSOCIATED COSTS FOR UNDERGROUND CONSTRUCTION IN EGYPT

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ABSTRACT

The underground Pipeline materials in Egypt due to frictional losses cause annual service cost which makes it uneconomic. For pressure pipe, head loss must be remunerated by pumping or larger diameter, while for gravity flow pipe head loss must be remunerated by slope of the installed pipe.

The present paper demonstrates the characteristic of pipe, the influence of flow loss and cost of frictional resistance.The performance of head loss of Glass Reinforced plastic Pipes to different materials with varying internal roughness were analyzed in this work.

The analysis demonstrated that in pressure pipe the head loss of Glass Reinforced plastic Pipes is less than ductile, prestressed concrete and steel pipes for different diameters by 4.65 % to 8.13 % when the pipes are in normal condition and by 10.39 % to 15.35 % when the pipes are in poor condition. For gravity pipe in Glass Reinforced plastic Pipe the slope and head loss is less by 68.87 % than ductile, prestressed concrete and steel pipes when the pipes are in normal condition.

Key words: Head losses,GRP, prestressed concrete, ductile and steel, Hydraulic Analysis, net present value,cost savings.

INTRODUCTION

The head loss and costs associate are important rudiments to proper selection of pipe materials, there for height of the roughness elements on the pipe wall and the flow characteristics can be used to define the pipe as being hydraulically smooth or rough.

The hydraulic Analysis used in determining to analyze head loss and energy requirements in pipes, according to the interior pipe surface in different pipe materials, and this will assist the engineer in the process of pipe material selection. By comparing the potential performances of the pipes systems and evaluate a result of the differences in head loss and costs associate.

STUDY APPROACH

The study made on both types of pipe application, full flow under pressure during typical operating conditions, partial flow for gravity pipes, the discharge rate have been used 1 m^3/sec, and the pipe length to be analyzed is 6 m. Materials used for comparison are prestressed concrete, steel and ductile pipes. Insertion of fittings is not necessary because the comparison is for piping materials.

Some pipe materials are vulnerable to corrosion than others, and the same conditions that cause corrosion can affect the flow characteristics of the pipe. Many engineers design a pipe system as if the pipe already were in use for several years, because, for many pipes, the flow characteristics change with time, typically having greater frictional loss as the pipe ages, the greater friction loss results from the pipe's interior surface becoming rougher, from corrosion product buildup or both.

In the present work the Pipe condition was assumed to be normal condition (pipe that has been in use for several years) and poor condition(pipe that has been in use for several years but it is relatively poor compared to pipe in "normal" condition).

The present work use a number of computational methods can be used to determine the head loss, and it is based on using universally methods accepted by practicing engineers. The suitability of each method depends on the type of flow and the level of accuracy required where the smooth interior surface of the pipe should be considered when selecting the roughness coefficient or friction factor.

For pressure pipe, the Colebrook-White equation, which can be used to determine the friction factor **f**, where **(e/D)** pipe's relative roughness and **(Re)** Reynolds Number:

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{e}{3.71D} + \frac{2.51}{R_e\sqrt{f}}\right) \qquad \text{------------------------------------(1)}$$

- A higher Reynolds number indicates a more turbulent fluid flow condition in the pipe.

Re = VD / n

…….where **V** = average flow velocity (m/s), **D** = pipe internal diameter (m), and **n** = kinematic viscosity of the fluid (1.141 x 10^{-6} m^2/sec for water at 15 degrees C).

The Darcy-Weisbach equation gives the head loss in either laminar or turbulent flows in both hydraulically smooth and rough pipes. The Darcy-Weisbach friction factor, f, is based on the absolute roughness of the selected pipe material, pipe internal diameter and the Reynolds number. The head loss calculations are for turbulent flow in the pipe is described by the Darcy-Weisbach formula. The friction loss, or head loss, is expressed in meters of water.

$$h_L = f \frac{L}{D} \frac{V^2}{2g} \quad \text{--}(2)$$

... Where h_L = head loss (m), (frictional loss) f = the D-W friction factor, L = pipe length (m), V = flow velocity (m/s), D = internal pipe diameter (m), and g = gravitational constant (9.81 meters/second/second). The pipe diameter used for pressure pipe based on the simple relationship: **V = Q / A** where **V** is the average flow velocity (m/s), **Q** is the flow rate (m^3/s) and **A** is the pipe cross-sectional area (m^2).

The Surface absolute roughness parameter, **e**, in mm is different for each pipe material as shown in Table (1).

Table (1) Values of e for some commercial (new) Pipes, From Ref. [1]

Material	***e, mm***
Concrete	0.2 to 2
Cast Iron	0.26
Commercial Steel or Wrought Iron	0.046
PVC/GRP	0.0021

For partial flow in an Open channel flow

There are to ways to design gravity flow pipe the first is to find the smallest diameter pipe to achieve the requirement flow rate for a given slope Or, the least slope to achieve the required flow rate.

$$D = \left[\frac{3.21 \; n \; Q}{S^{0.5}}\right]^{0.375} \quad \text{--}(3)$$

$$S = \left[\frac{n \; Q}{0.321 D^{0.667}}\right]^{2} \quad \text{--}(4)$$

Where D = internal diameter of pipe (m), n = Manning coefficient, Q = required flow rate (m^3/s) and S = slope (m/m).

The velocity and flow rate were checked for each pipe with the selected slope and diameter combination. The Manning equation is used and valid for hydraulically rough turbulent flow. The Manning coefficient value, n, is often used to describe the inner surface roughness of pipe materials. The coefficient of roughness is an empirically derived constant to reflect the average flow characteristic for a given pipe material for relatively low flow velocities or when the slope is less than 0.1. The Manning equation is:

$$V = \frac{1}{n} R^{2/3} S^{1/2} \qquad \text{--(5)}$$

... where:
R = hydraulic radius (m) = D/4 for a full flowing pipe
S = hydraulic slope (m/m) = h_L / L
n = Manning coefficient is different for each pipe material as shown in Table (2).

For gravity pipe the hydraulic slope was calculated by entering fixed diameter in equation **(4)**

Table (2) values of *n* for some commercial (new) Pipes, From Ref. [1]

Pipe Material	*n* Values (used in designing)
Concrete	0.01 - 0.017
GRP	0.009 - 0.013
Verified sewer pipe	0.01 - 0.017
Riveted steel	0.015 - 0.017
Galvanized Iron	0.015 -0.017

ECONOMICAL ANALYSIS

Taking unto consideration more sophisticated techniques (net present value, life cycle costing, etc.) that consider the time value of money can also be used to evaluate the relative economics of alternative pipe materials. These techniques consider the installed cost of pipe in the calculation and future cash flow are discounted by an appropriate discount rate. The typical value for life of the system in years is 20 years. Efficiency of pumping is 88%, the current cost of energy for the owner who operates this pumping plant equal to 0.25 L.E/kWh (for high usage industrial customers). The Estimated rate of Inflation (in the cost of energy) over 20 years equal to 5 % the estimated cost of capital (discount rate) over 20 years equal to 12 %. The NPV analysis includes the differences in costs for the life of the system (or analysis period) expressed in today's value.

STUDY RESULTS

The values of the selected assessment parameters mentioned above are calculated for Glass Reinforced plastic "GRP" pipe and other matereils under selected conditions. The results shown in Figures (1 - 6) highlight the importance of choosing the appropriate economic pipe materials.

Pressure Pipe

It is concluded that the differences in head loss as a percent of the investigated pipes versus the diameters in normal and poor conditions are shown in Figure (1) and the differences in friction factor as a percent of the investigated pipes versus the diameters in normal and poor conditions are shown in Figure (2) of Glass Reinforced plastic Pipe is less than other materials by 4.65% to 8.13% when the pipes are in normal condition according to diameters and less by 10.39% to 15.35% when the pipes are in poor condition.

The net present value per meter in L.E over the life of a typical piping system versus diameters in normal and poor conditions are shown in Figure (3 and 4) of Glass Reinforced plastic Pipe is less than other materials. This could contribute to substantial cost savings from 5% to 8.12% for Glass Reinforced plastic Pipe less than other materials when the pipes are in normal condition, and from 10.7% to 15.3% for Glass Reinforced plastic Pipe less than other materials when the pipes are in poor condition, it is concluded from Figure (5).

Gravity Pipe

Glass Reinforced plastic Pipes have less slope in a range between 66.67% to 68.87% than other materials when the pipes are in normal condition it is concluded from Figure (6).

CONCLUSION AND RECOMMENDATIONS

Limited to the conditions investigated in the present study and based on the obtained results, the following conclusions can be drawn:

- Glass Reinforced plastic Pipes avoid interference with the load regime with its smooth surface that impedes increase of cost of frictional resistance more than other materials. The differences in the Net Present Value per meter of pipe with smoother inner surface and resulting lower frictional losses, gives us a significant savings can be applied to the systems analysis to identify which pipe material offers the low cost solution.

- This mean by specifying smoother pipe, with its resulting lower friction loss, may allow a smaller diameter pipe to be used for the same flow rate, or the lower friction loss could be converted to a lower cost of pumping.

- For Gravity pipe, the smoother pipe allows a lower diameter for the same slope or a lower slope for the same diameter. Either of these advantages will typically result in a less costly installed pipe system when using the smoother-flow pipe material. The installation cost savings from shallower trenches or fewer lift stations can affect the project budget.

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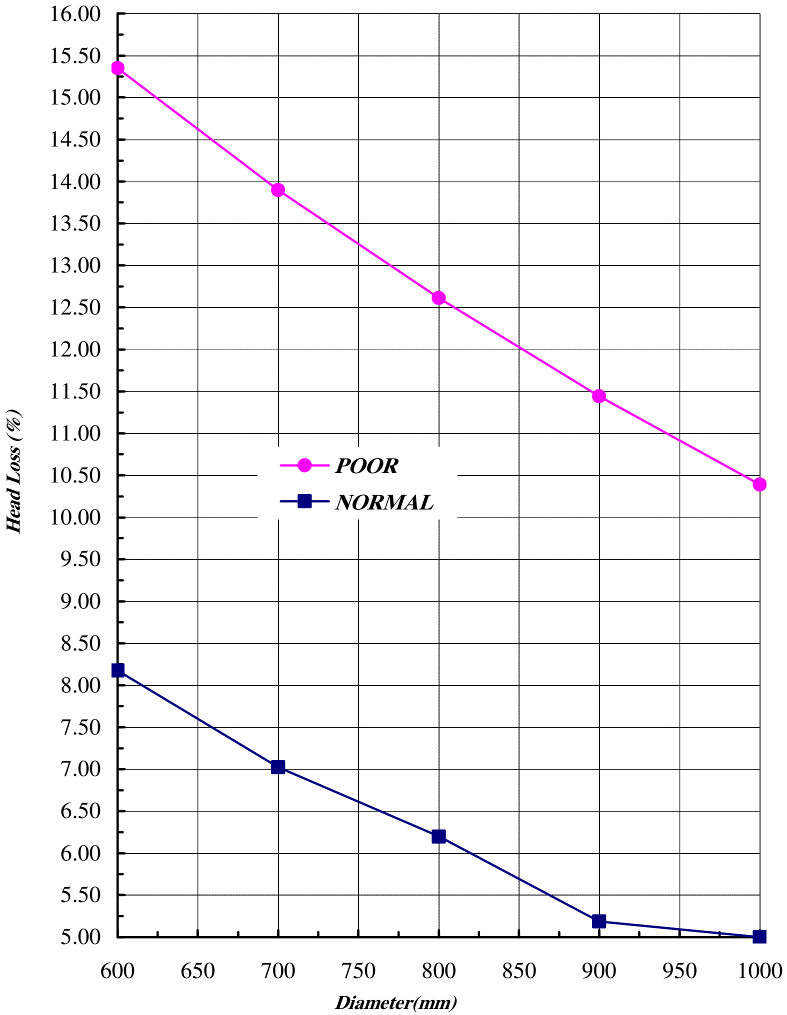

Fig.(1):Differences in Head Loss% vs. Diameter in normal and poor condition for GRP Pipe less than other materials

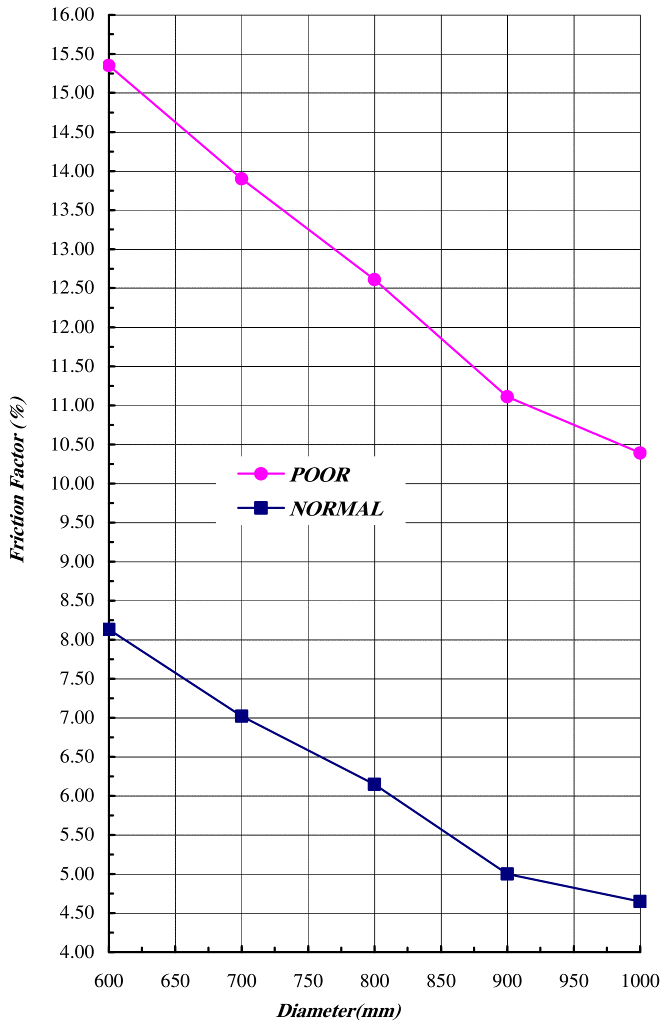

Fig.(2):Differences in Friction Factor % vs. Diameter in normal and poor condition for GRP Pipe less than other materials

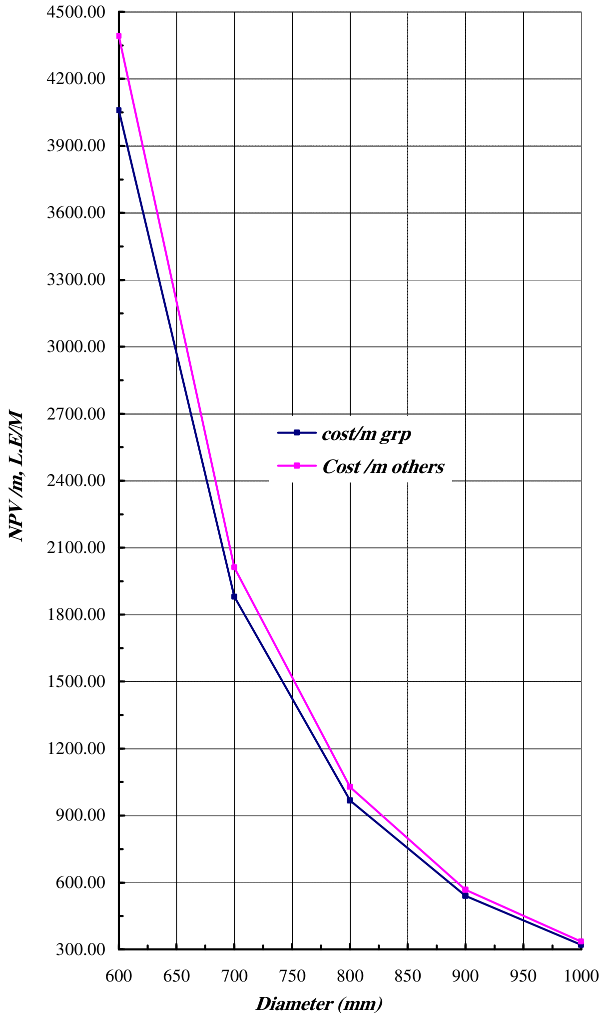

Fig.(3): Net present Value per meter L.E/m VS. Diameter in normal condition for GRP Pipes and Other Materials

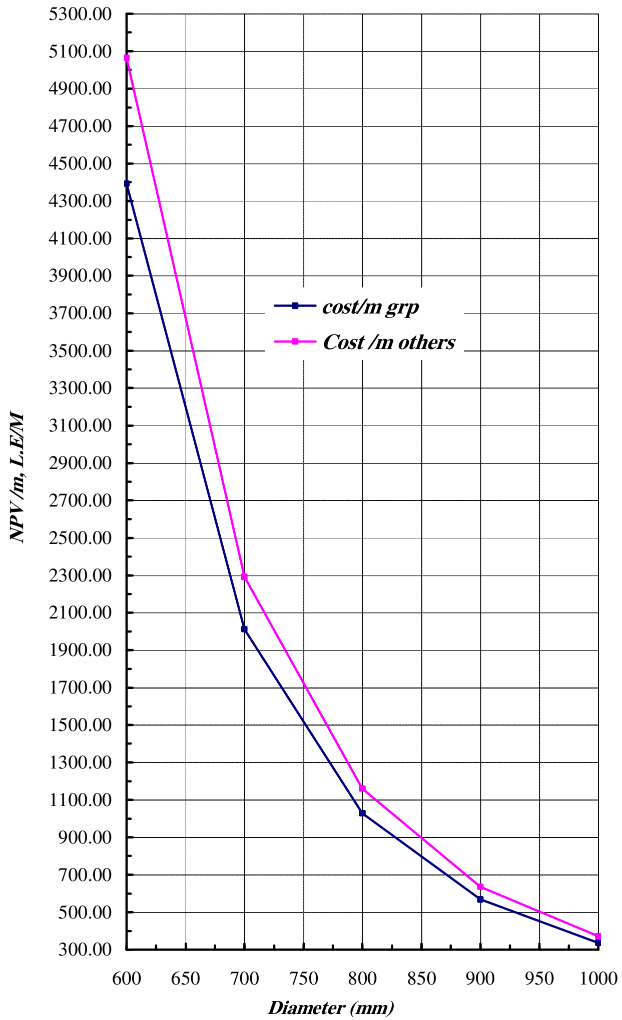

Fig.(4): Net present Value per meter L.E/m VS. Diameter in Poor condition for GRP Pipes and Other Materials

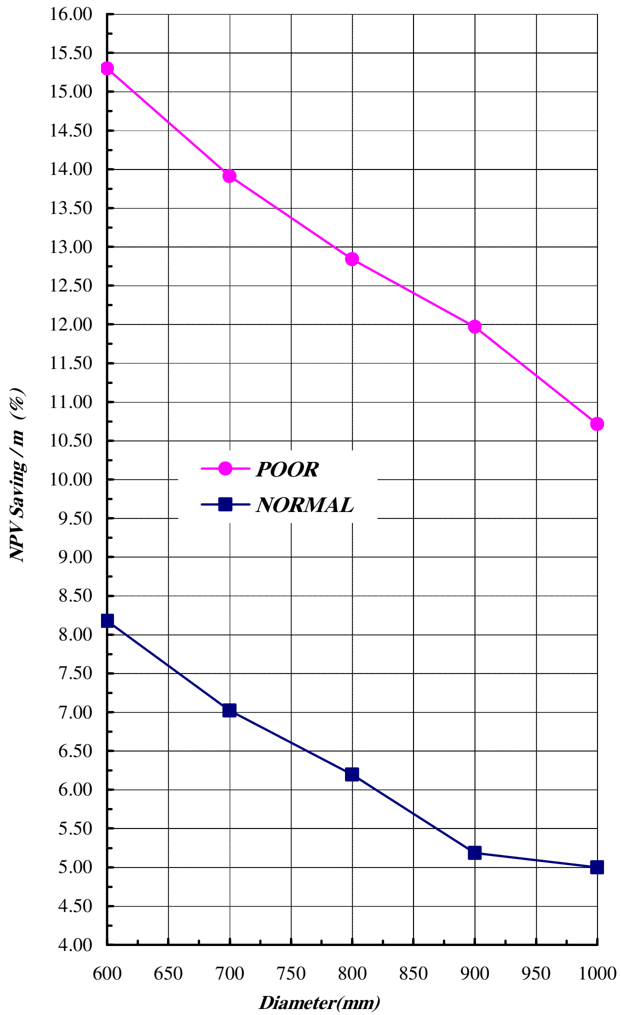

Fig.(5):Differences in Net Present Value Saving /m % vs. Diameter in normal and poor condition for GRP Pipe less than other materials

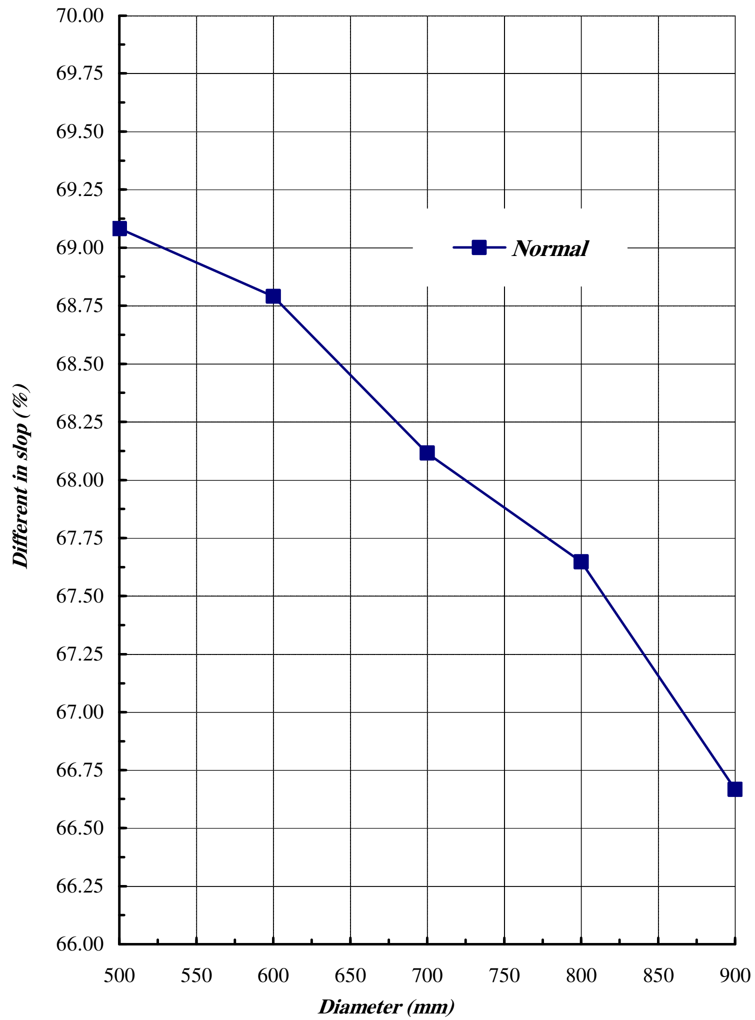

Fig.(6): Defference in slope vs. Diameter for GRP Pipes Less than other materials