Flow Characteristics of Reinforced Concrete and HDPE Pipe for Stormwater Drainage Applications

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Introduction

This report sets out relevant technical and engineering facts derived from a number of publications concerning the discharge capacity of pipelines constructed from reinforced concrete (R.C.) and high density polyethylene (H.DP.E.).

Pipe Flow Charts

There are a number of flow charts available relating pipe diameter, slope and discharge for different friction factors. The assumptions made in deriving such charts differ in a number of areas e.g. water temperature, water quality, 'field' or 'laboratory' conditions etc. In order to obtain a meaningful comparison of flow rates from different pipe materials it is essential to use data derived by making the same assumptions for each pipe material.

Pipe Friction

The pipe friction is influenced by:

(i) material pipe is made from and method of manufacture (roughness);
(ii) type of jointing and pipe laying technique used;
(iii) 'in-service' condition i.e. debris in water and sediment build up, and
(iv) number of fittings, bends, manholes etc.

For comparative purposes we will only deal with points (i) and (iii) above since the effects of (ii) and (iv) can be considered equal for different materials used in the same pipeline.

Roughness Co-efficients

The most widely used and accepted charts relating pipe flow to slope and diameter are the Colebrook-White charts which use a roughness coefficient 'ks'. Australian Standard 2200-1978(1) gives a list of values for ks in Table 1. The values we are concerned with are:

Concrete 0.03 - 0.I5 mm

Polyethylene 0.003 - 0.015 mm

Note that there is no value for "Black Brute" pipe quoted in A.S. 2200 but laboratory tests by Tullis et al (2) suggest that corrugated H.D.P.E. pipe with a smooth liner (such as 'Black Brute') may have a ks value ranging from 0.015 - 1.0 mm.

The footnotes to Table 1 of A.S. 2200-1978 give a number of factors influential on the 'ks' value and state that "the original surface of pipes may be of little consequence". This is mainly due to the build up of debris and sediment and the fact that the tabulated values of ks are for clean water and laboratory conditions. The Concrete Pipe Association of Australasia (3) recommends the adoption of a ks value of 0.6 mm for most stormwater drain designs, but this value should be modified through engineering judgment where additional data is available.

With these factors in mind it is reasonable to assume that the pipe friction coefficients for concrete and profile wall H.D.P.E. will be similar when calculating flows for 'in-service' conditions.

Pipe Diameter

The pipe internal diameter to be used when deriving flow rates should be the actual minimum pipe diameter and not the nominal diameter. This actual minimum diameter is derived by using the specified diameter less a tolerance for reinforced concrete pipe and the actual specified diameter for H.E.P.E. pipe. For most R.C. pipes the actual minimum diameter is slightly larger than the nominal diameter whereas for most H.D.P.E. pipes the actual minimum diameter is slightly less than the nominal diameter.

Pipe Deflections

Tests have shown that flexible walled pipes (e.g. H.D.P.E.) do not remain circular due to pressures exerted by backfill. This deflection changes the pipe cross-section to an elliptical shape thus reducing the area of waterway. It has been shown that for an elliptical pipe deflection of around 6%, the discharge capacity is reduced by about 2%. Hardie Iplex (4) state that it is accepted in Australia to design for a long term deflection of 7.5% which in effect reduces the discharge capacity by approximately 2%.

Comparison Flow Rates

The following table has been developed by considering a pipeline on a slope of 0.5% for various values of ks and pipe diameter. The flow rates given have been computed using the Colebrook- White formula with actual minimum diameters (specified diameter minus 7mm for R.C.P. and specified diameter for H.D.P.E.). No deduction has been applied to the H.D.P.E. values to allow for reduction of discharge capacity due to pipe wall deflections.

Nominal Diameter (mm)	Actual Diameter (mm)		Discharge (l/sec) for Slope of 0.5%			
	R.C.P.	H.D.P.E	ks = 0.6	ks = 0.06	ks = 0.03	ks = 0.01
450	450		229	281	290	299
		440	215	265	274	283
600	603		493	610	635	659
		590	464	571	592	612
750	755		888	1091	1130	1171
		740	842	1035	1072	1110
1200	1212		3067	3750	3894	4045
		1190	2923	3575	3712	3853

This table shows that for clean water values of ks in the range 0.06 - 0.01 there is very little difference in flow rates for H.D.RE. and R.C. pipes. If it is assumed that ks - 0.06 (the mid range specified by A.S. 2200-1978) applies to R.C.P and ks - 0.01 (the low end of the range quoted by Tullis et al) applies to H. D. P E. then for clean water design purposes the flow rates from these pipes can be assumed to be equal.

In pipelines where a build up of sediment and debris is likely, a ks value of 0.6 should be used if more accurate information is not available. This value of ks - 0.6 is independent of pipe material and hence the flow rates are independent of pipe material. In these cases the flow rate for R.C. pipe is slightly greater than that for H.D.P.E. pipe because of the difference in actual diameters, but for design purposes these flow rates can be considered as being equal.

Conclusion

When comparing flow rates derived from charts published by pipe manufacturers and others, care should be taken to establish the assumptions made in computing such charts, particularly the use of laboratory or field conditions. When selecting pipe sizes it is important to take into account the actual pipe diameter as compared to the nominal diameter. Overall, there does not appear to be a significant difference in the hydraulic performance of reinforced concrete pipes compared to profile wall H.D.P.E. pipes of the same nominal diameter.

References

1. Standards Association of Australia, "AS 2200-1978 Design Charts for Water Supply and Sewerage", p 23.

2. Tullis, J.P., Reynolds, K., Watkins, Barfuss, S.L., "Innovative New Drainage Pipe", Proceedings of International Conference on Pipeline Design and Installation, ASCE, March 25-27,1990.

3. Concrete Pipe Association of Australasia Technical Bulletin Number 01/92 "A Rational Approach to the Hydraulic Design of Pipe Conduits" April 1992.

4. Hardie Iplex brochure, "Black Brute Pipe" Flow Characteristics pp 14 and 15.