SEWERMAX® POLYPROPYLENE PIPES AND FITTINGS

HYDRAULIC DESIGN

HYDRAULIC PERFORMANCE

New SewerMAX® pipelines fall into the smooth polymer pipe category of AS2200 "Design charts for water supply and sewerage" and provide exceptionally good hydraulic performance. However these may in some instances be affected by various adverse service factors including:

- Growth of slime (varies with the age of the pipeline and available nutrient in the water)
- Siltation or settlement of suspended particulate matter
- Fitting types and configurations

The notation used for equations in this section is as follows:

d = internal diameter (m)

f = Darcy friction co-efficient

g = acceleration due to gravlty (m/sec^2)

k = equivalent hydraulic roughness (m)

n = Manning n

Q = flow or discharge (L/s)

Q_p = most probable peak dry weather flow (L/s)

Q_f = flow or discharge - pipe flowing full (L/s)

R = hydraulic mean radius i.e. flow area/perimeter (m)

R_p = hydraulic mean radius for partly full pipe (m)

R_j = hydraulic mean radius for full pipe i.e. d/4 (m)

S = hydraulic gradient,or slope of gravity flow sewer (m/m)

V = mean velocity (m/sec)

V_p = mean velocity in part full pipe (m/s)

V_f = mean velocity- pipe flowing full (m/s)

H_L = friction head loss (m)

y = depth of flow above pipe invert (m)

ρ = fluid density (kg/m^3)

ν = kinematic viscosity (m^2/sec)

2θ = angle (radians) subtended at pipe centre by water surface in invert - see Figure 4.0

τ = average boundary shear stress (Pa)

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$$V = -2\sqrt{2gdS}\,\log\left(\frac{k}{3.7d} + \frac{2.51\nu}{d\sqrt{2gdS}}\right)$$

The Colebrook White equation takes into account the variation of viscosity with temperature and pipe roughness and is recognised as being one of the most accurate in general use, but requires iterative solutions, the following flow resistance charts have been prepared based on the following assumptions:

- Temperature = 20°C
- Kinematic viscosity of water, ν=1.01 x $10^{-6}m^2/s$
- Roughness, k = 0.006mm and 0.06mm

When comparing SewerMAX® with other pipe systems, designers should take into account both the smooth surface characteristics of polypropylene and the anticipated pipeline service. Different applications may require a variation of the values of roughness coefficients chosen to conform to accepted practice. For example much higher values are commonly specified for stormwater systems to take into account of anticipated debris loading. In the case of sewers, it may be necessary to take into account possible slime development. Generally, smooth pipe materials have a Colebrook White k value equal to less than one fifth of the value used for rougher materials, such as cement lined pipes, concrete and vitrified clay pipes used for the same purpose. Typical comparative values are given in the following table.

TYPICAL COLEBROOK WHITE ROUGHNESS COEFFICIENTS k FOR DIFFERENT MATERIALS

APPLICATION	TYPICAL POLYMER PIPE ROUGHNESS k (mm)	TYPICAL NON-POLYMER PIPE ROUGHNESS k (mm)
Water Supply	0.006	0.03
Sewerage and drainage	0.06	0.6

Note that these values of roughness coefficient k are for clean water and assume the pipeline is straight, clean and concentrically jointed. Australian Standard AS 2200 "Design charts for water supply and sewerage", The above gives a range of values for polymers of 0.003 mm to 0.015 mm under these conditions and 0.03mm to 0.6mm for non-polymer pipes.

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Alternative empirical formulae, exponential in form, have been used over many years for flow calculations. Being relatively easy to use, they are still favoured by hydraulic engineers. The Manning Equation is the most common for non-pressure gravity flow. It can be written as:

Equation 2.0

$$Q = \frac{4000}{n}\pi\left(\frac{d}{4}\right)^{8/3} S^{1/2}$$

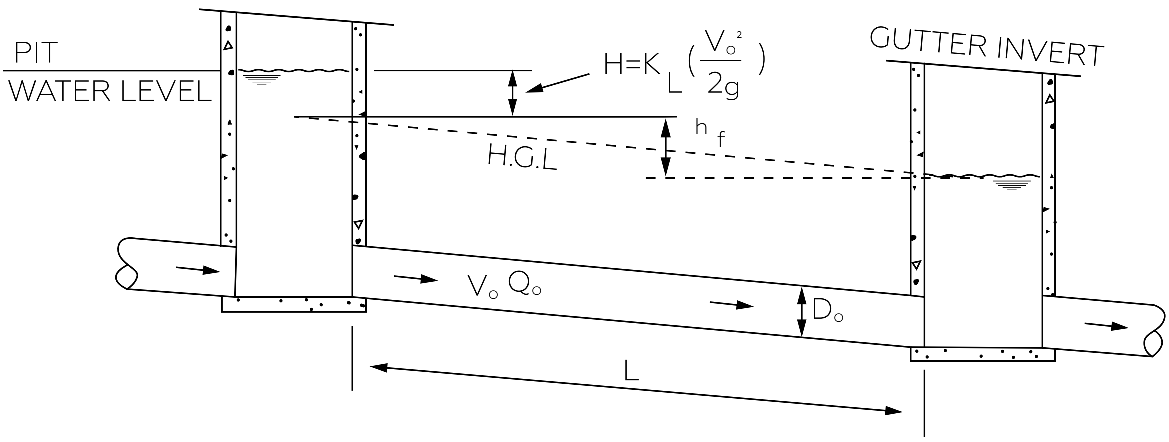
For clean polypropylene pipes such as SewerMAX® and, n is usually taken as being equal to 0.008. In the Australian Standard, AS 2200, n for polymeric materials is in the range of 0.008 to 0.009 whereas for vitrified clay n is in the range of 0.009 to 0.013. As a comparison, for the same internal diameter and gradient, this equates to a flow increase of between 12% to 44% for SewerMAX® pipes.

STORMWATER DRAINAGE DESIGN

The design of drainage pipe networks is discussed in "Australian Rainfall and Runoff " published by the Institution of Engineers Australia. There are differences compared with other applications due to the frequency of inlets and junction pits, having a significant effect on the hydraulic capacity of the system and high head losses.

Pits may be rectangular, circular, benched or un-benched, with or without lateral pipe inlets, entries from gutters in roadways collecting surface storm-water and often involve changes in flow direction. The value for K_L in Figure 3.0 can range from 0.2 to 2.5 or greater depending on the pit configuration. Appropriate values can be obtained from ARRB Report No. 34 "Stormwater drainage design in small urban catchments" by John Argue. Another consideration affecting flow capacity is the debris and sediment load, which is often carried in stormwater flow.

HEAD LOSSES THROUGH STORMWATER PITS



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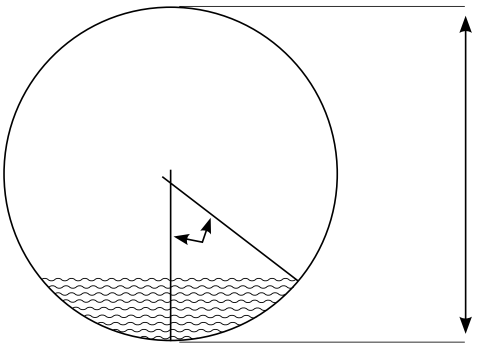
SEWER DESIGN

The design of gravity sewers can be complex due to the assumptions, which must be made to cover the wide variations between storm flows and low dry weather flows. Although pipes must be sized to carry high wet weather flows, the size and grade of the pipeline must also meet self-cleansing criteria under dry weather conditions.

Acceptable design methods will vary between authorities and whether the system is to be designed for sewage flows only or combined sewage and stormwater flows. In Australia the separated sewage flow is the usual requirement. Even so these systems often carry considerable stormwater flow in wet weather due to incidental inflow and infiltration of stormwater. For design purposes the normal average sewerage flow of say 0.003 L/s per head of population or *equivalent population* (EP) is increased by a series of empirical factors to allow for peak dry and wet weather flows. The resulting maximum design flow is therefore much higher than the estimated average flow. Sewer pipes are sized to carry the maximum design flow (Q_f flowing full. In addition a check is made to ensure that in dry weather there will be sufficient flow to ensure a self-cleansing flow at least once daily.

ANGLE OF REPOSE OF SEDIMENT FOR A SELF-CLEANSING FLOW



Historically, the normal design criterion was that a partial flow with a self-cleansing velocity of 0.6 m/s had to be achieved once a day. Today most design methods are based on the Fluid Boundary Layer Shear Theory. Research on the movement of sand particles on submerged pipe perimeters at low flows show that deposition will occur on the flatter parts of the pipe invert when the slope of the pipe wall is less than $\theta = 35°$, refer to Figure 4.0. The Boundary Layer design theory builds on this fact.

From open channel theory the following expression can be written in terms of average boundary shear stress τ.

$$\tau = \rho.g.R.S$$

For a circular sewer flowing part full and since $R_j = d/4$, Equation can be rewritten as

$$\tau = \rho.g.{}^{d}/_{4}.{}^{R_p}/_{R_f}.S$$

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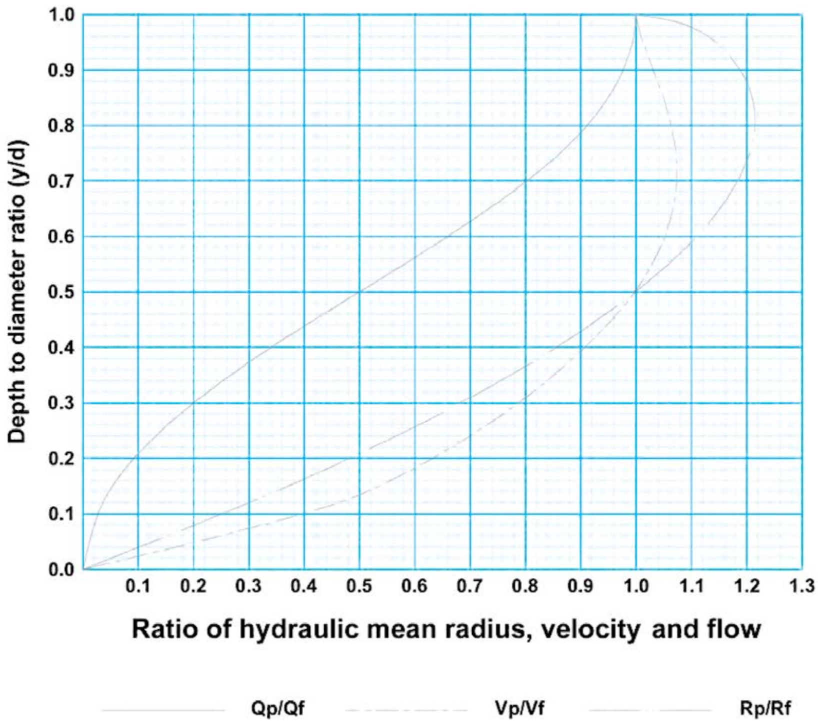
It can be assumed if $\tau \geq 1.5$ Pa that the pipe invert will be self-cleansing. Therefore taking this as the value for τ the minimum self cleansing slope can be determined by re-arranging equation:

$$S_{min} = \frac{4x}{\rho.g.d.\left(R_p / R_f \right)}$$

Using geometrical relationships and the Manning's Equation 3.2, the hydraulic elements in Figure 3.5 have been developed to relate the flow, depth and hydraulic mean radius ratios to each other. With the Q_p/Q_f ratio known, the depth to diameter ratio y/d can be found and then from this value the R_p/R_j ratio can be determined by substitution in equation.

PROPORTIONAL VELOCITY AND DISCHARGE IN PART-FULL PIPES



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EXAMPLE

Problem:

A DN450 SewerMAX® sewer carrier laid at a 0.2% gradient, with an assumed Colebrook White roughness k = 0.06 mm, will carry 170 L/s when flowing full (See Figure 3.1). The probable daily peak dry weather flow is estimated at 35 L/s.

Will this sewer be self-cleansing?

Solution:

The ratio Q_p/Q_f = 35/170 = 0.206

From Figure 3.5, y/d = 0.305 and for this depth the ratio R_p/R_j = 0.705

From Table 2.2, mean pipe internal diameter d = 447mm or 0.447m

Substituting for R_p/R_j in Equation 3.5

$$S_{min} = \frac{4x1.5}{1000x9.81x0.447x(0.705)}$$

$$= 0.00192 \text{ or } \underline{0.19\%}$$

The required grade of 0.19% is slightly less than the proposed 0.2%, therefore this pipeline will be self cleansing.

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