Equivalent Flow Capacity of Various Pipe Materials

Design of a non-pressure sewerage system requires selection of adequately sized pipe to carry maximum predicted flow, at a given slope, without flooding. If more than one type of pipe is considered, all pipe sizes of the various materials must have equivalent flow capacity. A comparison of pipe diameters with different surface roughness coefficients is an important design consideration.

For any given design flow and pipe slope, the Manning Formula is conveniently expressed as:

$$Q = \frac{1}{n} \times A \times R^{2/3} \times S^{1/2}$$

Where:

Q = discharge, cubic meters per second

S = Slope of pipe, meters of vertical drop per meter of horizontal distance

n = Manning's roughness coefficient

A = cross-sectional area of flow, square meters for circular pipe flowing full

$$A = \frac{\pi D^2}{4}$$

R = hydraulic radius, meters (equals the area of the flow divided by the wetted perimeter)

For circular pipe flowing full, the hydraulic radius is equal to the area of the pipe cross-section divided by the pipe circumference:

$$R = \frac{A}{W.P.} = \frac{\frac{\pi D^2}{4}}{\pi D} = \frac{D}{4}$$

Substitution of the values for A and R in the Manning Formula results in the following:

$$\frac{Q}{S^{1/2}} = \frac{1}{n} \times \frac{\pi D^2}{4} \times \left[\frac{D}{4}\right]^{2/3} = K \times \frac{D^{8/3}}{n}$$

where K is a discharge factor dependent on the ratio of the depth of flow to some other linear dimension of the cross-section. For circular pipe operating under full flow conditions, K = 0.312.

Because design and slope are the same regardless of the sizes or types of pipe under consideration:

$$K_{m,p} = \frac{D_{m,p}^{8/3}}{n_{m,p}} \quad K_c \frac{D_c^{8/3}}{n_c}$$

$K_{m,p}$, $D_{m,p}$ and $n_{m,p}$ represent the discharge factor, diameter and roughness coefficient of corrugated metal pipe and K_c, D_c and n_c represent the discharge factor, diameter and roughness coefficient of concrete and other smoothwalled pipe. The full flow value of K= 0.312 is the same for all circular pipe. For two different types of pipe flowing full on the same slope and designed to carry the same flow, the equation reduces to:

$$\frac{D_{m,p}^{8/3}}{n_{m,p}} = \frac{D_c^{8/3}}{n_c}$$

$$D_{m,p} = \left[\frac{n_{m,p}}{n_c}\right]^{3/8} D_c$$

The above equation illustrates that the relative pipe sizes are dependent on the ratio of the respective roughness coefficients.

Table 1 lists recommended values for Manning's Roughness Coefficients of various materials of pipe.

Table 1 Recommended Values of Mannings n		
Pipe Material	**Values of Manning's *n***	
	Laboratory Values	**ACPA Recommended Design Values**
Concrete Pipe	0.010	Storm Sewer - 0.012 Sanitary Sewer - 0.012-0.013
Corrugated HDPE (lined)	0.009-0.015	Storm Sewer - 0.012-0.024
Corrugated Metal Pipe	0.022-0.028	Storm Sewer - 0.029-0.034
Spiral Rib Metal Pipe	0.012-0.013	Storm Sewer - 0.016-0.018

Results of numerous test programs conducted under laboratory conditions have shown the roughness coefficient of concrete pipe to range between 0.009 and 0.011. The design values of 0.012 and 0.013, shown in Table 1, have been generally used to account for the possible build up of slime or grease in sanitary sewers and foreign debris in storm sewers. Therefore, design values should also be used for the other materials shown in the table to allow for a factor of safety as seen with concrete pipe. The larger variation in Manning's "n" lab values in Corrugated HDPE pipe can be accredited to various corrugation growth, or waviness, in the liner. The design values shown for HDPE pipe have also allowed for additional corrugation growth once load is applied in the installed condition. The variation found in Corrugated Metal Pipe is dependent on the specified corrugation size from 68 x 12 mm up to a 76 x 25 mm corrugation. All of the listed pipe materials have been tested at the Utah State University Water Research Laboratory. These laboratory values are from those test results. The concrete pipe test reports are available from ACPA's Resources. Contact ACPA or your local concrete pipe supplier for copies of specific reports.

Table 2 Equations for Comparing Relative Pipe Sizes		
	Comparative Diameter to Concrete Pipe	
	Mannings n for Concrete Pipe	
HDPE Pipe	n = 0.012	n = 0.013
n = 0.012	$D_p = 1.000\ D_c$	$D_p = 0.970\ D_c$
n = 0.024	$D_p = 1.297\ D_c$	$D_p = 1.258\ D_c$
Corrugated Metal Pipe		
n = 0.029	$D_m = 1.392\ D_c$	$D_m = 1.351\ D_c$
n = 0.034	$D_m = 1.478\ D_c$	$D_m = 1.434\ D_c$
Spiral Rib Metal Pipe		
n = 0.016	$D_m = 1.114\ D_c$	$D_m = 1.081\ D_c$
n = 0.018	$D_m = 1.164\ D_c$	$D_m = 1.130\ D_c$

Substituting the recommended n values in the equation for comparing flow capacities of concrete and other smooth-walled pipe with the three available corrugation patterns of corrugated metal pipe, results in the equations in Table 2. D_c is the diameter of concrete and other smooth walled pipe and Dm the diameter of corrugated metal pipe.

Tables 3 and 4 have been prepared for direct comparison of required corrugated metal pipe sizes to assure that the hydraulic capacity is at least equivalent to concrete or other smooth-walled pipe.

EXAMPLE

Given: A 1050 mm diameter concrete pipe with a Manning n value of 0.012 flowing full on a given slope.

Find: Size of corrugated metal pipe, HDPE, and spiral rib pipe required to carry the same flow on the same slope as the 1050 mm diameter concrete pipe.

Solution:

Type of Pipe	Size from Table 3
Concrete	1050
HDPE (n=0.12)	1050
HDPE (n=0.024)	1350
CMP (n=0.029)	1500
CMP (n=0.034)	1650
Spiral Rib (n=0.016)	1200
Spiral Rib (n=0.018)	1350

Table 3 Equivalent Flow Capacities Using Available Pipe Sizes, n_c = 0.012						
Concrete Pipe Diameter	HDPE Pipe Diameter		Corrugated Metal Pipe Diameter		Spiral Rib Metal Pipe Diameter	
n=0.012	n = 0.012	n = 0.024	n = 0.029	n = 0.034	n = 0.016	n = 0.018
300 375 450 525 600	300 375 450 525 600	450 525 600 675 825	450 525 675 750 825	450 600 675 825 900	375 450 525 600 675	375 450 525 600 750
675 750 825 900 1050	675 750 825 900 1050	900 1050 1200 1200 1350	1050 1050 1200 1350 1500	1050 1200 1350 1350 1650	750 825 1050 1050 1200	825 900 1050 1050 1350
1200 1350 1500 1650 1800	1200 1350 1500 1650 1800	1650 1800 1950 2250 2400	1800 1950 2100 2400 2550	1800 2100 2250 2550 2700	1350 1500 1800 1950 2100	1500 1650 1800 1950 2100
1950 2100 2250 2400 2550	1950 2100 2250 2400 2550	2550 2850 3000 3200 3350	2850 3000 3200 3500 3600	3000 3200 3500 3600	2250 2400 2550 2700 2850	2400 2550 2700 2850 3000
2700 2850 3000 3200 3350	2700 2850 3000 3200 3350	3600			3000 3350 3500 3600	3200 3500 3600
3500 3600	3500 3600					

Table 4 Equivalent Flow Capacities Using Available Pipe Sizes, n_c = 0.013						
Concrete Pipe Diameter	HDPE Pipe Diameter		Corrugated Metal Pipe Diameter		Spiral Rib Metal Pipe Diameter	
n=0.013	n = 0.012	n = 0.024	n = 0.029	n = 0.034	n = 0.016	n = 0.018
300 375 450 525 600	300 375 450 525 600	375 525 600 675 750	450 525 600 750 825	450 600 675 750 825	375 450 525 600 675	375 450 525 600 675
675 750 825 900 1050	675 750 825 900 1050	900 1050 1050 1200 1350	1050 1050 1200 1350 1500	1050 1200 1200 1350 1500	750 825 900 1050 1200	825 900 1050 1050 1200
1200 1350 1500 1650 1800	1200 1350 1500 1650 1800	1500 1800 1950 2100 2400	1650 1950 2100 2250 2550	1800 1950 2250 2400 2700	1350 1500 1650 1800 1950	1350 1650 1800 1950 2100
1950 2100 2250 2400 2550	1950 2100 2250 2400 2550	2550 2700 2850 3200 3350	2700 2850 3200 3350 3500	2850 3000 3350 3500	2100 2400 2550 2700 2850	2250 2400 2550 2700 3000
2700 2850 3000 3200 3350	2700 2850 3000 3200 3350	3500 3600			3000 3200 3350 3500	3200 3350 3500 3600
3500 3600	3500 3600					