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 express as:

$$Q = \frac{1.486}{n} \times A \times R^{2/3} \times S^{1/2}$$

Where:

- Q = discharge, cubic feet per second
- S = Slope of pipe, feet of vertical drop per foot of horizontal distance
- n = Manning's roughness coefficient
- A = cross-sectional area of flow, square feet for circular pipe flowing full $A = \frac{\pi D^2}{4}$
- R = hydraulic radius, feet (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:

$$\frac{Q}{S^{1/2}} = \frac{1.486}{n} \times \frac{\pi D}{4} \times \left[\frac{D}{4}\right]^{2/3} = K \times \frac{D^{8/3}}{n}$$

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 = 0.463.

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

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

$K_{m,p}$, $D_{m,p}$ 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= 0.463 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 2-2/3" x 1/2" up to a 3" x 1" 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 42-inch 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 42-inch diameter concrete pipe.

Solution:

Type of Pipe	Size from Table 3
Concrete	42
HDPE (n=0.12)	42
HDPE (n=0.024)	54
CMP (n=0.029)	60
CMP (n=0.034)	66
Spiral Rib (n=0.016)	48
Spiral Rib (n=0.018)	54

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
12	12	18	18	18	15	15
15	15	21	21	24	18	18
18	18	24	27	27	21	21
21	21	27	30	33	24	24
24	24	33	33	36	27	30
27	27	36	42	42	30	33
30	30	42	42	48	33	36
33	33	48	48	54	42	42
36	36	48	54	54	42	42
42	42	54	60	66	48	54
48	48	66	72	72	54	60
54	54	72	78	84	60	66
60	60	78	84	90	72	72
66	66	90	96	102	78	78
72	72	96	102	108	84	84
78	78	102	114	120	90	96
84	84	114	120	126	96	102
90	90	120	126	138	102	108
96	96	126	138	144	108	114
102	102	132	144		114	120
108	108	144			120	126
114	114				132	138
120	120				138	144
126	126				144	
132	132					
138	138					
144	144					

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
12	12	15	18	18	15	15
15	15	21	21	23	18	18
18	18	24	24	27	21	21
21	21	27	30	30	24	24
24	24	30	33	33	27	27
27	27	36	42	42	30	33
30	30	42	42	48	33	36
33	33	42	48	48	36	42
36	36	48	54	54	42	42
42	42	54	60	60	48	48
48	48	60	66	72	54	54
54	54	72	78	78	60	66
60	60	78	84	90	66	72
66	66	84	90	96	72	78
72	72	96	102	108	78	84
78	78	102	108	114	84	90
84	84	108	114	120	96	96
90	90	114	126	132	102	102
96	96	126	132	138	108	108
102	102	132	138		114	120
108	108	138			120	126
114	114	144			126	132
120	120				132	137
126	126				138	144
132	132					
138	138					
144	144					