CHAPTER 2

PRODUCT DETAILS & FABRICATION

INTRODUCTION

Various design challenges, and the application of corrugated steel pipe and other products to the solution of those challenges, have been described and illustrated in Chapter 1. These cover a wide segment of the construction field, including highways, railways, streets, urban areas, airports, industrial and commercial development, flood control and conservation.

These examples are not all-inclusive or complete solutions. They are intended only to show the adaptability and wide acceptance of one material - steel - for aiding in the solution of some of the problems facing the design engineer.

So vast are the annual expenditures for construction that the skills of resourceful qualified engineers are required to research (analyse), select, design and apply the available materials and products that most economically serve their purpose. For example, the cost of drainage facilities on the original U.S. interstate highway system was anticipated to be $4 billion, exclusive of bridges. Mass transportation, anti-pollution facilities, flood protection and other related construction projects can require drainage facilities in comparable measure. The need for carefully considering the economics of providing and maintaining these facilities is obvious.

Design Factors

Drainage design begins with reconnaissance and location surveys. The services of experienced soils and drainage engineers provide the best assurance of economical construction and subsequent minimum maintenance.

The following design factors must be considered:

1. Size, shape, alignment, grade and other configurations. These depend on hydrology and hydraulics, and on service requirements. (See Chapters 3, 4 and 5.)
2. Structural adequacy to meet embankment and superimposed live loads, along with hydraulic forces. (See Chapter 6.)
3. Trouble-free service through selection of materials to resist wear and provide durability. (See Chapter 8.)
4. Economics - First cost of materials and installation, plus maintenance cost evaluated on the basis of present worth. (See Chapter 9.)

In addition to these, the design engineer can make a value-analysis of such other factors as: suitable sources of supply, probable delivery schedule, influence of climate or season of the year, coordination with other construction schedules, supplier's assistance, and ease of repair or replacement in relation to the importance or service of the facility.

Alternate materials and designs should be considered so that the final selection will provide the most economical and satisfactory solution for the overall facility and its users.

Background of Corrugated Steel Conduits

Corrugating a flat sheet has long been known to increase its stiffness and strength. Corrugated steel sheets have been produced almost since the first rolling mill was built in England in 1784. But it was not until after 1890, when mass-produced steel sheets became abundant, that their use grew rapidly.

Corrugated steel pipe was first developed and used for culverts in 1896. As experience was gained in the use of this thin-wall, lightweight, shop-fabricated pipe, the diameters gradually increased to 2400 mm and larger. Fill heights became greater, even exceeding 30 m. A further development, in 1931, was structural plate pipe with larger corrugations, for field assembly. Diameters up to 8 m and arch spans up to 18 m have been installed successfully.

Shapes

The designer has a wide choice of standard cross-sectional shapes of corrugated steel and structural plate conduits as shown in Table 2.1. Size and service use may control the shape selected, with strength and economy as additional factors.

Corrugated steel pipe nested for shipment.

SECTION A: CORRUGATED STEEL PIPES

Description of Corrugations

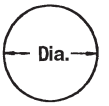
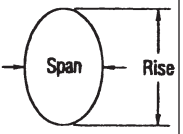
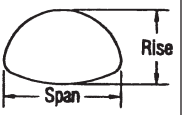
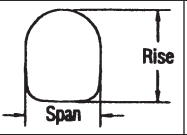
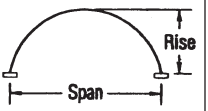
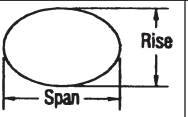
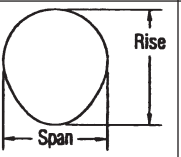
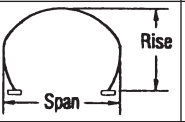
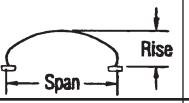
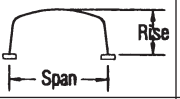
The principal profiles for corrugated steel pipe are shown in Figure 2.1. Corrugations commonly used for pipes or conduits are circular arcs connected by tangents, and are described by pitch, depth and inside forming radius. Pitch is measured at right angles to the corrugations from crest to crest. A corrugation is named using its pitch and depth as “pitch by depth”.

For riveted pipe with circumferential (annular) seams, the corrugations are 68 by 13 mm.

For lock seam pipe, the seams and corrugations run helically (or spirally) around the pipe. For small diameters of subdrainage pipe (150, 200, 250 mm) the corrugation is nominally 38 x 6.5 mm. Larger sizes (diameters to 3600 mm, depending on profile) use 68 x 13 mm, 76 x 25 mm and 125 x 25 mm corrugations.

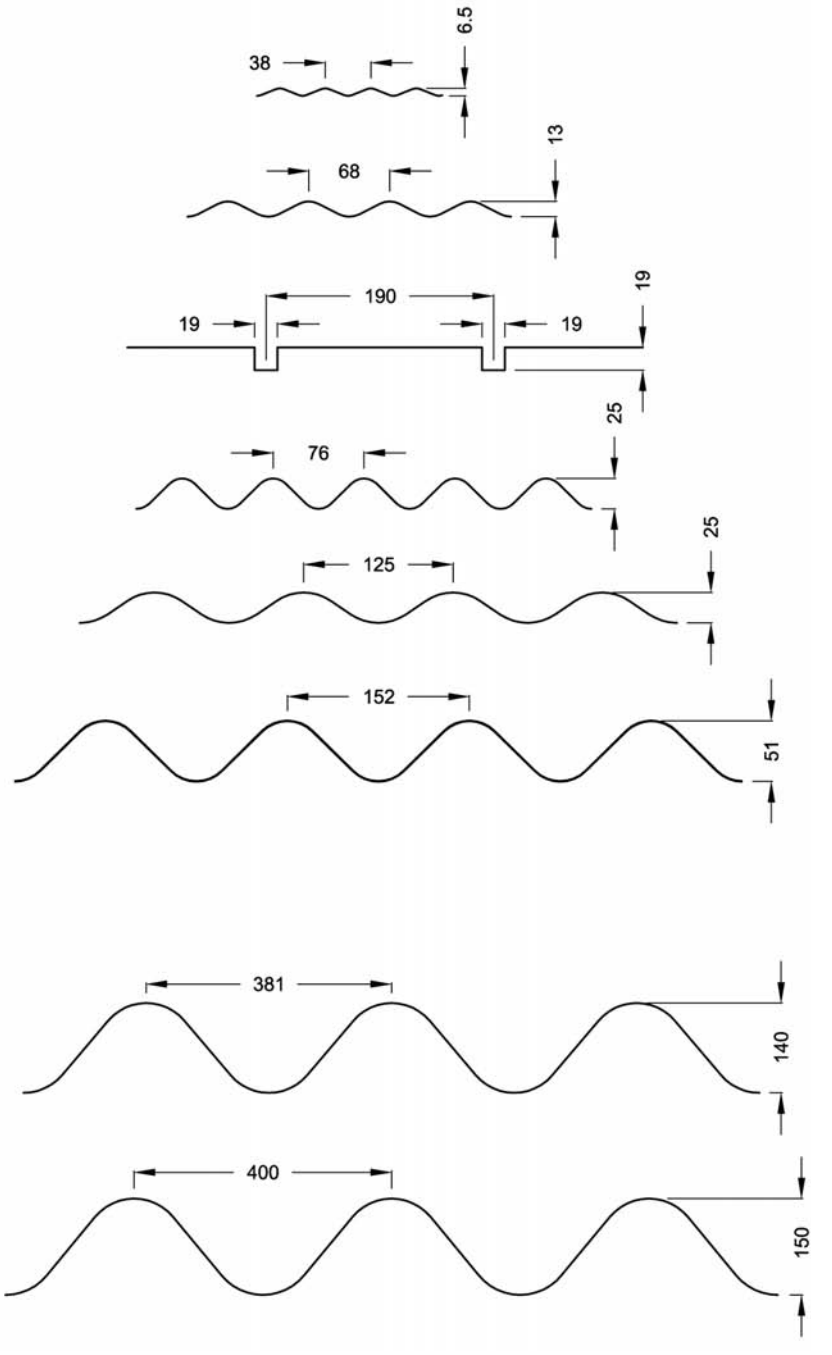
Another “corrugation” used for lock seam pipe is the spiral rib profile. Developed in the mid 1980's, the pipe wall is spirally formed using rectangularly

Table 2.1 Shapes and uses of corrugated conduits

Shape	Range of Sizes	Common Uses**
Round 	150 mm to 15.8 m	Culverts, subdrains, sewers, service tunnels, etc. All plates same radius. For medium and high fills (or trenches).
Vertical ellipse 5% nominal 	2440 mm to 6400 mm nominal; before elongating	Culverts, sewers, service tunnels, recovery tunnels. Plates of varying radii; shop fabrication. For appearance and where backfill compaction is only moderate.
Pipe-arch 	Span x Rise 450 x 340 mm to 7620 x 4240 mm	Where headroom is limited. Has hydraulic advantages at low flows.
Underpass 	Span x Rise 1755 x 2005 mm to 1805 x 2490 mm	For pedestrians, livestock or vehicles.
Arch 	Span x Rise 1520 x 810 mm to 20 x 10 m	For low clearance large waterway openings and aesthetics.
Horizontal Ellipse 	Span 1.6 m to 11.8 m	Culverts, grade separations, storm sewers, tunnels.
Pear 	Span 7.2 m to 8.6 m	Grade separations, culverts, storm sewers, tunnels.
High Profile Arch 	Span 6.3 m to 23.0 m	Culverts, grade separations, storm sewers and tunnels. Ammunition magazines, earth covered storage.
Low Profile Arch 	Span 6.1 m to 15.0 m	Low, wide waterway enclosures, culverts, storm sewers.
Box Culverts 	Span 3.2 m to 12.3 m	Low, wide waterway enclosures, culverts, storm sewers.
Specials	Various	Special fabrication for lining old structures or other special purposes.

For equal area or clearance, the round shape is generally more economical and simpler to assemble.

** Round pipe and pipe-arches are furnished as factory corrugated pipe, or structural plate pipe, depending on diameter or span. Other shapes are generally only furnished as structural plate or deep corrugated structural plate.



All dimensions in millimetres.

Figure 2.1 Commonly used corrugations.

formed ribs between flat wall areas. This unique profile configuration was developed for providing flow characteristics equal to those piping systems normally considered smooth wall. One profile configuration is available, with nominal dimensions 19 x 19 x 190 mm (rib pitch x rib depth x rib spacing), covering diameters from 450 through 2700 mm.

Section Properties

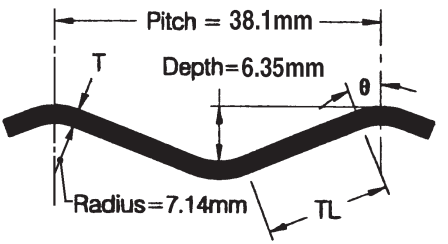
Section properties of the arc-and-tangent type of corrugation are derived mathematically using a design thickness which is a little different than the measured or specified thickness. The properties include area, A, moment of inertia, I, section modulus, S, and radius of gyration, r. Research by the American Iron and Steel Institute (AISI) has shown that failure loads in bending and deflection within the elastic range can be closely predicted by using computed section properties of the corrugated sheet. See Tables 2.2 through 2.6.

Sizes and Shapes

The number of corrugation profiles available is a result of the need for additional stiffness and strength for larger diameters of pipes. The standard sizes of round and pipe-arch corrugated steel pipes and spiral rib steel pipes, and their handling weights, are shown in Tables 2.7 through 2.11.

Table 2.2

Section design properties for corrugated CSP sheet
Corrugation profile: **38 x 6.5 mm** (helical)

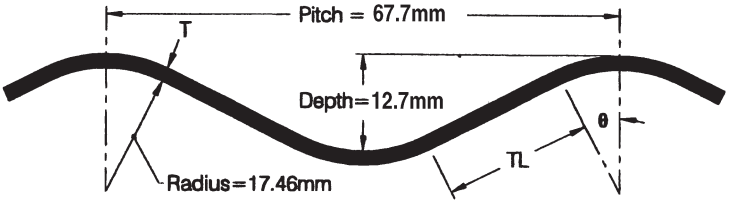


Wall Thickness		Area	Tangent Length	Tangent Angle	Moment of Inertia	Section Modulus	Radius of Gyration	Developed Width Factor
Specified	Design							
T	T	A	TL	θ	I	S	r	WF
mm	mm	mm^2/mm	mm	Degrees	mm^4/mm	mm^3/mm	mm	*
1.3	1.12	1.187	14.367	21.519	5.11	1.37	2.075	1.060
1.6	1.40	1.484	14.242	21.597	6.46	1.67	2.087	1.060
2.0	1.82	1.929	14.054	21.717	8.58	2.10	2.109	1.060

*WF is the ratio of the flat sheet width to the corrugated sheet width.
NOTE: Dimensions are subject to manufacturing tolerances.

Table 2.3

Section design properties for corrugated CSP sheet
Corrugation profile: **68 x 13 mm** (annular or helical)

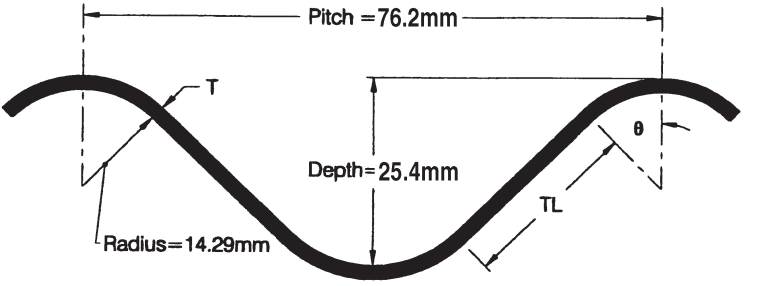


Wall Thickness		Area	Tangent Length	Tangent Angle	Moment of Inertia	Section Modulus	Radius of Gyration	Developed Width Factor
Specified	Design							
T	T	A	TL	θ	I	S	r	WF
mm	mm	mm^2/mm	mm	Degrees	mm^4/mm	mm^3/mm	mm	*
1.3	1.120	1.209	19.759	26.647	22.61	3.27	4.324	1.079
1.6	1.400	1.512	19.578	26.734	28.37	4.02	4.332	1.080
2.0	1.820	1.966	19.304	28.867	37.11	5.11	4.345	1.080
2.8	2.640	2.852	18.765	27.136	54.57	7.11	4.374	1.080
3.5	3.350	3.621	18.269	27.381	70.16	8.74	4.402	1.081
4.2	4.080	4.411	17.755	27.643	86.71	10.33	4.433	1.081

*WF is the ratio of the flat sheet width to the corrugated sheet width.
NOTE: Dimensions are subject to manufacturing tolerances.

Table 2.4

Section design properties for corrugated CSP sheet
Corrugation profile: **76 x 25 mm** (annular or helical)

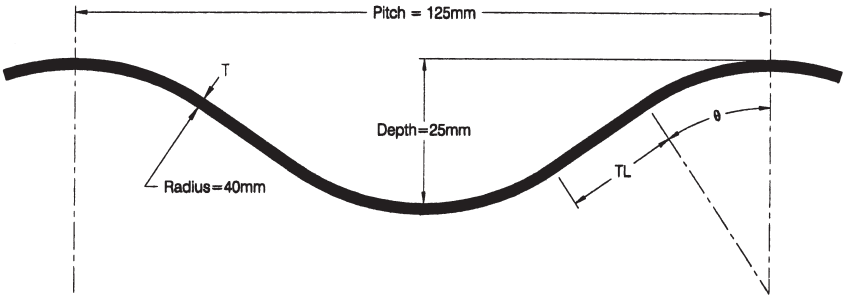


Wall Thickness		Area	Tangent Length	Tangent Angle	Moment of Inertia	Section Modulus	Radius of Gyration	Developed Width Factor
Specified	Design							
T	T	A	TL	θ	I	S	r	WF
mm	mm	mm^2/mm	mm	Degrees	mm^4/mm	mm^3/mm	mm	*
1.3	1.12	1.389	24.159	44.389	103.96	7.84	8.653	1.240
1.6	1.40	1.736	23.862	44.580	130.40	9.73	8.666	1.240
2.0	1.82	2.259	23.411	44.875	170.40	12.52	8.685	1.241
2.8	2.64	3.281	22.504	45.479	249.73	17.81	8.724	1.243
3.5	3.35	4.169	21.688	46.035	319.77	22.24	8.758	1.244
4.2	4.08	5.084	20.815	46.645	393.12	26.67	8.794	1.246

*WF is the ratio of the flat sheet width to the corrugated sheet width.
NOTE: Dimensions are subject to manufacturing tolerances.

Table 2.5

Section design properties for corrugated CSP sheet
Corrugation profile: **125 x 25 mm** (helical)

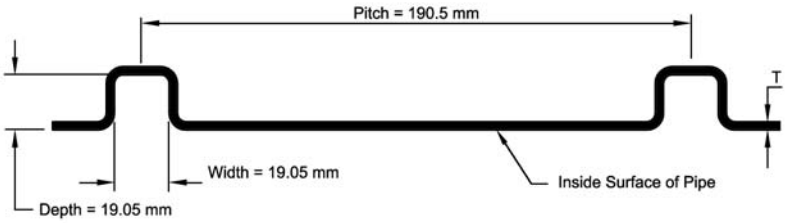


Wall Thickness		Area	Tangent Length	Tangent Angle	Moment of Inertia	Elastic Section Modulus	Plastic Section Modulus	Radius of Gyration	Developed Width Factor
Specified	Design								
T	T	A	TL	θ	I	S	Z	r	WF
mm	mm	mm^2/mm	mm	Degrees	mm^4/mm	mm^3/mm	mm^3/mm	mm	*
1.6	1.40	1.549	18.568	35.564	133.30	9.73	12.94	9.277	1.106
2.0	1.82	2.014	17.970	35.811	173.72	12.49	16.86	9.287	1.107
2.8	2.64	2.923	16.742	36.330	253.24	17.68	24.54	9.308	1.107
3.5	3.35	3.711	15.600	36.826	322.74	21.99	31.24	9.326	1.108
4.2	4.08	4.521	14.332	37.392	394.84	26.25	38.17	9.345	1.108

*WF is the ratio of the flat sheet width to the corrugated sheet width.
NOTE: Dimensions are subject to manufacturing tolerances.

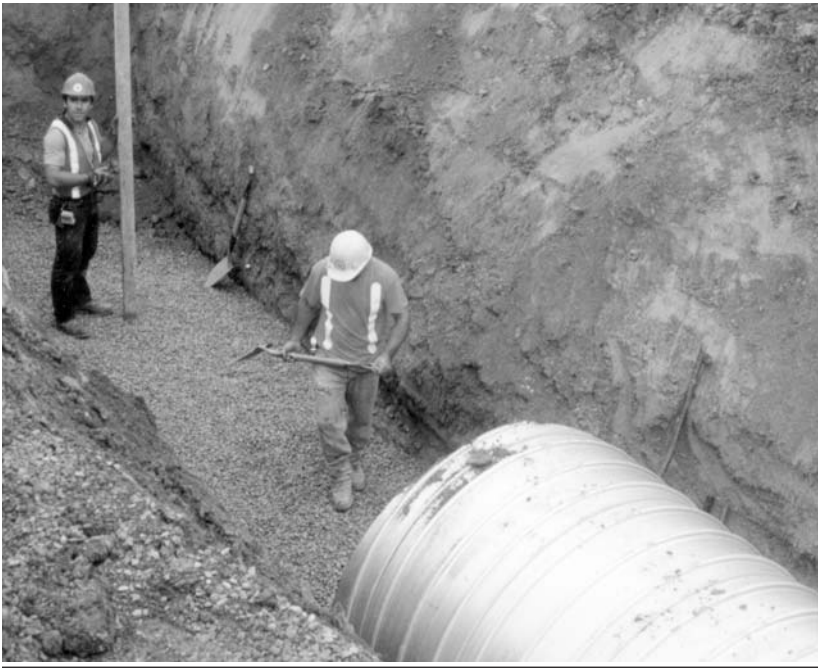
Table 2.6

Section design properties for spiral rib pipe
Rib profile: **19 x 19 x 190 mm** (helical)



Wall Thickness		Area	Moment of Inertia	Section Modulus	Radius of Gyration	Developed Width Factor
Specified	Design					
T	T	A	I	S	r	WF
mm	mm	mm^2/mm	mm^4/mm	mm^3/mm	mm	*
1.6	1.519	1.082	58.829	4.016	7.375	1.170
2.0	1.897	1.513	77.674	5.054	7.164	1.168
2.8	2.657	2.523	117.167	7.129	6.815	1.165

*WF is the ratio of the flat sheet width to the corrugated sheet width.
Properties are effective section properties at full yield stress.
Note: Dimensions are subject to manufacturing tolerances.



Placing and checking of elevation of pipe bedding.

Table 2.7

Corrugated steel pipe (CSP) - standard round diameters, end areas, and handling weights (kg/m)**

Diameter, mm	End Area, m^2	Plain Metallic Coated						Asphalt-Coated						Asphalt-Coated, *Paved-Invert						Asphalt-Coated, Smooth-Lined					
		A. Corrugation Profile: 38 x 6.5 mm																							
		Specified Wall Thickness, mm																							
		1.3	1.6	2.0	2.8	3.5	4.2	1.3	1.6	2.0	2.8	3.5	4.2												
150	0.018	5.9	7.2	-	-	-	-	7.2	8.5	-	-	-	-												
200	0.031	7.7	9.5	-	-	-	-	9.4	11	-	-	-	-												
250	0.049	9.6	12	-	-	-	-	12	14	-	-	-	-												
	End	**B.Corrugation Profile: 68 x 13 mm**																							
Diameter,	Area,	Specified Wall Thickness,mm																							
mm	m^2	1.3	1.6	2.0	2.8	3.5	4.2	1.3	1.6	2.0	2.8	3.5	4.2	1.3	1.6	2.0	2.8	3.5	4.2	1.3	1.6	2.0	2.8	3.5	4.2
300	0.07	12	14	18	-	-	-	15	17	21	-	-	-	17	19	23	-	-	-	22	24	28	-	-	-
400	0.13	16	19	24	-	-	-	20	23	28	-	-	-	22	25	30	-	-	-	30	33	38	-	-	-
500	0.20	19	24	30	41	-	-	24	29	35	46	-	-	27	32	38	49	-	-	36	41	47	58	-	-
600	0.28	23	28	35	49	-	-	28	33	40	54	-	-	32	37	44	58	-	-	44	49	56	70	-	-
700	0.38	-	33	41	57	-	-	-	39	47	63	-	-	-	44	52	68	-	-	-	57	65	81	-	-
800	0.50	-	37	47	65	-	-	-	44	54	72	-	-	-	49	59	77	-	-	-	64	74	92	-	-
900	0.64	-	42	53	73	90	108	-	50	61	81	98	116	-	56	67	87	104	122	-	73	84	104	121	139
1000	0.79	-	47	58	81	100	120	-	56	67	90	109	129	-	62	73	96	115	135	-	81	92	115	134	154
1200	1.13	-	56	70	97	120	144	-	66	80	107	130	154	-	74	88	115	138	162	-	97	111	138	161	185
1400	1.54	-	-	81	113	140	168	-	-	93	125	152	180	-	-	102	134	161	189	-	-	129	161	188	216
1600	2.01	-	-	93	130	160	192	-	-	107	144	174	206	-	-	117	154	184	216	-	-	148	185	215	247
1800	2.54	-	-	-	146	179	215	-	-	-	162	195	231	-	-	-	174	206	242	-	-	-	208	241	277
2000	3.14	-	-	-	162	199	239	-	-	-	179	216	256	-	-	-	192	229	269	-	-	-	230	267	307
2200	3.80	-	-	-	-	219	263	-	-	-	-	238	282	-	-	-	-	252	296	-	-	-	-	294	338
2400	4.52	-	-	-	-	-	287	-	-	-	-	-	308	-	-	-	-	-	323	-	-	-	-	-	369

NOTES: * Weight based on a pavement covering 25% of the periphery. **Other corrugation profiles in Table 2.8.

1. The weights are based on helical lockseam fabrication, and are approximate. Riveted CSP weighs slightly more.
2. Handling weights not shown indicate that particular size or steel thickness is either not generally recommended practice, or may not be possible to fabricate. Many size/thickness combinations not shown may be available. For further or specific details, consult your local CSP fabricators.

Table 2.8

Corrugated steel pipe (CSP) - standard round diameters, end areas, and handling weights (kg/m)**

Diameter, mm	End Area, m^2	Plain Metallic Coated					Asphalt-Coated					Asphalt-Coated, *Paved-Invert					Asphalt-Coated, Smooth-Lined				
		C. Corrugation Profile: 76 x 25 mm																			
		Specified Wall Thickness, mm																			
		1.6	2.0	2.8	3.5	4.2	1.6	2.0	2.8	3.5	4.2	1.6	2.0	2.8	3.5	4.2	1.6	2.0	2.8	3.5	4.2
1200	1.13	65	81	112	-	-	77	93	124	-	-	90	106	137	-	-	130	146	177	-	-
1400	1.54	75	94	131	161	-	89	108	145	175	-	104	124	160	190	-	151	170	207	237	-
1600	2.01	86	107	149	184	221	102	123	165	200	237	120	141	183	218	255	173	194	236	271	308
1800	2.54	96	120	167	206	248	114	138	185	224	266	134	158	205	244	286	194	218	264	304	346
2000	3.14	107	133	186	229	275	127	153	206	249	295	149	175	228	271	317	215	241	294	337	383
2200	3.80	117	147	204	252	302	139	169	226	274	324	163	193	250	298	348	236	266	323	371	421
2400	4.52	128	160	221	274	329	152	184	245	298	353	178	210	272	324	380	258	290	351	404	459
2700	5.73	144	179	250	308	370	171	206	277	335	397	201	236	307	365	427	290	325	396	454	516
3000	7.07	-	199	278	342	411	-	229	308	372	441	-	262	341	405	474	-	362	440	504	574
3300	8.55	-	-	305	376	451	-	-	338	409	484	-	-	374	445	520	-	-	484	555	630
3600	10.18	-	-	-	410	492	-	-	-	446	528	-	-	-	486	568	-	-	-	605	687
		D. Corrugation Profile: 125 x 25 mm																			
		Specified Wall Thickness, mm																			
Diameter, mm	End Area, m^2	1.6	2.0	2.8	3.5	4.2	1.6	2.0	2.8	3.5	4.2	1.6	2.0	2.8	3.5	4.2	1.6	2.0	2.8	3.5	4.2
1200	1.13	57	71	100	124	-	68	82	111	135	-	82	96	124	148	-	123	137	166	190	-
1400	1.54	66	83	116	144	-	79	96	129	157	-	95	112	145	173	-	143	160	193	221	-
1600	2.01	76	95	132	165	197	90	109	147	179	211	108	127	165	198	230	163	182	220	252	284
1800	2.54	85	106	148	185	221	101	122	165	201	237	122	143	185	222	258	184	205	247	284	320
2000	3.14	94	118	165	205	245	112	136	183	223	263	136	159	206	246	286	204	228	274	315	355
2200	3.80	104	129	181	225	269	123	149	201	245	289	149	175	226	270	314	224	250	302	346	390
2400	4.52	113	141	197	245	293	135	163	219	267	315	162	190	247	295	343	245	273	329	377	425
2700	5.73	127	159	222	276	330	151	183	246	300	354	183	214	277	331	385	275	307	370	424	478
3000	7.07	-	176	246	306	366	-	203	273	333	393	-	238	307	368	428	-	340	410	470	530
3300	8.55	-	-	270	336	402	-	-	300	366	432	-	-	338	404	470	-	-	451	517	583
3600	10.18	-	-	-	367	438	-	-	-	399	470	-	-	-	440	511	-	-	-	564	635

NOTE: *Weight based on a pavement covering 25% of the periphery. ** Other corrugation profiles in Table 2.7.

1. The weights are based on helical lockseam fabrication, and are approximate. Riveted CSP weighs slightly more.
2. Handling weights not shown indicate that particular size or steel thickness is either not generally recommended practice, or may not be possible to fabricate. Many size/thickness combinations not shown may be available. For further or specific details, consult your local CSP fabricators.

Table 2.9

CSP pipe-arch shapes and handling weights (kg/m)

Span x Rise, mm	Equivalent Round Diameter, mm	End Area, m^2	Plain Metallic Coated					Asphalt-Coated					Asphalt-Coated **Paved-Invert				
			Specified Wall Thickness, mm														
			1.6	2.0	2.8	3.5	4.2	1.6	2.0	2.8	3.5	4.2	1.6	2.0	2.8	3.5	4.2
A. Corrugation Profile: 68 x 13 mm																	
450 x 340	400	0.11	19	24	-	-	-	23	28	-	-	-	26	31	-	-	-
560 x 420	500	0.19	24	30	41	-	-	29	35	46	-	-	34	40	51	-	-
680 x 500	600	0.27	28	35	49	-	-	33	40	54	-	-	39	46	60	-	-
800 x 580	700	0.37	33	41	57	-	-	39	47	63	-	-	46	54	70	-	-
910 x 660	800	0.48	37	47	65	-	-	44	54	72	-	-	52	62	80	-	-
1030 x 740	900	0.61	42	53	73	90	108	50	61	81	98	116	59	70	90	107	125
1150 x 820	1000	0.74	47	58	81	100	120	56	67	90	109	129	66	77	100	119	139
1390 x 970	1200	1.06	56	70	97	120	144	66	80	107	130	154	78	92	119	142	166
1630 x 1120	1400	1.44	-	81	113	140	168	-	93	125	152	180	-	107	139	166	194
1880 x 1260	1600	1.87	-	93	130	160	192	-	107	144	174	206	-	123	160	190	222
2130 x 1400	1800	2.36	-	-	146	179	215	-	-	162	195	231	-	-	180	213	249
B. Corrugation Profile: 125 x 25 mm																	
1780 x 1360	1600	1.93	-	95	132	165	-	-	109	147	179	-	-	127	165	198	-
2010 x 1530	1800	2.44	-	106	148	185	-	-	122	165	201	-	-	143	185	222	-
2230 x 1700	2000	2.97	-	118	165	205	245	-	136	183	223	263	-	159	206	246	286
2500 x 1830	2200	3.44	-	129	181	225	269	-	149	201	245	289	-	175	226	270	314
2800 x 1950	2400	4.27	-	141	197	245	293	-	163	219	267	315	-	190	247	295	343
3300 x 2080	2700	5.39	-	-	222	276	330	-	-	246	300	354	-	-	277	331	385
3650 x 2280	3000	6.60	-	-	-	306	366	-	-	-	333	393	-	-	-	368	428
3890 x 2690	3300	8.29	-	-	-	-	402	-	-	-	-	432	-	-	-	-	470
4370 x 2870	3600	9.76	-	-	-	-	438	-	-		-	470	-	-	-	-	511

Notes: **Weight based on a pavement covering 40% of the periphery.

1. The weights are based on helical lockseam fabrication, and are approximate. Riveted CSP will weigh slightly more.
2. Handling weights not shown indicate that particular size or steel thickness is either not generally recommended practice, or may not be possible to fabricate. Many size/thickness combinations not shown may be available. For further or specific details, consult your local CSP fabricators.

Table 2.10

Spiral rib round pipe handling weights (kg/m):
19 x 19 x 190 mm rib profile
Galvanized Steel or Aluminized Steel Type 2

Diameter (mm)	End Area m^2	Specified Wall Thickness (mm)		
		1.6	2.0	2.8
450	0.16	21.9	26.8	-
525	0.22	25.6	31.3	42.6
600	0.28	29.2	35.8	48.6
750	0.44	36.5	44.7	60.8
900	0.64	43.8	53.6	72.9
1050	0.87	51.1	62.6	85.1
1200	1.13	58.4	71.5	97.3
1350	1.43	-	80.5	109.4
1500	1.77	-	89.4	121.6
1650	2.14	-	98.3	133.7
1800	2.54	-	107.3	145.9
2100	3.46	-	125.2	170.2
2400	4.52	-	-	194.5
2600	5.31	-	-	210.7

Notes: Handling weights are approximate.
Those weights not shown indicate that particular size or steel thickness is either not generally recommended practice, or may not be possible to fabricate.
Size/thickness combinations not shown may be available. For further or specific details, consult your local spiral rib pipe fabricator.

Table 2.11

Spiral rib pipe-arch shapes and handling weights (kg/m)
Aluminized Steel Type 2 or Galvanized Steel

Span (mm)	Rise (mm)	Equivalent Round Diameter (mm)	End Area (m^2)	Specified Wall Thickness (mm)		
				1.6	2.0	2.8
500	410	450	0.15	21.9	26.8	
580	490	525	0.21	25.6	31.3	42.6
680	540	600	0.27	29.2	35.8	48.6
830	660	750	0.43	36.5	44.7	60.8
1010	790	900	0.62	43.8	53.6	72.9
1160	920	1050	0.85		62.6	85.1
1340	1050	1200	1.12			97.3
1520	1200	1350	1.44			109.4
1670	1300	1500	1.79			121.6
1850	1400	1650	2.15			133.7

Notes: Handling weights are approximate.
Those weights not shown indicate that particular size or steel thickness is either not generally recommended practice, or may not be possible to fabricate.
Size/thickness combinations not shown may be available. For further or specific details, consult your local spiral rib pipe fabricator.

Perforated Pipe

Corrugated steel pipe is available with perforations for collection or dispersion of water underground.

Subdrainage, or groundwater control, is the most common use for perforated corrugated steel pipe. In this application, only the lower half of the pipe is perforated, following the standard shown in Figure 2.2 and Table 2.12. Most fabricators are equipped to furnish 9.5 mm round holes. Other sizes and configurations are available. The most common standard pattern is thirty 9.5 mm round holes per square metre of pipe surface.

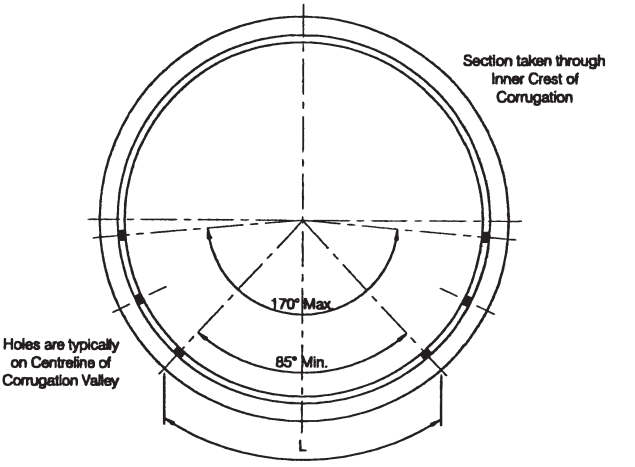


Figure 2.2 Invert perforating detail.

Table 2.12 Invert perforated pipe data and handling weights, kg/m

Inside Dia.	Minimum Rows of Perfor-ations	Minimum Arc Length L	End Area	Specified Wall Thickness, mm							
				Galvanized				Asphalt Coated			
mm		mm	m^2	1.0	1.3	1.6	2.0	1.0	1.3	1.6	2.0
150	4	120	0.018	4.5	5.9	7.2		5.8	7.2	8.5	
200	4	160	0.031		7.7	9.5	12		9.4	11	
250	4	195	0.049		9.6	12	15		12	14	
300	6	240	0.07		12	14	18		15	17	21
400	6	315	0.13		16	19	24		20	23	28
500	Random		0.20		19	24	30		24	29	35
600	Random		0.28		23	28	35		28	33	40

Fully-perforated helical CSP is ideally suited for retention of storm water, permitting slow infiltration, or recharge, into the trench walls. Underground disposal of storm water runoff in urban development design has the potential for saving millions of dollars in taxpayer money. Recharge design makes the concept of zero increase in runoff possible thus avoiding overloading trunk storm drains, and/or streams and rivers. The cost of reconstructing existing drains or channel improvements usually will prove to be far greater than recharge design.

Environmental considerations also favour recharge design. Natural streams can be maintained for fish passage, and water-poor areas can be enriched. See Chapter 6 of Modern Sewer Design for further details. In this application, the pipe is perforated for the full 360 degrees. Perforations in fully perforated helical pipe usually provide and opening area of not less than 2.3% of the pipe surface.

Conveyor Covers

Perhaps the most commonly used cover is a half-circle steel arch section (Figure 2.3), 1220 mm long, supported on band sheets 250 mm wide. These band sheets in turn are supported by bolting to the conveyor frame.

Diameters of support bands and cover sheets are optional, to meet the conveyor equipment manufacturer's designs, but usually range from 600 to 1800 mm. The corrugated sheets are supplied in suitable thicknesses of steel. Cover sheets are secured by one bolt at each corner and can be removed quickly when necessary. Preferably the corrugations should run transverse to the conveyor for greater strength with minimum framing. Where the arch covers not only the conveyor belt but also the walkway, sheets with larger corrugations (125 x 25 mm or 152 x 51 mm) can be provided.

A horseshoe shape is used where weighing equipment or other facilities require a high cover. A circular or elliptical shape can also serve as a beam to strengthen the span between bents in aerial conveyor systems.

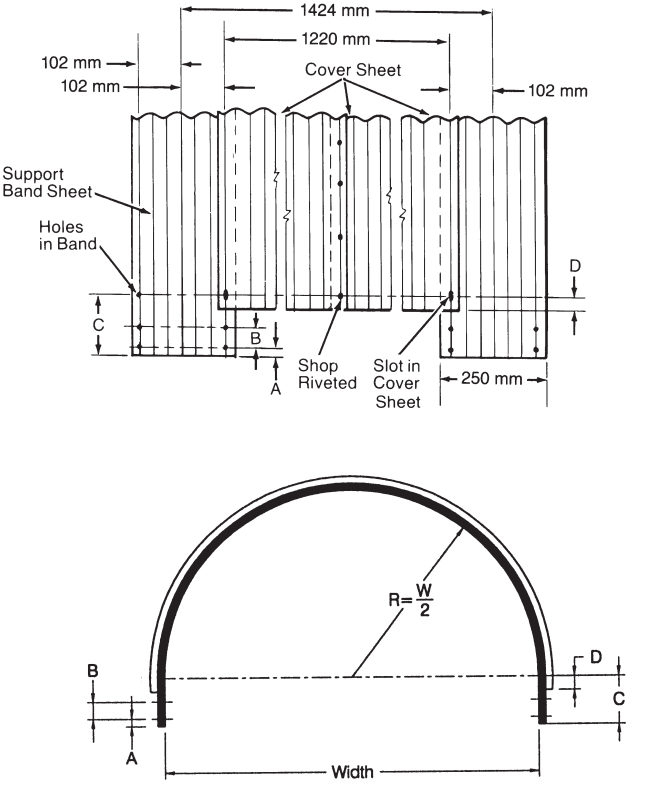


Figure 2.3 Typical corrugated steel conveyor cover with removable cover sheets.

Nestable Corrugated Steel Pipe

Nesting, a shipping technique developed in the 1930's, was devised to improve competitiveness of products bound for overseas markets. It provides an economical solution to reduce shipping space.

Nestable pipe offers a fast and economical solution to contractors and owners who require a strong casing to place around an already installed utility line. This can be done easily without disrupting the line to be encased. These casings may be used for lines under high fills, or buildings, where access for servicing becomes important.

With urethane foam insulation, the CSP utilidor has proven effective in servicing northern villages.

There are two standard methods used in attaching the half-round pipe segments together; interlocking notches and mating flanges. Flanged nestable pipe and notched nestable pipe details are shown in Figures 2.4 and 2.5 respectively. Handling weights for the two types of pipe are provided in Tables 2.13 and 2.14.

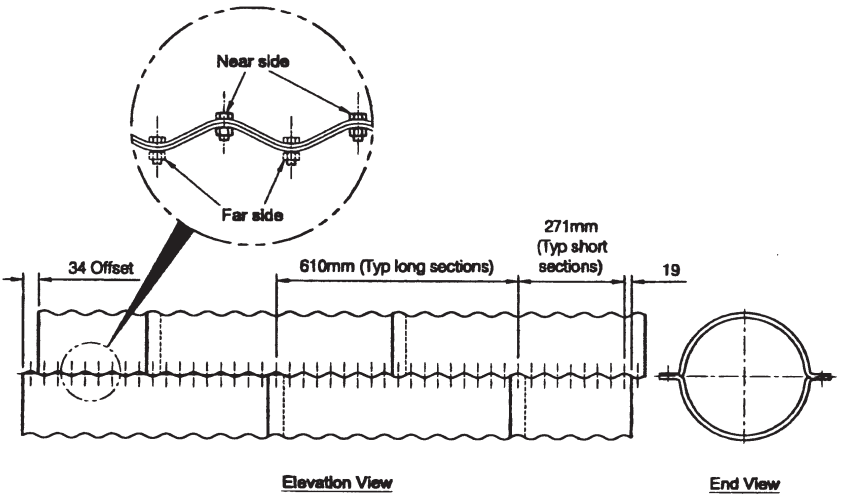


Figure 2.4 Flanged nestable pipe.

Table 2.13 Flanged nestable pipe handling weights, kg/m

Diameter	Specified Wall Thickness (mm)			
(mm)	1.6	2.0	2.8	3.5
300	18	22	31	39
400	22	28	39	49
450	24	31	43	54
500	27	34	48	60
600	31	39	54	68
700	36	45	62	79
800	41	51	70	89
900	45	56	77	97
1000	48	61	83	101
1200	59	74	102	126
1400	68	85	118	146
1600	78	97	134	166

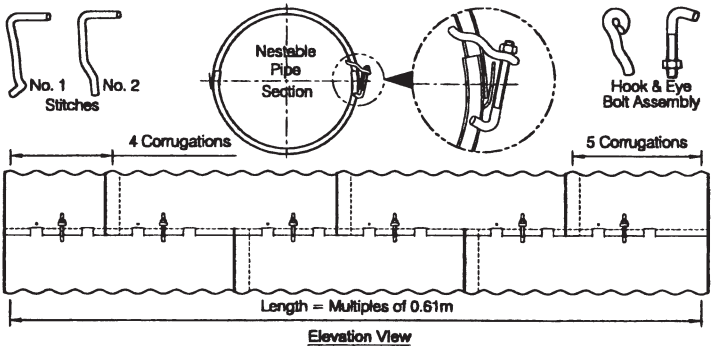


Figure 2.5 Notched nestable pipe can be joined with stitches or a hook and eye bolt assembly.

Table 2.14 Notched nestable pipe handling weights, kg/m

Diameter	Specified Wall Thickness (mm)				
(mm)	1.6	2.0	2.8	3.5	4.2
300	15	19	26	32	38
400	20	25	34	42	50
450	23	29	38	47	57
500	25	32	43	53	63
600	29	37	51	63	76
700	34	43	59	73	88
800	39	49	68	84	100
900	44	56	77	95	113
1000	49	61	85	105	126
1200	59	74	102	126	151
1400	69	85	119	147	176
1600	78	98	137	168	202
1800	88	110	153	118	226
2000	98	122	170	210	252

Ditch Liner

Half-round flanged nestable pipe is used widely as a flume or downslope drain. Wood sills and cross-braces with anchors embedded in the embankment stabilize the flume.

Concrete Lined CSP

This product consists of a corrugated steel pipe with an interior lining composed of an extremely dense, high strength concrete. The lining provides a superior wearing surface for extended structure life as well as a smooth interior for improved hydraulics.

CSP Slotted Drain Inlets

By welding a narrow section of grating in the top of a corrugated steel pipe, a continuous grate inlet is achieved. Originally conceived to pick up sheet flow in roadway medians, parking lots, airports, etc., this product has proven even more useful in curb inlets. Detailed hydraulic design information is provided in Chapter 4, Hydraulics.

CSP slotted drain inlet.

SECTION B: STRUCTURAL PLATE AND DEEP CORRUGATED STRUCTURAL PLATE PRODUCTS

1. STRUCTURAL PLATE

Product Description

Structural plate pipes are structures where corrugated steel sections are bolted together to form the shape of the structure. The sections are commonly referred to as plates.

The structural plate 152 x 51 mm corrugation is the standard in the Canadian structural plate industry. The corrugation is shown in Figure 2.1.

The corrugations are at right angles to the length of the plate. The length of a plate is measured in a direction parallel to the length of the structure. The width of a plate is, therefore, measured in a direction perpendicular to the length of the structure, around the periphery of the structure.

Standard plates are fabricated in three lengths and several widths, as shown in Table 2.15 and Figures 2.6 and 2.7. The plate width designation, N, is used to describe the various plate widths available. N is the distance between two circumferential bolt holes, or one circumferential bolt hole space (circumferential refers to the direction around the periphery of the structure, at right angles to the length of the structure). For instance, a 5N plate has a net width of 5 circumferential bolt hole spaces (see Figure 2.6) and an 8N plate has a net width of 8 circumferential bolt hole spaces (see Figure 2.7). The bolt hole space, N, is 9.6 inches or 243.84 mm (244 mm nominal). Note that not all widths are available in all lengths. The width-length combinations are shown in Table 2.16.

Plates are furnished curved to various radii and are clearly identified by the fabricator for field assembly.

The plates are available in thicknesses from 3.0 to 7.0 mm.

Masses of individual plate sections are shown in Table 2.16. While the correct terminology is “mass”, the term “weight” will be used in the following text and tables. Approximate weights of structural plate structures are readily calculated using these values.

Section Properties

Section properties, used for design, are provided in Table 2.17. As with corrugated steel pipe corrugations, properties of the arc-and-tangent structural plate corrugation are derived mathematically using the design thickness. The properties in the table include area, moment of inertia, section modulus and radius of gyration.

Sizes and Shapes

The plates are assembled into various shapes as indicated in Tables 2.18 through 2.26. The shapes include round, pipe-arch, single radius arch, horizontal ellipse, low profile arch, high profile arch, pear, underpass and vertical ellipse. Special shapes, and other sizes of standard shapes beyond what is shown in the tables, are also available. Detailed assembly instructions accompany each structure.

Table 2.15

Structural plate sections, 152 x 51 corrugation
Profile details of uncurved plates

Nominal Plate Width Designation N	Net Width, mm	Overall Width, mm	Spaces (N) at 244 mm	No. of Circumferential Bolt Holes
3N	732	846	3	4
4N	975	1090	4	5
5N	1219	1334	5	6
6N	1463	1577	6	7
7N	1707	1821	7	8
8N	1951	2065	8	9
9N	2195	2309	9	10
10N	2438	2553	10	11
11N	2682	2797	11	12
12N	2926	3040	12	13
13N	3170	3284	13	14
14N	3414	3528	14	15
15N	3658	3772	15	16
16N	3901	4016	16	17

N = 244 mm nominal (243.84 mm theoretical)

Table 2.16

Weight of structural plate sections

Plate Width Designation	Length, mm	Approximate Weight of Galvanized Plates[1], kg Specified Wall Thickness, mm					Number of Assembly Bolts/Plate
		3	4	5	6	7	
5N	3048	132	176	221	265	309	44
5N	3658	158	211	264	316	369	52
6N	3048	156	209	261	313	365	45
6N	3658	187	249	312	374	436	53
9N	3048	229	305	381	457	534	48
9N	3658	273	364	456	547	638	56
3N	1067	30	40	50	60	70	16
4N	1067	38	51	64	77	90	17
5N	1067	47	63	78	94	109	18
6N	1067	58	78	97	117	136	19
7N	1067	67	90	112	135	157	20
8N	1067	76	102	127	152	178	21
9N	1067	85	114	142	170	199	22
10N	1067	94	126	157	188	220	23
11N	1067	103	138	172	206	241	24
12N	1067	112	150	187	224	262	25
13N	1067	121	161	202	242	283	26
14N	1067	130	173	217	260	304	27
15N	1067	139	185	232	278	325	28
16N	1067	139	185	232	278	325	29

Notes 1. Bolt weight not included.

2. For galvanized plate thicknesses 3.0 and 4.0 mm, bolt lengths are 32 and 38 mm; for thicknesses 5.0 and 6.0 mm, bolt lengths are 38 and 44 mm; for 7.0 mm thickness, bolt lengths are 38 and 51 mm. Bolts are colour coded for the different lengths.

3. Weight of bolts and nuts in kg per hundred:
   32 mm = 23.6 51 mm = 27.0
   38 mm = 25.0 76 mm = 32.9
   44 mm = 25.9

4. To compute the approximate weight of structure per metre of length: (1) multiply the weight from the table by the number of plates in the periphery; (2) add weight of bolts and nuts; and (3) divide by plate length.

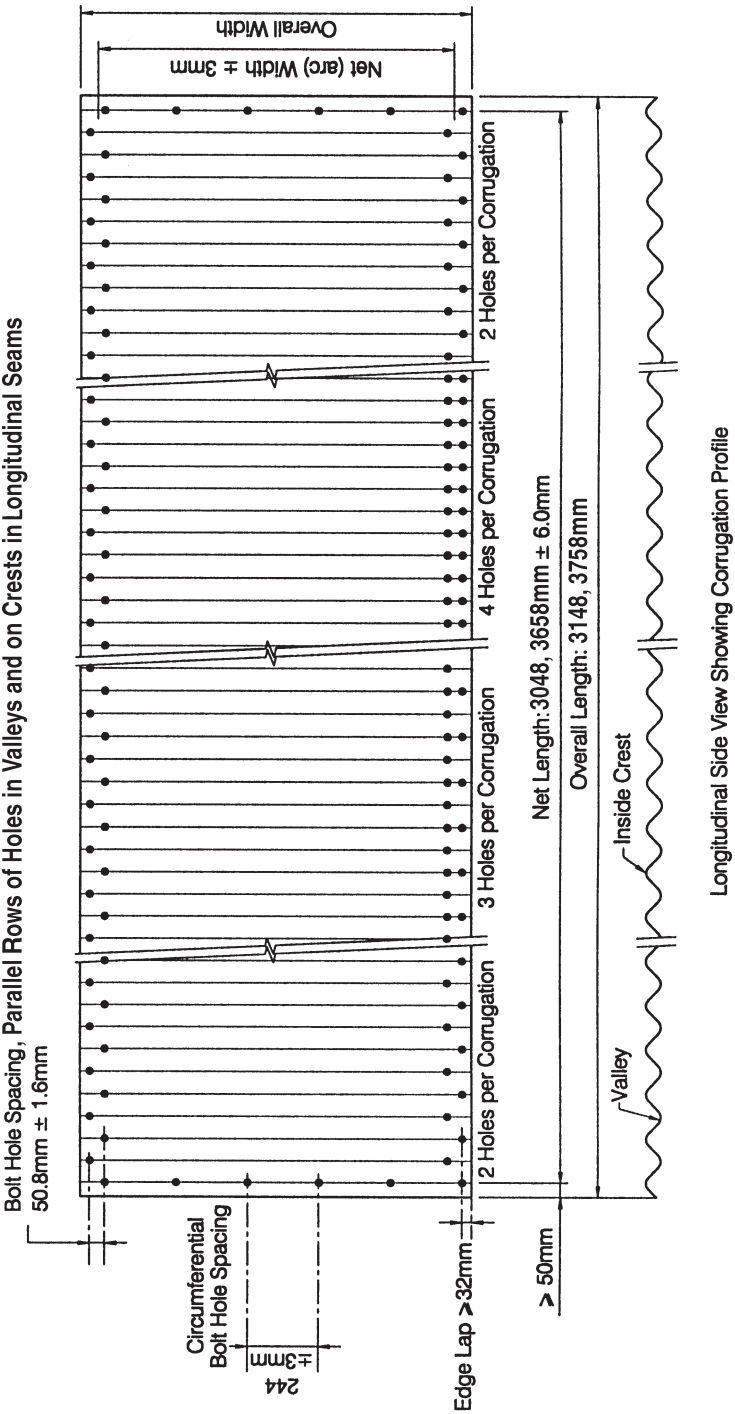


Figure 2.6 Configuration of structural plate sheets.

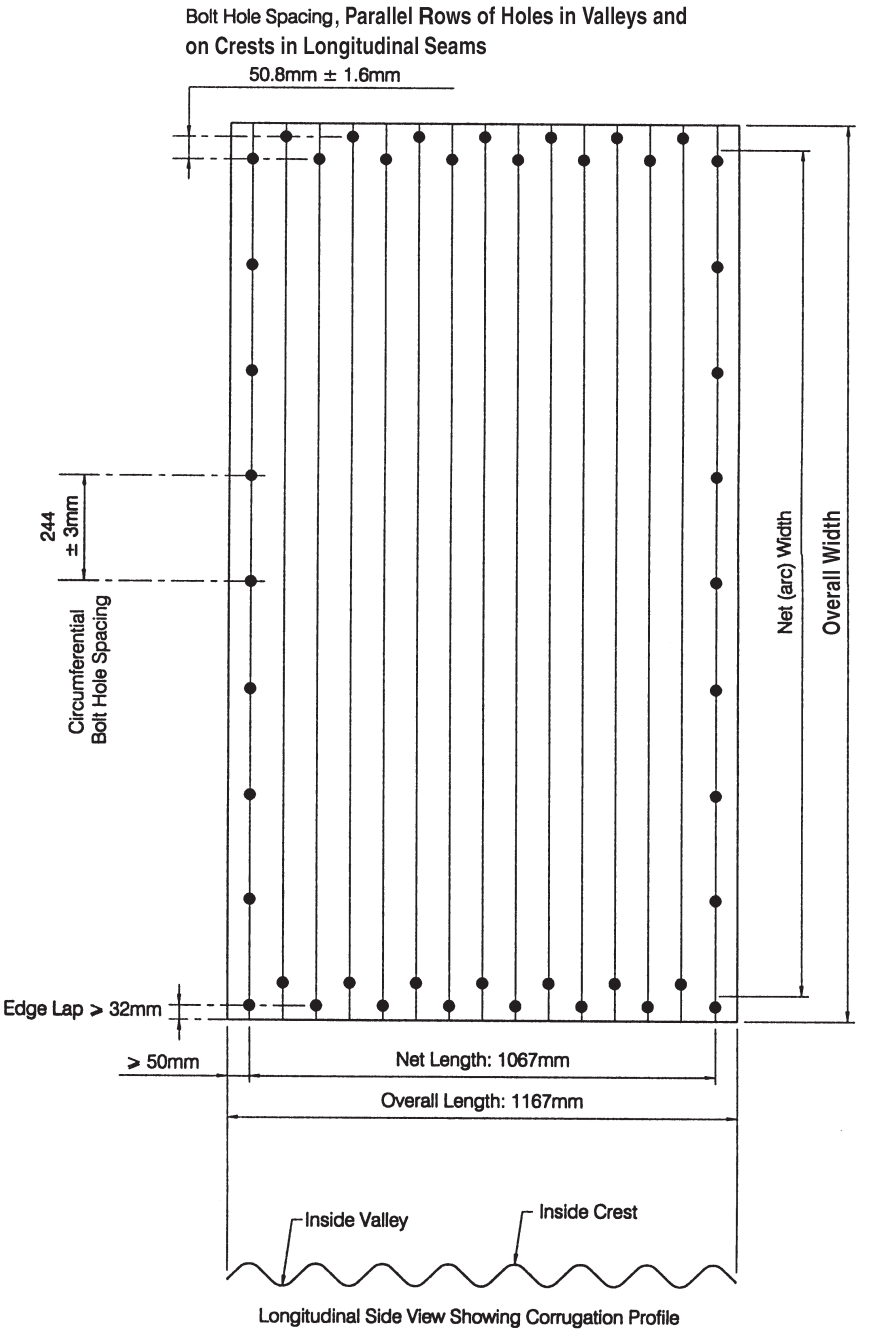
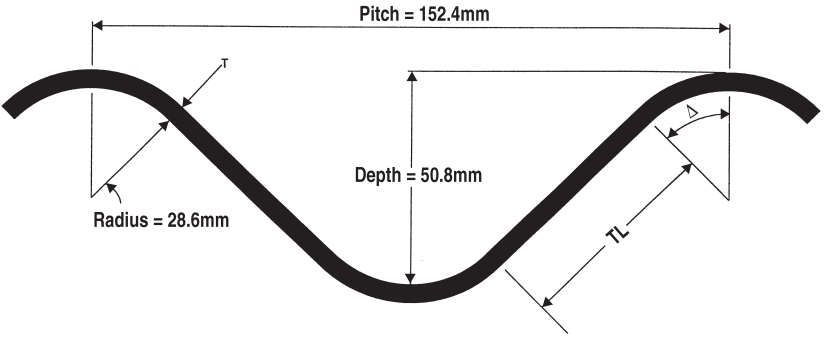


Figure 2.7 Alternate structural plate configuration.

Table 2.17

Section properties for corrugated structural plate
Corrugation profile: **152 x 51 mm**

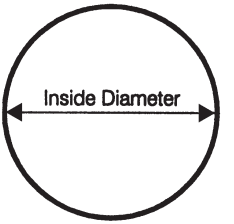


Wall Thickness								Developed
Specified	Design	Area	Tangent Length	Tangent Angle	Moment of Inertia	Section Modulus	Radius of Gyration	Width Factor
T	T	A	TL	Δ	I	S	r	WF
mm		mm^2/mm	mm	Degrees	mm^4/mm	mm^3/mm	mm	*
3.0	2.84	3.522	47.876	44.531	1057.25	39.42	17.326	1.240
4.0	3.89	4.828	46.748	44.899	1457.56	53.30	17.375	1.241
5.0	4.95	6.149	45.582	45.286	1867.12	66.98	17.425	1.242
6.0	6.00	7.461	44.396	45.686	2278.31	80.22	17.475	1.243
7.0	7.00	8.712	43.237	46.083	2675.11	92.56	17.523	1.244

*WF is the ratio of the flat plate width to the corrugated plate width.
Dimensions are subject to manufacturing tolerances.

Table 2.18

Structural plate corrugated round pipe
152 x 51 mm corrugation profile
Standard diameters and unit weight of assembled structure



Inside Diameter, mm	Periphery (Hole Spaces), N	End Area, m^2	Unit Weight of Structure,* kg/m Bolts Included				
			Specified Wall Thickness, mm				
			3.0	4.0	5.0	6.0	7.0
1500	20N	1.77	180	234	288	342	396
1660	22N	2.16	195	254	313	373	432
1810	24N	2.58	211	275	339	403	467
1970	26N	3.04	232	302	373	443	513
2120	28N	3.54	248	323	398	473	548
2280	30N	4.07	257	335	415	494	572
2430	32N	4.65	272	356	440	524	608
2590	34N	5.26	294	384	474	564	654
2740	36N	5.91	303	396	490	584	678
3050	40N	7.32	346	452	559	665	771
3360	44N	8.89	377	493	609	725	841
3670	48N	10.61	408	534	660	786	911
3990	52N	12.47	445	582	719	856	993
4300	56N	14.49	476	623	770	916	1063
4610	60N	16.66	507	663	820	977	1134
4920	64N	18.99	544	711	880	1047	1215
5230	68N	21.46	575	752	930	1108	1285
5540	72N	24.08	605	793	981	1168	1356
5850	76N	28.86	649	849	1049	1249	1449
6160	80N	29.79	680	889	1100	1309	1519
6470	84N	32.87	711	930	1150	1370	1589
6780	88N	36.10	748	978	1210	1440	1671
7090	92N	39.48	779	1019	1260	1501	1741
7400	96N	43.01	809	1060	1311	1561	1812
7710	100N	46.70	846	1108	1370	1631	1893
8020	104N	50.53	877	1149	1421	1692	1963

*Weights based on 3658 mm plate lengths (refer to Table 2.16). Dimensions are to inside of corrugation crests and are subject to manufacturing tolerances.

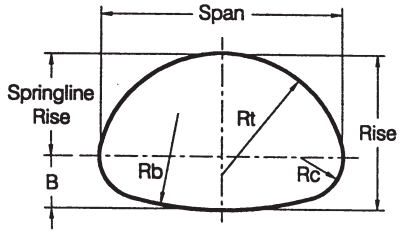


Table 2.19

Structural plate corrugated pipe-arch
152 x 51 mm corrugation profile
Standard dimensions and unit weight of structure (assembled)

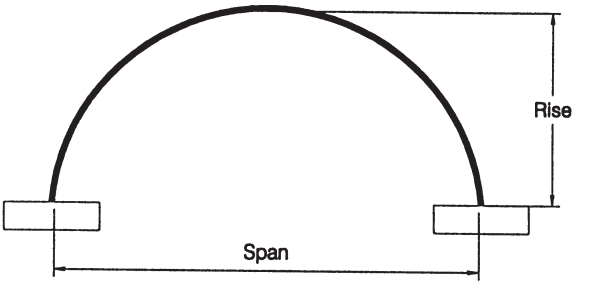
Span, mm	Rise, mm	End Area, m^2	Layout Dimensions* (to neutral axis), mm				Required N				Unit Weight of Structure, kg/m, Bolts Included				
											Specified Wall Thickness, mm				
			B	R_t	R_c	R_b	Top	Each Corner	Bottom	Total	3.0	4.0	5.0	6.0	7.0
2060	1520	2.49	700	1130	660	1875	9	5	5	24	210	274	339	403	467
2240	1630	2.90	680	1205	660	3370	11	5	5	26	232	302	373	443	513
2440	1750	3.36	730	1305	685	2995	12	5	6	28	248	323	398	473	548
2590	1880	3.87	735	1355	710	4420	14	5	6	30	263	343	423	503	583
2690	2080	4.49	815	1380	785	4050	16	5	6	32	285	371	458	544	630
3100	1980	4.83	790	1695	685	3850	15	5	9	34	294	384	474	564	654
3400	2010	5.28	840	2000	660	3510	15	5	11	36	316	412	508	604	700
3730	2290	6.61	900	2055	710	4045	18	5	12	40	346	452	559	665	771
3890	2690	8.29	915	1975	815	6015	23	5	11	44	384	501	618	735	852
4370	2870	9.76	1035	2265	815	4895	24	5	14	48	414	541	669	795	922
4720	3070	11.38	1015	2425	815	6430	27	5	15	52	445	582	719	856	993
5050	3330	13.24	1040	2570	840	7430	30	5	16	56	489	638	787	936	1085
5490	3530	15.10	1095	2790	840	7575	32	5	18	60	513	671	829	987	1145
5890	3710	17.07	1150	3020	840	7755	34	5	20	64	557	727	897	1067	1237
6250	3910	19.18	1120	3175	840	9630	37	5	21	68	588	767	948	1128	1308
7040	4060	22.48	1660	4090	1370	9650	31	11	21	74	653	851	1050	1248	1447
7620	4240	25.27	1750	4570	1370	9650	33	11	24	79	679	887	1096	1304	1513

*Refer to diagram above this table.

NOTES: Pipe-arch structures generally require more care in design and installation than round structures, particularly in the larger sizes.
All dimensions are inside unless otherwise noted.

Table 2.20

Structural plate corrugated steel arch
152 x 51 mm corrugation profile
Standard dimensions and unit weight of structure

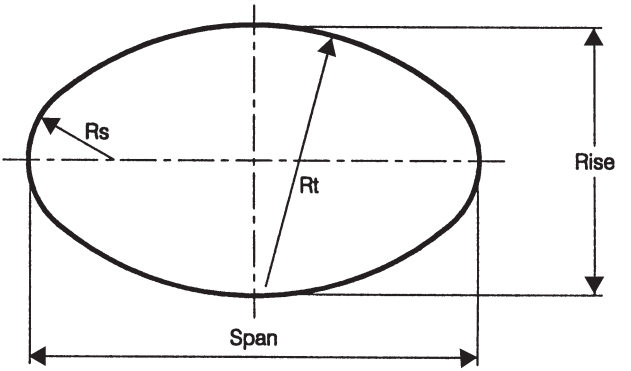


Span, mm	Rise, mm	Total Periphery (Hole Spaces), N	End Area*, m^2	Radius, mm	Unit Weight of Structure, kg/m Bolts Included				
					Specified Wall Thickness, mm				
					3.0	4.0	5.0	6.0	7.0
1520	810	10N	0.98	760	87	114	141	168	195
1830	840	11N	1.16	930	95	124	154	183	213
	970	12N	1.39	910	102	134	166	198	230
2130	860	12N	1.39	1090	102	134	166	198	230
	1120	14N	1.86	1070	118	155	192	229	266
2440	1020	14N	1.86	1230	118	155	192	229	266
	1270	16N	2.42	1220	139	183	226	269	312
2740	1180	16N	2.46	1400	139	183	226	269	312
	1440	18N	3.07	1370	148	195	242	289	336
3050	1350	18N	3.16	1540	148	195	242	289	336
	1600	20N	3.81	1520	170	223	276	329	382
3350	1360	19N	3.44	1710	163	213	264	314	365
	1750	22N	4.65	1680	192	251	310	370	429
3660	1520	21N	4.18	1850	178	233	289	344	400
	1910	24N	5.48	1830	201	264	327	390	453
3960	1680	23N	5.02	2010	203	264	326	388	449
	2060	26N	6.50	1980	223	292	361	430	499
4270	1840	25N	5.95	2160	215	282	348	415	481
	2210	28N	7.43	2130	238	312	386	460	534
4570	1870	26N	6.41	2340	223	292	361	430	499
	2360	30N	8.55	2290	254	332	412	491	569
4880	2030	28N	7.43	2480	238	312	386	460	534
	2520	32N	9.75	2440	269	353	437	521	605
5180	2180	30N	8.55	2620	254	332	412	491	569
	2690	34N	11.06	2590	291	381	471	561	654
5490	2210	31N	9.01	2820	268	350	433	516	598
	2720	35N	11.71	2740	299	391	484	576	669
5790	2360	33N	10.22	2950	277	363	450	536	622
	2880	37N	13.01	2900	314	411	509	606	704
6100	2530	35N	11.52	3100	299	391	484	576	669
	3050	39N	14.59	3050	329	432	534	637	739

*End area under soffit above the top of footing.
Notes: Other sizes and plate configurations are available. All dimensions are inside.

Table 2.21

Structural plate corrugated horizontal ellipse
152 x 51 mm corrugation profile
Sizes and layout details

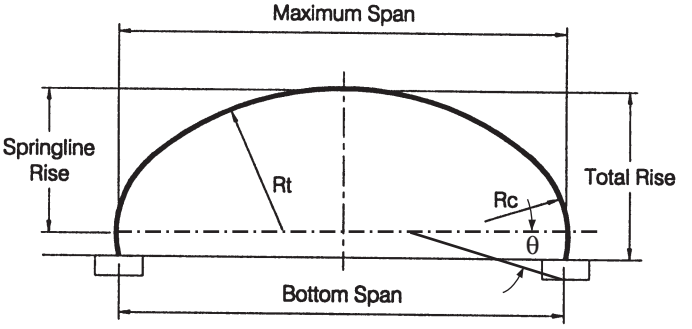


Span, mm	Rise, mm	End Area, m^2	Required N			R_t Top, mm	R_s Side, mm
			Top or Bottom	Each Side	Total		
1630	1350	1.74	5	5	20	970	610
2130	1420	2.41	6	6	24	1710	610
2540	1630	3.24	9	5	28	1770	610
2790	1630	3.57	9	6	30	2340	640
2900	1930	4.36	11	5	32	1850	690
3200	2260	5.64	12	6	36	1990	840
3760	2260	6.62	14	6	40	2630	760
3680	2440	6.85	15	5	40	2260	760
4420	2790	9.78	15	9	48	3200	1070
4826	3429	12.86	18	9	54	2972	1283
5156	3683	14.87	18	11	58	3289	1448
5283	3531	14.59	18	11	58	3607	1359
5715	3988	18.08	18	14	64	3924	1664
6120	3960	18.77	23	10	66	3985	1370
6230	3840	18.40	24	9	66	4165	1220
6460	3910	19.42	25	9	68	4345	1220
6680	3990	20.49	26	9	70	4520	1245
7010	4290	23.15	27	10	74	4700	1370
7470	4470	25.49	29	10	78	5030	1370
7950	5540	34.25	29	15	88	5030	2085
8280	5820	37.59	30	16	92	5025	2210
8560	5210	34.28	33	12	90	5740	1650
8970	6070	42.23	33	16	98	5740	2210
9220	5460	38.55	36	12	96	6275	1650
10110	6120	47.57	39	14	106	6780	1930
10640	6500	53.29	41	15	112	7135	2085
10970	6810	57.51	42	16	116	7315	2210
11250	7800	68.25	41	21	124	7135	2920
11580	8100	72.93	42	22	128	7315	3050
11790	8510	78.31	42	24	132	7315	3325

NOTES: Other sizes and plate configurations are available. All dimensions are inside.

Table 2.22

Structural plate corrugated low profile arch
152 x 51 mm corrugation profile
Sizes and layout details



Max. Span, mm	Bottom Span, mm	Total Rise, mm	End Area, m^2	Required N			R_t Top, mm	R_c Side, mm	Springline Rise, mm	Re-Entry Angle, θ, Degrees
				Top	Each Side	Total				
5920	5820	2080	9.75	23	5	33	3990	1090	1780	15.6
6120	6050	2290	11.18	23	6	35	3990	1370	1980	12.4
6550	6500	2360	12.39	25	6	37	4345	1370	2055	12.4
6780	6730	2410	13.01	26	6	38	4520	1370	2110	12.4
7010	6930	2440	13.64	27	6	39	4700	1370	2160	12.4
7240	7160	2490	14.29	28	6	40	4875	1370	2185	12.4
7470	7390	2540	14.94	29	6	41	5030	1370	2235	12.4
7670	7620	2570	15.62	30	6	42	5205	1370	2260	12.4
7900	7850	2620	16.30	31	6	43	5385	1370	2310	12.4
8310	8150	3280	22.04	31	9	49	5385	1930	2745	16.1
8760	8610	3350	23.74	33	9	51	5740	1930	2820	16.1
9420	9270	3480	26.39	36	9	54	6275	1930	2945	16.1
9630	9500	3680	28.69	36	10	56	6275	2210	3150	14.0
9860	9730	3730	29.64	37	10	57	6425	2210	3200	14.0
10080	9930	3780	30.61	38	10	58	6605	2210	3250	14.0
10110	9960	3610	29.15	39	9	57	6780	1930	3075	16.1
10490	10390	4040	34.09	39	11	61	6780	2490	3505	12.5
10540	10410	3680	31.06	41	9	59	7135	1930	3150	16.1
10770	10570	3730	32.03	42	9	60	7315	1930	3200	16.1
11560	11460	4780	44.30	41	14	69	7135	3325	4215	9.4
11790	11680	4800	45.51	42	14	70	7315	3325	4260	9.4

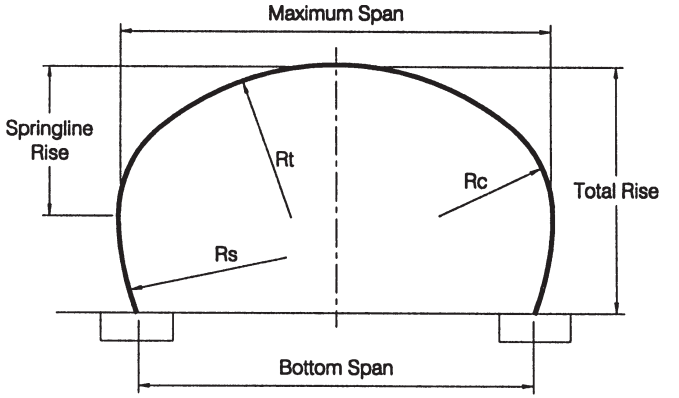
NOTES: Other sizes and plate configurations are available. All dimensions are inside.

Low profile arch with concrete and bin-type retaining wall end treatment.

Long-span high profile arch with concrete and bin-type retaining wall headwall.

Table 2.23

Structural plate corrugated high profile arch
152 x 51 mm corrugation profile
Sizes and layout details



Maximum Span, mm	Bottom Span, mm	Total Rise, mm	End Area, m^2	Required N				R_t Top, mm	R_c Upper Side, mm	R_s Lower Side, mm	Springline Rise, mm
				Top	Each Upper Side	Each Lower Side	Total				
6300	5740	3680	19.85	23	6	6	47	3990	1650	3985	2200
6550	6050	3560	19.93	25	5	6	47	4345	1370	4345	2070
6780	6270	3610	20.85	26	5	6	48	4520	1370	4520	2110
7010	6530	3660	21.78	27	5	6	49	4700	1370	4700	2150
7240	6760	3680	22.71	28	5	6	50	4875	1370	4875	2190
7670	7230	3740	24.61	30	5	6	52	5205	1370	5205	2270
7870	6920	4655	31.56	30	6	9	60	5205	1650	5205	2490
8100	7190	4650	32.78	31	6	9	61	5385	1650	5385	2520
8560	7500	5020	36.92	33	6	10	65	5740	1650	5740	2610
8590	7750	4630	34.09	34	5	9	62	5920	1370	5920	2440
9220	8420	4920	39.00	36	6	9	66	6275	1650	6275	2730
9450	8670	4970	40.25	37	6	9	67	6425	1650	6425	2770
9680	8740	5260	43.55	38	6	10	70	6605	1650	6605	2810
9910	8990	5280	44.91	39	6	10	71	6780	1650	6780	2850
10360	9500	5380	47.67	41	6	10	73	7135	1650	7135	2930
10360	9140	5830	51.86	41	6	12	77	7135	1650	7135	2930
10570	9730	5440	49.07	42	6	10	74	7315	1650	7315	2980
10590	9390	5870	53.39	42	6	12	78	7315	1650	7315	2980
11350	10130	6910	67.08	41	11	12	87	7135	3050	7135	4000
11580	10390	6930	68.86	42	11	12	88	7315	3050	7315	4000

NOTES: Other sizes and plate configurations are available. All dimensions are inside.

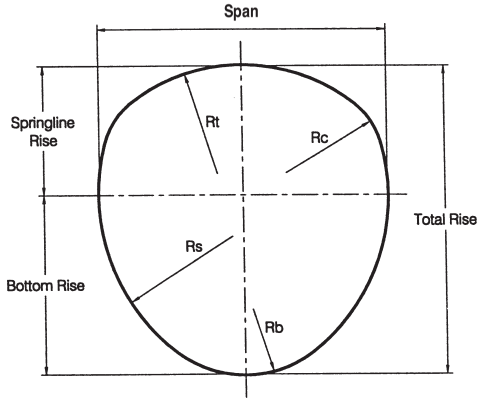


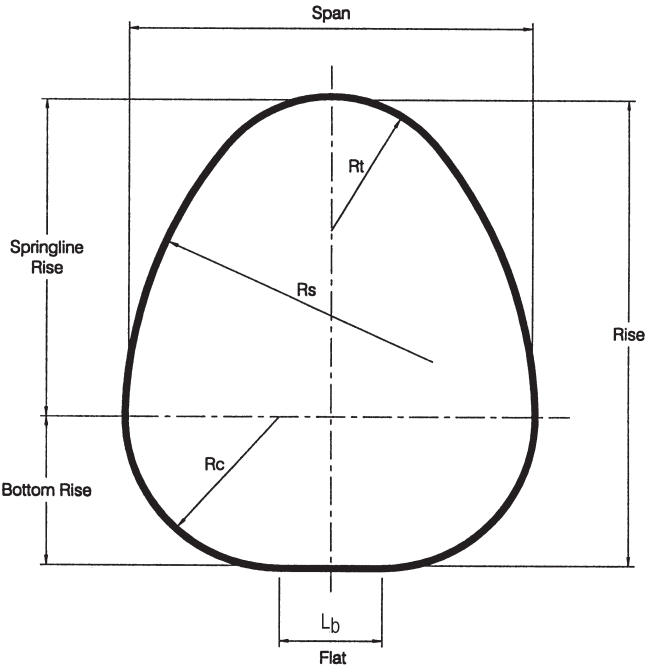
Table 2.24 Structural plate corrugated pear shape
152 x 51 mm corrugation profile
Sizes and layout details

Span, mm	Total Rise, mm	Bottom Rise, mm	End Area, m^2	Required N					R_b Bottom, mm	R_s Side, mm	R_c Corner, mm	R_t Top, mm
				Top	Each Corner	Each Side	Bottom	Total				
*7210	7820	4550	44.69	25	5	24	15	98	2720	5055	1905	4470
7570	8430	5100	50.54	27	5	25	18	105	2820	5995	1755	4850
8360	8230	5510	53.70	30	6	26	16	110	2920	6200	1395	6070
**8100	8610	5460	54.91	28	5	30	12	110	2440	6095	1475	6275
8560	8480	5130	57.97	27	8	22	25	112	3710	5790	2210	6225
***7320	8530	4880	48.87	27	5	24	18	103	2770	5790	2440	3960

*Meets AREMA clearance for bridges & tunnels.
**Meets AREMA clearance for single track tunnel.
***Meets AREMA CP Rail Clearance for single track tunnel.
NOTES: Other sizes and plate configurations are available. All dimensions are inside.

Table 2.25

Structural plate corrugated pedestrian and cattle underpass
152 x 51 mm corrugation profile
Sizes and layout details

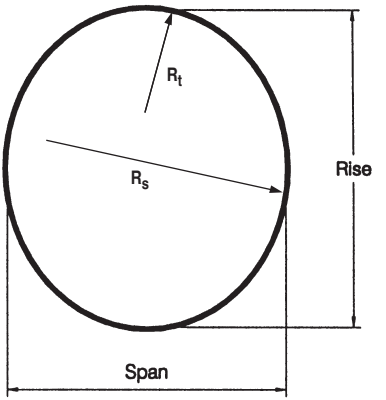


			Periphery , N								
Span, mm	Rise, mm	Bottom Rise, mm	Total N	Top	Each Side	Bottom	Each Corner	R_t mm	R_s mm	R_c mm	L_b mm
1755	1995	700	26	7	5	3	3	750	1980	485	730
1780	2250	790	28	7	6	3	3	725	2490	490	730
1780	2360	825	29	8	6	3	3	760	3125	485	730
1790	2490	900	30	7	7	3	3	710	2920	495	730

NOTES: Other sizes and plate configurations are available. All dimensions are inside.

Table 2.26

Structural plate corrugated steel pipe
5% vertically ellipsed
152 x 51 mm corrugation profile
Sizes and layout details



Span, mm	Rise, mm	End Area, m^2	Required N			Unit Weight of Structure, kg/m Bolts Included					Layout Dimensions	
			Each Side	Top or Bottom	Total	Specified Wall Thickness, mm					R_t	R_s
						3.0	4.0	5.0	6.0	7.0		
2310	2570	4.63	10	6	32	285	371	458	544	630	1045	1350
2460	2740	5.24	11	6	34	300	391	483	574	665	1100	1430
2620	2900	5.89	9	9	36	303	396	490	584	678	1220	1565
2920	3230	7.30	14	6	40	346	452	559	665	771	1265	1675
3200	3560	8.86	16	6	44	390	508	627	745	863	1370	1840
3580	3890	10.57	18	6	48	408	534	660	786	911	1470	2005
3810	4220	12.42	17	9	52	452	590	728	866	1004	1690	2200
4140	4570	14.41	19	9	56	482	630	779	926	1074	1800	2360
4340	4830	16.60	12	18	60	513	671	829	987	1145	2090	2720
4650	5160	18.92	14	18	64	544	711	880	1047	1215	2220	2855
4950	5460	21.38	14	20	68	588	767	948	1128	1308	2370	3065
5260	5820	23.99	18	18	72	605	793	981	1168	1356	2470	3150
5540	6120	26.75	18	20	76	649	849	1049	1249	1449	2620	3355
5840	6450	29.67	19	21	80	693	905	1117	1329	1541	2760	3530
6120	6780	32.74	21	21	84	724	945	1168	1390	1612	2885	3680

NOTES: The vertically ellipsed shape may be suited for high fills, or other site conditions. Other sizes and plate configurations are available. All dimensions are inside.

Bolts and Nuts

Galvanized 19 mm diameter bolts of special heat-treated steel meeting ASTM Specification A 449 or ASTM Specification F568 Class 8.8, are used to assemble structural plate sections. Galvanized nuts meet the requirements of ASTM A 563 Grade 12. The galvanizing on bolts and nuts must meet ASTM Specification A 153, CSA-G164 Class 5 or ASTM B 695 Class 50 Type II. See Figure 2.8 for dimensions of bolts and nuts. Lengths include: 32, 38, 44, 51 and 76 mm. The containers and bolts are colour coded for ease in identification as shown in Table 2.27.These are designed for fitting either the crest or valley of the corrugations, and to give maximum bearing area and tight seams without the use of washers. Power wrenches are generally used for bolt tightening, but simple hand wrenches are satisfactory for small structures.

Anchor bolts are available for anchoring the sides of structural plate arches into footings, and the ends of structural plate conduits into concrete end treatments (Figures 2.9 and 2.10). Material for these special 19 mm bolts must conform to ASTM Specification A 307, and nuts to ASTM A 563 Grade C. Galvanizing of anchor bolts and nuts must conform to ASTM A 153.

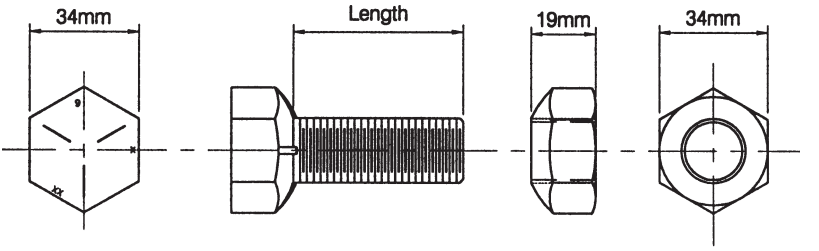


Figure 2.8: Dimensions of bolts and nuts for structural plate.

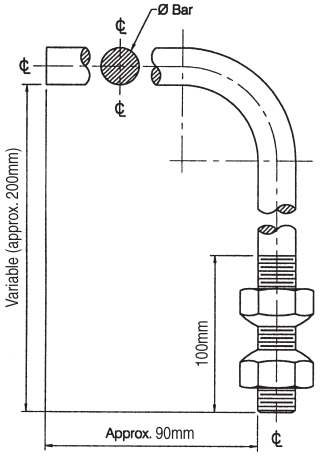


Figure 2.9: Hook bolts and nuts for embedment in headwalls.

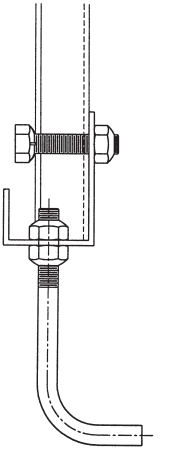


Figure 2.10: Hook bolt and base channel.

Table 2.27 Bolt and container colour coding

Bolt Length, mm	Colour	
	Bolt	Container
32	None	White
38	Green	Green
44	Red	Red
51	Black	Black
76	None	Yellow
Nuts	None	Blue

Arch Channels

For arch seats, galvanized unbalanced channels are available for anchoring the arch to concrete footings. The unbalanced channel is anchored to the footing either by anchor bolts or by integral lugs that are bent and twisted as shown in Figure 2.11.

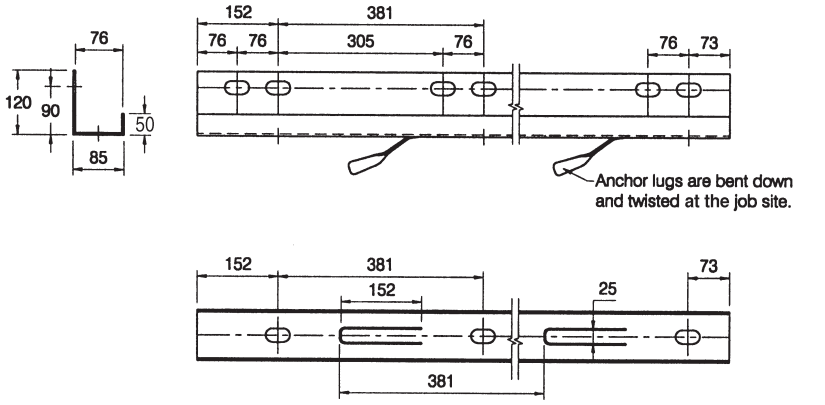


Figure 2.11: General dimensions of unbalanced channels for structural plate arches.

2. DEEP CORRUGATED STRUCTURAL PLATE

Deep corrugated structural plate is also a bolted structure. It has either a 381 x 140 mm corrugation (DCSP Type I) or a 400 x 150 mm corrugation (DCSP Type II).

As with structural plate, the corrugations are at right angles to the length of the plate. The length of a plate is measured in a direction parallel to the length of the structure. The width of a plate is, therefore, measured in a direction that is perpendicular to the length of the structure, around the periphery of the structure.

DEEP CORRUGATED STRUCTURAL PLATE TYPE I

Product Description

Deep corrugated structural plate pipe Type I has a 381 x 140 mm corrugation, which is shown in Figure 2.1.

Standard plates are fabricated in one length and several widths, as shown in Table 2.28 and Figure 2.12. The coverage length (excluding the side lips) is 762 mm.The plate width designation, S, is used to describe the various plate widths available. S is the distance between circumferential bolt holes, or one circumferential bolt hole space (circumferential refers to the direction around the periphery of the structure, at right angles to the length of the structure). For instance, a 5 S plate has a net width of 5 circumferential bolt hole spaces (see Figure 2.12). The bolt hole space, S, is 406.4 mm (406 mm nominal).

Plates are furnished curved to various radii and are clearly identified by the fabricator for field erection. The plates are available in 2.8 to 7.1 mm thicknesses. Weights of individual plate sections are shown in Table 2.29.

Section Properties

Section properties, used for design, are provided in Table 2.30. Properties of the arc-and-tangent corrugation are derived mathematically using the design thickness. The properties in the table include area, moment of inertia, section modulus and radius of gyration.

Sizes and Shapes

The plates are assembled into various shapes as indicated in Tables 2.31 through 2.34. The shapes include round, single radius arch, multi-radius arch, and box culvert. Special shapes, and other standard shape sizes not shown in the tables, are also available. Detailed assembly instructions accompany each structure.

Table 2.28 Deep corrugated structural plate sections
Type I: **381 x 140 mm** corrugation profile
Details of uncurved plates

Nominal Plate Width Designation, S	Net Width, mm	Overall Width, mm	No. of Circumferential Bolt Holes
1S	406.4	634.4	2
2S	812.8	1040.8	3
3S	1219.2	1447.2	4
4S	1625.6	1853.6	5
5S	2032.0	2260.0	6
6S	2438.4	2666.4	7
7S	2844.8	3072.8	8
8S	3251.2	3479.2	9
9S	3657.6	3885.6	10
10S	4064.0	4292.0	11
11S	4470.4	4698.4	12

S = 406 mm Nominal (406.4 mm theoretical)

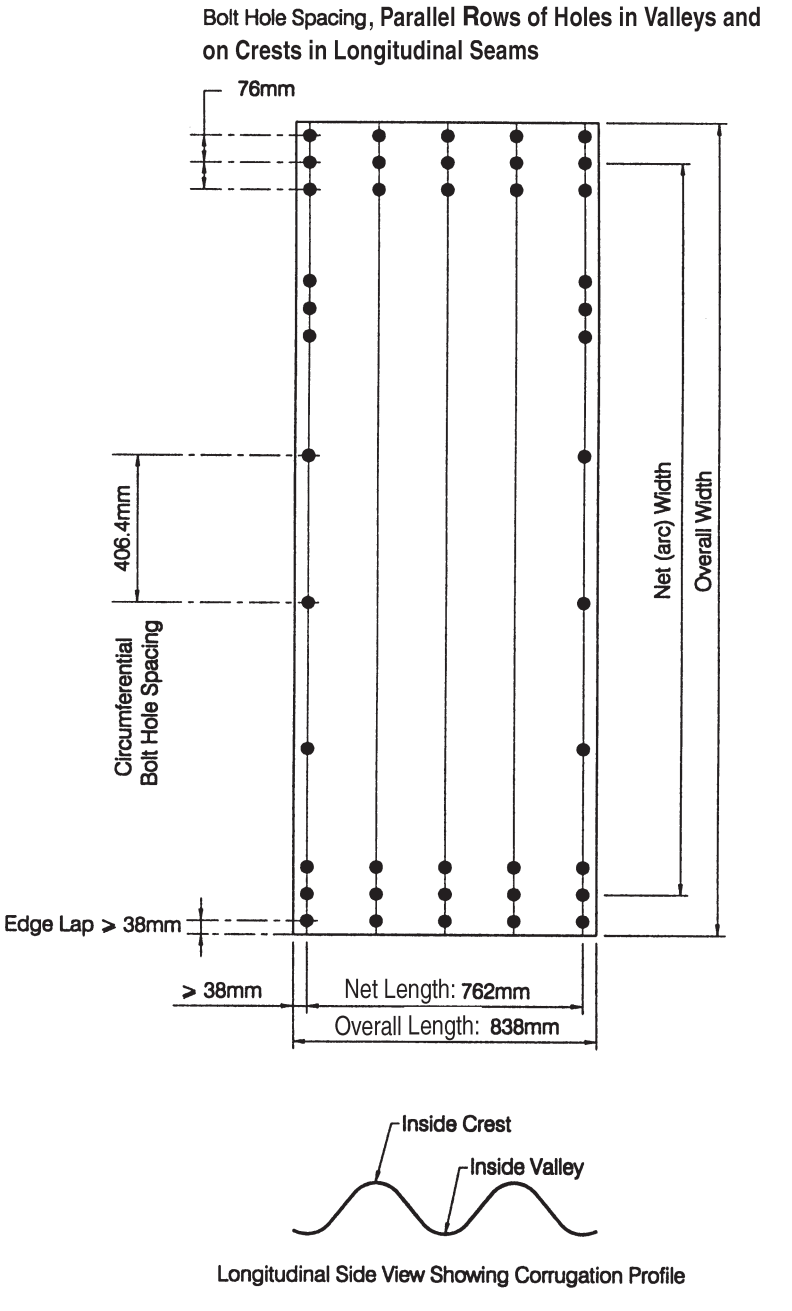


Figure 2.12 Deep Corrugated Structural Plate Type I plate configuration.

Table 2.29

Weight of deep corrugated structural plate sections
Type I: **381 x 140 mm** corrugation profile

Plate Width Designation	Length, mm	Approximate Weight of Galvanized Plates, kg Specified wall thickness							Number of Assembly Bolts/Plate
		2.77	3.50	4.27	4.78	5.54	6.32	7.11	
1S	762	15	20	24	27	32	37	42	14
2S	762	25	33	40	44	53	60	68	15
3S	762	35	46	55	62	73	83	94	16
4S	762	45	59	71	79	94	107	121	17
5S	762	55	72	86	96	114	130	147	18
6S	762	64	85	102	113	134	153	173	19
7S	762	74	98	117	131	155	177	200	20
8S	762	84	111	133	148	175	200	226	21
9S	762	94	124	148	165	196	223	252	22
10S	762	104	137	164	182	216	247	279	23
11S	762	113	150	179	200	236	270	305	24

Notes: 1. Bolt weight not included.

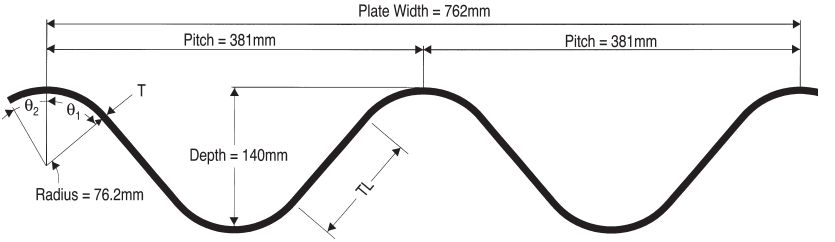
2. Bolt length used for all structures - 51 mm. Bolts are colour coded for the different lengths.

3. Weight of bolts and nuts in kg per hundred:
   51 mm = 27 kg
   76 mm = 32.9 kg
   102 mm = 38.8 kg

4. To compute the approximate weight of structures per meter of structure length: (1) multiply the weight from the table by the number of plates in the periphery; (2) add weight of bolts and nuts; (3) divide by plate length.

Table 2.30

Deep corrugated structural plate section properties
Type I: **381 x 140 mm** corrugation profile

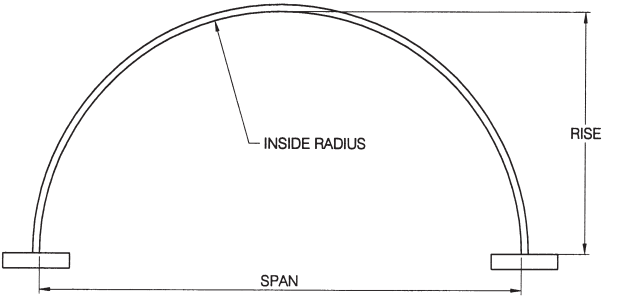


Specified T	Design T	Tangent Length	Tangent Angle 1	Tangent Angle 2	Area	Moment Axis of Inertia	Section Modulus	Radius of Gyration	Plastic Section Modulus	Developed Width Factor
		TL	θ_1	θ_2	A	I	S	r	Z	WF
mm	mm	mm	degrees	degrees	mm^2/mm	mm^4/mm	mm^3/mm	mm	mm^3/mm	*
2.81	2.66	111.74	49.61	30.59	3.72	9096.19	119.19	49.45	165.25	1.28
3.53	3.42	110.78	49.75	30.33	4.78	11710.74	152.72	49.48	212.67	1.28
4.27	4.18	109.81	49.89	30.06	5.85	14333.90	186.04	49.52	260.16	1.28
4.79	4.67	109.18	49.99	29.89	6.54	16038.98	207.54	49.54	291.03	1.28
5.54	5.45	108.18	50.13	29.62	7.63	18743.25	241.38	49.57	339.93	1.28
6.32	6.23	107.18	50.28	29.36	8.72	21445.89	274.87	49.60	388.77	1.28
7.11	7.01	106.15	50.43	29.09	9.81	24164.64	308.24	49.63	437.86	1.28

* WF is the ratio of the flat sheet width to the corrugated sheet width.

Table 2.31

Deep corrugated structural plate arch
Type I: **381 x 140 mm** corrugation profile
Size and layout details

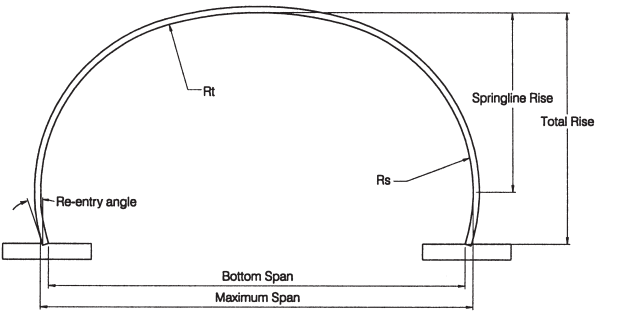


Span, mm	Rise, mm	Periphery (Hole Spaces), S	*End Area, m^2	Radius, mm
6990	3495	27	19.19	3495
7250	3625	28	20.64	3625
7510	3755	29	22.14	3755
7640	3820	30	23.70	3885
8030	4015	31	25.29	4015
8290	4140	32	26.95	4145
8550	4270	33	28.66	4275
8800	4400	34	30.42	4400
9060	4530	35	32.24	4530
9320	4660	36	34.10	4660
9580	4790	37	36.02	4790
9840	4920	38	38.00	4920
10100	5045	39	40.02	5050
10360	5175	40	42.10	5180
10620	5305	41	44.23	5310
10870	5435	42	46.41	5435
11130	5565	43	48.65	5565
11390	5695	44	50.94	5695
11650	5825	45	53.28	5825
11910	5955	46	55.67	5955
12170	6080	47	58.12	6085
12430	6210	48	60.61	6215
12690	6340	49	63.17	6345
12940	6470	50	65.76	6470
13200	6600	51	68.42	6600
13460	6730	52	71.13	6730
13720	6860	53	73.89	6860
13980	6985	54	76.71	6990
14240	7115	55	79.57	7120
14500	7245	56	82.49	7250
14760	7375	57	85.46	7380
15010	7505	58	88.49	7505
15270	7635	59	91.56	7635
15530	7765	60	94.69	7765
15790	7895	61	97.88	7895
16050	8025	62	101.10	8025
16310	8150	63	104.39	8155
16570	8280	64	107.74	8285
16830	8410	65	111.11	8415
17220	8610	66	114.56	8540
17290	8670	67	118.06	8670
17600	8800	68	121.62	8800
17860	8930	69	125.22	8930

***End area under soffit above top of footing.**
NOTE: Other arch structures may be designed to suit specific applications and/or sites. All dimensions are inside.

Table 2.32

Multi-radius deep corrugated structural plate arches
Type I: **381 x 140 mm** corrugation profile
Size and layout details



Maximum Span	Bottom Span	Total Rise	Springline Rise	Area	Required 'S'			Top Radius	Side Radius	Re-Entry Angle
					Top	Side (x2)	Total	R_t	R_S	
mm	mm	mm	mm	m^2				mm	mm	degrees
9190	9170	4585	4275	34.11	7.0	14.5	36	5730	4230	4.09
9165	8865	5380	4257	41.10	5.0	17.5	40	6530	4230	15.10
9420	9385	4690	4294	35.94	8.0	14.5	37	6030	4230	5.31
9340	9160	5290	4282	41.35	7.0	16.5	40	6330	4230	13.60
9720	9690	4795	4408	37.85	9.0	14.5	38	6130	4330	5.12
9760	9475	5595	4479	45.48	7.0	17.5	42	6530	4430	14.35
10085	10015	5070	4513	41.84	9.0	15.5	40	6730	4430	7.06
10060	9540	5790	4325	49.28	9.0	17.5	44	7630	4230	19.89
10400	10385	4655	4349	39.66	10.0	14.5	39	8230	4230	4.07
10485	10335	5275	4467	45.92	11.0	15.5	42	7430	4330	10.59
10400	10005	5990	4659	51.99	12.0	16.5	45	6330	4530	16.77
10690	10675	4770	4470	41.72	11.0	14.5	40	8130	4330	3.84
10700	10485	5355	4401	47.94	12.0	15.5	43	7930	4230	12.92
10680	10215	6075	4646	54.20	15.0	15.5	46	6430	4430	18.52
11000	10920	5030	4431	45.86	13.0	14.5	42	8330	4230	8.06
10985	10745	5440	4431	50.01	13.0	15.5	44	8230	4230	13.69
11000	10650	6385	4833	58.86	15.0	16.5	48	6630	4630	19.20
11225	11130	5140	4497	48.04	12.0	15.5	43	9330	4330	8.37
11300	10990	5680	4430	54.41	13.0	16.5	46	9430	4230	16.80
11240	10620	6495	4835	61.12	18.0	15.5	49	6630	4530	21.16
11580	11500	5230	4622	50.28	13.0	15.5	44	9330	4430	7.76
11600	11200	5760	4461	56.69	14.0	16.5	47	9630	4230	17.67
11535	10945	6548	4903	63.75	13.0	18.5	50	7930	4730	20.02
11900	11685	5450	4493	54.58	15.0	15.5	46	9930	4230	12.92
11900	11510	5885	4590	59.22	15.0	16.5	48	9430	4330	17.19
11865	11510	6760	5387	67.06	8.0	21.5	51	8530	5330	14.75
12140	11950	5575	4647	57.05	14.0	16.5	47	10730	4430	11.92
12155	11580	6140	4585	63.72	15.0	17.5	50	10430	4330	20.73
12160	11700	7060	5488	72.06	8.0	22.5	53	9130	5430	16.57
12455	12110	5835	4618	61.65	16.0	16.5	49	10730	4330	16.05
12500	12050	6280	4840	66.73	14.0	18.5	51	10930	4630	17.86
12500	11935	7050	5347	74.57	11.0	21.5	54	9730	5230	18.76
12770	12535	5960	4899	64.53	13.0	18.5	50	12930	4730	12.75
12800	12360	6395	4967	69.48	15.0	18.5	52	10730	4730	17.28
12800	12110	7335	5445	79.79	11.0	22.5	56	10430	5330	20.43
13090	12870	6120	5096	67.30	16.0	17.5	51	10630	4830	19.25
13100	12715	6505	5127	72.33	14.0	19.5	53	11630	4930	11.90
13105	12570	7525	5787	83.20	8.0	24.5	57	11530	5730	16.05
13330	12890	6310	4890	71.90	16.0	18.5	53	12730	4630	17.51
13330	12965	6660	5293	75.21	13.0	20.5	54	12330	5130	17.60
13330	12610	7580	5641	85.62	11.0	23.5	58	11130	5530	15.26
13640	13020	6320	4711	73.90	19.0	17.5	54	12630	4330	20.31
13625	13370	6855	5662	78.49	12.0	21.5	55	11830	5530	21.51
13705	13270	7805	6183	89.69	8.0	25.5	59	11130	6130	12.30
13950	13505	6490	5055	77.39	18.0	18.5	55	12630	4730	15.14
13940	13410	7015	5377	83.33	16.0	20.5	57	12130	5130	17.61
14100	13550	8030	5213	95.54	10.0	25.5	61	11430	6130	18.32
14205	13755	6660	5193	80.34	19.0	18.5	56	12030	4830	16.95
14267	13755	7125	5506	86.37	17.0	20.5	58	11930	5230	17.79

continued on next page

Table 2.32

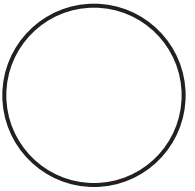
Multi-radius deep corrugated structural plate arches
Type I: **381 x 140 mm** corrugation profile
Size and layout details (*continued)*

Maximum Span	Bottom Span	Total Rise	Springline Rise	Area	Required 'S'			Top Radius	Side Radius	Re-Entrant Angle
					Top	Side (x2)	Total	R_t	R_S	
mm	mm	mm	mm	m^2				mm	mm	degrees
14300	13815	8250	6492	98.90	9.0	26.5	62	10730	6430	15.64
14540	14185	6780	5438	83.60	18.0	19.5	57	12730	5130	14.95
14560	14140	7280	6346	89.77	16.0	21.5	59	12230	5530	15.71
14575	13975	8260	5763	101.68	12.0	25.5	63	11130	6230	17.76
14808	14361	6938	5463	86.41	23.0	17.5	58	10930	4930	17.15
14840	14495	7490	6080	93.26	17.0	21.5	60	11030	5830	13.79
14860	14085	8555	6386	107.66	14.0	25.5	65	10930	6230	20.10
15155	14915	7085	5919	90.14	18.0	20.5	59	12330	5630	11.79
15205	14885	7580	6205	96.49	18.0	21.5	61	11130	5930	13.24
15110	14330	8690	6504	111.12	15.0	25.5	66	10730	6330	19.97

Other sizes and plate configurations are available. All dimensions are inside.

Table 2.33

Deep corrugated structural plate round pipe
Type I: **381 x 140 mm** corrugation profile



Diameter (mm)	End Area (m^2)	Total S
8450	57.2	66
8790	60.7	68
9040	64.2	70
9320	68.3	72
9580	72.0	74
9830	75.9	76
10080	79.9	78
10340	84.0	80
10620	88.5	82
10870	92.8	84
11130	97.2	86
11380	101.7	88
11630	106.3	90
12170	116.3	94
12680	126.3	98
13180	136.5	102
13720	147.8	106
14220	158.9	110
14760	171.1	114
15270	183.0	118
15770	195.4	122

Other sizes and plate configurations are available. All dimensions are inside.

Corrugated Steel Box Culverts

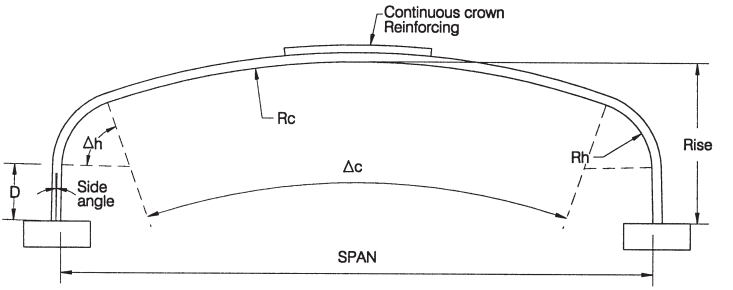
Corrugated steel box culverts approach the rectangular shape of a low, wide box. This is made possible by the addition of special rib plates (where required) to the standard deep corrugated structural plate sheets (see Figure 2.13). The resulting combined section develops the flexural capacity required for the very flat top and sharp corners.

The foundation for box culverts can be designed as a conventional concrete footing, steel footer pads (as shown in Figure 2.14), or a full steel invert.

Corrugated steel box culverts can be designed for low, wide waterway requirements with heights of cover between 450 mm and 1500 mm (measured from the outside crest of the main barrel) and various loading situations.

Box culverts are available in standard spans of 3.170 m to 12.315 m and rises of 1.180 m to 3.555 m. Table 2.34 provides representative sizes available. Special sizes are available by contacting the local manufacturer.

Table 2.34 Deep corrugated structural plate box culverts
Type I: **381 x 140 mm** corrugation profile
Size and layout details



Span	Rise	End Area	Crown Angle Δc	Haunch Angle Δh	Crown Radius R_c	Haunch Radius R_h	Side Length D	Side Angle
mm	mm	m^2	degrees	degrees	mm	mm	mm	degrees
3170	1180	3.12	7.35	72.36	8820	1016	407	14.00
3550	1420	4.33	9.97	75.04	8820	1016	559	10.00
3840	1465	4.94	12.59	77.72	8820	1016	509	6.31
3965	2210	7.35	9.97	72.36	8820	1016	1423	12.98
3865	1260	4.18	12.59	72.36	8820	1016	407	10.36
4105	1860	6.56	12.59	72.36	8820	1016	1017	11.67
4210	1310	4.76	15.21	72.36	8820	1016	407	9.05
4735	1960	8.16	17.83	72.36	8820	1016	1017	9.05
4550	1360	5.36	17.83	72.36	8820	1016	407	7.74
4890	1610	6.97	20.45	75.02	8820	1016	559	5.06
4860	2365	10.09	17.83	72.36	8820	1016	1423	9.05
5155	2420	11.06	20.45	72.36	8820	1016	1423	7.74
5215	1670	7.72	23.07	75.02	8820	1016	559	3.75
5360	2075	9.89	23.07	72.36	8820	1016	1017	6.43
5320	1440	6.62	23.57	69.69	8820	1016	419	8.53
5445	2480	12.07	23.07	72.36	8820	1016	1423	6.43
5655	1505	7.33	26.19	69.69	8820	1016	419	7.22
5955	2645	14.23	27.66	72.36	8820	1016	1473	3.81
6130	1495	7.83	30.28	72.36	8820	1016	254	2.50
6165	1900	10.33	30.28	72.36	8820	1016	660	2.50
6235	2715	15.36	30.28	72.36	8820	1016	1473	2.50
6320	1645	8.91	31.43	69.69	8820	1016	419	4.60
6480	1975	11.25	32.90	72.36	8820	1016	660	1.19
6495	2380	13.89	32.90	72.36	8820	1016	1067	1.19

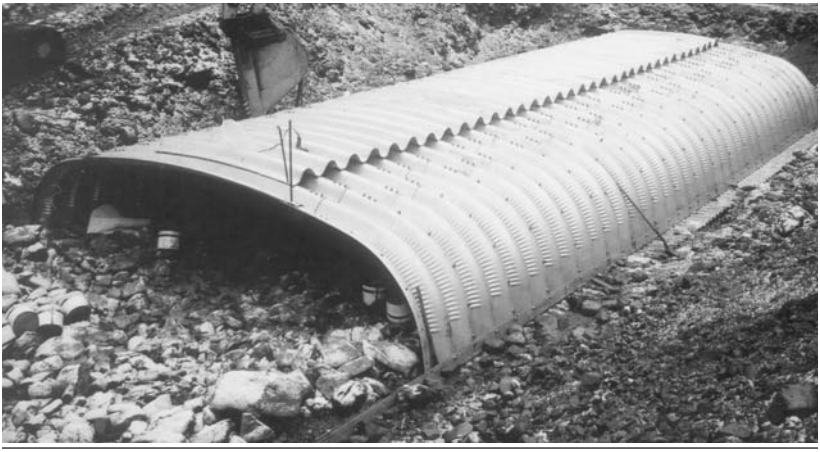
continued on following page...

Table 2.34

Deep corrugated structural plate box culverts
Type I: **381 x 140 mm** corrugation profile
Size and layout details (continued)

Span	Rise	End Area	Crown Angle Δc	Haunch Angle Δh	Crown Radius R_c	Haunch Radius R_h	Side Length D	Side Angle
mm	mm	m^2	degrees	degrees	mm	mm	mm	degrees
6645	1720	9.77	34.05	69.69	8820	1016	419	3.29
6970	1795	10.67	36.67	69.69	8820	1016	419	1.98
7000	2200	13.50	36.67	69.69	8820	1016	825	1.98
7025	2610	16.35	36.67	69.69	8820	1016	1232	1.98
7290	1875	11.62	39.29	69.69	8820	1016	419	0.67
7300	2285	14.58	39.29	69.69	8820	1016	825	0.67
7310	2690	17.56	39.29	69.69	8820	1016	1232	0.67
7315	3095	20.52	39.29	69.69	8820	1016	1638	0.67
7405	1680	10.21	39.29	58.98	8820	1016	419	11.38
7800	1965	12.71	41.91	58.98	8820	1016	622	10.07
7945	2370	15.87	41.91	58.98	8820	1016	1029	10.07
8575	1920	13.90	36.45	69.69	11430	1016	419	2.09
8605	2325	17.38	36.45	69.69	11430	1016	825	2.09
8635	2735	20.89	36.45	69.69	11430	1016	1232	2.09
9145	1940	14.64	39.48	64.32	11430	1016	419	5.94
9225	2345	18.35	39.48	64.32	11430	1016	825	5.94
9310	2750	22.10	39.48	64.32	11430	1016	1232	5.94
9810	2105	16.92	43.53	64.32	11430	1016	419	3.92
9865	2510	20.90	43.53	64.32	11430	1016	825	3.92
9920	2920	24.92	43.53	64.32	11430	1016	1232	3.92
10460	2285	19.43	47.58	64.32	11430	1016	419	1.89
10485	2690	23.68	47.58	64.32	11430	1016	825	1.89
10515	3100	27.95	47.58	64.32	11430	1016	1232	1.89
10895	2355	20.59	50.09	61.64	11430	1016	419	3.32
10940	2760	25.02	50.09	61.64	11430	1016	825	3.32
10990	3165	29.47	50.09	61.64	11430	1016	1232	3.32
11645	2530	23.31	54.67	58.96	11430	1016	419	3.71
11700	2935	28.04	54.67	58.96	11430	1016	825	3.71
11750	3345	32.81	54.67	58.96	11430	1016	1232	3.71
12270	2745	26.46	58.72	58.96	11430	1016	419	1.68
12290	3150	31.45	58.72	58.96	11430	1016	825	1.68
12315	3555	36.45	58.72	58.96	11430	1016	1232	1.68

Other sizes and plate configurations are available. All dimensions are inside.



Installation of a Type I deep corrugated structural plate box culvert.

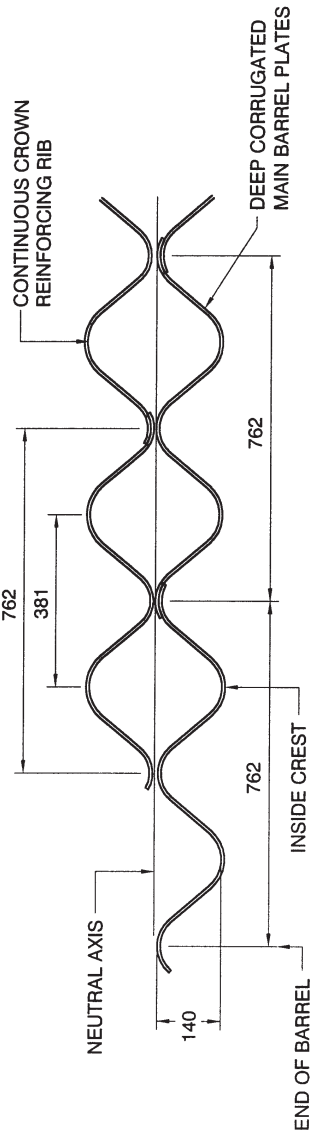
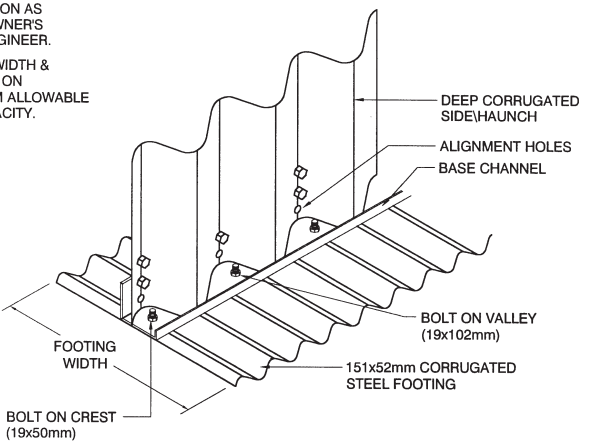


Figure 2.13 Reinforcing rib for deep corrugated structural plate Type I.

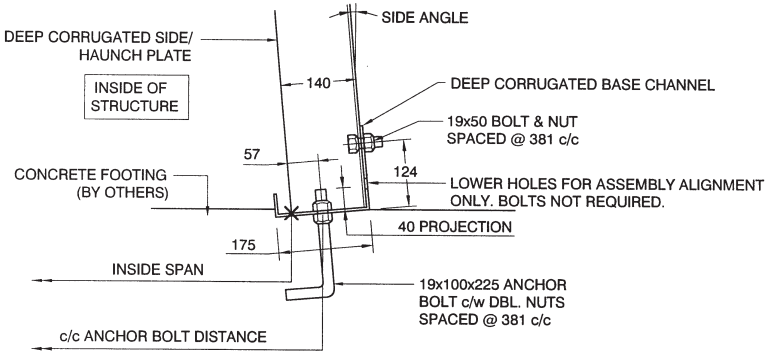
NOTE:

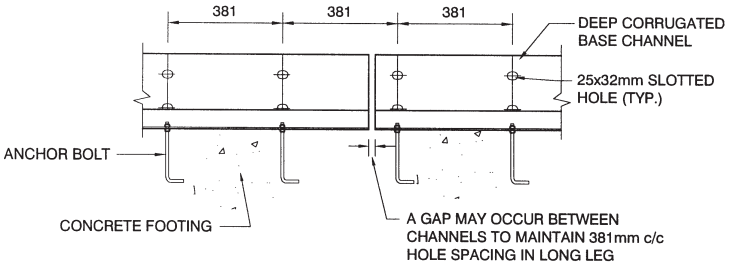
1) FOOTING ELEVATION MUST PROVIDE ADEQUATE FROST & SCOUR PROTECTION AS DETERMINED BY OWNER'S GEOTECHNICAL ENGINEER.

2) FOOTING DESIGN (WIDTH & THICKNESS) BASED ON SPECIFIED MINIMUM ALLOWABLE SOIL BEARING CAPACITY.



Detail - Typical Steel Footer





Details - Base Channel

Figure 2.14 Additional details for deep corrugated structural plate Type I.

Deep corrugated structural plate box culvert assembled at job site.

Deep corrugated structural plate box culvert on foundation with end walls attached.

DEEP CORRUGATED STRUCTURAL PLATE TYPE II

Product Description

Deep corrugated structural plate Type II has a 400 x 150 mm corrugation, which is shown in Figure 2.1.

Standard plates are fabricated in one length and several widths, as shown in Table 2.35 and Figure 2.15. The coverage length (excluding the side lips) is 1200 mm. The plate width designation, H, is used to describe the various plate widths available. H is the distance between circumferential bolt holes, or one circumferential bolt hole space (circumferential refers to the direction around the periphery of the structure, at right angles to the length of the structure). For instance, a 9 H plate has a net width of 9 circumferential bolt hole spaces (see Figure 2.15). The bolt hole space, H, is 425 mm.

Plates are furnished curved to various radii and are identified with a permanent mark which shows information such as the plate geometry. This marking is provided to simplify field erection and to make identification of the structure details, in the

future, as easy as possible. The plates are available in thickness' ranging from 3 to 7 mm. Weights of individual plate sections are shown in Table 2.36.

Section Properties

Section properties, used for design, are provided in Table 2.37. Properties of the arc-and-tangent corrugation are derived mathematically using the design thickness. The properties in the table include area, moment of inertia, section modulus and radius of gyration.

Sizes and Shapes

The plates are assembled into various shapes as the single radius arch shapes shown in Table 2.38. Round, two radius arches, special shapes, and other single radius arch sizes are also available. Detailed assembly instructions accompany each structure.

Table 2.35

Deep corrugated structural plate sections
Type II: **400 x 150 mm** corrugation profile
Details of uncurved plates

Plate Width Designation	Net Width, mm	Overall Width, mm
3H	1275	1555
4H	1700	1980
5H	2125	2405
6H	2550	2830
7H	2975	3255
8H	3400	3680
9H	3825	4105

H = 425 mm

Table 2.36

Weight of deep corrugated structural plate sections
Type II: **400 x 150 mm** corrugation profile

Plate Width Designation	Approximate Weight of Galvanized Plates, kg* Specified Wall Thickness, mm					Number of Assembly Bolts/Plate
	3.0	4.0	5.0	6.0	7.0	
3H	57.2	78.4	99.8	121.0	141.2	22
4H	72.8	99.8	127.0	154.1	179.8	23
5H	88.5	121.2	154.3	187.1	218.4	24
6H	104.1	142.7	181.6	220.2	257.0	25
7H	119.7	164.1	208.8	253.3	295.6	26
8H	135.4	185.5	236.1	286.3	334.2	27
9H	151.0	206.9	263.4	319.4	372.8	28

Notes 1. Weight of bolts not included.
2. Bolt length used for all structures = 51 mm
3. Weight of bolts and nuts in kg per hundred = 27.0 kg
4. To compute the approximate weight of structures per metre of structure length: (1) multiply the weight from the table by the number of plates in the periphery having that plate designation (2) multiply the number of bolts from the table by the number of plates in the periphery having that plate designation (3) add the two numbers together (4) divide by 1.2

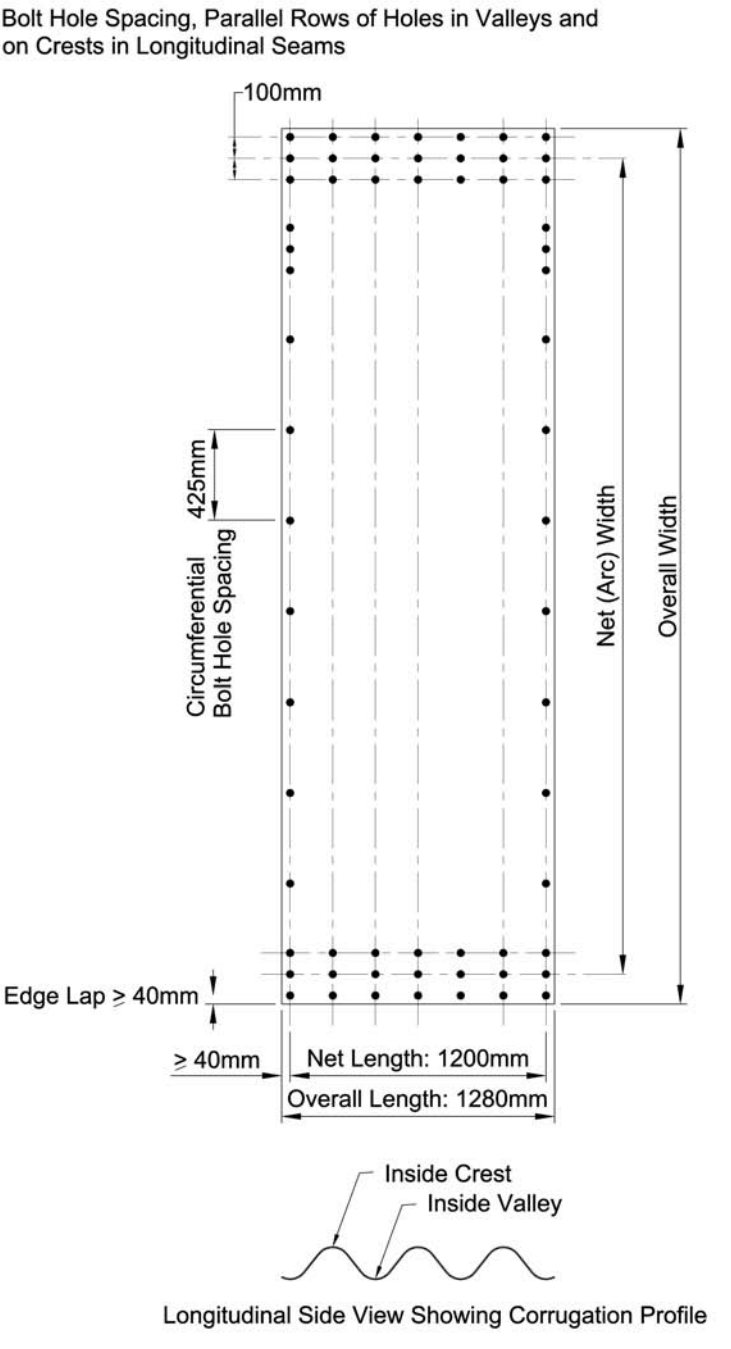
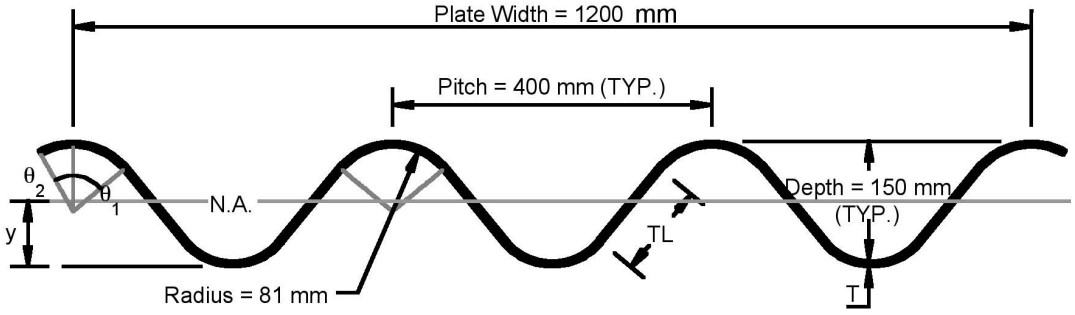


Figure 2.15 Deep Corrugated Structural Plate Type II plate configuration

Table 2.37 Deep corrugated structural plate sections
Type II: **400 x 150 mm** corrugation profile

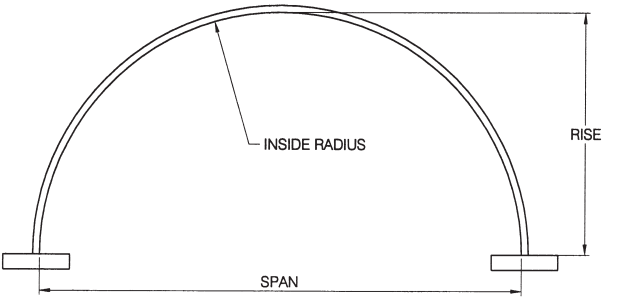


Specified Thickness mm	Design Thickness mm	Tangent Length TL mm	Tangent Angle 1 θ_1 degrees	Tangent Angle 2 θ_2 degrees	Area A mm^2/mm	Neutral Axis y mm	Moment of Inertia I mm^4/mm	Elastic Section Modulus S mm^3/mm	Radius of Gyration r mm	Plastic Section Modulus Z mm^3/mm	Developed Width Factor WF *
3.0	2.84	114.23	51.04	29.03	3.905	80.041	10886	136.01	52.80	184.16	1.375
4.0	3.89	112.84	51.23	28.83	5.351	80.563	14944	185.50	52.85	252.66	1.375
5.0	4.95	111.42	51.44	28.63	6.811	81.091	19060	235.04	52.90	322.05	1.376
6.0	6.00	110.00	51.64	28.44	8.260	81.614	23154	283.71	52.95	391.01	1.377
7.0	7.00	108.63	51.84	28.25	9.640	82.112	27071	329.69	52.99	456.91	1.377

*WF is the ratio of the flat plate width to the corrugated plate width.
Dimensions are subject to manufacturing tolerances.

Table 2.38

Deep corrugated structural plate arch
Type II: **400 x 150 mm** corrugation profile
Size and layout details



Span, mm	Rise, mm	Periphery, H	End Area, m^2	Radius, mm
8000	3905	29	24.36	4000
8500	4185	31	27.82	4250
9000	4465	33	31.51	4500
9500	4750	35	35.43	4750
10000	5030	37	39.57	5000
10500	5310	39	43.95	5250
11000	5595	41	48.55	5500
11500	5665	42	50.97	5750
12000	5950	44	55.93	6000
12500	6230	46	61.11	6250
13000	6510	48	66.52	6500
13500	6795	50	72.16	6750
14000	7075	52	78.03	7000
14500	7360	54	84.13	7250
15000	7430	55	87.30	7500
15500	7710	57	93.75	7750
16000	7995	59	100.43	8000

- End area is above footing.
- Other sizes available.
- All dimensions are inside.

SECTION C: SPECIFICATIONS

Specifications in Common Use

Specifications are divided into two basic classes – those covering design and construction, and those covering materials. Examples of design and construction specifications are the AASHTO and ASTM design specifications, and the Canadian Highway Bridge Design Code (CHBDC). Material specifications are published by CSA, AASHTO, ASTM and others. (See Tables 2.39 and 2.40.)

Material Specifications - Historical Background

CSA Standard G401 deals with material and fabrication requirements for the full range of corrugated steel pipe products currently used in Canada including riveted, helical lock seam, and structural plate pipe. Dimensional data is given for all types of round pipe and for standard pipe-arch made from corrugated steel pipe. Dimensional data is not provided for the wide variety of shapes available with structural plate, or for the fittings fabricated from corrugated steel pipe.

The CSA Standard is based on specifications previously prepared by the Corrugated Steel Pipe Institute. In 1970, the Corrugated Steel Pipe Institute first published Specification 501, representing an industry consensus concerning the materials and methods of fabrication that should be used in manufacturing corrugated steel pipe. In addition, the specification dealt with workmanship, repair, quality control, inspection and rejection.

In 1974, the Roads and Transportation Association of Canada, under the direction of the Metric Commission of Canada, undertook the task of developing metric standards for all highway products. As part of the task force, the Ontario Ministry of Transportation and Communications set up a Unified Drainage Standards Committee to examine existing standards for all drainage products. In 1978, the Corrugated Steel Pipe Institute published a revised Specification 501. The document proposed new product standards, predominantly in hard converted metric figures based on the recommendations from the Unified Drainage Standards Committee. It was from this background that the current CSA Standard G401 was developed.

Table 2.39 Design specifications

Agency	Reference
CSA	Canadian Highway Bridge Design Code - Section 7 - Buried Structures - CAN/CSA - S6
AASHTO	Standard Specification for Highway Bridges – Division 1, Section 12
AASHTO	LRFD Bridge Design Specifications - Section 12
ASTM	Standard Practice for Structural Design of Corrugated Steel Pipe, Pipe Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications - ASTM A796

Table 2.40 Material description and specifications

Material	Description	Specifications		
		AASHTO	ASTM	CSA
Zinc Coated Sheets & Coils	Steel base metal* with 610 g/m² zinc coating	M 218	A 929M	G401
Polymer Coated Sheets and Coils	Polymer coatings applied to sheets* and coils*	M 246	A 742M	G401
Aluminum Coated Coils	Steel base metal* coated with 305 g/m² of pure aluminum	M 274	A 929M	G401
Aluminum-Zinc Coated Coils	Steel base metal* coated with 214 g/m² of an aluminum-zinc alloy	M 289	A 929M	G401
Sewer and Drainage pipe	Corrugated pipe fabricated from any of the above sheets or coils. Pipe is fabricated by corrugating continuous coils into helical form with lockseam or welded seam, or by rolling annular corrugated mill sheets and plate, and riveting seams or field bolting seams as appropriate.			
	1. Galvanized corrugated steel pipe	M 36M	A 760M	G401
	2. Polymeric pre-coated sewer and drainage pipe	M 245	A 762M	G401
	3. Aluminized Steel Type 2 corrugated steel pipe	M 36M	A 760M	G401
	4. Aluminum-Zinc alloy coated corrugated steel pipe	-	A 760M	G401
	5. Galvanized spiral rib steel pipe	M 36M	A 760M	G401
	6. Aluminized Steel Type 2 spiral rib steel pipe	M 36M	A 760M	G401
	7. Structural plate pipe	M 167	A 761M	G401
Asphalt Coated Steel Sewer Pipe	Corrugated steel pipe of any of the types shown above with a 1.3 mm, high purity asphalt coating	M 190	A 849 A 862	G401
Invert Paved Steel Sewer Pipe	Corrugated steel pipe of any one of the types shown above with an asphalt pavement poured in the invert to cover the corrugation by 3.2 mm	M 190	A 849 A 862	G401
Fully Lined Steel Sewer Pipe	Corrugated steel pipe of the types shown above			
	With an internal asphalt lining centrifugally spun in place	M 190	A 849 A 862	G401
Cold Applied Bituminous Coatings	Fibrated mastic or coal tar base coatings of various viscosities for field or shop coating of corrugated pipe or structural plate	M 243	A 849	-
Gaskets and Sealants	1. Standard 0-ring gaskets	-	D1056	-
	2. Sponge neoprene sleeve gaskets			
	3. Gasketing strips, butyl or neoprene	-	C361	-
	4. Mastic sealant			

*Design yield strength = 230 MPa min.; tensile strength - 310 MPa min.; elongation (50mm) - 20% min.

SECTION D: CSP COUPLING SYSTEMS

A variety of pipe joints are available for connecting lengths of corrugated steel pipe.

The most common CSP joint uses a band around the pipe joint. Figure 2.16 illustrates what is meant by a band-type coupling.

The standard types of coupling bands are listed in Table 2.41 and shown in Figure 2.18. The band is drawn and secured on the pipe by connection devices, as shown in Figure 2.20. The pipe ends may be identical to the rest of the pipe barrel (plain ends), or in the case of helical pipe, the pipe ends may be reformed to an annular corrugation (reformed ends) as shown in Figure 2.17. A variety of gasket types can be used, according to band type, as shown in Figures 2.18 and 2.19. Table 2.41 includes information on the connection devices and the types of gaskets used with each type of coupling band, and on the type of pipe ends the band type can be used with.

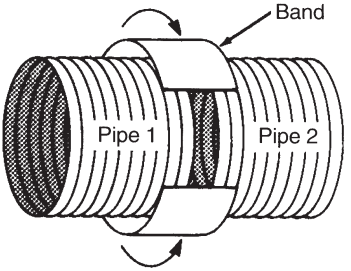


Figure 2.16: Typical band coupling for field joints.

Table 2.41 Coupling bands for corrugated steel pipe

Type Of Band	Cross - Section	Fastening Method			Gaskets			Pipe End Type Used With		
									Helical	
		Angles	Bar, Bolt & Strap	Wedge Lock	0 Ring	Sleeve or Strip	Mastic	Annular Plain	Plain	Reformed
Universal Dimple		x	x	x		x	x	x	x	x
Corrugated		x	x	x		x	x	x		x
Semi-Corrugated		x	x	x	x		x	x		x
Flat		x	x	x	x	x	x	x	x	x

Combination dog bone, and rod and lug coupler.

Semi-corrugated coupler installation.

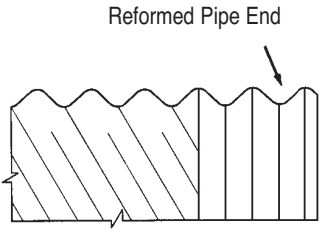


Figure 2.17 Reformed end of helically corrugated pipe.

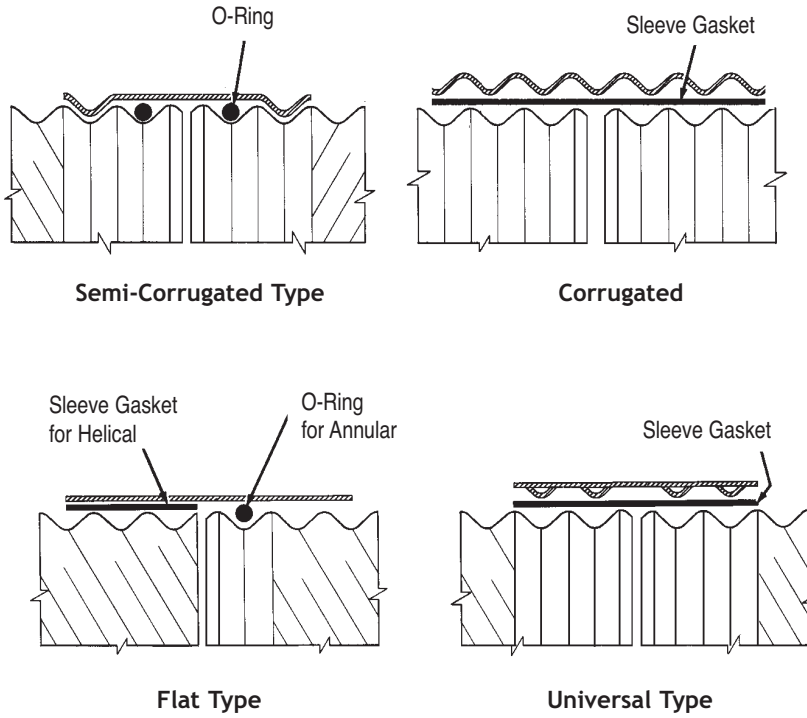


Figure 2.18 Standard CSP band types. Note: When gaskets are required they are installed with standard CSP band types as shown.

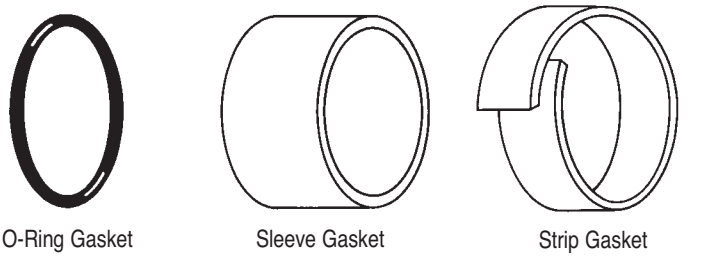
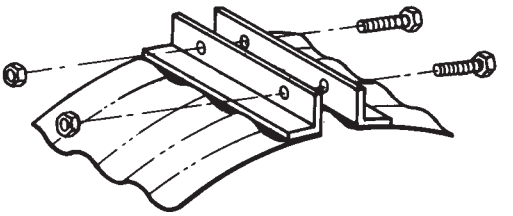
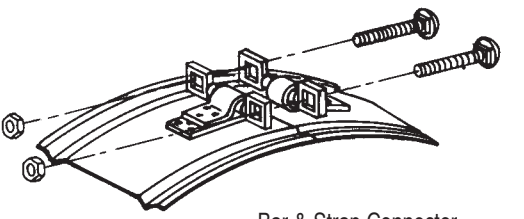


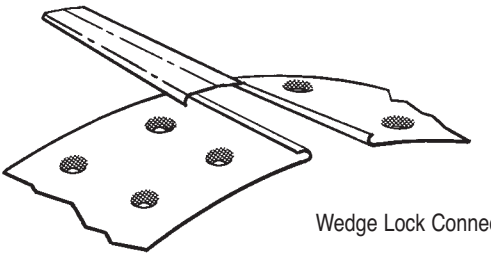
Figure 2.19 Standard gaskets for CSP.



Band Angle Connector



Bar & Strap Connector



Wedge Lock Connector

Figure 2.20 Standard band connectors for CSP .

Gain in Length

The nominal length of corrugated pipe and pipe-arch is usually increased at each coupling by a maximum amount dependent on the type of coupling. Where exact run lengths are required, such as between manholes or other fixed points, the designer should take this into account and include explicit instructions in the specification.

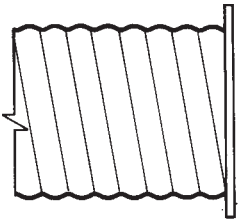
Leakage

With the exception of aerial sewer or water lines, the exfiltration (or infiltration) of moderate amounts of water may not be important. Where more restricted leakage is required (or airtightness in the case of ventilation lines), the couplings can be supplemented with gaskets (Figures 2.18 and 2.19).

A band puller eases installation of coupler.

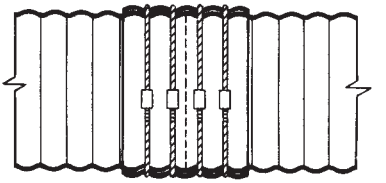
Special Joints

For unusual conditions, (i.e. high pressure, extreme disjointing forces, threading pipe inside existing pipe, jacking or boring pipe, and deep vertical drop inlets) a variety of special designs are available or a new special joint may be designed by the manufacturer to meet specific requirements. A variety of special joints are illustrated in Figure 2.21.



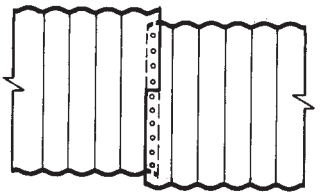
Flange Joint

Bolted flanges are attached to pipe ends.



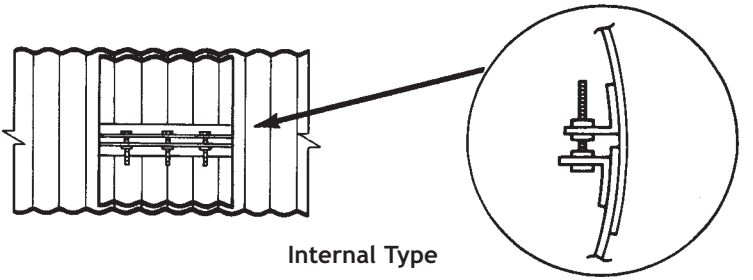
Rod & Lug

Band is secured by rod around band connected by lugs.



Open Lap Joint

Used in stab type joints for boring and jacking pipe. May be bolted if required



Internal Type

Figure 2.21 Illustration of various special CSP joints.

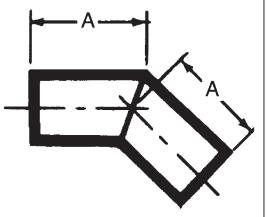
SECTION E: FITTINGS

One of the benefits of corrugated steel pipe is that it can be easily and economically fabricated into an assortment of fittings. Table 2.42 provides minimum dimensions for CSP elbows (round pipe). Table 2.43 provides minimum dimensions for CSP tees, crosses, laterals and wyes (round pipe).

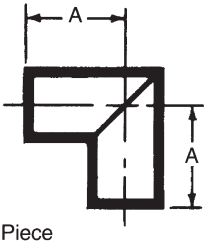
Structural plate fittings are shop cut from curved corrugated plates and welded together. These structures are usually assembled and bolted in the shop in a trial fit to assure that all parts mate properly. The parts are then clearly marked for field assembly.

Table 2.42

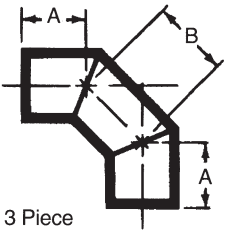
Minimum dimensions for elbows for round CSP



2 Piece

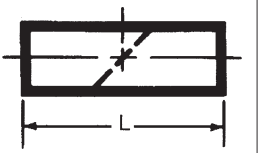


2 Piece

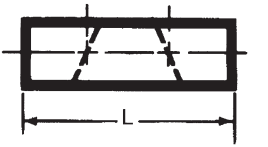


3 Piece

10° - 45° Elbow



46° - 90° Elbow



46° - 90° Elbow

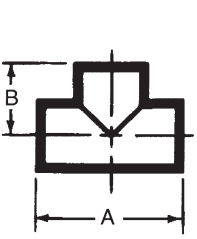
Pipe Diameter	A	Total Length
150 - 600	300	600
700 - 1400	600	1200
1600 - 2400	900	1800

Pipe Diameter	A	Total Length
150 - 250	300	600
300 - 800	600	1200
900 - 1200	900	1800
1400 - 1600	1200	2400
1800 - 2400	1500	3000

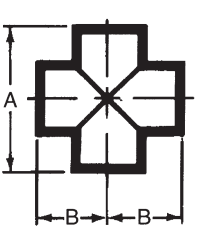
Pipe Diameter	A	B	Total Length
150	200	200	600
200	185	230	600
250	175	250	600
300	460	280	1200
400	450	300	1200
500	425	350	1200
600	410	380	1200
700	400	400	1200
800	360	480	1200
900	600	600	1800
1000	610	580	1800
1200	570	660	1800
1400	750	900	2400
1600	780	840	2400
1800	750	900	2400
2000	1000	1000	3000
2200	950	1100	3000
2400	925	1150	3000

NOTE: The total length (mm) and pipe diameter (mm) listed are minimum requirements for fitting fabrication. Fittings with other dimensions to satisfy specific needs are also available. All dimensions are nominal. All dimensions are in millimetres.

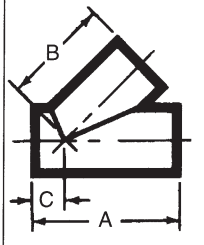
Table 2.43 Minimum dimensions for CSP round fittings



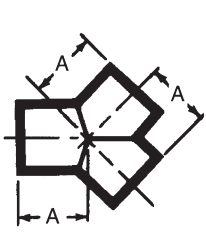
Tee



Cross



45° Lateral



45° Wye

Main Diam.	Stub Same or Smaller Than Main Diameter										Same Diam.	
	Tee			Cross			45° Lateral				45° Wye	
(mm)	A	B	TL	A	B	TL	A	B	C	TL	A	TL
150	600	300	900	600	300	1200	900	600	300	1500	300	900
200	600	300	900	600	300	1200	900	600	300	1500	300	900
250	600	300	900	600	300	1200	900	600	300	1500	300	900
300	800	400	1200	1200	600	2400	1200	600	400	1800	600	1800
400	1200	600	1800	1200	600	2400	1200	900	400	2100	600	1800
500	1200	600	1800	1200	600	2400	1500	900	450	2400	600	1800
600	1200	600	1800	1200	600	2400	1500	900	500	2400	600	1800
700	1200	600	1800	1200	600	2400	1800	1200	600	3000	600	1800
800	1800	900	2700	1800	900	3600	2400	1500	660	3900	900	2700
900	1800	900	2700	1800	900	3600	2400	1500	660	3900	900	2700
1000	1800	900	2700	1800	900	3600	2400	1500	760	3900	900	2700
1200	1800	900	2700	1800	900	3600	3000	1800	810	4800	900	2700
1400	2400	1200	3600	2400	1200	4800	3600	2100	1100	5700	1200	3600
1600	2400	1200	3600	2400	1200	4800	3600	2400	1200	6000	1200	3600
1800	3000	1500	4500	3000	1500	6000	4200	2700	1250	6900	1500	4500
2000	3000	1500	4500	3000	1500	6000	4800	3000	1400	7800	1500	4500
2200	3000	1800	4500	3000	1500	6000	4800	3300	1500	8100	1500	4500
2400	3000	1800	5400	3600	1800	7200	4800	3300	1550	8100	1800	5400

TL - total net length needed to fabricate fitting
Note: All dimensions are in millimetres

Saddle Branch

Saddle branches are used to connect smaller branch lines to the main line, as illustrated in Figure 2.22. Saddles make it practical to accurately tie in connections after the main line is laid, and new connections can be effectively made on old lines. Saddles can be used to connect almost any type of pipe to a CSP main line. A common "universal" type of saddle branch stub to do this is shown in Figure 2.23.

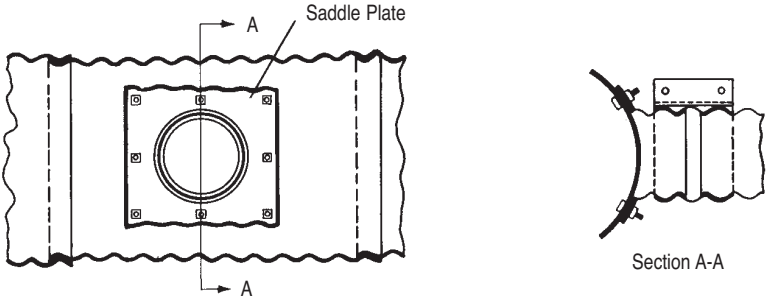


Figure 2.22 Saddle branch, bolted to main sewer on the job or at the plant, enables laterals and house connections to join the sewer.

Typical pre-fabricated CSP saddle branch fitting used in connecting house laterals or incoming pipe from catch basins.

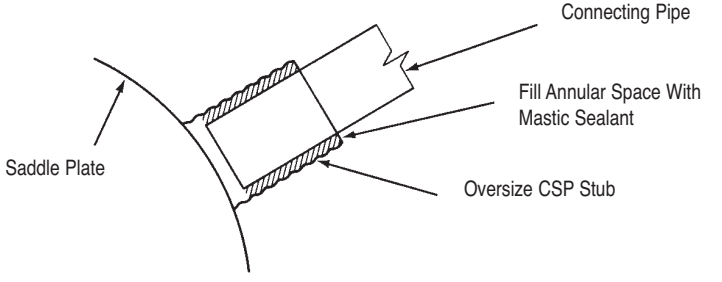


Figure 2.23 Universal connection detail using saddle branch.

Manhole riser on a detention tank with outlet pipe and groundwater drainage pipe.

Manholes and Catch Basins

Manholes and catch basins are available in corrugated pipe construction in two basic types as shown in Figure 2.24. The riser type of manhole is the simpler of the two and quite economical. It is only feasible for trunk lines of 900 mm diameter or greater. When junctions of smaller diameters are involved it is possible to use a vertical shaft of larger diameter CSP to connect the sewers. However, when the shaft is greater than 900 mm diameter, reduction details or a special manhole top must be used to suit the manhole cover. Typical reduction details are shown in Figure 2.24. Large diameter manholes or the connection between large diameter trunk lines and the CSP riser may require reinforcement. Standard catch basin details are illustrated in Figure 2.25.

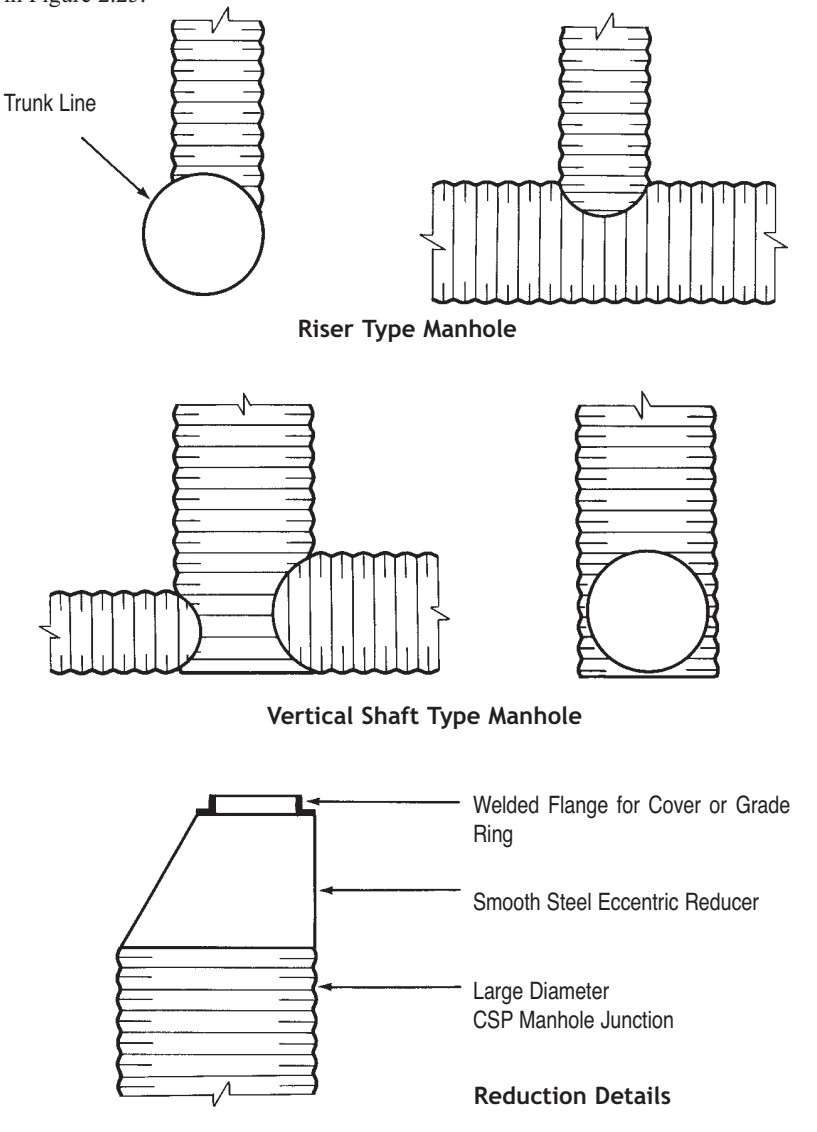


Figure 2.24 Illustration of types of CSP manholes.

Fabricated riser type CSP manhole.

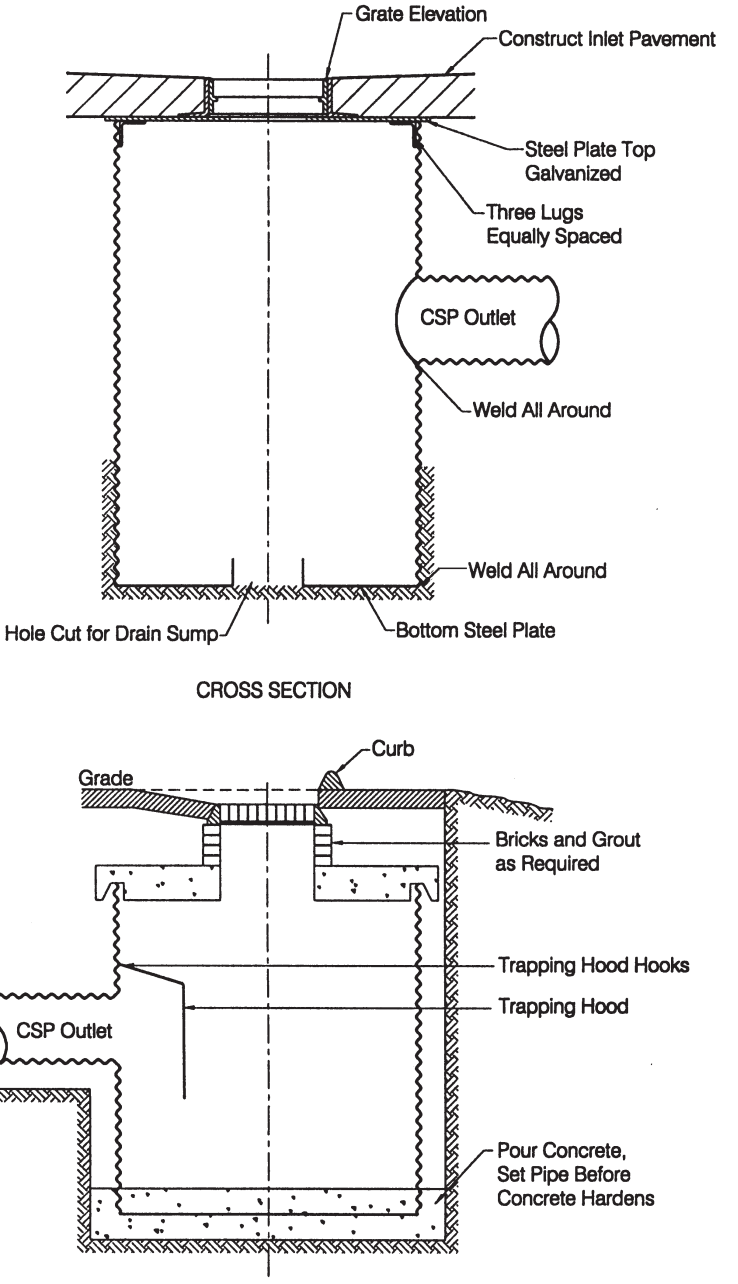


Figure 2.25 Cross sections of catch basins.

SECTION F: END FINISHES

Purpose

The principal purpose of an end finish on corrugated steel pipe culverts or spillways is hydraulic efficiency - to prevent scour at the inlet, to prevent undermining at the outlet and to increase capacity. Other purposes may be to provide structural reinforcement, retain the fill slope, discourage burrowing rodents, or improve appearance. For additional information, see Chapter 4 Hydraulics, and Chapter 6 Structural Design.

Types of Finish

Types of end finishes include (1) steel sheeting to serve as a low headwall and cutoff wall, (2) prefabricated flared end sections, (3) safety slope end sections, (4) riprap or retaining walls, and (5) skews and bevels.

1. Steel Sheeting. (Figure 2.26)
   One practical form of end protection consists of driving corrugated steel sheeting as a cutoff wall and low height headwall or endwall. It is cut to receive the last section of the culvert barrel, and capped at about mid-diameter with an unbalanced steel channel. This type of end finish is particularly appropriate for large culverts which may have the ends beveled or step beveled. The length of the sheeting below the bottom of the pipe should be adequate to resist scour impacts. This depth should be a minimum of 900 mm.

2. End Sections. (Figure 2.27)
   Steel end sections are shop fabricated for assembly in the field by attachment to round corrugated steel culverts ranging in size from 300 to 2400 mm in diameter and to pipe-arches ranging in size from 560 x 420 mm to 1880 x 1260 mm. Dimensions and other data are provided in Figure 2.27 and in Tables 2.44 and 2.45.

   These end sections are listed in standard specifications. They meet the requirements for efficient and attractive end finish on culverts, conduits spillways and sewer outfalls. They attach to the culvert ends by simple bolted connections of various designs (Figure 2.28), thus can be completely salvaged if lengthening or relocation is necessary.

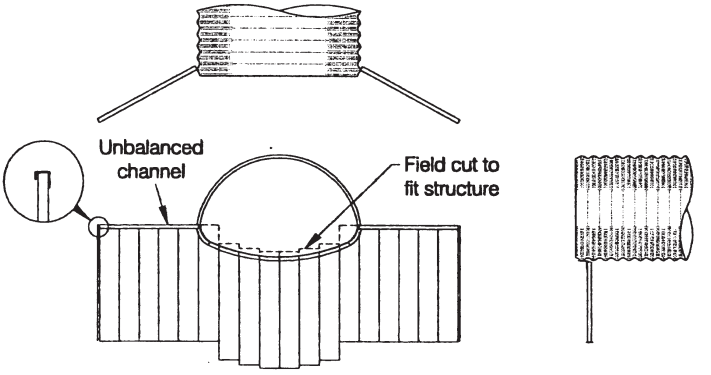


Figure 2.26 Illustration of how a steel sheeting headwall can be provided for a pipe-arch culvert.

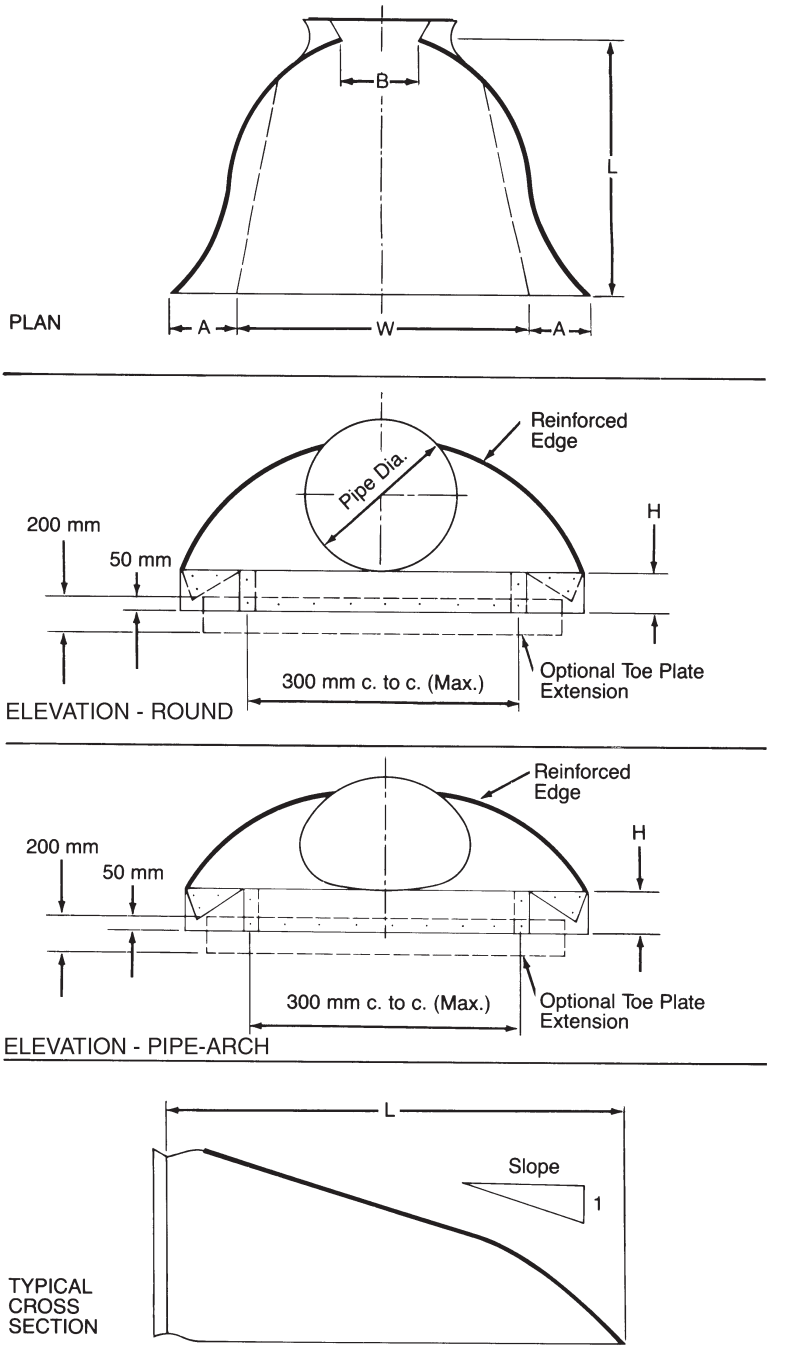


Figure 2.27 Details of end sections in round and pipe-arch shapes.

Table 2.44

Dimensions of galvanized steel end sections for round pipes
68 mm x 13 mm corrugation profile

Pipe Diameter mm	Galvanized Metal Thickness, mm	Approximate Dimensions, mm (See Figure 2.27) A min.	B max.	H min.	L ± 50	W min.	Approximate Slope	Body
300	1.6	125	150	150	535	560	2.25	1 Pc
400	1.6	150	200	150	660	710	2.25	1 Pc
500	1.6	200	300	150	915	1015	2.125	1 Pc
600	1.6	225	330	150	1040	1170	2.125	1 Pc
800	2.0	280	405	200	1295	1400	2.125	1 Pc
900	2.0	330	485	230	1525	1780	2.0	2 Pc
1000	2.8	380	635	295	1750	2085	2.125	2 Pc
1200	2.8	430	740	305	1980	2235	2.0	2 Pc
1400	2.8	430	840	305	2135	2540	2.0	2 Pc
1600	2.8/3.5	430	915	305	2210	2845	1.875	3 Pc
1800	2.8/3.5	430	1120	305	2210	3050	1.5	3 Pc
2000	2.8/3.5	430	1220	305	2210	3300	1.375	3 Pc
2200	2.8/3.5	430	1320	305	2210	3455	1.333	3 Pc
2400	2.8/3.5	430	1475	305	2210	3660	1.125	3 Pc

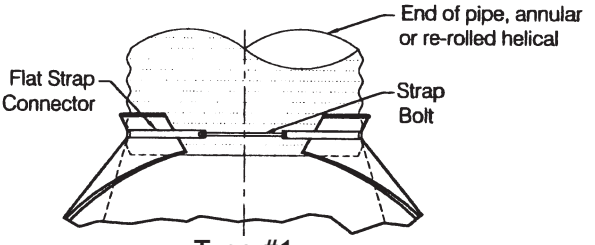
Notes:
1. All 3-piece bodies to have 2.8 mm sides and 3.5 mm center panels. Multiple panel bodies to have lap seams which are to be tightly joined by galvanized rivets or bolts.
2. For 1600 mm and larger sizes, reinforced edges to be supplemented with galvanized stiffener angles. The angles to be attached by galvanized nuts and bolts.
3. Galvanized toe plate to be available as an accessory when specified on the order, and will be the same thickness as the End Section.

Table 2.45

Dimensions of galvanized steel end sections for pipe-arches
68 mm x 13 mm corrugation profile

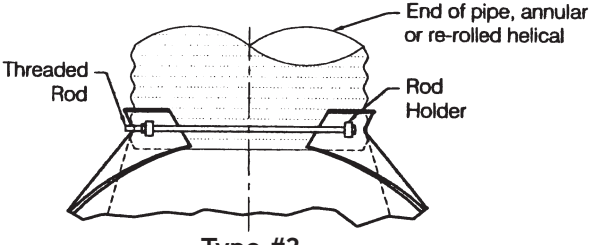
Span x Rise, mm	Galvanized Metal Thickness, mm	Approximate Dimensions, mm (See Figure 2.27) A min.	B max.	H min.	L ± 50	W min.	Approximate Slope	Body
560 x 420	1.6	150	280	150	610	865	2.0	1 Pc
680 x 500	1.6	180	405	150	810	1170	2.0	1 Pc
910 x 660	2.0	230	405	150	990	1475	1.875	1 Pc
1030 x 740	2.0	280	460	180	1170	1855	1.875	1 Pc
1150 x 820	2.8	305	535	230	1345	2080	1.75	2 Pc
1390 x 970	2.8	405	660	305	1575	2235	1.875	2 Pc
1630 x 1120	2.8	430	760	305	1755	2540	1.875	2 Pc
1880 x 1260	2.8/3.5	430	915	305	1955	3150	1.625	3 Pc

Notes:
1. All 3-piece bodies to have 2.8 mm sides and 3.5 mm center panels. Multiple panel bodies to have lap seams which are to be tightly joined by galvanized rivets or bolts.
2. For 1880 mm x 1260 mm size, reinforced edges to be supplemented with galvanized stiffener angles. The angles to be attached by galvanized nuts and bolts.
3. Galvanized toe plate to be available as an accessory when specified on the order, and will be the same thickness as the End Section.



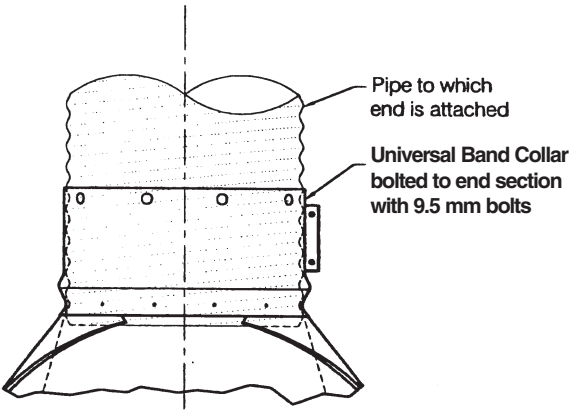
Type #1

Available in sizes 300 mm through 600 mm
Round and 560 x 420 mm through
680 x 500 mm Pipe-Arches.



Type #2

Available in sizes 800 mm and 900 mm
Round and 910 x 660 mm through
1390 x 970 mm Pipe-Arches.



Type #5

Available for all Round and Pipe-Arch sizes shown.

(Type 1 and Type 2 connections are recommended for
the smaller sizes with annular ends.)

Figure 2.28 Details of end section connections for round and pipe-arch shapes.

3. Safety Slope End Sections, (Figures 2.29, 2.30 and 2.31)
Recent data from U.S. state and federally sponsored research studies show that flatter slopes on roadside embankments greatly minimize the hazard potential to motorists. Application of this concept, with the design of 4 to 1 and 6 to 1 roadside embankments, has contributed significantly to improving the safety of highways. The use of safety slope end sections on highway culverts maintains the safety design of the flattened roadway embankments.

The pre-fabricated safety slope end sections are available with 4 to 1 or 6 to 1 slopes and are designed to fit round pipe sizes from 300 mm through 1400 mm and pipe-arch sizes from 450 x 340 mm through 2130 x 1400 mm.

While safety is the primary reason for using safety slope end sections, the tapered flare improves the hydraulic efficiency of the culvert at both the inlet and outlet ends. A deep skirt anchors the end section while preventing scouring and undercutting. The flat apron or bottom panels eliminate twisting or mis-alignment of the end treatment.

Motorists who encroach on these flattened slopes, defined as recoverable slopes, generally stop their vehicles or slow them enough to return to the roadway safely. When culverts are required on these recoverable slopes they must be made traversable or present a minimal hazard to an errant vehicle. The preferred treatment is to match the slope of the culvert with the embankment slope.

On cross drainage structures, a small culvert is defined as a pipe with a 750 mm span or less. On such small culverts no other treatment is required (See Figure 2.29). Single structures with end sections having spans greater than 750 mm can be made traversable for passenger size vehicles by using safety bars to reduce the clear opening spans (see Figures 2.30 and 2.31). The use of safety bars to make the safety slope end sections traversable should not decrease the hydraulic capacity of the culvert.

As referenced by AASHTO, 30 full scale vehicular crash tests have shown that passenger size vehicles can traverse cross drainage structures with safety slope end sections equipped with cross bars (Figure 2.30). The tests showed that, when bars are spaced on 762 mm centers, automobiles can safely cross at speeds as low as 30 km/hr and as high as 100 km/hr.

Parallel drainage structures are those oriented parallel to the main flow of traffic. They typically are used under driveways, field entrances, access ramps, intersecting side roads and median crossovers. These culverts present a significant safety hazard because they can be struck head-on by impacting vehicles. As with cross drains, the end treatments on parallel drains should match the traversable slope. Research shows that for parallel drainage structures, safety bars set on 610 mm centers will significantly reduce wheel snagging (Figure 2.31).

Safety slope end sections are efficient and provide an attractive end finish on cross and parallel drainage structures. They attach to the culvert end by simple bolted connections and can be completely salvaged if lengthening of the structure or relocation is required. Dimensions and other data are given in Tables 2.46 to 2.48.

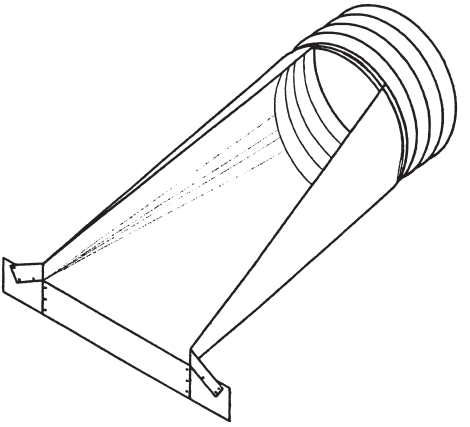


Figure 2.29 Safety slope end section.

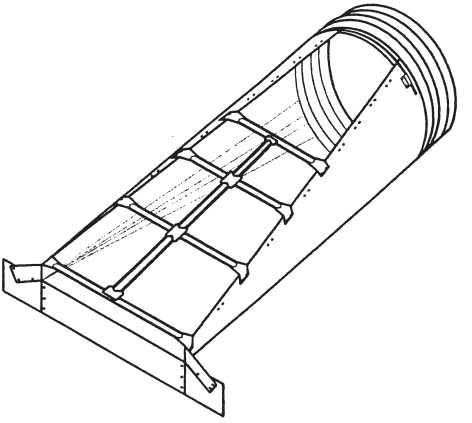


Figure 2.30: Cross drainage safety end section.

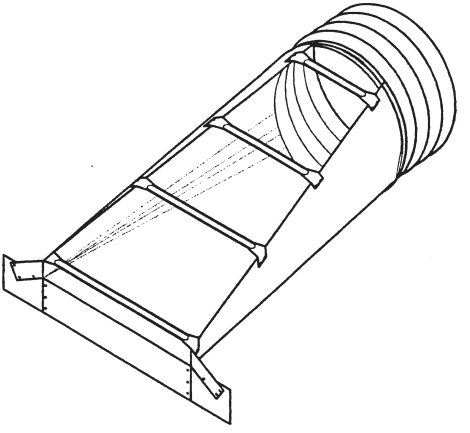
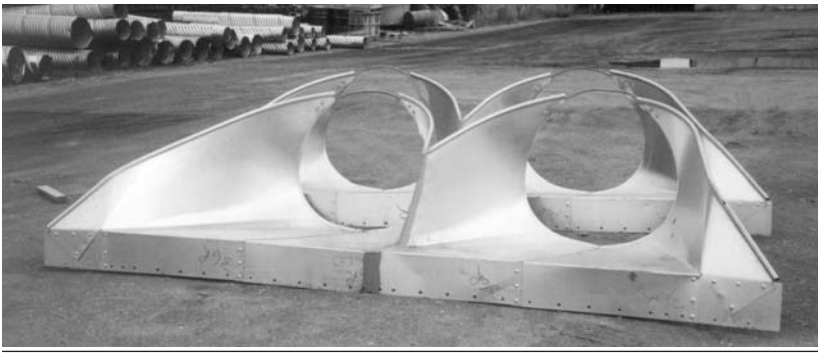


Figure 2.31: Parallel drainage safety end section.



Special fabricated twin end sections.

Table 2.46 Dimensions of safety end sections for round CSP (See Figure 2.27)

Pipe Diameter (mm)	Nominal Thickness (mm)	Toe Plate Dimensions (mm)				L Dimensions (mm)	
		A	H	W	Overall Width	1:4 Slope Length	1:6 Slope Length
300	1.6	200	150	450	850	n/a	700
400	1.6	200	150	550	950	800	1200
450	1.6	200	150	600	1000	1000	1500
500	1.6	200	150	650	1050	1200	1800
525	1.6	200	150	675	1075	1300	1950
600	1.6	200	150	750	1150	1600	2400
700	2.8	300	225	850	1450	1800	2700
750	2.8	300	225	900	1500	2000	3000
800	2.8	300	225	950	1550	2200	3300
900	2.8	300	225	1050	1650	2600	3900
1000	2.8	400	300	1150	1950	3000	4500
1050	2.8	400	300	1200	2000	3200	4800
1200	2.8	400	300	1350	2150	3800	5700
1350	2.8	400	300	1500	2300	4400	6600
1400	2.8	400	300	1550	2350	4600	6900

Table 2.47 Dimensions of safety end sections for CSP pipe-arches (See Figure 2.27)

Equivalent Diameter (mm)	Pipe-Arch Dimensions (mm)		Nominal Thickness (mm)	Toe Plate Dimensions (mm)				L Dimensions (mm)	
	Span	Rise		A	H	W	Overall Width	1:4 Slope Length	1:6 Slope Length
400	450	340	1.6	200	150	600	1000	560	840
500	560	420	1.6	200	150	710	1110	880	1320
600	680	500	1.6	200	150	830	1230	1200	1800
700	800	580	2.8	300	225	950	1550	1320	1980
800	910	660	2.8	300	225	1060	1660	1640	2460
900	1030	740	2.8	300	225	1180	1780	1960	2940
1000	1150	820	2.8	400	300	1300	2100	2280	3420
1200	1390	970	2.8	400	300	1540	2340	2880	4320
1400	1630	1120	2.8	400	300	1780	2580	3480	5220
1600	1880	1260	2.8	400	300	2030	2830	4040	6060
1800	2130	1400	2.8	400	300	2280	3080	4600	6900

Table 2.48 Dimensions of safety end sections of spiral rib pipe-arches (See Figure 2.27)

Equivalent Diameter (mm)	Pipe-Arch Dimensions (mm)		Nominal Thickness (mm)	Toe Plate Dimensions (mm)				L Dimensions (mm)	
	Span	Rise		A	H	W	Overall Width	1:4 Slope Length	1:6 Slope Length
450	500	390	1.6	200	150	650	1050	760	1140
525	580	465	1.6	200	150	730	1130	1060	1590
600	660	530	1.6	200	150	810	1210	1320	1980
750	830	660	2.8	300	225	980	1580	1640	2460
900	1010	790	2.8	300	225	1160	1760	2160	3240
1050	1160	920	2.8	400	300	1310	2110	2680	4020
1200	1340	1050	2.8	400	300	1490	2290	3200	4800
1350	1485	1190	2.8	400	300	1635	2435	3760	5640
1500	1670	1300	2.8	400	300	1820	2620	4200	6300
1650	1815	1450	2.8	400	300	1965	2765	4800	7200

4. Riprap or Retaining Walls.
   The slope at the end of a culvert (mitered or square cut) can be protected economically against erosion by riprap or retaining walls (see Chapter 13). Stone riprap may be sealed by portland cement grout or asphaltic concrete. A geotextile is normally used under riprap to prevent the smaller grained soil beneath it from washing out.

5. Skews and Bevels.
   Depending on the structural capability and hydraulic efficiencies desired, corrugated steel pipe and structural plate structures can be designed and manufactured with square, skewed or beveled ends.

   Square, skewed and beveled ends are shown in Figure 2.32. Manufacturers can provide assistance in designing these types of end finishes to meet specific project requirements.

   When head walls are not considered in the design, or when skews or beveled ends are used, the end treatment (especially of structural plate structures) requires special attention. Incomplete structural rings act as retaining walls, and must be reinforced or tied back to maintain structural integrity. Both skewed and beveled ends are usually reinforced as shown in Figure 2.33. Reinforcement of structure ends is a desired design practice, regardless of structure size.

   Details and essential considerations are discussed in Chapter 6, Structural Design.

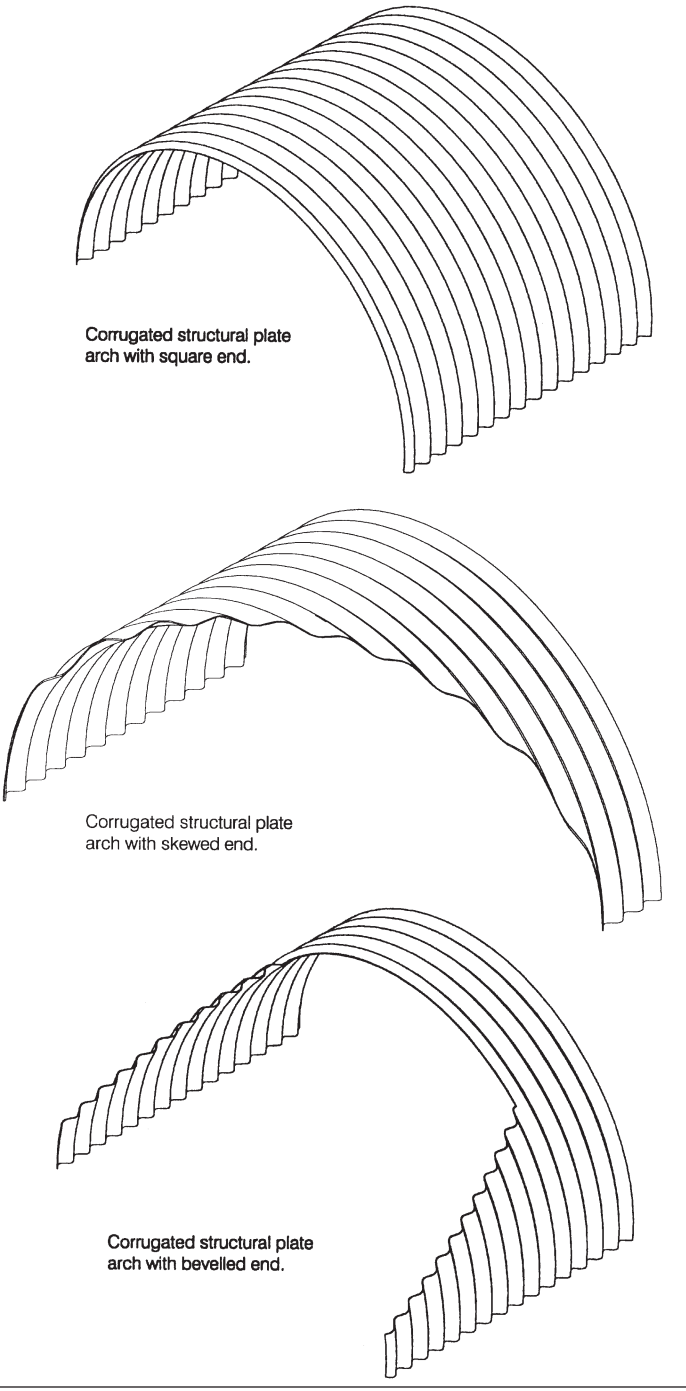
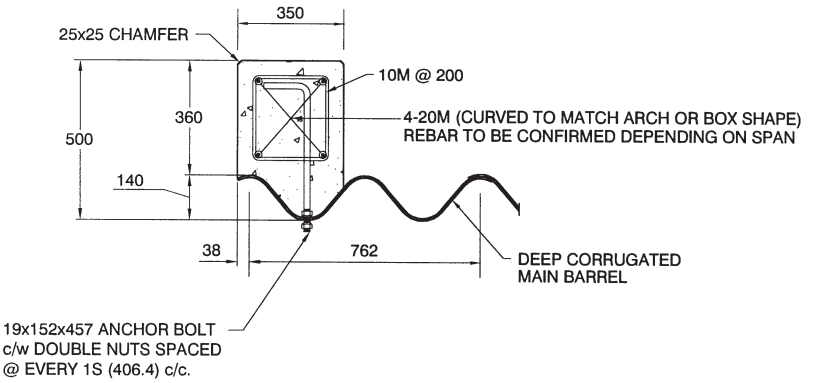


Figure 2.32 End type definitions.



Detail - Concrete Collar

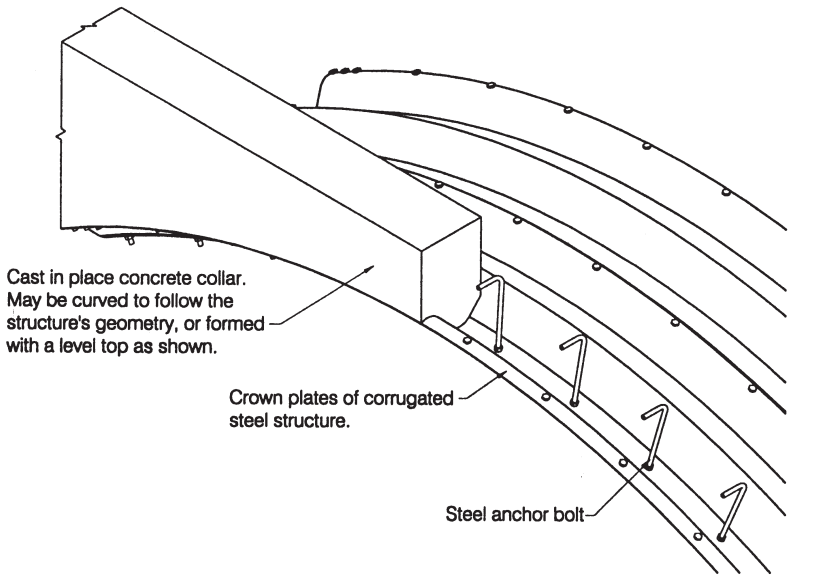


Figure 2.33 Concrete end reinforcing collar.

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