# CHAPTER two

# Product Details and Fabrication

## INTRODUCTION

The application of corrugated steel pipe to the solution of various drainage problems has been described and illustrated in Chapter 1. These products are applicable to a wide segment of the construction industry, including highways, railways, streets, urban areas, airports, industrial and commercial development, flood control and conservation.

The steel products presented in this CSP Design Manual may be available at locations around the world, but not all products are fabricated in the USA. The NCSPA prepared this manual with full knowledge that highway projects funded by the FHWA require inclusion of the "Buy America" clause in the contract documents and the use of US-Made steel in the project. For FHWA funded projects, designers and specifiers should verify the origin and availability of CSP products through contact with local corrugated steel pipe and plate fabricators.

NCSPA does not accept responsibility for the designer's selection of material for drainage applications, but encourages the designer to evaluate the numerous corrugated steel products that meet the requirements of their project. It is suggested that the designer check the NCSPA website at www.NCSPA.org for additional technical guidance related to the selection of drainage pipe and structures.

The examples presented in this design manual are not all-inclusive or complete solutions, they are intended only to show the adaptability and wide acceptance of one material—corrugated steel—in providing the solution to 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 (analyze), select, design and apply the available materials and products that most economically serve their purpose. Mass transportation, anti-pollution facilities, flood protection and other related construction, conceivably 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 are the best assurance of economical construction and subsequent minimum maintenance.

The following design factors must be considered:

1. Size, shape, alignment, grade and other pipe details depend on hydrology, hydraulics, site conditions and service requirements. (See Chapters 3, 4 and 5.)

2. Structural adequacy to meet embankment and superimposed live loads, along with hydraulic forces. (See Chapters 7 and 8.)
3. Trouble-free service through selection of materials to resist abrasion and assure long term durability. (See Chapter 9.)
4. Economics—first cost of materials, installation cost, maintenance cost over the life of the pipe. (See Chapter 11.)

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 year, coordination with other construction schedules, supplier's assistance, and ease of repair or replacement in relation to the importance or service of the installation.

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

# BACKGROUND

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 96 inches and larger. Fill heights became greater, even exceeding 100 feet A further development, in 1931, was structural plate pipe with larger corrugations, for field assembly. Diameters and arch spans beyond 26 feet have been installed successfully.

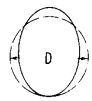
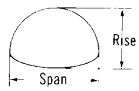
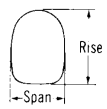
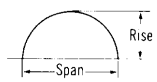
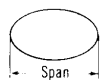
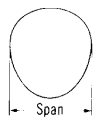
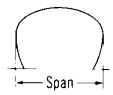
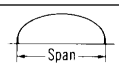
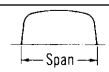
# SHAPES

The designer has a wide choice of standard cross-sectional shapes of corrugated steel and structural plate pipe as shown in Table 2.1. Size planned and site conditions use may control the shape selected, with strength and economy as additional factors. For sectional properties of corrugated steel sheets and plates, see Tables 2.3 through 2.15. For seam strengths, sizes, weights and other details, see Tables 2.16 through 2.49.

There are many kinds of corrugations, some of which are shown in Fig. 2.1 and 2.2. Corrugations profiles commonly used for pipes or conduits consist of circular arcs and alternating tangent segments or alternating rectangular ribs and flat segments. Corrugation profiles are typically described by pitch, depth and inside forming radius. Pitch is measured at right angles to the corrugations from crest to crest. The corrugation profiles shown in Figures 2.1 and 2.2 are not fabricated by every CSP manufacturer. Check with your local fabricator before specifying a corrugation profile.

## Table 2.1

Shapes and uses of corrugated conduits

| Shape | Range of Sizes | Common Uses |
|---|---|---|
| Round   | 6 in. - 51 ft | Culverts, subdrains, sewers,service tunnels, etc. All plates same radius. For medium and high fills (or trenches). |
| Vertical ellipse 5% nominal   | 4 - 21 ft 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 17 in. x 13 in. to 20 ft 7 in x 13 ft 2 in. | Where headroom is limited. Has hydraulic advantages at low flows. Corner plate radius. 18 inches or 31 inches for structural plate. |
| Underpass*   | Span x Rise 5 ft 8 in. x 5 ft 9 in. to 20 ft 4 in. x 17 ft 9 in. | For pedestrians, livestock or vehicles (structural plate). |
| Arch   | Span x Rise 5 ft x 1 ft 9 1/2 in. to 82 ft x 42 ft | For low clearance large waterway opening, and aesthetics (structural plate). |
| Horizontal Ellipse   | Span 7 - 40 ft | Culverts, grade separations, storm sewers, tunnels (structural plate). |
| Pear   | Span 25 - 30 ft | Grade separations, culverts, storm sewers, tunnels (structural plate). |
| High Profile Arch   | Span 20 - 83 ft | Culverts, grade separations, storm sewers and tunnels. Ammunition magazines, earth covered storage (structural plate). |
| Low Profile Arch   | Span 20 - 83 ft | Low-wide waterway enclosures, culverts, storm sewers (structural plate). |
| Box Culverts   | Span 10 - 53 ft | Low-wide waterway enclosures, culverts, storm sewers (structural plate). |
| Specials | Various | For lining old structures or other special purposes. Special fabrication. |

Notes: *For equal area or clearance, the round shape is generally more economical and easier to assemble.

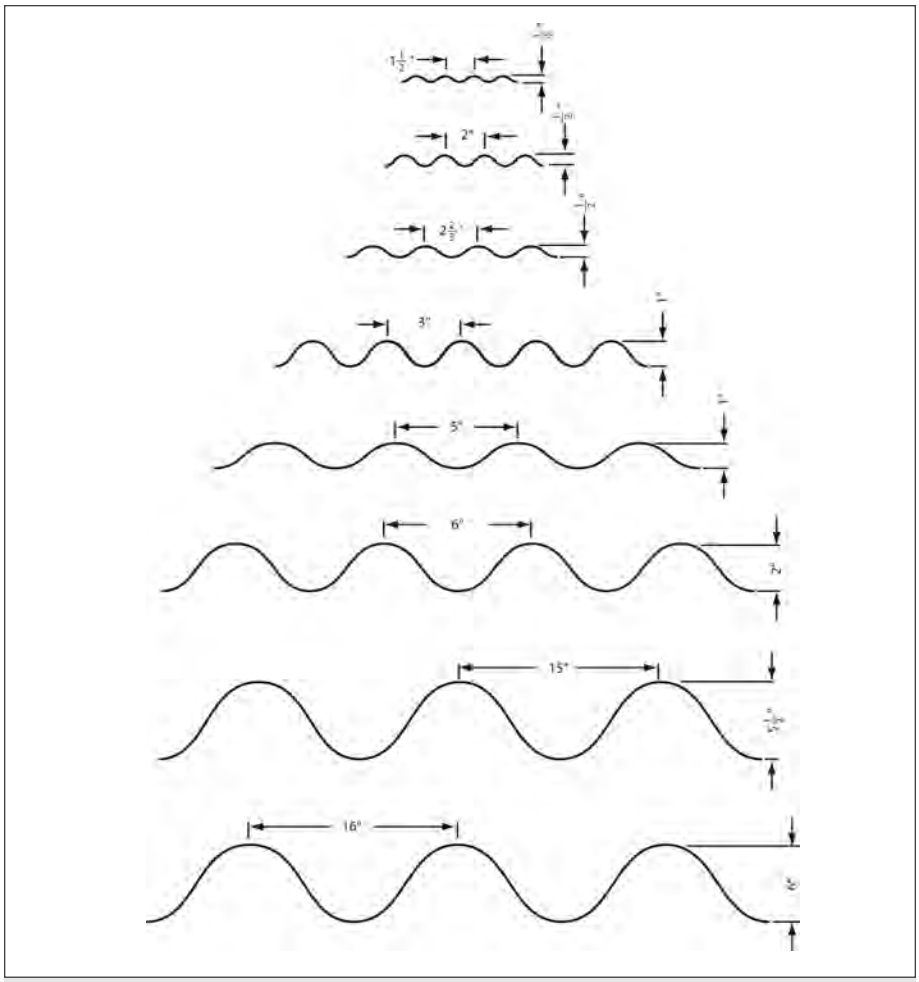
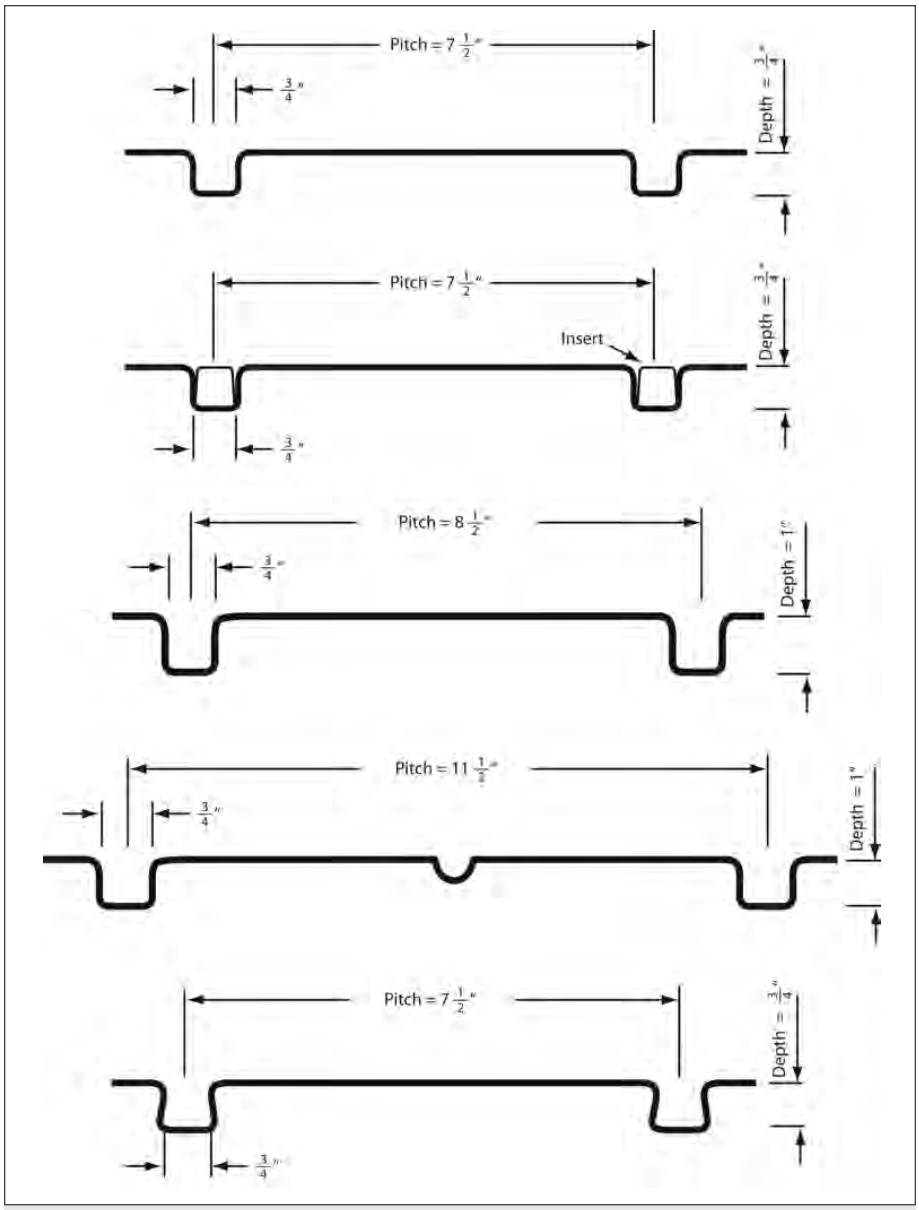



**Figure 2.1** Arc and tangent corrugations.

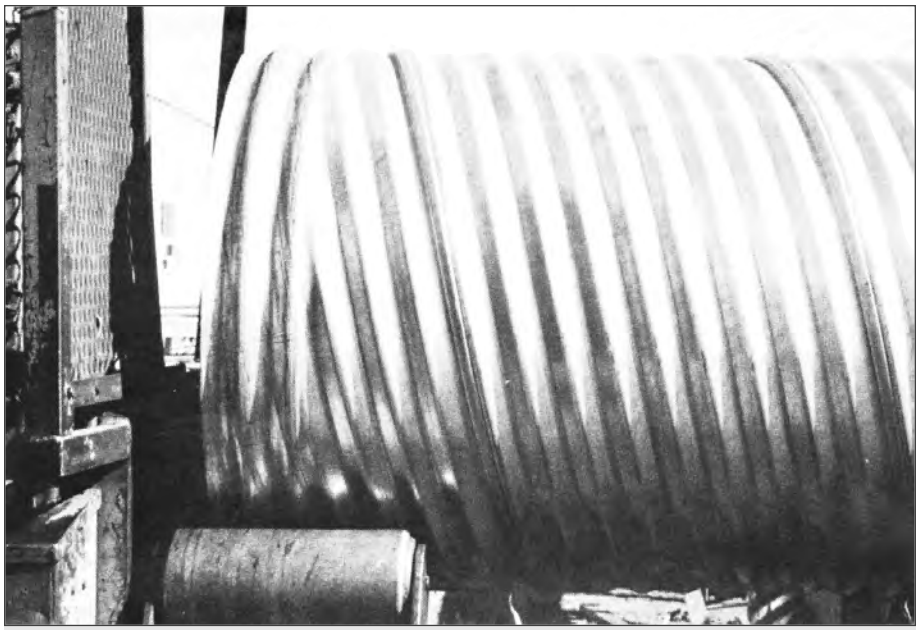
For riveted or resistance spot-welded pipe with circumferential (annular) seams, the corrugations are of 2 2/3 inches pitch by 1/2 inch depth or 3 inches by 1 inch. For lock seam pipe, the seams and corrugations run helically (or spirally) around the pipe. For small diameter subdrain pipe (6, 8, 10 inches, etc.) the pitch vs. depth dimension is 1 1/2 x 1/4 inches. Larger sizes (diameters to 144 inches depending on profile) use 2 x 1/2 inch, 2 2/3 x 1/2 inch, 3 x 1 inch, and 5 x 1 inch corrugations.

The most recent lock seam corrugations introduced to the market were the spiral rib profiles. Developed in the mid 1980's, the pipe wall is spirally formed using rectangular formed ribs between flat wall areas. This unique profile configuration was developed to provide flow characteristics equal to those piping systems normally considered smooth wall. Three profile configurations are available – 3/4 inch x 3/4 inch x 7 1/2 inches, 3/4 inch




■ **Figure 2.2** Spiral rib corrugations.

x 1 inch x 8 1/2 inches and 3/4 inch x 1 inch x 11 1/2 inches (covering diameters from 18 through 108 inches). Structural plate pipe consists of corrugated sheets that are bolted together to form the required shape. The 6 x 2 inch corrugation was the original structural plate corrugation profile. The most recent corrugation profiles introduced for structural plate are commonly referred to as 'deep' corrugated. Corrugation profiles for 'deep' corrugated structural plate include 15 x 5 1/2 inch and the 16 x 6 inch corrugations.



■ Rerolling an annular end on helical corrugated pipe.

■ Corrugated steel pipe nested for shipment.

# SECTIONAL PROPERTIES

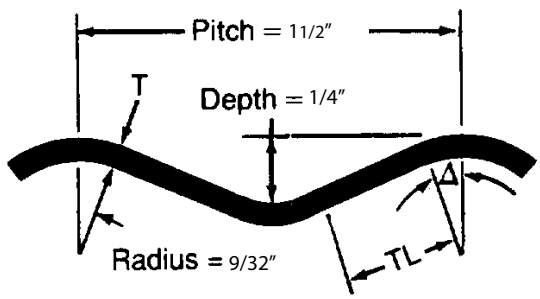
Sectional properties of the arc-and-tangent type of corrugation are derived mathematically. These include area, A, moment of inertia, I, section modulus, S, and radius of gyration, r. Research by the American Iron and Steel Institute has shown that failure loads in bending and deflection within the elastic range can be closely predicted by using computed sectional properties of the corrugated sheet. See Tables 2.3 through 2.15.

## Table 2.2

Conversion of nominal gage to thickness

| **Gage No.** | **22** | **20** | **18** | **16** | **14** | **12** | **10** |
|---|---|---|---|---|---|---|---|
| Uncoated Thickness (in.) | 0.0299 | 0.0359 | 0.0478 | 0.0598 | 0.0747 | 0.1046 | 0.1345 |
| Galvanized Thickness* (in.) | 0.034 | 0.040 | 0.052 | 0.064 | 0.079 | 0.109 | 0.138 |
| Galvanized Structural Plate Thickness (in.) | | | | | | 0.111 | 0.140 |
| **Gage No.** | **8** | **7** | **5** | **3** | **1** | **5/16″** | **3/8″** |
| Uncoated Thickness (in.) | 0.1644 | 0.1838 | 0.2145 | 0.2451 | 0.2758 | 0.3125 | 0.3750 |
| Galvanized Thickness* (in.) | 0.168 | | | | | | |
| Galvanized Structural Plate Thickness (in.) | 0.170 | 0.188 | 0.218 | 0.249 | 0.280 | 0.318 | 0.380 |

Notes: * Also referred to as specified thickness for corrugated steel pipe products.
For structural plate, tunnel liner plates and other products, see chapters on those products.

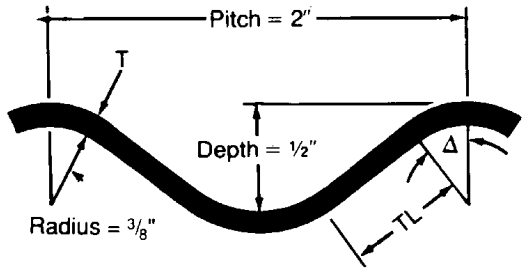



## Table 2.3

Sectional properties of 1 1/2 x 1/4 in. (Helical)

| **Specified Thickness** | **Uncoated Thickness *T*** | **Area of Section *A*** | **Tangent Length *TL*** | **Tangent Angle *Δ*** | **Moment of Inertia *I*** | **Section Modulus *S*** | **Radius of Gyration *r*** | **Developed Width Factor** |
|---|---|---|---|---|---|---|---|---|
| **(in.)** | **(in.)** | **(in.$^2$/ft)** | **(in.)** | **(Degrees)** | **(in.$^4$/in)** | **(in.$^3$/ft)** | **(in.)** | |
| 0.040* | 0.0359 | 0.456 | 0.571 | 21.44 | 0.00025 | 0.0213 | 0.0816 | 1.060 |
| 0.052 | 0.0478 | 0.608 | 0.566 | 21.52 | 0.00034 | 0.0277 | 0.0842 | 1.060 |
| 0.064 | 0.0598 | 0.761 | 0.560 | 21.61 | 0.00044 | 0.0340 | 0.0832 | 1.060 |
| 0.079 | 0.0747 | 0.950 | 0.554 | 21.71 | 0.00057 | 0.0419 | 0.0846 | 1.060 |
| 0.109* | 0.1046 | 1.331 | 0.540 | 21.94 | 0.00086 | 0.0580 | 0.0879 | 1.060 |
| 0.138* | 0.1345 | 1.712 | 0.526 | 22.17 | 0.00121 | 0.0753 | 0.0919 | 1.061 |
| 0.168* | 0.1644 | 2.093 | 0.511 | 22.42 | 0.00163 | 0.0945 | 0.0967 | 1.061 |

* Thickness not commonly available. Information only.
Notes: 1. Per foot of projection about the neutral axis.
To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating.
Dimensions are subject to manufacturing tolerances.



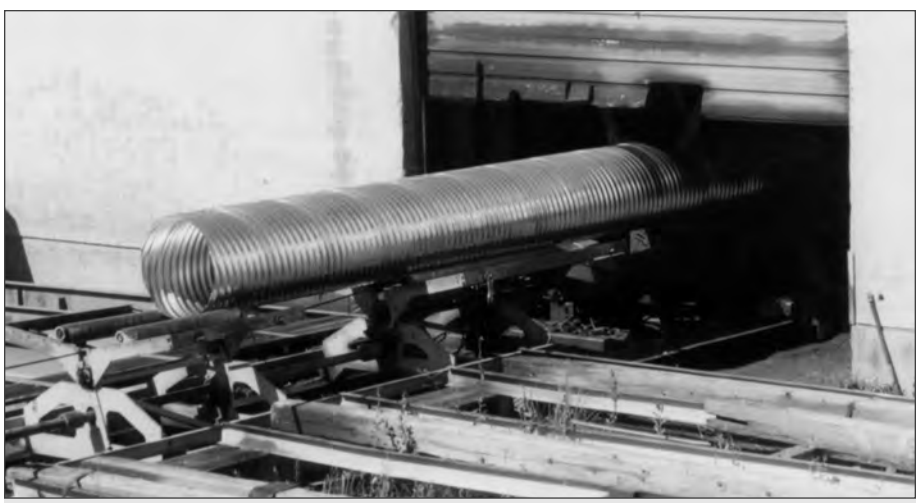

## Table 2.4

Sectional properties of 2 x 1/2 in. (Helical)

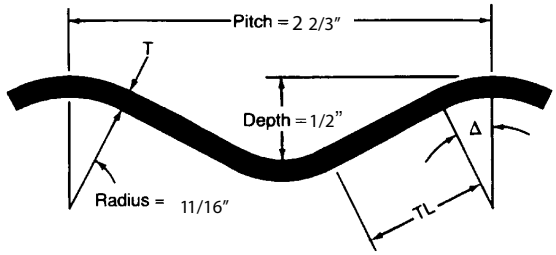
| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Tangent Length *TL* | Tangent Angle *Δ* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|---|---|
| (in.) | (in.) | (in.$^2$/ft) | (in.) | (Degrees) | (in.$^4$/in) | (in.$^3$/ft) | (in.) | |
| 0.040* | 0.0359 | 0.489 | 0.681 | 33.12 | 0.0011 | 0.0513 | 0.1676 | 1.136 |
| 0.052 | 0.0478 | 0.652 | 0.672 | 33.29 | 0.0015 | 0.0673 | 0.1682 | 1.136 |
| 0.064 | 0.0598 | 0.815 | 0.663 | 33.46 | 0.0019 | 0.0832 | 0.1690 | 1.136 |
| 0.079 | 0.0747 | 1.019 | 0.625 | 33.68 | 0.0025 | 0.1025 | 0.1700 | 1.137 |
| 0.109 | 0.1046 | 1.428 | 0.629 | 34.13 | 0.0035 | 0.1406 | 0.1725 | 1.138 |
| 0.138* | 0.1345 | 1.838 | 0.605 | 34.62 | 0.0047 | 0.1783 | 0.1754 | 1.139 |
| 0.168* | 0.1644 | 2.249 | 0.579 | 35.13 | 0.0060 | 0.2166 | 0.1788 | 1.140 |

* Thickness not commonly available. Information only.

Notes: 1. Per foot of projection about the neutral axis.
To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating.
Dimensions are subject to manufacturing tolerances.



Manufacturing of corrugated steel pipe.




## Table 2.5

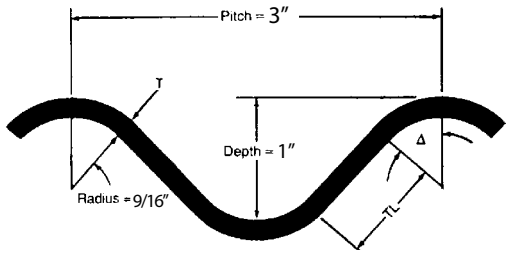
Sectional properties of 2 2/3 x 1/2 in. (Annular or Helical)

| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Tangent Length *TL* | Tangent Angle *Δ* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|---|---|
| (in.) | (in.) | (in.$^2$/ft) | (in.) | (Degrees) | (in.$^4$/in) | (in.$^3$/ft) | (in.) | |
| 0.040* | 0.0359 | 0.465 | 0.785 | 26.56 | 0.0011 | 0.0503 | 0.1702 | 1.080 |
| 0.052 | 0.0478 | 0.619 | 0.778 | 26.65 | 0.0015 | 0.0659 | 0.1707 | 1.080 |
| 0.064 | 0.0598 | 0.775 | 0.770 | 26.74 | 0.0019 | 0.0812 | 0.1712 | 1.080 |
| 0.079 | 0.0747 | 0.968 | 0.760 | 26.86 | 0.0024 | 0.0998 | 0.1721 | 1.080 |
| 0.109 | 0.1046 | 1.356 | 0.740 | 27.11 | 0.0034 | 0.1360 | 0.1741 | 1.080 |
| 0.138 | 0.1345 | 1.744 | 0.720 | 27.37 | 0.0045 | 0.1714 | 0.1766 | 1.081 |
| 0.168 | 0.1644 | 2.133 | 0.699 | 27.65 | 0.0057 | 0.2069 | 0.1795 | 1.081 |

* Thickness not commonly available. Information only.

Notes: 1. Per foot of projection about the neutral axis.
To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating.
Dimensions are subject to manufacturing tolerances.

■ Modern helical lock seam shop fabrication is the most common method of manufacturing corrugated steel pipe.



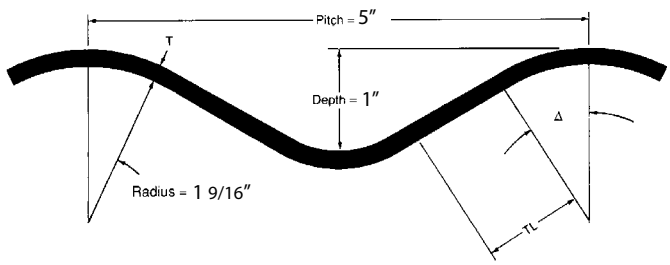

## Table 2.6

Sectional properties of 3 x 1 in. (Annular or Helical)

| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Tangent Length *TL* | Tangent Angle *Δ* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|---|---|
| (in.) | (in.) | ($in.^2$/ft) | (in.) | (Degrees) | ($in.^4$/in) | ($in.^3$/ft) | (in.) | |
| 0.040* | 0.0359 | 0.534 | 0.963 | 44.19 | 0.0052 | 0.1194 | 0.3403 | 1.239 |
| 0.052 | 0.0478 | 0.711 | 0.951 | 44.39 | 0.0069 | 0.1578 | 0.3410 | 1.240 |
| 0.064 | 0.0598 | 0.890 | 0.938 | 44.60 | 0.0087 | 0.1961 | 0.3417 | 1.240 |
| 0.079 | 0.0747 | 1.113 | 0.922 | 44.87 | 0.0109 | 0.2431 | 0.3427 | 1.241 |
| 0.109 | 0.1046 | 1.560 | 0.889 | 45.42 | 0.0154 | 0.3358 | 0.3448 | 1.243 |
| 0.138 | 0.1345 | 2.008 | 0.855 | 46.02 | 0.0202 | 0.4269 | 0.3472 | 1.244 |
| 0.168 | 0.1644 | 2.458 | 0.819 | 46.65 | 0.0251 | 0.5170 | 0.3499 | 1.246 |

* Thickness not commonly available. Information only.

Notes: 1. Per foot of projection about the neutral axis.
To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating.
Dimensions are subject to manufacturing tolerances.

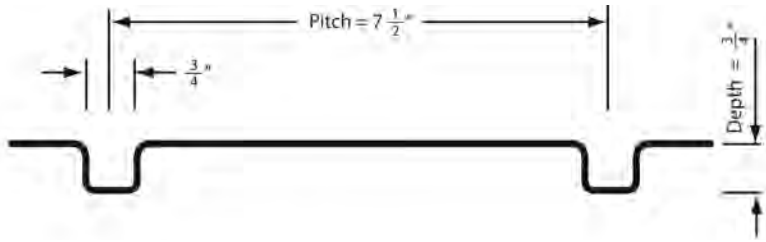



## Table 2.7

Sectional properties of 5 x 1 in. (Helical)

| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Tangent Length *TL* | Tangent Angle *Δ* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|---|---|
| (in.) | (in.) | ($in.^2$/ft) | (in.) | (Degrees) | ($in.^4$/in) | ($in.^3$/ft) | (in.) | |
| 0.064 | 0.0598 | 0.794 | 0.730 | 35.58 | 0.0089 | 0.1960 | 0.3657 | 1.106 |
| 0.079 | 0.0747 | 0.992 | 0.708 | 35.80 | 0.0111 | 0.2423 | 0.3663 | 1.107 |
| 0.109 | 0.1046 | 1.390 | 0.664 | 36.30 | 0.0156 | 0.3330 | 0.3677 | 1.107 |
| 0.138 | 0.1345 | 1.788 | 0.616 | 36.81 | 0.0203 | 0.4210 | 0.3693 | 1.108 |
| 0.168 | 0.1644 | 2.186 | 0.564 | 37.39 | 0.0250 | 0.5069 | 0.3711 | 1.108 |

Notes: 1. Per foot of projection about the neutral axis. To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile. Dimensions are subject to manufacturing tolerances.
3. Actual Pitch = 4.9213 in. and Actual Depth = 1.0236 in. Dimensions shown on sketch are nominal.

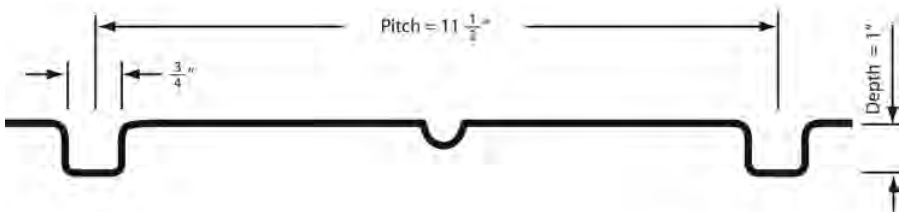



## Table 2.8

Effective sectional properties of 3/4 x 3/4 x 7 1/2 in. spiral rib (Helical)

| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|
| (in.) | (in.) | (in.$^2$/ft) | (in.$^4$/in.) | (in.$^3$/ft) | (in.) | |
| 0.064 | 0.0598 | 0.509 | 0.0028 | 0.0747 | 0.258 | 1.170 |
| 0.079 | 0.0747 | 0.712 | 0.0037 | 0.0940 | 0.250 | 1.168 |
| 0.109 | 0.1046 | 1.184 | 0.0055 | 0.1326 | 0.237 | 1.165 |
| 0.138 | 0.1345 | 1.717 | 0.0074 | 0.1706 | 0.228 | 1.162 |

Notes:
1. Per foot of projection about the neutral axis. To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating. Dimensions are subject to manufacturing tolerances.
3. Properties are effective section properties at full yield stress.

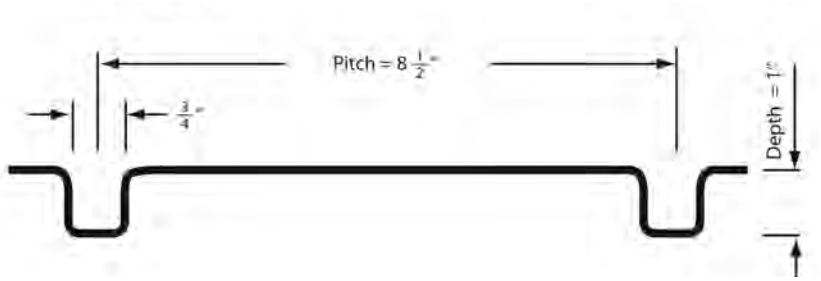



## Table 2.9

Effective sectional properties of 3/4 x 1 x 11 1/2 in. spiral rib (Helical)

| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|
| (in.) | (in.) | (in.$^2$/ft) | (in.$^4$/in.) | (in.$^3$/ft) | (in.) | |
| 0.064 | 0.0598 | 0.374 | 0.0046 | 0.0736 | 0.383 | 1.154 |
| 0.079 | 0.0747 | 0.524 | 0.0061 | 0.0931 | 0.373 | 1.153 |
| 0.109 | 0.1046 | 0.883 | 0.0093 | 0.1324 | 0.355 | 1.151 |

Notes:
1. Per foot of projection about the neutral axis. To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating. Dimensions are subject to manufacturing tolerances.
3. Properties are effective section properties at full yield stress.

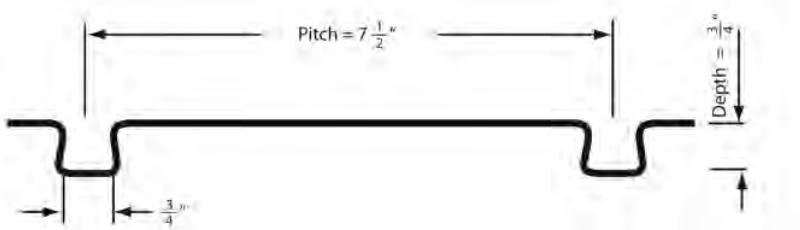



## Table 2.10

Effective sectional properties of 3/4 x 1 x 8 1/2 in. spiral rib (Helical)

| Specified Thickness | Area of Section *A* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|
| (in.) | (in.$^2$/ft) | (in.$^4$/in.) | (in.$^3$/ft) | (in.) | |
| 0.064 | 0.499 | 0.0060 | 0.0957 | 0.379 | 1.199 |
| 0.079 | 0.694 | 0.0079 | 0.1210 | 0.370 | 1.198 |
| 0.109 | 1.149 | 0.0120 | 01719 | 0.354 | 1.194 |

Notes:
1. Per foot of projection about the neutral axis. To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating. Dimensions are subject to manufacturing tolerances.
3. Properties are effective section properties at full yield stress.




## Table 2.11

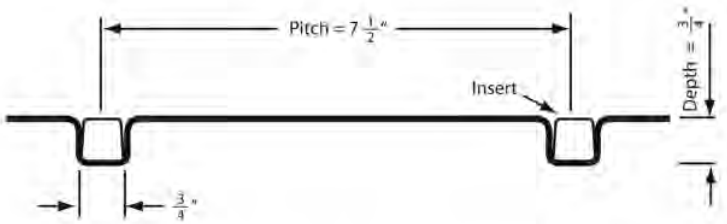
Effective sectional properties of 3/4 x 3/4 x 7 1/2 in. composite ribbed steel pipe (Helical)

| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|
| (in.) | (in.) | (in.$^2$/ft) | (in.$^4$/in.) | (in.$^3$/ft) | (in.) | |
| 0.064 | 0.0598 | 0.520 | 0.0028 | 0.0643 | 0.253 | 1.239 |
| 0.079 | 0.0747 | 0.728 | 0.0036 | 0.0817 | 0.245 | 1.233 |
| 0.109 | 0.1046 | 1.212 | 0.0054 | 0.1174 | 0.232 | 1.216 |
| 0.138 | 0.1345 | 1.758 | 0.0073 | 0.1541 | 0.223 | 1.199 |

Notes:
1. Per foot of projection about the neutral axis. To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating. Dimensions are subject to manufacturing tolerances.
3. Properties are effective section properties at full yield stress.

■ Perforated corrugated steel pipe is widely used for through-the-pile ventilation of perishable crops.

■ Multiple CSP lines form an underground stormwater storage facility.

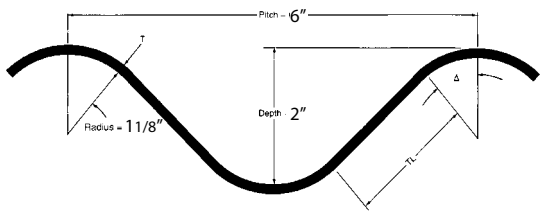



## Table 2.12

Effective sectional properties of 3/4 x 3/4 x 7 1/2 in. spiral rib with insert (Helical)

| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|
| (in.) | (in.) | (in.$^2$/ft) | (in.$^4$/in.) | (in.$^3$/ft) | (in.) | |
| 0.064 | 0.0598 | 0.509 | 0.0028 | 0.0747 | 0.258 | 1.170 |
| 0.079 | 0.0747 | 0.712 | 0.0037 | 0.0940 | 0.250 | 1.168 |
| 0.109 | 0.1046 | 1.184 | 0.0055 | 1.1326 | 0.237 | 1.165 |
| 0.138 | 0.1345 | 1.717 | 0.0074 | 0.1706 | 0.228 | 1.162 |

Notes: 1. Per foot of projection about the neutral axis. To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating. Dimensions are subject to manufacturing tolerances.
3. Properties are effective section properties at full yield stress.

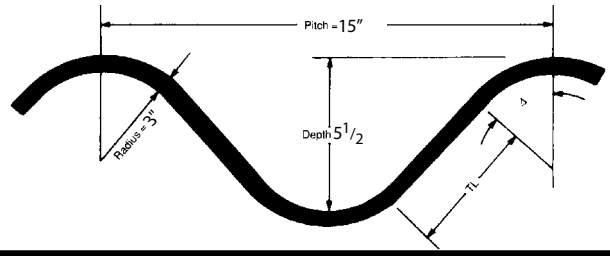



## Table 2.13

Sectional properties of 6 x 2 in. (Annular)

| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Tangent Length *TL* | Tangent Angle *Δ* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|---|---|
| (in.) | (in.) | (in.$^2$/ft) | (in.) | (Degrees) | (in.$^4$/in) | (in.$^3$/ft) | (in.) | |
| 0.111 | 0.1046 | 1.556 | 1.893 | 44.47 | 0.0604 | 0.689 | 0.682 | 1.240 |
| 0.140 | 0.1345 | 2.003 | 1.861 | 44.73 | 0.0782 | 0.879 | 0.684 | 1.241 |
| 0.170 | 0.1644 | 2.449 | 1.828 | 45.00 | 0.0962 | 1.066 | 0.686 | 1.242 |
| 0.188 | 0.1838 | 2.739 | 1.807 | 45.18 | 0.1080 | 1.187 | 0.688 | 1.242 |
| 0.218 | 0.2145 | 3.199 | 1.773 | 45.47 | 0.1269 | 1.376 | 0.690 | 1.243 |
| 0.249 | 0.2451 | 3.658 | 1.738 | 45.77 | 0.1462 | 1.562 | 0.692 | 1.244 |
| 0.280 | 0.2758 | 4.119 | 1.702 | 46.09 | 0.1658 | 1.749 | 0.695 | 1.245 |
| 0.318 | 0.3125 | 4.671 | 1.653 | 46.47 | 0.1900 | 1.968 | 0.698 | 1.246 |
| 0.380 | 0.3750 | 5.613 | 1.581 | 47.17 | 0.2320 | 2.340 | 0.704 | 1.247 |

Notes: 1. Per foot of projection about the neutral axis.
To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating. Dimensions are subject to manufacturing tolerances.

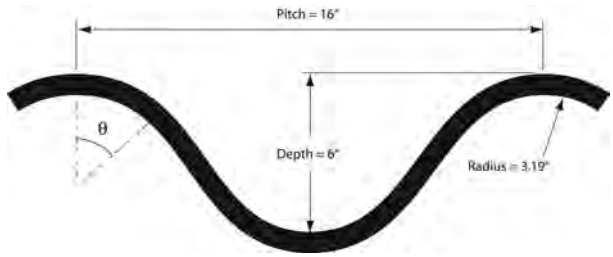



## Table 2.14

Sectional properties of 15 x 5 1/2 in. (Annular)

| Specified Thickness | Uncoated Thickness *T* | Area of Section *A* | Tangent Length *TL* | Tangent Angle *Δ* | Moment of Inertia *I* | Section Modulus *S* | Radius of Gyration *r* | Developed Width Factor |
|---|---|---|---|---|---|---|---|---|
| (in.) | (in.) | (in.$^2$/ft) | (in.) | (Degrees) | (in.$^4$/in) | (in.$^3$/ft) | (in.) | |
| 0.140 | 0.1345 | 2.260 | 4.361 | 49.75 | 0.7146 | 2.8406 | 1.9481 | 1.400 |
| 0.170 | 0.1644 | 2.762 | 4.323 | 49.89 | 0.8746 | 3.4602 | 1.9494 | 1.400 |
| 0.188 | 0.1838 | 3.088 | 4.299 | 49.99 | 0.9786 | 3.8599 | 1.9502 | 1.400 |
| 0.218 | 0.2145 | 3.604 | 4.259 | 50.13 | 1.1436 | 4.4888 | 1.9515 | 1.400 |
| 0.249 | 0.2451 | 4.118 | 4.220 | 50.28 | 1.3084 | 5.1114 | 1.9527 | 1.400 |
| 0.280 | 0.2758 | 4.633 | 4.179 | 50.43 | 1.4722 | 5.7317 | 1.9540 | 1.400 |
| 0.193 | 0.1875 | 3.150 | 4.293 | 50.00 | 0.9985 | 3.9359 | 1.9503 | 1.400 |
| 0.255 | 0.2500 | 4.200 | 4.213 | 50.31 | 1.3349 | 5.2107 | 1.9529 | 1.400 |
| 0.318 | 0.3125 | 5.250 | 4.131 | 50.62 | 1.6730 | 6.4678 | 1.9555 | 1.400 |
| 0.380 | 0.3750 | 6.300 | 4.047 | 50.94 | 2.0128 | 7.7076 | 1.9580 | 1.400 |

Notes: 1. Per foot of projection about the neutral axis.
To obtain ***A*** or ***S*** per ***inch*** of width, divide the above values by 12.
2. Developed width factor measures the increase in profile length due to corrugating.
Dimensions are subject to manufacturing tolerances.




## Table 2.15

Sectional properties of 16 x 6 in. (Annular)

| Nominal Thickness | Design Thickness | Tangent Length | Tangent Angle | Area of Section | Moment of Inertia | Section Modulus | Plastic Modulus | Radius of Gyration | Developed Width Factor |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (in.) | (in.) | (Degrees) | (in.$^2$/ft) | (in.$^4$/in) | (in.$^3$/in) | (in.$^3$ /in) | (in.) | |
| 0.157 | 0.166 | 4.426 | 51.294 | 2.736 | 0.988 | 0.311 | 0.424 | 2.0813 | 1.38 |
| 0.197 | 0.195 | 4.387 | 51.440 | 3.218 | 1.163 | 0.364 | 0.498 | 2.0827 | 1.38 |
| 0.236 | 0.236 | 4.331 | 51.640 | 3.902 | 1.413 | 0.440 | 0.605 | 2.0844 | 1.38 |
| 0.276 | 0.276 | 4.277 | 51.840 | 4.554 | 1.652 | 0.511 | 0.707 | 2.0863 | 1.38 |
| 0.315 | 0.313 | 4.225 | 52.032 | 5.166 | 1.877 | 0.577 | 0.803 | 2.0881 | 1.38 |

Notes: 1. Actual pitch = 15.748 in. and actual depth = 5.906 in.
2. Dimensions shown on the sketch have been soft converted on the basis of 1.0 in. = 25 mm.

# PIPE SEAMS

The type of pipe seam depends upon both the product and method of manufacture. Most shop-manufactured CSP is produced on a machine that forms helical corrugations; in such case, the seam may be either a continuous helical lock seam or a continuously helical welded seam, depending upon the capabilities of the production facility. However, some shop-manufactured CSP is produced on equipment that forms annular corrugations; in such case, the longitudinal and circumferential seams may be either riveted or spot welded, depending upon the production facilities capabilities and the project specifications. In contrast with CSP, structural plate pipe is always fabricated with annular corrugations and field bolted longitudinal and circumferential seams.

## Riveted Seams

Specifications for 2 2/3 x 1/2 inch corrugations call for the use of 5/16 inch diameter rivets for material thickness of 0.064 and 0.079 inches, and 3/8 inch diameter rivets for thickness of 0.109, 0.138, and 0.168 inches. For 3 x 1 inch corrugations, specifications call for 3/8 inch diameter rivets for material thickness of 0.064 and 0.079 inches, and 7/16 inch diameter rivets for thickness of 0.109, 0.138, and 0.168 inches. Longitudinal seams are riveted with one rivet in each corrugation with pipes 42 inches or larger diameter double-riveted. Circumferential rivets for joining sections are spaced on 6 inch centers. The strength of longitudinal seams for steel sheets and rivets is shown in Table 2.16.

**Table 2.16**

Ultimate longitudinal seam strength of riveted corrugated steel pipe
Tested as uncovered short columns in pounds per foot of seam*

| Specified Thickness (in.) | 5/16 in. Rivets | | 3/8 in. Rivets | | | 7/16 in. Rivets |
|---|---|---|---|---|---|---|
| | 2 2/3 x 1/2 in. | | 2 2/3 x 1/2 in. | | 3 x 1 in. and 5 x 1 in. | 3 x 1 in. and 5 x 1 in. |
| | Single | Double | Single | Double | Double | Double |
| 0.064 | 16,700 | 21,600 | | | 28,700 | |
| 0.079 | 18,200 | 29,800 | | | 35,700 | |
| 0.109 | | | 23,400 | 46,800 | | 53,000 |
| 0.138 | | | 24,500 | 49,000 | | 63,700 |
| 0.168 | | | 25,600 | 51,300 | | 70,700 |

Note: Values in this table are based on tests conducted by Utah State Dept. of Highways, 1964, and by Pittsburgh Testing Laboratories, 1966.

## Spot Welded Seams

Resistance spot welding of lapped seams is a fabricating method resulting in strength equivalent to riveted seams. Elimination of rivet heads allows a smoother pipe interior and better seating of the connecting band on the exterior.

## Bolted Seams and Joints

For structural plate products, high strength bolts, either 3/4 inch or 7/8 inch diameter, hot-dip galvanized, meeting ASTM Specification A 449 are used for field assembly of structural plate installations. Table 2.17 shows the strength of bolted longitudinal seams.

## Table 2.17

Ultimate strength of bolted structural plate longitudinal seams
In pounds per foot of seam

| Specified Thickness (in.) | 6 x 2 in.* | | | 15 x 5 1/2 in. * | | 16 x 6 in. * | |
|---|---|---|---|---|---|---|---|
| | 4 Bolts per Foot | 6 Bolts per Foot | 8 Bolts per Foot | 4.8 Bolts per Foot | Bolt Diameter (in.) | 4.5 Bolts per Foot | Bolt Diameter (in.) |
| 0.111 | 42000 | | | | | | |
| 0.140 | 62000 | | | 66000 | 0.75 | | |
| 0.169 | | | | | | 81600 | 0.75 |
| 0.170 | 81000 | | | 87000 | 0.75 | | |
| 0.188 | 93000 | | | 102000 | 0.75 | | |
| 0.197 | | | | | | 118900 | 0.75 |
| 0.218 | 112000 | | | 127000 | 0.75 | | |
| 0.236 | | | | | | 141300 | 0.75 |
| 0.249 | 132000 | | | 144000 | 0.75 | | |
| 0.276 | | | | | | 153300 | 0.75 |
| 0.280 | 144000 | 180000 | 194000 | 144000 | 0.75 | | |
| 0.315 | | | | | | 153300 | 0.75 |
| 0.249 | | | | 159000 | 0.875 | | |
| 0.276 | | | | | | 184000 | 0.875 |
| 0.280 | | | | 177000 | 0.875 | | |
| 0.315 | | | | | | 184000 | 0.875 |
| 0.318 | | | 235000 | | | | |
| 0.380 | | | 285000 | | | | |

Note: * Industry recognized seam strengths for 6 x 2 in. and 15 x 5 1/2 in. are published in ASTM A796. At the time this design manual went to publication, the design seam strengths for 16 x 6 in. were not recognized in ASTM A796. Seam strengths shown for 16 x 6 in. corrugation are proprietary values recommended by the manufacturer.

## Table 2.18

Handling weight of corrugated steel pipe (2 2/3 x 1/2 in.)
Estimated average weights - not for specification use*

| Inside Diameter (in.) | Specified Thickness (in.) | Approximate Pounds Per Linear Foot** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Metallic Coated | Polymer Coated | Full Bituminous Coated | Full Bituminous Coated and Invert Paved | Full Bituminous Coated and Full Paved | Steel Lined | Concrete Lined |
| 12 | 0.064 | 10 | 10 | 12 | 15 | | | |
| | 0.079 | 12 | 12 | 14 | 17 | | | |
| 15 | 0.064 | 12 | 13 | 15 | 18 | 28 | | |
| | 0.079 | 15 | 16 | 18 | 21 | 31 | | |
| 18 | 0.064 | 15 | 16 | 19 | 22 | 34 | | |
| | 0.079 | 18 | 19 | 22 | 25 | 37 | | |
| 21 | 0.064 | 17 | 18 | 21 | 26 | 39 | | |
| | 0.079 | 21 | 22 | 25 | 30 | 43 | | |

Notes: Pipe arch weights will be the same as the equivalent round pipe.
For example, for 42 x 29, 2 2/3 x 1/2 in. pipe arch, refer to 36 in. diameter pipe weight.
* Lock seam construction only; weights will vary with other fabrication practices.
** For other coatings or linings, the weights may be interpolated.

## Table 2.18 *continued*

Handling weight of corrugated steel pipe (2 2/3 x 1/2 in.)
Estimated average weights - not for specification use*

| Inside Diameter (in.) | Specified Thickness (in.) | Approximate Pounds Per Linear Foot** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Metallic Coated | Polymer Coated | Full Bituminous Coated | Full Bituminous Coated and Invert Paved | Full Bituminous Coated and Full Paved | Steel Lined | Concrete Lined |
| 24 | 0.064 | 19 | 20 | 24 | 30 | 45 | 30 | 65 |
| | 0.079 | 24 | 25 | 29 | 35 | 50 | 38 | 69 |
| | 0.109 | 33 | 34 | 38 | 44 | 59 | 47 | 77 |
| 30 | 0.064 | 24 | 25 | 30 | 36 | 55 | 42 | 82 |
| | 0.079 | 30 | 31 | 36 | 42 | 60 | 48 | 87 |
| | 0.109 | 41 | 42 | 47 | 53 | 72 | 59 | 96 |
| 36 | 0.064 | 29 | 30 | 36 | 44 | 65 | 51 | 98 |
| | 0.079 | 36 | 37 | 43 | 51 | 75 | 58 | 104 |
| | 0.109 | 49 | 50 | 56 | 64 | 90 | 71 | 116 |
| | 0.138 | 62 | 63 | 69 | 77 | 100 | 84 | 127 |
| 42 | 0.064 | 34 | 36 | 42 | 51 | 77 | 60 | 114 |
| | 0.079 | 42 | 44 | 50 | 59 | 85 | 68 | 121 |
| | 0.109 | 57 | 59 | 65 | 74 | 105 | 82 | 135 |
| | 0.138 | 72 | 74 | 80 | 89 | 115 | 98 | 149 |
| 48 | 0.064 | 38 | 40 | 48 | 57 | 85 | 67 | 128 |
| | 0.079 | 48 | 50 | 58 | 67 | 95 | 77 | 138 |
| | 0.109 | 65 | 67 | 75 | 84 | 120 | 94 | 154 |
| | 0.138 | 82 | 84 | 92 | 101 | 130 | 111 | 170 |
| | 0.168 | 100 | | 110 | 119 | 155 | | 186 |
| 54 | 0.079 | 54 | 56 | 65 | 76 | 105 | 87 | 156 |
| | 0.109 | 73 | 75 | 84 | 95 | 130 | 106 | 173 |
| | 0.138 | 92 | 94 | 103 | 144 | 155 | 125 | 191 |
| | 0.168 | 112 | | 123 | 134 | 175 | | |
| 60 | 0.109 | 81 | 83 | 92 | 106 | 140 | 117 | 192 |
| | 0.138 | 103 | 105 | 114 | 128 | 180 | 139 | 212 |
| | 0.168 | 124 | | 135 | 149 | 190 | | 232 |
| 66 | 0.109 | 89 | 91 | 101 | 117 | 160 | 129 | 211 |
| | 0.138 | 113 | 115 | 125 | 141 | 180 | 153 | 233 |
| | 0.168 | 137 | | 149 | 165 | 210 | | 255 |
| 72 | 0.138 | 123 | 126 | 137 | 154 | 210 | 167 | 254 |
| | 0.168 | 149 | | 163 | 180 | 236 | | 278 |
| 78 | 0.168 | 161 | | 177 | 194 | 260 | | 302 |
| 84 | 0.168 | 173 | | 190 | 208 | 270 | | 325 |

Notes: Pipe arch weights will be the same as the equivalent round pipe.
For example, for 42 x 29, 2 2/3 x 1/2 in. pipe arch, refer to 36 in. diameter pipe weight.
* Lock seam construction only; weights will vary with other fabrication practices.
** For other coatings or linings, the weights may be interpolated.

## Table 2.19

Handling weight of corrugated steel pipe (3 x 1 in. or 5 x 1* in.)
Estimated average weights – not for specification use**

| Inside Diameter (in.) | Specified Thickness (in.) | Approximate Pounds Per Linear Foot*** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Metallic Coated | Polymer Coated | Full Bituminous Coated | Full Bituminous Coated and Invert Paved | Full Bituminous Coated and Full Paved | Steel Lined† | Concrete Lined |
| 48 | 0.064 | 44 | 46 | 54 | 71 | 117 | 74 | |
| | 0.079 | 54 | 56 | 64 | 81 | 127 | 84 | |
| | 0.109 | 74 | 76 | 84 | 101 | 147 | 104 | |
| | 0.138 | 94 | 96 | 104 | 121 | 167 | 125 | |
| | 0.168 | 114 | | 124 | 141 | 187 | | |
| 54 | 0.064 | 50 | 52 | 66 | 84 | 138 | 84 | 197 |
| | 0.079 | 61 | 63 | 77 | 95 | 149 | 95 | 207 |
| | 0.109 | 83 | 85 | 100 | 118 | 171 | 118 | 226 |
| | 0.138 | 106 | 108 | 123 | 140 | 194 | 140 | 245 |
| | 0.168 | 129 | | 146 | 163 | 217 | | 264 |
| 60 | 0.064 | 55 | 57 | 73 | 93 | 153 | 93 | 218 |
| | 0.079 | 67 | 69 | 86 | 105 | 165 | 105 | 229 |
| | 0.109 | 92 | 94 | 110 | 130 | 190 | 130 | 251 |
| | 0.138 | 118 | 120 | 136 | 156 | 216 | 156 | 272 |
| | 0.168 | 143 | | 161 | 181 | 241 | | 293 |
| 66 | 0.064 | 60 | 63 | 80 | 102 | 168 | 102 | 240 |
| | 0.079 | 74 | 77 | 94 | 116 | 181 | 116 | 252 |
| | 0.109 | 101 | 104 | 121 | 143 | 208 | 145 | 276 |
| | 0.138 | 129 | 132 | 149 | 171 | 236 | 172 | 299 |
| | 0.168 | 157 | | 177 | 199 | 264 | | 322 |
| 72 | 0.064 | 66 | 69 | 88 | 111 | 183 | 112 | 262 |
| | 0.079 | 81 | 84 | 102 | 126 | 197 | 127 | 275 |
| | 0.109 | 110 | 113 | 132 | 156 | 227 | 157 | 301 |
| | 0.138 | 140 | 143 | 162 | 186 | 257 | 187 | 326 |
| | 0.168 | 171 | | 193 | 217 | 288 | | 351 |
| 78 | 0.064 | 71 | 74 | 95 | 121 | 198 | 120 | |
| | 0.079 | 87 | 90 | 111 | 137 | 214 | 136 | 298 |
| | 0.109 | 119 | 122 | 143 | 169 | 246 | 168 | 326 |
| | 0.138 | 152 | 155 | 176 | 202 | 279 | 202 | 353 |
| | 0.168 | 185 | | 209 | 235 | 312 | | 380 |
| 84 | 0.064 | 77 | 80 | 102 | 130 | 213 | 130 | |
| | 0.079 | 94 | 97 | 119 | 147 | 230 | 147 | 321 |
| | 0.109 | 128 | 131 | 154 | 182 | 264 | 181 | 351 |
| | 0.138 | 164 | 167 | 189 | 217 | 300 | 218 | 379 |
| | 0.168 | 199 | | 224 | 253 | 335 | | 409 |
| 90 | 0.064 | 82 | 86 | 109 | 140 | 228 | 139 | |
| | 0.079 | 100 | 104 | 127 | 158 | 246 | 157 | |
| | 0.109 | 137 | 141 | 164 | 195 | 283 | 194 | 376 |
| | 0.138 | 175 | 179 | 202 | 233 | 321 | 233 | 406 |
| | 0.168 | 213 | | 240 | 271 | 359 | | 438 |

Notes: Pipe arch weights will be the same as the equivalent round pipe. For example: for 81 x 59, 3 x 1 in. pipe arch, refer to 72 in. diameter pipe weight.
* Steel weights are 5 x 1 in. are approximately 12% less than those used in this table for metallic coated pipe.
** Lock seam construction only, weights will vary with other fabrication practices.
*** For other coatings or linings the weights may be interpolated.
† Steel lined available in 3 x 1 in. only.

## Table 2.19 *continued*

Handling weight of corrugated steel pipe (3 x 1 in. or 5 x 1* in.)
Estimated average weights – not for specification use**

| Inside Diameter (in.) | Specified Thickness (in.) | Approximate Pounds Per Linear Foot*** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Metallic Coated | Polymer Coated | Full Bituminous Coated | Full Bituminous Coated and Invert Paved | Full Bituminous Coated and Full Paved | Steel Lined† | Concrete Lined |
| 96 | 0.064 | 87 | 91 | 116 | 149 | 242 | 148 | |
| | 0.079 | 107 | 111 | 136 | 169 | 262 | 168 | |
| | 0.109 | 147 | 151 | 176 | 209 | 302 | 208 | 401 |
| | 0.138 | 188 | 192 | 217 | 250 | 343 | 249 | 433 |
| | 0.168 | 228 | | 257 | 290 | 383 | | 467 |
| 102 | 0.064 | 93 | 97 | 124 | 158 | 258 | 158 | |
| | 0.079 | 114 | 118 | 145 | 179 | 279 | 179 | |
| | 0.109 | 155 | 159 | 189 | 220 | 320 | 222 | 426 |
| | 0.138 | 198 | 202 | 229 | 263 | 363 | 264 | 460 |
| | 0.168 | 241 | | 272 | 306 | 406 | | 496 |
| 108 | 0.079 | 120 | 124 | 153 | 188 | 295 | 189 | |
| | 0.109 | 165 | 169 | 198 | 233 | 340 | 235 | |
| | 0.138 | 211 | 215 | 244 | 279 | 386 | 279 | 487 |
| | 0.168 | 256 | | 289 | 324 | 431 | | 525 |
| 114 | 0.079 | 127 | 132 | 162 | 199 | 312 | 200 | |
| | 0.109 | 174 | 179 | 209 | 246 | 359 | 248 | |
| | 0.138 | 222 | 227 | 257 | 294 | 407 | 295 | 514 |
| | 0.168 | 271 | | 306 | 343 | 456 | | 554 |
| 120 | 0.109 | 183 | 188 | 220 | 259 | 378 | 260 | |
| | 0.138 | 234 | 239 | 271 | 310 | 429 | 311 | 541 |
| | 0.168 | 284 | | 321 | 360 | 479 | | 583 |
| 126 | 0.109 | 195 | 200 | 233 | 274 | 400 | 276 | |
| | 0.138 | 247 | 252 | 285 | 326 | 452 | 327 | |
| | 0.168 | 299 | | 337 | 378 | 504 | | |
| 132 | 0.109 | 204 | 209 | 244 | 287 | 419 | 289 | |
| | 0.138 | 259 | 264 | 299 | 342 | 474 | 343 | |
| | 0.168 | 314 | | 354 | 397 | 529 | | |
| 138 | 0.109 | 213 | 219 | 255 | 300 | 438 | 300 | |
| | 0.138 | 270 | 276 | 312 | 357 | 495 | 357 | |
| | 0.168 | 328 | | 370 | 415 | 553 | | |
| 144 | 0.138 | 282 | 288 | 326 | 373 | 517 | 373 | |
| | 0.168 | 344 | | 388 | 435 | 579 | | |
| 150 | 0.138 | 294 | 300 | 340 | 389 | 538 | 389 | |
| | 0.168 | 358 | | 404 | 453 | 602 | | |
| 156 | 0.138 | 306 | 312 | 354 | 406 | 560 | 405 | |
| | 0.168 | 373 | | 421 | 473 | 627 | | |

Notes: Pipe arch weights will be the same as the equivalent round pipe. For example: for 81 x 59, 3 x 1 in. pipe arch, refer to 72 in. diameter pipe weight.
* Steel weights are 5 x 1 in. are approximately 12% less than those used in this table for metallic coated pipe.
** Lock seam construction only, weights will vary with other fabrication practices.
*** For other coatings or linings the weights may be interpolated.
† Steel lined available in 3 x 1 in. only.

## Table 2.20

Handling weight of spiral rib pipe and composite ribbed steel pipe
(3/4 x 3/4 x 7 1/2 in & 3/4 x 1 x 11 1/2 in. spiral rib pipe and 3/4 x 3/4 x 7 1/2 in. composite ribbed steel pipe)
Estimated average weights – not for specification use*

| Inside Diameter (in.) | Specified Thickness (in.) | Approximate Pounds Per Linear Foot** | | | |
|---|---|---|---|---|---|
| | | Galvanized | Asphalt Fully Coated | Asphalt Fully Coated & Invert Paved | Composite Ribbed Steel Pipe |
| 18 | 0.064 | 15 | 19 | 20 | |
| | 0.079 | 18 | 22 | 23 | |
| 21 | 0.064 | 17 | 21 | 22 | |
| | 0.079 | 21 | 25 | 26 | |
| | 0.109 | 29 | 33 | 33 | |
| 24 | 0.064 | 19 | 24 | 25 | 21 |
| | 0.079 | 24 | 29 | 32 | 25 |
| | 0.109 | 36 | 41 | 42 | 33 |
| 30 | 0.064 | 24 | 30 | 32 | 27 |
| | 0.079 | 30 | 36 | 38 | 32 |
| | 0.109 | 42 | 48 | 50 | 41 |
| 36 | 0.064 | 29 | 36 | 38 | 32 |
| | 0.079 | 36 | 43 | 45 | 28 |
| | 0.109 | 50 | 57 | 59 | 49 |
| 42 | 0.064 | 33 | 41 | 43 | 37 |
| | 0.079 | 42 | 50 | 52 | 44 |
| | 0.109 | 58 | 66 | 60 | 57 |
| 48 | 0.064 | 38 | 48 | 50 | 43 |
| | 0.079 | 48 | 58 | 60 | 50 |
| | 0.109 | 66 | 76 | 78 | 66 |
| 54 | 0.064 | 43 | 54 | 56 | 48 |
| | 0.079 | 54 | 65 | 67 | 56 |
| | 0.109 | 75 | 86 | 88 | 74 |
| 60 | 0.064 | 48 | 60 | 62 | 53 |
| | 0.079 | 60 | 72 | 74 | 62 |
| | 0.109 | 83 | 95 | 97 | 82 |
| | 0.138 | 99 + | 111 + | | |
| 66 | 0.064 *** | 53 | 66 | 68 | 58 |
| | 0.079 | 66 | 79 | 81 | 69 |
| | 0.109 | 91 | 104 | 106 | 90 |
| | 0.138 | 109 + | 121 + | | |
| 72 | 0.064 | | | | 63 |
| | 0.079 | 72 | 86 | 89 | 75 |
| | 0.109 | 99 | 113 | 116 | 98 |
| | 0.138 | 119 + | 133 + | | |
| 78 | 0.079 | 78 | 93 | 96 | 81 |
| | 0.109 | 108 | 115 | 118 | 106 |
| | 0.138 | 129 + | 144 + | | |
| 84 | 0.079 *** | 71 | 101 | 104 | 87 |
| | 0.109 | 116 | 133 | 136 | 114 |
| | 0.138 | 139 + | 156 + | | |
| 90 | 0.109 | 124 | 143 | 147 | 122 |
| | 0.138 | 149 + | 168 + | | |
| 96 | 0.109 | 132 | 152 | 156 | 130 |
| | 0.138 | 158 + | 178 + | | |
| 102 | 0.109 | 141 | 163 | 167 | 138 |
| | 0.138 | 168 + | 190 + | | |
| 108 | 0.109 *** | 150 | 172 | 176 | 146 |
| | 0.138 | 175 + | 197 + | | |
| 114 | 0.138 | 196 | 219 | 223 | |
| 120 | 0.138 | 206 | 230 | 235 | |

Notes: * Lock seam construction only. ** For other coatings or linings, the weights may be interpolated.
*** For 3/4 x 1 x 11 1/2 in. only. + For 3/4 x 3/4 x 7 1/2 in. only.


■ Relining of a failed concrete box with corrugated steel pipe arch.

## SPIRAL RIB STEEL PIPE

Spiral rib pipe is manufactured from a continuous strip of metallic coated or polymer coated steel passed through a roll forming line that forms the external ribs and the edges. The rolled shape section is then helically formed into pipe and the edges are joined by lock seaming. The finished product has the structural characteristics needed for installation and a smooth interior for improved hydraulics. See Tables 2.8 through 2.12 for profile shapes.

■ Spiral rib pipe.

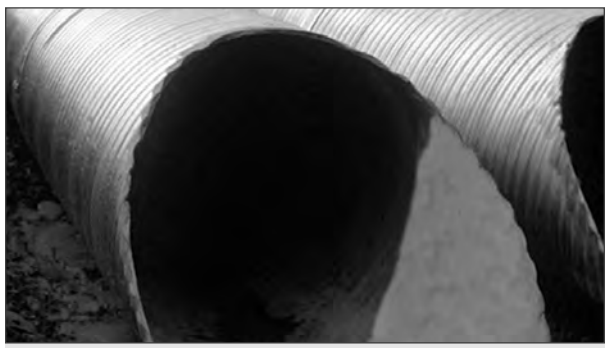
## DOUBLE WALL STEEL PIPE

Double Wall (steel lined) is a smooth interior corrugated steel pipe fabricated in full circular cross section with a smooth steel liner and helically corrugated shell integrally attached at the helical lock seams from end to end of each length of pipe. The steel interior lining provides for improved hydraulics.

■ Double wall pipe.

## CSP CONCRETE LINED PIPE

The interior lining of the corrugated steel pipe is 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.



■ Concrete lined corrugated steel pipe.

## COMPOSITE RIBBED STEEL PIPE

Composite ribbed steel pipe is manufactured from a continuous strip of metallic coated steel passed through a roll forming mill that forms external ribs. The coated steel is protected by a polymer film on the outside and has a 75 mil polyethylene interior liner for protection from effluent corrosion and/or abrasion as well as providing a smooth interior for improved hydraulics.

## CSP SLOTTED DRAIN INLETS

By welding a narrow section of grating in a continuous slot cut 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 as a curb inlet. Detailed hydraulic design information is provided in Chapter 4.

■ Slotted drain inlet pipe.

■ Slotted drain inlet pipe.

■ Slotted drain inlet pipe.

■ Slotted drain inlet pipe.

# PERFORATED PIPE

Corrugated steel pipe is available with perforations for collection or dissemination of water underground and is an effective means of storm water management. Subsurface, 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 as shown in Table 2.21. Most fabricators are equipped to furnish 3/8 inch diameter holes. The sizes and layout of perforations can be specified to match site requirements. The perforations are located on the inside crests or along the neutral axis of the corrugations, with one row of perforations in each corrugation.

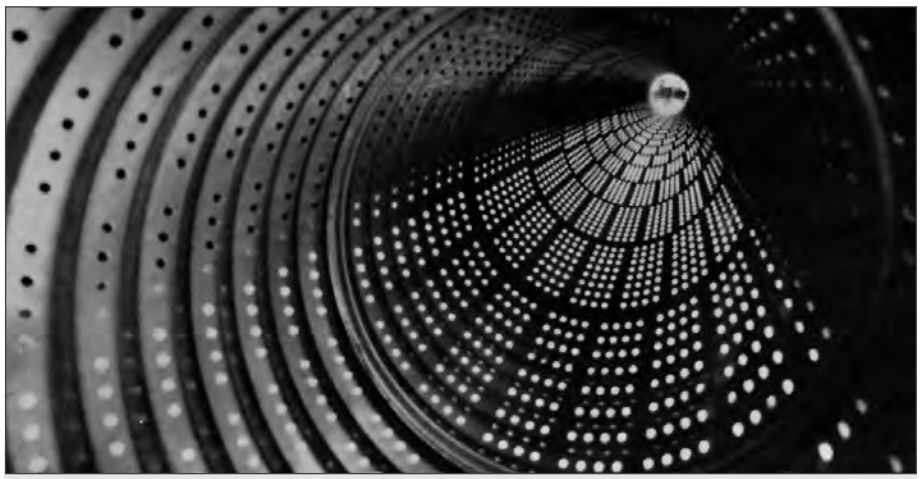
Fully perforated helical CSP is ideally suited for retention of storm water, permitting slow infiltration, or recharge, into the trench walls. Underground disposal of storm water runoff in urban development design has the potential for saving millions of dollars in taxpayer money. Recharge design makes 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 will usually prove to be far greater than recharge design. In the retention application, the pipe is typically perforated for the full 360 degrees. Perforations in fully perforated helical pipe usually provide an opening area of not less than 2.3% of the pipe surface.

**Table 2.21**

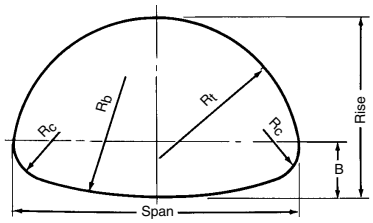
Perforated galvanized corrugated pipe data*
Dimensions, Weights, Perforations

| Nominal Perforations | | Minimum Width of Unperforated Bottom Segment | Specified Thickness | | | |
|---|---|---|---|---|---|---|
| Internal Diameter | Number of Rows | | 0.052 | 0.064 | 0.052 | 0.064 |
| | | | Weight, lbs per ft | | | |
| | | | Helically Corrugated Pipe | | Annular Corrugated Pipe | |
| (in.) | (in.) | (in.) | (in.) | (in.) | (in.) | (in.) |
| 6 | 4 | 3.8 | 3.8 | 4.7 | 5.0 | 5.6 |
| 8 | 4 | 5.1 | 5.0 | 6.2 | 6.3 | 7.3 |
| 10 | 4 | 6.4 | 6.5 | 7.6 | - | 9.0 |
| 12 | 6 | 7.7 | - | 9.9 | - | 10.5 |
| 15 | 6 | 9.6 | - | 12.4 | - | 12.9 |
| 18 | 6 | 11.5 | - | 14.8 | - | 15.3 |
| 21 | 6 | 13.5 | - | 17.2 | - | 17.7 |
| 24 | 8 | 15.4 | - | 19.3 | - | 20.0 |

Note: * AASHTO Spec. M 36.



■ The pipe is perforated for the full 360° to be used in a subsurface recharge system.




## Table 2.22

Sizes and layout details — CSP pipe arches
(2 2/3 x 1/2 in. corrugation)

| Equiv. Diameter | Design | | Waterway Area | Layout Dimensions | | | |
|---|---|---|---|---|---|---|---|
| | Span | Rise | | B | $R_c$ | $R_t$ | $R_b$ |
| (in.) | (in.) | (in.) | ($ft^2$) | (in.) | (in.) | (in.) | (in.) |
| 15 | 17 | 13 | 1.1 | 4 1/8 | 3 1/2 | 8 5/8 | 25 5/8 |
| 18 | 21 | 15 | 1.6 | 4 7/8 | 4 1/8 | 10 3/4 | 33 1/8 |
| 21 | 24 | 18 | 2.2 | 5 5/8 | 4 7/8 | 11 7/8 | 34 5/8 |
| 24 | 28 | 20 | 2.9 | 6 1/2 | 5 1/2 | 14 | 42 1/4 |
| 30 | 35 | 24 | 4.5 | 8 1/8 | 6 7/8 | 17 7/8 | 55 1/8 |
| 36 | 42 | 29 | 6.5 | 9 3/4 | 8 1/4 | 21 1/2 | 66 1/8 |
| 42 | 49 | 33 | 8.9 | 11 3/8 | 9 5/8 | 25 1/8 | 77 1/4 |
| 48 | 57 | 38 | 11.6 | 13 | 11 | 28 5/8 | 88 1/4 |
| 54 | 64 | 43 | 14.7 | 14 5/8 | 12 3/8 | 32 1/4 | 99 1/4 |
| 60 | 71 | 47 | 18.1 | 16 1/4 | 13 3/4 | 35 3/4 | 110 1/4 |
| 66 | 77 | 52 | 21.9 | 17 7/8 | 15 1/8 | 39 3/8 | 121 1/4 |
| 72 | 83 | 57 | 26.0 | 19 1/2 | 16 1/2 | 43 | 132 1/4 |

Note: Layout dimensions are typical manufactured dimensions. Specified dimensions are found in ASTM A760.

## Table 2.23

Sizes and layout details — CSP pipe arches
(3 x 1 or 5 x 1 in. corrugation)

| Equiv. Diameter | Nominal Size | Design | | Waterway Area | Layout Dimensions | | | |
|---|---|---|---|---|---|---|---|---|
| | | Span | Rise | | B | $R_c$ | $R_t$ | $R_b$ |
| (in.) | (in.) | (in.) | (in.) | ($ft^2$) | (in.) | (in.) | (in.) | (in.) |
| 48 | 53 x 41 | 53 | 41 | 11.7 | 15 1/4 | 10 3/16 | 28 1/16 | 73 7/16 |
| 54 | 60 x 46 | 58 1/2 | 48 1/2 | 15.6 | 20 1/2 | 18 3/4 | 29 3/8 | 51 1/8 |
| 60 | 66 x 51 | 65 | 54 | 19.3 | 22 3/4 | 20 3/4 | 32 5/8 | 56 1/4 |
| 66 | 73 x 55 | 72 1/2 | 58 1/4 | 23.2 | 25 1/8 | 22 7/8 | 36 3/4 | 63 3/4 |
| 72 | 81 x 59 | 79 | 62 1/2 | 27.4 | 23 3/4 | 20 7/8 | 39 1/2 | 82 5/8 |
| 78 | 87 x 63 | 86 1/2 | 67 1/4 | 32.1 | 25 3/4 | 22 5/8 | 43 3/8 | 92 1/4 |
| 84 | 95 x 67 | 93 1/2 | 71 3/4 | 37.0 | 27 3/4 | 24 3/8 | 47 | 100 1/4 |
| 90 | 103 x 71 | 101 1/2 | 76 | 42.4 | 29 3/4 | 26 1/8 | 51 1/4 | 111 5/8 |
| 96 | 112 x 75 | 108 1/2 | 80 1/2 | 48.0 | 31 5/8 | 27 3/4 | 54 7/8 | 120 1/4 |
| 102 | 117 x 79 | 116 1/2 | 84 3/4 | 54.2 | 33 5/8 | 29 1/2 | 59 3/8 | 131 3/4 |
| 108 | 128 x 83 | 123 1/2 | 89 1/4 | 60.5 | 35 5/8 | 31 1/4 | 63 1/4 | 139 3/4 |
| 114 | 137 x 87 | 131 | 93 3/4 | 67.4 | 37 5/8 | 33 | 67 3/8 | 149 1/2 |
| 120 | 142 x 91 | 138 1/2 | 98 | 74.5 | 39 1/2 | 34 3/4 | 71 5/8 | 162 3/8 |
| 126 | 150 x 96 | 146 | 102 | 81 | 41 | 36 | 76 | 172 |
| 132 | 157 x 101 | 153 | 107 | 89 | 43 | 38 | 80 | 180 |
| 138 | 164 x 105 | 159 | 113 | 98 | 45 | 40 | 82 | 184 |
| 144 | 171 x 110 | 165 | 118 1/2 | 107 | 47 | 41 | 85 | 190 |

Note: Layout dimensions are typical manufactured dimensions. Specified dimensions are found in ASTM A760.

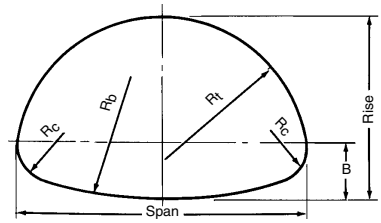



**Table 2.24**

Sizes and layout details, spiral rib pipe arch and composite ribbed steel pipe arch

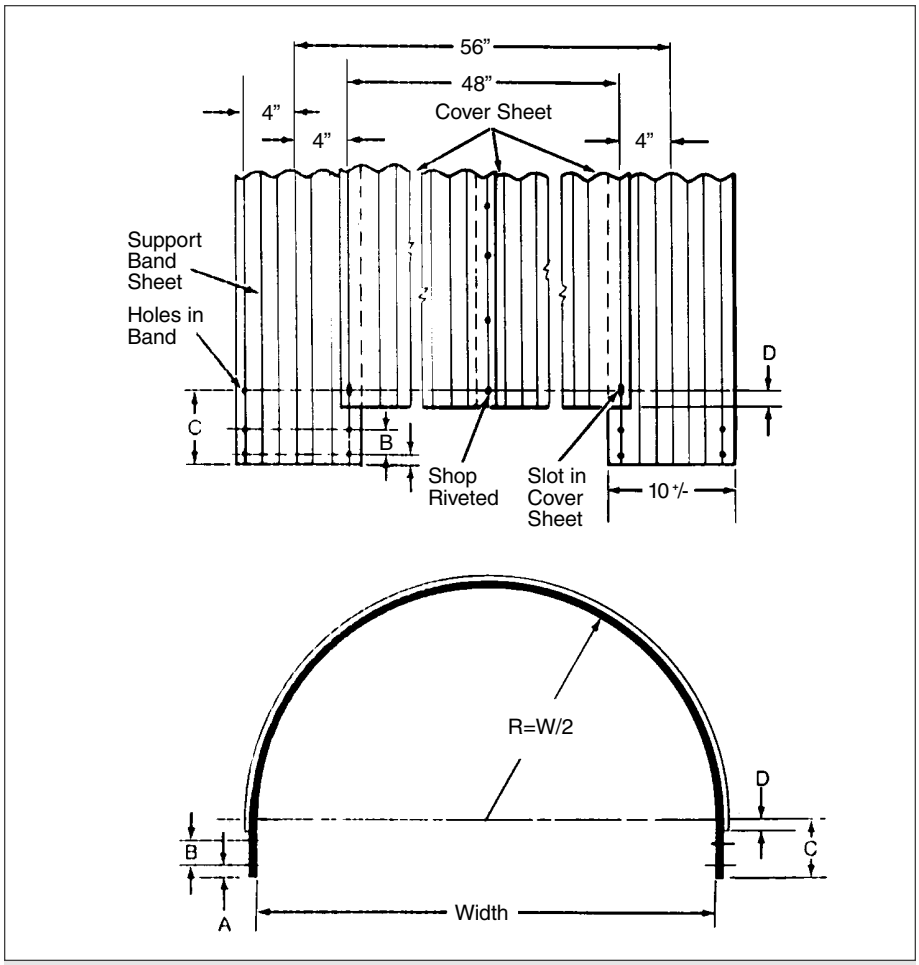
| Equiv. Diameter | Design | | Waterway Area | Layout Dimensions | | | |
|---|---|---|---|---|---|---|---|
| | Span | Rise | | B | $R_c$ | $R_t$ | $R_b$ |
| (in.) | (in.) | (in.) | ($ft^2$) | (in.) | (in.) | (in.) | (in.) |
| 18 | 20 | 16 | 1.7 | 5 1/8 | 5 | 10 1/4 | 27 1/2 |
| 21 | 23 | 19 | 2.3 | 5 7/8 | 5 3/8 | 11 5/8 | 34 1/4 |
| 24 | 27 | 21 | 3.0 | 6 3/4 | 5 3/4 | 13 1/2 | 40 7/8 |
| 30 | 33 | 26 | 4.7 | 8 3/4 | 7 1/8 | 16 5/8 | 51 3/8 |
| 36 | 40 | 31 | 6.7 | 10 3/8 | 8 3/8 | 20 1/4 | 62 1/2 |
| 42 | 46 | 36 | 9.2 | 12 3/8 | 9 3/4 | 23 1/4 | 73 |
| 48 | 53 | 41 | 12.1 | 14 | 11 1/8 | 26 5/8 | 83 1/2 |
| 54 | 60 | 46 | 15.6 | 20 1/2 | 18 3/4 | 29 3/8 | 51 1/8 |
| 60 | 66 | 51 | 19.3 | 22 3/4 | 20 3/4 | 32 5/8 | 56 1/4 |
| 66 | 73 | 55 | 23.2 | 25 1/8 | 22 7/8 | 36 3/4 | 63 3/4 |
| 72 | 81 | 59 | 27.4 | 23 3/4 | 20 7/8 | 39 1/2 | 82 5/8 |
| 78 | 87 | 63 | 32.1 | 25 3/4 | 22 5/8 | 43 3/8 | 92 1/4 |
| 84 | 95 | 67 | 37.0 | 27 3/4 | 24 3/8 | 47 | 100 1/4 |
| 90 | 103 | 71 | 42.4 | 29 3/4 | 26 1/8 | 51 1/4 | 111 5/8 |
| 96 | 112 | 75 | 48.0 | 31 5/8 | 27 3/4 | 54 7/8 | 120 1/4 |
| 102 | 117 | 79 | 54.2 | 33 5/8 | 29 1/2 | 59 3/8 | 131 3/4 |

Notes: Layout dimensions are typical manufactured dimensions. Specified dimensions are found in ASTM A760.

# CONVEYOR COVERS

**Arch Sections**. Perhaps the most commonly used cover is a half-circle steel arch section, 48 inches long, supported on band sheets 10 inches wide. See Figure 2.3. 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 36 to 72 inches, in suitable thicknesses of steel. Cover sheets are secured by one bolt at each corner and can be removed quickly when necessary. 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 (6 x 2 inches) can be provided.

**Horseshoe or Full Round**. The horseshoe shape finds use where weighing equipment or other facilities require a larger cover. A circular or elliptical shape can also serve as a beam to strengthen the span between bents.

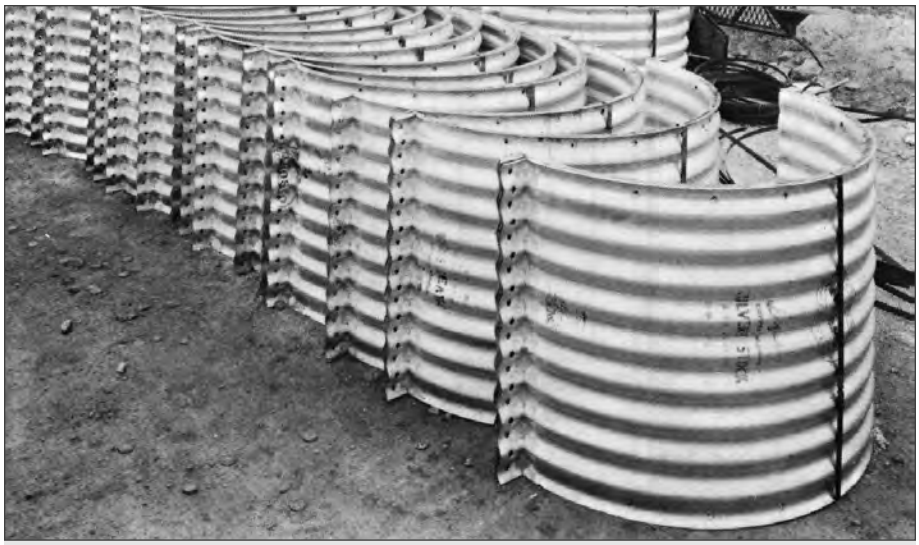



■ **Figure 2.3** Typical corrugated steel conveyor cover - with removable cover sheets supported by narrower band arches.

# NESTABLE CORRUGATED STEEL PIPE

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.

There are two standard methods used in attaching the half-round pipe segments together, interlocking notches and mating flanges. Nesting, a shipping technique developed in the 1930's, was devised to eliminate problems for overseas shipment. It provides an economical solution to conserve shipping space.



■ Nestable pipe segments to be assembled into corrugated steel pipe.

# STRUCTURAL PLATE PRODUCTS

## Product Description

Structural plate pipes are structures where corrugated steel sections are bolted together to form the required shape. The corrugated sections are commonly referred to as plates. The 6 x 2 inch corrugation shown in Figure 2.1 is the standard. Structural plate structures are specified where the pipe required exceeds the size that can be shipped to the job site, or where earth cover is so great that the wall thickness furnished by a shop-manufactured pipe will not meet design requirements.

The corrugations are formed at right angles to the length of the bridge or culvert. 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. See Figures 2.4 and 2.5.

Standard plates are fabricated in three lengths and several different widths. The plate width designation, N, is used to describe the various plate widths available. N is the spacing between two circumferential bolts, 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 and an 8N plate has a net width of 8 circumferential bolt hole spaces. The bolt hole space, N, is 9.6 inches (see Table 2.25). Note that not all widths are available in all lengths.

Plates are furnished curved to various radii and are clearly identified by the fabricator for field assembly. The fabricator provides assembly drawings to guide the installer. The plates are available in thicknesses from 0.111 inches to 0.380 inches See Table 2.13 for sectional properties. Weights of individual plate sections are shown in Table 2. 26. Approximate weights of structural plate structures are readily calculated using these values.

## Section Properties

Section properties, used for design, are provided in Table 2.13. 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 2.27 through 2.36. 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. The fabricator provides detailed assembly instructions with each structure.

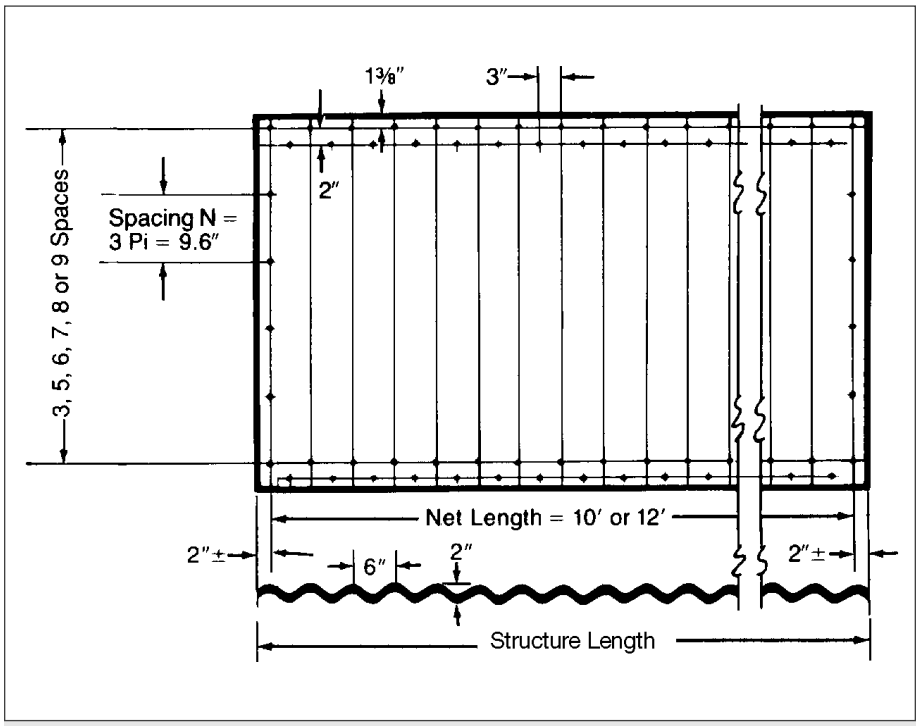



**Figure 2.4** Details of 6 x 2 in. uncurved structural plate.

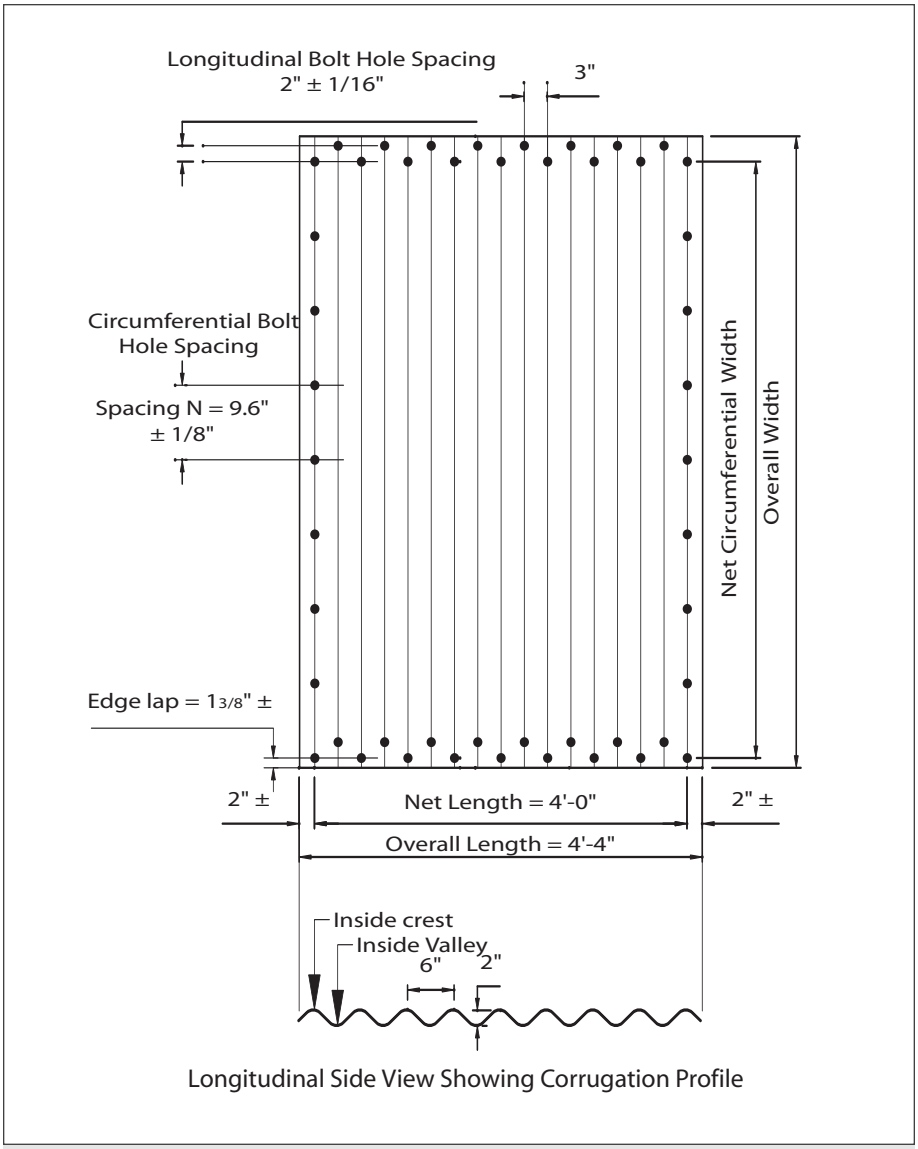



**Figure 2.5** 6 x 2 in. structural plate configuration.

## Table 2.25

6 x 2 in. corrugated structural plate sections — details of uncurved plates

| Nominal Plate Width, N* | Net Width | | Overall Width | | Number of Circumference Bolt Holes |
|---|---|---|---|---|---|
| | (in.) | | (in.) | | |
| 3N | 28.8 | 28 13/16 | 33 | 9/16 | 4 |
| 4N | 38.4 | 38 3/8 | 43 | 1/8 | 5 |
| 5N | 48.0 | 48 | 52 | 3/4 | 6 |
| 6N | 57.6 | 57 5/8 | 62 | 3/8 | 7 |
| 7N | 67.2 | 67 3/16 | 71 | 15/16 | 8 |
| 8N | 76.8 | 76 13/16 | 81 | 9/16 | 9 |
| 9N | 86.4 | 86 3/8 | 91 | 1/8 | 10 |
| 10N | 96.0 | 96 | 100 | 3/4 | 11 |
| 11N | 105.6 | 105 5/8 | 110 | 3/8 | 12 |
| 12N | 115.2 | 115 3/16 | 119 | 15/16 | 13 |
| 13N | 124.8 | 124 13/16 | 129 | 9/16 | 14 |
| 14N | 134.4 | 134 3/8 | 139 | 1/8 | 15 |
| 15N | 144.0 | 144 | 148 | 3/4 | 16 |
| 16N | 153.6 | 153 5/8 | 158 | 3/8 | 17 |

Note: *N = 3 Pi = 9.6 inches

Nested corrugated steel pipe.

## Table 2.26

Weight of 6 x 2 in. corrugated structural plate sections

| Nominal Plate Width, N* | Net Length ft | Approx. Wt. Of Individual Galvanized Plates Without Bolts, in Pounds Specified Thickness, in. | | | | | | | | | Number of Assembly Bolts/Plate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.111 | 0.140 | 0.170 | 0.188 | 0.218 | 0.249 | 0.280 | 0.318 | 0.380 | |
| 3N | 10 | 161 | 205 | 250 | 272 | 316 | 361 | 405 | 468 | 559 | 42 |
| 3N | 12 | 193 | 246 | 299 | 325 | 379 | 432 | 485 | 560 | 669 | 50 |
| 5N | 10 | 253 | 323 | 393 | 428 | 498 | 568 | 638 | 730 | 872 | 44 |
| 5N | 12 | 303 | 386 | 470 | 511 | 595 | 678 | 762 | 873 | 1043 | 52 |
| 6N | 10 | 299 | 382 | 465 | 506 | 589 | 671 | 754 | 859 | 1026 | 45 |
| 6N | 12 | 357 | 456 | 555 | 604 | 703 | 801 | 900 | 1027 | 1227 | 53 |
| 7N | 10 | 345 | 441 | 536 | 583 | 679 | 774 | 869 | 982 | 1185 | 46 |
| 7N | 12 | 412 | 526 | 640 | 697 | 810 | 924 | 1038 | 1186 | 1417 | 54 |
| 8N | 10 | 396 | 504 | 613 | 667 | 775 | 878 | 986 | | | 47 |
| 8N | 12 | 473 | 603 | 732 | 797 | 927 | 1050 | 1176 | | | 55 |
| 9N | 10 | 431 | 548 | 666 | 743 | 865 | 986 | 1108 | | | 48 |
| 9N | 12 | 517 | 657 | 799 | 892 | 1038 | 1183 | 1330 | | | 56 |
| 3N | 4 | 72 | 91 | 111 | 122 | 142 | 162 | 182 | | | 18 |
| 4N | 4 | 93 | 117 | 142 | 157 | 182 | 208 | 234 | | | 19 |
| 5N | 4 | 113 | 143 | 174 | 192 | 222 | 254 | 286 | | | 20 |
| 6N | 4 | 134 | 169 | 205 | 227 | 263 | 300 | 338 | | | 21 |
| 7N | 4 | 154 | 195 | 236 | 261 | 303 | 346 | 389 | | | 22 |
| 8N | 4 | 175 | 221 | 268 | 296 | 343 | 392 | 441 | | | 23 |
| 9N | 4 | 195 | 246 | 299 | 331 | 384 | 438 | 493 | | | 24 |
| 10N | 4 | 216 | 272 | 331 | 366 | 424 | 484 | 545 | | | 25 |
| 11N | 4 | 236 | 298 | 362 | 400 | 464 | 530 | 596 | | | 26 |
| 12N | 4 | 257 | 324 | 394 | 435 | 505 | 576 | 648 | | | 27 |
| 13N | 4 | 277 | 350 | 425 | 470 | 545 | 622 | 670 | | | 28 |
| 14N | 4 | 298 | 376 | 456 | 505 | 585 | 668 | 752 | | | 29 |
| 15N | 4 | 318 | 402 | 488 | 539 | 626 | 714 | 803 | | | 30 |
| 16N | 4 | 339 | 428 | 519 | 574 | 666 | 760 | 855 | | | 31 |

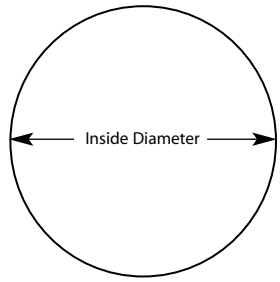
Notes: 1 Weights are approximate, based on standard 2 holes per corrugation in longitudinal seams. Plates are galvanized with an average coating mass of 3 oz/ft$^2$ (total both surfaces).

2 For galvanized plate thicknesses 0.111 to 0.188 in., bolt lengths are 1 1/4 and 1 1/2 in.; for thicknesses 0.218 and 0.249 in., bolt lengths are 1 1/2 and 1 3/4 in.; for thickness 0.280 in. bolt lengths are 1 1/2 and 2 in. Bolts are color coded for the different lengths.

3 Weight of bolts and nuts in lbs. per hundred:

1 1/4 in. = 52
1 1/2 in. = 55
1 3/4 in. = 57
2 in. = 59.5
3 in. = 72.5

4 To compute the approx. wt. of structures per foot of length: (1) multiply the number of plates in the periphery by the plate weights from the table; (2) add weight of the bolts; (3) divide by plate length.

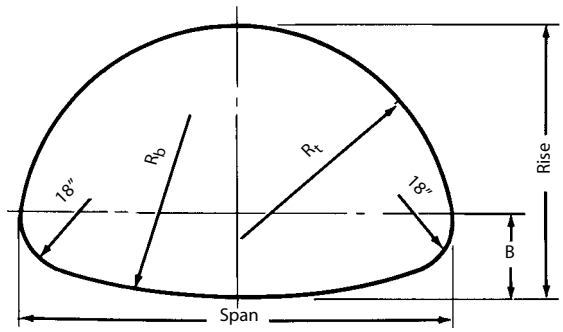



## Table 2.27

Structural plate pipe — sizes and end areas

| Pipe Diameter (ft) | End Area ($ft^2$) | Periphery No. of Plates | N | Pipe Diameter (ft) | End Area ($ft^2$) | Periphery No. of Plates | N |
|---|---|---|---|---|---|---|---|
| 5.0 | 20 | 4 | 20 | 16.0 | 201 | 10 | 64 |
| 5.5 | 24 | 4 | 22 | 16.5 | 214 | 10 | 66 |
| 6.0 | 28 | 4 | 24 | 17.0 | 227 | 10 | 68 |
| 6.5 | 33 | 4 | 26 | 17.5 | 241 | 10 | 70 |
| 7.0 | 38 | 4 | 28 | 18.0 | 254 | 12 | 72 |
| 7.5 | 44 | 6 | 30 | 18.5 | 269 | 12 | 74 |
| 8.0 | 50 | 6 | 32 | 19.0 | 284 | 12 | 76 |
| 8.5 | 57 | 6 | 34 | 19.5 | 299 | 12 | 78 |
| 9.0 | 64 | 6 | 36 | 20.0 | 314 | 12 | 80 |
| 9.5 | 71 | 6 | 38 | 20.5 | 330 | 12 | 82 |
| 10.0 | 79 | 6 | 40 | 21.0 | 346 | 12 | 84 |
| 10.5 | 87 | 6 | 42 | 21.5 | 363 | 14 | 86 |
| 11.0 | 95 | 8 | 44 | 22.0 | 380 | 14 | 88 |
| 11.5 | 104 | 8 | 46 | 22.5 | 398 | 14 | 90 |
| 12.0 | 113 | 8 | 48 | 23.0 | 415 | 14 | 92 |
| 12.5 | 123 | 8 | 50 | 23.5 | 434 | 14 | 94 |
| 13.0 | 133 | 8 | 52 | 24.0 | 452 | 14 | 96 |
| 13.5 | 143 | 8 | 54 | 24.5 | 470 | 14 | 98 |
| 14.0 | 154 | 8 | 56 | 25.0 | 491 | 16 | 100 |
| 14.5 | 165 | 10 | 58 | 25.5 | 510 | 16 | 102 |
| 15.0 | 177 | 10 | 60 | 26.0 | 530 | 16 | 104 |
| 15.5 | 189 | 10 | 62 | | | | |

■ Fish Passage Project on the Mc Cloud River under the Mc Cloud Rail Road in Northern California. 16 foot and 20 foot diameter structural plate pipes.



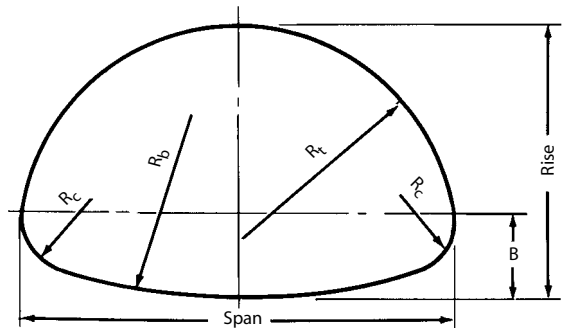

## Table 2.28

Structural plate pipe arch size and layout details
6 x 2 in. corrugation — bolted seams 18 in. corner radius, $R_C$

| Dimensions | | Waterway Area ($ft^2$) | Layout Dimensions | | | Periphery | |
|---|---|---|---|---|---|---|---|
| Span (ft-in.) | Rise (ft-in.) | | B (in.) | $R_t$ (ft) | $R_b$ (ft) | No. of Plates | Total N |
| 6-1 | 4-7 | 22 | 21.0 | 3.07 | 6.36 | 5 | 22 |
| 6-4 | 4-9 | 24 | 20.5 | 3.18 | 8.22 | 5 | 23 |
| 6-9 | 4-11 | 26 | 22.0 | 3.42 | 6.96 | 5 | 24 |
| 7-0 | 5-1 | 28 | 21.4 | 3.53 | 8.68 | 5 | 25 |
| 7-3 | 5-3 | 31 | 20.8 | 3.63 | 11.35 | 6 | 26 |
| 7-8 | 5-5 | 33 | 22.4 | 3.88 | 9.15 | 6 | 27 |
| 7-11 | 5-7 | 35 | 21.7 | 3.98 | 11.49 | 6 | 28 |
| 8-2 | 5-9 | 38 | 20.9 | 4.08 | 15.24 | 6 | 29 |
| 8-7 | 5-11 | 40 | 22.7 | 4.33 | 11.75 | 7 | 30 |
| 8-10 | 6-1 | 43 | 21.8 | 4.42 | 14.89 | 7 | 31 |
| 9-4 | 6-3 | 46 | 23.8 | 4.68 | 12.05 | 7 | 32 |
| 9-6 | 6-5 | 49 | 22.9 | 4.78 | 14.79 | 7 | 33 |
| 9-9 | 6-7 | 52 | 21.9 | 4.86 | 18.98 | 7 | 34 |
| 10-3 | 6-9 | 55 | 23.9 | 5.13 | 14.86 | 7 | 35 |
| 10-8 | 6-11 | 58 | 26.1 | 5.41 | 12.77 | 7 | 36 |
| 10-11 | 7-1 | 61 | 25.1 | 5.49 | 15.03 | 7 | 37 |
| 11-5 | 7-3 | 64 | 27.4 | 5.78 | 13.16 | 7 | 38 |
| 11-7 | 7-5 | 67 | 26.3 | 5.85 | 15.27 | 8 | 39 |
| 11-10 | 7-7 | 71 | 25.2 | 5.93 | 18.03 | 8 | 40 |
| 12-4 | 7-9 | 74 | 27.5 | 6.23 | 15.54 | 8 | 41 |
| 12-6 | 7-11 | 78 | 26.4 | 6.29 | 18.07 | 8 | 42 |
| 12-8 | 8-1 | 81 | 25.2 | 6.37 | 21.45 | 8 | 43 |
| 12-10 | 8-4 | 85 | 24.0 | 6.44 | 26.23 | 8 | 44 |
| For sizes below, consider using pipe arch with 31 in. corner radius if cover limits permit. (See Table 2.29) | | | | | | | |
| 13-5 | 8-5 | 89 | 26.3 | 6.73 | 21.23 | 9 | 45 |
| 13-11 | 8-7 | 93 | 28.9 | 7.03 | 18.39 | 9 | 46 |
| 14-1 | 8-9 | 97 | 27.6 | 7.09 | 21.18 | 9 | 47 |
| 14-3 | 8-11 | 101 | 26.3 | 7.16 | 24.80 | 9 | 48 |
| 14-10 | 9-1 | 105 | 28.9 | 7.47 | 21.19 | 9 | 49 |
| 15-4 | 9-3 | 109 | 31.6 | 7.78 | 18.90 | 9 | 50 |
| 15-6 | 9-5 | 113 | 30.2 | 7.83 | 21.31 | 10 | 51 |
| 15-8 | 9-7 | 118 | 28.8 | 7.89 | 24.29 | 10 | 52 |
| 15-10 | 9-10 | 122 | 27.4 | 7.96 | 28.18 | 10 | 53 |
| 16-5 | 9-11 | 126 | 30.1 | 8.27 | 24.24 | 10 | 54 |
| 16-7 | 10-1 | 131 | 28.7 | 8.33 | 27.73 | 10 | 55 |

Notes: Dimensions are to inside crests and are subject to manufacturing tolerances. N = 3 Pi = 9.6 in.

Pipe arches larger than 12′-10″ x 8′-4″ should be specified with a 31″ corner radius unless the application is an extension of an existing pipe arch with an 18″ corner radius or the relining of an existing culvert. For other applications involving larger size pipe arches with 18″ corner radii, consult with the structural plate manufacturer.

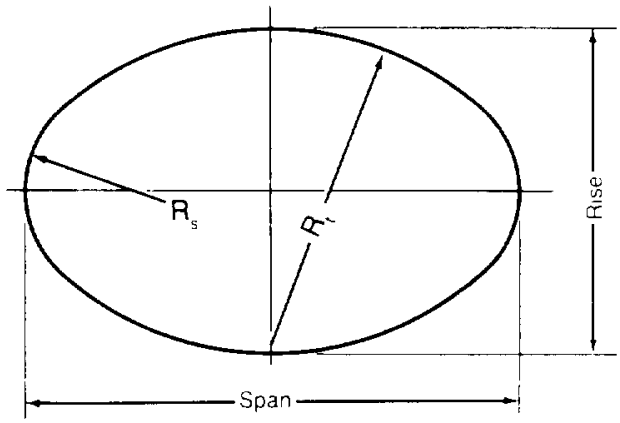



## Table 2.29

Structural plate pipe arch — size and layout details
6 x 2 in. corrugation — bolted seams – 31 in. corner radius, $R_C$

| Dimensions | | Waterway Area ($ft^2$) | Layout Dimensions | | | Periphery | |
|---|---|---|---|---|---|---|---|
| Span (ft-in.) | Rise (ft-in.) | | B (in.) | $R_t$ (ft) | $R_b$ (ft) | No. of Plates | Total N |
| 13-3 | 9-4 | 97 | 38.5 | 6.68 | 16.05 | 8 | 46 |
| 13-6 | 9-6 | 102 | 37.7 | 6.78 | 18.33 | 8 | 47 |
| 14-0 | 9-8 | 105 | 39.6 | 7.03 | 16.49 | 8 | 48 |
| 14-2 | 9-10 | 109 | 38.8 | 7.13 | 18.55 | 8 | 49 |
| 14-5 | 10-0 | 114 | 37.9 | 7.22 | 21.38 | 8 | 50 |
| 14-11 | 10-2 | 118 | 39.8 | 7.48 | 18.98 | 9 | 51 |
| 15-4 | 10-4 | 123 | 41.8 | 7.76 | 17.38 | 9 | 52 |
| 15-7 | 10-6 | 127 | 40.9 | 7.84 | 19.34 | 10 | 53 |
| 15-10 | 10-8 | 132 | 40.0 | 7.93 | 21.72 | 10 | 54 |
| 16-3 | 10-10 | 137 | 42.1 | 8.21 | 19.67 | 10 | 55 |
| 16-6 | 11-0 | 142 | 41.1 | 8.29 | 21.93 | 10 | 56 |
| 17-0 | 11-2 | 146 | 43.3 | 8.58 | 20.08 | 10 | 57 |
| 17-2 | 11-4 | 151 | 42.3 | 8.65 | 22.23 | 10 | 58 |
| 17-5 | 11-6 | 157 | 41.3 | 8.73 | 24.83 | 10 | 59 |
| 17-11 | 11-8 | 161 | 43.5 | 9.02 | 22.55 | 10 | 60 |
| 18-1 | 11-10 | 167 | 42.4 | 9.09 | 24.98 | 10 | 61 |
| 18-7 | 12-0 | 172 | 44.7 | 9.38 | 22.88 | 10 | 62 |
| 18-9 | 12-2 | 177 | 43.6 | 9.46 | 25.19 | 10 | 63 |
| 19-3 | 12-4 | 182 | 45.9 | 9.75 | 23.22 | 10 | 64 |
| 19-6 | 12-6 | 188 | 44.8 | 9.83 | 25.43 | 11 | 65 |
| 19-8 | 12-8 | 194 | 43.7 | 9.90 | 28.04 | 11 | 66 |
| 19-11 | 12-10 | 200 | 42.5 | 9.98 | 31.19 | 11 | 67 |
| 20-5 | 13-0 | 205 | 44.9 | 10.27 | 28.18 | 11 | 68 |
| 20-7 | 13-2 | 211 | 43.7 | 10.33 | 31.13 | 12 | 69 |

Note: Dimensions are to inside crests and are subject to manufacturing tolerances. N = 3 Pi = 9.6 in.

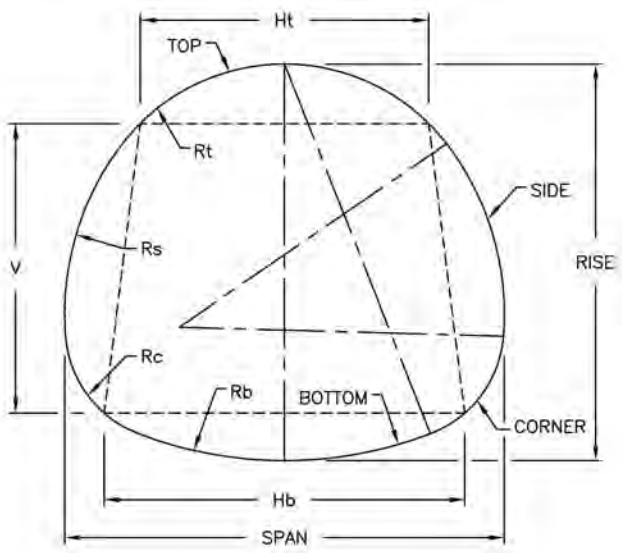



## Table 2.30

Structural plate horizontal ellipse — size and layout details
6 x 2 in. corrugation — bolted seams

| Span (ft-in.) | Rise (ft-in.) | Area ($ft^2$) | Periphery | | | Inside Radius | |
|---|---|---|---|---|---|---|---|
| | | | Top or Bottom | Side | Total | $R_t$ Top Radius (ft) | $R_s$ Side Radius (ft) |
| | | | N | N | N | | |
| 7-4 | 5-6 | 31.3 | 8 | 5 | 26 | 4-6 | 2-2 |
| 8-1 | 5-9 | 36.4 | 9 | 5 | 28 | 5-1 | 2-2 |
| 8-10 | 6-0 | 41.4 | 10 | 5 | 30 | 5-8 | 2-2 |
| 9-2 | 6-9 | 48.2 | 10 | 6 | 32 | 5-8 | 2-8 |
| 9-7 | 6-4 | 46.7 | 11 | 5 | 32 | 6-3 | 2-2 |
| 9-11 | 7-0 | 54.0 | 11 | 6 | 34 | 6-3 | 2-8 |
| 10-4 | 6-7 | 52.2 | 12 | 5 | 34 | 6-10 | 2-2 |
| 10-8 | 7-3 | 60.1 | 12 | 6 | 36 | 6-10 | 2-8 |
| 11-0 | 8-0 | 68.2 | 12 | 7 | 38 | 6-10 | 3-2 |
| 11-1 | 6-10 | 58.1 | 13 | 5 | 36 | 7-4 | 2-2 |
| 11-4 | 7-6 | 66.4 | 13 | 6 | 38 | 7-4 | 2-8 |
| 11-8 | 8-3 | 75.1 | 13 | 7 | 38 | 7-4 | 3-2 |
| 12-0 | 8-11 | 84.1 | 13 | 8 | 42 | 7-4 | 3-7 |
| 11-9 | 7-1 | 64.2 | 14 | 5 | 38 | 7-11 | 2-2 |
| 12-1 | 7-10 | 73.0 | 14 | 6 | 40 | 7-11 | 2-8 |
| 12-5 | 8-6 | 82.2 | 14 | 7 | 42 | 7-11 | 3-2 |
| 12-9 | 9-2 | 91.7 | 14 | 8 | 44 | 7-11 | 3-7 |
| 12-6 | 7-4 | 70.5 | 15 | 5 | 40 | 8-6 | 2-2 |
| 12-10 | 8-1 | 79.9 | 15 | 6 | 42 | 8-6 | 2-8 |
| 13-2 | 8-9 | 89.6 | 15 | 7 | 44 | 8-6 | 3-2 |
| 13-6 | 9-6 | 99.6 | 15 | 8 | 46 | 8-6 | 3-7 |
| 13-7 | 8-4 | 87.1 | 16 | 6 | 44 | 9-1 | 2-8 |
| 13-11 | 9-0 | 97.3 | 16 | 7 | 46 | 9-1 | 3-2 |
| 14-3 | 9-9 | 107.8 | 16 | 8 | 48 | 9-1 | 3-7 |
| 14-7 | 10-5 | 118.7 | 16 | 9 | 50 | 9-1 | 4-1 |
| 14-11 | 11-2 | 129.9 | 16 | 10 | 52 | 9-1 | 4-6 |

Note: Dimensions are to inside crest and are subject to manufacturing tolerances.
All dimensions, to the nearest whole number, are measured from inside crests.

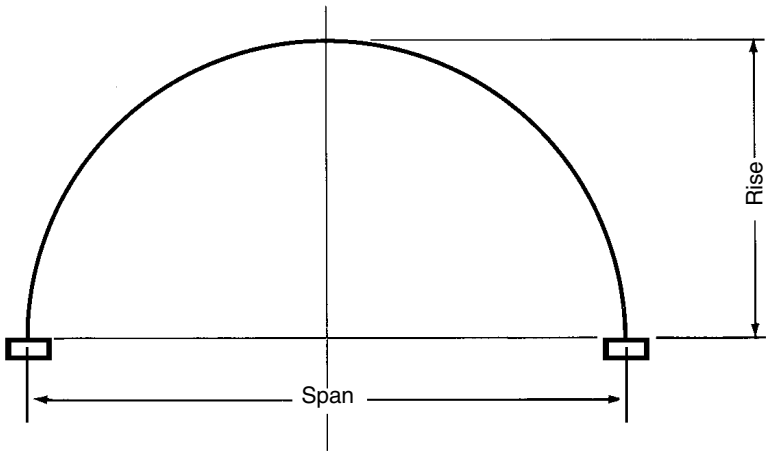



## Table 2.31

Structural plate underpass — size and layout details
6 x 2 in. corrugation — bolted seams

| Span x Rise (ft-in.) | | Periphery | | Clearance Box (ft- in.) | | | Layout Dimensions (in.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Waterway Area ($ft^2$) | N | HB | HT | V | No. of Plates per Ring | Top Radius $R_t$ | Side Radius $R_s$ | Corner Radius $R_c$ | Bottom Radius $R_b$ |
| 5-8 | 5-9 | 27 | 24 | | | | 6 | 27 | 53 | 18 | Flat |
| 5-8 | 6-6 | 32 | 26 | | | | 6 | 29 | 75 | 18 | Flat |
| 5-9 | 7-4 | 36 | 28 | | | | 6 | 28 | 95 | 18 | Flat |
| 5-10 | 7-8 | 38 | 29 | | | | 7 | 30 | 112 | 18 | Flat |
| 5-10 | 8-2 | 41 | 30 | | | | 6 | 28 | 116 | 18 | Flat |
| 8-6 | 8-6 | 58 | 35 | 4-6 | 4-6 | 7-6 | 7 | 44 | 96 | 31 | 144 |
| 8-8 | 8-8 | 62 | 36 | 5-0 | 5-0 | 7-6 | 7 | 47 | 96 | 31 | 191 |
| 8-11 | 8-11 | 65 | 37 | 6-0 | 6-0 | 7-2 | 7 | 49 | 100 | 31 | 243 |
| 9-8 | 9-4 | 73 | 39 | 6-0 | 6-0 | 7-9 | 7 | 53 | 84 | 38 | 191 |
| 10-10 | 9-6 | 81 | 41 | 7-0 | 7-0 | 7-5 | 7 | 59 | 96 | 38 | 123 |
| 11-5 | 10-3 | 93 | 44 | 8-0 | 8-0 | 7-6 | 7 | 66 | 100 | 38 | 174 |
| 12-2 | 11 -0 | 107 | 47 | 10-0 | 8-0 | 8-0 | 8 | 68 | 93 | 38 | 136 |
| 12-11 | 11 -2 | 116 | 49 | 10-0 | 8-0 | 8-6 | 9 | 74 | 92 | 38 | 148 |
| 13-2 | 11-10 | 126 | 51 | 10-0 | 8-0 | 9-6 | 11 | 73 | 102 | 38 | 161 |
| 13-10 | 12-2 | 136 | 53 | 10-0 | 8-0 | 10-0 | 11 | 77 | 106 | 38 | 168 |
| 14-1 | 12-10 | 147 | 55 | 12-0 | 10-0 | 9-0 | 11 | 77 | 115 | 38 | 183 |
| 14-6 | 13-5 | 158 | 57 | 12-0 | 10-0 | 9-6 | 11 | 78 | 131 | 38 | 174 |
| 14-10 | 14-0 | 169 | 59 | 12-0 | 10-0 | 10-6 | 11 | 79 | 136 | 38 | 193 |
| 15-6 | 14-4 | 180 | 61 | 12-0 | 10-0 | 11-0 | 12 | 83 | 139 | 38 | 201 |
| 15-9 | 15-1 | 192 | 63 | 12-0 | 10-0 | 12-0 | 12 | 82 | 151 | 38 | 212 |
| 16-4 | 15-5 | 204 | 65 | 12-0 | 10-0 | 12-6 | 12 | 86 | 156 | 38 | 217 |
| 16-5 | 16-0 | 217 | 67 | 12-0 | 10-0 | 13-0 | 12 | 88 | 159 | 38 | 271 |
| 16-9 | 16-3 | 224 | 68 | 12-0 | 10-0 | 13-6 | 12 | 89 | 168 | 38 | 246 |
| 17-3 | 17-0 | 239 | 70 | 12-0 | 10-0 | 14-0 | 12 | 90 | 174 | 47 | 214 |
| 18-4 | 16-11 | 252 | 72 | 16-0 | 12-0 | 12-0 | 12 | 99 | 157 | 47 | 248 |
| 19-1 | 17-2 | 266 | 74 | 16-0 | 12-0 | 13-0 | 13 | 105 | 156 | 47 | 262 |
| 19-6 | 17-7 | 280 | 76 | 16-0 | 12-0 | 13-6 | 13 | 107 | 158 | 47 | 295 |
| 20-4 | 17-9 | 295 | 78 | 16-0 | 12-0 | 14-0 | 13 | 114 | 155 | 47 | 316 |

Notes: Dimensions are to inside crests and are subject to manufacturing tolerances.
N = 3 Pi = 9.6 in.




## Table 2.32

Structural plate arch — representative sizes
6 x 2 in. corrugation — bolted seams

| Dimensions (1) | | | | | Nominal Arc Length |
|---|---|---|---|---|---|
| Span (ft) | Rise (ft-in.) | Waterway Area ($ft^2$) | Rise over Span | Radius (in.) | N (2) |
| 5.0 | 1-9 1/2 | 6.5 | 0.36 | | 8 |
| | 2-2 1/2 | 8.5 | 0.44 | | 9 |
| | 2-7 1/2 | 10.5 | 0.49 | | 10 |
| | 3-0 | 12.4 | 0.60 | 30 | 11 |
| 6.0 | 1-9 1/2 | 7.5 | 0.30 | 41 | 9 |
| | 2-3 1/2 | 10.0 | 0.38 | 37 1/2 | 10 |
| | 3-2 | 15.0 | 0.53 | 36 | 12 |
| | 3-6 | 17.4 | 0.59 | 36 | 13 |
| 7.0 | 2-4 | 12.0 | 0.34 | 45 | 11 |
| | 2-10 | 15.0 | 0.40 | 43 | 12 |
| | 3-8 | 20.0 | 0.52 | 42 | 14 |
| | 4-1 | 23.1 | 0.58 | 42 | 15 |
| | 4-5 | 25.7 | 0.63 | 42 | 16 |
| 8.0 | 2-11 | 17.0 | 0.37 | 51 | 13 |
| | 3-4 | 20.0 | 0.42 | 48 1/2 | 14 |
| | 4-2 | 26.0 | 0.52 | 48 | 16 |
| | 4-7 | 29.7 | 0.57 | 48 | 17 |
| | 4-11 | 32.7 | 0.62 | 48 | 18 |
| 9.0 | 2-11 | 18.5 | 0.32 | 59 | 14 |
| | 3-10 1/2 | 26.5 | 0.43 | 54 | 16 |
| | 4-8 1/2 | 33.0 | 0.52 | 54 | 18 |
| | 5-1 | 37.1 | 0.57 | 54 | 19 |
| | 5-6 | 40.5 | 0.61 | 54 | 20 |
| 10.0 | 3-5 1/2 | 25.0 | 0.35 | 64 | 16 |
| | 4-5 | 34.0 | 0.44 | 60 1/2 | 18 |
| | 5-3 | 41.0 | 0.52 | 60 | 20 |
| | 5-7 | 45.3 | 0.56 | 60 | 21 |
| | 6-0 | 49.1 | 0.60 | 60 | 22 |
| | 6-4 | 52.8 | 0.64 | 60 | 23 |

Notes: (1) Dimensions are to inside crests and are subject to manufacturing tolerances.
(2) N = 3 Pi = 9.6 in.
Manufacturers may offer additional sizes.

## Table 2.32 *continued*

Structural plate arch — representative sizes
6 x 2 in. corrugation — bolted seams

| Dimensions (1) | | | | | Nominal Arc Length |
|---|---|---|---|---|---|
| Span (ft) | Rise (ft-in.) | Waterway Area ($ft^2$) | Rise over Span | Radius (in.) | N (2) |
| 11.0 | 3-6 | 27.5 | 0.32 | 73 | 17 |
| | 4-5 1/2 | 37.0 | 0.41 | 67 1/2 | 19 |
| | 5-9 | 50.0 | 0.52 | 66 | 22 |
| | 6-1 | 54.3 | 0.56 | 66 | 23 |
| | 6-6 | 58.5 | 0.59 | 66 | 24 |
| | 6-11 | 62.7 | 0.63 | 66 | 25 |
| 12.0 | 4-0 1/2 | 35.0 | 0.34 | 77 1/2 | 19 |
| | 5-0 | 45.0 | 0.42 | 73 | 21 |
| | 6-3 | 59.0 | 0.52 | 72 | 24 |
| | 6-8 | 64.1 | 0.55 | 72 | 25 |
| | 7-0 | 68.8 | 0.59 | 72 | 26 |
| | 7-5 | 73.3 | 0.62 | 72 | 27 |
| 13.0 | 4-1 | 38.0 | 0.32 | 86 1/2 | 20 |
| | 5-1 | 49.0 | 0.39 | 80 1/2 | 22 |
| | 6-9 | 70.0 | 0.52 | 78 | 26 |
| | 7-2 | 74.8 | 0.55 | 78 | 27 |
| | 7-6 | 79.8 | 0.58 | 78 | 28 |
| | 7-11 | 84.8 | 0.61 | 78 | 29 |
| 14.0 | 4-7 1/2 | 47.0 | 0.33 | 91 | 22 |
| | 5-7 | 58.0 | 0.40 | 86 | 24 |
| | 7-3 | 80.0 | 0.52 | 84 | 28 |
| | 7-8 | 86.2 | 0.55 | 84 | 29 |
| | 8-1 | 91.7 | 0.58 | 84 | 30 |
| | 8-10 | 102.3 | 0.63 | 84 | 32 |
| 15.0 | 4-7 1/2 | 50.0 | 0.31 | 101 | 23 |
| | 5-8 | 62.0 | 0.38 | 93 | 25 |
| | 6-7 | 75.0 | 0.44 | 91 | 27 |
| | 7--9 | 92.0 | 0.52 | 90 | 30 |
| | 8-2 | 98.5 | 0.55 | 90 | 31 |
| | 8-7 | 104.4 | 0.57 | 90 | 32 |
| | 9-4 | 115.8 | 0.62 | 90 | 34 |
| 16.0 | 5-2 | 60.0 | 0.32 | 105 | 25 |
| | 7-1 | 86.0 | 0.45 | 97 | 29 |
| | 8-3 | 105.0 | 0.52 | 96 | 32 |
| | 8-8 | 111.6 | 0.54 | 96 | 33 |
| | 9-6 | 124.0 | 0.59 | 96 | 35 |
| | 9-10 | 130.1 | 0.62 | 96 | 36 |
| 17.0 | 5-2 1/2 | 63.0 | 0.31 | 115 | 26 |
| | 7-2 | 92.0 | 0.42 | 103 | 30 |
| | 8-10 | 119.0 | 0.52 | 102 | 34 |
| | 9-2 | 125.5 | 0.54 | 102 | 35 |
| | 10-0 | 138.7 | 0.59 | 102 | 37 |
| | 10-9 | 151.5 | 0.63 | 102 | 39 |
| 18.0 | 5-9 | 75.0 | 0.32 | 119 | 28 |
| | 7-8 | 104.0 | 0.43 | 109 | 32 |
| | 8-11 | 126.0 | 0.50 | 108 | 35 |
| | 9-9 | 140.2 | 0.54 | 108 | 37 |
| | 10-6 | 154.3 | 0.58 | 108 | 39 |
| | 11-3 | 167.9 | 0.63 | 108 | 41 |

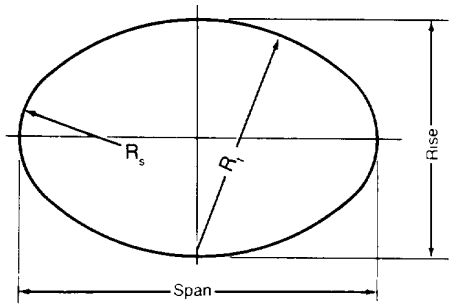
Notes: (1) Dimensions are to inside crests and are subject to manufacturing tolerances.
(2) N = 3 Pi = 9.6 in.
Manufacturers may offer additional sizes.

## Table 2.32 *continued*

Structural plate arch — representative sizes
6 x 2 in. corrugation — bolted seams

| Dimensions (1) | | | | | Nominal Arc Length |
|---|---|---|---|---|---|
| Span (ft) | Rise (ft-in.) | Waterway Area ($ft^2$) | Rise over Span | Radius (in.) | N (2) |
| 19.0 | 6-4 | 87.0 | 0.33 | 123 | 30 |
| | 8-2 | 118.0 | 0.43 | 115 | 34 |
| | 9-5 1/2 | 140.0 | 0.50 | 114 | 37 |
| | 10-3 | 155.8 | 0.54 | 114 | 39 |
| | 11-0 | 170.6 | 0.58 | 114 | 41 |
| | 11-10 | 185.1 | 0.62 | 114 | 43 |
| 20.0 | 6-4 | 91.0 | 0.32 | 133 | 31 |
| | 8-3 1/2 | 124.0 | 0.42 | 122 | 35 |
| | 10-0 | 157.0 | 0.50 | 120 | 39 |
| | 10-9 | 172.1 | 0.54 | 120 | 41 |
| | 11-6 | 187.8 | 0.58 | 120 | 43 |
| | 12-8 | 210.5 | 0.64 | 120 | 46 |
| 21.0 | 6-11 | 104.0 | 0.33 | 137 | 33 |
| | 8-10 | 140.0 | 0.42 | 128 | 37 |
| | 10-6 | 172.0 | 0.50 | 126 | 41 |
| | 11-3 | 189.3 | 0.54 | 126 | 43 |
| | 12-5 | 213.8 | 0.59 | 126 | 46 |
| | 13-3 | 229.7 | 0.63 | 126 | 48 |
| 22.0 | 6-11 | 109.0 | 0.31 | 146 | 34 |
| | 8-11 | 146.0 | 0.40 | 135 | 38 |
| | 11-0 | 190.0 | 0.50 | 132 | 43 |
| | 11-9 | 207.2 | 0.54 | 132 | 45 |
| | 13-0 | 233.0 | 0.59 | 132 | 48 |
| | 13-9 | 249.7 | 0.62 | 132 | 50 |
| 23.0 | 8-0 | 134.0 | 0.35 | 147 | 37 |
| | 9-10 | 171.0 | 0.43 | 140 | 41 |
| | 11-6 | 208.0 | 0.50 | 138 | 45 |
| | 12-8 | 235.1 | 0.55 | 138 | 48 |
| | 13-6 | 253.0 | 0.59 | 138 | 50 |
| | 14-8 | 279.0 | 0.64 | 138 | 53 |
| 24.0 | 8-6 | 150.0 | 0.35 | 152 | 39 |
| | 10-4 | 188.0 | 0.43 | 146 | 43 |
| | 12-0 | 226.0 | 0.50 | 144 | 47 |
| | 13-2 | 255.1 | 0.55 | 144 | 50 |
| | 14-0 | 273.8 | 0.58 | 144 | 52 |
| | 15-2 | 301.1 | 0.63 | 144 | 55 |
| 25.0 | 8-6 1/2 | 155.0 | 0.34 | 160 | 40 |
| | 10-10 1/2 | 207.0 | 0.43 | 152 | 45 |
| | 12-6 | 247.0 | 0.50 | 150 | 49 |
| | 13-9 | 275.9 | 0.55 | 150 | 52 |
| | 14-6 | 295.5 | 0.58 | 150 | 54 |
| | 15-8 | 324.0 | 0.63 | 150 | 57 |
| 26.0 | 8-0 1/2 | 149.0 | 0.31 | | 40 |
| | 9-7 | 183.0 | 0.37 | | 43 |
| | 10-11 | 214.0 | 0.42 | | 46 |
| | 13-0 | 266.0 | 0.50 | | 51 |
| | 14-3 | 297.6 | 0.55 | 156 | 54 |
| | 15-5 | 327.9 | 0.59 | 156 | 57 |
| | 16-7 | 357.3 | 0.64 | 156 | 60 |

Notes: (1) Dimensions are to inside crests and are subject to manufacturing tolerances.
(2) N = 3 Pi = 9.6 in.
Manufacturers may offer additional sizes.

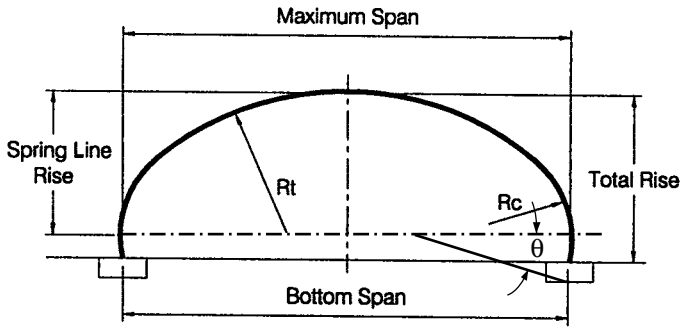



## Table 2.33

Structural plate long span horizontal ellipse — sizes and layout details [1]
6 x 2 in. corrugation — bolted seams

| Span (ft-in.) | Rise (ft-in.) | Area ($ft^2$) | Periphery [2] | | | Inside Radius | |
|---|---|---|---|---|---|---|---|
| | | | Top or Bottom | Side | Total | $R_t$ Top Radius (in.) | $R_s$ Side Radius (in.) |
| | | | N | N | N | | |
| 19-4 | 12-9 | 191 | 22 | 10 | 64 | 12-6 | 4-6 |
| 20-1 | 13-0 | 202 | 23 | 10 | 66 | 13-1 | 4-6 |
| 20-2 | 11-11 | 183 | 24 | 8 | 64 | 13-8 | 3-7 |
| 20-10 | 12-2 | 194 | 25 | 8 | 66 | 14-3 | 3-7 |
| 21- 0 | 15-2 | 248 | 23 | 13 | 72 | 13-1 | 5-11 |
| 21-11 | 13-1 | 221 | 26 | 9 | 70 | 14-10 | 4-1 |
| 22- 6 | 15-8 | 274 | 25 | 13 | 76 | 14-3 | 5-11 |
| 23- 0 | 14-1 | 249 | 27 | 10 | 74 | 15-5 | 4-6 |
| 23- 3 | 15-11 | 288 | 26 | 13 | 78 | 14-10 | 5-11 |
| 24- 4 | 16-11 | 320 | 27 | 14 | 82 | 15-5 | 6-4 |
| 24- 6 | 14-8 | 274 | 29 | 10 | 78 | 16-6 | 4-6 |
| 25- 2 | 14-11 | 287 | 30 | 10 | 80 | 17-1 | 4-6 |
| 25-5 | 16-9 | 330 | 29 | 13 | 84 | 16-6 | 5-11 |
| 26-1 | 18-2 | 369 | 29 | 15 | 88 | 16-6 | 6-10 |
| 26-3 | 15-10 | 320 | 31 | 11 | 84 | 17-8 | 4-11 |
| 27-0 | 16-2 | 334 | 32 | 11 | 86 | 18-3 | 4-11 |
| 27-2 | 19-1 | 405 | 30 | 16 | 92 | 17-1 | 7-3 |
| 27-11 | 19-5 | 421 | 31 | 16 | 94 | 17-8 | 7-3 |
| 28-1 | 17-1 | 369 | 33 | 12 | 90 | 18-10 | 5-5 |
| 28-10 | 17-5 | 384 | 34 | 12 | 92 | 19-5 | 5-5 |
| 29-5 | 19-11 | 455 | 33 | 16 | 98 | 18-10 | 7-3 |
| 30-1 | 20-2 | 472 | 34 | 16 | 100 | 19-5 | 7-3 |
| 30-3 | 17-11 | 415 | 36 | 12 | 96 | 20-7 | 5-5 |
| 31-2 | 21-2 | 512 | 35 | 17 | 104 | 20-0 | 7-9 |
| 31-4 | 18-11 | 454 | 37 | 13 | 100 | 21-1 | 5-11 |
| 32-1 | 19-2 | 471 | 38 | 13 | 102 | 21-8 | 5-11 |
| 32-3 | 22-2 | 555 | 36 | 18 | 108 | 20-7 | 8-2 |
| 33-0 | 22-5 | 574 | 37 | 18 | 110 | 21-1 | 8-2 |
| 33-2 | 20-1 | 512 | 39 | 14 | 106 | 22-3 | 6-4 |
| 34-1 | 23-4 | 619 | 38 | 19 | 114 | 21-8 | 8-8 |
| 34-7 | 20-8 | 548 | 41 | 14 | 110 | 23-5 | 6-4 |
| 34-11 | 21-4 | 574 | 41 | 1S | 112 | 23-5 | 6-10 |
| 35-1 | 24-4 | 665 | 39 | 20 | 118 | 22-3 | 9-1 |
| 35-9 | 25-9 | 718 | 39 | 22 | 122 | 22-3 | 10-0 |
| 36-0 | 22-4 | 619 | 42 | 16 | 116 | 24-0 | 7-3 |
| 36-11 | 25-7 | 735 | 41 | 21 | 124 | 23-5 | 9-7 |
| 37-2 | 22-2 | 631 | 44 | 15 | 118 | 25-2 | 6-10 |
| 38-0 | 26-7 | 785 | 44 | 22 | 128 | 24-0 | 10-0 |
| 38-8 | 27-11 | 843 | 42 | 24 | 132 | 24-0 | 10-11 |
| 40-0 | 29-7 | 927 | 43 | 26 | 138 | 27-11 | 11-10 |

Notes: (1) Dimensions are to inside crests and are subject to manufacturing tolerances.
(2) N = 3 Pi = 9.6 in.
Manufacturers may offer additional sizes.




## Table 2.34

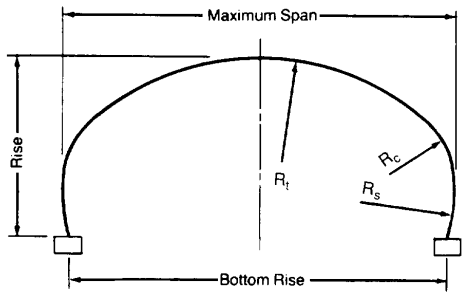
Structural plate long span low profile arch — sizes and layout details [1]
6 x 2 in. corrugation — bolted seams

| Max. Span (ft-in.) | Bottom Span (ft-in.) | Total Rise (ft-in.) | Area ($ft^2$) | Periphery [2] | | | Inside Radius | |
|---|---|---|---|---|---|---|---|---|
| | | | | Top | Side | Total | $R_t$ Top Radius (in.) | $R_s$ Side Radius (in.) |
| | | | | N | N | N | | |
| 20-1 | 19-10 | 7-6 | 121 | 23 | 6 | 35 | 13-1 | 4-6 |
| 19-5 | 19-1 | 6-10 | 105 | 23 | 5 | 33 | 13-1 | 3-7 |
| 21-6 | 21-4 | 7-9 | 134 | 25 | 6 | 37 | 14-3 | 4-6 |
| 22-3 | 22-1 | 7-11 | 140 | 26 | 6 | 38 | 14-0 | 4-6 |
| 23-0 | 22-9 | 8-0 | 147 | 27 | 6 | 39 | 15-5 | 4-6 |
| 23-9 | 23-6 | 8-2 | 154 | 28 | 6 | 40 | 16-0 | 4-6 |
| 24-6 | 24-3 | 8-4 | 161 | 29 | 6 | 41 | 16-6 | 4-6 |
| 25-2 | 25-0 | 8-5 | 169 | 30 | 6 | 42 | 17-1 | 4-6 |
| 25-11 | 25-9 | 8-7 | 176 | 31 | 6 | 43 | 17-8 | 4-6 |
| 27-3 | 27-1 | 10-0 | 217 | 31 | 8 | 47 | 17-8 | 6-4 |
| 28-1 | 27-11 | 9-7 | 212 | 33 | 7 | 47 | 18-10 | 5-5 |
| 28-9 | 28-7 | 10-3 | 234 | 33 | 8 | 49 | 18-10 | 6-4 |
| 28-10 | 28-8 | 9-8 | 221 | 34 | 7 | 48 | 19-5 | 5-5 |
| 30-3 | 30-1 | 9-11 | 238 | 36 | 7 | 50 | 20-7 | 5-5 |
| 30-11 | 30-9 | 10-8 | 261 | 36 | 8 | 52 | 20-7 | 6-4 |
| 31-7 | 31-2 | 12-1 | 309 | 36 | 10 | 56 | 20-7 | 7-3 |
| 31-0 | 30-10 | 10-1 | 246 | 37 | 7 | 51 | 21-1 | 5-5 |
| 32-4 | 31-11 | 12-3 | 320 | 37 | 10 | 57 | 21-1 | 7-3 |
| 31-9 | 31-7 | 10-3 | 255 | 38 | 7 | 52 | 21-8 | 5-5 |
| 33-1 | 32-7 | 12-5 | 330 | 38 | 10 | 58 | 21-8 | 7-3 |
| 33-2 | 33-0 | 11-1 | 289 | 39 | 8 | 55 | 22-3 | 6-4 |
| 34-5 | 34-1 | 13-3 | 377 | 39 | 11 | 61 | 22-3 | 8-2 |
| 34-7 | 34-6 | 11-4 | 308 | 41 | 8 | 57 | 23-5 | 6-4 |
| 37-1 | 37-7 | 15-8 | 477 | 41 | 14 | 69 | 23-5 | 10-11 |
| 35-4 | 35-2 | 11-5 | 318 | 42 | 8 | 58 | 24-0 | 6-4 |
| 38-8 | 38-4 | 15-9 | 490 | 42 | 14 | 70 | 24-0 | 10-11 |

Notes: (1) Dimensions are to inside crests and are subject to manufacturing tolerances.
(2) N = 3 Pi = 9.6 in.
Manufacturers may offer additional sizes.

■ 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.

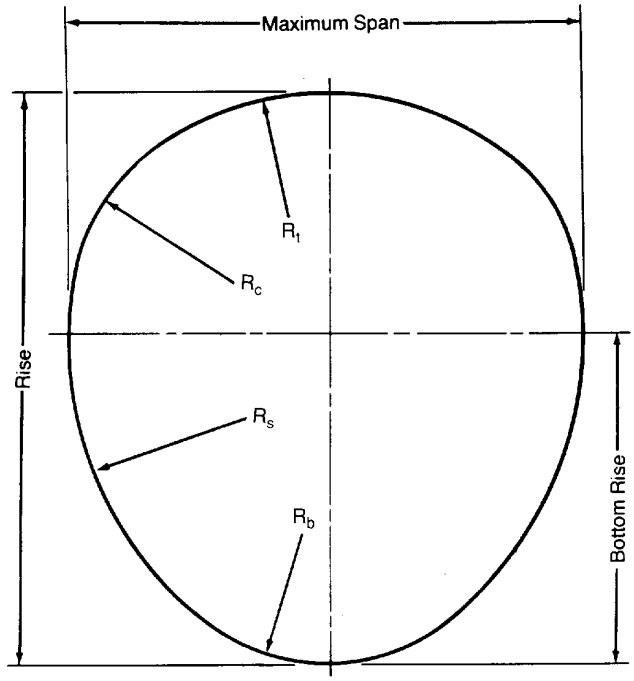



## Table 2.35

Structural plate long span high profile arch — sizes and layout details [1]
6 x 2 in. corrugation — bolted seams

| Max. Span (ft-in.) | Bottom Span (ft-in.) | Total Rise (ft-in.) | Area ($ft^2$) | Periphery [2] | | | | Inside Radius | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Top | Upper Side | Lower Side | Total | Top (ft-in.) | Upper Side (ft-in.) | Lower Side (ft-in.) |
| | | | | N | N | N | N | | | |
| 20-1 | 19- 6 | 9-1 | 152 | 23 | 5 | 3 | 39 | 13-1 | 4-6 | 13- 1 |
| 20-8 | 18-10 | 12-1 | 214 | 23 | 6 | 6 | 47 | 13- 1 | 5- 5 | 13- 1 |
| 21- 6 | 19-10 | 11-8 | 215 | 25 | 5 | 6 | 47 | 14- 3 | 4- 6 | 14- 3 |
| 22-10 | 19-10 | 14-7 | 285 | 25 | 7 | 8 | 55 | 14- 3 | 6- 4 | 14- 3 |
| 22- 3 | 20- 7 | 11-10 | 225 | 26 | 5 | 6 | 48 | 14-10 | 4- 6 | 14-10 |
| 22-11 | 20- 0 | 14-0 | 276 | 26 | 6 | 8 | 54 | 14-10 | 5- 5 | 14-10 |
| 23- 0 | 21- 5 | 12-0 | 235 | 27 | 5 | 6 | 49 | 15- 5 | 4- 6 | 15- 5 |
| 24- 4 | 21- 6 | 14-10 | 310 | 27 | 7 | 8 | 57 | 15- 5 | 6- 4 | 15- 5 |
| 23- 9 | 22- 2 | 12- 1 | 245 | 28 | 5 | 6 | 50 | 16- 0 | 4- 6 | 16- 0 |
| 24- 6 | 21-11 | 13- 9 | 289 | 29 | 5 | 8 | 55 | 16- 6 | 4- 6 | 16- 6 |
| 25- 9 | 23- 2 | 15- 2 | 335 | 29 | 7 | 8 | 59 | 16- 6 | 6- 4 | 16- 6 |
| 25- 2 | 23- 3 | 13- 2 | 283 | 30 | 5 | 7 | 54 | 17- 1 | 4- 6 | 17- 1 |
| 26- 6 | 24- 0 | 15- 3 | 348 | 30 | 7 | 8 | 60 | 17- 1 | 6- 4 | 17- 1 |
| 25-11 | 24- 1 | 13- 3 | 295 | 31 | 5 | 7 | 55 | 17- 8 | 4- 6 | 17- 8 |
| 27- 3 | 24-10 | 15- 5 | 360 | 31 | 7 | 8 | 61 | 17- 8 | 6- 4 | 17- 8 |
| 27- 5 | 25- 8 | 13- 7 | 317 | 33 | 5 | 7 | 57 | 18-10 | 4- 6 | 18-10 |
| 29- 5 | 27- 1 | 16- 5 | 412 | 33 | 8 | 8 | 65 | 18-10 | 7- 3 | 18-10 |
| 28- 2 | 25-11 | 14- 5 | 349 | 34 | 5 | 8 | 60 | 19- 5 | 4- 6 | 19- 5 |
| 30- 1 | 26- 9 | 18- 1 | 467 | 34 | 8 | 10 | 70 | 19- 5 | 7- 3 | 19- 5 |
| 30- 3 | 28- 2 | 15- 5 | 399 | 36 | 6 | 8 | 64 | 20- 7 | 5- 5 | 20- 7 |
| 31- 7 | 28- 4 | 18- 4 | 497 | 36 | 8 | 10 | 72 | 20- 7 | 7- 3 | 20- 7 |
| 31- 0 | 29- 0 | 15- 7 | 413 | 37 | 6 | 8 | 65 | 21- 1 | 5- 5 | 21- 1 |
| 31- 8 | 28- 6 | 17- 9 | 484 | 37 | 7 | 10 | 71 | 21- 1 | 6- 4 | 21- 1 |
| 32- 4 | 27-11 | 19-11 | 554 | 37 | 8 | 12 | 77 | 21- 1 | 7- 3 | 21- 1 |
| 31- 9 | 28- 8 | 17- 3 | 470 | 38 | 6 | 10 | 70 | 21- 8 | 5- 5 | 21- 8 |
| 33- 1 | 28- 9 | 20- 1 | 571 | 38 | 8 | 12 | 78 | 21- 8 | 7- 3 | 21- 8 |
| 32- 6 | 29- 6 | 17- 4 | 484 | 39 | 6 | 10 | 71 | 22- 3 | 5- 5 | 22- 3 |
| 33-10 | 29- 7 | 20- 3 | 588 | 39 | 8 | 12 | 79 | 22- 3 | 7- 3 | 22- 3 |
| 34- 0 | 31- 2 | 17- 8 | 514 | 41 | 6 | 10 | 73 | 23- 5 | 5- 5 | 23- 5 |
| 34- 7 | 30- 7 | 19-10 | 591 | 41 | 7 | 12 | 79 | 23- 5 | 6- 4 | 23- 5 |
| 35- 3 | 30- 7 | 21- 3 | 645 | 41 | 8 | 13 | 83 | 23- 5 | 7- 3 | 23- 5 |
| 37- 3 | 32- 6 | 23- 5 | 747 | 41 | 11 | 13 | 89 | 23- 5 | 10- 0 | 23- 5 |
| 34- 8 | 31-11 | 17-10 | 529 | 42 | 6 | 10 | 74 | 24- 0 | 5- 5 | 24- 0 |
| 35- 4 | 31- 5 | 20- 0 | 608 | 42 | 7 | 12 | 80 | 24- 0 | 6- 4 | 24- 0 |
| 36- 0 | 31- 5 | 21- 5 | 663 | 42 | 8 | 13 | 84 | 24-0 | 7- 3 | 24- 0 |
| 38- 0 | 33- 5 | 23- 6 | 767 | 42 | 11 | 13 | 90 | 24- 0 | 10- 0 | 24- 0 |

Notes: (1) Dimensions are to inside crests and are subject to manufacturing tolerances.
(2) N = 3 Pi = 9.6 in.
Manufacturers may offer additional sizes.




## Table 2.36

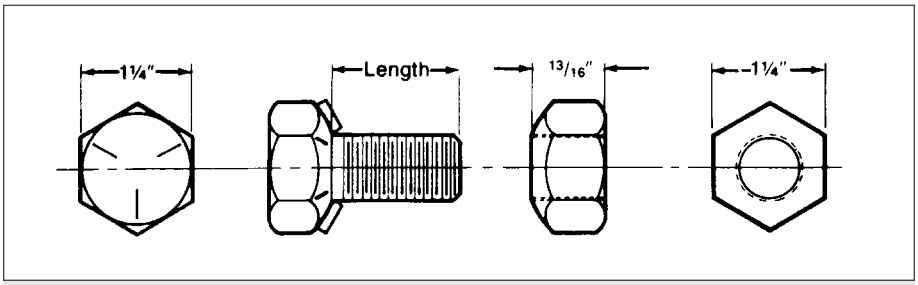
Structural plate long span pear shape — sizes and layout details[1]
6 x 2 in. corrugation — bolted seams

| Max. Span (ft-in.) | Rise (ft-in.) | Bottom Rise (ft-in.) | Area ($ft^2$) | Periphery [2] | | | | | Inside Radius | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Top | Corner | Side | Bottom | Total | Bottom | Side | Corner | Top |
| | | | | N | N | N | N | N | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) |
| 23-8 | 25-8 | 14-11 | 481 | 25 | 5 | 24 | 15 | 98 | 8-11 | 16-7 | 6-3 | 14-8 |
| 24-0 | 25-10 | 15-1 | 496 | 22 | 7 | 22 | 20 | 100 | 9-11 | 17-4 | 7-0 | 16-2 |
| 25-6 | 25-11 | 15-10 | 521 | 27 | 7 | 20 | 21 | 102 | 10-7 | 18-1 | 6-11 | 15-10 |
| 24-10 | 27-8 | 16-9 | 544 | 27 | 5 | 25 | 18 | 105 | 9-3 | 19-8 | 5-9 | 15-11 |
| 27-5 | 27-0 | 18-1 | 578 | 30 | 6 | 26 | 16 | 110 | 9-7 | 20-4 | 4-7 | 19-11 |
| 26-8 | 28-3 | 18-0 | 593 | 28 | 5 | 30 | 12 | 110 | 8-0 | 20-1 | 4-9 | 20-11 |
| 28-1 | 27-10 | 16-10 | 624 | 27 | 8 | 22 | 25 | 112 | 12-2 | 19-0 | 7-3 | 20-5 |
| 28-7 | 30-7 | 19-7 | 689 | 32 | 7 | 24 | 24 | 118 | 11-2 | 24-0 | 7-0 | 18-2 |
| 30-0 | 29-8 | 20-0 | 699 | 32 | 8 | 23 | 25 | 119 | 11-11 | 24-0 | 6-7 | 21-10 |
| 30-0 | 31-2 | 19-11 | 736 | 34 | 7 | 24 | 26 | 122 | 12-1 | 24-0 | 7-0 | 19-3 |

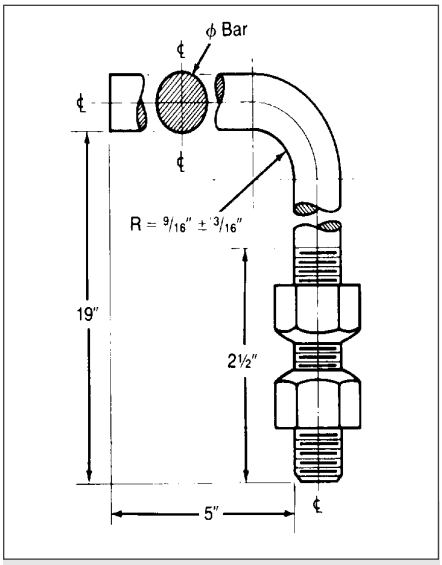
Notes: (1) Dimensions are to inside crests and are subject to manufacturing tolerances.
(2) N = 3 Pi = 9.6 in.
Manufacturers may offer additional sizes.

## Bolts and Nuts

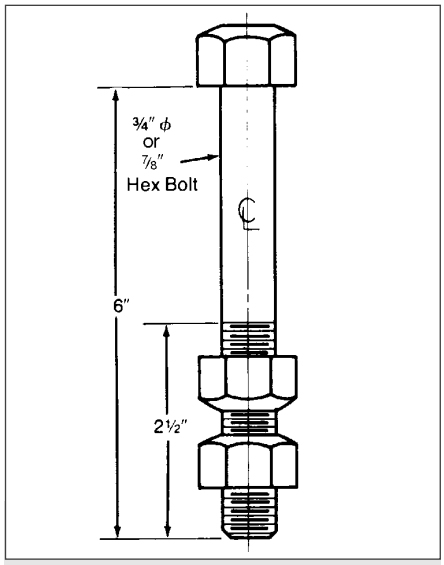
Galvanized 3/4 inch or 7/8 inch diameter bolts of special heat-treated steel meeting ASTM Specification A 449 or ASTM Specification F568 Class 8.8, are used to assemble structural plate sections. Galvanized nuts meet the requirements of ASTM A 563 Class C. The galvanizing on bolts and nuts must meet ASTM Specification A 153, Class C or ASTM B 695 Class 55 Type II. See Figure 2.6 for dimensions of bolts and nuts. Lengths include: 1 1/4, 1 1/2, 1 3/4, 2, 3 and 4 inches. The containers and bolts may be color coded for ease in identification. 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.




■ **Figure 2.6** Dimensions of bolts and nuts for structural plate. Lengths include: 1 1/4 in., 1 1/2 in., 1 3/4 in., 2 in., 3 in. and 4 in.




■ **Figure 2.7** Hook bolts and nuts for embedment in headwalls.




■ **Figure 2.8** Straight anchor bolt.

Anchor bolts are available for anchoring the sides of structural plate arches into footings, and the ends of structural plate pipe into concrete end treatments  Material for these special 3/4 inch or 7/8 inch 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 2.9** High-strength steel bolts are used for the circumferential and longitudinal seams of structural plate pipe. Four, six, or eight bolts per foot of longitudinal seam provide the strength required for the loading conditions.

## 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 2.10.

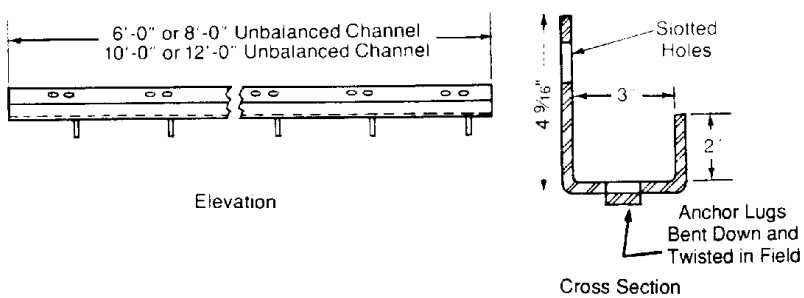



**Figure 2.10** General dimensions of unbalanced channels for 6 x 2 in. structural plate arches.

# DEEP CORRUGATED STRUCTURAL PLATE

Deep corrugated structural plate pipe is also a bolted structure. It has either a 15 x 5 1/2 inch corrugation (DCSP Type I) or a 16 x 6 inch corrugation (DCSP Type II). As with standard (6 x 2 inches) structural plate, the corrugations are at right angles to the length of the structure. 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 or circumference of the structure.

# DEEP CORRUGATED STRUCTURAL PLATE TYPE I

## Product Description

Deep corrugated structural plate pipe Type I has a 15 x 5 1/2 in. corrugation, which is shown in Figure 2.1. Standard plates are fabricated in one length and 12 different widths, as shown in Table 2.37 and Figure 2.11. The coverage length (excluding the side laps) is 30 inches 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. The bolt hole space, S, is 16 inches.

Plates are furnished curved to various radii and are clearly identified and located on the assembly drawings provided by the fabricator for field erection. The plates are available in 0.140 to 0.315 inch thicknesses. Weights of individual plate sections are shown in Table 2.38.

## Section Properties

Section properties, used for design, are provided in Table 2.14. 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 2.39 through 2.41. 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. See Figures 2.12 - 2.14 for additional details. Detailed assembly instructions accompany each structure.

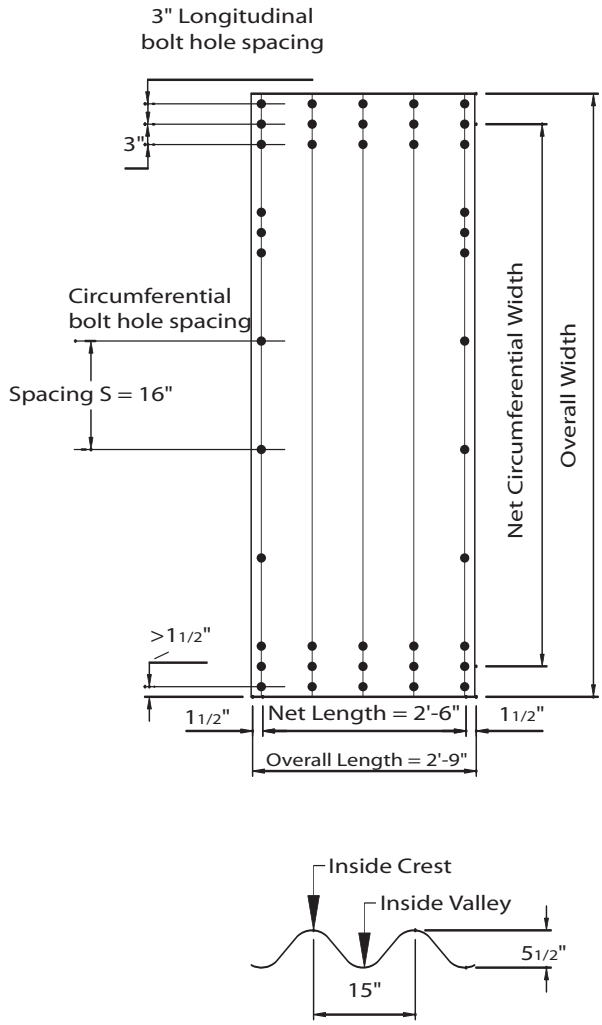



**Figure 2.11** Deep corrugated structural plate configuration.

## Table 2.37

15 x 5 1/2 in. deep corrugated structural plate sections
Details of uncurved plates

| Nominal Plate Width Designation, *S | Net Width, in. | Overall Width, in. | No. of Circumferential Bolt Holes |
|---|---|---|---|
| 1S | 16 | 25 | 2 |
| 2S | 32 | 41 | 3 |
| 3S | 48 | 57 | 4 |
| 4S | 64 | 73 | 5 |
| 5S | 80 | 89 | 6 |
| 6S | 96 | 105 | 7 |
| 7S | 112 | 121 | 8 |
| 8S | 128 | 137 | 9 |
| 9S | 144 | 153 | 10 |
| 10S | 160 | 169 | 11 |
| 11S | 176 | 185 | 12 |
| 12S | 192 | 201 | 13 |

*S = 16 inches

## Table 2.38

Weight of 15 x 5 1/2 in. deep corrugated structural plate sections

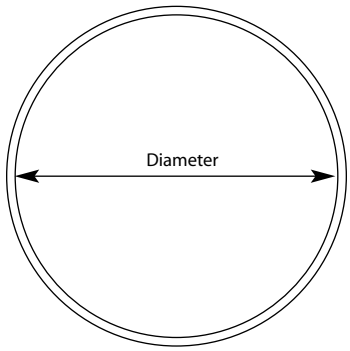
| Plate Width Designation, *S | Net Length, ft | Approx. Wt. Of Individual Galvanized Plates Without Bolts, in Pounds Specified Thickness, in. | | | | | | Number of Assembly Bolts/Plate |
|---|---|---|---|---|---|---|---|---|
| | | 0.140 | 0.170 | 0.188 | 0.218 | 0.249 | 0.280 | |
| 1S | 2.5 | 45 | 54 | 60 | 71 | 81 | 91 | 14 |
| 2S | 2.5 | 73 | 88 | 98 | 116 | 132 | 149 | 15 |
| 3S | 2.5 | 102 | 122 | 136 | 161 | 184 | 207 | 16 |
| 4S | 2.5 | 130 | 156 | 174 | 206 | 235 | 265 | 17 |
| 5S | 2.5 | 159 | 190 | 212 | 251 | 286 | 323 | 18 |
| 6S | 2.5 | 187 | 224 | 250 | 296 | 338 | 381 | 19 |
| 7S | 2.5 | 216 | 258 | 287 | 341 | 389 | 439 | 20 |
| 8S | 2.5 | 244 | 292 | 325 | 385 | 440 | 497 | 21 |
| 9S | 2.5 | 272 | 326 | 363 | 430 | 492 | 555 | 22 |
| 10S | 2.5 | 301 | 360 | 401 | 475 | 543 | 613 | 23 |
| 11S | 2.5 | 329 | 394 | 439 | 520 | 594 | 671 | 24 |
| 12S | 2.5 | 358 | 428 | 477 | 565 | 646 | 729 | 25 |

Notes: 1 Bolts are color coded for the different lengths.

2 Weight of bolts in pounds per hundred pieces:
2 in. = 59.5
3 in. = 72.5
4 in. = 85.5

3 To compute the approximate weight of structures per foot of length: (1) multiply the number of plates in the periphery by the plate weights from the table; (2) add weight of the bolts; (3) Divide by plate length.

*S = 16 in.



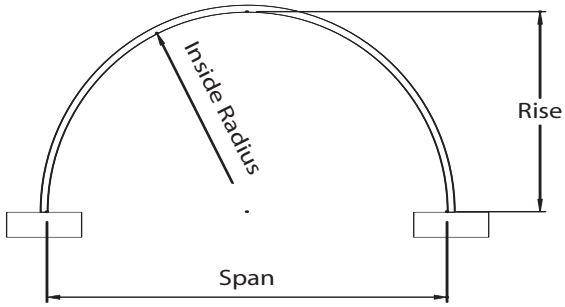

## Table 2.39

Structural plate long span round [1]
15 x 5 1/2 in. corrugation — bolted seams

| Inside Diameter ft - in. | Periphery S* | End Area $ft^2$ |
|---|---|---|
| 27 - 6 | 66 | 596 |
| 28 - 4 | 68 | 634 |
| 29 - 3 | 70 | 672 |
| 30 - 1 | 72 | 712 |
| 30 - 11 | 74 | 752 |
| 31 - 9 | 76 | 794 |
| 32 - 7 | 78 | 837 |
| 33 - 5 | 80 | 881 |
| 34 - 4 | 82 | 926 |
| 35 - 2 | 84 | 973 |
| 36 - 0 | 86 | 1020 |
| 36 - 10 | 88 | 1069 |
| 37 - 8 | 90 | 1119 |
| 39 - 5 | 94 | 1221 |
| 41 - 1 | 98 | 1329 |
| 42 - 10 | 102 | 1441 |
| 44 - 6 | 106 | 1557 |
| 46 - 2 | 110 | 1678 |
| 47 - 11 | 114 | 1804 |
| 49 - 7 | 118 | 1934 |
| 51 - 3 | 122 | 2069 |

Note: 1. All dimensions are to the inside crest and subject to manufacturing tolerances.
2. Other sizes are available.
3. All structures should be reviewed based on live load and geotechnical conditions

*S = 16 in.



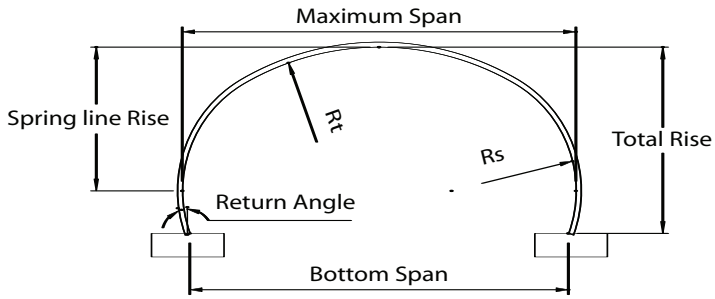

## Table 2.40

Deep Corrugated Arches — Sizes and layout details [1]
15 x 5-1/2 in corrugation profile — bolted seams

| Span (ft-in.) | Total Rise (ft-in.) | End Area ($ft^2$) | Inside Radius (ft-in.) | Total S* |
|---|---|---|---|---|
| 22' 11" | 11' 5" | 207 | 11' 5" | 27 |
| 23' 9" | 11' 11" | 222 | 11' 11" | 28 |
| 24' 8" | 12' 4" | 238 | 12' 4" | 29 |
| 25' 1" | 12' 6" | 255 | 12' 9" | 30 |
| 26' 4" | 13' 2" | 272 | 13' 2" | 31 |
| 27' 2" | 13' 7" | 291 | 13' 7" | 32 |
| 28' 1" | 14' 0" | 309 | 14' 0" | 33 |
| 28' 10" | 14' 5" | 327 | 14' 5" | 34 |
| 29' 9" | 14' 10" | 347 | 14' 10" | 35 |
| 30' 7" | 15' 3" | 367 | 15' 3" | 36 |
| 31' 5" | 15' 9" | 387 | 15' 9" | 37 |
| 32' 3" | 16' 2" | 409 | 16' 2" | 38 |
| 33' 2" | 16' 6" | 431 | 16" 7" | 39 |
| 34' 0" | 17' 0" | 453 | 17' 0" | 40 |
| 35' 8" | 17' 10" | 499 | 17' 10" | 42 |
| 37' 4" | 18' 8" | 548 | 18' 6" | 44 |
| 39' 1" | 19' 6" | 600 | 19' 6" | 46 |
| 40' 9" | 20' 4" | 652 | 20' 4" | 48 |
| 42' 6" | 21' 3" | 708 | 21' 3" | 50 |
| 44' 2" | 22' 1" | 765 | 22' 1" | 52 |
| 45' 10" | 22' 11" | 826 | 22' 11" | 54 |
| 49' 3" | 24' 11" | 953 | 24' 7" | 58 |
| 50' 11" | 25' 6" | 1019 | 25' 6" | 60 |
| 52' 8" | 26' 4" | 1088 | 26' 4" | 62 |
| 54' 8" | 27' 2" | 1159 | 27' 2" | 64 |
| 56' 6" | 28' 4" | 1234 | 28' 3" | 66 |
| 57' 8" | 28' 10" | 1309 | 28' 10" | 68 |
| 59' 5" | 29' 9" | 1387 | 29' 9" | 70 |
| 62' 10" | 31' 5" | 1677 | 31' 5" | 74 |
| 66' 3" | 33' 1" | 1722 | 33' 2" | 78 |
| 67' 11" | 34' 0" | 1812 | 34' 0" | 80 |
| 69' 7" | 34' 10" | 1903 | 34' 9" | 82 |
| 73' 0" | 36' 6" | 2094 | 36' 6" | 86 |
| 74' 8" | 37' 4" | 2191 | 37' 4" | 88 |
| 78' 9" | 39' 6" | 2448 | 39' 4" | 93 |
| 82' 0" | 41' 0" | 2641 | 41' 0" | 96 |

Note: 1. All dimensions are to the inside crest and subject to manufacturing tolerances.
2. Other sizes are available.
3. All structures should be reviewed based on live load and geotechnical conditions.

*S = 16 in.




## Table 2.41

Structural plate multi-radius arches — size and layout details
15 x 5-1/2 in. corrugations — bolted seams

| Max Span (ft-in.) | Bottom Span (ft-in.) | Total Rise (ft-in.) | End Area ($ft^2$) | Inside Radius Side (in.) | Inside Radius Crown (in.) | Return Angle degrees | Total S* |
|---|---|---|---|---|---|---|---|
| 26' 3" | 26' 3" | 11' 9" | 253.3 | 135 | 391 | 2.3 | 30 |
| 29' 6" | 29' 6" | 12' 4" | 303.0 | 135 | 391 | 0 | 33 |
| 29' 3" | 28' 7" | 16' 11" | 437.8 | 135 | 391 | 9.6 | 40 |
| 31' 2" | 31' 0" | 13' 0" | 339.5 | 135 | 391 | 6.5 | 35 |
| 32' 10" | 32' 8" | 13' 0" | 356.7 | 135 | 391 | 5.7 | 36 |
| 32' 10" | 31' 11" | 14' 11" | 419.0 | 135 | 391 | 15.6 | 39 |
| 32' 10" | 31' 9" | 17' 7" | 506.5 | 135 | 391 | 10.1 | 43 |
| 34' 5" | 34' 4" | 13' 9" | 374.0 | 135 | 391 | 4.8 | 37 |
| 36' 1" | 35' 11" | 13' 9" | 414.7 | 135 | 391 | 10.1 | 39 |
| 36' 1" | 35' 1" | 15' 8" | 482.9 | 135 | 391 | 0 | 42 |
| 36' 1" | 35' 3" | 19' 3" | 605.7 | 147 | 391 | 10.1 | 47 |
| 37' 9" | 37' 7" | 13' 10" | 433.3 | 135 | 391 | 6.1 | 40 |
| 39' 4" | 39' 3" | 14' 0" | 452.3 | 135 | 391 | 5 | 41 |
| 39' 4" | 38' 8" | 18' 6" | 614.6 | 174 | 391 | 12.8 | 47 |
| 39' 4" | 38' 0" | 20' 0" | 685.4 | 147 | 391 | 11.3 | 50 |
| 41' 0" | 40' 10" | 14' 9" | 497.9 | 135 | 391 | 7.2 | 43 |
| 42' 8" | 42' 6" | 14' 11" | 518.6 | 135 | 391 | 5.9 | 44 |
| 42' 8" | 41' 10" | 19' 4" | 693.1 | 174 | 391 | 13.8 | 50 |
| 42' 8" | 41' 6" | 21' 2" | 775.7 | 163 | 391 | 10.6 | 53 |
| 44' 3" | 44' 2" | 15' 2" | 539.5 | 135 | 391 | 4.5 | 45 |
| 45' 11" | 45' 10" | 16' 0" | 590.7 | 135 | 391 | 0 | 47 |
| 45' 11" | 45' 6" | 21' 6" | 817.1 | 214 | 391 | 0 | 54 |
| 45' 11" | 44' 9" | 23' 0" | 899.5 | 178 | 391 | 10.9 | 57 |
| 47' 7" | 47' 4" | 16' 11" | 644.4 | 135 | 391 | 8 | 49 |
| 49' 3" | 49' 1" | 17' 2" | 669.0 | 135 | 391 | 6.2 | 50 |
| 49' 3" | 48' 6" | 23' 0" | 939.9 | 214 | 391 | 11.6 | 58 |
| 49' 3" | 48' 1" | 24' 1" | 999.9 | 186 | 391 | 10.6 | 60 |
| 50' 10" | 50' 8" | 18' 1" | 727.1 | 135 | 391 | 7.5 | 52 |
| 52' 6" | 52' 4" | 16' 2" | 693.9 | 135 | 548 | 7.5 | 52 |
| 52' 6" | 52' 1" | 21' 10" | 962.4 | 214 | 548 | 8.9 | 59 |
| 52' 6" | 51' 0" | 26' 2" | 1195.9 | 194 | 548 | 10.4 | 66 |
| 54' 2" | 53' 10" | 16' 11" | 751.1 | 135 | 548 | 9.5 | 54 |
| 55' 9" | 55' 7" | 17' 2" | 775.2 | 135 | 548 | 8.2 | 55 |
| 55' 9" | 55' 6" | 22' 1" | 1022.1 | 214 | 548 | 7.6 | 61 |
| 55' 9" | 54' 0" | 27' 10" | 1345.2 | 202 | 548 | 11.1 | 70 |

Note: 1. All dimensions are to the inside crest and subject to manufacturing tolerances.
2. Other sizes are available.
3. All structures should be reviewed based on live load and geotechnical conditions.

*S = 16 in.

**Table 2.41** *continued*

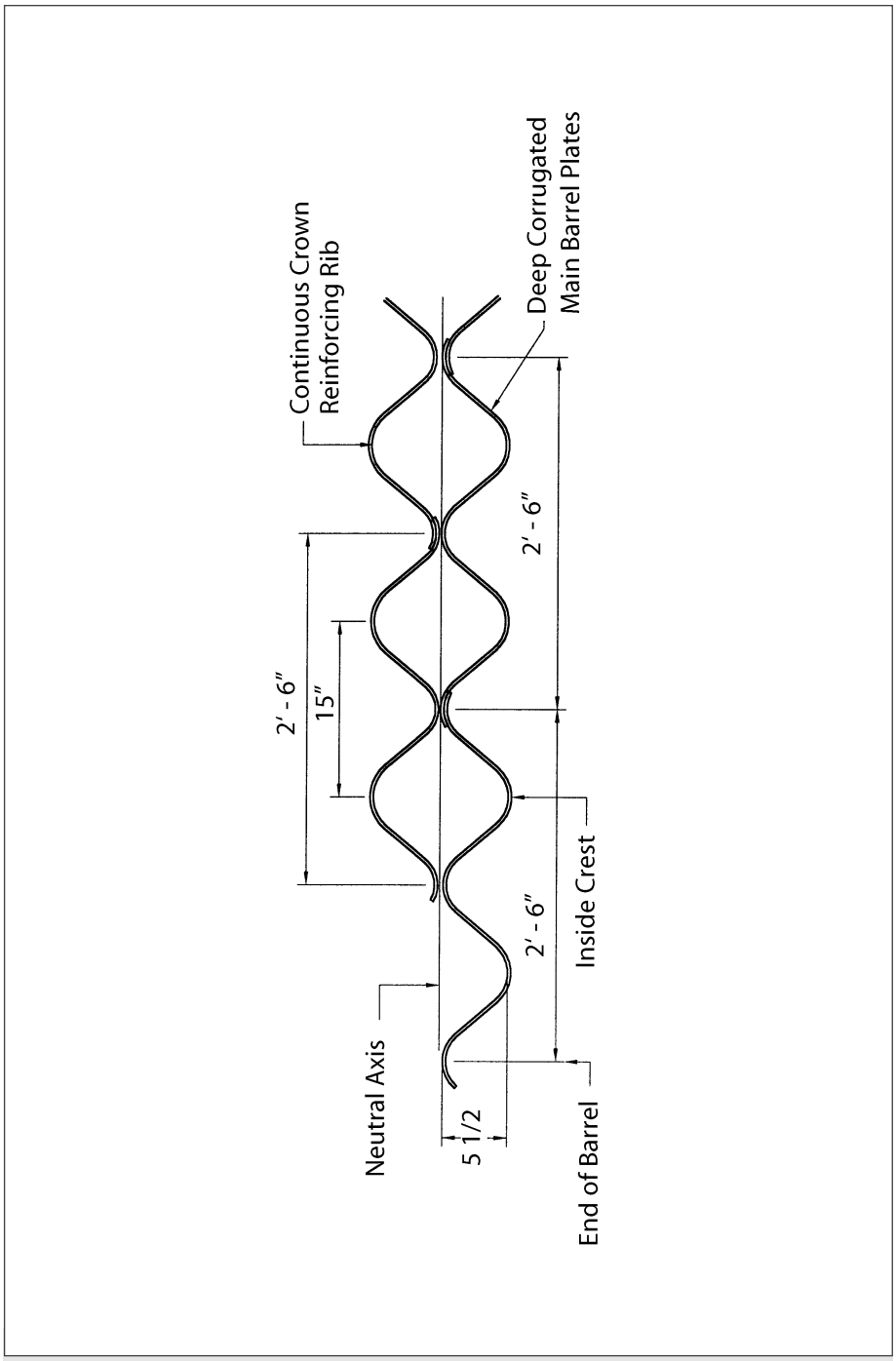
Structural plate multi-radius arches — size and layout details
15 x 5-1/2 in. corrugations — bolted seams

| Max Span (ft-in.) | Bottom Span (ft-in.) | Total Rise (ft-in.) | End Area ($ft^2$) | Inside Radius Side (in.) | Inside Radius Crown (in.) | Return Angle degrees | Total S* |
|---|---|---|---|---|---|---|---|
| 57' 5" | 57' 3" | 17' 4" | 799.6 | 135 | 548 | 6.8 | 56 |
| 59' 1" | 58' 10" | 18' 2" | 862.6 | 135 | 548 | 8.7 | 58 |
| 59' 1" | 58' 8" | 23' 0" | 1121.2 | 214 | 548 | 8.3 | 64 |
| 60' 8" | 60' 6" | 18' 5" | 889.0 | 135 | 548 | 7.1 | 59 |
| 62' 4" | 62' 1" | 19' 4" | 956.0 | 135 | 548 | 8.8 | 61 |
| 62' 4" | 62' 1" | 23' 3" | 1185.1 | 214 | 548 | 6.7 | 66 |
| 64' 0" | 63' 10" | 19' 7" | 984.4 | 135 | 548 | 7.1 | 62 |
| 65' 7" | 65' 4" | 20' 6" | 1055.9 | 135 | 548 | 8.6 | 64 |
| 65' 7" | 65' 4" | 24' 4" | 1293.5 | 214 | 548 | 7 | 69 |
| 67' 3" | 67' 1" | 20' 10" | 1086.5 | 135 | 548 | 6.6 | 65 |
| 68' 11" | 68' 6" | 27' 9" | 1553.5 | 253 | 548 | 7.4 | 75 |
| 70' 6" | 70' 4" | 22' 9" | 1240.4 | 135 | 548 | 8.8 | 69 |
| 72' 2" | 71' 11" | 19' 5" | 1121.5 | 135 | 745 | 8.6 | 68 |
| 72' 2" | 71' 10" | 26' 9" | 1607.2 | 253 | 745 | 7.7 | 77 |
| 73' 10" | 73' 5" | 20' 3" | 1202.0 | 135 | 745 | 10.5 | 70 |
| 75' 5" | 75' 1" | 22' 10" | 1394.2 | 174 | 745 | 8.9 | 74 |
| 75' 5" | 74' 11" | 29' 3" | 1837.1 | 273 | 745 | 8.9 | 82 |
| 77' 0" | 76' 10" | 23' 0" | 1426.6 | 174 | 745 | 7.8 | 75 |
| 78' 9" | 78' 4" | 23' 10" | 1510.6 | 174 | 745 | 9.3 | 77 |
| 78' 9" | 78' 4" | 29' 6" | 1918.0 | 273 | 745 | 7.8 | 84 |
| 80' 5" | 80' 0" | 24' 0" | 1545.0 | 174 | 745 | 8.1 | 78 |
| 82' 0" | 81' 10" | 24' 4" | 1580.0 | 174 | 745 | 6.9 | 79 |
| 82' 0" | 81' 6" | 30' 6" | 2053.2 | 273 | 745 | 8.2 | 87 |
| 83' 8" | 83' 4" | 25' 2" | 1669.4 | 174 | 745 | 8.2 | 81 |

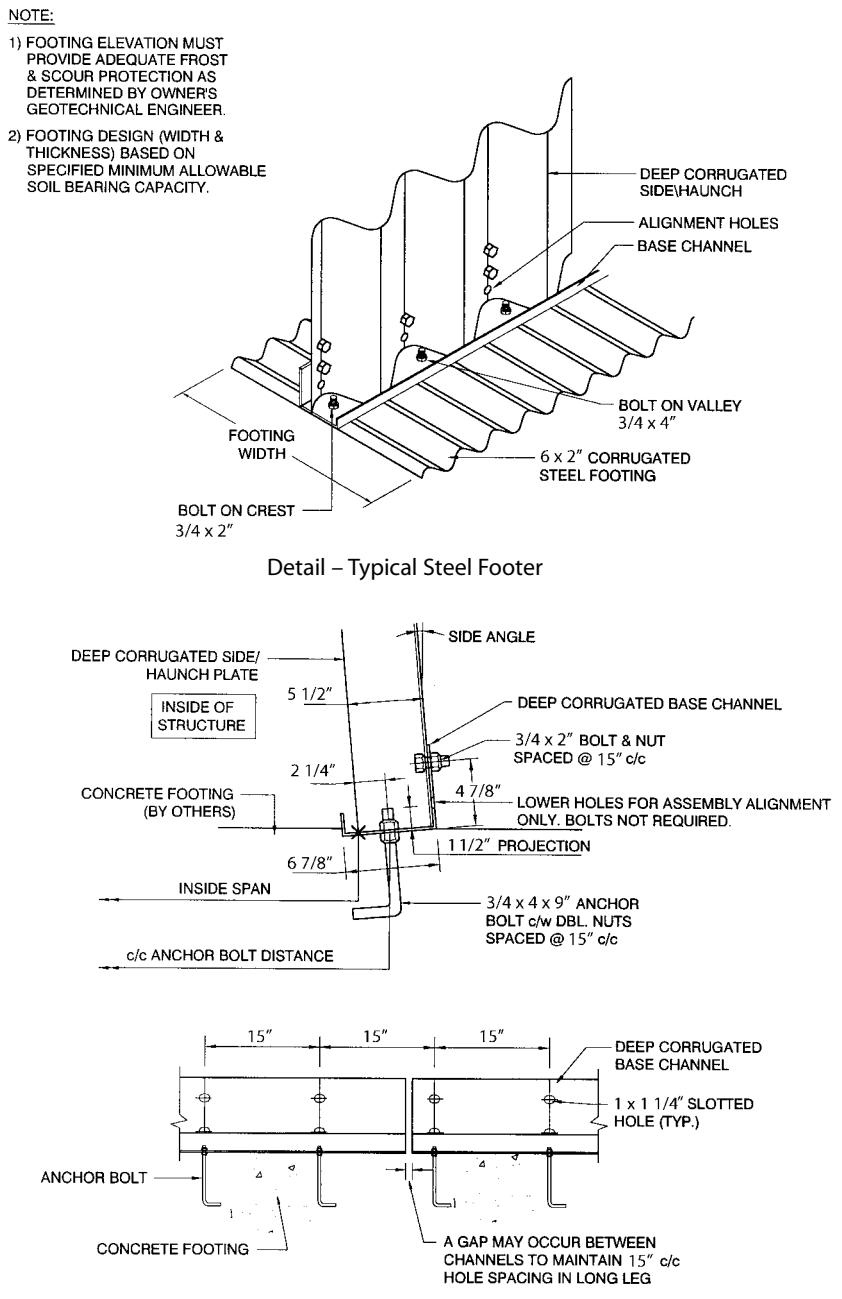
Note: 1. All dimensions are to the inside crest and subject to manufacturing tolerances.
2. Other sizes are available.
3. All structures should be reviewed based on live load and geotechnical conditions.

*S = 16 in.

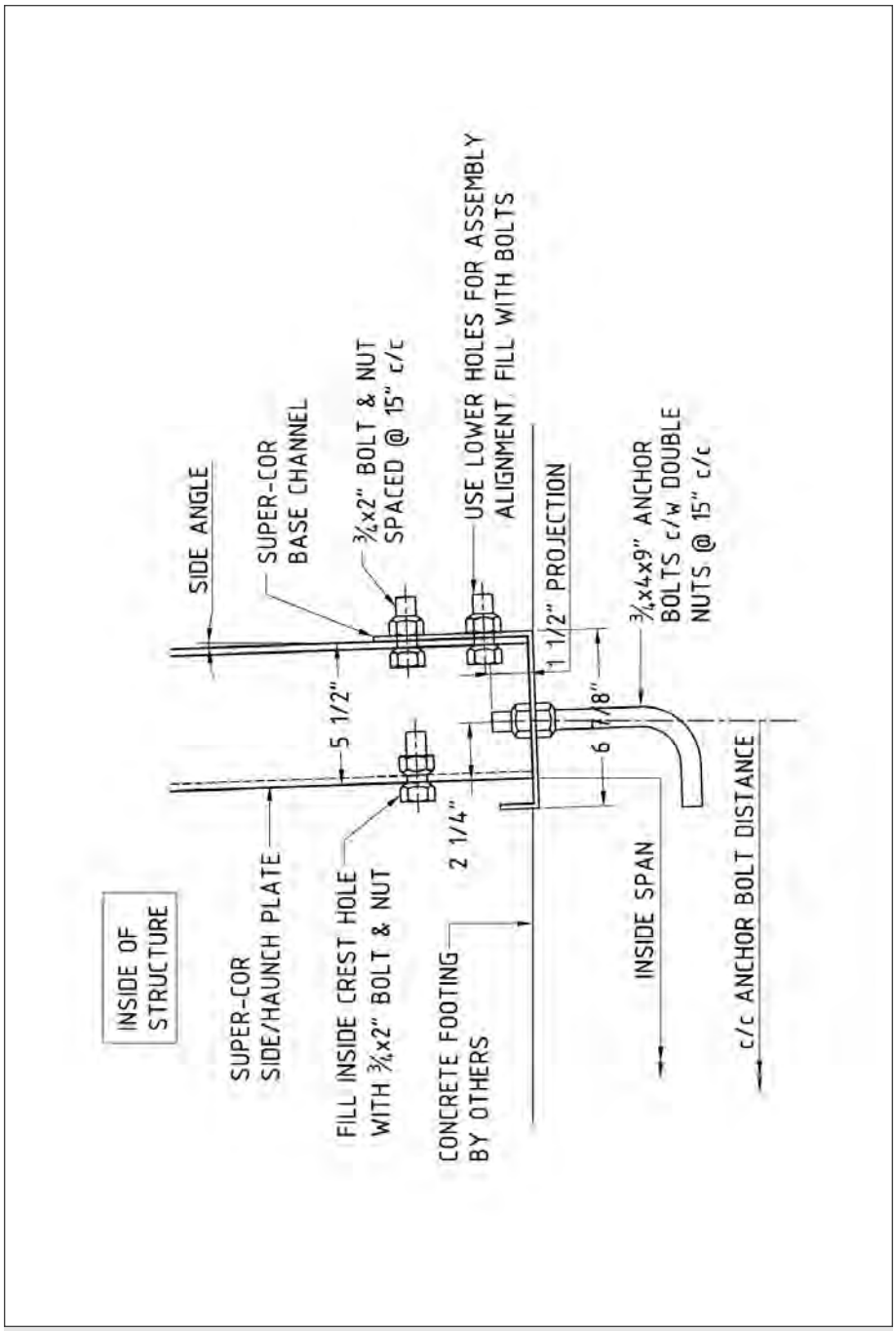
■ 35 foot span by 15 foot rise deep corrugated structural plate arch with beveled ends for a Fish Passage Project in the Willamette National Forest in Oregon.




■ **Figure 2.12** Reinforcing rib for deep corrugated structural plate 15 x 5 1/2 in. corrugation profile.




■ **Figure 2.13** Additional details for deep corrugated structural plate.




■ **Figure 2.14** General dimensions of unbalanced channel for 15 x 5 1/2 in. structural plate arches.

# DEEP CORRUGATED STRUCTURAL PLATE TYPE II

## Product Description

Deep corrugated structural plate Type II has a 16 x 6 inch corrugation, which is shown in Figure 2.1.

Standard plates are fabricated in one length and several widths, as shown in Table 2.42 and Figure 2.15. The coverage length (excluding the side laps) is 47 1/4 inches 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 16 3/4 inches.

Plates are furnished curved to various radii and are identified with a permanent mark. This marking is provided to simplify field erection and to make identification of the structure details, in the future, as easy as possible. The fabricator provides field assembly drawings to guide the installer. The plates are available in thickness ranging from 0.169 to 0.315 inches Weights of individual plate sections are shown in Table 2.42.

**Table 2.42**

Weight of 16 x 6 in. deep corrugated structural plate sections

| Plate Width Designation, 'H' ('H'=16.75") | Net Length ft | Approx. Wt. Of Individual Galvanized Plates Without Bolts, in Pounds | | | | | Number of Assembly Bolts/Plate |
|---|---|---|---|---|---|---|---|
| | | Specified Thickness, in. | | | | | |
| | | 0.169 | 0.197 | 0.236 | 0.276 | 0.315 | |
| 4 | 3.94 | 239 | 282 | 341 | 398 | 451 | 23 |
| 5 | 3.94 | 291 | 342 | 415 | 484 | 548 | 24 |
| 6 | 3.94 | 342 | 402 | 488 | 569 | 645 | 25 |
| 7 | 3.94 | 394 | 463 | 561 | 655 | 742 | 26 |
| 8 | 3.94 | 445 | 523 | 634 | 740 | 839 | 27 |
| 9 | 3.94 | 496 | 584 | 708 | 825 | 936 | 28 |
| 10 | 3.94 | 548 | 644 | 781 | 911 | 1033 | 29 |

Notes:
1. Bolt lengths used for all structures = 2"
2. Weight of bolts and nuts in pounds per hundred = 59.5 lbs.
3. To compute the approximate weight of structure per foot of length: (1) Multiply the number of plates in the periphery by the plate weights in the table; (2) add weight of bolts; (3) divide by the net plate length.

**Table 2.43**

16 x 6 in. deep corrugated structural plate sections
Details of uncurved plates

| Nominal Plate Width Designation, 'H'* | Net Width, in. | Overall Width, in. | No. of Circumferential Bolt Holes |
|---|---|---|---|
| 3H | 50.2 | 61.22 | 4 |
| 4H | 66.93 | 77.95 | 5 |
| 5H | 83.67 | 94.69 | 6 |
| 6H | 100.40 | 111.42 | 7 |
| 7H | 117.13 | 128.15 | 8 |
| 8H | 133.86 | 144.88 | 9 |
| 9H | 150.59 | 161.61 | 10 |
| 10H | 167.32 | 178.35 | 11 |

Note: DCSP Type ll is a metric profile. Values shown are hard converted on the basis 1.0 in. = 25.4 mm
*'H' = 16.75 in.

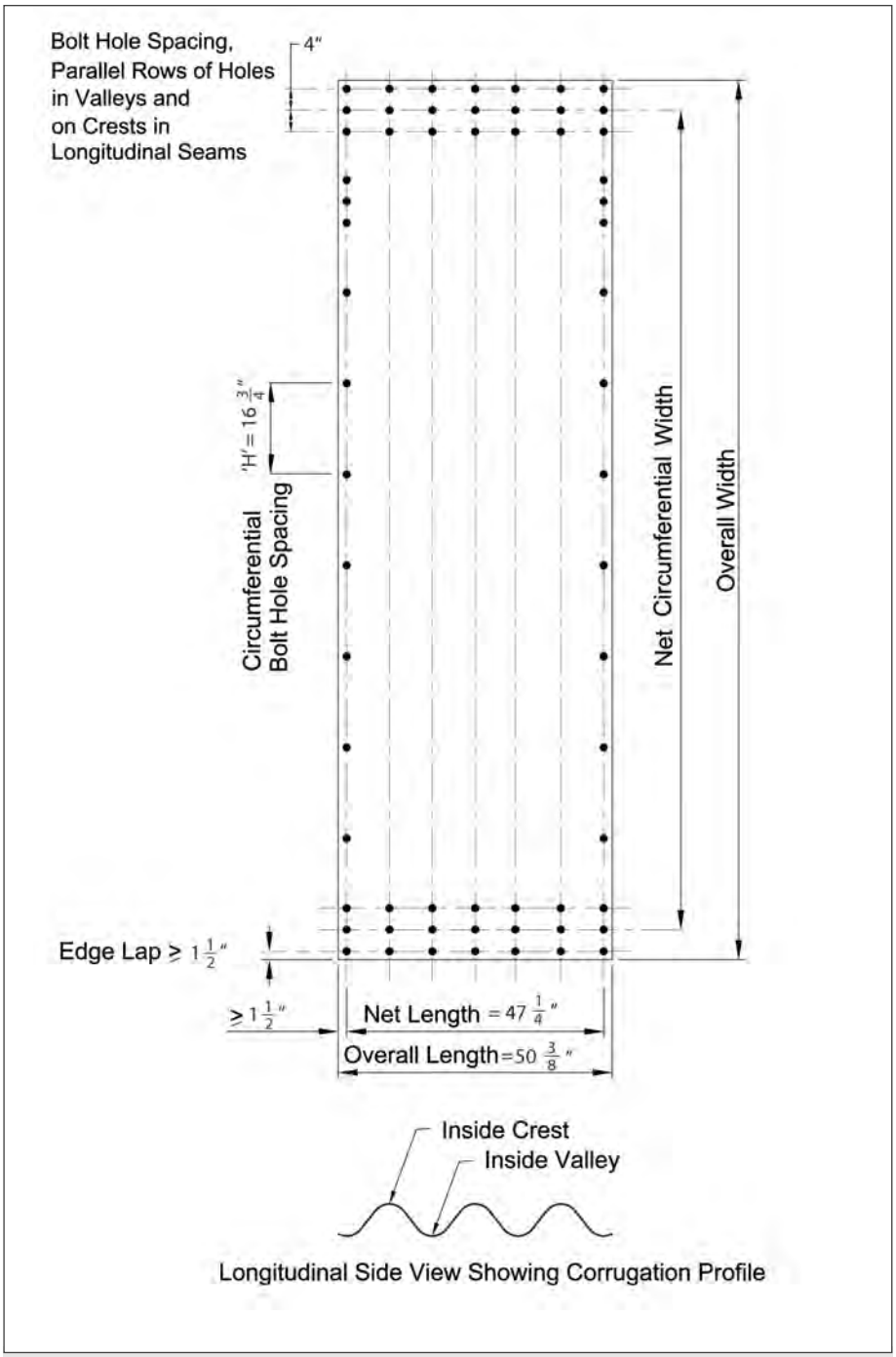



**Figure 2.15** 16 x 6 in. deep corrugated structural plate

## Section Properties

Section properties, used for design, are provided in Table 2.15. 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 2.44 through 2.46. The shapes include round, single-radius arch, two radius arches, and box culverts. Special shapes, and other standard shape sizes not shown in the tables, are also available. See Figures 2.16 - 2.18 for additional details. Detailed assembly instructions accompany each structure.

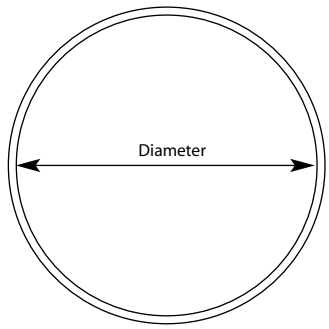



**Table 2.44**

Structural plate corrugated steel pipe
16 x 6 in. corrugations — bolted seams

| Inside Diameter ft - in. | Total Periphery H* | End Area $ft^2$ |
|---|---|---|
| 19 - 11 | 46 | 312 |
| 20 - 10 | 48 | 340 |
| 21 - 8 | 50 | 370 |
| 22 - 7 | 52 | 401 |
| 23 - 6 | 54 | 433 |
| 24 - 4 | 56 | 466 |
| 25 - 3 | 58 | 501 |
| 26 - 2 | 60 | 537 |
| 27 - 0 | 62 | 574 |
| 27 - 11 | 64 | 612 |
| 28 - 10 | 66 | 652 |
| 29 - 8 | 68 | 692 |
| 30 - 7 | 70 | 734 |
| 31 - 6 | 72 | 778 |
| 32 - 4 | 74 | 822 |
| 33 - 3 | 76 | 868 |
| 34 - 1 | 78 | 915 |

*H = 16.75 in.
Notes: 1. All dimensions are to the inside crest and are subject to manufacturing tolerances.
2. Sizes are representative, other sizes may be available, contact your manufacturer.

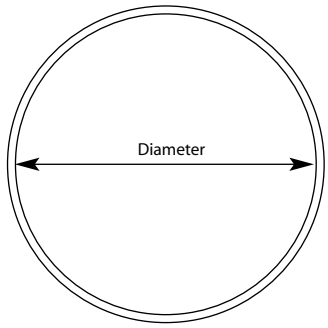
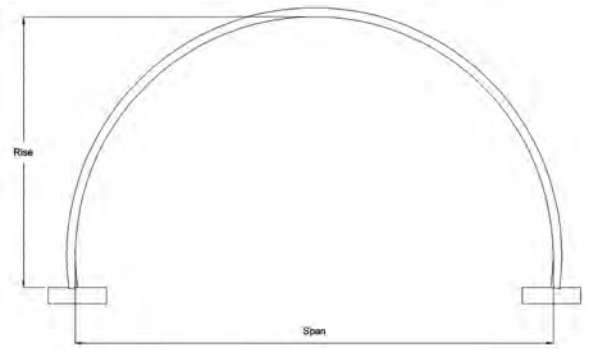



**Table 2.44** *continued*

Structural plate corrugated steel pipe
16 x 6 in. corrugations — bolted seams

| Inside Diameter ft - in. | Total Periphery H* | End Area $ft^2$ |
|---|---|---|
| 35 - 0 | 80 | 963 |
| 35 - 11 | 82 | 1012 |
| 36 - 10 | 84 | 1063 |
| 37 - 8 | 86 | 1115 |
| 38 - 7 | 88 | 1168 |
| 39 - 5 | 90 | 1223 |
| 40 - 4 | 92 | 1278 |
| 41 - 3 | 94 | 1335 |
| 42 - 1 | 96 | 1393 |
| 43 - 0 | 98 | 1452 |
| 43 - 11 | 100 | 1513 |
| 44 - 9 | 102 | 1575 |
| 45 - 8 | 104 | 1638 |
| 46 - 7 | 106 | 1702 |
| 47 - 5 | 108 | 1768 |
| 48 - 4 | 110 | 1834 |
| 49 - 3 | 112 | 1902 |
| 50 - 1 | 114 | 1972 |
| 51 - 0 | 116 | 2042 |
| 51 - 11 | 118 | 2114 |

*H = 16.75 in.
Notes: 1. All dimensions are to the inside crest and are subject to manufacturing tolerances.
2. Sizes are representative, other sizes may be available, contact your manufacturer.

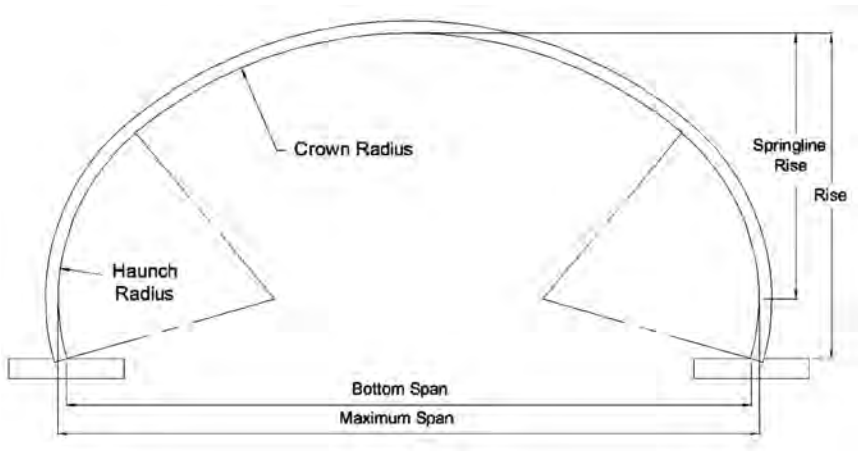



## Table 2.45

Structural plate single-radius arches — size and layout details
16 x 6 in. corrugations — bolted seams

| Span ft-in. | Rise ft-in. | End Area $ft^2$ | Inside Radius in. | Total Periphery H* |
|---|---|---|---|---|
| 26 – 3 | 12 - 10 | 262.2 | 157 | 29 |
| 27 – 1 | 13 - 3 | 280.5 | 162 | 30 |
| 27 – 11 | 13 - 9 | 299.4 | 167 | 31 |
| 28 – 8 | 14 - 2 | 319.0 | 172 | 32 |
| 29 – 6 | 14 - 8 | 339.2 | 177 | 33 |
| 30 – 4 | 15 - 1 | 359.9 | 182 | 34 |
| 31 – 2 | 15 - 7 | 381.4 | 187 | 35 |
| 31 – 12 | 16 - 1 | 403.3 | 192 | 36 |
| 32 – 10 | 16 - 6 | 425.9 | 197 | 37 |
| 33 – 8 | 16 - 12 | 449.2 | 202 | 38 |
| 34 – 5 | 17 - 5 | 473.1 | 207 | 39 |
| 35 – 3 | 17 - 11 | 497.5 | 212 | 40 |
| 36 – 1 | 18 - 4 | 522.6 | 217 | 41 |
| 36 – 11 | 18 - 10 | 548.3 | 221 | 42 |
| 37 – 9 | 18 - 7 | 548.6 | 226 | 42 |
| 38 – 7 | 19 - 1 | 575.0 | 231 | 43 |
| 39 – 4 | 19 - 6 | 602.0 | 236 | 44 |
| 40 – 2 | 19 - 12 | 629.6 | 241 | 45 |
| 41 – 0 | 20 - 5 | 657.8 | 246 | 46 |
| 41 – 10 | 20 - 11 | 686.6 | 251 | 47 |
| 42 – 8 | 21 - 4 | 716.0 | 256 | 48 |
| 43 – 6 | 21 - 10 | 746.0 | 261 | 49 |
| 44 – 3 | 22 - 4 | 776.7 | 266 | 50 |
| 45 – 1 | 22 - 9 | 808.0 | 271 | 51 |
| 45 – 11 | 23 - 3 | 839.9 | 276 | 52 |
| 46 – 9 | 23 - 8 | 872.4 | 281 | 53 |
| 47 – 7 | 24 - 2 | 905.5 | 285 | 54 |
| 48 – 5 | 24 - 7 | 939.2 | 290 | 55 |
| 49 – 3 | 24 - 5 | 942.9 | 295 | 55 |
| 50 – 0 | 24 - 10 | 974.0 | 300 | 56 |
| 51 – 0 | 25 - 4 | 1009.1 | 305 | 57 |
| 51 – 8 | 25 - 9 | 1044.7 | 310 | 58 |
| 52 – 6 | 26 - 3 | 1081.0 | 315 | 59 |

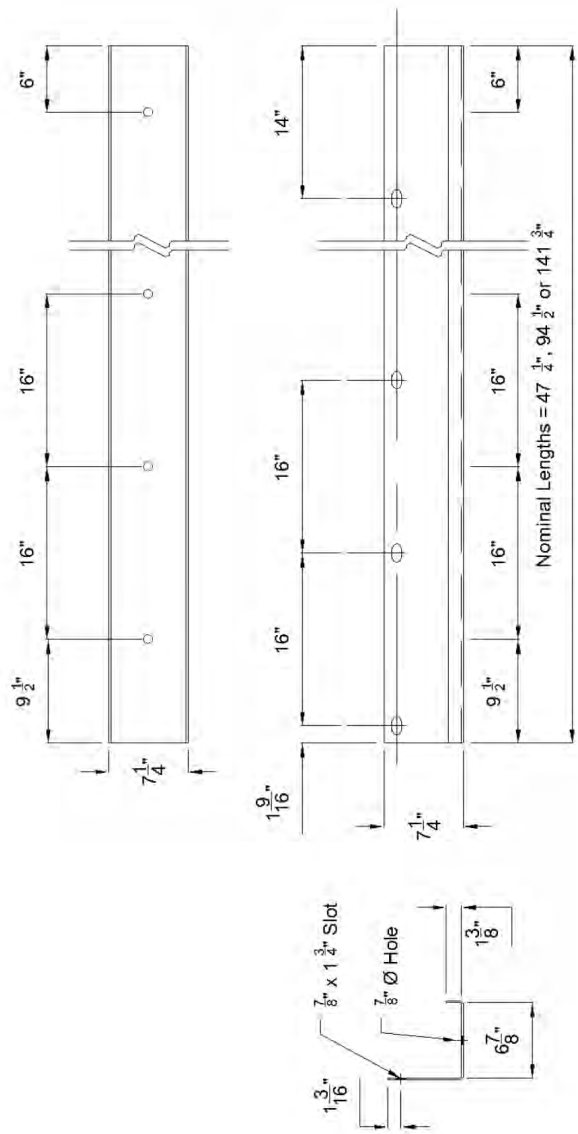
*H = 16.75 in.
Notes: 1. All dimensions are to the inside crest and are subject to manufacturing tolerances.
2. Sizes are representative, other sizes may be available, contact your manufacturer.



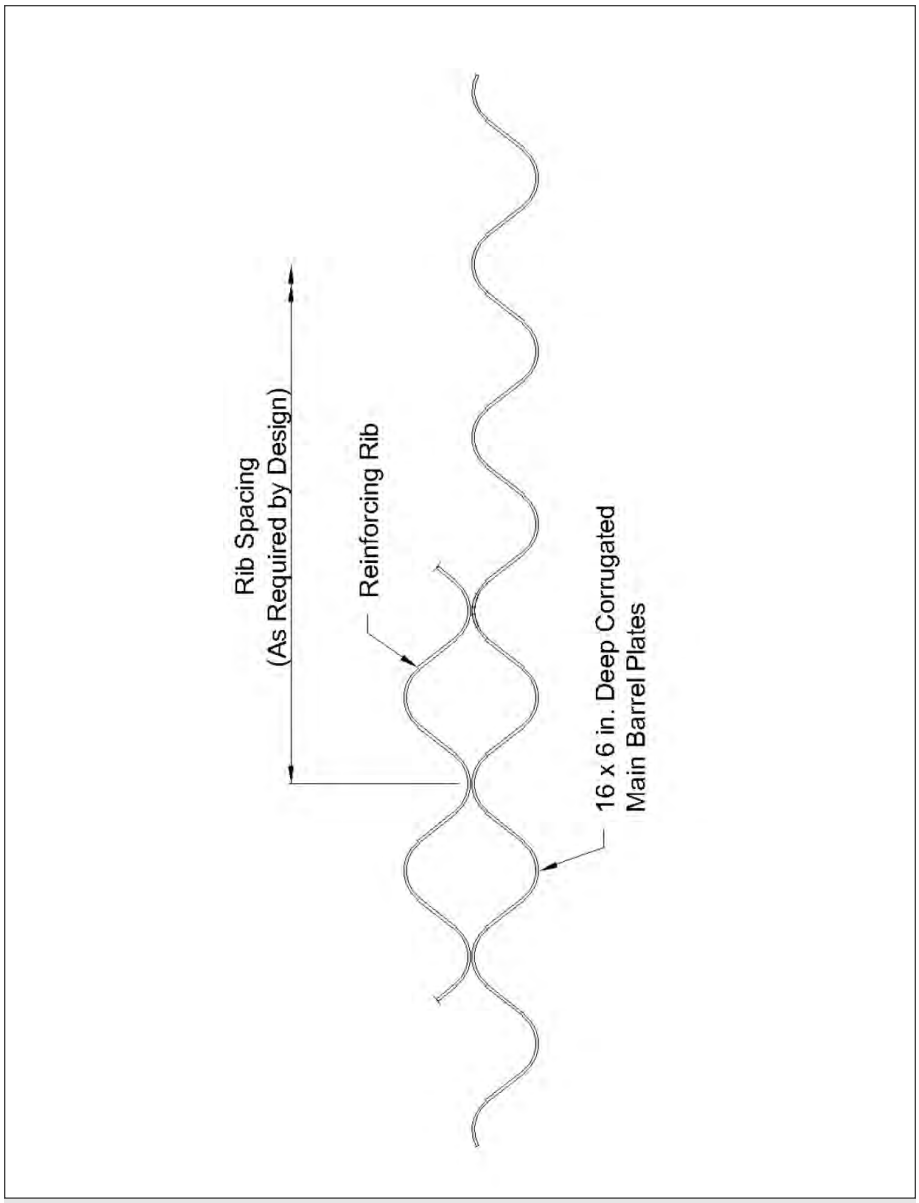

## Table 2.46

Structural plate two radius arches — size and layout details
16 x 6 in. corrugations — bolted seams

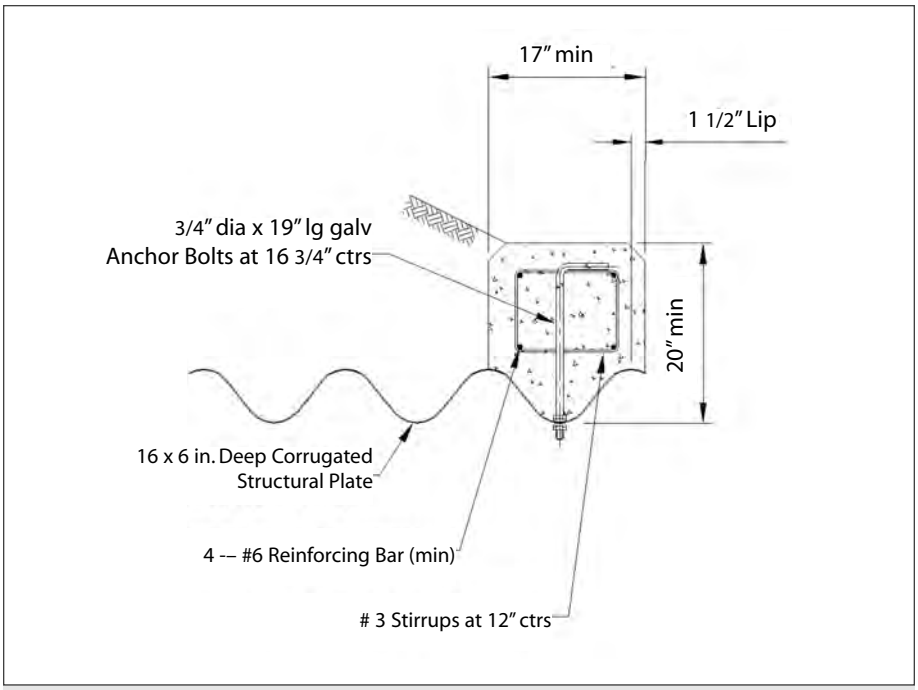
| Maximum Span ft-in. | Rise ft-in. | Bottom Span ft-in. | End Area $ft^2$ | Crown H | Crown Radius in. | Side H | Side Radius in. |
|---|---|---|---|---|---|---|---|
| 20 - 4 | 9 - 2 | 20 - 3 | 149.4 | 12 | 142 | 5 | 87 |
| 21 - 7 | 9 - 4 | 21 - 6 | 162.7 | 13 | 154 | 5 | 87 |
| 22 - 10 | 9 - 7 | 22 - 9 | 176.4 | 14 | 165 | 5 | 87 |
| 25 - 5 | 10 - 1 | 25 - 3 | 205.0 | 16 | 189 | 5 | 87 |
| 26 - 8 | 10 - 4 | 26 - 7 | 219.9 | 17 | 201 | 5 | 87 |
| 27 - 7 | 11 - 7 | 27 - 5 | 256.9 | 17 | 201 | 6 | 102 |
| 27 - 11 | 10 - 7 | 27 - 10 | 235.2 | 18 | 213 | 5 | 87 |
| 29 - 10 | 13 - 1 | 29 - 7 | 314.3 | 18 | 213 | 7 | 118 |
| 29 - 3 | 10 - 10 | 29 - 1 | 251.0 | 19 | 224 | 5 | 87 |
| 30 - 6 | 11 - 1 | 30 - 5 | 267.2 | 20 | 236 | 5 | 87 |
| 32 - 8 | 12 - 6 | 32 - 7 | 327.2 | 21 | 248 | 6 | 102 |
| 33 - 12 | 12 - 9 | 33 - 10 | 345.8 | 22 | 260 | 6 | 102 |
| 34 - 5 | 11 - 9 | 34 - 4 | 317.7 | 23 | 274 | 5 | 87 |
| 36 - 4 | 14 - 3 | 36 - 1 | 412.9 | 23 | 274 | 7 | 118 |
| 35 - 8 | 11 - 11 | 35 - 7 | 335.5 | 24 | 285 | 5 | 87 |
| 37 - 7 | 14 - 5 | 37 - 5 | 433.9 | 24 | 285 | 7 | 118 |
| 36 - 12 | 12 - 2 | 36 - 10 | 353.7 | 25 | 297 | 5 | 87 |
| 38 - 10 | 14 - 8 | 38 - 8 | 455.3 | 25 | 297 | 7 | 118 |
| 40 - 1 | 14 - 11 | 39 - 11 | 477.2 | 26 | 309 | 7 | 118 |
| 42 - 7 | 16 - 5 | 42 - 5 | 556.3 | 27 | 321 | 8 | 138 |
| 43 - 10 | 16 - 7 | 43 - 8 | 580.5 | 28 | 333 | 8 | 138 |
| 45 - 1 | 16 - 10 | 44 - 11 | 605.2 | 29 | 344 | 8 | 138 |
| 46 - 5 | 17 - 1 | 46 - 3 | 630.3 | 30 | 356 | 8 | 138 |
| 48 - 7 | 18 - 7 | 48 - 5 | 720.8 | 31 | 368 | 9 | 154 |
| 49 - 11 | 18 - 10 | 49 - 8 | 748.3 | 32 | 380 | 9 | 154 |
| 51 - 2 | 19 - 1 | 50 - 11 | 776.2 | 33 | 392 | 9 | 154 |
| 53 - 0 | 21 - 7 | 52 - 9 | 917.9 | 33 | 392 | 11 | 185 |




■ **Figure 2.16** General dimensions of unbalanced channel for 16 x 6 in. deep corrugated structural plate arches.




■ **Figure 2.17** Reinforcing rib details for deep corrugated structural plate, 16 x 6 in. corrugation profile.



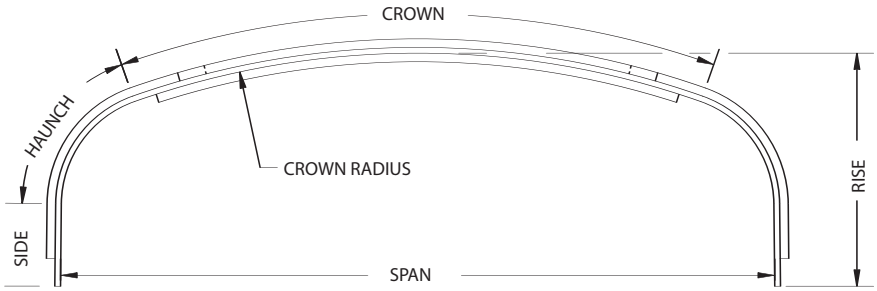

■ **Figure 2.18** Typical reinforced concrete collar detail for 16 x 6 in. deep corrugated structural plate.

# CORRUGATED STEEL BOX CULVERTS

Corrugated steel box culverts closely resemble the rectangular shape of a low, wide box. These bridges or culverts are manufactured from standard structural plate or deep corrugated structural plate (see preceding section). This is made possible by the addition of special reinforcing elements to standard structural plate or the addition of special rib plates (where required) to the standard and deep corrugated structural plate. 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, with steel footer pads (as shown in Figure 2.13), or a full steel invert.

Corrugated steel box culverts can be designed for low, wide waterway requirements with heights of cover between 1.4 to 5.0 feet (measured from the outside crest of main barrel) and various loading situations. Box culverts are available in standard spans of 9 feet 2 inches to 53 feet 0 inches and rises of 2 feet 6 inches to 13 feet 1 inch. Tables 2.47, 2.48 and 2.49 provides representative sizes available. Contact your CSP fabricator for information on box culvert sizes not listed in Tables 2.47, 2.48 and 2.49.




## Table 2.47

Low profile box culvert — size and end area
6 x 2 in. corrugations — bolted seams

| Nominal Size | | Waterway | Minimum | Nominal Size | | Waterway | Minimum |
|---|---|---|---|---|---|---|---|
| Span ft-in. | Rise ft-in. | Area $ft^2$ | Cover ft | Span ft-in. | Rise ft-in. | Area $ft^2$ | Cover ft |
| 9-8 | 2-7 | 20.2 | 1.33 | 12-6 | 2-11 | 30.6 | 1.33 |
| 10-1 | 3-4 | 27.9 | 1.33 | 12-10 | 3-9 | 40.6 | 1.33 |
| 10-7 | 4-2 | 35.9 | 1.33 | 13-2 | 4-6 | 50.8 | 1.33 |
| 11-0 | 4-11 | 44.2 | 1.33 | 13-6 | 5-4 | 61.4 | 1.40 |
| 11-5 | 5-8 | 53.0 | 1.33 | 13-10 | 6-1 | 72.2 | 1.40 |
| 11-10 | 6-5 | 61.9 | 1.33 | 14-2 | 6-10 | 83.1 | 1.40 |
| 12-3 | 7-3 | 71.2 | 1.33 | 14-6 | 7-8 | 94.4 | 1.50 |
| 12-8 | 8-0 | 80.9 | 1.33 | 14-10 | 8-5 | 105.99 | 1.50 |
| 10-5 | 2-8 | 23.1 | 1.33 | 13-3 | 3-1 | 33.88 | 1.33 |
| 10-10 | 3-5 | 31.2 | 1.33 | 13-6 | 3-10 | 44.3 | 1.40 |
| 11-2 | 4-3 | 39.7 | 1.33 | 13-10 | 4-8 | 55.1 | 1.40 |
| 11-7 | 5-0 | 48.4 | 1.33 | 14-1 | 5-5 | 66.0 | 1.40 |
| 12-0 | 5-9 | 57.7 | 1.33 | 14-5 | 6-2 | 77.22 | 1.40 |
| 12-5 | 6-7 | 67.0 | 1.33 | 14-9 | 7-0 | 88.8 | 1.50 |
| 12-10 | 7-4 | 76.9 | 1.33 | 15-0 | 7-9 | 100.55 | 1.50 |
| 13-3 | 8-2 | 85.1 | 1.33 | 15-4 | 8-7 | 110.1 | 1.50 |
| 11-1 | 2-9 | 25.1 | 1.33 | 13-11 | 3-2 | 36.6 | 1.40 |
| 11-6 | 3-6 | 34.0 | 1.33 | 14-2 | 3-11 | 47.88 | 1.40 |
| 11-10 | 4-4 | 43.1 | 1.33 | 14-6 | 4-9 | 59.1 | 1.50 |
| 12-3 | 5-1 | 52.5 | 1.33 | 14-9 | 5-6 | 70.7 | 1.50 |
| 12-7 | 5-10 | 62.3 | 1.33 | 15-00 | 6-4 | 82.4 | 1.50 |
| 13-00 | 6-8 | 72.3 | 1.33 | 15-4 | 7-1 | 94.5 | 1.50 |
| 13-5 | 7-5 | 82.6 | 1.33 | 15-7 | 7-11 | 106.8 | 1.60 |
| 13-9 | 8-2 | 93.2 | 1.40 | 15-10 | 8-8 | 119.2 | 1.60 |
| 11-10 | 2-10 | 28.0 | 1.33 | 14-7 | 3-3 | 40.2 | 1.50 |
| 12-2 | 3-8 | 37.4 | 1.33 | 14-10 | 4-1 | 51.8 | 1.50 |
| 12-6 | 4-5 | 47.0 | 1.33 | 15-1 | 4-10 | 63.6 | 1.50 |
| 12-10 | 5-2 | 57.0 | 1.33 | 15-4 | 5-8 | 75.6 | 1.50 |
| 13-3 | 6-0 | 67.1 | 1.33 | 15-7 | 6-5 | 88.0 | 1.60 |
| 13-7 | 6-9 | 77.6 | 1.40 | 15-10 | 7-3 | 100.3 | 1.60 |
| 13-11 | 7-6 | 88.2 | 1.40 | 16-1 | 8-0 | 113.0 | 1.60 |
| 14-3 | 8-4 | 97.5 | 1.40 | 16-4 | 8-10 | 123.0 | 1.60 |
| 15-3 | 3-5 | 43.3 | 1.50 | 18-0 | 3-11 | 58.8 | 1.80 |
| 15-6 | 4-2 | 55.9 | 1.60 | 18-1 | 4-9 | 73.3 | 1.80 |
| 15-9 | 5-0 | 68.1 | 1.60 | 18-3 | 5-7 | 87.9 | 1.80 |
| 16-0 | 5-9 | 80.7 | 1.60 | 18-4 | 6-4 | 102.66 | 1.80 |
| 16-2 | 6-7 | 93.2 | 1.60 | 18-6 | 7-2 | 117.3 | 1.90 |
| 16-5 | 7-4 | 106.5 | 1.70 | 18-7 | 7-11 | 132.3 | 1.90 |
| 16-8 | 8-2 | 119.7 | 1.70 | 18-9 | 8-9 | 147.3 | 1.90 |
| 16-10 | 8-11 | 133.0 | 1.60 | 18-10 | 9-6 | 162.4 | 1.90 |

Notes: 1. Maximum cover is 5 ft. Where cover in excess of 5 ft is required, consult with manufacturer.
2. To determine minimum allowable cover, add 3 in. to rise dimension to allow for material thickness
3. If interior ribs are used, reduce waterway area by 5%.

**Table 2.47** *continued*

Low profile box culvert — size and end area
6 x 2 in. corrugations — bolted seams

| Nominal Size | | Waterway | Minimum | Nominal Size | | Waterway | Minimum |
|---|---|---|---|---|---|---|---|
| Span ft-in. | Rise ft-in. | Area $ft^2$ | Cover ft | Span ft-in. | Rise ft-in. | Area $ft^2$ | Cover ft |
| 16-0 | 3-6 | 47.1 | 1.60 | 18-8 | 4-1 | 63.4 | 1.90 |
| 16-2 | 4-4 | 59.9 | 1.60 | 18-9 | 4-11 | 78.4 | 1.90 |
| 16-4 | 5-1 | 72.8 | 1.70 | 18-10 | 5-8 | 93.4 | 1.90 |
| 16-7 | 5-11 | 85.8 | 1.70 | 18-11 | 6-6 | 108.5 | 1.90 |
| 16-9 | 6-9 | 99.1 | 1.70 | 19-1 | 7-4 | 123.6 | 1.90 |
| 17-0 | 7-6 | 112.4 | 1.70 | 19-2 | 8-1 | 138.9 | 1.90 |
| 17-2 | 8-4 | 126.0 | 1.70 | 19-3 | 8-11 | 154.2 | 1.90 |
| 17-5 | 9-1 | 137.0 | 1.70 | 19-4 | 9-8 | 166.0 | 1.90 |
| 16-8 | 3-8 | 50.7 | 1.70 | 19-4 | 4-3 | 67.7 | 1.90 |
| 16-10 | 4-6 | 64.1 | 1.70 | 19-5 | 5-1 | 83.3 | 1.90 |
| 17-0 | 5-3 | 77.6 | 1.70 | 19-6 | 5-10 | 98.9 | 2.00 |
| 17-2 | 6-1 | 91.3 | 1.70 | 19-6 | 6-8 | 114.6 | 2.00 |
| 17-4 | 6-10 | 105.1 | 1.70 | 19-7 | 7-5 | 126.6 | 2.00 |
| 17-6 | 7-8 | 119.1 | 1.80 | 19-8 | 8-3 | 146.2 | 2.00 |
| 17-8 | 8-5 | 133.2 | 1.80 | 19-9 | 9-1 | 162.0 | 2.00 |
| 17-10 | 9-3 | 147.4 | 1.80 | 19-10 | 9-10 | 178.0 | 2.00 |
| 17-14 | 3-10 | 55.0 | 1.70 | 20-8 | 4-7 | 77.5 | 2.10 |
| 17-6 | 4-7 | 68.8 | 1.80 | 20-8 | 5-5 | 94.1 | 2.10 |
| 17-7 | 5-5 | 82.8 | 1.80 | 20-8 | 6-2 | 110.7 | 2.10 |
| 17-9 | 6-2 | 96.8 | 1.80 | 20-8 | 7-0 | 127.4 | 2.10 |
| 17-11 | 7-0 | 111.1 | 1.80 | 20-9 | 7-10 | 143.3 | 2.10 |
| 18-1 | 7-9 | 125.4 | 1.80 | 20-9 | 8-7 | 160.7 | 2.10 |
| 18-3 | 8-7 | 139.8 | 1.80 | 20-9 | 9-5 | 177.4 | 2.10 |
| 18-5 | 9-4 | 151.2 | 1.80 | 20-9 | 10-2 | 194.2 | 2.10 |

Notes: 1. Maximum cover is 5 ft. Where cover in excess of 5 ft is required, consult with manufacturer.
2. To determine minimum allowable cover, add 3 in. to rise dimension to allow for material thickness
3. If interior ribs are used, reduce waterway area by 5%.

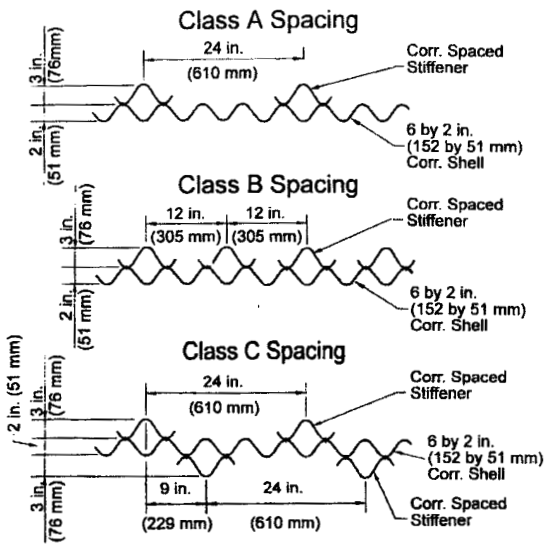
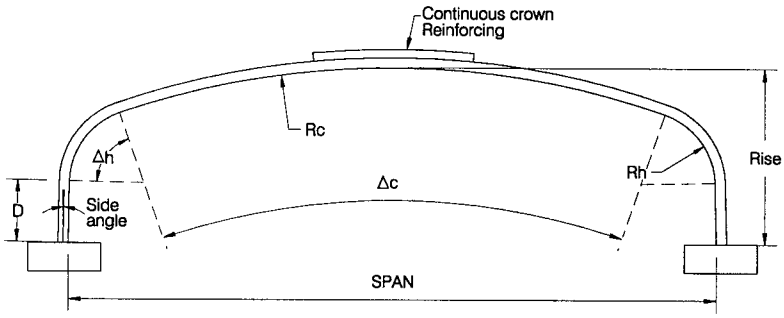



**Figure 2.19** Reinforcing rib details for 6 x 2 in. structural plate box.




## Table 2.48

DCSP Type I — size and layout details for box culverts
15 x 5 1/2 in corrugation profile — bolted seams

| Span ft-in. | Rise ft-in. | Area $ft^2$ | Crown Radius in. | Haunch Radius in. | Side Angle degree | Total *S |
|---|---|---|---|---|---|---|
| 10'-4 3/4" | 3'-10 1/2" | 33.6 | 347.2 | 40 | 14.00 | 11 |
| 11'-7 7/8" | 4'-7 7/8" | 46.6 | 347.2 | 40 | 10.00 | 13 |
| 12'-7 1/8" | 4'-9 5/8" | 53.2 | 347.2 | 40 | 6.00 | 14 |
| 13' 0" | 7' 3" | 79.1 | 347.2 | 40 | 12.66 | 17 |
| 12' 8 1/8" | 4'-1 3/4" | 45.0 | 347.2 | 40 | 11.35 | 13 |
| 13' 5 5/8" | 6' 1 1/4" | 70.6 | 347.2 | 40 | 11.35 | 16 |
| 13'-9 3/4" | 4'-3 1/2" | 51.2 | 347.2 | 40 | 10.04 | 14 |
| 15'-6 1/2" | 6'-5 1/4" | 87.8 | 347.2 | 40 | 8.73 | 18 |
| 14'-11 1/4" | 4'-5 1/2" | 57.7 | 347.2 | 40 | 8.73 | 15 |
| 16'-0 1/2" | 5'-3 1/2" | 75.0 | 347.2 | 40 | 4.76 | 17 |
| 15'-11 1/4" | 7'-9" | 108.6 | 347.2 | 40 | 8.73 | 20 |
| 16'-10 7/8" | 7'-11 1/4" | 119.0 | 347.2 | 40 | 7.42 | 21 |
| 17'-1 3/8" | 5'-5 3/4" | 83.1 | 347.2 | 40 | 3.45 | 18 |
| 17'-7" | 6'-9 3/4" | 106.5 | 347.2 | 40 | 6.11 | 20 |
| 17'-5 1/2" | 4'-8 7/8" | 71.3 | 347.2 | 40 | 8.53 | 17 |
| 17'-10 3/8" | 8'-1 5/8" | 129.9 | 347.2 | 40 | 6.11 | 22 |
| 18'-6 3/4" | 4'-11 1/4" | 78.9 | 347.2 | 40 | 7.22 | 18 |
| 19'-6 3/8" | 8'-8 1/8" | 153.2 | 347.2 | 40 | 3.81 | 24 |
| 19'-4" | 5'-2 3/4" | 87.9 | 347.2 | 40 | 3.49 | 19 |
| 20'-2 5/8" | 6'-2 7/8" | 111.2 | 347.2 | 40 | 2.50 | 21 |
| 20'-5 1/2" | 8'-10 7/8" | 165.3 | 347.2 | 40 | 2.50 | 25 |
| 20'-8 7/8" | 5'-4 3/4" | 95.9 | 347.2 | 40 | 4.60 | 20 |
| 21'-3 1/8" | 6'-5 3/4" | 121.1 | 347.2 | 40 | 1.19 | 22 |
| 21'-3 3/4" | 7'-9 3/4" | 149.5 | 347.2 | 40 | 1.19 | 24 |
| 21'-9 5/8" | 5'-7 5/8" | 105.2 | 347.2 | 40 | 3.29 | 21 |
| 22'-10 3/8" | 5'-10 3/4" | 114.8 | 347.2 | 40 | 1.98 | 22 |
| 22'-11 1/2" | 7'-2 5/8" | 145.3 | 347.2 | 40 | 1.98 | 24 |
| 23'-0 5/8" | 8'-6 3/4" | 176.0 | 347.2 | 40 | 1.98 | 26 |
| 23' 11" | 6'-1 7/8" | 125.1 | 347.2 | 40 | 0.67 | 23 |
| 23'-11 3/8" | 7'-5 7/8" | 156.9 | 347.2 | 40 | 0.67 | 25 |
| 23'-11 3/4" | 8'-9 7/8" | 189.0 | 347.2 | 40 | 0.67 | 27 |

*S = 16 in.

Note: 1. All dimensions are to the inside crest and subject to manufacturing tolerances.
2. Other sizes are available.
3. All structures should be reviewed based on live load and geotechnical condition.

**Table 2.48** *continued*

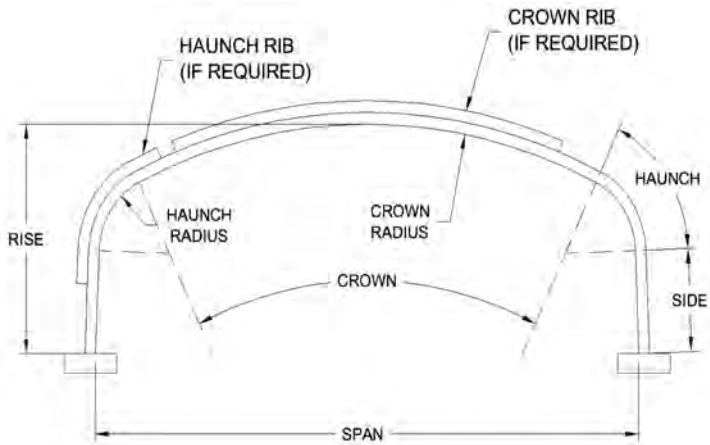
DCSP Type I — size and layout details for box culverts
15 x 5 1/2 in corrugation profile — bolted seams

| Span ft-in. | Rise ft-in. | Area $ft^2$ | Crown Radius in. | Haunch Radius in. | Side Angle degree | Total *S |
|---|---|---|---|---|---|---|
| 24'-0 1/8" | 10'-1 7/8" | 220.9 | 347.2 | 40 | 0.67 | 29 |
| 24'-3 1/2" | 5'-6 1/8" | 109.9 | 347.2 | 40 | 11.38 | 22 |
| 25'-7 1/8" | 6'-5 3/8" | 136.8 | 347.2 | 40 | 10.07 | 24 |
| 26'-0 3/4" | 7'-9 1/4" | 170.8 | 347.2 | 40 | 10.07 | 26 |
| 28'-1 5/8" | 6'-3 5/8" | 149.6 | 450.0 | 40 | 2.09 | 26 |
| 28'-2 3/4" | 7'-7 5/8" | 187.1 | 450.0 | 40 | 2.09 | 28 |
| 28'-4" | 8'-11 5/8" | 224.9 | 450.0 | 40 | 2.09 | 30 |
| 30'-0" | 6'-4 3/8" | 157.6 | 450.0 | 40 | 5.94 | 27 |
| 30'-3 1/4" | 7'-8 1/4" | 197.5 | 450.0 | 40 | 5.94 | 29 |
| 30'-6 1/2" | 9'-0 1/4" | 237.9 | 450.0 | 40 | 5.94 | 31 |
| 32'-2 1/8" | 6'-11" | 182.1 | 450.0 | 40 | 3.92 | 29 |
| 32'-4 1/4" | 8'-2 7/8" | 225.0 | 450.0 | 40 | 3.92 | 31 |
| 32'-6 1/2" | 9'-6 7/8" | 268.2 | 450.0 | 40 | 3.92 | 33 |
| 34'-3 7/8" | 7'-6" | 209.1 | 450.0 | 40 | 1.89 | 31 |
| 34'-4 7/8" | 8'-10" | 254.9 | 450.0 | 40 | 1.89 | 33 |
| 34'-5 7/8" | 10'-2" | 300.8 | 450.0 | 40 | 1.89 | 35 |
| 35'-8 7/8" | 7'-8 3/4" | 221.6 | 450.0 | 40 | 3.32 | 32 |
| 35'-10 3/4" | 9'-0 3/4" | 269.3 | 450.0 | 40 | 3.32 | 34 |
| 36'-0 1/2" | 10'-4 3/4" | 317.2 | 450.0 | 40 | 3.32 | 36 |
| 38'-2 1/2" | 8'-3 5/8" | 250.9 | 450.0 | 40 | 3.71 | 34 |
| 38'-4 5/8" | 9'-7 5/8" | 301.8 | 450.0 | 40 | 3.71 | 36 |
| 38'-6 3/4" | 10'-11 1/2" | 353.2 | 450.0 | 40 | 3.71 | 38 |
| 40'-3" | 9'-0" | 284.8 | 450.0 | 40 | 1.68 | 36 |
| 40'-4" | 10'-4" | 338.5 | 450.0 | 40 | 1.68 | 38 |
| 40'-4 3/4" | 11'-8" | 392.3 | 450.0 | 40 | 1.68 | 40 |
| 42' 9" | 9' 3" | 330.7 | 646.9 | 57.2 | 1.56 | 39 |
| 42' 10" | 10' 7" | 387.7 | 646.9 | 57.2 | 1.56 | 41 |
| 46' 3" | 10' 0" | 383.3 | 646.9 | 57.2 | 1.28 | 42 |
| 46' 4" | 11' 5" | 445.0 | 646.9 | 57.2 | 1.28 | 44 |
| 49' 3" | 10' 5" | 413.1 | 646.9 | 57.2 | 1.25 | 44 |
| 49' 4" | 11' 9" | 478.8 | 646.9 | 57.2 | 1.25 | 46 |
| 51' 1' | 12' 7" | 532.4 | 646.9 | 57.2 | 1.25 | 48 |
| 51' 8" | 13' 1" | 561.0 | 646.9 | 57.2 | 1.25 | 50 |

*S = 16 in.

Note: 1. All dimensions are to the inside crest and subject to manufacturing tolerances.
2. Other sizes are available.
3. All structures should be reviewed based on live load and geotechnical condition.

■ 36 foot span by 10 foot 5 inch rise deep corrugated box culvert with beveled ends, used for a Fish Passage project in the Willamette National Forest in Oregon.




## Table 2.49

DCSP Type II — size and layout details
16 x 6 in. corrugations — bolted seams

| Span ft-in. | Rise ft-in. | End Area $ft^2$ | Crown H* | Crown Radius in. | Haunch H* | Haunch Radius in. | Side H* | Side Radius in. |
|---|---|---|---|---|---|---|---|---|
| 13 - 1 | 4 - 0 | 42.4 | 5.2 | 160 | 3.2 | 49 | 0.2 | 160 |
| 13 - 3 | 4 - 7 | 50.7 | 5.2 | 169 | 3.7 | 49 | 0.2 | 169 |
| 14 - 9 | 4 - 7 | 56.9 | 6 | 233 | 3.8 | 49 | 0.2 | 233 |
| 16 - 5 | 4 - 7 | 63.0 | 7.2 | 273 | 3.7 | 49 | 0.2 | 273 |
| 18 - 1 | 4 - 7 | 62.2 | 9 | 184 | 2.8 | 49 | 0.2 | 184 |
| 12 - 6 | 4 - 11 | 51.8 | 4.4 | 162 | 3.8 | 49 | 0.5 | 162 |
| 14 - 1 | 4 - 11 | 58.6 | 5.6 | 203 | 3.8 | 49 | 0.4 | 203 |
| 15 - 9 | 4 - 11 | 65.0 | 7 | 225 | 3.7 | 49 | 0.3 | 225 |
| 13 - 5 | 5 - 3 | 59.7 | 5.1 | 180 | 3.7 | 49 | 0.75 | 180 |
| 17 - 1 | 5 - 3 | 73.6 | 8.7 | 195 | 3.3 | 49 | 0.35 | 195 |
| 20 - 0 | 5 - 3 | 52.2 | 10.4 | 286 | 3.6 | 49 | 0.2 | 286 |
| 15 - 1 | 5 - 11 | 77.1 | 6.2 | 230 | 3.8 | 49 | 1.1 | 230 |
| 17 - 1 | 5 - 11 | 85.4 | 8.2 | 215 | 3.4 | 49 | 1 | 215 |
| 19 - 0 | 5 - 11 | 92.8 | 10.3 | 214 | 3.2 | 49 | 0.65 | 214 |
| 22 - 4 | 5 - 11 | 107.6 | 12.7 | 270 | 3.3 | 49 | 0.35 | 270 |
| 13 - 11 | 6 - 7 | 78.7 | 5.1 | 190 | 3.5 | 49 | 1.95 | 190 |
| 16 - 1 | 6 - 7 | 88.4 | 7.5 | 171 | 2.9 | 49 | 1.85 | 171 |
| 18 - 1 | 6 - 7 | 96.9 | 10.6 | 161 | 2.7 | 49 | 1 | 161 |
| 20 - 0 | 6 - 7 | 102.9 | 12.6 | 175 | 2.7 | 49 | 0.5 | 175 |
| 21 - 4 | 6 - 7 | 113.7 | 12.8 | 213 | 3 | 49 | 0.6 | 213 |
| 23 - 11 | 6 - 7 | 130.9 | 14 | 295 | 3.5 | 49 | 0.5 | 295 |
| 14 - 9 | 7 - 3 | 89.3 | 5.2 | 181 | 3 | 49 | 2.9 | 181 |
| 16 - 5 | 7 - 3 | 99.6 | 7.9 | 163 | 2.7 | 49 | 2.35 | 163 |
| 17 - 1 | 7 - 3 | 108.5 | 7.4 | 280 | 3.7 | 49 | 2.1 | 280 |
| 22 - 12 | 7 - 3 | 137.7 | 13.5 | 252 | 3.1 | 49 | 1.15 | 252 |
| 24 - 11 | 7 - 3 | 146.5 | 15.3 | 263 | 3 | 49 | 0.85 | 263 |
| 16 - 1 | 7 - 10 | 110.0 | 6.3 | 238 | 3.4 | 49 | 2.95 | 238 |
| 18 - 1 | 7 - 10 | 121.7 | 8.5 | 213 | 3 | 49 | 2.75 | 213 |
| 20 - 0 | 7 - 10 | 132.7 | 10.8 | 209 | 2.8 | 49 | 2.3 | 209 |
| 21 - 8 | 7 - 10 | 142.8 | 12.8 | 218 | 2.9 | 49 | 1.7 | 218 |
| 23 - 4 | 7 - 10 | 153.2 | 13.9 | 246 | 3 | 49 | 1.55 | 246 |

*H = 16.75 in.

Notes: 1. All dimensions are to the inside crest and are subject to manufacturing tolerances.
2. Sizes are representative, other sizes may be available, contact your manufacturer.

**Table 2.49** *continued*

DCSP Type II — size and layout details
16 x 6 in. corrugations — bolted seams

| Span ft-in. | Rise ft-in. | End Area $ft^2$ | Crown H* | Crown Radius in. | Haunch H* | Haunch Radius in. | Side H* | Side Radius in. |
|---|---|---|---|---|---|---|---|---|
| 25 - 5 | 7 - 10 | 163.3 | 15.9 | 254 | 2.8 | 49 | 1.25 | 254 |
| 19 - 8 | 8 - 6 | 145.8 | 9.4 | 264 | 3.2 | 49 | 3.1 | 264 |
| 22 - 12 | 8 - 6 | 169.3 | 12.5 | 292 | 3.2 | 49 | 2.55 | 292 |
| 23 - 11 | 8 - 6 | 169.3 | 14.8 | 231 | 2.7 | 49 | 1.9 | 231 |
| 20 - 0 | 9 - 2 | 159.2 | 9.5 | 262 | 3.1 | 49 | 3.65 | 262 |
| 21 - 12 | 9 - 2 | 173.4 | 10.7 | 291 | 3 | 49 | 3.65 | 291 |
| 25 - 0 | 9 - 2 | 197.7 | 14.4 | 298 | 3.1 | 49 | 2.7 | 298 |
| 22 - 4 | 9 - 10 | 189.0 | 12.1 | 238 | 2.7 | 49 | 3.75 | 238 |
| 24 - 3 | 9 - 10 | 203.1 | 13 | 275 | 2.7 | 49 | 3.8 | 275 |
| 25 - 6 | 9 - 10 | 215.6 | 14.9 | 284 | 2.9 | 49 | 3.15 | 284 |
| 26 - 3 | 6 - 7 | 137.8 | 16.2 | 294 | 3.2 | 49 | 0.2 | 294 |
| 28 - 8 | 6 - 7 | 155.3 | 17.2 | 400 | 3.6 | 49 | 0.3 | 400 |
| 26 - 3 | 7 - 2 | 155.9 | 15.8 | 309 | 3.2 | 49 | 0.9 | 309 |
| 29 - 6 | 7 - 3 | 173.8 | 18.1 | 367 | 3.2 | 49 | 0.75 | 367 |
| 32 - 10 | 7 - 3 | 190.5 | 20.6 | 419 | 3.3 | 49 | 0.4 | 419 |
| 27 - 11 | 7 - 11 | 184.5 | 16.4 | 362 | 3.2 | 49 | 1.6 | 362 |
| 31 - 2 | 7 - 10 | 203.4 | 19 | 413 | 3.3 | 49 | 1.2 | 413 |
| 36 - 1 | 7 - 11 | 231.0 | 23 | 477 | 3.5 | 49 | 0.5 | 477 |
| 27 - 11 | 8 - 6 | 203.1 | 16.5 | 362 | 3.3 | 49 | 1.95 | 362 |
| 32 - 10 | 8 - 6 | 221.7 | 21.6 | 337 | 2.8 | 49 | 0.9 | 337 |
| 37 - 9 | 8 - 6 | 251.0 | 25.2 | 411 | 3 | 49 | 0.4 | 411 |
| 26 - 3 | 9 - 2 | 209.9 | 15.1 | 345 | 3.3 | 49 | 2.65 | 345 |
| 32 - 10 | 9 - 2 | 244.7 | 21.1 | 350 | 2.8 | 49 | 1.65 | 350 |
| 36 - 1 | 9 - 2 | 266.6 | 23.5 | 402 | 2.9 | 49 | 1.35 | 402 |
| 39 - 4 | 9 - 2 | 287.3 | 26.2 | 444 | 3.1 | 49 | 0.8 | 444 |
| 26 - 3 | 9 - 10 | 227.7 | 14.4 | 393 | 3.4 | 49 | 3.4 | 393 |
| 29 - 6 | 9 - 10 | 242.6 | 17.7 | 325 | 2.7 | 49 | 2.95 | 325 |
| 32 - 10 | 9 - 10 | 267.7 | 20.5 | 366 | 2.8 | 49 | 2.45 | 366 |
| 36 - 1 | 9 - 10 | 291.9 | 23 | 418 | 2.9 | 49 | 2.1 | 418 |
| 39 - 4 | 9 - 10 | 315.4 | 25.6 | 465 | 3 | 49 | 1.7 | 465 |
| 29 - 6 | 10 - 6 | 262.7 | 16.9 | 355 | 2.8 | 49 | 3.75 | 355 |
| 32 - 10 | 10 - 6 | 289.3 | 20.5 | 372 | 2.9 | 49 | 2.85 | 372 |
| 36 - 1 | 10 - 6 | 315.8 | 23.1 | 419 | 3 | 49 | 2.45 | 419 |
| 39 - 4 | 10 - 6 | 341.5 | 25.7 | 465 | 3.1 | 49 | 2.05 | 465 |
| 32 - 11 | 11 - 2 | 312.0 | 20.2 | 383 | 2.9 | 49 | 3.5 | 383 |
| 36 - 1 | 11 - 2 | 341.1 | 22.5 | 441 | 3 | 49 | 3.25 | 441 |
| 39 - 4 | 11 - 2 | 368.8 | 25.4 | 478 | 3.1 | 49 | 2.7 | 478 |
| 36 - 3 | 11 - 10 | 365.4 | 22.7 | 438 | 3 | 49 | 3.65 | 438 |
| 39 - 4 | 11 - 10 | 380.4 | 25.8 | 410 | 2.6 | 49 | 3 | 410 |
| 37 - 9 | 12 - 5 | 391.2 | 24.3 | 394 | 2.6 | 49 | 3.75 | 394 |
| 41 - 0 | 12 - 5 | 422.8 | 26.8 | 443 | 2.7 | 49 | 3.4 | 443 |

*H = 16.75 in.
Notes: 1. All dimensions are to the inside crest and are subject to manufacturing tolerances.
2. Sizes are representative, other sizes may be available, contact your manufacturer.

# SPECIFICATIONS

## Specifications in Common Use

Specifications are divided into three basic classes – those covering design, materials, and installation. These classes are covered in Tables 2.50, 2.51 and 2.52.

## Table 2.50

Design specifications

| Agency | Reference |
|---|---|
| AASHTO | Standard Specifications for Highway Bridges—Division I, Section 12<br>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 |
| AREMA | Manual for Railway Engineering – Section 4.9 |

## Table 2.51

Material description and specifications

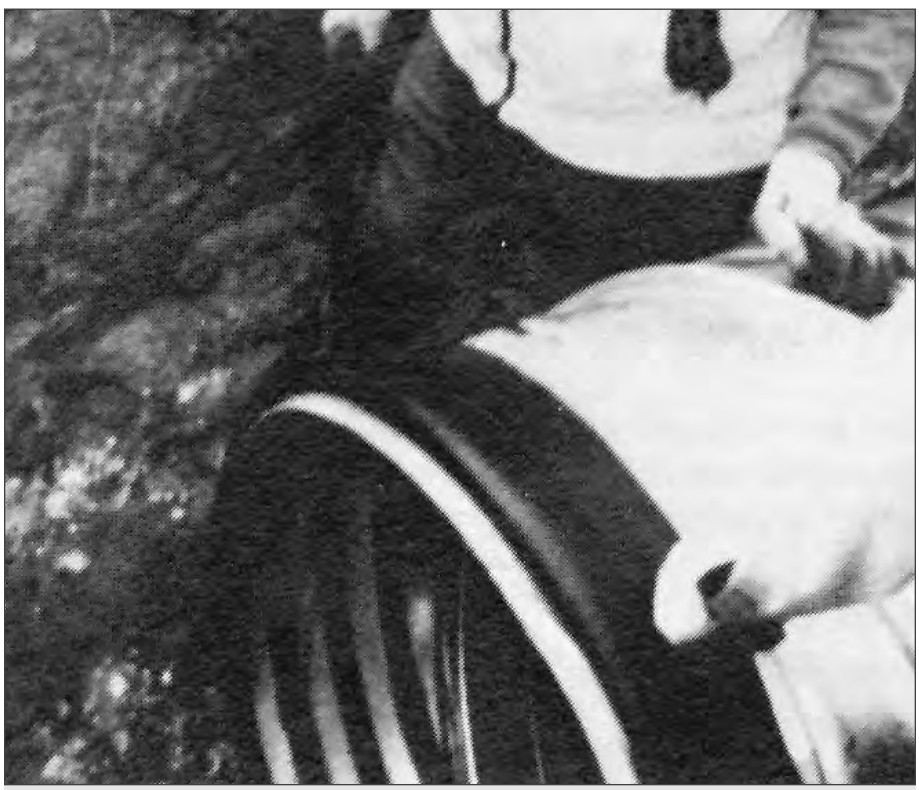
| Material | Description | Specifications AASHTO | Specifications ASTM |
|---|---|---|---|
| Zinc Coated Sheets & Coils | Steel base metal* with 2 oz per $ft^2$ zinc coating | M-218 | A929M |
| Polymer Coated Sheets and Coils | Polymer coatings applied to sheets* and coils*, 0.010 in. both sides | M-246 | A742M |
| Aluminum Coated Coils – Type 2 | Steel base metal* coated with 1 oz. per $ft^2$ of pure aluminum | M-274 | A929M |
| 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 lock seam or welded seam, or by rolling annular corrugated mill sheets and riveting or spot welding seams: | | |
| | 1. Galvanized corrugated steel pipe | M-36 | A760M |
| | 2. Polymeric pre-coated sewer and drainage pipe | M-245 | A762M |
| | 3. Aluminized Type 2 corrugated steel pipe | M-274 | A760M |
| | 4. Structural plate pipe | M-167 | A761M |
| Asphalt Coated Steel Sewer Pipe | Corrugated steel pipe of any of the types shown above with a 0.050 in. asphalt coating | M-190 | A849 |
| Invert Paved Steel Sewer Pipe | Corrugated steel pipe of any one of the types shown above: | | |
| | a. Asphalt coated pipe with 0.050 in. asphalt coating and pavement poured in the invert to cover the corrugation by 1/8 in. | M-190 | A849 |
| | b. With a field applied 3 in. (3250 psi) concrete invert or 1 1/2 in. high strength (9600 psi) concrete invert. | | A849 |
| | c. With polymer material applied 0.050 in. above the crest in the invert. | | A849 |
| Fully Lined Steel Sewer Pipe | Corrugated steel pipe of the types shown above: | | |
| | a. With an internal asphalt lining centrifugally spun in place. | M-190 | A849 |
| | b. With an internal concrete lining in place. | | A849 |
| | c. Corrugated steel pipe with a smooth steel liner integrally formed with the corrugated shell or. | M-36 | A760 |
| | d. Corrugated steel pipe with a single thickness of smooth sheet fabricated with helical ribs projected outward or. | M-36 | A760 |
| | e. With concrete pavement and linings installed in the field. | | A979 |
| Cold Applied Bituminous Coatings | Mastic or coal tar base coatings of various viscosities for field or shop coating of corrugated pipe or structural plate. | M-243 | A849 |
| Gaskets and Sealants | 1. Standard O-ring gaskets | | C443 |
| | 2. Sponge neoprene sleeve gaskets | | D1056 |
| | 3. Gasketing strips, butyl or neoprene | | |
| | 4. Mastic sealant | | |

* yield point – 33 ksi min.; tensile strength – 45 ksi min.; elongation (2 in.) – 20% min.

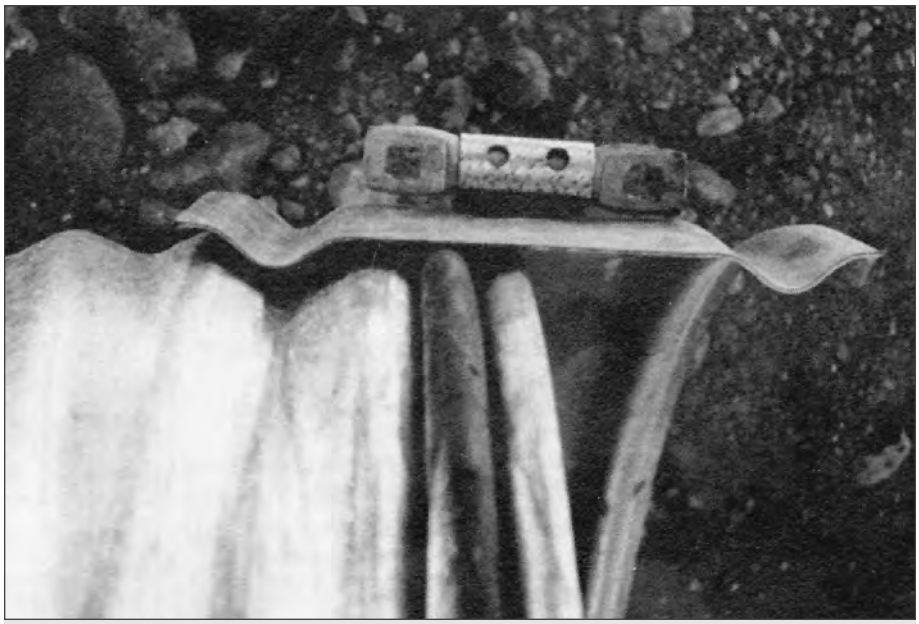
**Table 2.52**

Installation specifications

| Agency | Reference |
|---|---|
| AASHTO | Standard Specification for Highway Bridges-Division II, Section 26<br>LRFD Bridge Construction Specifications |
| ASTM | Standard Practice for Installing Factory Made Corrugated Steel Pipe for Sewers and Other Applications — ASTM A798<br>Standard Practice for Installing Corrugated Steel Structural Plate Pipe for Sewers and Other Applications — ASTM A807 |
| AREMA | Manual for Railway Engineering – Section 4.12 |
| U.S. Dept. of Agriculture — Natural Resources Conservation Service | Construction Specification Section 51 Paragraph 6 Service |
| U.S. Dept of Agriculture Forest Service | Specification for Construction of Roads and Bridges, Section 603.04 through 603.08. |
| Federal Lands Highway | FP92 Section 602.03, 602.05, 602.07, and 602.08 |



■ A flat gasket rolled back over itself ready to receive the next section of pipe.



An O-ring gasket in place in the valley of the last corrugation on the end of the pipe.

# CORRUGATED STEEL PIPE COUPLING SYSTEMS

## Field Joints for Corrugated Steel Pipe

The performance and material requirements for CSP coupling systems are scattered among several ASTM and AASHTO specifications. The two most commonly used specifications for defining CSP coupling systems are Section 26 of the AASHTO Standard Construction Specification for Highway Bridges and ASTM A760, Standard Specification for Corrugated Steel Pipe, Metallic Coated for Sewers and Drains. All CSP coupling systems involve one of the coupling bands depicted in Table 2.53 and may require a flat or o-ring gasket as also depicted in the same table. Figure 2.20 shows cross-section of assembled CSP coupling systems.

The performance of these coupling systems is defined by the amount of water or soil particles that pass through the joint. The basic joint specifications is the soil tight coupling system which has been the CSP joint specified for most culverts and storm sewers for nearly 100 years, with proven performance. The coupling system is defined by limiting the size of the openings that allow backfill materials to infiltrate into the pipe. If the specifications for a coupling system is made more restrictive, it may be necessary to include or improve a gasket as part of that system, and/or possibly include a geotextile wrap around the joint area on the outside of the pipe. Joining systems classified as leak resistant, will limit leakage to a limited amount of water passing through the joint. Consult NCSPA's website at www.ncspa.org or your local CSP fabricator for guidance on the coupling system appropriate for your project.

## Table 2.53

Coupling bands for corrugated steel pipe

| Type Of Band | Cross Section | Angles | Bar, Bolt & Strap | Wedge Lock | Gaskets | | | Pipe Type | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | O Ring | Sleeve or Strip | Mastic | Annular | Helical | |
| | | | | | | | | | Plain End | Reformed End |
| Universal | | X | X | X | | X | X | X | X | X |
| Corrugated | | X | X | X | | X | X | X | X | X |
| Semi-Corrugated | | X | X | X | X | | X | X | | X |
| Channel | | X | X | | X | | X | | | X |
| Flat | | X | X | X | | X | X | X | X | X |
| Hat | | X | X | | | | X | | | X |

■ Two-piece corrugated band joins length of annular riveted pipe.

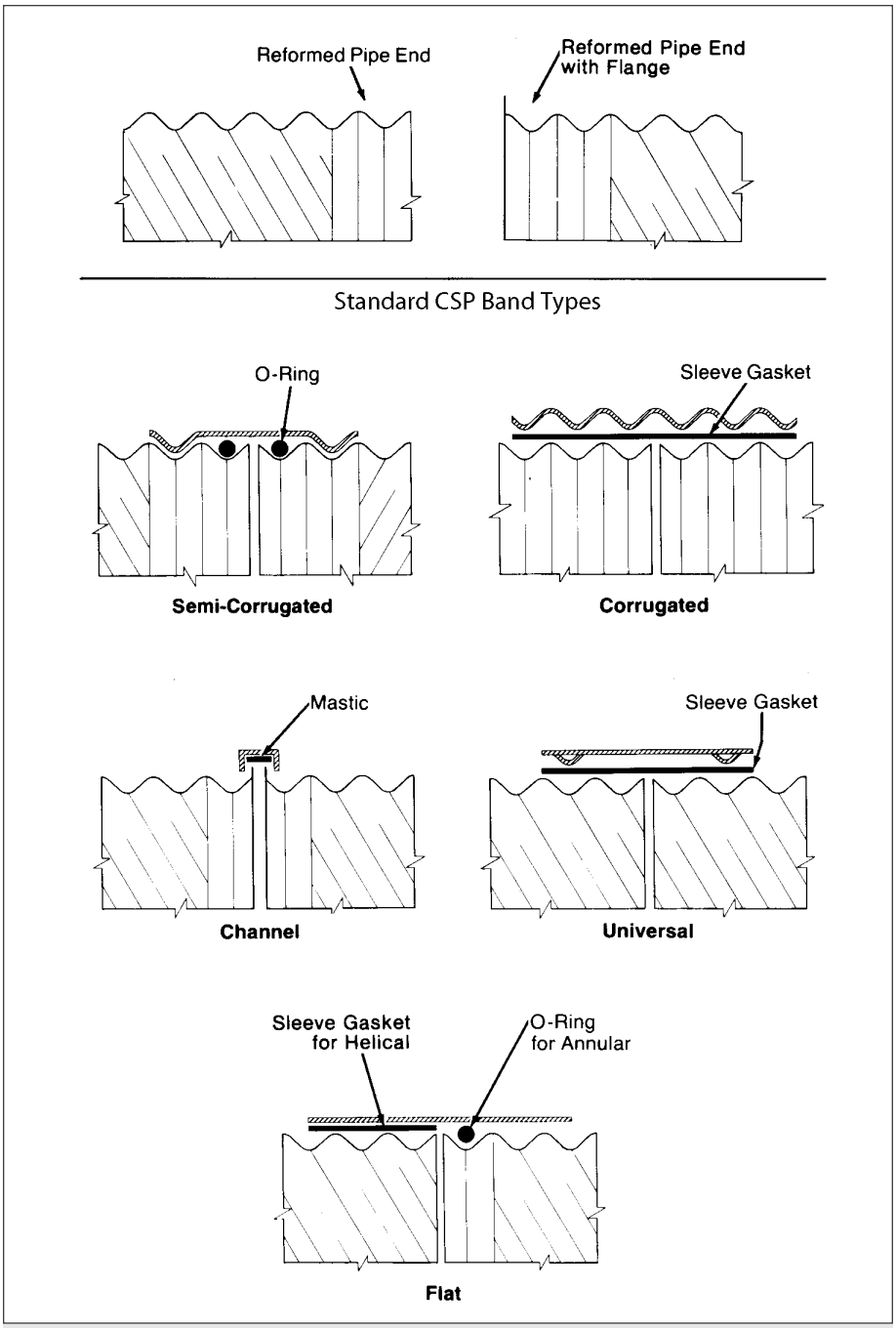
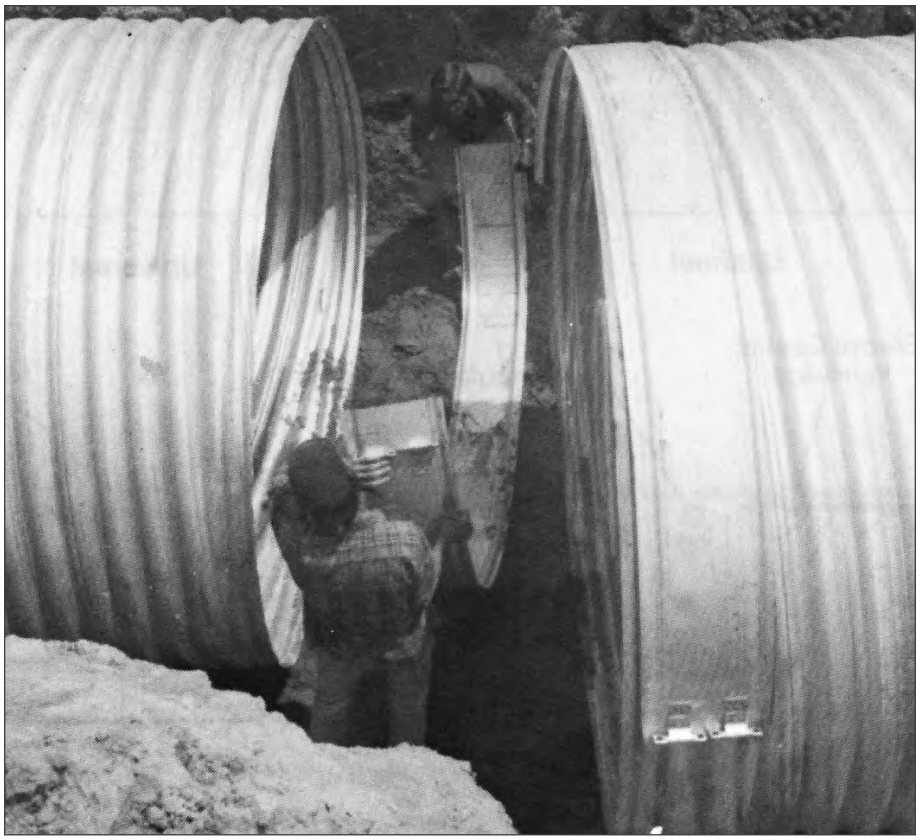
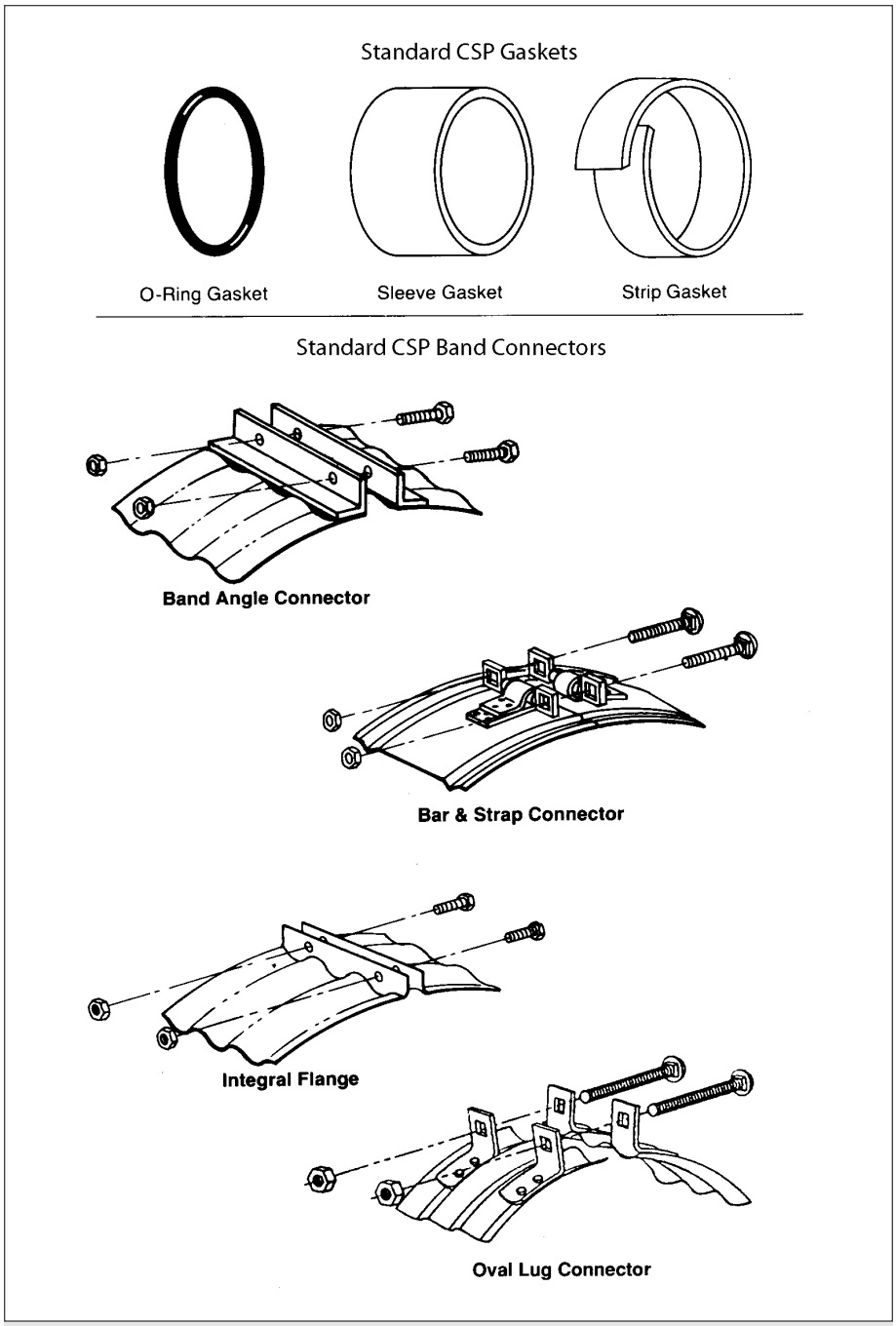



**Figure 2.20** Standard corrugated steel bands.




■ Two-piece bands being installed on reformed ends of CSP.

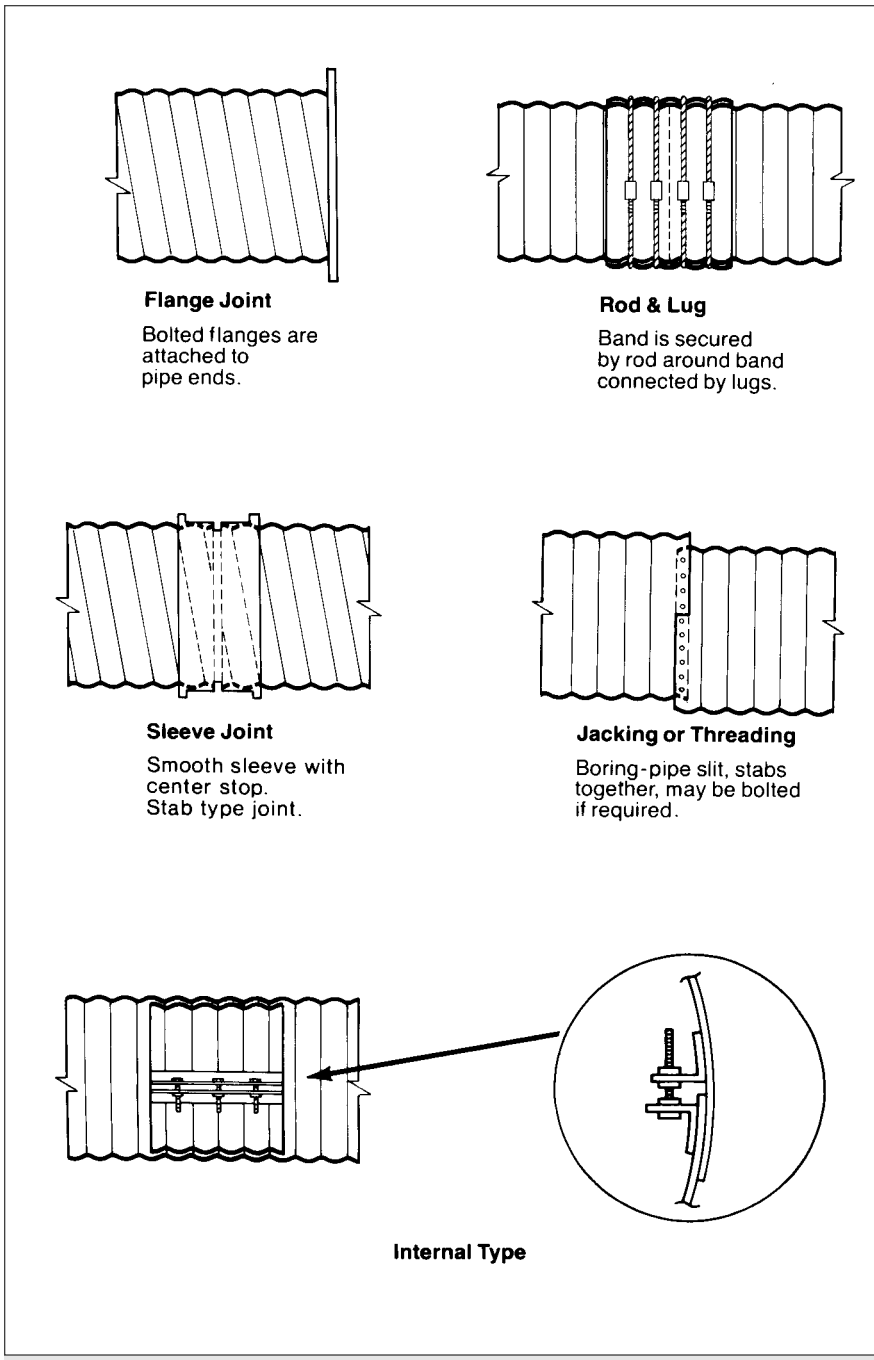



■ **Figure 2.21** Standard corrugated steel pipe band connectors and gaskets.


■ Corrugated steel pipe band connectors.

## CSP Field Joints

For unusual conditions, such as high pressures, extreme disjointing forces, threading pipe inside existing pipe, jacking or boring pipe, and deep vertical drop inlets, a variety of special designs are available. New joints can be readily designed by manufacturers to meet particular requirements.

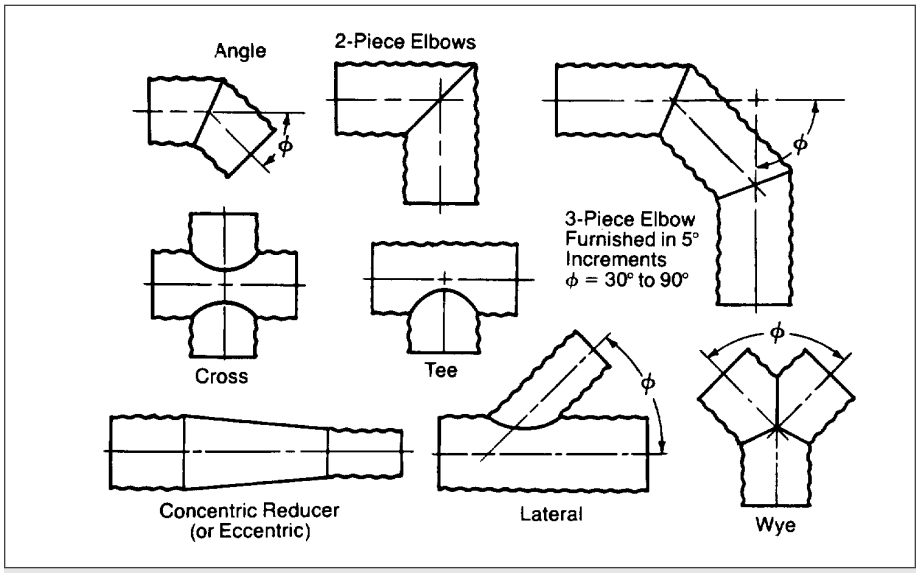



■ **Figure 2.22** Special connectors.

## Fittings

One of the benefits of corrugated steel pipe is that it can be easily and economically fabricated into an assortment of fittings. Table 2.54 provides minimum dimensions for CSP elbows (round pipe). Table 2.55 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. Theses 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.

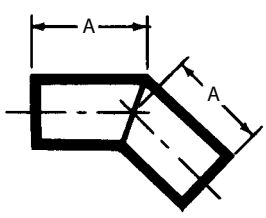



■ **Figure 2.23** Shop fittings for corrugated steel pipe and pipe arch. Shop fabricated fittings are available for a wide variety of conditions.

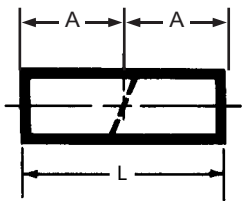
■ Moderate horizontal curvature in a culvert or sewer can be achieved with ordinary couplings. Greater changes in alignment will require fabricated fittings.

## Table 2.54

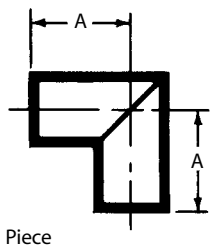
Minimum dimensions for elbows for round CSP –– all corrugations



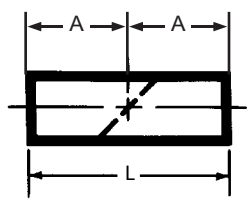

2 Piece



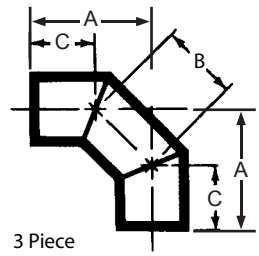

10° - 45° Elbow



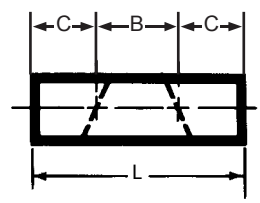

2 Piece




46° - 90° Elbow




3 Piece



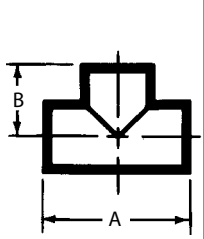

46° - 90° Elbow

| Pipe Diameter (in.) | A (ft) | Total Length (ft) | Pipe Diameter (in.) | A (ft) | Total Length (ft) | Pipe Diameter (in.) | A (in.) | B (in.) | C (in.) | Total Length (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| 6-18 | 1 | 2 | 6-10 | 1 | 2 | 6 | 13 1/2 | 8 | 8 | 2 |
| 21-48 | 2 | 4 | 12-27 | 2 | 4 | 8 | 14 | 9 | 7 1/2 | 2 |
| 54-96 | 3 | 6 | 30-42 | 3 | 6 | 10 | 14 | 10 | 7 | 2 |
| | | | 48-66 | 4 | 8 | 12 | 25 1/2 | 11 | 18 1/2 | 4 |
| | | | 72-84 | 5 | 10 | 15 | 26 1/2 | 12 | 18 | 4 |
| | | | 90-96 | 6 | 12 | 18 | 27 | 14 | 17 | 4 |
| | | | | | | 21 | 27 | 15 | 16 1/2 | 4 |
| | | | | | | 24 | 27 1/2 | 16 | 16 | 4 |
| | | | | | | 27 | 27 1/2 | 17 | 15 1/2 | 4 |
| | | | | | | 30 | 40 | 19 | 26 1/2 | 6 |
| | | | | | | 33 | 40 | 20 | 26 | 6 |
| | | | | | | 36 | 40 1/2 | 21 | 25 1/2 | 6 |
| | | | | | | 42 | 41 | 23 | 24 1/2 | 6 |
| | | | | | | 48 | 53 1/2 | 26 | 35 | 8 |
| | | | | | | 54 | 54 | 28 | 34 | 8 |
| | | | | | | 60 | 54 1/2 | 31 | 32 1/2 | 8 |
| | | | | | | 66 | 54 | 33 | 31 1/2 | 8 |
| | | | | | | 72 | 67 1/2 | 36 | 42 | 10 |
| | | | | | | 78 | 68 | 39 | 40 1/2 | 10 |
| | | | | | | 84 | 68 1/2 | 41 | 39 1/2 | 10 |
| | | | | | | 90 | 70 | 46 | 37 | 10 |
| | | | | | | 96 | 82 | 46 | 49 | 12 |

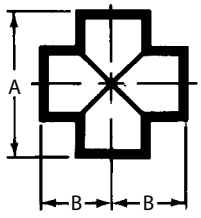
Notes: The total length (ft) and pipe diameter (in.) listed are minimum requirements for fitting fabrication. Fittings with other dimensions to satisfy specific needs are also available. All dimensions are nominal.

## Table 2.55

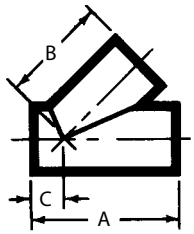
Minimum dimensions for CSP round fittings



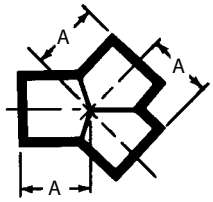

Tee




Cross




45° Lateral



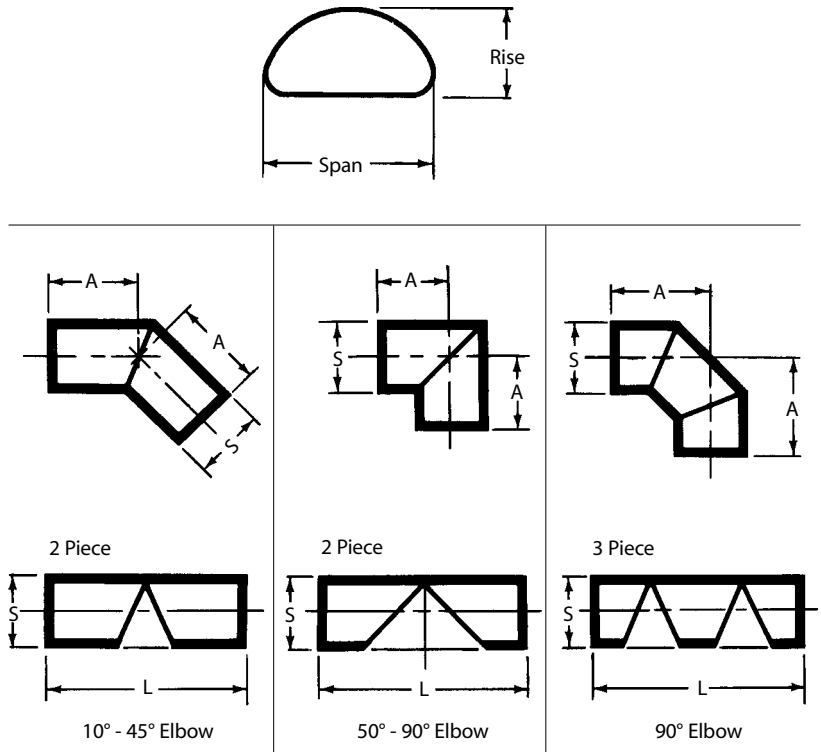

45° Wye

| Main Diam. | Stub Same or Smaller Than Main Diameter | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tee | | | Cross | | | 45° Lateral | | | | 45° Wye | | |
| | A | B | TL | A | B | TL | A | B | C | TL | A | B | TL |
| (in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) | (ft-in.) |
| 6 | 2-6 | 1-3 | 3-9 | 2-6 | 1-3 | 5-0 | 2-9 | 1-6 | 1-2 | 4-3 | 1-1 | 1-3 | 3-7 |
| 8 | 2-8 | 1-4 | 4-0 | 2-8 | 1-4 | 5-4 | 3-0 | 1-8 | 1-2 | 4-8 | 1-2 | 1-4 | 3-10 |
| 10 | 2-10 | 1-5 | 4-2 | 2-10 | 1-5 | 5-8 | 3-2 | 1-10 | 1-2 | 5-0 | 1-2 | 1-5 | 4-0 |
| 12 | 3-0 | 1-6 | 4-6 | 3-0 | 1-6 | 6-0 | 3-5 | 2-0 | 1-3 | 5-5 | 1-3 | 1-6 | 4-3 |
| 15 | 3-3 | 1-8 | 4-11 | 3-3 | 1-8 | 6-6 | 3-9 | 2-3 | 1-3 | 6-0 | 1-3 | 1-8 | 4-7 |
| 18 | 3-6 | 1-9 | 5-3 | 3-6 | 1-9 | 7-0 | 4-2 | 2-6 | 1-4 | 6-8 | 1-4 | 1-9 | 4-10 |
| 21 | 3-9 | 1-11 | 5-10 | 3-9 | 1-11 | 7-6 | 4-6 | 2-9 | 1-4 | 7-3 | 1-4 | 1-11 | 5-2 |
| 24 | 4-0 | 2-0 | 6-0 | 4-0 | 2-0 | 8-0 | 4-10 | 3-0 | 1-5 | 7-10 | 1-5 | 2-0 | 5-5 |
| 27 | 4-3 | 2-2 | 6-5 | 4-3 | 2-2 | 8-6 | 5-2 | 3-3 | 1-6 | 8-5 | 1-5 | 2-2 | 5-9 |
| 30 | 4-6 | 2-3 | 6-9 | 4-66 | 2-3 | 9-0 | 5-6 | 3-6 | 1-6 | 9-0 | 1-6 | 2-3 | 6-0 |
| 33 | 4-9 | 2-5 | 7-2 | 4-9 | 2-5 | 9-6 | 5-11 | 3-9 | 1-7 | 9-8 | 1-7 | 2-4 | 6-3 |
| 336 | 5-0 | 2-6 | 7-6 | 5-0 | 2-6 | 10-0 | 6-3 | 4-0 | 1-8 | 10-3 | 1-8 | 2-6 | 6-8 |
| 42 | 5-6 | 2-9 | 8-3 | 5-6 | 2-9 | 11-0 | 7-0 | 4-6 | 1-9 | 11-6 | 1-9 | 2-9 | 7-3 |
| 48 | 6-0 | 3-0 | 9-0 | 6-0 | 3-0 | 12-0 | 7-8 | 5-0 | 1-10 | 12-8 | 1-10 | 3-0 | 7-10 |
| 54 | 6-6 | 3-3 | 9-9 | - | - | - | 8-4 | 5-6 | 1-11 | 13-10 | 1-11 | 3-3 | 8-5 |
| 60 | 7-0 | 3-6 | 10-6 | - | - | - | 9-1 | 6-0 | 2-0 | 15-1 | 2-0 | 3-6 | 9-0 |
| 66 | 7-6 | 3-9 | 11-3 | - | - | - | 9-9 | 6-6 | 2-2 | 16-3 | 2-2 | 3-9 | 9-8 |
| 72 | 8-0 | 4-0 | 12-0 | - | - | - | 10-6 | 7-0 | 2-3 | 17-6 | 2-3 | 4-0 | 10-3 |
| 78 | 8-6 | 4-3 | 12--9 | - | - | - | 11-2 | 7-6 | 2-4 | 18-8 | 2-4 | 4-3 | 10-10 |
| 84 | 9-0 | 4-6 | 13-6 | - | - | - | 11-11 | 8-0 | 2-5 | 19-11 | 2-5 | 4-6 | 11-5 |
| 90 | 9-6 | 4-9 | 14-3 | - | - | - | 12-8 | 8-6 | 2-7 | 21-2 | 2-7 | 4-9 | 12-1 |
| 96 | 10-0 | 5-0 | 15-0 | - | - | - | 13-4 | 9-0 | 2-8 | 22-4 | 2-8 | 5-0 | 12-8 |

Notes: 12 in. minimum stub dimension to allow for use of 12 in. wide connecting band.
TL - total net length needed to fabricate fitting.

## Table 2.56

Minimum dimensions for CSP pipe arch fittings

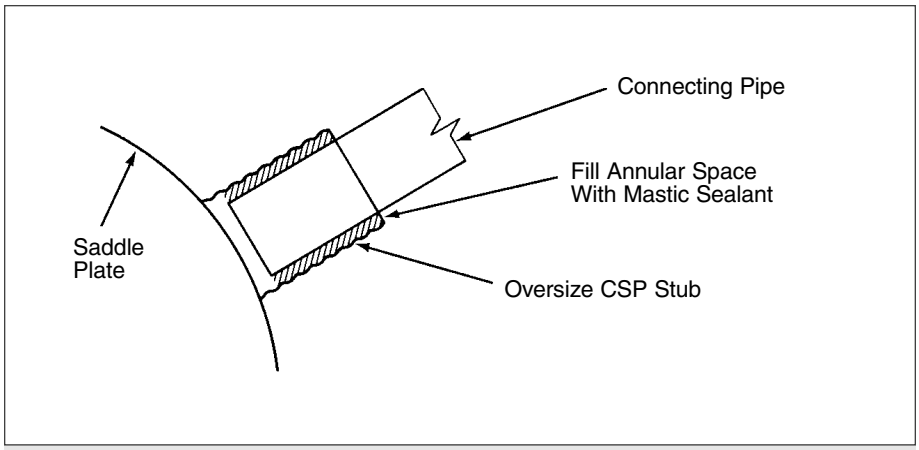



| Equivalent Round Diameter | Span S | Rise R | 45° Elbow 2 Piece | | 90° Elbow 2 Piece | | 90° Elbow 3 Piece | |
|---|---|---|---|---|---|---|---|---|
| | | | A | L | A | L | A | L |
| (in.) | (in.) | (in.) | (in.) | (ft) | (in.) | (ft) | (in.) | (ft) |
| 15 | 17 | 13 | 20 | 4 | 27 | 6 | 31 | 6 |
| 18 | 21 | 15 | 20 | 4 | 25 | 6 | 30 | 6 |
| 21 | 24 | 18 | 19 | 4 | 24 | 6 | 29 | 6 |
| 24 | 28 | 20 | 18 | 4 | 34 | 8 | 28 | 6 |
| 30 | 35 | 24 | 16 | 4 | 30 | 8 | 38 | 8 |
| 36 | 42 | 29 | 27 | 6 | 38 | 10 | 35 | 8 |
| 42 | 49 | 33 | 25 | 6 | 35 | 10 | 45 | 10 |
| 48 | 57 | 38 | 24 | 6 | 43 | 12 | 42 | 10 |
| 54 | 64 | 43 | 34 | 8 | 52 | 14 | 52 | 12 |
| 60 | 71 | 47 | 33 | 8 | 60 | 16 | 62 | 14 |
| 66 | 77 | 52 | 43 | 10 | 56 | 16 | 60 | 14 |
| 72 | 83 | 57 | 42 | 10 | 56 | 18 | 70 | 16 |

Notes: All dimensions are nominal.
L—length for fabrication

## Saddle Branch

Saddle branches are used to connect small branch lines to the main. Saddles make it practical to tie in connections accurately after the main line is laid, or, new connections can be made effectively on old lines with saddles. Saddles can be used to connect almost any type of pipe to a CSP main. A common universal type of saddle branch stub is shown below.




■ **Figure 2.24** Universal connection detail using saddle branch.

■ **Figure 2.25** Typical pre-fabricated CSP saddle branch fitting.

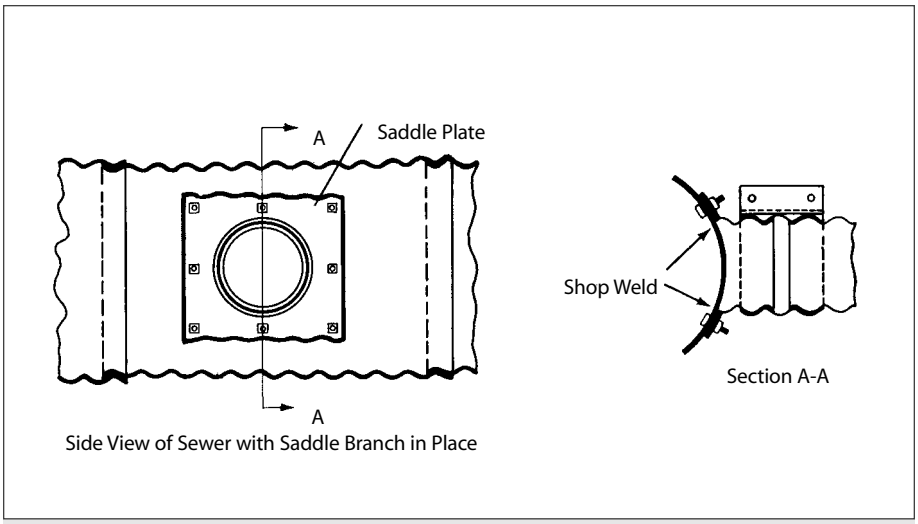
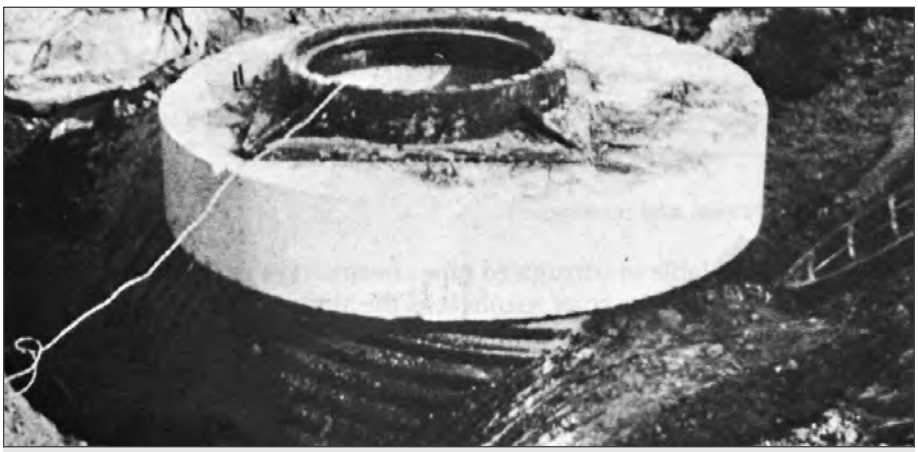



**Figure 2.26** Saddle branch.

Manholes are available in corrugated steel pipe construction in two basic types as shown in Figure 2.27. The riser type of manhole is the simpler of the two and very economical. It is only feasible for trunk lines with a 36 inch 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 36 inches diameter, some reduction details must be used to suit the cover. Typical reduction details are shown. Larger sizes may require reinforcement.



Standard cast iron covers and/or steel grates are used with CSP manholes and catch basins.

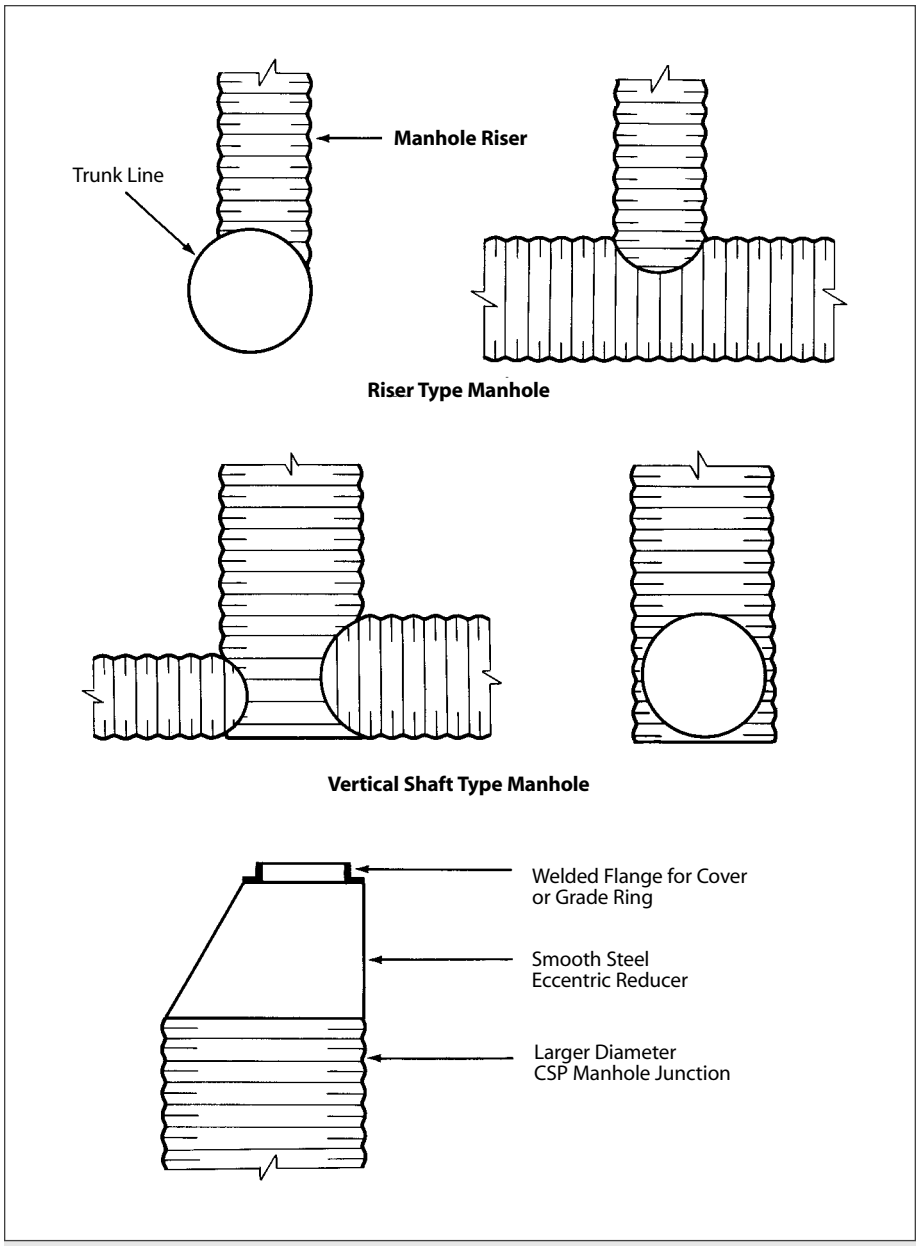
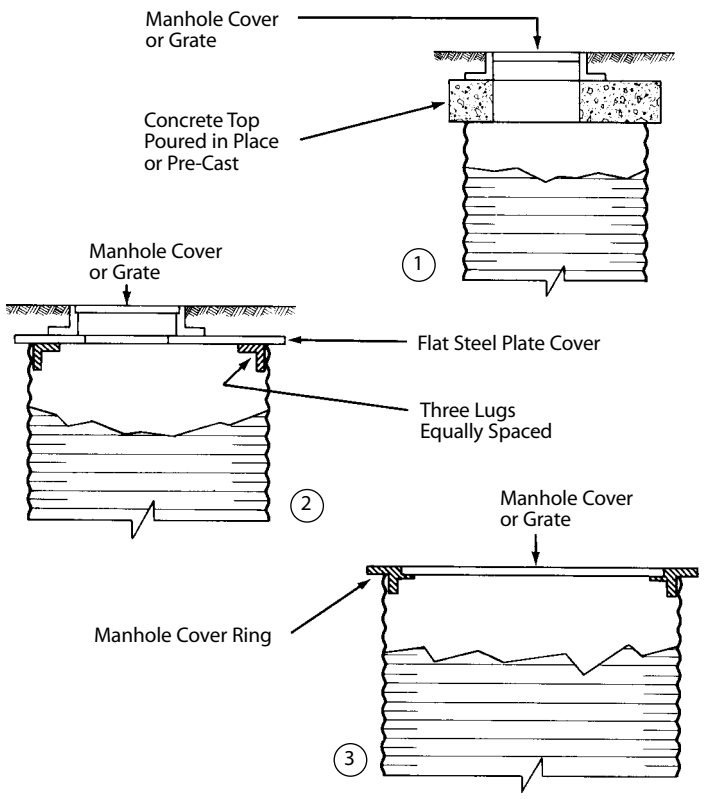



**Figure 2.27** Manholes and catchbasins.




Detail (1) can be used with almost any type of surface cover or grate. Concrete grade ring may be augmented with brick to raise cover elevation in the future. Alternatively, added concrete may be poured. Direct connections of cast or fabricated plates or rings as in (2) and (3) are particularly suitable for grated inlet openings.

■ **Figure 2.28** Manhole and catchbasin covers.

The manhole covers shown in Figure 2.28 transfer any load on the cover directly to the manhole riser. For this reason, manhole covers of this type should be placed only where vehicular traffic is not expected. If the manhole will be subjected to wheel loads, the manhole riser should be designed as per Chapter 8 of this manual.

■ Special galvanized steel fitting for lake water intake of power station. Sealant ribbons were used on all seams. Divers made under water bolted connection between sections.

■ King-size wye or lateral for large storm sewer was shop-assembled, then dismantled and shipped to the job site for final erection.

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

# END FINISH

## Purposes

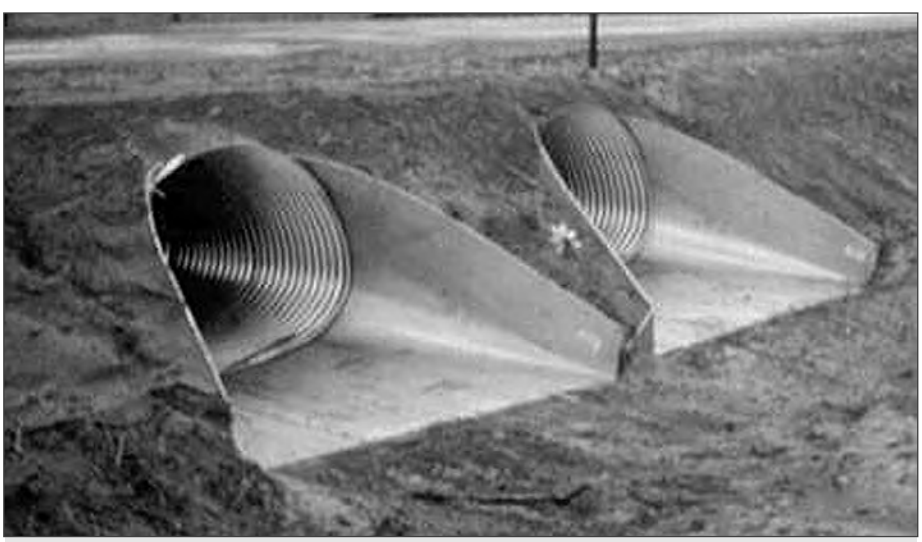
The principal purpose of end finish on corrugated steel pipe culverts or spillways is hydraulic efficiency—to prevent scour at the inlet, undermining at the outlet and to increase capacity. Other purposes may be to retain the fill slope, discourage burrowing rodents, or improve safety. For additional information, see Chapters 4 and 5, on Hydraulic Design, and Chapters 7 and 8, Structural Design and Special Design.

## Types of Finish

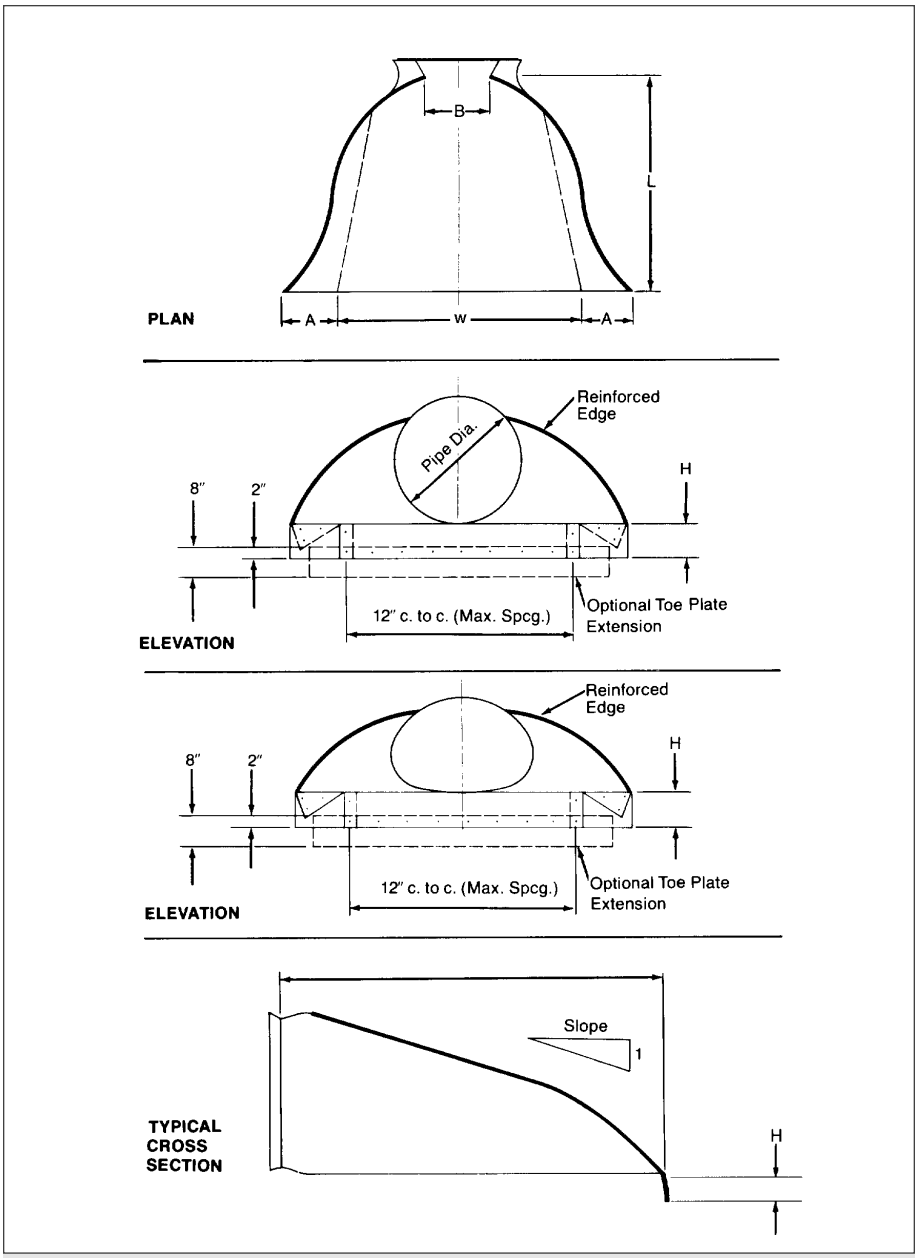
Types of steel end finishes include (1) end sections, flared and prefabricated, (2) safety slope end sections, (3) riprap and others, (4) skews and bevels, and (5) steel sheeting to serve as a low headwall and cutoff wall.

1. End Sections. Steel end sections are shop fabricated for assembly in the field by attachment to corrugated steel culverts from 6 to 96 inches diameter or pipe arches from 17 x 13 inches to 142 x 91 inches Dimensions and other data are given in Tables 2.57 to 2.59 and Figures 2.29 and 2.30.

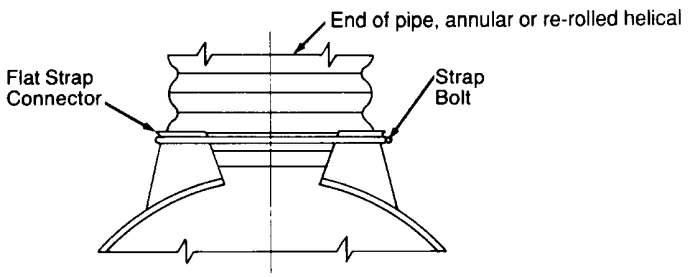
   These end sections are listed in standard specifications of state highway departments, county road departments, railroads and others. They meet the requirements for efficient and attractive end finish on culverts, conduits, spillways and sewer outfalls. They attach to the culvert ends by simple bolted connections of various designs and can be completely salvaged if lengthening or relocation is necessary.



■ Arch flared end sections.

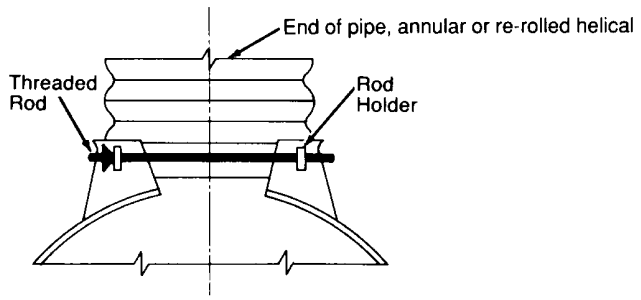



■ **Figure 2.29** End sections for round and pipe arch shapes.



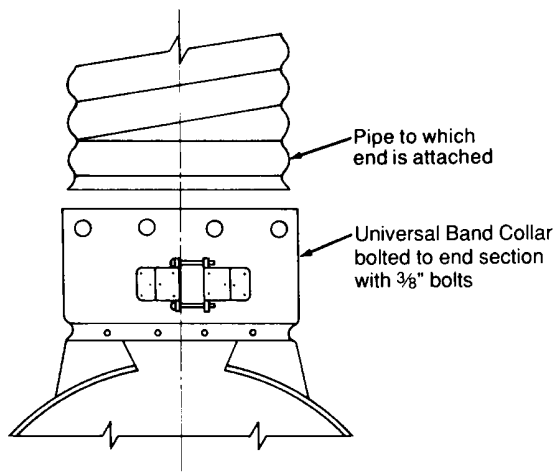

**TYPE #1**

Available in sizes 6 in. through 24 in. Round and
17 × 13 in. through 28 × 20 in. Pipe-Arches




**TYPE #2**

Available in sizes 30 in. and larger Round and
35 x 24 in. and larger Pipe-Arches.



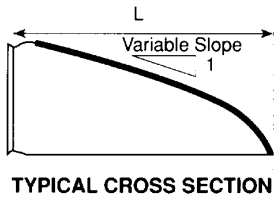

**TYPE #5**

Available for all Round and Pipe-Arch sizes equivalent round.
(Type 1 and Type 2 connections are recommended for
the smaller sizes with annular ends)

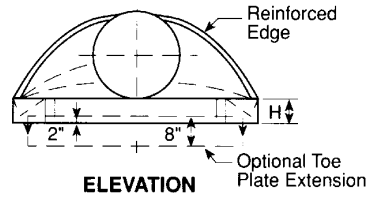
■ **Figure 2.30** End section connection details for round and pipe arch shapes.

## Table 2.57

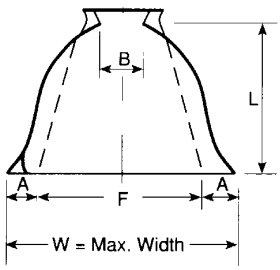
Dimensions of steel end sections for round pipe

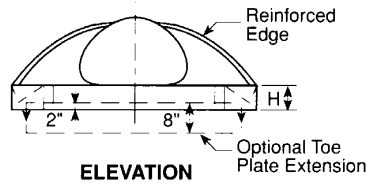



TYPICAL CROSS SECTION




ELEVATION




ELEVATION

| Pipe Diameter (in.) | Specified Thickness (in.) | A Min. (in.) | B Max. (in.) | H Min. (in.) | F Min. (in.) | L ± 2 (in.) | W Max Width (in.) | Average End Section Slope* (in.) |
|---|---|---|---|---|---|---|---|---|
| 6 | 0.052 | 3 | 1 | 3 | 10 | 8 | 24 | 13/4 |
| 8 | 0.052 | 5 | 5 | 4 | 14 | 14 | 32 | 23/8 |
| 10 | 0.052 | 5 | 6 | 6 | 18 | 14 | 39 | 2 |
| 12 | 0.064 | 5 | 7 | 6 | 22 | 21 | 44 | 21/4 |
| 15 | 0.064 | 6 | 8 | 6 | 28 | 26 | 52 | 21/4 |
| 18 | 0.064 | 7 | 10 | 6 | 34 | 31 | 58 | 21/8 |
| 21 | 0.064 | 8 | 12 | 6 | 40 | 36 | 66 | 21/8 |
| 24 | 0.064 | 9 | 1 3 | 6 | 46 | 41 | 72 | 21/8 |
| 30 | 0.079 | 11 | 16 | 8 | 55 | 51 | 88 | 21/8 |
| 36 | 0.079 | 13 | 19 | 9 | 70 | 60 | 105 | 2 |
| 42 | 0.109 | 15 | 25 | 10 | 82 | 69 | 122 | 21/8 |
| 48 | 0.109 | 17 | 29 | 12 | 88 | 78 | 131 | 2 |
| 54 | 0.109 | 17 | 33 | 12 | 100 | 84 | 143 | 2 |
| 60 | 0.109 | 17 | 36 | 12 | 112 | 87 | 157 | 17/8 |
| 66 | 0.109 | 17 | 39 | 12 | 118 | 87 | 162 | 15/8 |
| 72 | 0.109 | 17 | 44 | 12 | 120 | 87 | 169 | 11/2 |
| 78 | 0.109 | 17 | 48 | 12 | 130 | 87 | 178 | 13/8 |
| 84 | 0.109 | 17 | 52 | 12 | 136 | 87 | 184 | 11/3 |
| 90 | 0.109 | 17 | 58 | 12 | 142 | 87 | 188 | 11/4 |
| 96 | 0.109 | 17 | 58 | 12 | 144 | 87 | 197 | 11/8 |

Notes: *Fill slope need not match the end section slope. Fill can be shaped at each site to fit.

1. End sections available in galvanized steel or aluminized steel, Type 2.
2. Some larger sizes may require field assembly.
3. Optional toe plates may be provided to depths specified.

## Table 2.58

Dimensions of steel end sections for pipe arch 2 2/3 x 1/2 in. corrugations

| Span x Rise (in.) | Equiv/ Round (in.) | Specified Thickness (in.) | A Min. (in.) | B Max. (in.) | H Min. (in.) | F Min. (in.) | L ± 2 (in.) | W Max Width (in.) | Approx. Average End Section Slope* (in.) |
|---|---|---|---|---|---|---|---|---|---|
| 17 x 13 | 15 | 0.064 | 5 | 9 | 6 | 28 | 20 | 52 | 2 1/8 |
| 21 x 15 | 18 | 0.064 | 6 | 11 | 6 | 34 | 24 | 58 | 2 |
| 24 x 18 | 21 | 0.064 | 7 | 12 | 6 | 40 | 28 | 63 | 2 1/8 |
| 28 x 20 | 24 | 0.064 | 7 | 16 | 6 | 46 | 32 | 70 | 2 |
| 35 x 24 | 30 | 0.079 | 9 | 16 | 6 | 58 | 39 | 85 | 1 7/8 |
| 42 x 29 | 36 | 0.079 | 11 | 18 | 7 | 73 | 46 | 104 | 1 7/8 |
| 49 x 33 | 42 | 0.109 | 12 | 21 | 9 | 82 | 53 | 117 | 1 3/4 |
| 57 x 38 | 48 | 0.109 | 16 | 26 | 12 | 88 | 62 | 132 | 1 7/8 |
| 64 x 43 | 54 | 0.109 | 17 | 30 | 12 | 100 | 69 | 144 | 1 7/8 |
| 71 x 47 | 60 | 0.109 | 17 | 36 | 12 | 112 | 77 | 156 | 1 7/8 |
| 77 x 52 | 66 | 0.109 | 17 | 36 | 12 | 124 | 77 | 167 | 1 5/8 |
| 83 x 57 | 72 | 0.109 | 17 | 44 | 12 | 130 | 77 | 177 | 1 1/2 |

Notes: *Fill slope need not match the end section slope. Fill can be shaped at each site to fit.
1. End sections available in galvanized steel or aluminized steel, Type 2.
2. Some larger sizes may require field assembly.
3. Optional toe plates may be provided to depths specified.

## Table 2.59

Dimensions of steel end sections for pipe arch 3 x 1 in. and 5 x 1 in. corrugations

| Span x Rise (in.) | Equiv/ Round (in.) | Specified Thickness (in.) | A Min. (in.) | B Max. (in.) | H Min. (in.) | F Min. (in.) | L ± 2 (in.) | W Max Width (in.) | Approx. Average End Section Slope* (in.) |
|---|---|---|---|---|---|---|---|---|---|
| 53 x 41 | 48 | 0.109 | 17 | 26 | 12 | 88 | 63 | 130 | 1 3/4 |
| 60 x 46 | 54 | 0.109 | 17 | 36 | 12 | 100 | 70 | 142 | 1 7/8 |
| 66 x 51 | 60 | 0.109 | 17 | 36 | 12 | 112 | 77 | 156 | 1 3/4 |
| 73 x 55 | 66 | 0.109 | 17 | 36 | 12 | 124 | 77 | 168 | 1 1/2 |
| 81 x 59 | 72 | 0.109 | 17 | 44 | 12 | 136 | 77 | 179 | 1 5/8 |
| 87 x 63 | 78 | 0.109 | 17 | 44 | 12 | 136 | 77 | 186 | 1 1/2 |
| 95 x 67 | 84 | 0.109 | 1 7 | 44 | 1 2 | 1 60 | 87 | 210 | 1 1/2 |
| 103 x 71 | 90 | 0.109 | 17 | 44 | 12 | 172 | 87 | 222 | 1 1/3 |
| 112 x 75 | 96 | 0.109 | 17 | 44 | 12 | 172 | 87 | 226 | 1 1/4 |
| 117 x 79 | 102 | 0.109 | 20 | 62 | 12 | 154 | 87 | 234 | 1 1/2 |
| 128 x 83 | 108 | 0.109 | 20 | 68 | 12 | 176 | 87 | 256 | 1 1/2 |
| 137 x 87 | 114 | 0.109 | 20 | 73 | 12 | 194 | 100 | 274 | 1 1/2 |
| 142 x 91 | 120 | 0.109 | 20 | 75 | 12 | 204 | 98 | 284 | 1 1/2 |

Notes: *Fill slope need not match the end section slope. Fill can be shaped at each site to fit.
1. End sections available in galvanized steel or aluminized steel, Type 2.
2. Some larger sizes may require field assembly.
3. Optional toe plates may be provided to depths specified.

2. Safety Slope End Sections. 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, 6 to 1, and 10 to 1 roadside embankments, has contributed significantly to improving the safety of our highways. The use of safety slope end sections on highway culverts maintains the safety design of the flattened roadway embankments. See figures 2.31 - 2.33. The pre-fabricated safety slope end sections are available with 4 to 1, 6 to 1, and 10 to 1 slopes and are designed to fit round pipe sizes from 12 inches through 60 inches and pipe arch sizes from 17 x 13 inches through 83 inches x 57 inches 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 scour and undercutting. The flat apron or bottom panels eliminate twisting or misalignment 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.

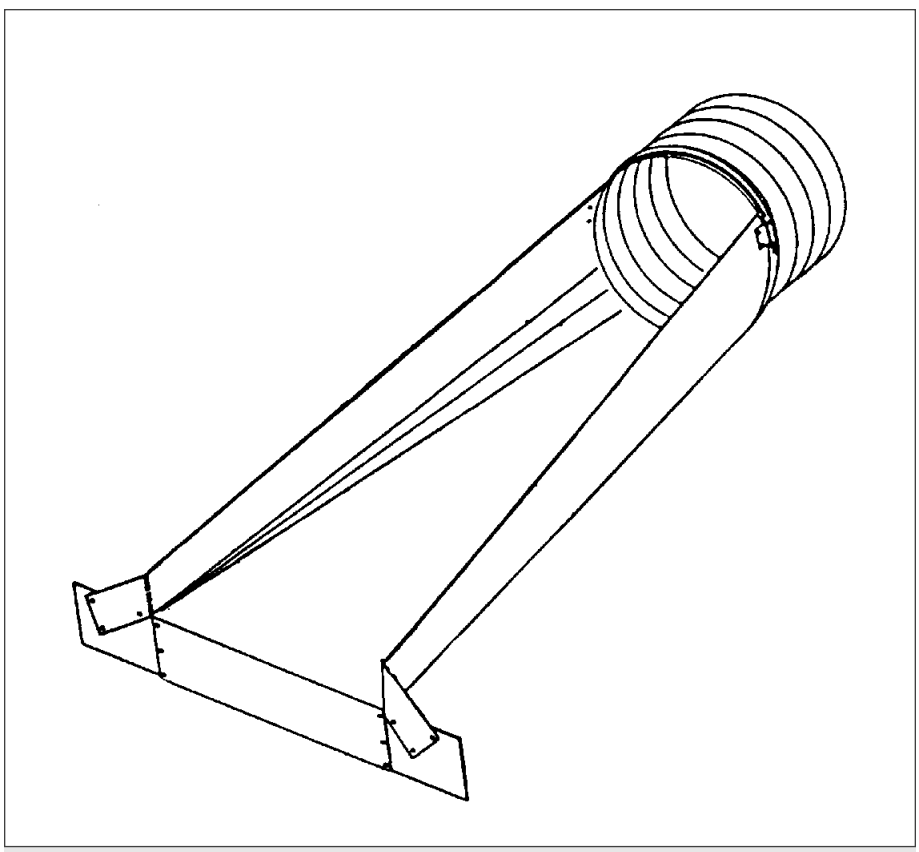


**Figure 2.31** Safety slope end section.

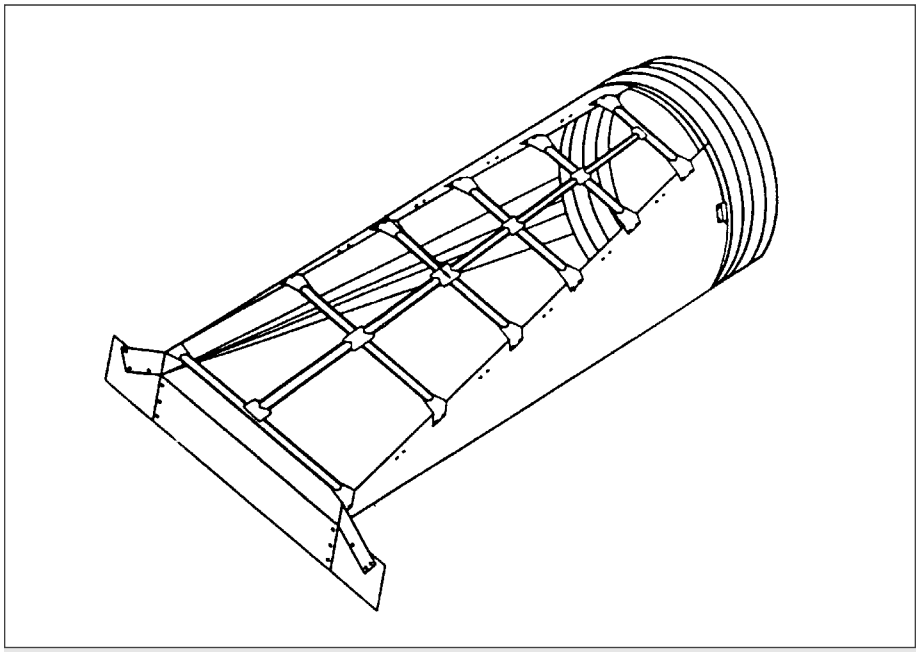


**Figure 2.32** Cross drainage bars on safety slope end section.

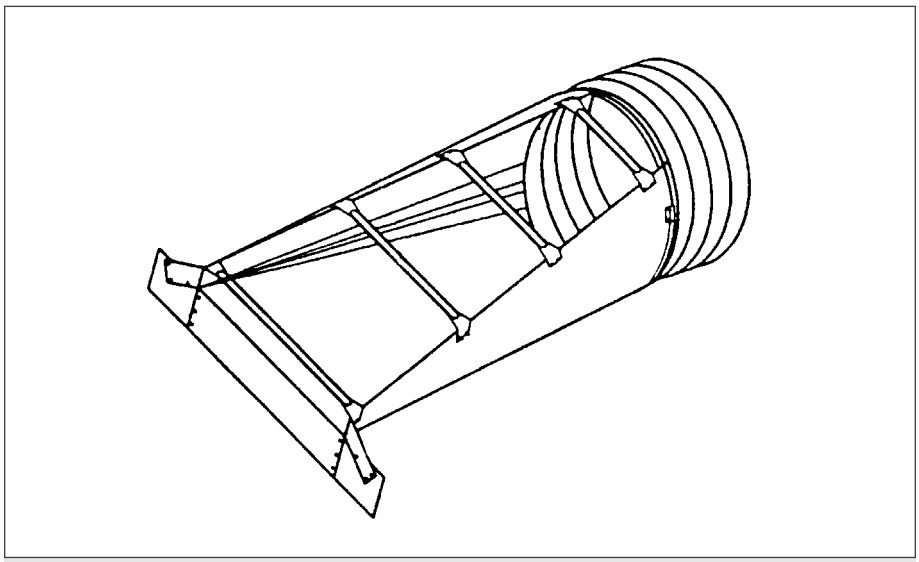


**Figure 2.33** Parallel bars on safety slope end section.

Cross drainage structures are those oriented under the main flow of traffic. On cross drainage structures, a small culvert is defined as a pipe with a 36 inch span or less or multiple pipes with a 30 inch span or less. Safety bars are not required on 30 inch spans or less when used in a cross drain application. Single structures with end sloped sections having spans greater than 36 inches can be made traversable for passenger size vehicles by using 3 inch safety bars to reduce the clear opening spans. 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, full scale crash tests have shown that passenger size vehicles can traverse cross drainage structures with safety slope end sections equipped with cross drainage bars. This work has shown when bars are spaced on 30 inch centers, automobiles can safely cross at speeds as low as 20 mph and as high as 60 mph.

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, 3 inch diameter safety bars set on 24 inch centers will significantly reduce wheel snagging.

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 2.60, 2.61 and 2.62.

■ Round pipe with flared end sections and head wall.

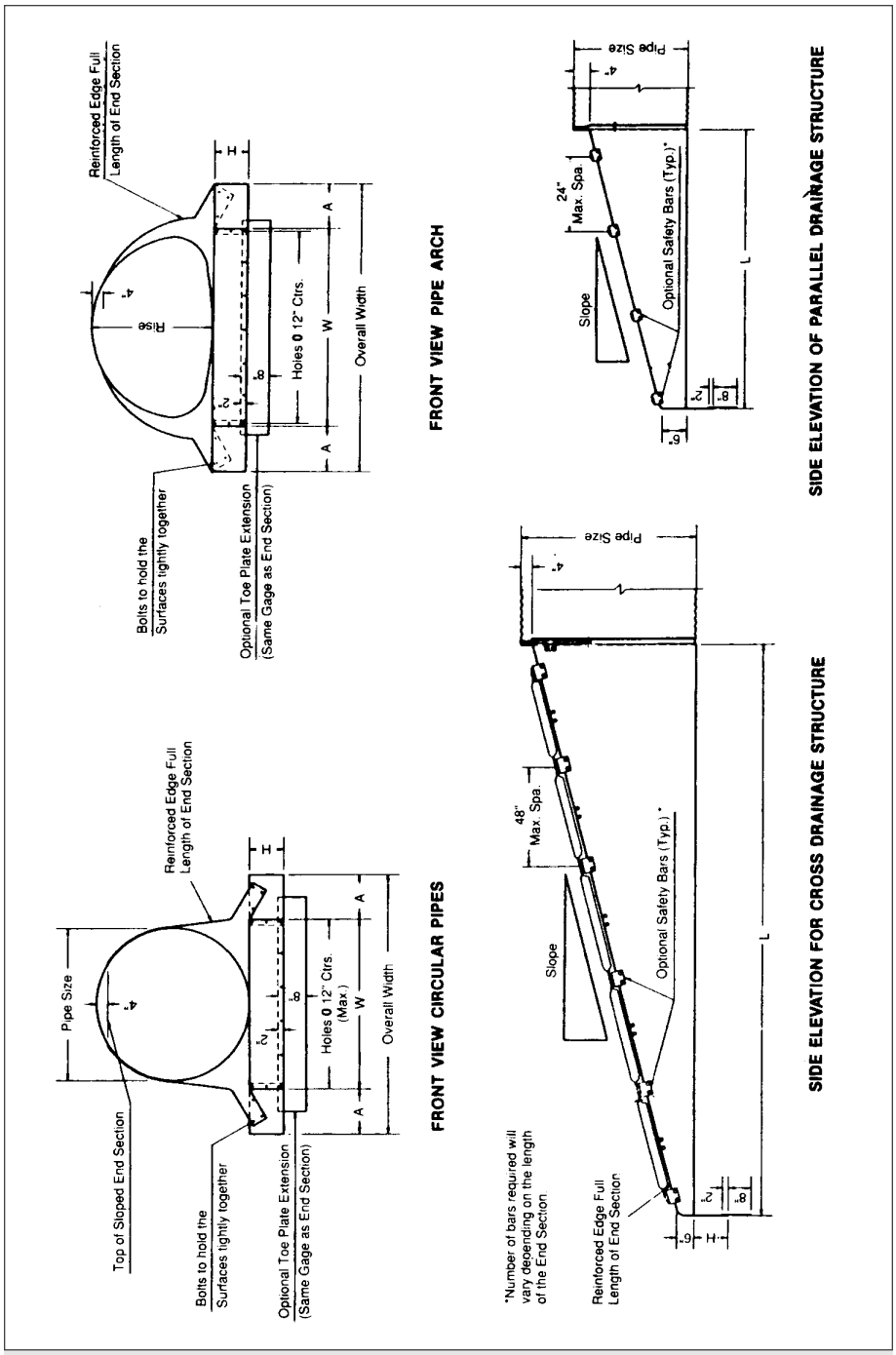



**Figure 2.34** Safety slope end section details for round and pipe arch shapes.

## Table 2.60

Dimensions of safety slope end sections for round pipe.
2 2/3 x 1/2 in., 3 x 1 in. and 5 x 1 in. corrugations

| Pipe Dia. (in.) | Specified Thickness (in.) | Dimensions (in.) | | | | L Dimensions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | H | W | Overall Width | Slope | Length (in.) | Slope | Length (in.) | Slope | Length (in.) |
| 12 | .064 | 8 | 6 | 18 | 34 | 4:1 | N/A | 6:1 | 29 | | |
| 15 | .064 | 8 | 6 | 21 | 37 | 4:1 | 20 | 6:1 | 30 | 10:1 | 70 |
| 18 | .064 | 8 | 6 | 24 | 40 | 4:1 | 32 | 6:1 | 48 | 10:1 | 100 |
| 21 | .064 | 8 | 6 | 27 | 43 | 4:1 | 44 | 6:1 | 66 | 10:1 | 130 |
| 24 | .064 | 8 | 6 | 30 | 46 | 4:1 | 56 | 6:1 | 84 | 10:1 | 160 |
| 30 | .109 | 12 | 9 | 36 | 60 | 4:1 | 80 | 6:1 | 120 | 10:1 | 220 |
| 36 | .109 | 12 | 9 | 42 | 66 | 4:1 | 104 | 6:1 | 156 | 10:1 | 280 |
| 42 | .109 | 16 | 12 | 48 | 80 | 4:1 | 128 | 6:1 | 192 | | |
| 48 | .109 | 16 | 12 | 54 | 86 | 4:1 | 152 | 6:1 | 228 | | |
| 54 | .109 | 16 | 12 | 60 | 92 | 4:1 | 176 | 6:1 | 264 | | |
| 60 | .109 | 16 | 12 | 66 | 98 | 4:1 | 200 | 6:1 | 300 | | |
| 66 | 0.109 | 16 | 12 | 72 | 104 | 4:1 | 224 | | | | |
| 72 | 0.109 | 16 | 12 | 78 | 110 | 4:1 | 248 | | | | |

## Table 2.61

Dimensions of slope end sections for pipe arch.
2 2/3 x 1/2 in. corrugations

| Pipe Dia. (in.) | Span x Rise (in.) | Specified Thickness (in.) | Dimensions (in.) | | | | L Dimensions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | H | W | Overall Width | Slope | Length (in.) | Slope | Length (in.) | Slope | Length (in.) |
| 15 | 17 x 13 | .064 | 8 | 6 | 23 | 39 | 4:1 | 20 | 6:1 | 30 | 10:1 | 70 |
| 18 | 21 x 15 | .064 | 8 | 6 | 27 | 43 | 4:1 | 20 | 6:1 | 30 | 10:1 | 70 |
| 21 | 24 x 18 | .064 | 8 | 6 | 30 | 46 | 4:1 | 32 | 6:1 | 48 | 10:1 | 100 |
| 24 | 28 x 20 | .064 | 8 | 6 | 34 | 50 | 4:1 | 40 | 6:1 | 60 | 10:1 | 120 |
| 30 | 35 x 24 | .079 | 12 | 9 | 41 | 65 | 4:1 | 56 | 6:1 | 84 | 10:1 | 160 |
| 36 | 42 x 29 | .109 | 12 | 9 | 48 | 72 | 4:1 | 76 | 6:1 | 114 | 10:1 | 210 |
| 42 | 49 x 33 | .109 | 16 | 12 | 55 | 87 | 4:1 | 92 | 6:1 | 138 | | |
| 48 | 57 x 38 | .109 | 16 | 12 | 63 | 95 | 4:1 | 112 | 6:1 | 168 | | |
| 54 | 64 x 43 | .109 | 16 | 12 | 70 | 102 | 4:1 | 132 | 6:1 | 198 | | |
| 60 | 71 x 47 | .109 | 16 | 12 | 77 | 109 | 4:1 | 148 | 6:1 | 222 | | |
| 72 | 83 x 57 | .109 | 16 | 12 | 89 | 121 | 4:1 | 188 | 6:1 | 282 | | |

Notes:
1. End sections available in galvanized steel or aluminized steel, Type 2.
2. Cross bars and parallel bars are 3 in. Schedule 40 galvanized pipe with flattened ends bent to match end section contour.
3. Edge of side wall to be rolled edges reinforced with a 7/16 in. diameter or #4 galvanized steel rod.
4. For attachment to structure use Type 1 for circular pipe through 24 in. diameter, use Type 2 for 30 in. and larger circular pipes and all arch pipes (see Figure 2.29).

## Table 2.62

Dimensions of metal slope end sections for pipe arch.
3 x 1 in. corrugations

| Equiv. Dia. (in.) | Span (in.) | Rise (in.) | Specified Thickness (in.) | Dimensions (in.) | | | | L Dimensions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A | H | W | Overall Width | Slope | Length (in.) | Slope | Length (in.) |
| 48 | 53 | x 41 | 0.109 | 16 | 12 | 59 | 91 | 4:1 | 132 | 6:1 | 198 |
| 54 | 60 | x 48 | 0.109 | 16 | 12 | 66 | 98 | 4:1 | 152 | 6:1 | 228 |
| 60 | 66 | x 51 | 0.109 | 16 | 12 | 72 | 104 | 4:1 | 172 | 6:1 | 258 |
| 66 | 73 | x 55 | 0.109 | 16 | 12 | 79 | 111 | 4:1 | 188 | 6:1 | 282 |
| 72 | 81 | x 59 | 0.109 | 16 | 12 | 87 | 119 | 4:1 | 204 | 6:1 | 306 |

Notes: 1. End sections available in galvanized steel or aluminized steel, Type 2.
2. Cross bars and parallel bars are 3 in. Schedule 40 galvanized pipe with flattened ends bent to match end section contour.
3. Edge of side wall to be rolled edges reinforced with a 7/16 in. diameter or #4 galvanized steel rod.
4. For attachment to structure use Type 2 (see Figure 2.29).

3. Other Protection. The slope at the end of a culvert (mitered or square cut) can be protected economically against erosion by riprap, gabions and other means. Stone riprap may be sealed by portland cement grout or asphaltic concrete.

4. Skews and Bevels. Skew and bevel ends may be ordered to fit local conditions, or may consist of a standard design as shown in Figures 2.36, 2.37 and 2.38. Details and essential considerations are discussed in Chapter 8, Special Design.

5. Steel Sheeting. 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, as shown in Figure 2.35. This type of end finish is particularly appropriate for large culverts which may have the ends beveled or step beveled. Length of the sheeting below the flow line should be one-half to one diameter of the culvert, with a minimum of 3 feet.

■ Standard end sections.

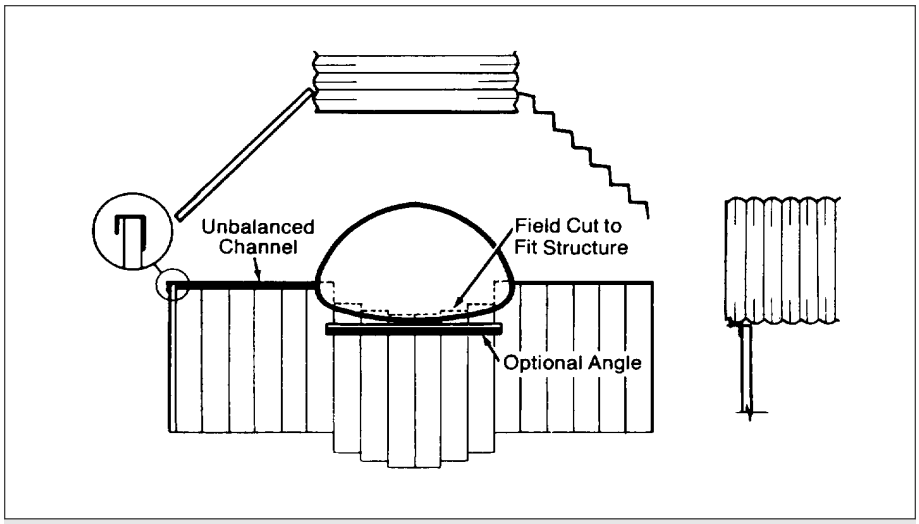



**Figure 2.35** How a steel sheeting headwall can be provided on a pipe arch culvert.

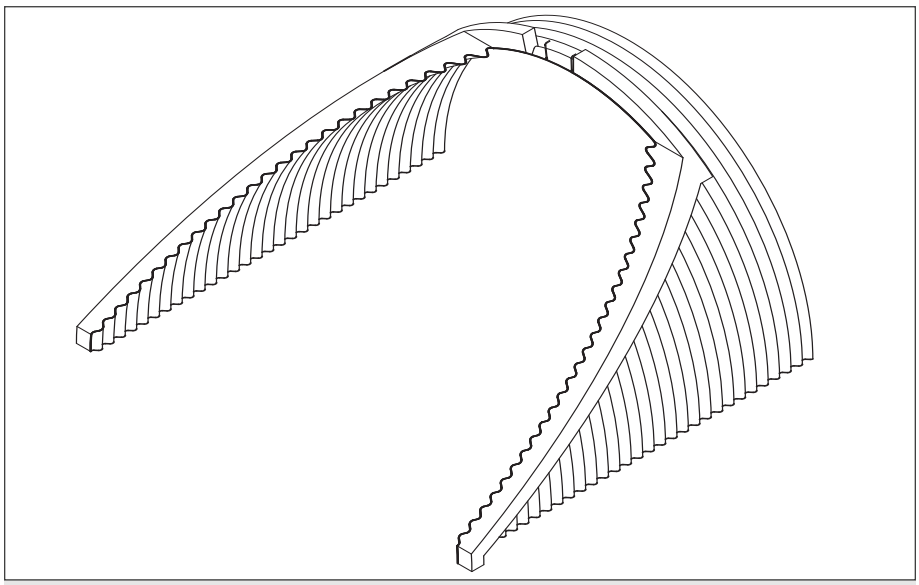


**Figure 2.36** Typical concrete collar on a structural plate arch with a beveled end.

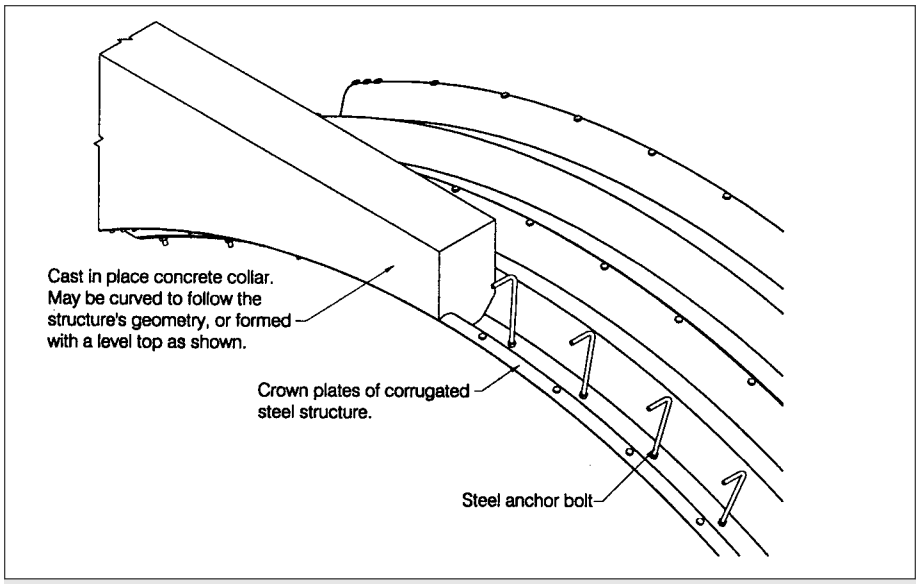



**Figure 2.37** Concrete end reinforcing collar.

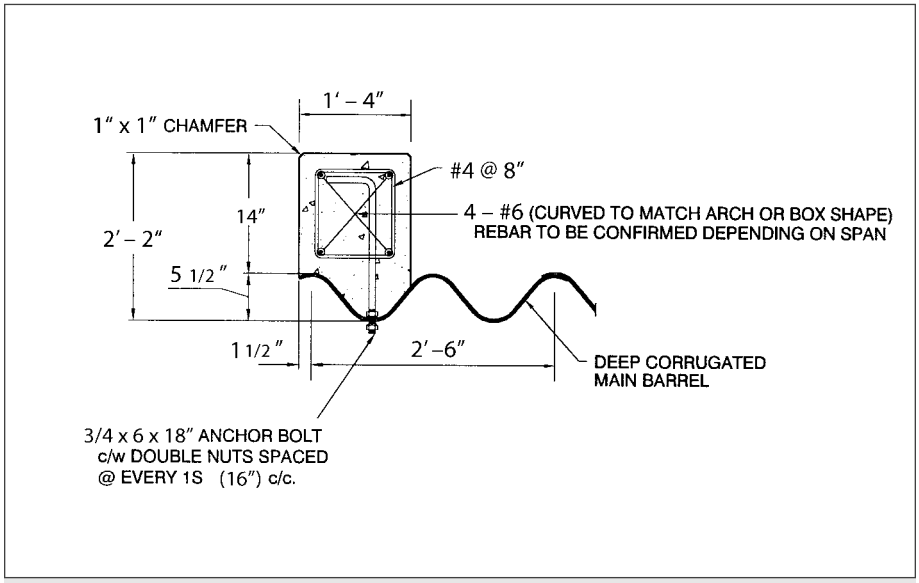



**Figure 2.38** Concrete collar detail – 15 x 5 1/2 in. structural plate.

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■ Deep corrugated structural plate arch during high flow.