Bethlehem

Steel Sheet

Piling

Bethlehem

Steel Sheet Piling Table of Contents

Foreword

Sheet piling products produced by Bethlehem are defined as hot-rolled structural sections with interlocks on the flange tips. Interlocks permit the joining of individual sections to form a continuous steel wail which is earth-tight and reasonably water resistant.

Bethlehem has been designing and supplying hot-rolled sheet piling sections to the construction industry for more than 75 years. This extensive experience in the production and application of sheet piling has given us the opportunity to become intimately involved in the evolution, engineering and field use of our current line of sheet piling sections.

By specifying these sections, the designer has selected sheet piling with excellent engineering properties. The Z-shaped sections provide efficient strength to weight ratios, and the shallow-arch and straight-web sections provide reliable and, when specified, high interlock strengths. Also, hot-rolled sheet piling is rugged and durable under difficult driving conditions and long-term exposure because of its interlocks and minimum 3/8-in, thickness.

The following pages will provide both the designer and the user with information to select, lay out and apply Bethlehem steel sheet piling sections.

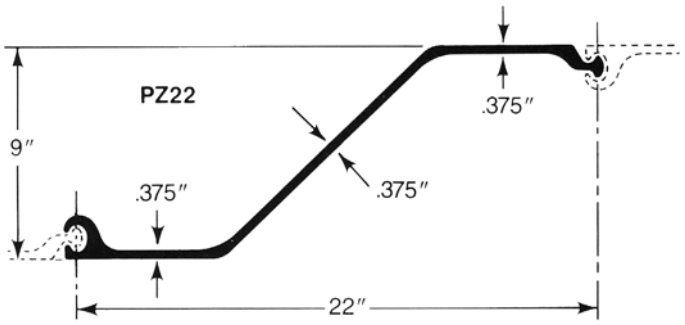
If you need additional product data, or information more specific to your particular project, please call our Piling Product Sales Office in Bethlehem direct: (800) 521-0432.

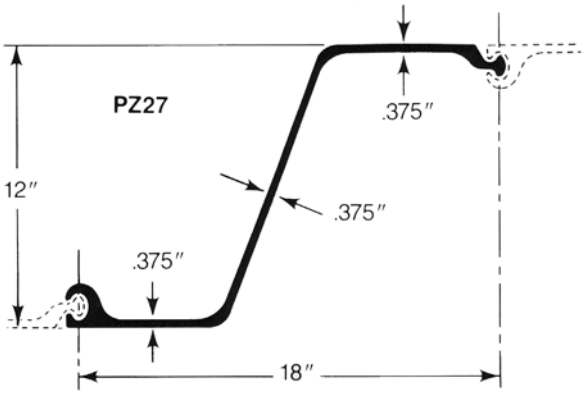
This publication contains information on the properties of Bethlehem hot-rolled sheet piling and H-piles based on accepted engineering practices. The use of the data contained herein must be supplemented with qualified professional judgment.

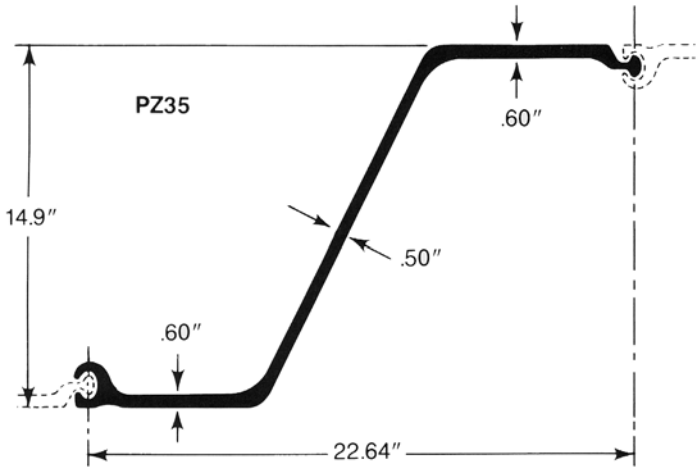
Dimensions and Properties of Sections

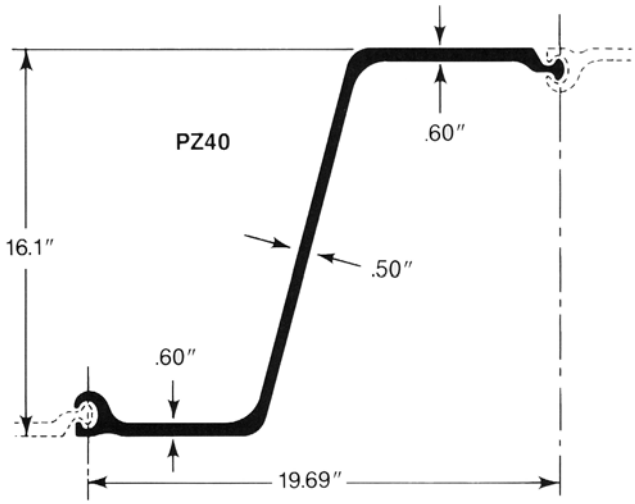
Sections designed for bending strength

(See page 6 for Z-piling data)



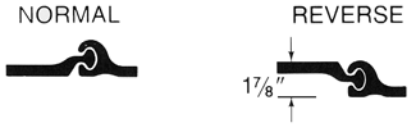






Interlocking

Because ball and socket dimensions are the same for all Bethlehem Z-piling sections, all Z-piling sections can interlock with one another. Also, because of the shape of the interlock, they can be joined in either of two arrangements.



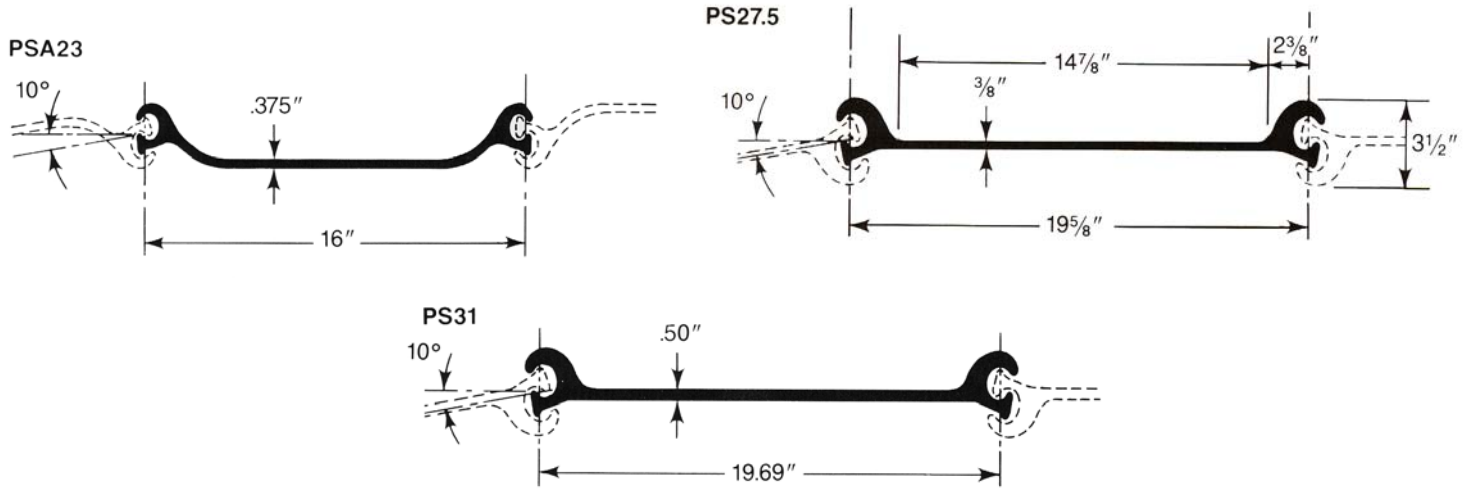
Sections Which Interlock With Each Other

PZ22	PZ27	PZ35	PZ40
	PSA23*		
PS27.5		PS31	

*See page 8 for information on interlocking PSA23 with Bethlehem Z-piling.

Sections PS27.5 and PS31 will interlock with each other, but will not interlock with any other section.

Sections designed for interlock strength
(See page 22 for data on cellular design)



Interlock strength:

PSA23, when properly interlocked, develops a minimum ultimate interlock strength of 12 kips per in. Excessive interlock tension results in web extensions for section P5A23. Therefore, the interlock tension for this section should be limited to a maximum working load of 3 kips per in.

PS27.5 and PS31, when properly interlocked, develop a minimum ultimate interlock strength of 16 kips per in. If a greater interlock strength is required, see page 23.

Swing:

PSA23, PS27.5 and PS31, when properly interlocked, are designed for a minimum swing of up to 10 degrees (in either direction) for lengths up to 70 ft. The ability to obtain a full 10 degree swing decreases because of the difficulty in handling the longer pieces. With longer pieces, it is necessary to anticipate a reduction in obtainable swing of 1.5 degrees for each 10 ft increase in length over 70 ft.

Properties and Weights

Section Designation	Area sq in.	Nominal Width, in.	Weight in Pounds		Moment of Inertia, in.^{4}	Section Modulus in.^{3}		Surface Area sq ft per lin. ft of bar	
			Per lin. ft of bar	Per sq ft of wall		Single Section	Per lin. ft of wall	Total Area	Nominal Coating Area*
PZ22	11.86	22	40.3	22.0	154.7	33.1	18.1	4.94	4.48
PZ27	11.91	18	40.5	27.0	276.3	45.3	30.2	4.94	4.48
PZ35	19.41	22.64	66.0	35.0	681.5	91.4	48.5	5.83	5.37
PZ 40	19.30	19.69	65.6	40.0	805.4	99.6	60.7	5.83	5.37
PSA23	8.99	16	30.7	23.0	5.5	3.2	2.4	3.76	3.08
PS27.5	13.27	19.69	45.1	27.5	5.3	3.3	2.0	4.48	3.65
PS31	14.96	19.69	50.9	31.0	5.3	3.3	2.0	4.44	3.65

*Excludes socket interior and ball of interlock

Dimensions:

The dimensions shown on these pages are nominal. (See pages 10 and 25 for dimensions for detailing.)

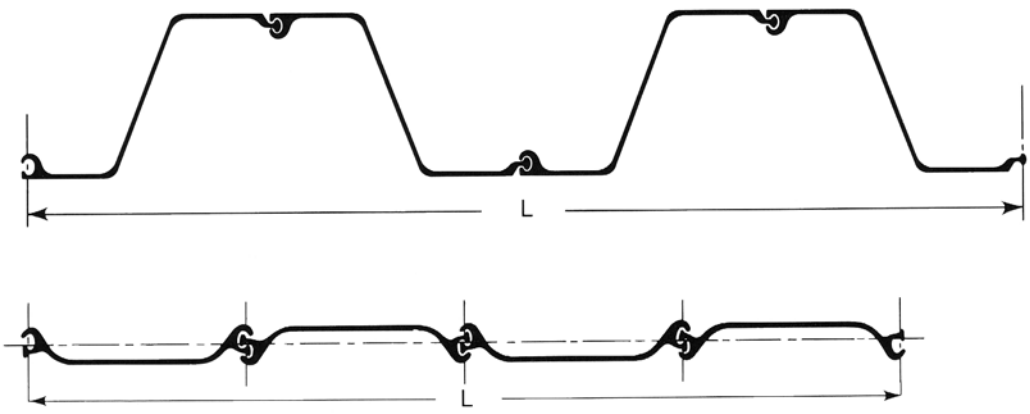
Steel Grades:

Bethlehem steel sheet piling can be supplied in standard ASTM A328 and in high-strength, low-alloy grades ASTM A572 - Grades 50 and 60 and ASTM A690.

Impact Resisting Steel:

Bethlehem steel sheet piling can be supplied to meet Charpy (CVN) requirements. (See page 35 for further information.)

Wall Lengths
Formed with Bethlehem Sheet Piling



Number of Pieces	PSA23 16" = 1.3333'	PZ22 22" = 1.8333'	PZ27 18" = 1.50'	PZ35 22.64" = 1.8867'	PZ40, PS27.5 & PS31 19.69" = 1.6408'
	L (length), feet	L (length), feet	L (length), feet	L (length), feet	L (length), feet
1	1.33	1.83	1.50	1.89	1.64
2	2.67	3.67	3.00	3.77	3.28
3	4.00	5.50	4.50	5.66	4.92
4	5.33	7.33	6.00	7.55	6.56
5	6.67	9.17	7.50	9.43	8.20
6	8.00	11.00	9.00	11.32	9.85
7	9.33	12.83	10.50	13.21	11.49
8	10.67	14.67	12.00	15.09	13.13
9	12.00	16.50	13.50	16.98	14.77
10	13.33	18.33	15.00	18.87	16.41
11	14.67	20.17	16.50	20.75	18.05
12	16.00	22.00	18.00	22.64	19.69
13	17.33	23.83	19.50	24.53	21.33
14	18.67	25.67	21.00	26.41	22.97
15	20.00	27.50	22.50	28.30	24.61
16	21.33	29.33	24.00	30.19	26.25
17	22.67	31.17	25.50	32.07	27.89
18	24.00	33.00	27.00	33.96	29.54
19	25.33	34.83	28.50	35.85	31.18
20	26.67	36.67	30.00	37.73	32.82
21	28.00	38.50	31.50	39.62	34.46
22	29.33	40.33	33.00	41.51	36.10

Number of Pieces	PSA23 16" = 1.3333'	PZ22 22" = 1.8333'	PZ27 18" = 1.50'	PZ35 22.64" = 1.8867'	PZ40, PS27.5 & PS31 19.69" = 1.6408'
	L (length), feet	L (length), feet	L (length), feet	L (length), feet	L (length), feet
24	32.00	44.00	36.00	45.28	39.38
25	33.33	45.83	37.50	47.17	41.02
26	34.67	47.67	39.00	49.05	42.66
27	36.00	49.50	40.50	50.94	44.30
28	37.33	51.33	42.00	52.83	45.94
29	38.67	53.17	43.50	54.71	47.58
30	40.00	55.00	45.00	56.60	49.23
31	41.33	56.83	46.50	58.49	50.87
32	42.67	58.67	48.00	60.37	52.51
33	44.00	60.50	49.50	62.26	54.15
34	45.33	62.33	51.00	64.15	55.79
35	46.67	64.17	52.50	66.03	57.43
36	48.00	66.00	54.00	67.92	59.07
37	49.33	67.83	55.50	69.81	60.71
38	50.67	69.67	57.00	71.69	62.35
39	52.00	71.50	58.50	73.58	63.99
40	53.33	73.33	60.00	75.47	65.63
41	54.67	75.17	61.50	77.35	67.27
42	56.00	77.00	63.00	79.24	68.92
43	57.33	78.83	64.50	81.13	70.56
44	58.67	80.67	66.00	83.01	72.20
45	60.00	82.50	67.50	84.90	73.84
46	61.33	84.33	69.00	86.79	75.48
47	62.67	86.17	70.50	88.67	77.12
48	64.00	88.00	72.00	90.56	78.76
49	65.33	89.83	73.50	92.45	80.40
50	66.67	91.67	75.00	94.33	82.04
51	68.00	93.50	76.50	96.22	83.68
52	69.33	95.33	78.00	98.11	85.32
53	70.67	97.17	79.50	99.99	86.96
54	72.00	99.00	81.00	101.88	88.61
55	73.33	100.83	82.50	103.77	90.25
56	74.67	102.67	84.00	105.65	91.89
57	76.00	104.50	85.50	107.54	93.53
58	77.33	106.33	87.00	109.43	95.17
59	78.67	108.17	88.50	111.31	96.81
60	80.00	110.00	90.00	113.20	98.45
61	81.33	111.83	91.50	115.09	100.09
62	82.67	113.67	93.00	116.97	101.73

Number of Pieces	PSA23 16" = 1.3333'	PZ22 22" = 1.8333'	PZ27 18" = 1.50'	PZ35 22.64" = 1.8867'	PZ40, PS27.5 & PS31 19.69" = 1.6408'
	L (length), feet	L (length), feet	L (length), feet	L (length), feet	L (length), feet
64	85.33	117.33	96.00	120.75	105.01
65	86.67	119.17	97.50	122.63	106.65
66	88.00	121.00	99.00	124.52	108.30
67	89.33	122.83	100.50	126.41	109.94
68	90.67	124.67	102.00	128.29	111.58
69	92.00	126.50	103.50	130.18	113.22
70	93.33	128.33	105.00	132.07	114.86
71	94.67	130.17	106.50	133.95	116.50
72	96.00	132.00	108.00	135.84	118.14
73	97.33	133.83	109.50	137.73	119.78
74	98.67	135.67	111.00	139.61	121.42
75	100.00	137.50	112.50	141.50	123.06
76	101.33	139.33	114.00	143.39	124.70
77	102.67	141.17	115.50	145.27	126.34
78	104.00	143.00	117.00	147.16	127.99
79	105.33	144.83	118.50	149.05	129.63
80	106.67	146.67	120.00	150.93	131.27
81	108.00	148.50	121.50	152.82	132.91
82	109.33	150.33	123.00	154.71	134.55
83	110.67	152.17	124.50	156.59	136.19
84	112.00	154.00	126.00	158.48	137.83
85	113.33	155.83	127.50	160.37	139.47
86	114.67	157.67	129.00	162.25	141.11
87	116.00	159.50	130.50	164.14	142.75
88	117.33	161.33	132.00	166.03	144.39
89	118.67	163.17	133.50	167.91	146.03
90	120.00	165.00	135.00	169.80	147.68
91	121.33	166.83	136.50	171.69	149.32
92	122.67	168.67	138.00	173.57	150.96
93	124.00	170.50	139.50	175.46	152.60
94	125.33	172.33	141.00	177.35	154.24
95	126.67	174.17	142.50	179.23	155.88
96	128.00	176.00	144.00	181.12	157.52
97	129.33	177.83	145.50	183.01	159.16
98	130.67	179.67	147.00	184.89	160.80
99	132.00	181.50	148.50	186.78	162.44
100	133.33	183.33	150.00	188.67	164.08
200	266.67	366.67	300.00	377.33	328.17
300	400.00	550.00	450.00	566.00	492.25

Number of Pieces	PSA23 16" = 1.3333'	PZ22 22" = 1.8333'	PZ27 18" = 1.50'	PZ35 22.64" = 1.8867'	PZ40, PS27.5 & PS31 19.69" = 1.6408'
	L (length), feet	L (length), feet	L (length), feet	L (length), feet	L (length), feet
500	667.67	916.67	750.00	943.33	820.42
600	800.00	1100.00	900.00	1132.00	984.50
700	933.33	1283.33	1050.00	1320.67	1148.58
800	1066.67	1466.66	1200.00	1509.33	1312.66
900	1200.00	1650.00	1350.00	1698.00	1476.75
1000	1333.33	1833.33	1500.00	1886.67	1640.83
2000	2666.67	3666.67	3000.00	3773.33	3281.67

Note: The length of walls tabulated are based on catalog widths of the piling sections. The usual mill variations in rolling the sections and particularly the methods used in setting and driving may cause deviation from the lengths shown.

Bethlehem Z-Piling
For Cantilevered, Tied-Back and Braced Walls

Reasons for Specifying Z-Piling

Z-piles, with their optimum distribution of material, are the most efficient sheet piling sections available for bending strength. With the interlocks located on the outer fibers of the wall, rather than at the center line, as is the case with arch-shaped piling, the designer is assured of the published section modulus of Bethlehem sheet piling.

Bethlehem Z-piling is designed to provide bending strength with an efficient strength to weight ratio. Furthermore, the sections are engineered to insure section stability under all normal loading conditions. Refer to "Maximum Spans Under Water Loads" on page 9 for discussion of this important, but often neglected, subject.

The following table gives the allowable bending moment capacity for Bethlehem Z-piling sections based on the accepted engineering practice of designing sheet piling to 0.65 F in longitudinal bending.

Section	Section Modulus in. ^{3}/ft of wall	Allowable Bending Moment ft-kips/ft of wall		
		A328	A572 Gr 50 or A690	A572 Gr 60
PZ22	18.1	38	49	59
PZ27	30.2	64	82	98
PZ 35	48.5	102	131	158
PZ40	60.7	128	164	197

Importance of Bethlehem's Interlock System

Bethlehem's Z-piling is produced with a ball-and-socket type interlock. This popular interlock system facilitates the setting, driving, and reuse of Bethlehem hot-rolled Z-piling. This interlock system permits flexibility while setting the wall, yet it is extremely rugged and durable under driving conditions where other types of interlocks might be suspect.

Since all our Z-piles have similar interlocks, the designer has the complete freedom to change sections required in a wall without resorting to compromise piles. This enables the designer to avoid the extra cost of such compromise piles and to utilize the most efficient section required.

Setting and Driving Tips

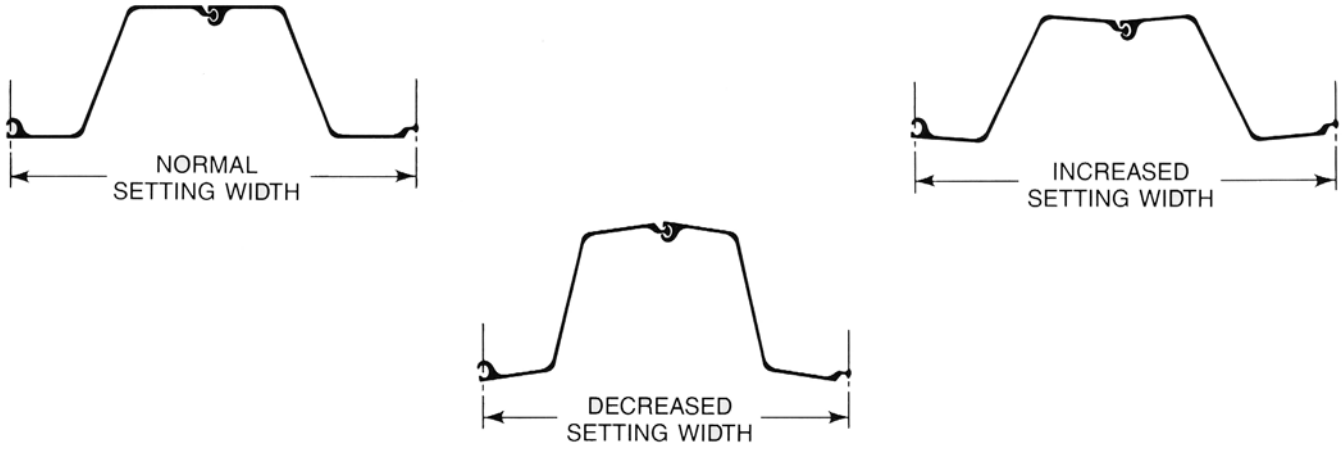
Although setting and driving techniques vary with conditions, several basic principles can generally be applied. The lack of good setting and driving practices can result in problems which are far more expensive than the cost of applying proper techniques.

- Splicing should be avoided if possible. When splicing is necessary, sections should be ordered full length from the mill. They should be cut and match-marked at the jobsite. These match-marked pieces must be spliced to reconstruct the original section as it was shipped from the mill. This procedure will eliminate mismatching of cross sections - a problem inherent in the splicing of randomly selected Z-pile sections. Splices on adjacent sheets must be staggered by several feet. If full section modulus is required at the splice, it will be necessary to use splice plates on the flanges to overcome the deficiency created by not welding the interlocks. A combination of butt welding and cover plates or a complete plate splice can be used.

- Have an adequate driving template. Using an adequate driving template will facilitate setting and driving and result in a superior end product.

- Mark the driving template for each pair of Z-piles. This will indicate whether the line of piling being set is gaining or losing wall length. This procedure is particularly important for structures such as cofferdams which must be closed or for tied bulkheads where tie rod location is important.

- Set piles one at a time or in loose (not fixed) pairs. This allows for adjustments during threading to increase or decrease the length of a wall. Sheet piling, furnished in fixed pairs, does not offer this advantage. The drawings below show how such changes can be made.



- Remove several inches of finger before threading. If allowed, this permits overlapping of steel piles before interlocks are engaged. This procedure is particularly helpful when the piles are long or when they are being threaded in windy conditions. Once threaded and plumbed, a pile should be allowed to drop under its own weight. Mechanical threading devices are available and their use precludes the need for cutting back the finger. (Caution: On leased material, the removal of several inches of finger may increase liquidation charges.)

- Z-piling should be driven with the ball-end leading. This eases driving of the pile because the socket end does not become clogged with soil. When the socket end must lead, place a bolt or similar object in the open space at the bottom end to minimize clogging.

- Drive piles in pairs. Once sheet piles are threaded and set, it's more economical to drive two at a time. (Some experts suggest that the energy needed to drive a pair may be only 50% more than that required to drive a single pile.)

- Set a panel of piling and drive piles in stages. This allows the piles to be guided by those previously driven. It also lessens the chance of driving a pile out of interlock. The distance a pile, or pair of piles should be driven at any one time will depend upon the driving conditions.

Rolled Corners
Interlocking with PSA23

Although PSA23 has a thumb-and-finger type of interlock, it does interlock with the ball and socket on Bethlehem Z-piling.

This feature allows the designer the option of incorporating PSA23 sections, such as rolled corners, into a Z-piling wall. The acceptability of this interlock configuration depends upon several factors including the type of structure and the soil (driving) conditions.

Figures 1 and 2 show the details for rolled corners and bent-web piles made from PSA23. Fabricated connections should be specified if leg dimensions are critical or if ASTM A690 steel is required. Rolled corners, in ASTM A328 or A572-Grade 50, are generally available from stock. Bent-web piles must be produced to order with potentially extended deliveries.

Figure 1 – ROLLED CORNERS

Figure 2 – BENT WEB PILES

The most desirable interlock combinations are shown in Fig. 3. Also acceptable, is the interlock shown in Fig. 4. However, the interlock shown in Fig. 5 is not acceptable because a slight rotation may cause it to disengage.

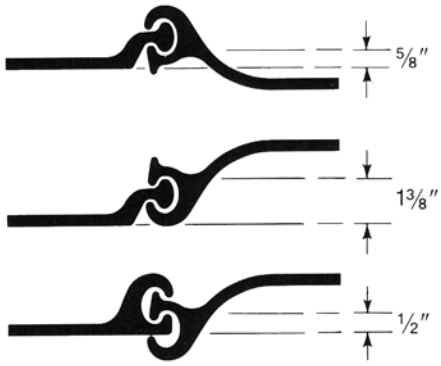


Figure 3 – BEST

Figure 4 – OK

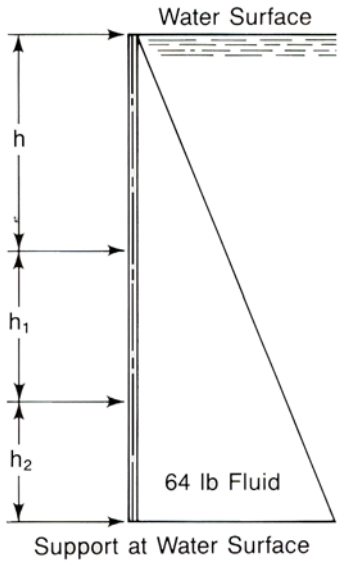
Figure 5 - NO

Maximum Spans under Water Loads

When constructing cofferdams in open water, make sure that all bracing between the water level and the concrete seal or firm soil is in position before dewatering is started. For the spans shown on this page, the sheet piling will be over-stressed in bending if an attempt is made to install one set of bracing at a time as the water is pumped down. The table below is included only to provide design guidance and is not intended to be a substitute for competent and sound engineering practice.

The spacing shown applies only for spans between rigid braces (wales), or between a rigid brace and a concrete seal poured under water. It does not apply for a span between a brace and the earth at the bottom of a cofferdam. In such cases, special consideration must be given to the properties of the soil that provides the bottom support.

The spans shown in the table below are governed by section modulus, but are based on the geometry of the sections produced by Bethlehem Steel and should not be applied to sections from other producers without proper engineering analysis. Accepted engineering practice is to design sheet piling to 0.65 F in bending. The spans shown in the table are based on allowable longitudinal bending stresses of 25 ksi for ASTM A328 steel and 32.5 ksi for ASTM A572 Grade 50 steel.



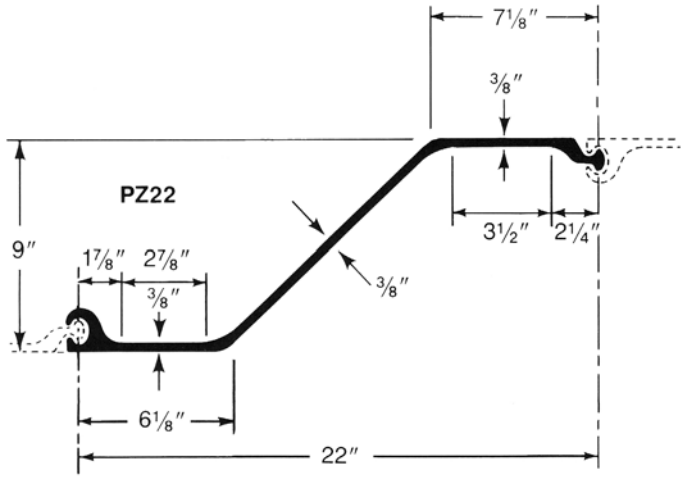
Maximum Spans Under Water Loads*						
Section Number	A328, maximum span, ft			A572 Grade 50, maximum span, ft		
	h	h_1	h_2	h	h_1	h_2
PZ22	20.9	14.5	11.9	22.9	15.8	13.0
PZ27	24.8	17.1	14.2	27.1	18.7	15.5
PZ35	29.1	20.1	16.6	31.7	21.9	18.1
PZ40	31.4	21.7	17.9	34.2	23.6	19.5
*Refer to the text for limitations on the use of this table.						

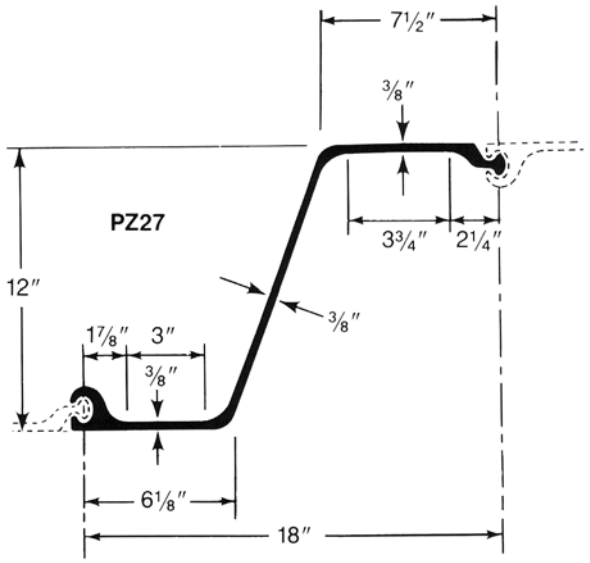
Designers Note:

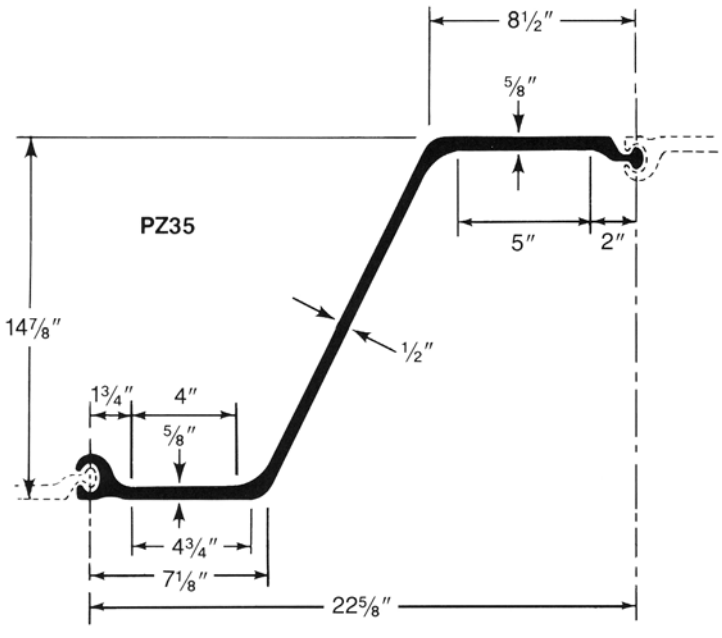
The ability of a sheet pile section to withstand pressures is not solely a function of section modulus. A detailed analysis discloses that it is a function of combined stresses resulting from longitudinal and transverse bending, shear forces and wale reactions, plus section stability. Longitudinal bending stresses, as well as stresses due to wale reactions and shears, are functions of the wale spacing and overall section properties. Transverse bending stresses and section stability are a function of design pressures, web and flange thickness, and web and flange length. At relatively shallow depths, section modulus is the controlling factor, but at greater depths, combined stresses and overall section stability become the governing criteria.

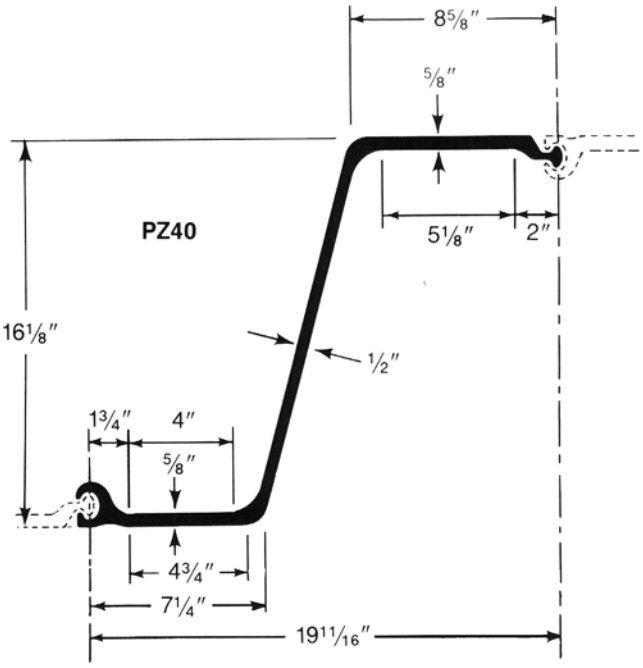
The spans in the table on this page represent maximum water depths at which section modulus is the governing criterion. Designers should not expand the table to include greater water depths without detailed consideration of combined stresses. Designers are also cautioned not to use this table for sections from other producers which may not be structurally equal to Bethlehem Sections.

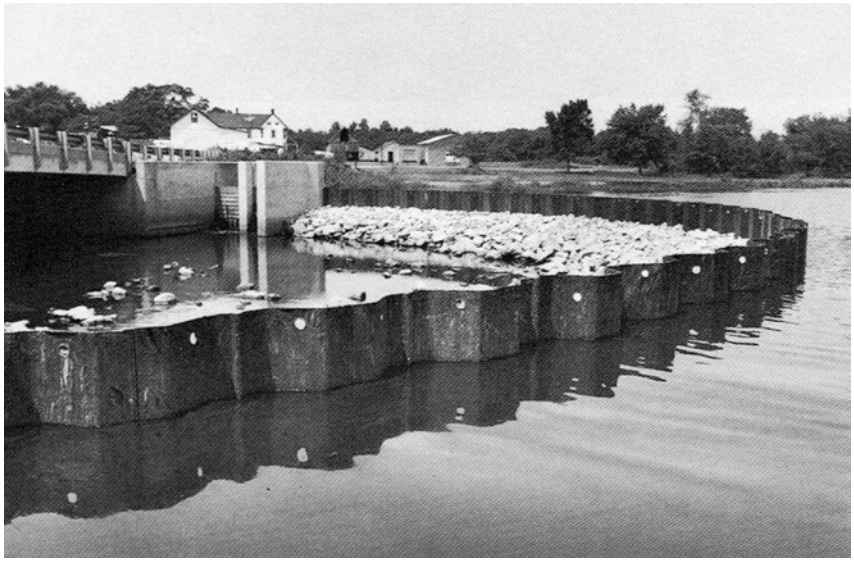
Dimensions for Detailing





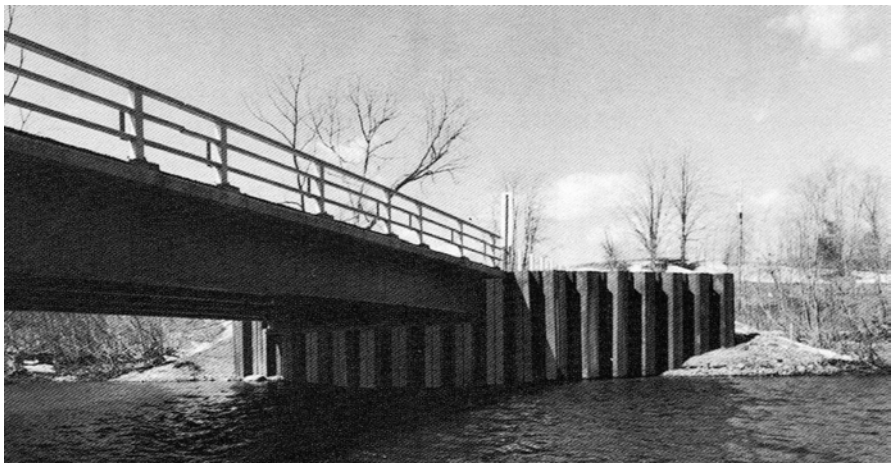




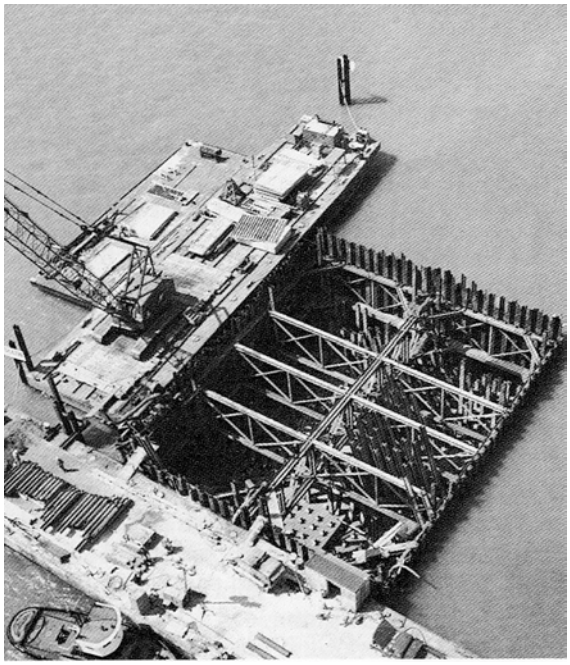


Left: Environmental disturbance is minimized during dam construction through the use of Z-piling.

Right: Z-piling provides a cost-efficient method of constructing bridge abutments while protecting them from scour.



Below: Heavy, hot-rolled Z-piling provides the most efficient method of constructing major bridge piers in deep water.

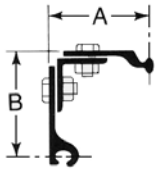


Above: Paired sheet piling sections simplify handling and setting.

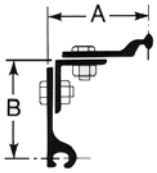
Standard Fabricated Connections
Used with PZ22 and/or PZ27

90° Corners

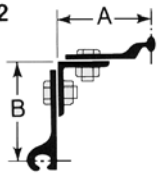
ZC270



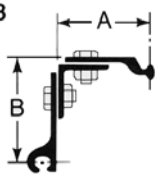
ZC271



ZC272

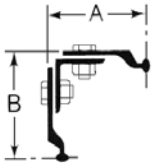


ZC273

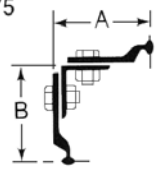


90° Corners

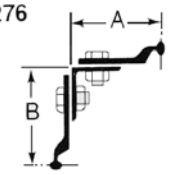
ZC274



ZC275



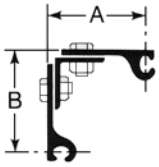
ZC276



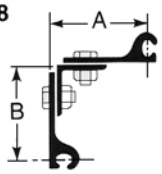
Note: When both A and B dimensions of fabricated corners are six inches, their weights are 35 lb/ft.

90° Corners

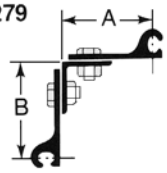
ZC277



ZC278

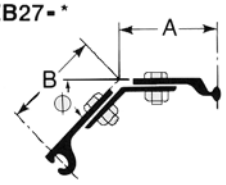


ZC279



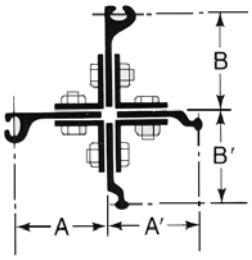
Bent Corner

ZB27-*



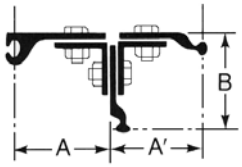
Cross

ZX270 87 lb/ft

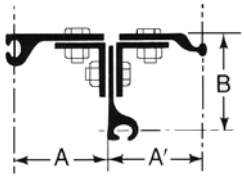


Tees

ZT270 57 lb/ft



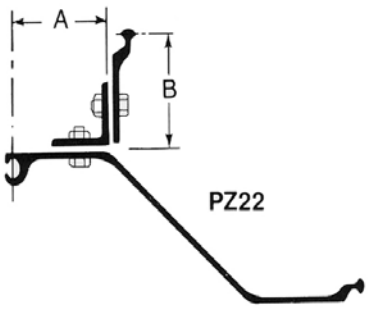
ZT271 57 lb/ft



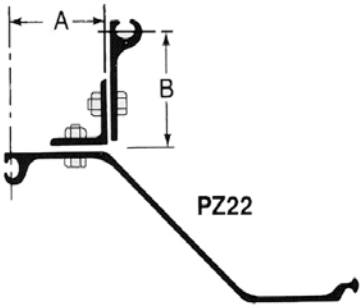
*When ordering bent corners, add third digit to identify interlock arrangement.

Full Section Tees

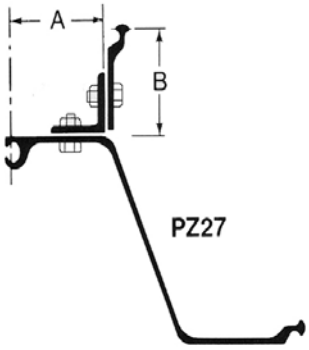
ZT222 64 lb/ft



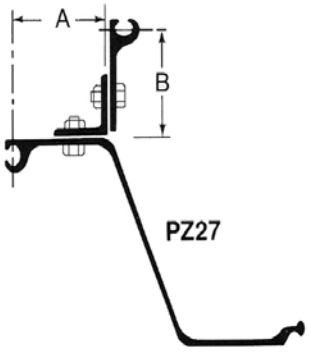
ZT223 64 lb/ft



ZT272 64 lb/ft

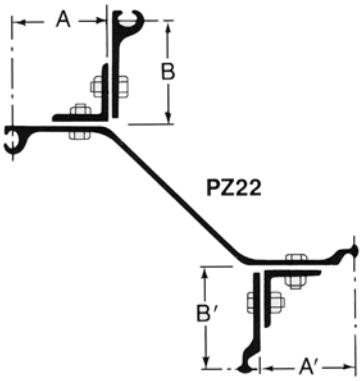


ZT273 64 lb/ft

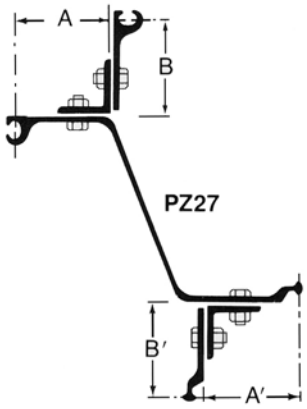


Full Section Cross

ZX221 87 lb/ft



ZX271 87 lb/ft



Notes:

- Weights shown per linear foot are based on standard A and B leg dimensions. Changes in leg dimensions may result in weight changes.

- Standard A, B, A' and B' dimensions for PZ22 and PZ27 equal 6 in. Connections can be fabricated to dimensions other than standard when so specified. Specifiers should avoid leg dimensions in excess of 12 in.

- Standard angle size for PZ22 and PZ27 is 3-1/2 X 3-1/2 X 3/8 in. Larger 3/8-in, angles or 3/8-in.-thick bent plates will be supplied as required to accommodate leg dimensions greater than standard. Specifiers should consider thicker angles or plates when designing long leg dimensions and/or long section lengths.

- Fasteners are 7/8-in, high-strength bolts spaced on 6-in, centers throughout the length of the section, except for 2 ft at each end where they are located on 3-in. centers.

- Corner connections ZC270 through ZC279 represent all possible interlock arrangements. Bent corners can be furnished with any interlock arrangement ZC270 through ZC279. When ordering bent corners, specify the angle well as the type interlock arrangement desired d the A and B dimensions*. For example, if interlock arrangement ZC273 is required with a 25 degree angle and standard legs, order: ZB273, ø = 25 degrees, A = 6 in., B = 6 in.

- Connections other than the standards shown can be fabricated to meet special requirements.

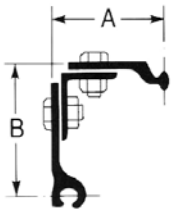
- Fabricated sections not utilizing full sections are inherently weak in bending strength, i.e., low section modulus. Extra care must be exercised when transporting and handling such sections. Excessive leg dimensions and/or long section lengths compound the shipping and handling problems of these sections. In the case of excessive leg lengths, Bethlehem Steel may elect to weld straps between the interlocks to stabilize the cross section. Such strapping should be removed by the contractor before driving the member. When fabricated lengths are in excess of 70 ft, Bethlehem Steel may elect to ship the section in two pieces prepared for field splicing in place.

See General Specifications (page 34) for additional details on fabricated connections.

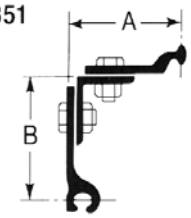
Standard Fabricated Connections
Used with PZ35 and/or PZ40

90° Corners

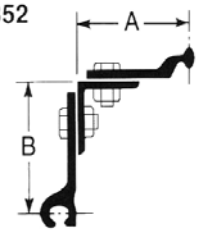
ZC350



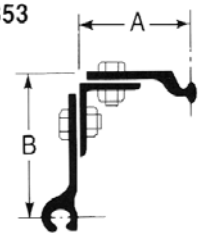
ZC351



ZC352

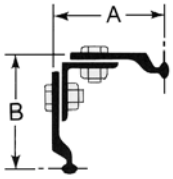


ZC353

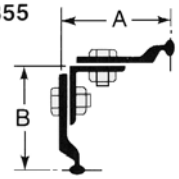


90° Corners

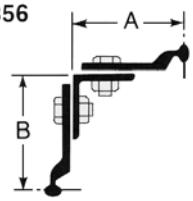
ZC354



ZC355



ZC356

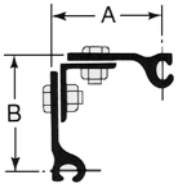


Note: When both A and B dimensions of fabricated corners are seven inches, their weights are 45 lb/ft.

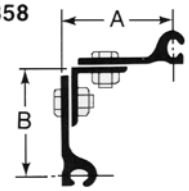
*When ordering bent corners, add a third digit to identify the desired interlock arrangement.

90° Corners

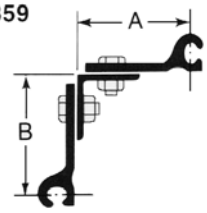
ZC357



ZC358

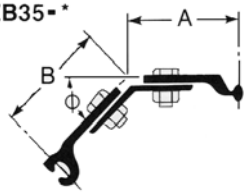


ZC359



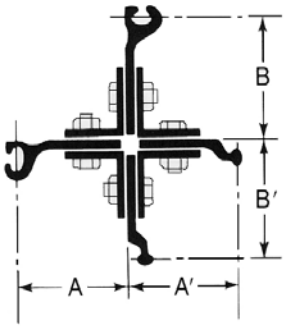
Bent Corner

ZB35-*



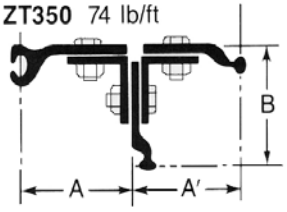
Cross

ZX350 116 lb/ft

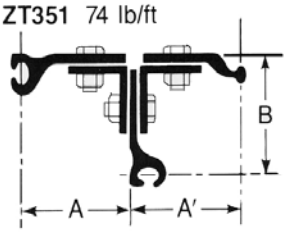


Tees

ZT350 74 lb/ft

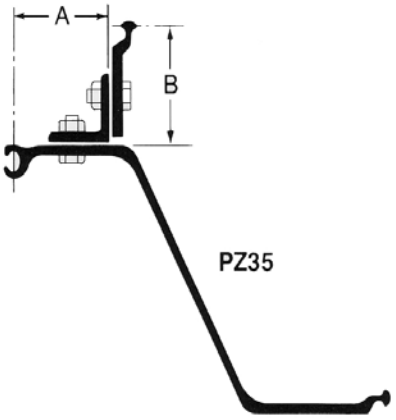


ZT351 74 lb/ft

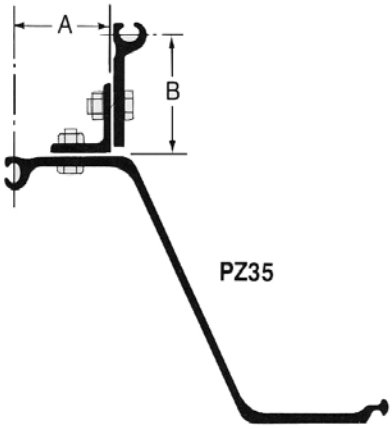


Full Section Tees

ZT352 97 lb/ft

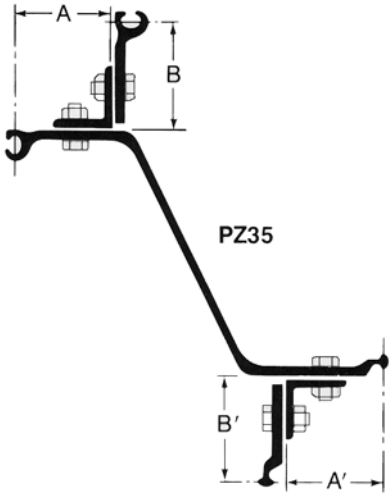


ZT353 97 lb/ft

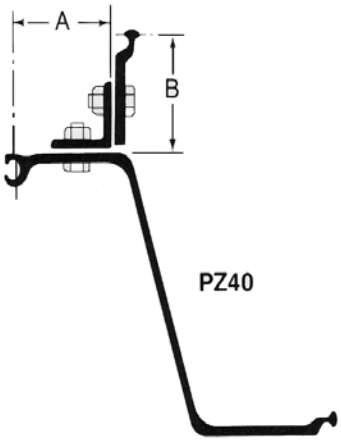


Full Section Cross

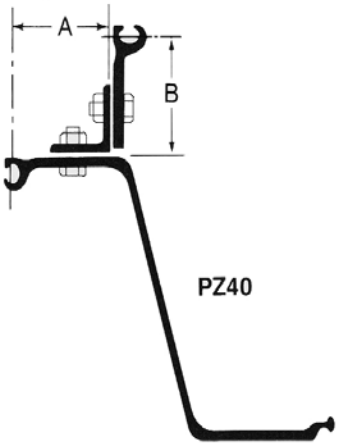
ZX351 128 lb/ft



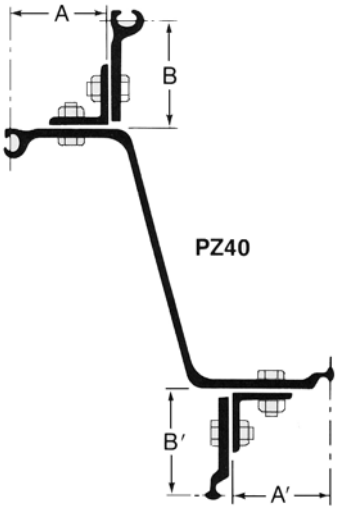
ZT402 97 lb/ft



ZT403 97 lb/ft



ZX401 128 lb/ft



Notes:

- Weights shown per linear foot are based on standard A and B leg dimensions. Changes in leg dimensions may result in weight changes.

- Standard A, B, A' and B' dimensions for PZ35 and PZ4O equal 7 in. Connections can be fabricated to dimensions other than standard when so specified. Specifier should avoid leg dimensions in excess of 12 in.

- Standard angle size for PZ35 and PZ4O is 4 X 4 X 1/2 in. Larger 1/2-in. angles or 1/2-in.-thick bent plates will be supplied as required to accommodate leg dimensions greater than standard. Specifiers should consider thicker angles or plates when designing long leg dimensions and/or long section lengths.

- Fasteners are 7/8-in. high-strength bolts spaced on 6-in. centers throughout the length of the section, except for 2 ft at each end where they are located on 3-in. centers.

- Corner connections ZC350 through ZC359 represent all possible interlock arrangements. Bent corners can be furnished with any interlock arrangement ZC350 through ZC359. When ordering bent corners, specify the angle as well as the type interlock arrangement desired and the A and B dimensions*. For example, if interlock arrangement ZC352 is required with a 35 degree angle and standard legs, order: ZB352, ø = 35, A = 7 in., B = 7 in.

- Connections other than the standards shown can be fabricated to meet special requirements.

- Fabricated sections not utilizing full sections are inherently weak in bending strength, i.e., low section modulus. Extra care must be exercised when transporting and handling such sections. Excessive leg dimensions and/or long section lengths compound the shipping and handling problems of these sections. In the case of excessive leg lengths, Bethlehem Steel may elect to weld straps between the interlocks to stabilize the cross section. Such strapping should be removed by the contractor before driving the member. When fabricated lengths are in excess of 70 ft, Bethlehem Steel may elect to ship the section in two pieces prepared for field splicing in-place.

See General Specifications (page 34) for additional details on fabricated connections.

High Section Modulus Requirements

There may be occasions when even PZ4O in high-strength grades of steel is not sufficiently strong to satisfy the calculated design moments. When this is the case, the designer has several available options to consider:

Cellular Design

This design can be very efficient and an option that should be explored for facilities such as deep draft bulkheads and large graving docks. Cellular construction provides a solid-faced wharf in deep water without the need for elaborate anchorage systems. The feasibility of a cellular design is somewhat dependent on site and soil conditions. Refer to page 22 for additional information on cellular design.

Cover Plated Z-Piling

This approach extends the range of Z-piling by increasing the moment carrying capacity in the area where the design moment exceeds the capacity of the plain Z-pile.

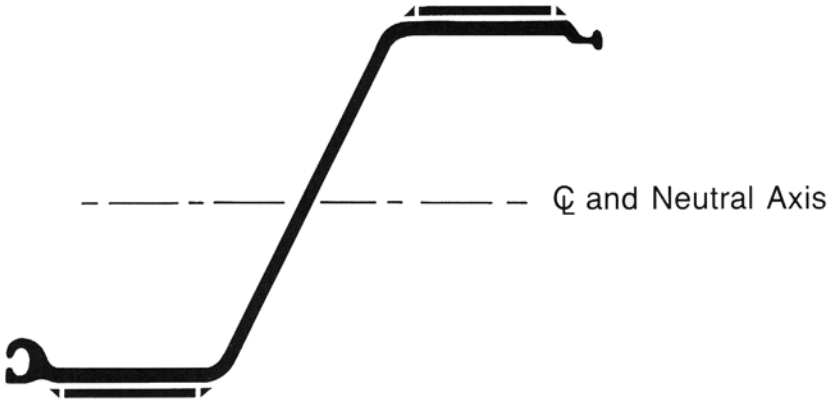


Plate Size (in)	PZ35		PZ40	
	Section Modulus $in.^3/ft$ of wall	Weight lb/ft^2 of wall	Section Modulus $in.^3/ft$ of wall	Weight lb/ft^2 of wall
None	48.5	35.0	60.7	40.0
4-1/2 x .25	-	-	70.2	44.7
4-1/2 x .375	-	-	74.8	47.0
4-1/2 x .50	63.2	43.1	79.5	49.3
4-1/2 x .625	67.0	45.1	84.2	51.7
4-1/2 x .75	70.8	47.2	89.0	54.0
4-1/2 x .875	74.6	49.2	93.7	56.3
4-1/2 x 1.00	78.4	51.2	98.5	58.6
4-1/2 x 1.125	82.3	53.2	103.4	61.0
4-1/2 x 1.25	86.2	55.3	108.3	63.3

Note:

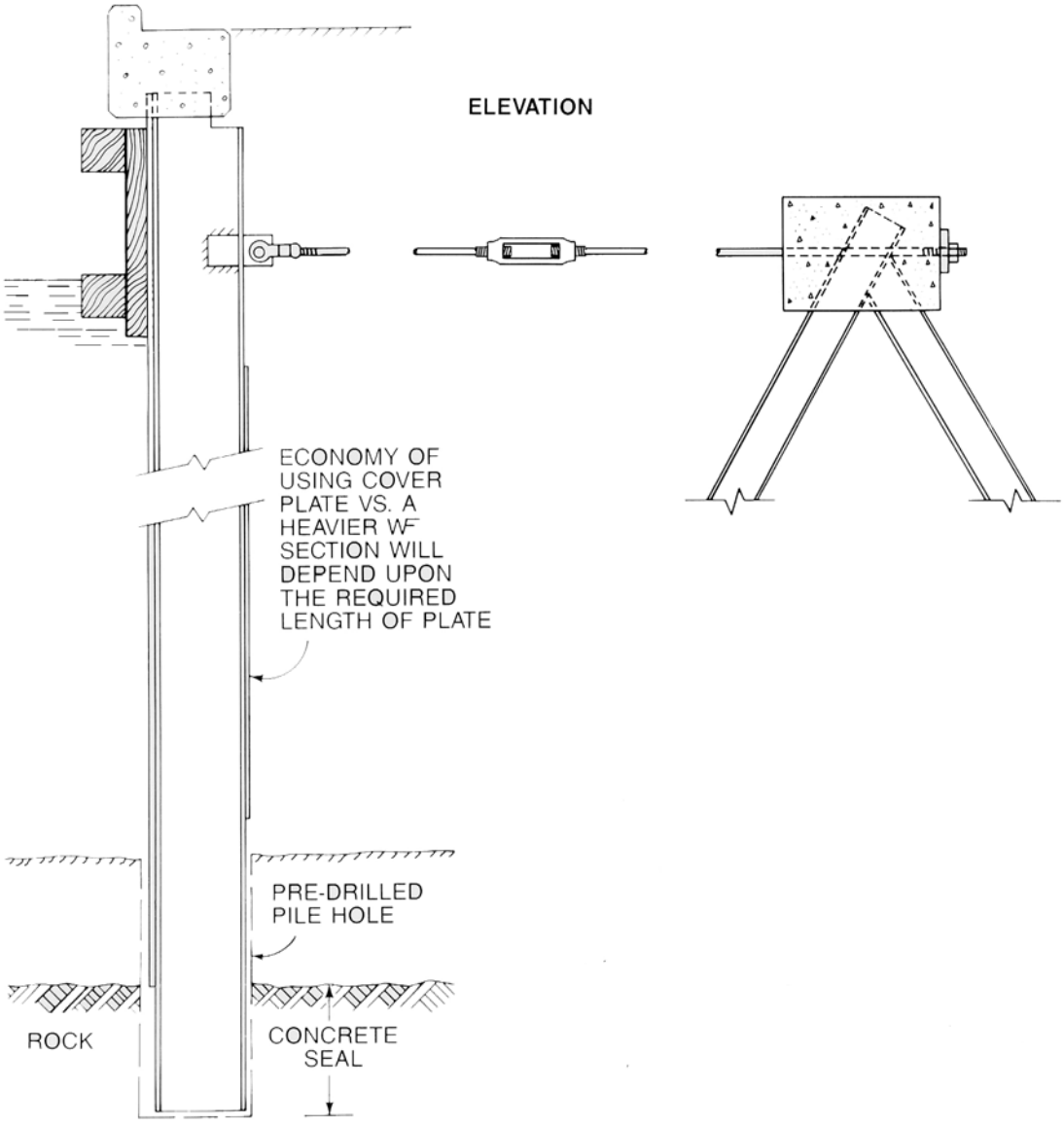
- Filet weld should be sized to adequately resist design loads and should be continuous and all around.
- Cover plate length depends upon moment curve.
- Weight shown in lb/ft^2 of wall is for the section in the cover-plated location. The average weight in lb/ft^2 of wall will be lower.

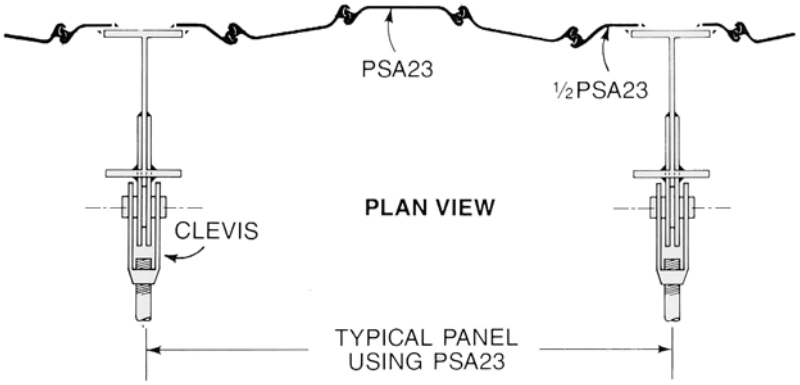
Master Pile System

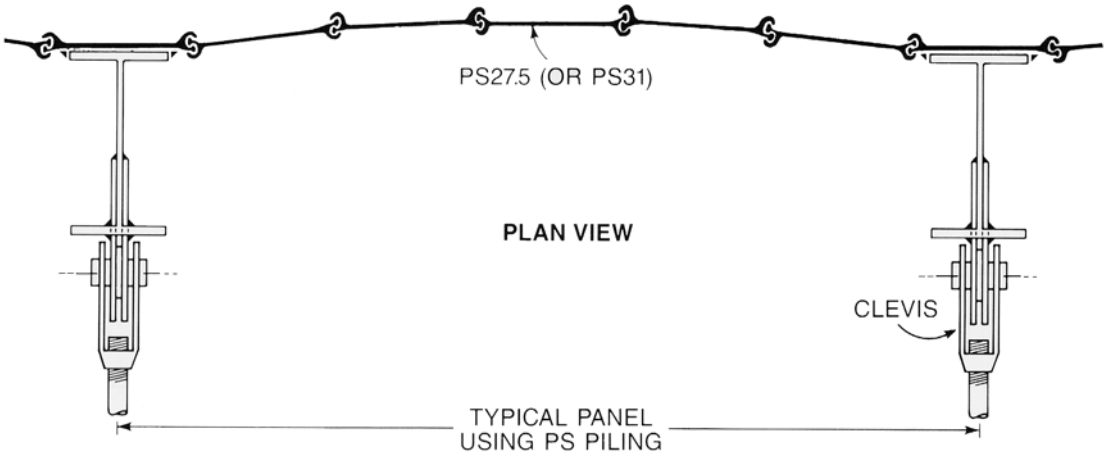
This system combines moment resisting and cellular design. The PSA or PS sheet piling sections transmit the soil pressures on the arcs by interlock tension to the moment-resisting master piles.

A master pile design is ideally suited to sites where very hard driving is anticipated or rock is at a high elevation and sufficient penetration is not available for adequate toe resistance. In such cases, the master pile can be installed in a predrilled hole and grouted in place.

Depending on the number of intermediate sheets, section moduli in excess of 200 $in.^3$/ft of wall can be obtained utilizing this design concept.




PSA23
½PSA23
PLAN VIEW
CLEVIS
TYPICAL PANEL
USING PSA23


PS27.5 (OR PS31)
PLAN VIEW
CLEVIS
TYPICAL PANEL
USING PS PILING

The following table, using selected wide-flange sections (unreinforced and reinforced), shows design properties obtainable using this approach. This table should be used by the designer as a guide. Actual master pile size and system geometry (master pile spacing, arc radius, etc.) must be determined by the engineer based on site conditions. Connection details are extremely important and must be designed with care.

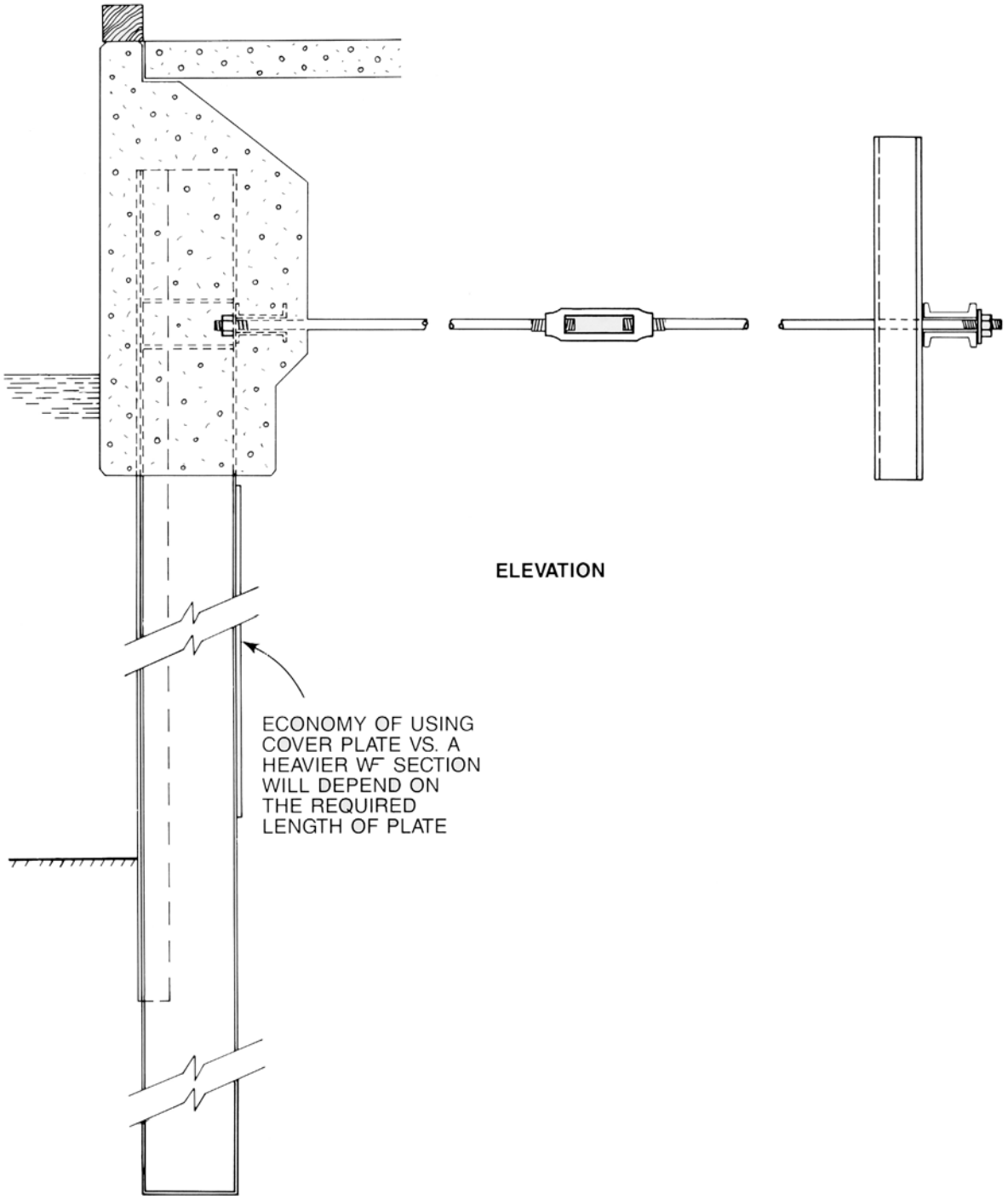
Master Pile	Intermediate Piles					
	3 Sections PSA 23			5 Sections PS27.5 (or PS31)		
	Spacing L	Section Modulus $in.^3/ft$ of wall	Weight lb/ft^2 of wall	Spacing L	Section Modulus $in.^3/ft$ of wall	Weight lb/ft^2 of wall
W14 x 132	6' - 0"	36.6	42.4	9' - 8"	23.8	41.7
		(51.4)			(35.0)	
W14 x 257	6' - 3"	69.2	60.7	9' - 8"	46.4	54.6
		(81.5)			(54.8)	
W14 x 342	6' - 3"	92.9	74.5	9' - 8"	62.1	63.5
		(104.1)			(68.9)	
W24 x 162	6' - 0"	72.7	47.4	9' - 8"	46.8	44.8
		(99.9)			(68.8)	
W27 x 178	6 - 0"	88.1	50.0	9' - 8"	56.5	46.4
		(118.4)			(81.2)	
W33 x 152	5' - 9"	90.7	47.7	9' - 8"	56.0	43.7
		(130.7)			(88.5)	
W36 x 135	5' - 9"	83.0	44.7	9' - 8"	51.5	42.0
		(126.2)			(87.1)	
W36 x 170	5' - 9"	107.8	50.8	9' - 8"	66.5	45.6
		(150.6)			(101.2)	
W36 x 210	5' - 9"	132.6	57.8	9' - 8"	81.5	49.7
		(174.3)			(114.9)	
W36 x 260	6' - 3"	158.7	61.2	10' - 6"*	96.8	50.6
		(195.3)			(125.3)	
W36 x 300	6' - 3"	183.2	67.6	10' -6"*	111.6	54.4
		(219.0)			(138.9)	
*PS pile is attached in 2 pieces.						

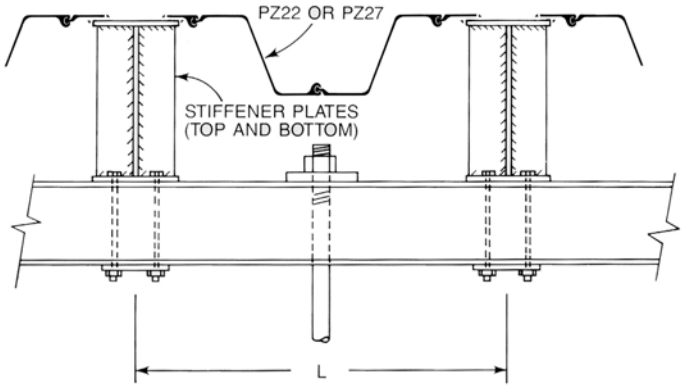
Note:

- Numbers in parentheses represent section moduli with cover plates on back of the master piles.
- The plate (measuring 9 in. x 1 in. for a PSA23 layout and 10 ½ in. x 1 ¼ in. for a PS27.5 layout) is welded continuously all around. The weld must be sized to resist the design loads.
- All welds are continuous and all around.

King Pile System

This system combines Z-piling and structural sections. Large section moduli can be developed using this approach. The flexibility of the ball-and-socket interlock design allows this heavy wall system to be more readily installed than similar systems.





PLAN VIEW

The following table, using selected wide-flange sections (unreinforced or reinforced), shows design properties obtainable using this approach.

King Pile	Intermediate Piles					
	PZ			PZ27		
	Spacing L	Section Modulus $in.^3/ft$ of wall	Weight lb/ft^2 of wall	Spacing L	Section Modulus $in.^3/ft$ of wall	Weight lb/ft^2 of wall
W24 x 117	5' - 3"	63.3	41.9	4' - 6"	77.3	49.0
		(88.3)			(107.5)	
W30 x 173	5' - 6"	105.8	50.1	4' - 9"	125.2	58.1
		(135.2)			(159.5)	
W33 x 201	5' - 6"	132.5	55.3	4' - 9"	155.9	64.1
		(164.5)			(193.1)	
W33 x 221	5' - 6"	145.7	58.9	4' - 9"	171.2	68.3
		(177.3)			(208.0)	
W36 x 135	5' - 3"	92.9	45.3	4' - 6"	110.8	53.0
		(129.6)			(153.8)	
W36 x 170	5' - 3"	120.0	52.0	4' - 6"	142.5	60.8
		(156.7)			(185.5)	
W36 x 230	5' - 6"	160.5	60.5	4' - 9"	188.2	70.2
		(194.1)			(227.2)	
W36 x 260	5' - 6"	182.3	66.0	4' - 9"	213.4	76.5
		(215.4)			(251.9)	
W36 x 300	5' - 6"	210.0	73.3	4' - 9"	245.5	85.0
		(242.5)			(283.3)	

Note:

- Numbers in parentheses represent section moduli with cover plates on the back of the king piles.
- The plate, measuring 11 in. x 5/8 in. is welded continuously all around. The weld must be sized to resist the design loads.
- All welds are continuous and all around.

Bethlehem PSA23, PS27.5 and PS31
For Cellular Structures

Cellular Structure Requirements

Cellular design and construction require sheet piling sections which are designed for interlock strength rather than beam strength. The resulting sections, although quite strong in interlock tension, have very small section moduli. It is, therefore, extremely important that these sections, particularly in long lengths, be handled with the greatest of care to avoid damage which ultimately will lead to installation problems.
The amount of interlock strength required for a project is a function of many factors including the cell fill, cell diameter and design depths. The state-of-the-art of cellular design requires that the cells be founded on or in firm foundation material - and that the cells be filled with clean, free-draining granular material. In general, it may be stated that increased interlock loads are developed with increasing cell diameters and design heights.

A Cellular Structure Defined

A cellular structure may be as simple as a single independent cell. Examples include mooring dolphins for securing barges or cells used to protect bridge piers.
On the other hand, a cellular structure can be very complex, involving many large cells joined together with connecting arcs to form a continuous cellular wall. 1ypical examples of this type of construction include deep draft bulkheads and graving docks for the construction of large ships. Complex cell structures are also used in the construction of locks and dams within the inland waterway system.

Cellular Construction Offers Numerous Advantages

- Provides a massive, self-sustaining structure that is safe and durable.
- Simplifies construction since a circular cell provides a stable working platform once it is backfilled.
- Speeds construction because steel sheet piling can be driven quickly even under adverse weather conditions.
- Can be installed by the average-size marine contractor without the need for unusually large equipment.
- Eliminates the need for construction and maintenance of slope protection and other disadvantages of open pile supported platforms because cells provide a solid-faced wharf.
- Offers long service life in marine environments through the use of advanced corrosion protection methods.

Thumb-and-Finger Interlock System

The type of interlock method best suited for cellular design and construction is referred to either as the "Lackawanna Lock" or the "thumb-and-finger" interlock. When properly interlocked, this three-point contact interlock system can withstand severe setting and driving conditions and still function as intended. This is not necessarily true of other types of interlock systems.
Bethlehem's thumb-and-finger interlock system provides high interlock strengths, and at the same time, has superior swing properties. Swing of up to 10 degrees is provided by PSA23, PS27.5 and PS31 for lengths up to 70 feet. For greater lengths, the 10 degree swing should be reduced by 1.5 degrees for every 10 feet increase in ordered length.

Correct vs. Incorrect Interlocks

For the interlock system to perform as specified, it is absolutely necessary to interlock the sections properly as shown in Figure 1. Any other interlock configurations, such as those shown in Figure 2, are incorrect and will result in interlock capacities of a low and unknown magnitude. Improper interlocks result from negligent setting practices or from attempting to construct a circular cell with an odd number of sheets.

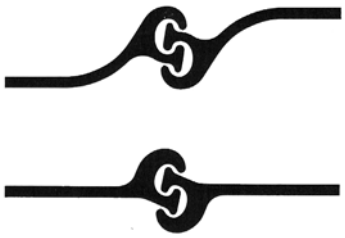


Figure 1 – PROPER

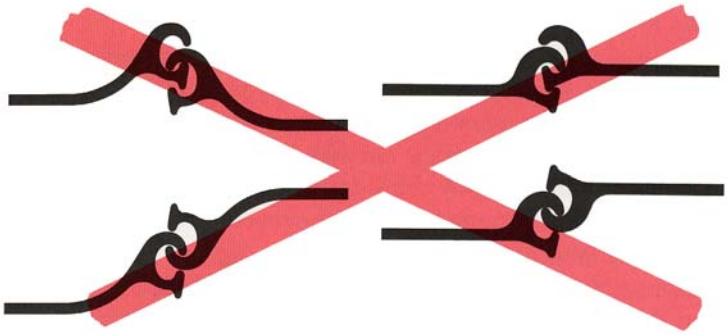


Figure 2 - IMPROPER

Interlock Strength*

Section PSA23

PSA23, when correctly interlocked, develops a minimum ultimate interlock strength of 12 kips per inch. Excessive interlock tension results in web extension for section PSA23. Therefore, the interlock tension for this section should be limited to a maximum working load of 3 kips per inch.

Sections PS27.5 and PS3J

PS27.5 and PS31, when correctly interlocked, provide the minimum ultimate interlock strengths in kips per inch as shown in the following table.

Section	Steel Grade		
	A328	A572-Grade 50 or A690	A572-Grade 60
PS27.5	16	20	N/A
PS31	16	20	24

If other strengths are required, the designer should consult with Bethlehem steel for possible availability. PS27.5 and PS31 sections have straight webs and, therefore, their geometry is not altered significantly by the interlock load. Normal engineering practice is to limit the interlock load of these sections to one-half the minimum ultimate interlock strength.

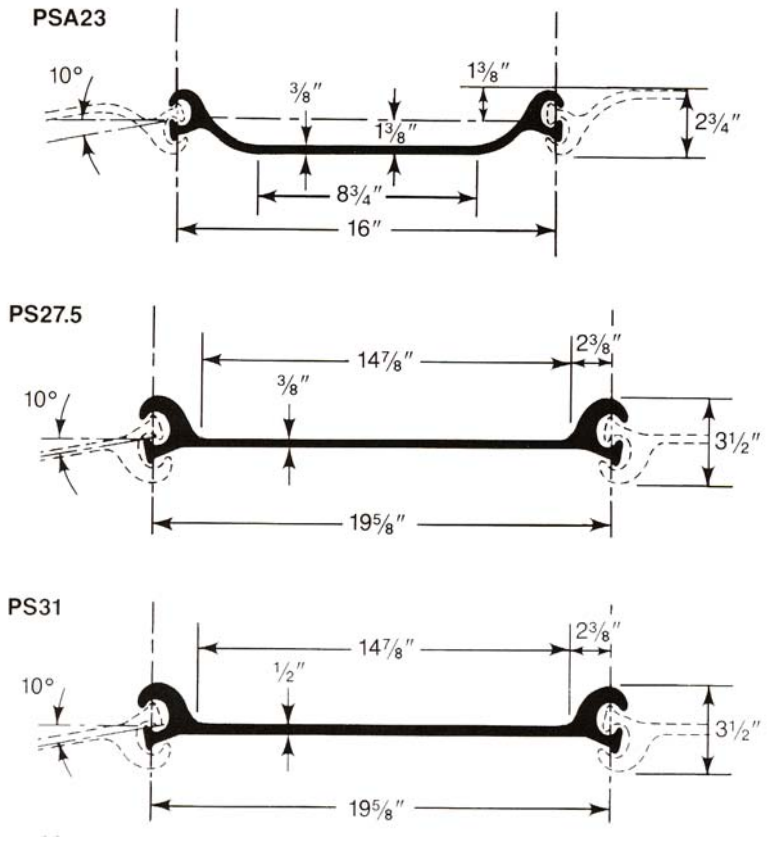
* Any published interlock strengths in this publication are valid only for properly interlocked Bethlehem Steel sections. The interlock strength of improperly interlocked sections or of Bethlehem Steel sections interlocked with sections from another producer is unknown.

Setting and Driving Tips

Although setting and driving techniques vary with the individual contractor and site conditions, several basic principles can generally be applied. It should be realized that the lack of good setting and driving practices can result in job delays and an unsatisfactory structure. The following suggestions are offered to help avoid problems at the site:

- Have an adequate driving template. This will facilitate setting and driving and result in a superior end product.
- The diameter of the template is predicated on the contractor's method of setting circular cells. It must be realized, however, that the PSA or PS sheet piling section width may vary somewhat from the published nominal width. For the purposes of template sizing and sheet setting, it should be assumed that the sheet width may vary by ±2% from the published width. Upon filling, the finished cell will expand to meet or exceed published values.
- Accurately locate and set a fabricated connection. The connection will have greater stiffness than a plain sheet and will, thereby, provide a solid starting point. If a single cell with long sheets is being constructed, it may be advisable to stiffen the starter sheet by reinforcing it full length with a structural shape.
- Splicing, site conditions permitting, might be considered when constructing cells with sheet piling lengths in excess of 80 ft. Splices on adjacent sheets should be staggered several feet.
- Mark the driving template for each pile or pair of piles. This allows for wall adjustments to be made during the setting phase, insuring that the sheets are located properly for cell closure.
- Insure that the sheets are properly interlocked when set. Improper interlocks become the "weak links" and result in job delays and/or failures.
- Set all sheets in the cell before driving any of the sheets, other than nominal pinning of the starter sheet(s).
- Shake out several sheets at any closure point. This will insure that the sheets are free sliding, and thereby minimize the chance of driving a sheet out of interlock.
- Drive piles in pairs. Once sheet piles are threaded and set, it is more economical to drive two at a time. (Some experts suggest that the energy needed to drive a pair may be only 50% more than that required to drive a single pile.)
- Drive piles in stages and work around the entire cell by alternating sheets (pairs). This allows the piles to be guided by those previously driven, and lessens the chance of driving a sheet out of interlock. The distance a pile, or pair of piles, should be driven at any one time will be governed by the driving conditions.

Dimensions for Detailing

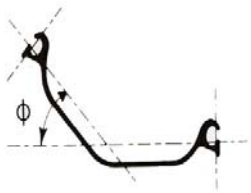


PS-type, long-length sheet piling enables very deep cofferdams to be built for lock and dam construction on major rivers.

Standard Fabricated Connections
Used with PSA23

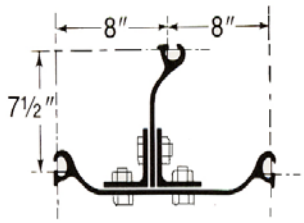
Bent Web Piles

BW230 30.7 lb/ft



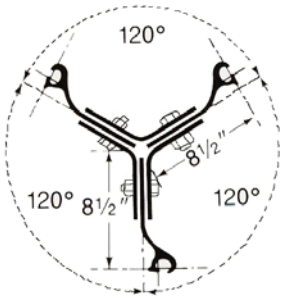
90° T Piles

FT230 69 lb/ft



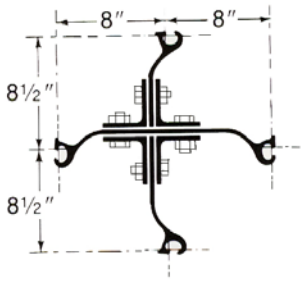
120° Y Piles

FY234 90 lb/ft

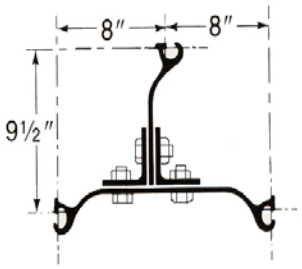


Cross

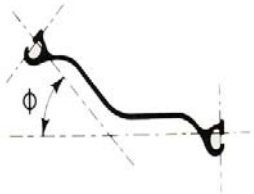
FX230 103 lb/ft



FT231 69 lb/ft



BW231 30.7 lb/ft



Notes:

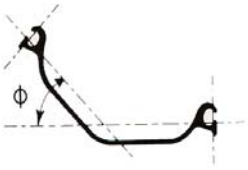
- Standard angle: 3- ½ x 3- ½ x ⅜ in.
- Standard bent plate size for 120° Y: ⅜ x 10 in.
- Fasteners are ⅞ -in. high-strength bolts spaced on 6-in. centers throughout the length of the section, except for 2 ft at each end where they are located on 3-in. centers.
- A different arrangement of the interlocks is obtained by reversing the connections end for end.

See General Specifications (page 34) for additional information.

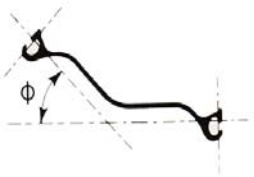
Standard Fabricated Connections
Used with PS27.5 or PS31
With specified interlock strength of 16 kips/in.

Bent Web Piles

BW230 30.7 lb/ft

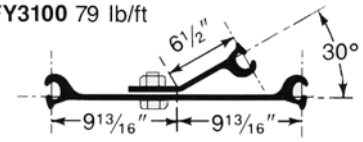


BW231 30.7 lb/ft

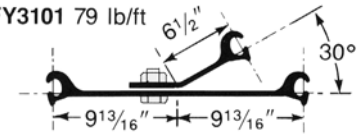


30° Y Piles

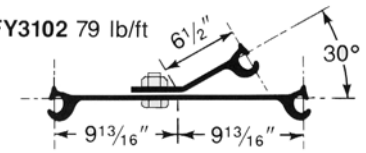
FY3100 79 lb/ft



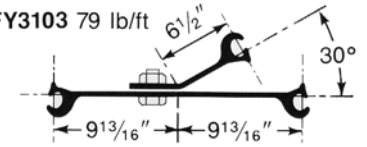
FY3101 79 lb/ft



FY3102 79 lb/ft

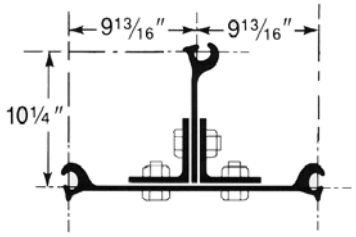


FY3103 79 lb/ft

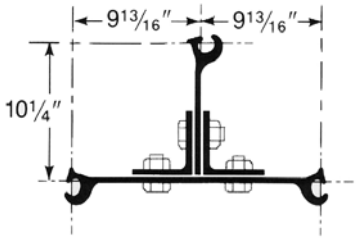


90° T Piles

FT3100 118 lb/ft



FT3101 118 lb/ft



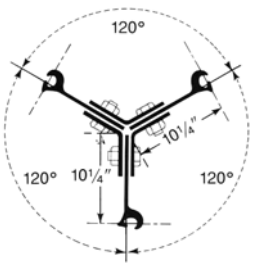
Notes:

- *It is suggested that the designer consider using section PS31 for all fabricated connections. The connections shown on this page are based on using PS31.*
- Angles, plates and bolts are as follows:

Connection	Angle in.	Bent Plate in.	Bolt Diameter in.
30 Y	-	-	7/8
90 T	5 x 5 x 1/2	-	7/8
120 Y	-	10 1/2 x 1/2	1

120° Y Pile

FY3104 143 lb/ft



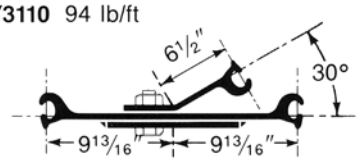
- Angles and plates will be furnished in ASTM A36 steel.
- Fasteners are high-strength ASTM A325 bolts, with washers, spaced on 4 ½ -in. centers throughout the length of the section, except for the last 2 ft at each end where they are located on 3-in. centers.
- A different arrangement of the interlock is obtained by reversing the connection end for end.

See General Specifications (page 34) for additional information.

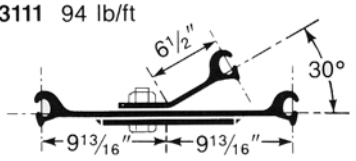
Standard Fabricated Connections
Used with PS27.5 or PS31
With specified interlock strength of 20 kips/in. or 24* kips/in.

30° Y Piles

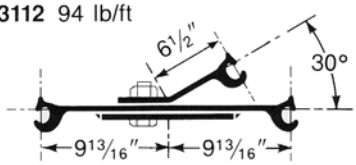
FY3110 94 lb/ft



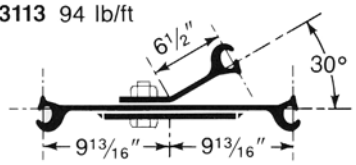
FY3111 94 lb/ft



FY3112 94 lb/ft

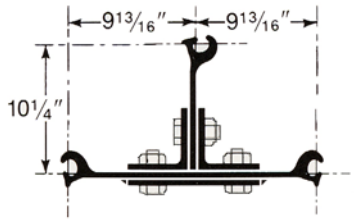


FY3113 94 lb/ft

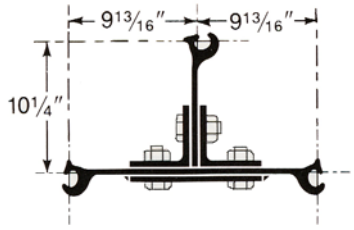


90° T Piles

FT3110 135 lb/ft

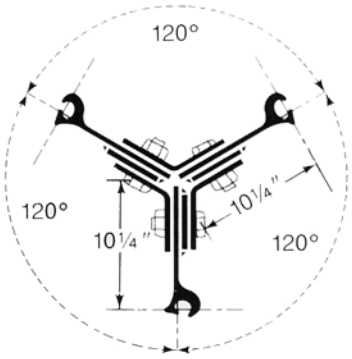


FT3111 135 lb/ft



120° Y Piles

FY3114 169 lb/ft



Notes:

- *It is suggested that the designer consider using section PS31 for all fabricated connections. The connections shown on this page are based on using PS31.*
- Angles, plates and bolts are as follows:

Connection	Angle in.	Bent Plate in.	Reinforcing Plate in.	Bolt Diameter in.
30 Y	-	-	10 1/2 x 3/8	1
90 T	5 x 5 x 1/2	-	10 1/2 x 3/8	1
120 Y	-	10 1/2 x 1/2	5 x 3/8	1 1/8

- Angles and plates will be furnished in ASTM A36 steel.
- Fasteners are high-strength ASTM A325 bolts, with washers, spaced on 4 ½ -in. centers throughout the length of the section, except for the last 2 ft at each end where they are located on 3-in. centers.
- A different arrangement of the interlock is obtained by reversing the connection end for end.

See General Specifications (page 34) for additional information.

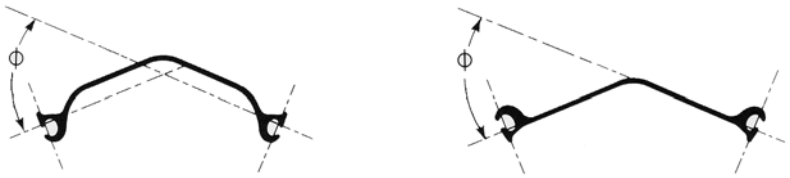
*Not available in PS27.5. See page 23 for information on interlock strength.

Diameters and Areas of Circular Cells
Using PSA23, PS27.5 and PS31

Number of Pieces	PSA23		PS27.5 & PS31		Required* Swing deg	Theoretical Bend deg	Furnished Bend ø deg
	D ft	Area ft^2	D ft	Area ft^2			
12	5.09	21	6.27	31	30.0	20.0	30.0
14	5.94	28	7.31	42	25.7	15.7	25.0
16	6.79	36	8.36	55	22.5	12.5	20.0
18	7.64	46	9.40	69	20.0	10.0	20.0
20	8.49	57	10.45	86	18.0	8.0	15.0
22	9.34	69	11.49	104	16.4	6.4	15.0
24	10.19	82	12.53	123	15.0	5.0	15.0
26	11.03	96	13.58	145	13.8	3.6	10.0
28	11.88	111	14.62	168	12.9	2.9	10.0
30	12.73	127	15.67	193	12.0	2.0	10.0
32	13.58	145	16.71	219	11.3	1.3	10.0
34	14.43	164	17.76	248	10.6	.6	10.0
36	15.28	183	18.80	278	10.0		
38	16.13	204	19.85	309	9.5		
40	16.98	226	20.89	343	9.0		
42	17.83	250	21.94	378	8.6		
44	18.67	274	22.98	415	8.2		
46	19.52	299	24.03	453	7.8		
48	20.37	326	25.07	494	7.5		
50	21.22	354	26.11	536	7.2		
52	22.07	383	27.16	579	6.9		
54	22.92	413	28.20	625	6.7		
56	23.77	444	29.25	672	6.4		
58	24.62	476	30.29	721	6.2		
60	25.46	509	31.34	771	6.0		
62	26.31	544	32.38	824	5.8		
64	27.16	580	33.43	878	5.6		
66	28.01	616	34.47	933	5.5		
68	28.86	654	35.52	999	5.3		

Number of Pieces	PSA23		PS27.5 & PS31		Required* Swing deg
	D ft	Area ft^2	D ft	Area ft^2	
70	29.71	693	36.56	1050	5.1
72	30.56	733	37.61	1111	5.0
74	31.41	775	36.65	1173	4.9
76	32.26	817	39.69	1238	4.7
78	33.10	861	40.74	1304	4.6
80	33.95	905	41.78	1371	4.5
82	34.80	951	42.83	1441	4.4
84	35.65	998	43.87	1512	4.3
86	36.50	1046	44.92	1585	4.2
88	37.35	1096	45.96	1659	4.1
90	38.20	1146	47.01	1736	4.0
92	39.05	1198	48.05	1813	3.9
94	39.89	1250	49.10	1893	3.8
96	40.74	1304	50.14	1975	3.8
98	41.59	1359	51.18	2057	3.7
100	42.44	1415	52.23	2143	3.6

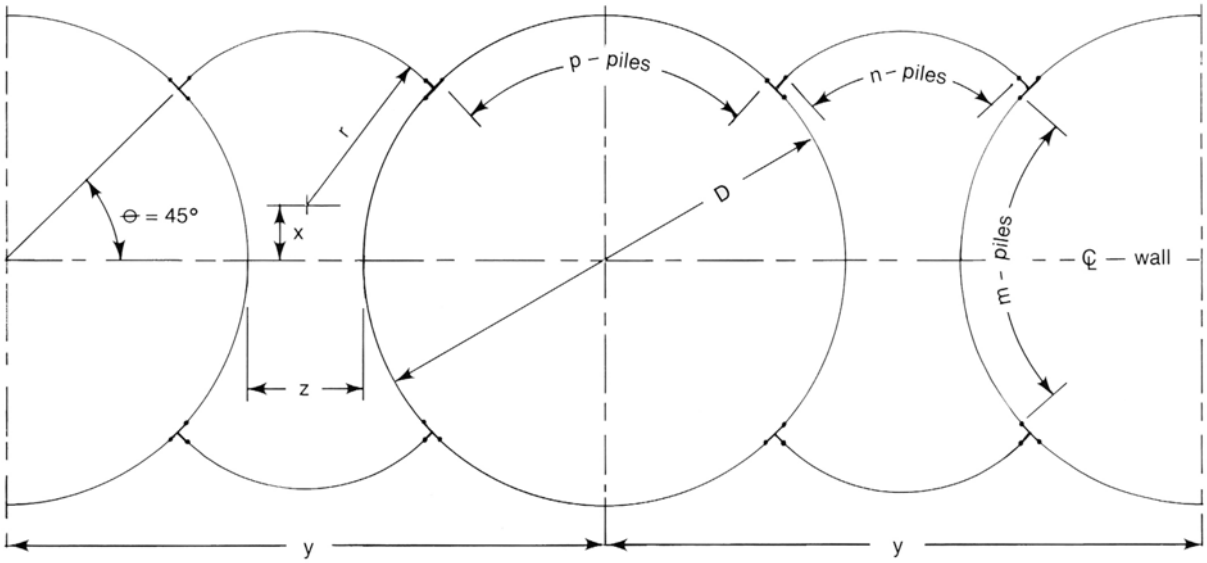
PSA23, PS27.5 and PS31, when properly interlocked, are designed to provide a swing up to 10 degrees (in either direction) for lengths up to 70 ft. The ability to obtain a lu1110 degree swing decreases with length because of the difficulty in handling the longer pieces. For lengths over 70 ft, it is necessary to anticipate a reduction in obtainable swing of 1.5 degrees for each 10 ft increase in length.



Small cells constructed with bent web piles must have half of the piles bent with fingers inside and half with fingers outside. For example, with Section PSA 23, half the piles would be BW230 and the remainder would be BW231. Refer to pages 26 and 27 for section data on bent web piles.

See page 24 for “Setting and Driving Tips” including guidance for template sizing.

Cellular Layout Using PSA23
Circular Type With 90° T Connections

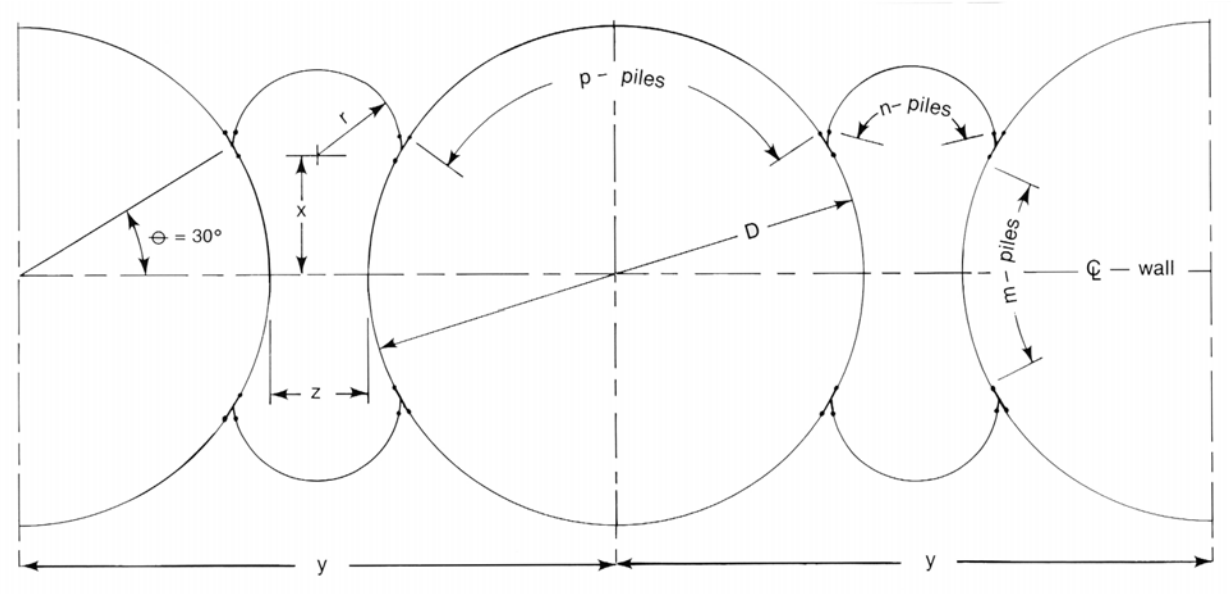


SECTION PSA23											
*Number of Piles in Cell	D ft	z ft	y ft	r ft	x ft	Number of Piles			Area, sq ft		Average Width ft
						m	n	p	Within circle	Between circles	
48	20.37	6.11	26.48	8.54	1.16	11	9	11	326	156	18.2
52	22.07	5.62	27.69	8.54	1.76	12	9	12	383	161	19.6
56	23.77	6.32	30.09	9.39	1.76	13	10	13	444	193	21.2
60	25.46	5.82	31.28	9.39	2.36	14	10	14	509	197	22.6
64	27.16	5.33	32.49	9.39	2.96	15	10	15	579	200	24.0
68	28.86	6.03	34.89	10.24	2.96	16	11	16	654	236	25.5
72	30.56	5.53	36.09	10.24	3.56	17	11	17	733	239	27.0
76	32.26	5.03	37.29	10.24	4.16	18	11	18	817	242	28.4
80	33.95	5.74	39.69	11.09	4.16	19	12	19	905	282	29.9
84	35.65	5.24	40.89	11.09	4.76	20	12	20	998	284	31.4
88	37.35	5.94	43.29	11.94	4.76	21	13	21	1096	328	32.9
92	39.05	5.44	44.49	11.94	5.36	22	13	22	1197	330	34.3
96	40.74	6.15	46.89	12.79	5.36	23	14	23	1304	377	35.9
100	42.44	5.65	48.09	12.79	5.96	24	14	24	1415	379	37.3
104	44.14	5.15	49.29	12.79	6.56	25	14	25	1530	380	38.7
108	45.84	5.86	51.70	13.63	6.56	26	15	26	1650	431	40.3
112	47.53	5.36	52.89	13.63	7.17	27	15	27	1775	432	41.7
116	49.23	6.06	55.29	14.48	7.17	28	16	28	1904	487	43.2
120	50.93	5.57	56.50	14.48	7.77	29	16	29	2037	487	44.7
124	52.63	5.07	57.70	14.48	8.37	30	16	30	2175	487	46.1
128	54.32	5.77	60.09	15.33	8.37	31	17	31	2318	546	47.7
132	56.02	5.27	61.29	15.33	8.97	32	17	32	2465	545	49.1

SECTION PSA23											
*Number of Piles in Cell	D ft	z ft	y ft	r ft	x ft	Number of Piles			Area, sq ft		Average Width ft
						m	n	p	Within circle	Between circle	
140	59.42	5.48	64.90	16.18	9.57	34	18	34	2773	607	52.1
144	61.12	4.98	66.10	16.18	10.17	35	18	35	2934	605	53.5
148	62.81	5.69	68.50	17.03	10.17	36	19	36	3099	672	55.1
*Including four T piles											

The dimensions shown above require one FT 230 and one FT231 in each connecting arc.
Average width shown = [area within circle + area between circles] / y.
See page 24 for “Setting and Driving Tips,” including guidance for template sizing.

Cellular Layout Using PS27.5 and/or PS31
Circular Type With 30° Y Connections



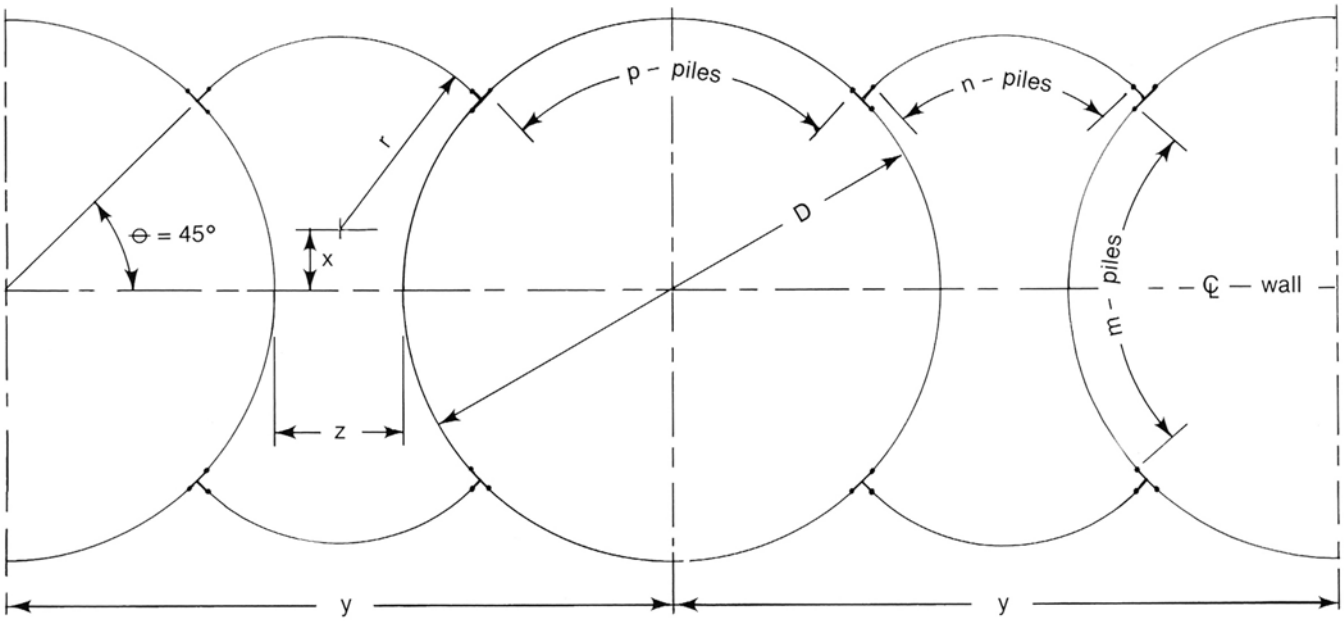
SECTION PS27.5 and PS31											
*Number of Piles in Cell	D ft	z ft	y ft	r ft	x ft	Number of Piles			Area, sq ft		Average Width ft
						m	n	p	Within circle	Between circles	
84	43.87	14.66	58.53	10.27	10.97	13	19	27	1512	694	37.7
90	47.01	15.28	62.29	10.79	11.75	14	20	29	1735	773	40.3
96	50.14	15.91	66.05	11.31	12.54	15	21	31	1975	855	42.9
102	53.27	16.54	69.81	11.83	13.32	16	22	33	2229	942	45.4
108	56.41	17.16	73.57	12.36	14.10	17	23	35	2499	1033	48.0
114	59.54	17.78	77.32	12.88	14.89	18	24	37	2784	1127	50.6
120	62.68	18.41	81.09	13.40	15.67	19	25	39	3085	1226	53.2
126	65.81	19.03	84.84	13.92	16.45	20	26	41	3401	1329	55.8
132	68.94	19.65	88.59	14.45	17.24	21	27	43	3733	1436	58.4
138	72.08	20.28	92.36	14.97	18.02	22	28	45	4080	1547	60.9
144	75.21	20.90	96.11	15.49	18.80	23	29	47	4443	1663	63.5
150	78.34	21.53	99.87	16.01	19.59	24	30	49	4821	1782	66.1
156	81.48	22.15	103.63	16.53	20.37	25	31	51	5214	1905	68.7

*Including four Y Piles

Average width shown = [area within circle + area between circles] / y

See page 24 for “Setting and Driving Tips,” including guidance for template sizing.

Cellular Layout Using PS27.5 and/or PS31
Circular Type With 90° T Connections



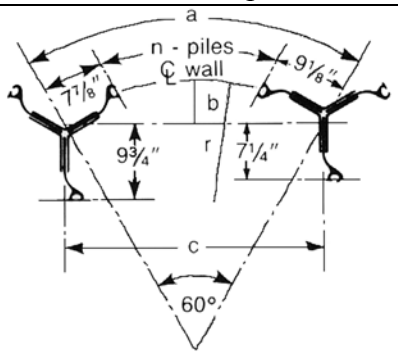
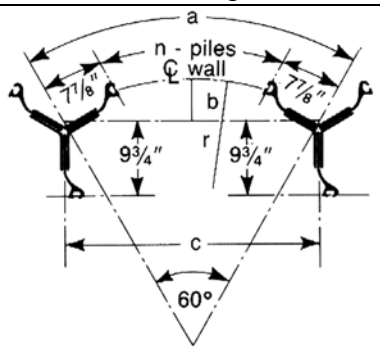
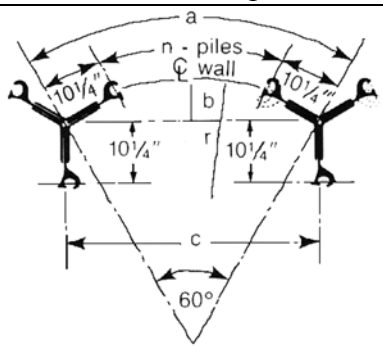
SECTION PS27.5 and PS31											
*Number of Piles in Cell	D ft	z ft	y ft	r ft	x ft	Number of Piles			Area, sq ft		Average Width ft
						m	n	p	Within circle	Between circles	
44	22.98	8.10	31.08	10.49	.71	10	9	10	415	228	20.7
48	25.07	7.49	32.56	10.49	1.45	11	9	11	493	236	22.4
52	27.16	6.88	34.04	10.49	2.18	12	9	12	579	242	24.1
56	29.25	6.27	35.52	10.49	2.92	13	9	13	672	247	25.9
60	31.34	5.66	37.00	10.49	3.66	14	9	14	771	251	27.6
64	33.43	6.52	39.95	11.53	3.66	15	10	15	877	302	29.5
68	35.52	5.91	41.43	11.53	4.40	16	10	16	990	305	31.3
72	37.61	5.30	42.91	11.53	5.14	17	10	17	1110	308	33.1
76	39.69	6.16	45.85	12.58	5.14	18	11	18	1237	365	34.9
80	41.78	5.55	47.33	12.58	5.88	19	11	19	1370	367	36.7
84	43.87	6.42	50.29	13.62	5.88	20	12	20	1511	429	38.6
88	45.96	5.80	51.76	13.62	6.62	21	12	21	1658	430	40.4
92	48.05	6.67	54.72	14.66	6.62	22	13	22	1812	498	42.2
96	50.14	6.06	56.20	14.66	7.35	23	13	23	1974	499	44.0
100	52.23	5.45	57.68	14.66	8.09	24	13	24	2141	499	45.8
104	54.32	6.31	60.63	15.71	8.09	25	14	25	2316	573	47.7
108	56.41	5.70	62.11	15.71	8.83	26	14	26	2498	573	49.5
112	58.50	6.57	65.07	16.75	8.83	27	15	27	2686	652	51.3
116	60.59	5.95	66.54	16.75	9.57	28	15	28	2881	651	53.1

SECTION PS27.5 and PS31											
*Number of Piles in Cell	D ft	z ft	y ft	r ft	x ft	Number of Piles			Area, sq ft		Average Width ft
						m	n	p	Within circle	Between circles	
120	62.68	6.82	69.50	17.80	9.57	29	16	29	3084	736	55.0
124	64.76	6.21	70.97	17.80	10.31	30	16	30	3293	735	56.8
128	66.85	5.59	72.44	17.80	11.05	31	16	31	3508	733	58.6
*Including four T piles											

Average width shown = [area within circle + area between circles] / y.

See page 24 for “Setting and Driving Tips,” including guidance for template sizing.

Cellular Layout Using PSA23, PS27.5 or PS31
Diaphragm Type With 120° Y Connections

SECTION PSA23		SECTION PS27.5 or PS31
Arrangement A even number of piles	Arrangement B odd number of piles	Either even or - odd number of piles
		

No. of Piles-n	a ft	r & c ft	b ft	Area* ft^2	a ft	r & c ft	b ft	Area* ft^2	a ft	r & c ft	b ft	Area* ft^2	No. of Piles-n
5					7.98	7.62	1.02	5	9.91	9.47	1.57	8	5
6	9.42	8.99	1.20	7					11.55	11.03	1.48	11	6
7					10.65	10.17	1.36	9	13.19	12.60	1.69	14	7
8	12.08	11.54	1.55	12					14.84	14.17	1.90	18	8
9					13.31	12.71	1.70	15	16.48	15.73	2.11	22	9
10	14.75	14.09	1.89	18					18.12	17.30	2.32	27	10
11					15.98	15.26	2.04	21	19.76	18.87	2.53	32	11
12	17.42	16.63	2.23	25					21.40	20.43	2.74	38	12
13					18.65	17.81	2.39	29	23.04	22.00	2.95	44	13
14	20.08	19.18	2.57	33					24.68	23.57	3.16	50	14
15					21.31	20.35	2.73	38	26.32	25.13	3.37	57	15
16	22.75	21.72	2.91	43					27.96	26.70	3.58	65	16
17					23.98	22.90	3.07	48	29.60	28.27	3.79	72	17
18	25.42	24.27	3.25	53					31.24	29.84	4.00	81	18
19					26.65	25.44	3.41	59	32.89	31.40	4.21	89	19
20	28.08	26.82	3.59	65					34.53	32.97	4.42	98	20
21					29.31	27.99	3.75	71	36.17	34.54	4.63	108	21
22	30.75	29.36	3.93	78					37.81	36.10	4.84	118	22
23					31.98	30.54	4.09	84	39.45	37.67	5.05	129	23
24	33.42	31.91	4.28	92					41.09	39.24	5.26	139	24
25					34.65	33.08	4.43	99	42.73	40.80	5.47	151	25

No. of Piles-n	a ft	r & c ft	b ft	Area* ft^2	a ft	r & c ft	b ft	Area* ft^2	a ft	r & c ft	b ft	Area* ft^2	No. of Piles-n
26	36.08	34.46	4.62	108					44.37	42.37	5.68	163	26
27					37.31	35.63	4.77	115	46.01	43.94	5.89	175	27
28	38.75	37.00	4.96	124					47.65	45.50	6.10	188	28
29					39.98	38.18	5.11	132	48.29	47.07	6.31	201	29
30	41.42	39.55	5.30	142					50.93	43.64	6.52	214	30
*Area between chord and subtended arc.													

See page 24 for “Setting and Driving Tips,” including guidance for template sizing.

General Specifications

Material

Bethlehem Steel Sheet Piling is furnished to the requirements of the Standard Specification for Steel Sheet Piling of the American Society for Testing and Materials, ASTM Designation A328. In addition, Bethlehem can supply sheet piling in high-strength, low-alloy grades - ASTM A572Grades 50 and 60 and ASTM A690. Bethlehem can also supply sheet piling to meet Charpy (CVN) requirements. All grades of steel are readily available from regular mill rollings.

Number of Tests

Two tension tests shall be made from each heat. In addition, two interlock tests shall be made from each heat for sections P5A23, PS27.5 and PS31.

Tolerances

When using steel sheet piling, it is necessary to make allowances for deviations from theoretical exactness. The degree of precision obtainable in the production of steel sheet piling is limited by the basic character of the rolling processes and normal limitations of mill equipment. Interlocks should be continuous and reasonably free-sliding when threaded.
Care must be taken during installation to assure that each pair of sheets is being set at the desired driving dimension. All steel sheet piling and fabricated connections have an allowable weight variation of ±2-1/2% and are invoiced on theoretical weight. Length tolerance is -0 in., +5 in.

Fabricated Connections

Unless otherwise specified, all connections will be fabricated with angles or bent plates, with appropriate grades as necessary, and with high-strength bolts. ASTM A690 connections will be furnished with angles or plates made from ASTM A588 steel and with ASTM A325 Type 3 bolts.

Lengths

Sheet piling sections are rolled and cut to the ordered length. For best economy, the designer should specify the actual length as calculated in the design process. An exception would be when many different lengths are required, such as in a sloped wall. Economy is best achieved in such cases by ordering in one-ft increments.
All sections are readily available in lengths up to 70 ft from regular rollings. Bethlehem can supply longer lengths, sometimes in excess of 100 ft, but requires sufficient lead time to properly schedule such material. Before ordering lengths exceeding 70 ft, it is best to check availability by calling the Bethlehem product office.

Splicing

If possible, splicing of Z-piling should be avoided. See page 6 for additional information.

Handling Holes

Unless otherwise specified, all plain piling sections shipped directly from the mill are provided with standard handling holes in the centerline of the web. The standard handling hole is a 2-9/16-in.-diameter hole approximately 6 in. from the end.

Z-Piling - one hole in each end.
PSA and PS Piling - one hole in one end only.

Orders should specify if no holes are required.
All fabricated connections have handling holes that are 1-3/8 in. in diameter. They are located about 6 in. from the top of each leg.

Pairing

Z-Piling in lengths up to 60 ft can be supplied in pairs. The pairs will be shipped without welding or crimping which will insure maximum flexibility when setting a wall.

Driving

Assembly of panels of steel sheet piling before driving is suggested. This facilitates driving, maintains piling verticality, and makes it possible I o obtain the nominal width of piling sections.
Z-piles should be driven with the ball edge leading. In addition, care should be taken - in the selection of connections and in planning for closed structures (cofferdams, etc.) - to provide for the proper sequence of driving. For normal interlocking, alternate Z-piles must be reversed end for end.
For setting and driving tips see page 6 for Z-piling and page 24 for PSA and PS piling.

Technical Information

Bethlehem is prepared to furnish additional technical information on sheet piling and its uses and will consult with engineers who are preparing designs that involve Bethlehem Steel Sheet Piling. Call your nearest Bethlehem representative or get in touch with Piling Products, Bethlehem Steel Corporation, Bethlehem, PA 18016.

Chemical Composition Percent (Heat Analysis)

Grade	Carbon Max	Manganese	Phosporus	Sulfur Max	Silicon Max	Vanadium	Copper Min	Nickel
A328	-	-	.04 max	.05	-	-	**	-
A572 - Gr 50	.23	1.35 max	.04 max	.05	.40	.01/.15*	**	-
- Gr 60	.26	1.35 max	.04 max	.05	.40	.01/.15*	**	-
A690	.22	.60/.90	.08/.15	.05	.40	-	.50	.40/.75
*In lieu of vanadium, 0.005/0.05% columbium may be used.								
**When copper-bearing steel is specified, the minimum copper is 0.20 percent.								

Mechanical Properties

Grade	Min Yield Point, Ksi	Min Tensile Strength, Ksi	Elongation in 8 in., min%
A328	39	70	17
A572 - GR 50	50	65	18
- GR 60	60	75	16
A690	50	70	18

V-STAR 50* Impact Resisting Steel

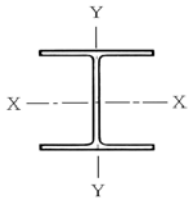
Section	Charpy (CVN) Energy**
PZ22, PZ27 PSA23 PS27.5, PS31	15 ft-lb @ -50F
PZ35, PZ40	15 ft-lb @ 0F
*Meets all the requirements of ASTM A572 - Grade 50	
** Inquire about availability of other toughness requirements	

Bethlehem H-Piles

Bethlehem Steel pioneered the rolling of wide-flange shapes in 1908. Since then, one of these shapes-steel H-piles-has achieved wide application as foundation supports for bridges, piers, buildings, industrial plants, and other structures. H-piles possess the following advantages.

- Great ability to stand up under hard driving.
- Capacity to develop high bearing value when driven to rock, and as friction piles in suitable soils.
- High column strength.
- Low cost of driving.
- Small soil displacement, permitting close spacing where necessary.
- Long life.
- Full-strength splicing easily attained.

H-Piles in Soldier Beam Construction



Steel H-piles are used extensively and advantageously in the construction of sheeted trenches for sewers, subways, and similar structures. They are driven in advance of the excavation, usually on 6- to 8-ft centers. As excavation proceeds, horizontal timber lagging is set in place between the pile flanges.

The trench is braced by means of cross-struts of steel framed against the inside flanges of the piles or into horizontal waling pieces. After the trench is completed, the piles are pulled and reused in the same manner.

In addition to providing a "backbone" of steel for the trench lagging, H-piles used in this manner have the important advantage that they can be driven well in advance of the excavation. In city streets, the piles can be driven through small holes cut in the pavement. These holes can be filled after the piles are driven so that traffic may proceed until the excavation approaches.

Design Properties

Section Number	Weight Per Foot	Area of Section	Depth of Section	Flange		Web Thick-ness	Axis X-X			Axis Y-Y			Surface Area
				Width	Thickness								
	lb	A $in.^2$	d in.	b_f in.	t_f in.	t_w in.	I_x $in.^4$	S_x $in.^3$	r_x in.	I_y $in.^4$	S_y $in.^3$	r_y in.	ft^2/ft
HP14X	117	34.4	14.21	14.885	0.805	0.805	1220	172	5.96	443	59.5	3.59	7.11
	102	30.0	14.01	14.735	0.705	0.705	1050	150	5.92	380	51.4	3.56	7.06
	89	26.1	13.83	14.695	0.615	0.615	904	131	5.88	326	44.3	3.53	7.02
	73	21.4	13.61	14.585	0.505	0.505	729	107	5.84	261	35.8	3.49	6.96
HP12X	84	24.6	12.28	12.295	0.685	0.685	650	106	5.14	213	34.6	2.94	5.97
	74	21.8	12.13	12.215	0.610	.605	569	93.8	5.11	186	30.4	2.92	5.91
	63	18.4	11.94	12.125	0.515	0.515	472	79.1	5.06	153	25.3	2.88	5.86
	53	15.5	11.78	12.045	0.435	0.435	393	66.8	5.03	127	21.1	2.86	5.82
HP10X	57*	16.8	9.99	10.225	0.565	0.565	294	58.8	4.18	101	19.7	2.45	4.91
	42*	12.4	9.70	10.075	0.420	.415	210	43.4	4.13	71.7	14.2	2.41	4.83
HP8X	36*	10.6	8.02	8.155	0.445	.445	119	29.8	3.36	40.3	9.88	1.95	3.92
*Sections currently produced by Bethlehem Steel													