Note:

Designs presented in this chapter are in accordance with the Eighth Edition of the Standard Specifications for Highway Bridges of the American Association of State Highway and Transportation Officials (AASHTO) dated 1961. They should be reviewed for adequacy in conforming to the latest edition of the AASHTO Specifications and subsequent interims.

Cost information in this chapter should be reviewed in light of present material and labor costs.

II/10
Steel Substructures

Steel Abutments

The abutment drawings shown in this chapter evolved from studies which attempted to develop an ideal design that would be inexpensive, simple and have a long life. In addition it was considered desirable to be able to use the design as a full height (20′ grade to grade) or a stub abutment.

It was evident that the wing wall treatment should be such as would help keep the cost down. Further, the basic design details for the back wall and wings should apply throughout the range of heights.

To assure long life certain features were incorporated into the design that exceed normal design requirements. To take into account mechanical or vandalism damage, the corrugated sheets are 18 gage rather than the 28 gage design requirement. The 6 x 6 angles on the wing are twice the design length for added stability not contemplated in the design. No provision has been made for special protection of the buried faces below finished ground other than the galvanizing on the corrugated sheets. If soil conditions warrant such special protection a protective coating can, of course, be applied.

The abutment, as shown, includes a vertical bearing H section under each stringer. The H section is selected to have sufficient capacity for cantilever action. A smaller H section extending from below the top of the stringer seat to the roadway surface is to be welded to the back of the larger H section. A split-tee section, shaped to roadway crown, is placed across the tops of the upper H sections to form the top of the backwall. This split-tee section was selected to resist wheel loads.

The abutment accommodates a twenty-four foot roadway with 10 foot wide shoulders. A standard material with 3 inch by 1 inch corrugations spans vertically between 4 inch I-beam members which are placed horizontally between the vertical H sections and the vertical corner angles.

A series of nine abutments was established based on the above scheme. Both bearing piles and WF shapes were designed for each of the nine abutments, the size and weight varying as necessary to resist the load. WF shapes were selected because of lighter sections. In place prices of $0.15 per pound for structural steel and $0.26 per pound for galvanized corrugated sheets were used to develop Figure 1.

Figure 1 shows that above the eight to ten foot height range, the slope of the curve is such that doubling the abutment height more than triples the cost. This leads to the problem of the combined effect of span length on superstructure and substructure costs.

In order to investigate the combined effect, costs were derived for the steel semi-orthotropic superstructure in Chapter 9 of this volume for spans from 40 ft. on up. Using minimum openings of 40′, 50′ and 60′ with full height abutments, the spans were increased and the abutment heights decreased to get the combined cost effect plotted in Figure 2.

The curves indicate optimum *structure* economy where the abutments are from 10′ to 12′ high and the spans 23′ to 28′ longer than minimum opening. The medium abutment included in this chapter is 8′ to 9′ high. Consideration of the curves shows very slight additional cost. From $100 on the 40′ curve to $1,000 on the 60′, the additional structure cost permits opening up the respective spans by 5′ and 10′. This provides a better appearance for the structure than the optimum span arrangement and is completely or partially offset by the savings in roadway quantities. In a specific problem the roadway

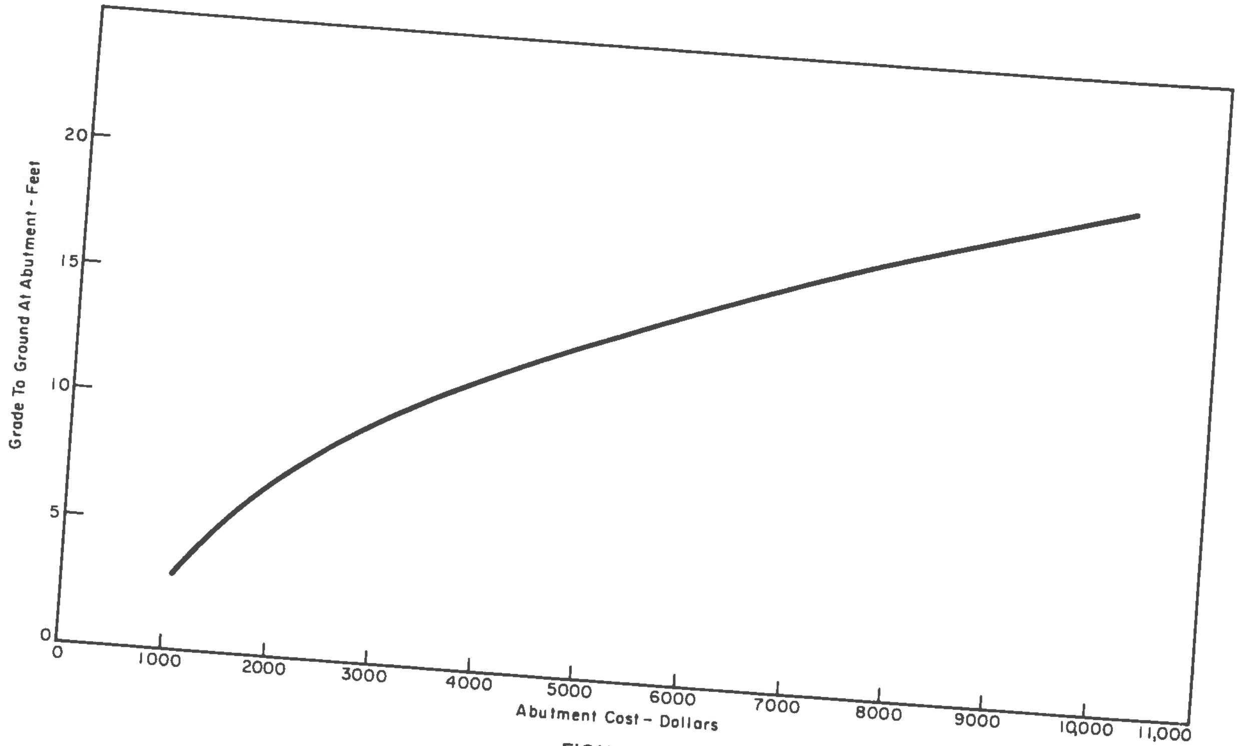


FIGURE 1

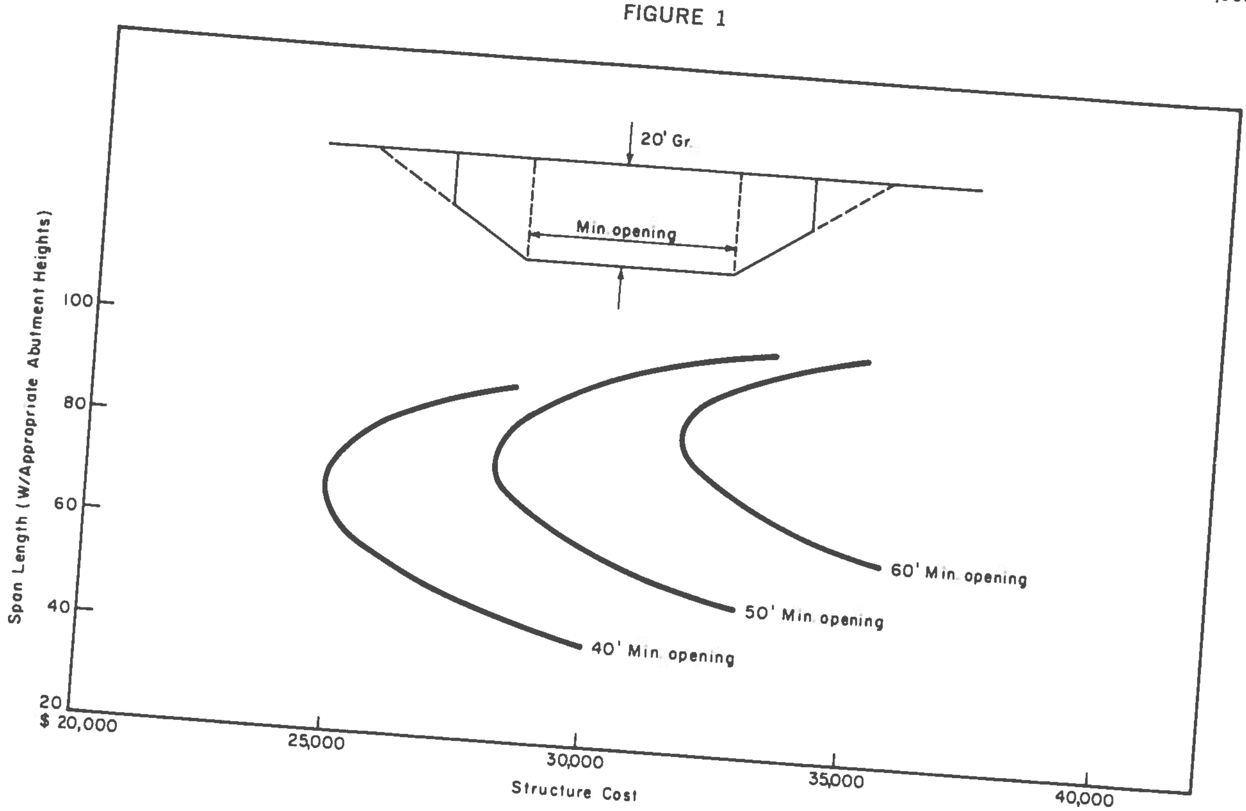


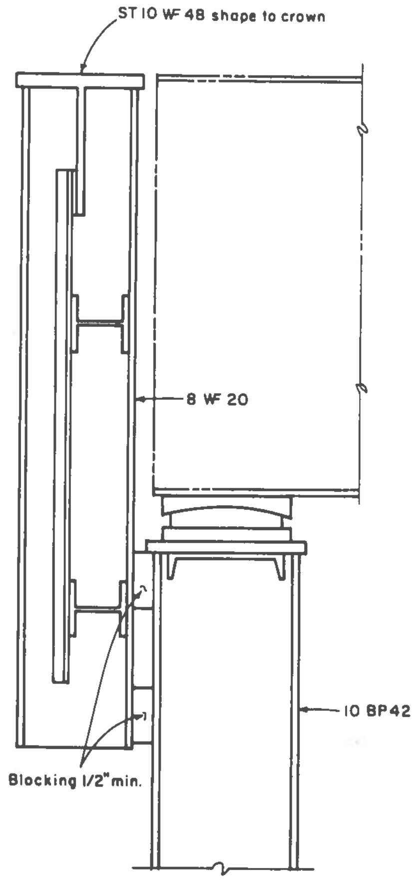
FIGURE 2

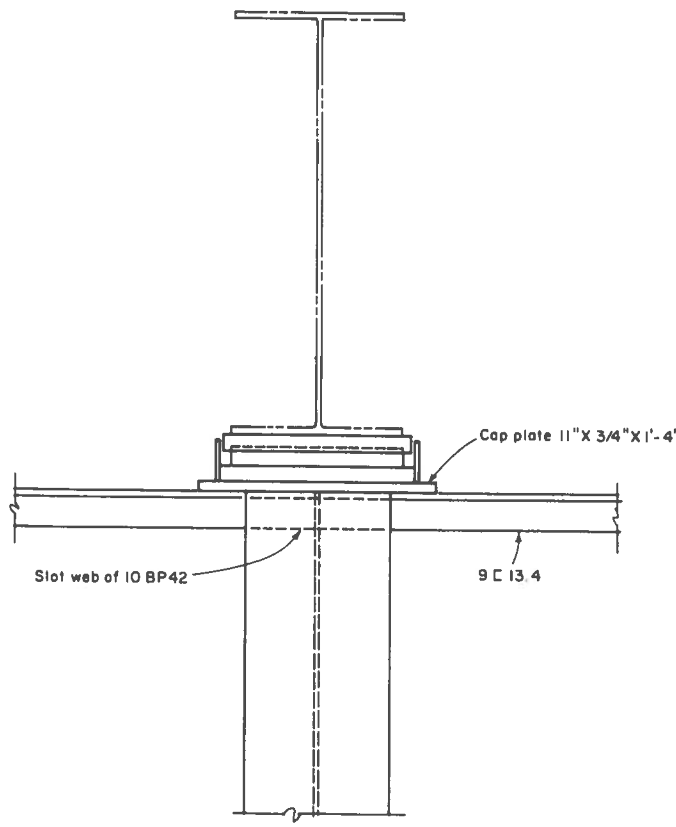
[section connecting tops of piles

L = 8 × 12 = 96"

Use 9[13.4 Cor.Ten.   r = 0.67

$$\frac{L}{r} = \frac{96}{0.67} = 143 < 200$$





Extend 9[13.4 9" beyond web of exterior pile.

LL + DL = 55.6^K & 46.3^K (No Impact, AASHO p. 17)
55,600# ÷ 6,000 (AASHO p. 58) = 9.3□" req'd.
8BP36   A = 10.6□"   S = 29.9

$$f_s = \frac{55,600}{10.6} + \frac{42,300 \times 12}{29.9} = 5250 + 17,000 = 22,250\#/\square''$$

Use 10BP42   A = 12.35□"   S = 43.4

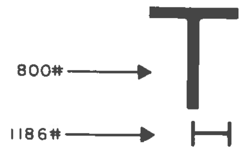
$$f_s = \frac{55,600}{12.35} + \frac{42,300 \times 12}{43.4} = 4500 + 11,700 = 16,200\#/\square''$$

For f_s = 20,000   M: $20,000 - 4500 = 15,500 = \frac{M \times 12}{43.4}$

M = 56,000#' $\frac{M}{8} = 7,000\#'/'$

$$\begin{aligned} 100 \times (14 + x) &= 1400 + 100x \\ 100 \times (5.5 + x) &= 550 + 100x \\ 500 \times (6.67 + x) &= \underline{3330 + 500x} \\ & \quad 5280 + 700x = 7000 \quad x = 2.45' \end{aligned}$$

Max. spill-through height for this pile = 4 + 2.45 = 6.5'
∴ From 3' to 6.5' @ no increase in cost.



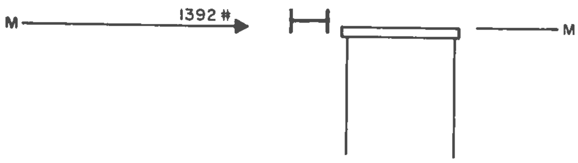
$$\left.\begin{matrix}80\\120\end{matrix}\right\} 100 \times 8' = 800\#$$

$$147 \times 8' = 1176\#$$

$$174 \times 8' = 1392\#$$

$$\text{Mom.}\quad \begin{aligned} 800\# \times 2.5' &= 2000\#' \\ 1186\# \times 2.0 &= \underline{2352} \\ & 4352\#' \end{aligned}$$

$$S \text{ req'd} = \frac{4352 \times 12}{27{,}000} = 1.95 \text{ in.}^3$$



8WF20 S = 17.0
Vertical member

Cantilever Moment of Lower 4[

$$M = \frac{1}{2} wl^2 = \frac{1}{2} \times 174 \times 10^2 = 8700\#'$$

$$S \text{ req'd.} = \frac{8700 \times 12}{27{,}000} = 3.87 \text{ in.}^3 \quad 4 \times 4M13.0 \quad S = 5.2 \text{ in.}^3$$

Requires moment connection to 8WF20.

Data from Superstructure:

	40′ Span				50′ Span				60′ Span			
	Int.		Ext.		Int.		Ext.		Int.		Ext.	
D.L.	4.8	51.3^K	5.0	41.8^K	6.3	55.6^K	7.3	46.3^K	8.1	59.4^K	8.4	49.0^K
L.L.	46.5		36.8		49.3		39.0		51.3		40.6	
Imp.	14.0		11.0		14.1		11.2		13.9		11.0	
	65.3^K		52.8^K		69.7^K		57.5^K		73.3^K		60.0^K	

	70′ Span				80′ Span			
	Int.		Ext.		Int.		Ext.	
D.L.	9.8	62.4^K	10.5	52.1^K	12.0	65.6^K	12.8	55.2^K
L.L.	52.6		41.6		53.6		42.4	
Imp.	13.5		10.6		13.1		10.3	
	75.9^K		62.7^K		78.7^K		65.5^K	

Abut. 4′ Fill 12WF36 as piles

40′ Span: M = 42,300#′ N = 51,300#

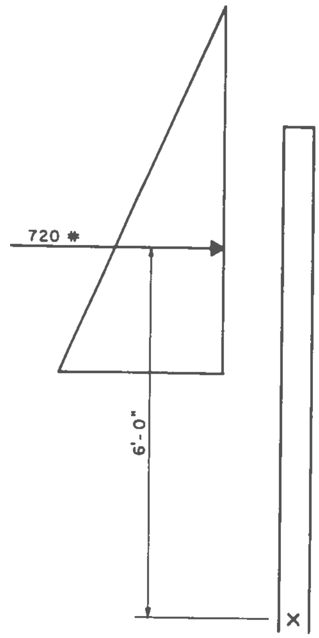
$$f_s = \frac{51{,}300}{10.59} + \frac{42{,}300 \times 12}{45.9} = 4850 + 11{,}050 = 15{,}900\#/\square''$$

$$50' \text{ Span: } f_s = 16{,}350\#/\square''$$

$$60' \text{ Span: } f_s = \frac{59{,}400}{10.59} + 11{,}050 = 5620 + 11{,}050 = 16{,}670\#/\square''$$

$$70' \text{ Span: } f_s = \frac{62{,}400}{10.59} + 11{,}050 = 5900 + 11{,}050 = 16{,}950\#/\square''$$

$$80' \text{ Span: } f_s = \frac{65{,}600}{10.59} + 11{,}050 = 6200 + 11{,}050 = 17{,}250\#/\square''$$



Side Pile:

$6 \times 40 = 240 \qquad \frac{240}{2} \times 6 = 720\#$

M: $720\# \times 6' = 4320'\#$/ft. wall

S for 6' wall $\frac{4320 \times 12 \times 6}{20{,}000} = 15.6$ in.^{3}

Use 8BP36 S = 29.9

12' Wings 14BP73, 28' long
8' Fill Height $f_s = 20{,}000\#/\square''$ Pile at Capacity

Capacity of 14BP89 A = 26.19□" S = 131.2 in.^{3}

$55{,}600 \div 26.19 = 2120 \quad 20{,}000 - 2120 = 17{,}880\#/\square'' = \frac{M \times 12}{131.2}$

$M = 195{,}000$

$\frac{M}{8} = 24{,}400\#'/'$

$$\begin{aligned} 100 \times (19 + x) &= 1{,}900 + 100x \\ 100 \times (10.5 + x) &= 1{,}050 + 100x \\ 2000 \times (8.33 + x) &= 16{,}660 + 2000x \\ &= 19{,}610 + 2200x = 24{,}400 \\ x &= 2.2' \end{aligned}$$

Height Range 8' to (8 + 2.2) = 8' to 10.2'

Try 14WF68 A = 21.76□" S = 103.0 in.^{3}

$f_s = \frac{55{,}600}{21.76} + \frac{157{,}000 \times 12}{103} = 2560 + 18{,}300 = 20{,}860\#/\square''$

Try 18WF64 A = 18.80□" S = 117.0 in.^{3}

Limit $20{,}000 - \left(\frac{55{,}600}{18.80} = 2960\right) = 17{,}040 = \frac{M \times 12}{117.0} \quad M = 166{,}000 \quad \frac{M}{8} = 20{,}700\#'/'$

$19{,}610 + 2200x = 20{,}700 \quad 2200x = 1090 \quad x = 0.5 \quad \underline{8.5'}$

Try 18WF77 A = 22.63□" S = 141.7 in.^{3}

Limit $20{,}000 - \left(\frac{55{,}600}{22.63} = 2460\right) = 17{,}540 = \frac{M \times 12}{141.7} \quad M = 207{,}000 \quad \frac{M}{8} = 25{,}800\#'/'$

$19{,}610 + 2200x = 25{,}800 \quad 2200x = 6170 \quad x = 2.8 + 8' = 10.8'$

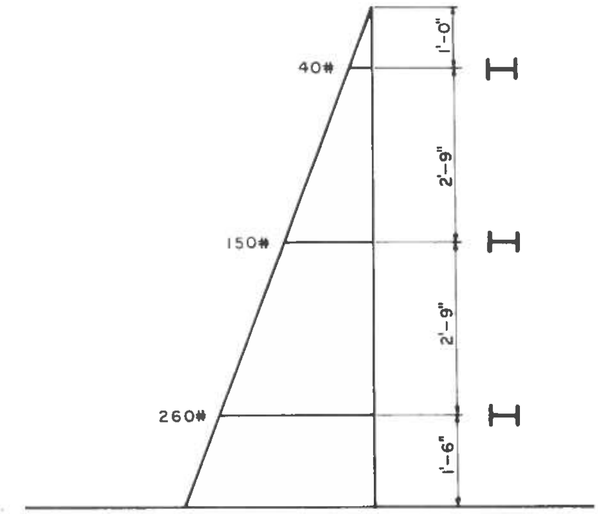
See Data from Superstructure—Minimum Abutment

12' Wings 8' Fill

Using 18WF64 as piles A = 18.80□" S = 117.0 in.^{3}

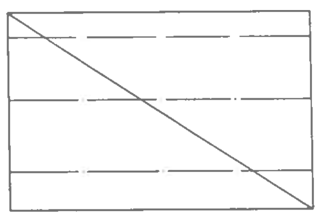
40' Span: M = 157,000#' N = 51,300#

$f_s = \frac{51{,}300}{18.80} + \frac{157{,}000 \times 12}{117.0} = 2730 + 16{,}100 = 18{,}830\#/\square''$

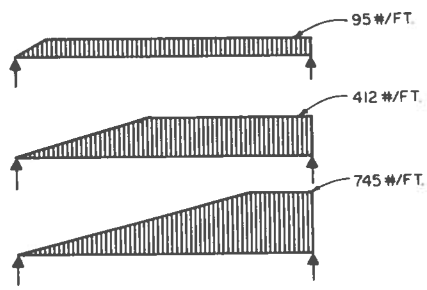


Side wall:—

40# × 2.37′ = 95#/′ over 11′ ±
150# × 2.75′ = 412#/′ over 7′ ±
260# × 2.87′ = 745#/′ over 3′ ±



Wall Elevation



Load Diagrams

$$M_{MAX.}\ 0.1283 \times \frac{800}{2} \times 12' \times 12' = 7400\#'$$

$$S \text{ req'd.} = \frac{7400 \times 12}{27{,}000} = 3.3 \text{ in.}^3$$

4 × 4M13.0 S = 5.20 in.^{3}

Estimate for Medium Abutment

1 — ST10WF48	= 48#	× 44′	= 2120
4 — 8WF20	= 80#	× 4′	= 320
4 — L 6 × 6 × 7/16	= 70#	× 20′	= 1400
4 — 4 × 4M13.0	= 52#	× 44′	= 2290
3 — 4 × 4M13.0	= 39#	× 24′	= 936
1 — 9[13.4	= 13.4#	× 28′	= 375
2 — PL 19 × ¾	= 96.9#	× 1.33′	= 129
2 — PL 19 × ¾	= 96.9#	× 1.67′	= 162
12 — Blocking PL @ 7#			= 84

Basic Structural = 7816# @ $0.15 = $1173

Corrugated PL:
44 × 9′ = 396
8 × 8′ = 64
8 × 7′ = 56
8 × 4′ = 32
548□′ @ 2.84#/□′ = 1557# @ $0.26 = $ 405

Steel Piles:
4 — 18WF64 × 28′ = 2170#′ @ 0.15 = $1075

Cost per abutment $2653

Say $2660
per abutment