ABUTMENTS FOR SMALL HIGHWAY BRIDGES

PART 4

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This report covers part "H" (Comparative Costs of Different Types for 25, 50, 75, and 100 ft spans) of the general outline of all factors relating to the design of abutments for small highway bridges.

Comparative designs and estimates of costs for several of the abutment types previously described and tabular data are given as a guide towards economy of type. Bridge reactions for two and three lane bridges of 25, 50, 75, and 100 ft spans are imposed on each type of abutment to show the variation in design and cost with different bridge sizes.

This report is the concluding part of the three previously published in *Proceedings*, Highway Research Board, Vol. 23, p 403 (1943), Vol, 24, p 332 (1944), and Vol. 25, p 399 (1945). It deals with the section of the general outline:

H. *Comparative Costs of Different Types for 25, 50, 75, and 100 ft spans.*

The information given in this report is for the guidance of the designing engineer and must be construed in the light of unit costs assumed for the various types of classified work. Relative costs of different materials vary with local experience and availability of specialized trades.

The cost of an abutment, if properly designed and built, can well be assumed as a fixed charge with no maintenance or depreciation for the life of the structure. Certainly, the abutments will outlast the bridge which they support and often are re-used for the support of bridge replacements. Careful attention is necessary to drainage and bearing details, as described in Section E (*Proceedings*, Vol. 25, 1945, p 399) of this report.

Loads. Total load (dead, live and impact) is taken at 300 lb per sq ft of bridge area. The reactions of the bridges allow for end overhangs necessary for bridge bearings (Fig. 1). In addition to roadway widths at 12 ft per lane, allowance is made for 4½-ft side clearances and railings. Bridge girders are assumed at 14-ft spacing for a 2-lane bridge with an added center spacing of 12 ft for a 3-lane bridge.

Two general soil types are assumed for backfill, with K_a of 0.50 and 0.25, equivalent to ϕ of about 20 deg and 38 deg, or average silty sand weighing 110 lb per cu ft and dry sand weighing 100 lb per cu ft respectively. Height of walls from footing level to bridge seat is taken at 15 ft. Allowing 3 ft for

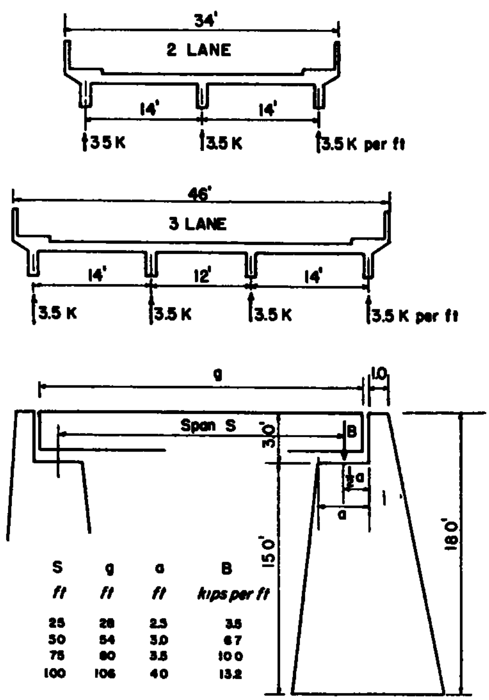
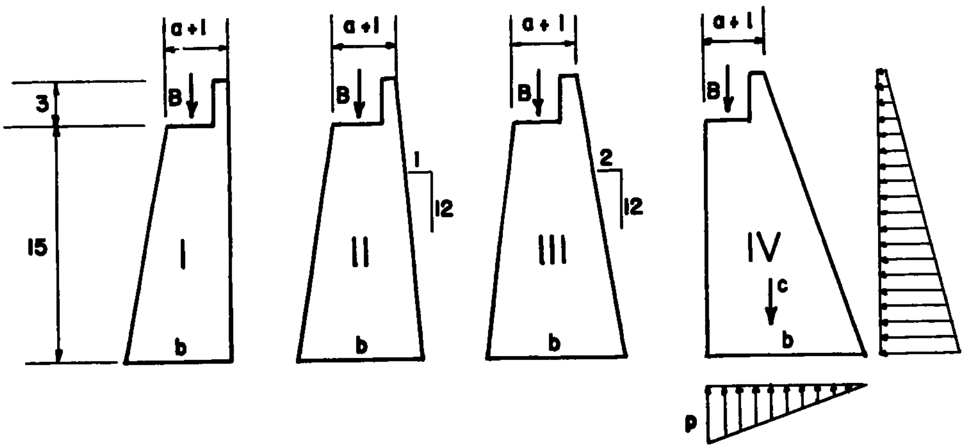


Figure 1. Bridge Sections and Loads

bridge depth and 2 ft as the equivalent surcharge for the live load, the total earth pressure is for a depth of 20 ft. From Table 4 (*Proceedings*, Vol. 23, 1943, p. 405), the point of application of the earth pressure is at 0.36 of the height of 18 ft., or at 6.5 ft above the base.

Designs of abutments of eight types were prepared for each of the two assumed soil backfills and for each of four bridge spans, i.e., 25, 50, 75, and 100 ft. Four gravity types were studied for base widths necessary to provide a resultant base reaction at the front edge of the middle third, which, on the assumed conditions are coincident with those encountered.

Two gravity types, V and VI, with vertical and horizontal relieving ribs are shown in Figure 3. In Type V, the reduction of base area in the rear of the wall has little effect on base pressures since the ribs provide suffi-



	Type I			Type II			Type III			Type IV			s
	b	*c*	*p*	*b*	*c*	*p*	*b*	*c*	*p*	*b*	*c*	*p*	
	ft	*cu ft*	*Kips per sq ft*	*ft*	*cu ft*	*Kips per sq ft*	*ft*	*cu ft*	*Kips per sq ft*	*ft*	*cu ft*	*Kips per sq ft*	*ft*
ϕ = 20°	9.2	98	4.8	9.9	106	4.8	10.7	114	4.7	13.5	146	4.5	25
w = 110	8.5	97	5.9	9.4	106	5.7	10.4	116	5.4	14.3	156	4.9	50
ϕ' = 15°	8 0	97	7.1	9.1	107	6.6	10.3	119	6.2	15.0	165	5.3	100
K_a = 0.50	7.7	98	8.3	9.0	115	7.7	10 2	122	7.0	15.8	175	5.6	75
ϕ = 38°	6 1	75	5.8	6.9	83	5.5	7.6	91	5.3	8 7	102	5 0	25
w = 100	5.8	77	7 3	6.7	86	6.7	7.8	96	6.2	9.1	109	5.6	50
ϕ' = 30°	5.6	79	8.8	6.8	90	7.8	8.0	101	7.1	9.5	116	6.4	75
K_a = 0.25	5.6	83	10 2	7 0	95	8.7	8.2	107	7 9	9.8	121	7.0	100

Note: b = Base Width. c = Volume of Abutment Per Foot. p = Maximum Base Pressure Per Sq. Ft.

Figure 2. Abutment Types I, II, III, IV

assumption of linear distribution is equivalent to a zero unit reaction at the heel.

Designs. Figure 2 shows the dimensions of the sections, Types I, II, III, and IV, for each case. Some minor simplifications were incorporated in the designs to reduce the amount of work, but they do not affect the conclusions. Actual designs for any type must include the correct soil and loading characteristics, and it is not intended that the dimensions listed be used for actual construction unless the cient area for the low compressive stresses existing at the rear. Type VI should receive special attention in backfilling and may require the postponement of the placing of backfill until the bridge loading is first applied on the abutment seat. This precaution is especially necessary if the foundation is on weak soil. In these two types, the base pressure, on the assumption of linear distribution is zero at the heel.

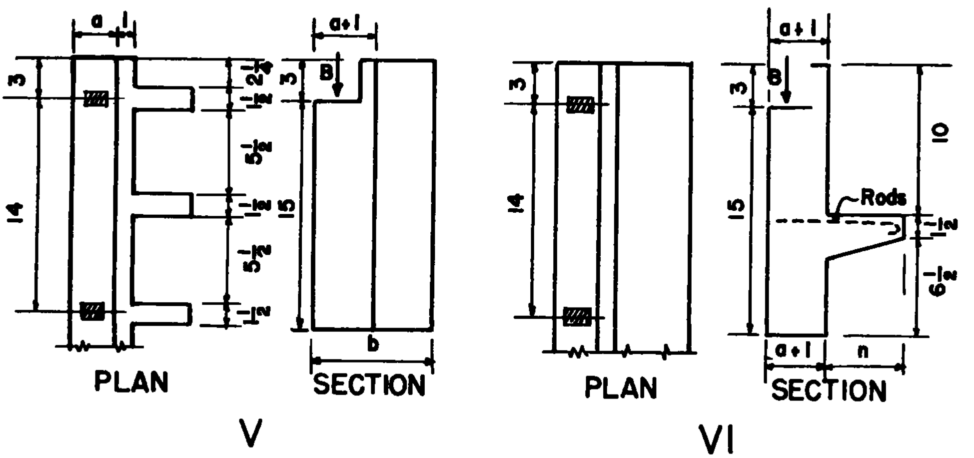
Two reinforced concrete types, VII and

VIII, cantilevered and buttress designs, are shown in Figure 4. Maximum concrete stress is 750 lb per sq in. and the reinforcement stress is 18,000 lb per sq in. Reinforcement is designed for the net moment resulting from the reduction of the earth pressure moment by the counterbalancing effect of the vertical loads.

Costs. Unit costs for comparison of design costs are:

a. Concrete including straight form work and excavation—$1.00 per cu ft.
b. Special formwork for ribs and counterforts—0.50 per sq ft
c. Reinforcement in place—0.12 per lb.

Costs per foot of abutment are shown in Table 1. In the reinforced concrete designs, allowance has been made in the weights of steel estimated for temperature and spacer bars, and for dowels into the foundations.



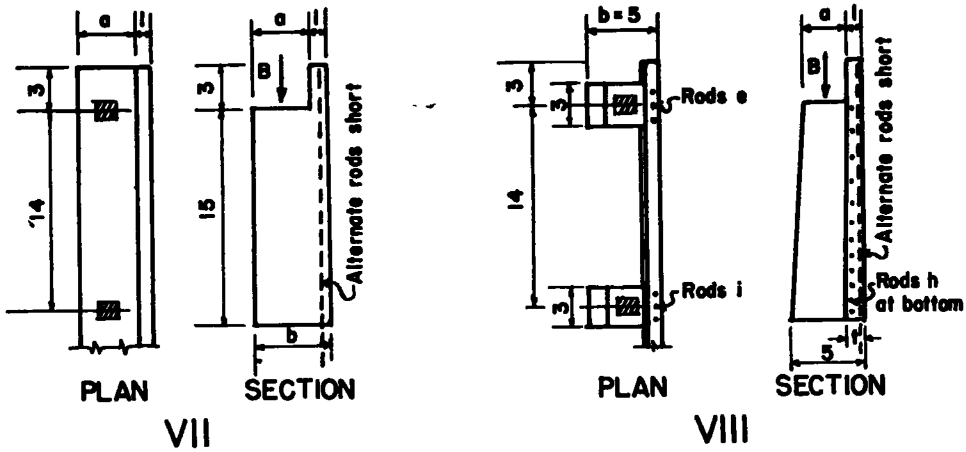
	Type V			Type VI				a	s
	b	c	p	n	c	p	Rods		
	ft	cu ft	Kips per sq ft	ft	cu ft	Kips per sq ft	in. in.	ft	ft
$\phi = 20°$	11.3	96	6.0	7.3	72	14.2	$\frac{3}{4}\phi$ @ 6	2.5	25
$w = 110$	12.1	105	6.5	6.8	78	14.5	$\frac{3}{4}\phi$ @ 7	3.0	50
$\phi' = 15°$	12.8	113	6.8	6.3	85	14.7	$\frac{3}{4}\phi$ @ $8\frac{1}{2}$	3.5	75
$K_a = 0.50$	13.3	121	7.3	5.8	91	14.4	$\frac{3}{4}\phi$ @ 10	4.0	100
$\phi = 38°$	7.6	71	6.0	3.8	64	10.8	$\frac{1}{2}\phi$ @ 9	2.5	25
$w = 100$	8.1	79	6.7	3.3	70	11.5	$\frac{1}{2}\phi$ @ 12	3.0	50
$\phi' = 30°$	8.4	86	7.5	2.8	77	12.0	$\frac{1}{2}\phi$ @ 18	3.5	75
$K_a = 0.25$	8.4	91	8.2	2.3	83	12.0	$\frac{1}{2}\phi$ @ 24	4.0	100

Note: b = Base width including ribs; n = Overhang width; c = Average volume of abutment per ft. of length; p = Maximum base pressure per sq. ft.

Figure 3. Abutment Types V and VI

No comparative designs or estimates are submitted for the various special types of abutments, using timber or steel sheeting, because of their rather limited application to special conditions and because the costs to be comparable must include the foundations. It is hoped that some of these special types will be included in the discussions of this report.

Notes on Foundations. Any of the walls, Types I to VI inclusive, can be placed on rock or hardpan without any special provisions, except leveling off course. All will have



	Type VII				Type VIII						s
	b	c	Rods		t	c	Rods e	Rods i	Rods h		
	ft	*cu ft*	*in.*	*in.*	*ft*	*cu ft*	*in.*	*in.*	*in.*	*in.*	*ft*
$\phi = 20°$	3.5	56	$1\frac{1}{8}$ @	12	1.17	32	$5\text{–}1\frac{1}{4}$□	$8\text{–}1\frac{1}{4}$□	1□@	12	25
$w = 110$	4.0	63	1 @	12	1.17	33	$5\text{–}1\frac{1}{4}$□	$7\text{–}1\frac{1}{4}$□	1□@	12	50
$\phi' = 15°$	4.5	71	1ϕ @	12	1.17	34	$5\text{–}1\frac{1}{4}$□	$7\text{–}1\frac{1}{4}$□	1□@	12	75
$K_a = 0.50$	5.0	78	$\frac{7}{8}\phi$ @	10	1.17	35	$4\text{–}1\frac{1}{4}$□	$6\text{–}1\frac{1}{4}$□	1□@	12	100
$\phi = 38°$	3.5	56	$\frac{3}{4}\phi$ @	10	1.0	30	$2\text{–}1\frac{1}{4}$□	$3\text{–}1\frac{1}{4}$□	$\frac{3}{4}\phi$ @	$10\frac{1}{2}$	25
$w = 100$	4.0	63	$\frac{5}{8}\phi$ @	10	1.0	31	$2\text{–}1\frac{1}{8}$□	$3\text{–}1\frac{1}{8}$□	$\frac{3}{4}\phi$ @	$10\frac{1}{2}$	50
$\phi' = 30°$	4.5	71	$\frac{5}{8}\phi$ @	12	1.0	32	$2\text{–}1\frac{1}{8}$□	$3\text{–}1\frac{1}{8}$□	$\frac{3}{4}\phi$ @	$10\frac{1}{2}$	75
$K_a = 0.25$	5.0	78	$\frac{1}{2}\phi$ @	11	1.0	33	2–1 □	3–1 □	$\frac{3}{4}\phi$ @	$10\frac{1}{2}$	100

Note: b = Base width; c = Volume of abutment per foot; t = Slab thickness at base of wall; f_c = 750 lb per sq in Concrete stress; f_s = 18 kips per sq. in. Reinforcing stress.

Figure 4. Abutment Types VII and VIII

TABLE 1
COSTS PER FOOT OF ABUTMENT

ϕ	Span	Type I	II	III	IV	V	VI	VII[a]	VIII[a]
		Cost							
deg	*ft*	$	$	$	$	$	$	$	$
20	25	98	106	114	146	116	76	66	51
20	50	97	106	116	156	126	82	72	51
20	75	97	107	119	165	135	88	78	52
20	100	98	115	122	175	142	93	85	52
38	25	75	83	91	102	82	65	61	41
38	50	77	86	96	109	89	71	67	42
38	75	79	90	101	116	96	77	74	43
38	100	83	95	107	121	100	84	81	43

[a] Rods into footing or rock.

triangular base distribution with maximum edge pressure (Type VI) of 14.5 kips per sq ft for ϕ = 20 deg and 12.0 kips per sq ft for ϕ = 38 deg.

For Types VII and VIII anchorage must be provided at least equal to the main reinforcement into the rock or foundation. The true total cost comparison must include the foundation design, but there is very little difference in cost or design of foundations for any definite soil condition for Types I to VI inclusive. Foundations for Types VII and VIII must develop the necessary resistance for the tension rods. Where soil conditions are good, the reinforced designs permit smaller and more economical foundations. Where piles are used, the concentration of loadings in the buttress and cantilever types, permit a more economical grouping of piles, as well as a decrease in the number of piles because of their smaller mass and dead weight.

Conclusions Of the eight types of self supporting abutments listed herein:

1. Type VIII is the most economical design—a reinforced slab spanning between buttresses which carry the bridge loads.
2. Type I is the most economical plain concrete design, although more expensive than any of the reinforced designs.
3. Type I is the most economical gravity design, a vertical back face is conducive to a better balance of the acting loads.
4. Type IV produces the lowest base pressures.
5. Bridge loadings on spans of from 25 to 100 ft have little effect on the relative costs of the various types, especially on Type I and Type VIII walls.
6. The cost of an abutment backfilled with a silt is 25 percent or more above the cost of the same type backfilled with sand. This factor should be carefully considered. It may pay to import good backfill materials in silt and clay areas, so as to permit more economical wall designs.

In these days of high and possibly even higher future costs—especially in the construction industry, more care must be taken in design. The report indicates where economy is possible in the design of highway bridge abutments and is offered so that the highway dollar can be stretched a little.

MINUTES, ANNUAL BUSINESS MEETING

HIGHWAY RESEARCH BOARD

December 6, 1946, Washington, D. C.

The meeting was called to order by Chairman Morrison at 8:00 P.M. with the following in attendance:

Executive Committee

R. L. Morrison, Chairman
F. V. Reagel, Vice-Chairman
Thomas H. MacDonald
Louis Jordan representing Frederick M. Feiker
Hal H. Hale
Pyke Johnson
Burton W. Marsh
R. A. Moyer
Charles M. Upham
Stanton Walker

Staff

R. W. Crum, Director
Fred Burggraf, Associate Director
Wainwright Bridges, Administrative Assistant

Member Organizations

American Association of State Highway Officials
  Hal H. Hale
American Automobile Association
  Burton W. Marsh
American Concrete Institute
  F. H. Jackson representing H. J. Gilkey
American Institute of Consulting Engineers
  Guy Kelcey representing George C. Diehl
American Iron and Steel Institute
  R. R. Zipprodt
American Road Builders' Association
  Charles M. Upham
American Society for Testing Materials
  B. E. Gray representing Prevost Hubbard
American Society of Civil Engineers
  Wm. N. Carey
Army Air Forces
  Lt. Col. Frank J. Drittler
The Asphalt Institute
  B. E. Gray
The Associated General Contractors of America, Inc.
  Harry J. Kirk
Association of Asphalt Paving Technologists
  J. T. Pauls
Automotive Safety Foundation
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