THE DESIGN OF RAILWAY BRIDGE ABUTMENTS.*

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The following paper gives the result of an investigation ordered by C. F. Loweth, chief engineer of the Chicago, Milwaukee & St. Paul, and made by the writer.

A railway bridge abutment is ordinarily a masonry structure which gives vertical support to one end of a steel span, and at the same time gives whatever lateral support is necessary to prevent the adjoining embankment from slipping into the stream.

The most common type has a cross-section similar to that shown in Fig. 1, in which *a* is the bridge seat, consisting of a horizontal surface carrying the steel span; *b* is the back wall which supports the embankment and prevents its spilling forward on the bridge seat; the base *e* of the back wall *b* being made of such width as will make the back wall stable against overturning on account of the lateral pressure *R*-1 of the earth; *c* is the main body of the neatwork, and must have sufficient base *f* so that it will also be stable against overturning from the lateral pressure of the earthwork *R*-2; *d* is the footing, which must have a base *g* large enough to carry all the vertical

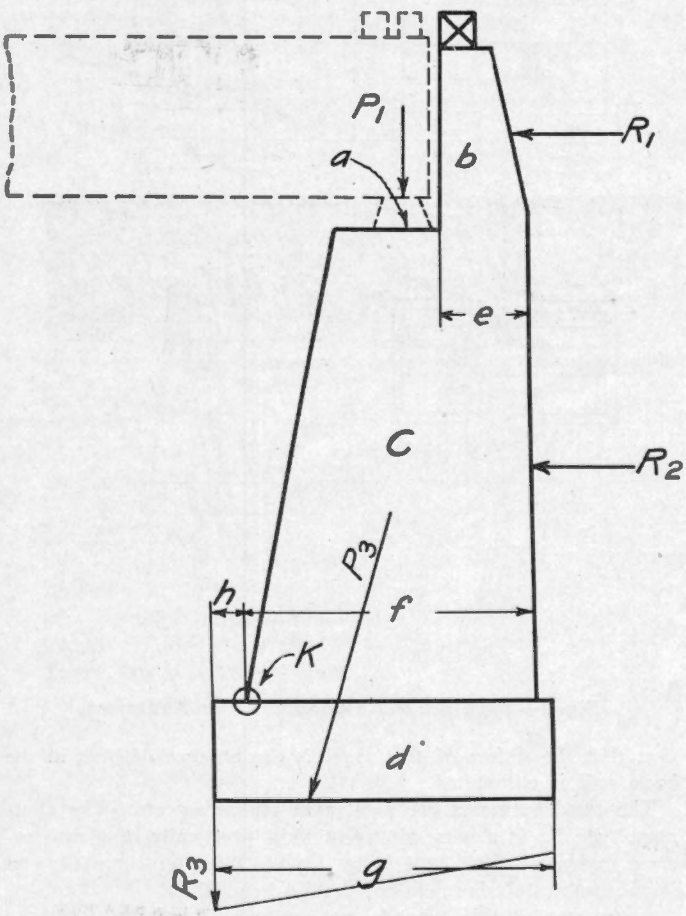

Fig. 1—Common Type of Abutment.

loads, and offset *h* should be large enough to keep the pressure at the toe of the footing *R*-3 within the allowable limit.

The three principal types are the wing, U, and T abutments. In the wing abutment the wings keep the embankment from slipping into the stream. In the U abutment the wings are made parallel to the track, thus giving the lateral support to the embankment which is required to extend the embankment to the bridge seat. In the T abutment the floor is supported directly back of the bridge seat by the stem of the abutment, which carries the track back to a point where the embankment is of sufficient height to support it.

In addition to conforming to the ordinary laws of structural design, properly designed abutments should have the following properties, which may be called major requirements, because they affect the integrity of the structure:

m_1. The neatwork should be stable against overturning by revolving on the line *k*, Fig. 1, at the intersection of the front face of the neatwork and footing, and should also be safe against crushing on the same line.

m_2. The abutments should be stable against sliding, either

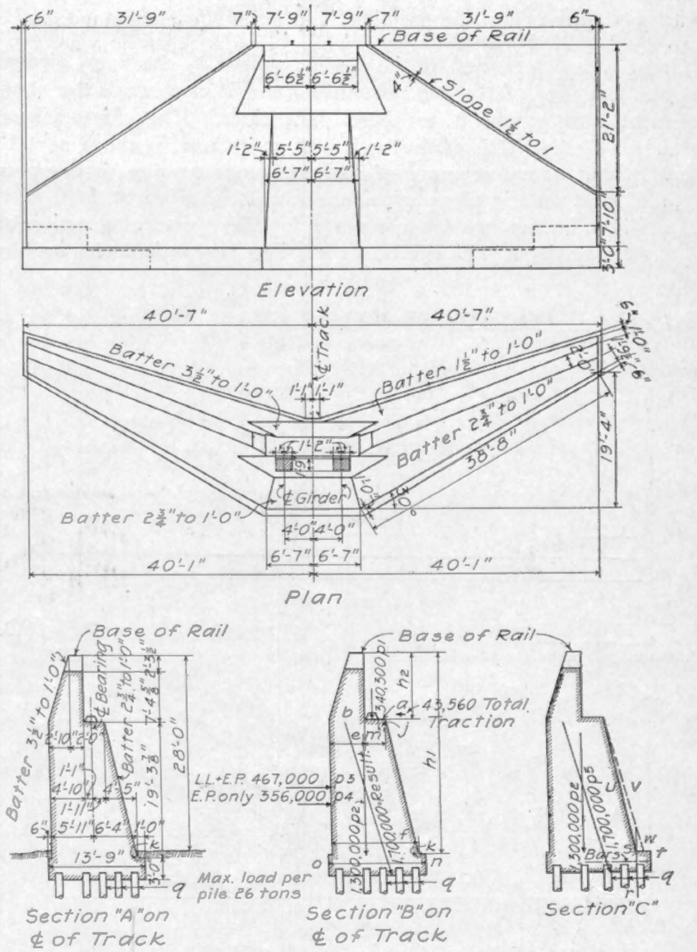

Fig. 2—Type B_1; Plain Concrete Wing Abutment, with Plain Concrete Backwall.

by the neatwork sliding on the footing or the footing sliding upon the foundation bed.

m_3. The pressure of the toe of the footing upon the foundation should not be excessive.

They should have the following properties, among others, which may be called minor requirements:

n_1. The abutments should protect the bank against scour.

n_2. The abutments should prevent the embankment drainage from washing away the shoulder of the bank adjacent to the back wall.

n_3. The abutments should provide a joint which will support the track in an easy and continuous manner from embankment to superstructure.

n_4. The abutment should be easily drained.

As by far the greater number of abutments being built are either of plain or reinforced concrete, the term "Design of Bridge Abutments" at present means the design of bridge abutments in concrete masonry.

In order to compare the properties and economy of the various types, it was necessary to assume the same conditions in the

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design of all types. The more important assumptions which were made for this purpose are as follows:

(1) The height of the abutment is the distance from the base of rail to the natural ground.

(2) Slope of fill 1½ to 1.

(3) Slope of the natural ground away from stream or bridge opening 4 to 1.

PLAIN CONCRETE ABUTMENTS.

Type B_1.—The plain concrete masonry abutment without reinforcement in the back wall, type B_1, is shown in Fig. 2. The cross-section of the abutment, marked "section B on the center line of track" is determined about as follows:

The distance h_2, from the base of rail to the top of the bridge seat *a*, is determined by the depth required by the floor, girders and bearings of the superstructure; and in new work the abutment must conform to these dimensions. The dimension *e*, which is the width of the back wall at its base, is taken as 4/10 h_2 if the lateral pressure of the earthwork tending to overturn the back wall is alone considered, or it is taken at 5/10 h_2 if a slight further provision is made for the overturning action of frost in the bank. The width of the bridge seat *m* is determined by

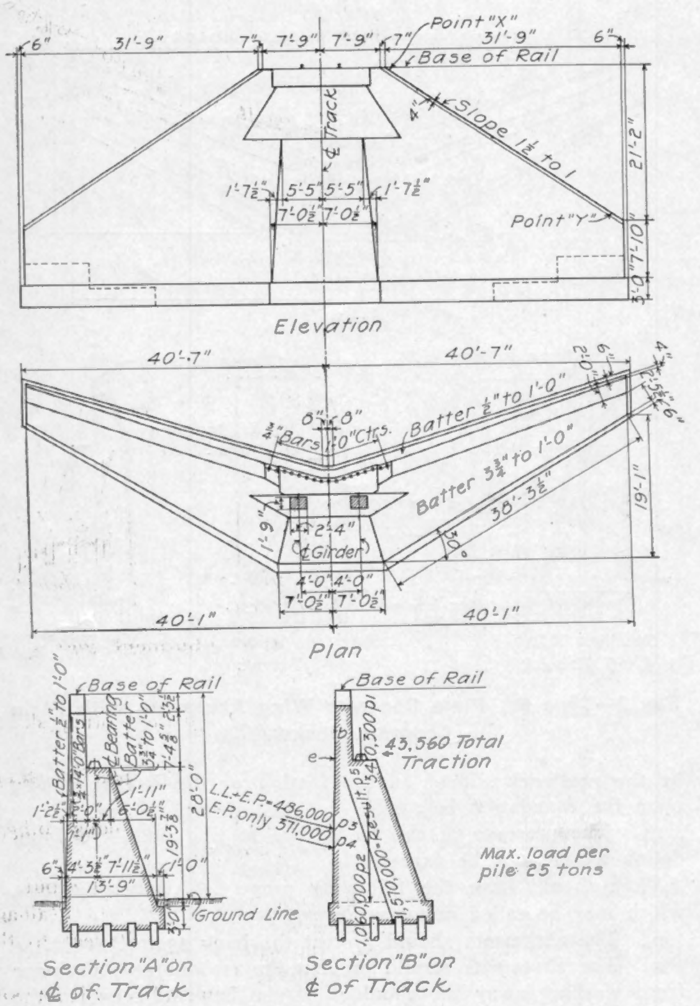

Fig. 3—Type B_2; Plain Concrete Wing Abutment with Reinforced Backwall.

the width required for the superstructure bearings plus whatever distance *j* is required to keep the bearings back far enough from the outer edge of the bridge seat to prevent the outside corner of the bridge seat from being sheared off in a diagonal direction.

The position of the ground line and the character of the foundation determine the distance h_1 from the base of rail to top of footing. If the base of the neatwork *f* is made 4/10 of the distance h_1, the neatwork is stable against overturning or crushing on the line *k*, at the lower edge of the neatwork. The dimension *f* together with the width of bridge seat *m* and thickness of back wall *e* having been determined, we have the choice of setting the bridge seat and back wall vertically over the rear edge of the footing, or of locating the bridge seat and back wall nearer the front of the footing, thus decreasing the length of our superstructure at the expense of an increased bearing on the toe of the foundation.

Type B_2.—Abutment B_2 is similar to abutment type B_1, ex-

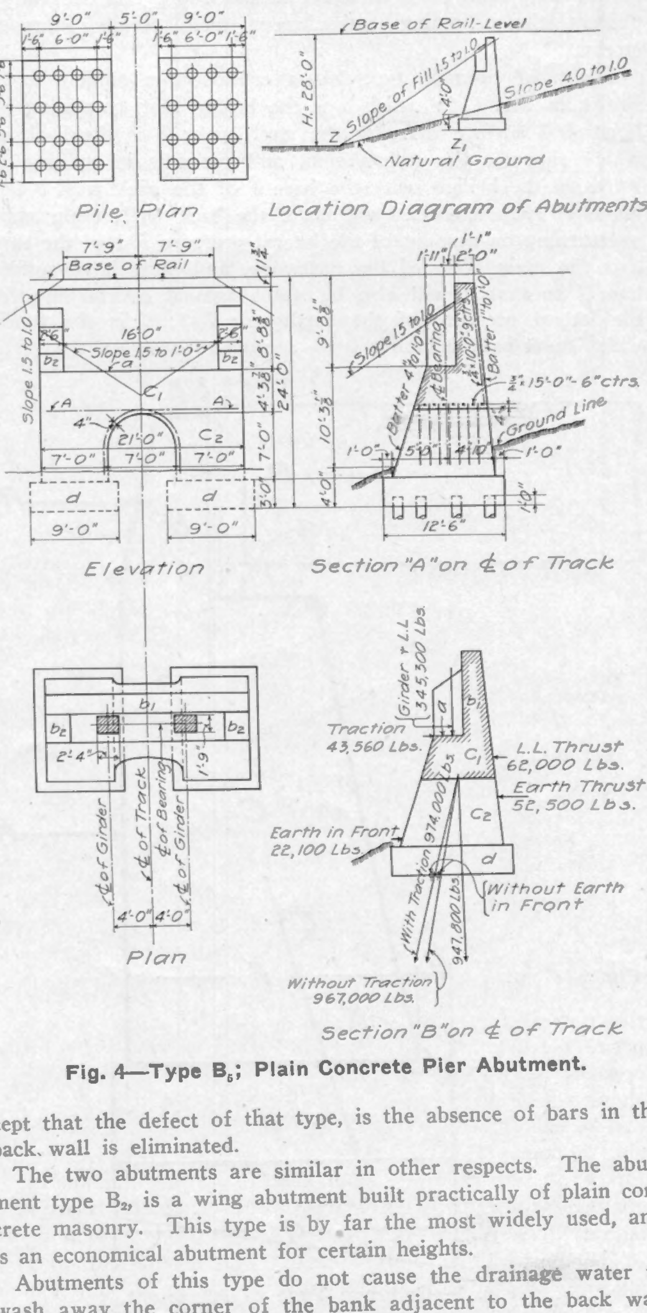

Fig. 4—Type B_5; Plain Concrete Pier Abutment.

cept that the defect of that type, is the absence of bars in the back wall is eliminated.

The two abutments are similar in other respects. The abutment type B_2, is a wing abutment built practically of plain concrete masonry. This type is by far the most widely used, and is an economical abutment for certain heights.

Abutments of this type do not cause the drainage water to wash away the corner of the bank adjacent to the back wall at *x* in Fig. 3, but at the lower point *y* on the bank, where the amount of the drainage water is greater, there seems to be a tendency to wash the portion of the bank adjacent to the end of the wing wall, and, therefore, this point is often found protected by loose rip-rap.

Type B_3. The U abutment of plain concrete masonry, type B_3, is shown in Fig. 11. This abutment is designed with the side walls, c_4, long enough to provide for an embankment slope of 1½ to 1, as experience shows that the slopes at the end of the embankment cannot be made much steeper than the side slopes of the same embankment. This lengthening of the side walls results in making the neatwork yardage for abutment B_3

greater than for abutment B_2. This difference in yardage in the neatwork is overcome by the lower foundation costs of abutment B_3 so that the total cost of abutment B_3 is somewhat less than abutment B_2 for heights over 23 ft.

Type B_5. An examination of section B, Fig. 3, shows that it is more difficult to make provision in an abutment to resist the lateral forces p_3 and p_4 tending to overturn the abutment than it is to take care of the vertical loads p_1 and p_2. The lateral forces are exceeded in magnitude by the vertical forces, but

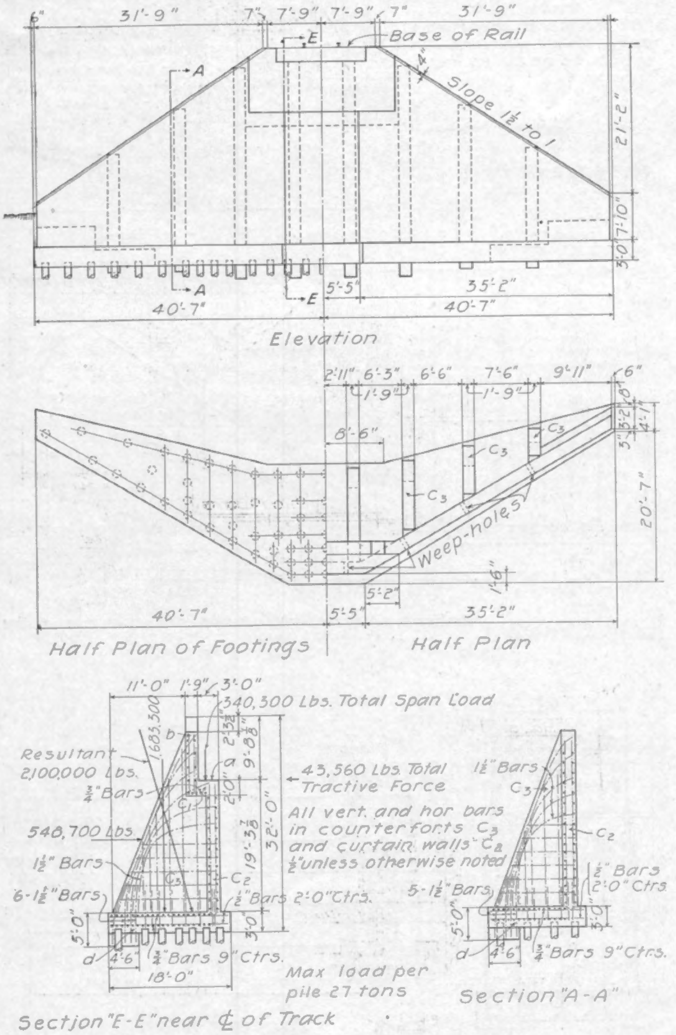

Fig. 5—Type C_1; Reinforced Concrete Counterfort Abutment.

the vertical forces are directly opposed by the equal and opposite reaction on the foundation, whereas no such equal and opposite reaction can be placed on the line p_3 continued, which shows the direction and location of the lateral pressure of the earthwork. As a consequence it would seem that a considerable economy could be effected in a design in which the lateral forces p_3 and p_4 were eliminated or greatly diminished. In abutment B_5, Fig. 4, little provision is made for resisting the lateral pressure of the earthwork. Instead, provision is made for diminishing the lateral pressure by omitting the wings and allowing the bank to spill around in front of the abutment. Abutment type B_5 consists, as shown in the elevation and Section B, of two short piers, which carry a beam c-1, the top of which forms the bridge seat a. The earthwork is kept off the bridge seat by the back wall b_1, and the side walls b_2. The bank is permitted to run around in front of the abutment to the point z where the natural slope of the fill intersects the ground line.

If an abutment type B_5 and an abutment type B_1 were so located as to have their bridge seats in the same position, the abutment B_5 would give a smaller waterway than the abutment type B_1 by the distance from z to z_1 in Fig. 4, to which the fill extends in front of the abutment. In order to get the abutment B_5 on the same basis for comparison as the other abutments, it is necessary to add to the cost of abutment B_5 the cost of extending the superstructure so as to permit the location of the abutment to be moved from z to z_1. As shown in the table herewith, this element of cost is an important item, amounting to 59 per cent. of the total.

REINFORCED CONCRETE ABUTMENTS.

Type C_1. The reinforced concrete wing abutment type C_1, shown in Fig. 5, is similar to the abutment type B_2 except that it is constructed of reinforced concrete instead of plain concrete. If the abutment is properly proportioned, the curtain wall c_2 can not be pushed outward by the lateral pressure of the earthwork without carrying with it the buttresses c_3 and without lifting the slab d from the pile foundations and also lifting the entire weight of the earth which rests vertically on the slab d. At the front of the abutment, the curtain wall c_2 is

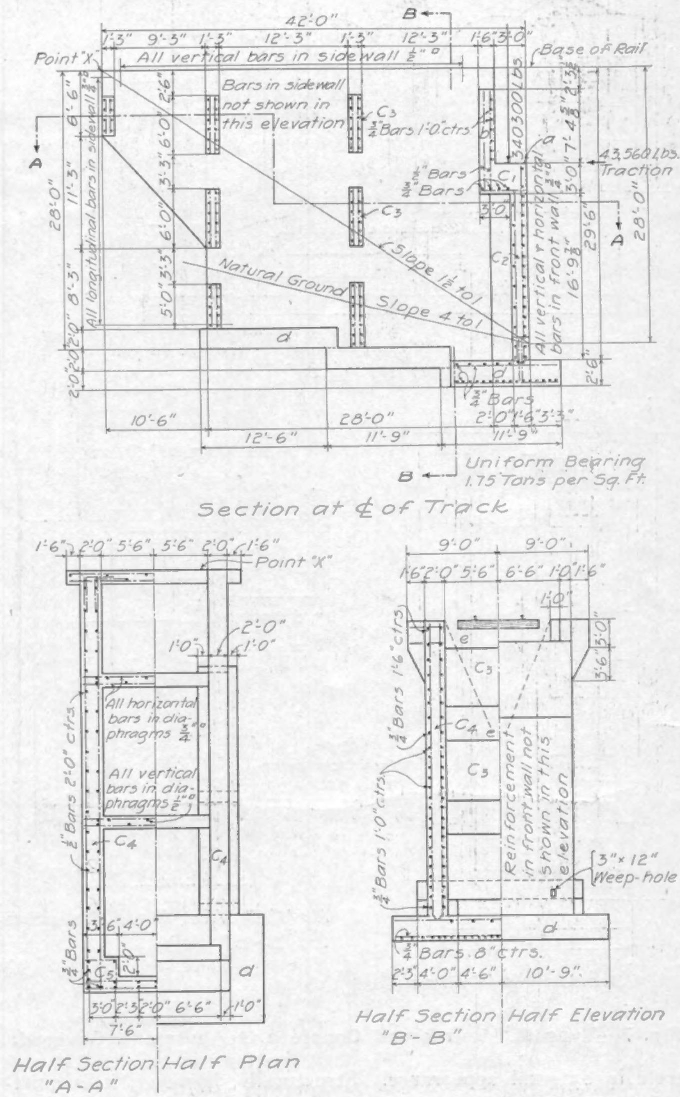

Fig. 6—Type C_2; Reinforced Concrete U Abutment Filled; Long Sidewalls.

given a horizontal offset c_1 as shown in section E-E to provide for the bridge seat a. The curtain wall is carried up vertically from the bridge seat a, forming the back wall b shown in the same section.

The abutment shown in Fig. 5 has no particular advantage over type B_2, the introduction of buttresses not decreasing the cost of neatwork and the provisions for anchoring buttresses to the footings greatly increasing the cost of footings for fills above 20 ft. Fig. 5 does not, however, show the best design that can be made of reinforced concrete wing abutment. It contains two defects; the bridge seat is set too far forward and the footings have insufficient projecton in front of the neatwork.

If these defects are corrected we have an improved and cheaper abutment. Estimates show that it costs about 10 per cent. less than type B_2 for the 36-ft. height and 25 per cent. less for the 50 ft. height which is outside the limits of the diagram.

If, in addition, the sections of all walls and buttresses are reduced to the minimum which can be placed by experienced workers under proper supervision, the economy over B_2 is still further increased.

Type C_2.—Abutment type C_2, Fig. 6, is a U abutment of reinforced concrete. It resembles the U abutment of plain con-

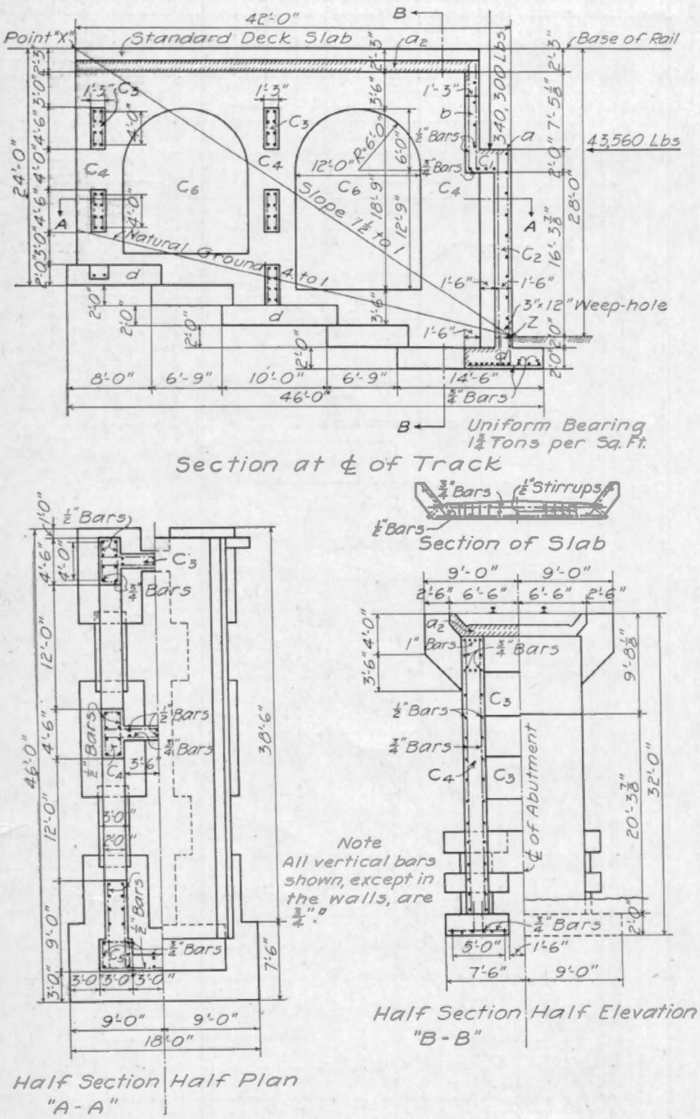

Fig. 7—Type C_4; Reinforced Concrete U Abutment, Covered.

crete in external appearance. Structurally, however, it is quite different. It consists in plan of a rectangular box open at the top and at the embankment end, which is filled with earth. The track is directly supported on the earth filling. The sides of the box c_4 are prevented from being forced outward by the lateral pressure of the earth by ties c_8 which connect the two opposite sides c_4. The front of the box is the curtain wall c_3, which is a beam between the two side walls c_4, and restrains the lateral pressure of the earthwork in longitudinal direction.

This abutment easily satisfies requirements against overturning. The width of footings, measured along the center line of track, which is effective against overturning of type B_2, is 13 ft. 9 in. That of type C_1 is 18 ft. The corresponding dimension on abutment C_2 is the distance from the front to back of abutment, or 45 ft.

It is true that the wing walls of abutments B_2 and C_1 protect, perhaps, five times as much of the embankment against scour as does abutment C_2, but if we compare the protection afforded

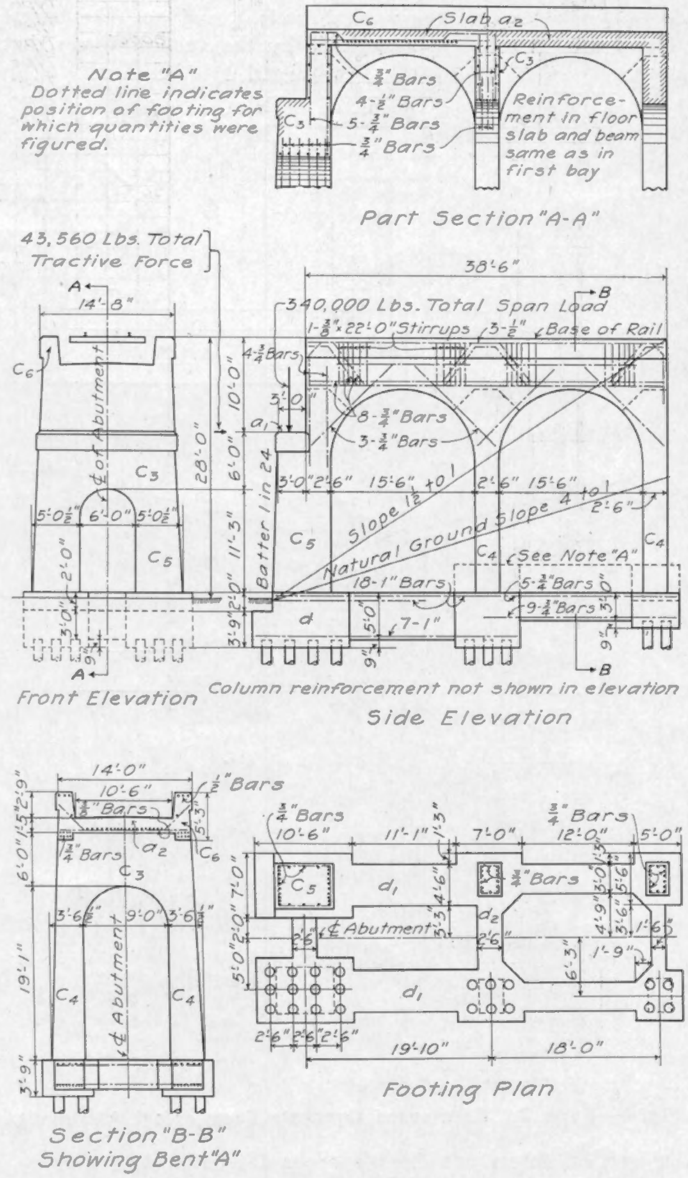

Fig. 8—Type C_5; Reinforced Concrete Arch Abutment.

by either type B_2 or C_2 with the total amount of bank protection required, the difference between the two abutments in this respect is not much. One of the defects of this abutment is that practically all of the surface water from the track for the entire length of abutment must drain past the point *x*, Fig. 6. As the amount of water is considerable, it tends to wash away the embankment at the end of the wing wall, which is, of course, an important matter, as the material is washed away at a point not far from the end of the track ties and requires much more attention than if the material was washed away at the end of the wing wall.

Type C_4.—Abutment type C_4, and all of the abutments which follow have one feature differing from any of the abutments previously mentioned, that of carrying the track directly on the body of the abutment over the entire length of the abutment instead of on the bank.

To save material and to equalize the pressure of the earthwork on both sides of the side walls c_4, two large openings c_6 are

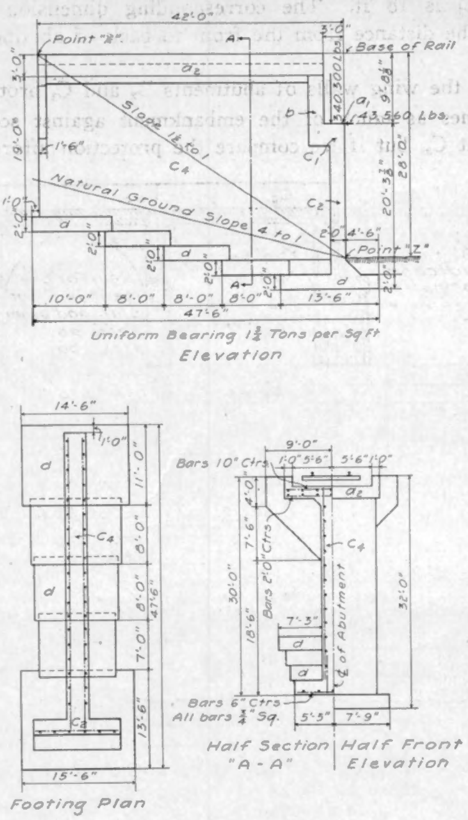

Fig. 10—Type C_6; Reinforced Concrete T Abutment.

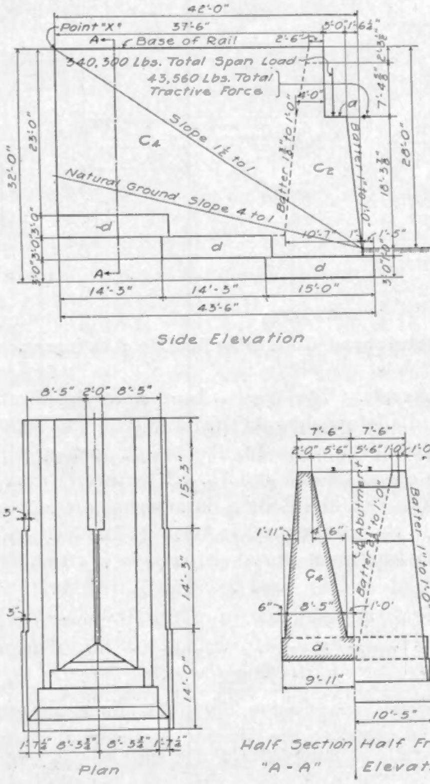

Fig. 11—Type B_3; Plain Concrete U Abutment, Filled.

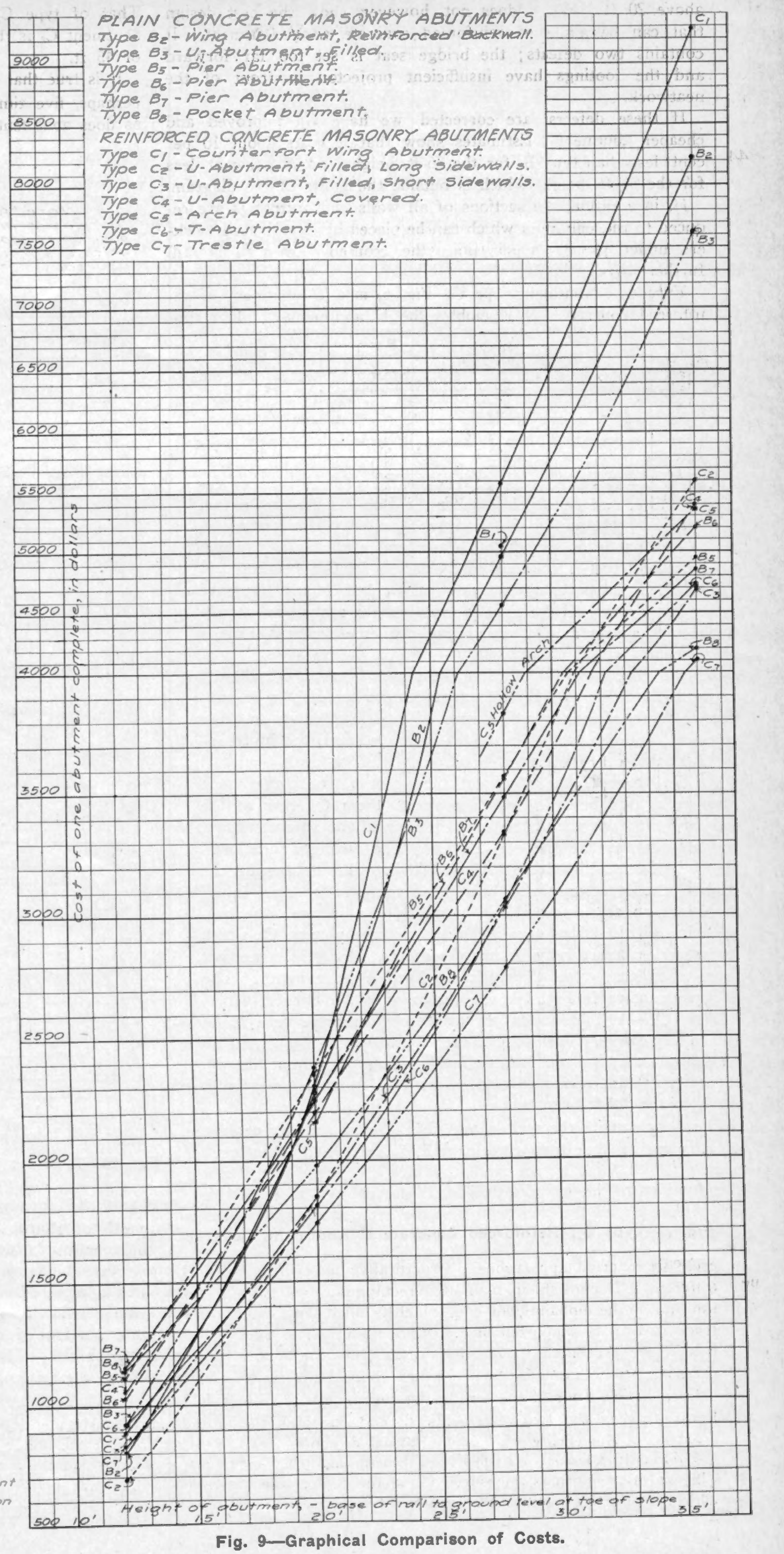

Fig. 9—Graphical Comparison of Costs.

made in the walls. The portion of the side wall remaining between the openings c_8 forms a column; and the portion of the side walls above the openings forms a beam between columns. The openings are shown circular on top, although structurally they could have been as easily made square.

Abutment C_4 has an advantage over abutment C_2 in that its foundation loads are less, due to the fact that the interior of the abutment is only partially filled with earth. The side walls of C_4 are subjected to practically no unbalanced lateral pressure of the earthwork. It has the disadvantage that it requires a considerable amount of material for the construction of the floor slab a_2, and as a consequence it does not show much economy for low fills.

As there are practically no unbalanced lateral earthwork pressures in action against abutment C_4 no provision need be made to make it conform to the requirements m_1, and m_2 and m_3. This abutment gives, perhaps, slightly less protection to the embankment against scour than abutment C_2, but it will probably not wash away at the shoulder of the embankment at x, as drainage for the top of the abutment is provided through holes in the sides of the floor slabs.

Type C_5.—Abutment type C_5, consists in general of six vertical posts c_4 and c_5, which support the slab a_2. At the bottom they are tied together by the footings a_1 and d_2. The footings d_1 and d_2 act partly as foundation beams and partly as ties, which hold the bottoms of columns in their true relative position and afford them support against any unbalanced lateral pressure of the earthwork. At the top the cross beam c_3 spans transversely between the posts c_4. Two posts and the cross beam c_3 form a single bent.

At the top, also longitudinal beam c_6 spans longitudinally between the bents A. By this arrangement the slab a_2 is supported on four sides, the two ends of the slab resting on cross beams c_3, and the two sides of the slab are supported by longitudinal beam c_6.

At the front of the abutment the posts c_5 are made much heavier, as the beam c_3 which connects them together at the top carries the weight of the adjacent span of the superstructure, and also carries one end of a slab a_2. The divisions mentioned are only those which have to be made in order to execute the design; the structure itself being tied together by steel in all directions so as to resemble a monolith. In service this abutment has all the advantages and disadvantages of type C_4, which it resembles structurally in many respects, As it is somewhat more open than type C_4, it drains itself a little better. The abutment shown in Fig. 8 is the design of W S. Lacher.

Type C_6.—A T abutment of reinforced concrete type C_6 is shown in Fig. 10. The stem of this abutment consists of a slab a_2, which is supported longitudinally along its center line by the central wall of the stem c_4. The wall is carried vertically down to the spread footings d.

The floor a_2 with the wall c_4 are given lateral stability against overturning by the front curtain wall c_2 and by the reinforcement on both faces of the wall c_4, which extends directly into the footings. The curtain wall c_2 is carried up to form the bridge seat c_1 and the back wall b in the same manner as in the C_4 abutments.

This abutment has the defect that it is not safe under a derailed locomotive. The derailed locomotive produces in this structure much greater stresses than in the other types. If we increase the reinforcement to take care of the exceptional case of a derailment, we need a quantity of steel nearly double that shown in the table, increasing the cost of reinforcing steel practically $4,000 and filling the structure so full of bars that the cost of laying the concrete would be largely increased. Provision for derailment in this structure is, therefore, out of the question, and its weakness under a derailment must stand a grave defect.

Type C_7.—The trestle abutment type C_7, in a general way is a concrete trestle of sufficient length to carry the track from the point z, or from the end of the superstructure, to the point x, where the bank has attained its full height. Commencing at the top, this abutment consists of two standard U-shaped trestle slabs a_2 which contain the ballast, which in turn supports the ties and rails. These slabs rest on the neatwork of the bents c_2 and c_4, which are ordinarily reinforced concrete trestle bents with spread footings d. To resist unbalanced longitudinal pressure of the earthwork, and also to add longitudinal stability to the abutment, the struts c_3 are introduced between the tops of the bents c_2 and c_4, and the struts d_1 introduced between the bottoms of the same bents. In addition to acting as struts these members c_3 and d_1 combine the three bents and the two spans

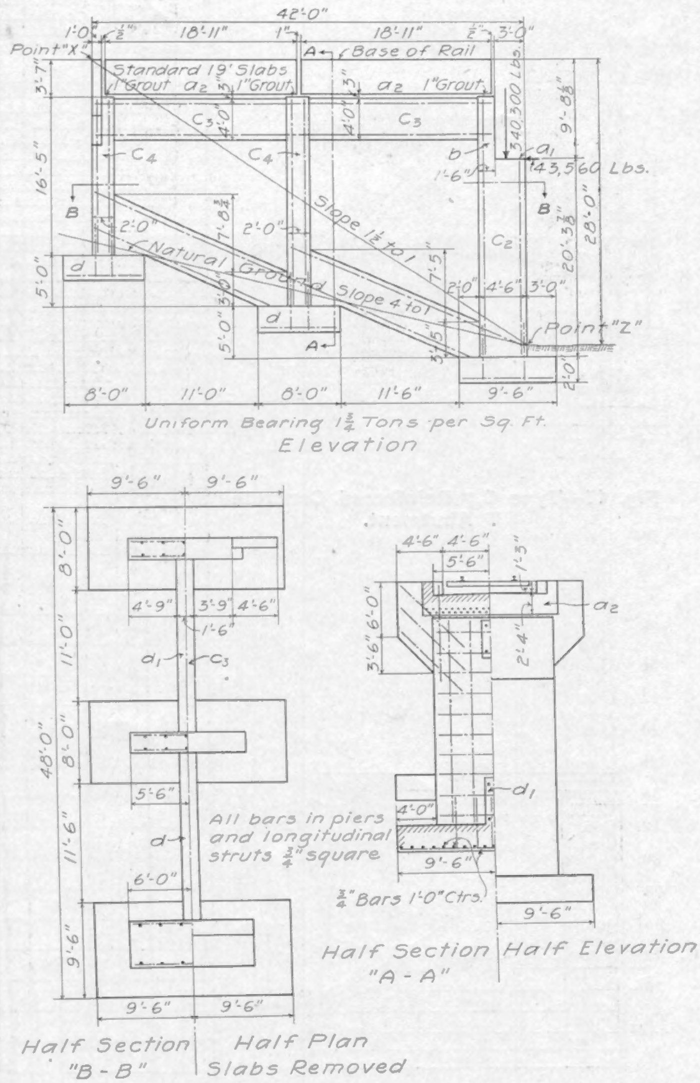

Fig. 12—Type C_7; Reinforced Concrete Trestle Abutment.

into two rigid quadrilaterals. The trestle bent c_2 at the front end of the abutment is made considerably thicker than the bents c_4 in the bank in order to leave room for the bridge seat a_1. In service this abutment is much like C_4 and C_5. Structurally it resembles C_4 more closely in that the floor a_2 is a separate member and can be placed after the abutment has been built. The remaining portion of the abutment forms a complete structure without the slab. The slab is only used to afford direct vertical support to the track.

MEMORANDUM ON TOTAL COSTS OF VARIOUS TYPES.

The table shows the manner in which the total estimated costs of the foregoing abutments were made up. This table should give dependable estimated costs, as the division of the total costs into their elements has been carried as far as could be conveniently done. It shows the quantities as well as the unit costs and makes it possible for the reader to substitute different unit costs for those shown, where the conditions are such that the unit costs given in the table would not apply. It is not believed, however, that any ordinary changes will affect the relations between the totals.

In Fig. 9 the total cost of abutments are platted as ordinates to the heights platted as abscissas.

The objection most frequently made to abutments types C_2 to C_7 is their high cost, especially, it is said, if constructed by men experienced mostly in the construction of plain concrete work. On account of this objection the principal unit costs for this type were taken rather high, as it was believed that there was enough economy in the design of some of these types to more than offset the highest unit cost which could be reasonably selected. Examination of Fig. 9 will show that this prediction was substantially correct.

In examining these cost curves, it is important that the following should be noted:

Types C_6 and C_7 are untried, and unexpected weaknesses may develop in their use. C_6 does not take care of derailment.

B_5 or C_7 cannot be used where much scour is anticipated or where the high water is near the bridge seat, without the use of rip-rap, whose cost has not been included.

It should be observed that the necessity of carrying the footings further below the ground will make a proportionately greater increased cost in types B_1 to B_5 than in types C_2 to C_7.

The use of any type of superstructure which gives a less depth of bridge seat below base of rail will mean a greater

TABLE SHOWING METHOD OF CALCULATING COST OF ABUTMENTS.

Height in Ft.	Item.	Floor. Cu. Yds. of Conc.	Floor. Lbs. of Steel.	Floor. Sq. Yds. of Forms.	Neatwork. Cu. Yds. of Conc.	Neatwork. Lbs. of Steel.	Neatwork. Sq. Yds. of Forms.	Footings. Cu. Yds. of Conc.	Footings. Lbs. of Steel.	Footings. Sq. Yds. of Forms.	Cu. Yds. of Excavation.	Piles.	Cu. Yds. of Fill.	False-work.	Change in Length of Bridge one Abutment.	Engng. and Incidentals.	Grand Total.
B_1 28	Quant...	......	......	......	406	......	425	103	......	63	260	71	1,500	......	4.42 ft.	(5%)	......
	Cost....	......	......	......	$2,030	......	$510	$515	......	$76	$390	$568	$375	$50	$270	$239	$5,022
B_2 12	Quant...	......	......	......	60	270	121	21	......	23	65	......	170	......	.71 ft.	(5%)	......
	Cost....	......	......	......	$300	$9	$145	$105	......	$28	$98	......	$43	......	$43	$38	$809
20	Quant...	......	......	......	160	270	220	56	......	49	120	34	600	......	2.79 ft.	(5%)	......
	Cost....	......	......	......	$800	$9	$264	$280	......	$59	$180	$272	$150	......	$170	$109	$2,293
28	Quant...	......	......	......	387	270	420	102	......	60	260	64	1,500	......	6.04 ft.	(5%)	......
	Cost....	......	......	......	$1,935	$9	$504	$510	......	$72	$390	$512	$375	$50	$368	$236	$4,961
36	Quant...	......	......	......	696	270	628	142	......	75	400	108	3,100	......	8.38 ft.	(5%)	......
	Cost....	......	......	......	$3,480	$9	$754	$710	......	$90	$600	$864	$775	$50	$511	$392	$8,235
B_3 12	Quant...	......	......	......	74	......	125	31	......	......	60	......	60	......	......	(5%)	......
	Cost....	......	......	......	$370	......	$150	$155	......	......	$90	......	$15	$100	......	$44	$924
20	Quant...	......	......	......	229	......	285	59	......	......	115	......	250	......	.85 ft.	(5%)	......
	Cost....	......	......	......	$1,145	......	$342	$295	......	......	$173	......	$63	$200	$52	$113	$2,383
28	Quant...	......	......	......	496	......	450	103	......	......	210	......	525	......	1.52 ft.	(5%)	......
	Cost....	......	......	......	$2,480	......	$540	[illegible]	......	......	$315	......	$131	$300	$93	$219	$4,593
36	Quant...	......	......	......	880	......	780	137	......	......	290	......	1,075	......	2.27 ft.	(5%)	......
	Cost....	......	......	......	$4,400	......	$936	$685	......	......	$435	......	$269	$400	$139	$363	$7,627
B_5 12	Quant...	......	......	......	26	540	64	26	......	......	45	......	76	......	10 ft.	(5%)	......
	Cost....	......	......	......	$130	$19	$77	$130	......	......	$68	......	$19	......	$610	$53	$1,106
20	Quant...	......	......	......	52	540	96	25	......	......	48	27	400	......	22 ft.	(5%)	......
	Cost....	......	......	......	$260	$19	$115	$125	......	......	$72	$216	$100	......	$1,340	$112	$2,359
28	Quant...	......	......	......	80	945	134	25	......	......	46	32	960	......	34 ft.	(5%)	......
	Cost....	......	......	......	$400	$33	$161	$125	......	......	$69	$256	$240	$45	$2,075	$170	$3,574
36	Quant...	......	......	......	103	945	172	36	550	......	68	45	1,860	......	46 ft.	(5%)	......
	Cost....	......	......	......	$515	$33	$206	$180	$19	......	$102	$360	$465	$60	$2,800	$237	$4,977
C_1 12	Quant...	......	......	......	38	680	120	24	700	32	79	......	171	......	......	(12%)	......
	Cost....	......	......	......	$247*	$24	$144	$156*	$25	$38	$119	......	$43	......	......	$96	$892
20	Quant...	......	......	......	100	5,050	316	45	2,380	48	182	......	630	......	......	(12%)	......
	Cost....	......	......	......	$650*	$177	$379	$293*	$83	$58	$273	......	$158	......	......	$249	$2,320
28	Quant...	......	......	......	183	9,950	608	113	7,754	80	358	85	1,702	......	......	(12%)	......
	Cost....	......	......	......	$1,190*	$348	$730	$735*	$271	$96	$537	$680	$426	......	......	$602	$5,615
36	Quant...	......	......	......	306	16,600	1,007	176	12,070	86	602	141	3,450	......	......	(12%)	......
	Cost....	......	......	......	$1,989*	$581	$1,208	$1,144*	$422	$103	$903	$1,128	$862	......	......	$1,001	$9,341
C_3 12	Quant...	......	......	......	37	2,440	134	10	200	14	30	......	80	......	......	(8%)	......
	Cost....	......	......	......	$241*	$85	$161	$50	$7	$17	$45	......	$20	$10	......	$51	$687
20	Quant...	......	......	......	102	6,730	349	20	900	34	65	......	300	......	......	(8%)	......
	Cost....	......	......	......	$663*	$236	$419	$130*	$32	$41	$98	......	$75	$20	......	$137	$1,851
28	Quant...	......	......	......	189	12,130	602	37	1,180	41	130	......	630	......	......	(8%)	......
	Cost....	......	......	......	$1,229*	$425	$722	$241*	$41	$49	$195	......	$158	$30	......	$247	$3,337
36	Quant...	......	......	......	304	20,000	1,015	42	840	74	140	54	1,200	......	......	(8%)	......
	Cost....	......	......	......	$1,976*	$700	$1,218	$210	$29	$89	$210	$432	$300	$30	......	$416	$5,610
C_4 12	Quant...	8	2,180	48	31	1,950	25 99	16	400	24	60	......	70	......	......	(10%)	......
	Cost....	$52*	$76	$120*	$202*	$68	$63* $119	$80	$14	$29	$90	......	$18	$20	......	$95	$1,046
20	Quant...	15	4,100	81	69	4,340	45 224	31	2,110	47	100	......	200	......	......	(10%)	......
	Cost....	$98*	$144	$203*	$449*	$152	$113* $269	$202*	$74	$56	$150	......	$50	$40	......	$200	$2,200
28	Quant...	21	5,370	115	114	7,180	100 298	41	2,790	65	130	......	550	......	......	(10%)	......
	Cost....	$137*	$201	$288*	$741*	$251	$250* $358	$267*	$98	$78	$195	......	$138	$60	......	$306	$3,368
36	Quant...	27	7,360	148	175	11,000	125 534	68	1,500	94	220	62	1,050	......	......	(10%)	......
	Cost....	$176*	$258	$370*	$1,138*	$385	$313* $641	$340	$53	$113	$330	$496	$262	$60	......	$493	$5,428
C_5 20	Quant...	30	2,740	80	49	2,668	130	48	2,373	......	67	26	239	......	2.2 ft.	(10%)	......
	Cost....	$195*	$96	$96	$319*	$93	$156	$312*	$83	......	$101	$208	$60	$100	$140	$196	$2,155
28	Quant...	48	5,250	135	90	6,873	250	84	7,198	......	130	44	550	......	0.5 ft.	(10%)	......
	Cost....	$312*	$184	$162	$585*	$241	$300	$546*	$252	......	$195	$352	$138	$200	$30	$350	$3,847
36	Quant...	51	5,296	140	125	8,922	345	113	9,852	......	145	52	1,050	......	8.0 ft.	(10%)	......
	Cost....	$332*	$185	$168	$813*	$312	$414	$735*	$345	......	$218	$416	$262	$200	$490	$489	$5,379
44	Quant...	81	7,781	200	234	15,165	570	153	12,254	......	244	80	1,912	......	5.2 ft.	(10%)	......
	Cost....	$527*	$272	$240	$1,521*	$531	$684	$995*	$429	......	$366	$640	$478	$300	$320	$730	$8,033
C_6 12	Quant...	13	1,038	33	33	1,084	80	20	890	21	50	......	63	......	......	(10%)	......
	Cost....	$85*	$36	$83*	$215*	$38	$96	$130*	$31	$25	$75	......	$16	$10	......	$84	$924
20	Quant...	23	1,835	58	72	2,365	177	33	2,000	37	83	......	224	......	......	(10%)	......
	Cost....	$150*	$64	$145*	$468*	$83	$212	$215*	$70	$44	$125	......	$56	$20	......	$165	$1,817
28	Quant...	33	2,633	84	133	4,371	301	50	5,066	52	130	......	467	......	......	(10%)	......
	Cost....	$215*	$92	$210*	$865*	$153	$361	$325*	$177	$62	$195	......	$117	$30	......	$280	$3,082
36	Quant...	43	3,430	108	208	6,840	471	82	8,320	82	200	......	1,100	......	......	(10%)	......
	Cost....	$280*	$120	$270*	$1,352*	$239	$565	$533*	$291	$98	$300	......	$250	$30	......	$433	$4,761
C_7 12	Quant...	12	2,960	54	24	910	76	14	250	18	40	......	60	......	......	(8%)	......
	Cost....	$78*	$104	$135*	$156*	$32	$91	$70	$9	$22	$60	......	$15	......	......	$62	$834
20	Quant...	21	5,170	91	58	2,190	186	26	1,380	31	70	......	190	......	......	(8%)	......
	Cost....	$137*	$181	$228*	$377*	$77	$223	$169*	$48	$37	$105	......	$48	......	......	$130	$1,760
28	Quant...	41	10,100	129	87	3,290	283	36	1,910	37	100	......	500	......	......	(8%)	......
	Cost....	$267*	$354	$323*	$566*	$115	$340	$234*	$67	$44	$150	......	$125	......	......	$207	$2,792
36	Quant...	45	11,100	166	145	5,480	451	61	3,240	53	150	......	950	......	......	(8%)	......
	Cost....	$293*	$389	$415*	$943*	$192	$541	$397*	$113	$64	$225	......	$238	......	......	$305	$4,115

Note.—The unit prices used in calculating costs in the above table were as follows:
Concrete, $5.00 per yard, except in cases where the total cost is marked with an asterisk (*), where $6.50 per cu. yd. was used.
Steel, 3½ cents per pound.
Forms, $1.20 per sq. yd., except in cases marked with an asterisk (*), where $2.50 per sq. yd. was used.
Excavation, $1.50 per cu. yd.
Piles, $8 each.
Fill, 25 cents per cu. yd.

proportionate increase in cost in types B_1 to B_8 and C_8 than in types C_1 to C_8 and C_7.

Type C_1 is highest in cost of any abutment for heights over 21 ft. As previously mentioned, this type is created by the substitution of reinforced concrete in a mediocre design intended for plain concrete, making the least number of changes in the design which would permit the use of the new material.

If this design is improved, its cost can be reduced by an amount which will make it of less cost than type B_4 for heights above 28 ft. If advantage is taken of other known refinements in design of abutments of this character, its cost can be still further reduced.

For nearly all heights types C_3, C_6 and C_7 are the lowest in cost of those types in which the neatwork is carried to a sufficient depth to place footings on the natural ground.

CONCLUSION.

The writer finds that a general statement about the foregoing abutments has to be qualified in so many directions that it becomes merely a group of more or less disconnected facts.

Inspection, however, will show that the cheapest abutments for the higher fills, C_3, C_6 and C_7 are those in which no provision is made to restrain the lateral pressure of the earthwork, but where instead the earthwork is allowed to spill forward to its own natural slope.

As soon as departure is made from the gravity abutment, the greatest latitude is obtained for the ingenuity and skill of the designer. The types mentioned in this paper are only a few of the large number of abutment types which promise considerable economy.

As the minimum sections adopted are more liberal in the reinforced concrete abutments than in the plain abutments, it is probable that there is a wider margin for new economies in the reinforced than there is in the plain abutments.

FOREIGN RAILWAY NOTES.

At the end of 1910 the extent of railways in Cuba was 2,123 miles. This makes Cuba, in proportion to its size, one of the best served republics in the Americas in respect to railway transportation.

The extension of the Cairns Railway, Queensland, from Atherton to Evelyn, has been completed and opened to traffic. This line opens up splendid brush and forest country, and is the highest railway in the state. The average altitude for 20 miles is over 3,000 ft., and the highest point is 3,200 ft. above sea level.

A proposal is under consideration for a line to connect the Great Southern and the Southwestern railway systems in Western Australia at points near Mount Barker and Bridgeton. Between these places there is a vast area of cultivable country suitable for mixed agriculture and horticulture, and carrying very fine timber. This country is almost without a settler, although its development has been for many years a subject of ministerial promise. If carried out this work will greatly add to the trade of Albany as an exporting port.

The Longitudinal Railway is the plan toward which Chile is persistently devoting its energies. The peculiar contour of the country has hitherto confined communication largely to the coast line, except south of Santiago through the central valley, but the policy of the government is to develop means whereby the extreme north and the extreme south may be in touch with the center, altogether on land. Therefore it is extending this railway system as rapidly as possible. The distance from Arica in the north to Puerto Montt in the south is 2,132 miles, of which about 1,100 miles are in operation and 850 miles are under construction, while the remainder is being surveyed. The railways from the coast to the interior are chiefly private lines, serving special interests such as the nitrate fields, but the government controls the railway between Santiago and Valparaiso, and has purchased the Copiapo Railway.

TRAIN ACCIDENTS IN SEPTEMBER.[1]

Following is a list of the most notable train accidents that occurred on the railways of the United States in the month of September, 1911. This record is based on accounts published in local daily newspapers, except in the case of accidents of such magnitude that it seems proper to write to the railway manager for details or for confirmation.

Collisions.

Date.	Road.	Place.	Kind of Accident.	Kind of Train.	Kil'd.	Inj'd.
*4.	L. S. & M. S.	Erie, Pa.	xc.	P. & F.	3	13
7.	Central Ga.	Cedartown.	bc.	F. & F.	0	1
14.	N. Y. Central	Albany.	xc.	P. & F.	1	2
*14.	N. Y. Central	Rice's.	rc.	F. & F.	0	3
14.	N. Y., N. H. & H.	New Haven.	xc.	F. & F.	1	0
14.	Atlantic C. L.	Quitman.	bc.	P. & F.	0	3
18.	Atlantic C. L.	Smithfield.	bc.	P. & F.	1	0
20.	Boston & M.	Somersworth.	xc.	P. & F.	0	3
21.	Mo. Pac.: A. T. & S. F.	Kansas City.	xc.	P. & P.	1	20
22.	Southern	Atlanta.	bc.	P. & F.	2	10
24.	Penn.	Larimer.	xc.	F. & P.	1	5
27.	Wheeling & L. E.	Canton.	xc.	F. & P.	2	12

Derailments.

Date.	Road.	Place.	Cause of derailmt.	Kind of Train.	Kil'd.	Inj'd.
3.	Union Pac.	Kersey, Col.	acc. obst.	P.	0	12
4.	Pere Marq.	Hard.	d. track.	P.	1	4
5.	M., St. P. & S. S. M.	Fremont.	ms.	P.	4	40
5.	Penn.	Mayport.	slide.	P.	1	1
6.	Texas Mid.	Enloe.	unx.	F.	1	2
7.	Wab., C. & West.	Pinckneyville.	d. track.	P.	0	14
8.	Southern	Anniston.	d. track.	P.	0	0
7.	Atl. C. L.	Tennille.	d. engine.	F.	0	3
7.	St. Louis & S. F.	Cordova.	unx.	F.	1	2
10.	Mo., K. & Tex.	Brookshire.	unx.	F.	2	0
10.	Sou. Pacific	Los Angeles.	st. car.	P.	..	..
13.	L. E. & Pittsburgh	Cleveland.	d. track.	F.	4	17
15.	Chi., R. I. & Pac.	Ainsworth.	unx.	P.	0	3
17.	Chi., M. & St. Paul	Monroe.	unx.	F.	0	5
29.	L. S. & M. S.	Delray.	der. sw.	P.	0	5
29.	N. Y. C. & H. R.	Newark.	acc. obst.	P.	0	1

The collision at Erie, Pa., on the 4th at about 9 p. m., was between a passenger train of the Pennsylvania and a freight of the Lake Shore, at the junction of the two roads, four miles west of the city. It is said that the passenger train had run past more than one block signal, and that steam had not been shut off when it struck the freight train. Both engines and many cars were wrecked, and the wreck took fire, and the bodies of the persons killed were pinned under the mass of wreckage.

The collision at Larimer, Pa., on the 24th, at about 1 a. m., was between the eastbound Pennsylvania special express train No. 28 and a westbound freight. At Larimer westbound freight trains regularly cross to the south side of the roadway preparatory to entering the yard at Pitcairn. Both trains were running slowly, but the fireman of the passenger train was killed by being caught between the engine and the tender. The engineman of the freight and the signalman in the tower appear to have been at fault.

The derailment at Kersey, Colo., on the 3d, was due to the displacement of a switch by a mail bag which fell violently against the switch stand when thrown out of the mail car of the train, and, according to the reports, the bag was thrown off at this place because the mail clerk saw a group of children standing at the place where he ordinarily threw it off, and who held it a few seconds until he had passed the station platform. The two rear cars of the train only were thrown off the track. Ten passengers were injured.

The derailment at Fremont, Wis., on the 5th, is said to have been due to the misplacement of a switch by a boy of fifteen years, the son of a former section foreman. According to the reports, the boy had a grudge against the road, because he had been refused a ride.

Miscellaneous.—Among the serious accidents on railways in September which do not appear in our table are a collision between a work train and a live-stock train on the Canadian Pa-

[1] Abbreviations and marks used in Accident List:
rc, Rear collision——bc, Butting collision——xc, Other collisions——b, Broken——d, Defective——unf, Unforeseen obstruction——unx, Unexplained——derail, Open derailing switch——ms, Misplaced switch——acc. obst., Accidental obstruction——malice, Malicious obstruction of track, etc.——boiler, Explosion of locomotive on road——fire, Cars burned while running——P. or Pass., Passenger train——F. or Ft., Freight train (including empty engines, work trains, etc.)——Asterisk, Wreck wholly or partly destroyed by fire——Dagger, One or more passengers killed.