SPECIAL PROBLEM

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RENEWAL OF SOUTHERN PACIFIC STRUCTURE 496-F
over San Gabriel River

Location & Description

The structure under consideration carries the main line of the Southern Pacific Railroad over the San Gabriel River at a point near Bassett, just up-stream from the Valley Boulevard. It is an old pile trestle, 1275 feet in length, and built in 1901. There are 85 bents, each composed of four cedar piles converging toward the top, with 12" x 14" caps and 3" x 12" cross-bracing, and the ties are laid on eight 8" x 17" stringers, which are drift-bolted to the caps. The construction of these bents is very well illustrated by the accompanying photographs, which were taken by the authors on February 11, 1922.

Reasons for and Type of Renewal

This trestle is apparently in quite good condition, but its age is sufficient, for pile bents, to justify the questioning of its strength. Then, too, the piles were injured when they were first driven by the boulders through which it was necessary to put them. This injury has been multiplied by the effects of several excessive floods, among them being the very recent one of the past winter. The dynamic effect of the water alone is illustrated in Figure 4. The bents are so close together, being only fifteen feet apart, that debris carried down by flood waters has little chance to get by without being thrown against the piles. In some instances, when trestles farther upstream have been washed out, whole bents have been hurled down on this railroad structube and the effect has been quite damaging. In Figure 4, a gang is seen removing one of these bents, lodged there during the last flood. Figures 2 and 3 show, to better advantage, its location. In Figure 2, it may be seen directly below the gang, and in Figure 3 it appears between the fifth and sixth bents from the left, being supported by a block and tackle. In addition to the destructive forces of nature, the increase in the weight of the rolling stock of the Southern Pacific Railroad has considerably lowered the factor of safety on the bridge, and rendered it advisable not only to repair but to reconstruct the existing structure, or to replace it with a more costly bridge. In view of the renewal policy of this railroad, to replace all temporary structures on main lines with permanent masonry and steel, this has been the only phase of the renewal considered in this investigation and design.

Drainage Area

The drainage area of the San Gabriel River at this point, as given on the Southern Pacific Company's map, is 264,000 acres. This checks very closely with the area as determined with a planimeter from the Government Quadrangles, these giving 266,000 acres. The amounts on each sheet were as follows:

Sheet	Sq. in.	Acres
Cucamonga	20.65	
Pomona	203.34	
Pasadena	38.65	
Tujunga	10.57	
San Antonio	45.97	
Rock Creek	97.49	
Total	416.67	266,000

Velocity

On February 11, 1922, the date on which the accompanying photographs were taken, the velocity of the water was determined by the use of a surface float. This float was a piece of driftwood, approximately 16" x 16" x 5', and it was timed for a distance of 350 feet, beginning at the railroad trestle under discussion and ending at the highway bridge on the Valley Boulevard. The time was recorded independently by each of the authors and was found to be 46 seconds. The velocity of the float, therefore, was 350/46 = 7.62 feet per second. Using a constant of 0.8, the average velocity of the river was found to be 0.8 x 7.62 = 6.09 feet per second. The determination of this constant was made from a study of the authorities on hydraulics, and in particular those on the flow of water in open channels. The constant given by each author is as follows:

Daugherty ---------------- 0.9

Flinn, Weston, & Bogert ---- 0.83

Foster ------------------- 0.83

Kent --------------------- 0.83

King	0.8 (shallowest) 0.95 (very deep)
Leeds	0.8
Lock	0.8
Mead	0.9
Newell & Murphy	0.8
Parker	0.9
Trautwine	0.8

Area of Waterway Required

In the determination of the area of waterway required, use was made of Talbot's formula, $A = C\sqrt[4]{(\text{Drainage area in acres})^3}$, taking a constant of 1/2 for that part of the area which lies in the mountains and is quite steep, and of 1/4 for the remaining area which is composed of rolling and gently sloping land.

$$A_1 = 1/2\sqrt[4]{(200,000)^3} = 4,725 \text{ sq. ft.}$$
$$A_2 = 1/4\sqrt[4]{(66,000)^3} = \underline{1,030} \text{ " "}$$
$$\text{Total area} = 5,755 \text{ sq. ft.}$$

Using this area of waterway and the average velocity determined as above, the discharge = 6.09 x 5,755 = 35,000 cubic feet per second. This value is slightly less than that of the maximum recorded flood flow of 40,000 cubic feet per second, which was recorded near Azusa on January 18, 1916. However, the high water mark on the trestle, as noted on the Southern Pacific Company's map, is 278, which leaves an area of 4400 square feet beneath it, and at the same velocity would allow only 26,800 cubic feet per second to flow under it. With a flow of 40,000 cubic feet per second and a velocity of 6.09 feet per second, an area of waterway would be required of 6,570 square feet. This would raise the high water mark to 279.7, and in order to allow for the area displaced by the piers, it will be taken as 280 in the design of the bridge renewal.

Preliminary calculation reveals the fact that long truss spans for this location would be uneconomical, and even impossible. The concrete piers and abutments must be supported by piles and, as the maximum number of piles which can be placed under one pier is approximately 35, this is later found to be the limiting factor in fixing the length of span. Considering, then, the use of a through plate girder, the lowest point on the bridge will be three feet below the base of the rail, which places it at an elevation of 281.5. If the water is allowed to come up to this point and no higher, in times of maximum flood such as was considered in the preceding paragraph, it was found possible to fill in part of the river bed from each end of the existing trestle. The maximum length of fill was found to be 315 feet, being 75 feet from the west end and 240 feet from the east end. This entire fill could be made from the east end, but an examination of the accompanying photographs, Figure 2 in particular, will show that it is advisable to fill in about 75 feet from the west end. A comparison of the values in the table

Piles and Fill

of fills also shows that the most economical distribution of the fill is as already stated.

Span Length and Length of Fill

In the preliminary estimate of the cost of the structure, using different span lengths, the height of the piers above the foundation was taken as 30 feet, and the weights of steel were taken from those of the Harriman Lines, conforming to a loading of Cooper's E_{55}. Steel was estimated to cost five cents per pound, in place, and masonry, in place, was estimated to cost $24.80 per cubic yard. The cost of piles, including driving, was taken at $2.25 per pile. In these comparative estimates no notice was taken of the fact that sufficient piles could not be placed under the piers for spans exceeding sixty feet. This was done in order to show that the entire cost, using a sixty-foot span length, would not greatly exceed that of the most economical span length. In fact, the excess is so small that it is unnecessary to attempt to overcome the pile difficulty and consequently the final decision is that the existing trestle be renewed with sixteen sixty-foot through plate girders, filling in 75 feet from the west end and 240 feet from the east end.

Area of waterway as taken from the profile. Up to elevation of 280

Distance from east end	Area in sq. ft.	Sum
45	2 x 45 -- 90	90
	5 x 45 -- 225	315
90		
	5 x 45 -- 225	540
135		
	5.5 x 120 - 660	1200
255		
	6 x 90 -- 540	1740
345		
	6 x 60 -- 360	2100
405		
	6 x 45 -- 270	2370
450		
	6 x 30 -- 180	2550
480		
	5 x 45 -- 225	2775
525		
	3 x 135 -- 405	3180
660		
	6 x 120 -- 720	3900
780		
	7 x 30 --- 210	4110
810		
	5 x 105 -- 525	4635
915		
	5.5 x 360 --1980	6615

Total ----- 6615 sq. ft.

Economic Span

Total length is 1275 feet

Each span could be 400 feet and fill 75 feet.

On this assumption, a Pratt truss would not be used, but instead a Petit truss.

Single track railroad, through, riveted, Petit truss spans for Cooper's E_{60} loading, - the total weight of metal in pounds per lineal foot of span is 5150. Therefore the weight per span equals 2,060,000# and for the three spans equals 6,180,000#.

Structural steel, in place, at present costs about five cents per pound. Then the entire bridge would cost 309,000 dollars.(that is, the steel in the entire bridge).

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400 Foot Span

Total live load ------- 1313 Tons
Total Dead load -------1030 "
Total load on one pier- 2343 Tons

2343 x 2000 = 4,686,000#

Allowing 25 Tons per pile, 2343/25 = 94 piles needed.

This is impossible!

Estimated yardage of masonry:

2 Piers @ 399 ---- 798 cu. yds.
2 Abutments @ 500-1000 " "
Total ------ 1798 " "

Cost of masonry per yard:

Cement --- 1.16 bbl.@ 2.73 ---- $ 3.16
Sand ----- .52 yds.@ 1.50 ---- .78
Crushed stone- .86 yds.@ 1.00 - .86
Labor per yard ---------------- 20.00
Total ------------------ $24.80

1798 x 24.80 = $44,650
Adding to this $ 1,000 for the cost of piles = $ 45,650

100 Foot Span

Total live load on one pier -- 411 Tons or 822,000#

$I = (300/300 + 100)S = 3/4\ S$

3/4 x 822,000 = 616,500#
822,000
1438,500#
Steel -------- 237,500
1,676,000#

$\frac{1,676,000}{25 \times 2000}$ = 33.5 piles needed, without the pier.

Masonry:

9 ~~11~~ Piers @ 234 ---- 2106 ~~[illegible]~~
2 Abutments @ 500 - 1000
Total ----- 3106 ~~[illegible]~~ cu. yds.

3106 ~~[illegible]~~ x 24.80 ------- $77,200
385 ~~[illegible]~~ piles @ 2.25 ----- 867 ~~[illegible]~~
Total ----- $78,067 ~~[illegible]~~

Steel cost ----- 10 @ 182,000# ---- 1,820,000#

1,820,000 x .05 --- $90,900

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