

**RELATIVE ECONOMY IN COST OF CULVERT CONSTRUCTION.\***

The question of relative economy in the cost of construction of various types of drainage openings often arises. Below are estimates of the cost of four types of construction for the same drainage opening on the Madisonville, Hartford & Eastern R.R., now under construction in Western Kentucky. The unit prices used in these estimates are those paid by the railroad company to the contractors doing the construction work. Therefore the cost estimates are on the basis of cost to the railroad company having the work done, and not on the basis of actual cost of contractors.

The general character of the surrounding country at the opening in question is hilly and covered with thick woods. The opening itself is in a fill containing 48,000 cubic yards of material, there being 33 feet of filling at the culvert, the total length of fill from grade point to grade point being about 1,000 feet. The water passing through the culvert is normally a small brook, which empties into Rough River about 300 yards below the railroad fill.

The estimates of cost are now taken up in detail.

**Estimate No. 1.**

Structure:—A 9-ft. concrete arch culvert of cross-section, as shown in Fig. 1. This is the structure that has been built by the railroad company. The concrete in the foundation or below plane C-D and in the wings and head walls was mixed in the proportion of 1:3:6. The concrete in the

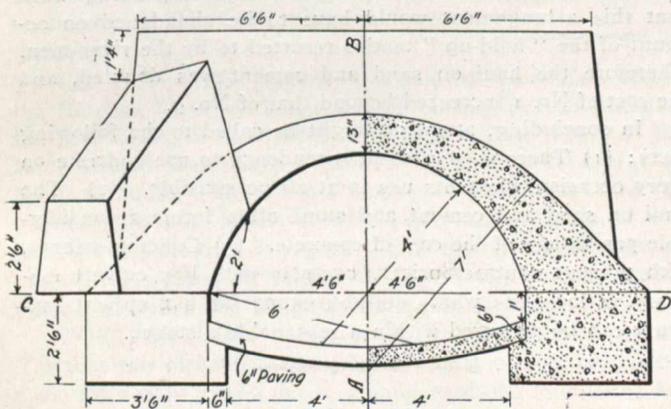


Fig. 1.

arch or above plane C-D was mixed in the proportion of 1:2½:5 in order to obtain additional strength in the arch wing.

Foundation: The foundation for the culvert was not altogether satisfactory. The soil at the opening was underlaid by a mixed stratum of dirt and gravel, and under this ordinary clay. It was thought best to place the foundation on the gravel strata instead of moving the same and greatly increasing the cost of structure by digging to rock or using piles. To aid in distributing the pressure an offset of 1 foot wide and 1 foot deep was made on the outside of each bench wall for 18 feet each side of the centre of the track (this in order to "take up" the greater pressure directly under the roadbed). The paving for this culvert was also increased from a thickness of 6 to 12 inches, and arched downwards, as shown in the sketch. Reinforcing of paving by wire fencing running from wall to wall was also considered.

The experience of the chief engineer, Mr. George W. Feagin, has been that culverts founded as this one fail somewhat in the following manner: First, the building of such a high fill puts an enormous weight on the original ground surface immediately beyond each bench wall. The earth at this opening is of a rubber-like description, and the great stresses imposed on the earth surface on either side of the

fill are transmitted somewhat as in water pressure or hydraulics where pressure is equal in all directions. In the failure of a culvert this pressure goes down under the bench walls carrying the weight of the fill, and pushes upward on the paving. If the paving is not strong enough it cracks; and this cracking of the paving destroys the homogeneity of the structure and throws additional weight to one of the bench walls. This additional weight in a case of complete failure causes the wall to settle, and thereby cracks the arch above. The actual cost to the railroad company of building the 9-ft. arch of concrete is as follows:—

|  |            |
|--|------------|
| 238 cubic yards of concrete masonry, at \$8.50.... | \$2,023.00 |
| 387 ton-miles of concrete hauled, at 60c.....      | 232.20     |
| 656 yards-miles of sand hauled, at 60c.....        | 393.60     |
| 418 cubic yards of dry excavation, at 40c.....     | 167.20     |
| Total .....  | \$2,816.00 |

Therefore the total cost to cost per cubic yard of concrete equals \$11.83. Also an additional sum of probably 50c. per yard for inspection should be charged to this masonry. This inspection charge is for one man in addition to the regular residency force. This man's time at the culvert was about two months. The cement used was a Portland cement made in St. Louis and hauled from the nearest railroad station on the Illinois Central R.R. In calculating cement and sand hauled, one mile is considered free haul. The total distance from the railroad station to the culvert is 8.4 miles, or 7.4 miles pay haul. The length of the culvert from face to face of head wall is 95 feet. The sand for the concrete was also hauled from the railroad station 8.4 miles distant. All of this hauling was done on dirt roads during October and November, 1907, when the roads were in very bad condition. (The roads of this part of Kentucky are as bad as can be found anywhere.) The total number of sacks of cement used was 1,101. The sand used amounted to 89 yards. The item of dry excavation was bid by the contractors for all excavations for pipe and culvert foundations and such excavation for bridge foundations as would not be classed "water excavation." The work was done by a subcontractor in November and December, 1907, under very bad weather conditions. The contractor was not allowed to lay or mix any concrete in freezing weather, and was required to quit work on afternoons at least 1½ hours before the time at which it was estimated the temperature would reach the freezing point.

**Estimate No. 2.**

Below is tabulated an estimate of the cost of a 4 x 8 reinforced concrete box culvert for the same opening as above:

|   |            |
|---|------------|
| 1. 72 cubic yards of reinforced concrete (1:2½:5), at \$9 ..... | \$ 648.00  |
| 2. 122 cubic yards of plain concrete (1:3:6), at \$8.50 .....   | 1,037.00   |
| 3. 18 cubic yards of stone paving (cobble), at \$3.50 .....     | 63.00      |
| 4. 6,560 lbs. of iron in reinforced concrete, at 5c..           | 328.00     |
| 5. 577 yards-miles of sand hauled, at 60c.....                  | 346.20     |
| 6. 310 ton-miles of cement hauled, at 60c.....                  | 186.00     |
| 7. 400 yards of dry excavation, at 40c.....                     | 160.00     |
| Total .....   | \$2,768.20 |

Reinforced concrete in the above estimate includes all concrete in the culvert top or above a horizontal plane 3½ feet above the paving. (See sketch Fig. 2.) Plain concrete includes all concrete below this plane and in head walls and wing walls. The sand and cement hauls in the above were, of course, calculated from the same railroad station as in estimate No. 1.

**Estimate No. 3.**

The structure in which the cost is estimated in estimate No. 3 is an ordinary 4 x 8 box culvert, with a reinforced top, as shown in Fig. 3 (paving cobblestone).

\* Paper by E. W. Cooper, read before the Engineering Association of the South.