Such a culvert will stand up under more severe conditions imposed by traffic and nature than one not reinforced, and if both were subjected to the same test the reinforced structure would remain intact for a much longer period of time.

Semi-circular arch culverts are in very common use in Canada, without reinforcing. They are used almost entirely



Half Cross Section

Half End Elevation



Fig. 15.—Standard (N. T. Ry.) Semi-circular Arch, 6-Foot Span.

by the National Transcontinental Railway and a good example of their abuse is shown there. The standard designs for ten-foot and six-foot spans are shown in Figs. 14 and 15. These culverts are put in, in the majority of cases, without any reinforcing whatever and with foundation conditions far from ideal. Piling is driven, but in a great many cases there is such a large body of poor clay material overlying the solid stratum beneath, that the piling receives very little lateral support, and so, when the fill is made and the pressure comes on the back of the abutments the piling gives away laterally causing longitudinal cracks in the arch. This condition may be prevented by putting in a solid floor of concrete, reinforced diagonally with twenty-pound rails, so as to form a grillage. This enables the culvert to withstand the lateral pressure and the uneven settlement, if it is not too pronounced. With the arch reinforced as well the culvert is practically insured against failure.

The character of the failures in these culverts is well shown in a report compiled by Mr. C. R. Young, B.A.Sc., on a number of the culverts in District "B" of the National Transcontinental Railway. This report shows that about seventy-one per cent. of the culverts on the report show cracks.

The only conclusion that can be arrived at from a view of Mr. Young's report is that all culverts of greater span than five feet should be reinforced, and that provision should be made for expansion joints in those of long barrel.



Fig. 16.-Reinforced Concrete Arch Culvert.

Below is given a description of a reinforced concrete arch culvert built at Kalamazoo, Michigan. This is shown in section in Fig. 16.

The culvert is one thousand and eighty feet in length, with a clear width of nine feet ten inches and clear height of six feet. Its grade is from 0.4 to 0.5 per cent. The masonry is entirely concrete, composed of sand, gravel and Portland cement in the general proportions of about one part of Portland cement to six parts of sand and gravel. Actually the upper arch was made with a little stronger mixture and the lower arch a little weaker. Anywhere there was likely to be a little extra pressure a richer mixture was used, under street crossings and where the underlying soil was particularly treacherous.

For reinforcing, a woven steel wire was used. The members of this fabric extending around the culvert were No. 11 steel wire and two layers of the fabric were used, making a total length of wire surrounding the culvert of 175 feet per linear foot. The dotted lines in the figure show changes in the shape of the bearing portion of the concrete, according to the earth on which the culvert is laid. Under parts of the culvert, resting on quicksand two lines of tile drains are laid under the invert to remove the excess water. When drained, it became firm and a good foundation. Before backfilling, interior and exterior of the arch surface were well brushed with neat cement grout.

Costs of Culvert Construction.—Eighteen-foot, semicircular arch.

The culvert was built under a trestle sixty-five feet high before the trestle was filled in.

The foundation being such that piling was necessary, the railway company drove piling to support a concrete foundation two feet thick and a concrete paving twenty inches thick. The barrel of the culvert was one hundred and forty feet long, but no expansion joints were provided. Cracks developed later, about fifty feet apart, due to the lack of provision for expansion.

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