They need a very good foundation, and care must be taken that the opening is built to the net measurement, and not to the gross, the net measurement being that of a box, say, ten feet long, that would fit in between the walls. The safe grade for a masonry culvert built on ledge rock is supposed to be 1 in 1 or 45, that being the angle of friction between rock and rock, but anyone building a culvert as steep as that would be taking chances, and a slope of 1 in 2 is as steep as it is advisable to build.

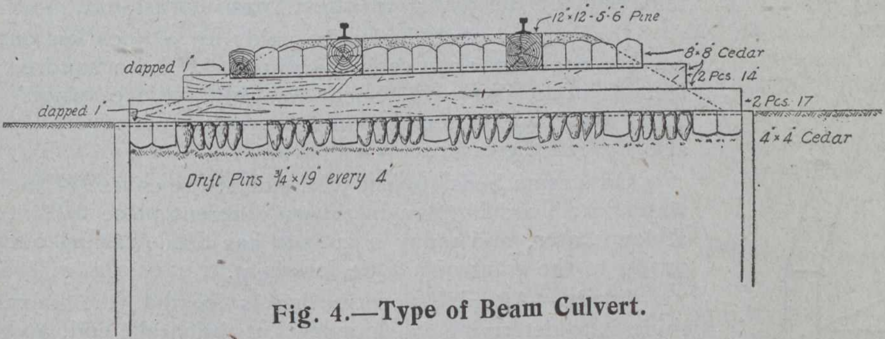

Fig. 4.—Type of Beam Culvert.

Rubble Masonry.—If men can be found who can do this class of work this style of culvert can be built of smaller stones than the former at the same cost, and the mortar, by smoothing the inside, lessens the chances of sticks lodging and impeding the flow. If large stones are available, the top can be flat, otherwise a semi-circular arch can be built. The economical limit of size for either a flat-top dry masonry culvert or an arch in rubble masonry is 4 feet by 4 feet.

Concrete.—There are three main types of concrete culverts commonly built—the arch, the embedded I-beam and the reinforced—(Figs. 7 and 8), but often the characteristics of two or three of these types may be combined in the one design. A true reinforced culvert is one in which all four sides are reinforced to resist external pressure, and the only type of plain concrete is, of course, the semi-circular arch.

Each of these three types have their ardent advocates, but it yet remains to be proved that one is better than another to any great extent. The plain semi-circular arch, of course, follows a precedent established for centuries, and its only drawback is, that above the springing line, the area of the opening decreases; whereas, with a flat-topped culvert the width of opening is constant to the roof.

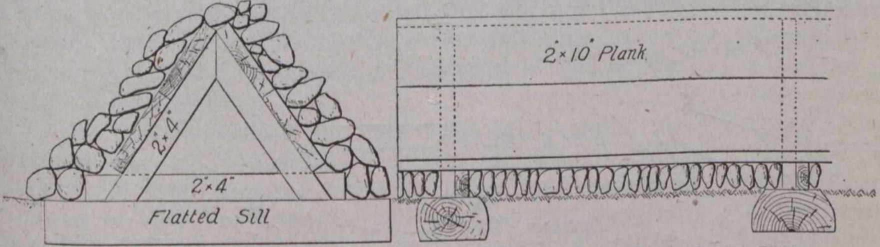

Fig. 5.—Wooden Highway Culvert for Use in Very Low Fills.

Advocates of reinforced concrete sometimes claim that it is impossible to build a plain concrete culvert that will not crack in some direction or other. This idea is based on wrong hypotheses, for if one considers the brick and stone arches that have been built for centuries, it is hard to understand why these should stand up and not concrete. A great many liberties are taken with concrete that would not be thought of with other materials, and when a failure occurs, any reason is given except the true one. A concrete culvert is buried under an embankment, and is, therefore, subject to very slight variations in temperature. The mixture is usually lean and the amount of moisture present is practically constant, so that the only reason for cracking can be poor foundations and poor workmanship. No concrete of any kind, not even for a 3-ft. arch, should be allowed to go in except under strict supervision. On a 150-mile stretch of railway construction in eastern Canada it was not thought necessary to employ an inspector, the result being that all of them developed faults, some failing entirely.

The Location of the Culvert.—Although the determination of the correct size and type is in the main the most difficult part of the work, yet there remains the work of locating and constructing, so as to obtain the greatest efficiency. These last two points are often overlooked, and it often happens that of a thousand dollars expended, only three-quarters has served a useful purpose, the remaining $250 being thrown away for want of a little forethought and planning. Too often the culvert is staked out on the ground that is the easiest place to drive stakes, or where the water happens to be running at the time.

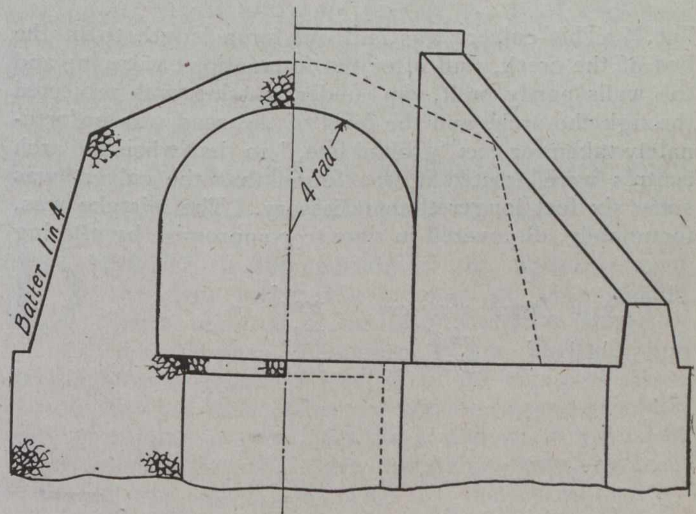

Fig. 7.—Typical Arch Concrete Culvert.

No culvert, not even an 18-inch pipe, should be staked until the immediate neighborhood has been thoroughly examined; and, of course, the larger the structure the more careful should be this examination. In all cases levels should be run on the bed of the stream, and a profile plotted. If the stream is very crooked or the gully wide, a rough plan is also advisable. For the levels, stadia readings are accurate enough, and the best method of taking the topography is with a prismatic compass and a cloth tape or stadia shots. Soundings on the proposed site should be taken in all cases, the number and depth depending upon the size of the culvert. These soundings are shown on the profile as a dotted line.

Upon this profile is platted a cross-section of the embankment, a grade line struck for the invert, and the length determined, both up and down stream, for if there is much fall, the down-stream end will be longer than the