other quantities, distances, and elevations needed in preparing plans and in the execution of the work.

The simplest type of bridge or culvert that will be considered here is the wooden plank floor bridge for very short spans. This may be strengthened for increased spans, up to certain limits, by supporting the floor upon logs or sawed timbers. The life of timber, especially in bridges and culverts, is at best only a few years, in some cases ten, but usually, in the flooring at least, it is not more than three years. The price of timber is constantly advancing, and the liability of accidents from misplaced, worn-out, or broken plank is very great. While a timber bridge admits of theoretical design, there is no real need for its use to be encouraged, and it is the purpose of this article to deal with types of construction of a more permanent and substantial nature, such as concrete and steel.

The simplest form of concrete construction for bridges or culverts is the concrete floor or slab, corresponding to the wooden plank floor mentioned above. The concrete slab may be used for greater spans than the plank floor, and it may also be strengthened for greater spans by constructing concrete beams beneath the floor to support it. This is then known as the "T-beam" type of construction.

These types of concrete construction may be strengthened further by placing steel rods, expanded metal, or woven-wire cloth near the bottom of the slab, and steel rods near the bottoms of the beams. The advantages of using the steel reinforcement are that it has a greater tensile strength than concrete and that its location in the lower part of the concrete slab or beam brings it into tension when the beam is loaded. (Fig. 2a.) Moreover the compressive strength of concrete is greater than its tensile strength, and therefore the steel strengthens that part of the concrete structure which is subject to tensile stresses and is most liable to fail first.

This method is therefore more economical and makes it possible to bridge greater spans, within practical limits of cost, than can be done with plain concrete alone.

The application of the concrete slab is to be found first in the construction of box culverts. (Pl. V., Fig. 2.)

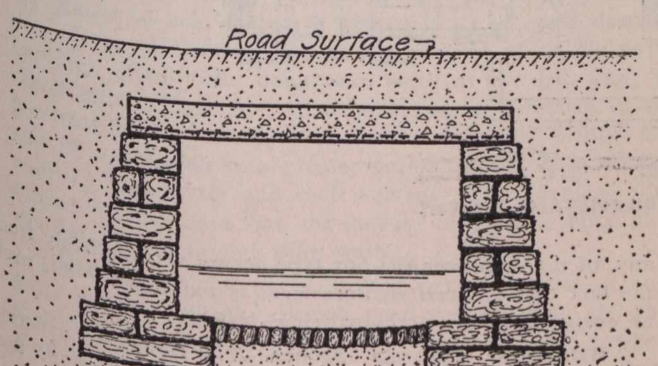

Fig. 2b.—Reinforced Concrete Slab on Masonry Abutments.

The box culvert gets its name from its similarity to a box with open ends. It has a floor, which may be of plain concrete or may be paved with stone. The two sides and wing walls at the two ends may be of plain concrete or reinforced with steel, but the cover and parapets should always be of reinforced concrete.

The sketch shown in Fig. 3a is made from a working plan prepared for a concrete box culvert, which has an opening 2 feet wide by 2 feet high.

This type of construction is practical under the majority of conditions for spans up to about 8 feet, which, as a matter of fact, forms a large percentage of all the culverts needed. Conditions may occur where it will be practicable to apply the box type, with some modifications, to greater spans than those mentioned, such as where the foundation is soft or liable to much erosion from swift currents. The floor may then be reinforced with steel, so that it will have greater strength to act as a beam to distribute the load over a greater area. It may also be extended back of the side walls to act as a footing. With suitable "cut-off" walls

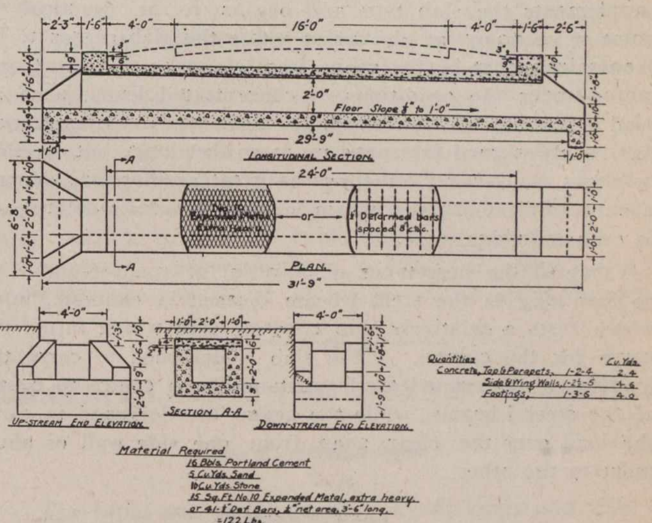

Fig. 3a.—Plan for a Concrete Box Culvert.

to prevent currents of water from running beneath this floor, the foundation will be well protected from erosion. Under such conditions this modified type, with further modifications in the cover, which will be discussed later on, may be practical for spans up to 20 or 30 feet. Figure 2a illustrates the principle under discussion. Here the reinforced concrete floor serves the same purpose as the logs, but the result is more permanent.

The length of the spans over which reinforced concrete slabs may be built within the limits of practicability and safety depends much upon the loads to be carried. The depth and amount of fill over the culvert, which may distribute the effect of the concentrated load, is also an important factor.

On main roads, where concentrated loads, such as road rollers or traction engines, are to be provided for and the depth of fill over the culvert is sufficient only to provide a cushion of earth from 1 to 2 feet in depth, the concrete slab is practical for spans up to about 10 or 12 feet, while for greater spans than this, under these conditions, other types better adapted to the longer spans should be used.

Under conditions of less severe loading the spans for the slab may be increased up to 16 or possibly 20 feet, but it does not seem advisable to use them for these greater spans in view of the possibilities of a nominal future growth of traffic requirements.

In some localities conditions may be favorable for building the footings and side walls of quarried or suitable field stone laid in cement mortar. While these will not prove more satisfactory than good concrete, it may be a matter of economy to do this, because of the saving in expense in crushing the stone for concrete. The reinforced concrete slab may be built quite as well upon such walls.

There are also many cases where masonry walls are already built, but have a poor wooden floor for the bridge. These floors may be replaced with a substantial reinforced concrete slab, which will be permanent.

Traffic should not be allowed directly on the concrete surface of the slab. Consequently it may be necessary to take off the top of the masonry abutments, so that the slab