may be set low enough to allow an earth cushion about 18 inches in depth to be placed on the concrete slab. There are also many other locations where the present bridge is set so low that it improves the grade of the road to construct the slab on the masonry abutments as they are found and then raise the grade of the road by placing the earth cushion over the slab (Fig. 2b.)

The reinforced concrete T-beam type of construction supplements the slab type and begins to be practical in point of economy at the point where the slab ceases to be economical—that is, for spans from about 10 to 12 feet and more—under the conditions of concentrated loads, such as road rollers or traction engines. This type of construction has been designed for spans up to 50 feet long, but whether or not it is practical for spans as great as that may depend upon several conditions, which must be carefully determined in each individual case.

One of the best types of culverts for spans from 10 to 30 feet long is the steel I-beam incased in concrete, upon which rests a relatively thin concrete slab which forms the cover for the culvert. The slab is designed to carry the load for a span equal to the distance from centre to centre of the steel I-beams, while the beams are designed to carry the load over the clear span from one side wall or abutment to the other.

Among the best features of this type of construction are its safety and ability to withstand severe and unfavorable conditions, such as the unequal settlement of abutments, which may cause cracks in the concrete that would cause other types to fail. In this type, however, the load is carried principally by the steel I-beams, whose strength is not destroyed by the settlement of the abutments.

Many structures of this type have been built without incasing the I-beams in concrete, but by merely painting the beams instead, to protect them from rust. The painting, however, must be repeated every few years, at some considerable expense. There is, of course, a great possibility that this painting may never be done, and the better way is decidedly to incase the beams in concrete during the construction, and thus protect them permanently.

This type also admits of arch construction between the beams for the floor system. By this means space may be saved in the depth of the floor system that may be of value in locations where the area of the waterway or the "head room" is a controlling factor. Plate VIII. is made from a working plan prepared in the Office of Public Roads for a 24-foot span concrete steel I-beam culvert.

Plain Concrete Arches.—The arch culvert is well adapted for locations in deep ditches or ravines, where there is an abundance of "head room," and it may be built over spans from 2 feet up. Many have been built over spans of from 50 to 75 feet in length. The Connecticut Avenue bridge in Washington, D.C., consists of a series of five arches, each 150 feet in span and built of plain concrete. A bridge in Germany has a single arch span of 215 feet, built of plain concrete. These two structures are rather exceptional, however, and are mentioned because of their general interest and not because it is intended to treat in detail of them or of structures of their magnitude in this bulletin. There are some noteworthy structures with a series of arches, and among them may be mentioned the railroad bridge at Rockville, Pa., which consists of 48 arches, each having a span of 70 feet.

The illustration shown in Fig. 3b is made from a working plan prepared for a plain concrete arch-culvert with a 6-foot span, which may be of service more often than those of larger spans.

The difference in the cost between an arch culvert for this span and that for a box culvert of the same span is not a matter of much importance. The advantage, if there is any, of the arch over the box type occurs very probably from the fact that no steel reinforcement is required for this arch as designed in the accompanying drawing.

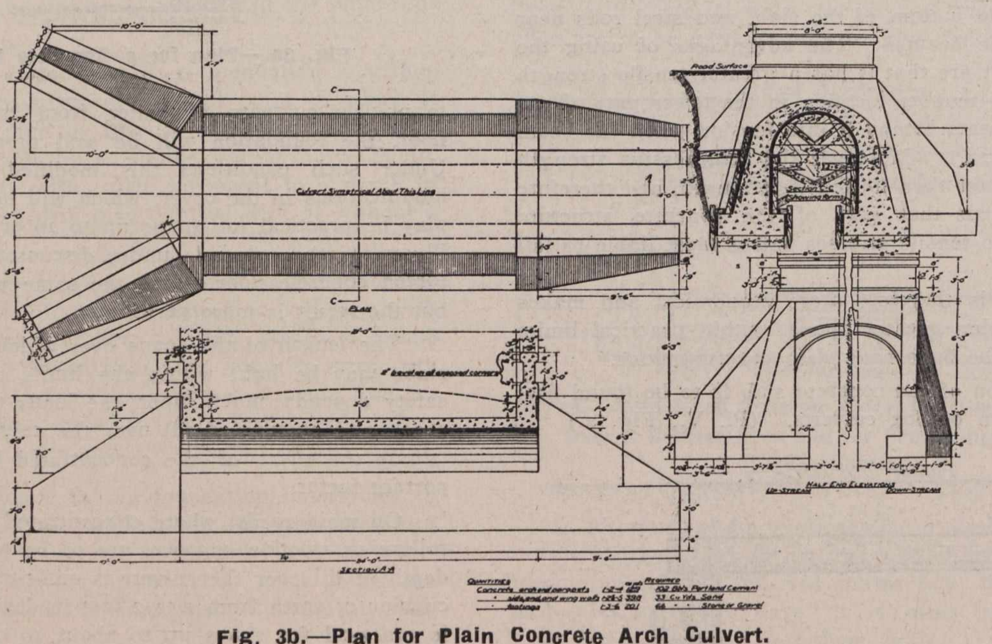

Fig. 3b.—Plan for Plain Concrete Arch Culvert.

Reinforced Concrete Arches.—The reinforced concrete arch has an advantage over the plain concrete arch in the fact that the curve of the reinforced structure may be made more nearly flat than the plain concrete arch, and thereby save in the total height of the structure. This permits it to be used where it otherwise could not. Under favorable conditions there may be an additional advantage in point of economy, although this can not be stated generally as true in all cases.

The steel reinforcement in the arch curves serves the same purpose as in the concrete slab—that is, to increase the strength of the arch rib where the concrete has excessive tensile stresses. In some cases, however, the concrete is also reinforced against compression. It is also possible, when steel reinforcement is used, to reduce the quantity of concrete in the arch rib from the amount that would be required for a plain concrete arch. The reinforced-arch type