masonry will cost slightly less than the iron, because the estimate of the latter can be made quite accurately, whereas the actual expenditure incident to river masonry construction will usually be in excess of preliminary estimates unless made with great judgment, especially in deep rivers of uncertain bottoms.

ARTICLE 22.—BRIDGE ABUTMENTS.

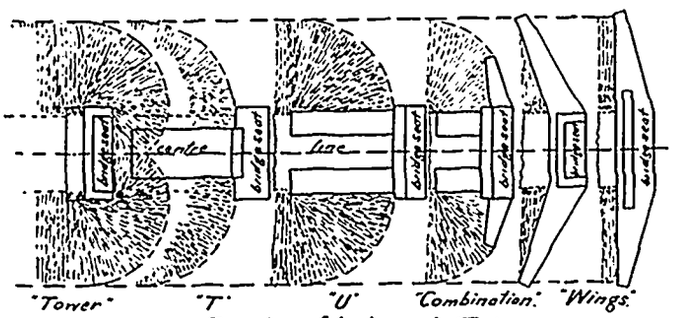
The most suitable design for an abutment will depend on the ground configuration, the position of the face of the abutment relatively to running water liable to scour, and to the amount of earth filling available—the various types in use are shown in Fig. 47. Of these, the tower abutment is always the cheapest, but can be used only when the embankment may be made all around it, on dry ground; the filling at the sides and front should be carefully made so as not to endanger its stability, practically it is used in two cases: First—Often as an abutment to an iron viaduct, with an adjacent heavy cutting and no stream to interfere with the foot of the slopes; and second, when a ravine is partly filled by a necessarily heavy cutting; but no borrow is convenient to complete the remainder, and an iron span must be used to bridge an insignificant stream.

The "T" abutment consists practically of a pier to carry the bridge span, and a masonry approach to carry the track onto the bridge. The objections to the "T" abutment are, that the masonry is damaged by vibration from the trains, and that the front cannot well be protected from river scour. The first objection is met by designing the stem of the "T" to be filled with two feet of rock ballast, to take up vibration; but the abutment must be kept well back from the bank of a stream liable to scour. The cost of a "T" abutment is less than any other (except the tower), when the conditions are favorable. These conditions are, that it is to carry a deck truss, and that the stem of the abutment is stepped into an ascending hillside, thereby lessening the quantity of masonry in it considerably. See Plate XII, Fig. 46. Essential advantages of this abutment are that it is practically in stable equilibrium from earth thrusts as the earth slopes run around the stem, and that water cannot lodge behind it. For through trusses needing wide piers, a "T" abutment is not especially economical, unless the saving on the hillside steps is considerable. The masonry for the pier should be first or second-class bridge masonry, but the interior of the stem may be of heavy rubble, with a cut facing, thus reducing the cost of the abutment to an average price of $8 to $10 per cubic yard.

The "U" abutment is similar to a "T," except that the stem is split into two parts and separated until considerable filling can be placed between the two parts. For deck spans up to 25 feet in height and through spans up to about 30 feet in height, the masonry in this abutment is less than in a "T" abutment, but above this height the quantities increase very rapidly owing to the increased lateral dimensions of the wings, which are designed as level retaining walls. The class of masonry necessary, however, is superior in the wings to that of the masonry in the stem of the "T" abutment, and the average cost of masonry will range from $1 to $2 per cubic yard more, or, say, $9 to $12 per cubic yard, so that it is very seldom less expensive to build than the "T" abutment, but it is very much used, owing to an impression that the wings are not affected by the train vibration. It must be kept well back from a scouring stream, and the toe of the slope in both of these classes of abutments should be protected by rip-rap, if there is any running water. Another serious objection to a "U" abutment is that it is liable to lodge water between the wings. This should always be provided for by weep holes. Whether this abutment is cheaper than a wing abutment will depend on the allowable slope of the earth, and also on the economy that can be effected by stepping the wings into the hillside, see Fig. 48. Some engineers economize masonry in the stems of "T" and wings of "U" abutments by introducing semi-circular arches of 10 ft. to 20 ft. span, just back of the pier-portion of the abutments

The wing abutment is usually used where the ground is level behind the abutment, and where the face is close to running water liable to scour, in which case the wings are flared back about 30° so as to prevent any contraction of the waterway. This abutment presents a neat appearance, and the backing may be made of rubble masonry, thus reducing the cost of the whole to about the price of "T"

Plate XIII



Bridge Abutment Types. Fig. 47

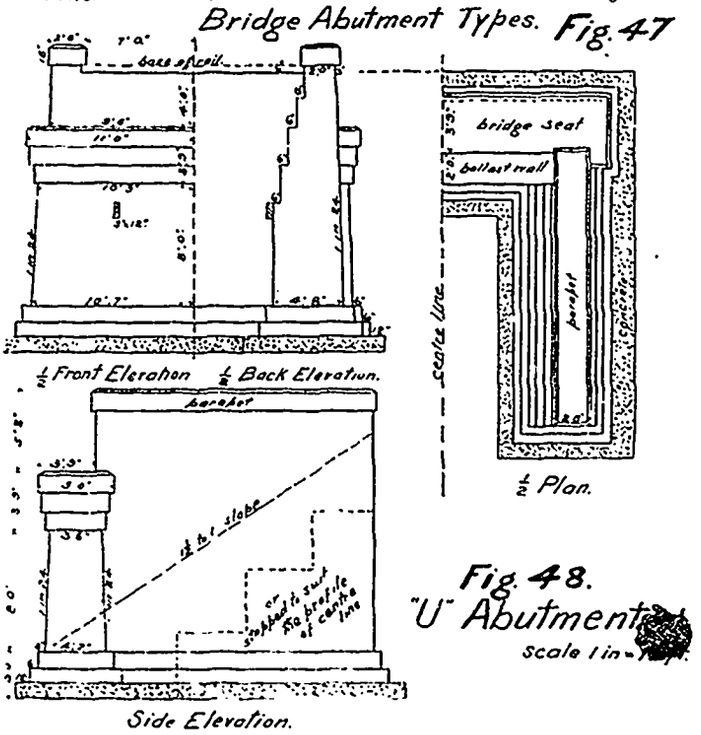


Fig. 48. "U" Abutment.

Scale 1 in.

abutment masonry, *i.e.*, $8 to $10 per cubic yard, but it has several objectionable features: if the foundation below footings is deep, to good bottom, the quantity of masonry in the foundation is excessive. See table XV. (C). And also, its design as a level retaining wall is always a question of more or less doubt. The ordinary rule of the width at base, being $\frac{4}{10}$ of the height + the front batter, is satisfactory if the filling behind is of average quality, but if made of heavy wet slippery clay, the structure may be in danger. Again, in designing the foundation it is necessary to know that it will always receive support in front or else the rule of $\frac{4}{10}$ must be carried down to the foundation bed. For these reasons, an abutment with a straight back and only a tapering to the wings is preferable to one with