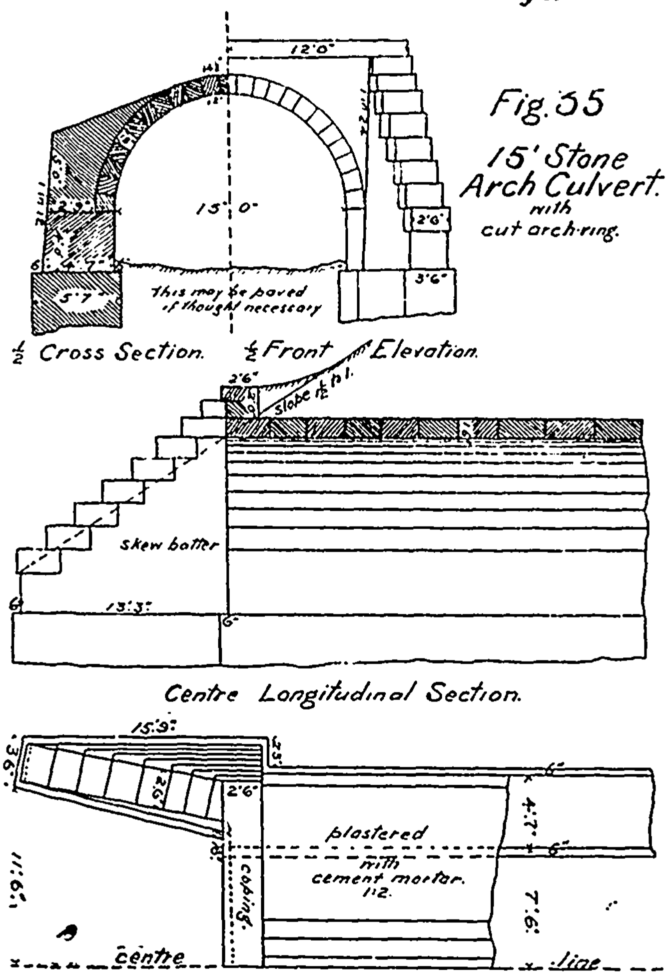
their construction presents no structural difficulties, beyond the precaution of defining occasional lines of separation in the arch sheeting so as to avoid irregular contraction lines.

Plate VIII



The chief features of arch culvert designing are:—

(a) The shape of the end walls.

(b) The depth, class and form of the arch sheeting.

(c) The dimensions of the arch abutments.

(a) The shape of the end walls will depend on the span of the arch and its rise.

For small semi-circular arch culverts, say from 5 to 8 feet span, the retaining head-wall shown, Plate X., Fig. 39, and Plate VII., Fig. 33, is generally used; for segmental arches of somewhat longer span the same may be advantageous, but as soon as a larger retaining wall becomes necessary its use should be abandoned in favor of stepped wings; the reason for this is that a surcharged retaining wall, with nothing but mortar to bond it to the back of the ring stones and often loaded with wet, slippery clay filling, is liable to be displaced, unless made very heavy, and thus the designs, as shown, Plate VII., Fig. 34, and Plate VIII., Fig. 35, of the types shown on Plate X., are found more suitable. The choice between straight wings and flaring ones, or between wings flush with the faces of the barrel of the arch, and those set back clear of the ring stones will depend much on the taste of the designer; for small spans liable to catch driftwood the choice should rest on flush wings, with some flare to avoid contraction, but with larger spans, of say 15 feet or over, a wing set back so as to show the arch ring stones will have a better appearance, and give equally good or better bond between the wing and the abutment or parapet wall. The small parapet wall of a culvert with stepped wings is well buttressed and very stable; the wings themselves usually have a face batter of 1 in 12 to 1 in 24, and a section at any point suitable for a level retaining wall (*i.e.*) about 4/10 height + batter, their length will be economically curtailed at a point where the steps are 2 feet or 3 feet above the ground level. Stepped wings are preferable to those with inclined copings, as the latter are liable to become dislodged in time, and do not give an easy means of climbing the bank, and, also, the coping of a parapet wall of a brick arch culvert should preferably be a stone one, as bricks are liable to be displaced by ties, boulders, etc., rolling down the bank.

(b) The form of the arch will depend on the depth of bank; wherever headroom permits, a semi-circular arch is used, partly because the arch sheeting stones are less expensive than those for any other than segmental arches, being all cut from one template, and partly because the abutments need not be so heavy; but as the quantity of cut arch sheeting is greatest in a semi-circular arch the saving is not very great on the structure as a whole, but when the depth of bank is the limiting feature, a much greater waterway can be obtained by the use of arches of small rise to span, elliptical, segmental, or basket-handled, at a slight increase in cost. In small arches, it is cheaper to use roughly cut or even rubble arch sheeting of a greater depth, than to build one of first-class cut stone of less depth; but as the span increases, the economy of carefully cut and bedded arch sheeting will point to the use of the minimum depth. The workmanship on stone arch sheeting should be of the quality figured on, and if cut stone is called for, it should be as shown in the upper diagram of Fig. 40, because if left narrow at the back, the mortar that fills up the discrepancy being weaker and more compressible than the stone tends to throw exces-

Plate IX

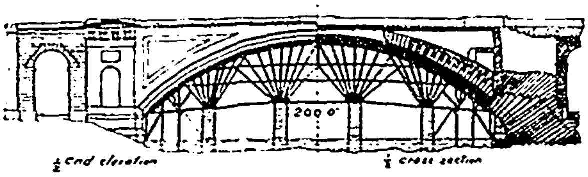


Fig. 36 Segmental Arch

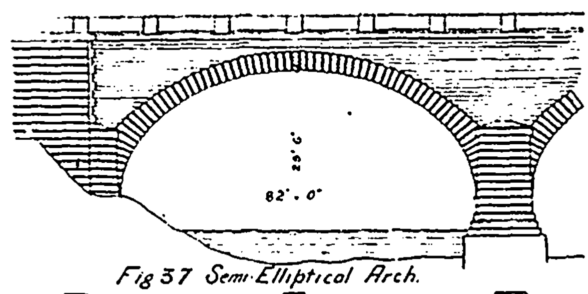


Fig 37 Semi-Elliptical Arch.

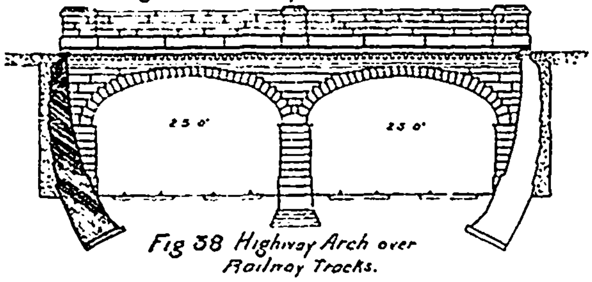


Fig 38 Highway Arch over Railway Tracks.

sive loads on the inner faces of the stones; this is a point over which too great an amount of inspection can hardly be given, especially if the stones are of minimum depth. When deep rubble arch sheeting is used, the mortar will be strong enough to stand the pressures allowed.