on the saturated masonry, and if the crown of the arch is near the bottom of the ties there will be severe heaving of track in extremely cold weather.

Class (3)—Settlement of track, including ballast into the subgrade in wet cuts and on clay embankments during wet weather or spring thaw, will form a trough which will carry rainfall and seepage water from cuts slowly along the depressed subgrade until it meets an obstruction where it will soften up the embankment and cause constant settlement of the track. Quite frequently these soft spots develop just at or near the lower end of the cuts, there being a difference in the amount of settlement, the subgrade being depressed more in the cut than on the fill; this resulting in an offset forms a dam impounding the water which softens up the clay, causing its lateral movement from under the track and consequent settlement of track.

The track is usually resurfaced, and occasionally the ballast, which has been churned full of mud, is dug out and replaced with locomotive cinder. Where these spots are of long standing it is a common thing to see the ends of pieces of board sticking out from the shoulder of the ballast as illustrated, these having been used under the ties to surface the track in the winter when the ballast is frozen and being carried down and outward by the movement of the ballast and subgrade.

Class (4)—The construction of new second track or siding and the filling of the old ditch with ballast will obstruct the flow of water in the ditch, retaining it long enough to allow it to soften up the subgrade, causing settlement of track, or in case of rock cuts causing track to churn and pump the water up to the top of the ties after a spell of wet weather. A case of this kind is illustrated in Fig. 4,

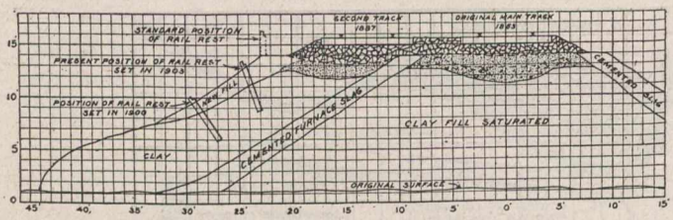

Fig. 2—Section of Track West of Bridge at Warren, O.

showing cross-section of tracks at Phalanx, Ohio, where the subgrade is a shaly soapstone. For a distance of 2,000 feet it was impossible to maintain surface on the westbound track on account of the water from the old ditch overflowing the subgrade of the new track. About five years ago this track was dug out and 18 inches of hard furnace slag ballast put under the ties, which simply increased the storage capacity of water and was of no benefit to the track.

The construction of an additional main or side track on an embankment, at the same time raising the subgrade, produced the result shown in the Fig. 4A. The impounded water from the two adjoining wet rock cuts and from rainfall softened the old fill so that it had about the consistency of mush, a portion of it sliding into the adjoining field.

Class (5)—'Sink Holes.'—The absence of lateral deformation of the embankment distinguishes this from the preceding classes. The settlement will continue until the bottom of the embankment reaches a depth below the surface of the swamp, where the weight of the material of the swamp between the surface and the plane of the bottom of the depressed embankment is sufficient to balance the horizontal force of the material which is being forced out from under the embankment. This depth will vary, increasing as the material of the swamp approaches the "perfect fluid" state.

In the case of the Tamarack Swamp "sink holes," east of Sharpsville, Pa., on the Erie Railroad, this state of equilibrium was obtained when the bottom of the fill had penetrated the swamp from 30 to 40 feet. The depth of the swamp in this case exceeds 100 feet, spliced piles of that length being driven without finding stable bottom. The material displaced by the embankment moved outward and upward, raising the surface of the swamp into ridges and causing large trees to lean or overturn as far as 200 feet away from the embankment. The top of the fill is about 15 feet above the surface of the swamp.

The settlement of the track under traffic is, in all cases, due to the horizontal displacement of the supporting soil, either in the embankment or in the original surface under the embankment (excepting, of course, the natural settlement of new fills due to the compacting of the material). The amount of horizontal movement under a given traffic will depend on the relative fluidity of the soil. Since the fluidity of the soil depends, for the pressure considered, almost entirely upon the amount of water contained, it is apparent that a reduction of the water contained will reduce the rate of movement, and an entire elimination of the water will stop the movement. Naturally, then, the proper remedy for the elimination of soft spots is complete and thorough drainage of a permanent character. For soft spots of the first class, drain tile should be laid in the ditch and at short intervals across the track, the depth being first determined by cutting trenches across the track at all of the worst spots and continuing the excavation down through the ballast and the underlying clay until a point is reached a foot or two down in the clay below the bottom of the ballast where the clay is firm enough not to move under the pressure of traffic. The main tile in the ditch should be laid about 12 inches deeper than the deepest test trench, three or

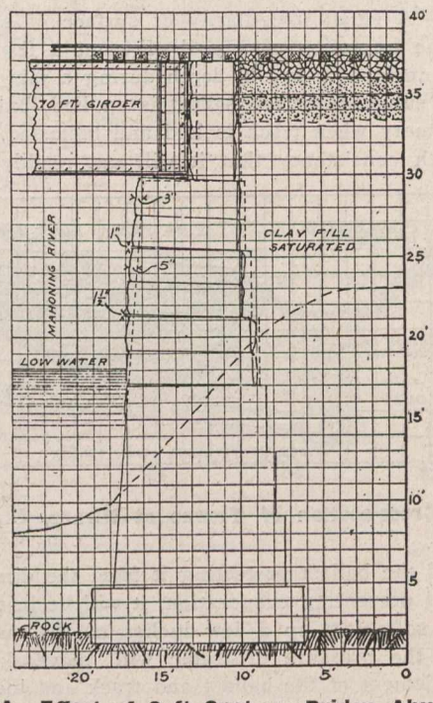

Fig. 2A—Effect of Soft Spot on Bridge Abutment at Warren, O.

four inches of locomotive cinders being put in the bottom of all trenches before the tile is laid and the entire trench filled with locomotive cinders up to the level of the subgrade.

Locomotive cinders should be used, because the clay will not mix with them as it does with broken stone, gravel or furnace slag, this being demonstrated in cutting the inspection trenches across the track where the original ballast had been locomotive cinders. In such cases there was a well-defined line between the cinders and the clay, the clay penetrating the cinders not more than an inch or two after fifty years of service; while coarse furnace slag and clay were mixed for a depth of two feet or more. Cross trenches should be dug and tile laid from the main tile, across the track at the middle of all soft spots and in wet cuts, at intervals of fifty feet or less, the location of each cross drain being marked by planting a piece of tile on end in the side of the bank. The longitudinal trough or depression under the track not having a uniform grade, it may be necessary to put in an intermediate cross drain should a soft spot develop between those already put in.

The accompanying illustration (Fig. 1) shows the conditions found in and remedy applied to a very bad case at