The difference of cost, as shown in the table, the less cost of handling and laying of the sewer pipe and its absolute freedom from corrosion will always be greatly in favor of its adoption where well-burnt, salt-glazed, double-strength sewer pipes can be obtained within reasonable length of railroad and team-haul.

Open Culverts.—Where a large flow of water is to be carried across a shallow bank some engineers use two or three lines of pipes, but the danger of this method lies in the possibility of debris collecting around the middle walls and gradually choking up the waterway. This can be guarded against by building a screen or paling some distance above the entrance, which catches the debris. Generally speaking, however, a large stream and shallow bank demands an open culvert. In many cases these may answer the double purpose of waterway and cattle guard, or waterway and cattle-pass, for giving passage for cattle under the track. Such structures may be of timber, stone, concrete or brick walls, capped with stone; but whatever kind may be used, they should be decked with a complete trestle floor, such as to make them safe for derailed trains to pass over. And indeed, latterly, some roads are adopting a solid timber floor, on which the ordinary road ballast is laid, or better still, a floor of discarded steel rails, laid longitudinally, filled in with concrete and covered with ballast; in either case the roadbed is continuous, and free from danger by derailment or fire, and presents a more elastic and uniform bearing for the track ties.

On Plate II. (Figs. 23 and 24) are shown plans for a 6-foot open culvert of timber or stone. If the bank were deeper, the stone walls would need to be thicker, being designed as level retaining walls, and the timber culvert would need a more thorough system of interior struts, etc., for stability. If the embankment cross-section were to show a rapid descent just at the mouth of the culvert, it would be more economical to place the stepped wings at right angles to the walls, in the form of head walls, about six feet from the centre line. This is not done, ordinarily because less economical, less stable, and subject to vibration and thrust from the train.

The timber open culverts should be well drift-bolted in each course, and have the stringers also notched down slightly and drift-bolted to the walls—the mud sills well sunk into the solid earth, and preferably with paving between them and a sheet piling apron at each end to prevent under-flow and undermining, as shown on Plate IV. (Fig. 28.) If the foundations are not good, a structure, on piles, similar to the one shown on Plate III. (Fig. 25), will need to be used. The earth being retained by a layer of four inches to six inches cedar flatted on three sides, and the two walls held vertical by drift-bolting and notching down the stringers, or if necessary, by additional struts placed from top to top of piles as shown in the figure. The use of high-framed timber openings on mud-sills, lagged behind with cedar like that in Fig. 25 is not advised, they are not stable and are liable to be undermined. Wherever a depth sufficient for cattle passes or farmers' undercrossings is required, it is better to put the structure on well driven piles extending up to grade, if a stone opening cannot be afforded.

The valid objections to open culverts with vertical walls are:

(*a*) That the structure being fixed in elevation, offers a rigid support to the track which, on banks, and on freshly made ones particularly is elastic and settles down for several years, and rises and falls with the frost; therefore, at such structures there is more or less of a hump, and always a poor piece of track.

(*b*) That in case of the timber culverts, the lagging behind the piles rots quickly, and is rather awkward to replace.

These considerations have led to the use, especially in the southern United States, of a form of structure shown on Plate III. (Fig. 26), which consists of two bents of piles, or two frame bents on pile foundations, with three 15 foot spans of trestle floor, having the two end supports made of mudsills resting well on to the banks. It is probable that 45 feet of trestle floor is not appreciably more dangerous than 15 feet of it, and the only valid objection to this form of structure is that the frost will heave the ends out of surface in climates like that of Canada or the northern United States, but its openness for repairs, the elasticity

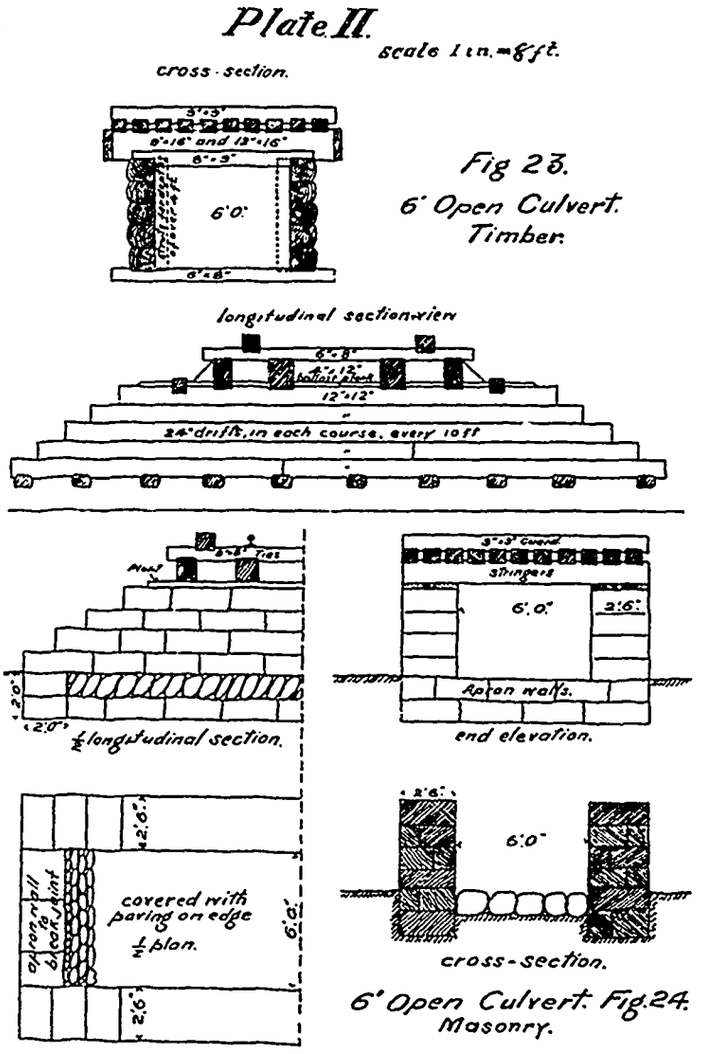

Fig 23. 6' Open Culvert. Timber.

6' Open Culvert. Fig. 24. Masonry.

of the ends which rise and fall with the embankments, its freedom from rot, except the easily replaced mudsills, and the possibility of an enlarged waterway by rip-rapping the sloping banks, to allow for an exceptional flood, are all points much in favor of such a structure. This structure is evidently limited to banks less than eight feet high.

The class of masonry for open culvert walls will need to be superior, owing to the effects of vibration from the trains, to avoid part of which oak planks should be placed under the ends of the stringers. The class usually specified is second-class bridge masonry, and will cost from $8 to $10 per cubic yard upward, depending on the quantities in each structure and total quantity in the contract. The economy of rubble concrete walls capped with a stone coping is being now recognised.