and realizing the great pressure there was against the sides, the engineer decided to leave in the sheeting in the worst parts and to fill parts of the trench (originally intended for clay filling) with concrete up to the bottom of the vertical runners. This meant bringing the concrete up to within about 17 feet of the surface instead of 45 feet, as shown on the typical section. Had all the circumstances been foreseen, it would have been much better to have formed the trench in this very bad ground with two or even three settings of vertical timbering, as the wall, even when thus reduced, would have been thick enough as formed in concrete.

Another design of trench is that in which a definite width is fixed at the probable bottom or at the rock line and slopes outward sufficient to permit the insets of vertical timbering are shown on the typical cross-section.

The first reservoir the writer was on was designed something after this plan and there was no difficulty in adhering to the original proposal as the work actually

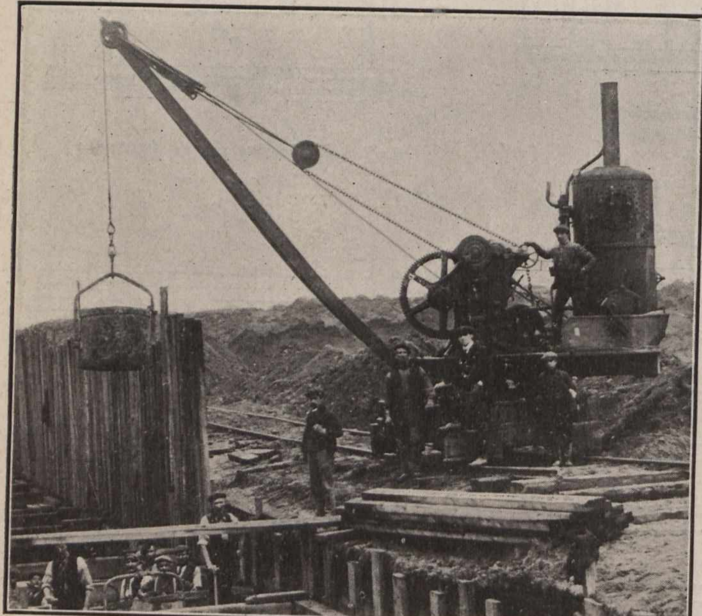

Fig. 6.—Trench Excavation Method, Delph Reservoir.

done by the contractor was about equal in quantity to that involved in the cross-section shown.

After experiencing the many makeshifts and uncertainties arising from the difficulties of adhering to the vertical sided trench in bad ground the writer is of the opinion that there is much to be said for a design which suits the use of vertical timbering. Why should not the design be such that it can be carried out in a safe manner and the payments be so made that the contractor has no inducement to do otherwise than follow the drawings? Of course, the engineer might take up the literal interpretation of his specification and say to the contractor, "Well, if you can't do it with vertical sides, take out the extra width necessary for your own system of timbering and fill in the extra width at your own expense"; but that is not a fair attitude, for the engineer by specifying a vertical sided trench has limited the contractor to a particular method of working and, if he (the engineer) has been mistaken in thinking this method possible then he has more or less misled the contractor and should help him out of the difficulty.

All these contracts were measured jobs and paid for at rates per cubic yard, etc. There was in every case a rate per cubic yard for all excavation from the surface of the ground to 10 feet in depth and another rate for excavation from 10 feet to 20 feet in depth, and so on.

Several large reservoir trenches have been done in Britain by administration, without the aid of a contractor, and there is a good deal to be said for this way of doing work where there is much uncertainty as regards probable depths to impervious strata.

One thing is clear: the engineer should never specify the form or size of timbering. It is even a mistake to say that the contractor shall submit drawings of his proposed methods of timbering for approval. The contractor takes the risk of accident and should, therefore, have a free hand to do his work in a way of his own choosing. Any approval of designs of temporary work carries with it more or less responsibility. Of course, if an engineer thought there was danger arising from the state of the timbering he would probably mention it to the contractor and the contractor would probably look into the matter, but that is a different thing from giving formal approval or disapproval of a proposal. Though an engineer should avoid interference with temporary work, that is not to say he should not give the fullest consideration to the probable way in which the contractor will build the piece of work he is designing.

To return to the amount of pressure exerted by the earth against the timbers. The writer measured the deflection of many of the planks and, by loading a similar plank with bricks until it showed the same deflection, obtained an idea of the force acting against the sides. At 30 feet from the surface in wet sand the deflection showed a pressure of over 1,000 pounds per square foot. In this case the ground had broken up to the surface where a crack could be seen about 20 feet away from the side of the trench.

The illustrations give the exact dimensions of the trench timbering, so some measure of the pressure might be worked out in another way by multiplying the end area of a 9-in. x 8-in. strut by the pressure per square inch necessary to force it one inch into the pitch pine soldiers and dividing this by the area of sheeting supported by the strut. The planks were actually broken at twenty feet from the surface and so down to forty feet, and there seemed to be little difference in appearance between one place and the other. The fibres of these timbers were sprung on the surface and showed as projecting splinters, but the planks were not so far gone that they fell out of their places because before that happened they had received new support. These planks were of hemlock and, of course, always dripping wet.

There is very little enlightening literature on the subject of earth pressures. If one could get the measure of the pressures in a number of cases by deflections of timber, etc., these results of experience would be very useful.

Fortunately, timber gives warning before it breaks, as a rule, and errors of judgment can be rectified by adding more supports if the dangers are noticed in time.

All trenches should be looked over every day by a practical timberman, especially if for any reason they have been standing open for some time.

It is astonishing how much silt will come through a knot-hole in a week, and once settlement has started it is hard to keep timbering right.