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The Usk scheme for the water supply of Swansea †
by
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Discussion

The following contributions were received in writing.

Mr T. R. M. Wakeling (Senior Assistant Engineer, Metropolitan Water Board) observed that the methods which had been developed were of considerable value. They would undoubtedly lead to greater economies in the design of earth dams and permit the use of soils which would otherwise be regarded as unsuitable.

144. He referred to the profile selected for the cross-section of the embankment (Fig. 4a) and asked the Authors to discuss the reasons for the particular levels of the berms and the gradients of the slopes connecting them.

145. In designing an earth dam, there were generally two basic stability requirements to be considered. The first was slipping round a circular arc. To reduce the disturbing moment to the minimum, the embankment should have as much material as possible placed in the outer half near the toe, thus acting as a counter-weight. The second condition was slipping along a horizontal plane, caused by active pressures developed either in the core wall, or in the embankment fill.⁷ The resisting force was the sum of the shear strength along the horizontal plane and the resistance of the passive wedge developed near the toe of the embankment. For that to be a maximum, the slope of the embankment near the toe should be as steep as possible, thus preventing the passive wedge from prematurely breaking the slope surface and short-circuiting some of the horizontal shear path.

146. With respect to those conditions, it might have been possible to obtain a significant increase in the overall factor of safety of the embankment, for the same volume of fill, by steepening the bottom slopes and placing the lower berms at the maximum possible elevation. The upstream slope would appear to be most affected by such a modification.

147. Turning to the basic design of the dam itself, the coefficient of permeability of the embankment fill had been found to be 2×10^{-7} cm/sec, which value was probably little greater than the coefficient of permeability of the puddle clay actually used. Thus the centre part of the embankment bounded by the inside extremities of the drainage layers would probably offer much the same resistance to the seepage of water as the puddle-clay core wall. Could the Authors say if any consideration had been given to constructing the dam with a central core formed by the compaction of selected fill material?

148. After compacting the embankment fill with a wobbly-wheel roller, a 4-ton smooth-wheel roller had been used to secure a smooth surface. That might well cause the fill to stratify with consequently a lower shear strength parallel to the compacted layers.

† Proc. Instn Civ. Engrs, vol. 7, p. 246 (June 1957).

⁷ A. W. Bishop. "Some factors involved in the design of a large earth dam in the Thames Valley." Proc. 2nd Int. Conf. Soil Mech. and Fdn Engng, 1948.

Had any tests been carried out to investigate that, or had the smooth surface been broken up before placing the next layer?

The Authors, in reply, observed that the berm positions at Usk had been fixed partly from other considerations, as well as those applying to stability. It was advantageous to break up the downstream slope into three units so as to reduce the velocity and quantity of rainfall run-off. The berms did that very conveniently and accommodated the longitudinal surface-water drains. At the same time suitable starting-off points, as it were, were provided for the pillar drains. Berms also made the maintenance operation and grass cutting and collecting much simpler. Although it was, theoretically, possible to assign precise positions to the berms for the most stable section, the labour involved in the pore-water pressure case would have been immense and could not be justified.

150. On the question of stability, the Authors felt that there were one or two misconceptions which needed clarifying.

151. In the first place, whilst it was true that in the $\phi = 0$ analysis, slip surfaces tended to be deep, that was not the case when pore-water pressure was taken into account. Reference to Figs 10, 12, or 14 in the Paper showed that the "worst circles" broke out at about the level of the first berm, so that any alteration of the lowest slope would have no effect. On the other hand those circles which did pass through the lowest slope showed that it was about as steep as possible and any steepening would have reduced the factor of safety to an undesirably low figure.

152. Referring to the puddle pressure, the case which Mr Wakeling had quoted⁷ concerned a puddle-cored gravel bank resting on London Clay. The top of the London Clay had softened (as was frequently the case) thus providing a thin soft horizontal layer on which the dam rested. Since the bank was of gravel, negligible construction pore pressures were developed in it. Moreover, in a later reference Bishop⁸ had shown by the recent analysis that the puddle pressure was considerably less than that given by his earlier method. For a 10-ft-wide core, for example, the pressure was reduced by about 40% in the case of a 100-ft-high dam. The puddle-pressure criterion was, therefore, not applicable at Usk, where the ruling factor was the very high construction pore pressures.

153. The permeability of the bank fill was undoubtedly very low. Indeed that had been the cause of all the trouble. It was always easy to be wise after the event, but looking back, the Authors agreed that if it could have been foreseen that such low permeabilities would have resulted from the methods of compaction used, then they would have seriously considered a dam consisting of material largely homogeneous across the section, with a core distinguished only by the absence of drains.

154. A number of trial pits put down into the fill had disclosed no evidence of stratification nor had any such effect been observed in the numerous samples taken.

⁸ A. W. Bishop, "The stability of earth dams." Ph.D. Thesis, Univ. of London, May 1952.