DISCUSSION

Use of soft rockfill at Evretou Dam, Cyprus

A. J. BROWN (1988). *Géotechnique* 38, No. 3, 333–354

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Mr Brown's Paper covers all the formal testing of the Evretou rockfill, and demonstrates the need for a more convenient system of classifying rockfills. Grading, permeability and density are the only characteristics of the rockfill usually measured on site as routine, although with some difficulty, and are useful for construction control. However, to the designer the deformation and dilatancy characteristics are the most important and it is useful to know the real bulk permeability, and directly how one rockfill compares in these respects with others on which there is performance data.

OTHER TESTS

In an attempt to find out more about the Evretou rockfill on site other less formal tests were discussed, and some tried.

A 200 litre oil drum with filter connected to a pipe in its base was filled with typical rockfill compacted in layers; the amount of water needed to saturate this sample, and the amount that would drain, were measured. This crude test suggested an initial porosity of 33%, and a specific yield, as a percentage of total volume of the sample, of 10%. Such a test has obvious possibilities with soft rockfill, and might be a more useful indication of the rockfill characteristic than grading.

Fines from samples of rockfill were compacted into the bottom of a CBR mould in conditions aimed at matching those in the field. The CBR piston was loaded on to the thin samples and the deformation that accompanied saturation of samples was found to be considerable; the reason for this was never properly explained.

The possibilities of direct deformation tests were looked into: the most promising approach appeared to be to use a concrete anchor plate, e.g. 1.5 m dia. set in a rockfill layer, later drilled and anchored to form a second plate set two or three layers vertically above the first. Using recoverable stressing bars and a central hole for a pressure sleeve such a test could give a measure of deformation and dilatancy for a cost comparable to that of a few density tests. Such deformation tests

could give a fairly direct measure of the characteristics on which the design depends, and would allow easier comparison to be made between various rockfills if a standard arrangement could be developed. Unfortunately such research was not justifiable at Evretou.

DESIGN COMMENT

The drainage layers in the upstream shoulder are of benefit for dispersing possible excess pore pressures in the rockfill following any movement in earthquake. For limiting drawdown excess pore pressures a single low level layer would suffice if it could be guaranteed that the rockfill permeability was reasonably constant, or decreasing with elevation in the upstream shoulder.

OTHER CONSTRUCTION EXPERIENCE

In sample areas during construction more water was added to the rockfill. It was found that adding significantly more than 10% by volume left the rockfill spongy after compaction, although the impression was that the disadvantage would be further particle breakdown by grinding rather than rutting.

Since Mr Brown drafted his paper the embankment has continued to perform as expected: the small extra settlement that occurs in the rockfill of the upstream shoulder on first saturation appears to be a once-only phenomenon, but as the reservoir rises so do the post-construction pore pressures in the core below reservoir level. It is presumed that this is happening as the reservoir pressure reduces the core strength at its upstream edge, and the core loses some of its support from the rockfill; this is consistent with Mr Brown's remarks on the core arching, and further improves safety against any immediate hydraulic fracturing.

Author's reply

The Author agrees that there is a need for a more convenient system of classifying rockfills, both from the point of view of the designer and in terms of practicable methods of construction control on site. Of particular importance is the

Table 12. Pore pressures on dam centre line before and after impounding

Date	Reservoir level: m	Elevation of rockfill: m			
		152 m	140 m	125 m	112 m
		Pore pressure: kN/m ²			
Nov. 1986	117	105	190	400	650
April 1988	162	125	240	450	660

boundary between what are classified as suitable and unsuitable materials. The Paper attempts to show that what traditionally may have been regarded as an unsuitable material, was in fact a suitable material when handled appropriately.

The Author was aware of these other tests. The concept of specific yield, or the amount of water which is removable by gravitational drainage, is an interesting measure of rockfill behaviour, particularly for this broadly graded soft rockfill which has a full grading similar to that of the Fuller grading. However, the value given is difficult to relate directly to the field rockfill owing to the absence of information on laboratory grading, dry density and initial moisture content. The Author agrees that *in situ* deformation tests appear promising; although edge effects would be significant, they are likely to be small in relation to variability of compressibility. The tests would have to be sized in relation to particle size and layer thickness, and could become impractical for coarser rockfills. As well as comparison between rockfill types these tests could be useful in evaluating alternative compaction procedures on one rockfill source, and could therefore be incorporated in any trial embankment programme.

At Evretou the design approach was that the rockfill should be sufficiently dense such that it is dilatant on shearing; therefore excess pore pressures should not develop as a result of earthquake shaking. However, the drainage layers should accelerate dissipation of excess pore pressures whether caused by rapid drawdown or earthquake shaking, the latter provided that any displacements are not sufficiently great to disrupt the drainage layers. Specification of drainage layer spacing in the upstream shoulder is largely subjective, as for instance if the rockfill had significantly higher horizontal than vertical permeability the effectiveness of the drainage layers is substantially reduced. A reasonable case could be made for specifying only a single low level drainage layer, but as Mr Reeves points out the

effectiveness of a single layer will depend on rock-fill variability.

With regard to addition of water to the rockfill, the Author considers that the upper limit was largely dictated by the point at which the rockfill became saturated. Owing to variability of specific gravity and particle porosity this is difficult to substantiate quantitatively. The Author agrees that a practical disadvantage of excessive moisture content is further particle breakdown under the grinding action associated with rockfill movements in the vicinity of cuts.

Instrumented performance of the embankment with continued impounding is of great interest. It is likely that the rise of pore pressures in the core is largely due to the loss of support from the adjacent rockfill, because of the reduction in horizontal effective stress, leading to reduced arching action. There is unlikely to be any significant loss of strength of the core over the period of impounding, owing to its low coefficient of consolidation. The Author understands that the increases in pore pressures were as given in Table 12, with a 25% increase in pore pressure at elevation 140 m. The reservoir level continued to fall slowly from a level of 150 m, reached in April 1987 (Fig. 23) to a level of 147 m in January 1988, when it started rising before again reaching a level of 162 m in mid April 1988. Maximum retention level is 165 m. Total stresses in the core also increased at the same time as increases in pore pressures. Publication of the complete set of total stress and pore pressure measurements in the core during construction and impounding would be of great interest, as a valuable case history.

Corrigendum

On Table 11, p. 351, the headings to the main columns should read '112–126' and 'Stripped foundation—112'.