with the compacted sand layer above. The authors regret that this information was not given in the paper. Furthermore, as suggested by the discussors, the study could be extended to loose sands as well and the term load ratio may perhaps be adopted instead of 'group efficiency'.

Load carried by the pile group ($2 \times 2 = 4$ Nos.) for a deformation of 2·54 mm is given in Table IV. When a single pile or the group is allowed to settle further to say 5·0 mm, it is observed that it supports higher load as already mentioned in the paper, in dicating that the mobilization of strength continues. In general, for larger deformation the trend of results similar to that shown in Figure 5 is observed.

In this paper an attempt is made to study two important aspects of the problem of pile foundations. Firstly, load supported by a pile group of $2 \times 2 = 4$ piles in granular soil is compared with the load carried by a single pile and secondly, the influence of the presence of rigid layer below the pile tips on the behaviour of piles is examined. It may be added that the load supported by the pile group as affected by both these aspects is compared with that of a single pile in semi-infinite medium only, in all the cases to bring out the combined influence of both these aspects.

It is seen that the resistance to settlement of piles increases when the rigid layer is close thereby allowing more load to be transferred to the tip by bearing rather than through friction around the shaft. It is thus clear that the distribution of load through friction or bearing is governed by the distance of the rigid layer and also by the mechanism of the group action which is generally dependent on the spacing between the piles, confinement conditions, etc., as discussed in the paper.

These points together with the test data indicate that the pattern and mechanism of load transfer get affected in the problem of pile foundations as brought out in the paper. However, it has to be agreed that this is rather an inference drawn from test results and the real or direct assessment in this respect would be possible only by conducting instrumented tests preferably with bigger piles.

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Seepage through an Imperfect Cut-off Wall*

by

Suresh P. Brahma

D. BABU RAO**

The author is to be complimented for presenting the theoretical results of the problem of leaky cut-off walls. It should be noted that the distribution of leaks is usually random. Thus, in the case of sheet pile cut-off open seams between the pilings, distortion in the piling would contribute to random distribution. It would be a gross simplification to assume the leak at a given location, and mathematical technique, as presented by the author, may not be much helpful. An electrical analogue, using a

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conductive paper with a series of slits in it, would seem to give results in such a case. Dachler (Casagrande, 1961) has employed a slit model.

While suggesting that the cut-off is used under water supply and water power dams, the author has solved the problem of an isolated cut-off, rather than that under a dam of given width. For cut-offs under wide dams, it should be expected that the decrease in the effectiveness of the cut-off would be much more abrupt than it is for isolated cut-offs or those under narrow dams. Under wide dams, there would be relatively little difference in the quatity of flow through fully and partially penetrating cut-offs.

Mention may be made of related Russian literature, wherein, Chugaew (1952) has advanced the concept of leakiness parameter, and Numerow (1956) has given a theoretical approach to the leaky cut-off problem for conditions of horizontal free-field flow.

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AUTHOR'S REPLY

The discussion by Rao is most welcome because it provides the writer an opportunity to clear up the points raised in the discussion. The writer presented an analytical solution for the case of cut-off with only one discontinutiy and the location of such discontinuity could be at any location and of any size. Rao correctly states that an electrical analogue with a 'series of slits' in it would seem to give results for more down to earth case, i.e., with randomly distributed imperfections. The writer thought of it earlier and has presented (Brahma 1971) his studies for design of cut-off wall with more than one slit of different sizes located randomly in the cut-off wall with the help of an analogue model. It is in order here to mention that Dachler (Casagrande 1961) has presented solution for the case with slits located at equal spacing and the slits were of equal size, which in writer's opinion does not truly represent the case of randomly distributed imperfections.

Water supply and water power dams are often built with an impervious core having both upstream and downstream portions constructed of highly permeable material and such dams do have wide bases. The writer's solution applies well to such cases. Moreover, the writer could not get what Rao meant by wide dams. If he meant by wide dams the ratio of the impervious width of dam to the thickness of the pervious foundation layer was high, i.e., of the order of 1 to 2, in such cases, contrary to Rao's expectation, there would be large difference in the quantity of flow through fully and partially penetrating cut-offs (Harr 1962).

Lastly, Rao mentions two works published in Russian and it is indeed unfortunate that these works in the translated form are unavailable to many researchers at this time. However, such literatures would