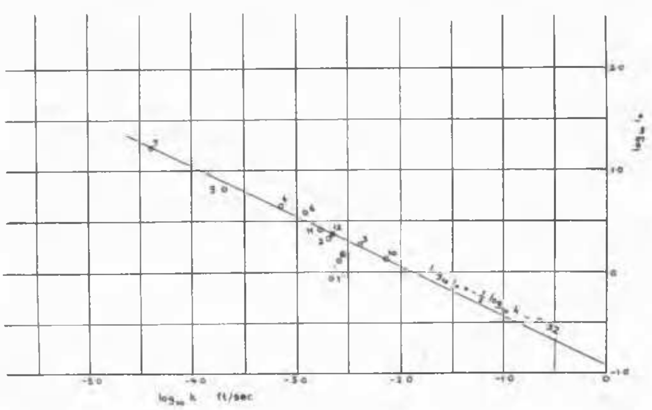

FIG.1

10 are shallow, and in these two cases the water level was drawn down into the lower beds. In the former group the values of K as calculated from the output of the wells was found to be:-

1)	Battersea	K=0.065 cm/sec.
2)	Beckton	K=0.060 cm/sec.
8)	Russia Yard	K=0.079 cm/sec.
11)	Plaistow Wharf (1)	K=0.055 cm/sec.
12)	Plaistow Wharf (2)	K=0.067 cm/sec.

Mean Value for Thames Gravel = 0.065 cm/sec.

in the latter group where the water was drawn down into the coarse bed the values of K were:

3)	Kingston	K = 0.119 cm/sec.
10)	Uxbridge	K = 0,218 cm/sec.

RANGE OF INFLUENCE.

The value of R, the range of influence of a group of wells is the most difficult quantity to assess in water lowering calculations. In cases 11 and 12 the limits of appreciable lowering were at 500 feet and 800 feet respectively. In case 10 where pumping was carried on for many months the level of water in a market gardener's well 1,000 feet from the site and on the opposite side of a canal was lowered.

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SUB-SECTION Xb

SEEPAGE PROBLEMS OF DAMS AND LEVEES.

Xb 1 CRITICAL HEAD FOR THE EXPANSION OF SAND ON THE DOWNSTREAM SIDE OF WEIRS

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1. INTRODUCTION.

The purpose of the following investigations is to obtain reliable data from which we can derive rules for designing weir structures. These structures are in danger to be destroyed by water percolating through the sand beneath them, which leads to the formation of piping. The mechanics of piping were tested many times. The review of this problem can be found in Terzaghi, Theoretical soil mechanics (1943, p.257).

The author has studied experimentally and mathematically piping in his article, Grundbruch unter der Spundwand (Die Bautechnik 1940), which deals with piping under an impermeable diaphragm. Further tests concerning piping beneath weirs, were studied in his article Critical head for piping beneath weirs in the Proceedings of Congress of Large Dams, in Stockholm 1948. Now he presents the result of tests concerning the determination of critical head with respect to expansion of sand on the downstream side of weir which preceeds the piping. Tests were made in the foundation laboratory of the University of Technical Sciences of Prague.

2. NOTATION. (see fig. 1a)

h_p = critical head with respect to piping
h = head, expressing the difference of the levels upstream and downstream
h_e = head for the beginning of expansion of sand
D_1 = depth of foundation below upstream surface
D_2 = depth of foundation below downstream surface
2B = width of foundation
e = void ratio
$N_p = \frac{h_e}{h_p}$

3. DESCRIPTION OF SOIL AND TESTING APPARATUS.

The sand used for tests had grain sizes from 0,2 to 0,5 mm. Sand originated from diluvial deposits of the river Vitava near

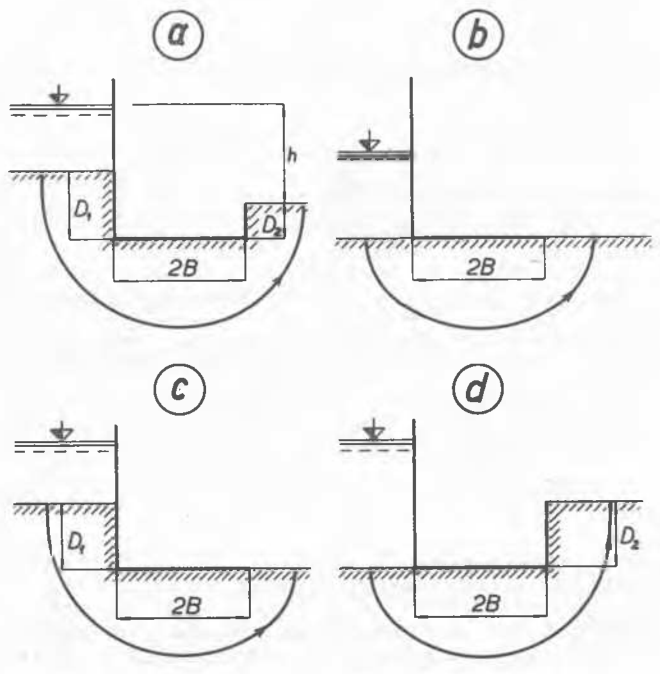

FIG.1

Štěchovice. Its specific gravity was 2,58 kg/dm³ maximum void ratio e = 0,92 minimum void ratio e = 0,59, permeability k = 0,1 lcm/sec, angle of internal friction φ = 46°.

The tests were performed in a small flume having the following dimensions: width 20 cm, length 80 cm and height 45 cm. Sand was deposited in the maximum thickness of 17,5 cm beneath base of foundation.

4. PROGRAM OF TESTS.

Three forms of models were used for testing. They are sketched in Fig. 1b to 1d. Model Fig. 1b gives results which are suitable for comparison with the mathematical solution of the problem. Model Fig. 1c represents the case of a weir, which has on the downstream side a scour, reaching to the base of foundation. The opposite of Fig. 1c is Fig. 1d. Tests for the fourth case, with the surface of soil higher than the base on both sides, could not be performed due to the small height of flume.

5. DESCRIPTION OF THE TEST PROCEDURE.

The disposition of the model and the de-

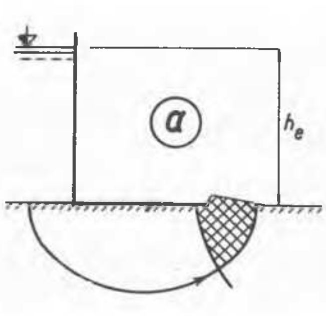

FIG.2

positing of sand in the flume under the model was described in detail in the authors article published in the Proceedings of Stockholm Conference on Large Dams 1948. The piping does not occur for h_p = const, but it varies. For each case the lower and upper limit of h_p was determined. Tests were performed as short-time tests, during 2 to 10 minutes.

The expansion of sand was specially studied this time. It is created, when h rises over a certain head, designated as h_e. The expansion of sand occurs on the downstream side of the foundation and it can be observed as the lifting of surface. On Fig. 2 the expansion is expressed as cross-hatched area. The appropriate head h_e has great importance, as it shows that in sand an unstable stage is beginning which can lead to piping. This head h_e has similar significance as limit of elasticity in the strength of materials. The safe head must show a certain degree x of security against h_e, that is it must be x times smaller than h_c.

6. RESULT OF TESTS.

182 tests were performed from the 12-2-47 to 12-13-47. The number of types tested was 25. Models were used with 2B = 0, 30, 50, 100 mm and D_1 = D_2 = 0, 15, 30, 50 mm. Each type, determined by certain width 2B and depth of foundation D_1 or D_2, was tested 4 to 9 times. To obtain limiting heads h_c and h_p with security it was necessary to perform at least 6 tests; a smaller number was permissible only

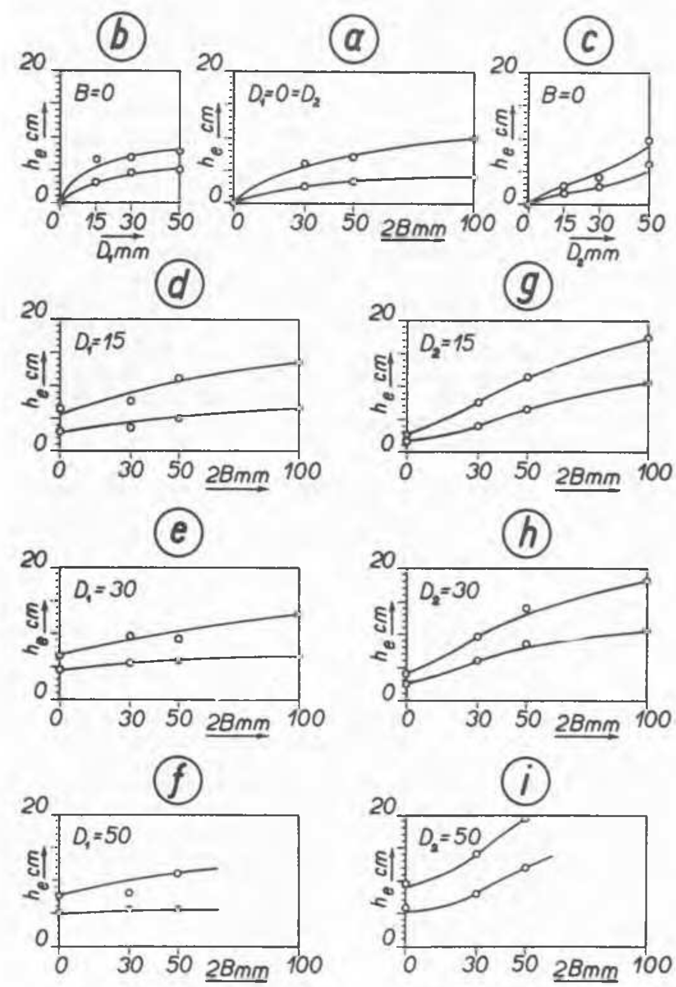

FIG.3

in these cases, where we could rely on previous tests, described in Proceedings Stockholm 1948.

Fig. 3 represents the result of tests with respect to h_e. Only the limits, are

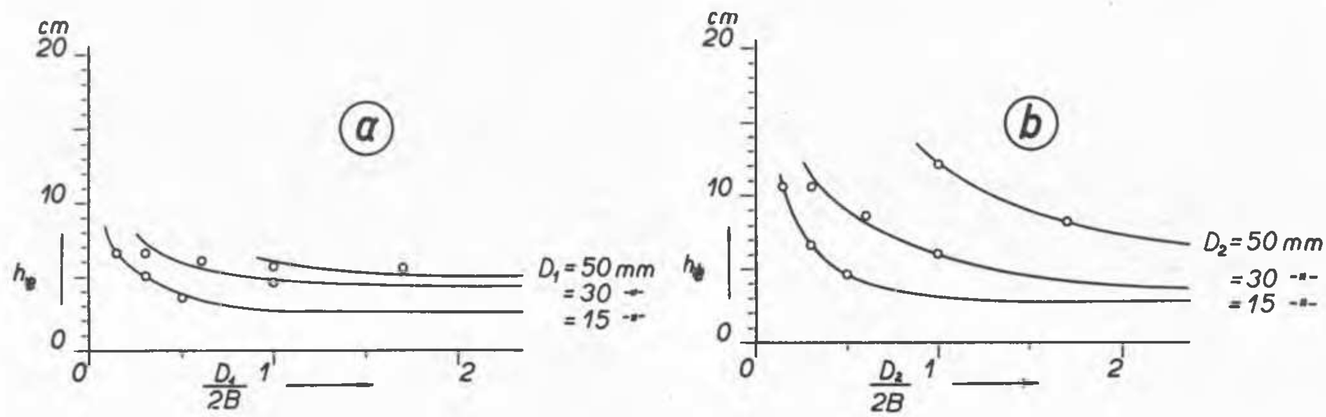

FIG.4

checked, which are represented by circles. The curve which is plotted between them, connect circles belonging to the same limit (upper or lower). This line permits interpolation and extrapolation for not measured sizes of models. Charts are plotted for variable width 2B and constand D_1 or D_2 with exception of Fig. 3b and c, where is 2B = 0 and remains as variable only D_1 or D_2. The head h_c is plotted vertically as ordinate.

Fig. 3a refers to plane foundations sketched on Fig. 1b, Fig. 3b,c refer to diaphragm filled up with sand upstream (D_1) or downstream (D_2). Figs. 3d to f are sketched for foundation Fig. 1c, where D_2 = 0 and D_1 is respectively 15, 30 and 50 mm. Figs. 3g to i refer to foundation Fig. 1d, where D_1 = 0 and D_2 varies from 15 to 30 and 50 mm.

The variability of both quantities D and B can be checked when we chose as variable $\frac{D}{2B}$. This is made on Fig. 4. Fig.4 a is plotted for model Fig. 1c, Fig. 4b for model Fig.1d. To obtain a clear view only lower limits are plotted, which are more important for design. The curves connect circles which belong to D= constant.

The ratio $N_h = \frac{h_c}{h_p}$ was observed further. It was observed that for model Fig. 1d was N_h = 1 for h_e = h_p. The piping was forming very quickly without previous warning by expansion. In the opposite case, on model Fig. 1c, was observed N_h = 0,4 to 1. Min. N_h was achieved for our dimensions models when max 2B and max D_1 are reached. As model Fig. 1b was N_h = 0,5 to 1, showing also for growing dimensions the inclination to diminish. Further it was observed that min N_h corresponds to min h_e and max N_h to max h_e.

More precise tests in greater flume and greater models are now in preparation. The same applies to the theoretical solution and its consequences for the praticical design of weirs, which can lead to similar rules as those by W.G.Bligh or E.W. Lane (Proceeding ASCE 1934).

7. SUMMARY.

The case of piping was studied and it was found that piping is preceeded by expansion of sand. Expansion occurs for head h_e. This head was tested for models Fig. 1b,c,d, which were constructdd with different widths 2B and depths D. The variation of head h_e for different cases is plotted on Fig. 3. Diagram Fig. 4 shows the relation between h_e and $\frac{D}{2B}$. Further the ratio $N_h = \frac{h_e}{h_p}$ was observed, which varied from 0,4 to 1.

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