as n = 23 i.e. greater than 20, (n - 1) = n can be put (Cf. illustration Vol I, p. 788/790 in Bendel: Engineering Geology 1944)

bb) Dispersion and Extreme Values

(cf. Table 2)

cc) Inferences from the value of the numbers of the research.

The frequency of 72% of the values of observation which lie in the Range of Spread (e) and the more or less dymmetrical division of positive and negative Outsiders correspond to the expectations of the Gauss-law.

For this reason it is possible to carry out further statistical researches in the rising and falling of the Fixed-points, depending from the level of the lake and to draw inferences from them.

2. Observations of the variations of the lake surface and the variations of the level of underground water.

a) Places of observation.

Numerous Piezometer pipes were put into the ground at Lugano to find out the variations of the level of surface water in relation to the variations of the level of the lake. The observations were carried out at a distance of 300 metres from the shore of the lake.

b) Fall and Rise of the Fixed-points depending on the differences between high and low water - level of Lake.

In order to be able to determine whether the falls and the rises of the Fixed-points between the various low levels or between low and high levels occur in accordance with certain laws the differences between falls and rised between the various lake levels were calculated and graphically evaluated in diagramm 2.

c) Inferences.

aa) From the enclosure 2 it is clear that the falls between the different low and high lake levels diminish with the distance from shore of the lake.

bb) With the help of fixed-point observations isohypses of falls and rises of the buildings and the ground could be determined. They run parallel with the shore of the lake.

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VI c 3

WATER-DAMS

MODEL - TRIALS FOR DETERMINING THE SETTLEMENT AND RISING OF SURFACE OF SOIL

Dr. L. BENDEL - ING.

Privatdozent, Ecole Polytechnique de l'Université de Lausanne

LUZERN

1) Purpose of Model-trials

Model-trials should determine whether the settling and rise of buildings, works, technical constructions and polygon-points mean a casual incident, or whether they represent a regular result of nature.

2) Description of Test-apparatus.

(C.f. illustration 4)

The essential component parts of the apparatus are:

a) An iron receptacle of 400 x 400 cross-section surface, whose surrounding sides are 15 mm thick. The sample of soil which is formed in the vessel by the infiltration of mud rests on a finely perforated sieve. The latter is covered with filter paper, so that no fine sand can come out through the sieve.

b) The sample of soil can be loaded down with different weights by a trial bucket of 100 x 100 mm cross-section.

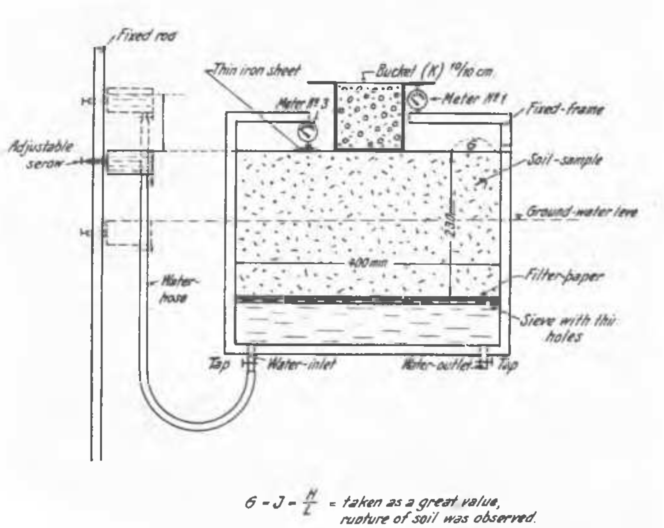
c) Next to the iron vessel there is a water vessel fastened to a rod, and adjustable as to its height. From the height H of the water-vessel over the upper edge of the sample of soil and the depth L of the sample of soil the slope J can be calculated.

$$J = \frac{H}{L} = p \text{ (pressure of current)}$$

see illustration 3 and 5.

3) Instruction for Test

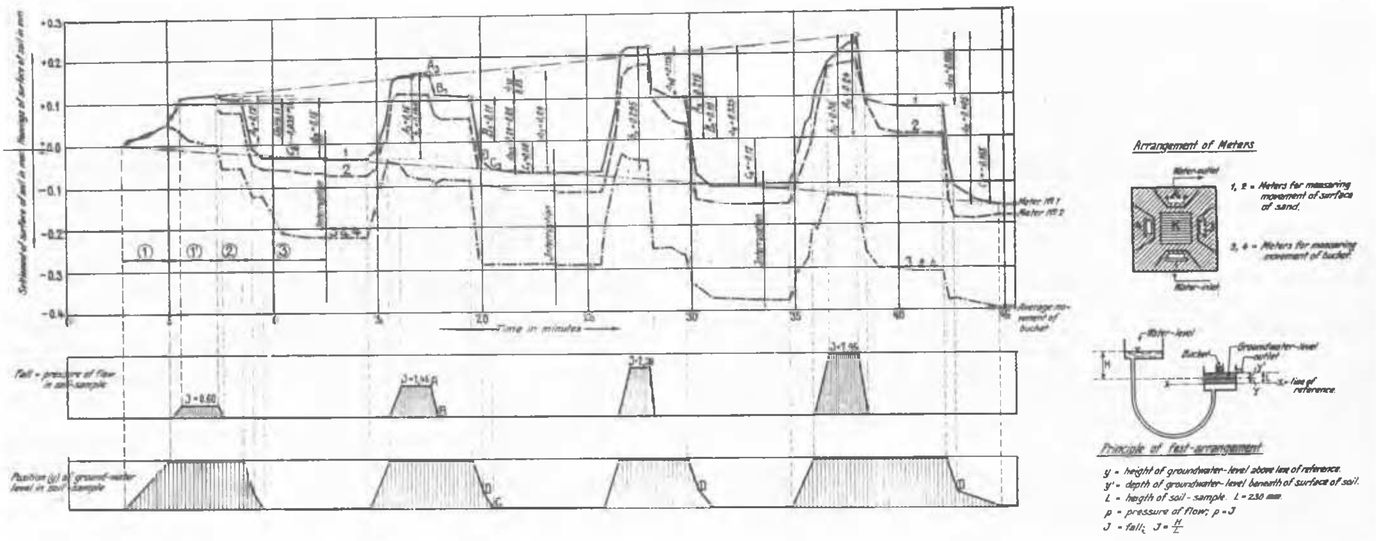
For the carrying out of the tests were



J = fall
4 metres
Trial bucket (K)
Thin iron plate

Apparatus for determination of settlements and heavings of surface of soil.

FIG.3



Settlement and heaving (Model - Trial) Material of Lugano. Fine sand with sericit-content bucket loaded with 0,1 kg/cm^2.

FIG.5

Apparatus for determination of settlement and heaving of surface of soil in dependance of ground-water level.

FIG.4

selected:

J was altered from J = 0 to J = 3,0 (Weight on the surface of the ground) from 0 to 1 kg/cm^2.

c) <u>Shearing-Strength</u>

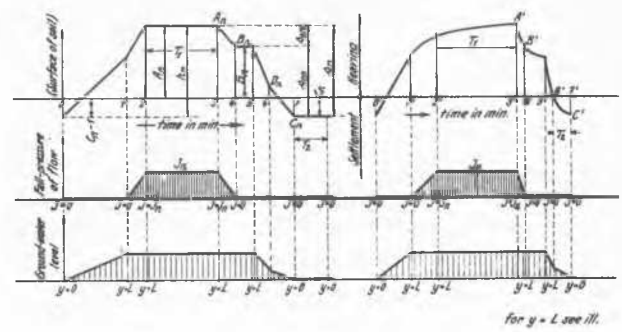
The angle of the inside friction amounted to ρ = 33° 30' to 44° 10'

d) <u>Permeability</u>

The permeability K was ascertained

Incoherent Material	: K = 2 x 10^{-2} to 5 x 10^{-3} cm/s
Coherent Material	: K = (6 to 8) x 10^{-6} cm/s
Cleansed sand	: K = 10^{-6} to 10^{-8} cm/s

4) <u>Physical properties of the test-material</u> (Viz.Table 3)



Sketch showing principles of settlements and heavings of points of surface of soil.
a. with incoherent material
b. with coherent material

FIG.6

5) <u>Results of Trial</u>

Illustration 5 shows the observations of sinking and rising of the trial-bucket with the rising and falling of the level of surface water. From more than 200 single trials with loamy sands from very different districts, south and north of the Alps, the principle-sketch could be made as shown by illustration 6.

6) <u>Mathematical Evaluation of the Results of Trials</u>

a) First rising and sinking of the level of underground water.

In order to be able io evaluate mathematically the results of trials as shown in illustration 5 and 6, the rise and fall of the earth's surface, depending on the slope J were recorded D. f. e. g. Illustration.

From this Illustration the law could be derived:

Rise $h_n = a_h + b \cdot J$

Fall $s_n = a_s + b \cdot J$

b) <u>Repeated Rise and Fall of the level of Underground Water.</u>

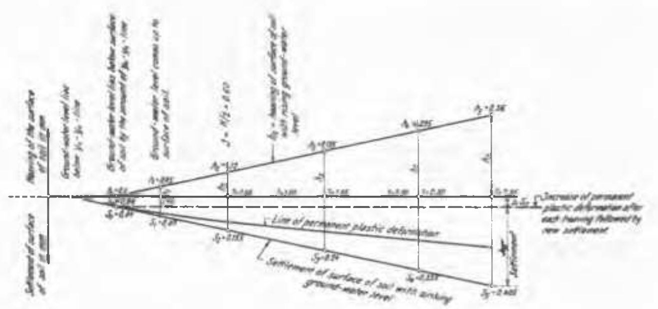
When the rise and fall of the surface of the water were repeated, the result was that the increase of the permanent setting of

Table 3

a) Composition of a grain of sand	Coherent Material	Incoherent Material	Cleansed sand
Granulation 0,02 mm	5 %	3 %	60 %
" 0,2 to 2 mm	66 %	21 %	40 %
" 2 to 20 mm	29 %	76 %	--

b) Compressibility	K - Worth (1)	σ- Worth
Coherent Material	6,80 %	0,56 kg/cm^2
Incoherent Material	4,2 %	1,00 "
Gleansed sand	4,5 %	2,00 "

(1) Cf. Vol. I, p. 399, Bendel : Engineering - Geology, 1944.



H_n = 0,05 + 0,105 J in mm
s_n = 0,09 + 0,105 J in mm
O = measured values
h_h = elastic heaving of surgace of soil with rising ground water level
s_n = elastic - plastic deformation of soil with falling ground water level
Δs_{n_1} = s_n - h_n = plastic deformation of soil = permanent settlement of soil
Δs_{n_1} = (0,09 + 0,105 J) - (0,05 + 0,105) = 0,04 mm = Fixed value after each heaving and subsequent settling of surface of soil.

<u>Heavings and settlements of surface of soil in dependance of fall J</u>

J = fall = pressure on the grains

<u>Material</u>: Lugano, fine sand, containing sericit

<u>Loading</u>: through bucket: = 0,1 kg/cm^2

FIG.7

the ground (plastic deformation of the ground) became a constant value immaterial, whether the level of underground water rose very high or had risen only a little.

c) <u>Influences</u>

aa) Every change in the level of underground water over y. situation (C. f. Ill. 5, sketch a) increased the setting of a point of observation by the amount of s_n.

bb) The setting s_n is independent of the amplitude of the variation of the level of underground water above the y. level.

cc) The total setting S after repeated rises and falls of the level of underground water above the y. line depends from the frequency (f) of the variations of the level of underground waters.

dd) Expressed as a formula it is

$$S = f. [\Delta s_n]$$

f = frequency
Δs_n = plastic deformation of the ground after each rise and fall of the level of underground water.
Δs_n = Fixed value, which is independent of the height of the rise of the level of underground water.

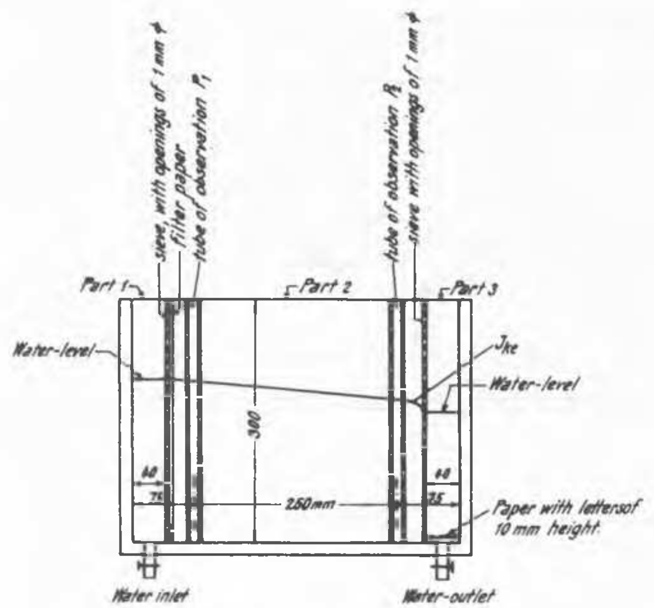
7) <u>Coherent Material</u>

With coherent materials the rise and setting of the surface of the earth and of the buildings begin only in the course of time. C. f. Illustration 6 with the time data T_1 and T_2.

D) <u>MECHANICAL EROSION</u>.

1) <u>Meaning</u>

By the critical erosion slope J_{kr} of the level of underground water we mean the incline of a level of underground water, whereby the particles of sand of size about 20 μ are carried away by the flow of underground water.



Principal arrangement for determination of critical fall J for erosion.

FIG.8

In this case the water becomes turbid, so that 10 mm high letters at W_a of Illustration 8 can no longer be read.

2) <u>Arrangement for Tests.</u>
The arangement for tests to determine the critical erosion incline J_h is shown by Illustration 8 and 9.

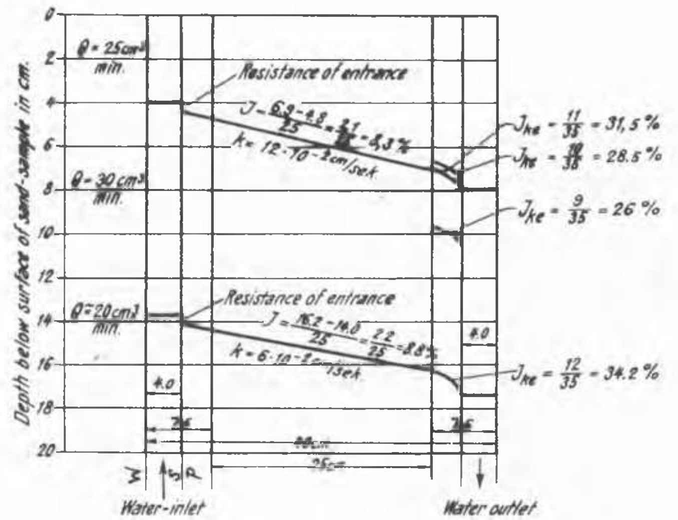
3) <u>Results of Tests.</u>
With trial-sand 0/2 mm the critical slope began at

J_{ko} = 0,26 to 0,342.

E) <u>CHEMICAL EROSION.</u>

Chemical Erosions occur:

1) <u>With soils containing lime</u>
The author ascertained e.g. (cf. Bendel, Geology and Hydrology of the Irchel, Zürich 1923, p. 52) that a spring with an average lime-content of 10, 8 French degrees of hardness and 63,1 l/Min productiveness, carries away out of the ground in one year a quantity of 3,68 tons $CaCO_3$.



W = wall of trial vessel
s = sieve
P = tube of piezzi
W_e = Water inlet
W_a = Water outlet
J_{ke} = critical fall of water for danger of erosion

Principal arrangement for determination of effect of erosion within soil - sample.

FIG.9

This causes underground hollows. The collapse of these hollows causes a settling down of the earth's surface.

2) <u>With soils containing peat.</u>
Washing-out of the sub-soil could be observed in large masses in loamy-peaty soils. Springs in such districts carry with them large quantities of Sulphate and organic matter (dry residue up to 100 mg/l). High soil temperatures favour chemical washings-out.

F) <u>DISTURBANCES OF STRUCTURES OF THE SOIL AT THE LOWERING OF UNDERGROUND WATER.</u>

With rapid lowering of lake surfaces or sudden changes of the level of underground water there often occur, namely in soils containing organic substances, changes in the structure. Connected herewith are the settling of the ground and the beginning of breaking-off, and sliding down of shores.

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