March 24th, 1918, investigation of which afterward gave an unusual opportunity for studying some of the conditions that grew out of the methods of placing material that had been used.

Core material becomes solid when it is dried. Core material dried in the summer sun at Calaveras was consolidated until only 35% of voids remained. In this condition, it was only a little less strong and stable than the natural sandstone in the neighboring hills.

Core material consolidated to 35% of voids would form the strongest and most stable kind of an earth dam. No large toes would be required to contain it, for on any reasonable slope it would be stable by itself. Such consolidation, however, as far as is known, is reached only by complete drying. Unfortunately, drying cannot be applied to the core of a large dam.

Without attempting precision of statement, it is the writer's judgment that if core material like that at Calaveras could be consolidated to 40% of voids, it would be sufficiently stable to do its share toward resisting the pressures that come upon the dam without tending to disruption. Perhaps this degree of stability would be reached before consolidation had proceeded as far as 40% of voids. There is a middle ground of uncertainty. Material with 50% of voids is still unstable; and between this limit and 40%, one cannot be certain just where to draw the line.

It is interesting to note that the 1½-in. pipe used in the penetration tests only reaches to points where the material is still unstable. It follows that tests of this kind do not and cannot demonstrate stable material. Tests made by cannon balls or other less searching means are equally defective. It cannot be considered, in the light of the Calaveras experience, that tests made by such methods throw much light on conditions of stability. They may at times serve a purpose in showing lack of stability, but that is as far as use can be made of them.

It is the writer's thought that the best method of investigating consolidation and stability is by making borings. There are difficulties, for boring usually involves stopping the sluicing of material while the holes are being put down; but it does lead to more definite results. Borings can be driven and samples taken from the bottom of the borings for physical inspection and for determination of the percentage of voids.

Determining Percentage of Voids

This is a very simple matter, but experience shows that it is easy to go wrong, and for that reason a brief statement of methods that have been found suitable will be given.

The samples taken from the bottom of test borings are saturated with water. A determination of water content, therefore, can be made a measure of voids. This procedure is sound so far and only so far as the voids are completely filled with water. A useful check can be obtained from the specific gravity of the moist material.

The specific gravity of the solid particles of core material may be taken as 2.65. It may be that in some locations other specific gravities will be found, but in the writer's experience, actual values differ little from this mean value.

In determining the specific gravity of these exceedingly small particles, the most careful manipulation is required to get all the air out of the dry material. Methods similar to those used for determining the specific gravity of Portland cement are appropriate, but water can be used.

A table can be made showing the weight of the solid particles, the weight of water, the percentage of water by weight, and the specific gravity of core material containing various percentages of voids. Table 1, in convenient and somewhat condensed form, gives these values for saturated clay.

When a sample is taken from a test boring, a portion is put in a dish and weighed. The weighed material is dried at or above the boiling point to constant weight, and the percentage of moisture computed. As even a little drying before the first weight affects the result, the samples should be weighed on the spot when first brought to the surface; to do this, portable equipment must be used. After the first weighing, samples may be taken to the office or laboratory for the completion of the process. When the percentage of moisture by weight is found, the corresponding percentage of voids is obtained from Table 1.

As a check, the specific gravity of another part of the sample is determined. This is obtained by putting a weighed portion of the moist mass into a graduated cylinder partly filled with water and noting the increase in water level. The specific gravity is the ratio between the weight of material added and the weight of the water that corresponds to the increase in level, and so to the volume of material placed in the cylinder. With this specific gravity determined, Table 1 indicates the percentage of voids.

The percentage of voids determined by the two methods with good manipulation should check within 1 or 2%. If it does not, there is something wrong and the error must be found and eliminated.

TABLE 1—SATURATED CLAY*

(Specific Gravity of Solid Particles, 2.65)

Percentage of Voids	Percentage of Water by Weight	Specific Gravity Wet	Weight —Per Cubic Foot— Wet	Dry
40	20.1	1.990	124.2	99.2
41	20.8	1.974	123.1	97.5
42	21.5	1.957	122.1	95.9
43	22.2	1.940	121.1	94.2
44	22.9	1.924	120.0	92.6
45	23.6	1.908	119.0	91.0
46	24.3	1.891	118.0	89.3
47	25.0	1.874	117.0	87.6
48	25.8	1.858	116.0	86.0
49	26.6	1.841	115.0	84.3
50	27.4	1.825	114.0	82.7
51	28.2	1.808	112.9	81.0
52	29.0	1.791	111.9	79.3
53	29.8	1.775	110.8	77.7
54	30.6	1.759	109.8	76.0
55	31.5	1.743	108.7	74.4
56	32.4	1.726	107.6	72.8
57	33.3	1.709	106.6	71.1
58	34.2	1.692	105.6	69.5
59	35.1	1.676	104.5	67.8
60	36.1	1.660	103.5	66.1
61	37.1	1.643	102.5	64.5
62	38.1	1.626	101.5	62.8
63	39.1	1.609	100.5	61.2
64	40.1	1.593	99.5	59.5
65	41.2	1.577	98.5	57.8
66	42.3	1.560	97.4	56.2
67	43.4	1.543	96.4	53.5
68	44.5	1.527	95.4	52.9
69	45.6	1.511	94.4	51.2
70	46.8	1.495	93.4	49.6

*This table is not to be used for any material that has lost water by evaporation so that the voids are not completely filled with water.

To determine the weight of the coarse and hard toe material, no better method has been found than to make an excavation accurately to a dimension of 1 cu. yd., or other convenient size, and to weigh the excavated material on platform scales. Percentages of moisture vary, and the weight of dry material affords the best basis of comparison. An average sample of material on the scales is taken for determining the percentage of moisture, and the results are reduced to weight of dry material per cubic foot.

Draining Fine Material

The writer is fully satisfied that there is no practical way of rapidly draining core material as fine in grain size as that described previously. He has considered it from a theoretical standpoint and also from the standpoint of practical experience.

After the material reaches a condition of 50% of voids, 6 cu. yds. must be compressed into 5 cu. yds. of 40% material by the exclusion of 1 cu. yd. of water before full stability