adding to the architectural effect. The lower part of one of these is shown in Fig. 372. They are massive and of generous dimensions. One of them was designed to be surmounted by a statue of a lion on a pedestal.

The dam was designed and started in 1896, and was completed since 1902, as it is reported to have been in service for several years. The engineer of this notable structure was Señor Sebastian Reyes.

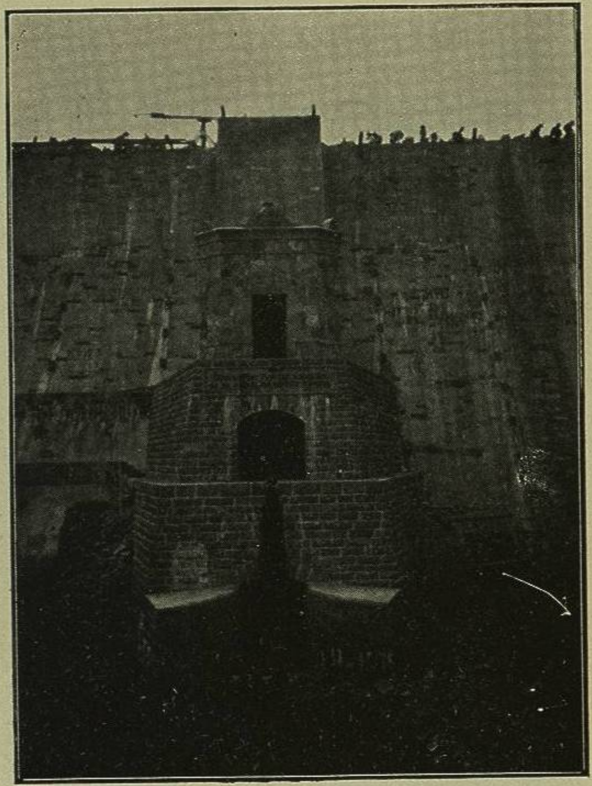

Fig. 372.—One of the Two Gate-houses of the San José Dam, San Luis Potosi, Mexico.

The reservoir has been filled several times, but as the distributing-pipe system in the city of San Luis Potosi is still under construction, the water is not yet utilized for domestic supply except in very small quantities, but is used for irrigation. In a report submitted to the Government by the engineer it was estimated that the supply from this source would not only furnish the city with domestic water but would also irrigate 2642 hectares (6525 acres) of valley land.

Señor Luis S. Cuevas, an engineer of San Luis Potosi, has kindly supplied the data as to the present condition of the dam, from which it is learned that the masonry has proven to be absolutely water-tight, and the dam withstands the strains of water pressure without evidence of weakness.

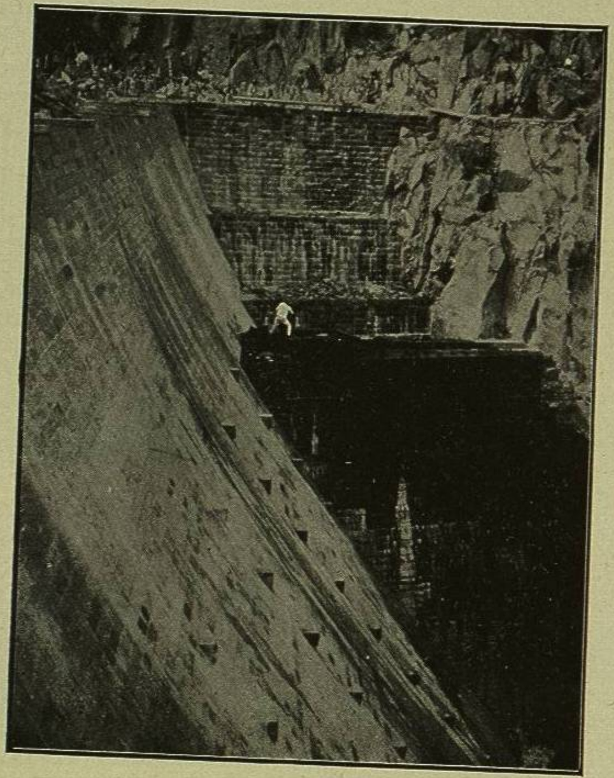

Fig. 373.—Looking along the Face of the San José Dam, at San Luis Potosi, showing Face of Wall Supporting Side of Principal Spillway.

The Santo Amaro Dam, Brazil.—At the end of May, 1908, there remained but 18,600 cubic yards of this great dam to complete it, out of a total of 737,539 cubic yards. The photograph, Fig. 376, was taken March 3d, from practically the same point of view as Fig. 105, page 146, and shows the dam well along toward completion. The progress made in the construction of this dam as summarized in the semi-monthly reports, constitutes a most interesting record of that class of work, which is here presented in tabulated form, as the most complete and continuous record of the work accomplished by a given quantity of water in hydraulic sluicing that has even been published:

FIG. 374.—MASONS AT WORK ON THE SAN JOSÉ DAM, MEXICO.

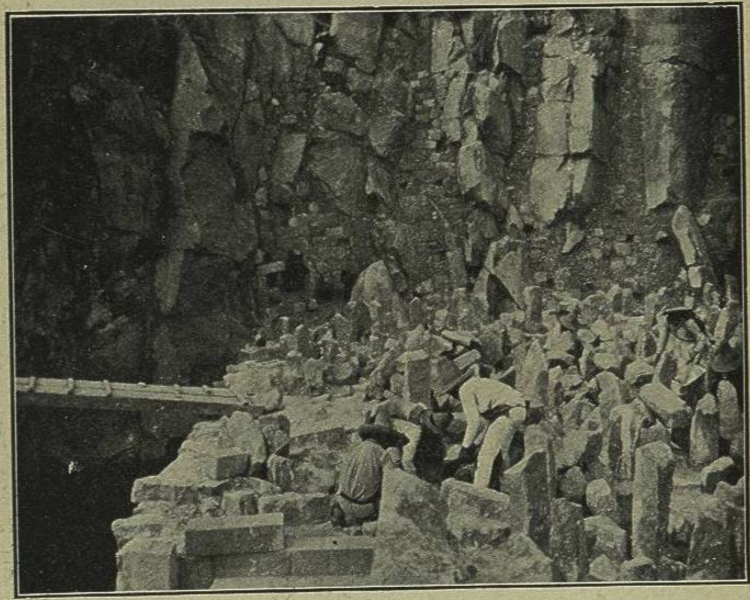

FIG. 375.—ILLUSTRATING THE BONDING OF THE MASONRY OF THE SAN JOSÉ DAM MEXICO.

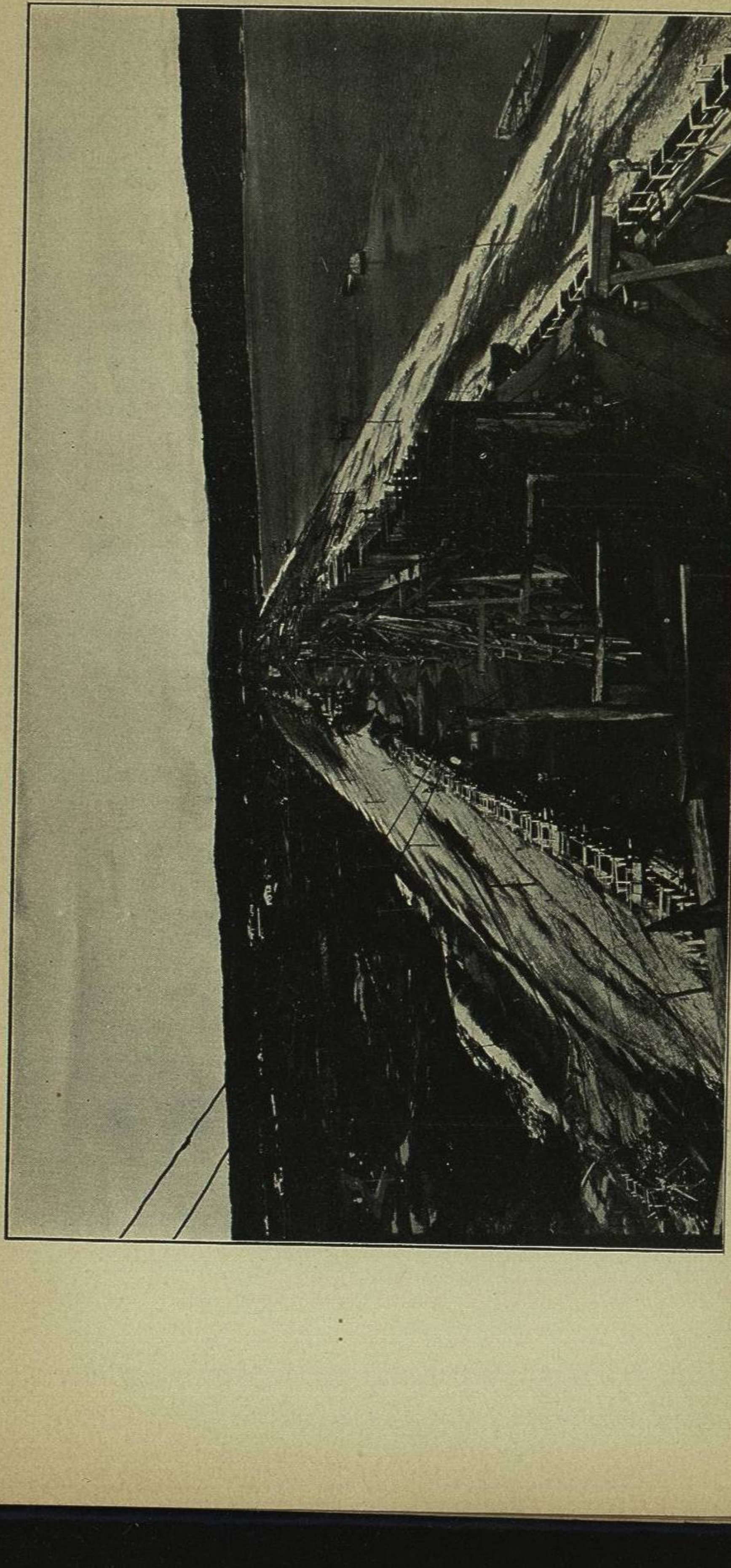

FIG. 376.—THE SANTO AMARO DAM, BRAZIL, APPROACHING COMPLETION, MARCH 3, 1908.

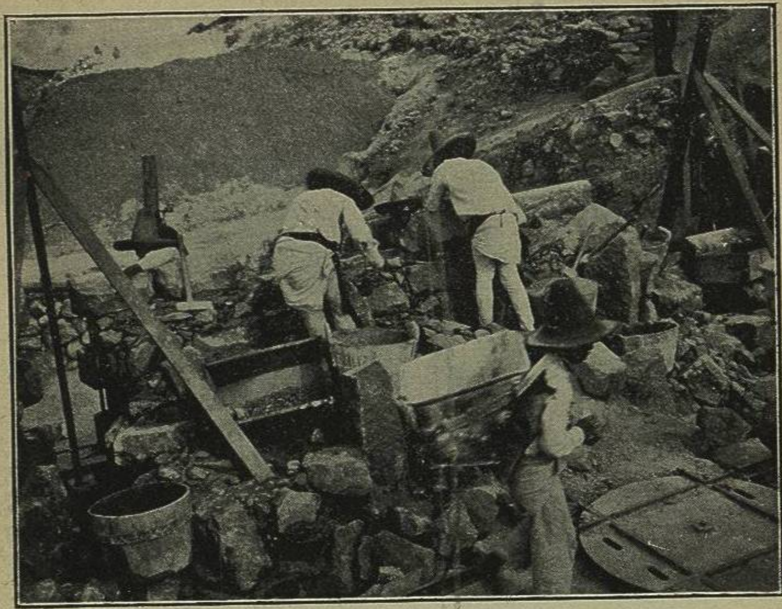

FIG. 374.—MASONS AT WORK ON THE SAN JOSÉ DAM, MEXICO.

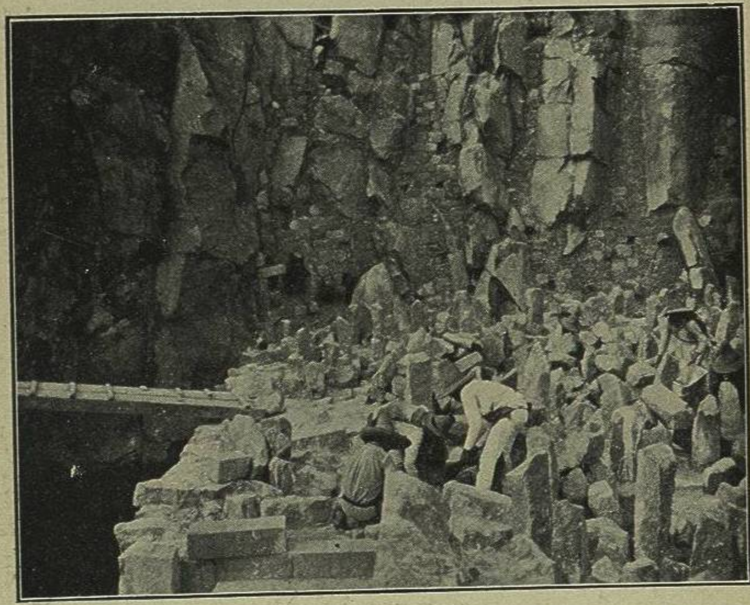

FIG. 375.—ILLUSTRATING THE BONDING OF THE MASONRY OF THE SAN JOSÉ DAM MEXICO.

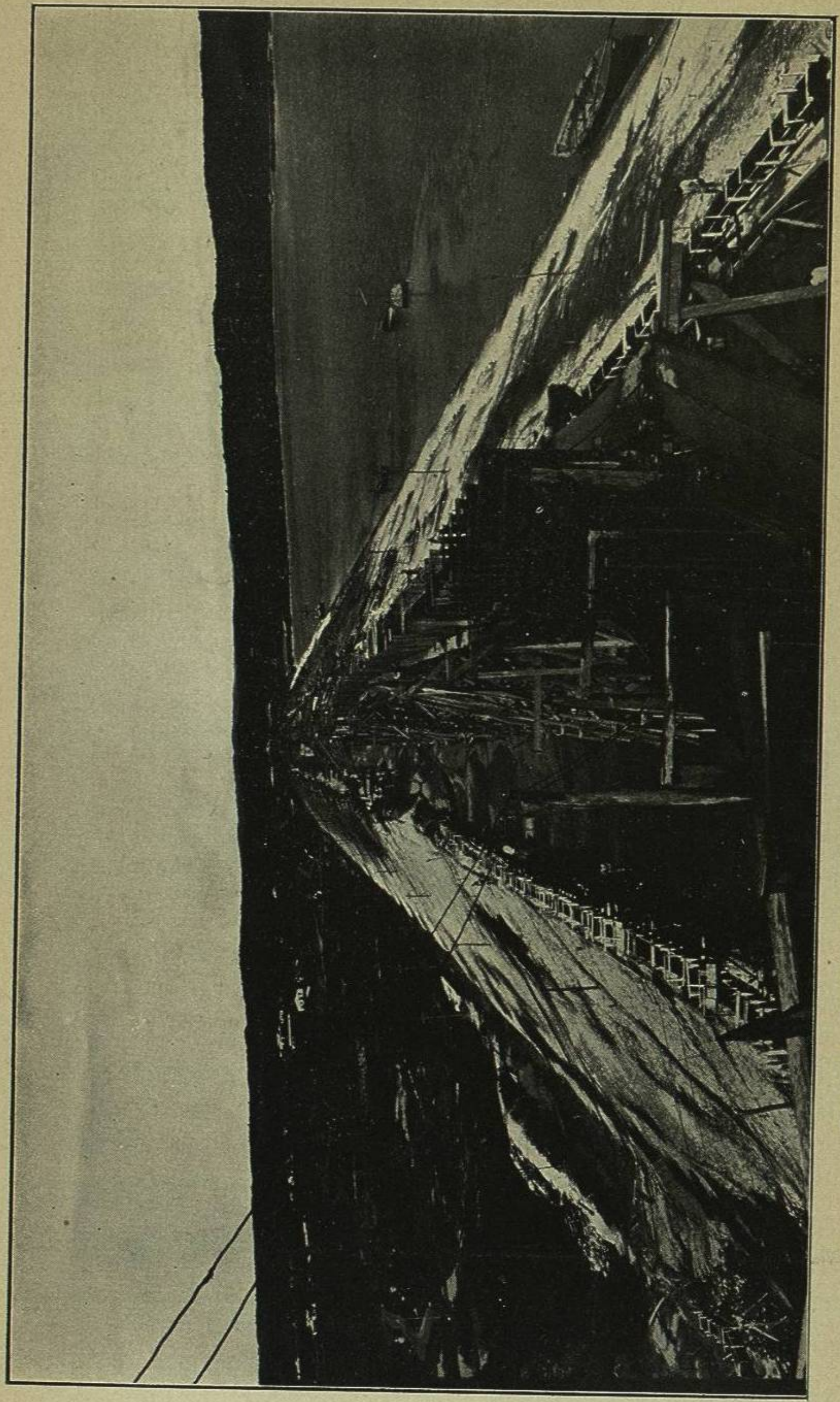

FIG. 376.—THE SANTO AMARO DAM, BRAZIL, APPROACHING COMPLETION, MARCH 3, 1908.

PROGRESS TABLE, SANTA AMARO DAM.

Month.	No. Days.	Actual Running Time.		Daily Average Running Time.		Monitor Discharge.	Material in Dam.	Ratio Material to Water.	Material in Dam Daily Average.	Material in Dam, Hourly Average Actual Work.
		Hrs.	Min	Hrs.	Min.	Cu. Yds.	Cu. Yds.		Cu. Yds.	Cu. Yds.
June		15	00			10,265				
July	6	23	50	6	28	32,051	7,586	17.9%	1264	195
Aug.	15	61	21	4	05	71,183	8,756	12.3	584	143
"	16	193	42	12	06	158,309	32,996	20.8	2062	170
Sep.	15	142	01	9	28	123,343	18,625	15.1	1241	131
"	15	327	39	21	50	343,221	77,392	22.5	5159	236
Oct.	15	355	50	23	44	390,670	80,923	20.7	5395	227
"	16	370	05	23	08	419,717	75,169	17.9	4698	203
Nov.	15	118	25	7	54	127,173	24,246	19.0	1616	205
"	15	261	21	17	25	308,411	55,230	17.9	3682	211
Dec.	15	305	12	20	21	356,398	58,468	16.4	3898	191
"	16	289	45	18	03	333,973	21,010	6.3	1313	72
Jan.	15	125	54	8	24	159,796	12,500	7.8	833	99
"	16	303	27	18	58	380,631	45,408	11.9	2838	149
Feb.	14	275	54	19	42	327,214	34,078	10.4	2434	125
"	15	315	32	21	02	331,925	30,907	9.3	2060	98
Mar.	15	243	43	16	15	241,727	35,889	14.8	2392	147
"	16	261	49	16	22	256,646	21,756	8.5	1359	83
Apr.	15	235	25	15	42	132,709	26,700	20.1	1780	113
"	15	126	28	8	26	66,808	14,000	20.9	933	111
May	15	176	08	11	44	98,477	16,000	16.2	1067	91
"	15	197	10	13	08	117,053	20,391	17.4	1359	
	310	4725	41	15	25	4,787,700	718,030	14.9	2316	152

The average volume of water used in all this period of time, covering a little more than ten months, was 7.6 cubic feet per second. The maximum was 10.0 second-feet, and the minimum 3.8 second-feet.

After the end of March, 1908, when practically all the material was delivered to the extreme eastern end of the dam, or east of the center, it was necessary to handle it a second time with a "booster" pump, of smaller capacity than the main pump. The volume was thenceforward reduced to about 4 second-feet, but the percentage of solids carried was maintained or increased.

The material was excavated to the spillway level out of the high hill at the west end of the dam. A spillway was there made with a minimum width of 250 feet, and a maximum discharge capacity of 10,000 second-feet. The floor of the spillway reached down into a fairly hard quality of granite. At one stage of the work a hydraulic elevator was used to lift the sluiced material to the height of the west end of the main flume, after it had been excavated by the monitor and flowed by gravity across the spillway area. An isolated section of the hill was left between the spillway channel and the dam, and up the steep face of this island

the elevator pipe was placed with a jet of water added from the main pump, which raised the stream carrying earth in suspension and deposited it into the flume, some 25 feet higher.

The remarkable picture shown in Fig. 377 is the best possible demonstration of the effect of hydraulic sluicing in the segregation of pure clay from a mass of coarser materials, and its deposit in a condition of stable solidity within a short time. It is a picture of the clay core of the Santo Amaro dam accidentally exposed to view by a break in one of the lateral levees, the effect of which was to empty the pond on the dam and wash away the levee and its supporting base of coarser material for a distance of about 50 feet. The break, which occurred in the up-stream slope, caused the loss of 400 cubic yards of material, but the demonstration of the stability of the clay core, none of which had been deposited three months, and some of it but a few days, was worth far more than the loss. The clay as exposed was left standing almost vertically, and it had successfully withstood the wash of water pouring over it from the emptying of a pond several hundred feet long, 50 to 60 feet wide, and 2 to 4 feet deep, with comparatively slight erosion. The break was caused by the saturation of the levee, built of material brought in by cars, which, not being sluiced and assorted, the finer particles from the

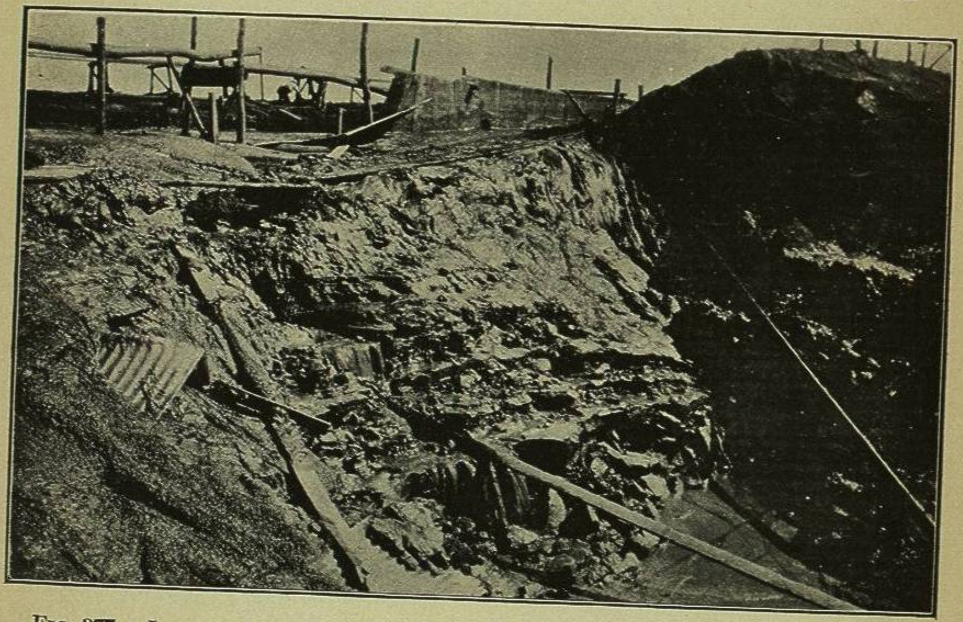

FIG. 377.—ILLUSTRATING THE COMPACT CHARACTER OF THE CLAY CORE OF THE SANTO AMARO DAM, ACCIDENTALLY EXPOSED TO VIEW BY A BREAK FROM THE POND ON TOP OF THE DAM.

coarser, there was no gradation from fine to coarse, and consequently a comparative lack of drainage. The break occurred on the line of contact between the sluiced clay and the material deposited by cars. This method of building the levee was employed only east of the center of the dam.

The conditions of solidity and maturity in the clay core shown in this case is a most reassuring endorsement of the superiority of the hydraulic sluicing method of dam construction.

A similar demonstration was made in very much the same manner of the stable and satisfactory condition of the clay core of the Necaxa dam a few months ago. The pond on top of the dam was accidentally emptied by a cutting down of the overflow channel, causing a loss of a quantity of soft, immature material, but showing a bank of firm clay formed a few feet beneath the surface. It is somewhat difficult to conceive of percolation through such a mass of clay as is usually segregated and assembled in the center of hydraulic-fill dams after it has matured. It must be even superior in impermeability to such a puddle core as was built in the north and south dikes of the Wachusett dam, which consisted of 6-inch layers of fine loam soil, well sprinkled and rolled. Recent experiments to determine the permeability of this type of earth or loam core in an earth dam have been made by means of a series of pipes driven into the embankments of the Wachusett dikes. The results as reported by the *Engineering Record*, July 18, 1908, indicate that while the plane of saturation on the reservoir side of the loam core was level with the water in the reservoir, it dropped immediately below this core to a level slightly above the base of the dam. Weekly measurements proved that the amount of water draining out of the dike was not in excess of what might be expected, as the natural drainage from precipitation on the area of the dike itself. No masonry or concrete core-wall ever built in an earth dam can show better results than these, and few can compare with them in the absence of percolation from the reservoir. The dike type of dam is undoubtedly a reliable type, when properly made with suitable materials, especially where the core can be sluiced out of the available material and deposited under water.

A High Japanese Dam.—Fig. 378 is a contour plan of a dam of unusual height projected as a hydraulic-fill structure, to impound water for power purposes on the Oigawa river, in Japan. The dam has been planned by J. M. Howells, chief engineer of the Anglo-Japanese Hydro-Electric Company, and is to be 300 feet in height above the river-bed at its up-stream toe, or 325 feet in maximum height. It will occupy a narrow gorge, whose width at the low-water line of the river is 200 feet, and at the crest of the dam but 700 feet.

The volume of water to be cared for during construction in by-pass tunnels may reach 80,000 to 100,000 cubic feet per second in time of extreme flood. Three tunnels, each 30′×24′, are planned for this purpose.

A section of the dam as proposed by the board of consulting engineers, of which the author was a member, who were called upon to review the general plans of the project for power development, is shown in Fig. 379. From this section it will be seen that two concrete cut-off walls are proposed to be carried down to bed-rock through the gravel deposit of the channel, both above the center line. The upper wall is to be at the down-stream toe of the temporary coffer-dam of loose rock, faced with plank, which will form the up-stream toe of the large dam.

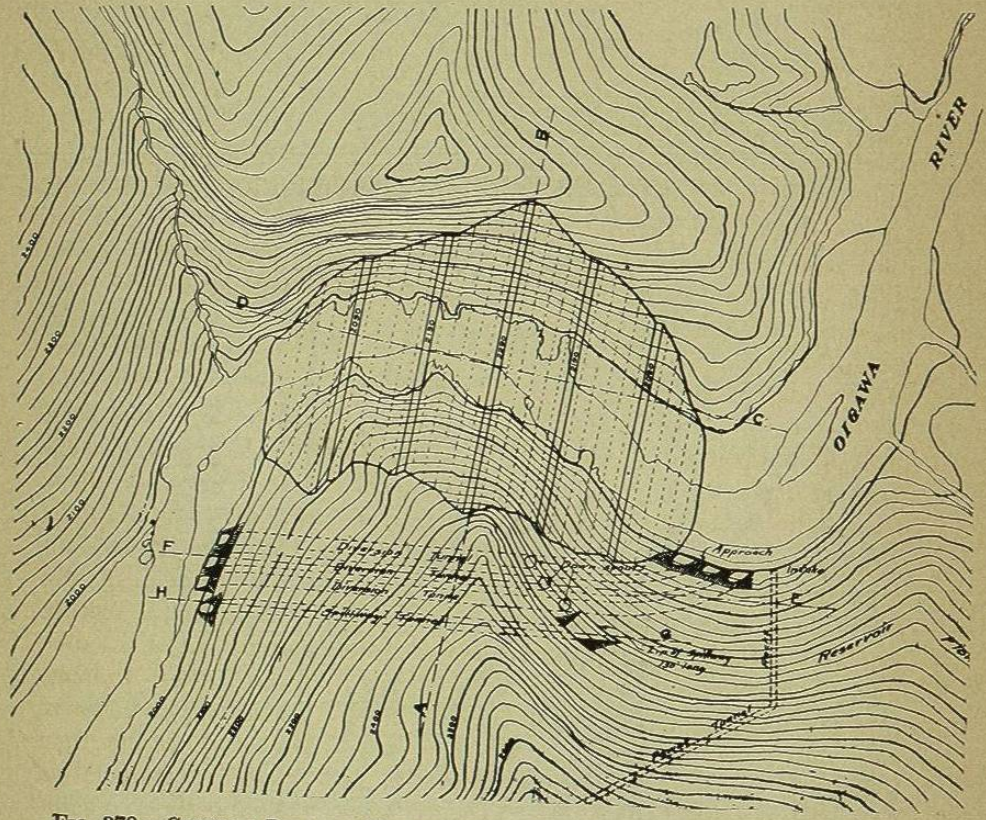

FIG. 378.—CONTOUR PLAN OF HYDRAULIC-FILL DAM PROJECTED FOR POWER STORAGE AT IKAWA ON THE OIGAWA RIVER, JAPAN.

On top of the concrete wall a diaphragm of sheet steel plates is to be built to the height of 100 feet, reaching to the face of the dam on the