UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: DIGEST OF TESTS OF STONE, PERCOLATION AND WATER TABLE - MADDEN DAM

HYDRAULIC LABORATORY REPORT NO. .3

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by

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Under direction of

TECHNICAL MEMORANDUM NO. 125

Denver, Colorado

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Memorandum to the Chief Designing Engineer
(E. W. Lane, Research Engineer)

Subject: Digest of Tests of Stone, Percolation, and Water Table.

Digest of Chemical Tests of Stone

	Average Strata B	Average Strata C
Phosphorus Pentozide P_2O_5	0.18	0.20
Sulphur Trioxide SO_3	0.6	0.2
Total Alkalies Na_2O	3.2	2.2
Ignition Loss	18.4	26.8
Magnesia MgO	3.1	3.0
Calcium Oxide CaO	16.3	26.4
Alumna Al_2O_3	16.0	11.9
Total Iron Fe_2O_3	5.8	3.4
Silica SiO_2	35.6	27.1
Carbon Dioxide CO_2	9.2	21.7

Digest of Physical Tests of Stone

	Average Stratum B	Average Stratum C
Density, artificially dried, sp. gr.	1.75	1.93
Lbs. per cu. ft.	110	120
Density, artificially saturated, sp. gr.	2.049	2.206
Lbs. per cu. ft.	127	137
Apparent specific gravity	1.72	1.92
Specific gravity (as of cement)	2.57	2.66
Water absorbed, % by weight	16.9	13.4
" " " " volume	27.3	25.3
Voids, %	31.3	26.6
Hardness (abrasive)	3.8	2.4
Linear dimension charge		
Perpendicular to bedding		
Original cond. to saturation, %	+0.0023	+0.0024
" " " dry, "	-0.0589	-0.0782
Saturated to dry, "	-0.0612	-0.0798
Parallel to bedding direction A		
Original cond. to saturation, %	+0.0008	+0.0063
" " " dry, "	-0.0352	-0.0480
Saturated to dry, "	-0.0360	-0.0544
Parallel to bedding direction B		
Original cond. to saturation, %	+0.0039	+0.0028
" " " dry, "	-0.0394	-0.0623
Saturated to dry, "	-0.0433	-0.0596
Number of soaking and drying cycles producing disintegration	10	15
Number of cycles of boiling and drying producing disintegration		2

Digest of Compressive Tests on Stone of Foundation

Six-Inch Cubes. Normal to Bedding Plane.

	Average Strata B	Average Strata C
Compressive strength on bed		
As received at laboratory	1573	986
Artificially dried	2675	2194
" saturated	1367	897
After several drying and saturating cycles	690 (10 cycles)	325 wet (4 cycles) 310 (9 cycles)
Modulus of elasticity		
As received at laboratory	628,000	522,000
Artificially dried	567,000	420,000
" saturated	462,000	320,000
Shearing across grain in condition received	310	
Poisson's ratio		
As received at laboratory	0.27 to 1.06	0.34
Artificially dried	0.25 to 0.46	0.35
" saturated	0.47	0.20 to 0.35

A comparison was made of the compressive strength of drill cores from damsites No. 1 and No. 5. The results of these tests are shown graphically on Figure 1 attached hereto and summarized in the following table:

Comparison of Core Compressive Tests at Damsite No. 1 and No. 5.

Location	Damsite No. 1				Damsite No. 5		Av. of old cores			Av. of new cores			Av. of all cores		
							Damsite No.1	Damsite No.5	No. 1 exceeds No. 5	Damsite No.1	Damsite No.5	No. 1 exceeds No. 5	Damsite No.1	Damsite No.5	No. 1 exceeds No. 5
Holes	L-1	L-2	L-5	L-6	L-3	L-4	L-1&L-3	L-3		L-5&L-6	L-4		L-1, L-2, L-5& L-6	L-3&L-4	
No. of tests	25	23	23	26	26	22									
Age when tested, days	216	257	29	26	241	31	236	241		27	31		132	136	
Max. compr. lbs./sq.in.	1550	1775	2332	2620	1710	1933	1663	1710	-3%	2476	1933	28%	2069	1821	14%
Min. compr. lbs./sq.in.	607	602	1166	1292	150	799	604	150	300%	1229	799	54%	917	474	94%
Av. top 5, compr. lbs./sq.in.	1101	870	2150	2226	567	1301	985	567	74%	2188	1301	68%	1587	934	70%
Av.top 10,compr. lbs./sq.in.	940	916	1803	1900	612	1352	928	612	51%	1851	1352	37%	1339	982	36%
Av.of all compr.lbs./sq.in.	1029	997	1649	1737	772	1341	1013	772	32%	1693	1341	26%	1353	1056	28%

Applying this formula, assuming the ratio of peak to 24-hour flow at 1.53, as determined above, gives the following as the probability of floods at Alhajuela:

Time	Maximum Discharge of Flood to be Expected. c.f.s. Momentary	24-hour
1 year	41,300	27,000
5 years	94,200	61,600
10 years	117,000	76,500
25 years	147,200	96,200
50 years	170,000	111,100
100 years	192,800	126,000
400 years	240,000	156,000

The one and five-year floods of this table seem too high, but the 50 and 100-year frequencies are not unreasonable.

A study of the records of the 48 years beginning 1879 indicates alternate periods of high and low floods, beginning with 12 years of high floods, then 15 years of low floods, followed by 5 years of high, then 12 years of low and ending with 4 years (or more) of high floods.

From Memo. No. 3. Retention Volume Necessary. The purposes of the Madden Dam (Alhajuela project in order of importance are:

(a) Increased water storage for dry season lockages, and incidental power production at Gatun, if practicable.

(b) Flood control to obviate the necessity of excessive use of Gatun spillway to regulate the height of Gatun Lake.

(c) Power production at Alhajuela.

(d) Prevention of excessive currents in the canal channel at Gamboa. (This is of minor importance.)

Digest of Compressive Tests on Drill Cores from Foundation

A comparison of the strengths of Strata B and Strata C give the following results:

	Average strength in lbs. per sq. in.	
	Strata B	Strata C
Compression as received	1669	1528
Artificially saturated	1598	1427
Oven-dried 110-120° C.	2780	2462
After 4 cycles dry to wet, tested wet	319	901

Another test of the compressive strength of core samples from Strata B and C, 18 samples from each strata, from holes L-4 to L-9 inclusive gave the following results:

	Compressive strength in lbs. per sq. in.	
	Strata B	Strata C
As received	1669	1528
Artificially saturated	1598	1427
Oven-dried	2780	2880

Summary of Percolation Tests

Cores from Madden Damsite

Mark	Elev. Depths	Av. amount of water passed in 24 hours	Change of flow with time	Av. increase in solids content of water parts per million	Av. increase in fixed residue content of water in parts per million
L-4-B . .	--	0	0	----	----
L-4-C . .	--	4 c. c.	0	1283	913
L-5-B . .	+59.3	0	0	----	----
L-5-C . .	-34.1	65	Decrease	354	173
L-6-B . .	+71.2	0	0	----	----
L-6-C . .	-24.1	1	0	----	----
L-7-B . .	+43.1	0	0	----	----
L-7-C . .	+13.6	58	Decrease	1501	1098
L-8-B . .	+52.2	1	0	----	----
L-8-C . .	+18.3	19	0	993	718

Tests of Water Table

Records were kept of the elevation of the ground water in drill holes, in order to determine the position of the water table. The results of the test are shown on Figure 2 attached hereto.

Weight of Concrete

Tests on the weight of concrete showed weights varying from 134 to 144.5 lbs. per cu. ft., generally close to 150 lbs. per cu. ft., with an average of 150.7 lbs. per cu. ft.