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OWYHEE DAM — 1982
Concrete Core Investigation

August 1982
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16. ABSTRACT
This report is a discussion of tests made on concrete cores taken from Owyhee Dam, Owyhee Project, Oregon. This dam, which was built between 1928 and 1932, is a concrete, thick-arch structure. Test results on compressive strength, density, tensile strength, modulus of elasticity, and Poisson's ratio are included for the concrete specimens. Shear and sliding friction tests were performed on specimens thought to contain construction joints. Results of these tests are included, as well as a complete petrographic analysis of the concrete. These tests were done due to concern of increased cracking visible in the dam.

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by
T. A. Gaeto

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August 1982

UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION

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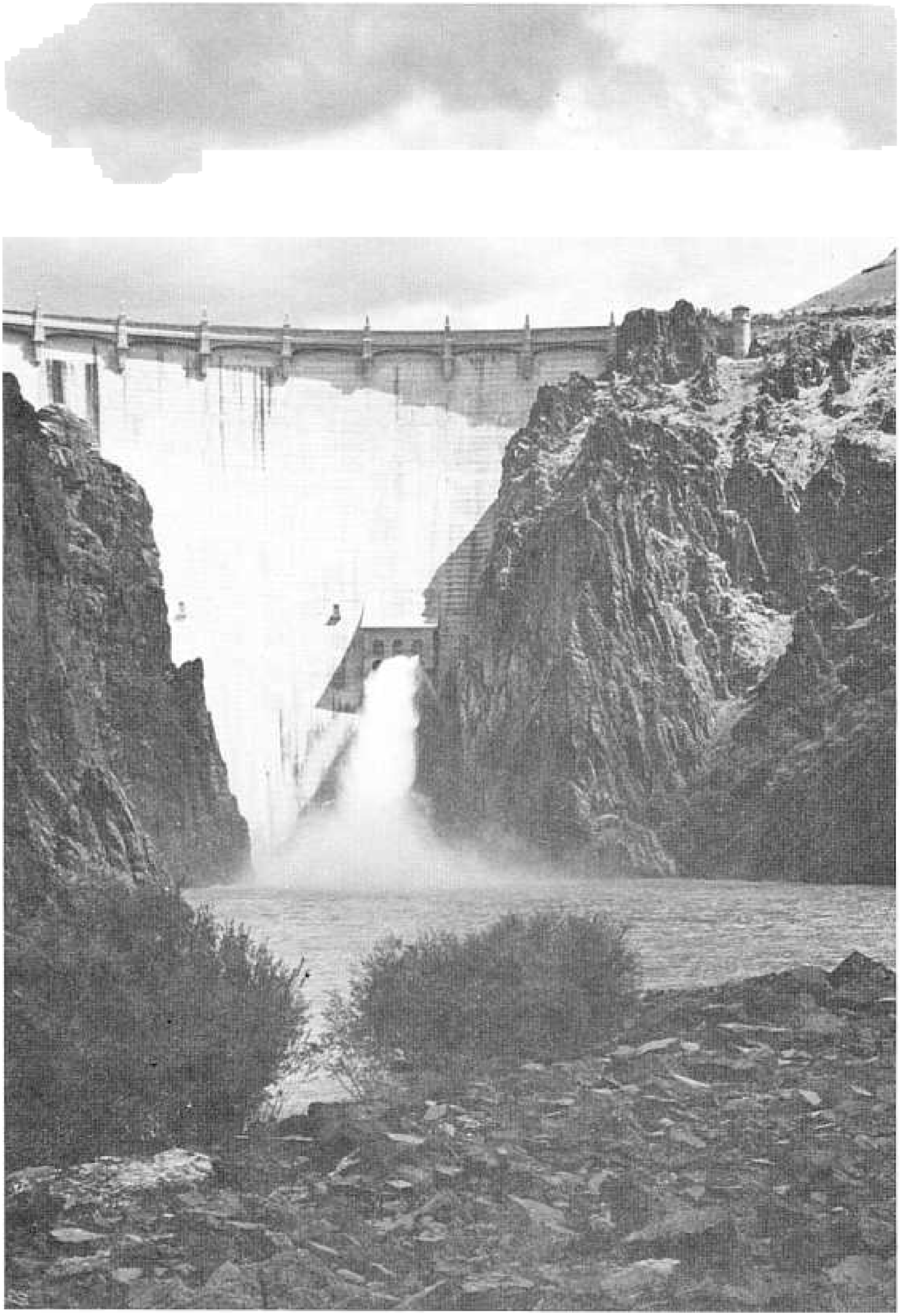

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INTRODUCTION

Owyhee Dam, built from 1928 to 1932 on the Owyhee River about 18 km (11 mi) southwest of Adrian, Oregon, acts as both a storage and diversion structure. The dam is a concrete, thick-arch structure which was designed to carry about three-fourths of the water load by arch action and the remainder by gravity action. The dam rises 127 m (417 ft) above the foundation in the river section, and 162 m (530 ft) above the low point of the excavated fault zone. At the time of its construction, Owyhee ranked as the world's highest dam. The arch section is 190 m (623 ft) long, and a gravity tangent extends 64 m (210 ft) to the right abutment. The capacity of the reservoir, Lake Owyhee, is 1382 million cubic meters (1.12 million acre-feet).

This report includes the results of testing and evaluating about 29 m (95 ft) of 250-mm (10-in) diameter concrete core, and 90 m (295 ft) of 150-mm (6-in) diameter concrete core extracted from Owyhee Dam during the spring of 1981. Testing was completed in January 1982. These are the only cores ever extracted from the dam for physical properties testing.

This study and evaluation were prompted when cracking was noticed during a safety of dam inspection by the Bureau of Reclamation. Instrumentation in the dam is inadequate to provide data needed to properly evaluate the structure. The physical properties test data included in this report will help determine structural integrity of the dam.

CONCLUSIONS

Based on results from testing and evaluating the 150- and 250-mm-diameter cores, the following conclusions are made:

1. Construction records indicate that a concrete mix with a water-cement ratio of about 1.0 was used, which is very high. Moreover, concrete quality control and placement practices used during construction were poor compared to present standards. However, in comparison with other dams of about the same age, the overall quality of the concrete in the dam is satisfactory.

2. The average ratio of tensile to compressive strength in the concrete core specimens was about 2.8 percent, which is a little below normal for mass concrete.

3. Tests indicated the upper 0.6 to 0.9 m (2 to 3 ft) of the dam to be of lower quality than the concrete below, probably due to freeze-thaw deterioration.

4. Cracking due to alkali-aggregate reaction has occurred in many areas of the dam. Monitoring of the structure should be continued.

5. Petrographic evaluation indicates the concrete in the dam is in fair condition.

PHYSICAL TESTING PROCEDURES AND PROPERTIES

Cores were taken from seven different drill holes at four general locations across the dam. Drill hole locations are shown on figure 1. Both 150- and 250-mm-diameter cores were extracted, and all were drilled vertically. All cores were tested in a vacuum saturated condition (pressure saturated to achieve complete saturation). This condition usually yields strengths lower than those from unsaturated cores and would give the most conservative results. Summaries of the core testing are presented in tables 1 and 2.

Shipping and Receiving Cores

Each core was extracted in sections and packed in wooden boxes with damp sawdust. The cores were marked with drill hole number and depth, and photographed for future reference. The cores were then shipped to the Bureau's Engineering and Research Center in Denver, Colo. After arrival, the cores were examined, logged, and marked for cutting into test specimens (fig. 2).

Density

Before conducting applicable tests, the density of each marked specimen was determined by first weighing the sample and then weighing the water displaced by the submerged sample. The densities, as shown in table 1, were within the expected range for mass concrete.

Compressive Strength, Elasticity, and Poisson's Ratio

All cores were tested for compressive strength, modulus of elasticity, and Poisson's ratio. The 150-mm cores were sawed into 300-mm (12-in) lengths, and the 250-mm cores were sawed into 500-mm (20-in) lengths. Modulus of elasticity and Poisson's ratio were determined using an extensometer-compressometer frame with dial gages mounted so that longitudinal and lateral deformations could be monitored as the actual load was applied. All specimens underwent a preload of 6.9 MPa (1000 lb/in^2) before actual test readings were taken. This was done to check the operation of the gages, and to determine the approximate elastic properties of the specimen. Stress-strain data were recorded at different intervals from zero to maximum test strain. From these readings, the elastic modulus and Poisson's ratio were computed. The elasticity frame was then removed and the specimen was loaded to failure in compression, as specified by ASTM: C 39, Compressive Strength of Cylindrical Concrete Specimens.

The overall average compressive strength was 25.4 MPa (3690 lb/in^2), with a low of 12.4 MPa (1800 lb/in^2) and a high of 39.5 MPa (5730 lb/in^2). Eleven of the specimens were 250-mm-diameter cores whose average compressive strength was 19.2 MPa

(2790 lb/in²). This lower average is probably because most of the 250-mm cores were extracted from the very top portion of the dam, an area which shows signs of freeze-thaw deterioration. Specimen size may have also had some effect on the strength. Results of compressive strength tests are shown in table 1 and summarized on figures 3 and 4.

The average modulus of elasticity of the dam concrete is low, 19.3 GPa (2.8×10^6 lb/in2), which means the concrete is more flexible than would be expected in a modern dam. The correlation between the 150- and 250-mm-diameter specimens is good for both modulus of elasticity and Poisson's ratio. These data can be found in table 1 and on figures 5 and 6.

Tensile Strength

The bonding of concrete at construction joints is important because this is where the weakest bond is normally found. This obviously affects the load-carrying characteristics of the dam. Many of these joints were examined and tested, particularly for tensile strength. In many cases, the construction joints were very difficult to locate, and some of the specimens identified as containing a construction joint may not in fact have contained a joint. Cores to be tested in tension were sawed to 300- and 500-mm (12- and 20-in) lengths for the 150- and 250-mm-diameter specimens, respectively. Joints were centered within the length of the test specimen. Steel plates, 50 mm (2 in) thick, were epoxy cemented to the ends of each specimen. Following a 24-hour atmospheric cure of the epoxy, the specimens were placed in the testing machine with the end plates fastened to the test machine. The specimens were then tested to failure. The average tensile strength for all specimens tested was 0.72 MPa (105 lb/in²). The 250-mm-diameter specimen average was 0.54 MPa (78 lb/in²). This lower average for the larger specimen is probably because of core location, which was previously mentioned in the discussion on compressive strength. Tensile strength results are shown in table 1 and summarized on figures 7 and 8.

Break Bond and Sliding Friction

Selected intact specimens were subjected to a loading condition generally referred to as a break bond test, and followed by sliding friction tests. A few unbonded specimens were tested using only the sliding friction test (figs. 9 and 10); all of these specimens contained a construction joint. The cores were cut into about 100-mm (4-in) lengths with the joints as close as possible to midlength. Break bond data were obtained by subjecting each specimen to a constant normal load while simultaneously increasing the horizontal shearing load until the specimen failed (broke bond). The maximum horizontal and constant normal loads were recorded. The failed surfaces were then subjected to a series of increasing normal loads, and the shear loads required to displace the surface at each normal load were determined. The results of the break bond and sliding friction tests are shown in table 2 and plotted on figures 11 and 12. Values for cohesion and the tangent of the angle of friction (tan ϕ) are also shown in table 2. The least squares line (fig. 12) for sliding friction has a correlation coefficient of 0.89 for 71 points.

Petrographic Analyses

Petrographic anaylses were performed on selected specimens, including some afterbreak examinations of failed test specimens. The concrete in Owyhee Dam was found to be in fair petrographic condition, although the upper 0.6 to 0.9 m (2 to 3 ft) is of lower quality. The complete petrographic analyses are included in appendix A.

BIBLIOGRAPHY

Dunstan, Edwin R., Jr., *Stewart Mountain Dam Concrete Core Investigations*, Report No. REC-ERC-79-14, Bureau of Reclamation, Denver, Colo. November 1979.

Gaeto, T. A., *Theodore Roosevelt Dam Concrete Core Investigations*, Report No. GR-81-12, Bureau of Reclamation, Denver, Colo. October 1981.

Bureau of Reclamation, Draft SEED (Safety Evaluation of Existing Dams) "Report on Safety of Owyhee Dam and Appurtenant Works," Bureau of Reclamation, Denver, Colo.

Table 1. — Physical properties testing — Owyhee Dam

Drill hole	Specimen depth from top		Compressive strength		Modulus of elasticity		Poisson's ratio	Saturated density		Tensile strength		Diameter	
	m	ft	MPa	lb/in²	GPa	lb/in² x 10⁶		kg/m³	lb/ft³	MPA	lb/in²	mm	in
CD-1	0.6	2.0	18.0	2610	11.0	1.60	0.10	147.8	2368	-	-	230	9.06
CD-1	1.3	4.4	-	-	-	-	-	150.8	2416	0.27	39		
CD-1	3.7	12.0	21.7	3150	12.6	1.83	0.12	150.7	2414	-	-		
CD-1	5.9	19.5	-	-	-	-	-	151.6	2428	0.63	92		
CD-2	1.2	3.9	17.0	2470	9.7	1.40	0.16	148.4	2377	-	-	151	5.94
CD-2	2.5	8.1	-	-	-	-	-	151.6	2428	0.51	75		
CD-2	4.8	15.6	31.7	4600	14.0	2.03	0.07	151.9	2433	-	-		
CD-2	7.3	23.9	-	-	-	-	-	149.9	2401	0.48	69		
CD-2	10.2	33.4	34.7	5030	16.7	2.42	0.13	152.8	2448	-	-		
CD-2	13.9	45.6	-	-	-	-	-	153.9	2465	2.08	302		
CD-2	15.4	50.7	-	-	-	-	-	152.6	2444	0.87	127		
CD-2	16.3	53.6	-	-	-	-	-	152.3	2440	0.86	124		
CD-2	18.2	59.8	39.5	5730	22.8	3.31	0.15	152.2	2438	-	-		
CD-2	22.9	75.0	-	-	-	-	-	152.6	2444	0.66	96		
CD-2	23.5	77.2	36.7	5330	20.3	2.95	0.14	152.0	2435	-	-		
CD-2	30.9	101.3	32.4	4700	16.1	2.34	0.12	151.5	2427	-	-		
CD-2	31.3	102.6	-	-	-	-	-	154.4	2473	0.34	50		
CD-3	0.3	1.1	13.7	1980	66.1	9.59	0.45	150.4	2409	-	-	230	9.06
CD-3	3.0	9.9	-	-	-	-	-	151.7	2430	0.36	52		
CD-3	4.0	13.0	-	-	-	-	-	152.4	2441	0.34	50		
CD-3	5.3	17.4	23.9	3460	13.9	2.02	0.16	153.0	2451	-	-		
CD-4	2.9	9.4	30.7	4450	14.3	2.08	0.16	153.3	2456	-	-	151	5.94
CD-4	6.1	20.0	-	-	-	-	-	152.2	2438	0.92	133		
CD-4	7.7	25.4	23.3	3380	14.7	2.13	0.35	153.7	2462	-	-		
CD-4	10.7	35.0	-	-	-	-	-	153.1	2452	0.39	56		
CD-4	11.5	37.8	23.8	3450	14.8	2.14	0.29	151.7	2430	-	-		
CD-4	12.3	40.3	-	-	-	-	-	151.7	2430	0.39	56		
CD-4	14.1	46.1	16.5	2390	10.8	1.56	0.06	151.3	2424	-	-		
CD-4	15.3	50.2	-	-	-	-	-	150.4	2409	0.22	32		
CD-4	18.6	61.1	26.6	3860	23.9	3.46	0.18	152.2	2454	-	-		
CD-4	19.8	64.9	-	-	-	-	-	151.1	2420	1.51	219		
CD-4	24.4	79.9	-	-	-	-	-	152.9	2449	0.77	112		
CD-4	25.0	82.0	32.5	4710	28.4	4.12	0.16	154.5	2475	-	-		
CD-4	29.0	95.0	-	-	-	-	-	151.4	2425	0.74	108		
CD-4	30.3	99.5	28.5	4130	29.8	4.32	0.21	150.0	2403	-	-		
CD-5	0.2	0.8	15.8	2290	13.4	1.94	0.11	148.8	2384	-	-	232	9.12
CD-5	0.9	3.0	-	-	-	-	-	148.0	2371	0.32	46		
CD-5	2.6	8.5	19.7	2860	14.8	2.14	0.12	150.9	2417	-	-		
CD-5	5.8	18.9	-	-	-	-	-	152.2	2438	0.87	127		
CD-6	0.8	2.6	-	-	-	-	-	150.1	2404	0.32	46	232	9.12
CD-6	2.7	8.8	23.1	3340	17.9	2.59	0.09	153.1	2452	-	-		
CD-6	4.9	16.0	-	-	-	-	-	153.1	2452	1.00	145		
CD-6	5.5	18.2	27.3	3960	31.3	4.54	0.19	150.0	2403	-	-		
CD-6A	0.4	1.3	-	-	-	-	-	149.1	2388	0.26	37	232	9.12
CD-6A	1.2	3.8	12.4	1800	11.9	1.72	0.26	151.4	2425	-	-		
CD-6B	0.6	2.1	13.7	1980	14.0	2.03	0.07	149.3	2392	-	-	232	9.12
CD-7	0.3	1.0	-	-	-	-	-	150.4	2409	0.41	60	232	9.12
CD-7	0.9	3.1	22.2	3210	15.8	2.29	0.11	151.6	2428	-	-		
CD-7	2.5	8.2	32.4	4700	28.9	4.19	0.22	148.4	2377	-	-	148	5.81
CD-7A	0.2	0.5	22.8	3310	12.5	1.82	0.12	150.7	2414	-	-	148	5.81
CD-7A	1.5	4.9	-	-	-	-	-	151.2	2422	1.10	159		
CD-7A	4.5	14.8	-	-	-	-	-	148.4	2377	1.38	201		
CD-7A	6.7	22.1	31.5	4580	16.3	2.37	0.10	149.1	2388	-	-		
CD-7A	7.7	25.2	-	-	-	-	-	151.0	2419	1.26	182		
CD-7A	10.0	32.7	30.3	4400	20.3	2.95	0.06	150.2	2406	-	-		
CD-7A	12.1	39.6	-	-	-	-	-	151.5	2427	0.81	117		
CD-7A	14.2	46.6	-	-	-	-	-	149.5	2395	0.66	96		
CD-7A	14.8	48.4	25.9	3760	20.6	2.99	0.10	149.6	2396	-	-		
CD-7A	18.0	59.0	28.5	4130	20.3	2.94	0.17	147.5	2363	-	-		
CD-7A	18.5	60.7	-	-	-	-	-	151.6	2428	1.30	188		
CD-7A	20.6	67.5	36.0	5230	27.0	3.91	0.16	151.4	2425	-	-		
CD-7A	21.6	70.8	-	-	-	-	-	152.0	2435	0.53	76		
CD-7A	24.7	81.1	21.6	3130	12.6	1.83	0.17	150.7	2414	-	-		

Table 2. - Direct shear tests (construction joints) - Owyhee Dam

Drill hole	Specimen depth		Specimen diameter		Normal stress(σ)		Shear stress(τ)		Linear regression				Angle Envelope						Remarks
									Equation	Phi	Cohesion		Phi (degrees)			Cohesion, MPa (lb/in^2)			BB - Break-bond
	m	ft	mm	in	MPa	lb/in^2	MPa	lb/in^2	MPa τ =	(degrees)	MPa	lb/in^2	Max.	Min.	Avg.	Max. phi	Min. phi	Avg. phi	SF - Sliding friction
CD-2	7.62	25.0	152	5.99	0.17	25	2.86	415	2.61 + 1.46(σ)	55.6	2.61	379	74.8	58.8	68.1	2.23	2.58	2.43	BB
					0.17	25	0.63	90								(323)	(374)	(353)	SF
					0.69	100	1.79	260											SF
					1.38	200	2.78	405											SF
					2.39	345	3.95	575	0.60 + 1.46(σ)	55.6	0.60	87							SF
CD-2	17.98	59.0	152	5.99	0.41	60	4.29	620	3.85 + 1.08(σ)	47.2	3.85	558	61.4	50.5	57.0	3.54	3.79	3.66	BB
					0.41	60	0.74	110								(513)	(550)	(531)	SF
					0.69	100	1.15	170											SF
					1.40	205	2.01	290											SF
					2.41	350	2.93	425	0.39 + 1.08(σ)	47.2	0.39	56							SF
CD-3	1.52	5.0	240	9.43	0.34	50	2.10	305	1.74 + 1.07(σ)	47.0	1.74	253	78.5	58.2	71.1	0.43	1.56	1.12	BB
					0.34	50	1.67	240								(63)	(226)	(162)	SF
					0.68	100	2.08	300											SF
					1.38	200	2.87	415											SF
					2.40	350	3.89	565	1.34 + 1.07(σ)	47.0	1.34	194							SF
CD-3	4.42	14.5	232	9.13	0.34	50	2.44	355	1.99 + 1.30(σ)	52.4	1.99	289	79.0	61.5	72.7	0.68	1.81	1.34	BB
					0.34	50	1.77	255								(98)	(262)	(194)	SF
					0.69	100	2.36	340											SF
					1.42	205	3.45	500											SF
					2.48	360	4.54	660	1.43 + 1.30(σ)	52.4	1.43	208							SF
CD-3	6.13	20.1	237	9.34	0.34	50	1.53	220	1.15 + 1.10(σ)	47.7	1.15	167	75.0	56.1	67.5	0.24	1.02	0.70	BB
					0.34	50	1.29	190								(35)	(148)	(101)	SF
					0.69	100	1.81	265											SF
					1.41	204	2.58	375											SF
					2.47	360	3.66	530	0.99 + 1.10(σ)	47.7	0.99	143							SF
CD-4	16.86	55.3	154	6.05	0.39	55	1.62	235	1.18 + 1.13(σ)	48.6	1.18	171	67.3	53.1	61.3	0.70	1.10	0.91	BB
					0.39	55	0.93	135								(101)	(160)	(132)	SF
					0.69	100	1.32	190											SF
					1.38	200	2.29	330											SF
					2.41	350	3.21	465	0.56 + 1.13(σ)	48.6	0.56	80							SF
CD-4	19.96	65.5	152	5.99	0.46	65	4.62	670	4.05 + 1.26(σ)	51.5	4.05	587	62.5	54.4	59.2	3.74	3.98	3.85	BB
					0.48	70	0.92	135								(543)	(578)	(559)	SF
					0.69	100	1.25	180											SF
					1.38	200	2.17	315											SF
					2.41	350	3.36	490	0.37 + 1.26(σ)	51.5	0.37	54							SF
CD-4	25.94	85.1	151	5.96	0.59	85	4.81	700	3.56 + 2.11(σ)	64.7	3.56	517	75.3	70.3	73.2	2.56	3.16	2.85	BB
					0.59	85	2.25	325								(372)	(458)	(413)	SF
					0.69	100	2.32	340											SF
					1.38	200	3.86	560	0.94 + 2.11(σ)	64.7	0.94	136							SF
CD-4	27.98	91.8	152	6.00	0.63	90	1.14	165											SF
					0.69	100	1.06	155											SF
					1.38	200	1.70	245											SF
					2.35	340	4.97	720	-0.59 + 2.22(σ)	65.7	-0.59	-85							SF

Table 2. - Direct shear tests (construction joints) - Owyhee Dam - Continued

Drill hole	Specimen depth		Specimen diameter		Normal stress (σ)		Shear stress (τ)		Linear regression				Angle Envelope						Remarks
									Equation	Phi	Cohesion		Phi (degrees)			Cohesion, MPa (lb/in^2)			BB - Break-bond
	m	ft	mm	in	MPa	lb/in^2	MPa	lb/in^2	MPa τ =	(degrees)	MPa	lb/in^2	Max.	Min.	Avg.	Max. phi	Min. phi	Avg. phi	SF - Sliding friction
CD-7	3.08	10.1	144	5.67	0.14	20	3.87	560	3.67 + 1.51(σ)	56.4	3.67	532	75.5	59.0	67.8	3.34	3.65	3.54	BB
					0.14	20	0.53	75								(485)	(529)	(513)	SF
					0.69	100	1.62	235											SF
					1.38	200	2.65	385											SF
					2.41	350	4.01	580	0.46 + 1.51(σ)	56.4	0.46	67							SF
CD-7A	3.08	10.1	150	5.90	0.14	20	4.88	710	4.71 + 1.25(σ)	51.4	4.71	683	64.0	52.9	59.8	4.60	4.70	4.64	BB
					0.14	20	0.28	40								(667)	(681)	(673)	SF
					0.63	90	1.19	170											SF
					1.27	185	2.05	300											SF
					2.41	350	3.20	465	0.28 + 1.25(σ)	51.4	0.28	41							SF
CD-7A	6.16	20.2	149	5.88	0.14	20	3.37	490	3.18 + 1.36(σ)	53.7	3.18	462	77.2	58.0	69.4	2.76	3.15	3.01	BB
					0.14	20	0.61	90								(401)	(457)	(436)	SF
					0.69	100	1.89	275											SF
					1.36	195	2.55	370											SF
					2.40	350	3.83	555	0.66 + 1.36(σ)	53.7	0.66	96							SF
CD-7A	9.39	30.8	150	5.89	0.21	30	2.61	380	2.37 + 1.15(σ)	48.9	2.37	344	69.4	52.8	61.8	2.05	2.33	2.22	BB
					0.23	35	0.61	90								(297)	(338)	(322)	SF
					0.71	105	1.40	205											SF
					1.38	200	2.08	300											SF
					2.41	350	3.19	460	0.46 + 1.15(σ)	48.9	0.46	67							SF
CD-7A	15.21	49.9	150	5.89	0.34	50	4.81	700	4.46 + 1.02(σ)	45.5	4.46	647	76.9	56.4	68.6	3.33	4.29	3.93	BB
					0.34	50	1.48	215								(483)	(622)	(570)	SF
					0.70	100	1.90	275											SF
					1.38	200	2.35	340											SF
					2.41	350	3.63	525	1.11 + 1.02(σ)	45.5	1.11	161							SF
CD-7A	16.92	55.5	149	5.89	0.39	55	3.14	455	2.70 + 1.14(σ)	48.6	2.70	392	70.1	54.2	63.8	2.08	2.61	2.36	BB
					0.39	55	1.06	155								(301)	(378)	(342)	SF
					0.69	100	1.47	215											SF
					1.38	200	2.56	370											SF
					2.41	350	3.34	485	0.73 + 1.14(σ)	48.6	0.73	105							SF
CD-7A	19.32	63.4	149	5.86	0.44	65	1.05	150											SF
					0.68	100	1.05	150											SF
					1.37	200	1.79	260											SF
					2.40	350	2.58	375	0.60 + 0.83(σ)	39.6	0.60	88							SF
CD-7A	21.88	71.8	150	5.89	0.50	70	3.54	515	3.09 + 0.92(σ)	42.5	3.09	448	63.2	48.4	56.2	2.56	2.98	2.80	BB
					0.50	70	0.80	115								(371)	(433)	(406)	SF
					0.69	100	1.37	200											SF
					1.38	200	1.74	255											SF
					2.41	350	2.72	395	0.52 + 0.92(σ)	42.5	0.52	75							SF
CD-7A	23.96	78.6	149	5.88	0.54	80	1.74	250											SF
					0.69	100	1.28	185											SF
					1.38	200	2.16	315											SF
					2.41	350	2.93	425	1.05 + 0.78(σ)	37.8	1.05	153							SF

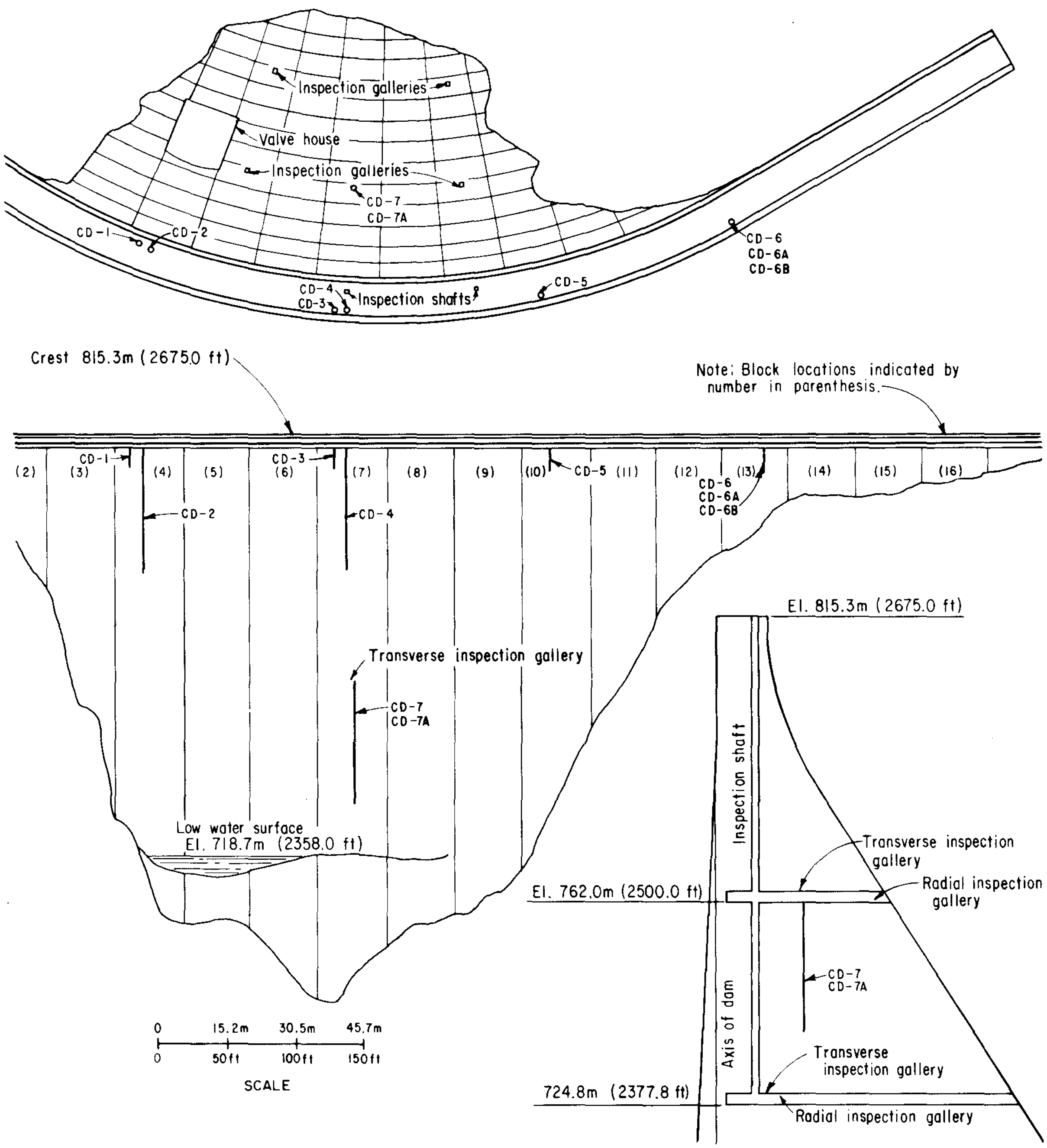

Figure 1. — Drill hole locations. Owyhee Dam.

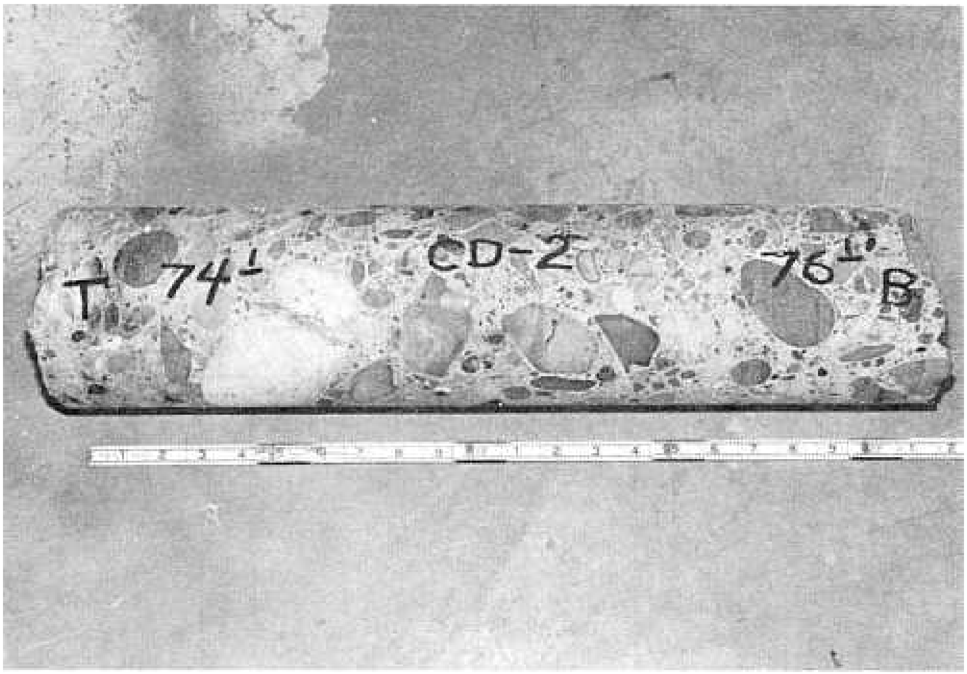

Figure 2. — Typical concrete core test specimen. Owyhee Dam. P801-D-80038

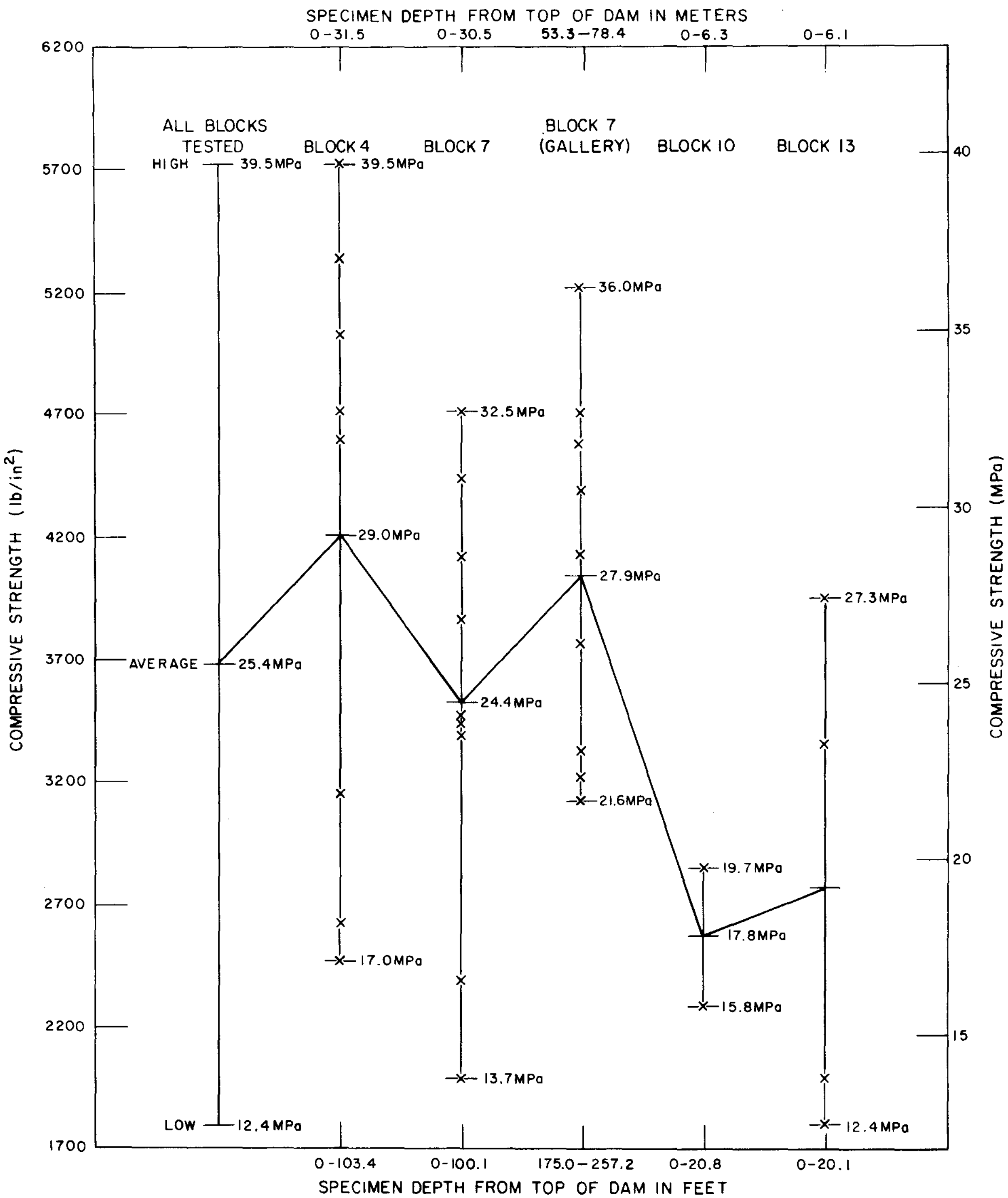

Figure 3. — Compressive strength in blocks tested. Owyhee Dam.

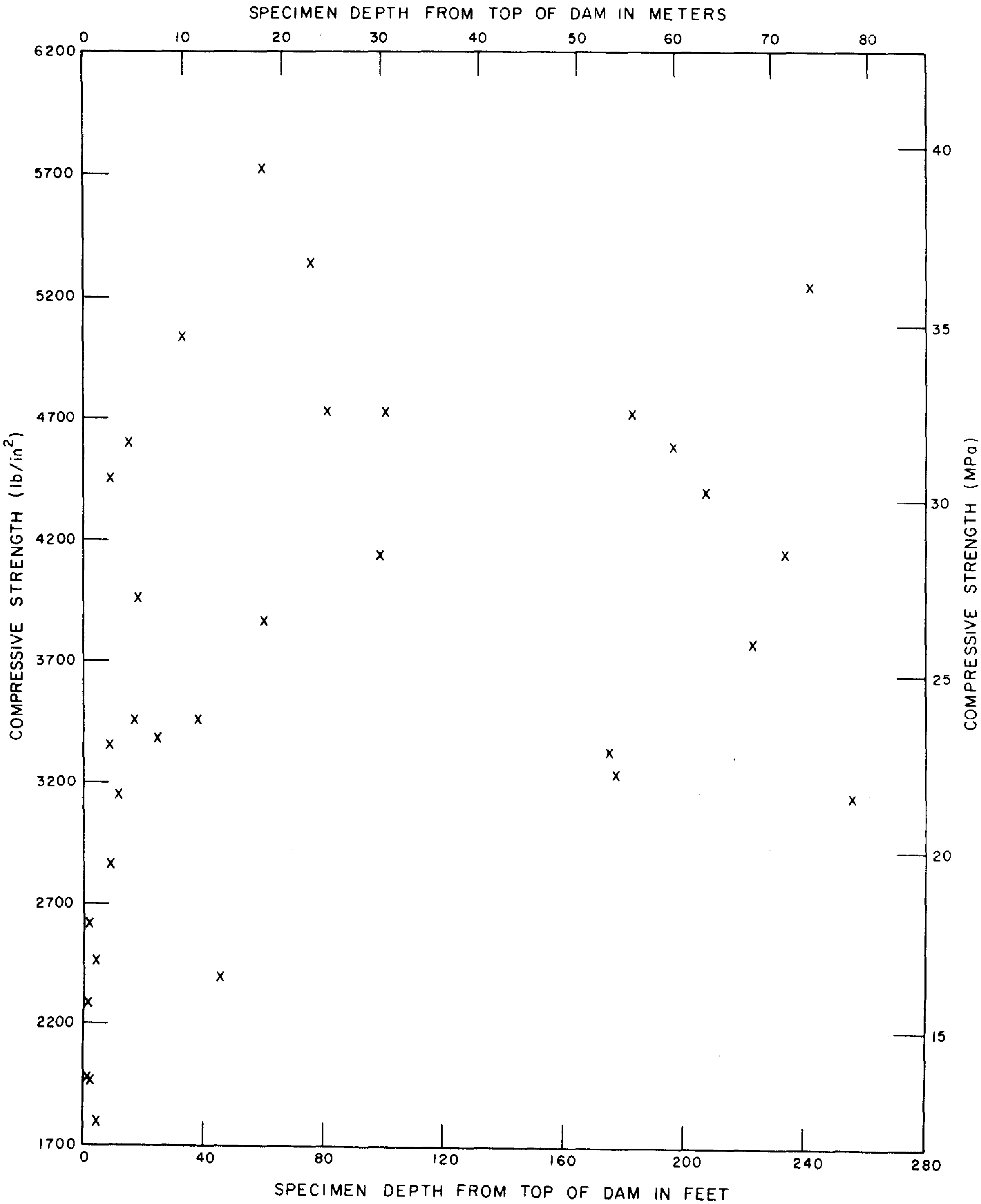

Figure 4. — Specimen depth from top of dam versus compressive strength. Owyhee Dam.

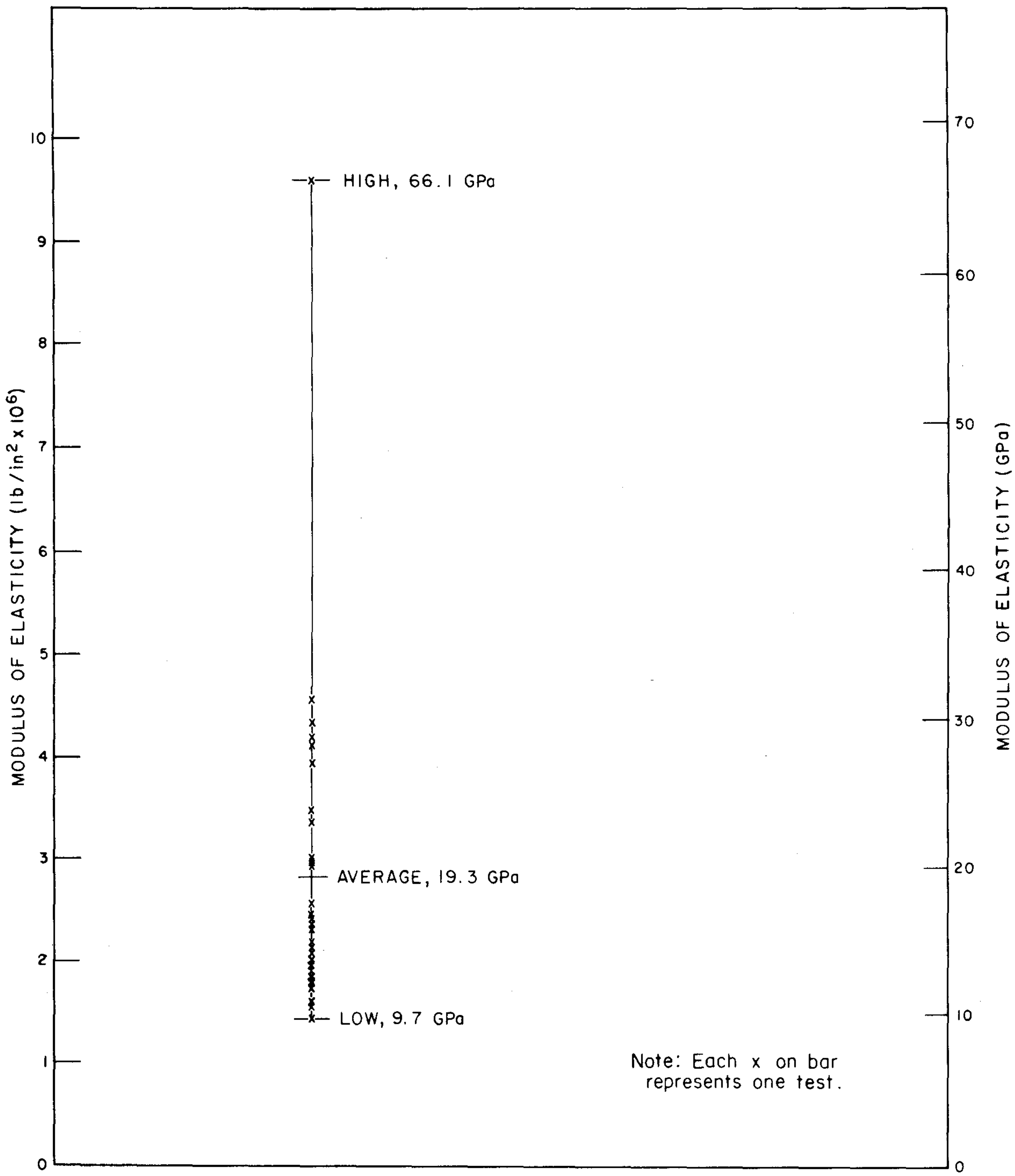

Figure 5. — Modulus of elasticity summary. Owyhee Dam.

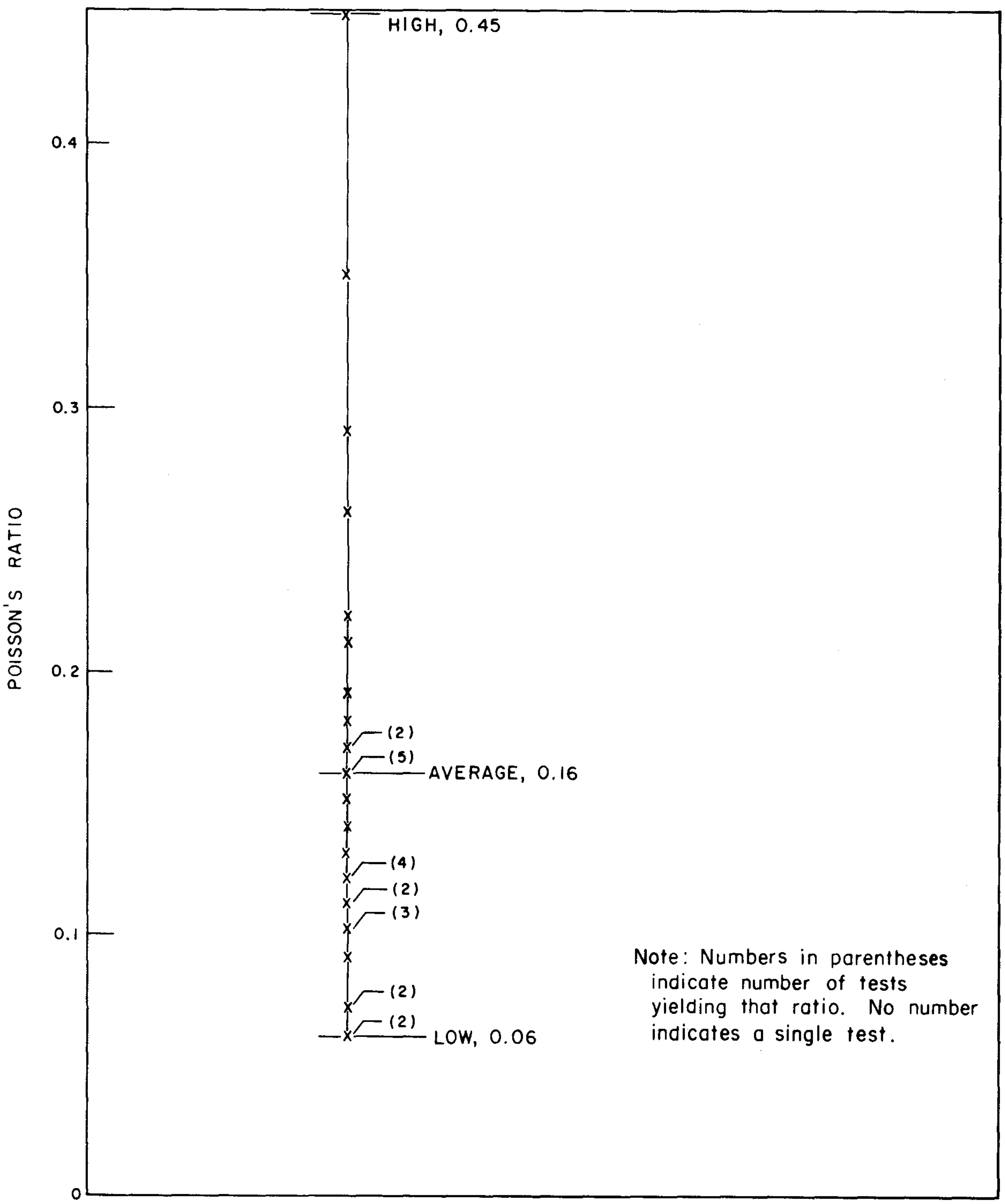

Figure 6. — Poisson's ratio summary. Owyhee Dam.

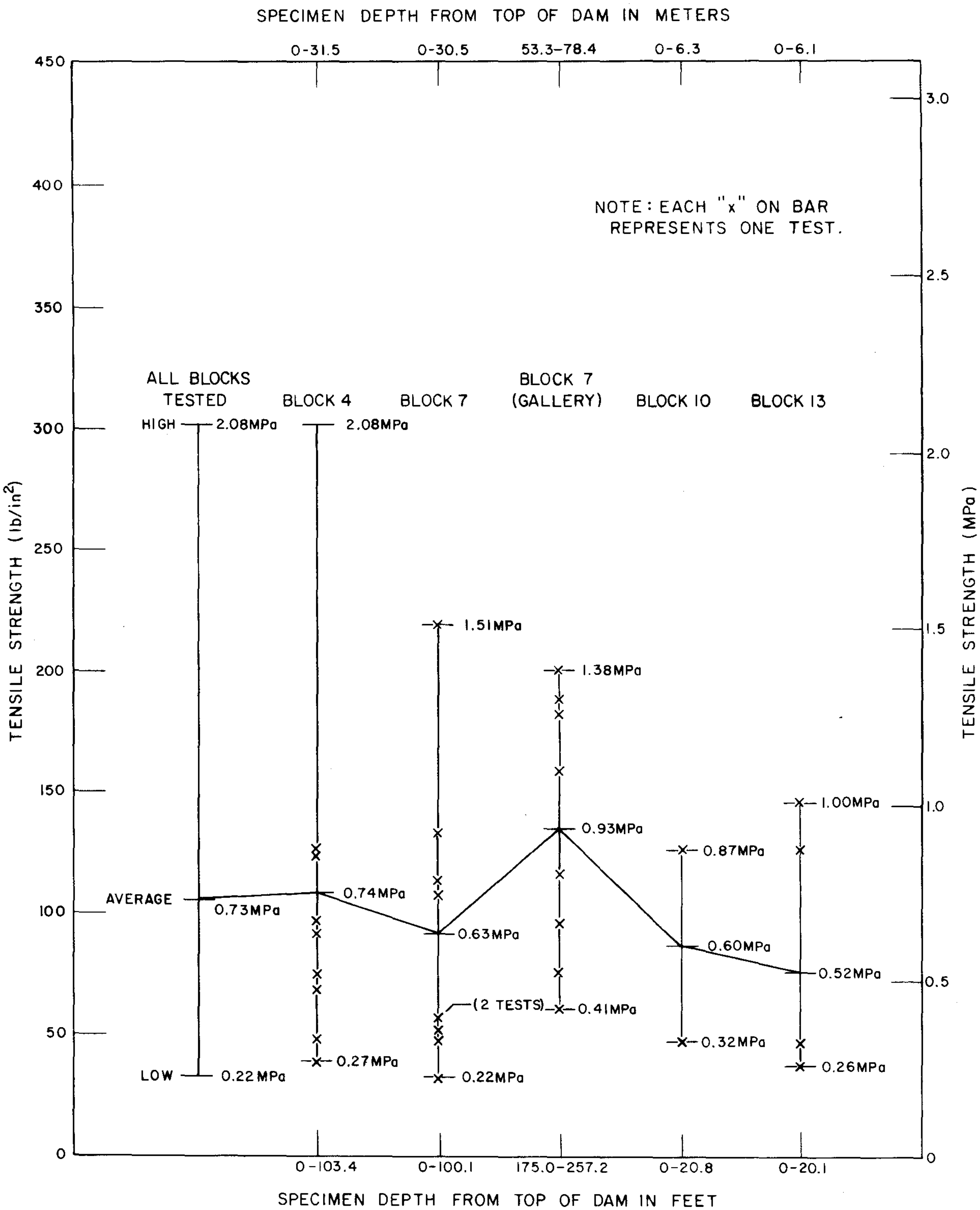

Figure 7. — Tensile strength in blocks tested. Owyhee Dam.

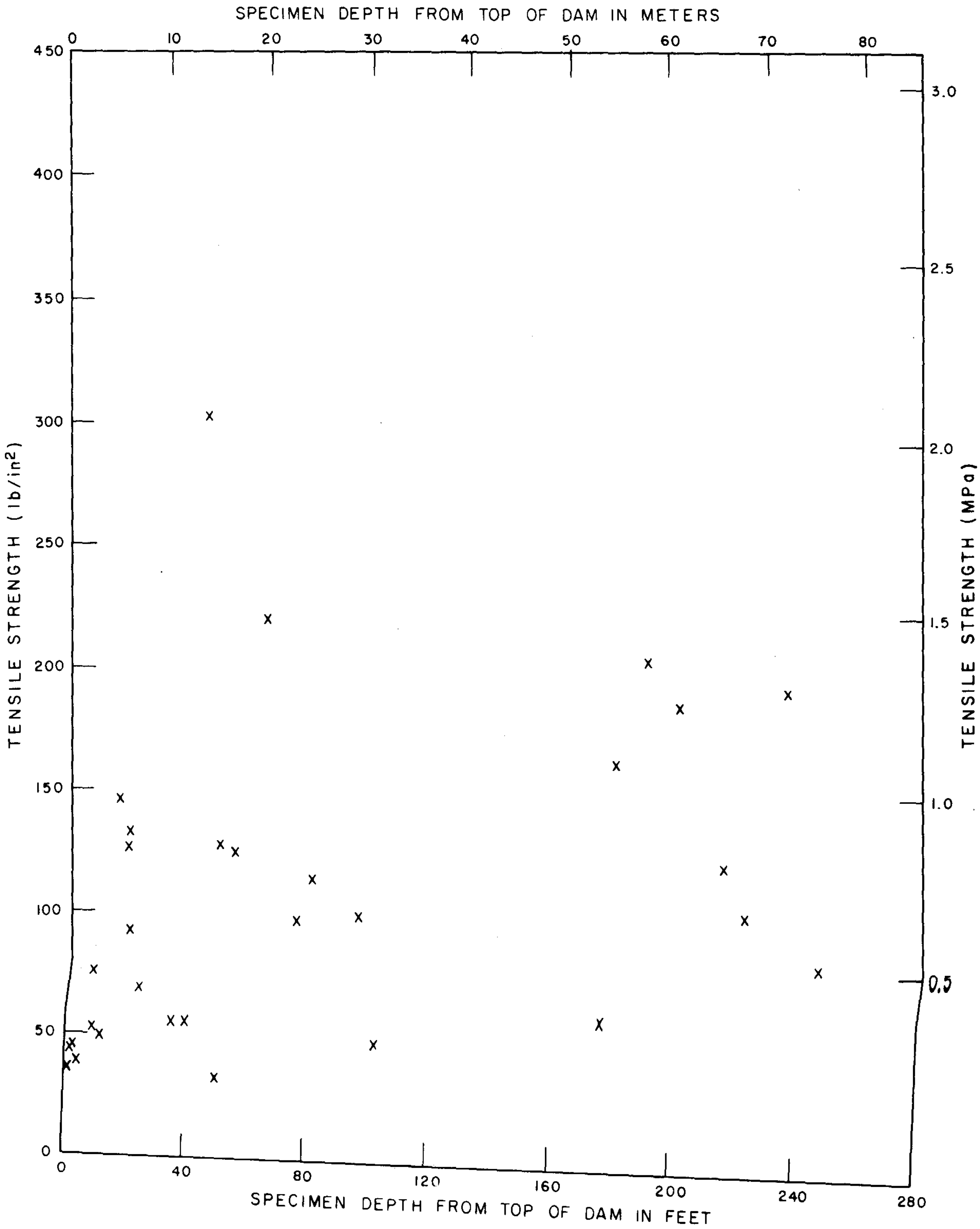

Figure 8. — Specimen depth from top of dam versus tensile strength. Owyhee Dam.

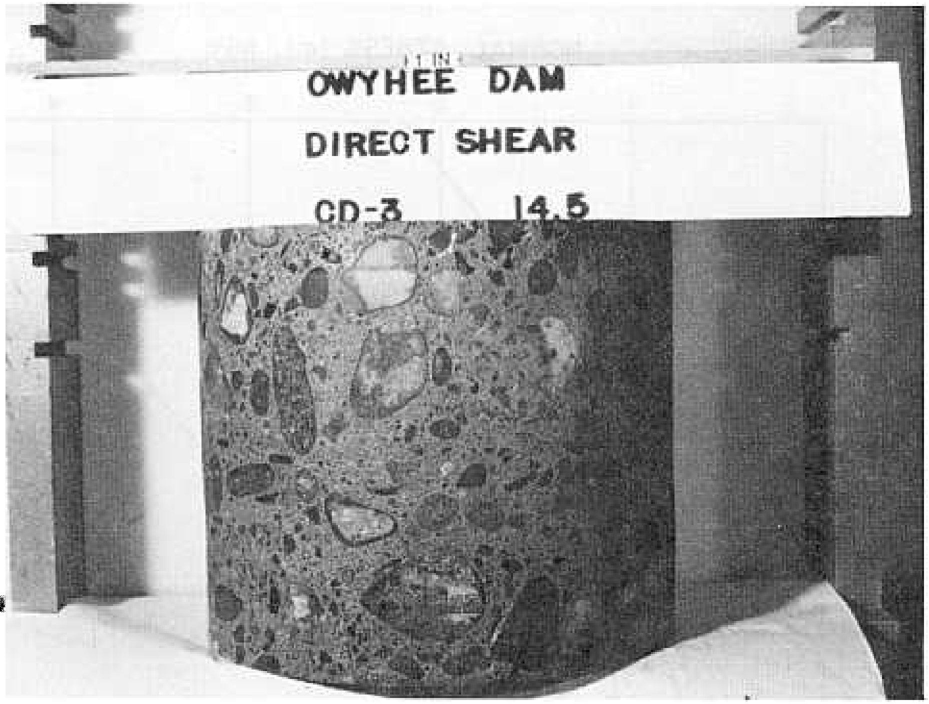

Figure 9. — Typical direct shear test specimen before test. Owyhee Dam
P801-D-80039

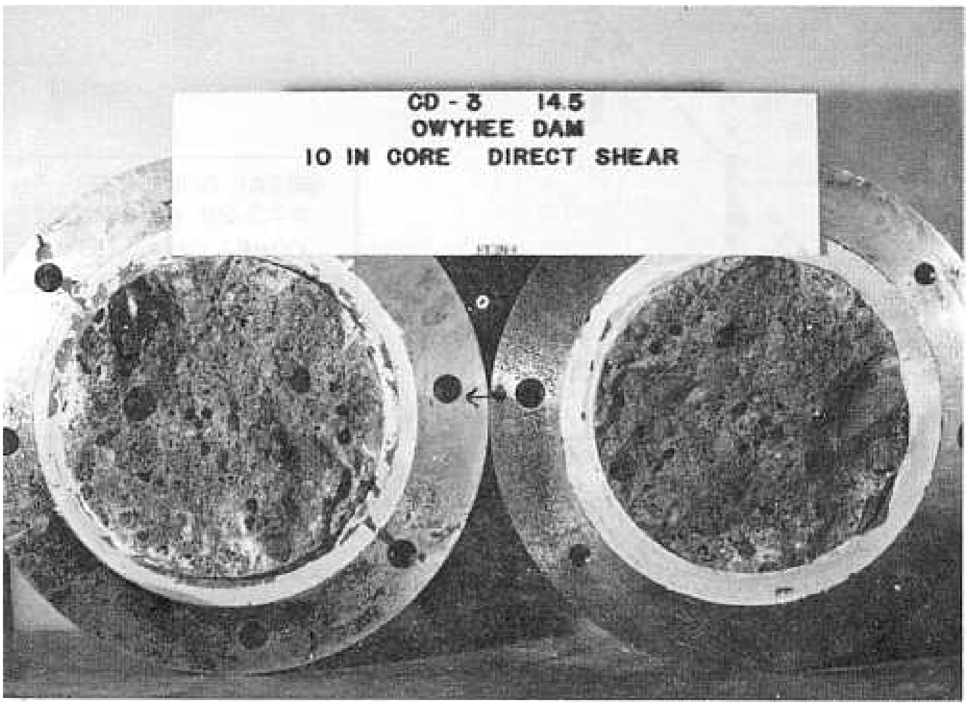

Figure 10. — Typical direct shear test specimen after test. Owyhee Dam.
P801-D-80040

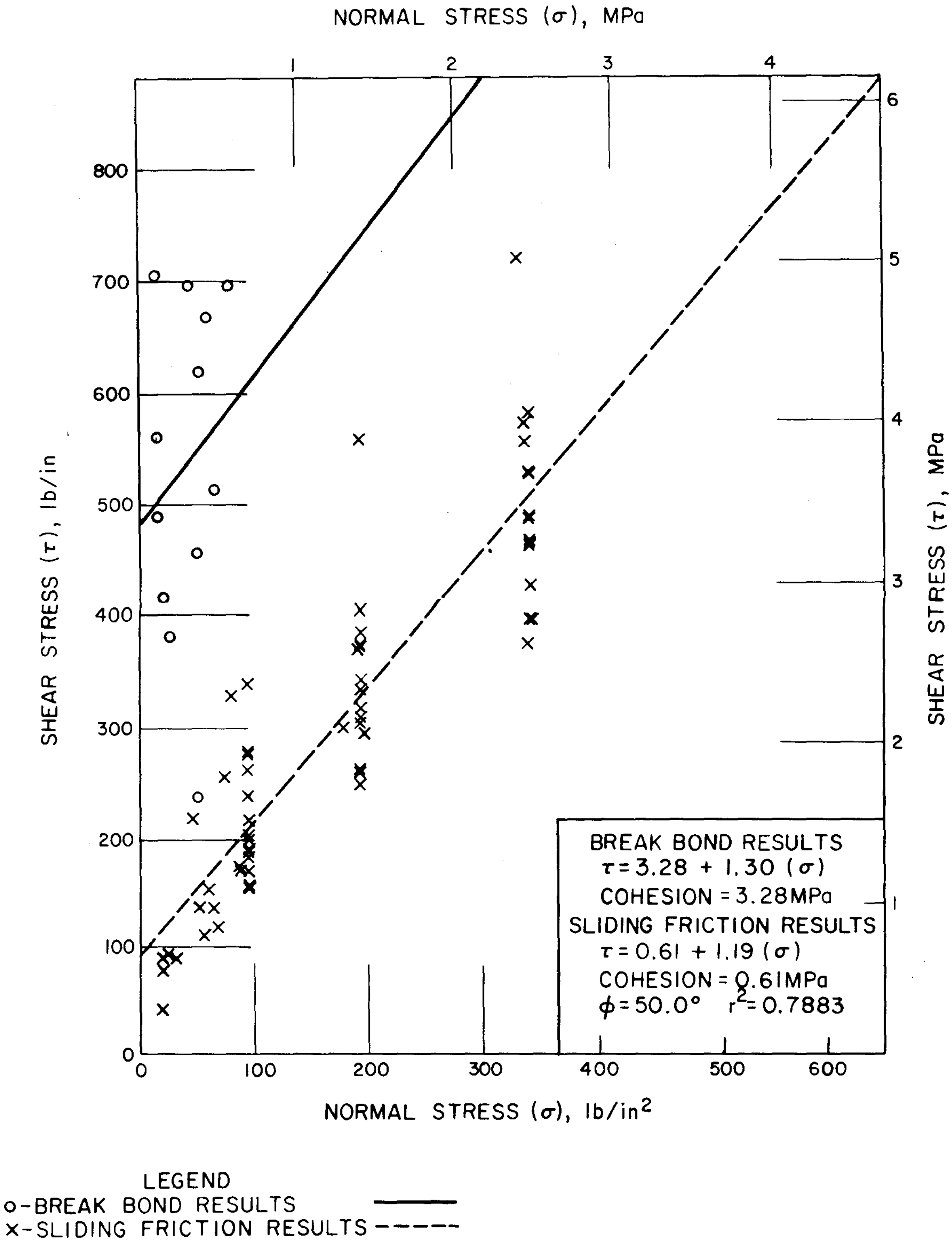

Figure 11. — Direct shear test linear regression results for 150-mm (6-in) cores. Owyhee Dam.

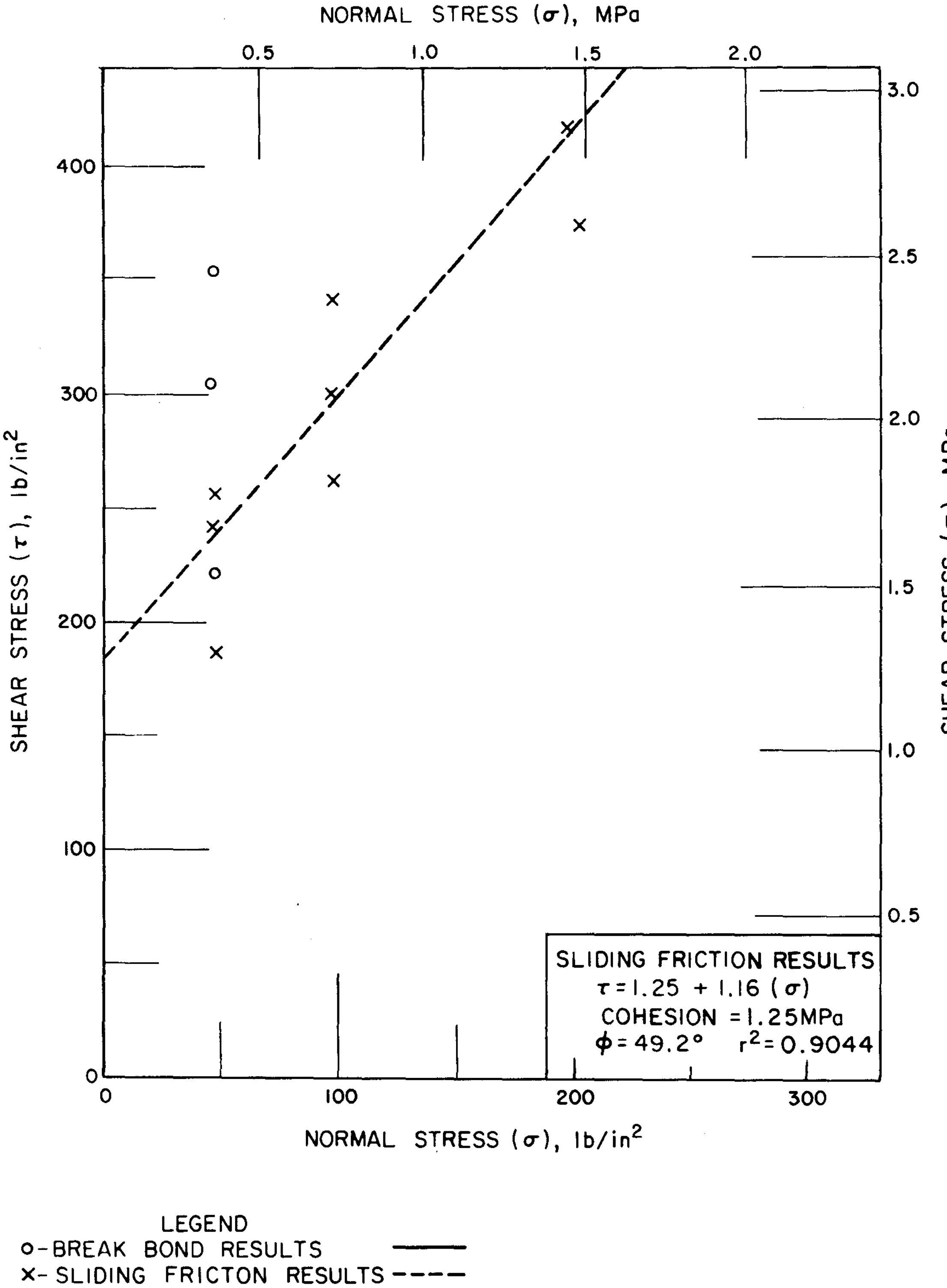

Figure 12. — Direct shear test linear regression results for 250-mm (10-in) cores. Owyhee Dam.

APPENDIX A

PETROGRAPHIC EXAMINATION MEMORANDUM

OPTIONAL FORM NO. 10
JULY 1973 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

Memorandum
Denver, Colorado

TO : Chief, Concrete and Structural Branch

DATE: March 17, 1982

FROM : Chief, Applied Sciences Branch

SUBJECT: Petrographic Examination of Concrete Core - Owyhee Dam - Owyhee Project, Oregon

Petrographic examination by: C. A. Bechtold

Petrographic referral code: 82-8

MATERIAL AND METHOD OF STUDY

Owyhee Dam concrete drill cores, 6 and 10 inches in diameter, were given a cursory examination in the Concrete Laboratory to select representative fragments to be further examined and tested in the Petrographic Laboratory. The examination was requested to determine the petrographic quality of the concrete.

The cores were examined megascopically, microscopically, by X-ray diffraction and differential thermal analyses, and by some qualitative physical and chemical tests.

PETROGRAPHIC EXAMINATION

Detailed "Petrographic Examination of Concrete" sheets are attached which include the cursory observations and petrographic descriptions of the aggregate, paste, air voids, secondary and hydration products, and fractures.

Evidence for the longitudinal shrinkage crack which developed shortly after construction was not observed in the submitted concrete cores.

CONCLUSIONS

The examined concrete from Owyhee Dam is petrographically of fair quality. The concrete from the upper 2 or 3 feet is petrographically of low fair quality due to evidence of moderate freeze-thaw deterioration enhanced by alkali-aggregate reaction. The concrete below 2 or 3 feet is petrographically of high fair quality due to only minor evidence of alkali-aggregate reaction and no evidence of freeze-thaw deterioration.

- Depth 2 or 3+ feet: voids, few random fractures, and rock sockets occasionally lined to partly filled with desiccated silica gel generally associated with calcium silicates, some ettringite, and/or calcium carbonate; occasional reaction rims, desiccated silica gel deposits and a few areas of silica gel soaked paste concentrated around glassy rhyolite or chert particles; some silica gel developed in concrete soaked in Denver tapwater for several weeks; no sulfate ions but considerable chloride ions chemically detectable

Hydration products - Depth 0 to 2 or 3 feet: moderate amounts of calcium silicates; contains about one-half the amount of portlandite, $Ca(OH)_2$, detected in concrete below 2 or 3 feet; a few poorly preserved remnants of unhydrated cement particles; water of hydration appears adequate

- Depth 2 or 3+ feet: moderate amounts of calcium silicates; contains about twice the amount of portlandite, $Ca(OH)_2$, detected in concrete above 2 or 3 feet; a few poorly preserved remnants of unhydrated cement particles; water of hydration appears adequate

Fractures - Depth 0 to 2 or 3 feet: numerous fractures parallel to structure surface generally filled with silica gel, ettringite and occasionally calcium carbonate; numerous discontinuous unfilled or silica gel and/or ettringite-filled microfractures radiate into paste from alkali-reactive rock particles

- Depth 2 or 3+ feet: few fractures and microfractures present; unfilled or filled with silica gel, ettringite and rarely calcium carbonate; a few discontinuous microfractures radiate into paste from alkali-reactive rock particles

PETROGRAPHIC EXAMINATION OF CONCRETE

Subject: Owyhee Dam
Owyhee Project, Oregon

Field No. Drill holes CD-1, -2, -3, -4, -5, -6A, -6B, -7, and -7A

Cursory observations: 6- and 10-inch-diameter core; varies from well-compacted to rather poorly compacted concrete; gray to whitish paste; white secondary deposits in many voids and fractures and lining rock sockets, especially in the upper 2 to 3 feet; many filled parallel freeze-thaw formed fractures in upper 1 to 2 feet

Petrographic examination:

Aggregate - Gravel: subrounded in shape; consists of granite, gneiss, basalt, altered and glassy rhyolite, chert, sandstone, obsidian, and quartzite; reaction rims around glassy rhyolite and chert particles

- Sand: generally subangular in shape; includes same rock types found in the gravel as well as monomineralic grains of quartz, feldspar, amphibole, mica, and garnet and a few miscellaneous detrital minerals

- Gravel and sand: petrographically of fair physical quality and deleteriously reactive with high-alkali cement

Paste - Depth 0 to 2 or 3 feet: light gray to white; variable from dull and earthy to vitreous; moderately to slightly absorptive; moderately parallel fractured; intact fragments break with a moderate hammer blow around and through aggregate particles indicating primarily a moderately strong paste-aggregate bond weakest in areas containing secondary deposits of ettringite, silica gel, and/or occasionally calcium carbonate; generally well distributed with aggregate and poorly to well compacted; numerous channel voids; essentially noneffervescent with dilute HCl (hydrochloric acid)

- Depth 2 or 3+ feet: light to dark gray; generally vitreous; slightly absorptive; few fractures; intact fragments break with a hard hammer blow around and through aggregate particles indicating a stong paste-aggregate bond; generally well distributed with aggregate and poorly to well compacted; numerous channel voids; no effervescence with dilute HCl

Air voids - Few entrapped air voids; no entrained air voids; some channel and water voids; somewhat concentrated below aggregate particles

Secondary products - Depth 0 to 2 or 3 feet: voids, numerous parallel and occasional random fractures, and rock sockets generally filled to partly filled with desiccated silica gel associated with calcium silicates, some ettringite, and/or occasionally calcium carbonate; reaction rims, desiccated silica gel deposits and a few areas of silica gel soaked paste generally concentrated around glassy rhyolite or chert particles; moderate amounts of chloride ions and minor amounts of sulfate ions chemically detectable

Low Fair Quality Concrete - 0 to 2 or 3 Feet

The aggregate is petrographically of fair physical quality and deleteriously reactive with high-alkali cement due to the presence of chert and glassy rhyolite particles containing reaction rims. The paste is moderately parallel fractured, poorly to well compacted, and generally well distributed with aggregate and contains numerous channel voids. The paste-aggregate bond is primarily moderately strong and weakest in areas containing secondary deposits. Locally significant silica gel, ettringite, and/or occasionally calcium carbonate deposits fill voids and line rock sockets and are concentrated around glassy rhyolite and chert particles and along many parallel fractures. Numerous discontinuous fractures and microfractures radiate from alkali-reactive rock particles.

High Fair Quality Concrete - 2 or 3+ Feet

The aggregate is petrographically of fair physical quality and deleteriously reactive with high-alkali cement due to the presence of chert and glassy rhyolite particles which occasionally contain reaction rims. The paste is slightly fractured, poorly to well compacted, and generally well distributed with aggregate and contains numerous channel voids. The paste-aggregate bond is generally strong. Occasionally, silica gel, minor ettringite, and/or rarely calcium carbonate fill voids and line rock sockets and are concentrated around chert and glassy rhyolite particles and along fractures. A few discontinuous fractures and microfractures radiate from alkali-reactive rock particles.

No evidence of adverse deterioration due to chloride or sulfate ions is present.

The concrete from Owhyee Dam can be expected to continue to deteriorate due to alkali-aggregate reaction in view of the silica gel developed in the sample immersed in Denver tapwater and freeze-thaw activity due to the lack of air entrainment.

L. O. Timblin Jr.

Attachment

Copy to: D-220
D-915
D-1523

GPO 838-684

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.