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EVALUATION OF AGGREGATE SOURCES

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by

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EVALUATION OF AGGREGATE SOURCES

The original purpose of this investigation as begun in May of 1947 was to correlate, if possible, the quality, composition, and distribution of Michigan aggregate deposits with their origin and geologic history. It was planned to group present known deposits into areas of similar geologic influence and performance characteristics so that some foreknowledge might be obtained concerning possible new sources as they are opened.

Previous reports under this research project on specific sources include our letter of May 9, 1950 to W. W. McLaughlin on Petoskey limestone and Research Laboratory Report No. 154 on Marshall Creek aggregates. On November 12, 1952, laboratory reports and a tabulated summary of results were also transmitted covering durability tests on all aggregates received in 1952 and tested prior to that date.

The purpose of this report is to summarize the information obtained on all aggregates received from the beginning of 1952 to the present date. Laboratory reports have been prepared giving test results for each sample of aggregate received since October 31, 1952 and are being transmitted separately. Included with these laboratory test reports are a few which are supplementary to reports of tests on aggregate samples which were not complete at the time they were first issued.

Although the aggregates covered by all of these previous reports were tested for specific information on individual sources, the data thus obtained will be used also in conjunction with the results of previous tests in working toward the initial objective of the project.

Test Procedures

The first series of tests were performed on aggregates in concrete beams made with Type I cement and no air-entraining agent. These beams were also cured only 13 days in the fog room and 1 day in water prior to the freeze-thaw test. The current freeze and thaw durability program utilizes both regular and air-entrained concrete specimens.

In addition to freezing and thawing in concrete, the aggregates were tested for soundness by magnesium sulfate and 25 cycles of freezing and thawing in water. A lithological count was made and the absorption and specific gravity of the aggregates determined. All of these test results, as well as durability data from freeze and thaw tests have been recorded and submitted on separate laboratory report sheets.

Preparation of Specimens: All of the coarse aggregates were seived and recombined into an average 6A grading of 100 percent passing 1-½-inch seive, 75 percent passing a 1-inch, 40 percent passing ½-inch, and 0 percent passing a No. 4. This 6A graded material was used for all tests except the soundness tests and in these the standard grading as found in Part 4b of ASTM C 88 was used.

Prior to mixing and molding the 2- by 2- by 12-inch mortar or 3- by 3- by 15-inch concrete test beams, the aggregates were saturated for 24 hours under excess water. The concrete was designed according to the mortar voids method using a b/b_0 of 0.74 and a cement content of 5.5 sacks per cubic yard. Peerless Type I cement from Detroit was used throughout and the fine aggregate was obtained from the Boichot pit. A 2 to 3-inch slump was used and the air-entrained mixes were designed for approximately 4.5 percent air using Darex solution.

The coarse aggregate, fine aggregate, cement, mix water and Darex (when needed) were added to the mixer in that order. The materials were mixed for 5 minutes and dumped into a moist pan. After turning with a shovel the slump, unit weight, and air content were measured. The beams were molded in two layers, rodding each layer 50 times with a 3/8-inch bullet nosed rod, the sides and ends spaded with a trowel, and the top finished off with a wooden float. The specimens were placed in the fog room immediately after molding and cured at approximately 75°F. for 26 days. The beams were then saturated under water at 75°F. for 48 hours prior to the initial freeze-thaw cycle.

Freezing and Thawing: The length, weight, specific gravity, and dynamic modulus were determined before placing the beams, in groups of three, under water in rubber containers for lowering into the freezing unit. The rubber "boots" containing specimens were surrounded by an isopropyl alcohol-water mixture maintained at -15°F. for the freezing cycle of 16 hours and by running tap water at 55°F. for the thawing cycle of 8 hours.

The above procedure was set up originally in 1940 for testing specimens from the Durability Project of the Michigan Test Road on M 115, and has been followed in nearly all subsequent accelerated durability tests of concrete and aggregates in order to maintain a basis of comparison for different materials over a considerable period of time. This procedure represented the accepted methods and prevailing thought at the time. However, when the new automatic freezing and thawing equipment is put in operation at the Research Laboratory, procedures will be revised to conform with the recently promulgated ASTM methods, and employ vacuum saturation of aggregates in air-entrained concrete for testing aggregate durability.

Discussion of Results

A complete tabulation of all aggregates tested, including four fine aggregates, with their freeze and thaw performance, is presented in Table I. Included in the summary are the aggregates reported by letter of November 12, 1952. Of all of the aggregate samples received for test, only a very few remain in the freeze and thaw test.

In three instances it was necessary to obtain additional samples either due to the first sample not passing specifications or because there was not sufficient material to make air-entrained specimens. In all three cases, the second sample was a better quality material.

The curves in Figures 1, 2, and 3 present graphically the relative rate of decrease in dynamic modulus of the various test beams with cycles of freezing and thawing. In Figure 3 it is possible to separate the curves into three groups which have been tentatively identified as coarse aggregates of good performance, borderline performance, and poor performance. Table II is a summary of pertinent physical characteristics of each coarse aggregate source grouped according to its performance as shown in Figure 3.

The four aggregate sources comprising the poor group contained two gravel types. The Van Fleet and Price materials were quite high in chert and hard, absorbent siliceous limestone. The Bennett and King materials were high in soft stone, chert, or encrusted particles. The effect of the high deleterious count of the Bennett stone is shown in Figures 4 and 5.

In group two, comprising the so-called borderline material, the rather high percentage of aggregate encrustation in some cases may account for their relatively low durability under freezing and thawing. Also the average percent of deleterious stone in this group was comparatively high. Test beams made with the L. A. Davidson gravel exhibited the worst breakdown of surfaces as can be seen in Figures 6 and 7.

The coarse aggregates falling in the good performance group had no encrustation, were generally low in bad rock types, and the material was practically 100 percent crushed. Two of the materials, North Baltimore and Waterville Ohio were 100 percent crushed limestone aggregates. It is of interest to note that the North Baltimore material has a good durability record in this test in spite of the fact that it had a high percentage of marine shale.

The results of the freeze-thaw tests on five sands, one of which was used as the control, are shown in Figure 1. Although the number of samples is small, the curves again fall into three groups of good, intermediate, and poor performance. The one "poor" sand came from the Harbor Beach pit. This sand had a rather high absorption and did not pass the sulfate soundness test.

TABLE I

SUMMARY OF DURABILITY TESTS ON AGGREGATES

FREEZE AND THAW IN WATER

One cycle per day. -15° to $55^{\circ}F$.

Lab No.	Type of Material	Source	Date Received	Quantity Received	Submitted by	Regular Concrete Beams: Date Molded	Percent Air (gross)	Begin F & T	No. Cycles	% Modulus Reduction	A. E. Concrete Beams: Date Molded	Percent Air (gross)	Begin F & T	No. Cycles	% Modulus Reduction	Remarks
52 AR-3	Crushed Gravel, 6A	Stevick Gravel Co., Jackson, Mellencamp pit #38-23	5-27-52	8 bags	R. F. Durfee E. W. Krause	6- 6-52	1.6	7- 3-52	14.9	50.0	6- 6-52	5.2	7- 3-52	111.0	50.0	Sum of 1, 2, & 3 stone equals 6.5%
52 AR-5	Gravel, 6A	Whittaker-Gooding, Manchester, Kuhl pit #81-8	6-18-52	6 bags	J. F. Bailey	6-26-52	1.3	7-25-52	6.0	50.0	6-26-52	4.3	7-25-52	96.0	50.0	Very high encrusted count, 26%
52 AR-6	Bank run	Northland Construction Co., Petoskey, Price pit #15-15	7- 2-52	5 bags	R. F. Durfee	7-11-52	1.7	8- 8-52	17.0	50.0	7-11-52	4.6	8- 8-52	57.9	50.0	Absorption = 1.76%; encrusted more than 1/3, 8.9%; hard absorbent stone, 4.2%
52 AR-7	Bank run	Bennett pit #2, pit #39-42	7-14-52	5 bags	R. F. Durfee	12- 9-52	1.4	1- 8-53	11.7	50.0	12- 9-52	4.9	1- 8-53	38.9	50.0	Fails specs. for soft, non-durable stone & chert. Encrusted count equals 36.7%
52 AR-8	Sand, 2NS	Wagner Sand and Gravel, Harbor Beach pit #32-17	7-15-52	4 bags	L. C. Dunn	8- 8-52	- -	9- 5-52	51.0	50.0	- - -	- -	- - -	- -	- -	16% loss in sulfate test 2.47% absorption
52 AR-9	Bank run	King pit #46-28	7-23-52	5 bags	R. F. Durfee	7-29-52	1.7	8-27-52	11.3	50.0	8- 1-52	4.9	8-29-52	47.9	50.0	Air entrained beams failed rapidly. High in encrusted stone.
52 AR-10	Gravel, 4A & 10A	C. G. Bridges, Hayward pit #55-21	7-24-52	4 bags	J. C. Brehler	8-13-52	1.2	9-10-52	8.1	50.0	See 52 AR-22					High in soft non-durable sandstone. Abs. = 1.85
* 52 AR-11	Crushed Limestone, 6A	France Stone Co, N. Baltimore, Ohio	8-13-52	5 bags	T. H. Green	8-26-52	1.2	9-24-52	6.3	50.0	8-26-52	5.7	9-24-52	170.0	23.4	High marine shale content (13.0%)
52 AR-12	Bank run	L. A. Davidson pit #30-35	8-14-52	6 bags	R. F. Durfee	9-10-52	1.7	10- 8-52	6.8	50.0	Mixed with 52 AR-14					Fails specs. for soft non-durable and encrusted. Abs. high (2.44%)
52 AR-13	Sand, 2NS	C. G. Bridges, Hayward pit #55-21	9- 8-52	2 bags	J. C. Brehler	11-21-52	- -	12-19-52	110.0	39.5	- - -	- -	- - -	- -	- -	12% loss in sulfate test 1.93% absorption
52 AR-14	Bank run Gravel	L. A. Davidson pit #30-35 (Ann Arbor samples)	9-16-52	3 bags	R. F. Durfee W. E. Parr	9-26-52	1.55	10-24-52	12.4	50.0	10-31-52	5.2	11-28-52	126.8	50.0	Fails specs. on soft non-durable and chert count
52 AR-17	Gravel, 6A	Whittaker-Gooding, Manchester, Kuhl pit #81-8	9-24-52	3 bags	T. H. Green	10-10-52 11-25-52	1.3 1.6	11- 7-52 12-24-52	8.5 14.0	50.0 50.0	11-25-52	4.9	12-24-52	110.0	42.0	Passed specs. on encrusted count
52 AR-18	Sand, 2NS	C. G. Bridges, Escanaba, Girardi pit #22-37	10- 2-52	2 bags	E. W. Krause	2-26-53	- -	3-26-53	50.0	2.5	- - -	- -	- - -	- -	- -	9.1% loss in sulfate test
52 AR-19	Gravel, 4A & 10A	C. G. Bridges, Escanaba, Girardi pit #22-37	10- 2-52	4 bags	E. W. Krause	- - - -	- -	- - -	- -	- -	- - -	- -	- - -	- -	- -	To be tested for information. Sum of 1, 2, 3 stone = 5.1%. 3.2% loss on sulfate test of 6A material
52 AR-20	Crushed Gravel, 6B	E. P. Brady, Hawks, Michigan, Big Cut pit #71-15	10-27-52	3 bags	T. H. Green	12-10-52	2.0	1- 8-53	6.5	50.0	12-10-52	6.5	1- 8-53	100.0	8.8	75% crushed limestone Thin elongated = 6%
* 52 AR-21	Crushed Limestone, 6B	France Stone Co., Waterville, Ohio	10-29-52	3 bags	T. H. Green	12- 2-52	1.4	12-31-52	9.4	50.0	12- 2-52	6.4	12-31-52	110.0	6.5	Good Limestone.
52 AR-22	Gravel, 4A & 10A	Hayward Pit #55-21	11-12-52	2 bags of each	E. W. Krause	12- 3-52	1.8	12-31-52	31.5	50.0	12- 3-52	5.6	12-31-52	110.0	4.0	Absorption = 1.43%
52 AR-23	Gravel, sorted sizes	King pit #46-28	11-25-52	5 bags	R. F. Durfee	12- 4-52	1.4	1- 5-53	7.3	50.0	12- 4-52	5.3	1- 5-53	110.0	35.4	Air entrained beams holding up fairly well. Some damage from chert
53 AR-1	Gravel, 10A	Van Fleet pit #63-49	1- 8-53	2 bags	T. H. Green	Combined with 53 AR-8										
53 AR-2	Sand, 2NS	Van Fleet pit #63-49	1-20-53	2 bags	T. H. Green	3- 4-53	- -	4- 1-53	50.0	6.4	- - -	- -	- - -	- -	- -	
53 AR-8	Gravel, 4A	Van Fleet pit #63-49	3- 6-53	2 bags	J. A. DeKamp	3-12-53	1.45	4- 9-53	13.8	50.0	3-12-53	4.2	4-9-53	40	34.8	Sum of 1, 2, & 3 stone = 14%. Air entrained beams failing fast in freeze & thaw
53 AR-9	Gravel, 10A	Shell pit #13-30	6-24-53	1 bag	T. H. Green	- - - -	- -	- - -	- -	- -	- - -	- -	- - -	- -	- -	To be held for more material

* Limestone aggregates.

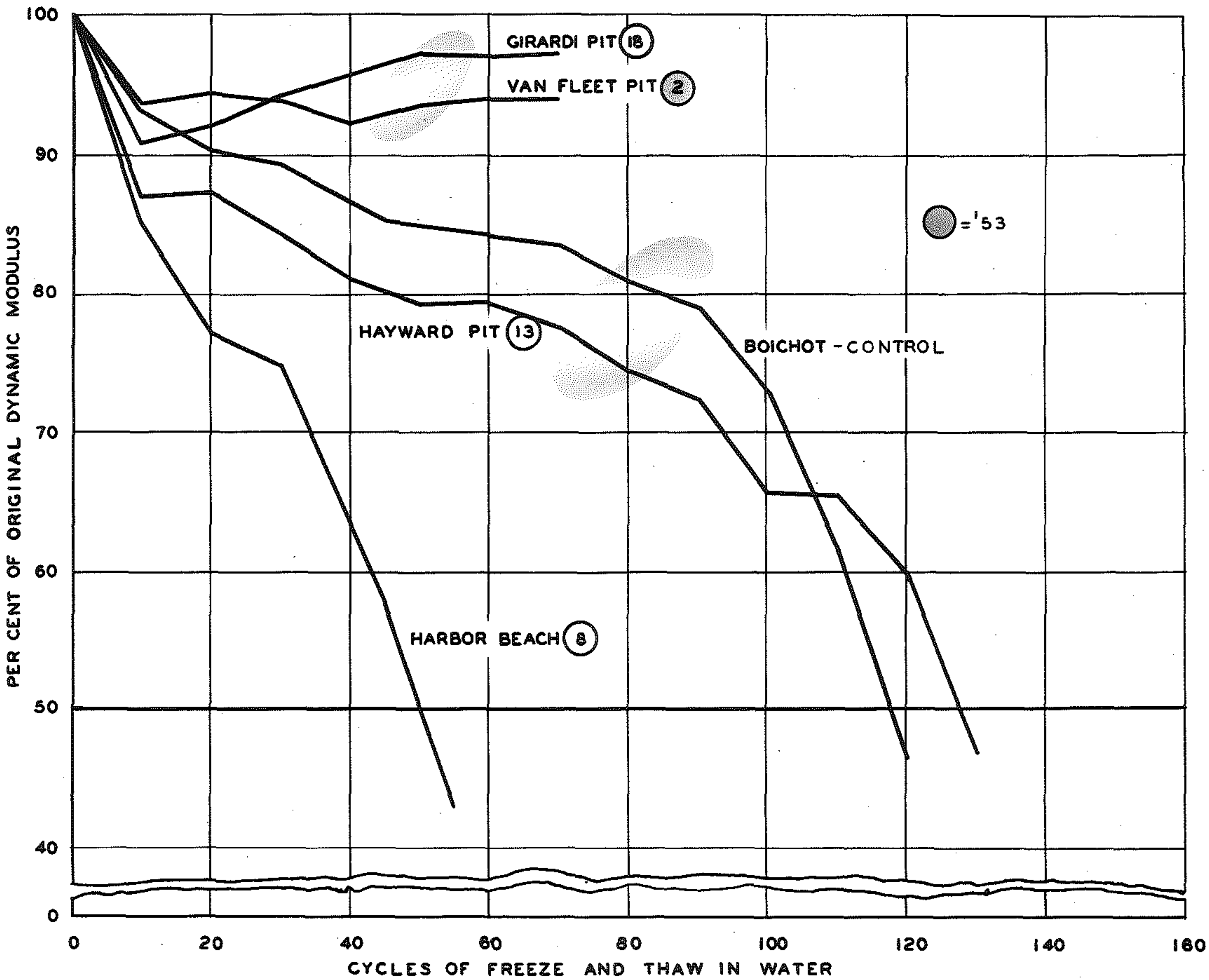
TABLE II

RELATIVE DURABILITY OF COARSE AGGREGATES DETERMINED BY AIR ENTRAINED BEAM PERFORMANCE

Lab. No.	Source	Gross Air Content of Concrete	Physical Characteristics of the Coarse Aggregate: Absorption	S.N.D. 1	Chert 2	H.A. 3	Sum of 1,2,&3	Encr. 1/3 +	Sulfate Soundness
				Group 1. Poor Performance					
53 AR-1,8	Van Fleet pit 63-49	4.2	1.39	3.30	5.58	5.18	14.06	- -	1.84
52 AR-6	Price pit 15-15	4.6	1.76	1.80	2.70	4.2	8.7	8.9	4.38
52 AR-7	Bennett pit 39-42	4.9	1.38	4.40	8.85	2.92	16.17	0.9	4.54
52 AR-9	King pit 46-28	4.9	1.39	2.71	1.66	0.37	4.74	10.0	6.14
	Average	4.65	1.48	3.05	4.70	3.17	10.92		4.23
				Group 2. Borderline Performance					
52 AR-3	Stevick pit 38-23	5.2	1.21	1.87	1.78	2.81	6.46	1.10	1.87
52 AR-5	Kuhl pit 81-8	4.3	1.54	2.20	1.30	1.10	4.6	26.0	2.19
52 AR-12,14	Davidson pit 30-35	5.2	2.44	4.43	3.89	3.37	11.69	8.19	9.93
52 AR-17	Kuhl pit 81-8	4.9	1.54	3.05	4.92	3.33	11.3	6.6	- -
52 AR-23	King pit 46-28	5.3	1.24	2.55	2.60	1.00	6.15	0.3	3.71
	Average	4.98	1.59	2.82	2.90	2.32	8.04		4.43
				Group 3. Good Performance					
52 AR-11	No. Baltimore, Ohio	5.7 5.1*	1.39	13.0**	0.0	0.0	13.0	None	5.61
52 AR-20	Big Cut pit, 71-15	6.5 5.7*	1.44	0.0	0.0	0.0	0.0	None	0.71
52 AR-21	Waterville, Ohio	6.4 5.6*	1.02	0.0	0.0	0.0	0.0	None	1.92
52 AR-22	Hayward pit, 55-21	5.6 5.4*	1.43	2.5	0.5	2.4	5.4	None	1.40
	Average	6.05 5.45*	1.32	3.9	.13	0.6	4.63	- -	2.41

*Air Content corrected to that of a comparable mix with rounded coarse aggregate particles.

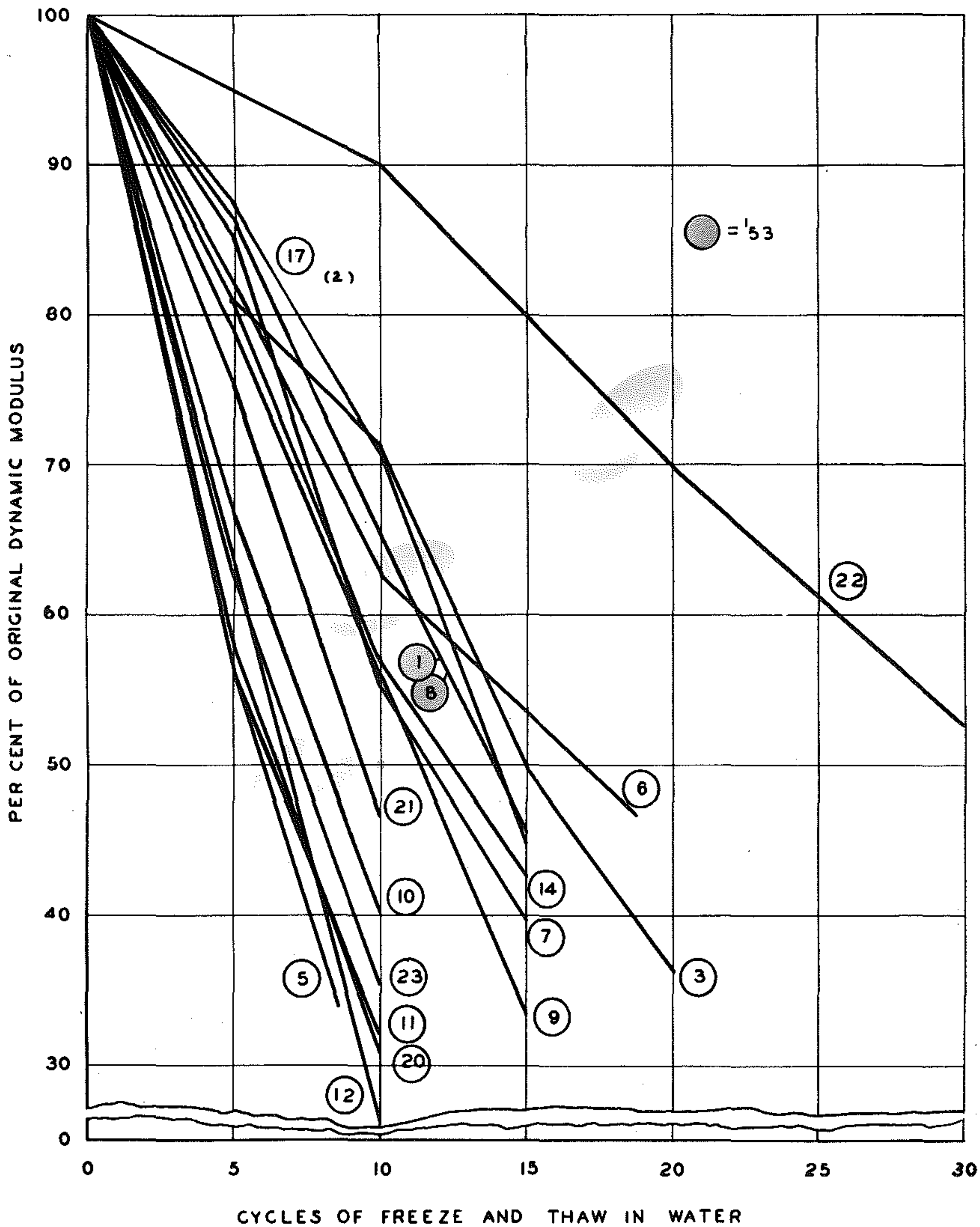
**Marine Shale.



PERFORMANCE OF MORTAR TEST BARS

VARIABLE = FINE AGGREGATE

FIGURE 1



DURABILITY OF NON-AIR-ENTRAINED CONCRETE TEST BEAMS

VARIABLE = COARSE AGGREGATE, 6A

FIGURE 2

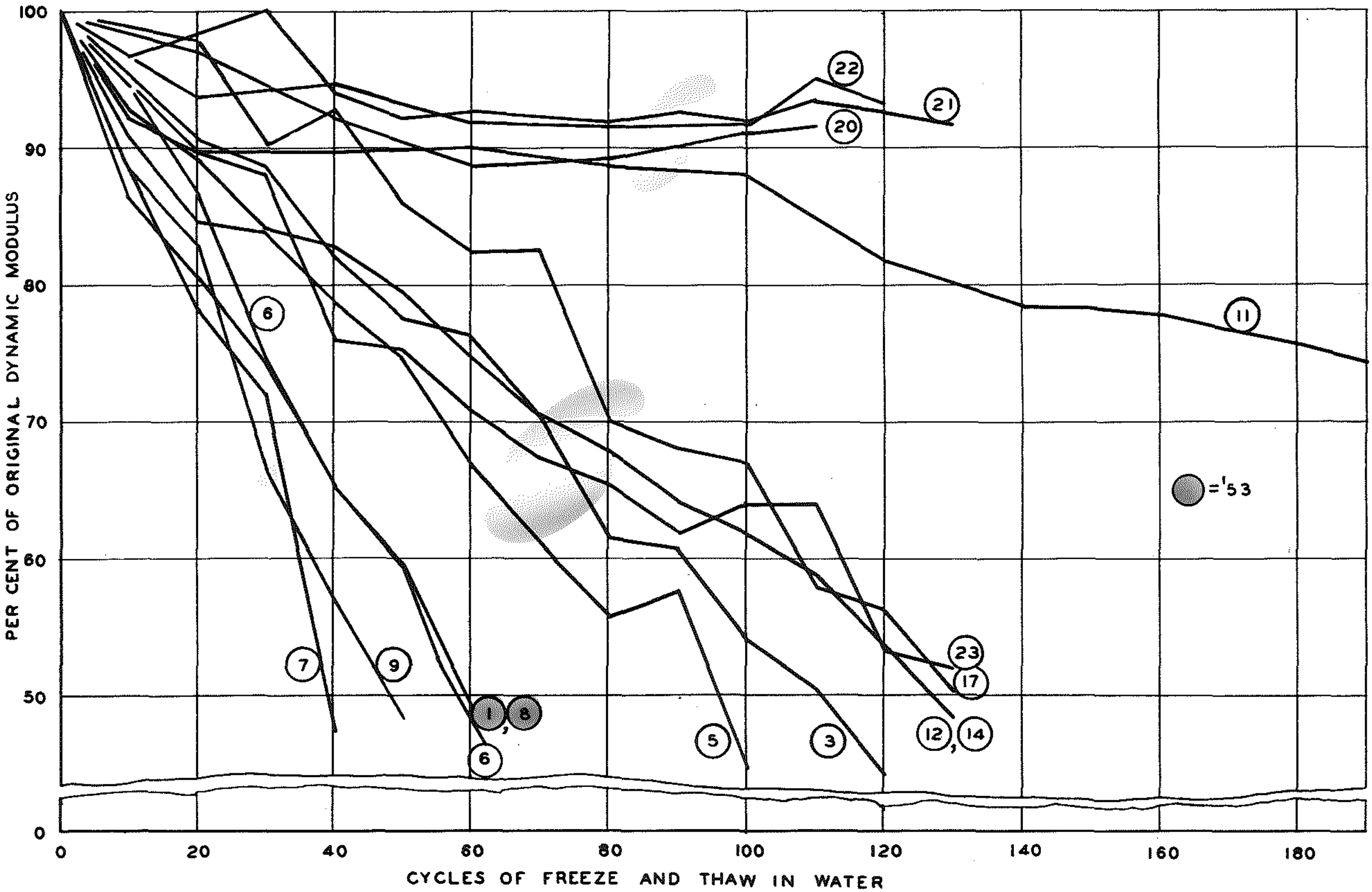


FIGURE 3

DURABILITY OF AIR-ENTRAINED CONCRETE TEST BEAMS

VARIABLE - COARSE AGGREGATE 6A

Figure 4. Example of concrete breakdown in air-entrained test beams due to high percentage of chert and iron bearing siltstone. 40 cycles of freeze and thaw in water.

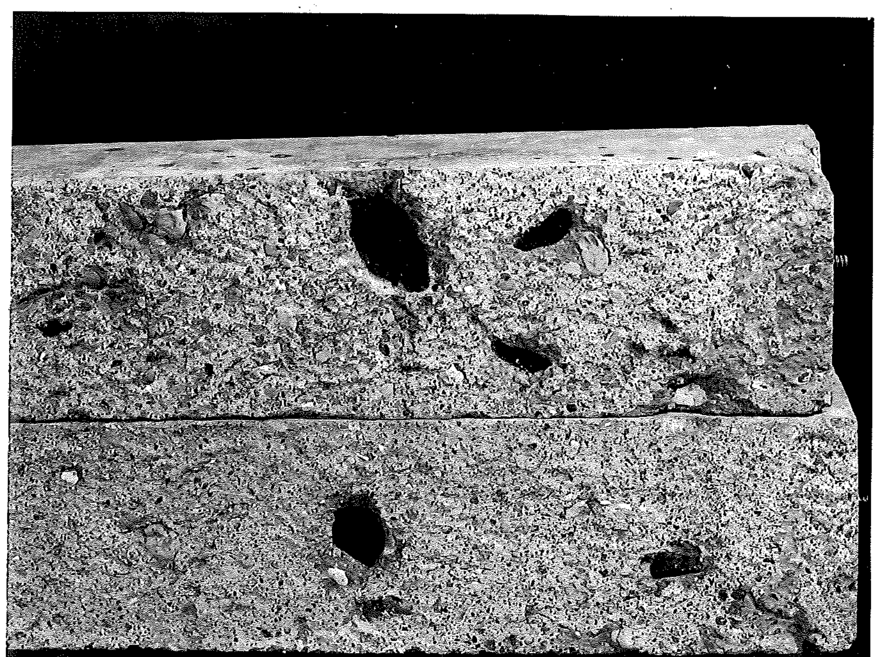


Figure 5. Pop-outs in top surfaces of air-entrained beams caused by iron-clay concretions and iron siltstone. 40 cycles of freeze and thaw.

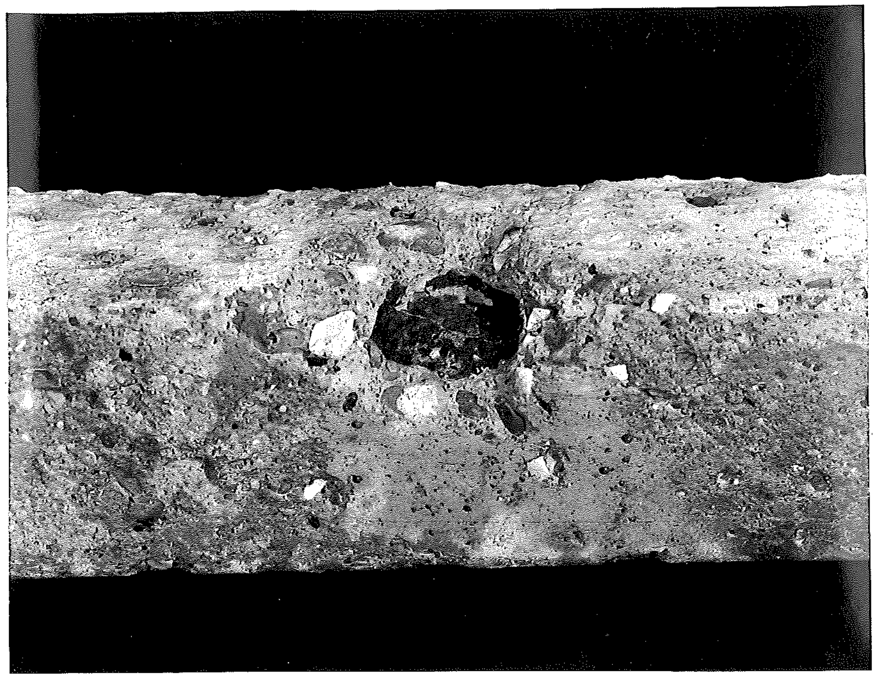


Figure 6. Large pop-out in air entrained beam due to iron-clay concretion. Coarse aggregates 52 AR-12 and 14 after 90 cycles of freeze and thaw in water.

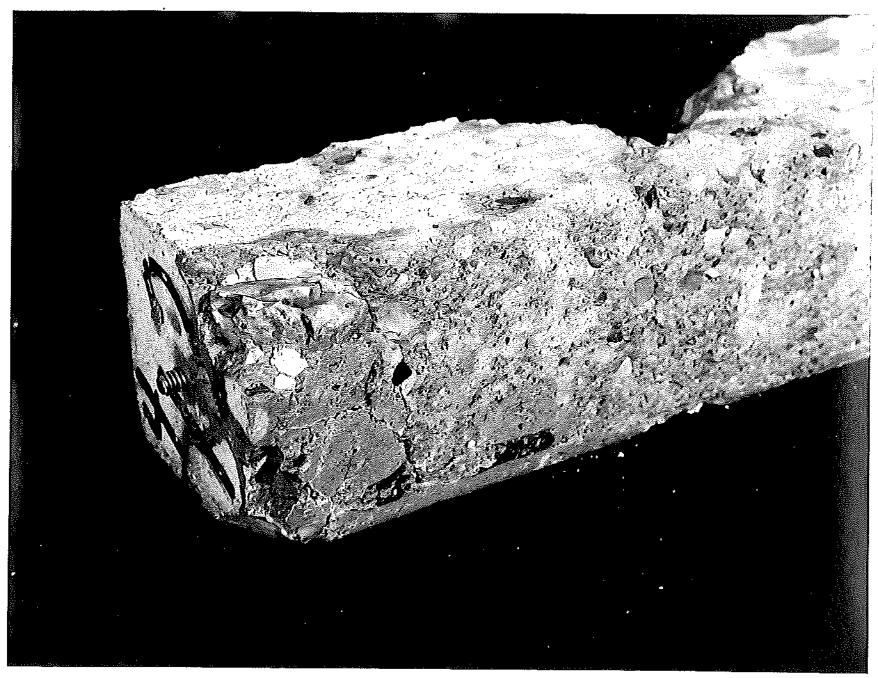


Figure 7. Disintegration of air entrained beam corners caused by chert and iron bearing siltstones in aggregates 52 AR-12 and 14. 90 cycles of freeze and thaw.