This thesis was contributed by

Mr. L. G. Kurtz

under the date indicated by the department stamp, to replace the original which was destroyed in the fire of March 5, 1916.

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THESIS

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[illegible] ABILITY OF [illegible]

WATER-[illegible] COMPOUNDS

by

Loren Grant

L. G. [illegible]

Louis Bailey

L. B. [illegible]

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MICHIGAN AGRICULTURAL COLLEGE

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THESIS

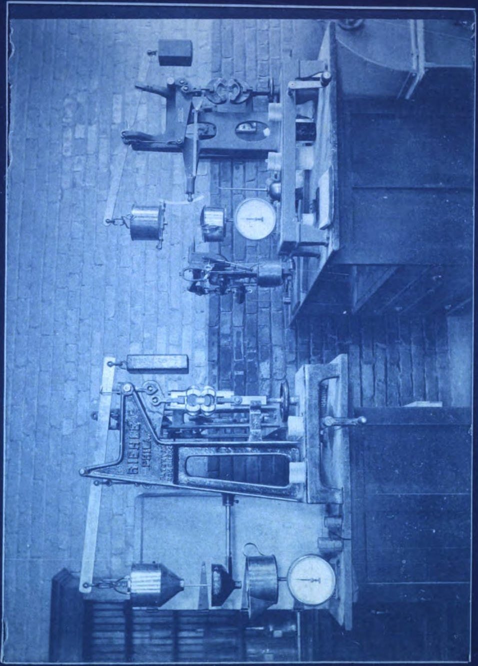
INTRODUCTION

I

Although the general use of concrete as a building material dates back but a few years, yet it is already replacing wood and iron to a large extent in almost all classes of construction. It is one of the cheapest of building materials. Structures of concrete are comparatively simple and easy of construction. It is very hard, durable, and strong in compression. But one of the greatest drawbacks to its general use is that water is able to permeate through it. This permeating water corrodes the steel in reinforced concrete. It renders basement walls damp and unhealthy. In cold weather, it causes the concrete to crack from freezing. It deteriorates dams and retaining walls, and makes them unsightly. For these and many other reasons there has been a long felt want for some substance to make the concrete water-proof. This may be accomplished by the proper selection and mixing of materials, but the time and skill required makes this method prohibitive. There are, however, on the market to-day a number of water-proofing compounds claiming to satisfy this want, but of uncertain effectiveness.

For this thesis we have selected nine well known and extensively advertised commercial compounds and have attempted by experiments to determine their effectiveness and their relative merits as water-proofing agents. We have also run tests to determine whether or not the compounds have any effect on the tensile or compressive strength of the concrete treated.

The general idea carried out in these tests is similar to that originated by W. [illegible] [illegible] and A. [illegible] Sargeant, of the class of 190[illegible] to whom acknowledgement is hereby made.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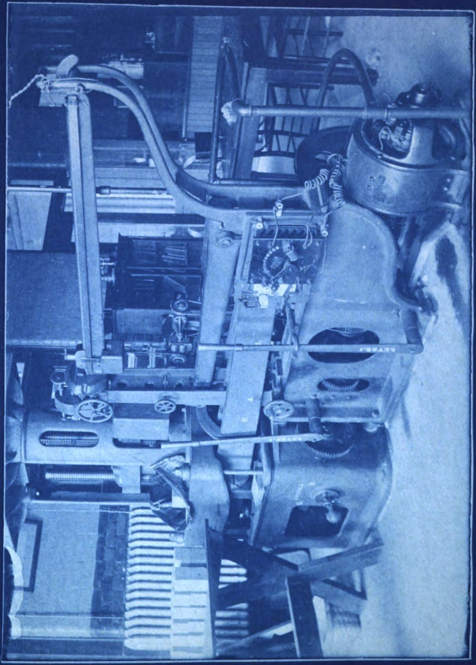
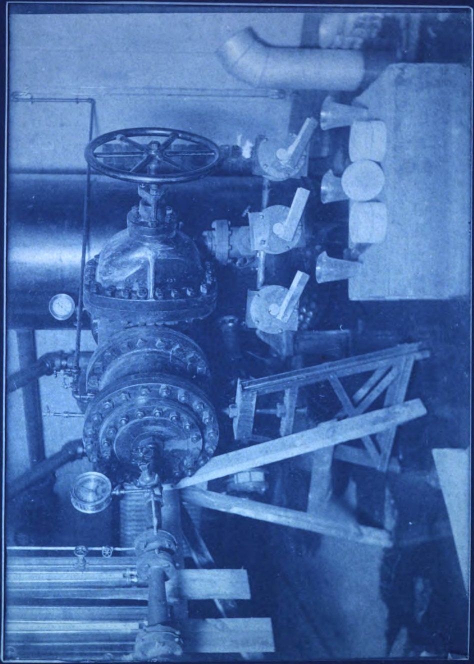




DESCRIPTION OF APPARATUS USED.

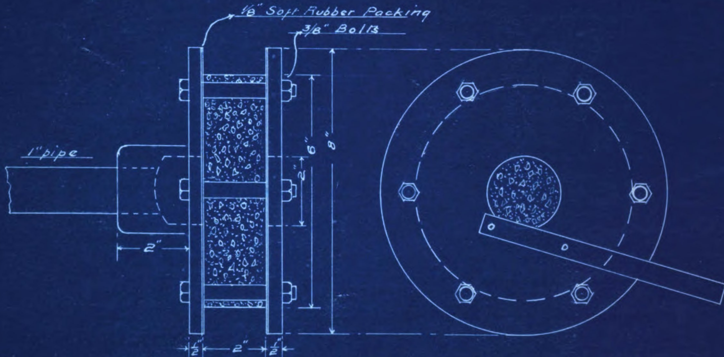
II

A Riehle 100,000# testing machine was used to obtain the compressive strength of the treated cubes.

A Tinius Olsen 2,000# special tensile machine was used to obtain the tensile strength of the treated briquettes.

A special machine embodying the ideas conceived by Hartman and Sargeant was constructed, by means of which the water permeating the concrete was determined. As shown in the drawing and photograph, it consisted essentially of two cast iron discs between which the specimens of treated concrete were securely bolted. Water pressure was applied on one side of the concrete through a two inch circular opening in the iron plate. The percolating water passed out of a concentric two-inch circular orifice in the other plate, and was caught by a tin spout rivited into this plate just below the opening, and conveyed to one side into a graduated flask where it was measured. The joints between the iron and concrete were made as water tight as possible by packing with an $\frac{1}{8}$" soft rubber gasket.

This permeability machine was connected to the pressure tank in the Hydraulic Laboratory, and the various static heads were obtained by making the pressure in the tank equivalent to the required pressure, in feet of water. The pressures obtained were read on a standard pressure gauge connected to the pressure tank.



PERMEABILITY MACHINE FOR DISCS

MATERIALS USED

III

The cement used was Peninsular Portland Cement, made by the Peninsular Cement Co., Jackson, Michigan.

Tests were made on this cement and it satisfactorily fulfilled all the standard requirements.

The gravel used was a good grade of clean sharp, gravel sand screened through a ¼" mesh.

The water used was well water, and was mixed into the concrete at a temperature of about 70 degrees Fahrenheit.

The water-proofing compounds tested were the following:

COMPOUND NAME	MANUFACTURER	DESCRIPTION
Medusa	Sandusky Portland Cement Co., Sandusky, Ohio.	A fine white powder, to be mixed with the dry cement.
Hydritite	A. C. Horn Co., New York, N. Y.	A fine white powder to be mixed with the dry cement.
Shamrock	McCormick Co., St. Louis, Mo.	A fine pink powder to be mixed with the dry cement.

COMMERCIAL NAME	MANUFACTURER	DESCRIPTION
Maume	Maume Chemical Co., Toledo, Ohio.	A fine white powder to be mixed with the dry cement.
Toxement	Obtained from a contractor. Detroit, Mich.	A fine white powder to be mixed with the dry cement.
Ceresit	Ceresit Waterproofing Co., Chicago, Ill.	A white paste to be mixed with the water.
Sterling	American Asphaltum & Rubber Co., Chicago, Ill.	A white paste to be mixed with the water.
Liquid	American Asphaltum & Rubber Co., Chicago, Ill.	A thin liquid, similar to varnish, to be applied like paint.
Hydratate	A. C. Horn Co., New York, N. Y.	A thick black liquid to be applied like paint.

METHOD OF PROCEDURE

IV

All the concrete was made of one part of cement to three parts of gravel sand. This being a rich mixture but not uncommon for small specimens.

The water-proofing compounds consisting of a fine powder were all used in the proportion of two and one-half per cent., by weight, of the cement. This average being a liberal amount of the compound in each case.

The compounds consisting of a paste were used in the proportion of two per cent., by weight, of the water, as suggested by the manufacturer.

The liquid compounds were applied to only the face of the concrete discs against which the water pressure came, as would be done in actual practice.

Sufficient material for four discs, 6" in diameter by 2" thick, four cubes, 2" on a side, and eight briquettes was weighed out. The compound and cement were first thoroughly mixed by hand with a trowel on a glass plate. Then this mixture was similarly mixed with the gravel sand until the whole mass was of a uniform color. The water was then added to make the mass of the proper consistency. (The gravel contained a great deal of moisture so it was impossible to measure accurately the amount of water used.)

The moulds for the discs consisted of 2" sections of a 6" iron pipe. These were placed on a glass plate and filled with the treated concrete. Great care was taken to obtain a solid and uniform mass by thorough tamping. The moulds for the cubes and briquettes were regular moulds in use in the laboratory. They were similarly filled with the treated concrete.

After being made the specimens were stored in damp room and a wet canvas placed over them.

The tests were run when the specimens were 28 days old.

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The discs were bolted in place in the machine and the water applied on one side under a pressure of 10 feet (4.33# per sq. in.) The quantity of water permeating the concrete through the two inch circular hole (3.14 sq. in.) was measured and recorded every 30 minutes for four hours. Then the pressure was increased to 20 feet (8.66# per sq. in.) and similar readings taken. Pressures of 30, 40, and 50 feet were likewise successively applied. The length of the run in each case being four hours, thus subjecting the concrete to a continual water pressure for 20 hours.

The results are given in the following tables.

The amount of water flowing through the 2 inch circular section is given in grams.

The rate of flow is given in grams per square feet per hour.

TENSION TESTS

The results are shown in the following tables.

The breaking load is given in pounds per square inch and is the average of eight specimens in each case.

COMPRESSION TESTS

The results are shown in the following tables.

The breaking load is given in pounds per square inch and is the average of four specimens in each case.

PERMEATION OF UNTREATED CONCRETE DISCS #1

Time	10 ft. Head		20 ft. Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	trace	0.0
90 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	trace	0.0
120 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	trace	0.0
150 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	trace	0.0
180 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	trace	0.0
210 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	trace	0.0
240 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	trace	0.0

PERMEATION OF CONCRETE DISCS TREATED WITH PAINT #2

Time	10 ft. Head		20 ft. Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
150 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
180 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
210 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
240 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PERMEATION OF CONCRETE DISCS TREATED WITH PAINT - #3

Time	10 ft Head		20 ft Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	trace	0.0
60 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	"	0.0
90 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	"	0.0
120 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	"	0.0
150 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	4.6
180 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	4.6
210 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	4.6
240 "	0.0	0.0	0.0	0.0	0.0	0.0	trace	0.0	2.0	4.6

PERMEATION OF CONCRETE DISCS TREATED WITH MEDUSA - #4

Time	10 ft. Head		20 ft. Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
150 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
180 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
210 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
240 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PERMEATION OF CONCRETE DISCS TREATED WITH HYDRITITE #5

Time	10 ft. Head		20 ft. Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min	3.0	275	0.0	0.0	1.0	92	0.0	0.0	0.0	0.0
60 "	7.75	436	2.0	183	2.25	115	0.5	46	Trace	0.0
90 "	10.75	275	3.5	138	2.25	92	0.75	23	"	0.0
120 "	13.5	252	4.75	115	2.5	23	1.0	23	"	0.0
150 "	15.5	183	5.25	46	3.0	46	1.25	23	0.5	46
180 "	17.0	138	6.0	69	3.25	23	1.5	23	0.75	23
210 "	18.5	138	6.5	46	3.5	23	1.75	23	1.0	23
240 "	20.0	138	7.25	69	4.0	46	2.0	23	1.0	0.0

PERMEATION OF CONCRETE DISCS TREATED WITH SHAMROCK #6

Time	10 ft. Head		20 ft. Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min	Trace	0.0	0.0	0.0	0.5	46	0.5	46	1.0	92
60 "	"	0.0	2.0	183	1.0	46	1.25	69	2.0	92
90 "	.25	23	3.5	138	1.25	23	2.0	69	2.75	68
120 "	.25	0.0	4.75	115	1.5	23	2.25	23	4.0	115
150 "	.25	0.0	5.25	46	2.0	46	2.75	46	4.5	46
180 "	.25	0.0	6.0	69	2.5	46	3.25	46	5.0	46
210 "	.25	0.0	6.5	46	3.0	46	3.5	23	6.0	92
240 "	.25	0.0	7.25	69	3.25	23	3.75	23	6.5	46

PERMEATION OF CONCRETE DISCS TREATED WITH MAUME #7

Time	10 ft. Head		20 ft. Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min.	10 c.c.	918 grams	29 c.c.	2560 gram.	20 c.c	1835 gram	18 c.c.	1650 gram.	14 c.c.	1286 gram
60 "	54 "	4040 "	52 "	2105 "	40 "	1835 "	35 "	1560 "	29 c.c.	1375 "
90 "	82 "	2585 "	70 "	1650 "	55 "	1375 "	48 "	1190 "	43 c.c.	1286 "
120 "	100 "	1650 "	86 "	1460 "	71 "	1470 "	57 "	826 "	56 c.c.	1190 "
150 "	118 "	1650 "	104 "	1650 "	86 "	1375 "	66 "	826 "	69 c.c.	1190 "
180 "	130 "	1100 "	120 "	1460 "	100 "	1287 "	73 "	642 "	82 c.c.	1190 "
210 "	142 "	1100 "	132 "	1100 "	112 "	1100 "	86 "	1190 "	94 c.c.	1100 "
240 "	151 "	826 "	143 "	1010 "	120 "	735 "	97 "	1010 "	106 c.c.	1100 "

PERMEATION OF CONCRETE DISCS TREATED WITH TOXEMENT #8

Time	10 ft. Head		20 ft. Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min.	0.0 c.c.	0.0	Trace	0.0	Trace	0.0	Trace	0.0 gram	2 c.c.	183 gram
60 "	trace	"	0.5 c.c.	49.5 gram	"	"	0.5 c.c.	49.5 "	4 c.c.	188 "
90 "	"	"	" "	"	"	"	0.7 "	64.2 "	5.5 "	138 "
120 "	"	"	" "	"	"	"	" "	64.2 "	7.0 "	138 "
150 "	"	"	" "	"	"	"	" "	64.2 "	8.5 "	138 "
180 "	"	"	" "	"	"	"	0.75 "	69 "	10 "	138 "
210 "	"	"	" "	"	"	"	0.8 "	73.5 "	11 "	91.8 "
240 "	"	"	" "	"	"	"	1.0 "	91.8 "	12 "	91.8 "

PERMEATION OF CONCRETE DISCS TREATED WITH CERESIT #9

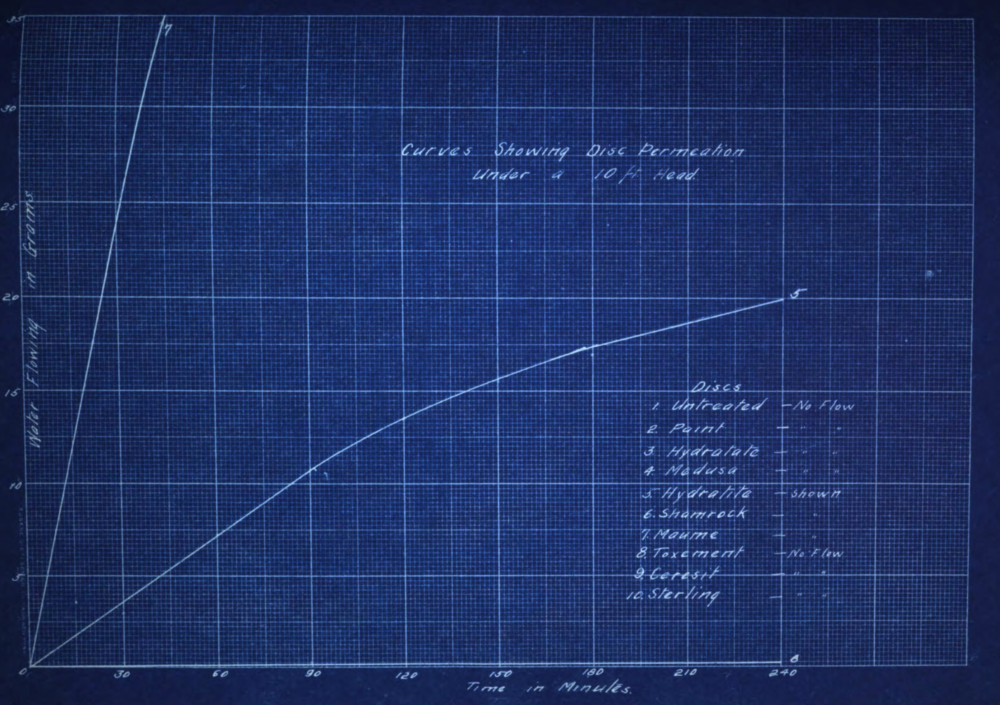
Time	10 ft. Head		20 ft. Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
150 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
180 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
210 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
240 "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PERMEATION OF CONCRETE DISCS TREATED WITH STERLING #10

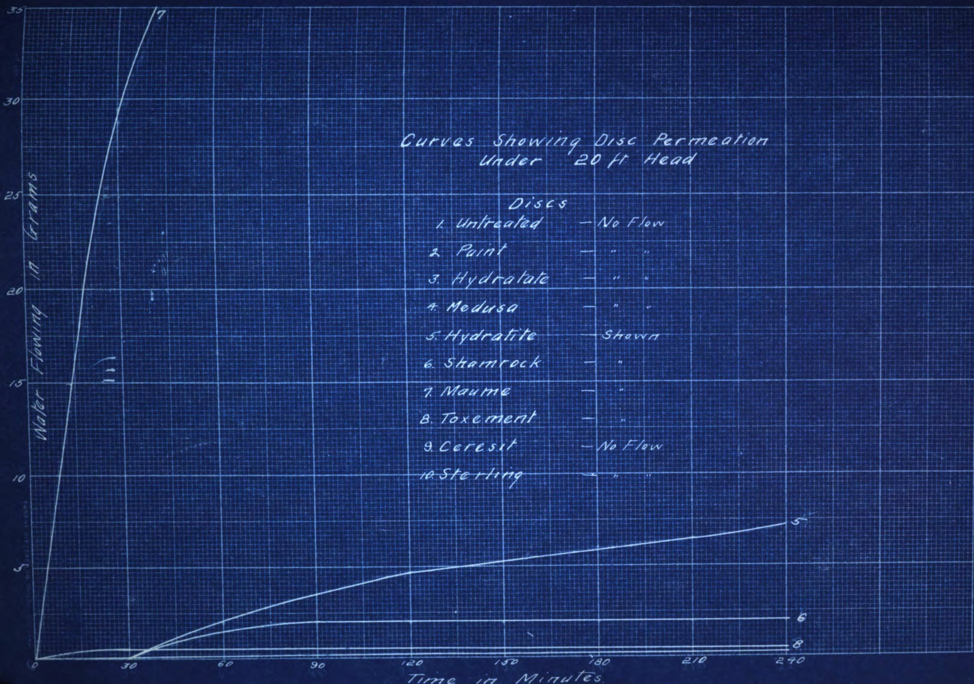
Time	10 ft. Head		20 ft. Head		30 ft. Head		40 ft. Head		50 ft. Head	
	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow	Amt. of Flow	Rate of Flow
30 min.										
60 "										
90 "										
120 "										
150 "										
180 "										
210 "										
240 "										

BREAKING LOADS OF TREATED CONCRETE SPECIMENS

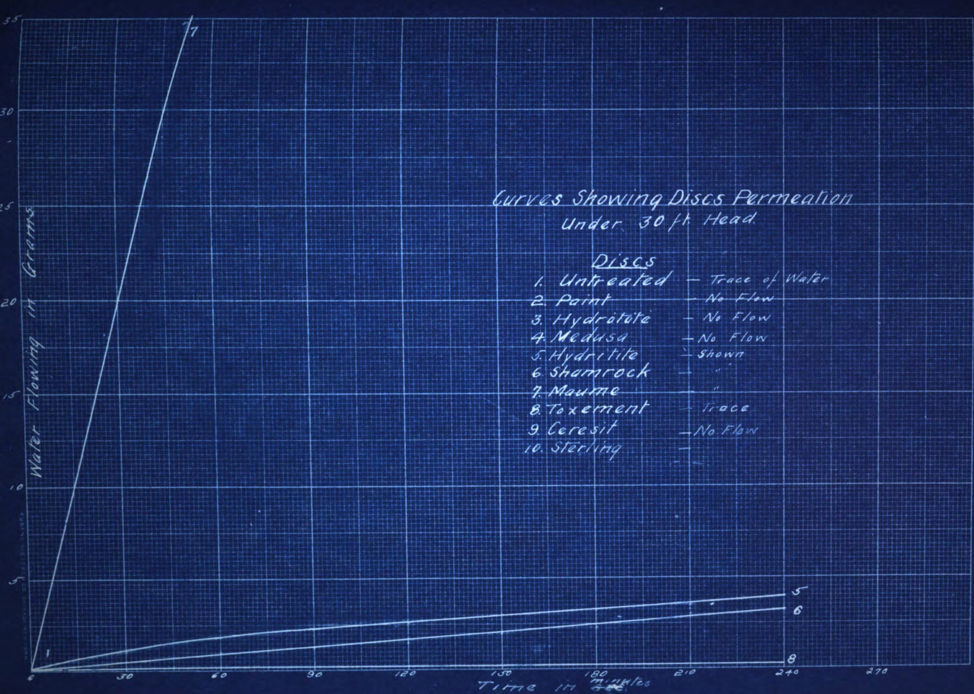
Compound Used	Compressive Strength	Tensile Strength
Untreated	1519 #/□²	224 #/□²
Paint #2	1690 # "	289 # "
Hydratate	1370 # "	164 # "
Medusa	1341 # "	200 "
Hydritite	1900 # "	256 "
Shamrock	1520 # "	287 "
Maume	1320 # "	219 "
Toxement	1970 # "	223 "
Ceresit	1840 # "	306 "
Sterling	1420 # "	209 "



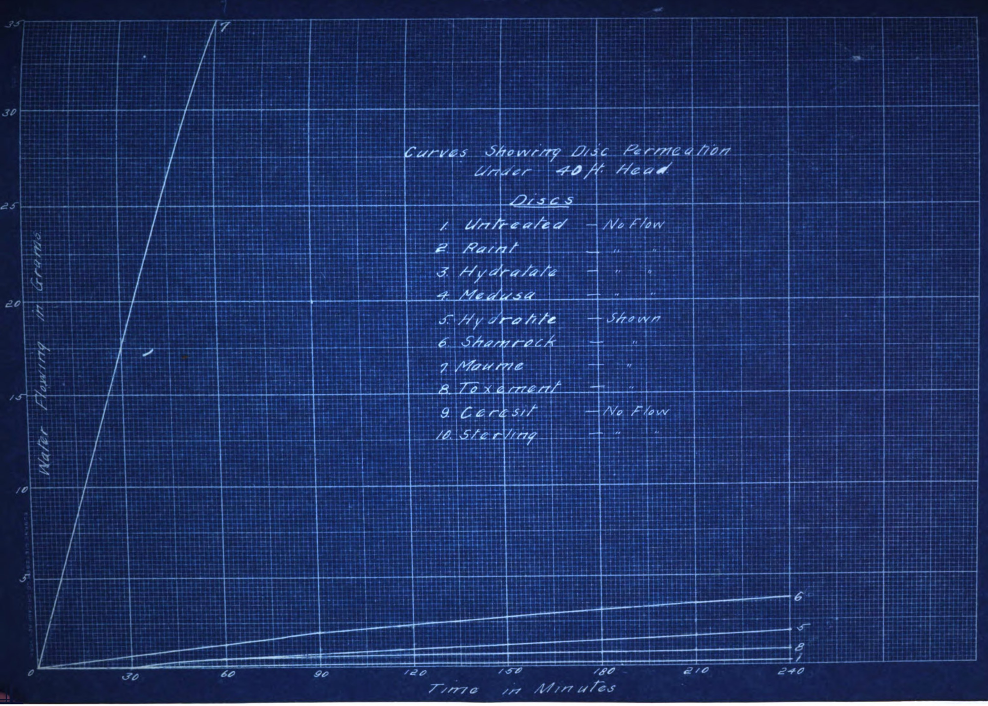
Curves Showing Disc Permeation
Under a 10 ft. Head.
Discs
1. Untreated — No Flow
2. Paint — " "
3. Hydratate — " "
4. Medusa — " "
5. Hydratite — Shown
6. Shamrock — "
7. Maume — "
8. Toxement — No Flow
9. Ceresit — " "
10. Sterling — " "
Water Flowing in Grams
Time in Minutes.
0
30
60
90
120
150
180
210
240
5
10
15
20
25
30
35
7
5
8



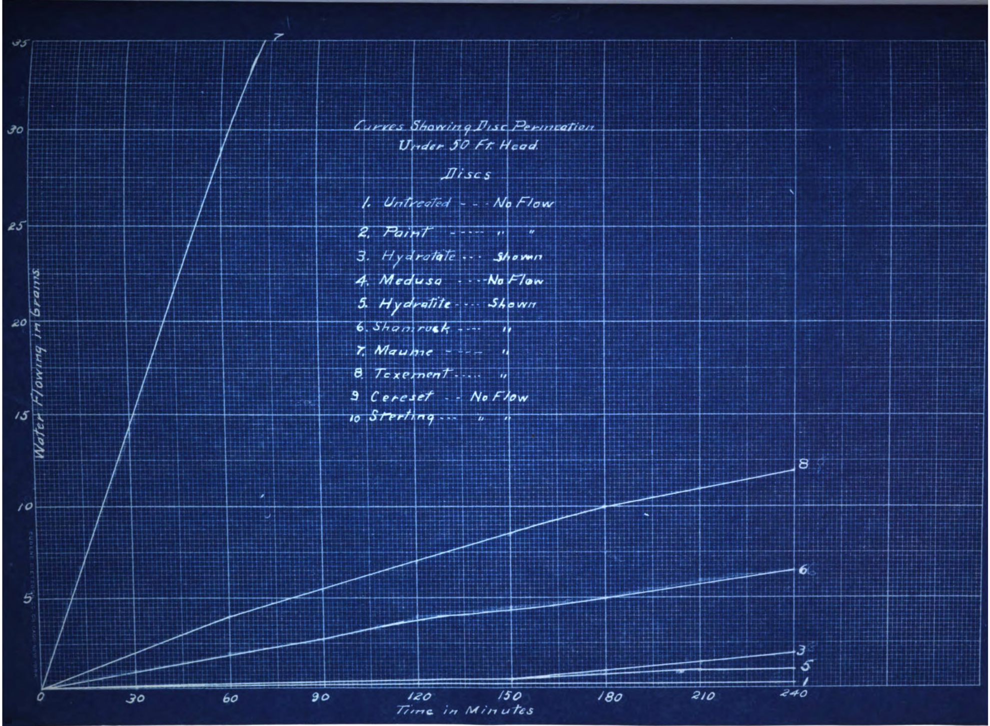
Curves Showing Disc Permeation
Under 20 ft Head
Discs
1. Untreated — No Flow
2. Paint — " "
3. Hydratate — " "
4. Medusa — " "
5. Hydratite — Shown
6. Shamrock — "
7. Maume — "
8. Toxement — "
9. Ceresit — No Flow
10. Sterling — " "
Water Flowing in Grams
Time in Minutes
0
5
10
15
20
25
30
35
30
60
90
120
150
180
210
240
7
5
6
8



Curves Showing Discs Permeation
Under 30 ft. Head
Discs
1. Untreated — Trace of Water
2. Paint — No Flow
3. Hydratite — No Flow
4. Medusa — No Flow
5. Hydritite — Shown
6. Shamrock — "
7. Maume — "
8. Toxement — Trace
9. Ceresit — No Flow
10. Sterling —
Water Flowing in Grams
Time in minutes
35
30
25
20
15
10
5
0
30
60
90
120
150
180
210
240
270
1
5
6
7
8


Curves Showing Disc Permeation
Under 40 ft. Head
Discs
1. Untreated — No Flow
2. Raint — " "
3. Hydratata — " "
4. Medusa — " "
5. Hydratite — Shown
6. Shamrock — "
7. Maume — "
8. Toxement — "
9. Ceresit — No Flow
10. Sterling — " "
Water Flowing in Grams
Time in Minutes
0
5
10
15
20
25
30
35
30
60
90
120
150
180
210
240
7
6
5
8
1


Curves Showing Disc Permeation



Curves Showing Disc Permeation
Under 50 Ft. Head
Discs
1. Untreated - - - No Flow
2. Paint - - - - " "
3. Hydratate - - - Shown
4. Medusa - - - No Flow
5. Hydratite - - - Shown
6. Shamrock - - - "
7. Maume - - - "
8. Toxement - - - "
9 Cereset - - No Flow
10 Sterling - - - " "
Water Flowing in Grains
Time in Minutes
0
30
60
90
120
150
180
210
240
5
10
15
20
25
30
35
7
8
6
3
5
1

CONCLUSIONS

V

A 1:3 concrete mixture (as described above) will not allow a measurable permeation of water under any head up to and including 50 feet of water. But water does penetrate it to such an extent as to be harmful to reinforcing, thus bearing out statements made in our introduction.

No commercial compound tested affected the compressive or tensile strength of the concrete to any appreciable extent.

The flow of water through the concrete decreased with the time, especially noticeable in the specimen containing Hydratite.

The apparatus available did not permit of using heads high enough to determine the extreme pressure at which specimens containing Paint #2, Medusa, Ceresit, and Sterling would still be effective.

Paint from the "American Asphaltum & Rubber Co."

This compound rendered the concrete impervious under heads up to and including 50 feet.

Hydratate.

This compound rendered the concrete impervious under heads up to and including 40 feet.

It may be used for foundations, etc., where the head is small and where it may be applied on the face of the wall against which the pressure comes.

Medusa

This compound rendered the concrete impervious under heads up to and including 50 feet.

This was the only powder compound tested that showed water proofing qualities.

Hydratite.

This compound proved worthless.

Shamrock

This compound proved worthless.

Maume

This compound proved worthless.

Toxement

This compound proved worthless.

Ceresit

This compound rendered the concrete water proof under heads up to and including 50 feet.

Sterling

This compound rendered the concrete impervious under heads up to and including 50 feet.

As a result of these tests we can recommend Paint #2, Medusa, Ceresit, and Sterling to produce an absolutely water-proof concrete under heads up to and including 50 feet of water.

--[illegible]--