The Water Permeability of Concrete
And Some Factors Which Affect It

By

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INTRODUCTION:

For a subject which has so great and vital a bearing on a large number of different types of engineering structures, the factors which govern the water permeability of concrete have received surprisingly little consideration, at least from a concerted research standpoint. Results of a few studies, on one or more of the factors which influence this property, have appeared in the literature, but with the exception of some work published by the Bureau of Standards in 1911, there has been no publication of results covering a complete or satisfactory study.

The importance of the water permeability of concrete has long been realized, and statements by engineers have appeared which attribute many failures and unsatisfactory conditions to this factor. The evidence seems to point to a field of application for definite (though relative) data to all classes of concrete structures.

"A permeable concrete, full of pores, voids, and passages, presents to the solvent action of water many times the surface of attack that an impermeable concrete does. With the latter there is no exposure except on the surface of contact and there can be no question as to the greatly superior endurance of such concrete. Therefore, impermeability and water tightness are qualities of prime importance in concrete hydraulic structures."[1]

"To prevent deterioration of concrete subject to water pressure and extreme low temperature, it is necessary that an impervious concrete be obtained."[2] The water content of concrete exposed to frost action has a great bearing on the life of the concrete, and hence on the life of the structure, and has resulted in at least one notable dam reconstruction.[2]

C. E. Grunsky wrote in connection with arch dam thickness: "Less thickness due to greater permeability, may render the life of a structure, and after a number of years, its safety, a factor uncertain."[3] "It may be repeated that the perviousness

1. H. F. Faulkner, "Impermeable Concrete for Permanance." Western Construction News. Dec. 1927
2. Multiple Arch Dam at Gem Lake, Fred O. Dolson. Volume 89, Transactions A. S. C. E.
3. C. E. Grunsky. Volume 100, No. 10. Engineering News Record.

of concrete will be the principle factor to be considered in this connection and, that before reaching final conclusions relating to the minimum allowable arch thickness, some experimental data with the materials which are to enter into the composition of the concrete may haveto be secured."[4]

In the field of harbor construction the factor of permeability of concrete is again of importance. In this type of structure there occurs a kind of deterioration somewhat different than in the ones before mentioned. "Much mass concrete has been placed where it is in contact with sea water, and while a great deal has stood the test, especially in Europe, a considerable number of structures have shown marked disintegration. In cases of failure, this seems to be an accompaniment of one of the Following: porous concrete, seams due to interruptions of work, and accidental rupture or abrasion of the original surface."[5] "Close investigation has shown that the failures referred to were largely, if not entirely due

4. Journal of Electricity. June 20, 1919.

5. Metropolitan Sewer Department of New York City. Report of Arthur S. Tuttle, Chief Engineer.

to defects in the concrete itself and owe their origin to the porosity of the concrete and the infiltration of sea water from the tideway, into and out of the same, if the material is porous the sea water soaks into and then drains out of it, the magnesium salts in the sea water withdraw a portion of the lime of the cement in the form of calcium salts and leave a deposit of magnesia in its place."[6] In the case of reinforced concrete structures the deterioration is caused by an increase of volume of iron oxide as against iron. The reinforcing steel is oxidized by the dissolved oxygen of the sea water. At the zone of intermittent dryness and wetness this action is accelerated because there is a constant supply of oxygen due to intermittent inflow and outflow of the oxygen bearing sea water. It is obvious, therefore, that with a relatively impervious concrete this action will be decelerated to a minimum.

The deterioration of concrete sewers and sewage disposal structures may also, in part, be attributed to the perviousness of the concrete. "Hydrogen sulfid is formed both by bacterial decomposition of sulphur containing proteins and related compounds and by the reduction of the sulphates from the water

6. Proceedings of the Institute of Civil Engineers, 1920. Report on Deterioration of Structures in Sea Water.

supply. They found that the escaping hydrogen sulfid which is dissolved by the moisture on the walls above the sewage, is oxidized, not alone by the air, but also by bacterial action. Examinations of septic tanks show that a soluble sulphur (SO_4) content in the raw sewage equal to 427 parts per million was sufficient to produce disintegration in a concrete closing chamber."[7] The amount of deterioration depends directly upon the depth to which the sulphuric acid permeates.

The purpose of this study was to relate the laws governing the permeability of concrete to the accepted practice in proportioning concrete and to evaluate the importance of some of the factors which affect its permeability. This has been accomplished in a realative way only.

EXPERIMENTAL PROCEDURE:

It was necessary, first of all, to select a type of apparatus to be used. Most of those used by investigators in this country were reviewed. The apparatus used by Professor M. O. Withey[8] of the University of Wisconsin was not used because of the difficulty and expense of preparing specimens and

7. Barr and Buchanan--Bulletin 26, Iowa State College.

8. Permeability of Broken Stone Concrete by M. O. Withey, Bulletin of the University of Wisconsin.

because this apparatus measures the water entering the specimen, and therefore is not a true measure of the permeability. The apparatus used by the Bureau of Standards which is, in many ways, similar to the one used by the Los Angeles Harbor Commission, Mr. Evald Anderson in his study on the "Relation between Water Permeability and Water Absorption,"[8] and the one described in the Tentative Standards of the American Society for Testing Materials,[9] has the difficulty that it is impossible to get accurate readings when small volumes of water are passed, and in the latter three cases there is no assurance that the water will pass directly through the concrete.

Accordingly an apparatus was designed with a view of overcoming the difficulties and imperfections apparent in the apparatus reviewed.

As first assembled, the apparatus consisted of two short pieces of six inch pipe which were capped at one end, the other end being fitted with a standard pipe flange. The specimen, which was cast in a welded galvanized iron collar, eight and one-fourth inches in diameter and two and one half inches high, was bolted,

8. Relation between the Water Permeability of Concrete and Absorption, by Evald Anderson, Industrial Engineering Chemistry, Vol. 18, 1926

9. American Society of Testing Material, Standards, 1920, page 693.

with two thin rubber gaskets, between the flanges. The compartments on either side of the concrete diaphragm were filled with water. Compressed air was introduced above the water on one side and a flexible tube connected the other compartment with a burette which was partially filled with water at the beginning of the test. Pressure was applied until the water was forced through the specimen. It will be seen that any passage of water from the pressure side through the concrete must displace an equal amount of water on the receiving side, and cause a rise in level of the water in the burette. The volume of water measured in the burette together with the time required for the passage of this volume of water determined the rate of permeability.

Leakage occurred between the specimen and the gaskets because the gaskets were too thin to permit a good seating of the concrete. Thick gaskets were tried but these blew out after several tests due to overstressing. After a compromise was struck between leakage and blow-outs, results of a fairly satisfactory nature were obtained. These results, which embody most of the first year's work, are of use in a qualitative way only, and have been used only as such in this study.

With a view of obtaining the advantages of the thick gasket, together with greater simplicity, accuracy, and flexibility of operation, plans were drawn for a new apparatus. Patterns were made from which the upper and lower compartments were cast. In this apparatus, as shown in Figure 1, the first inset was cast in the flange to provide lateral support for the thick gaskets. It was planned to use the apparatus in connection with a reserve water tank, so that it was possible to reduce the size of the second inset compartment on the pressure side. Special gaskets were made by the E. M. Smith Company, and a new compressor, furnished by the E. B. Lacer Company of Los Angeles, equipped with a diaphragm pressure regulator valve, was used to deliver air at any desired pressure up to two hundred pounds per square inch. The old apparatus was assembled as a reserve water tank. Quarter inch copper tubing equipped with standard automobile gasoline line fittings were used to connect the compressor to the reserve water tank, and a similar line was run from the lower part of the reserve water tank to the pressure compartment of the apparatus proper. A pressure gauge syphon was placed in the top of the pressure side. The receiving side was fitted with two short copper tubes, one of which was fitted with a valve used to permit the filling of

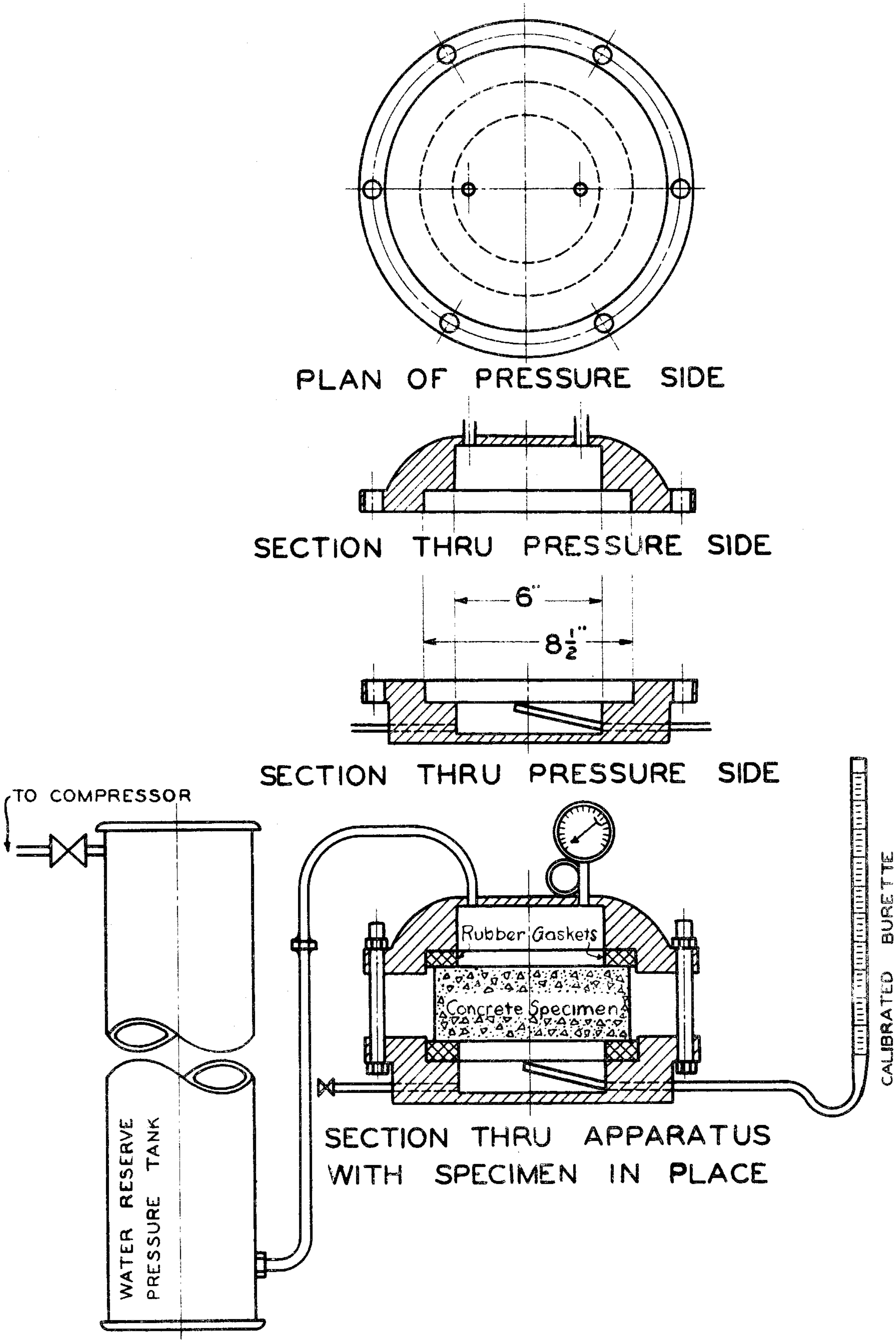
PLAN OF PRESSURE SIDE
SECTION THRU PRESSURE SIDE
6"
8 1/2"
SECTION THRU PRESSURE SIDE
TO COMPRESSOR
Rubber Gaskets
Concrete Specimen
CALIBRATED BURETTE
WATER RESERVE PRESSURE TANK
SECTION THRU APPARATUS WITH SPECIMEN IN PLACE

FIG. I

the receiving side with water. The second tube was connected to the burette.

The principal involved in the second apparatus was identical with that of the first. All of the difficulties encountered with the first model were overcome in the second and it was possible to devote most of the available time to actual test runs, rather than to adjustments and tuning up. After trying various gasket forming pastes, it was found that a well surfaced specimen, ground flush with the iron collar, gave only occasional leakage. Coarse carborundum was used for grinding. It was also found that it was necessary to chip all the laitance and surface skin from both surfaces, in order to obtain uniform results from identical specimens. The surface skin is a variable quantity even with identical specimens and affords an effective water seal.

The method used to evaluate the factors which affect the permeability of concrete, was to keep constant all the factors except the one being investigated. The major portion of the experimental work was done to determine the effect of the water cement ratio and the cement aggregate ratio, so that in this work the factors of curing, pressure applied, and thickness were kept constant. These specimens were cured under water which was stored in a room the temperature of which was kept within two degrees of seventy degrees Farhenheit. The pressure supplied from the compressor was kept within two pounds of eighty pounds per square inch. The thickness standardized on was three inches, because this thickness gave measurable values of the permeability in reasonable periods of time, and because it was four times the size of the largest aggregate. The results obtained with this thickness were more consistent than those obtained with the two and one-half inch specimens.

A Fuller Curve mix was used throughout all of the tests. The aggregate was separated into its component sizes with standard screens and recombined according to the Fuller Curve to produce an aggregate of maximum density. Riverside cement was used throughout. All measurements of the air dryed aggregate were made by weight. Separate batches were weighed out and made up for each specimen.

Groups A, B, C, and D comprised the tests run during the year 1926-1927, and the results of these tests are presented here in a descriptive way only. The first two groups were practically worthless, for much of the time during the periods of tests was spent in adjustment and elimination of leakage.

The tests on the specimens of Group E, Series I were made to determine the effect of the water cement ratio on a 1:5 Fuller Curve mix. The conditions of curing, pressure applied, and thickness of specimen were, respectively: water cured, eighty pounds per square inch, and three inches.

The conditions of test for Group E, Series II and III were identical with the above except that 1:4 and 1:6 Fuller Curve mixes, respectively, were used.

In Series IV of Group E, the effect of curing was determined on specimens identical with those of Group E, Series I, having a water cement ratio of 1.2:1.0. The conditions of curing to which these specimens were subjected were water curing (control), damp sand curing, and air curing.

The specimens of Group E, Series V were identical with those of Group IV except that in this case the specimens were cast in collars of various heights. Three, six, nine, and twelve inch heights were used. Water curing and eighty pounds applied pressure were used throughout.

Group E, Series VI comprises tests at various applied pressures on three inch water cured specimens selected from Groups I, II, and III. No additional specimens were made, and the separate designation is for various applied pressures from those of the constant pressure of the first three groups.

EXPERIMENTAL RESULTS:

Individual observations, or even average observations on single specimens, showed a considerable variation with identical specimens. It was found, that in most cases, by a careful control of experimental procedure, that it was possible to maintain the percentage error within the limits necessary to demonstrate the effect of the variation of a single factor. The average variation between identical specimens was usually small as compared with the average variation between different specimens.

One of the first things discovered was that the permeability of a concrete specimen was greatly reduced by the surface laitance or skin. Attempts to evaluate the effect of this skin as a percentage or function of the actual permeability were unsuccessful. The results seem to indicate, however, that the value of the permeability of concretes tested with the surface laitance intact was about two to five percent that of the same specimen tested with the surface laitance removed. The failure to evaluate this factor in no way affected the other results for the reason that in all tests the surface skin was carefully removed.

The results of the experiments on the specimens in Groups I, II, and III will be discussed collectively because these experiments were conducted for direct comparison. From Plates I, II, and III it is readily seen that the rate of water permeability of concrete decreases rapidly as the water cement ratio decreases, to a point where the value of the water cement ratio is approximately .65 to .80 parts of water to 1.0 part of cement, by volume. In the mixes which are drier than those indicated above, the rate of water permeability increases very rapidly. In other words the rate of water permeability follows the trend of the law[10] of proportioning for strength according to the water cement ratio theory, except for the drier mixes.

Plate IV shows the rate of permeability of specimens having identical water cement ratios but with different cement aggregate ratios. It is not probable that the mix having a cement to aggregate ratio of 1:5 is the absolute optimum of water impermeability. The curves do indicate, however, that the effect of the cement aggregate ratio is important and that, for a constant water cement ratio it is possible to use too much cement. It is inferred that with a

10 Portland Cement Association.

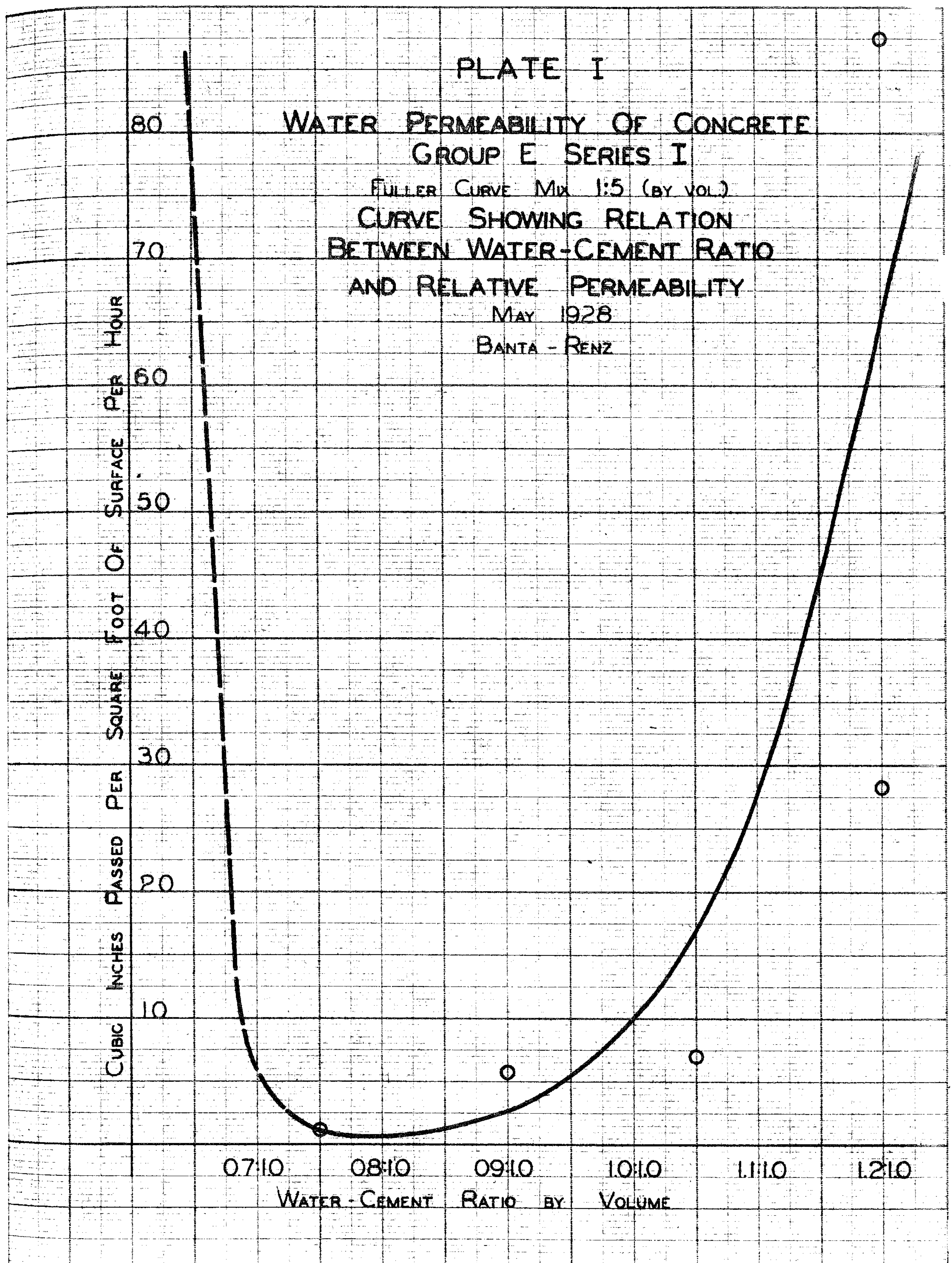
PLATE I
WATER PERMEABILITY OF CONCRETE
GROUP E SERIES I
FULLER CURVE MIX 1:5 (BY VOL.)
CURVE SHOWING RELATION
BETWEEN WATER-CEMENT RATIO
AND RELATIVE PERMEABILITY
MAY 1928
BANTA - RENZ
CUBIC INCHES PASSED PER SQUARE FOOT OF SURFACE PER HOUR
80
70
60
50
40
30
20
10
0.7:1.0
0.8:1.0
0.9:1.0
1.0:1.0
1.1:1.0
1.2:1.0
WATER-CEMENT RATIO BY VOLUME

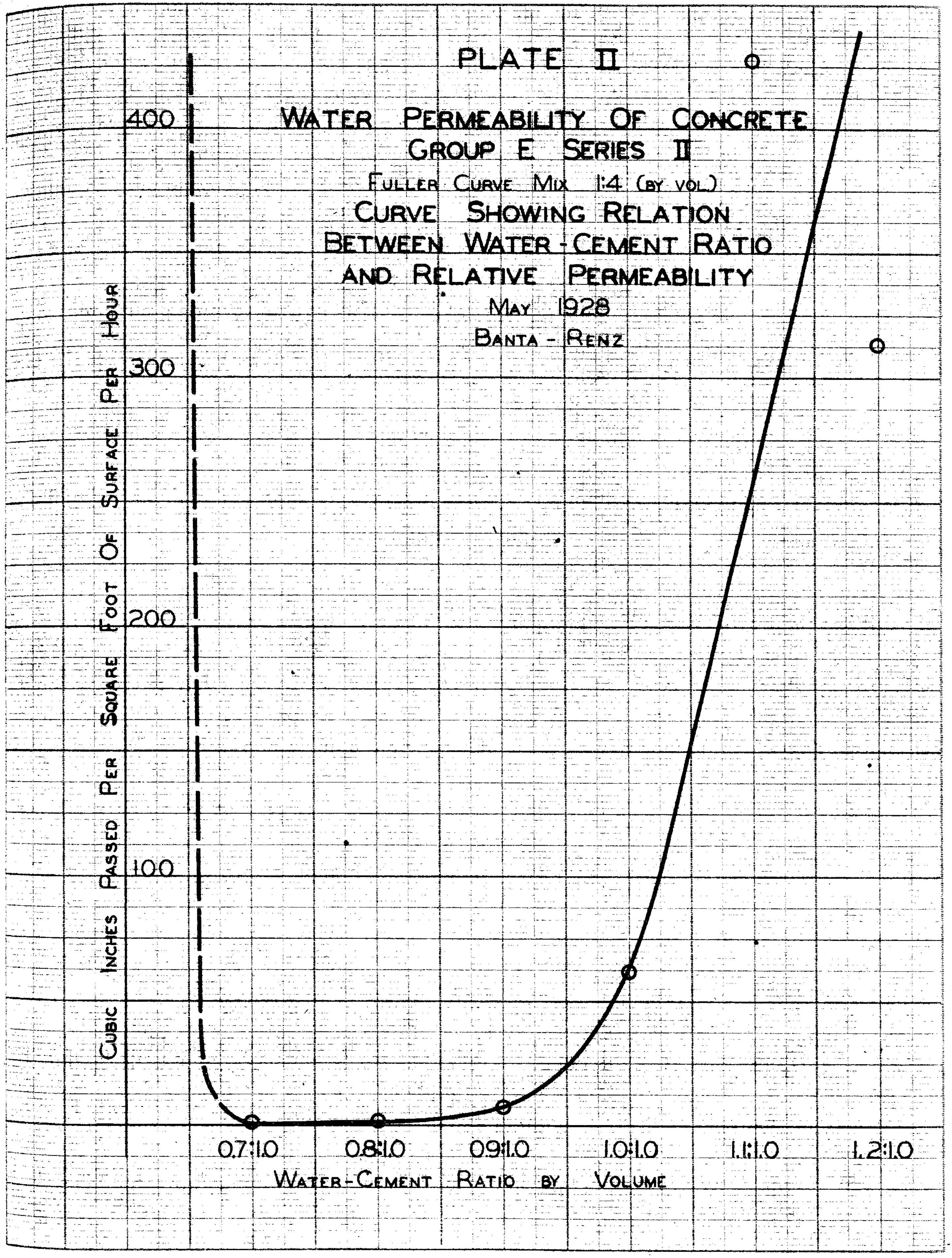
PLATE II
WATER PERMEABILITY OF CONCRETE
GROUP E SERIES II
FULLER CURVE MIX 1:4 (BY VOL.)
CURVE SHOWING RELATION
BETWEEN WATER-CEMENT RATIO
AND RELATIVE PERMEABILITY
MAY 1928
BANTA - RENZ
400
300
200
100
CUBIC INCHES PASSED PER SQUARE FOOT OF SURFACE PER HOUR
0.7:1.0
0.8:1.0
0.9:1.0
1.0:1.0
1.1:1.0
1.2:1.0
WATER-CEMENT RATIO BY VOLUME

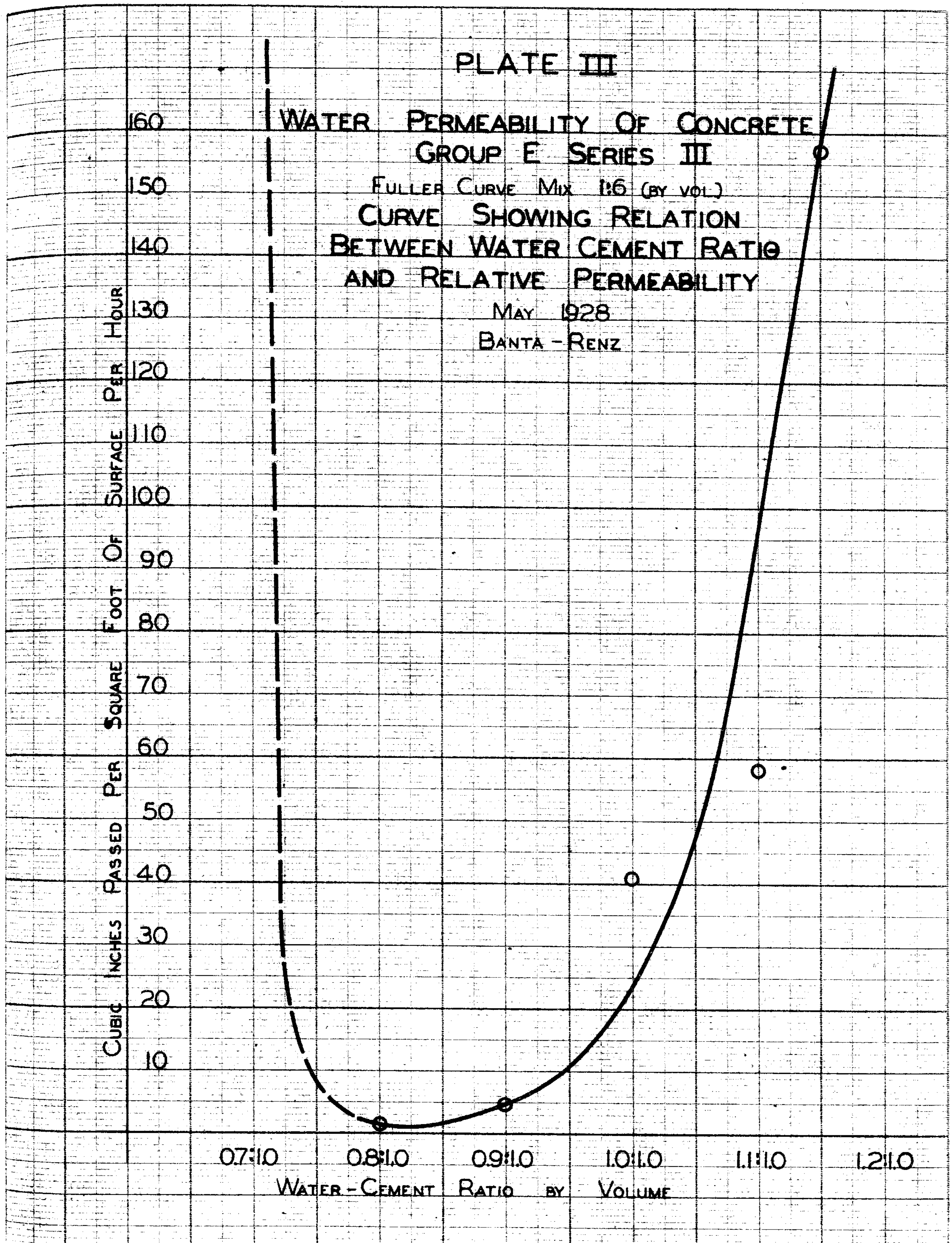

PLATE III
WATER PERMEABILITY OF CONCRETE
GROUP E SERIES III
FULLER CURVE MIX 1:6 (BY VOL.)
CURVE SHOWING RELATION BETWEEN WATER CEMENT RATIO AND RELATIVE PERMEABILITY
MAY 1928
BANTA - RENZ
CUBIC INCHES PASSED PER SQUARE FOOT OF SURFACE PER HOUR
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0.7:1.0
0.8:1.0
0.9:1.0
1.0:1.0
1.1:1.0
1.2:1.0
WATER - CEMENT RATIO BY VOLUME

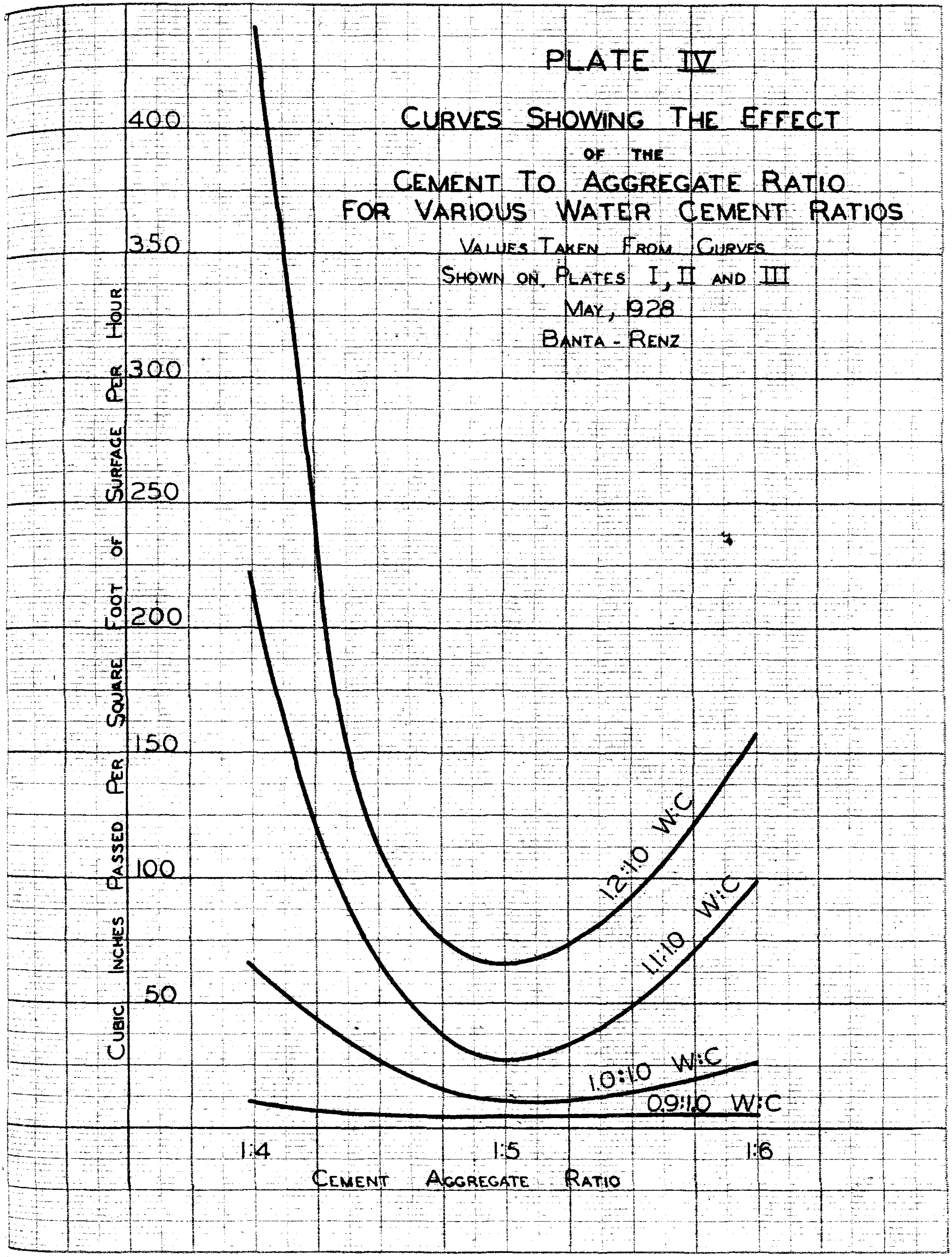
PLATE IV
CURVES SHOWING THE EFFECT
OF THE
CEMENT TO AGGREGATE RATIO
FOR VARIOUS WATER CEMENT RATIOS
VALUES TAKEN FROM CURVES
SHOWN ON PLATES I, II AND III
MAY, 1928
BANTA - RENZ
CUBIC INCHES PASSED PER SQUARE FOOT OF SURFACE PER HOUR
400
350
300
250
200
150
100
50
1.2:1.0 W:C
1.1:1.0 W:C
1.0:1.0 W:C
0.9:1.0 W:C
1:4
1:5
1:6
CEMENT AGGREGATE RATIO

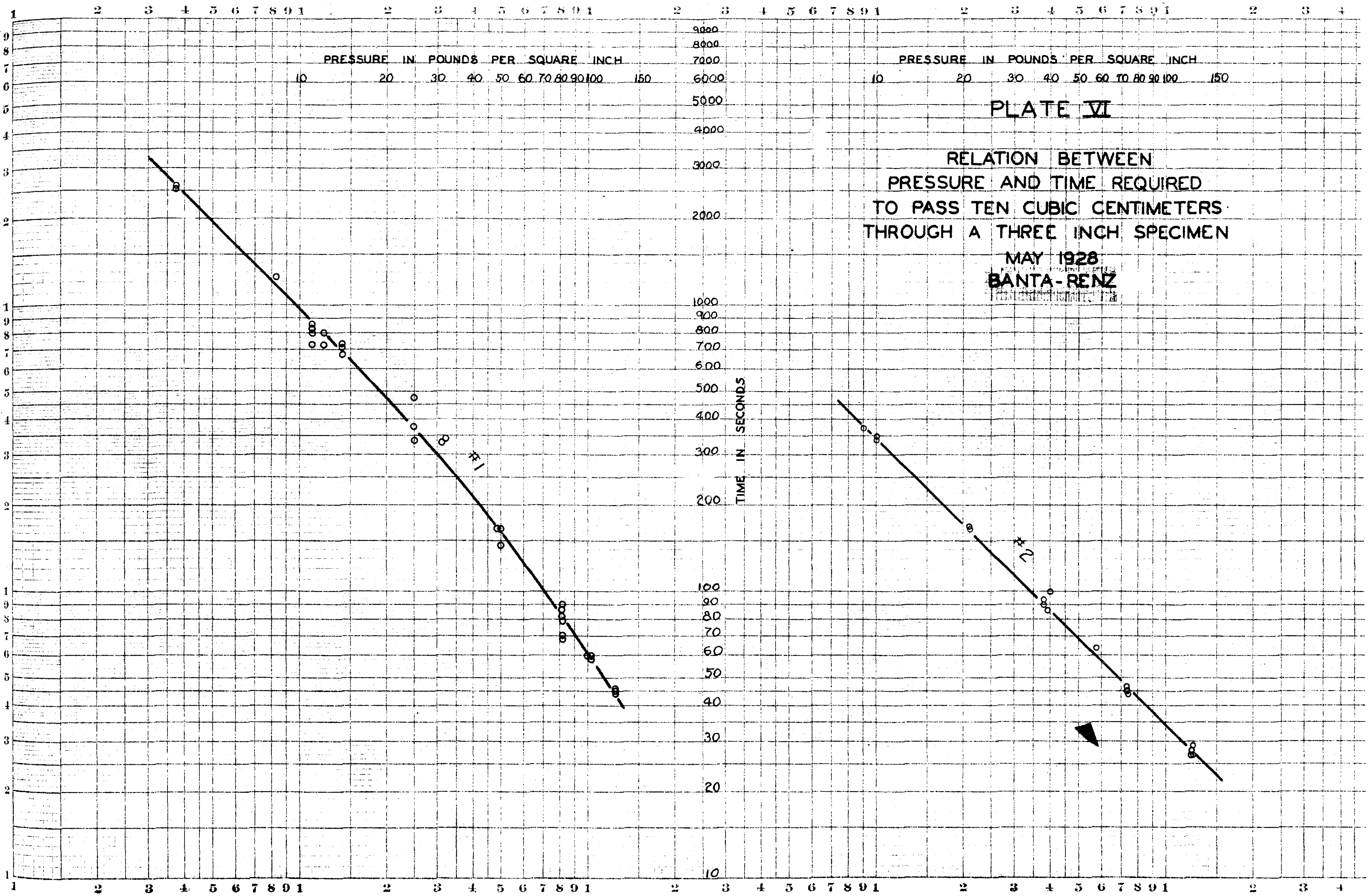
PLATE VI
RELATION BETWEEN
PRESSURE AND TIME REQUIRED
TO PASS TEN CUBIC CENTIMETERS
THROUGH A THREE INCH SPECIMEN
MAY 1928
BANTA-RENZ
PRESSURE IN POUNDS PER SQUARE INCH
10 20 30 40 50 60 70 80 90 100 150
PRESSURE IN POUNDS PER SQUARE INCH
10 20 30 40 50 60 70 80 90 100 150
TIME IN SECONDS
9000 8000 7000 6000 5000 4000 3000 2000 1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10
#1
#2

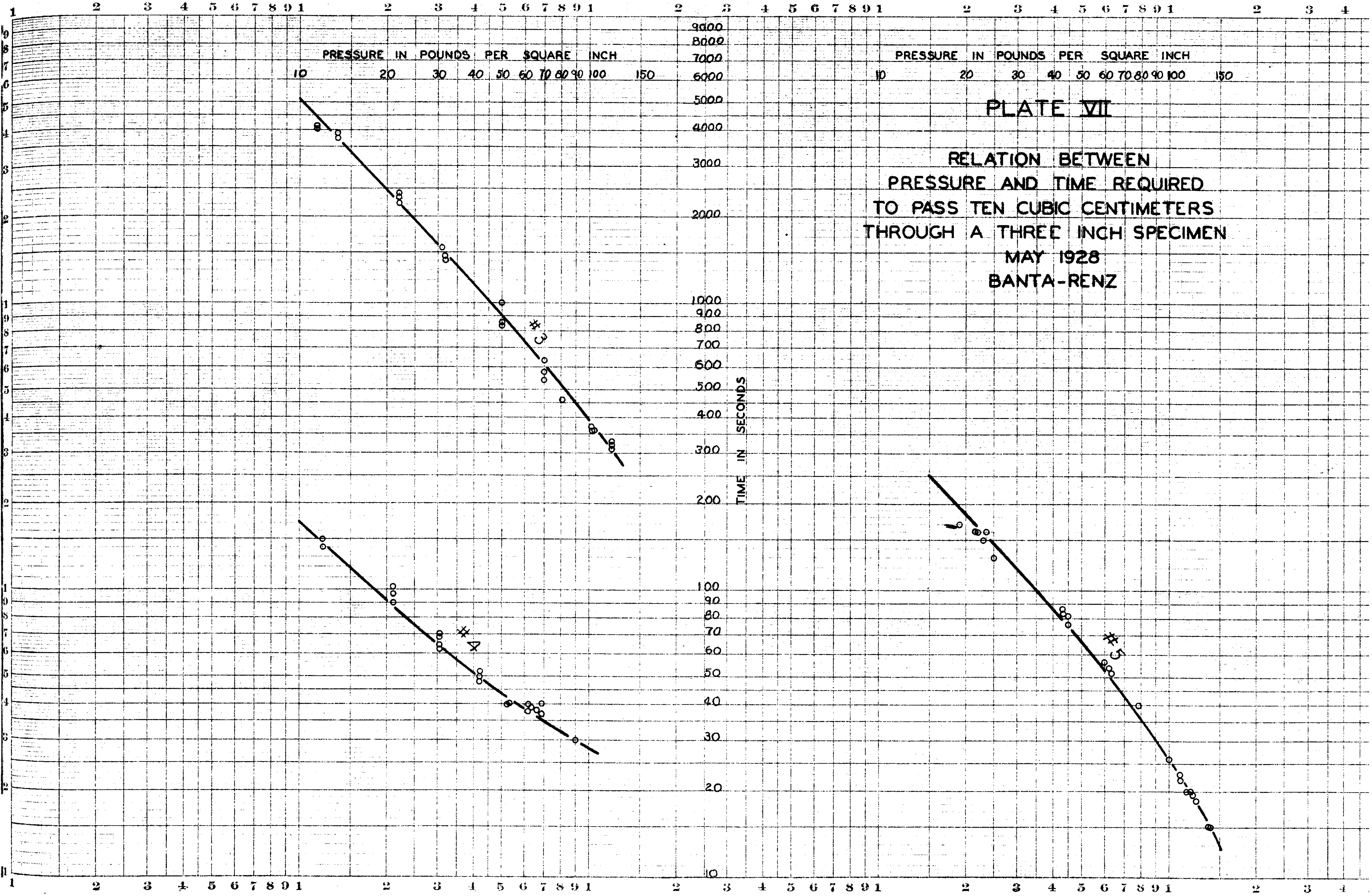
PLATE VII
RELATION BETWEEN
PRESSURE AND TIME REQUIRED
TO PASS TEN CUBIC CENTIMETERS
THROUGH A THREE INCH SPECIMEN
MAY 1928
BANTA-RENZ
PRESSURE IN POUNDS PER SQUARE INCH
10
20
30
40
50
60
70
80
90
100
150
TIME IN SECONDS
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
#3
#4
#5

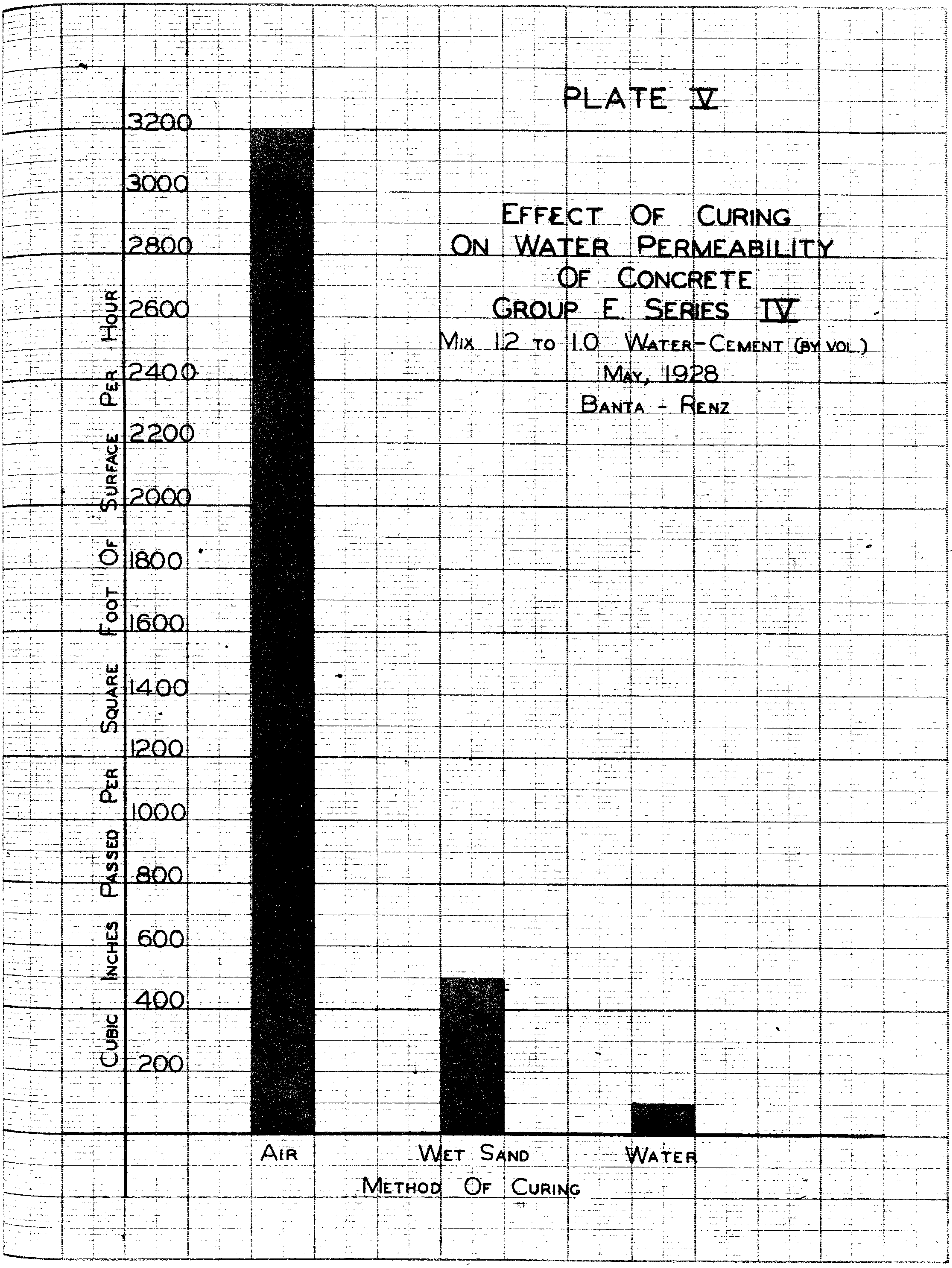
PLATE V
EFFECT OF CURING
ON WATER PERMEABILITY
OF CONCRETE
GROUP E. SERIES IV
MIX 12 TO 1.0 WATER-CEMENT (BY VOL.)
MAY, 1928
BANTA - RENZ
CUBIC INCHES PASSED PER SQUARE FOOT OF SURFACE PER HOUR
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
AIR
WET SAND
WATER
METHOD OF CURING

are the time in seconds and the pressure required to pass ten cubic centimeters of water through various specimens selected at random from the first four groups of Series E. The true logarithimic scale was used in plotting these data that the equation of the time and pressure relation could be evaluated. The equations so derived are:

Curve Number		
1	$t = \frac{10,000}{P} - 40$	(a)
2	$t = \frac{3,450}{P}$	(b)
3	$t = \frac{52,000}{P} - 130$	(c)
4	$t = \frac{1,600}{P} + 12$	(d)
5	$t = \frac{4,000}{P} - 14$	(e)

Changing these equations over to the form R = (f)p where R equals the rate of permeability in cubic inches passed per square foot per hour, the equations are:

Curve Number

1 $$R = \frac{1}{\frac{.8965}{P} - .003585} \qquad (f)$$

2 $$R = \frac{1}{\frac{.3095}{P}} \qquad (g)$$

3 $$R = \frac{1}{\frac{4.665}{P} - .01165} \qquad (h)$$

4 $$R = \frac{1}{\frac{.1434}{P} + .001077} \qquad (i)$$

5 $$R = \frac{1}{\frac{.3585}{P} - .001259} \qquad (j)$$

The rate of permeability is a function of the first power of the pressure plus or minus a constant. Considering the equation in the general form:

$$R = \frac{1}{\frac{K}{P} \pm C}$$

It appears that for values of K less than .3095 the constant C is added and for values of K greater than .3095 the constant C is subtracted. The magnitude of the constant C seems also to bear a direct relation to the magnitude of the constant K. Other than the relation between the constants there appears to be nothing systematic about the variation of the rate of permeability with variations in the pressure applied. It is probable then, that the variation is purely an hydraulic phenomena and might readily be evaluated as a function of the permeability at a predetermined pressure. The experiments along this line conducted in this study are not sufficiently exhaustive to evaluate such a relation.

The conclusions to be drawn from the experiments of Group E, Series VI are not of a quantitative nature. The rate of permeability is not a first power function of thickness, at least in the ranges under test. The rates were small for the thicker specimens increasing to large values for the three inch specimens.

CONCLUSIONS:

1. The surface laitance or skin is a relatively effective water seal.

2. Mixes having water cement ratios from .70 to .80 parts of water to 1.0 part of cement, by volume, have the lowest water permeability rates.

3. The mixes having water cement ratios less than .65 to .75 parts of water to 1.0 part of cement have very large water permeability rates.

4. For a given water cement ratio too much as well as too little cement increases the water permeability rate.

5. The rate of the water permeability of concrete may be expressed as a function of the first power of the pressure applied, plus or minus a constant.

6. The variation of the rate of permeability with the variation in pressure is an hydraulic phenomena and, for a given specimen, is independant of the character of the concrete.

7. The rate of permeability of concrete does not vary directly with the thickness within the limits investigated in this study.

8. Water curing results in a lower rate of water permeability than either damp sand curing or air curing.

9. The method of curing is the most important factor in determining the rate of permeability.

Group E

Series 1

Fuller Curve Mix 1:5 by weight

Size	Percent Passing Sieve	Percent Retained	Amounts per specimen lbs.
.75	100	0	0
.38	65	35	5.6
.185	46	19	3.04
.093	37.3	8.8	1.41
.046	31.5	5.9	0.95
.023	25.7	5.9	0.95
.0116	20.8	4.9	0.78
.0058	16.9	3.7	0.59
cement		16.7	2.67
		99.9	15.99

Water Cement Ratio

Specimen	Volume Ratio	Weight Ratio	Weight in lbs. per specimen Water	Cement	Number made
1a	.6/1	.398/1	1.063	2.67	2
1b	.75/1	.498/1	1.330	2.67	2
1c	.9/1	.596/1	1.591	2.67	2
1d	1.05/1	.697/1	1.861	2.67	2
1e	1.2/1	.797/1	2.128	2.67	2

Note: All specimens were water cured for twenty-eight days before testing.

Group E

Series 1

Specimen 1 a Numbers 1 and 2 passed unmeasurable amounts of water at low pressures. Tested 11/19/27

Specimen 1 b. No 1. Tested 11/23/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading C.C.	Amount c.c.	Amount cu.in.
9:15		80	96.5		
9:25	10	80	95.8	0.7	.043
9:35	10	80	95.3	0.5	.031
9:45	10	80	94.7	0.6	.037
			Average		.037

Average cubic inches passed per specimen per hour 0.222
Average cubic inches passed per square foot of exposed surface per hour 1.13

Specimen 1 b. No. 2. Tested 11/23/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
10:18		80	64.9		
10:28	10	80	63.9	1.0	(.061)
10:38	10	80	63.5	.4	.024
10:48	10	80	62.9	.6	.037
10:58	10	80	62.4	.5	.031
			Average		.031

Average cubic inches passed per specimen per hour 0.186
Average cubic inches passed per square foot of exposed surface per hour 0.945

Group E

Series 1

Specimen 1 c. Number 1. Tested 11/14/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
8:40		80	87.0		
8:55	15	80	82.9	4.1	0.25
9:10	15	80	78.5	4.9	0.27
9:25	15	80	74.9	3.6	0.22
9:40	15	80	70.9	4.0	0.29
			Average		.245

Average cubic inches passed per specimen per hour .98
Average cubic inches passed per square foot of exposed surface per hour 4.98

Specimen 1 c. Number 2. Tested 11/24/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
6:48		80	86.5		
7:03	15	80	84.8	1.7	
7:22	19	80	79.0	5.8	0.35
7:37	15	80	73.5	5.5	0.33
7:56	19	80	63.1	9.6	Leak
			Average (for 15 min)		0.31

Average cubic inches passed per specimen per hour 1.24
Average cubic inches passed per square foot of exposed surface per hour 6.30

Group E

Series 1.

Specimen 1 d. Number 1. Tested 12/3/27

Time hr:min.	ΔTime min.	Pressure lbs. sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
11:15		80	89.6		
11:25	10	82	88.0	1.6	(0.097)
11:35	10	84	84.3	3.7	0.23
11:45	10	86	79.7	4.6	0.28
11:55	10	88	74.7	5.0	0.31
				Average	0.27

Average cubic inches passed per specimen per hour 1.62
Average cubic inches passed per square foot of exposed surface per hour 8.23

Specimen 1 d. Number 2. Tested 12/5/27

Time hr:min.	ΔTime min.	Pressure lbs. sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
8:27		75	97.1		
8:37	10	75	96.0	1.1	(0.067)
8:47	10	78	94.3	1.7	0.103
8:57	10	80	91.1	3.2	0.195
9:07	10	80	87.1	4.0	0.244
			Average		0.181

Average cubic inches passed per specimen per hour 1.086
Average cubic inches passed per square foot of exposed surface per hour 5.51

Group E

Series 1

Specimen 1 e. Number 1. Tested 11/23/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
7:10		80	85.5		
7:20	10	80	79.7	5.8	.35
7:30	10	80	77.8	1.9	.12
7:40	10	80	74.1	3.7	.23
7:50	10	80	70.5	3.6	.22
			Average		.23

Average cubic inches passed per specimen per hour 1.38
Average cubic inches passed per square foot of exposed surface per hour 7.01

Specimen 1 e. Number 2. Tested 11/23/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
9:25		80	94.3		
9:35	10	80	76.0	18.3	1.12
9:45	10	80	44.0	32.0	1.95
9:55	10	80	13.5	30.5	1.86
10:05	10	80	-11.7	25.2	1.55
				Average	1.62

Average cubic inches passed per specimen per hour 9.72
Average cubic inches passed per square foot of exposed surface per hour 49.38

Date for Graphical Treatment

Group E   Series I

1:5 Fuller Curve Mix

Specimen	Water Cement Ratio By Vol.	Cubic Inches Passed per square foot of surface per hour.	Average cubic inches passed per square foot of surface per hour.
1a-1	.6/1	Not measurable	Not measurable
1a-2	.6/1		
1b-1	.75/1	1.13	
1b-2	.75/1	0.945	1.037
1c-1	.9/1	4.98	
1c-2	.9/1	6.30	5.64
1d-1	1.05/1	8.23	
1d-2	1.05/1	5.51	6.87
1e-1	1.2/1	7.01	
1e-2	1.2/1	49.38	28.20

Group E

Series II

Fuller Curve mix 1:4 by weight

Size	Percent Passing Sieves	Percent Retained	Amounts per specimen lbs.
.75	100.0	0	0
.38	65.0	35	5.6
.185	46.0	19	3.04
.093	37.4	8.6	1.38
.046	31.3	6.1	.98
.023	26.5	4.8	.77
.0116	22.8	3.7	.59
.0058	20.0	2.8	.44
Cement		20.0	3.20
		100.0	16.0

Water Cement Ratios

Specimen	Volume Ratio	Weight Ratio	Weight in lbs. per specimen Water	Cement	Number made
2a	.7/1	.465/1	1.49	3.2	2
2b	.8/1	.531/1	1.7	3.2	2
2c	.9/1	.597/1	1.91	3.2	2
2d	1.0/1	.715/1	2.29	3.2	2
2e	1.1/1	.731/1	2.34	3.2	2
2f	1.2/1	.797/1	2.55	3.2	2

Note: All specimens were water cured for twenty-eight days before testing.

Group E
Series II

Specimen 2 a. Number 1. Tested 12/21/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
10:05		78	92.3		
10:25	20	78	92.1	0.2	.012
10:45	20	78	92.1	0.0	.000
11:05	20	78	92.0	0.1	.006
				Average	.006

Average cubic inches passed per specimen per hour .018
Average cubic inches passed per square foot of exposed surface per hour .091

Specimen 2 a. Number 2. Tested 12/21/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
11:50		78	95.3		
12:10	20	78	94.9	0.4	.024
12:30	20	80	94.8	.1	.006
12:50	20	80	94.7	.1	.006
				Average	.012

Average cubic inches passed per specimen per hour .036
Average cubic inches passed per square foot of exposed surface per hour .182

Group E
Series II

Specimen 2 b. Number 1. Tested 12/21/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
1:00		80	90.6		
1:15	15	78	90.3	.3	.018
1:30	15	78	90.1	.2	.012
1:45	15	78	90.0	.1	.006
				Average	.012

Average cubic inches passed per specimen per hour .048
Average cubic inches passed per square foot of exposed surface per hour .244

Specimen 2 b. Number 2. Tested 12/21/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
2:40		78	91.1		
2:55	15	85	89.9	0.2	.012
3:10	15	80	89.8	0.1	.006
3:25	15	82	89.5	0.3	.018
3:40	15	78	89.4	0.1	.006
				Average	.0102

Average cubic inches passed per specimen per hour .0408
Average cubic inches passed per square foot of exposed surface per hour .2076

Group E
Series II

Specimen 2 c. Number 1. Tested 12/28/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
7:11		79	86.6		
7:21	10	76	83.7	2.9	.177
7:31	10	82	79.9	3.8	.232
7:41	10	80	74.8	5.1	.312
7:51	10	80	69.0	5.8	.354
				Average	.215

Average cubic inches passed per specimen per hour 1.290
Average cubic inches passed per square foot of exposed surface per hour 6.56

Specimen 2 c. Number 2. Tested 12/28/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
8:25		79	86.7		
8:35	10	79	81.4	5.3	.324
8:45	10	79	76.0	5.4	.330
8:55	10	80	70.5	5.5	.335
9:05	10	79	65.0	5.5	.335
				Average	.331

Average cubic inches passed per specimen per hour 1.98_6
Average cubic inches passed per square foot of exposed surface per hour 10.100

Group E
Series II

Specimen 2 d. Number 1. Tested 12/28/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
9:29		80	100.0		
9:39	10	80	(100.) 33.5	61.5	3.76
9:49	10	80	(100.) 34.9	65.1	3.97
9:59	10	80	37.0	63.0	3.85
				Average	3.86

Average cubic inches passed per specimen per hour 23.16
Average cubic inches passed per square foot of exposed surface per hour 117.5

Specimen 2 d. Number 2. Tested 12/28/27

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
4:38		80	90.6		
4:48	10	79	85.8	4.8	.294
4:58	10	77	79.9	5.9	.360
5:08	10	75	76.7	3.2	.195
5:18	10	73	72.0	3.8	.232
5:28	10	72	69.0	3.9	.238
				Average	.264

Average cubic inches passed per specimen per hour 1.584
Average cubic inches passed per square foot of exposed surface per hour 8.08

Group E
Series II

Specimen 2 e. Number 1. Tested 1/9/28

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
7:25		80	100.0		
7:27	2	80	52.0	48.0	2.92
7:29	2	80	(100.0) 6.0	46.0	2.80
7:31	2	80	53.0	47.0	2.86
7:33	2	80	(100.0) 3.0	50.0	3.05
7:35	2	80	51.0	49.0	2.98
7:37	2	80	1.0	50.0	3.05
				Average	2.94

Average cubic inches passed per specimen per hour 88.20
Average cubic inches passed per square foot of exposed surface per hour 449.0

Specimen 2 e. Number 2. Tested 1/9/28

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
7:50		80	100.0		
7:52	2	80	51.0	49.0	2.98
7:54	2	80	(100.0) 3.0	48.0	2.92
7:56	2	80	55.0	45.0	2.74
7:58	2	80	(100.0) 9.0	46.0	2.80
8:00	2	80	61.0	39.0	2.36
8:02	2	80	24.0	37.0	2.25
				Average	2.67

Average cubic inches passed per specimen per hour 80.10
Average cubic inches passed per square foot of exposed surface per hour 408.0

Group E
Series II

Specimen 2 f. Number 1. Tested 1/14/28

Time hr:min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
3:12		80	100.0		
3:17	5	80	80.0	20.0	1.22
3:22	5	80	57.8	22.2	1.36
3:27	5	80	33.7	24.1	1.47
3:32	5	80	10.0	23.7	1.45
				Average	1.375

Average cubic inches passed per specimen per hour 16.5
Average cubic inches passed per square foot of exposed surface per hour 80.42

Specimen 2 f. Number 2. Tested 1/14/28

Time hr:min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
7:00		80	100.0		
7:01	1	80	66.6	33.4	2.04
7:02	1	80	33.2	33.4	2.04
7:03	1	80	7.6	26.6	1.62
7:04	1	80	72.8	27.2	1.65
7:05	1	80	45.7	27.1	1.65
				Average	1.80

Average cubic inches passed per specimen per hour 108.0
Average cubic inches passed per square foot of exposed surface per hour 549.0

Data for Graphical Treatment
Group E Series II
1:4 Fuller Curve Mix

Specimen	Water Cement Ratio By Vol.	Cubic inches passed per square foot of surface per hour.	Average cubic inches passed per square foot of surface per hour.
2a-1	.7/1	.091	
2a-2	.7/1	.182	.137
2b-1	.8/1	.244	
2b-2	.8/1	.2076	.2258
2c-1	.9/1	6.56	
2c-2	.9/1	10.10	8.33
2d-1	1.0/1	117.5	62.79
2d-2	1/1	8.08	
2e-1	1.1/1	449.0	
2e-2	1.1/1	408.0	428.5
2f-1	1.2/1	80.42	
2f-2	1.2/1	549.0	314.71

Group E
Series III

Fuller Curve Mix 1:6 by weight

Size	Percent Passing Sieves	Percent Retained	Amounts per specimen lbs.
.75	100		
.38	65	35	5.6
.185	46	19	3.04
.093	37.4	8.6	1.38
.046	31.3	6.1	0.98
.023	25.5	5.8	0.93
.0116	20.6	4.9	0.78
.0058	16.9	3.7	0.59
Finer than .0058	14.3	2.6	0.41
Cement		14.3	2.29
		100.0	16.00

Water Cement Ratio

Specimen	Volume Ratio	Weight Ratio	Weight in lbs. per specimen Water	Weight in lbs. per specimen Cement	Number made
3a	.7/1	.464/1	1.06	2.29	2
3b	.8/1	.530/1	1.22	2.29	2
3c	.9/1	.596/1	1.37	2.29	2
3d	1.0/1	.663/1	1.52	2.29	2
3e	1.1/1	.729/1	1.67	2.29	2
3f	1.2/1	.795/1	1.82	2.29	2

Note: All specimens were water cured for twenty-eight days before testing.

Group E

Series III

Specimen 3 a. Number 1 and 2. Tested 2/4/28
Passed unmeasurable quantities of water.

Specimen 3 b. Number 1. Tested 2/4/28

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
3:03		84	92.1		
3:13	10	84	91.2	0.9	.055
3:23	10	86	90.1	1.1	.067
3:33	10	85	88.9	1.2	.073
3:43	10	87	87.5	1.4	.085
3:53	10	84	86.2	1.3	.080
4:03	10	80	85.0	1.2	.073
				Average	.072

Average cubic inches passed per specimen per hour .432
Average cubic inches passed per square foot of exposed surface per hour 2.194

Specimen 3 b. Number 2. Tested 2/4/28

Time hr:min	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
4:36		84	86.2		
4:46	10	78	85.9	.3	.0184
7:46	180	78	80.1	5.8	.355
11:06	200	81	77.0	3.1	.190
	(Weighted) Average (for 10min.)				.0158

Average cubic inches passed per specimen per hour .0948
Average cubic inches passed per square foot of exposed surface per hour .482

Group E
Series III

Specimen 3 c. Number 1. Tested 2/4/28

Time hr:min	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
7:21		82	57.7		
7:31	10	81	55.9	1.8	0.11
7:41	10	81	54.2	1.7	0.102
7:51	10	81	52.5	1.7	0.102
8:01	10	81	50.7	1.8	0.11
8:11	10	78	48.8	1.9	0.118
8:21	10	78	47.0	1.8	0.11
8:31	10	77	45.0	2.0	0.122
			Average		0.111

Average cubic inches passed per specimen per hour 0.666
Average cubic inches passed per square foot of exposed surface per hour 3.38

Specimen 3 c. Number 2. Tested 2/4/28

Time hr:min	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
8:50		85	54.0		
9:00	10	80	50.9	3.1	.190
9:10	10	76	47.9	3.0	.183
9:20	10	74	45.0	2.9	.177
9:30	10	75	42.1	2.9	.177
9:40	10	74	39.3	2.8	.171
				Average	.180

Average cubic inches passed per specimen per hour 1.080
Average cubic inches passed per square foot of exposed surface per hour 5.49

Group E
Series III

Specimen 3 d. Number 1. Tested 2/62/28

Time hr:min.	ΔTime min.	Pressure lbs.sq. in.	Reading c.c.	Amount c.c.	Amount cu.in.
9:45		85	98.9		
9:55	10	83	80.2	18.7	1.14
10:05	10	81	54.0	26.2	1.61
10:15	10	77	27.1	26.9	1.65
10:25	10	77	1.1	26.0	1.59
			Average		1.50

Average cubic inches passed per specimen per hour 9.00
Average cubic inches passed per square foot of exposed surface per hour 45.72

Specimen 3 d. Number 2. Tested 2/6/28

Time hr:min	ΔTime min.	Pressure lbs.sq. in.	Reading c.c.	Amount c.c.	Amount cu.in.
10:31		85	89.9		
10:41	10	83	73.7	16.2	.99
10:51	10	80	54.7	19.0	1.16
11:01	10	78	53.0	21.7	1.33
			Average		1.16

Average cubic inches passed per specimen per hour 6.96
Average cubic inches passed per square foot of exposed surface per hour 35.40

Group E
Series III

Specimen 3 e. Number 1. Tested 2/11/28

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
2:44		79	75.8		
2:54	10	78	50.7	25.1	1.54
3:04	10	77	25.8	24.9	1.52
3:14	10	77	1.6	24.2	1.49
			Average		1.52

Average cubic inches passed per specimen per hour 9.12
Average cubic inches passed per square foot of exposed surface per hour 46.40

Specimen 3 e. Number 2. Tested 2/11/28

Time hr:min.	ΔTime min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
3:38		78	85.7		
3:48	10	80	4644	39.3	2.41
3:58	10	78	9.4	37.0	2.26
4:08	10	79	64.8	35.2	2.16
		Average			2.28

Average cubic inches passed per specimen per hour 13.68
Average cubic inches passed per square foot of exposed surface per hour 69.5

Group E
Series III

Specimen 3 f. Number 11 Tested 2/27/28

Time hr:min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
9:47		82	99.0		
9:52	5	79	57.8	41.2	2.52
9:57	5	82	14.3	43.5	2.66
9:58		82	99.1		
10:03	5	79	56.9	56.9	2.58
10:08	5	78	15.8	41.1	2.51
10:09		81	100.0		
10:14	5	83	55.6	44.4	2.72
10:19	5	83	14.0	41.6	2.55
			Average		2.59

Average cubic inches passed per specimen per hour 13.20
Aver.cubic inches passed per square foot of exposed surface per hour 158.00

Time hr:min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
9:15		80	100.0		
9:20	5	79	52.5	47.5	2.90
9:25	5	81	5.7	46.8	2.86
9:26		81	99.3		
9:31	5	80	61.1	38.2	2.34
9:36	5	78	26.5	35.6	2.17
9:37		80	99.5		
9:42	5	79	55.8	43.7	2.67
9:47	5	79	15.3	40.5	2.47
				Average	2.57

Average cubic inches passed per specimen per hour 13.10
Average cubic inches passed per square foot of exposed surface per hour 156.5

Data for Graphical Treatment
Group E Series III
1:6 Fuller Curve Mix

Specimen	Water Cement Ratio By Vol.	Cubic inches passed per square foot of surface per hour.	Average cubic inches passed per square foot of surface per hour
3a-1	.7/1	unmeasurable	unmeasurable
3a-2	.7/1		
3b-1	.8/1	2.194	
3b-2	.8/1	.482	1.338
3c-1	.9/1	3.38	
3c-2	.9/1	5.49	4.44
3d-1	1.0/1	45.72	
3d-2	1/1	35.40	40.56
3e-1	1.1/1	46.40	
3e-2	1.1/1	69.5	57.95
3f-1	1.2/1	158.00	
3f-2	1.2/1	156.50	157.25

Group E
Series IV
Fuller Curve Mix 1:5 by weight

Size	Percent Passing	Percent Retained	Amounts per specimen lbs.
.75	100	0	0
.38	65	35	5.6
.185	46	19	3.04
.093	37.3	8.8	1.41
.046	31.5	5.9	0.95
.023	25.7	5.9	0.95
.0116	20.8	5.0	0.79
.0058	16.9	3.7	0.59
Cement		16.7	2.67
		100.0	16.00

Water Cement Ratio Constant
for all specimens
1.2/1.0 by Volume .8/1.0 by Weight

Specimen	Method of Curing	Date Made	Date Tested	Number made
4a	Water	1/30/28	2/27/28	2
4b	Air	1/30/28	2/27/28	2
4c	Wet Sand	2/1/28	2/29/28	2

Group E
Series IV

Specimen 4 a. Number 1. Tested 2/27/28

Time hr:min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
10:41		81	93.9		
10:46	5	81	71.7	22.2	1.36
10:51	5	81	46.1	25.5	1.56
10:56	5	81	20.2	25.9	1.59
11:00		81	90.0		
11:05	5	81	64.0	26.0	1.60
11:10	5	81	38.4	25.6	1.57
11:15	5	81	13.1	25.3	1.55
				Average	1.54

Average cubic inches passed per specimen per hour 18.48
Average cubic inches passed per square foot of exposed surface per hour 93.88

Specimen 4 a. Number 2. Tested 2/27/28

Time hr:min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
12:00		82	97.5		
12:05	5		68.2	29.3	1.80
12:10	5		37.5	30.7	1.88
12:15	5		6.9	30.6	1.87
12:18		82	99.6		
12:23	5		68.2	31.4	1.92
12:28	5		37.9	30.3	1.85
12:33	5	82	6.8	31.1	1.91
				Average	1.85

Average cubic inches passed per specimen per hour 22.2
Average cubic inches passed per square foot of exposed surface per hour 111.77

Group E
Series IV

Specimen 4 b. Number 1. Tested 2/28/28

Time hr:min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
9:31		84			
9:32	1	80	183	183	11.2
9:33	1	80	366	183	11.2
9:34	1	80	541	175	10.7
9:35	1	80	732	191	11.65
9:36	1	80	923	191	11.65
9:37	1	79	1123	200	12.20
9:38	1	81	1323	200	12.20
9:39	1	81	1514	191	11.65
9:40	1	81	1705	191	11.65
9:41	1	81	1905	200	12.20
				Average	11.6

Average cubic inches passed per specimen per hour 696.0
Average cubic inches passed per square foot of exposed surface per hour 3540.

Specimen 4 b. Number 2. Tested 2/28/28

Time hr;min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
10:01		80			
10:02	1	80	150	150	9.15
10:03	1	80	300	150	9.15
10:04	1	80	450	150	9.15
10:05	1	80	608	158	9.65
10:06	1	81	766	158	9.65
10:07	1	81	924	158	9.65
10:08	1	82	1074	150	9.15
10:09	1	81	1232	158	9.65
10:10	1	81	1390	158	9.65
10:11	1	81	1540	150	9.15
				Average	9.40

Average cubic inches passed per specimen per hour 564
Average cubic inches passed per square foot of exposed surface per hour 2865

Group E
Series IV

Specimen 4 c. Number 1. Tested 2/29/28

Time hr:min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
7:48		81			
7:49	1	81	37.5	37.5	
7:50	1	81	75.0	37.5	2.29
7:51	1	80	112.5	37.5	2.29
7:52	1	80	148.9	36.4	2.29
7:53	1	80	186.4	37.5	2.20
7:54	1	80	223.9	37.5	2.29
7:55	1	80	260.3	37.5	2.29
7:56	1	80	297.8	36.4	2.29
7:57	1	80	335.3	37.5	2.20
7:58	1	80	373.8	37.5	2.29
				37.5	2.29
					2.29
			Average		2.27

Average cubic inches passed per specimen per hour 136.2
Average cubic inches passed per square foot of exposed surface per hour 691.9

Specimen 4 c. Number 2. Tested 2/29/28

Time hr:min.	Δ Time min.	Pressure lbs.sq.in.	Reading c.c.	Amount c.c.	Amount cu.in.
8:45		80			
8:46	1	80	31.6	31.6	1.93
8:47	1	80	63.2	31.6	1.93
8;48	1	80	94.8	31.6	1.93
8:49	1	80	124.8	30.0	1.83
8:50	1	80	156.4	31.6	1.93
8:51	1	80	183.6	27.2	1.66
8:52	1	79	213.6	30.0	1.83
8:53	1	79	243.6	30.0	1.83
8:54	1	79	275.2	31.6	1.93
8:55	1	79	305.2	30.0	1.83
				Average	1.86

Average cubic inches passed per specimen per hour 111.60
Average cubic inches passed per square foot of exposed surface per hour 566.9

Data for Graphical Treatment
Group E Series IV
1:5 Fuller Curve Mix
Water Cement Ratio Constant 1.2/1.0 by Volume

Specimen	Method of Curing	Cubic inches passed per square foot of surface per hour	Average cubic inches passed per square foot of surface per hour
4a-1	water	93.88	
4a-2	water	111.77	102.3
4b-1	air	3540.0	
4b-2	air	2865.0	3202.5
4c-1	wet sand	691.9	
4c-2	wet sand	566.9	629.4

Group E Series V

Fuller Curve Mix 1:5

Water Cement Ratio 1.2 to 1.0 (by vol.)

Curing--Water

Time	Average cubic centimeters passed per specimen per hour.			
	3" specimen	6" specimen	9" specimen	12" specimen
1st 12 hours	183.00	0.36	0.05	0.033
2nd 12 hours	192.00	0.71	0.15	0.020
3rd 12 hours	300.00	0.86	0.45	0.416
4th 12 hours	310.00	0.94	0.45	0.416
5th 12 hours	312.00	0.98	0.50	-----

Variation of Pressure Data

Group E. Series VI

Specimen #1

Fuller Curve Mix 1:6

Water-Cement Ratio 1.2:1.0

Time required to pass ten cubic centimeters through a specimen at given temperatures.

Pressure # per sq. in.	Time Sec.	Pressure # per sq. in.	Time Sec.
11	800	124	44
11	725	124	45
12	800	102	58
14	725	82	70
14	675	81	80
25	475	50	145
25	375	27	340
48	155	26	330
50	165	25	337
50	145	14	710
81	86	12	725
81	82	11	825
82	90	11	900
82	68	11	960
100	60	8.25	1250
102	60	3.75	2000
124	45	3.75	2500
124	44	3.75	2570
124	46		

Variation of Pressure Data

Group E. Series VI

Specimen # 2

Fuller Curve Mix 1:4

Water-Cement Ratio 1.1:1.0

Time required to pass ten cubic centimeters through a specimen at given temperatures.

Pressure # per sq. in.	Time Sec.
9	370
10	340
21	167
21	165
38	94
38	90
39	86
57.5	64
57.5	64
73	47
74	44
122	27
122	28
124	27

Pressure # per sq. in.	Time Sec.
124	29
73	45
57.5	64
40.0	100
21	165
10	350

Variation of Pressure Data

Group E. Series VI

Specimen # 3

Fuller Curve Mix 1:6

Water-Cement Ratio 1.1:1.0

Water Cured 28 days

Time required to pass ten cubic centimeters through a specimen at given temperatures.

Pressure # per sq. in.	Time Sec.	Pressure # per sq. in.	Time Sec.
13.5	3750	119.5	310
13.5	3750	103.0	360
22.0	2400	81.0	460
22.0	2325	70.0	540
33.0	1460	50.0	1000
33.0	1410	32.0	1560
50.0	850	22.0	2220
50.0	840	13.5	3900
50.0	840		
70.0	625		
70.0	575		
81.0	460		
81.0	460		
102.0	370		
102.0	360		
119.5	330		
119.5	310		
119.5	320		

Variation of Pressure Data

Group E. Series VI

Specimen # 4

Fuller Curve Mix 1:4

Water Cement Ratio 1.2:10

Time required to pass ten cubic centimeters through a specimen at given temperatures.

Pressure # per sq. in.	Time Sec.
12	150
12	140
21	102
21	96
21	96
30.5	68
30.5	66
30.5	70
42.0	48
42.0	50
42.0	52
52.5	40
52.5	41
52.5	42
62.0	38
62.0	40
63.0	39
66.0	40
66.5	38
90.0	30

Pressure # per sq. in.	Time Sec.
90	30
69	40
69	37
63	39
52.5	41.5
42.0	52
42.0	50
30.5	64
30.5	70
21	94
21	94
12	140

Variation of Pressure Data

Group E. Series VI

Specimen # 5

Fuller Curve Mix 1:4

Water-Cement Ratio 1.1:1.0

Time required to pass ten cubic centimeters through a specimen at given temperature.

Pressure # per sq. in.	Time Sec.	Pressure # per sq. in.	Time Sec.
21.5	160	138.0	15.0
23.0	150	123.0	18.5
23.5	160	110.0	22.0
25.0	130	100.0	26.0
43.0	86	78.0	41
45.0	82	60.0	56.5
45.0	76	44.0	83
62.0	54	22.0	16.0
63.0	52	19.0	17.0
78.0	41		
78.0	40		
100.0	26		
100.0	26		
109.0	23		
109.0	23		
115.0	20		
119.0	20		
121.0	19.5		
138.0	15.0		
139.0	15.0		