EFFECT UPON THE COMPRESSIVE STRENGTH OF CONCRETE BY ELIMINATING CURING WATER

Thesis for the Degree of B. S.

Harold J. Rathfoot

1927

Cecil [illegible]

HAROLD J. RATHFOOT, a Grand Ledge native who supervised construction of hundreds of miles of Michigan's state highway system in the 1950s and then supervised maintenance of the system for nine years, died Friday in a Florida hospital at the age of 77. A graduate of Grand Ledge High School and Michigan State University (1927), Rathfoot joined the state highway department in 1934 as a concrete inspector. He retired after 34 years service in 1967 and moved to Fort Lauderdale, Fla. He is survived by his wife Alice and a son, Harold Jr., an engineer with the Delta County road commission. Services in Florida are being arranged.

EFFECT UPON THE COMPRESSIVE STRENGTH OF CONCRETE BY ELIMINATING CURING WATER

Thesis Submitted to the Faculty

Of

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By

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Candidate for the Degree

of

Bachelor of Science

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THESIS

EFFECT UPON THE COMPRESSIVE STRENGTH OF CONCRETE BY ELIMINATING CURING WATER

It is a custom, and one hard to enforce, in the highway department that requires pavement to be thoroughly wetted for the first seven days after it is placed. The supposition is that the curing water makes a stronger pavement. Having worked on pavement construction both as a laborer and as an inspector and realising how hard it is to secure a thorough job of wetting; this thesis was performed to determine the value, if any, of such a procedure. Since not eneough time was available to cast blocks of pavement and test under actual road conditions it was necessary to substitute cylinders and laboratory methods of keeping the cylinders wetted. Cylinders were made to cover an age of from one to twenty-eight days wetted from one to seven days.

For a working basis a concrete of 2500# per sq. inch unit strength at the age of twenty-eight days, having a slump of six to seven inches, with maximum size of aggregate as three-fourth inches was chosen. Only this type of mix was used and all data pretains to the above designed strength.

The above mix was designed according to Professor Abram's Water Ratio Theory and the complete design is given below:--

Strength 2500# per Sq. In.   28 days
Slump 6 to 7 inches
Maximum size of aggregate $\frac{3}{4}$ inch
Water-Cement Ratio -- Curve B -- .78

Real mix -- 1:3
Fineness Modulus -- 5.13

Field Mix.

Fineness modulus for	sand	2.66
" " "	coarse	6.48
" " "	combined	5.13

$$r = \frac{6.48 - 5.13}{6.48 - 2.66} = 35.3\%$$

Weight per cubic foot combined aggregate 126.8 #

Volume required when measured seperate

Sand -- .353 x 115 = 40.6 #
Stone - .647 x 112 = 72.79#
113.39#

It will require $\frac{113.4}{126.8}$ = .894 volumes of mixed aggregate to correspond to one volume of aggregate mixed seperately.

Field mix = $1 : \frac{3}{.894}$ = 1 : 3.6

Weight of sand damp and loose = 100 # per Cu. Ft.
100 # when dry weighs 97.18 #
One cubic foot dry and rodded weighs 115 #

Bulking of sand = $\frac{115}{97.18}$ =1.183

Weight of stone damp and loose   105 # per Cu. Ft.
105 # when dry weighs   103.75 #
One cubic foot dry and rodded   112.5 #

Bulking of stone $\frac{112.5}{103.75}$ = 1.071

Volume of loose damp Sand 3.6 x .353 x 1.183 = 1.5
Stone 3.6 x .647 x 1.071 = 2.5

Field mix -- 1 : 1.5 : 2.5

Correction for absorption and moisture

Water-Cement ratio = .78. This is equivalint to
7.48 x .78 = 5.834 gals. of water

Water to be added to take absorption

Sand -- 150 x 97 x .01 = 1.45 # or .17 gal.
Stone 2.5 X 103.7 x .01 - 2.67 # Or .32 gal.

Total .494 gallons per sack of cement.

Deductions for water contained in aggregate

Sand 1.5 x 2.82 = .423 gal.
Stone 2.5 x 1.25 = .313 "

Total .736 gallons per sack of cement

Total water to be added per sack of cement
5.834 + .494 - .736 = 5.592 gallons

Quantity of materials to be used

For a real mix of 1 : 3 use 8 bags of cement per cubic yard of finished concrete.

Sand to be added 8 x 1.5 = 12 cu. ft.
Stone " " " 8 x 2.5 = 20 " "
Water " " " 8 x 5.592 = 44.736 gallons

Concrete required for experiment = .165 cu. yds.

Quantity of cement 94 x 8 x .165 = 124 #
" " sand 100 x 12 x .165 = 198 "
" " stone 105 x 20 x .165 = 346 "
" " water 44.74 x 8.33 x .165 = 61.4 #

After the mix was designed one hundred twenty-six cylinders were filled and placed in the moist chamber, being removed in the following order:- twenty-seven after being in the moist chamber one day; two days twenty-four; three days twenty-one; four days eighteen; five days fifteen; six days twelve and seven days nine.

At the age of one day three cylinders were broken in a compression machine to determine their strength in compression. All the cylinders were in the moist chamber one day. At the age of two days six were broken, three having been in the moist chamber one day and three for two days. At the age of three days nine cylinders were broken, three having been in the chamber one day, three for tw days and three for three days. At the age of four days twelve cylinders were broken, three having been in the moist chamber one day, three two days, three for three days and three for four days. At the age of five days fifteen cylinders were broken, three for one day in the moist chamber and three each for two, three, four and five days. The sixth day eighteen cylinders were broken, three each for one, two, three, four, five, and six days in the moist chamber. At the age of seven, fourteen, and twenty-eight days twenty-one cylinders were broken each day, three each for one, two, three, four, five, six, seven days in the moist chamber.

The breaking strength of each cylinder was recorded and the average of the three taken as the strength of the test. No cylinder was used in computing the average which varied by more than three thousand pounds per cylinder.

The Results. (Average)

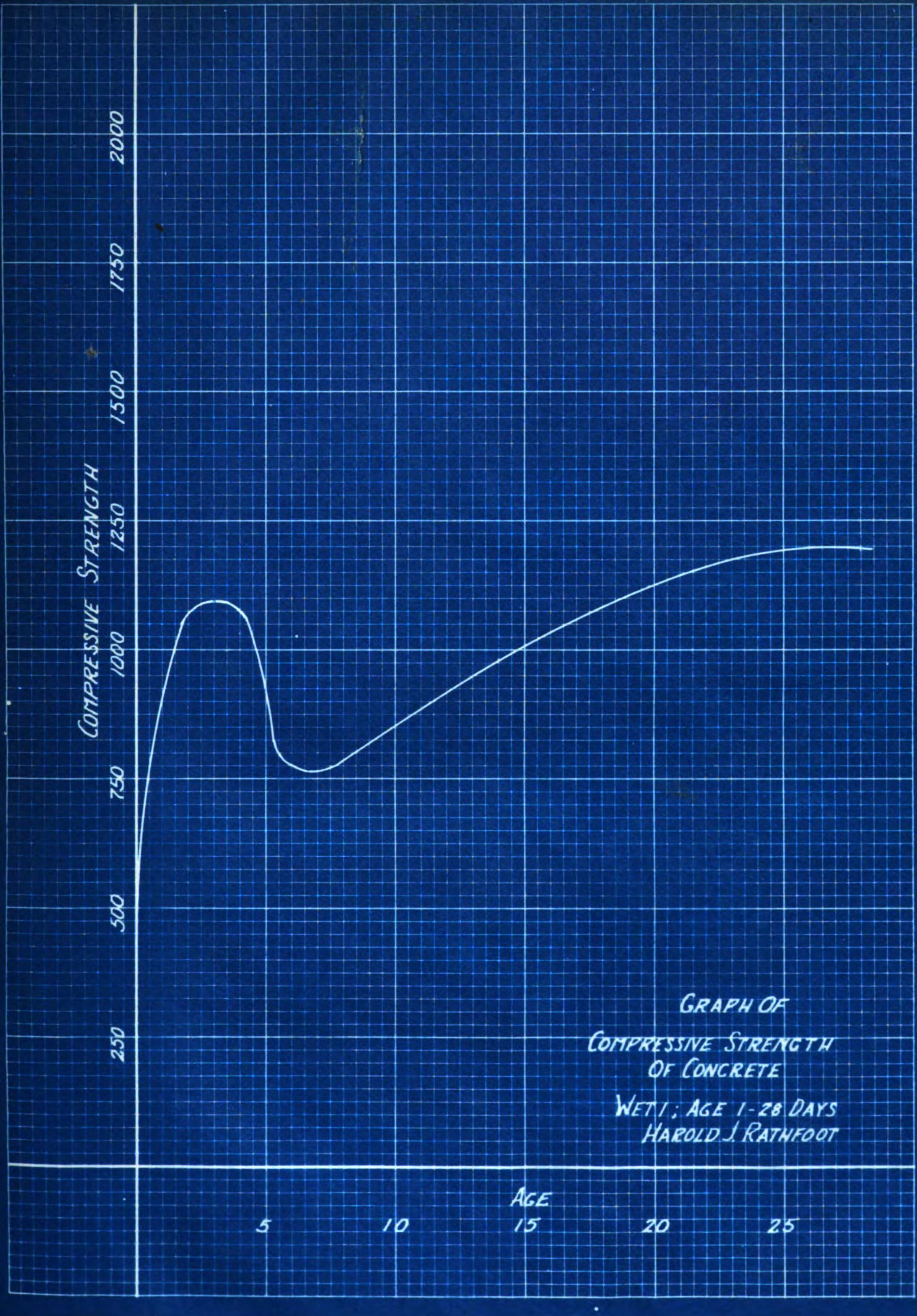
Broken Days / Wet Days	1	2	3	4	5	6	7	14	28
1	730	884	1090	1035	920	777	792	990	1195
2		540	688	966	1040	823	930	955	1050
3			895	845	979	1090	1260	1220	1200
4				1065	1175	1225	1035	1610	1710
5					1195	1175	1145	1555	1865
6						1062	1520	1685	2150
7							1590	2040	2190

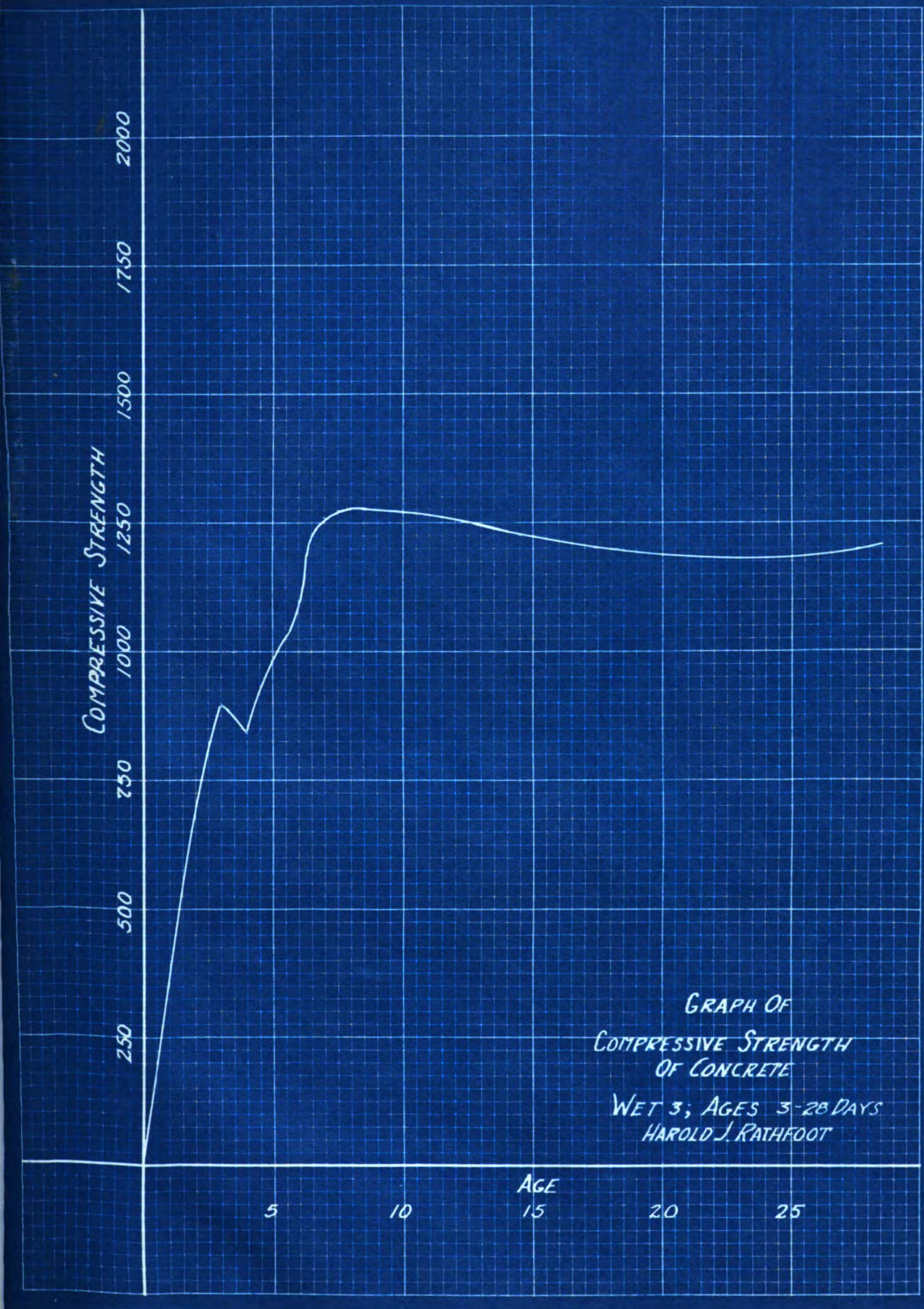
A graph was made for each of the following conditions. One for the cylinders which had been in the moist chamber for one day and broken from the ages of one to twenty-eight days. One for the cylinders which had been in the moist chamber for two days and broken at the ages of two to twenty-eight days. A graph for the cylinders which had been in the moist chamber for three days and broken from the ages of three to twenty-eight days. One for the cylinders which had been in the moist chamber for four days and broken at the ages of four to twenty-eight days. One for the cylinders which had been wetted five days and broken from the ages of five to twenty-eight days. Agraph was made for the cylinders in the moist chamber six days and broken ate the age of six to twenty-eight days. One for the cylinders in the moist chamber for seven days and broken at the age of seven, fourteen, and twenty-eight days. A graph was then made comparing the above strengths.

Four more graphs were drawn, one for each the seven, fouteen, and twenty-eight day strengths showing the variation in strength due to being in the moist chamber for varying lengths of time. The last graph is one comparing the curves of the seven, fourteen, and twenty-eight day strengths.

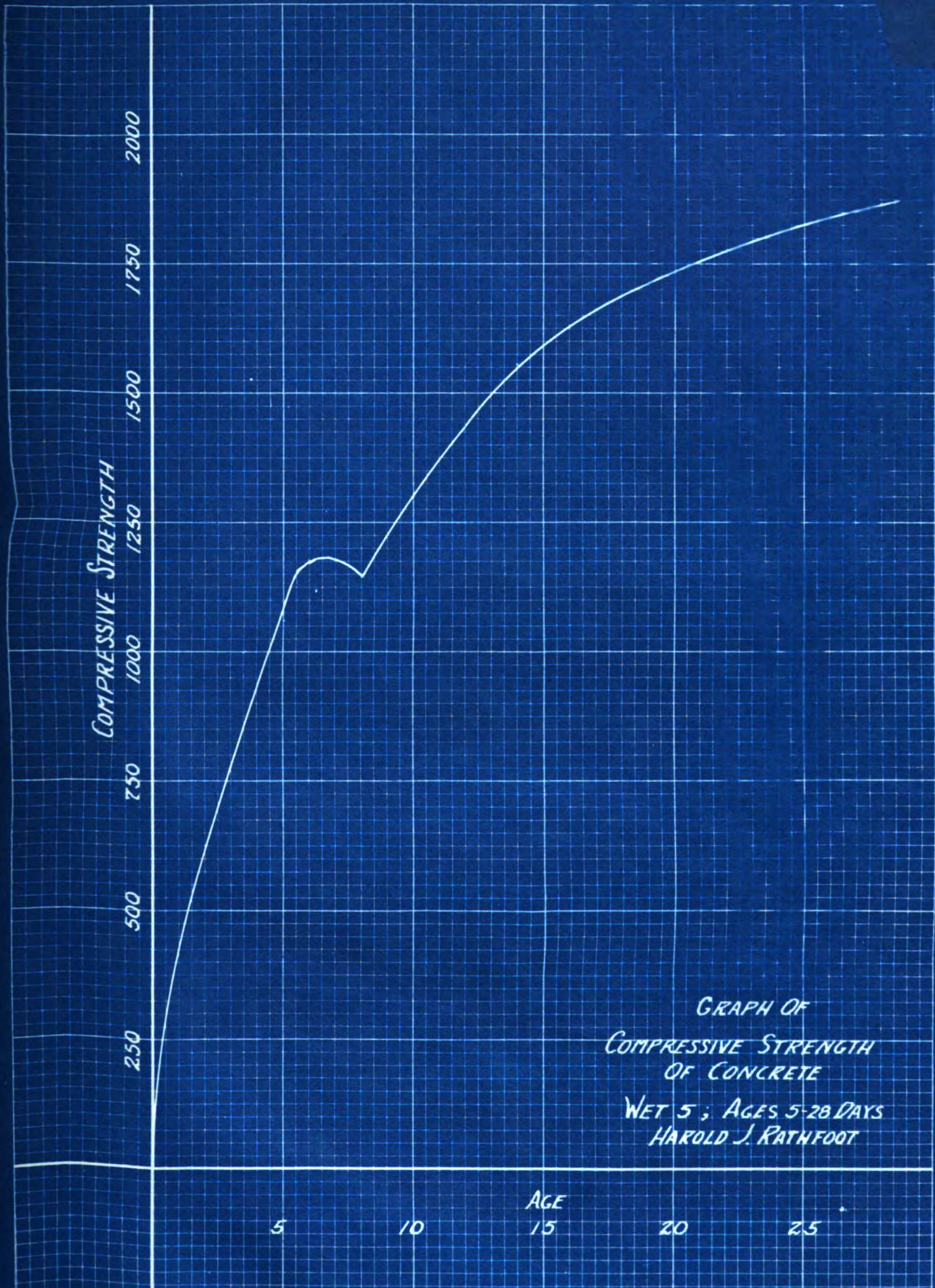
The results of this experiment are by no means certain. Several hundred tests should be run on this strength and a like amount on other strengths and then some definite conclusions could be drawn. The results obtained show that with the same mis and with an age of twenty-eight days a concrete which has been wetted only one day will be only about one-half as strong as one wetted seven days. This ratio also holds for the seven and fourteen day ages. On the lesser ages the results are less varying and below five days it is not

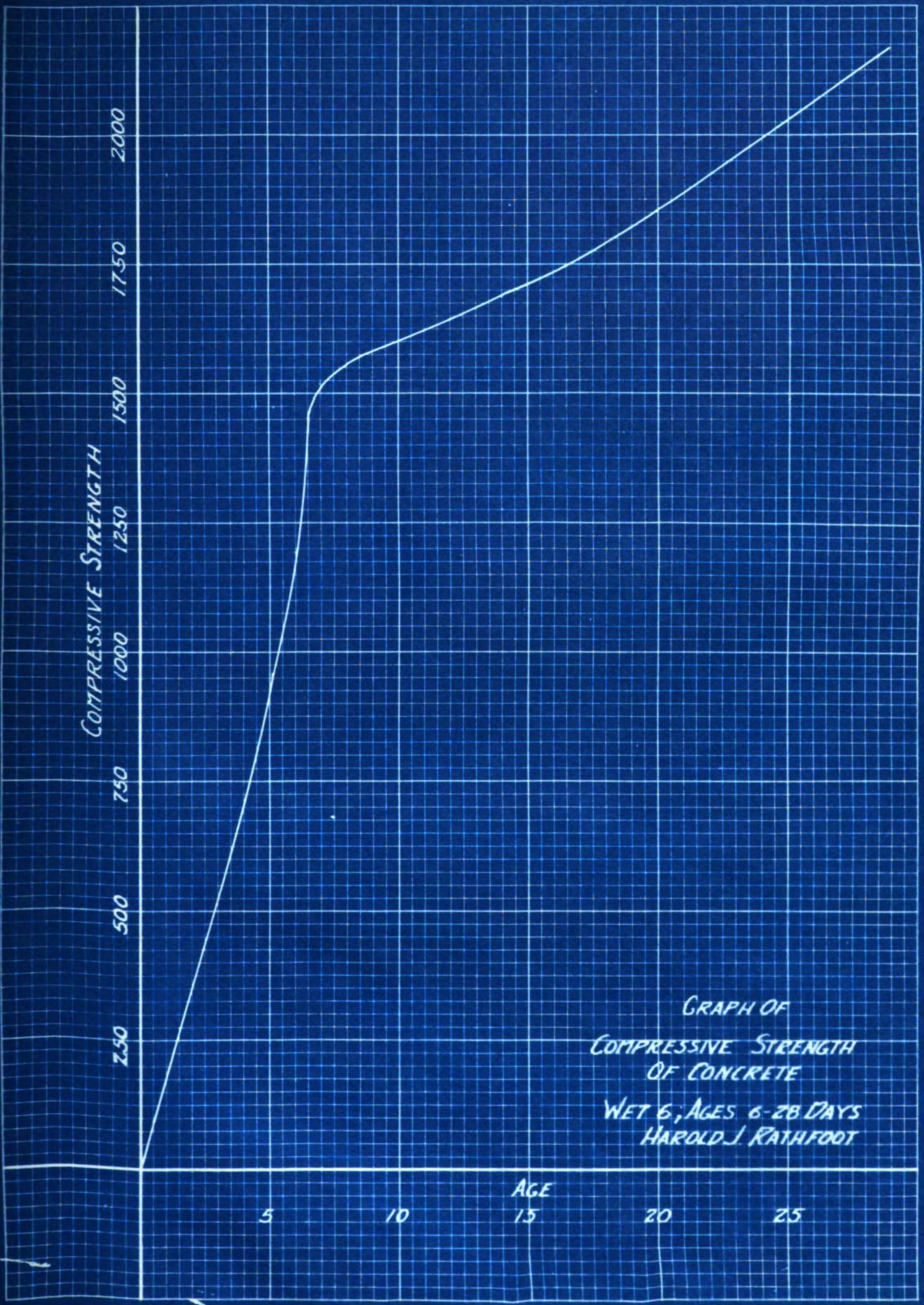
easy to notice any change in the strength due to the different lengths of thim that the cylinders were left in the moist chamber. It is therefore a matter of much concern for the State to be sure the pavement is well wetted for the first seven days, since they may be sure the resulting concrete is about twice as strong and thus better than a pavement which has been wetted one day.


COMPRESSIVE STRENGTH
2000
1750
1500
1250
1000
750
500
250
AGE
5
10
15
20
25
GRAPH OF
COMPRESSIVE STRENGTH
OF CONCRETE
WET 1; AGE 1-28 DAYS
HAROLD J. RATHFOOT

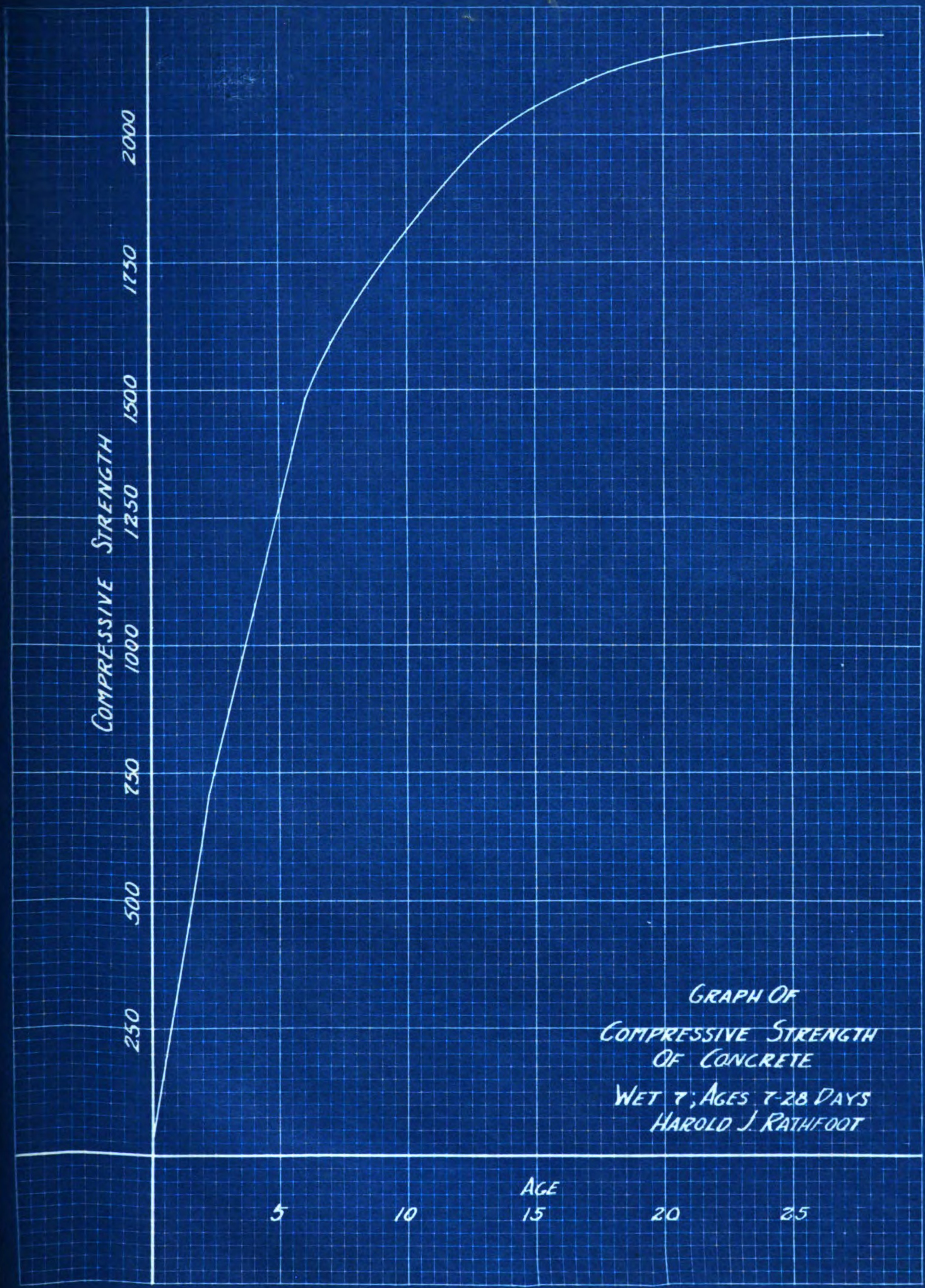


COMPRESSIVE STRENGTH
2000
1750
1500
1250
1000
750
500
250
AGE
5
10
15
20
25
GRAPH OF
COMPRESSIVE STRENGTH
OF CONCRETE
WET 3; AGES 3-28 DAYS
HAROLD J. RATHFOOT

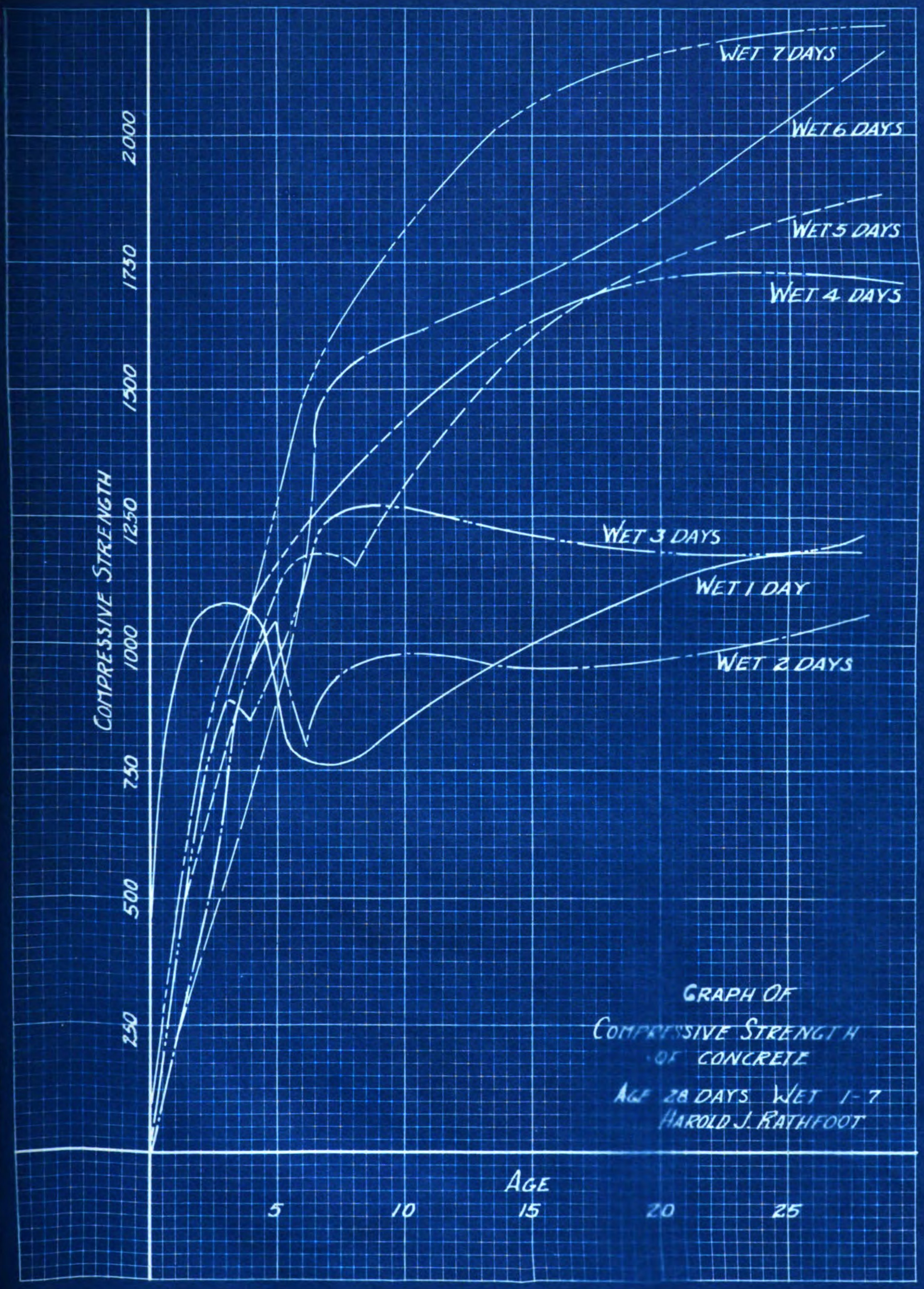

Compressive Strength
2000
1750
1500
1250
1000
750
500
250
Age
5
10
15
20
25
Graph of
Compressive Strength
of Concrete
Wet 5 ; Ages 5-28 Days
Harold J. Rathfoot



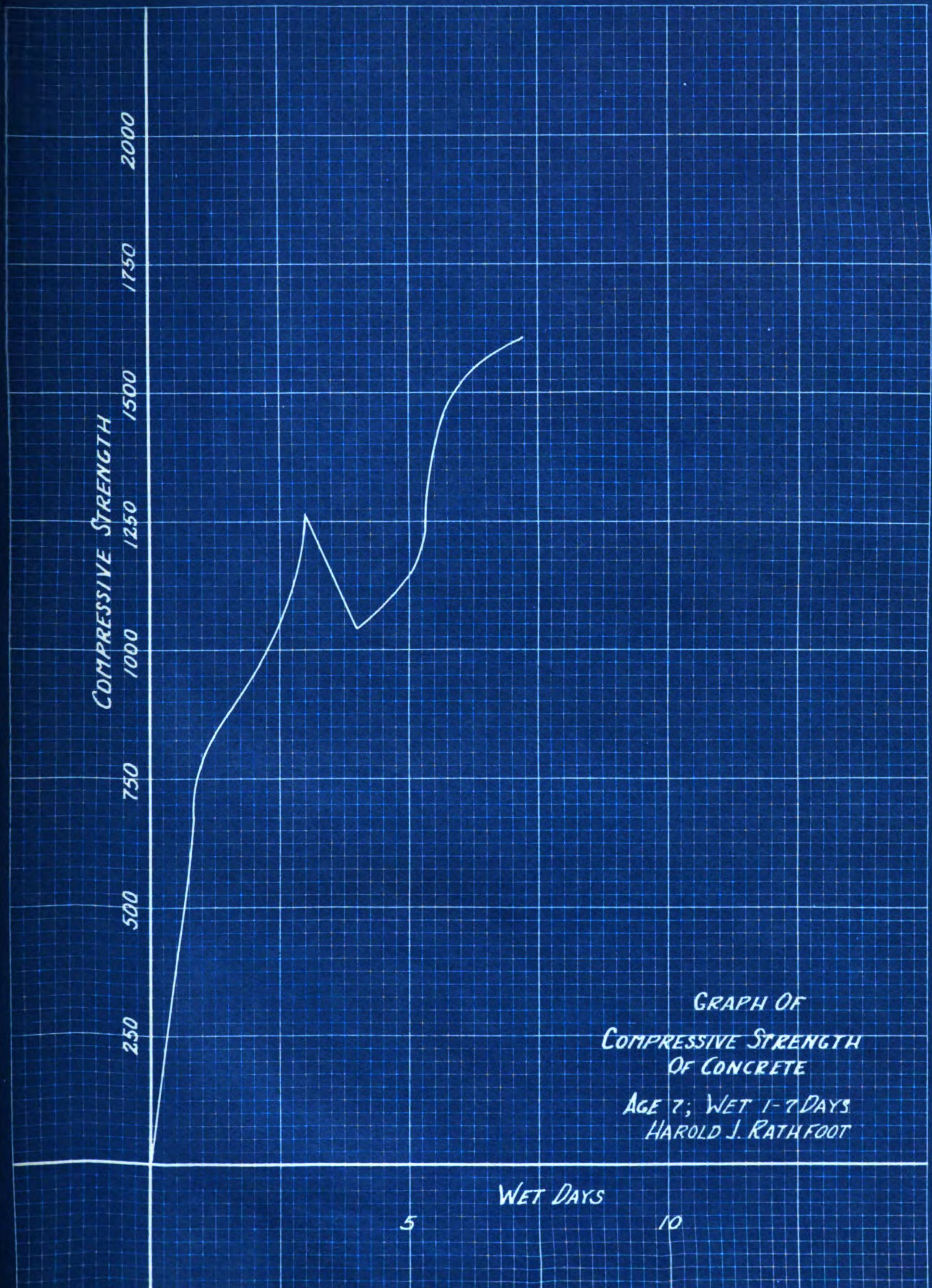
COMPRESSIVE STRENGTH
2000
1750
1500
1250
1000
750
500
250
AGE
5
10
15
20
25
GRAPH OF
COMPRESSIVE STRENGTH
OF CONCRETE
WET 6; AGES 6-28 DAYS
HAROLD J. RATHFOOT



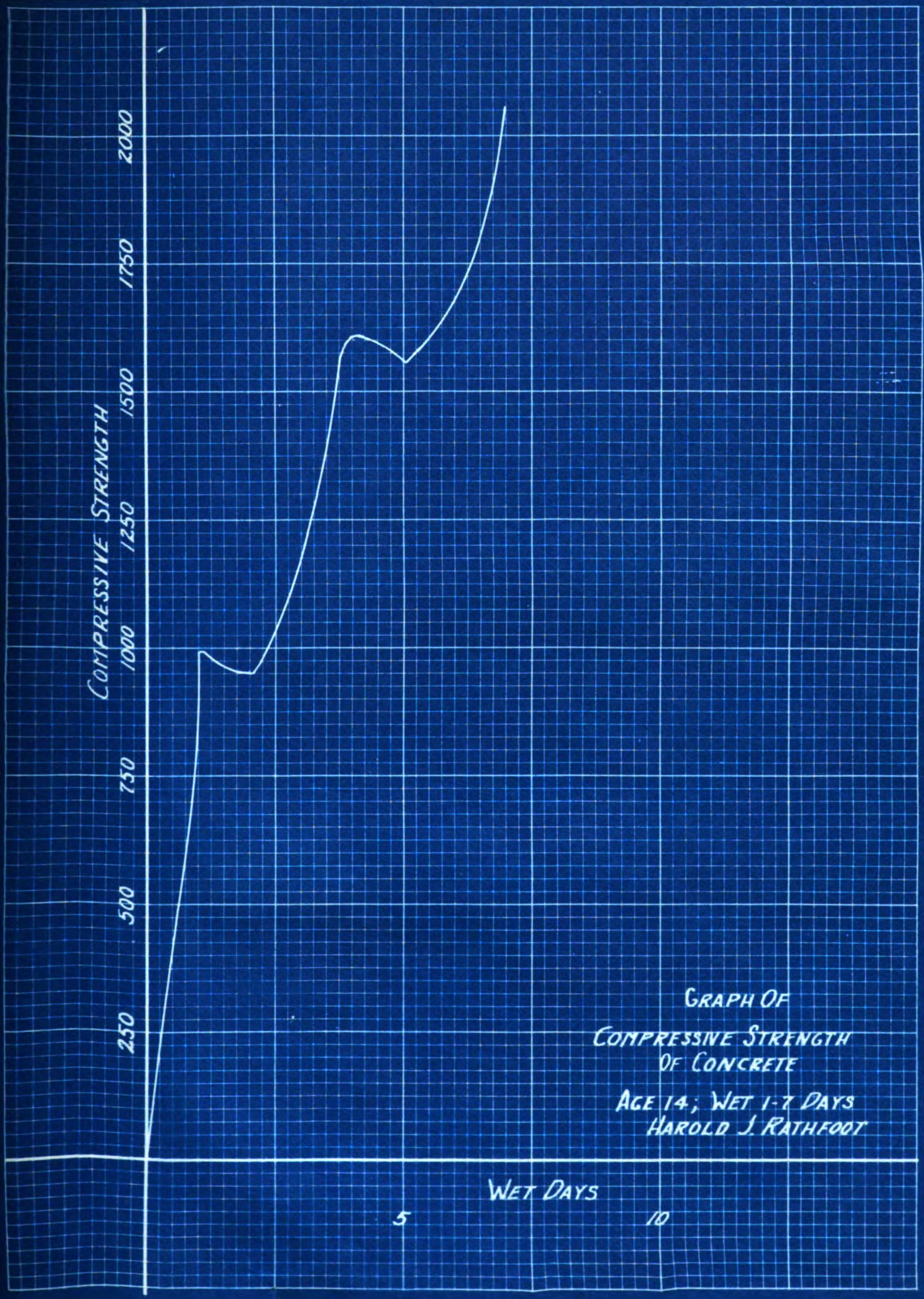
COMPRESSIVE STRENGTH
2000
1750
1500
1250
1000
750
500
250
AGE
5
10
15
20
25
GRAPH OF
COMPRESSIVE STRENGTH
OF CONCRETE
WET 7; AGES 7-28 DAYS
HAROLD J. RATHFOOT



WET 7 DAYS
WET 6 DAYS
WET 5 DAYS
WET 4 DAYS
WET 3 DAYS
WET 1 DAY
WET 2 DAYS
COMPRESSIVE STRENGTH
250
500
750
1000
1250
1500
1750
2000
AGE
5
10
15
20
25
GRAPH OF
COMPRESSIVE STRENGTH
OF CONCRETE
AGE 28 DAYS WET 1-7
HAROLD J. RATHFOOT



Compressive Strength
2000
1750
1500
1250
1000
750
500
250
Graph Of
Compressive Strength
Of Concrete
Age 7; Wet 1-7 Days
Harold J. Rathfoot
Wet Days
5
10


Compressive Strength
2000
1750
1500
1250
1000
750
500
250
Wet Days
5
10
Graph Of
Compressive Strength
Of Concrete
Age 14; Wet 1-7 Days
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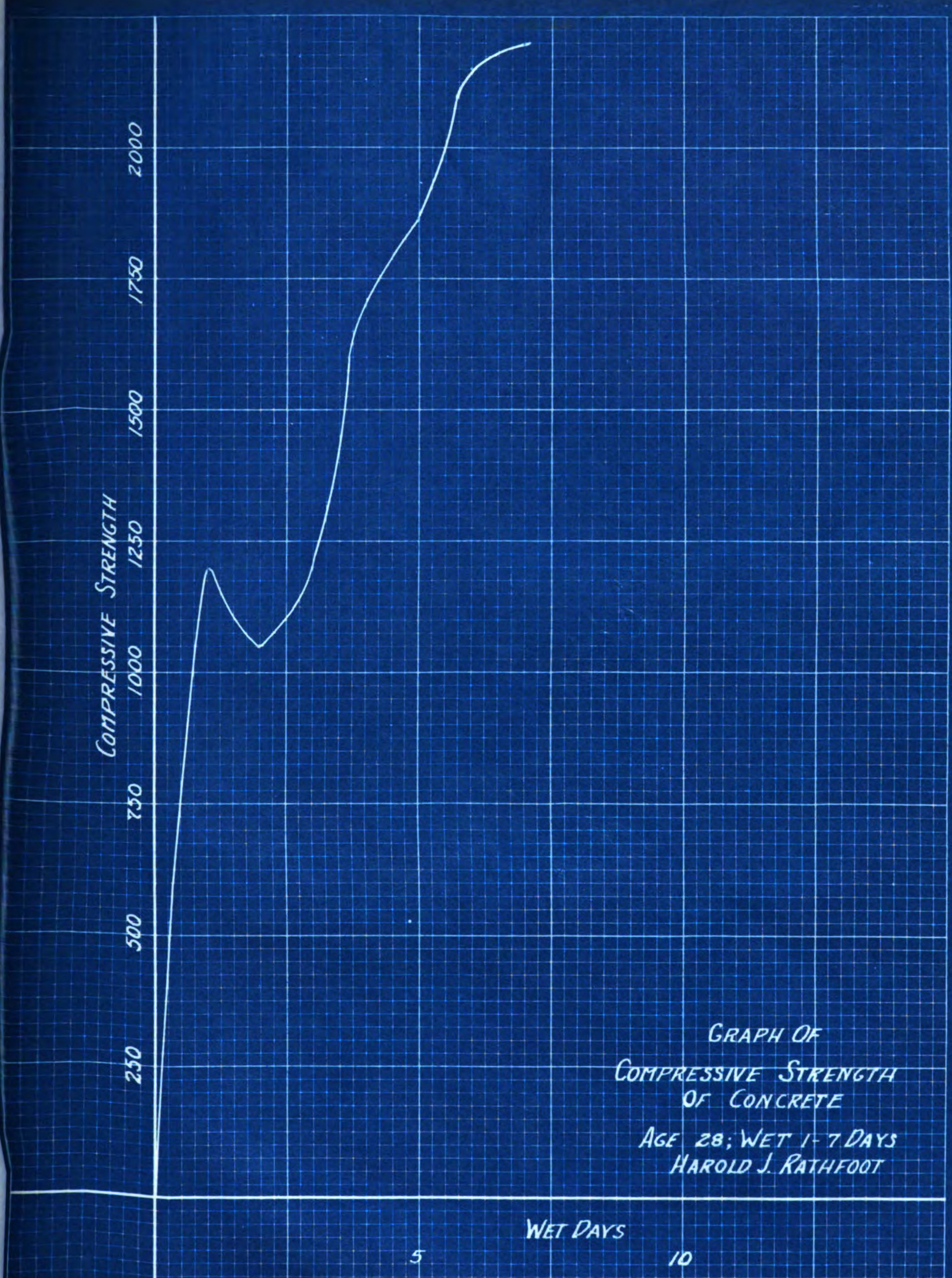
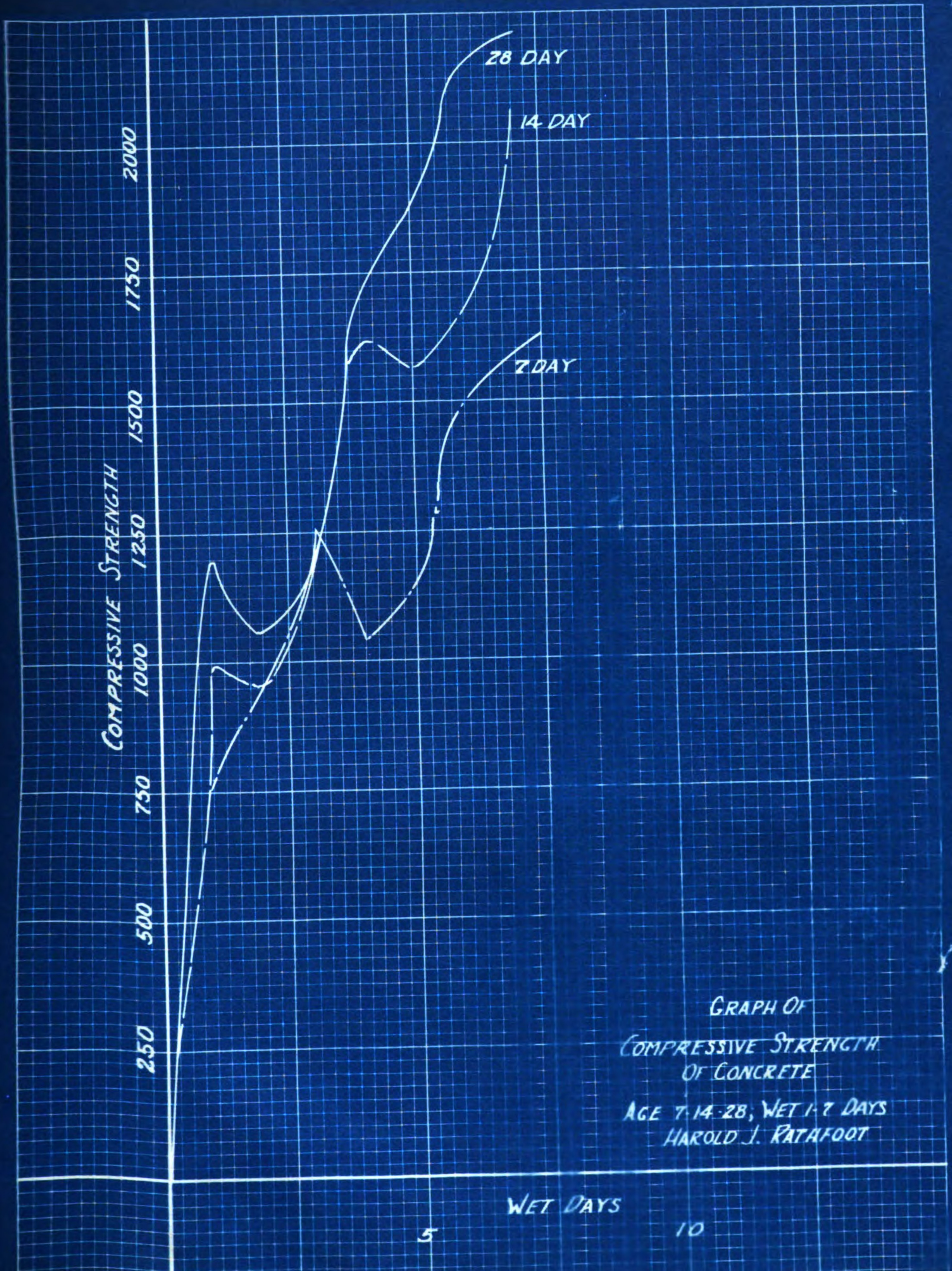

Compressive Strength
250
500
750
1000
1250
1500
1750
2000
Wet Days
5
10
Graph of
Compressive Strength
of Concrete
Age 28; Wet 1-7 Days
Harold J. Rathfoot


28 DAY
14 DAY
7 DAY
COMPRESSIVE STRENGTH
2000
1750
1500
1250
1000
750
500
250
WET DAYS
5
10
GRAPH OF
COMPRESSIVE STRENGTH
OF CONCRETE
AGE 7-14-28; WET 1-7 DAYS
HAROLD J. RATAFOOT