UREA AND ITS EFFECTS ON CONCRETE

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE
R. F. Salazar
1946

THESIS

Urea and Its Effects on Concrete

A Thesis Submitted to
The Faculty of
MICHIGAN STATE COLLEGE
of
AGRICULTURE AND APPLIED SCIENCE
by

R. F. Salazar

Candidate for the Degree of

Bachelor of Science

June 1946

I DEDICATE THIS THESIS

TO MY

FATHER AND MOTHER

ACKNOWLEDGMENTS

I WISH TO HEREBY THANK PROF.

C. L. ALLEN AND ASST. PROF. L. A.

ROBERT WITHOUT WHOSE HELP THIS THESIS

WOULD NOT HAVE BEEN POSSIBLE.

CONTENTS

INTRODUCTION

Concrete behavior, under different conditions such as loading, mixing or addition of new substances to its components, has become a very important matter to engineers, contractors, architects, etc., who have been always interested in the production of a better concrete with ideal conditions as to weight, impermeability, color and specially low cost.

Much research work has been performed by investigators and they have found after a great deal of work, different characteristics which have been added to the already known characteristics of cement or concrete to produce better and better combinations with the result of producing a concrete of today's specifications.

But investigation has not stopped there, and will always continue as long as we try to make a better world for ourselves.

My investigations on urea mixed with concrete mortar might not cover 1/4 of the work I should have done in order to obtain final and acceptable results but it shows basic characteristics which will help to continue any investigation desired to be performed on this type of research.

SPECIFICATIONS

1- The cement used in this thesis is Aetna cement

2- Mix shall be 1 : 3 for the mortar briquettes and 1 : 2.77 for the mortar cubes

3- Sand used for tension specimens must be Standard Ottawa Sand passing No. 20 sieve and retained in No. 30 sieve

For compression specimens use graded Ottawa sand as determined by A. S. T. M. Designation C109-37T

4- All cement used in this thesis shall be passed through No. 20 sieve.

5- Urea concentration will be based on water used by weight.

6- Curing must be done in the following way:

First 24 hours specimens in the molds will be stored in moist room at 67 to 73 deg. F. with at least 90% humidity.

Then the specimens will be removed from the molds and stored in a water tank until testing.

7- Time of mixing, by hand, 4 1/2 minutes.

8- Molds used for the briquettes and cubes must be the regular molds used by the M. S. C. Civil Engineering Department. Each mold contains 4 briquettes or 3 cubes.

9- Testing machines are:

For tension	Riehle Shot Machine
For compression	Olsen's Universal Machine, 50,000 lbs. Cap. Speed 0.111 inch per minute.

10- Specimens will be tested as soon as they come out of the water tank.

METHODS OF PROCEDURE

NORMAL CONSISTENCY

In order to determine the percentage of water to be used in making tension specimens, a Normal Consistency test was run on the cement to be used, as determined by A. S. T. M. Designation C77-32. A Vicat apparatus was used. It consists of a frame which holds a rod with an index. This rod can be used at both ends, one being 1 cm. in diameter and the other holds a needle 1 mm. (0.39 in.) in diameter. The end with the needle is the one used for Normal Consistency Test.

It is said that a cement paste is of Normal Consistency when the plunger or Vicat needle penetrates 10 mm. below the surface of the cement paste in 30 sec.

In order to performe this test, 500 gms. of cement passing #30 sieve was used. Different neat cement specimens were made having different percentages of water.

The following procedure was taken from "Plain Concrete" by Edward E. Bauer, Test No. 3, Page 264.

"Mix 500 gms. of cement with any determined amount of water in the following manner:

Place the cement on a nonabsorbent surface, which has not been moistened. Form a crater and pour the water into it. Turn the material on the outer edge toward the center with a trowel within a period of 30 sec.

During the following steps the hands should be protected with rubber gloves. After and additional interval of 30 sec. for the absorption of the water, complete the operation by continuous vigorous mixing,

squeezing and kneading with the hands for 1 1/2 min.

Form the paste quickly into a ball with the hands. Maintaining the hands about 6 in. apart, toss the ball six times from one hand to the other.

In the following operation take care not to compress the paste. With the ball resting in the palm of one hand, press the paste into the larger end of the ring provided for this test held in the other hand. (Ring is of conical shape. Inside diameters: base 7cm., top 6 cm., height 4cm.)

Fill the ring completely with the paste. Remove the excess paste at the larger end by a single movement of the hand. Place the ring with the paste on a glass plate. Remove excess paste at smaller end by single oblique stroke of the trowel held at a slight angle with the top of the ring. Smooth the top, if necessary, with a few light touches of the pointed end of the trowel. Do not puddle surface.

Test the sample in the Vicat apparatus, waiting 30 sec. after the completion of the mixing before the release of the needle. Be sure the plunger is clean and moves freely in the guides and that there are not vibrations. Place the sample under the plunger. The larger end should be down. Bring the plunger into contact with the surface of the paste. Release the plunger for 30 sec. and note the amount of settlement.

The paste is of normal consistency when the plunger settles 10 mm. in 30 sec. If the first trial does not give the desired 10 mm. penetration, repeat test using new batch of cement but with different amount of mixing water. Repeat until the desired consistency is secured."

It was observed that the percentage of mixing water for the particular cement used was 27% by weight.

To determine the percentage of water for mortar of 1 part of cement and 3 parts of Standard Ottawa Sand, table on Page 276 of "Plain Concrete" by Edward E. Bauer, was used. The percentage of water came out to be 11%. This percentage was used on all the tension specimens made for this thesis.

TENSION SPECIMENS

In order to make tension specimens briquette molds were used. The molds were first cleaned with a wire brush and a piece of cloth and then very well oiled. Glass plates were also used to support the molds during the first 24 hours of the curing period. The glass plates were also oiled.

The material used to make these tension specimens was selected according to specifications.

When making the concrete mortar, cement was first mixed with the water having the required concentration of urea and after all the cement had been mixed, half of the amount of sand was added. This paste was mixed for about 3/4 of a minute and then the rest of the sand was added and mixing continued until completion of the 4 1/2 minutes mixing time. A mold containing 4 briquettes was then placed on a glass plate and filled with the concrete mortar. The mold was filled full and pressure was applied to each briquette using the thumbs. Pressure applied ranged from 15 to 20 lbs., six times on each briquette. Then by using a trowel the surface was smoothed off.

At this time an oiled glass plate was placed on top of the mold, the mold turned over and the other glass plate removed. Pressure was applied to this other side in the same manner as above and mortar was added to fill the cavities. The surface of the briquettes was smoothed

ing way:

0.0% - 0.1% - 0.2% - 0.3% - 0.4% - 0.5% - 1.0% - 1.5% - 2.0% - 2.5% - 3.0% - 3.5% - 4.0% - 4.5% - 5.0% - 10.0% - 20.0%

Tests were run on specimens cured 7 - 14 - 28 - 60 days.

Up to 0.3% concentration of urea specimen, Atlas cement was used. From there on Aetna cement was used. Tests on 0.3% specimens showed that there is not much or any difference between the two cements. Due to this fact all specimens were considered to have been made of the same cement.

COMPRESSION TESTS RESULTS
Area: 4 sq. in.

% urea	7 days	14 days	28 days	60 days
0.0	7900	8810	9155	13810
	7820	8435	9632	13235
	7030	7955	8813	9114
	Ave. 1900	Ave. 2100	Ave. 2300	Ave. 3375
0.1	4540	6900	8995	9375
	4925	5700	7840	9755
	5820	6055	8520	11375
	Ave. 1277	Ave. 1555	Ave. 2111	Ave. 2542
0.2	8690	8840	11930	10655
	7245	7945	10270	15520
	6675	8775	8710	8535
	Ave. 1883	Ave. 2130	Ave. 2775	Ave. 2897
0.3	6184	6327	10600	7640
	6665	6477	9280	10000
	6370	5050	9455	9100
	Ave. 1635	Ave. 1488	Ave.2445	Ave. 2388
0.4	5145	9160	11955	12150
	5575	7500	9630	13875
	5875	8800	10180	13850
	Ave. 1383	Ave. 2122	Ave. 2644	Ave. 3223
0.5	6445	10985	11660	15700
	8180	11030	10220	14190
	7640	11625	10495	13480
	Ave. 1855	Ave. 2800	Ave. 2690	Ave. 3614
1.0	9020	10700	10465	16195
	9480	11155	12265	11910
	8730	9880	10775	12570
	Ave. 2270	Ave. 2586	Ave. 2792	Ave. 3060

% urea	7 days	14 days	28 days	60 days
1.5	9000	10155	11420	13940
	8420	9000	8175	13350
	8380	9150	10900	13110
	Ave. 2150	Ave. 2360	Ave. 2790	Ave. 3370
2.0	8600	9600	11530	14310
	9200	9225	11650	14535
	8900	10575	10710	14580
	Ave. 2225	Ave. 2450	Ave. 2824	Ave. 3650
2.5	8770	10875	12545	16500
	9100	9532	11410	15130
	10451	11394	12690	18110
	Ave. 2380	Ave. 2650	Ave. 3054	Ave. 4150
3.0	9223	9545	12520	16500
	8791	11400	14220	13120
	10186	10565	10725	14925
	Ave. 2350	Ave. 2600	Ave. 3443	Ave. 3560
3.5	8517	9215	11755	14600
	8843	10100	12710	15735
	9376	8887	11810	14085
	Ave. 2228	Ave. 2350	Ave. 3023	Ave. 3700
4.0	8765	9410	10280	13920
	8195	9325	10770	13450
	6326	10569	9410	17000
	Ave. 2120	Ave. 2442	Ave. 2538	Ave. 3690
4.5	8748	10000	11725	14230
	8530	9873	11020	13145
	8523	10128	10315	14310
	Ave. 2150	Ave. 2500	Ave. 2755	Ave. 3470

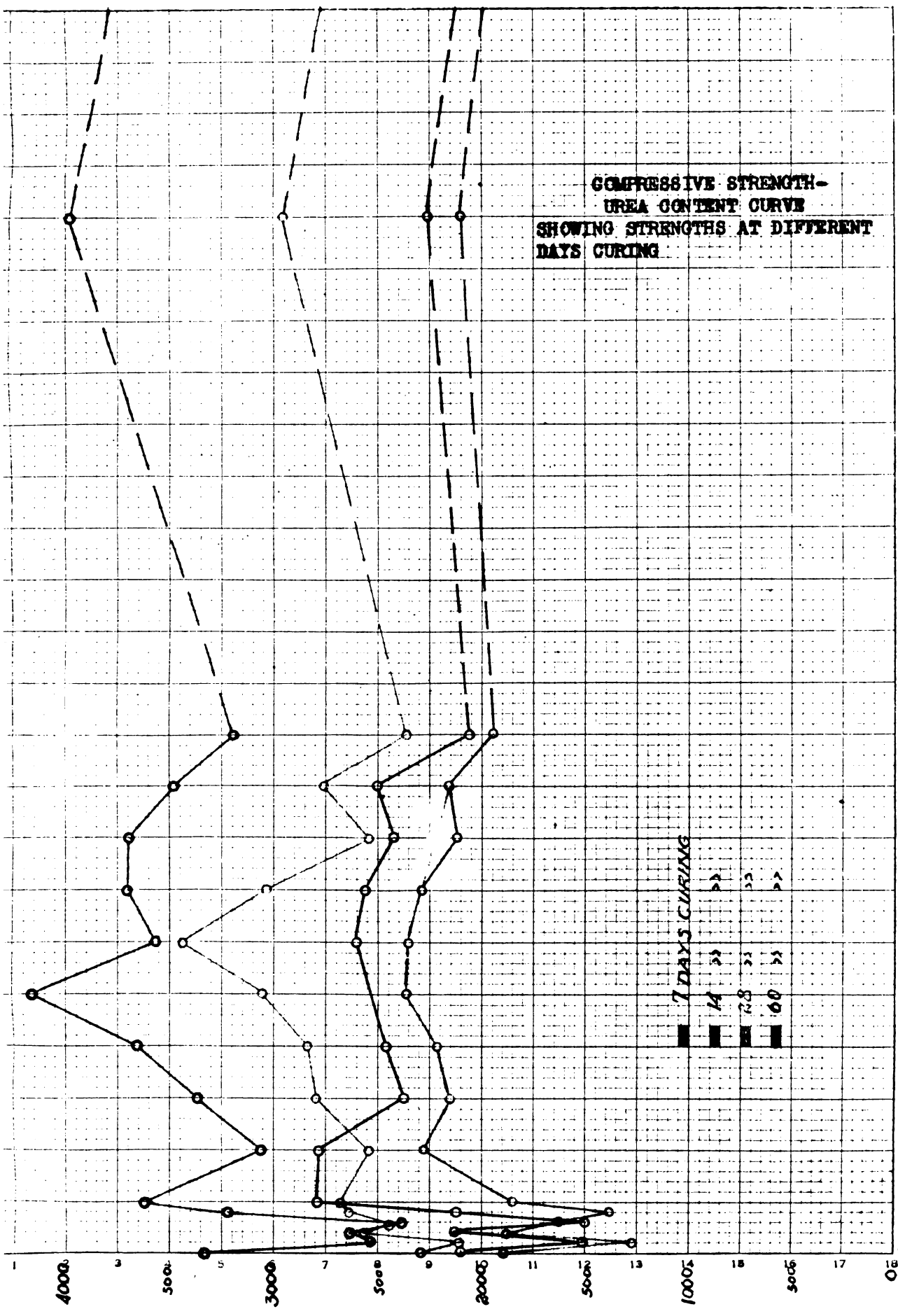
% urea	7 days	14 days	28 days	60 days
5.0	7819	8220	8060	12270
	7403	8130	11120	14455
	8058	8250	9080	11520
	Ave. 1940	Ave. 2050	Ave 2355	Ave. 3190
10.0	8230	8810	10775	14260
	8167	8505	9760	13160
	8804	9625	12805	15015
	Ave. 2100	Ave. 2245	Ave. 2948	Ave. 3950
20.0	6425	7327	7510	12475
	5762	6152	9500	13125
	5814	6321	----	12740
	Ave. 1500	Ave. 1650	Ave. 2130	Ave. 3190

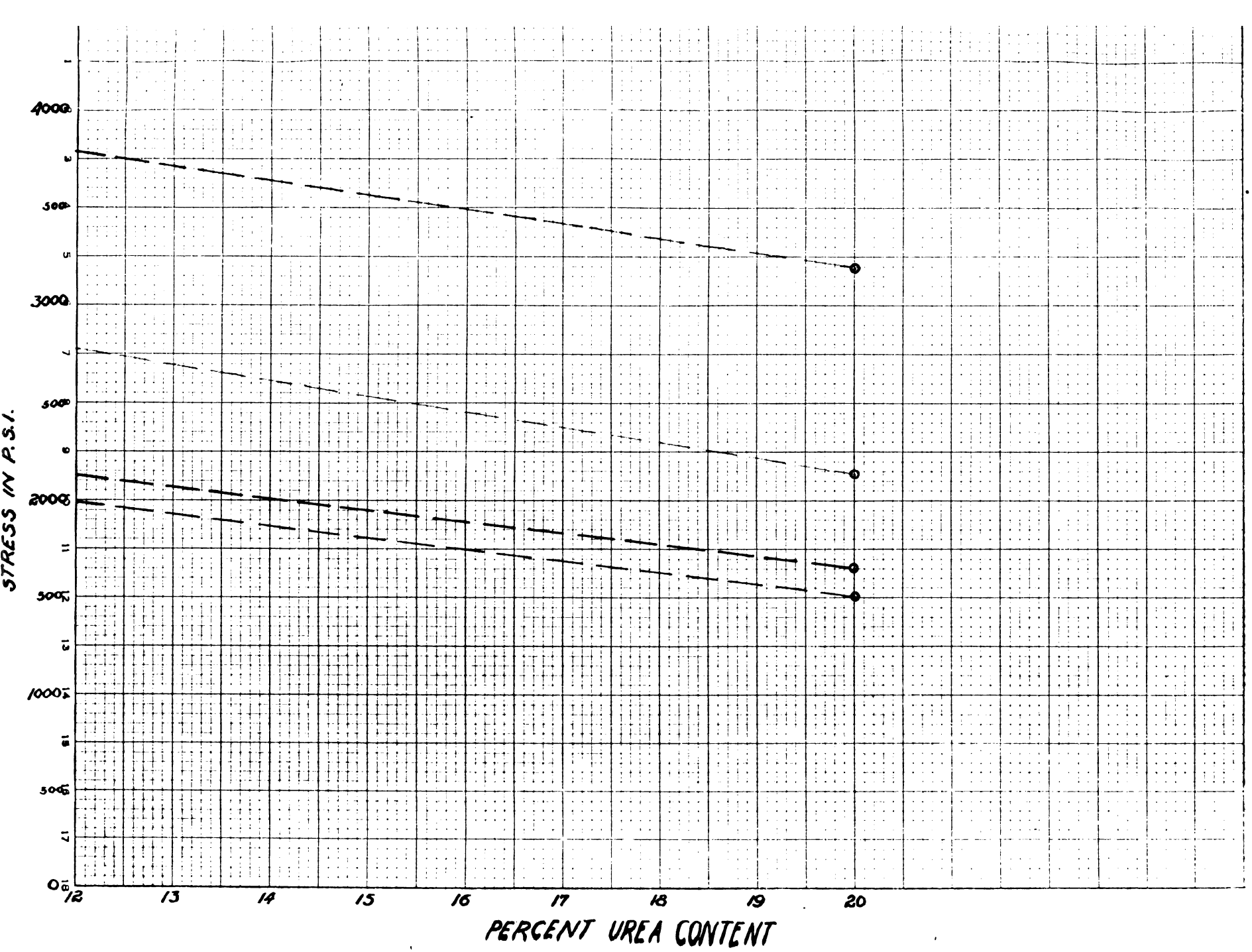
TENSION TESTS RESULTS
Area of Rupture: 1 sq. in.

% urea	7 days	14 days	28 days	60 days
0.0	268	315	375	451
	258	341	385	367
	263	352	410	380
	Ave. 263	Ave. 336	Ave. 390	Ave. 399
0.1	291	343	306	450
	298	342	280	455
	284	425	395	405
	Ave. 291	Ave. 370	Ave. 327	Ave. 428
0.2	296	359	413	435
	305	391	360	400
	330	370	405	452
	Ave. 310	Ave. 373	Ave. 393	Ave. 429
0.3	208	260	323	343
	220	245	351	380
	179	255	324	316
	Ave. 202	Ave. 260	Ave. 333	Ave. 346
0.4	279	303	404	400
	292	353	358	400
	265	340	388	—
	Ave. 275	Ave. 332	Ave. 350	Ave. 400
0.5	288	349	432	432
	272	340	354	432
	310	377	386	432
	Ave. 290	Ave. 355	Ave. 391	Ave. 432
1.0	315	405	395	418
	327	305	375	446
	288	388	429	440
	Ave. 310	Ave. 366	Ave. 400	Ave. 435

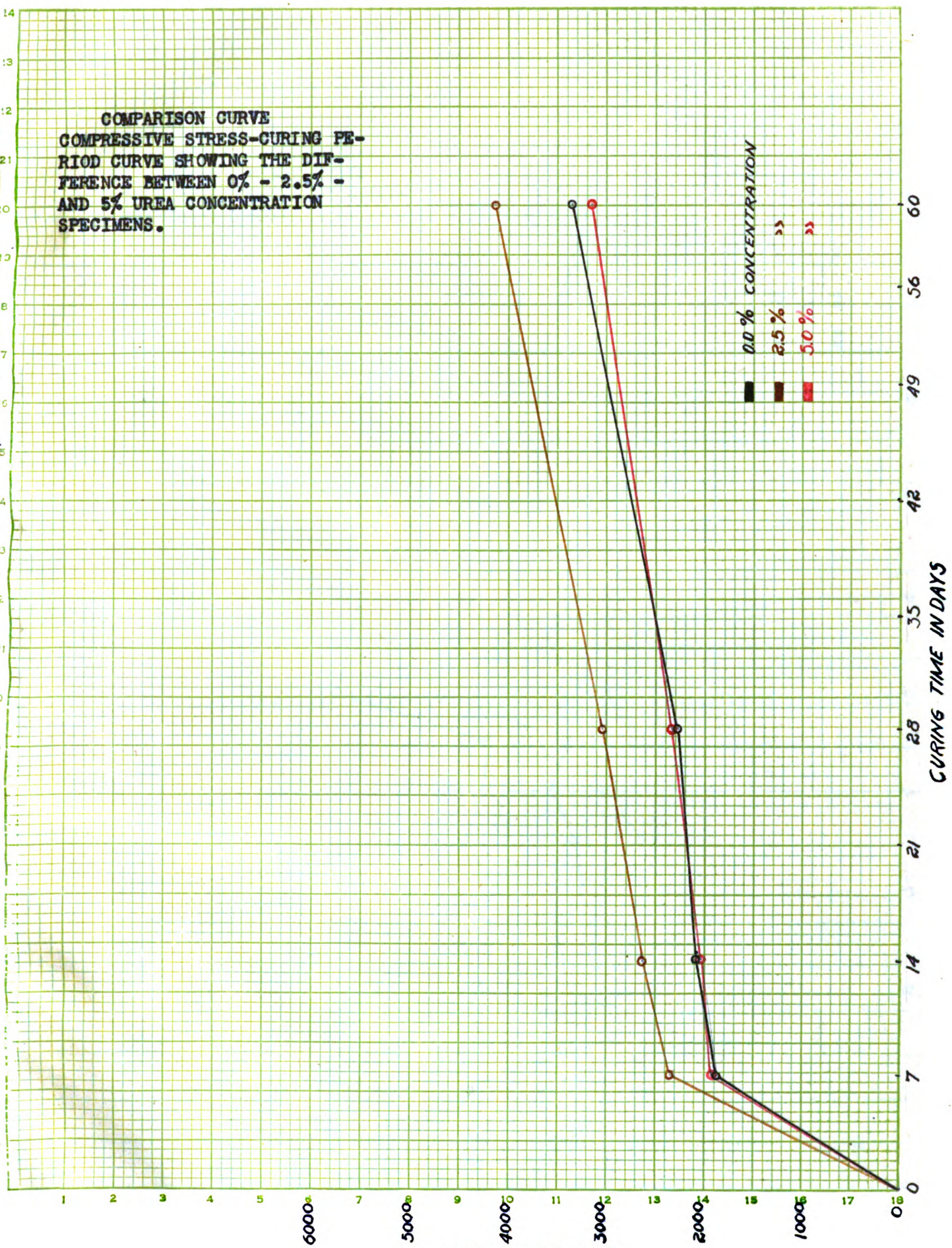
% urea	7 days	14 days	28 days	60 days
1.5	185	231	290	283
	153	205	206	275
	187	180	257	312
	Ave. 175	Ave. 205	Ave. 276	Ave. 290
2.0	272	338	395	385
	247	359	411	442
	258	322	421	390
	Ave. 259	Ave. 340	Ave. 407	Ave. 426
2.5	247	377	411	440
	273	304	443	486
	284	350	432	450
	Ave. 268	Ave. 343	Ave. 429	Ave. 444
3.0	235	331	365	430
	253	315	386	416
	282	325	315	387
	Ave. 240	Ave. 324	Ave. 355	Ave. 411
3.5	245	322	385	445
	257	315	381	460
	285	356	400	420
	Ave. 262	Ave. 331	Ave. 389	Ave. 442
4.0	275	338	377	380
	325	357	377	460
	302	370	377	435
	Ave. 300	Ave. 355	Ave. 377	Ave. 425
4.5	267	350	385	410
	283	316	390	410
	260	355	355	434
	Ave. 270	Ave. 340	Ave. 377	Ave. 418

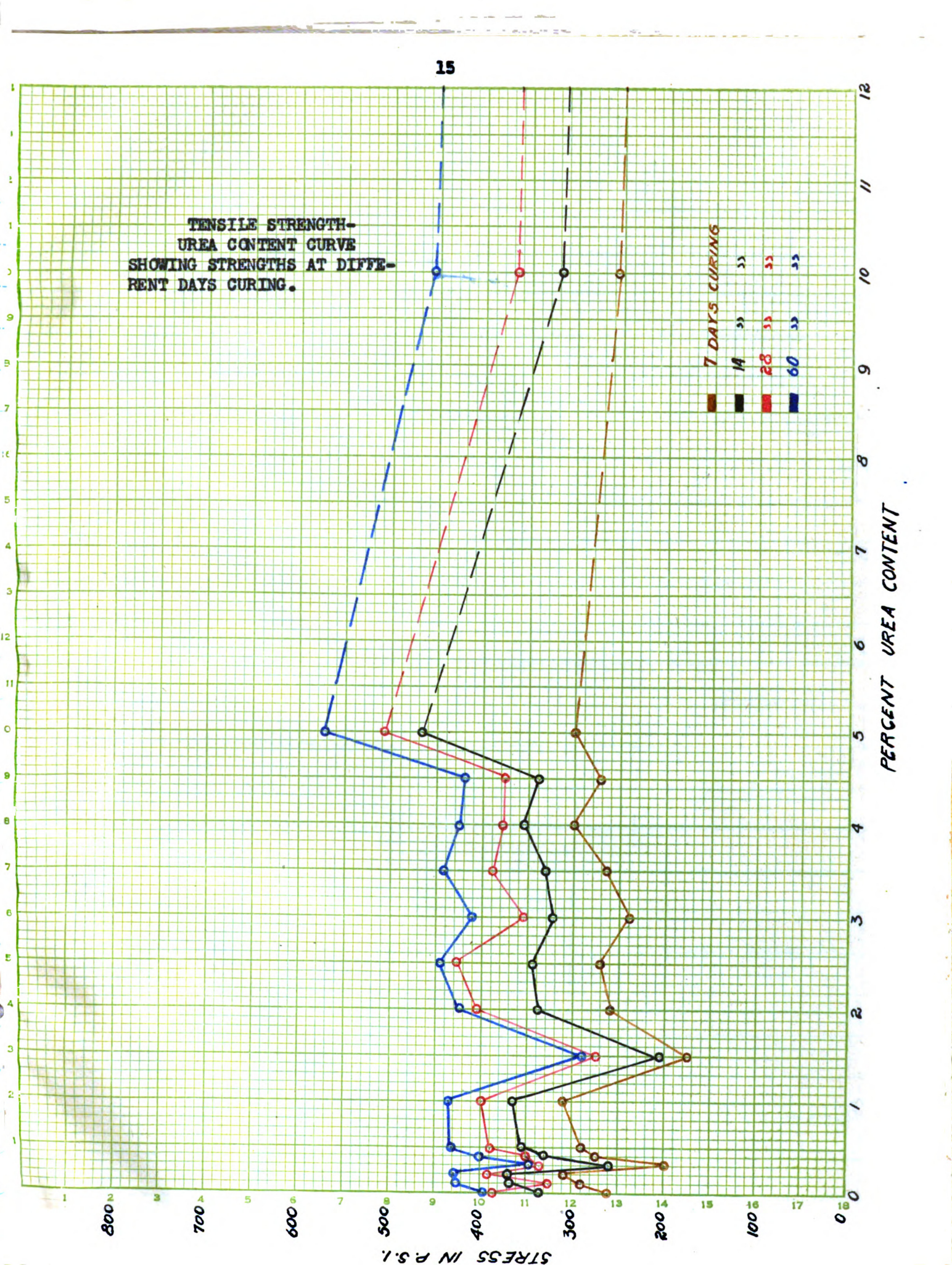
% urea	7 days	14 days	28 days	60 days
5.0	262	480	473	587
	315	500	530	550
	284	425	523	575
	Ave. 287	Ave. 468	Ave. 509	Ave. 571
10.0	263	302	390	457
	260	316	360	417
	242	340	340	439
	Ave. 255	Ave. 319	Ave. 363	Ave. 454
20.0	198	290	342	459
	235	287	355	410
	234	298	350	395
	Ave. 222	Ave. 292	Ave. 349	Ave. 421


COMPRESSIVE STRENGTH-
UREA CONTENT CURVE
SHOWING STRENGTHS AT DIFFERENT
DAYS CURING
7 DAYS CURING
14 "
28 "
60 "
PERCENT UREA CONTENT
STRESS IN P.S.I.

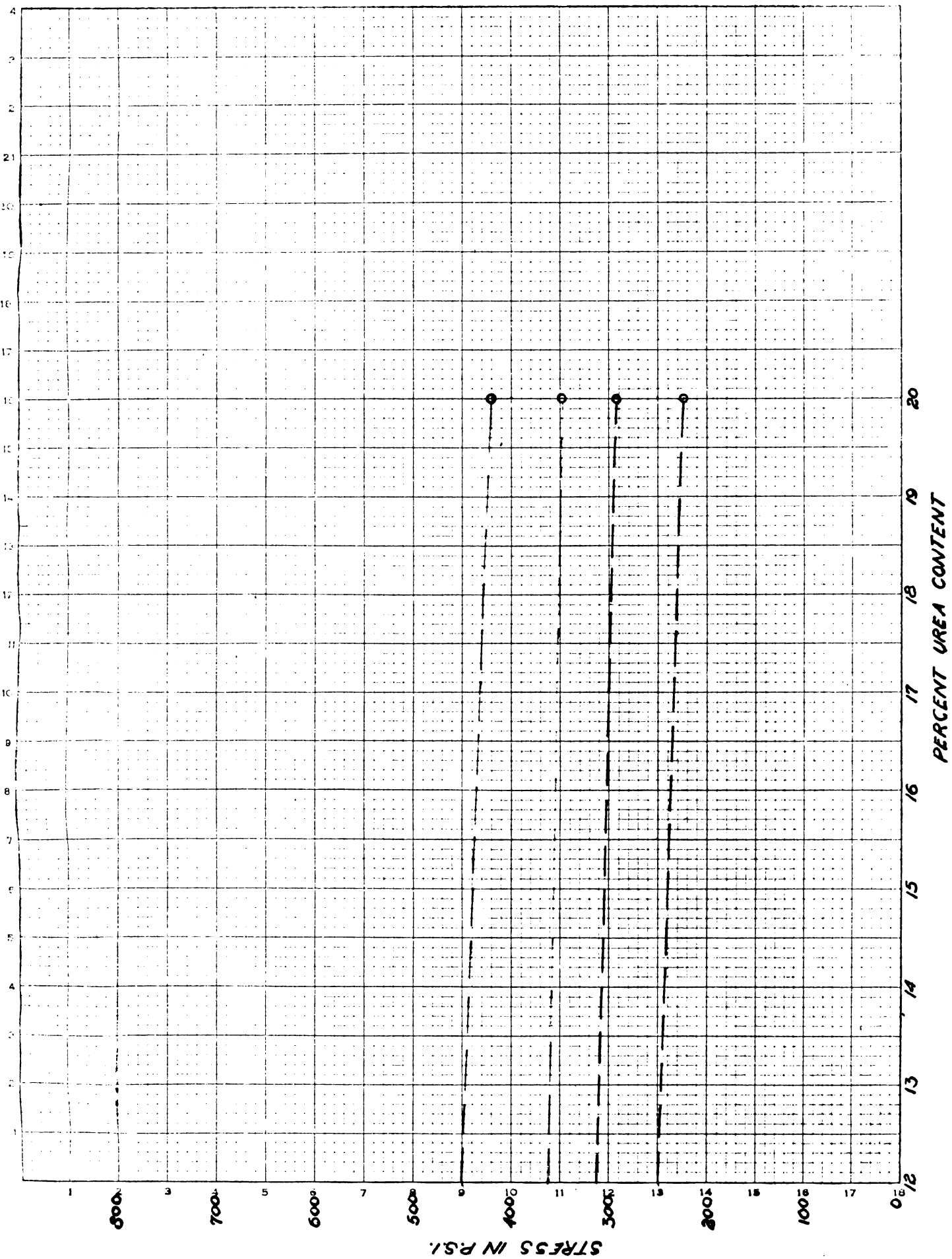

4000
3000
2000
1000
0
12
13
14
15
16
17
18
19
20
STRESS IN P.S.I.
PERCENT UREA CONTENT

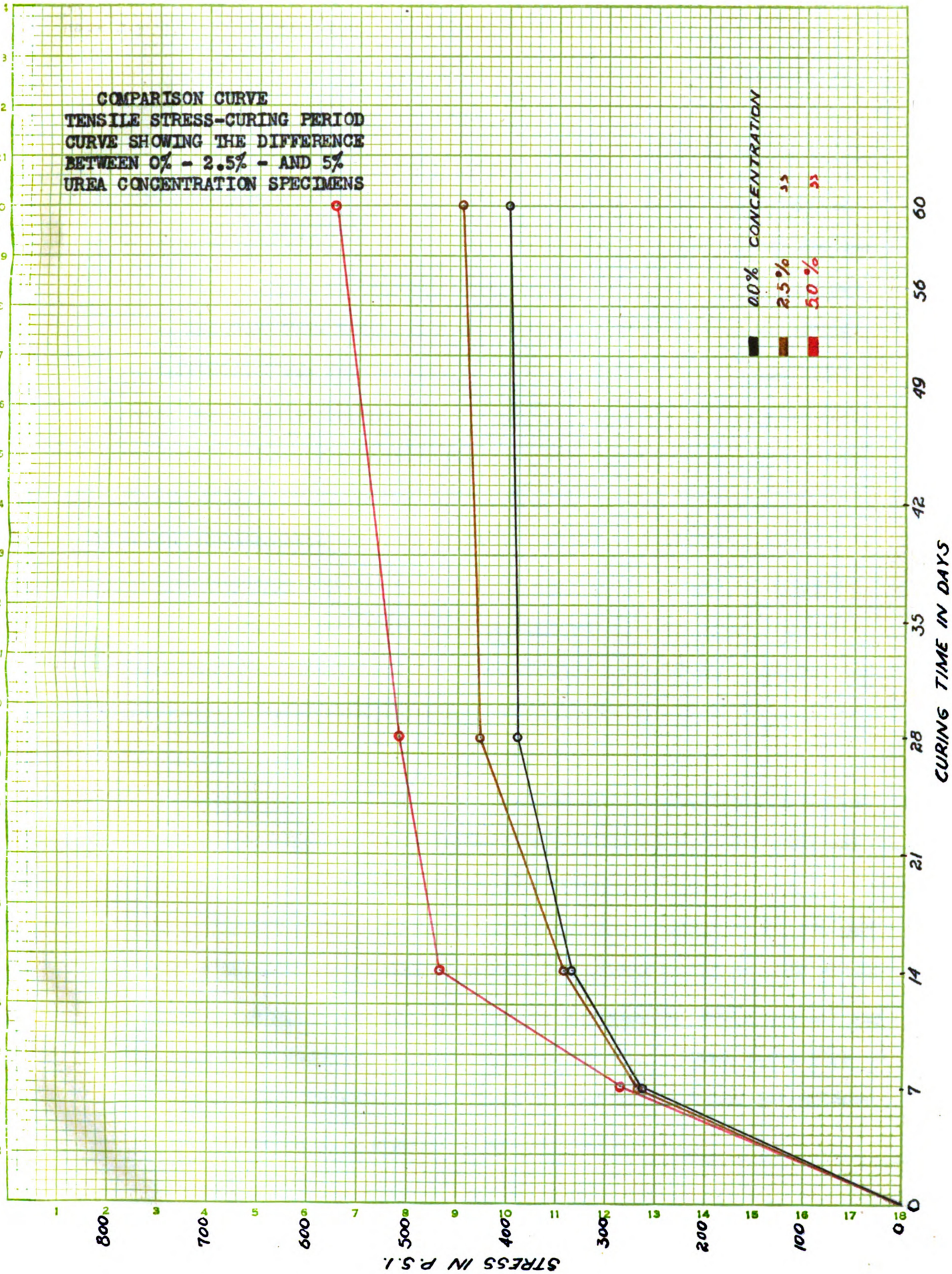
COMPARISON CURVE
COMPRESSIVE STRESS-CURING PERIOD CURVE SHOWING THE DIFFERENCE BETWEEN 0% - 2.5% - AND 5% UREA CONCENTRATION SPECIMENS.




TENSILE STRENGTH-
UREA CONTENT CURVE
SHOWING STRENGTHS AT DIFFE-
RENT DAYS CURING.
7 DAYS CURING
14 "
28 "
60 "
PERCENT UREA CONTENT
STRESS IN P.S.I.
800
700
600
500
400
300
200
100
0

15-A


STRESS IN PSI.
800
700
600
500
400
300
200
100
0
PERCENT UREA CONTENT
12
13
14
15
16
17
18
19
20


COMPARISON CURVE
TENSILE STRESS-CURING PERIOD
CURVE SHOWING THE DIFFERENCE
BETWEEN 0% - 2.5% - AND 5%
UREA CONCENTRATION SPECIMENS
0.0% CONCENTRATION
2.5%
5.0 %
CURING TIME IN DAYS
STRESS IN P.S.I.
800
700
600
500
400
300
200
100
0
7
14
21
28
35
42
49
56
60

CONCLUSIONS

The results obtained in this thesis are not as successfull as I expected them to be.

By studying the compression and tension curves it can be noticed that a ratio of increase or decrease between the results obtained does not exist. That is to say that there being an increase in the results obtained in the tension tests, the same should occur in the results obtained from equal specimens tested on compression. One of the explanations I can find is that being the urea an organic base it affects the friction between the cement paste and the particles of sand. Due to this fact, when the concrete is working in compression the particles of sand slide more than they do when covered by simple cement paste, not resisting as much pressure as they would otherwise.

The best results were obtained, in tension, using 5% urea but similar specimens gave results lower than normal when tested in compression. In compression, 2.5% urea specimen gave the best results and in tension it also showed increase of strength but not as much as the 5% urea specimen.

My basis in judging a normal value are the results obtained in the no urea specimens. To determine the normal values, many specimens were made in order to obtain acceptable average values.

According to my determinations and observations, if it was desired to use urea mixed with concrete, the percentage to be used should be 2.5% which would add more strength to the mixture. But I can not say the same thing about the other properties of cement since tests were not run in order to obtain the effect of urea on the other properties.

Following is a summary of my conclusions:

1- 2.5% urea concentration increases the strength of concrete in tension and compression.

2- Urea - $CO(NH_2)_2$ - is very soluble in water and it does not procure any extra work when mixing it.

3- The cost of urea is very low. Using 2.5% concentration, an average cost would be $0.10 per sack of cement. The increase in cost is not much but it always depends on the percentage of mixing water. In this case the cost is based on 11% mixing water.

4- Urea decreases the friction between the particles of sand and the cement paste. There is a possibility of an existing layer of urea cristals between the surface of the sand particles and the cement paste. This layer of urea cristals breaks when too much pressure is applied. This happens during compression. In tension this effect does not exist because the cement paste takes all the load.