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# THE EFFECT OF SALTS UPON THE STRENGHT OF CONCRETE CURED AT LOW TEMPERATURES

Concrete – Testing

# THE EFFECT OF SALTS UPON THE STRENGTH OF CONCRETE CURED AT LOW TEMPERATURES

by

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THESIS

## INTRODUCTORY.

This is a report of tests made during the winter and spring of 1912 by Mr. H. L. Pulver, C. E., Research Assistant in Mechanics at the University of Wisconsin and the writer, instructor in Mechanics at the same University.

The object of the tests conducted was to determine if there were any virtue in using salts to lower the freezing temperature, and incidentally to increase the rate of hardening of concrete, and if so the proper percentage to use to get the most desirable effect.

In performing the tests, common salt (NaCl) and calcium chloride ($CaCl_2$) were used dissolved in the mixing water, the percentage of the salts being varied over what seemed to be any practicable range. The effort was made to get the conditions as close as possible to the most rigorous obtaining ordinarily in the field. To this end the aggregate was taken directly from the outside atmosphere or from a refrigerator in which the temperature was maintained below freezing, the water was taken from the city mains, and the cubes when made were placed, as quickly as convenient in the atmosphere in which they were to be cured, the maximum time between mixing and exposing being about half an hour. The water was usually at a temperature of about 55°F., the sand and stone about 20°F.

Since it seemed desirable to know if all the change in strength obtained were due to the lowering of the

freezing temperature, and also to know if the salts had a detrimental effect on concrete as ordinarily made, tests were also made on cubes mixed with materials at normal temperatures and stored in the laboratory under normal conditions.

## Scope of the Tests.

All cubes were four inches on a side. For the first set of specimens the percentage of NaCl to water was varied between the limits 5% and 15% by weight. For the second set the percentage of $CaCl_2$ was varied from 2% to 10%. For the next set the water contained both NaCl and $CaCl_2$, NaCl varying from 5% to 15% and $CaCl_2$ varying from 2% to 8%. All the above were stored in air immediately after being mixed, at an initial temperature of between 10° and 20° Fahrenheit and the temperature kept below 32° throughout the curing, except that on two days before some of the specimens were placed in the refrigerator the outside temperature rose to about 35°.

For other sets of specimens the same variables were used as in the first set but materials used were at normal temperature, around 70°, and cubes, after curing in air for 24 hours were placed under running water at about 68° for thirteen days, then stored in air till broken. Specimens, four for each point wanted, were broken at fourteen and at sixty days. All low temperature specimens were stored in the laboratory for one day before

breaking to permit of thawing. All the normal temperature cubes were taken from the water of the tank at fourteen days, four of each being broken, the others being stored in the air in the laboratory.

Material Used.

The cement used was Atlas Portland, tensile tests of which follow on Table I. These tests were made in accordance with the rules of the American Society for Testing Materials. In order that there might be no variation in the quality a sufficient quantity for the entire work was mixed thoroughly at the beginning and stored in air tight cans until used.

The sand was of good quality from Janesville, Wisconsin, and all used was from the same bin.

The stone was limestone from quarries near Madison, Wisconsin.

The NaCl used was common grainer salt and the $CaCl_2$ was from a barrel obtained for use in the laboratory.

The concrete used was a 1:2:4 mix by volume, this being adopted as being typical of that which would be used in practice in most instances. The weight of sand was found to average 110 lbs per cu. ft., stone 90 lbs. per cu. ft. and cement was assumed as weighing 100 lbs. per cu. ft.

Since the total quantity of concrete in any one batch was less than a half cubic foot it was considered

best to weigh quantities used. All materials were thoroughly mixed together by hand, dry, then the liquid added in sufficient quantity to give a just wet mixture that would flow and form a smooth surface in the moulds. The wet mixture was turned with a trowel until it appeared to be of uniform consistency. About 10% by weight of water was required to produce a mixture of the proper consistency though this percentage was varied slightly for the different batches. Specimens were surfaced by trowelling till fairly smooth.

The Tempering Liquid.

A mixture of water and NaCl was made using 25% by weight of salt. This was stored in a can and sufficient used with water to give the proper percentage. In the same way a mixture containing 20% of $CaCl_2$ was used.

Testing.

A set of four cubes of each batch was broken at the end of sixty days. A 100,000 lb Riehle Universal testing machine was used for the loading. The cubes rested on a spherical bearing block and care was taken to insure the cube being centrally placed on the block. Cubes were bedded on several thicknesses of blotting paper both above and below.

Results of Tests.

The results of tests on low temperature cubes are given in tables 2 to 7 inclusive. In the cubes of table 2 NaCl alone was used, in those of table 3 $CaCl_2$ alone was

used, while in those of tables 4, 5, 6, and 7 both salts were used in varying percentages.

The results of the tests with cubes cured at normal temperatures are given in tables 8 to 13 inclusive, the variables and arrangement of tables being the same as in the case of the low temperature cubes.

Curve sheets 14 to 18 inclusive show graphically the results obtained.

On sheet 14 are the curves obtained using but one salt in the tempering water, both for low temperature and normal cubes at 14 and at 60 days. On sheets 15 and 16 unit loads are plotted as ordinates and percents. $CaCl_2$ as abscissae and curves drawn for various percentages of NaCl, sheet 15 being for fourteen days and sheet 16 for sixty days.

In the same way on sheets 17 and 18 curves are plotted for various percentages of $NaCl_2$, NaCl percentages being ordinates.

## CONCLUSIONS.

The curves show an almost straight line decrease in the strength of concrete cured under normal conditions as the percentage of NaCl is increased, up to 12%, at the rate of about 2% decrease for each 1% salt added to the mixing liquid, after which there is apparently a slight increase (which a check on results would probably show, did not occur.)

The effect of NaCl alone added to concrete cured at low temperatures probably is to reduce the freezing temperature and so permit of the setting and hardening of the concrete. The curves show a strength increase of about 20% for each 1% salt up to twelve percent, after which there is a decrease in strength. It is probable that beyond twelve percent the weakening of the concrete due to the excess of salt more than offsets the gain in strength due to the reduction of the freezing temperature.

The effect of the addition of $CaCl_2$ alone to concrete cured either normally or at low temperature is to increase the strength by an almost straight line variation up to 4% $CaCl_2$ at which point maximum strength is obtained. The rate of increase is the most marked in the case of the fourteen day low temperature concrete, probably due to the acceleration of the setting of the cement by the $CaCl_2$. Serious disintegration was observable on the surface in the case of the 6% and 8% $CaCl_2$ concrete

cured at low temperature, but did not appear on any of the cubes cured normally, or where NaCl was also used in the mixing water.

The most desirable effect seems to be obtained when both NaCl and $CaCl_2$ are used in the mixing water, and from a study of the curves it seems that the use of 2% $CaCl_2$ and 6% NaCl will give the most satisfactory results. This is probably due to the fact that the percentage of NaCl used is sufficiently high to retard freezing but not enough to greatly reduce the strength, while the percentage of $CaCl_2$ also does its share in retarding freezing and, further, accelerates the time of setting very appreciably. The normal strength of the concrete is reduced only about 10%, and the increase in strength of low temperature concrete, particularly at 14 days, over that of concrete containing no salt or containing $CaCl_2$ or NaCl alone is very marked. The use of higher percentages than the above is not recommended, because the normal temperature curves point to the probability that after a long period there may be sufficient disintegration to cause a considerable reduction in the strength of the concrete.

These tests were made using but one brand of cement. It is probable that there will be some variation in results with other brands. It is not anticipated that this will be sufficiently marked to affect the general conclusions.

It is possible that at times common salt will be obtained which will contain a sufficiently high percentage of calcium sulphate to affect the results somewhat.

It is suggested that a further field for researches of this character would be in mixing the materials as is frequently done at the present time, i.e., by using the aggregates heated somewhat, and by using a mixing water heated to a temperature of from 125° to 175°F. It may be that in this case the accelerating effect of the $CaCl_2$ on the setting would enable the concrete to harden so rapidly that the forms could be removed much earlier than is now done when concrete is poured in cold weather. It would be well to obtain all possible information regarding the effects of electrolysis on concretes containing these salts before using them in concrete to be used in structures where the effect of electrical currents might be detrimental.

At the time of making the cubes for the above tests another set of each was made to be cured for a year or more in order to observe the effect of the salts over an extended period of time.

# CEMENT TESTS

| AGE | BREAKING LOAD | | | |
|---|---|---|---|---|
| | NEAT | | 1:3 | |
| IN DAYS | BRIQ. | AVERAGE | BRIQ. | AVERAGE. |
| 1 | 285 | | | |
| | 273 | | | |
| | 265 | | | |
| | 283 | 277 | | |
| 7 | 638 | | 166 | |
| | 621 | | 185 | |
| | 660 | 640 | 174 | |
| | | | 183 | 177 |
| 28 | 825 | | 276 | |
| | 755 | | 300 | |
| | 836 | | 284 | |
| | 800 | 804 | 272 | 283 |
| 60 | 1015 | | 400 | |
| | 1010 | | 415 | |
| | 950 | | 380 | |
| | 905 | 970 | 430 | 406 |

# TESTS OF CONCRETE CURED AT LOW TEMPERATURE.
## 4 INCH CUBES
## WITH AND WITHOUT Na. Cl. IN WATER
UNIT LOADS ARE IN LBS. PER SQ. IN.

| DATE MADE | TEMPERATURES WHEN MIXED | | | SALT CONTENT | RESULTS OF LORD TESTS. | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 14 DAY | | | 60 DAY. | | | |
| | INSIDE AIR | OUTSIDE AIR | BATCH | | TOTAL | UNIT | AV. UNIT | TOTAL | UNIT | AV. UNIT | |
| JAN 20-12 | 64° | 13° | 42° | NONE | 2600 | 163 X | | 6910 | 431 | | |
| | | | | | 3330 | 208 | | 5830 | 364 | | |
| | | | | | 3300 | 206 | | 6610 | 414 | | |
| | | | | | 3590 | 224 | 213 | 6980 | 436 | 427 | |
| JAN 30-12 | 61° | 13° | 51° | 6 % Na. Cl. | 7350 | 459 | | 11300 | 706 | | |
| | | | | | 7660 | 479 | | 10600 | 662 | | |
| | | | | | 7580 | 474 | | 11900 | 744 | | |
| | | | | | 8250 | 515 | 482 | 10040 | 628 | 685 | |
| JAN 30-12 | 61° | 13° | 51° | 9 % Na. Cl. | 11950 | 746 | | 14680 | 918 | | |
| | | | | | 10600 | 662 | | 15070 | 942 | | |
| | | | | | 9460 | 591 | | 15270 | 955 | | |
| | | | | | 11500 | 719 | 680 | 15230 | 952 | 942 | |
| JAN 30-12 | 61° | 13° | 51° | 12 % Na. Cl. | 12000 | 750 | | 19630 | 1228 | | |
| | | | | | 12000 | 750 | | 18590 | 1161 | | |
| | | | | | 13000 | 812 | | 19910 | 1246 | | |
| | | | | | 15050 | 940 | 813 | 18130 | 1133 | 1192 | |
| JAN 20-12 | 64° | 13° | 42° | 15 % Na. Cl. | | | | 15610 | 976 | | |
| | | | | | 7680 | 480 | X | 17160 | 1072 | | POOR BASE ON #1-14 DAY. |
| | | | | | 10230 | 640 | | 16310 | 1020 | | |
| | | | | | 9410 | 588 | 614 | 18770 | 1173 | 1060 | |

X OMITTED FROM AVERAGE

(2)

# TESTS OF CONCRETE CURED AT LOW TEMPERATURE.
## 4 INCH CUBES
## $CaCl_2$ IN MIXING WATER.

| DATE MADE | TEMPERATURES WHEN MIXED: INSIDE AIR | TEMPERATURES WHEN MIXED: OUTSIDE AIR | TEMPERATURES WHEN MIXED: BATCH | SALT CONTENT | RESULTS OF LOAD TESTS: 14 DAY. TOTAL | 14 DAY. UNIT | 14 DAY. DIFF. UNIT | 60 DAY. TOTAL | 60 DAY. UNIT | 60 DAY. DIFF. UNIT | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5350 | 335* | | 8550 | 535 | | |
| FEB 5-12 | 69° | 17° | 41° | 2% $CaCl_2$ | 6650 | 416 | | 7510 | 469 | | |
| | | | | | 6640 | 415 | | 6430 | 402 | | |
| | | | | | 6850 | 428 | 420 | 7220 | 451 | 464 | |
| | | | | | 7640 | 477 | | 9180 | 573 | | #2-14 DAY, TOP DISINTEGRATED SOMEWHAT #3-60 DAY, POOR TOP |
| FEB 5-12 | 69° | 17° | 44° | 4% $CaCl_2$ | 5550 | 347* | | 9090 | 567 | | |
| | | | | | 6200 | 388 | | 7180 | 449* | | |
| | | | | | 7480 | 467 | 444 | 8780 | 549 | 564 | |
| | | | | | 4900 | 306 | | 6720 | 420 | | ALL 8 CUBES DISINTEGRATED SOME ON SURFACE. |
| FEB 5-12 | 69° | 18° | 55° | 6% $CaCl_2$ | 5700 | 357 | | 5910 | 369 | | |
| | | | | | 6200 | 388 | | 5920 | 370 | | |
| | | | | | 5500 | 344 | 349 | 4950 | 309 | 367 | |
| | | | | | 5050 | 315 | | 4700 | 294 | | ALL CUBES SEEMED SOFT FOR A DEPTH OF ABOUT ¼ INCH. |
| FEB 8-12 | 72° | 1° | 46° | 8% $CaCl_2$ | 3150 | 197* | | 6440 | 402 | | |
| | | | | | 4450 | 278 | | 5450 | 341 | | |
| | | | | | 4240 | 265 | 286 | 4800 | 300 | 337 | |
| | | | | | 3140 | 196 | | 4720 | 295 | | |
| FEB 8-12 | 67° | 1° | 46° | 10% $CaCl_2$ | 4400 | 275 | | 6270 | 392 | | |
| | | | | | 3290 | 205 | | 4770 | 298 | | |
| | | | | | 4140 | 258 | 234 | 6500 | 406 | 348 | |

ON THIS ENTIRE SET THE TEMPERATURE ROSE SLIGHTLY ABOVE FREEZING ON THREE DIFFERENT DAYS

*OMITTED FROM AVERAGE.

# TESTS OF CONCRETE CURED AT LOW TEMPERATURE.

## 4 INCH CUBES

## WITH 2% $Ca.Cl_2$ AND VARYING % s $Na.Cl$. IN WATER.

UNIT LOADS ARE IN LBS. PER. SQ.IN.

| DATE MADE | TEMPERATURES WHEN MIXED | | | SALT CONTENT | RESULTS OF LOAD TESTS. | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 14 DAY | | | 60 DAY | | | |
| | INSIDE AIR | OUTSIDE AIR | BATCH | | TOTAL | UNIT | AV. UNIT | TOTAL | UNIT | AV. UNIT | |
| FEB 12-12 | 68° | 15° | 52° | 2% $CaCl_2$ | 12290 | 768 | | 15800 | 988 | | |
| | | | | | 12930 | 808 | | 16080 | 1005 | | |
| | | | | 6% $Na.Cl.$ | 13850 | 864 | | 15000 | 937 | | |
| | | | | | 13280 | 830 | 817 | 16600 | 1038 | 992 | |
| FEB. 12-12 | 68° | 15° | 52° | 2% $CaCl_2$ | 13100 | 818 | | 19320 | 1207 | | |
| | | | | | 12140 | 759 | | 18500 | 1157 | | |
| | | | | 9% $NaCl.$ | 14720 | 920 | | 19660 | 1223 | | |
| | | | | | 14350 | 896 | 848 | 18400 | 1150 | 1185 | |
| FEB 9-12 | 68° | 7° | 38° | 2% $CaCl_2$ | 9650 | 602 | | 13430 | 840 | | |
| | | | | | 10050 | 628 | | 13160 | 823 | | |
| | | | | | 8400 | 525 | | 9300 × | 580 | | |
| | | | | 15% $NaCl$ | 9250 | 577 | 583 | 12150 | 760 | 807 | |
| FEB 9-12 | 66° | 7° | 41° | 2% $CaCl_2$ | 10850 | 678 | | 15210 | 951 | | |
| | | | | | 10800 | 675 | | 13380 | 1149 | | |
| | | | | | 12100 | 756 | | 15640 | 977 | | |
| | | | | 12% $NaCl$ | 10400 | 650 | 690 | 17640 | 1102 | 1045 | |

× OMITTED FROM AVERAGE.

# TESTS OF CONCRETE CURED AT LOW TEMPERATURE.

## 4 INCH CUBES

WITH 4% $CaCl_2$ AND VARYING % S $NaCl$ IN WATER

UNIT LOADS ARE IN LBS. PER SQ. IN.

| DATE MADE | TEMPERATURES WHEN MIXED | | | SALT CONTENT | RESULTS OF LOAD TESTS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 14 DAY | | | 60 DAY | | | |
| | INSIDE AIR | OUTSIDE AIR | BATCH | | TOTAL | UNIT | AV. UNIT | TOTAL | UNIT | AV. UNIT | |
| FEB 13-12 | 58° | 21° | 52° | 4% $CaCl_2$ | 13450 | 840 | | 14690 | 919 | | |
| | | | | | 11860 | 740 | | 14450 | 902 | | |
| | | | | | 11370 | 710 | | 14740 | 920 | | |
| | | | | 6% $NaCl$ | 13560 | 849 | 785 | | | 914 | |
| FEB 13-12 | 58° | 20° | 51° | 4% $CaCl_2$ | 13000 | 812 | | 13800 | 862 | | |
| | | | | | 11680 | 729 | | 15630 | 976 | | |
| | | | | | 12130 | 758 | | 15030 | 940 | | |
| | | | | 9% $NaCl$ | 11530 | 721 | 755 | | | 926 | |
| | | | | | 11,100 | 693 | | 18300 | 1144 | | |
| FEB 20-12 | 63° | 15° | 45° | 4% $CaCl_2$ | 12,800 | 800 | | 20900 | 1306 | | |
| | | | | | 13,850 | 866 | | 18900 | 1181 | | |
| | | | | 12% $NaCl$ | 11,300 | 705 | 766 | 19630 | 1229 | 1215 | |
| FEB 20-12 | 63° | 15° | 45° | 4% $CaCl_2$ | 11700 | 732 | | 20300 | 1268 | | |
| | | | | | 9500 | 593 | | 17320 | 1081 | | #2-14 DAY HAD POOR TOP. |
| | | | | | 9860 | 612 | | 18600 | 1161 | | |
| | | | | 15% $NaCl$ | 12650 | 790 | 682 | 20620 | 1290 | 1200 | |

# TESTS OF CONCRETE CURED AT LOW TEMPERATURE.

## 4 INCH CUBES

## WITH 6% $CaCl_2$ AND VARYING % OF $NaCl$ IN WATER

| DATE MADE | TEMPERATURES WHEN MIXED. INSIDE AIR | OUTSIDE AIR | BATCH | SALT CONTENT | RESULTS OF LOAD TESTS 14 DAY TOTAL | UNIT | AV. UNIT | 60 DAY TOTAL | UNIT | AV. UNIT | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FEB 21-12 | 54° | 20° | 43° | 6% $CaCl_2$ | 12,100 | 756 | | 18070 | 1160 | | |
| | | | | 6% $NaCl$ | 9900 | 618 | | 13660 | 855 | | |
| | | | | | 10400 | 650 | | 15200 | 950 | | |
| | | | | | 11,100 | 693 | 680 | 15820 | 989 | 988 | |
| FEB 21-12 | 53° | 20° | 38° | 6% $CaCl_2$ | 7500 | 468 | | 13320 | 833 | | |
| | | | | 9% $NaCl$ | 8000 | 500 | | 14120 | 883 | | |
| | | | | | 7550 | 472 | | 14500 | 907 | | |
| | | | | | 7700 | 481 | 480 | 12430 | 778 | 850 | |
| FEB 27-12 | 63° | 21° | 52° | 6% $CaCl_2$ | 8230 | 514 | | 9220 | 576 | | |
| | | | | 12% $NaCl$ | 7450 | 465 | | 10650 | 666 | | |
| | | | | | 7370 | 460 | | 9330 | 583 | | |
| | | | | | 9280 | 579 | 505 | 10160 | 635 | 615 | |
| FEB 27-12 | 63° | 21° | 52° | 6% $CaCl_2$ | 8600 | 538 | | 12160 | 760 | | |
| | | | | 15% $NaCl$ | 8400 | 524 | | 14750 | 923 | | |
| | | | | | 7970 | 498 | | 14550 | 910 | | |
| | | | | | 8800 | 549 | 527 | 13760 | 860 | 863 | |

# TESTS OF CONCRETE CURED AT LOW TEMPERATURE.

## 4 INCH CUBES

## WITH 8% $Ca.Cl_2$ AND VARYING %'s $NaCl$ IN WATER

| DATE MADE | TEMPERATURES WHEN MIXED | | | SALT CONTENT | RESULTS OF LOAD TESTS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 14 DAY. | | | GO DAY. | | | |
| | INSIDE AIR | OUTSIDE AIR | BATCH | | TOTAL | UNIT | AV. UNIT | TOTAL | UNIT | AV. UNIT | |
| FEB 27-12 | 63° | 21° | 51° | 8% $CaCl_2$ | 6280 | 392 | | 11320 | 709 | | GO DAY CUBES DISINTEGRATED SLIGHTLY ON CORNERS AND EDGES |
| | | | | 6% $NaCl$ | 5400 | 338 | | 9550 | 597 | | |
| | | | | | 7200 | 450 | | 7150 | 447 | | |
| | | | | | 6050 | 378 | 390 | 9720 | 607 | 590 | |
| FEB. 28-12 | 65° | 30° | 50° | 8% $CaCl_2$ | 7300 | 456 | | 10980 | 686 | | #4-GO DAY HAD CORNER BROKEN OFF |
| | | | | 9% $NaCl$ | 7770 | 486 | | 10550 | 659 | | |
| | | | | | 7950 | 497 | | 10610 | 664 | | |
| | | | | | 8160 | 510 | 487 | 9730 | 608 | 654 | |
| FEB 28-12 | 65° | 30° | 52° | 8% $CaCl_2$ | 6060 | 380 | | 9000 | 562 | | |
| | | | | 12% $NaCl$ | 6320 | 395 | | 9050 | 565 | | |
| | | | | | 7200 | 450 | | 10150 | 634 | | |
| | | | | | 6150 | 385 | 402 | 9500 | 593 | 589 | |
| FEB 29-12 | 65° | 14° | 44° | 8% $CaCl_2$ | 8750 | 559 | | 10600 | 662 | | |
| | | | | | 8270 | 517 | | 10,000 | 625 | | |
| | | | | 15% $NaCl$ | 8750 | 547 | | 12,170 | 760 | | |
| | | | | | 8250 | 515 | 535 | 9400 | 587 | 658 | |

# TESTS OF CONCRETE CURED AT NORMAL TEMPERATURE.

## 4 INCH CUBES

## WITH AND WITHOUT Na.Cl IN MIXING WATER.

| ATE ADE | TEMPERATURES WHEN MIXED | | | SALT CONTENT | RESULTS OF LOAD TESTS. | | | | | | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | INSIDE AIR | OUTSIDE AIR | BATCH | | 14 DAY | | | 60 DAY | | | |
| | | | | | TOTAL | UNIT | AV. UNIT | TOTAL | UNIT | AV. UNIT | |
| AR.9 912 | 63 | | 52 | NONE | 33,300 | 2080 | | 51,250 | 3202 | | |
| | | | | | 29,990 | 1873 | | 45,800 | 2861 | | |
| | | | | | 31,880 | 1985 | | 48,540 | 3035 | | |
| | | | | | 27,080 | 1738 | 1994 | 46,780 | 2921 | 3005 | |
| EB.3. 912 | 63 | | 58 | NONE - CURED IN INSIDE AIR. | 19,800 | 1240 | | 21,040 | 1315 | | |
| | | | | | 19,220 | 1200 | | 22,700 | 1419 | | |
| | | | | | 18,240 | 1140 | | 20,070 | 1255 | | |
| | | | | | 22,130 | 1380 | 1240 | | | 1330 | |
| AR.9 912 | 63 | | 52 | 6% Na.Cl. | 27,400 | 1728 | | 39,500 | 2470 | | |
| | | | | | 28,760 | 1796 | | 45,450 | 2840 | | |
| | | | | | 28,600 | 1787 | | 40,000 | 2500 | | |
| | | | | | 23,070 | 1443 | 1688 | 42,550 | 2660 | 2617 | |
| EB.10 912 | 65 | | 65 | 9% Na.Cl. | 23,750 | 1483 | | 36,250 | 2266 | | |
| | | | | | 25,200 | 1573 | | 40,250 | 2515 | | |
| | | | | | 24,600 | 1537 | | 39,000 | 2438 | | |
| | | | | | 24,200 | 1513 | 1526 | 36,870 | 2360 | 2395 | |
| EB.12 912 | 68 | | 68 | 12% Na.Cl. | 20,600 | 1287 | | 32,000 | 2000 | | |
| | | | | | 17,350* | | | 36,480 | 2281 | | |
| | | | | | 20,250 | 1260 | | 29,140 | 1820 | | |
| | | | | | 20,000 | 1250 | 1270 | 34,040 | 2132 | 2060 | |
| EB.3 912 | 63 | | 58 | 15% Na.Cl. | 21,900 | 1370 | | 35,640 | 2228 | | |
| | | | | | 21,350 | 1335 | | 35,070 | 2192 | | |
| | | | | | 18,940 | 1185 | | 36,940 | 2308 | | |
| | | | | | 23,230 | 1450 | 1335 | 34,350 | 2145 | 2220 | |

*OMITTED FROM AVERAGE.

# TESTS OF CONCRETE CURED AT NORMAL TEMPERATURE.
## 4 INCH CUBES
## WITH $Ca.Cl_2$ IN MIXING WATER.

| DATE MADE | TEMPERATURES WHEN MIXED | | BATCH | SALT CONTENT | RESULTS OF LOAD TESTS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 14 DAY | | | 60 DAY | | | |
| | INSIDE AIR | OUTSIDE AIR | | | TOTAL | UNIT | AVG UNIT | TOTAL | UNIT | AVG UNIT | |
| FEB. 13 1912 | 69 | | 59 | 2% $CaCl_2$ | 32,100 | 2007 | | 50,000 | 3122 | | |
| | | | | | 27,750 | 1733 | | 56,700 | 3540 | | |
| | | | | | 30,340 | 1893 | | 47,400 | 3043 | | |
| | | | | | 32,550 | 2,034 | 1920 | 50,000 | 3122 | 3207 | |
| FEB 14 1912 | 67 | | 60 | 4% $CaCl_2$ | 34,000 | 2123 | | 53,300 | 3335 | | |
| | | | | | 30,000 | 1875 | | 47,750 | 2983 | | #4 OF 14 DAY HAD VERY IRREGULAR TOP. |
| | | | | | 37,060 | 2317 | | 59,750 | 3728 | | |
| | | | | | 21,400* | | 2105 | 64,100 | 4006 | 3510 | |
| FEB 15 1912 | 69 | | 60 | 6% $CaCl_2$ | 29,200 | 1824 | | 52,500 | 3280 | | |
| | | | | | 24,550 | 1532 | | 48,600 | 3038 | | |
| | | | | | 30,500 | 1907 | | 56,300 | 3520 | | |
| | | | | | 26,050 | 1631 | 1723 | 39,300* | | 3280 | |
| FEB 15 1912 | 69 | | 61 | 8% $CaCl_2$ | 24,400 | 1524 | | 49,500 | 3093 | | |
| | | | | | 20,450* | | | 45,800 | 2860 | | |
| | | | | | 24,300 | 1518 | | 41,100* | | | |
| | | | | | 23,800 | 1488 | 1510 | 52,100 | 3255 | 3070 | |
| FEB 16 1912 | 68 | | 61 | 10% $CaCl_2$ | 25,000 | 1563 | | 46,500 | 2902 | | |
| | | | | | 27,800 | 1738 | | 44,800 | 2800 | | |
| | | | | | 27,200 | 1700 | | 48,900 | 3060 | | |
| | | | | | 26,000 | 1624 | 1656 | 53,400 | 3338 | 3025 | |

*OMITTED FROM AVERAGE.

# TESTS OF CONCRETE CURED AT NORMAL TEMPERATURE.
## 4 INCH CUBES.
## WITH 2% $Ca.Cl_2$ AND VARYING %s $Na.Cl.$ IN MIXING WATER.

| DATE MADE | TEMPERATURES WHEN MIXED. INSIDE AIR | TEMPERATURES WHEN MIXED. BATCH | SALT CONTENT | RESULTS OF LOAD TESTS. 14 DAY TOTAL | 14 DAY UNIT | 14 DAY AV. UNIT | 60 DAY TOTAL | 60 DAY UNIT | 60 DAY AV. UNIT | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| FEB. 16 1912 | 70 | 59 | 2% $CaCl_2$ 6% $NaCl$ | 24,100 | 1507 | | 39,900 | 2494 | | |
| | | | | 24,350 | 1520 | | 45,000 | 2809 | | |
| | | | | 29,200 | 1826 | | 43,800 | 2718 | | |
| | | | | 24,650 | 1538 | 1598 | 40,800 | 2550 | 2643 | |
| FEB 17 1912 | 71 | 63 | 2% $CaCl_2$ 9% $NaCl$ | 22,670* | | | 38,000 | 2375 | | #1-14 DAY HAD POOR TOP. |
| | | | | 27,870 | 1743 | | 42,400 | 2660 | | |
| | | | | 28,580 | 1785 | | 44,300 | 2770 | | |
| | | | | 24,900 | 1556 | 1695 | 41,200 | 2575 | 2592 | |
| FEB. 17 1912 | 71 | 64 | 2% $CaCl_2$ 12% $NaCl$ | 21,550 | 1347 | | 45050 | 2819 | | |
| | | | | 19,570* | | | 35670 | 2232 | | |
| | | | | 23040 | 1439 | | 41400 | 2585 | | |
| | | | | 23,500 | 1468 | 1418 | 33,900 | 2121 | 2439 | |
| FEB 20 1912 | 63 | 60 | 2% $CaCl_2$ 15% $NaCl$ | 19,300 | 1207 | | 30940* | | | |
| | | | | 22,400 | 1400 | | 37620 | 2354 | | |
| | | | | 20,700 | 1294 | | 35930 | 2245 | | |
| | | | | 22,200 | 1388 | 1322 | 39400 | 2460 | 2353 | |

*OMITTED FROM AVERAGE.

# TESTS OF CONCRETE CURED AT NORMAL TEMPERATURE.
## 4 INCH CUBES.
## WITH 4% $CaCl_2$ AND VARYING % s $NaCl$ IN MIXING WATER.

| DATE MADE | TEMPERATURES WHEN MIXED | | SALT CONTENT | RESULTS OF LOAD TESTS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | INSIDE AIR | BATCH | | 14 DAY | | | 60 DAY | | | |
| | | | | TOTAL | UNIT | AV. UNIT | TOTAL | UNIT | AV. UNIT | |
| FEB 22 1912 | 66 | 56 | 4% $CaCl_2$ 6% $NaCl$ | 26200 | 1637 | | 45950 | 2870 | | |
| | | | | 24050 | 1503 | | 36270 | 2267 | | |
| | | | | 27200 | 1700 | | 40250 | 2517 | | |
| | | | | 24100 | 1506 | 1586 | 40950 | 2558 | 2553 | |
| FEB 22 1912 | 68 | 58 | 4% $CaCl_2$ 9% $NaCl$. | 23100 | 1443 | | 29050 | * | | |
| | | | | 22900 | 1431 | | 37950 | 2371 | | |
| | | | | 28500 | 1780 | | 38800 | 2423 | | |
| | | | | 24900 | 1556 | 1552 | 37900 | 2368 | 2390 | |
| MAR 2 1912 | 63 | 58 | 4% $CaCl_2$ 12% $NaCl$ | 29120 | 1840 | | 44850 | 2800 | | |
| | | | | 24750 | 1546 | | 49700 | 3103 | | |
| | | | | 28720 | 1796 | | 47000 | 2938 | | |
| | | | | 26710 | 1670 | 1713 | 46320 | 2895 | 2934 | |
| MAR 4 1912 | 65 | 55 | 4% $CaCl_2$ 15% $NaCl$ | 18860 | 1167 | | 30200 | 1888 | | |
| | | | | 19270 | 1203 | | 31030 | 1940 | | |
| | | | | 21280 | 1330 | | 28800 | 1800 | | |
| | | | | 20200 | 1263 | 1241 | 30300 | 1894 | 1880 | |

* OMITTED FROM AVERAGE.

180
390

# TESTS OF CONCRETE CURED AT NORMAL TEMPERATURE.
## 4 INCH CUBES
## WITH 6% $CaCl_2$ AND VARYING % s $Na.Cl.$ IN MIXING WATER.

| DATE MADE | TEMPERATURES WHEN MIXED | | SALT CONTENT | RESULTS OF LOAD TESTS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | INSIDE AIR | BATCH | | 14 DAY | | | 60 DAY | | | |
| | | | | TOTAL | UNIT | AV. UNIT | TOTAL | UNIT | AV. UNIT | |
| FEB 26 1912 | 68 | 60 | 6% $CaCl_2$ 6% $NaCl$. | 21600 | 1350 | | 41000 | 2560 | | #4 OF 14 DAY HAD RATHER POOR TOP |
| | | | | 20770 | 1298 | | 39200 | 2448 | | |
| | | | | 22430 | 1402 | | 31750* | | | |
| | | | | 19180 | 1200 | 1312 | 38460 | 2402 | 2470 | |
| MAR 4 1912 | 65 | 54 | 6% $CaCl_2$ 9% $NaCl$ | 20090 | 1258 | | 40900 | 2558 | | #2 OF 14 DAY HAD RATHER POOR TOP. |
| | | | | 18060 | 1128 | | 36850 | 2240 | | |
| | | | | 24140 | 1508 | | 35340 | 2208 | | |
| | | | | 21120 | 1320 | 1303 | 38280 | 2392 | 2349 | |
| MAR 6 1912 | 62 | 54 | 6% $CaCl_2$ 12% $NaCl$. | 20620 | 1290 | | 44500 | 2780 | | |
| | | | | 21060 | 1316 | | 36870 | 2306 | | |
| | | | | 20830 | 1302 | | 39100 | 2440 | | |
| | | | | 23500 | 1469 | 1344 | 34200 | 2138 | 2416 | |
| MAR. 6 1912 | 62 | 52 | 6% $CaCl_2$ 15% $NaCl$ | 22300 | 1393 | | 37650 | 2365 | | |
| | | | | 21650 | 1352 | | 36300 | 2268 | | |
| | | | | 22670 | 1418 | | 38000 | 2375 | | |
| | | | | 21650 | 1352 | 1629 | 44400 | 2775 | | |
| | | | | | | | 43500 | 2718 | | |
| | | | | | | | 37900 | 2365 | | |
| | | | | | | | 36400 | 2276 | | |
| | | | | | | | 33100 | 2068 | | |
| | | | | | | | 39350 | 2460 | | |
| | | | | | | | 41400 | 2584 | | |
| | | | | | | | 37,300 | 2330 | | |

* OMITTED FROM AVERAGE.

# TESTS OF CONCRETE CURED AT NORMAL TEMPERATURE.
## 4 INCH CUBES
## WITH 8% $CaCl_2$ AND VARYING % S NaCl IN MIXING WATER.

| DATE MADE | TEMPERATURES WHEN MIXED | | SALT CONTENT | RESULTS OF LOAD TESTS | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | INSIDE AIR | BATCH | | 14 DAY | | | 60 DAY | | | |
| | | | | TOTAL | UNIT | AV. UNIT | TOTAL | UNIT | AV. UNIT | |
| FEB 26 1912 | 68 | 60 | 8% $CaCl_2$ 6% NaCl | 20300 | 1270 | | 32600 | 2039 | | |
| | | | | 19000 | 1188 | | 32300 | 2020 | | |
| | | | | 15800 | 988 | | 35860 | 2242 | | #3 OF 14 DAY HAD BAD TOP. |
| | | | | 16500 | 1032 | 1120 | 31850 | 1990 | 2073 | |
| MAR. 8 1912 | 62 | 58 | 8% $CaCl_2$ 9% NaCl | 19810 | 1238 | | 32400 | 2025 | | |
| | | | | 17030 | 1065 | | 32100 | 2007 | | |
| | | | | 18480 | 1155 | | 34850 | 2180 | | |
| | | | | 17360 | 1085 | 1136 | 34070 | 2130 | 2085 | |
| MAR 8 1912 | 62 | 60 | 8% $CaCl_2$ 12% NaCl | 17920 | 1121 | | 29760 | 1860 | | POORLY MOULDED. |
| | | | | 17050 | 1066 | | 37300 | 2330 | | |
| | | | | 20160 | 1258 | | 27450 | 1716 | | |
| | | | | 16060 | 1004 | 1112 | 33180 | 2075 | 1995 | |
| MAR. 7 1912 | 63 | 59 | 8% $CaCl_2$ 15% NaCl | 23750 | 1483 | | 41900 | 2620 | | |
| | | | | 24950 | 1557 | | 42700 | 2665 | | |
| | | | | 25340 | 1582 | | 38600 | 2415 | | |
| | | | | 25260 | 1577 | 1550 | 43450 | 2715 | 2604 | |