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EFFECT OF CALCIUM CHLORIDE
ON PLAIN AND
REINFORCED CONCRETE

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1924

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EFFECT OF CALCIUM CHLORIDE
ON
PLAIN AND REINFORCED CONCRETE.

A Report Submitted to the Faculty
of
MICHIGAN AGRICULTURAL COLLEGE

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Candidates for the Degree
of
BACHELOR OF SCIENCE.

June, 1924.

THESIS

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EFFECT OF CALCIUM CHLORIDE
ON
PLAIN AND REINFORCED CONCRETE.

There has been a problem of rapid and economic curing without any injurious effect on the concrete or the reinforcing since the time that Portland Cement has been used with various aggregates to produce concrete. Up to the present date various salts and chemical compounds, which weaken the concrete, attack the steel, or stain the surface, have been tried. While the laboratories were working on this problem, the most efficient methods of curing concrete were: first, ponding or covering with moist earth for pavements, and second, keeping the forms moist for structures. These methods are very uneconomical for the present day system of building pavements and structures.

With a quick set, roads may be opened to traffic and forms for structural work may be removed at an earlier date than is possible, otherwise. The opening of roads at an earlier date will greatly reduce the expense to the traveling public and also the expense to the community in the upkeep of detours. It will reduce the contractor's expense; so that, ultimately, the concrete can be laid more economically than by former methods.

In structural work the owner's expenses will be lowered if the contractor is able to remove the forms

and complete the structure more quickly. In cold weather, the time and cost of protecting the concrete from freezing will be materially reduced.

A few years ago, calcium chloride was placed upon the market to accomplish these purposes. Very few tests of this salt, used for curing concrete, are now available. At the present time, the Portland Cement Association, the Illinois Division of Highways, and the U. S. Department of Agriculture are the main investigators.

The chemical action of calcium chloride in curing concrete is not known. The theory is that it depends upon the hygroscopic properties of the calcium chloride and its ability to absorb moisture.

Tests were made for bond, compression, tension, time of set, hardness and surface condition of the concrete when treated externally with calcium chloride. Four specimens were used for each test.

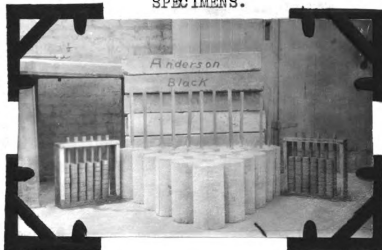
SPECIFICATIONS.

The volumetric mix of 1:2:4 was used for all specimens except briquettes. Huron cement was used in all cases and the aggregate used was washed pebble and sand. The volumetric mix for the briquettes was 1:3, using Ottawa sand, except in the case of neat cement specimens.

For internal treatment, the calcium chloride was dissolved in the mixing water in various percentages according to the weight of the cement. The external treatment was by placing calcium chloride on the surface in lbs. per sq. yd. of surface treated. The calcium chloride was that commercially known as Dow Flake.

All coarse aggregate specimens were allowed to cure in the open without any covering or attention. The briquettes were cured in a moist chamber for 24 hours and then part were cured in water and the remainder were cured in air. All specimens that did not contain calcium chloride were cured in water.

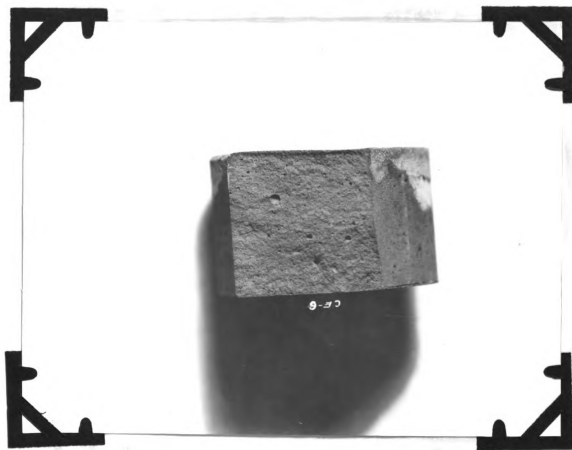
SPECIMENS.



EXTERNAL TREATMENT.

When the surface is treated with CaCl_2 for the purpose of curing the concrete, the effect is noticable for a depth of $\frac{1}{4}$ to $\frac{3}{4}$ of an inch. The concrete for this depth remains soft and spongy for some time but finally sets up forming a scale on the surface which wears off very rapidly. The penetration depth is shown in Fig. 2, for a neat cement briquette.

SHOWING THE DEPTH OF PENETRATION ON NEAT CEMENT.

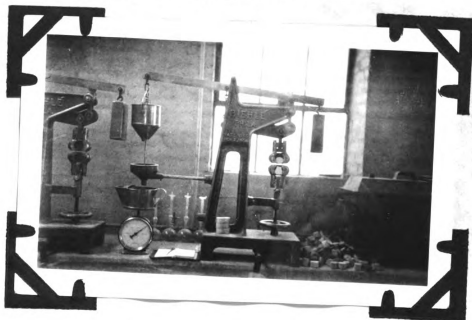


If the air is dry and warm the surface layer sets in a few days but if cold and moist it takes much longer. The surface hardness is affected by the chemical whereas the hardness of plain untreated neat cement is $3 \frac{3}{4}$, treated with 2 lbs. per sq. yd. is $2 \frac{1}{2}$, treated with 3 lbs. per sq. yd. is 2.

The surface treatment discolors the surface, giving it a mottled effect. When the chemical is not evenly distributed it will pit the surface where the chemical lays in lumps, giving it the appearance of having been rained upon before it had its initial set.

Dow Flake has a deleterious effect upon the surface layer but the main body of the concrete is equally good to concrete cured by the ponding and moisture earth methods.

SHOWING THE RIEHLE TESTING MACHINE.



SHOWING THE MOTTLING EFFECT AND PITS.



INTERNAL TREATMENT.

Tension tests were made upon specimens containing different percentages of calcium chloride dissolved in the mixing water. The specimens that were cured in air showed a greater tensile strength than those cured in water. By observing the curves plotted on the following pages representing the two curve specimens having the same amount of calcium chloride in the run nearly parallel after they reach the peak.

The chemical action, as far as we have investigated, cannot be determined, but we do know that calcium carbonate was the result of the chemical action. This may have been an action with the water as the mixing water contained carbonate from the chemical analysis. The calcium carbonate formed came to the lower portion of the briquette and formed stalactites, as shown in the Fig. 4,

The chemical had the same effect on neat cement briquettes as it had on the briquettes of the 1:3 mix. It was more noticeable in the neat cement specimens, as there was a greater difference in the tensile strength at the end of twenty eight days, than in the test made on the former.

Although concrete is very seldom called upon to take any tension, there might be a time when the tensile strength would be necessary. However, from the above facts we draw our conclusion that when calcium chloride

was used internally there must have been some injurious chemical action to reduce the tensile strength, cured in water.

The time of set is shown by the graphs. The greater the percentage of calcium chloride the greater the set.

CURED IN AIR.
PERCENT OF CALCIUM CHLORIDE.

Days	0	.2	3	4	5	6
2		241	243	257	262	208
4		280	282	285	310	235
7		285	285	285	304	223
14		290	285	279	271	202
21		297	280	249	241	198
28		298	280	245	238	198

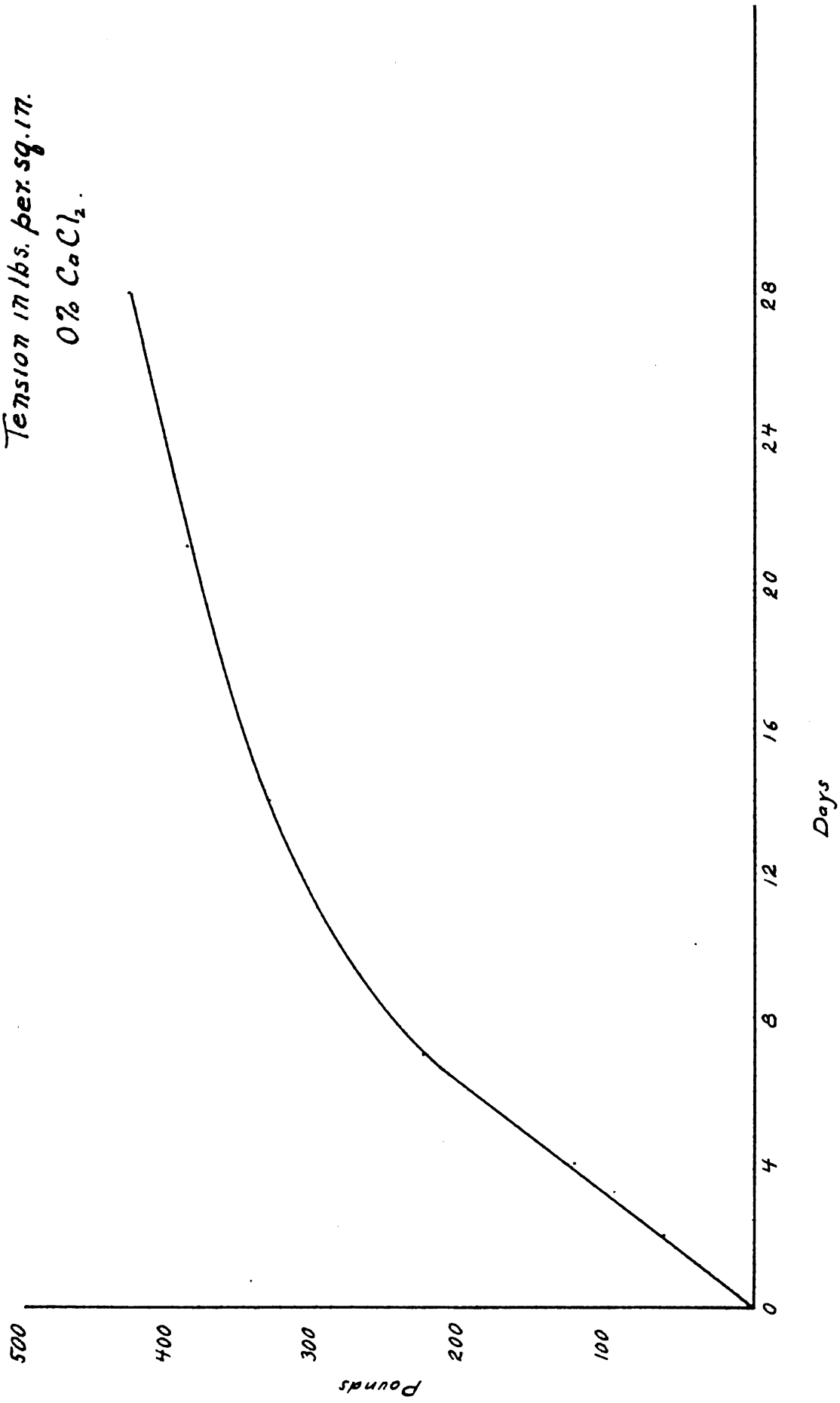
CURED IN WATER.

2	62	190	190	180	153	120
4	124	253	245	230	173	153
7	227	271	255	240	187	161
14	332	274	263	247	193	165
21	390	277	266	230	195	165
28	430	280	268	230	195	165

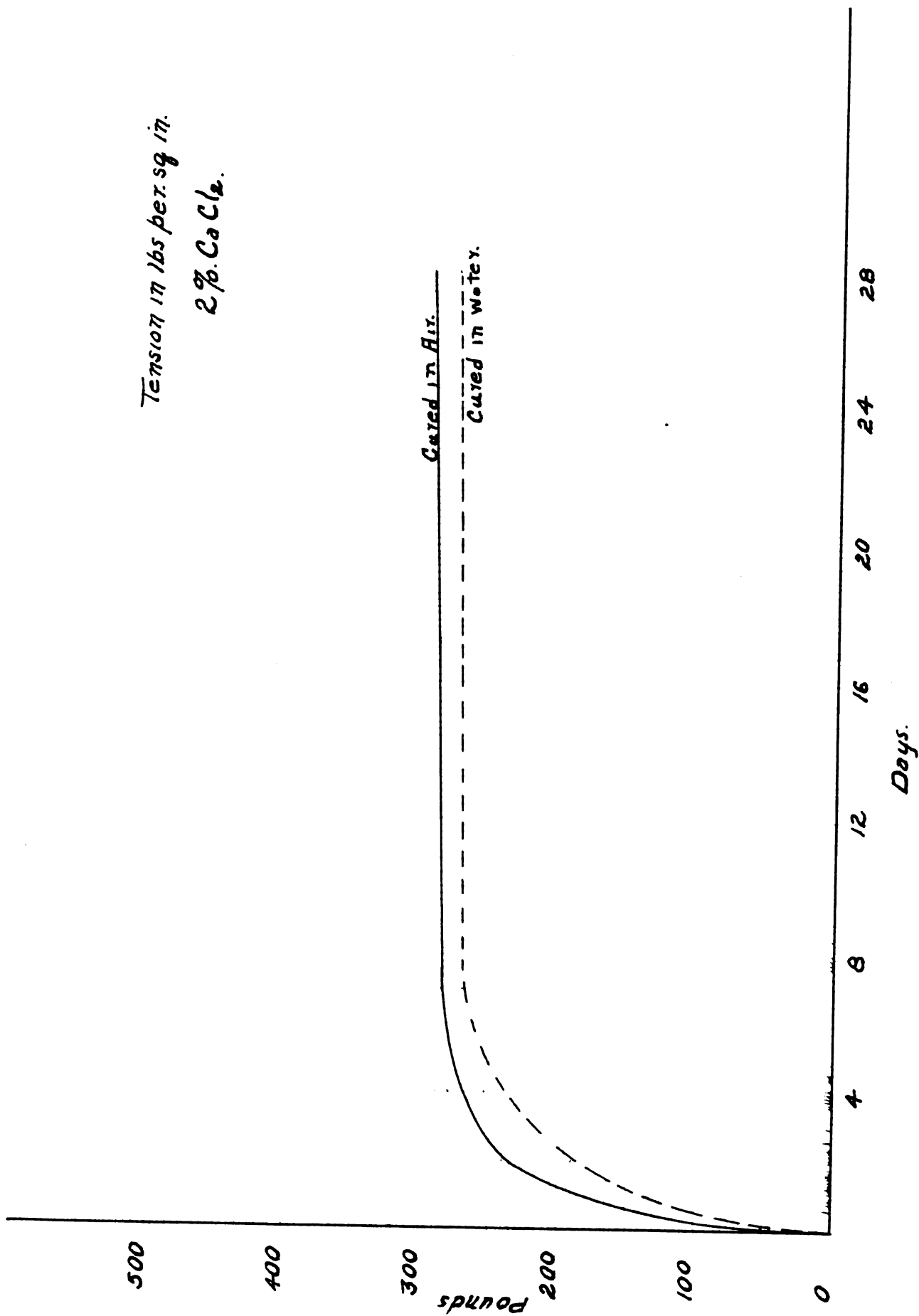
FIGURE 4.
SHOWING STALCTITES OF CALCIUM CARBONATE.



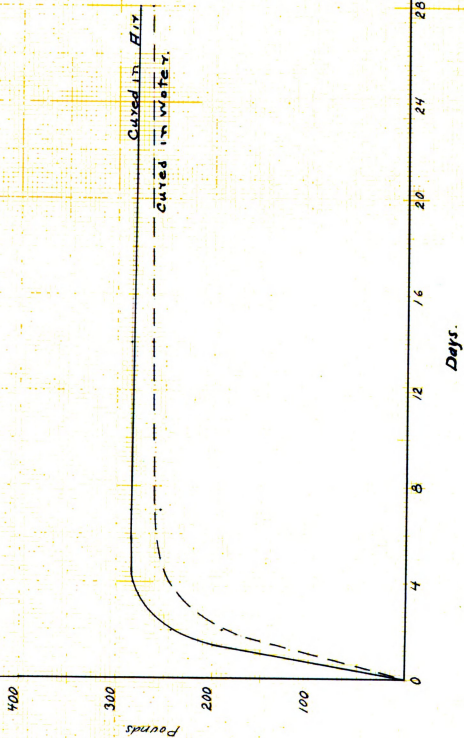
Tension in lbs. per sq. in.
0% CaCl_2 .



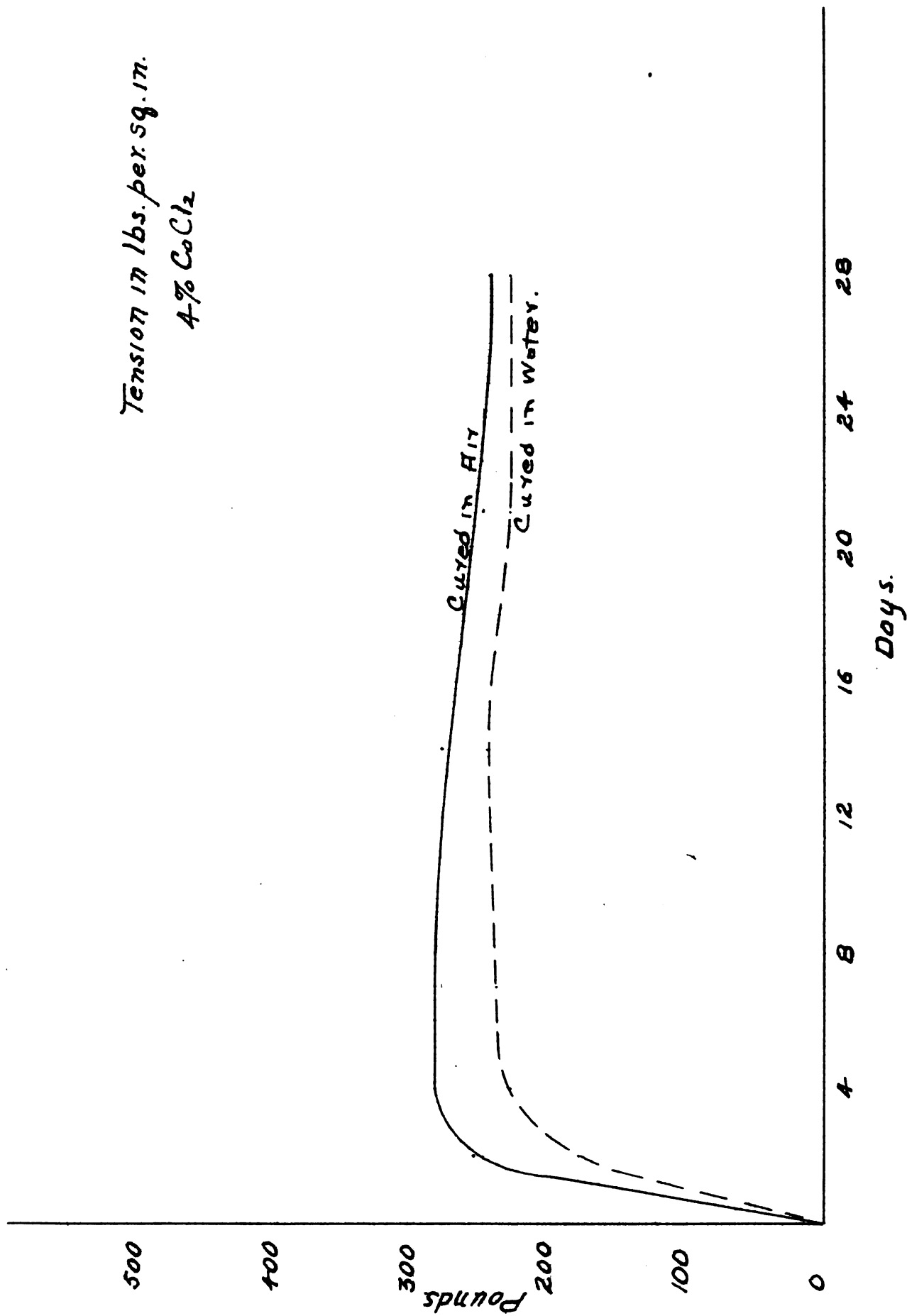
Tension in lbs per sq in.
2% CaCl_2 .



Tension in lbs. per in.
3% CaCl_2 .

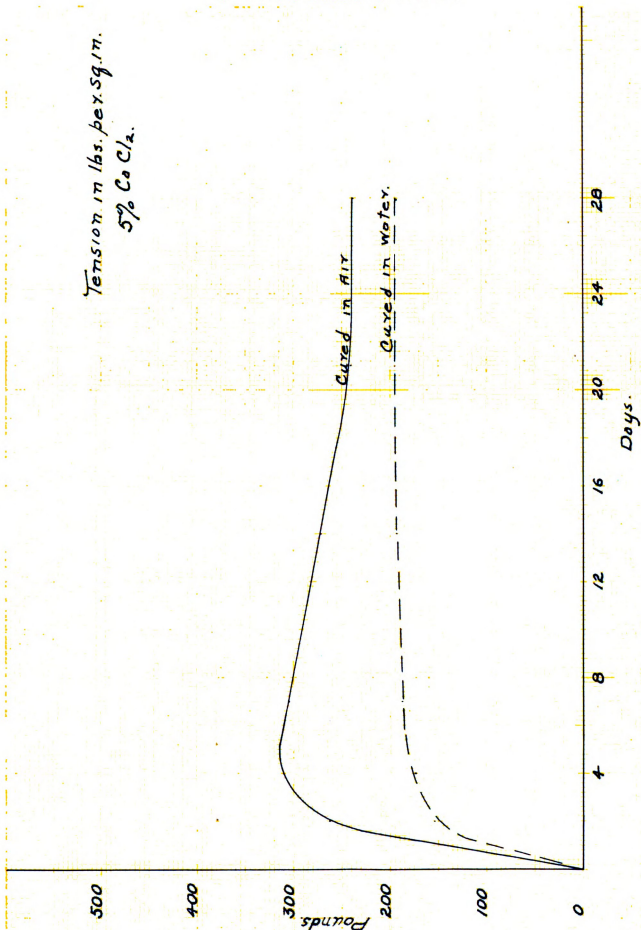


Tension in lbs. per sq. in.
4% CoCl_2

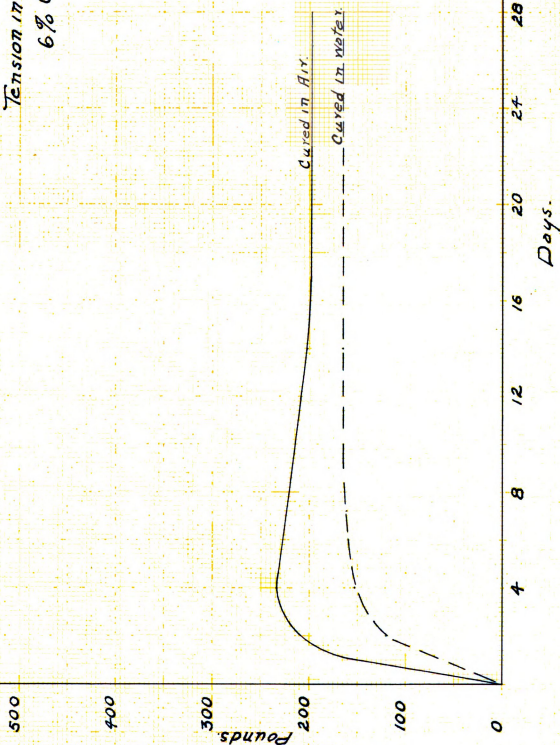


Tension in lbs. per sq. in.
5% Co C₁₂.

NO. 1000 A. S. C. S. T. A. S. T. A. S. T.



Tension in lbs. per sq. in.
6% CoCl_2 .



Tension in lbs. per sq. in.

Neat Cement.

0% CaCl_2 3% CaCl_2 6% CaCl_2

Days.

28.

24

20

16

12

8

4

800

600

Pounds

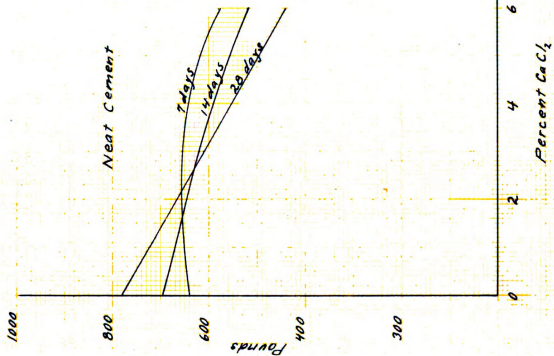
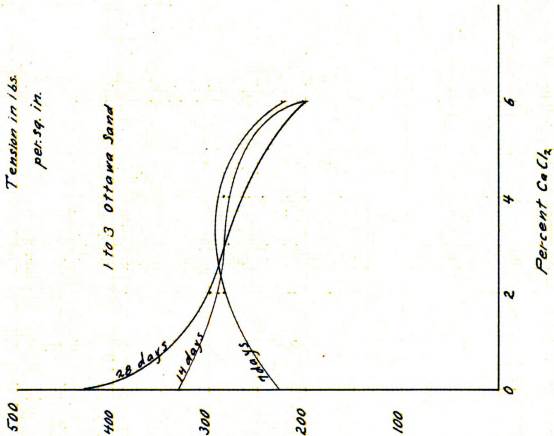
400

200

0

Tension in lbs.
per sq. in.

1 to 3 Ottawa Sand

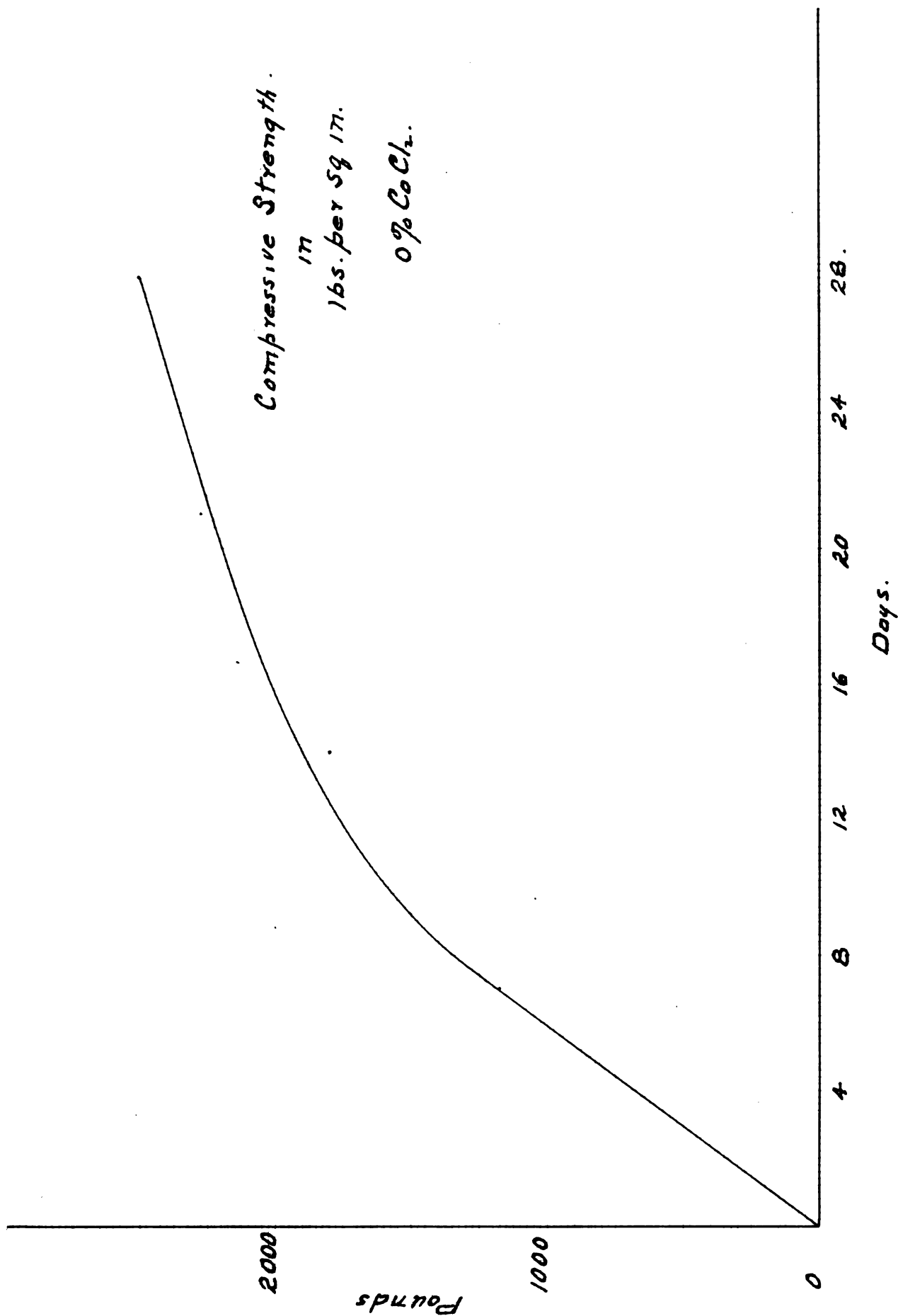


After inspecting the results of the compression tests made by the Illinois Division of Highways, we hesitate to advance any theory, as to the results of the compressive tests. Their tests were made using twelve different brands of cement, all of which passed the state specifications for both physical and chemical tests.

We found that the compressive strength of the specimens containing calcium chloride increases up to and including 3%, after which the compressive strength decreased. All compression tests were embedded in plaster paris which were allowed to set before putting any stress upon the specimens.

COMPRESSIVE STRENGTH IN LBS. PER SQ. IN.

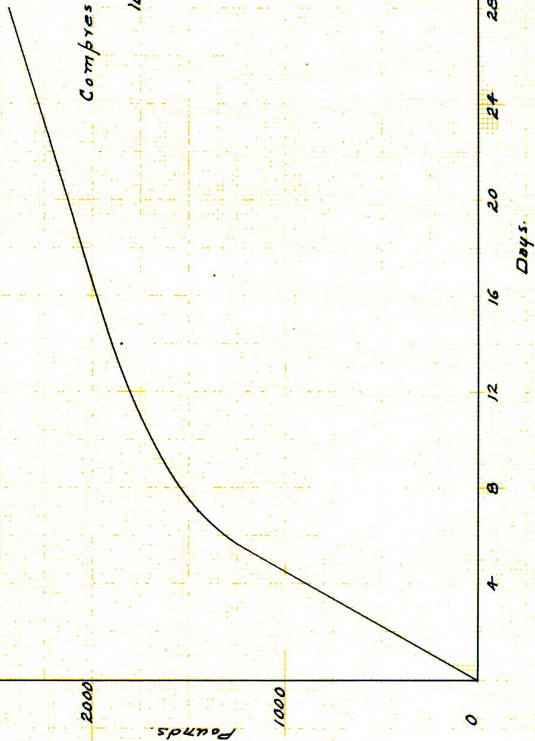
<u>CaCl₂ percent</u>	<u>7 days</u>	<u>14 days</u>	<u>21 days</u>	<u>28 days.</u>
0	1170	1800	2265	2500
2	1450	1855	2375	2625
3	1870	1925	2220	2715
4	1960	2100	2135	2160
5	1760	1900	2020	2260
6	1685	1895	1955	2190



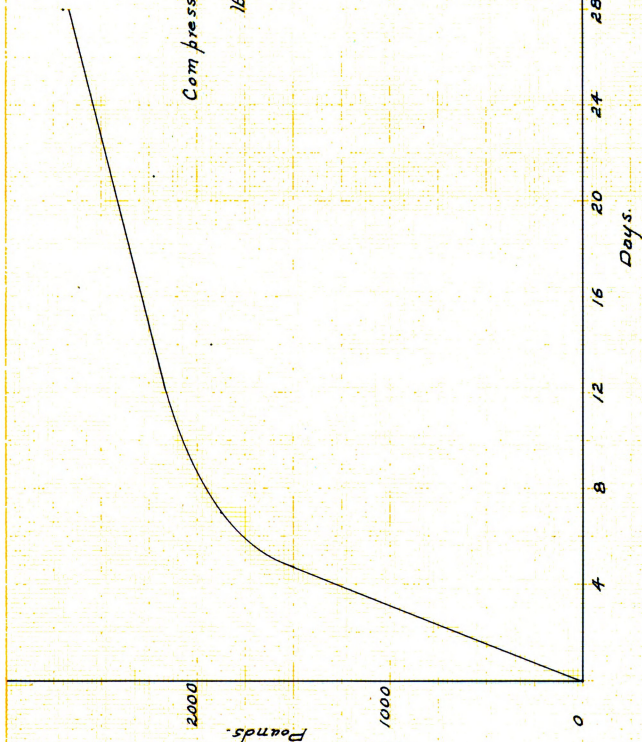
Compressive Strength
in

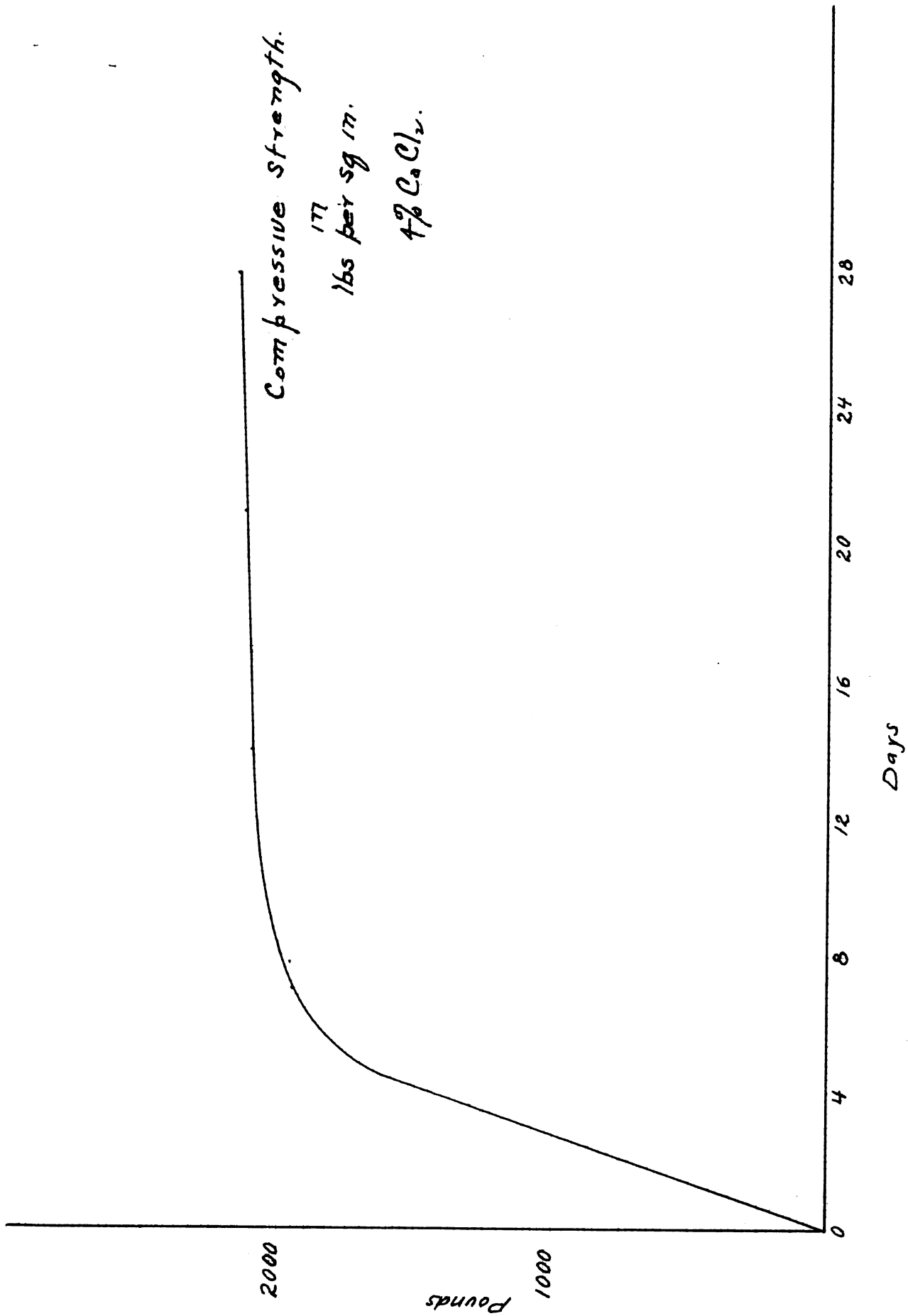
lbs. per sq. in.

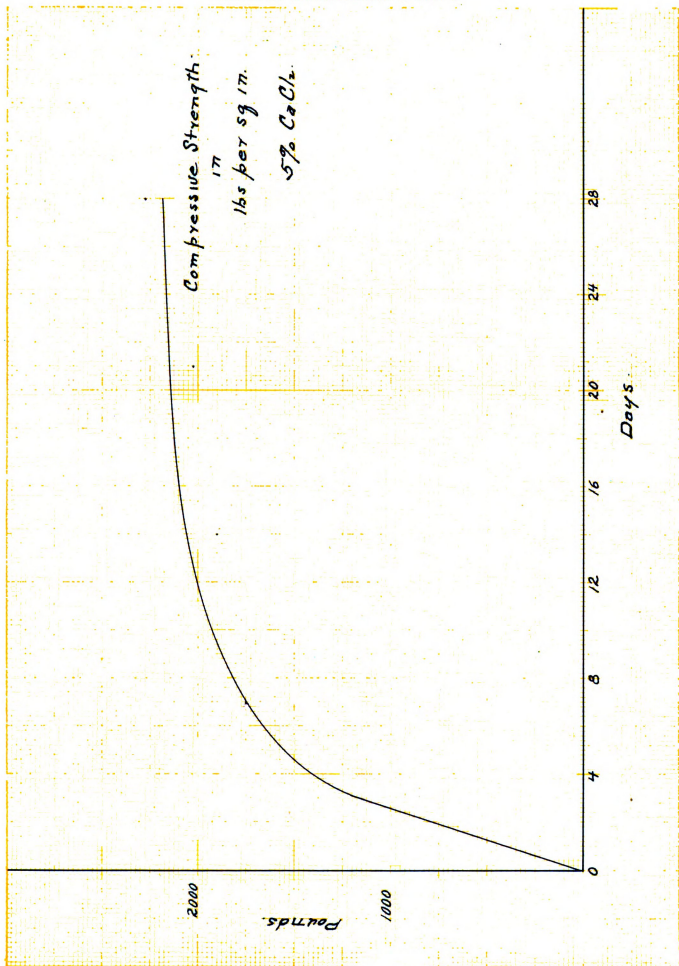
2% CoCl.



Compressive Strength

¹⁷
lbs. per sq. ft. $3\frac{3}{4}\text{ CaCl}_2$ 





Compressive Strength.

17

lbs per Sq in.

6% CaCl_2 .

2000

Pounds

1000

0

4

8

12

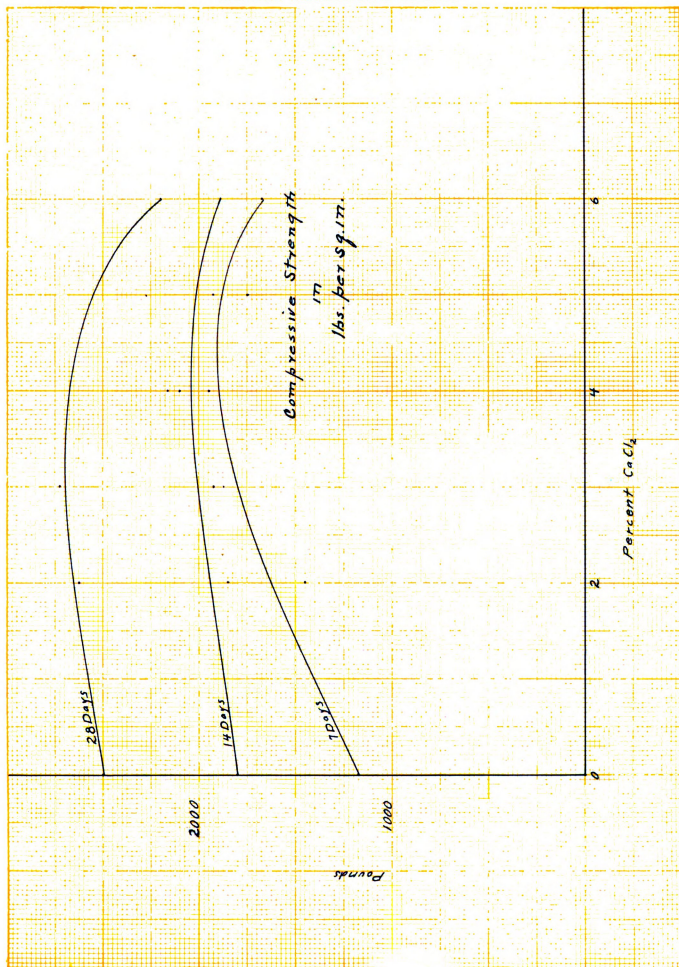
16

20

24

28

Days.



EFFECT ON STEEL.

The bond strength of concrete containing 6% calcium shloride was greater than that which was not treated internally. The only way we can account for this is that the chemical attacked the smooth surface and gave the concrete a chance to cling to the surface. The bond strength was a great deal higher than that allowed in Hool and Johnson's Handbook, but this is accounted for by the factor of safety. But we could not say whether the bond would be affected by time, as the bars were rusted, which will be discussed in the next paragraph.

The effect of calcium chloride in the concrete tended to rust and pit the steel. All steel embedded in the specimens was inspected carefully before it was placed in the concrete. The steel used was smooth cold rolled with a low carbon content. Steel placed in concrete that was not treated with the chemical, was not affected, even though it remained in water for 28 days. When steel was placed in water for 10 days, it showed corrosion, but not as fast as when it was placed in concrete that was treated with the chemical. A specimen showing the corrosion of the steel is shown.

BOND STRENGTH.

BOND IN LBS. PER SQ. IN. AT 28 DAYS.

Per cent of Ca Cl_2

0	2	3	4	5	6
130	215	247	270	293	332

SHOWING RIEHLE COMPRESSION MACHINE



FIGURE
SHOWING CORROSION OF STEEL.



NORMAL CONSISTENCY.

Standard tests for normal consistency by the use of a Vicat needle were performed. The amount of water expressed as a percentage of the dry cement to obtain the normal consistency was reduced by the addition of calcium chloride. These results were as follows for neat cement.

% of CaCl_2	0%	1%	2%	3%	4%	5%	6%
% of water	26	26	25	25	24	24	23

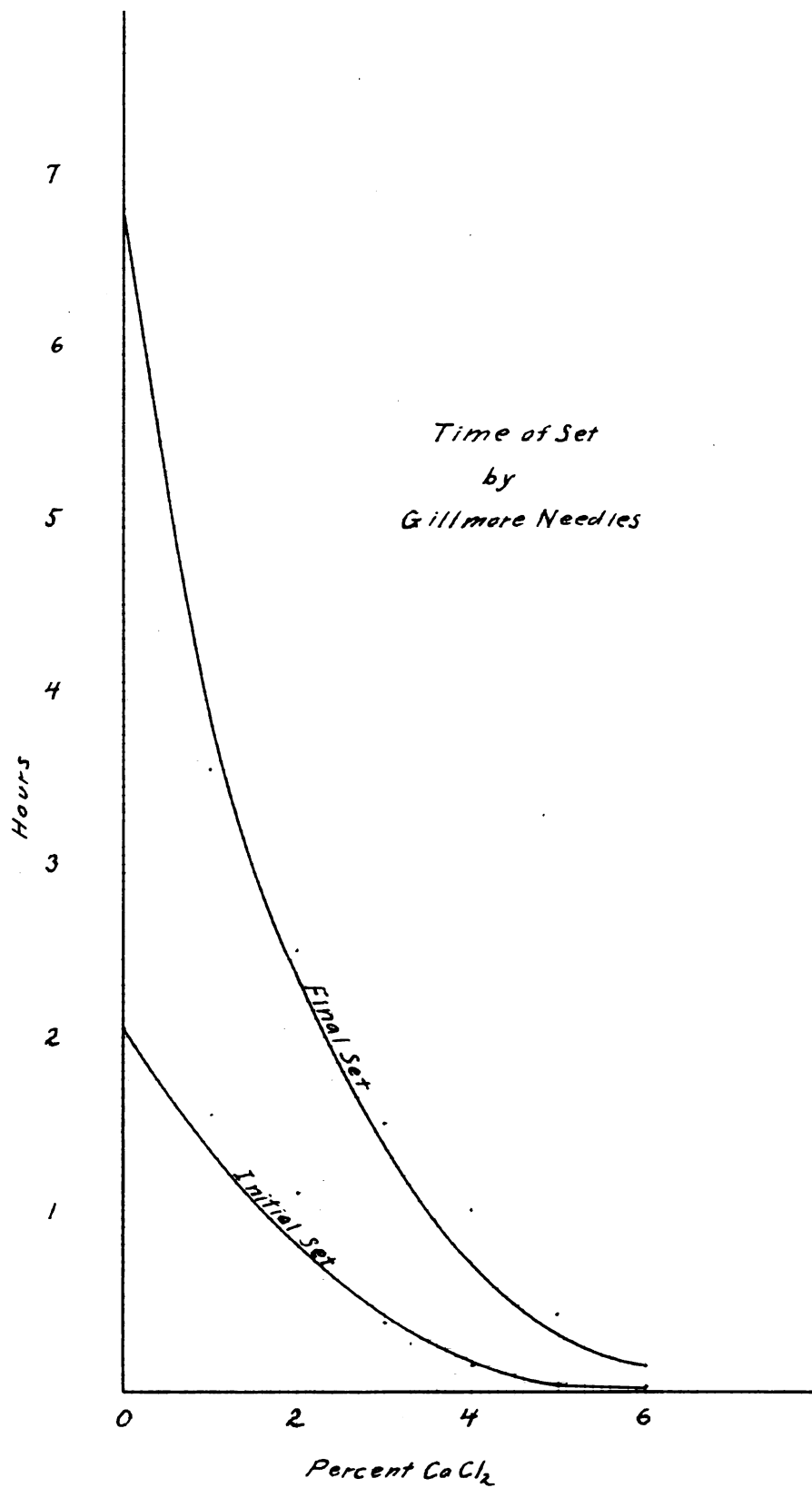
Standard Gillmore needles were used in making the tests for the time of set. The cement was mixed to normal consistency.

These tests were made when various percentages of calcium chloride were used. A cement may set so quickly that it will be worthless for some kinds of work; since handling cement after it commences to set weakens it and causes it to disintegrate.

From the data and the graphs which follow it is seen that calcium chloride greatly accelerates the set.

TIME OF SET.

% of CaCl_2	0		1		2		3		4		5		6	
	h. m.		h. m.		h. m.		h. m.		h. m.		h. m.		h. m.	
Initial Set	2	5	1	35	1	13	0	24	0	9	0	2	0	1
Final Set	6	50	3	46	2	33	1	48	1	2	0	28	0	10



CONCLUSION.

The results secured in these investigations, to hasten the set, satisfy us that calcium chloride could be incorporated in concrete to advantage under certain conditions, such as concrete which will be used for pavements, and slabs that do not contain reinforcing steel.

The surface treatment for curing can be used in place of the ordinary methods of ponding or using damp earth for covering, but care should be taken in spreading the chemical over the surface so as to insure an even coat to prevent unnecessary pitting.

We found that by treating internally the bond strength was increased in proportion to the amount of calcium chloride used, but in turn, the effect upon the steel is very deleterious as rusting takes place immediately.

Also, that calcium chloride when used internally in concrete which is allowed to set in water does not get the desired strength.

In conclusion we recommend using calcium chloride as an agent, for curing and hastening the set, that it be limited to 3% of the weight of the cement for internal treatment, and 2lbs. per sq. yd. for surface treatment.

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