THE EFFECT OF THE PELLET FORM OF CALCIUM CHLORIDE, AS AN ADMIXTURE, ON THE STRENGTH OF PORTLAND CEMENT CONCRETE

By

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I. INTRODUCTION

A. Purpose

It is the purpose of this thesis to determine the effect of the pellet form of calcium chloride on the compressive strength of portland cement concrete, at early ages, when used as an admixture.

B. Reasons for Conducting this Project

Studies carried on by the Bureau of Standards in 1934 indicated that the use of the flake form of calcium chloride as an admixture resulted in a portland cement concrete having a higher compressive strength at ages up to 28 days than concrete not containing the admixture. This project was undertaken because improvements since 1934 in the manufacture of cement (such as better quality-control of raw materials and finer grinding) and the recent production of calcium chloride in the form of pellets, rather than flakes, has made some of the available information obsolete.

II. ORGANIZATION OF TESTING SCHEDULE

In order to allow for variations in different batches of concrete, due to the impossibility of controlling the gradation and moisture content of the aggregate exactly, it was decided to pour the cylinders in four series of five batches each. The batches contained 0, 1, 2, 3, and 4 percent of pellet calcium chloride, respectively, and consisted of five cylinders each. Four of these cylinders were used for the tests reported in this thesis and the fifth was stored for a long time study. (The percentages mentioned were used because the previous tests in 1934 indicated that the optimum amount would fall somewhere within this range. Results of this test appear to have borne this fact out.) The cylinders from each batch were tested at the ages of 1, 3, 7, and 28 days. By this method it was possible to get four test results (one from each series) for each percent admixture at each of the ages mentioned. The value reported for compressive strength is in each case the average of these four test results.

III. MATERIALS--GENERAL DESCRIPTION, SOURCE, AND STORAGE

A. Calcium Chloride

The calcium chloride was obtained from the Dow Chemical Company, Midland, Michigan. This product, as well as having a different shape, has a different purity than the flake form. The latter contains about 77 percent pure anhydrous calcium chloride while the pellet form is about 96 percent pure. An idea of the particle size, size distribution, and shape may be obtained from the photograph in Figure 1 and the sieve analysis in Table I. The calcium chloride used in this project was stored in moisture proof steel drums until immediately before using.

TABLE I

SIEVE ANALYSIS OF PELLET CALCIUM CHLORIDE

Sieve Size	Percent Retained	Percent Passing
3/8"	0	100
#4	2.5	97.5
#8	63.2	34.3
#10	25.7	8.6
#16	5.4	3.2
#30	1.7	1.5
#50	0.5	1.0
#100	0.2	0.8

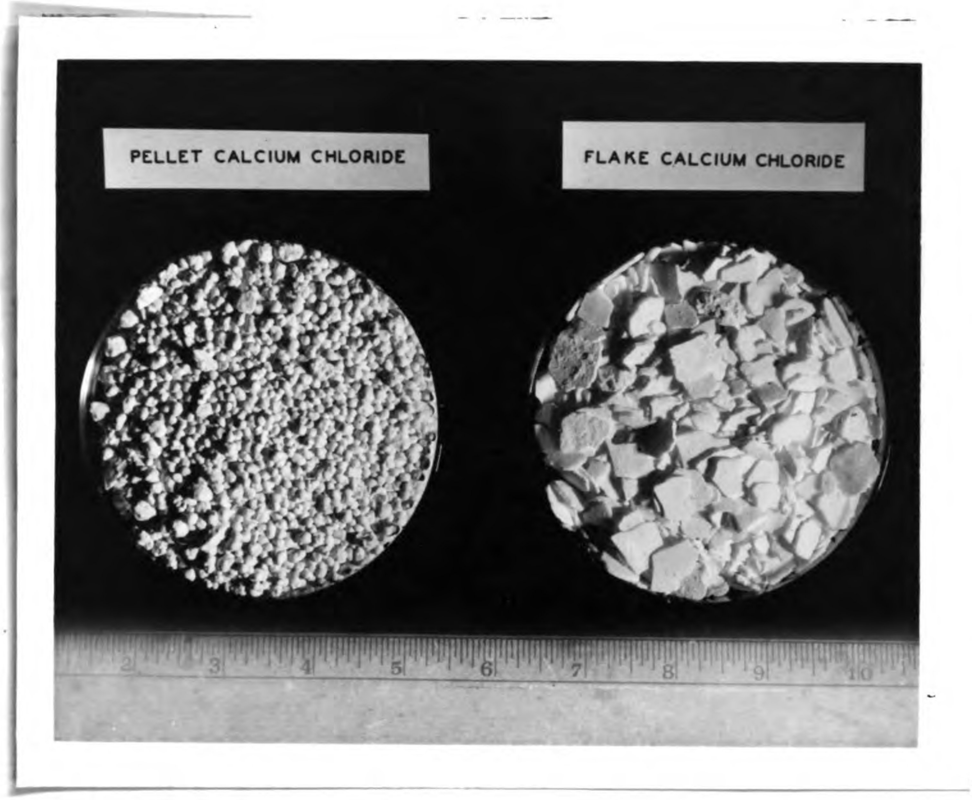

Figure 1

B. Aggregate

The aggregate used was obtained from the American Aggregate Corporation, Brighton, Michigan. The sand was to meet Michigan State Highway Department specifications for 2NS and the gravel the same specifications for 6A. As may be seen by referring to Table II, the sand met specifications, but the gravel did not. This gave a slightly harsher mix than would have resulted if the gravel had contained a higher percentage of fine material, but in no other way affected the test.

TABLE II

SPECIFICATIONS FOR AND SIEVE ANALYSIS OF AGGREGATES

	Sieve Size	Percent Passing	Specifications* Percent Passing
Coarse aggregate	2"	100.0	100.0
	1 1/2"	100.0	95-100
	1"	63.1	60-90
	1/2"	14.0	25-55
	#4	0.4	0-8
Fine aggregate	3/8"	100.0	100.0
	#4	97.9	95-100
	#8	84.6	65-95
	#16	66.2	35-75
	#30	46.9	20-55
	#50	19.8	10-30
	#100	4.9	0-10

*Specifications are those of the Michigan State Highway Department for "NS natural sand and 6A gravel.

As the quantity of aggregate required for the project exceeded the capacity of inside storage bins, it was stored in outside bins which were rectangular in shape and two feet high. Waterproof canvas tarpaulins were used to protect the aggregate from dirt and freezing. Several days before being used, the aggregate was placed in inside bins so that it could come to room temperature.

C. Cement

Type I-normal portland cement was used in the project. This is cement that contains no air entraining agent and is suitable for use in general concrete construction. All cement used in the project came from the same "grind" and was obtained from the Peerless Cement Company, Detroit, Michigan. It was delivered in the customary moisture-resistant paper bags and stored on platforms in the concrete laboratory.

D. Water

The water used was from the main supply to Michigan State College.

IV. DETAILS OF PROCEDURE

A. Design of the Concrete Mix Used

The mix for the concrete used in this project was designed using the Michigan State Highway Department mortar voids method of proportioning. It was designed with a cement factor of 5.5 sacks of cement per cubic yard of concrete, a slump of three inches to four inches, and a water-cement ratio of 6.06 gallons per sack of cement. The resulting proportions, by weight of dry materials, were 1 part cement, 2.46 parts of sand, and 3.76 parts of coarse aggregate. Trial mixes were made up before the project was started and resulted in a plastic, workable concrete having a slump of three inches.

B. Proportioning, Mixing, and Molding Cylinders

1. Proportioning

The ingredients used in making the concrete--water, cement, and aggregates--were weighed on a Toledo platform scales having a dial indicator reading to the closest one ounce. The calcium chloride admixture was weighed on a Toledo laboratory balance, accurate to the closest half gram.

2. Mixing

In order to prevent the caking of cement and sand to the inside of the rotating drum type mixer, it was necessary to add the materials to the mixer in the following manner:

Add the gravel (coarse aggregate) and then the sand (fine aggregate) to the mixer, start the mixer rotating and add cement, pour in water slowly so that it mixes with the cement and aggregate as it is added and does not splash out of the mixer, and finally throw in the admixture. A mixing time of two minutes was used; this started immediately after the addition of water was completed and just as the calcium chloride was added.

3. Molding Cylinders

After the completion of the mixing, the fresh concrete was dumped into a large metal pan from which it was placed by a metal hand scoop into 6 inch by 12 inch cylindrical steel molds. The cylinders were filled by thirds, each third being rodded 25 times with a five-eigth inch round steel rod having a rounded end. After the final rodding the molds were struck off with a steel trowel and then finished with a flat wooden float.

The molds used were made by cutting six inch seamless steel tubing in 12 inch lengths, splitting it, and attaching brackets and thumbscrews to hold the longitudinal seam closed and also to hold the cylinder to 10 inch by 10 inch by 1/2 inch steel base plates. Although all joints were machined it was necessary to seal them to prevent leakage. Scotch masking tape proved satisfactory for the vertical longitudinal joints, while paraffin was used on the joints where the cylinder and base plate came in contact.

C. Curing

After the molding of the cylinders was completed they were covered with damp burlap to prevent evaporation. Twenty four hours later the burlap and steel molds were removed and identifying marks placed on all cylinders. The one day specimens were capped and tested at this time while the other cylinders were placed in the moist room to be cured until tested.

The moist room is an insulated room of controlled humidity and temperature. The temperature is 70 degrees Fahrenheit and the relative humidity is 98 percent. Specimens stored in the moist room were removed just prior to testing.

D. Testing

1. Test Performed on Fresh Concrete

Slump. After dumping the concrete from the mixer and prior to filling the molds, two slump tests were made on each batch.

Air content. At the same time that the slump tests were being made, another test was performed to determine the percent of entrained air in the concrete. The Klein pressure-type entrained air indicator was for this determination.

2. Testing Cylinders for Compressive Strength

Immediately upon removal from the moist room, specimens to be tested were capped with plaster of Paris. (Note: Only the top surfaces of the cylinders were capped as the bottom surfaces which had been in contact with the base plates met the American Society for Testing Materials specifications for planeness.) After standing for about an hour so that the caps could set and harden, the cylinders were placed in the 300,000 pound Rhiele hydraulic compression testing machine. Load was applied at the rate of 35 pounds per square inch per second until the cylinders failed.

Because the diameter of the individual molds varied from top to bottom, and because the diameter of different molds were not the same it was necessary to find an average area for each cylinder. This was done by measuring, with caliphers, the daimeter at the top, middle, and bottom of each cylinder, selecting each diameter so that it made an angle of 120 degrees with preceding one.

V. RESULTS

It may be easily seen by referring to Figure 2 that the addition of calcium chloride in any of the percents used results in a higher compressive strength, at ages up to seven days, than if no calcium chloride is used. At 28 days, however, concrete to which 3 percent and 4 percent calcium chloride was added, had a lower compressive strength than concrete having no admixture; while the concrete containing 1 percent and 2 percent still showed an improvement.

Figure 3 presents the same information as Figure 2 and shows that the percent increase in compressive strength for a given amount of calcium chloride was greatest at one day.

Slump, which was used as measure of consistency, showed an increase as 1 percent and 2 percent calcium chloride were added to the mix and then a decrease as 3 percent and 4 percent were used. This is shown graphically in Figure 4. Although slump gives some measure of the workability, the latter is impossible to measure exactly. It was noticed, however, that concrete containing calcium chloride in any percent seemed to be more sticky and plastic than concrete containing none.

The air content of all mixes containing up to 2 percent of admixture was constant. Beyond this point, as may be seen in Figure 5 there was an increase in air content with an increase in the percent of admixture.

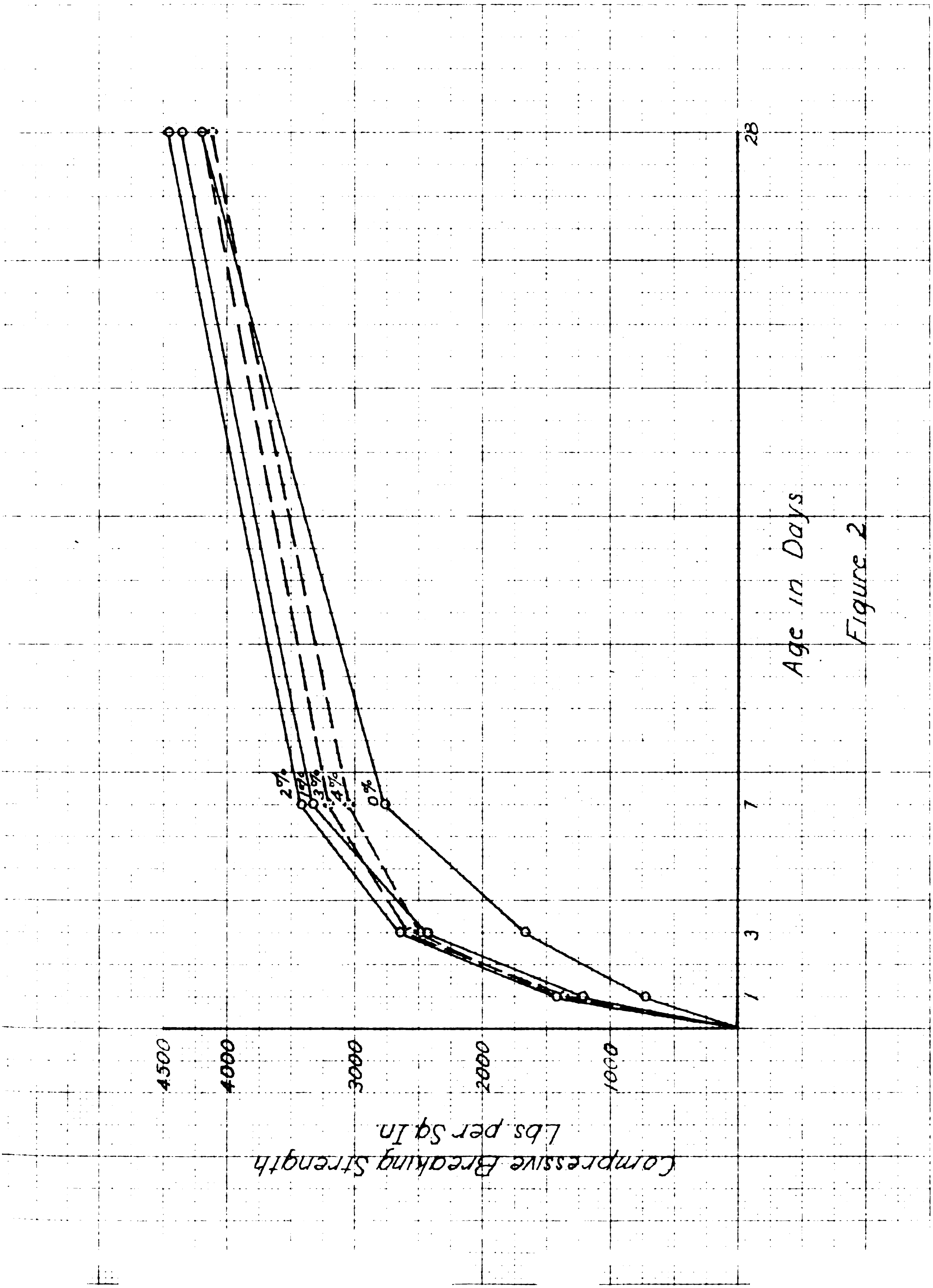
4500
4000
3000
2000
1000
Compressive Breaking Strength
Lbs. per Sq. In.
1
3
7
28
Age in Days
2%
3%
4%
0%

Figure 2

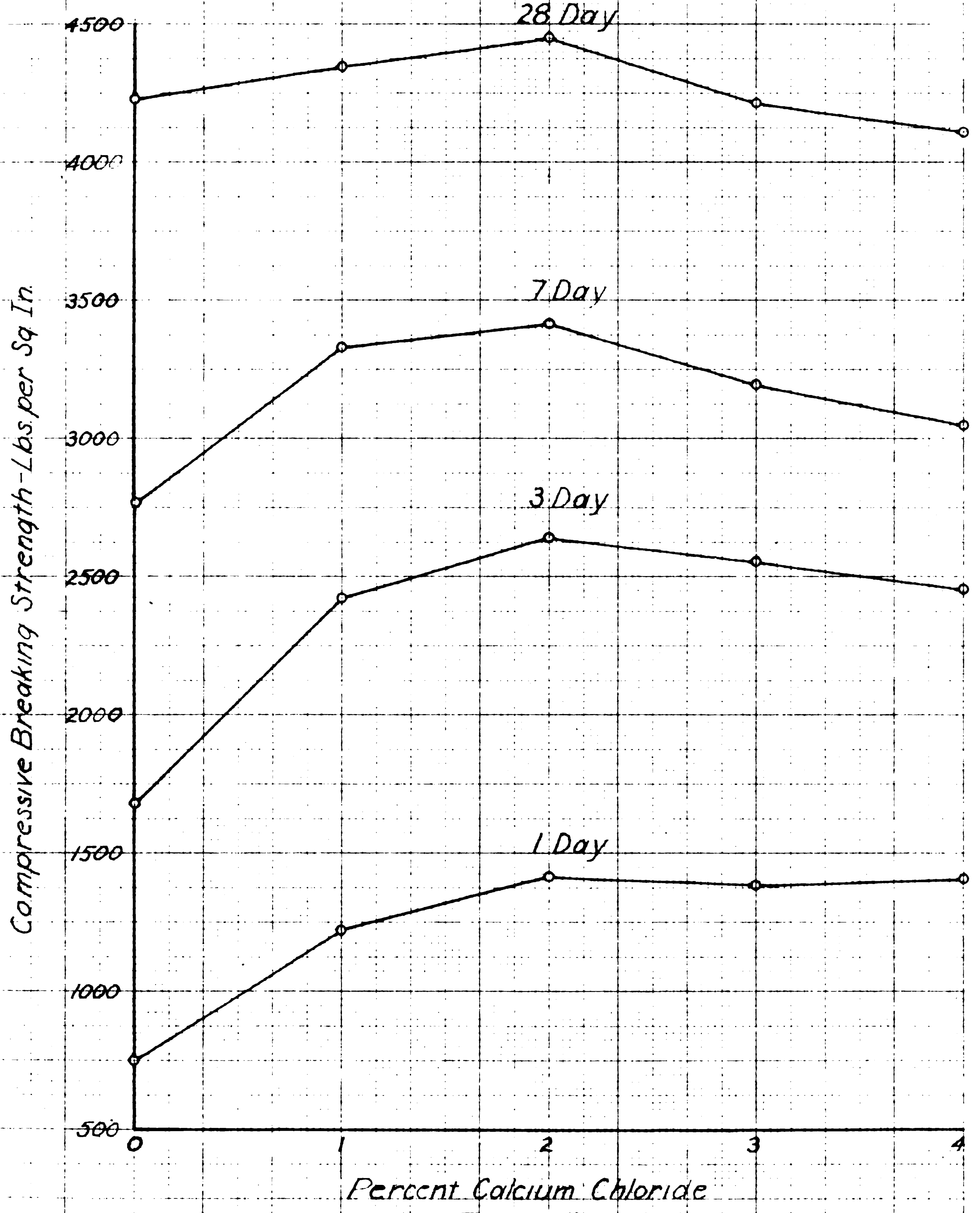
28 Day
7 Day
3 Day
1 Day
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1
2
3
4
Compressive Breaking Strength - Lbs. per Sq. In.
Percent Calcium Chloride

Figure 3.

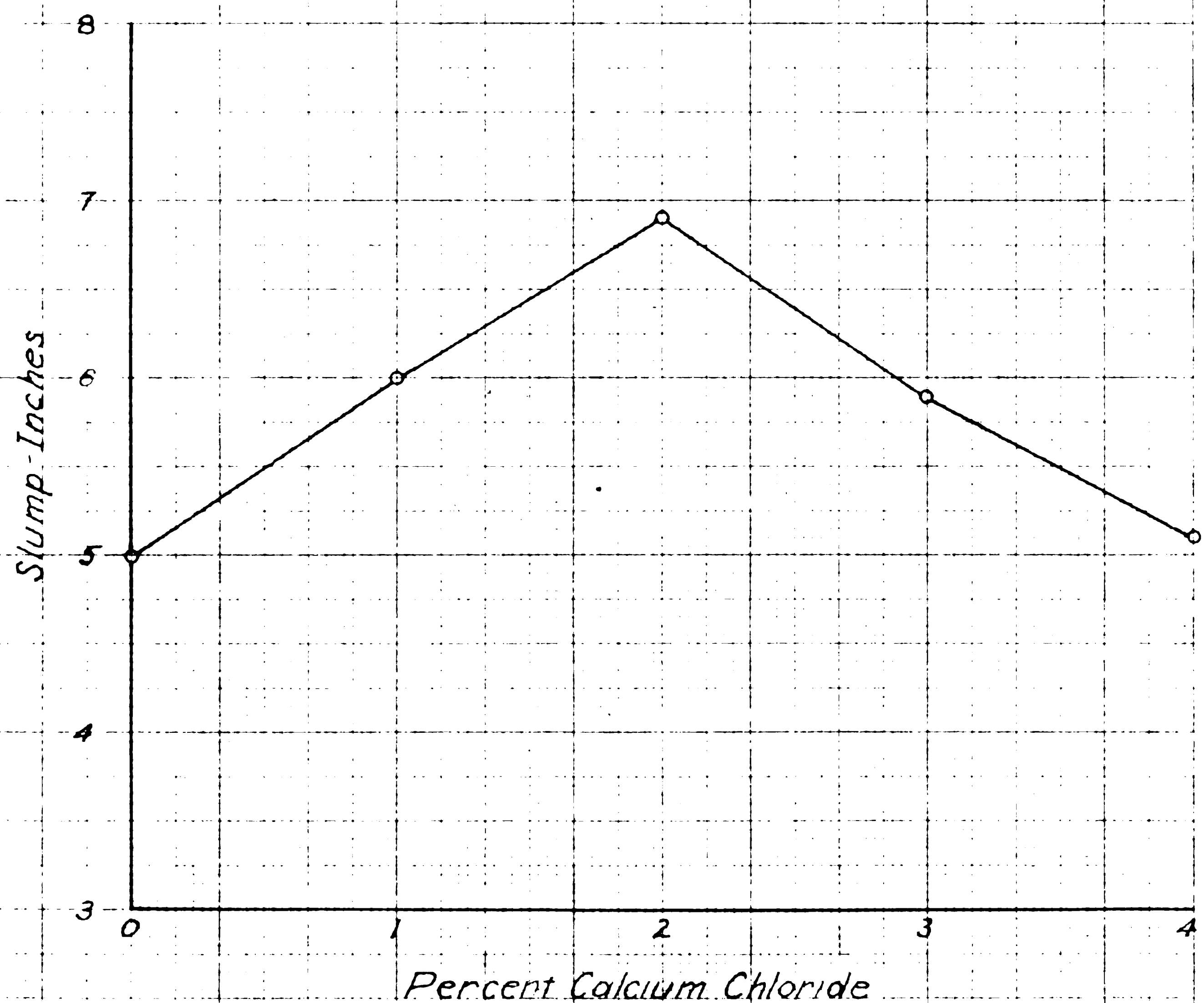

Figure 4

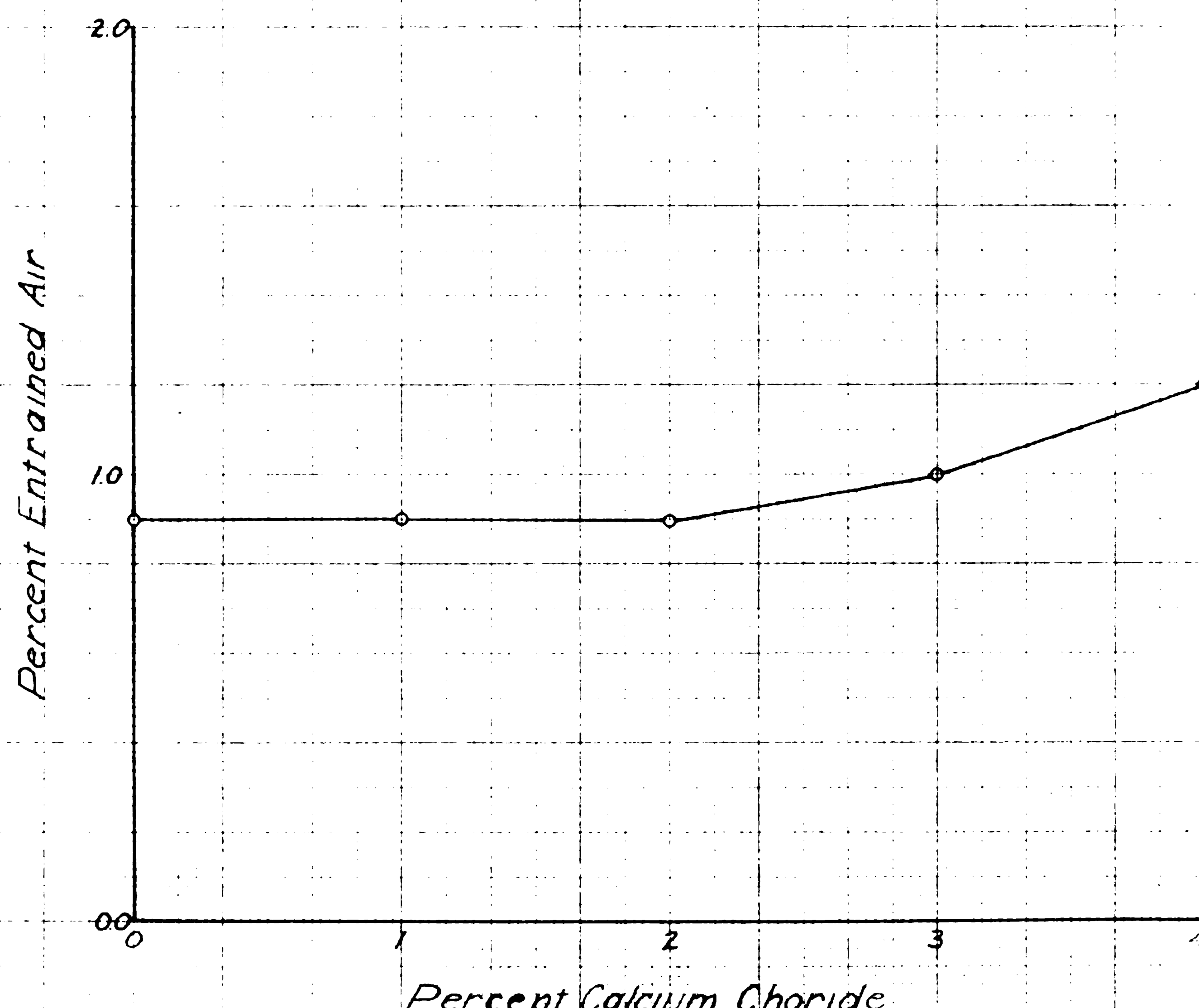
2.0
1.0
0.0
Percent Entrained Air
0
1
2
3
4
Percent Calcium Choride

Figure 5

VI. COMPARISON OF RESULTS WITH PREVIOUS TESTS ON FLAKE CALCIUM CHLORIDE

The results of tests using the pellet form of calcium chloride may be compared, by means of Table III, to tests performed by the listed agencies, prior to 1934.

TABLE III

INCREASE IN COMPRESSIVE STRENGTH OF CONCRETE DUE TO THE ADDITION OF 2 PERCENT OF COMMERCIAL CALCIUM CHLORIDE*

(All specimens stored in moist atmosphere)

Age at test	Portland Cement Assoc.	District of Columbia	National Bureau of Standards	This Test
	percent	percent	percent	percent
1 day		80	114	91
2 days	48	52		
3 days		46	62	46
7 days	25	21	29	19
28 days	7		14	5

*Rapp, Paul. Effect of Calcium Chloride on Portland Cements and Concretes, Proceedings of the Fourteenth Annual Meeting of the Highway Research Board, December 1934. (Note: Results of pellet calcium chloride were added to original table.)

Tests on slump, as indicated in Figure 4 showed an increase in slump up to 2 percent calcium chloride and then

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of
con
pos

a decrease. Previous tests, using flake calcium chloride with a purity of about 77 percent, indicated an increase in consistency up to 3 percent of commercial calcium chloride. This curve was still increasing at 3 percent but its slope was decreasing. Because of the lower purity of the flake calcium chloride the difference in the maximum points of the curves might be expected; however, in these previous tests the flow of fresh concrete, and not slump, was used as a measure of concistency and consequently an exact comparison is not possible.

VII. CONCLUSIONS

1. The use of the pellet form of calcium chloride, in amounts up to 2 percent by weight of cement, results in an increase in the strength of portland cement concrete at all ages up to 28 days. Two percent is the optimum amount of admixture to use as far as strength is concerned.

2. The consistency of concrete changes as calcium chloride, up to 2 percent, is used as an admixture. This results in a more workable concrete; however, it it is desired to hold a given slump it would be possible to reduce the water content. This would, of course, lower the water cement ratio and result in a further increase in strength.

3. The percent of entrained air in concrete made with Type I cement is not affected by the use of pellet calcium chloride in amounts up to 2 percent. As the amount of calcium chloride is increased up to 4 percent, the amount of air entrained is also increased.

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