EFFECT OF CALCIUM CHLORIDE ON THE WATER REQUIREMENTS, SPECIFIC WEIGHTS AND COMPRESSIVE STRENGTHS OF CONCRETES MADE WITH PLAIN AND TREATED CEMENTS

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SYNOPSIS

Slump and flow tests were made on concretes using a portland cement, a wide range of water-cement ratios, and two cement factors Comparative tests were made on concretes containing two percent commercial calcium chloride Calcium chloride increased the workability of all concretes tested, being slightly more effective on the richer mix in the range of slump of two to six inches.

Water requirement, compressive strength and specific weight tests were also made on concretes of constant slump using four plain cements and four cements containing an interground air-entraining agent. Comparative tests were made with two percent calcium chloride. Compared to the plain concretes, the concretes made with treated cements required from 0 to 2% less mixing water and had lower specific weights, and in most cases had lower compressive strengths; the addition of calcium chloride to the vinsol resin cement concretes decreased the required water and increased the early strengths and the specific weights

It is recognized that the water content of concrete should not exceed the minimum necessary for proper placement of the mixture. Rapp (1)[1], Newman (2) and Russell (3) have reported that the integral use of calcium chloride (2 per cent by weight of cement) increases the flow or slump of concrete and consequently should permit a reduction in water content without loss of workability. This report presents data on the effect of calcium chloride on the slump and flow of concretes with two different cement factors and with a wide range of water-cement ratios. Tests are also reported on the effect of calcium chloride on the water requirements, specific weights and compressive strengths of concretes made with four plain and four vinsol-resin cements.

MATERIALS AND TEST METHODS

The calcium chloride (flake form) was a standard brand of commercial material. Potomac River aggregates, graded up to 1 in. maximum size, were used in the laboratory air dried condition. Sand, that had a fineness modulus of 2 6, constituted 40 per cent by weight of the total aggregate. A portland cement obtained from a local warehouse was used in the study of the effect of calcium chloride on slump and flow of the concretes. For convenience this study is called series I. The cement factors for this series were maintained at nominal values of five and six bags per cubic yard, and the net quantities of mixing water were increased by ½ gal increments from 5.0 up to 8.5 gal. per bag of cement.

For the study of the effect of calcium chloride on concretes made with air-entraining cements (termed series II), a vinsol resin cement and the corresponding plain cement were obtained from each of four mills. Three of these cements were A.S T M type I and the fourth was A S.T.M. C 150 – 42, type II. The concrete was proportioned 1:2.14·3.90 by weight and the slumps were maintained at 3 ± ½ in. Compressive strength tests were made on damp-cured 6-by 12-in cylinders at ages of 1, 2, 3, 7 and 28 days. Specific weight determinations were made with a $\frac{1}{10}$-cu ft. standard measure. The flow is expressed as percentage increase in diameter after dropping the 30-in. table a distance of ½ in , 15 times in 10 sec.

SERIES I. EFFECT OF CALCIUM CHLORIDE ON THE SLUMP AND FLOW OF CONCRETE

A summary of the data on slump and flow is given in Table 1. From this table it can be

[1] Numbers in parentheses refer to the list of references at the end of the paper

seen that the lowest water contents for which measurable slumps could be obtained were 6.5 and 5 0 gal. per bag for the five- and six-bag concretes, respectively. The spread between the duplicate determinations was of the same order for both the plain and calcium chloride concretes but was slightly greater for the slump than for the flow tests. For those tests in which measurable flows were obtained, the calcium chloride admixture increased the flow. These increases are shown in Figure 1. Figure 2 shows the increase of slump, where measurable slumps were obtained, with the use of calcium chloride.

TABLE 1
EFFECT OF CALCIUM CHLORIDE ON SLUMPS AND FLOWS OF CONCRETES OF VARYING WATER CONTENTS
(Average of Two Determinations)

Water	Cement Factor— 5 bags per cubic yard				Cement Factor—6 bags per cubic yard			
	Plain Concrete		With 2% $CaCl_2$†		Plain Concrete		With 2% $CaCl_2$†	
	Slump	Flow	Slump	Flow	Slump	Flow	Slump	Flow
Gal per bag	*in*	%	*in*	%	*in*	%	*in*	%
5 0					0 2	*	0 5	19
5 5					1 2	23	1 8	33
6 0	0	*	0	*	1 8	29	2 9	40
6 5	0 7	23	1 2	31	3 1	41	5 4	60
7 0	1 7	35	2 7	41	6 0	59	7 6	86
7 5	2 5	48	3 5	65	7 7	107	8 5	116
8 0	6 4	64	7 3	72				
8 5	6 8	99	8 8	130				

* Beyond the normal limits of the flow-table tests
† Commercial grade

Although generalizations cannot be made from tests on but one cement, the data corroborate the findings of others that when calcium chloride is used the amount of mixing water in concrete may be reduced without loss of workability. For the cement tested, the water was reduced on the average of 0.4 and 0 3 gal per bag of cement respectively for the six- and five-bag concrete mixes The tests included water contents above as well as below those which gave concretes within the range normally considered workable Within the 2-in. to 6-in. slump range the calcium chloride was slightly more effective in increasing the flow and slump than for extremely wet or extremely dry concretes For instance, with a cement factor of 6 bags (as may be specified in road construction) it may be noted in Figure 1 (flow range 30-60) that substantially equal flow was maintained with the use of calcium chloride and with approximately 0.5 gal. less water per bag than required for plain concrete. The same characteristic was obtained with the slumps.

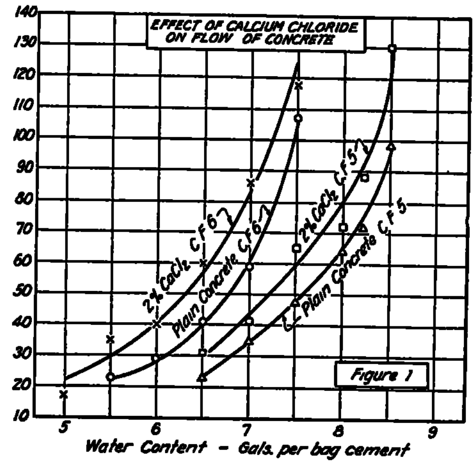

Figure 1. Effect of Calcium Chloride on Flow of Concrete

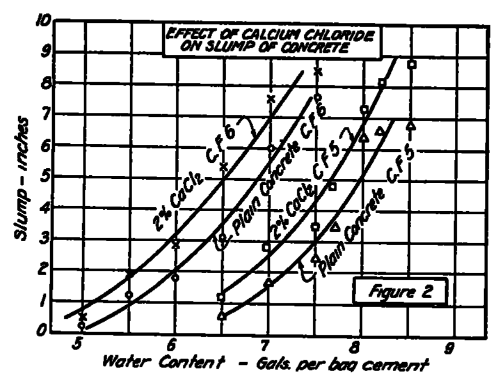

Figure 2. Effect of Calcium Chloride on Slump of Concrete

SERIES II. EFFECT OF CALCIUM CHLORIDE ON VINSOL RESIN CEMENTS

Table 2 gives the water requirements of concrete made with plain cements, vinsol-resin cements and with calcium chloride added to the concretes made with both types of cements. With reference to the water requirements of the plain cement concretes, on a constant slump basis, it may be seen that the addition of calcium chloride permitted a reduction of water with each of the four cements

tested, ranging from 0 3 to 0 5 gal. per bag The use of vinsol resin alone did not change the water content in concretes with two cements but permitted a reduction of water (0.5 gal per bag) with each of the other two cements. Concretes made with vinsol resin cements with calcium chloride added required less water for constant slump than those concretes made with vinsol resin cement alone When used with both the plain and treated cements, calcium chloride permitted a reduction in water with each cement used The reduction in mixing water requirements and the changes in air contents resulted in changes in cement factors of the various concretes These variations in cement factors are also shown in Table 2.

A resumé of the compressive strengths of these concretes is given in Table 3 and is shown graphically in Figure 3 In confirmation of the results of other investigators it is shown that calcium chloride considerably increased the strengths at 1, 2, 3, and 7 days of all the plain-cement concretes. The 28-day strengths of the concretes made with two of the cements were not changed appreciably by the addition of calcium chloride, while the 28-day strengths of the concretes with the other two cements were increased by the use of calcium chloride. In all cases the percentage increase in strength caused by the addition of calcium chloride diminished with the test age.

The strengths of the concretes made with the four vinsol resin cements were slightly lower at 1, 2 and 3 days than those obtained for the corresponding ages with the plain cement concretes, except for the 1-day strength with cement "B" and the 3-day strengths with cements "C" and "D". At 28 days the strengths of the concretes made with vinsol resin cements ranged from 6 to 29 per cent (average 20 per cent) lower than the 28 days strengths of the plain cement concretes The addition of calcium chloride to the concretes made with vinsol resin cements increased the compressive strengths markedly at the early ages. Thus, at 1 day the increase in strengths resulting from the addition of calcium chloride ranged from 87 to 170 per cent The percentage increase, however, decreased regularly with testing age until at 28 days the increase ranged from 1 to 28 per cent for the four cements. Except for the 7-day strength of the concrete containing cement "A" the strengths of the vinsol-resin-cement concretes with calcium chloride added, exceeded the strengths of the

TABLE 2

EFFECT OF CALCIUM CHLORIDE ON SLUMP AND WATER REQUIREMENT OF CONCRETES MADE WITH EACH OF 4 BRANDS OF PLAIN AND VINSOL RESIN TREATED PORTLAND CEMENTS

Cement	Admixture	Slump	Water	Cement factor	Water reduction resulting from admixture		
					V R	$CaCl_2$	V R + $CaCl_2$
		in	*gal per bag*	*bags per cu yd*	*gal per bag*	*gal per bag*	*gal per bag*
A	none	2¼	6 5	6 35			
AA	V R	2¾	6 5	6 05	0		
A	$CaCl_2$	3¼	6 1	6 38		0 4	
AA	V R + $CaCl_2$	3	6 2	6 23			0 3
B	none	3½	6 4	6 33			
BB	V R	3¼	6 4	5 85	0		
B	$CaCl_2$	3½	6 1	6 32		0 3	
BB	V R + $CaCl_2$	3½	5 7	6 20			0 7
C	none	3½	6 5	6 32			
CC	V R	3	6 0	6 15	0 5		
C	$CaCl_2$	3½	6 0	6 40		0 5	
CC	V R + $CaCl_2$	3	5 7	6 30			0 8
D	none	3¼	6 4	6 35			
DD	V R	3½	5 9	5 92	0 5		
D	$CaCl_2$	3½	5 9	6 38		0 5	
DD	V R + $CaCl_2$	3	5 7	6 15			0 7
Average.					0 2	0 4	0 6

V R —vinsol resin
$CaCl_2$—2 per cent of commercial calcium chloride.

reference plain-cement concretes from 1 up through 7 days. On the other hand, at 28 days the strengths of the concretes containing vinsol resin together with calcium chloride ranged from 84 per cent to 100 per cent of the strengths of the plain-cement concretes.

TABLE 3

EFFECT OF CALCIUM CHLORIDE ON COMPRESSIVE STRENGTHS OF CONCRETES MADE WITH EACH OF 4 BRANDS OF PLAIN AND OF VINSOL RESIN TREATED PORTLAND CEMENTS

(Average of three determinations)

(1) Age	(2) Plain concrete	(3) Concrete with $CaCl_2$	(4) Ratio column 3 to 2 × 100	(5) Concrete with V R Cement	(6) Concrete with V R + $CaCl_2$	(7) Ratio column 6 to 5 × 100	(8) Ratio column 6 to 2 × 100
Cement A							
days	*psi*	*psi*	*psi*	*psi*	*psi*	*psi*	*psi*
1	490	1190	242	400	750	187	153
2	1260	1950	155	1010	1460	144	116
3	1770	2440	138	1440	2080	144	117
7	2750	3320	120	2260	2650	117	96
28	4590	4620	100	3490	3830	110	84
Cement B							
1	580	1630	280	640	1700	266	294
2	1290	2660	206	1240	2380	192	184
3	2050	2970	145	1860	2780	149	135
7	3100	3650	118	2560	3200	125	103
28	4370	4600	105	3100	3840	124	88
Cement C							
1	710	2000	280	700	1900	272	265
2	1360	2690	197	1260	2490	197	183
3	1870	2890	154	2060	2910	141	155
7	2695	3480	129	2530	3330	132	124
28	4050	4840	119	3800	3830	101	95
Cement D							
1	600	1640	273	560	1440	257	240
2				1260	2440	194	
3	1470	2470	168	1580	2710	172	185
7	2220	3800	171	2050	3190	155	143
28	3920	4810	123	3090	3970	128	101
Average of above values							
1	595	1610	270	575	1450	252	244
2	1300	2440	188	1195	2190	183	169
3	1790	2700	151	1740	2620	150	146
7	2690	3560	132	2350	3100	132	115
28	4230	4710	111	3370	3870	115	92

V R = vinsol resin
$CaCl_2$ = 2 per cent of commercial calcium chloride

The specific weights and calculated air contents of the concretes are summarized in Table 4. The air content is calculated from the difference between the observed specific weight and the theoretical specific weight as calculated from the weights and the solid volumes of all the ingredients. Each value represents the average of three determinations. It is shown that both the treated cement concrete and the treated cement concrete with calcium chloride, had markedly higher air contents than the concretes with the four plain cements tested. The use of the vinsol resin cement resulted in an aeration from 4.7 per cent for the concrete with cement "C" up to 8 7 per cent for that with cement "D". With the addition of calcium chloride the air content was reduced and ranged from 3.1 per

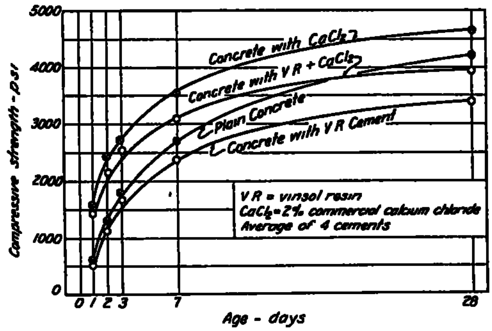

Figure 3. Effect of Calcium Chloride on Compressive Strengths of Concretes made with Plain and Treated Cements.

TABLE 4

EFFECT OF CALCIUM CHLORIDE ON AIR CONTENT OF CONCRETE MADE WITH PLAIN AND TREATED CEMENTS

Cement	Admixture	Theoretical specific weight	Observed specific weight	Calculated air content	Difference in total percentage of air in concrete with V R and that with V R + $CaCl_2$
		lb per cu ft	*lb per cu ft*	%	
A	none	147 9	147 7	0 14	
AA	V. R.	147 9	140 4	5 1	2 0
AA	V R. + $CaCl_2$	148 5	143 9	3 1	
B	none	148 1	147 1	0 67	
BB	V R	148 1	135 9	8 2	2 6
BB	V R. + $CaCl_2$	149 6	141 2	5 6	
C	none	147 9	147 8	0 07	
CC	V R	149 1	142 1	4 7	0 6
CC	V R. + $CaCl_2$	150 1	144 0	4 1	
D	none	148 2	146 8	0 95	
DD	V. R	149 4	136 4	8 7	2 0
DD	V. R + $CaCl_2$	150 3	140 0	6 7	

V. R —vinsol resin
$CaCl_2$—2 per cent of commercial calcium chloride

cent for concrete with cement "A" to 6 7 per cent for that with cement "D". It is generally considered that the aeration of concrete is the predominant factor contributing to improvement of frost resistance accompanying the use of certain admixtures. However, according to Kennedy (4) any increase of air content greater than 3 per cent has doubtful value for increasing durability, and may unnecessarily reduce the strength. Although the degree of aeration obtained with the open bowl-laboratory mixer used in these tests cannot be considered as indicative of the degree of aeration that would be obtained with a commerical mixer, the results indicate that the use of calcium chloride tends to reduce the aeration obtained with the vinsol resin cement.

SUMMARY

With mixing water constant, the slump of concrete is increased by the addition of 2 per cent of calcium chloride. In tests, which were made with but one cement, upon addition of 2 per cent calcium chloride the mixing water was reduced by $\frac{1}{3}$ to $\frac{1}{2}$ gal. per bag of cement without loss of workability. The reduction was greater for the 6-bag concrete in the range of slump of 2 to 6 in. than for the leaner concretes or for consistencies outside this range.

The four vinsol-resin-cement-concretes mixed 5 min. in an open bowl mixer had calculated air contents ranging from 4.7 to 8.7 per cent. The use of calcium chloride in the concretes made from these same cements reduced the aeration so that the air content ranged from 3 1 to 6.7 per cent.

The addition of 2 per cent calcium chloride to concretes made with each of four vinsol resin cements increased the compressive strengths at 1, 7 and 28 days by an average of 152, 32 and 15 per cent respectively. The average strengths of the vinsol-resin-cement-concretes, to which 2 percent calcium chloride had been added, exceeded the strengths of the plain-cement concretes (no vinsol resin or calcium chloride) by 144 and 15 per cent at 1 and 7 days respectively. At 28 days the strengths of the vinsol resin-calcium chloride concretes averaged 8 per cent lower than the strengths of the plain concretes.

REFERENCES

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3. Russell, H. W., "Report on Effect of Calcium Chloride Admixture on Strength of Concrete Cured at Low Temperatures," Illinois Department of Highways, 1943.
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