Effects of Two Non-Chloride Accelerating Agents on Setting Characteristics of Portland Cement Mortars

by P. Smith

Synopsis: Effects of two non-chloride accelerating agents -- sodium thiocyanate and calcium nitrate -- on time to achieve initial set of two brands of Type I cement were determined at 70 F (21 C) and 40 F (4 C).

Results with these two non-chloride accelerators were compared with results with calcium chloride, the conventional accelerator.

Tests show:

- Low or moderate dosages of the two non-chloride accelerators can reduce time to achieve initial set by 1-2 hr.
- Any one of the three accelerators may be more effective with one cement than with another cement having similar setting characteristics without accelerators.
- In general, all three of the accelerators are more effective at 40 F than at 70 F.

Keywords: accelerating agents; calcium chlorides; calcium nitrates; mortars (material); setting (hardening); sodium thiocyanates

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INTRODUCTION

A major consideration in choosing an accelerator to be used in concrete must, of course, be its effectiveness in accelerating setting. That is the characteristic studied in this investigation. Other characteristics that should be considered in choosing an accelerator include:

- cost
- influence on corrosion of steel reinforcement and other metal embedments, and
- enhancement of compressive strength of concrete.

It is well known that non-chloride accelerators are more expensive than chloride accelerators. Sodium thiocyanate is the most expensive of the three chemicals used as accelerators in this test program. Calcium nitrate is somewhat less expensive. Both are far costlier per ounce than calcium chloride.

It is well known also that chloride accelerators can contribute to corrosion of steel reinforcement. However, non-chloride accelerators are not necessarily noncorrosive. A particular non-chloride accelerator may or may not contribute to corrosion.

This investigation did not cover effects of the accelerators on corrosivity or concrete compressive strength. Nor did it cover all of the many possible non-chloride accelerators. As Chapter 3 of ACI 212.1R states, "Studies have shown that a wide range of soluble inorganic salts, such as chlorides, bromides, fluorides, carbonates, nitrates, thiosulfates, silicates, aluminates, and alkali hydroxides, will accelerate the setting and early hardening of portland cement." ACI 212.1R also discusses organic accelerators such as triethanolamine, which are used in admixtures with water-reducing constituents to counteract their retarding effects. Triethanolamine could also be used with other non-chloride or chloride accelerators. But it is costly and of limited effectiveness. Calcium formate and other inorganic accelerating admixtures are discussed by Rosskopf, Linton, and Peppler (1975).

ACCELERATORS STUDIED

In the study, a 55% aqueous solution of sodium thiocyanate was prepared in the laboratory by dissolving sodium thiocyanate technical grade crystals in distilled deionized water. The calcium nitrate solution used was 66% tetrahydrate, 45.9% active. The 35% aqueous solution of calcium chloride was prepared from anhydrous calcium chloride, 94-97% pure, dissolved in distilled deionized water. The concentration solutions prepared in the laboratory were based on the total weight of the solids introduced into the distilled deionized water. These concentrations are as high as is practical for general field use.

The dosage rate of these accelerating solutions is reported in liquid ounces at the stated concentration per 100 lb of cement.

TEST METHOD

The initial setting times of mortars were determined in accordance with ASTM C 403-80 with the following exceptions:

1. A concrete mixture was proportioned in the laboratory using 470 lb of cement per cubic yard of concrete (279 kg/m^3) -- which is a "five sack" mixture -- to yield a 5-in. slump. Mortars from this mix were then separated from the concrete and a flow determined in accordance with ASTM C 230-83 (flow table dropped five times). For this mixture, it was determined that the 5-in. slump concrete would produce a mortar with a flow of 96%.

2. The mortars used in these series of tests were then prepared using the same cement, sand, and water ratio as used in the test mixture, and the flows were maintained between 90 and 100% using the aforementioned method for determining flows.

The volume of the total liquid content was kept approximately the same, regardless of the dosage rate of accelerator. The non-water-reducing aspects of these accelerators allowed us to accomplish this and still maintain a consistency of mortar between 90 and 100% flow.

In this test program, one set of samples was stored at 70 F, about the highest temperature at which accelerators are used. A second set was stored at 40 F, the minimum placing and curing temperature allowed in most specifications. One hour after initial contact between cement and mixing water was made, and at intervals of ½-hr thereafter, the resistance of the mortar to penetration by a standard needle was measured.

Mortars were maintained at the selected test temperature during mixing, placing, and testing.

MATERIALS

The two cements used were from different regions of the United States, but had similar setting characteristics without accelerators, as shown in Table 1.

For each accelerator dosage in the test program, three batches of mortar were prepared using the same proportions of cement, fine aggregate, and water; flows were maintained between 90 and 100%. Mortars were mixed in accordance with ASTM C 305-82. Then initial setting time was determined according to ASTM C 403-85.

RESULTS AND CONCLUSIONS

Figs. 1-4, which appeared in Concrete Products for October 1985, compare the data obtained.

Fig. 1 shows the effects of a range of dosages of the three accelerators on Cements A and B at 70 F ambient temperature. Fig. 2 presents similar information for 40 F.

Figs. 3 and 4 present the same data plotted in Figs. 1 and 2. But Fig. 3 presents the effects of the three accelerators on Cement A at 70 F and 40 F. Fig. 4 presents similar information for Cement B.

In Fig. 1, with calcium nitrate Cement A appears to set about ¼ hr sooner than Cement B over the range of working dosage rates. With sodium thiocyanate at 16 oz/100 lb of cement, Cement A appears to set about 3/4 hr sooner than Cement B. However, with calcium chloride, Cement B sets sooner than Cement A.

In Fig. 2, with calcium nitrate the difference in setting times for Cements A and B is even more pronounced; over much of the dosage range Cement A sets about 3/4 hr sooner. With sodium thiocyanate, Cement B consistently sets somewhat sooner than Cement B. However, with calcium chloride, Cement A sets about ½ to 1½ hr sooner than Cement B and the difference is wider at 16-32 oz/100 lb of cement than at 48-64 oz per 100 lb.

Figs. 3 and 4 demonstrate that, as might be expected, for both Cement A and Cement B all three accelerators are more effective in hastening setting at 40 F than at 70 F. With sodium thiocyanate, the difference is more pronounced for Cement B than for Cement A. However, for calcium chloride the difference is more pronounced for Cement A than for Cement B.

When interpreting Figs. 3 and 4, one should note that, as Table 1 shows: 1) Cement A mortar at 40 F with no admixture took 2 hr 47 min longer than did the same mortar at 70 F to reach initial set. 2) Cement B mortar at 40 F took 2 hr 37 min longer than did the same mortar at 70 F to reach initial set. Therefore, in order for the mortars at 40 F to have the same setting characteristics as the mortars at 70 F, they would have to have demonstrated an acceleration over that of the 70 F mortar of approximately 2 hr 40 min.

Also, it should be remembered that ounce for ounce, sodium thiocyanate is the most expensive, calcium nitrate somewhat less expensive, and calcium chloride far less expensive.

From the test data and cost data, it appears that the most effective dosage rates in terms of cost are for sodium thiocyanate approximately 2-8 oz/100 lb of cement and for calcium nitrate 12-40 oz/100 lb.

REFERENCES

ACI Report

ACI 212.1R-81 Admixtures for Concrete

ASTM Standards

C 230-183 Specification for Flow Table for Use in Tests of Hydraulic Cement

C 305-82 Method for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 403-85 Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

Articles Cited

Rosskopf, P. A.; Linton, F.J. and Peppler, R. B., "Effect of Various Accelerating Chemical Admixtures on Setting and Strength Development of Concrete," Journal of Testing and Evaluation, ASTM V. 3, No. 4, pp. 322-330, 1975

Smith, P. A., "The Effects of Non-Chloride Accelerating Admixtures on the Setting Characteristics of Concrete," Concrete Products, Maclean Hunter Publishing Co.; Oct. 1985, pp. 26-27

Additional Reading

Ramachandran, V.S., Concrete Admixtures Handbook, Noyes, 1984

TABLE 1--TIME OF INITIAL SETTING OF CEMENTS A AND B

	At 70 F (21 C)	At 40 F (4 C)
	hr:min	hr:min
Cement A	4:45	7:32
Cement B	4:50	7:27

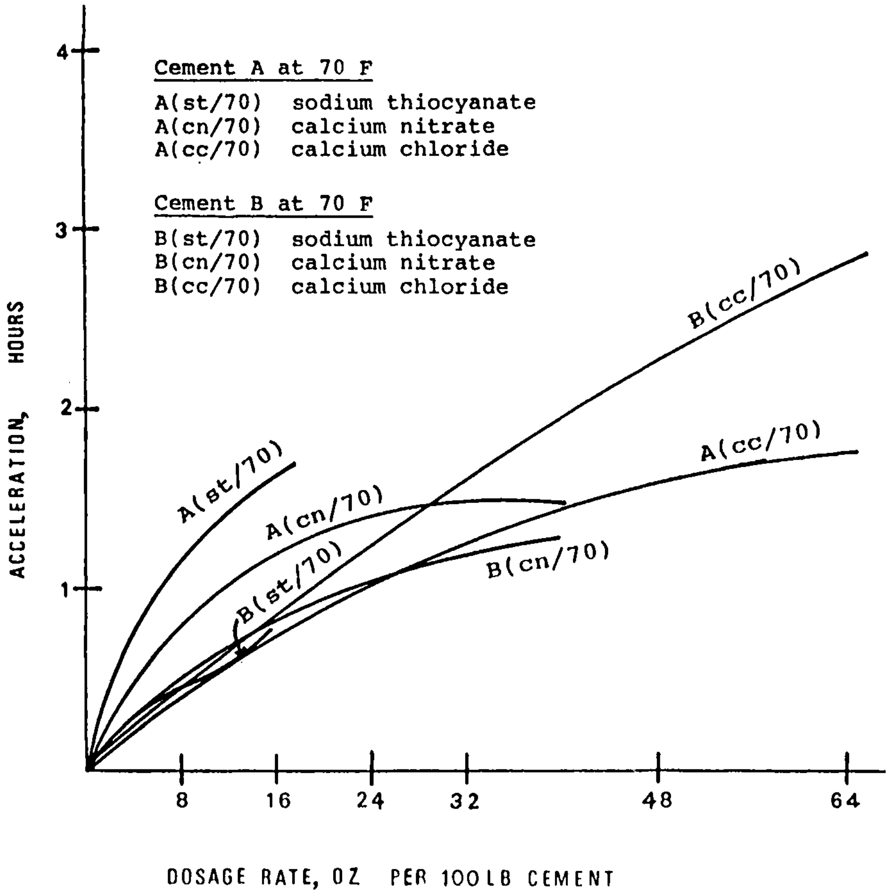

Fig. 1--For Cements A and B at 70 F, effect of dosage rate on time to set for three accelerators

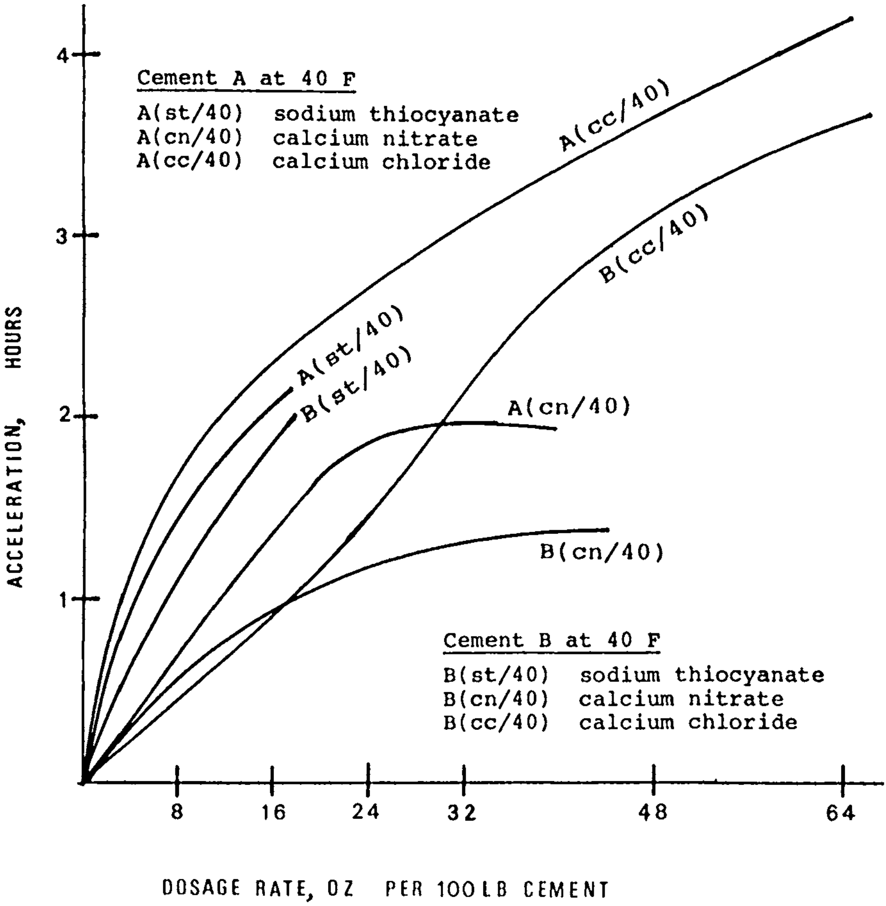

Fig. 2--For Cements A and B at 40 F, effect of dosage rate on time to set for three accelerators

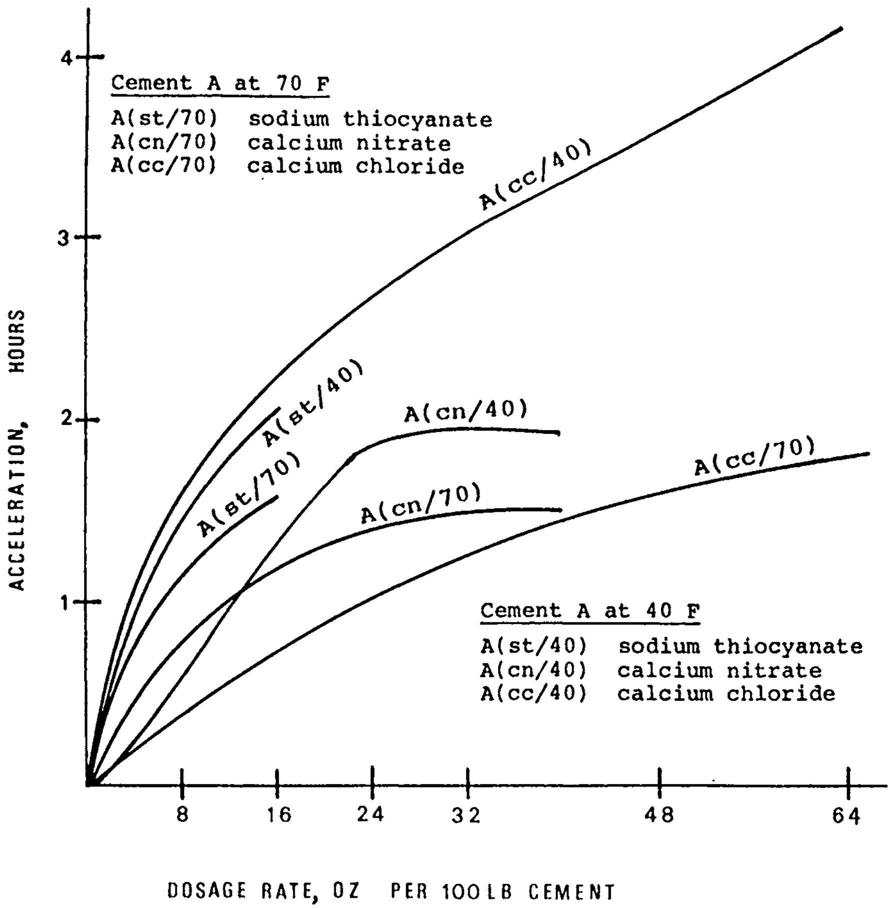

Fig. 3--For Cement A at 70 F and 40 F, effect of dosage rate on time to set for three accelerators

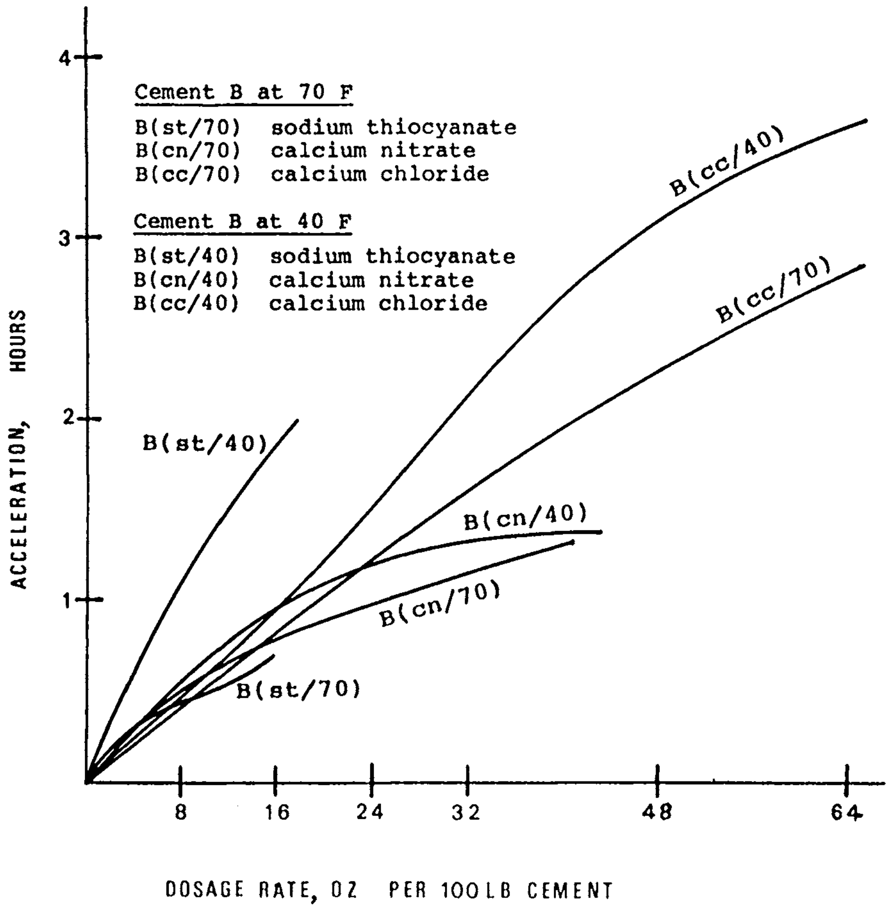

Fig. 4--For Cement B at 70 F and 40 F, effect of dosage rate on time to set for three accelerators