Bulletin 349 November, 1929

EFFECT OF LUMNITE CEMENT AND PLASTER OF PARIS CAPS ON STRENGTH OF CONCRETE TEST CYLINDERS

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EFFECT OF LUMNITE CEMENT AND PLASTER OF PARIS CAPS ON STRENGTH OF CONCRETE TEST CYLINDERS

BY DON J. TRIPP, TESTING ENGINEER

For the last 8 or 9 years, thru a cooperative agreement, the Road Materials Laboratory of the Colorado Agricultural College has been testing the field cylinders of the Colorado State Highway Department. Because of the difficulty and time required for capping the cylinders in the field, these cylinders come to the laboratory uncapped and are usually about 10 days old. It is necessary to cap these cylinders before testing them and it is our regular procedure to cap them with lumnite cement mortar. This method requires 2 days, 1 day to thoroly wet the cylinders and the other for the caps to harden. The cylinders sometimes reach the laboratory with less time than this remaining before being tested and when this is the case we use plaster of paris caps, which require only 15 or 20 minutes to harden.

To determine whether or not our methods of capping were satisfactory, it was thought advisable to run a short series of tests to determine what effect the different caps had on the compressive strength of the specimens. This was particularly true of the lumnite cap which has been the subject of some criticism.

It was thought that rather than make experiments covering all conditions it would be better to experiment with extreme conditions only, and if the methods of capping were satisfactory for these conditions, they would certainly be satisfactory for intermediate conditions. Accordingly, only two different mixes were used. One, a mix giving concrete of a strength of about 1800 pounds per square inch at 28 days, was proportioned 1:4.57:5.55 by weight. The other, which made a concrete of approximately 4800 pounds strength per square inch at 28 days, was proportioned of 1:1.97:2.89 by weight. The water-cement ratio used in the first mix was 1.15 and in the second, 0.70. The low-strength cylinders were tested only at 28 days but the high-strength cylinders were tested both at 7 and 28 days. In this way we experimented with high- and low-strength cylinders and with cylinders tested at the two ages of 7 and 28 days. We also made some of the cylinders with rough ends and some with relatively smooth ends.

It is desired to acknowledge the helpful assistance given by Fred A. Riddell and Ira R. Rubottom, former laboratory assistants who assisted in making the tests.

MATERIALS AND MAKING OF TEST SPECIMENS

The following materials were used in making the concrete test cylinders:

The cement used was a portland cement manufactured by the Boettcher Plant of the Colorado Portland Cement Company. That this cement is stronger than the average portland cement is shown by the high strengths obtained in the following tests.

The sand used was a granitic river sand, of hard angular particles which had the following grading:

Passing 4-mesh sieve	100.0 percent
Passing 8-mesh sieve	83.3 percent
Passing 14-mesh sieve	64.4 percent
Passing 28-mesh sieve	34.3 percent
Passing 48-mesh sieve	13.8 percent
Passing 100-mesh sieve	4.2 percent
Silt by eleutriation	1.0 percent

The gravel used was hard granitic river gravel, partly crushed, which had the following grading:

Passing 1½-inch screen	100.0 percent
Passing ¾-inch screen	51.2 percent
Passing ⅜-inch screen	20.5 percent
Passing 4-mesh sieve	0.0 percent

In order to assure the same grading of sand and gravel in each batch of concrete, the sand was split into two parts, and the gravel into three parts by hand sieving. These parts were recombined in each batch to give as nearly the original gradings as possible.

The concrete was mixed by hand in batches large enough to fill five 6- by 12-inch steel cylinder molds; and ordinarily not more than 2 batches were mixed in 1 day. The molds were filled in the regular way, which is to rod each third as it is placed in the mold, except that to eliminate the variation due to imperfect cylinders, each third was rodded more than the customary 25 times. This partly accounts for the high strengths obtained. Figure 1 shows the cylinder molds ready for filling.

The day after the cylinders were molded they were removed from the molds and stored in water until the day before they were to be tested. At this time they were removed from the water and capped as will be described later. After capping they were covered with wet burlap until just before they were to be tested.

Of the 5 cylinders made from each batch, 1 was capped shortly after molding with what we term a standard cap. This method of capping will be described later. Two of the remaining 4 were left with what we call ordinary ends. These ends were produced by molding the cylinders on a piece of unplaned lumber and striking the tops off with a straight edge. The ends of the other 2 cylinders were left extremely rough. The lower ends

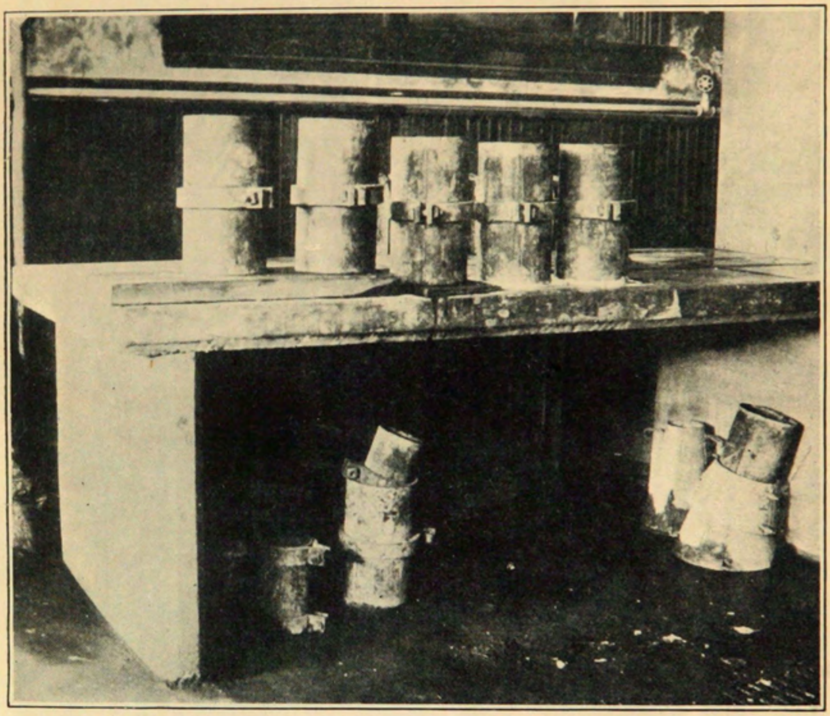

Fig. 1.—Cylinder molds ready for filling. Notice that the two on the left have been placed on unplaned lumber, the two on the right on rough plaster of paris bases and the center one has been set on a machined steel plate.

were made rough by molding the cylinders on roughened bases of plaster of paris, 2 of which are shown in Figure 2, and upper ends were made as rough as possible with a trowel.

Figure 3 shows the 5 cylinder molds after all have been filled and the standard cap has been applied to the center cylinder. The 2 cylinders on the left are the 2 with ordinary ends and the 2 on the right are those with rough ends. Figure 4 shows the end conditions obtained on the 5 cylinders. The lower ends of the 2 outside cylinders have been turned up to show the end conditions obtained with the unplaned lumber and the plaster of paris bases.

Apparatus and Methods of Capping

On the day before the cylinders were to be tested, all of them, including the cylinder already capped with the standard cap, were removed from the water. To each end of 1 rough-ended cylinder and 1 cylinder with ordinary ends, plaster of paris caps were applied. The 2 other uncapped cylinders were capped in the same way with the lumnite cap. The apparatus used in applying these caps and obtaining square ends on the test specimens is shown in Figure 5. Figure 6 shows the apparatus being used to cap a cylinder with plaster of paris.

The plates on which the cylinders were placed were perfectly horizontal and the cylinders were set vertical as is shown in the

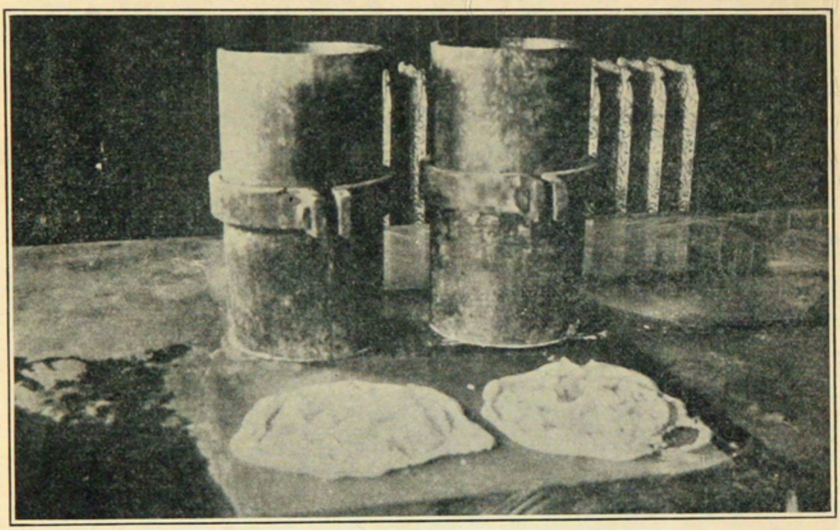

Fig. 2.—Showing two rough plaster of paris bases.

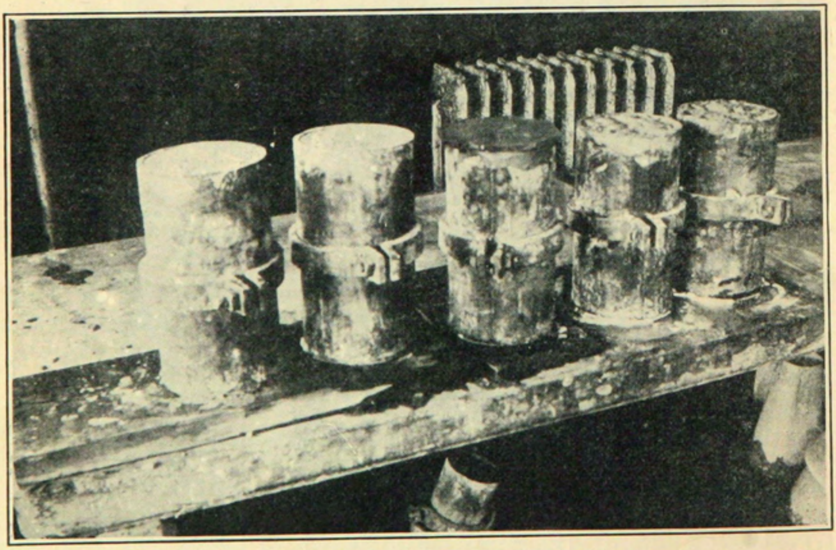

Fig. 3.—Showing the cylinders in the molds. The glass plate used in applying the standard cap to the center cylinder is in place.

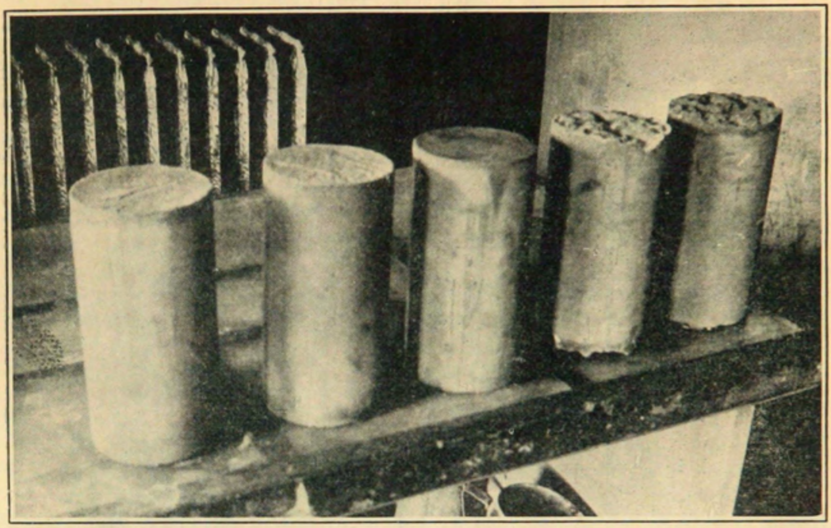

Fig. 4.—Showing the end conditions obtained on the cylinders. The bottom ends of the two outside cylinders have been turned up to show the effect of the bases. A standard cap has been applied to the center cylinder.

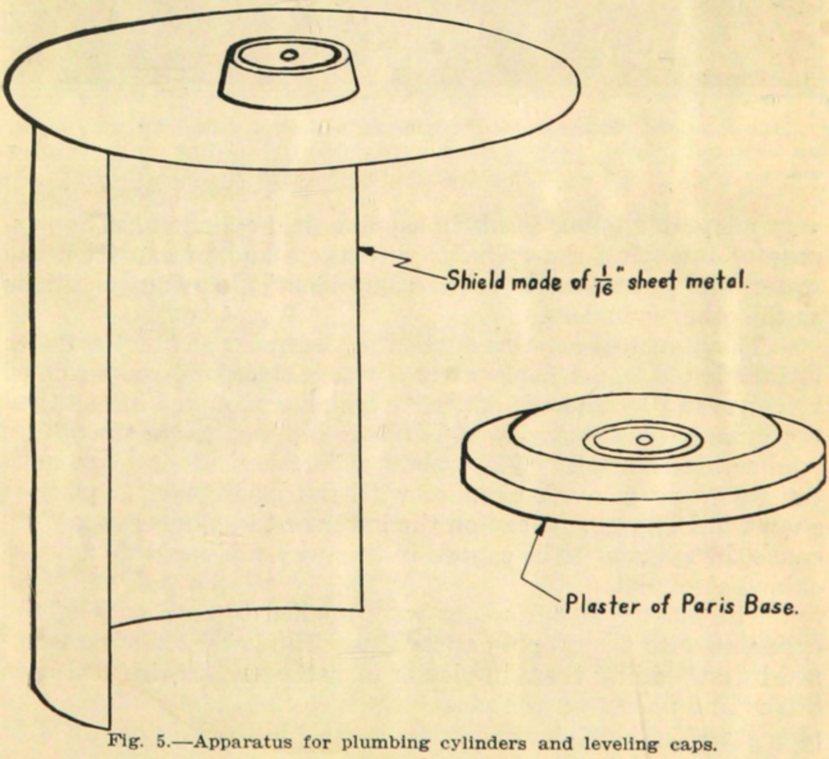

Fig. 5.—Apparatus for plumbing cylinders and leveling caps.

picture on the left. In this way the lower cap ends were made perpendicular to the cylinder sides.

As soon as the lower caps became sufficiently solid the upper caps were applied and made parallel to the bottom caps by leveling the upper glass plates. This equipment has proved itself

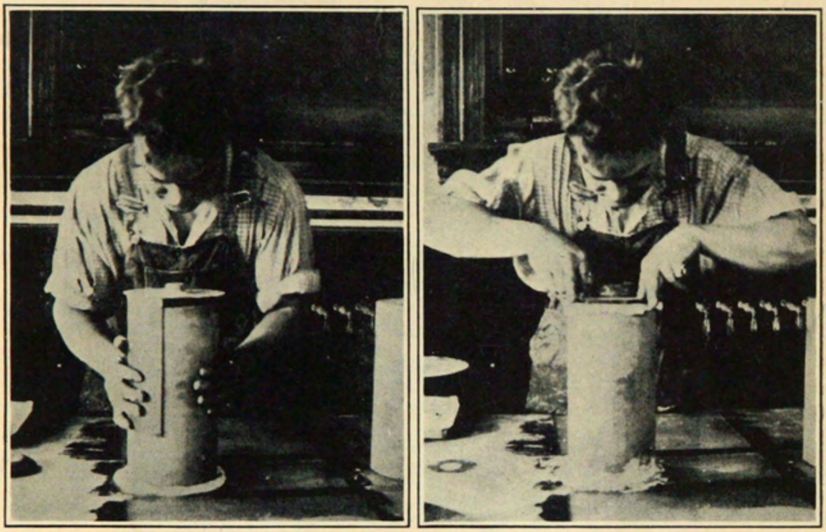

Fig. 6.—Left. Setting cylinder vertical on horizontal glass plate while applying lower cap. Right. Leveling upper glass plate while applying cap to the upper end.

very adaptable to our needs in capping field cylinders. The purpose of removing the cylinder with the standard cap from the water was to subject it to the same identical curing conditions as the other cylinders.

The standard cap was applied to the upper end of 1 cylinder in each batch 2 to 4 hours after it was molded and was made of retempered portland cement paste which was mixed at the time the cylinders were made. The upper cap was made smooth by application of a heavy glass plate which was left in place until the following day. A cylinder with the glass plate in place is shown in Figure 2. A cap on the lower end was unnecessary because the cylinder to be capped in this way was molded on a machined steel plate.

The plaster of paris caps were applied to both ends of the cylinders with the capping apparatus. The lower ends were capped by embedding them in plaster of paris paste which had been mixed and placed on the perfectly level glass plates of the capping stand. The upper ends were capped by covering them with

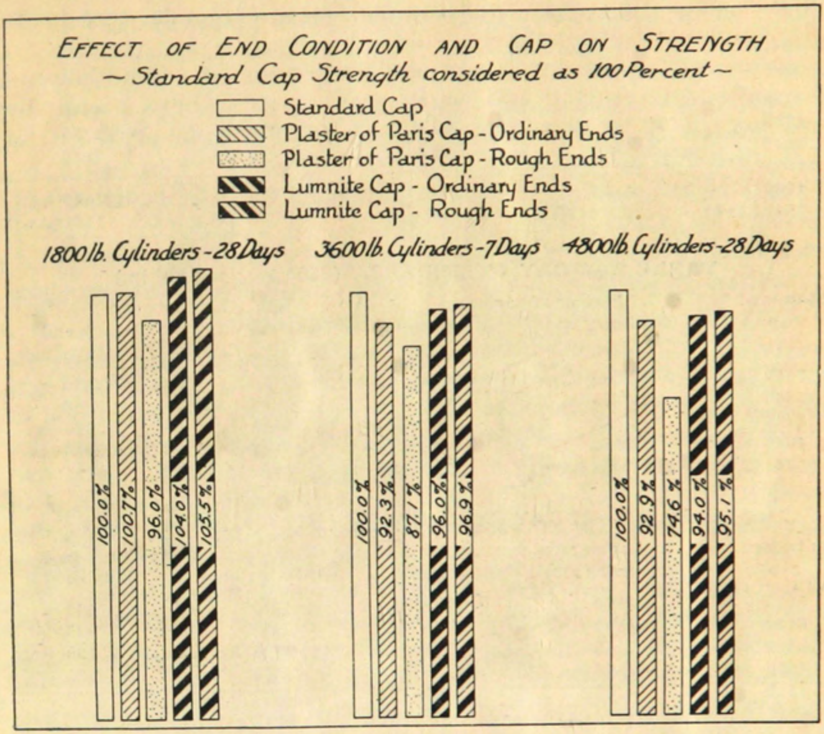

Fig. 7.—Showing the effect of end condition on cap and strength.

plaster of paris paste and smoothing them off with heavy glass plates which were left in place until the paste had thoroly hardened. Two views of capping a cylinder with plaster of paris are shown in Figure 5.

The lumnite caps were applied in the same way as the plaster of paris caps except that a mortar of lumnite cement and fine sand which had been mixed 1 to 3 hours before and retempered just before using was used instead of the plaster of paris paste. The sand used in the mortar passed a 20-mesh sieve.

All of the cylinders were tested on the day following the application of the lumnite and plaster of paris caps with a 150,000-pound testing machine.

RESULTS

In the following tables are given the compressive strengths in pounds per square inch of the test specimens capped in the different ways. The strengths of the cylinders made from each separate batch are placed opposite one another.

TABLE 1.—28-DAY CYLINDERS. (1800 lbs. per sq. in.)

Standard cap	Plaster of paris cap		Lumnite cap	
	Ordinary end	Rough end	Ordinary end	Rough end
1720	1705	1635	1815	1755
1685	1905	1715	2020	1985
2040	1935	1890	1975	2010
1995	1970	1935	2010	2200
1860	1855	1750	1855	1855
1860(Ave)	1874(Ave)	1785(Ave)	1935(Ave)	1961(Ave)

TABLE 2.—7-DAY CYLINDERS. (3600 lbs. per sq. in.)

Standard cap	Plaster of paris cap		Lumnite cap	
	Ordinary end	Rough end	Ordinary end	Rough end
3340	3170	2970	3215	3205
3895	3330	3180	3450	3610
3660	3285	3290	3565	3720
3765	3835	3410	3800	3620
4045	3650	3445	3920	3980
3741(Ave)	3454(Ave)	3259(Ave)	3590(Ave)	3627(Ave)

TABLE 3.—28-DAY CYLINDERS. (4800 lbs. per sq. in.)

Standard cap	Plaster of paris cap		Lumnite cap	
	Ordinary end	Rough end	Ordinary end	Rough end
5225	4570	4220	4765	5140
5130	4800	3560	5190	4835
5410	5085	3510	4750	5190
4920	4550	4010	4875	4575
4215	4125	3265	3825	3940
4980(Ave)	4624(Ave)	3713(Ave)	4681(Ave)	4736(Ave)

Figure 7 shows graphically the averages in the above tables expressed as percentages of the average standard cap strength.

To obtain further proof that the method of capping did effect the strength of field cylinders we tried capping half of each set of the field cylinders of the Colorado State Highway Department with the lumnite cap and the other half with the plaster of paris cap. In most cases a little portland cement was added to the plaster of paris to keep it from setting so fast. Of the 251 sets treated in this way, better than 70 percent tested higher with the lumnite cap. The average strength of the lumnite capped cylinders was 5.69 percent higher than that of the plaster of paris capped cylinders. Most of the sets consisted of only 2 cylinders but some were sets of 4.

In studying Table 1, it will be seen that the maximum variation between strengths of different batches as shown by the standard capped cylinders was about 355 pounds per square inch, or 19.1 percent. From Table 2 the maximum variation in the strength of different batches of 3700-pounds-per-square-inch cylinders was 705 pounds per square inch, or 18.8 percent. Table

3 shows the maximum variation between batches for 4800-pounds-per-square-inch cylinders to be 1295 pounds, or 26.0 percent. It must be remembered that the above figures are based on only 1 cylinder from each batch and that variations caused by the differences in cylinders are included in the variations given. Also nearly all of the batches were made on different days so that the variations due to atmospheric conditions were also included. Nevertheless, it shows that the variation in concrete from day to day even under the closest control is far greater than any error caused by method of capping which is likely to occur.

However, in dealing with field tests of concrete it is the average with which we deal rather than the strength of individual specimens. The sample for any piece of concrete work usually includes 3 or 4 test cylinders from different batches of concrete and the error due to differences in cylinders is compensating, but if we break all of these cylinders after capping them with caps which cause them to give less strength than they should, then all of the set of cylinders are too low and such an error is not compensating but remains the same and the average for that job or that particular set is lower than it should be by the differences caused by the caps. It is seen, therefore, that the method of capping does deserve a great deal of attention, especially when we consider that a plaster of paris cap on a rough-ended cylinder may show only a little better than 70 percent of the true strength. This fact is shown by Figure 7.

Also from Figure 7 it will be seen that various methods of capping do not give the same relative differences in strength when used on cylinders of different strengths. For the 1800-pound cylinders, only the plaster of paris cap on a cylinder with rough ends gave a lower strength than the standard cap method, while for the two higher-strength sets neither the strength of the cylinders with the lumnite cap nor the plaster of paris cap came up to the standard cap. The lumnite cap, judging from the results obtained, always gave a strength higher than the plaster of paris cap.

One of the principal advantages in favor of the lumnite cap is the fact that rough or smooth ends have very little effect on the strength when this cap is used. When the plaster of paris cap is used the end condition has a marked effect on the strength. For all 3 sets of cylinders, the lumnite cap gave a slightly higher strength on a roughened cylinder than on a smooth-ended cylinder. With the plaster of paris cap the reverse was true.

The experiments with field cylinders already referred to also show that capping cylinders with lumnite caps caused them to give higher strengths than when they were capped with plaster of paris caps. Field cylinders vary considerably in strength, but the average difference of 5.69 percent is probably very close to true difference produced by the use of the 2 caps on cylinders of about 3000 pounds per square inch. This was about the average of the field cylinders tested at that time.

CONCLUSIONS

1. The variation in the strength of individual cylinders is probably greater than any variation likely to occur due to method of capping.

2. Altho the variation due to capping under ordinary conditions is probably negligible when considering individual cylinders, it should be given attention when considering the average of a number of cylinders since the variation due to capping is not compensating.

3. From the results obtained, it appears that the different methods of capping do not give the same relative differences in strength when used on cylinders of various strengths. In other words, the method of capping which gives the highest strength for 1800-pound concrete may not give the highest for 5000-pound concrete.

4. Rough ends appear to have little effect on the strength when the lumnite cap is used.

5. Rough ends give a considerably lower strength when plaster of paris caps are used. The strength shown may be only 70 percent of the true strength in the case of high-strength cylinders.

6. Altho there may be better caps than the lumnite cap, the maximum variation between the strength given by this cap and strength shown by the standard cap is only about 5 percent. Then, too, it appears from the results obtained that strengths shown by these 2 caps are about the same for 3000-pound concrete which is probably very close to the average of all of the cylinders tested. Since the standard cap is the accepted one, it appears that there can be no serious objections to the use of the lumnite cap.

7. An important advantage of the lumnite cap is that it has shown itself to be far easier to apply to uncapped field cylinders than any other cap tried in this laboratory.

8. Apparently it is the strength of the cylinders and not the age which determines the effect which different methods of capping have on the strengths obtained.