FINAL REPORT

USE OF NEOPRENE PADS IN TESTING CONCRETE CYLINDERS

by

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SYNOPSIS

This study investigated the feasibility of using neoprene pads confined by steel end caps instead of sulfur-mortar caps in compressive strength tests on concrete cylinders. The 1/2 in. (13 mm) thick neoprene pads had a 50 durometer hardness and were cut to fit in the end caps, which had an inside diameter of 6-1/4 in. (159 mm) with a tolerance of +0 and -1/16 in. (-2 mm). Compressive strength data were obtained from 438 pairs of cylinders prepared in the field from commercial batches of concrete. One cylinder of each pair was tested with neoprene pads and the other with sulfur-mortar caps. Although the results indicate statistically significant differences in the values obtained by the two capping methods, the differences are considered negligible from a practical standpoint. A linear regression analysis indicated a good correlation between the two methods.

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INTRODUCTION

In a previous study utilizing laboratory specimens, it was found that the compressive strengths of 6 x 12 in. (150 x 300 mm) cylinders tested with neoprene pads confined by steel end caps on both ends were in close agreement with strengths obtained on cylinders tested with the standard sulfur-mortar caps.(1) The 1/2 in. (13 mm) thick neoprene pads had a 50 durometer hardness, and were placed in the 6-1/4 in. (159 mm) inside diameter steel end caps. In general, the compressive strengths of the specimens tested with neoprene pads were slightly lower than those of the specimens capped with sulfur-mortar. However, based on a limited number of specimens the differences between the two methods were not significant at the 95% confidence level.

Work conducted by the New York Department of Transportation (NY DOT) also has shown that neoprene pads are an acceptable substitute for sulfur-mortar caps.(2) In the NY DOT tests, the neoprene pads were of the same thickness and type as described above but they were used in steel end caps having a 6-3/16 in. (157 mm) (in the initial NY DOT report mistakenly stated as being 6-1/2 in. [165 mm]), instead of 6-1/4 in. (159 mm) diameter. Specimens tested in the NY DOT study gave strength values slightly higher than those tested at the same time with sulfur-mortar caps. At present, the neoprene pads in steel end caps are widely used by the NY DOT to determine the compressive strength of 6 x 12 in. (150 x 300 mm) cylinders.

A study by a consulting firm showed that uncapped specimens tested using steel end caps with rubber inserts yielded compressive strength values that, for all practical purposes, were about the same as those obtained on specimens capped with sulfur-mortar.(3) They used steel end caps with a diameter of 6-1/2 in. (165 mm) and the 1/2 in. (13 mm) thick rubber inserts, which had a 50 durometer hardness, were snugly fitted into the caps.

The use of neoprene pads instead of sulfur-mortar caps is significantly advantageous in that it reduces the costs of sample preparation and eliminates the hazards from handling the hot toxic materials and the air pollution from sulfurous fumes. Consequently, the study reported here was conducted to compare the results of tests on companion field specimens by the alternative methods. The concrete in field specimens usually is not as well controlled and the top surface is not as uniform as that found in specimens prepared in the laboratory.

OBJECTIVE AND SCOPE

The objective of this study was to investigate the feasibility of determining the compressive strength of concrete by testing uncapped field specimens using neoprene pads confined in steel caps as an alternate to testing specimens capped with sulfur-mortar. A total of 438 pairs of 6 x 12 in. (150 x 300 mm) cylinders were tested by each procedure, and the average and standard deviation of the differences in test results were noted.

PROCEDURE

Participating Labs

The Richmond, Lynchburg, Salem, and Staunton districts participated in this study. Each was asked to provide 100 pairs of test specimens, which would give approximately the required number of pairs based on an estimated variability of 300 psi (2.07 MPa) of paired differences at the 0.01 significance level with a 0.01 probability of detecting a difference of 150 psi (1.03 MPa).(4) This difference is the smallest value considered significant, from an engineering standpoint, for this study. Also, the previous laboratory experience had indicated that pads could be used at least 100 times without any significant deterioration of the surface texture or hardness. This observation was confirmed in the present study; in fact, the Richmond District furnished 138 pairs of cylinders tested with the same pads without any significant apparent damage to the surface touching the cylinder ends.

Two of the districts (Lynchburg and Salem) tested cylinders in their laboratories. The test apparatus in Richmond and the Staunton district labs did not have enough clearance to accommodate the height of the specimen with the steel caps. Therefore, Richmond furnished the specimens to the Department's nearby Central Materials Laboratory for testing, and the Staunton District sent the cylinders to the Research Council. The remaining four districts did not participate in the study because of the limited clearance in their testing machines. However, the clearances in these machines can be adjusted, if the neoprene pads are adopted for use.

Cylinders and Capping Materials

Cylinders were cast from batches of concrete furnished during the 1980 construction season. From each batch, a pair of cylinders were cast in steel molds and cured in a moist room until tested at 14 days — one with a sulfur-mortar cap and the other with neoprene pads. All the concretes tested met the requirements of the Department's Road and Bridge Specifications,(5) but had variable strength levels.

The sulfur-mortar used was a commercially available material meeting ASTM requirements. The steel end caps were manufactured by a single company and a separate set was furnished each participant. The specified diameter of the end caps, as shown in Figure 1, was 6-1/4 in. (159 mm) with a tolerance of +0 and -1/16 in. (-2 mm). The base plate of the steel end cap was hot-rolled steel cut in a square shape. However, it can be cut in a circular shape for more convenient centering against the machine heads. The neoprene pads were all the same type and thickness. They were cut to fit the inside ring and were equal to or slightly larger than 6-1/8 in. (156 mm) in diameter. After a few tests, the neoprene pad flows sufficiently to snugly fit the inside of the ring.

The specified inside diameter of the ring was selected so as to keep it small enough to prevent the flow of neoprene around the ends during loading, but also large enough to permit setting the cylinders conveniently into the ring.

Data Obtained

In addition to the compressive strength, each participant furnished information on the type of break. Failure types ranged from a shear or cone type to splitting or columnar type, as discussed later.

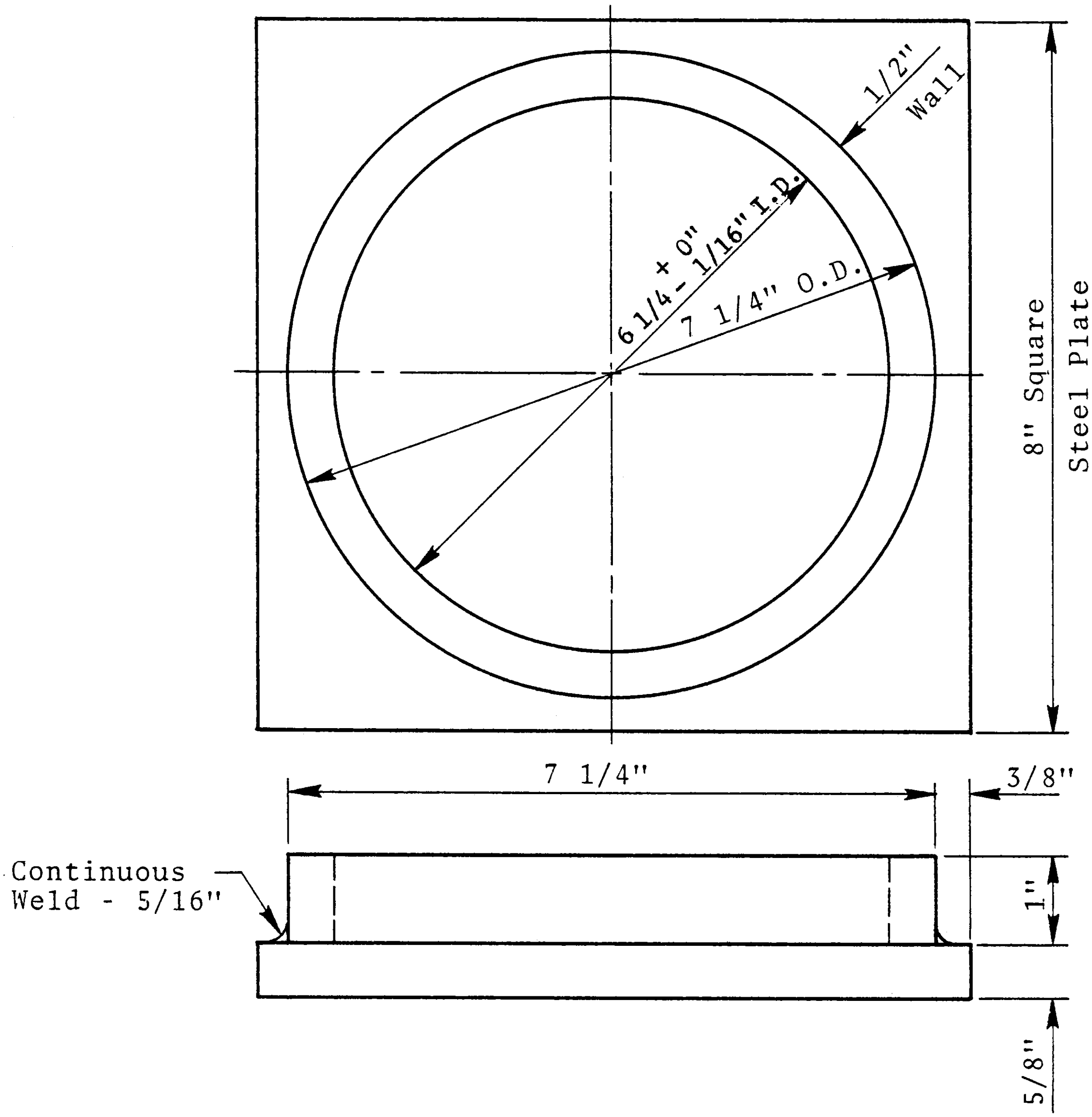

Figure 1. Sketch of a steel end cap.
(1 in. = 25.4 mm)

RESULTS

Compressive Strength

The 14-day compressive strength values for tests with sulfur-mortar caps ranged from 2,700 psi (18.6 MPa) to 6,930 psi (47.8 MPa), and for the neoprene pads from 2,360 psi (16.3 MPa) to 6,960 psi (48.0 MPa). The average compressive strength test data with both sulfur-mortar caps and neoprene pads and the associated standard deviations for each district as well as the combined data are given in Table 1. The results indicate that the average strength values and the standard deviations for the two test methods were very close to each other.

The largest difference in average strength values between the two methods was found to be 108 psi (745 kPa). For all data, the average difference was 55 psi (379 kPa). The standard deviations of the differences shown in Table 1 were obtained from the differences of individual values in paired tests, and in all cases they were smaller than the 300 psi (2.07 MPa) used in determining the number of samples for the statistical analysis.

A statistical paired t test was applied to the data for each district and to the total data to determine whether the average compressive strength values were significantly different.[4] Based on a 0.01 significance level, as shown in Table 2, it was found that data from two districts had statistically significant differences. However, these data as well as those from the other two districts had differences so small as to have no practical significance.

Table 1. 14-Day Compressive Strengths in psi

District	No. of Tests	Sulfur Avg.	Sulfur Std. Dev.	Neoprene Avg.	Neoprene Std. Dev.	Avg.Diff. = Sulfur-Neoprene	Std. Dev. of Differences
Richmond	138	4,504	676	4,396	705	108	236
Lynchburg	100	3,986	601	3,957	637	29	240
Salem	100	4,203	657	4,198	654	5	176
Staunton	100	4,115	572	4,057	591	58	206
All Districts	438	4,228	661	4,173	673	55	221

1 psi = 6.89 kPa

An F-ratio test was applied to the test data to compare the variability of the two test methods, and no statistical difference was found at a 0.01 significance level, as shown in Table 3.

In addition, a linear regression analysis was made on the data to determine the degree of association between the two test methods. Test results for neoprene pads were taken as the independent variable and those for sulfur-mortar caps as the dependent variable. The slope and the intercept of the best fitting line and the correlation coefficients are given in Table 4. The correlation coefficients ranged from 0.927 to 0.964, indicating a high correlation between the two capping methods. Thus, more than 86% of the variation in one measurement is explainable by the other. The slopes obtained from the linear regression analyses were compared to the line of equality using a statistical test, and it was found that at the 0.01 significance level the slopes were statistically different from a 45° line for the total data and also for the data for each district except one. This is shown in Table 5.

A plot of the linear regression analysis on the total data is shown in Figure 2. The standard error of estimate was 216 psi (1.49 MPa), which is low and indicates a good relationship between the two test methods. The regression line indicates that strength values for the test methods are equal at 4,920 psi (33.9 MPa). Below this value the cylinders tested with neoprene pads yielded slightly lower values, and above it they yielded slightly higher results. However, the differences in values are small and can be neglected for the strength ranges tested. The slightly lower values at low strength levels could result from the stretching or flowing of the neoprene pad. At higher loads the flow of the pad is restricted and the values would be closer to those for the specimens, with the sulfur-mortar caps. It is also possible that at high strength levels the ultimate strength of sulfur-mortar is reached, local stresses are created, and the result is lower strength values.

At a 3,000 psi (20.7 MPa) strength value for neoprene pads, the regression line predicts a 3,138 psi (21.6 MPa) value for the sulfur-mortar caps. The difference is not judged to be significant from an engineering standpoint.

Table 2. Results of Paired t-Test
(Ref. 4, p. 3.31)

District	Avg. Diff. Sulfur-Neoprene, psi	Std. Dev., psi	No. of Tests	$u = t_{.995} \frac{S_d}{\sqrt{n}}$	Significant
Richmond	108	236	138	53	Yes
Lynchburg	29	240	100	63	No
Salem	5	176	100	46	No
Staunton	58	206	100	54	Yes
All 4 Districts	55	221	438	27	Yes

Table 3. Results of F-Ratio Test
(Ref. 4, p. 4.8)

District	Std. Dev. Sulfur, S_S, psi	Std. Dev. Neoprene, S_N, psi	$F = \frac{S_s^2}{S_N^2}$	$F_{.995}$	$1/F_{.995}$	Significant
Richmond	676	705	0.92	1.61	0.62	No
Lynchburg	601	637	0.89	1.68	0.59	No
Salem	657	654	1.01	1.68	0.59	No
Staunton	572	591	0.94	1.68	0.59	No
All 4 Districts	661	673	0.96	1.29	0.78	No

Table 4. Results of Linear Regression Analysis

District	Slope	Std. Error of Estimate, psi	Intercept, psi	% Correlation
Richmond	0.903	227	533	94.2
Lynchburg	0.874	226	527	92.7
Salem	0.968	176	139	96.4
Staunton	0.907	200	436	93.8
All 4 Districts	0.928	216	354	94.6

Table 5. Comparison of Slopes to Line of Equality

District	Std. Dev. of Slope, s	$t = \frac{1 - \text{slope}}{s}$	$t_{0.01}$	Significantly Different
Richmond	0.0275	3.527	2.62	Yes
Lynchburg	0.0357	3.530	2.62	Yes
Salem	0.0270	1.185	2.62	No
Staunton	0.0339	2.743	2.62	Yes
All 4 Districts	0.0153	4.706	2.58	Yes

*1 psi = 6.89 kPa

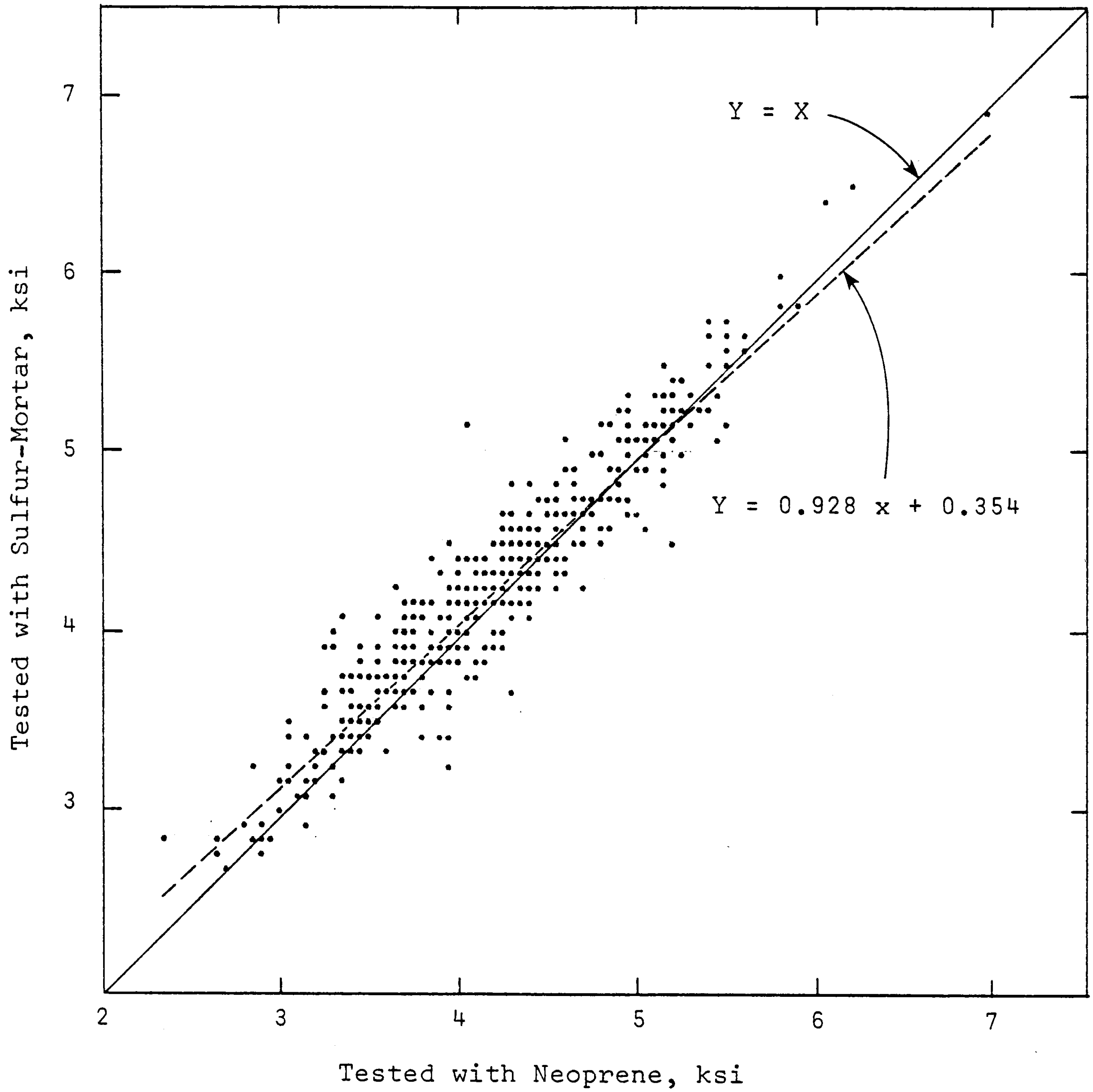

Figure 2. Simple linear regression analysis of 14-day compressive strength test data correlating tests with sulfur-mortar caps to neoprene pads. Standard error of estimate was 216 psi (1.49 MPa).

NOTE: 1 ksi = 6.89 MPa.

Type of Failure

Data on the occurrence of different types of failure, as depicted in Figure 3, are tabulated in Table 6. Figure 4 displays the types of breaks in a histogram for the total test data. The results indicate that most of the breaks for both test methods are a combination of shear and splitting types of failure. However, there is a tendency for more shear, or conical, type failure for cylinders tested with sulfur-mortar caps than for those with neoprene pads, and more splitting type failures in the latter. One would anticipate that at higher strength levels there would be more restraint to the flow of neoprene pads causing tangential stresses at the surface as found in specimens with sulfur-mortar caps. Therefore, the types of failure for specimens with strengths above 4,500 psi (31.0 MPa) were plotted in a histogram as shown in Figure 5. It appears that on a percentage basis, less splitting failure was observed for these specimens as compared to all specimens. However, the percentage of conical type failures was not as much as that with sulfur-mortar caps shown in Figure 4.

Some of the specimens attaining high strength when tested with neoprene pads shattered when they failed, as did some tested with sulfur-mortar caps. There was no dangerous scattering of concrete pieces beyond the bounds of the machine in any of the tests. However, for safety reasons, it is advisable to use a restraining net, such as a cage, around the specimen during testing with both test methods, especially at high strength levels.

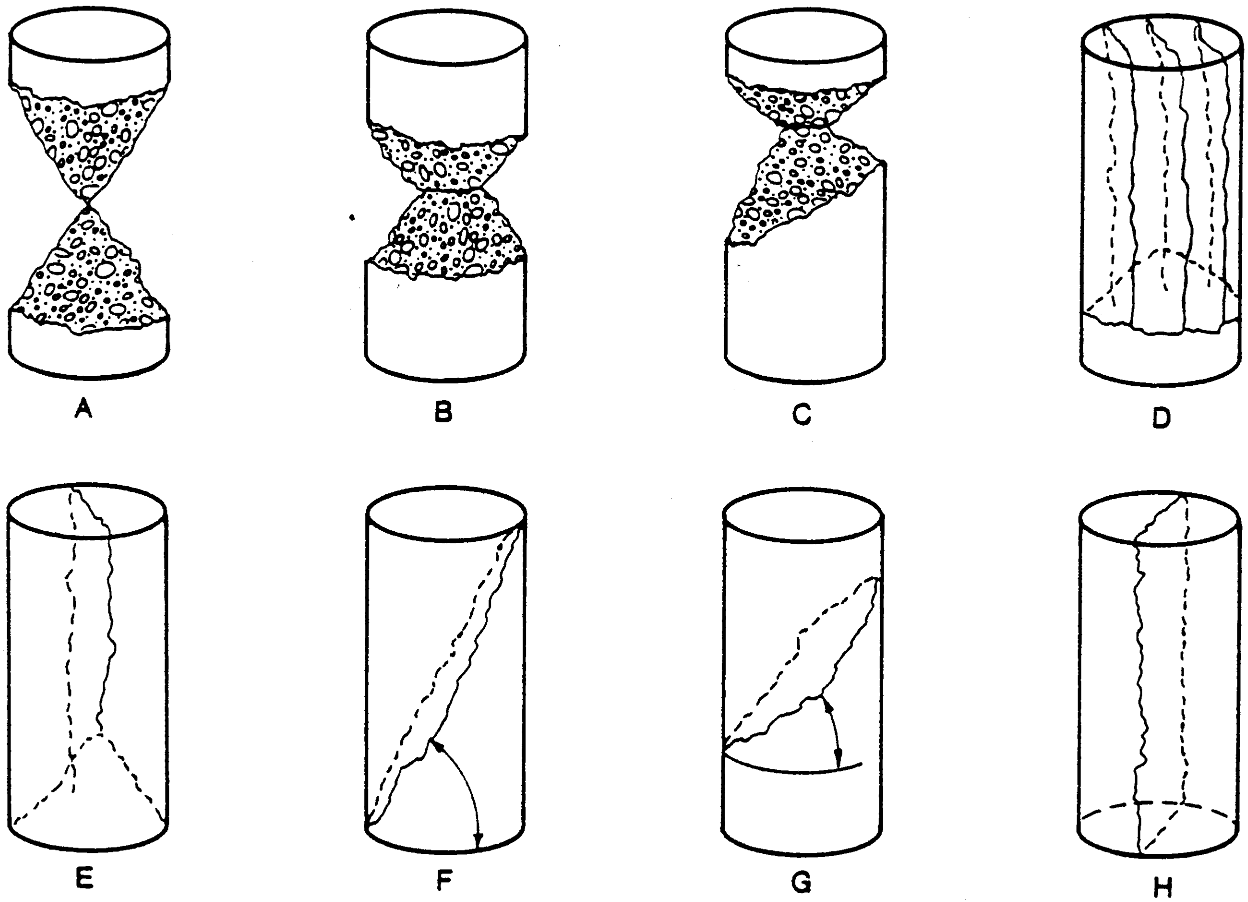

Figure 3. Types of failure of 6 x 12 in. (150 x 300 mm) cylinders. (From Ref. 2)

Table 6

Occurrence of Break Types Shown in Figure 3 as a Percentage of Totals
(S = Sulfur, N = Neoprene)

Type of Breaks	Richmond S	Richmond N	Lynchburg S	Lynchburg N	Salem S	Salem N	Staunton S	Staunton N	TOTAL S	TOTAL N
A	22	2	-	3	7	1	1	3	9	2
B	8	2	-	-	-	-	-	6	2	2
C	38	9	2	4	15	26	20	10	21	12
D	15	27	32	25	22	26	61	40	31	29
E	6	25	3	12	6	15	4	4	5	15
F	9	20	24	31	40	12	9	14	20	19
G	2	14	38	25	8	15	2	22	11	19
H	-	1	1	-	2	5	3	1	1	2

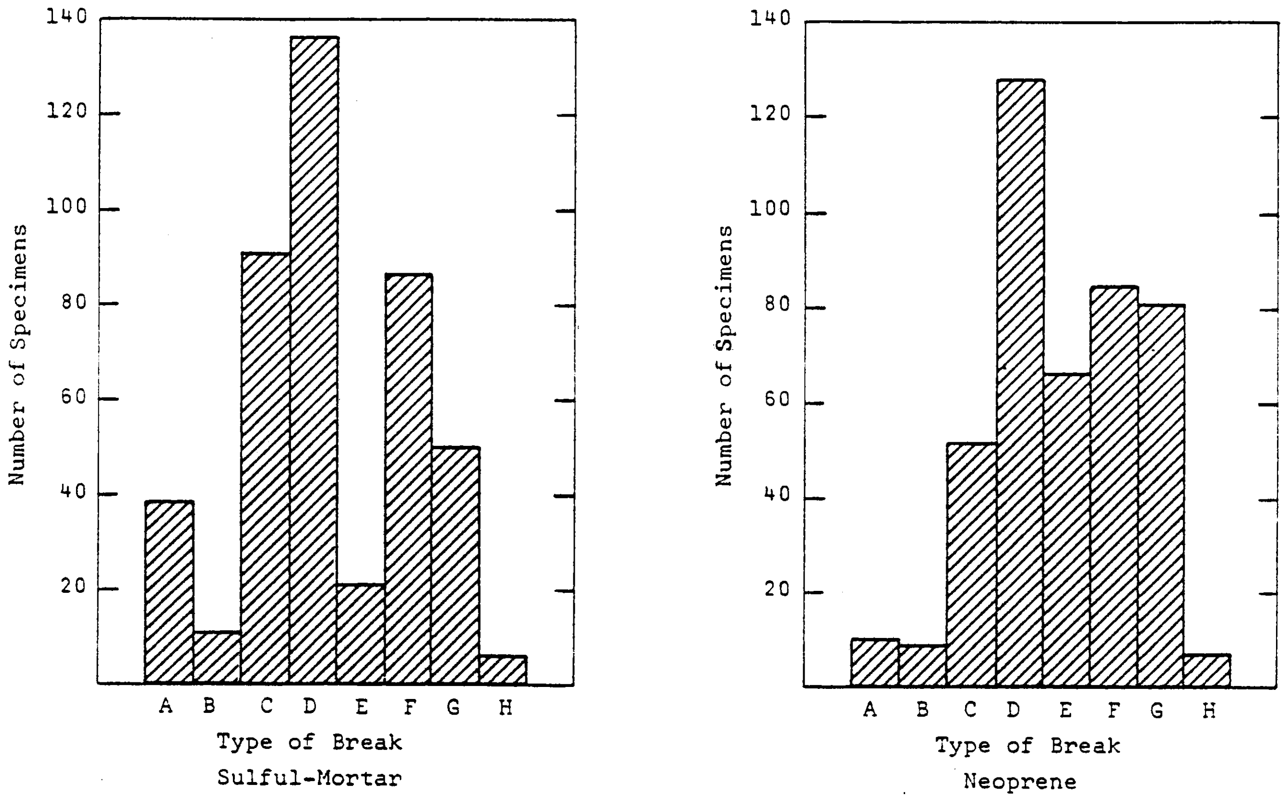

Figure 4. Types of breaks for total test data in accordance with Figure 3.

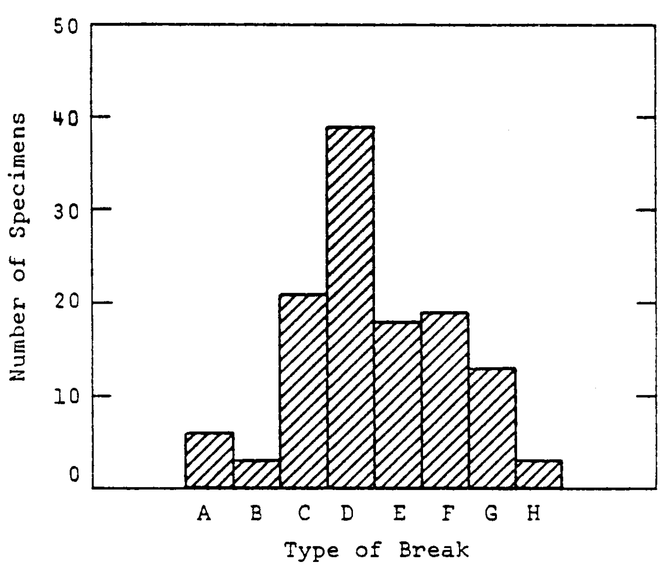

Figure 5. Types of breaks for cylinders with compressive strengths above 4,500 psi (310 MPa) and tested with neoprene pads.

CONCLUSIONS

1. From the standpoint of engineering evaluations of strength levels and quality assurance testing, negligible differences were found between the results of tests made on uncapped 6 x 12 in. (150 x 300 mm) concrete cylinders tested with neoprene pads confined in steel end caps and cylinders capped in the standard manner with sulfur-mortar. Even though the difference between the two procedures was statistically significant at the 0.01 significance level, the average of all tests with the neoprene pads was only 55 psi (379 kPa) lower than the average for the cylinders capped with sulfur-mortar based on 438 pairs of test data. The linear regression analysis indicated a good correlation between the two test methods. At strengths below 4,920 psi (33.9 MPa) the results for the cylinders tested with neoprene pads were slightly lower than the results for cylinders capped with sulfur-mortar, but at strengths above 4,920 psi (33.9 MPa) the opposite was true. The difference in strength values is considered negligible from an engineering standpoint.

2. The comparison of the overall variability of the two test methods at a 0.01 significance level revealed no statistical differences.

3. Cylinders with high strengths shattered when they failed, thus for reasons of safety, care should be exercised. A restraint around the cylinder is desirable.

4. The inside diameter of the ring used in this study was 6-1/4 in. (159 mm) with +0 and -1/16 in. (-2 mm) tolerance. Diameters larger than 6-1/4 in. (159 mm) are not recommended because of the possibility that the neoprene could flow around the ends and affect the test results. The size of the inside diameter is restricted by the convenience of locating the specimen in the steel cap and the normal variability of specimen diameter.

5. The neoprene pads with a 50 durometer hardness can be used until physical damage is observed. In this study, all the pads were still in usable condition after 100 tests.

RECOMMENDATION

The testing of concrete cylinders with neoprene pads confined in steel end caps is recommended as an acceptable alternate to testing with sulfur-mortar caps. Neoprene pads may be used until they show damage. A neoprene hardness of 50 durometer should be used until more information is available on the effects of hardness on strength.

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