necessity be lower at the upper portion of the capillary column. If the author's development forces him to conclude that the pressure in the capillary column is constant and consequently that the head increases with elevation above the free water surface, it is apparent that the new concept violates an accepted principle of hydraulics.

As a final illustration one may point to the differences in supporting power exhibited by a sand near the edge of a pond. The supporting power is least when the sand is submerged. It is greatest when the sand is saturated by capillarity, and has an intermediate value when the sand is dry. The supporting capacity depends upon the intergranular pressures in the sand and these in turn are influenced by the presence and state of stress in the water occupying its voids. Equilibrium requires that the intergranular pressure be greatest when the supporting power is greatest. This is believed to imply that the void water is in tension when the intergranular stresses are high.

In consideration of the foregoing remarks the writer is unable to perceive that the author has clarified or simplified in a satisfactory manner the subject of surface tension or capillarity.

LIME-FLY ASH COMPOSITIONS FOR USE IN HIGHWAY CONSTRUCTION

L. John Minnick, *Chief Chemist, G. and W. H. Corson, Inc.*, and Richard H. Miller, *Instructor Civil Engineering Department, University of Pennsylvania*

SYNOPSIS

A study has been made relating to the use of a group of lime-fly ash compositions in highway base construction. The use of small amounts of lime together with fly ash and aggregate materials including New Jersey Type A-3 soil, boiler slag, and crushed stone was considered. By carefully controlling the percentages of the ingredients, compositions have been produced which develop high compressive strength after aging for periods of one week or longer. Speciments subjected to wetting and drying and freezing and thawing tests indicate excellent performance when optimum quantities of lime and fly ash are employed. Field tests which have been started on the compositions developed in the laboratory indicate that the use of these materials in the construction of the base course of highways may give superior results at low cost.

The literature (*1*) [1] gives many references to the use of fly ash (produced by the combustion of pulverized fuel) as a pozzolan in compositions in which lime or another alkali is present. For example, when fly ash is used in concrete (*2*), the calcium hydroxide produced by the hydrolysis of the portland cement combines with the fly ash forming cementitious silicates which appreciably increase the strength of the concrete. Various structural products are reported (*3*) which utilize the reaction of hydrated lime with fly ash during their manufacture and further demonstrate the pozzolanic nature of fly ash when used in these compositions.

Some years ago Havelin and Kahn (*4*), Philadelphia Electric Company engineers, made the discovery that when small amounts of hydrated lime are added to fly ash in the presence of water and aggregates, such as sand, in carefully controlled amounts, a very surprising product is produced showing the property of high compressive strength when aged for a period of 28 days or longer. Typical data representing results of this early work are shown in Figure 1. It is to be noted in this graph that a critical range of compositions exists wherein high strengths are obtained and that the use of either smaller or greater amounts of lime result in compositions of much lower compressive strength.

The investigation reported in this paper covers an adaptation of this discovery to the field of base course construction of roads and was financed by the Philadelphia Electric Company. The study involves the use of lime

[1] Italicized figures in parentheses refer to the list of references at the end of the paper.

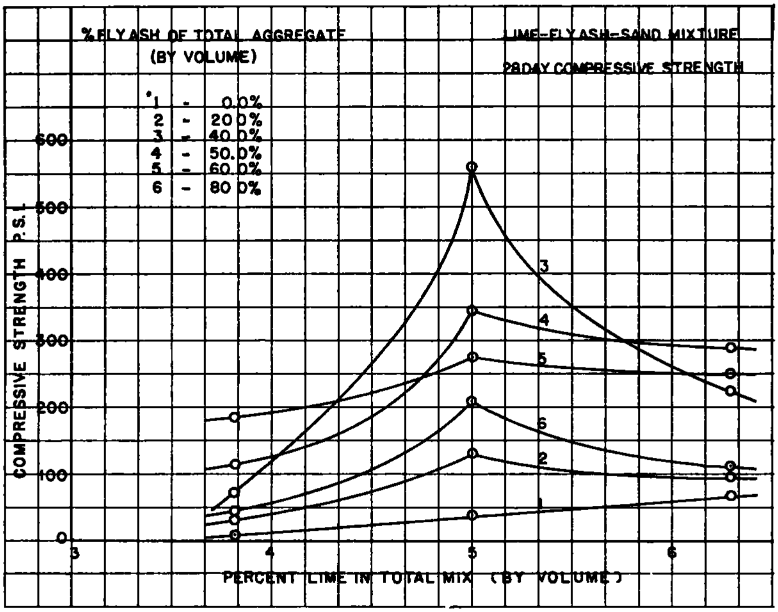

Figure 1

TABLE 1
PROPERTIES OF NEW JERSEY SOIL

Mechanical Analysis:	
Sieve No.	
4 (total percent retained)	0.43
8 " " "	4.10
16 " " "	10.50
30 " " "	21.45
50 " " "	60.08
100 " " "	87.42
200 " " "	94.36
Liquid Limit	0
Plastic Index	NP
H.R.B. Soil Classification	A-3
Dry Rodded Density, lb. per cu. ft.	100
Maximum Dry Density[a], lb. per cu. ft.	119
Optimum Moisture Content[a], percent	5.9

[a] Modified AASHO

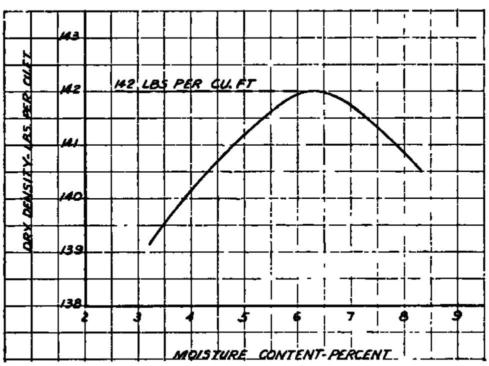

Figure 2. Moisture-Density Relation of Burlington Boiler Slag-Fly Ash Mixture (Modified AASHO)

TABLE 2
PROPERTIES OF AGGREGATES

	Fly Ash-Boiler Slag	Crushed Lime-stone	Crushed Gypsum Rock
Mechanical Analysis:			
Sieve No.			
4 (total percent retained)	2.4	10.1	0.9
8 " " "	10.3	32.4	14.6
16 " " "	37.9	47.2	38.0
30 " " "	66.0	51.5	54.5
50 " " "	73.8	58.0	65.9
100 " " "	78.2	89.8	77.1
Fineness Modulus	2.68	2.89	2.51
Specific Gravity	2.88	2.63	2.34
Dry Rodded Density—lb. per cu. ft.	130	93	98.6

TABLE 3
PROPERTIES OF HYDRATED LIME AND FLY ASH

	Hydrated Lime	Fly Ash
Chemical Analysis:		
SiO_2	1.0	40.32
Fe_2O_3	0.4	13.39
FeO	0.0	3.95
Al_2O_3	0.2	32.92
CaO	47.8	2.34
MgO	33.8	0.74
Loss on Ignition	16.3	5.79
CO_2	0.8	—
H_2O	0.5	—
Sieve Analysis:		
Sieve No.		
60 (total percent retained)	1.0	2.0
100 " " "	2.8	10.1
200 " " "	5.6	21.0
Specific Gravity	2.60	2.20
Dry Rodded Density—lb. per cu. ft.	45	60

and fly ash mixed with a New Jersey A-3 soil and a similar mixture of lime and fly ash combined with the bottom slag from pulverized fuel boilers. In addition, some tests are reported in which the aggregate was a crushed limestone and also a crushed gypsum rock.

MATERIALS

Careful consideration was given to the selection of the materials used in the investigation were carefully selected in order that the materials used in the laboratory would represent accurately the materials available in the field.

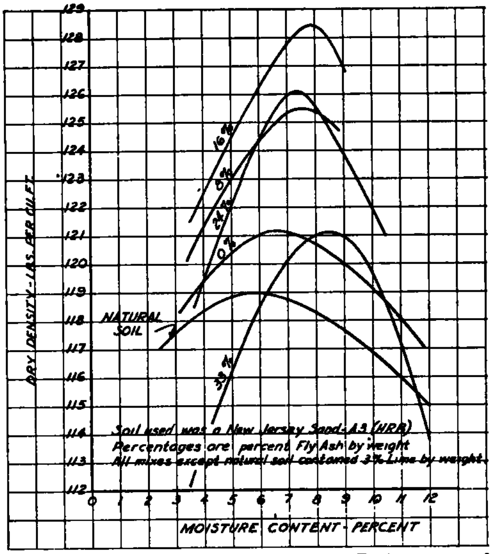

Figure 3. Moisture Density Relations of Lime-Fly Ash-Soil Mixtures (Modified AASHO)

New Jersey Soil. The material was selected from Ocean County, New Jersey and was typical of material found in widespread quantities throughout the southern section of the Stated. The mechanical analysis, soil classification and modified AASHO density, and moisture content are given in Table 1. According to these data the soil may be classified as Type A-3, Highway Research Board Classification.

Boiler Slag. The boiler slag used was available at the Burlington Station of the Public Service Electric & Gas Company of New Jersey. The stock pile of this material has been accumulating for a number of years and contains substantial amounts of fly ash well mixed and spread over a considerable area of ground. This product corresponds to similar materials available in large quantities in many sections of the country. A typical analysis of the fly ash-boiler slag mixture is given in Table 2 and the moisture-density relationships are given in Figure 2. No attempt was made to separate the fly ash from this mixture.

Crushed Limestone. The material used was selected from a large stock pile of screenings "B" available in a commercial limestone operation. The screen analysis is given in Table 2 together with other pertinent data.

TABLE 4
COMPRESSIVE STRENGTHS FOR VARIOUS MATERIALS WITH FLY ASH AND LIME ADMIXTURES

Basic Material	Fly Ash (By Weight)	Lime (By Weight)	Compressive Strength	
	%	%	*psi.*	
			28 days	
New Jersey Soil	16	1	165	
		3	450	
		6	345	
			28 days	*56 days*
Boiler Slag	25±	1	125	
		2	235	
		3	375	490
		5	465	
			7 days	
Gypsum Rock	20	0	90	
		1	365	
		2	390	
		3	380	
		4	260	
			7 days	*28 days*
Crushed Limestone	25	3	292	604

Gypsum Rock. A typical gypsum rock obtained from a large commercial producer was selected. Several samples were used during the course of the investigation. The analysis given in Table 2 is typical of the material used.

Hydrated Lime. A standard dolomitic hydrated lime, such as is commonly used for structural purposes, was used in the tests. The chemical and physical properties of this material are given in Table 3.

Fly Ash. The fly ash selected for study with the New Jersey soil and crushed stone materials was typical of material available in the Philadelphia area. The analysis of the fly ash is given in Table 3. The fly ash contained in the boiler slag mixture corresponded essentially to the material used in the other tests and represents that fraction of the fly ash-

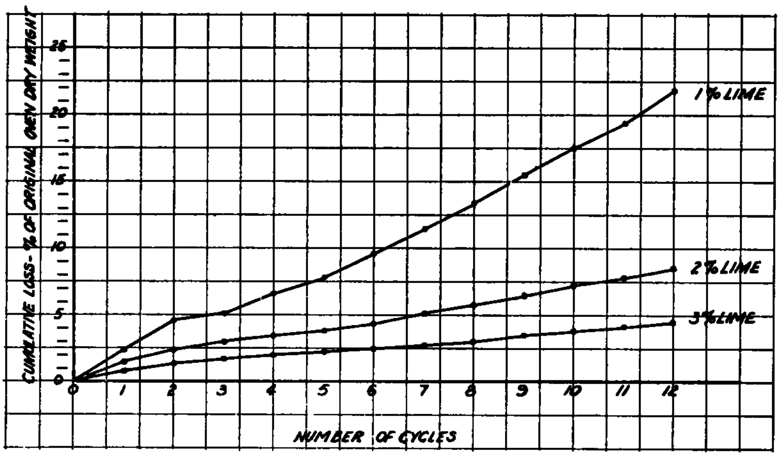

Figure 4. Weight Loss During Wet-Dry Test—Material Tested-Burlington Boiler Slag and Fly Ash with Lime Admixture

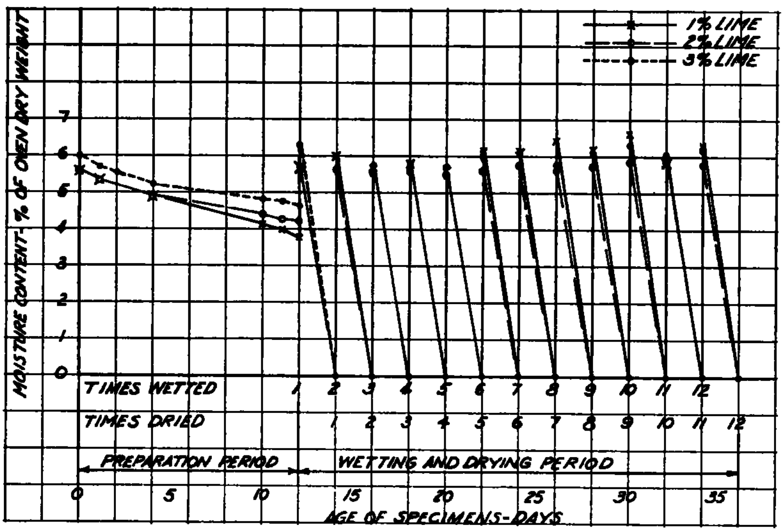

Figure 5. Moisture Changes During Wet-Dry Test—Material Tested-Burlington Boiler Slag and Fly Ash with Lime Admixture

boiler slag mixture given in Table 2 which passes the 100 mesh sieve. A number of samplings of the stock pile indicated that the fly ash content of the mixture ranged between 20 and 28 percent by weight.

TEST PROCEDURE

After considerable preliminary investigation of the properties of the several mixtures, a decision was reached to confine the tests largely to the following:

1. Wetting and Drying Test
2. Freezing and Thawing Tests
3. Unconfined Compression Tests

For the wetting and drying and freezing and thawing tests, Standard AASHO procedure was used with the exception that longer aging periods were used during the curing of the test specimens. While the lime-fly ash reaction in the mixtures develops appreciable compressive strength in 7 days, the reaction continues for months and years. It was, therefore, felt de-

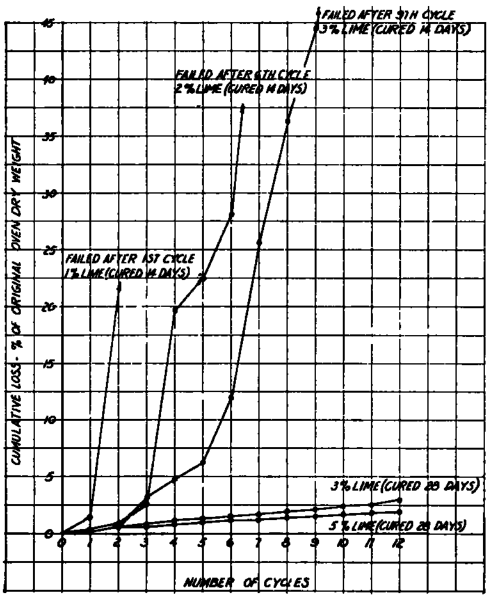

Figure 6. Weight Loss During Freeze-Thaw Test.—Material Tested—Burlington Boiler Slag and Fly Ash with Lime Admixture

pression after the 12 cycles of wetting and drying had been completed.

The mixing procedure was to weigh out the dry materials in previously established increments. The mixtures were proportioned by weight using the density values given in Tables 1, 2, and 3. After mixing completely in the dry state, water was added and the mixing continued by hand by a procedure similar to that used in the preparation of mortar specimens for compressive strength determinations. The determination of proportions for the New Jersey soil and for the crushed stone products was established by the use of Proctor procedure. This is illustrated for the soil mixtures in Figure 3 where the optimum fly ash content is established by determining the maximum density of a number of fly ash-aggregate mixtures containing a small amount of hydrated lime. Using the optimum percentage of fly ash, specimens were then made up containing variable percentages of hydrated lime (up to 6 percent by weight).

Since the fly ash-boiler slag mixture con-

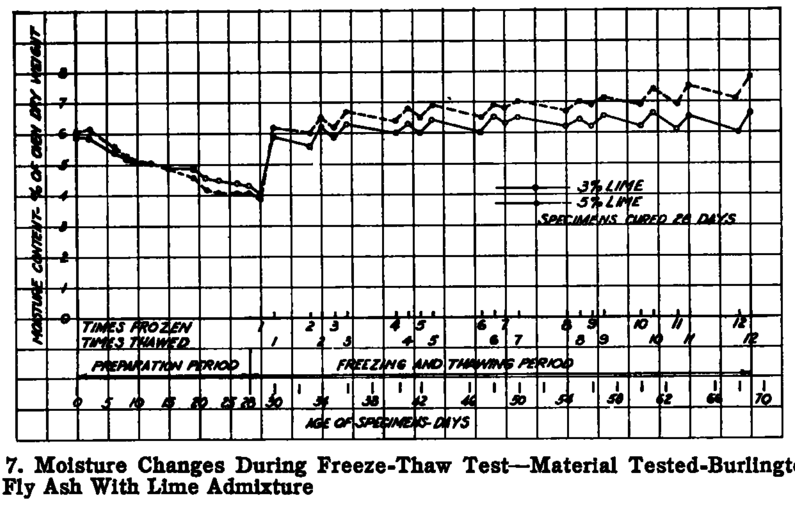

Figure 7. Moisture Changes During Freeze-Thaw Test—Material Tested-Burlington Boiler Slag and Fly Ash With Lime Admixture

sirable to give the specimens at least 28 days aging before proceeding with the tests, although in a few cases specimens were aged for shorter periods of time. The unconfined compression tests were run on specimens molded in the 4 in. diameter Proctor mold. These specimens were cured in a moist closet for 28 days. In addition the No. 1 specimens of the wetting and drying tests were broken in com-

tains fly ash in about optimum amounts, no attempt was made to vary the fly ash-boiler slag proportions in this series. Tests run with this material involved the addition of lime only in amounts up to 5 percent by weight.

TEST RESULTS

New Jersey Soil Series. The optimum fly ash content is shown in Figure 3 to be 16 percent fly ash by weight. The effect of lime additions to this optimum mix on the wetting and drying and freezing and thawing are shown in Figures 8, 9, 10, and 11 and the effect of the lime additions on unconfined compression is given in Table 4.

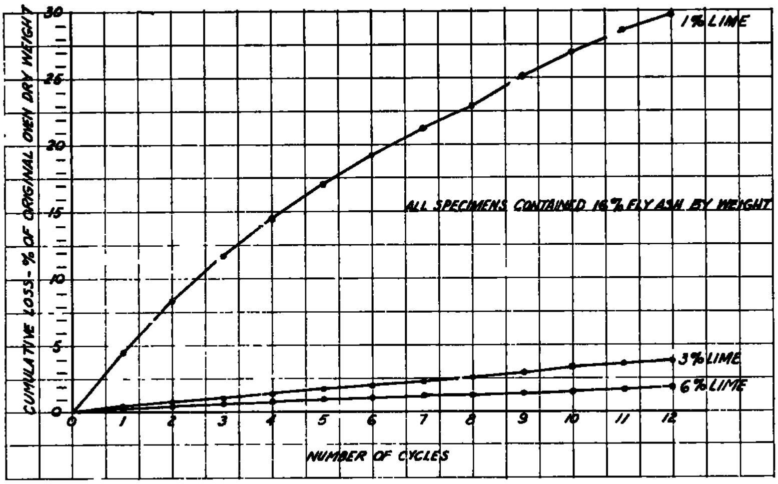

Figure 8. Weight Loss During Wet-Dry Test—Material Tested-New Jersey Sand (A-3) With Fly Ash and Lime Admixtures

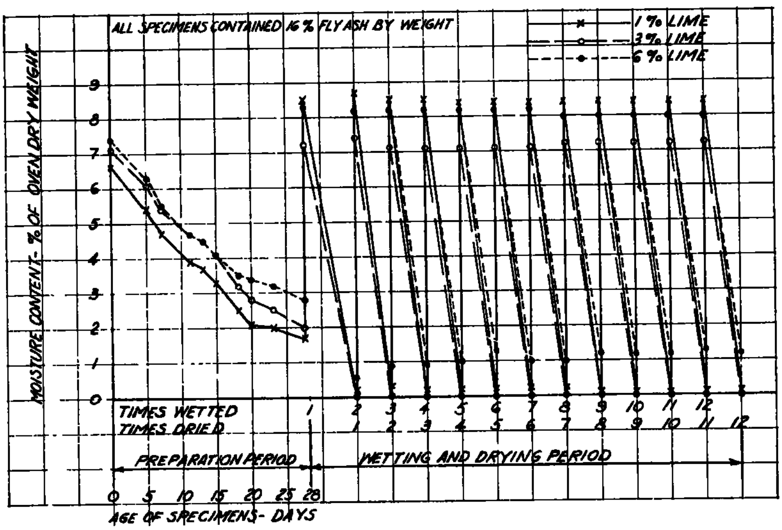

Figure 9. Moisture Changes During Wet-Dry Test—Material Tested-New Jersey Sand (A-3) With Fly Ash and Lime Admixtures

Boiler Slag. Since no adjustment of the fly ash content was made in this series, the results include only those tests in which the lime content was varied (from 0 to 5 percent by weight). The results of the wetting and drying and freezing and thawing tests are given in Figures 4, 5, 6, and 7 and the unconfined compression tests are given in Table 4. Several compression tests were also made on specimens to which was added 1 percent of calcium chloride (by weight). While the test results are

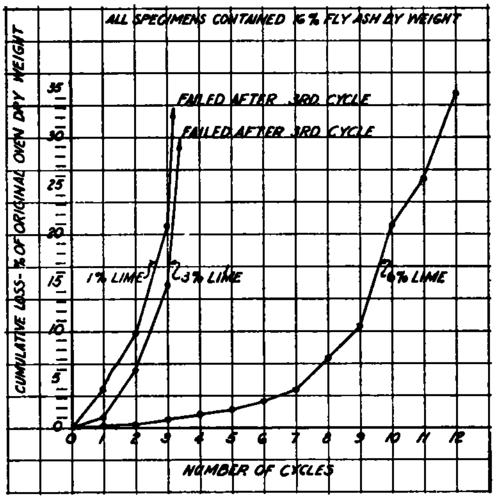

Figure 10. Weight Loss During Freeze-Thaw Test—Material Tested—New Jersey Sand (A-3) With Fly Ash and Lime Admixtures

series shown in Figure 4, the results being as follows:

Amount of Hydrated Lime in Mix (percent by wt.)	1.0	2.	3.0
Average Compressive Strength (lb. per sq. in.)	385	1100	1850

These tests were made on specimens of total age of 38 days including the curing, storage, and the wetting and drying cycles.

Pulverized Stone. The results of the tests run with crushed gypsum rock together with a few tests run with crushed limestone are given in Table 4. These series were run primarily to determine if other aggregates which were lacking in silica also conform to the general pattern established with soil, sand, and slag. For this reason the tests were limited to compressive strengths.

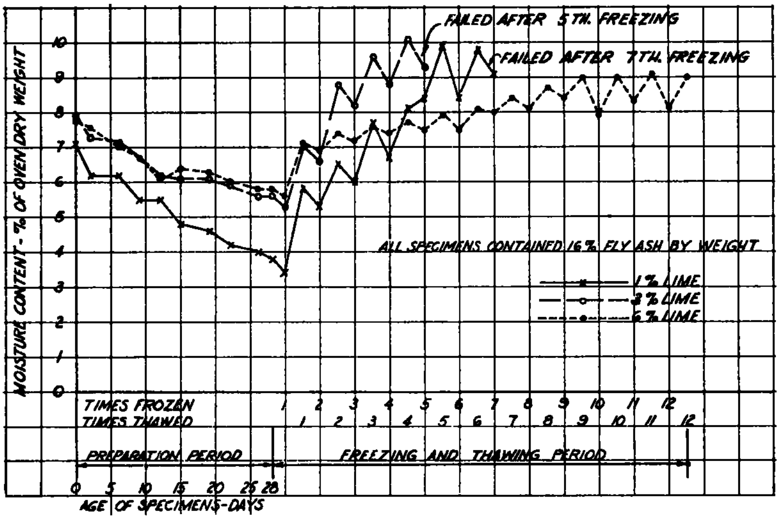

Figure 11. Moisture Changes During Freeze-Thaw Test—Material Tested-New Jersey Sand (A-3) With Fly Ash and Lime Admixtures

not included in the table, it was found that the 7-day strengths were approximately three to four times that obtained with the mixtures not containing calcium chloride. In addition unconfined compressive strengths were determined after completion of the wetting and drying tests on the specimens used in the

CONCLUSIONS

The tests show that small amounts of lime used with fly ash develop considerable strength when mixed with aggregates such as sandy soil, slag, and crushed stone. Good resistance to wetting and drying and freezing and thawing is also evident. Since compositions of this type are readily available in this country in enormous quantities at low cost, it is believed that these materials may be considered for use in the construction of the base course of highways and that improved properties and lasting performance may be expected. The resistance to freezing and thawing is greater in the specimens which have been cured for longer periods of time. This is to be expected since the lime-fly ash reaction proceeds slowly. The use of calcium chloride increases the early strength and should therefore be considered for use in the field when freezing weather is expected.

In order to supplement the laboratory work several test roadways have been constructed (*5*) using compositions as described above. The results of the field tests will be presented in a separate paper, but it may be mentioned that some of the test sections which have been in place for over a year are at present time showing excellent performance. Compressive strength tests made on specimens removed from the field indicate results in agreement with those given in the laboratory series.

The investigation has also been extended to a study of various other soil types commonly found along the eastern seaboard and similar effects due to the addition of lime and fly ash have been noted. These tests will also be presented in a subsequent paper.

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3. H. C. Peffer and P. W. Jones, U. S. Patent Nos. 1, 942, 770 and 1, 942, 769.
4. J. E. Havelin, Senior Engineer and F. Kahn, Engineer of Special Tests Branch, Philadelphia Electric Company.
5. L. John Minnick and J. E. Havelin, American Road Builders Association, Report to Committee on Lime Soil Stabilization, March 8, 1950.

DISCUSSION

R. F. BAKER, *State Road Commission of West Virginia*—The basis for the following discussion has been partially obtained by experiences with fly-ash mixtures in the laboratories of the Department of Soil Mechanics of the West Virginia State Road Commission. The work has been under the supervision of Mr. L. S. Smith, and has consisted of tests on one soil, a Meigs Clay, classified as A-4 (6). Most of the work has involved the use of cement as an admixture rather than lime. In addition, tests have been conducted using a granular material, a Dekalb Sandy Loam, classified as A-2-4(0) as the variable instead of fly-ash. Two types of fly-ash have been used, one with an approximate carbon content of 10 percent (Fly-Ash No. 1), and the other with no carbon content (Fly-Ash No. 2). Table A gives the chemical composition and physical characteristics of the fly-ash, as well as the engineering properties of the soils.

The features which should be discussed further are as follows:

1. The method of "proportioning," or determination of the percentage of fly-ash to be used, needs some clarification.
2. The quantity of fly-ash is rather sizable when considered on a volume basis.
3. A definition of "good resistance" to freeze and thaw would be desirable.
4. Emphasis should be placed on the requisite of a 28-day curing period, or as an alternative the possible use of calcium chloride.

As to the first, the assumption involved with the use of fly-ash in soil or aggregate mixtures is that valuable pozzolanic action takes place if an alkali is present. It would appear to be a coincidence if the maximum density that can be obtained for various proportions of fly-ash and soil would also be the proportions of maximum pozzolanic action. Under the presented facts, a more desirable method would appear to be an empirical approach varying the percentage of admixtures, even to the extent of separate series of tests for compressive strength and durability. This latter method appears to be the approach of Messrs. Havelin and Kahn, insofar as compressive strength is concerned. It is probable that the pending upon their basis for comparison. This would mean that for every cubic yard of compacted mixture, one quarter to one-half of a cubic yard (loose) fly-ash would be required. Quite obviously the practicability of such quantities will be dependent upon the length of haul and the cost of the fly-ash. The comparison

TABLE A

PHYSICAL TEST DATA PERTAINING TO MEIGS CLAY AND DEKALB SANDY LOAM SOILS

Soil	HRB Classification	Grain Size Distribution—Hydrometer Method						LL	PI	Specific Gravity	Standard AASHO	
		Gravel	C Sand	Fine Sand	Silt	Clay	Colloids				Optimum Moisture	Maximum Density
		%	%	%	%	%	%				%	pcf.
Meigs Clay	A-4 (6)	16.0	4.0	16.0	28.0	36.0	17.0	28	8	2.71	15.9	113.3
Dakalb Sandy Loam	A-2-4 (0)	0.0	24	440	15.0	17.0	8.0	26	NP	—	15.9	113.6

PHYSICAL AND CHEMICAL TEST DATA PERTAINING TO FLY ASH

Type of Fly-Ash	Carbon	Silica	Aluminum Oxide	Iron Oxide	Grain Size Distribution—Hydrometer Method					Specific Gravity	LL	PI	Loose Density
					C. Sand	F. Sand	Silt	Clay	Colloids				
	%	%	%	%	%	%	%	%	%				pcf.
Fly Ash No. 1	None	41.84	23.25	31.8	30.0	58.0	58.0	0.0	0.0	2.59	0	0	46.7
Fly Ash No. 2	10.08	47.0	30.98	10.8	1.0	34.0	65.0	0.0	0.0	2.19	70.0	0	29.2

28-day compressive strength of the heavier, more dense mix would be as high or higher than a lighter, less dense mix, and yet the lighter mix, could have better durability characteristics. Further, from a practical viewpoint, the desirable solution is one that permits the smallest quantity of fly-ash. In Figures A, B and C, it can be seen that only the 6 percent cement and 50 percent fly-ash mixture had a high resistance to freeze and thaw tests. Table B indicates only a slight difference in density between the 30, 40 and 50 percent fly-ash mixes.

As to the quantity of fly-ash used, the figures on a volume basis are more descriptive of the practical problem of using fly-ash. It was found for the Meigs Clay Loam, that 30 to 50 percent fly-ash by total volume (volume percents as computed in AASHO Test T 135–45, T 136–45) was required to obtain satisfactory durability. The volume percentages are based on the same principles normally applied to soil-cement mixtures. Messrs. Minnick and Miller indicate that 16 to 28 percent by weight is necessary, which is equivalent to 25 to 50 percent by volume, de-

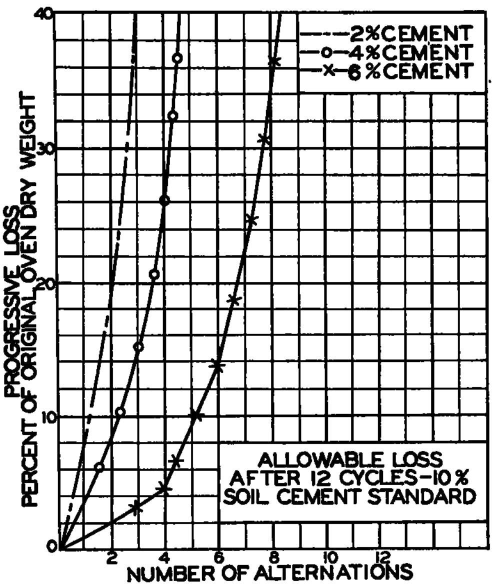

Figure A. Soil Cement-Fly Ash Losses Resulting from Freeze-Thaw Laboratory Tests—Specimen consisted of 30 percent Fly-Ash No. 1 by volume with Meigs Clay—Highway Research Board Classification A-4 (6)

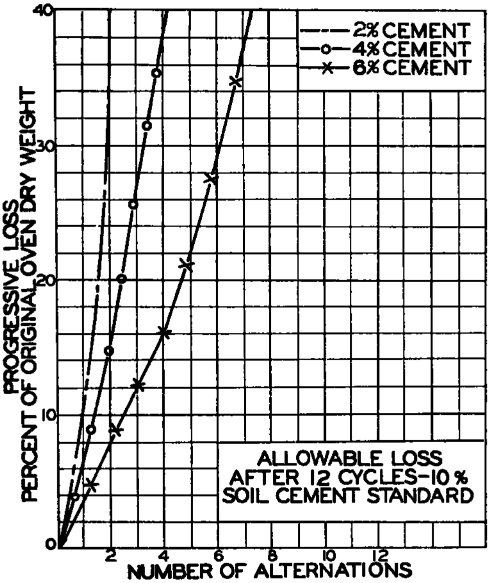

Figure B. Soil Cement-Fly Ash Losses Resulting from Freeze-Thaw Laboratory Tests—Specimen consisted of 40 per cent Fly-Ash No. 1 by volume with Meigs Clay—Highway Research Board Classification A-4 (6)

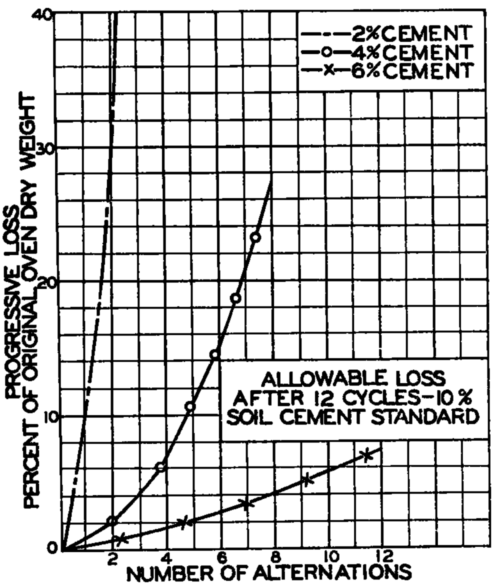

Figure C. Soil Cement-Fly Ash Losses Resulting from Freeze-Thaw Laboratory Tests—Specimen consisted of 50 percent Fly-Ash No. 1 by volume with Meigs Clay—Highway Research Board Classification A-4 (6)

between weight and volume percentages for the work in West Virginia is shown in Table B.

It might be pointed out that our experiences thus far check those of Minnick and Miller as to the relatively large percentages of fly-ash required.

Mention was made in the preceding report of "good resistance" to freeze and thaw for the New Jersey A-3 soil. Yet, it was noted that for their best combination of admixtures shown in Figure 10 of that report, the loss was 35 percent after 12 cycles. Since the AASHO and ASTM tests do not set limits for the allowable loss, one might infer that if a specimen holds

TABLE B
VOLUME AND WEIGHT PERCENTAGES
MEIGS CLAY AND FLY-ASH

	Percent of Fly-Ash by Volume[a]	Percent of Fly-Ash by Weight[b]	Maximum Density
			pcf.
Soil No. 339 and Fly-Ash No. 1	50	29.1	111.4
Soil No. 389 and Fly-Ash No. 1	40	21.4	111.0
Soil No. 389 and Fly-Ash No. 1	30	14.8	110.6
Soil No. 389 and Fly-Ash No. 2	30	10.9	99.25

[a] Volume of fly-ash (loose) divided by volume of compacted soil-fly cement mixtures.
[b] Weight of fly-ash divided by weight of soil plus fly-ash.

together, the mixture is satisfactory. The Portland Cement Association, however, recommends an upper limit of loss of 14 percent for this type of soil when mixed with cement.

While it does not follow that these limits should be adopted for all comparable mixes, or even for all A-3 types soils, there does appear to be some necessity for defining resistance to freeze and thaw in terms of measurable quantities.

In West Virginia, we have attempted to stay within the limits of loss set by the Portland Cement Association, and we have found proportions which fall within these limits. In Figure D, the best results obtained in the freeze-thaw test are shown. It is questionable whether such durability tests can predict resistance to natural weathering, but we have sufficient faith in the results that an experimental section will be constructed in the Meigs Clay soil area in the Spring of 1951.

Perhaps the most disappointing feature thus far reported on the use of lime and fly-ash for soils is the fact that a 28-day curing period or the use of calcium chloride is necessary. I am rather pessimistic concerning the use of the latter since it would become the third admixture. Further, I would hesitate to place traffic on a road which has not been sufficiently cured to obtain adequate compressive strength and good resistance to weathering. The compressive strength at 7-days for the lime-fly ash mixture is not given for the New Jersey soil, but from the data presented is presumably in the range of 200 to 300 psi. If loads are placed on the road under such conditions, permanent failures might result.

Apparently cement has a faster action than lime, or, at least, our experiences with cement indicate adequate durability in 7-days of cure. Further, there is some indication of pozzolanic action. In Figure D, it will be noted that the Dekalb Sandy Loam-Meigs Clay with 10 percent cement compares favorably in durability characteristics with fly ash-Meigs Clay, and only 6 percent cement. However, the former mixture has a considerably higher compressive strength. Figure E shows the relative compressive strengths of the various mixtures.

Our experiences with lime have been too brief to more than mention. We were anxious to find an immediate combination of the Meigs Clay and fly-ash that would resist weathering and when 7-day cured samples of 30 percent fly-ash and 2, 4 and 6 percent lime did not react as favorably as the same soil and fly-ash with 2, 4 and 6 percent cement we temporarily suspended operations with lime. Figure F shows the freeze-thaw test results for these six combinations. The 30-day cured compressive strength of the lime-fly ash-soil combinations are shown in Figure G. The inadequacy of the lime in this particular series is not meant to infer condemnation of lime as an admixture. Rather, it is included to indicate our change to cement as an admixture.

Dr. Dale T. Harroun, *University of Pennsylvania*—Due to the necessarily limited time allotted for the presentation of individual papers, it is natural that actual examples and results should be cited rather than methods, soil technique and reasoning on which these results were based.

However, in the field of soil stabilization, since the proper mixture for peak or optimum strength and durability is unlikely to be exactly optimum for another type of soil, much time and effort on the part of the writer, in connection with his supervision of the subject investigation at the University of Pennsyl-

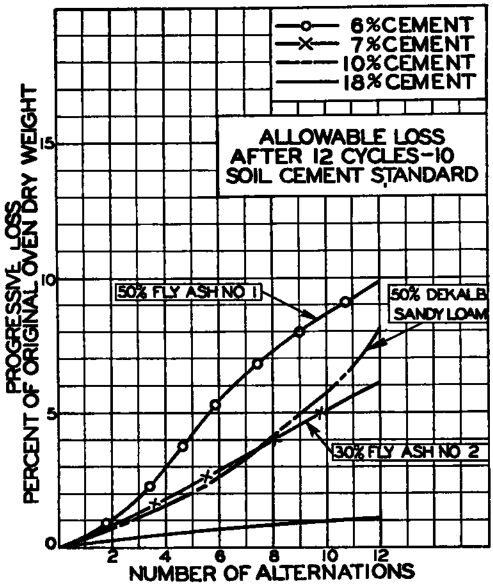

Figure D. Comparative Freeze-Thaw Test Results Using Meigs Clay. Highway Research Board Classification A-4 (6)

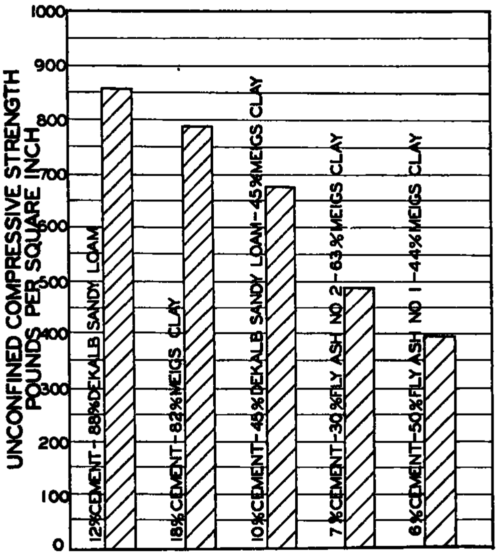

Figure E. Comparative 28-Day Compressive Strengths for Various Mixtures—Percentages on a volume basis

vania's Soil Mechanics Laboratory, was devoted to the development of a general key to the optimum proportions of lime-fly ash mix-to 1500 lb. per sq. in. in 14 days. On the basis of these field tests we believe it is demonstrated that the slow setting time of the lime-fly ash mixtures does not necessarily present a disadvantage and in some ways is a distinct advantage. Therefore, we also feel that from a practical standpoint, the use of calcium chloride need not be considered for use in the field except for particular conditions where high early strength may be required.

Concerning a definition of "good resistance" to freezing and thawing, we agree that it would be desirable to set up a suitable standard. In view of the complexity of the problem, however, it seems that this would require considerably more investigation both in the laboratory and in the field. In addition, it is questionable whether freezing or thawing tests alone would establish sufficient evidence for good performance in a road. The tremendous ease with which lime will reduce the plasticity of a soil and the advantage which is demonstrated by the use of both lime and fly ash in overcoming drying shrinkage might also be considered in terms of road performance. Figure 12 shows the effect of additions of lime and fly ash on a plastic Maryland soil. We would also like to refer to the paper by M. G. Spangler and O. H. Patel, "Modification of a Gumbotil Soil by Lime and Portland Cement Admixtures" *Proceedings*, Highway Research Board, Vol. 29, 1949, which shows the definite advantage that lime has in this connection. Mr. Baker's results with lime and the Meigs clay do not agree with the work of many other investigators, for instance the work which is being done at Purdue University and in Texas, Iowa, Minnesota, and California. It would seem that Mr. Baker abandoned his investigation of lime-fly ash stabilization prematurely or the soil with which he worked had some unusual property which affected its performance when lime was added.

We wish to take this opportunity to express our sincere thanks to Dr. Dale T. Harroun, Associate Professor of Civil Engineering, University of Pennsylvania for the valuable suggestions and assistance which he gave us during the course of the investigation. We appreciate the interest shown by Mr. Baker and Dr. Harroun in this work and we hope that other engineers will also contribute to our knowledge of this important subject since it is, of course, by investigations of this type that the construction of the highways in our country will be improved.