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Stabilization of Two Iowa Limestones With Fly Ash Alone

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Stabilization of Two Iowa Limestones With Fly Ash Alone[1]

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Abstract. Fly ash has been used together with lime in the stabilization of soils. Some fly ashes were found to harden and develop strength without addition of lime. One of these fly ashes was used to stabilize two crushed limestones. After 28 days moist curing, specimens of limestone mixed with 20 per cent fly ash showed water stable strengths of 400 psi. The stabilization of soils with fly ashes that react without lime is one of the cheapest soil stabilization methods.

Soil stabilization, a relatively new science, aims at the improvement of the engineering characteristics of soils. Improvement can be either by physical means or by treating the soils with different products. Some of the successful stabilizing agents are cement, lime, and lime plus fly ash.

Fly ash, an artificial pozzolan, requires mixing with lime and water to produce strength through cementation. Fly ash always has been used either with lime or as an additional additive in other methods of soil stabilization. Recent studies have shown that some fly ashes already contain sufficient lime that they can produce strength without additional lime (1). In molded and cured test specimens of seven fly ashes from Iowa, six gave some strength without lime. One gave such surprisingly high results that further studies were conducted to check its behavior when used with soils. The studies made to evaluate that fly ash for stabilization of two Iowa limestones are presented herein.

MATERIALS

Fly Ash

The fly ash used was from the Des Moines Power Plant of the Iowa Power and Light Company (2). The sample was collected by mechanical precipitators (multicone dust collector). The coal is from Iowa (Monroe, Polk, Marion and Mahaska Counties); it is unwashed steam coal which is pulverized and tangencial fired.

The chemical and physical analyses are given in table 1.

Soils

Two Iowa limestones were selected. One of them, the Solon limestone, is considered of good quality and is used in concrete; the other, Rapid limestone, is very soft and is of too poor quality

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to be used in concrete (3). The Rapid limestone overlies the Solon limestone in the Cedar Valley formation of the Devonian age. Both limestone samples were taken from the Burton Avenue Quarry of Waterloo, Iowa (table 2).

Table 1. Chemical and Physical Analyses of Fly Ash

Compound or property	Amount
S_1O_2,%	40.1
Fe_2O_3,%	36.6
Al_3O_3,%	13.1
C_aO,%	5.8
M_gO,%	0.3
SO_3,%	2.4
C, %	0.1
Passing No. 100 sieve, %	98
Passing No. 200 sieve, %	92
Passing No. 325 sieve, %	32
Specific gravity, g/cm^3	2.82
Specific surface (Blaine) cm^2/g	1460

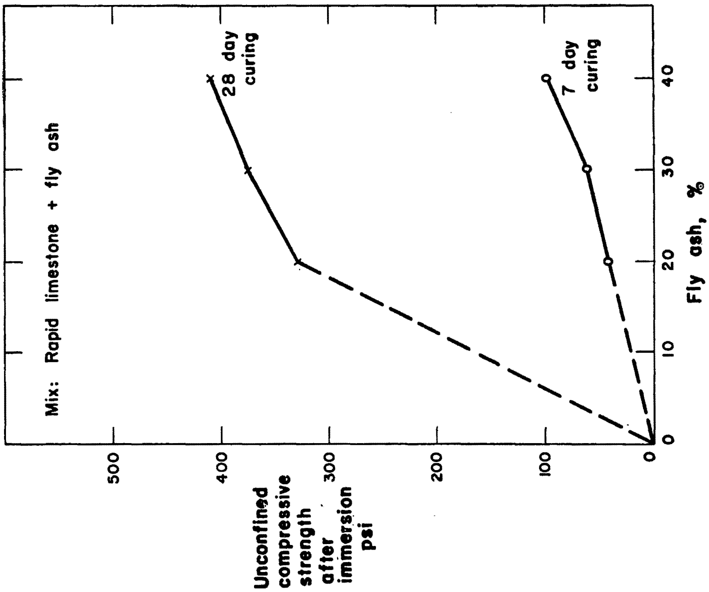
Table 2. Gradation of the Crushed Limestones

Sieve size	Passing, % by weight	
	Solon limestone	Rapid limestone
¾ inches	100	100
⅜ inches	71	59
No. 4	32	30
No. 10	15	17
No. 20	9	10
No. 40	6	8
No. 100	4	7
No. 200	3	6

Procedures

The dry crushed stone was first mixed with the dry fly ash in a laboratory mixer for 0.5 minutes, the required amount of water was added and mixing continued for four more minutes. Test specimens 4 in. in diameter by 4.6 in. in height were molded by dynamic compaction following the instruction of ASTM Specification D558-57 (4). Specimens for strength determination were molded at the optimum moisture content which gave a maximum unconfined compressive strength after seven days curing.

After being molded, the specimens were wrapped in waxed paper, sealed with cellophane tape, and stored for curing in a moist room kept at 70±2°F and over 90 percent relative humidity. The specimens were cured for 7 and 28 days, after which they were removed from the moist room and immersed in water for one day. They were then tested under unconfined compression to determine their water-stable strength. In the compression test, the rough side of the specimen was covered with a 4 in. diameter disc of Celotex to absorb the surface irregularities.



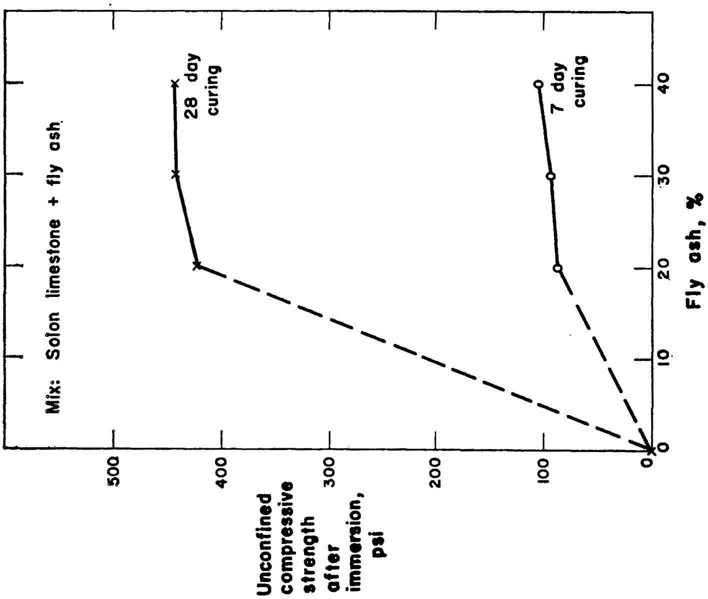


Figure 1. Effect of addition of fly ash on the strength of crushed Solon limestone.
Figure 2. Effect of addition of fly ash on the strength of crushed Rapid limestone.

Results

The strengths obtained after 7 and 28 days moist curing indicate that there is effective cementation by the use of fly ash alone. Strengths from 50 to 100 psi were obtained after 7 days and from 330 to 440 psi after 28 days (figures 1, 2). An improved base course for pavements can thus be obtained by mixing the crushed limestones with fly ash. Although the crushed stone has no unconfined compressive strength, when used in a base or subbase course of a pavement it has strength due to the high internal friction of the confined particles. The cementing action of fly ash is in addition to the natural strength of the crushed stone, and should permit the use of a thinner base course for the same applied loads. The nature of the improvement should be similar to that obtained by treating a base course with cement. In the AASHO Road Test it was found that one inch of cement-treated base was equivalent to 1.6 inches of untreated base for loads of 18,000 pounds per axle (5). Using these figures for a fly ash treated base with the strengths obtained in these tests, a reduction of one third in the pavement thickness can be considered.

The finding that some fly ashes can be used alone in the stabilization of soils is of the utmost importance, since fly ashes that react alone are one of the cheapest soil stabilizing agents. Fly ash can be bought at the power plants at about $1 per ton, while cement costs about $15 per ton at the manufacturing plant. From previous experiments with lime-fly ash stabilization, from 20 to 30 percent fly ash is needed to stabilize soils (6). This is from 2 to 5 times the amount of cement needed to stabilize most soils. In the worst case there is an economical balance of about 3 to 1 in favor of fly ash, considering the prices of cement and fly ash at the manufacturing plant. Transportation expenses will modify these figures.

Higher strengths were obtained with Solon limestone, but the soft Rapid limestone gave strengths that are considered adequate for a base course.

The results obtained with the fly ash from Des Moines Power Plant may not be reproducible with other fly ashes. The pozzolanic quality of a fly ash is difficult to determine (7). Nevertheless it is possible to use an accelerated curing test to select a fly ash that could be used without lime. First, test specimens are molded with the fly ash alone and cured in steam (248°F, 1 atm) for 24 hours, following the outline given in references 1 and 7. Then, specimens are immersed for 24 hours prior to testing for strengths. Those fly ashes giving an unconfined compressive strength greater than 500 psi could be considered suitable to stabilize soils without the addition of lime.

Conclusions

Based on the results obtained here, the following conclusions are pertinent:

Some fly ashes can be used alone in the stabilization of soils. The selected fly ash used in these studies produced cementation of two crushed limestones and gave strengths of 50 to 100 psi after 7 days curing, and about 400 psi after 28 days.

The addition of about 20 percent of the fly ash tested may allow a reduction of 40 percent in the thickness of a base course built with crushed limestone.

Acknowledgements

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