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by

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ABSTRACT

A locally produced lime manufactured by burning lime stone has been used to stabilize a micaceous sandy clay gravel for use in the construction of the base of a trunk road. In a laboratory trial, the gain in strength of the soils stabilized with imported quick lime was compared with the gain in strength produced by the local lime. It is concluded that lime which can be produced locally in this way can be successfully used in improving the qualities of gravels containing higher percentages of clay and having higher plasticity index than the specifications allow.

INTRODUCTION

Road building in Ghana, and indeed, in several countries of tropical Africa have been based on the use of local materials, notably, soil and gravel obtained from borrow pits at relatively shallow depths. In many of these countries vehicle ownership started very slowly, apparently due to economic restraints; and thus the demand for road transport did not become appreciably high until recently.

Up to about 1960, the total mileage of improved roads in Ghana was 4,425 miles with only 2,000 miles of bitumen surfaced roads. The figures as at 1970 stood at approximately 20,000 and 5,000 respectively. This remendous increase in road construction activity, coupled with the increase both in numbers and weight of axles in recent years has brought in its wake, the need for more STABLE and DURABLE materials for road bases. Indeed, most road failures in Ghana have been identified as being due to the use of inferior base materials (Yeboa, 1971).

In 1954, a specification was put out by the Public Works Department for use in connection with the construction of all new trunk roads. The specification required all base materials to have a good grading with less than 10 per cent passing the No 200 BS sieve, a liquid limit of not more than 25 per cent, and a Plasticity Index of not more than 6. Soaked CBR of at least 80% at optimum Ghana compaction was an additional requirement.

Subsequent sampling of base gravels (Lyon Associates and BRRI (1971)) indicates that the specifications disqualify almost all the clay-gravels used for base course, and restrict suitable naturally occurring materials to quartzite gravels, decomposed rock and river gravels. Deposits of these non-plastic materials, are however, difficult to find, and when they are found, high haulage costs are involved. A sensible alternative would appear to be soil stabilization. Though the construction of cement stabilized bases was started in 1956, the Ghanaian road construction industry has continually shied away from lime stabilization for road bases. The main reason would appear to be cost. Indeed, from the unit cost of imported lime, the cost of stabilizing 1 cu yard of pavement with 3% lime would be 150% of the cost of stabilizing a cu yd of pavement with 5% cement.

About a year ago lime production was started locally on an experimental basis through a joint venture undertaken by the Building and Road Research Institute of Ghana and the Transport and Road Research Laboratory of Great Britain. Some of this locally produced lime is about to be used in the construction of a 3,700 feet of road for observation. This paper describes the deficiencies in the gravel and its gain in strength through lime stabilization.

LIME STABILIZATION

Lime stabilization involves the treatment of fine grained soils, or borrow materials which are intended as sub-base material, or clay-gravels which can be improved for use as base. Lime changes the physical characteristics of the clay fractions in most soils in varying degrees. For example,

i. Lime stabilization results in a sharp decrease of the Plasticity Index. This is generally achieved through the plastic limit increasing and the liquid limit decreasing.

ii. Lime and water accelerate the disintegration of clay clods during pulverization and the soil becomes more friable.

iii. Lime stabilization also results in agglomerating the fines thus reducing the soil binder content.

iv. The linear shrinkage and swell decrease after treatment with lime.

v. The strength of the soil measured by the California Bearing Ratio increases considerably.

vi. The lime stabilized layer forms a water resistant barrier by impeding penetration of gravity water from above and capillary moisture from below.

The chemical reaction of lime with clayey soils is two-fold. First, it agglomerates the fine clay particles into coarse, friable particles (silt and sand sizes) through base exchange.

Second, it produces a definite cementing or hardening action (pozzolanic effect) in which the lime reacts chemically with available silica and some alumina in the raw soil forming calcium silicates and aluminates.

Generally, when lime content of a stabilized soil is increased beyond a certain point about 3 to 8 per cent, there is little or no further gain in strength (Dumbleton, 1962). In fact in many cases increasing the lime content beyond an optimum value results in a decrease in strength of the stabilized soil. Methods of determining the optimum lime content include pH tests (Eades and Grim, 1966) and Plasticity Index and binder content (McDowell, 1966). The plasticity index method was used in this paper. The chart used is shown in figure 1.

MATERIALS

LIME: The local lime which was used in the trial stabilization in the laboratory was manufactured by burning high calcium lime-stone with firewood. The actual process of manufacture is beyond the scope of this paper. The finished product which was used in the stabilization was slaked lime.

As control, an imported quick lime was also used to stabilize identical specimens.

SOIL: Two soils were investigated. The first was a micaceous sandy silt, a weathered product of granite. This material was obtained at the site for the proposed road. The grading and other physical properties are shown in Table 1. The binder content (per cent passing No 36 BS Sieve) was 34 per cent. The Plasticity Index was 32, and its CBR at optimum moisture content of Ghana compaction, soaked for 24 hours was 25 per cent. (The Ghana Compactive Effort is equivalent to 25 blows of a 10 lb weight dropping through 18 inches on each of the five layers in a standard CBR mould).

The second soil was a clay-gravel obtained from a borrow pit some eight miles away from the proposed road. The binder content of the second soil was 26 per cent, the Plasticity Index was 16; and the CBR after 24 hour soaking was 32%. This material had in fact been used in the construction of a second class road.

Clearly neither of the two materials would satisfy the specifications.

MIX DESIGN

The binder content of 34 per cent and Plasticity Index of 32 for the

micaceous soil suggest (figure 1) that the optimum lime content could be about $3\frac{1}{2}$ per cent. Similarly, for the clay-gravel, the optimum lime content appeared to be around $2\frac{1}{2}$ per cent.

At the time of the trial stabilization, the chemical analysis of the local lime had not been determined, thus the percentage of calcium hydroxide in the lime was not known. It was, therefore, decided to try lime contents of 2, $2\frac{1}{2}$, 3 and 4 per cent on each of the materials. In the control tests using the imported lime, stabilizer contents of 3 and 4 per cent only were used.

The CBR test was considered more preferable than unconfined compressive strength for assessing the strength of the stabilized soil because of the sandy nature of the micaceous soil and the gravelly nature of the clay gravel.

Stabilized specimen were compacted at optimum moisture content of Ghana Compaction, and were cured for 7 days in a temperature controlled room at an average temperature of 28°C.

RESULTS

The results are shown in Table 2. Both soils showed tremendous increase in load bearing values as measured by the California bearing ratio. The unstabilized CBR of the clay-gravel was 35 per cent. On the addition of 3 per cent of local lime and cured for 7 days, the CBR jumped to 145 per cent. Similarly, for the micaceous sandy clay the CBR went from 35 per cent to 142 per cent. These values compare very favourably with results obtained with the imported lime. The CBR values after 7 days soaking in this case were 144 and 142.

It is usual in lime stabilization to obtain a lime content which is most effective. This lime content depends on the type of soil and in particular the amount and type of clay present. In the clay-gravel, the optimum lime content from the laboratory trial was 3 per cent, whilst the micaceous sandy clay had an optimum level at 2.5 per cent lime.

The seven days curing chosen for the load bearing test is certainly very short for the rather slow reaction of soil-lime mixes. But the gain in strength for the 7 days curing at 28°C is very significant.

CONCLUSION

1. A major deficiency in the laterite gravels generally available for road construction in Ghana is the rather high plasticity index and clay content. Lime stabilization can be successfully used to render the otherwise disqualified materials suitable for use in bituminous surfaced roads.

2. The major obstacle in employing lime stabilization in Ghana had been the comparatively high cost of imported lime. It is now possible using wood as fuel to burn lime locally for use in soil stabilization.

3. The gain in strength of soil stabilized with the locally produced lime compares favourably with that stabilized with the same percentage of imported lime.

4. The section of road now under construction using the local lime for stabilization will provide an important step towards using lime on a large scale to correct deficiencies in clay-gravels.

ACKNOWLEDGEMENTS

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TABLE 1

PHYSICAL CHARACTERISTICS OF BORROW MATERIALS

	BORROW MATERIAL	
	1. Clay-Gravel	2. Micaceous Sandy Clay
Percent Passing ¾" BS Sieve	100	100
Percent Passing No 7 BS Sieve	45	58
Percent Passing No 36 BS Sieve	26	34
Percent Passing No 52 BS Sieve	25	32
Percent Passing No 200 BS Sieve	21	29
Liquid Limit %	40.8	50.5
Plastic Limit %	25.2	18.6
Plasticity Index %	15.6	31.9
Optimum Moisture Content %	11.6	10.4
Maximum dry density lb/cu ft	132.0	124.0
CBR at OMC	35	35
CBR after 24 hours soaking	32	25

TABLE 2

RESULTS OF TESTS ON LIME STABILIZED MATERIALS

PERCENT OF LIME	CBR AFTER 7 DAYS CURING			
	1. CLAY-GRAVEL		2. MICACEOUS SANDY CLAY	
	LOCAL LIME	IMPORTED LIME	LOCAL LIME	IMPORTED LIME
2.0	74	-	127.5	-
2.5	78	-	158	-
3.0	145	144	142	149
4.0	110	129	105	136

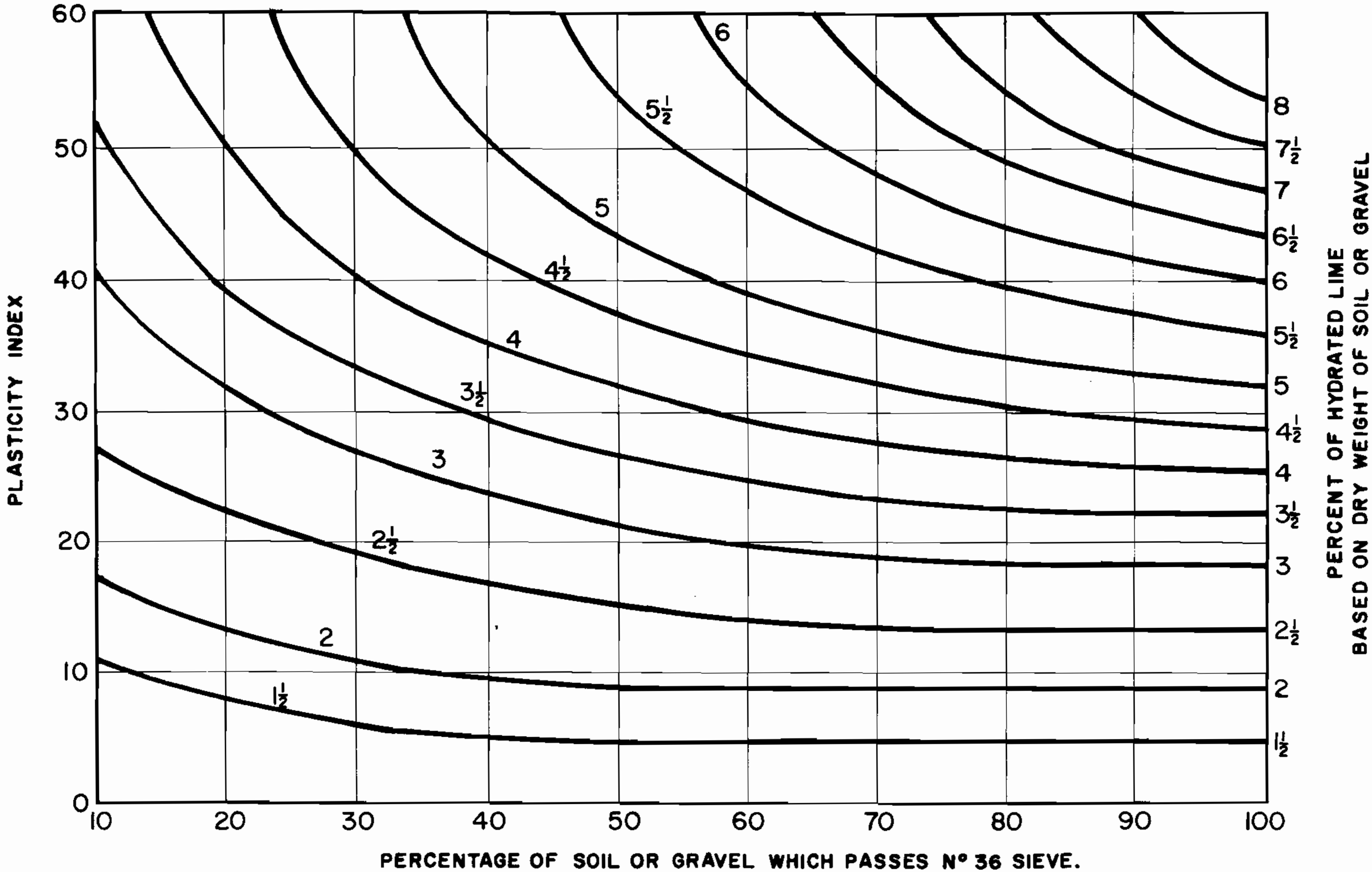

FIG. I.

NOTE: THIS CHART IS DRAWN FOR A HYDRATED LIME CONTAINING 77% OF CALCIUM HYDROXIDE.

ADAPTED FROM C. R. B. (Victoria, Australia)