LABORATORY INVESTIGATION OF CHIKOKO MUD AS A POZZOLANA

GEORGE ROWLAND OTOKO
Civil Engineering Department, University of Science and Technology, Port Harcourt, Nigeria.

ABSTRACT

The need for economic use of cement in soil stabilization arises from consideration of the trend in the cost of cement.

This paper presents a laboratory investigation of the engineering characteristics of soil-cement and soil-pozzolana made from a lateritic soil and pozzalana made from a silty clay (locally known as chikoko mud) respectively.

The results show that less than 50% of the cement requirement given by the Portland Cement Association is required for efficient stabilization of a lateritic soil; and that up to 30% of this cement requirement can be replaced by calcined and ground chikoko mud (otherwise referred to in this paper, as Chikoko Pozzolana) without adversely affecting the performance of the soil cement.

It is therefore concluded that the Chikoko Pozzolana be commercially produced to supplement the fly ash (most common pozzolana) that is presently produced from only one power station in Nigeria.

INTRODUCTION

The usual range in cement requirements for subsurface soils of the various soil groups specified by the American Association of State High Way Officials (AASHO) is tabulated in soil cement laboratory handbook of the Portland Cement Association (PCA 1959). These tables present the general relationship between soil character and cement percentage required to produced soil – cement of standard quality. Savings in the given cement requirements is considered along with the desire to design a conventional coil-cement against a performance need.

The need for economic use of cement in soil stabilization arises from consideration of the trend in the cost of cement. Within the past decade or so, in Port Harcourt City, Nigeria, price increases up to March 2000 were in the range of 2500 – 3000% for cement. (See figure 1).

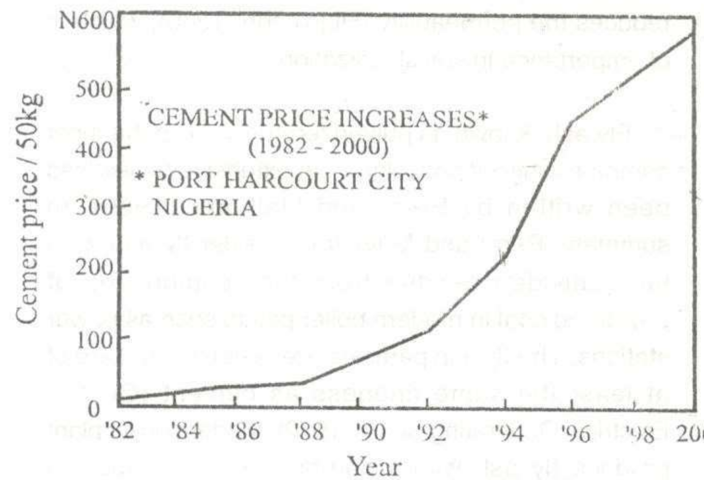

Fig. 1 Cost progression for cement in Port Harcourt City, Nigeria.

How can economies be made? The need to reduce costs will cause options such as making blended cements to be examined with some commitment (Kumar and Sunder, 1981).

In Nigeria, there is little or no control over cement costs, especially as both bulk and bagged cements are mostly imported at very high foreign exchange rates. Economic use of cement in stabilization can therefore mainly be achieved by considering partial replacement of the cement requirements for a given subsurface soil by cheaper local pozzolana.

POZZOLANAS

As defined in ASTM specification C618-78, pozzolanas are siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. It has been suggested that, in addition to reacting with $Ca(OH)_2$, pozzolanas react also with C_3A or its products of hydration (Collepardi et al 1978).

Pozzolanas are usually cheaper than the Portland cement that they replace but their chief advantage lies in slow hydration and, therefore, low rate of heat development (Bamforth, 1980) which is of great importance in tropical construction works (Otoko and Chinwah 1991). Also, significant pozzolanic reaction reduced the porosity of the paste (Kovacs, 1975); and reduces the permeability (Higginson, 1966); which is of importance in soil stabilization.

Fly ash, known as pulverized-fuel ash, is the most common artificial pozzolana; an extensive review has been written by Berry and Malhotra (1980). In summary, Berry and Malhotra consider fly ash as a finely divided residue from the combustion of powdered coal in modern boiler plants such as power stations. The fly ash particles are spherical and are of at least the same fineness as cement (Central Electrical Generating Board, 1972). Modern boiler plant produce fly ash with a carbon content of about 3 percent but much higher values up to 12 percent is acceptable (Price, 1975).

Although Nigeria has about 1296 million metric tonnes reserve of coal at Enugu and substantial deposits at Kabba in Kogi State, only Oji River Power Station is using it for the generation of electricity and therefore the only source of fly ash in the Country (Ngwu, 1984). Since the annual production rate of fly ash from only one station in Nigeria may not meet local demands, there is therefore the need to explore the potential of the abundant deltaic mangrove silty clay (locally called 'Chikoko' mud) as pozzolana.

SELECTION AND PREPARATION OF SAMPLE

To prepare the pozzolana, chikoko mud was obtained from Eagle Island, Port Harcourt (fig. 2) and calcined at 700 ^{0} C, which is falls within the range of 550^0 C – 1100^0 C given by price (1975). It was then grounded and sieved through the 45μm sieve which is a convenient basis of classification of size (Owens, 1979).

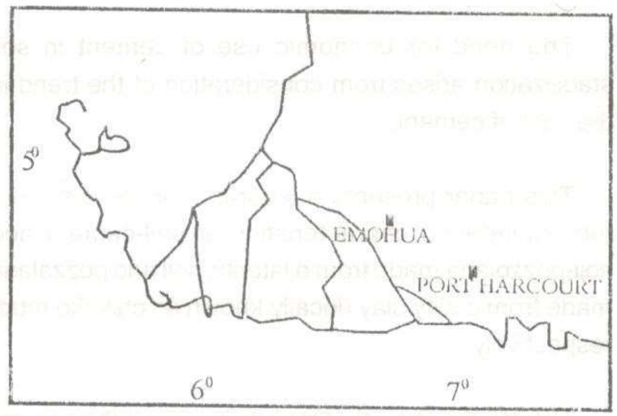

Fig. 2. Map of the Niger Delta, Nigeria, showing the location of Emohua and Port Harcourt City, Nigeria.

To select the soil to be used in the soil cement tests, the limits of soils that can be economically stabilized, as suggested by the Highway Research Board of America (1943), was sought. These criteria include soils with:

(1) Liquid limit less than 40%

(2) Plasticity index less than 18%,

(3) Percentage passing No. 200 BS. Sieve less than 50%.

The properties of the selected soil are:

(1) Liquid limit 41.8%;

(2) Plasticity index, 16.4%

(3) Percentage passing No . 200 BS sieve 43.67%;

These properties place the soil selected just almost within the limit of acceptable soil for stabilization, and in group A-7-6 of the AASHTO soil group. The estimated cement given by the Portland Cement Association Handbook (Portland Cement Association,

1959) is 13%, with a maximum of 15%. The location of the sample is the Emohua borrow pit, Rivers State, Nigeria (fig. 2). The soil is a reddish brown lateritic silty clay. The properties of the soil and the Chikoko mud are shown in Table 1.

Table 1 – Engineering properties of soil sample

Tests	Results	
	Laterite Soil	Chikoko Mud
Natural moisture content, as a percentage	18.0	67.3
Liquid limit, as a percentage	41.8	64.5
Plastic limit, as a percentage	25.4	30.4
Plasticity index, as a percentage	16.4	34.1
Specific gravity	2.64	2.30
Percentage passing No. 200 BS sieve	43.67	90.00
Optimum Moisture content as a percentage	17.0	-
Maximum dry density (MDD) in kN/m³	17.6	-
CBR as a percentage	33	-

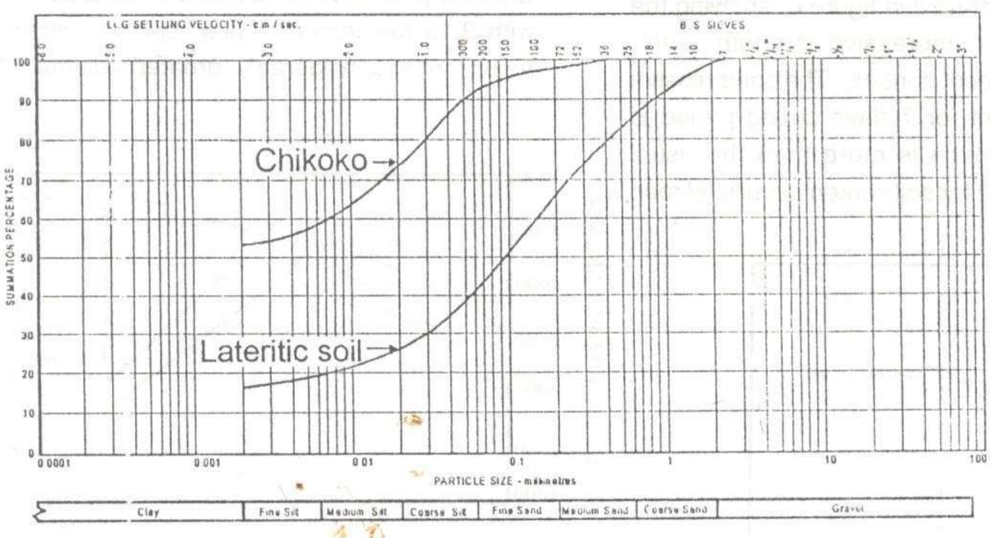

Fig.3 Particle size distribution curves for the Chikoko and the lateritic soil

SOIL CEMENT TESTS

The particle size distribution, as a result of wet sieving, is shown in fig. 3; and the results of the proctor compaction curves for various percentages of cement, are shown in fig. 4. From this data the optimum moisture content to be used in the CBR tests and in the partial pozzolanic replacement tests were obtained.

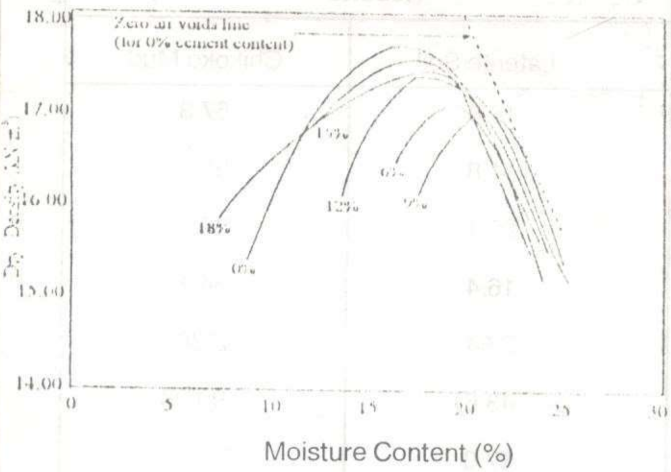

Fig.4. Proctor compaction curves for various cement mixes.

The CBR test results in fig. 5 indicates that a soaked CBR of 75 could be obtained with 7% cement; which is only half of the cement requirement (14%) recommended by PCA (1956). However, the unsoaked CBR values show much lesser figures demonstrating the influence of the hydration of the cement on the strength. The same result is portrayed in figure 6, showing the relation between the compressive strength of the specimens and the cement content. The compressive strength at 7% cement for 7 days curing period is almost 2000 kN/m^2 which is more than the usual acceptable 1,720kN/m2 for soil cement stabilized road bases.

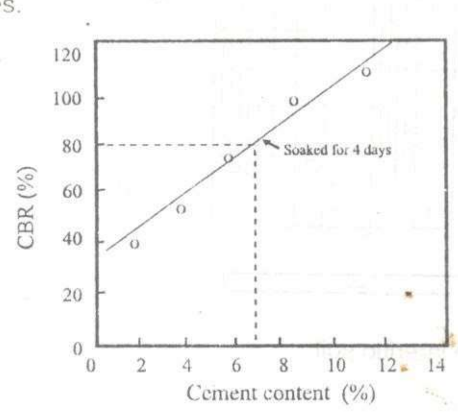

Fig. 5 Variation of CBR (%) with cement content

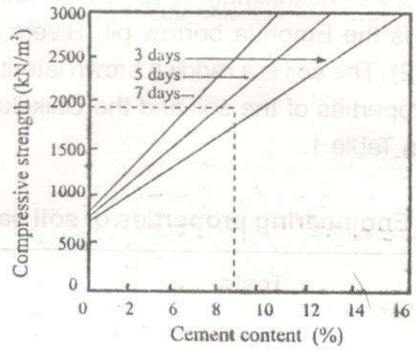

Fig. 6 Variation of compressive strength with cement content (100mm cube specimens for various curing periods.

POZZOLANIC REPLACEMENT TESTS

It is clear from the preceding tests that less than 50% of the cement requirement given by the Portland Cement Association is required for efficient stabilization of the lateritic soil tested. It is therefore the purpose of the pozzolanic replacement test to find how much of the cement requirement that can be replaced with pozzolana without adversely lowering the performance need of the soil cement.

25% and 30% by weight replacement of the cement requirement were tried (fig. 7) Partial replacement of Portland cement by pozzolana has to be carefully defined, as the specific gravity of pozzolanas is much lower than that of cement. The specific gravity of the Chikoko pozzolana was found to be 2.30, compared with 3.15 for cement. Thus replacement by weight results in a considerably greater volume of

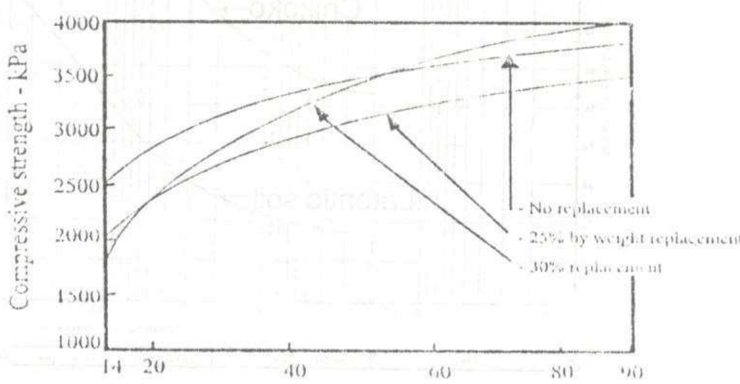

Fig. 7 Effect of partial replacement of Portland cement by Chikoko pozzolana on the strenght development of soil cement.

the cementitious material in the soil cement. With replacement, a lower early strength was obtained than when Portland cement was used, but beyond about three months there is no loss of strength for the 30% replacement test (figure 7). With lean mixes, there may even be a long term gain in strength due to the replacement (see fig 7).

It must be remembered that, although pozzolana may be cheaper than Portland cement, the use of an additional material on site (and especially of an extremely fine one) results in additional cost. This fact must be borne in mind where cost is a major consideration. Energy considerations as well as technical reasons may however lead to a renewed interest in the material.

Indeed, there is need for the Nigerian government to embark on commercial production of the Chikoko pozzolana due to the abundance of the Chikoko mud in the Niger Delta of the country and the need to supplement the limited supply of fly ash from Oji River Station, which is at the moment, the only source of fly ash in Nigeria. If this is done, the 2000s will see an extensive use of Portland-pozzolana cements. In fact, the U.S. government has already specified, within the past two decades, the use of pozzolana in all appropriate construction involving federal funds.

CONCLUSIONS

The results show that less than 50% of the cement requirement given the Portland Cement Association if required for efficient stabilization of a lateritic, soil and that up to 30% of this cement requirement can be replaced by the chikoko pozzolana without adversely affecting the performance need of the soil cement.

Since fly ash produced from only one power station in Nigeria, and at a production rate that may not meet demands, it is concluded that the Nigerian government should embark on comcercial production of pozzolana, especially as the chikoko mud is abundant in the Niger Delta of Nigeria, and thereafter, specify the use of the pozzolana in all appropriate construction involving government funds.

ACKNOWLEDGEMENT

The author is grateful to Mr. G. B. Obinna for help with some aspects of field and laboratory work..

REFERENCES

ASTM standard specification 618-78 (1978). Specification for fly ash and raw or calcined natural pozzolana for use as a mineral admixture in Portland cement concrete. American Society for Testing and Materials, Philadelphia.

BAMFORTH, P. B. (1980). In situ measurement of the effect of partial Portland cement replacement using either fly ash or granulated blast- furnace slag on the performance of mass concrete, Proc Inst. C. E. London, part 2, 69, pp. 777 – 800.

BERRY, E. E. and MALHOTRA, V. M. (1980). Fly ash for use in concrete. A critical review, J. Amer. Cocr. Inst., 77 No. 8, pp. 59 – 73.

CENTRAL ELECTRICITY GENERATING BOARD (1972) Pfa utilization, pp104 (Wolverhampton).

COLLEPARDI, M.; BALDINI, G.; and PAURI, M. (1978). The effect of pozzolanas on the tricalcium aluminate hydration. Cement and concrete Research, 8, no. 6, pp 741 – 51. London.

HIGGINSON E. C. (1966). Mineral admixtures, ASTM Special Tech. Publication, No. 169 – A, pp 543-55. Philadelphia.

HIGHWAY RESEARCH BOARD (1943). Use of soil cement mixture for base courses. Wartime Road problems No. 7 National Research Council, Division of Engineering & Industrial Research, Washington, D. C.

KOVACS, R. (1975). Effect of hydration products on the properties of fly-ash cements. Cement and concrete research, London. 5, No. 1, pp. 73 – 82.

KUMAR, S. S. and SUNDER, K. S. (1981). Role of lignin slurry thinner in cement production. World cement technology,London. pp. 298 – 306.

NGWU, F. N. (1984). Nigeria Coal Corporation: Production of Ore Coals. Sunday, February 5, Weekly Star, Nigeria.

OTOKO, G. R. and CHINWAH, J. G. (1991). The use of 'Garri' as admixture in hot weather concreting. The journal of the Nigerian Institute of Structural Engineers, vol. 1. No. 4, pp 13 - 18

OWENS, P. L. (1979). Fly ash and its usage in concrete.. Concrete, London,13, No. 7, pp 21-6.

PCA (1956). Soil Cement Construction Handbook.. Portland Cement Association, Chicago.

PCA (1959). Soil Cement Laboratory Handbook. Portland Cement Association, Chicago.

PRICE, W. H. (1975). Pozzolans – A review. J. Amer. Concr. Inst., Detroit, 72, No.5, pp 225 – 32.