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**Research article**

# ON THE ECONOMIC USE OF CEMENT IN SOIL STABILIZATION

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## ABSTRACT

The need for the economic use of cement in soil stabilization arises from consideration of increasing trend in the cost of cement. In this paper a laboratory investigation of the engineering characteristics of a soil – cement and soil – cement – pozzolana made from a lateritic soil and silty clay respectively is reported.

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 while 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 need and strength of the soil cement. It was recommended that the Chikoko pozzolana be commercially produced to supplement the fly ash (most common pozzolana) production that is presently produced from only one power station in Nigeria. 

**Keywords:** Cost of cement; soil - cement; soil - cement pozzolana; chikoko pozzolana; cement requirement

## INTRODUCTION

The usual range in cement requirements for subsurface soils of the various ASHTO soil groups is tabulated in PCA (1959). These tables present the general relationship between soil character and cement percentage required to produce soil – cement of standard quality. Savings in the given cement requirements is considered along with the desire to design a conventional soil-cement against a performance need.

The need for economic use of cement in soil stabilization arises from consideration of the need in the cost of cement. Within the past decade or so, price increases of cement has been in the range of 2500 – 3000% and has only recently stabilized due to government intervention. The question then arises as to how can economics be considered in the usage of cement? The need to contain costs will cause options such as making blended cements to be examined with some commitment (Kumar ad Sunder, `1981). However there is a limit to which cement making can be modified and such use of modified cement may demand changes in construction practice and materials awareness (Butler, 1982).

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. The economic use of cement in stabilization can be achieved by consideration of partial replacement of the cement requirements for a given subsurface soil by cheaper local pozzolana.

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 temperaturesto form compounds possessing cementitious properties. In addition to reacting with $Ca(OH)_2$, pozzolanas react also with $C_3A$ or its products of hydration (Collepardi et al 1978). A good review of the subject of pozzolanicity has been written by Massazza and Costa (1979).

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 which is of great importance in topical construction works (Otoko and Chinwah 1991). Also, significant pozzolanic reaction reduces the porosity of the paste (Kovacs, 1975); and reduces the permeability which is of importance in soil stabilisation.

Fly ash, known also as pulverized – fuel ash, is the most common artificial pozzolana. The fly ash particles are spherical and are of at least the same finances as cement (Central Electricity Generating Board, 1972). Modern boiler plant produce fly ash with a carbon content of about 3% but much higher values up to 12% is acceptable (Price, 1975).

Although Nigeria has about 12% million metric tonnes reserve of coal at Enugu and substantial deposits at Kaba in Kwara 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 falls within the range of $550^0$C – $1100^0$C suggested by Price (1975). It was then ground and sieved through the 45µm sieve which is a convenient basis of clarification of size Smith and Halliwell 1979.

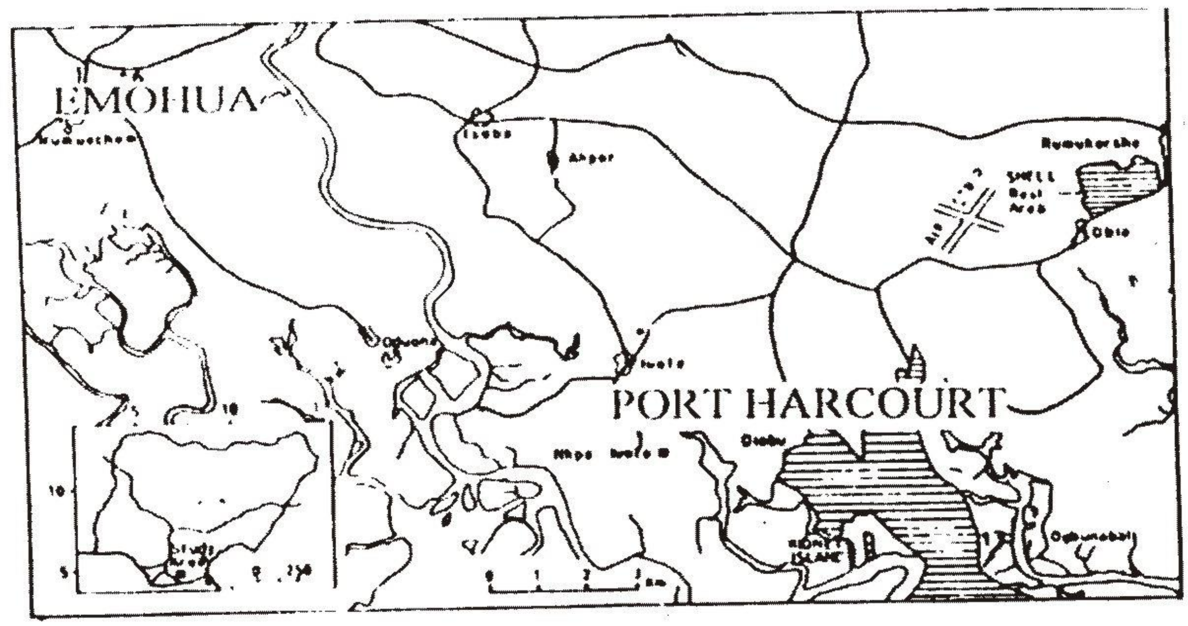


**Figure 1:** Map of the Niger Delta, Nigeria, showing the location of Emohua and Port Harcourt City, Nigeria.

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 was sought. These criteria include soils with: (1) Liquid limit less than 40%; (2) plasticity index, 16.4%; and (3) percentage passing No. 200 BS, sieve less than 50%. The properties of the selected soil are Liquid limit 41.8%; plasticity index, 16.4%; and 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 content given by the Portland Cement Association Handbook is 13%, with a maximum of 15%. The location of the sample is the Emohua borrow pit, Rivers State, Nigeria.

The soil is a reddish brown lateritic silty clay. The properties ofthe 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 | 18.0 | 67.3 |
| Liquid limit | 41.8 | 64.5 |
| Plastic limit | 25.4 | 30.4 |
| Plasticity index | 16.4 | 34.1 |
| Specific gravity | 2.64 | 2.30 |
| % passing No. 200 BS sieve | 43.7 | 90.0 |

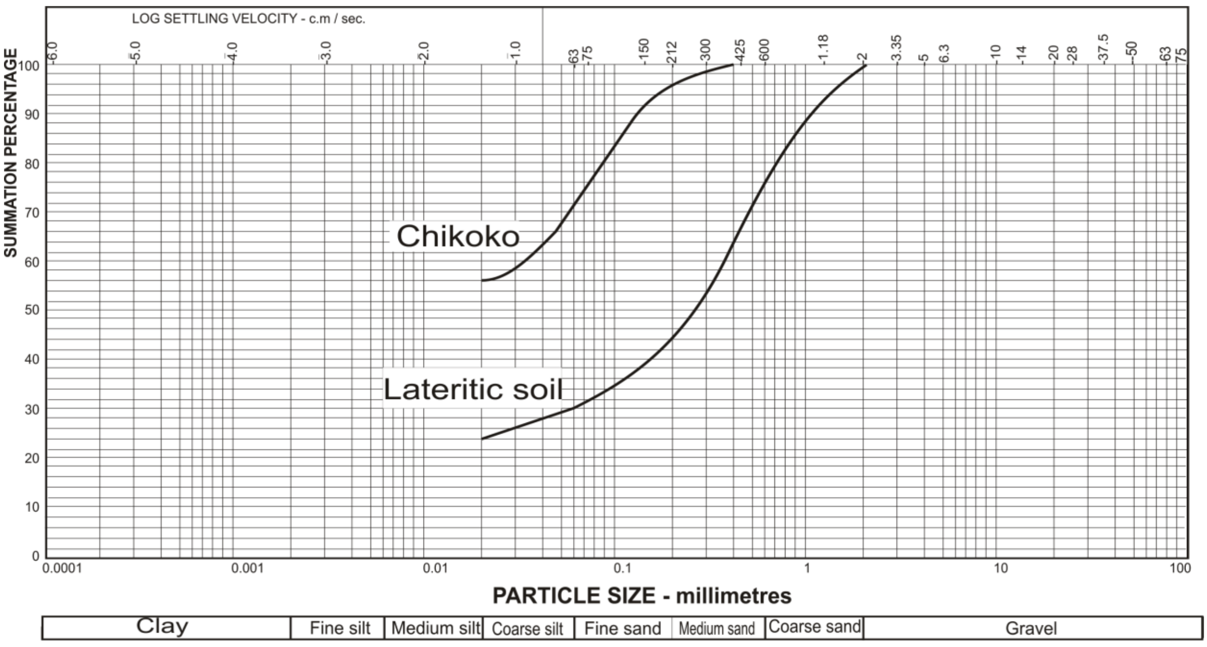


**Figure 2:**Particle size distribution curves for the Chikoko and the lateritic soil

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## SOIL CEMENT TESTS

The particle size distribution, as a result of wet sieving, is shown is fig. 2, while the results of the proctor compaction curves for various percentages of cement, are shown in fig. 3. From this data the optimum moisture content to be used in the CBR tests and in the partial pozzolanic replacement tests were obtained.

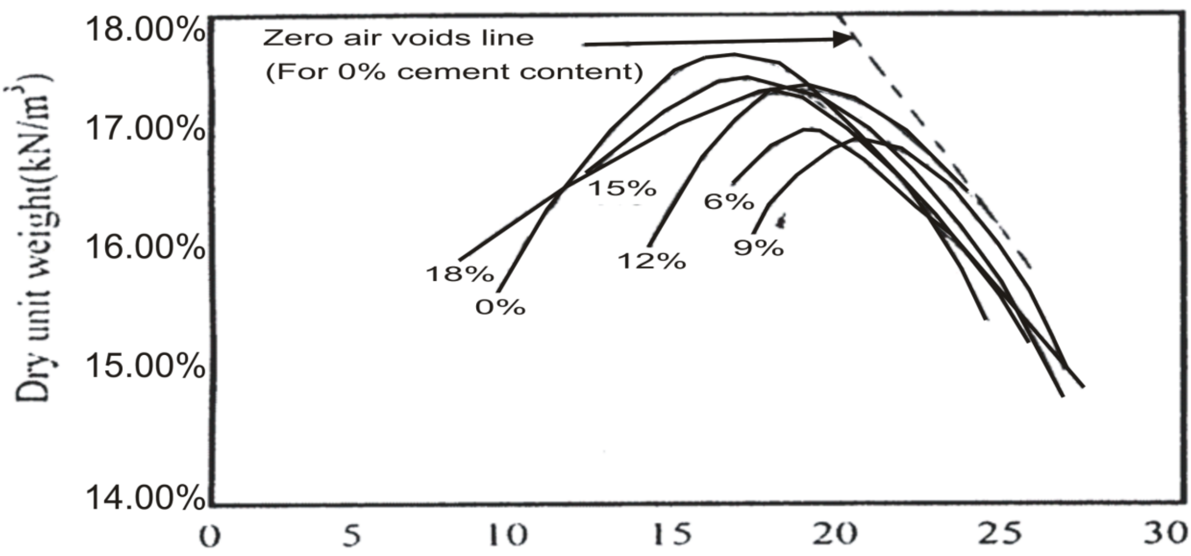


**Figure 3:** Proctor compaction curves for various cement mixes.

The CBR test results shown in fig. 4 indicate that a soaked CBR of 75 could be obtained with 7% cement. This 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 Flig.5, showing the relation between the compressive strength of the specimens and the cement content. The compressive strength of 7% cement for 7 days curing period is almost 2000KN/m$^2$ which is more than the usual acceptable 1,720KN/m$^2$ for soil cement stabilized road bases.

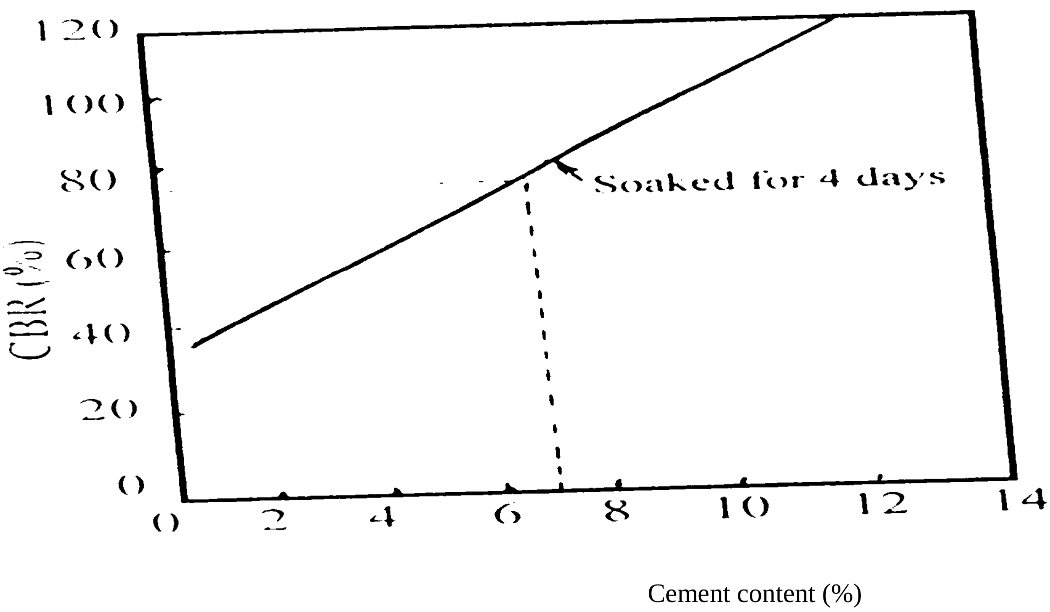


**Figure 4:** Variation of CBR (%) with cement content

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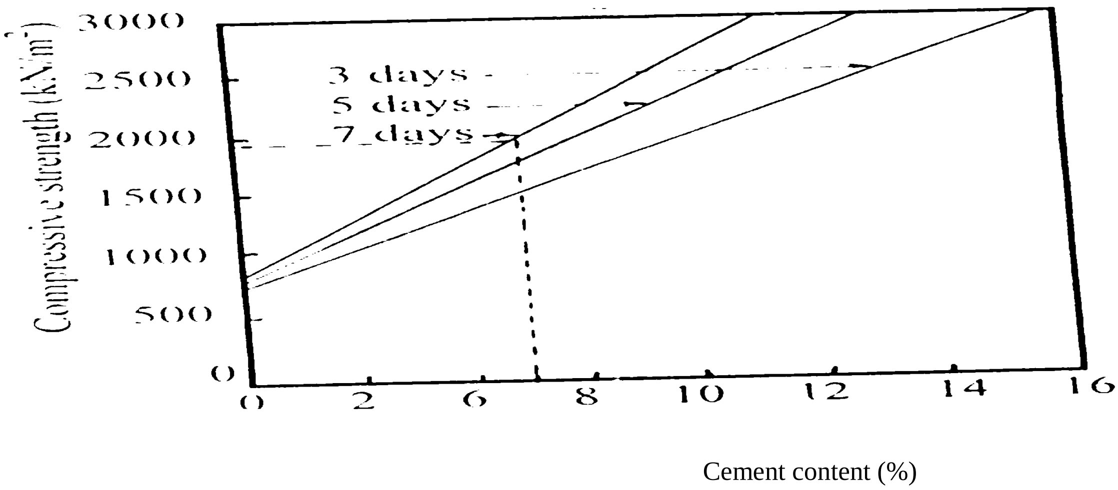


**Figure 5:**Variation of compressive strength withCement content (100mm cube specimens) for various curing periods

## POSSOLANIC REPLACEMENT TESTS

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

A 25 and 30% by weight replacement of the cement requirement were tried (fig.6). Partial replacement of Portland cement by pozzolana has to be carefully defined since the specific gravity of pozzolanas is much lower than that of cement. The specific gravity of the Chikokopossolana was found to be 2.30, compared with 3.15 for cement. Thus replacement by weight

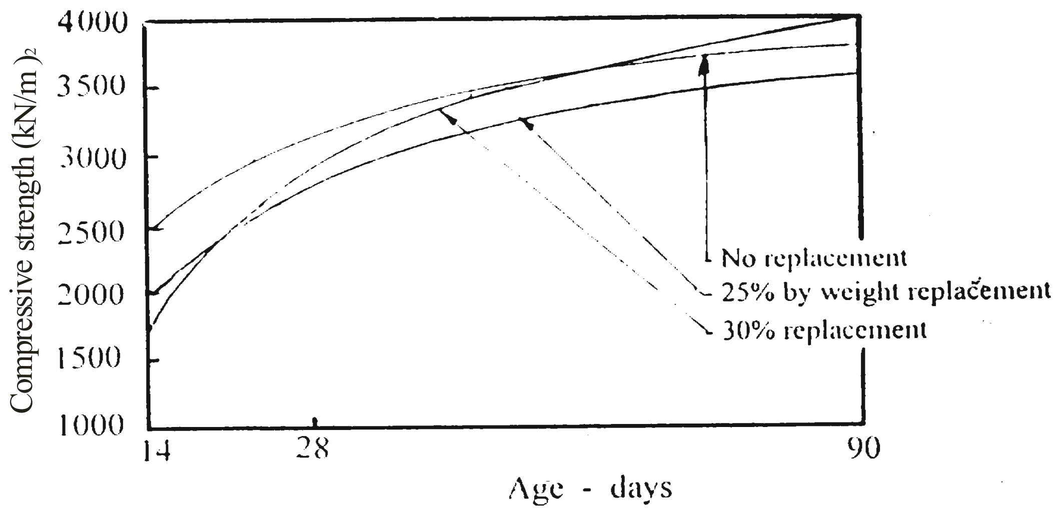


**Figure 6:**Effect of partial replacement of Portland cement by Chikokopozzolana on the strength development of soil cement.

resultsin a considerably greater volume of the cementitious material in the soil cement. With replacement, a lower early strength was obtained than when Portland cement was used. However, beyond 3 months there is no loss of strength for the 30% replacement test (Fig.6). With targeted mixes, there may even be a long term gain in strength due to the replacement (see fig. 6).

Although pozzolana may be cheaper than Portland cement, the use of an additional material on site most especially 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 Niger Delta of the country as well as the need to supplement the limited supply of fly ash from Oji Rivers Station, which at the moment, is the only source of fly ash in Nigeria. This development may lead to see to the extensive use of Portland – pozzolana cements in future. 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 by the Portland Cement Association is required for efficient stabilization of a lateritic soil. Similarly 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 is produced from only one power station in Nigeria, with a production rate that may not meet demands, it is recommended that the Nigerian Government should embark on commercial production of Chikoko pozzolana, since the chikoko mud is abundant in the Niger Delta of Nigeria. Thereafter, government can specify the use of the pozzolana in appropriate construction especially, those funded directly by government.

## ACKNOWLEGEMENT

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## REFERENCES

[1] ASTM specification 618 – 78.Specification for fly ash and raw or calcined naturalpozzolan for use as a mineral admixture in Portland Cement Concrete.

[2] BAMFORTH, P.B. 1980.In the 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.

[3] BERRY, E.E. and MALHOTRA, V.M. 1980.Fly ash for use in concrete.A critical review, J. Amer. Concr. Inst., 77, No. 8, pp. 59-73

[4] BUTLER, F.NCE, 28.1 1982,p.21.

[5] CENTRAL ELECTRICITY GENERATING BOARD. 1972. Pfa utilization, 104 pp. (Wolverhampton)

[6] COLLLEPARDI, M,; BALDINI, G.; and PAURI, M 1978.The effect of pozzolanas on the tricalcium aluminate hydration.Cement and Concrete Research, 8, no6.pp 741 - 51.

[7] HIGGINSON E.C. 1966. Mineral admixtures, ASTM Sp. Tech. Publication, No. 160 – A,pp 543-55

[8] HIGHWAY RESEARCH BOARD, 1943Use of Soil-Cement Mixture for Base courses. Wartime Road Problems No. 7 National Research Council, Division of Engineering & Industrial Research, Washington, D.C.

[9] KOVACS, R. 1975.Effect of hydration products on the properties of fly-ash cements. Cement and concrete Research, 5, No. 1,pp. 73-82

[10] KUMAR, S.S. and SUNDER, K.S. 1981.Role of lignin shury thinner in cement production. World Cement Technology,pp.208-506.

[11] MASSAZZA, E. and COSTA, U. 1979. Aspects of the pozzolanic activity and properties of pozzolanic cements. II cement, 76, Noi.1,pp.3-18

[12] NGWU, E.N. 1984Nigeria Coal Corporation, Production of Ore Coals.Weekly Star. Nigeria.

[13] 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

[14] PCA (1956). Soil Cement Construction Handbook. Portland CementAssociation, Chicago.

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

[16] PRICE, W.H. 1975Pozzolans – a review. J. Amer. Concr. Inst., 72, No. 5, pp. 225-32.

[17] SMITH, M. A. and HALLIWELL, F. 1979.The application of the BS 4550 test for pozzolanic cements to cements containing pulverized – fuel ashes. Mag. Concr. Res., 31, No. 108,pp 159 – 70

[18] STRINGER, J. A. 1979.Cement in the 1980's. Paper given at a Teach- in entitled cement – based materials and Technology in the 1980's and the Technical Training Implications, Brunal University. Sponsored by the Institute of ceramics.