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EFFECTS OF VARYING CURING AGE AND WATER/CEMENT RATIO ON THE ELASTIC PROPERTIES OF LATERIZED CONCRETE

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ABSTRACT

This paper reports the results of investigations carried out on the effect of varying curing age and water/cement ratio on the modulus of elasticity and modulus of deformability of laterized concrete. The test specimens were made with sieved samples of selected grain size ranges of laterite used as fine aggregates to replace sand in normal concrete. Batching was by weight. Three mix ratios of (1:1½:3), (1:2:4) and (1:3:6) were used. Water/cement ratio of 0.5, 0.6, 0.7 and 0.75 were used for each of the mix ratios. The specimens were tested at curing ages of seven to 28 days. The results showed that there was a corresponding increase in both modulus of elasticity and modulus of deformability of laterized concrete due to increase in curing ages. The mix proportion, compressive strength and water/cement ratio were found to have significant effects on both modulus of elasticity and modulus of deformability of laterized concrete.

Keywords: *laterized concrete, elastic properties, modulus, compressive strength.*

INTRODUCTION

The quest for affordable housing in Nigeria brought out the need for this study. Since materials cost accounted for two-third of the building production cost, it is necessary to look for ways of cutting down conventional material costs. One of the suggestions in the forefront has been the sourcing, development and use of readily available local materials suitable for the production of any component of a building. Lateritic soils belong to a category of such materials. The term 'laterite' according to Hamilton [1] was first used by Buchnan in 1807 to describe a ferruginous vesicular, unstratified and porous materials with yellow ochres (due to high iron content) occurring in Malabar, India. It is mainly found in the tropics.

Lateritic soils are known to be available in large quantities, and in different types, all over Nigeria as well as in most tropical countries of the world. They are essentially products of tropical or sub-tropical weathering, usually found in areas where natural drainage is impeded. Though lateritic soils have been used in the construction industry as a substitute for the fine aggregate in concrete, there have not been accepted standards as regards their performance characteristics. This may explain why there is still scepticism about their behaviour and hence acceptability continues to be a problem. Concrete in which sand component is partially or wholly replaced by laterite is called laterized concrete. Whole replacement is also referred to as terracrete.

The elastic characteristics of a material are measures of its stiffness. Determination of elastic properties of laterized concrete is necessary for stress analysis associated with environmental effects and for computation of the design stresses, deformations and deflections under load in concrete and reinforced concrete structures [2].

This study is part of the author's effort to investigate elastic properties of laterized concrete in order to develop the design parameters for the effective structural applications of lateritic soils in concrete. Specifically, this research looks into the effects of various curing ages and water/cement ratios on the modulus of elasticity and modulus of deformability of laterized concrete.

PREVIOUS WORK

Some interesting studies have been carried out in the field of laterite technology especially in the recent past. Most of the studies focused on the stabilisation and utilisation of laterite and lateritic soils with the addition of lime, cement, or bentonite [3].

Adepegba [4] was the first to study the effect of using laterite as fine aggregate in concrete. He compared the properties of concrete made with regular aggre-

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gates, with those of concrete in which the sand was replaced by laterite. He concluded that concrete containing laterite fines in place of sand could be used for structural members. Balogun [5] also considered the possibility of replacing sand in concrete with laterite. In another study, Balogun and Adepegba [6] discovered that the most suitable mix of laterized concrete for structural purposes is (1:1½:3), using batching by weight with a water/cement ratio of 0.65, provided that the laterite content is kept below 50 percent of the total fine aggregate content. Lasisi, et. al. [7] have shown that the durability of laterized concrete and laterite/cement mortar specimens can be enhanced by the low permeability characteristics of the lateritic soil contents of such specimens.

In a study on the effect of mix proportion and reinforcement size on the anchorage bond stress of laterized concrete; Osunade and Babalola [8] established that both mix proportion and the size of reinforcement have a significant effect on the anchorage bond stress of laterized concrete specimens. Also, the anchorage bond stress between plain round steel reinforcement and laterized concrete increases with increase in the size of reinforcement used.

In another study by Osunade [9], it was found that increase in shear and tensile strength of laterized concrete was obtained as grain size ranges and curing ages increased. Also, greater values of shear and tensile strengths were obtained for rectangular specimens than those obtained for cylinders. Neville [10] opined that laterite could rarely produce concrete stronger than 10Mpa. However, Osunade [11], Ata [12] and Olusola [13] proved this finding not to be true and submitted that laterite could produce concrete of higher grades.

In a recent study by Ata, et al [14], it was discovered that Poisson's ratio of laterized concrete ranges between 0.25 and 0.35 and increases with age at a decreasing rate. Methods of curing, compaction method and water/cement ratio have little influence on Poisson's ratio. Poisson's ratio of laterized concrete increases as the mix becomes less rich.

MATERIALS AND EXPERIMENTAL PROCEDURES

The laterite and gravel used in this experiment were collected from borrow pits situated on the Ife-Ibadan express road. The cement used was from the Sagamu Factory of the West African Portland Cement Company and conformed with BS12 [15] for Ordinary Portland Cement. The coarse aggregate used varied from 14– 20mm and the maximum size of fine aggregate was 2.36mm

Three mix proportions, namely (1:1½:3), (1:2:4) and (1:3:6) were used. Batching was by weight. Water/cement ratios of 0.5, 0.6, 0.7 and 0.75 were used for each of the mix ratios. A total number of 288 cubes were prepared. This number was arrived at from 24 cubes per mix at each water/cement ratio. Three specimens each were crushed to obtain the average compressive strength of various mixes at different water/cement ratios at curing ages of 7, 14, 21 and 28 days. The remaining specimens were used in a like number for the main test as later explained below.

Various tests and analyses were carried out on some selected samples of gravel and laterite used as coarse and fine aggregates respectively in this experiment to verify their compliance with various established standards. Some of the analysis carried out on the samples include; sample grading, moisture content determination and Atterberg limit determination.

The size of the specimens used for this investigation was 150x150x150mm cube. The procedures adopted for casting the test specimens are in accordance with British Standard [16]. The different mixtures of cement content lateritic soils and coarse aggregates were worked manually. Batching was by weight. The specimens were demoulded 24 hours later and water cured to the desired curing ages up to 28 days.

An ELE 2000 compressive machine was used for testing the strength of the laterized concrete specimens. Two dial gauges were attached to the machine to measure extensions. The gauges were on the vertical plane to measure the lateral extensions.

The tests were carried out in accordance with BS1881 [16, 17]. The laterized concrete cubes were loaded in compression at a constant loading rate. Initially the cubes were loaded with a load, which caused compressive stress equal to five percent of the ultimate compressive strength. (The average ultimate compressive strength of the specimen has been determined earlier by using three replicates of the cubes). In the second minute of loading, the readings from the dial gauges were taken. The loading continued until stress of ten percent of the ultimate compressive strength was reached and the corresponding extensions recorded. The sample was then unloaded back to five percent of the ultimate compressive strength and the value of the elastic deformation (ε_e) was determined. The successive loading and unloading cycles continued at ten percent intervals up to the stress level of 70 percent of the ultimate compressive strength. At each load level, readings on dial gauges were taken.

The relative total deformations $\Delta\varepsilon_d$ and the relative elastic deformations $\Delta\varepsilon_e$ were determined using the following formulae:

$$\Delta\varepsilon_d = \frac{a_1 - a_o}{L_o} \tag{1}$$

$$\Delta\varepsilon_e = \frac{a_1 - a_u}{L_o} \tag{2}$$

Where:

a_1 = the reading at the end of the loading
a_u = the reading at the end of the unloading
a_o = the reading at five percent of the ultimate compressive strength
L_o = the gauge length

The modulus of elasticity (E_e) that corresponds to elastic deformations and modulus of deformability (E_d) corresponding to total deformations (elastic and plastic) were calculated using the following formulae:

$$E_e = \frac{\Delta\sigma}{\Delta\varepsilon_e} \tag{3}$$

$$E_d = \frac{\Delta\sigma}{\Delta\varepsilon_d} \tag{4}$$

Where $\Delta\sigma$ is the increase of the stress.

The modulus of elasticity and the modulus of deformability depend on the level of applied stress chosen (expressed as percentage of ultimate load) [18, 19]. In calculations of the modulus of elasticity and modulus of deformability the point on the curve corresponds to 33 percent of the ultimate strength was chosen as prescribed in BS 1881[17].

RESULTS AND DISCUSSION

Sieve analysis of the lateritic soils sample used shows that the coefficient of uniformity (CU) as being approximately equal to 4.30. The value shows the laterite sample to be well graded. The Atterberg's limits tests indicated values of 36.5%, 17.5%, 19.0% and 1.13 for the liquid limit, the plastic limit, the plasticity index and the liquid index respectively. From the British Soil Classification System for engineering purposes [20], soils having liquid limit between 35 and 50% are said to have intermediate or medium compressibility of plasticity. Thus, with a liquid limit value of 36.5%, the lateritic soil sample used in this research work can be said to have intermediate plasticity and as a result very clayey. Similarly, with a plasticity index of 19.0, the lateritic soil sample falls into the group of medium cohesive soil (PI between 20 and 30%, [21]).

Figures 1 to 4 show the effect of mix proportions, curing age, compressive strength and water/cement ratio on modulus of elasticity and modulus of deformability of laterized concrete. Figures 1 and 2 reveal that both moduli increase with an increase in the curing age. Since laterized concrete strength increases with increase in curing age, it can be said that its exhibition of low strain at high strength is responsible for this. This falls in line with Neville [10] submission that high-strength concrete has higher modulus of elasticity. This increase in modulus of elasticity and modulus of deformability with time (curing age) is only proportional to the strength but it (the increase in the moduli) is less than the corresponding increase of strength with time. That is, the modulus per unit strength decreases with age. The decrease is greater at the early ages of laterized concrete. But at later ages, strength increases more rapidly than the moduli of laterized concrete.

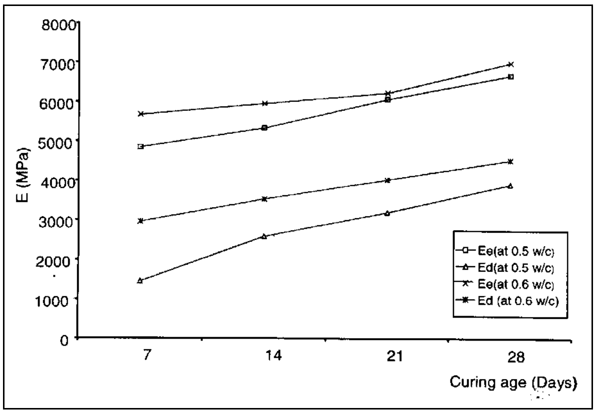

Figure 1. Effects of curing age and water/cement ratio on modulus of elasticity and modulus of deformability of laterized concrete for mix (1:1.5:3)

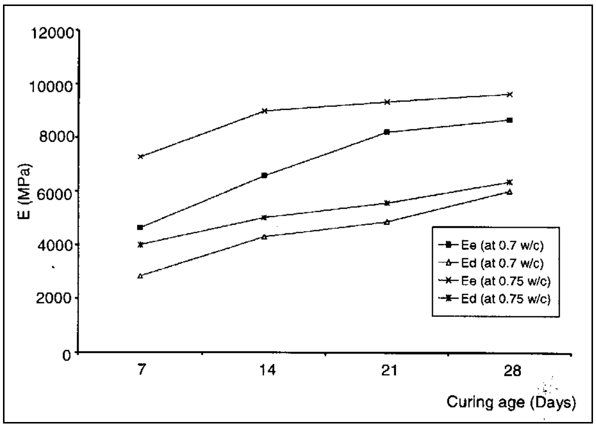

Figure 2. Effects of curing age and water/cement ratio on modulus of elasticity and modulus of deformability of laterized concrete for mix (1:1.5:3)

The figures also show that the modulus of elasticity of laterized concrete is always higher than its corresponding modulus of deformability. This is as a result of elastic deformations being always less than plastic deformations. The difference between modulus of elasticity and modulus of deformability is greater at early curing ages.

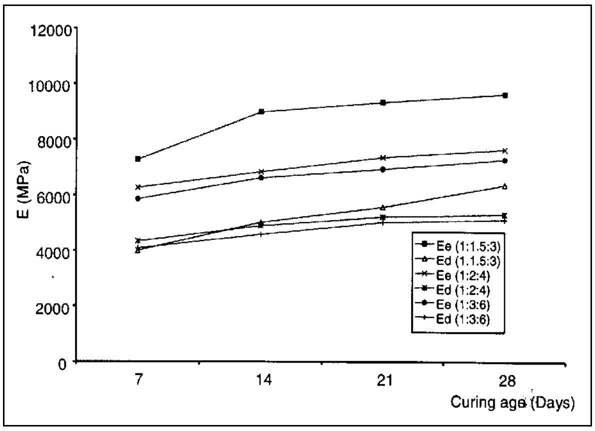

Figure 3. Effects of mix proportion and curing age on modulus of elasticity and modulus of deformability of laterized concrete at 0.75 water/cement ratio

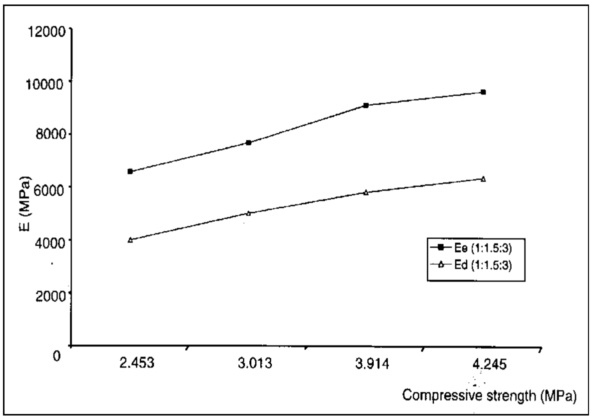

Figure 4. Modulus of elasticity and modulus of deformability of laterized concrete at different compressive strengths and 0.7 water/cement ratio

Figure 4 shows different compressive strengths in laterized concrete plotted against the modulus of elasticity and modulus of deformability. The Figure reveal that the stronger the laterized concrete, the higher the modulus of elasticity and the modulus of deformability. This can be explained by the fact that the stronger the laterized concrete the stronger is the gel and hence less is the strain for a given load. In other word, the lower the strain; the higher the modulus of elasticity and modulus of deformability of laterized concrete. The relationship between the two moduli and the strength of laterized concrete is also a function of the mix proportions. This is probably due to aggregates having higher modulus than the cement paste. The richer the mix; the higher the moduli.

Since the water/cement ratio of laterized concrete influences its strength; it can be reasonably inferred that the water/cement ratio influences the moduli of elasticity and deformability of laterized concrete at different degrees.

CONCLUSIONS

The following major conclusions emerge from the experimental study reported in this paper on the effect of varying curing age and water/cement ratio on the elastic properties of laterized concrete:

1) The modulus of elasticity of laterized concrete lies between 7000 and 9500MPa, while that of deformability lies between the range of 5000 and 6000MPa.
2) Modulus of elasticity and modulus of deformability of laterized concrete increase with an increase in curing age.
3) The value of modulus of elasticity of laterized concrete is always higher than its corresponding modulus of deformability.
4) The richer the mix; the higher the moduli of elasticity and deformability of laterized concrete.
5) The stronger the laterized concrete; the higher the modulus of elasticity and the modulus of deformability.
6) Any water/cement ratio that will give laterized concrete high strength will increase its modulus of elasticity and modulus of deformability.

REFERENCES

1. Hamilton, E., *Laterite–The Whole Story–Everything You Want to Know About Laterite.* www.thekrib.com, 1995.

2. Abadjieva, T.G., Effect of Some Factors on the Modulus of Elasticity and Modulus of Deformability of Lightweight Concrete, *Botswana Journal of Technology,* 1(1), 1998, pp.28-33.

3. Kumar, S., A Respective Study on Fly Ash-Lime-Gypsum Bricks and Hollow Blocks for Low Cost Housing Development, *Construct Build Mater,* 16(8), 2002, pp.443-552.

4. Adepegba, D., A Comparative Study of Nnormal Concrete with Concrete which Contained Laterite Instead of Sand. *Building Science,* 10(2), 1975, pp.135-141.

5. Balogun, L.A., The Use of Lateritic Soils in Structural Concrete. *Proceedings 1st National Conference; Nigerian Geotechnical Association,* Lagos, Nigeria, 1982.

6. Balogun, L.A. and Adepegba, D., Effect of Varying Sand Content in Laterized Concrete. *International Journal of Cement Composites and Lightweight Concrete,* 4(4), 1982, pp.235-241.

7. Lasisi, F., Osunade, J.A. and Adewale, A.O., Short-Term Studies on the Durability of Laterized Concrete and Laterite-Cement Mortars, *Building and Environments*, 25(4), 1990, pp.77-83.

8. Osunade, J.A. and Babalola, J.I., Effect of Mix Proportion and Reinforcement Size on the Anchorage Bond Stress of Laterized Concrete. *Building and Environment*, 2(4), 1991, pp.447-452.

9. Osunade, J.A., Effect of Grain Size Ranges of Laterite Fine Aggregate on the Shear and Tensile Strengths of Laterized Concrete *International Journal for Housing Science and its Applications,* 4(1), 1994, pp.8-15.

10. Neville, A.M., *Properties of Concrete*, Addison Wesley, Longman Limited, England, 1995.

11. Osunade, J.A., Effect of Replacement of Lateritic Soils with Granite Fines on the Compressive and Tensile Strength of Laterized Concrete. *Building and Environmen,*. 37(6), 2002, pp.491-496.

12. Ata, O., The effects of Applied Stress on the Modulus of Elasticity and Modulus of Deformability of Terracrete, *Unpublished M.Sc Thesis*, Department of Building, Obafemi Awolowo University, Ile-Ife, 2003.

13. Olusola, K.O., *Some Factors Affecting Compressive Strength and Elastic Properties of Laterite Concrete, Unpublished Ph.D Thesis*, Department of Building, Obafemi Awolowo University, Ile-Ife, 2005.

14. Ata, O., Olusola, K.O. and Aina, O.O., Factors Affecting Poisson's Ratio of Laterized Concrete, *Jurnal Sains Dan Teknologi, EMAS*, Jakarta, 15(2), 2005, pp.77-84.

15. British Standard Institution, *Specification for Portland Cements, BS12*, BSI, London, 1991.

16. British Standard Institution, *Method for Determination of Compressive Strength of Concrete Cubes, BS1881: Part116*, BSI, London, 1983.

17. British Standard Institution, *Method of Determination of Static Modulus of Elasticity in Compression, BS1881: Part 121*, BSI, London, 1983.

18. Darakchiev, B., Nikolov, I. and Abadjieva, T., *Manual for Testing of Construction Materials*, Technika, Sofia, Bulgaria, 1990.

19. British Standard Institution, *The Structural Use of Concrete: Part 1, Design, Materials and Workmanship, BS8110*, BSI, London, 1985.

20. Terzaghi, K. and Peck, R.B., *Soil Mechanics in Engineering Practice*, 2nd edition, John Wiley, New York, 1967.

21. Jackson, N. and Dhir, R.K., *Civil Engineering Materials,* Macmillan Press Limited, London, 1996.