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The Effects of Applied Stress on the Modulus of Elasticity and Modulus of Deformability of Laterized Concrete

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ABSTRACT

This research work assessed the effects of applied stress on the modulus of elasticity and modulus of deformability of laterized concrete. Laterized cubes of size 150x150x150mm were prepared as test samples. Three mix ratios of (1:1½:3), (1:2:4) and (1:3:6) were used. The specimens were tested at curing ages of 7 to 28 days. The results have shown that increase in the level of applied stress brings about decrease in modulus of elasticity and modulus of deformability. Modulus of elasticity of laterized concrete is always less than the corresponding modulus of deformability, but both increase with an increase in strength.

KEYWORDS

Laterized Concrete
Modulus of Elasticity
Modulus of Deformability
Compressive Strength
Applied Stress

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INTRODUCTION

Laterite has been used in building construction for thousands years and approximately 30% of the world's present population still lives in laterite structures (Confirman, et. al, 1990). Lateritic soil has been one of the major building materials in Nigeria (Osunade, 2002). In addition to easy availability, laterite has the advantage of requiring no specialised skilled labour for its production.

Laterite is found extensively all over Nigeria and for that matter, all over the tropical regions of the world. Lateritic soils are essentially products of tropical or sub-tropical weathering usually found in areas where natural drainage is impeded (Lasisi and Osunade, 1984). Laterized concrete is concrete in which sand component is partially or wholly replaced by laterite. Whole replacement is often referred to as terracrete.

Today, the use of lateritic soils for building seems to be restricted to rural areas. This may not be unconnected with the fact that there have not been accepted standards design parameters for the effective structural applications of laterite in laterized concrete. Although the use of laterite as a substitute for sand as fine aggregate in concrete has been studied by many, not much is known about the elastic properties of laterized concrete.

Determination of the elastic modulus of concrete is necessary for stress analysis associated with environmental effects and for computation of the design stresses, deformation and deflections under load in concrete and reinforced concrete structures (Abadjieva, 1998).

Results of investigation presented in this paper are parts of the authors' effort aimed at developing design parameters for the effective structural application of lateritic soils in concrete. This study specifically looks into the effect of applied stress on the modulus of elasticity and modulus of deformability of laterized concrete.

PREVIOUS WORK

Most studies reported in the literature focused on the stabilisation and utilisation of laterite and lateritic soils with the addition of lime, cement, or bentonite (Kumar, 2002). The first published work on laterized concrete, according to Osunade (2002), appears to have been by Adepegba in 1975 – a study in which the strength properties of normal concrete were compared with those of laterized concrete. The conclusion of that study was that a concrete in which laterite fines are used instead of sand, can be used as a structural material in place of normal concrete. In another study, Balogun and Adepegba (1982) discovered that the most suitable mix of laterized concrete for structural purposes is (1:1½:3) with a water/cement ratio of 0.65, provided that the laterite content is kept below 50 per cent.

While studying the effect of mix proportion and reinforcement size on the anchorage bond stress of laterized concrete, Osunade and Babalola (1991) established that both mix proportion and the size of reinforcement have a significant effect on the anchorage bond stress of laterized concrete specimens. The richer, in terms of cement content, the mix proportion, the higher the anchorage bond stress of laterized concrete.

Osunade (1994) in another study found that increase in shear and tensile strengths 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 (1995), submitted that laterite could rarely produce concrete stronger than 10MPa. However, Osunade (2002), Ata (2003) and Olusola (2005) proved this assertion to be wrong and went further to establish that laterite could produce concrete of higher grades.

In a recent study by Ata, Olusola and Aina (2005), it was found 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 the Poisson's ratio. Poisson's ratio of laterized concrete increases as the mix becomes less rich.

EXPERIMENTAL METHODOLOGY

Laterite, gravel and ordinary Portland cement are the major materials used in this research work. Though all the materials were sourced from within Ile-Ife in Ife Central Local Government Area of Osun State, Nigeria, the cement was manufactured by West Africa Portland Cement at Sagamu and conformed with the requirements of BS12 (1991). The washed gravel used as coarse aggregate had an almost uniform size of 20mm while the laterite fine aggregate was of maximum size of 2.36mm.

Three mix proportions of (1:1½:3), (1:2:4) and (1:3:6) were used. The optimum water/cement ratios for workable mixes were determined using the following expression (Lasisi and Ogunjimi, 1984)

$$y = -0.9 + 3.85x$$

where y = cement/laterite ratio
x = water/cement ratio

The ratios 0.623, 0.753 and 1.013 were used for (1:1½:3), (1:2:4) and (1:3:6) mix proportions respectively.

After the collection of gravel and laterite used as coarse and fine aggregates respectively in this research work, various tests and analyses were carried out on some selected samples in order to ensure their compliance with various established standards. Some of the analyses carried out on the samples include sample grading, moisture content determination and Atterberg limit determination.

The ingredients were mixed manually on a neat platform with the predetermined amount of water. Batching was done by weight. Laterite and gravel were thoroughly mixed before the introduction of cement. The whole mixture was thoroughly mixed before water was added. Mixing was fast and assumed to be completed when a homogenous mix was obtained.

Before casting, the inner parts of 150x150x150mm cubic moulds were coated with mould oil to ensure easy demoulding and smooth surface finish. Immediately after the mixing, the wet mixture was cast into the moulds using hand trowel and compacted in accordance with BS 1881: Part 116 (1983). The specimens were demoulded 24 hours later and water cured till they were tested.

The strength characteristics of each cube were tested on an ELE 2000 compression machine. Three specimens for each curing age were brought out of the curing tank and tested in accordance with BS 1881: Parts 116 and 121:1983. Two dial gauges were attached to the machine to measure extensions. The gauges were on the vertical plane to measure the longitudinal extensions.

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 5 per cent of the ultimate compressive strength. In the second minute of loading, the readings from the dial gauges were taken. The loading continued until stress of 10 per cent of the ultimate compressive strength was reached and the corresponding extensions recorded. The sample was then unloaded back to 5 per cent of the ultimate compressive strength and the value of the elastic deformation (ε_e) was determined. The successive loading and unloading cycles continued at 10 per cent intervals up to the stress level of 70 per cent 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:

$$\Delta\varepsilon_d = \frac{a_l - a_o}{L_o}$$

$$\Delta\varepsilon_e = \frac{a_l - a_u}{L_o}$$

Where:

a_l is the reading at the end of the loading
a_u is the reading at the end of the unloading
a_o is the reading at 5 per cent of the ultimate compressive strength
L_o is 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) was calculated using the following formulae:

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

$$E_d = \frac{\Delta\sigma}{\Delta\varepsilon_e}$$

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) (BS 8110: 1985, Darakchiev, Nikolov and Abadjieva, 1990). In calculations of the modulus of elasticity and modulus of deformability the point on the curve corresponds to 33 per cent of the ultimate strength was chosen as prescribed in BS 1881: Part 121:1983.

RESULTS AND DISCUSSIONS

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 (Terzaghi and Peck, 1967), 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

Figure 1 Influence of the level of applied stress on the modulus of elasticity and modulus of deformability of laterized concrete at 7 days curing age

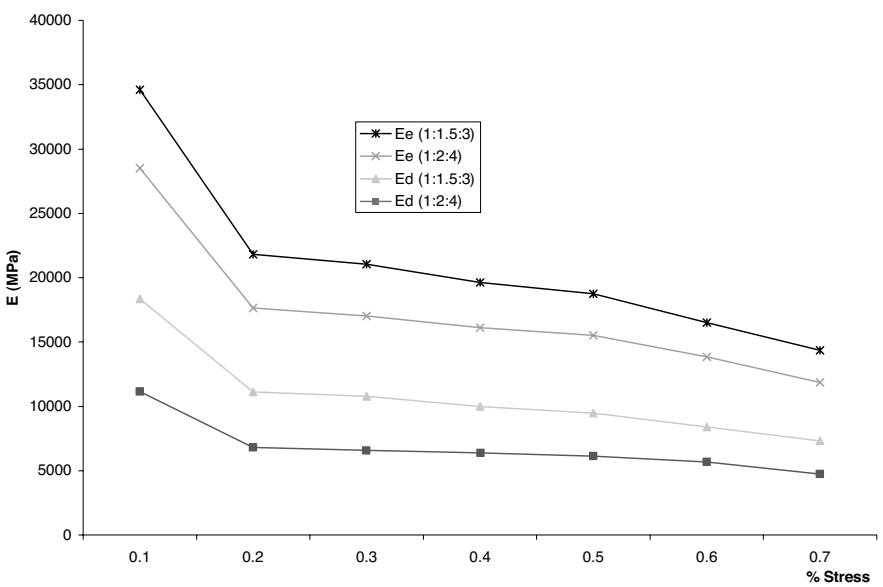


Figure 2 Influence of the level of applied stress on the modulus of elasticity and modulus of deformability of laterized concrete at 14 days curing age

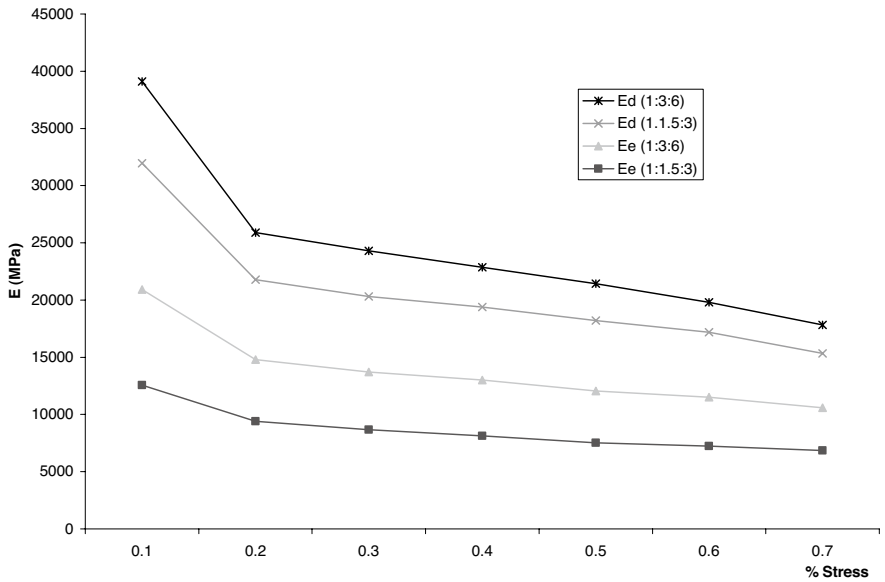


Figure 3 Influence of the level of applied stress on the modulus of elasticity and modulus of deformability of laterized concrete at 21 days curing age

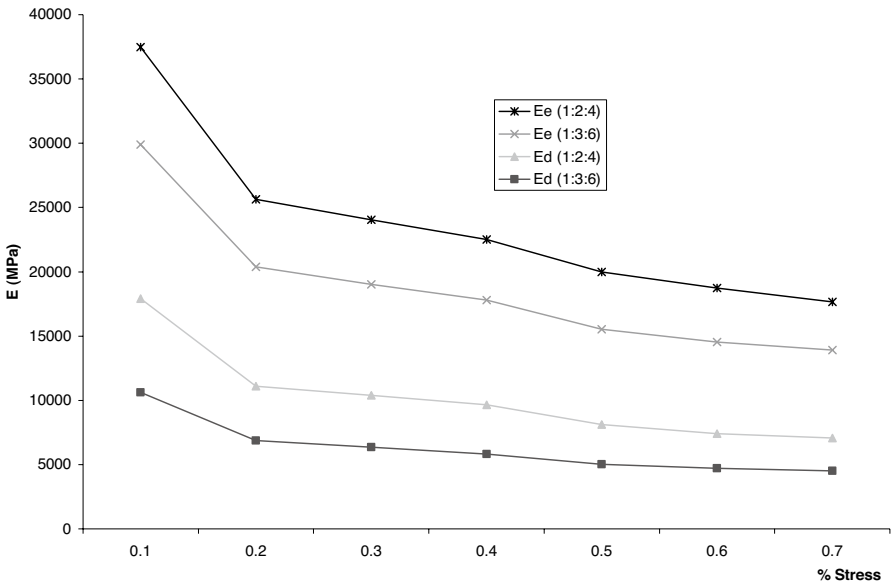


Figure 4 Influence of the level of applied stress on the modulus of elasticity and modulus of deformability of laterized concrete at 28 days curing age

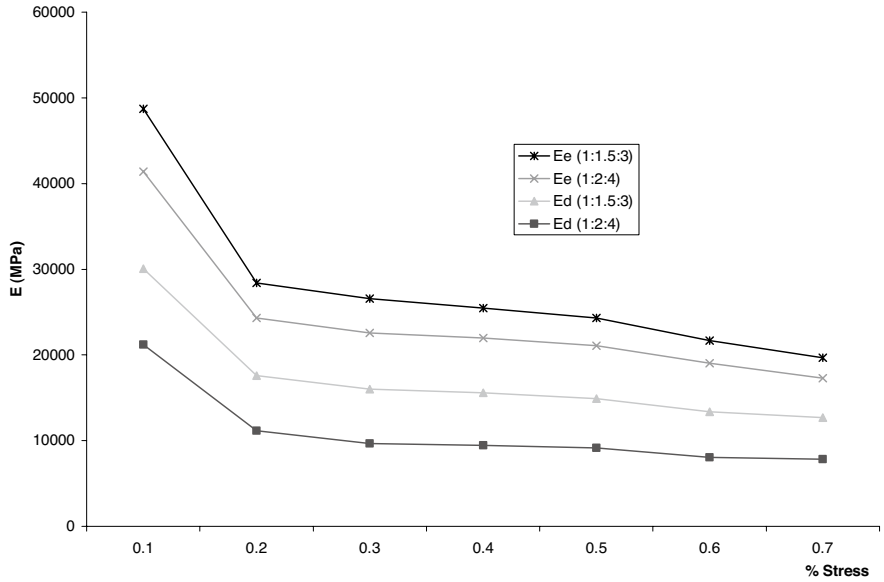
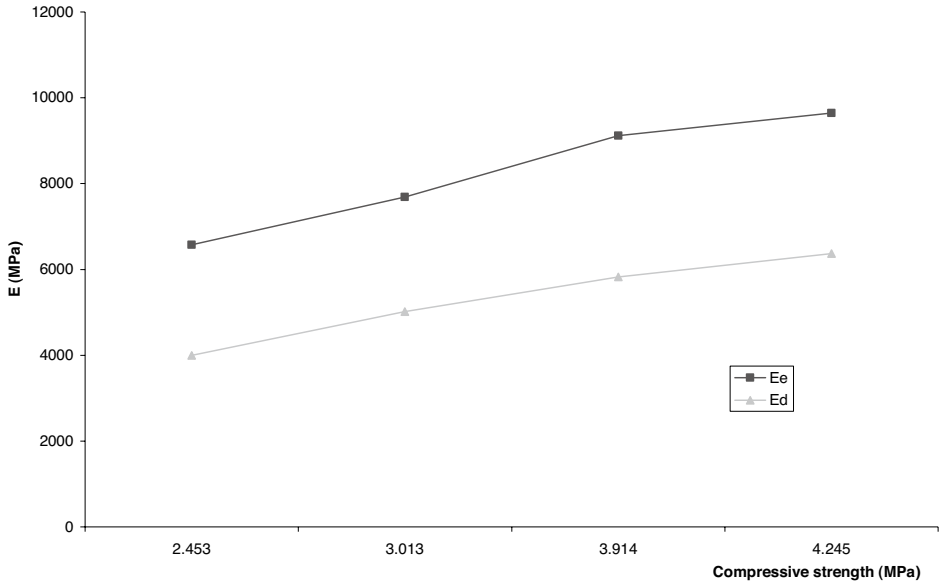


Figure 5 Modulus of elasticity and modulus of deformability of laterized concrete at different compressive strengths



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%, Jackson and Dhir, 1996).

Figures 1 to 4 are typical graphs showing the influence of the level of the applied stress on the modulus of elasticity and modulus of deformability of laterized concrete at ages of 7 and 28 days. The stress level is expressed as the ratio of the existing stress in the laterized concrete to ultimate compressive strength of the cube. Figure 5 shows the effect of different

compressive strength on modulus of elasticity and modulus of deformability of laterized concrete.

The Figures show that both modulus of elasticity and modulus of deformability decrease with an increase in the level of the applied stress of laterized concrete. For instance, sample (1:1.5:3) at 0.75w/c and curing age of 7 days, with the increase of level of loading from 10 per cent to 70 per cent of the ultimate load; the modulus of elasticity decreases 2.35 times and the modulus of deformability decreases 2.91 times. While at the age of 21 days with a similar increase in the loading level, the modulus of elasticity decreases 2.07 times and the modulus of deformability decreases 2.47 times. When the applied stress increases beyond approximately 70 per cent of the ultimate strength; mortar cracking (connecting the bond cracks) develops. The development of a continuous crack system reduces the load-carrying capacity of the specimen as its ultimate strength is reached faster. The increase in strain while the loading is acting is due to creep effect in laterized concrete, which is more at higher stress.

The Figures also reveal 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 lower levels of loading.

Mix proportion affects both modulus of elasticity and modulus of deformability. For example, at 28 day curing age and 30% applied stress; mix (1:1½:3) produces modulus of elasticity and modulus of deformability of 9647.73MPa and 6367.18MPa respectively. Whereas, mix (1:2:4) at the same ages and applied stress could only produce modulus of elasticity and modulus of deformability of 6550.00MPa and 4014.52MPa respectively. This is not unconnected with the fact that mix proportion affects strength. The richer the mix then is the higher the moduli.

It can also be deduced from the Figures that both moduli increase with 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's (1995) 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.

CONCLUSIONS

From the foregoing discussion of results, the following conclusions can be made:

1. The modulus of elasticity and modulus of deformability of laterized concrete decrease with an increase in level of the applied stress.

2. Both moduli increase with an increase in the strength of laterized concrete with time but the increase in the moduli is less than the corresponding increase in strength with time.

3. Modulus of elasticity of laterized concrete is always higher than the corresponding modulus of deformability. The difference between the moduli is greater at lower levels of applied stress.

4. The modulus of elasticity of laterized concrete lies between the range of 7000 and 9500MPa, while that of deformability lies between the range of 5000 and 6000MPa.

REFERENCES

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

Ata O (2003), 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.

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

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

British Standard Institution (1983), Method for Determination of Compressive Strength of Concrete Cubes, *BS 1881: Part 116, BSI,* London.

British Standard Institution (1983), Method of Determination of Static Modulus of Elasticity in Compression, *BS 1881: Part 121, BSI,* London.

British Standard Institution (1985), The Structural Use of Concrete: Part 1, Design, Materials and Workmanship, *BSI, BS 8110,* London.

British Standard Institution (1991), Specification for Portland Cements, *BS 12, BSI,* London.

Confirman R, Agnew N, Auiston G and Doehne E (1990), Adobe Mineralogy: Characterisation of Adobes from Around the World. In: *6th International Conference on the Construction of Earthen Architecture,* has Cruces, NM; 14-19 October.

Darakchiev B, Nikolov I and Abadjieva T (1990), *Manual for Testing of Construction Materials, Technika,* Sofia, Bulgaria, pp.153 –159.

Jackson N and Dhir RK (1996), *Civil Engineering Materials.* Macmillan Press Limited, London.

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

Lasisi F and Ogunjimi B (1984), Source and Mix Proportions as Factors in the Characteristics Strength of Laterized Concrete. *Int. Journal for Development Tech.,* 2:3, 8-13.

Lasisi F and Osunade JA (1984), Effect of Grain Size on the Strength of Cubes made from Lateritic Soils. *Building and Environment,* 19:2, 55-58.

Neville AM (1995), *Properties of Concrete,* Addison Wesley, Longman Limited, England.

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

Osunade JA and Babalola JI (1991), Effect of Mix Proportion and Reinforcement Size on the Anchorage Bond Stress of Laterized Concrete. *Building and Environment,* 26:4, 447-452.

Osunade JA (1994), 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,* 4:2, 8-15.

Osunade JA (2002), Effect of Replacement of Lateritic Soils with Granite Fines on the Compressive and Tensile Strength of Laterized Concrete. *Building and Environment,* 37:4, 491-496.

Terzaghi K and Peck RB (1967), *Soil Mechanics in Engineering Practice*, 2nd edition, John Wiley, New York.