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Influence of Temperature Increase on Poisson's Ratio of Laterized Concrete

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Abstract
This paper reports the result of investigations carried out on the effect of temperature increase on the Poisson's Ratio of laterized concrete. Values of Poisson's Ratio are needed for the structural analysis and design of many types of concrete structures. The test specimens were made with sieved samples of selected grain sizes range of lateritic soil used as fine aggregate to replace sand in normal conventional concrete. Batching was by weight. Three mix ratios of (1:1.5:3), (1:2:4) and (1:3:6) were used. Water/cement ratio of 0.6 was used throughout the experiment. The cylindrical shape specimens of size 150mm x 50mm were tested at 28days curing age after heated to various high temperatures 40^0 C, 60^0C, 80^0 C and 100^0C, for 24 hours and allowed to cool for another 24 hours. The results showed that Poisson's Ratio of laterized concrete decreases as the temperature increases. The results can be used to estimate the influence of high temperature on the structural behaviour and integrity of laterized concrete component which follow the pattern of conventional concrete at increased temperature.

Keywords: poisson's ratio, laterized concrete, lateritic soil, compressive strength, conventional concrete

INTRODUCTION

Concrete is one of the most important building materials manufactured in the building industry. Generally, concrete is made up of water, cement, fine and coarse aggregates. The mechanical and physical properties of concrete are more complex than most materials as they impacted by the environmental conditions when it is poured and cured (Naus and Graves, 2006). The need to provide for different uses at relatively cheap and reasonable costs has led to the use of different materials as substitutes for the constituents of concrete. 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.

There are varieties of definitions of lateritic soil stemmed from the fact that each investigation approaches the study of the material from its own professional view point. The term 'laterite' according to Hamilton (1995) was first used by Buchnan in 1807 to describe a ferruginous vesicular, unstratified and porous materials with yellow euchres due to high iron content occurring in Malabar, India. The freshly dug material was soft enough to be rapidly hardened on exposure to air and was remarkably resistant to the weathering effect of climate. Lateritic soil are recognized as tropical and sub-tropical weathering products of various crystalline igneous rocks, sediments, detrital deposits and volcanic ash, and it was morphologically identified as surface or near surface occurrence in various tropical and sub-tropical regions of the world. Concrete in which sand component is partially or wholly replaced by Laterite is called laterized concrete. Terracrete is the product formed by replacing sand as fine aggregate in concrete wholly with laterite. In other words, it is a product formed by bathing cement, coarse aggregate, laterite and water in standard mix to form a construction material of similar characteristics to concrete.

The elastic characteristics of a material are measures of its stiffness. Stiffness influences the deformation and load distribution. 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 concrete structures (Abadjieva, 1998). Poisson's Ratio and young modulus are the two fundamental constants characterizing the general mechanical behaviour of linear, elastic, homogenous and isotropic materials. Isotropic materials have the same properties in all directions while homogenous materials are those composed of the same material throughout. Poisson Ratio is the ratio of the lateral strain accompanying an axial strain to the applied longitudinal strain and may be expressed as

$$E\ \text{Lateral} = \text{Ɲ}\ \text{Longitudinal} \quad (1)$$

Where the constant of proportionality Ɲ is the Poisson's Ratio and E is the Strain. Another way of finding Poisson's Ratio is from the modulus of Elasticity Ɛ, as determined in Longitudinal or transverse mode of vibration and the modulus of rigidity thus:
Where G = Modulus of rigidity.

G is normally determined from the resonant frequency of torsional vibration and this is intermediate between those values obtained directly and those from dynamic test. The physical significance of Ɲ is revealed by various interrelations between theoretical elastic properties (Love,1944). Values for Poisson's Ratio are needed for the structural analysis and design of many types of concrete structures. Also it is necessary to know the value of Poisson's Ratio when interpreting strain data obtained in test structures. For the small strain analysis of concrete structures, knowledge of the strength and the elastic modulus is sufficient. However, when large strains are involved as in a structural integrity analysis, knowledge of the stress-strain relationship of the concrete at elevated temperatures is also required.

This study quantifies the influence of a rise in temperature on Poisson's Ratio of terracrete. The results can be used to estimate the influence of high temperature on the structural behaviour and integrity of laterized concrete components.

SIGNIFICANCE OF THE STUDY

The present state of economic condition has accentuated the necessity of implementing local capacity to curtail dependence on foreign capacity. This is the time to raise our economy by making use of indigenous construction capacity and also to develop it to meet the foreign capacity standard. Terracrete is cheaper than concrete because laterite which is used as the fine aggregate constituent is much more readily available than sand used as fine aggregate in normal concrete. It can even be collected from the construction site therefore eliminating necessary transportation cost. Presently, there is a great need to further research on the topic so as to get more information on its performance at elevated temperature when compared with normal concrete. In summary, the study provides more information on the performance of laterized concrete under high temperature conditions. This would enable the designers to check the factor of safety and the adequacy of the structure to sustain the applied loads safely.

PREVIOUS STUDY

The abundance of the laterite in tropical region has generated research interest in the material. The possibility of replacing sand in concrete with laterite have been investigated into by many researchers, but to date, the information available on the performance under high and low temperature condition is limited (Kodur,2008). Various structures are being exposed to continuous variations in temperature especially this era of global warming, this necessitate more concern on how laterized concrete behaves after curing under varying temperature.

Ata et al (2005) established that Poisson's Ratio of laterized concrete ranges between 0.25 and 0.35 and increases with age. In addition, it was noted that methods of curing, compaction and water / cement ratio have little influence on Poisson's Ratio. Investigation by Udoeyo et al (2006) shows that concrete with up to 40% replacement level of sand by laterite attained compressive strength of $20N/mm^2$. This indicates that it is possible to use laterite as partial replacement for sand up to this level. In another study, Balogun and Adepegba (1982) found out that the most suitable mix of laterited concrete for structural purposes is 1: 1.5:3, using batching by weight with water / cement ratio of 0.65 provided that the laterite content is kept below 50% of the fine aggregate content. It was found that shear and tensile strength of laterized concrete increased with curing duration.

Previous studies on conventional concrete indicated that it exhibits change in its compressive strength and it's modulus of elasticity as environmental conditions change (Gardner et al 2005, Lec, 2008 and Yuan, 2002). Lec et al (1988) showed that compressive strength and Poisson's Ratio increases as temperature decreases. The young modulus of concrete was also found to increase at low temperature but in a smaller rate than the compressive strength. In the study carried out by Phan and Carino (2003) concrete would permanently lose strength if exposed to repeated extreme temperature. This result conformed to the study carried out by Lawson et. al (2000) which indicated that the concrete loses 50% of its compressive strength for every 100^oc rise in temperature up to about 200^oc, after which the strength starts to drop significantly.

MATERIALS AND EXPERIMENTAL PROCEDURES

Materials

The laterite used to replace sand in this study was from a pit at the back of civil engineering block Obafemi Awolowo University, Ile – ife. The maximum size of laterite used passed through 2.36mm BS sieve. The gravel used throughout the tests was obtained from the capital project division of the University and varied in sizes from 12mm – 20mm. The cement used was from west African Portland Cement Company Ewekoro, Ogun State and conformed with BS 12 [4] for Ordinary Portland Cement. Clean tap water available in the concrete laboratory was used in manufacturing the specimens.

Characterization of Laterite and Sand

The physical and chemical characteristic of laterite according to Adepegba (1975) are furnished in table 1 and table 2 respectively. Table 3 present the basic properties of Sand and Laterite

Table 1 physical characteristic of laterite

Component	Percentage composition(%)
Gravel	5
Sand	48
Silt	12
Clay	35

Source: Adepegba (1975)

Table 2 Chemical composition of laterite

Component	Percentage composition(%)
SiO_2	67
Al_2O_3	17.1
TiO_2	1.0
Fe_2O_3	5.6
MgO	0.1
K_2O	0.1
SO_3	0.3

Source: Adepegba (1975)

Table 3 Basic properties of laterite and sand

Physical properties		Sand	Laterite
Specific density		2.6	-
Bulk Density (Kg/m^3)	Loose condition	1405	1162
	Dense condition	1547	1294
Fineness Modulus		2.27	5.46

EXPERIMENTAL PROCEDURES

The specimens used in the experiment were 150 x 150mm cylindrical shape. The cylindrical moulds were coated with mould oil to ensure easy de-moulding and smooth surface finish. The procedures adopted for casting the test specimens are in accordance with British Standard Institution (1983). The batching of the terracrete was done by weighing the different constituent materials based on the adopted mix ratio of 1:1.5:3, 1:2:4 and 1:3:6. The different mixtures of cement content lateritic soils and coarse aggregates were worked manually. The water cement ratio for all the mix was 0.6 by weight. The freshly mixed terracrete was then filled in moulds with the use of hand trowel. Capping was provided for each mould and the identification marks showing the date of casting and mix ratio were made on each specimen. The specimens were de-moulded 24 hours later and cured in water for 28 days.

Exposure of Specimen to High Temperatures

At the end of the specimens curing age, they were removed from the curing tank and allowed to dry after which they were heated in the oven at elevated temperature 40^0C, 60^0C, 80^0C and 100^0C for 24 hours before being subjected to compressive load from compression machine armed with dial gauges after cooling. One guage was fixed on the vertical plane and one on the Circumference of the centre section on the lateral plane to determine the longitudinal and lateral extensions respectively (plate 1 and 2). The lateral strain was determined from the attached lateral dial guage. Similarly, the longitudinal strain was obtained from the longitudinal dial guage. The value of Poisson's Ratio is obtained by dividing the lateral strain by the corresponding longitudinal strain.

ΔH = change in length (Lateral)
ΔV = change in length (longitudinal)
L = Original Length (150mm)

$$\text{Lateral strain (EH)} = \frac{\Delta H}{L}$$

$$\text{Longitudinal strain (EV)} = \frac{\Delta V}{L}$$

$$\text{Therefore } N \text{ (Poisson's Ratio)} = \frac{EH}{EV}$$

Plate 1: Sample of specimen inside the oven

Plate 2: Compression machine armed with dial gauges

RESULTS AND DISCUSSION

Table 4 to 6 and figure 1, show the effect of temperature increase on Poisson's Ratio of laterite concrete. The results show that the value of Poisson's Ratio decreases as the temperature increases in all the mix ratios. The result follows the pattern of conventional concrete at increase temperature (Lee et al, 1988). When conventional concrete is exposed to elevated temperature, it begins to experience dehydration reactions in the hydrated cement paste, possible thermal incompatibilities between paste and aggregate and eventual physiochemical deterioration of aggregate. This typical degradation is accompanied by a decrease in the stiffness (modulus of elasticity) of the concrete. Repeated thermal cycling as a result of temperature increase reduces the peak strength and could loosen the bond between the concrete and the reinforcing bars.

Table 4 Effect of temperature increase on Poisson's Ratio of laterized concrete for mix (1:1.5: 3)

Temperature ^{0}C	ΔH (mm)	ΔV (mm)	EH	EV	Ɲ
40	4.21	6.45	0.0281	0.043	0.6535
60	3.82	6.07	0.0255	0.0405	0.6296
80	3.53	5.67	0.0235	0.0378	0.6217
100	2.84	4.99	0.0189	0.0333	0.5676

Table 5: Effect of Temperature increase on Poisson's Ratio of laterized concrete for mix (1:2:4)

Temperature 0C	ΔH (mm)	ΔV (mm)	EH	EV	Ɲ
40	4.05	6.29	0.027	0.0419	0.6444
60	3.61	5.83	0.0241	0.0389	0.6195
80	3.31	5.24	0.0221	0.0349	0.6332
100	2.42	4.06	0.0161	0.0271	0.5941

Table 6: Effect of Temperature increase on Poisson's Ratio of laterized conerate for mix (1: 3:6)

Temperature ^{0}C	ΔH (mm)	ΔV (mm)	EH	EV	Ɲ
40	3.97	5.89	0.0265	0.0389	0.6812
60	3.59	5.74	0.0239	0.0383	0.624
80	3.27	5.09	0.0218	0.0339	0.6431
100	2.22	4.01	0.0148	0.0267	0.5543

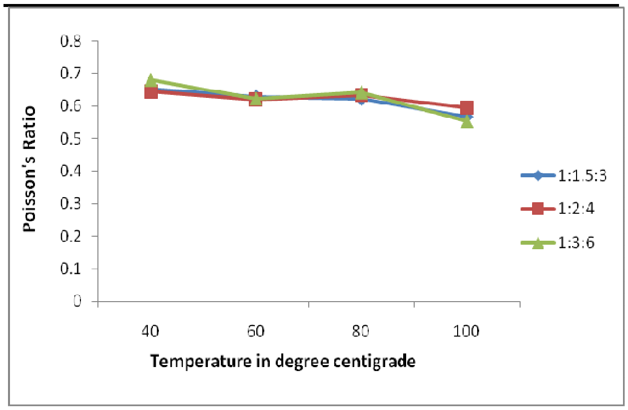

Fig 1 Effect of Temperature increase on Poisson's Ratio of samples

CONCLUSIONS

From the research work carried out on the effect of temperature on laterized concrete it is concluded that the Poisson's Ratio of laterized concrete (Terracrete) decreases with increase in temperature. This result is in line with that of conventional concrete. Temperature changes caused the horizontal strain and vertical strain to change. In general high temperature cause both horizontal and vertical strain to increase. Colder temperature causes both strains to decrease. The net effect on Poisson's Ratio was found to be small since both horizontal and vertical strain change by a similar amount.

RECOMMENDATION

Based on the conclusions above it is recommended that the design of laterized concrete structures take into account the variability of the properties with temperature levels as they could influence the structural behaviour, strength and stiffness.

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