STRENGTH CHARACTERISTICS OF CUBE AND CYLINDER SPECIMENS OF LATERIZED CONCRETE **

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Summary

In recent years, research efforts have been directed towards the investigation of the practical usefulness of lateritic soils in the construction industry. This paper presents the results of one such research effort. This is the continuation of the research work going on in the Department of Agricultural Engineering on lateritic soils. The strength of cubes and cylinders made from landcrete** has been compared when different mix proportions and water/cement ratios were used at different curing ages.

The results have shown that higher compressive strengths were obtained for cube specimens than for cylinder specimens. Also, increase in water/cement ratio brought about decrease in compressive strength of landcrete specimens and that increase in cement content of both landcrete and concrete mixes resulted in increase in compressive strength obtained. The cylinder/cube strength ratios for both landcrete and concrete decreased with increase in curing age. There was also similarity in the mode of failure of specimens made of landcrete and those made of concrete.

INTRODUCTION

The problems besetting the construction industry in Nigeria are numerous but of paramount importance is the unavailability or scarcity of construction materials with the resultant increase in cost. These have dictated the need to look critically at lateritic soils with a view to determining the extent to which they can be used either as substitutes or as radically new materials in the building industry. Lateritic soils respond more favourably to cement stabilization than temperate soils as reported by Lasisi.[1] Although laterite is a material that has been used in the building construction industry of Nigeria for a very long time, especially in the rural areas, there is a lack of adequate data to fully understand the behaviour of this abundant material. Such data is essential for effective utilization.

This paper therefore presents the results of some of the research work on the strength characteristics of landcrete cube and cylinder specimens. This forms part of the research programme currently going on at the University of Ife with a view to developing design paramaters for the effective structural applications of lateritic soils as a component in concrete.

PREVIOUS WORK

The move towards improvement in indigenous technology has prompted research activities on the practical usefulness of lateritic soils. Earlier studies by Lasisi and Osunade [2, 3] have found out that that finer the grain size of the lateritic soils, the higher the compressive strength of the unstabilized cubes made of such soils. They have also reported that the possible formation processes form a factor in the strength determination, and that the compressive strength of lateritic soils is a function of the source from where they are collected. Mesida [4] has reported that the lateritic soils in Okitipupa area of Ondo State of Nigeria need only 10–12% cement stabilization to become reliable for building purposes in that area. Stabilization with cement, lime, bitumen, etc. has been found by Ola [5] to be an effective means of improving engineering properties of lateritic soils both for road construction and for lowcost housing. He has also reported the successful use of soils around Zaria with a minium compressive strength of 4.14 MNm^{-2} after drying to constant weight. Okunnu [6], who also worked on stabilized lateritic soils, discovered that stabilized lateritic soils can compare favourably with cement-sand mixes. Stabilized lateritic soils are capable of being used in many areas of building construction i.e. as load-bearing walls, partition walls, etc. This was part of the study reported by Aderibigbe et al.

** Landcrete is concrete in which the fine aggregate is from lateritic soils.

Manuscript received on 2nd May, 1986.

[7] Lasisi and Ogunjide [8] who worked on the effect of grain size on the strength characteristics of cement-stabilized lateritic soils have reported that the compressive strength is inversely proportional to the grain size, i.e. within the grain size ranges of between 0.425mm (lower limit) and 4.75mm (upper limit), the finer the grains, the greater the strength. They also submitted that the laterite/cement mix proportion at, and below, which cubes made from grain-size ranges in their study, would gain strength with age is 3:1. Work has alos been done (Akinmusuru and Adebayo [9] on the fibre-reinforcement, using local rope fibre with a mean tensile strength of 50 Nmm^{-2} as a way of improving the properties of masonry units for construction. At ambient temperatures, the crushing strength of mud blocks made of lateritic soils are reinforced with pieces of repe material, also locally produced and available, was studied. Maximum compressive strength was obtained using about 2.5% by weight fibres. This compressive strength was improved by up to 50% over that of unreinforced blocks. Recent investigations by Lasisi and Osunade [10] have shown that increase in cement content and decrease in optimum water/cement ratio (ranging between 0.494 and 1.013) of laterized concrete prisms bring about increase in the compressive strength obtained. The mix ratio of 1 part lateritic soils plus 1½ parts river sand as a replacement of sand in normal concrete, produced a slightly higher strength than the conventional concrete grade 20. They also reported that different curing ages and imposed load considered resulted in corresponding increase in the values of the creep of laterized concrete prisms obtained.

METHODOLOGY

Material Collection

The lateritic soils used for this investigation were collected from a borrow pit situated along the Ife-Ibadan road. Sand was collected from one of the construction sites on the campus while the coarse aggregates were from crushed granite of igneous origin with most grains of a uniform size of between 8mm and 12mm. The cement used was local cement from Shagamu Factory of West African Portland Cement Company, whose properties conform to BS12 for ordinary Portland Cement.

Grain Size Selection

Sieve analysis of the lateritic soil sample was carried out with details shown in Figure 1. In addition to this, the lateritic soil sample was seived using sieve No. 8 (aperture 2.36mm) and sieve No. 50 (aperture 0.30mm) to obtain the materials regarded as lateritic sand to be used as fine aggregate. The selection of these sieve sizes (i.e. 0.30mm to 2.36mm) was based on Table 1. [12] The range of size of the crushed aggregate used is 8 — 18mm, with the grain size distribution shown in Figure 1 also.

Water-cement ratio

The variation of water-cement ratio with compressive strength was first established experimentally in the course of this work. This was done for each mix proportion used. The procedure followed was simply by measuring a specific quantity of water, added it to the already prepared mixture of cement, lateritic sand and gravel and then stirred together until a workable mix was obtained. The weight of water in the prepared workable paste divided by the weight of cement in the same paste gives the water-cement ratio. For this study the values of the water-cement ratio used were 1.4, 1.6, 1.8, and 2. 0. It is to be noted that materials have been kept under cover for extended period and were effectively air dried before use.

Batching, Mixing and Moulding of Specimen

The pre-determined mix proportions of concrete according to CP114 was adopted. The mix proportions considered were 1:2:3, 1:2:4:, and 1:3:6. The batching was by weight using on Avery weighing scale.

Two types of mould (cube moulds of 100x100x100mm) and cylindrical moulds of 150x300mm) were used for making the specimens. The different mixtures of cement, lateritic sand and gravel and those of cement, sand and gravel were 'worked' manually. The working process involves the gradual addition of water to the mixtures already made and the continuous stirring with a shovel until an even paste which gives a slump of about 30mm was obtained. No mixer was used in the "working" process because the quantity of the materials involved was small. There are secondary problems related to stickness produced by the clay in laterite.

Each cube specimen was made by filling each mould in three layers and compacting manually each layer with 35 strokes of a steel rod which was 480mm long and ramming surface of 25mm diameter. In case of the cylindrical specimens, the fresh landcrete and concrete mixes were poured each into each mould in six layers with 35 strokes delivered on each layer for sufficienc compaction. The specimens were allowed to set inside the moulds for 24 hours before they were stripped. They were then water cured and their compressive strengths determined after 7, 14, 21, and 28 days.

Specimen testing for strength characteristics

The strength characteristics of the landcrete cubes and landcrete cylinders together with corresponding concrete cubes and cylinders were tested using a loading rate of 120kN min $^{-1}$ on a 600kN Avery-Denison Universal Testing Machine. A standard 2000kN Avery-Denison Concrete Compression Machine was used for the regular concrete specimens. Four specimens for each age, which were brought out from the curing tank were allowed to rest for 2 hours to allow the excess water to drain off before crushing. The mean values of the maximum loads at which each group of four specimens failed were found and the compressive strength determined. The results are shown in Figure 2, 4 to 8.

DISCUSSION OF RESULTS

From this experiment, the following observations were made: From Figure 2, the compressive strength of the landcrete cube decreases with increase in water/cement ratio. For example, for 1: 2: 4, mix proportion the compressive strength for 1.2 water/cement ratio was 5.8Nmm $^{-2}$ which is 4.1Nmm $^{-2}$ higher than the value obtained for 1.8 water/-cement ratio. Also for 1: 3: 6 mix proportion, the compressive strength for 1.0 water/cement ratio was 9.9Nmm $^{-2}$ which is 54.5 percent higher than the value of 4.5Nmm $^{-2}$ obtained for 1.6 water/cement ratio. However, a decrease in compressive strength resulting from a corresponding increase in water/cement ratio agrees with the findings of Shacklock. [11]

From Figures 4, 5, and 6, the compressive strength of landcrete cubes and cylinders increased with increasing curing age. The same trend occured in the case of concrete cubes and cylinders as shown in 7, 8, and 9. However, in all cases, the compressive strength values obtained for cubes were higher than those obtained for the cylinders. For example, from Figure 4, the compressive strength of landcrete cube at 21 day curing was 3.8Nmm $^{-2}$ while it was 2.65Nmm $^{-2}$ for the landcrete cylinder. Also from Figure 5, the compressive strength of landcrete cube at 28 day curing was 7.25Nmm $^{-2}$ which was 2.00Nmm $^{-2}$ higher than the value of 5.25Nmm $^{-2}$ obtained for landcrete cylinder at the same curing age. For the concrete for example, from Fig. 8, the compressive strength obtained for concrete cube at 14 day curing was 16.95Nmm $^{-2}$ while it was 13.5Nm m $^{-2}$ for concrete cylinder at the same curing age. From Figure 9, at 28 day curing the compressive strength obtained for concrete cube was 27.6Nmm $^{-2}$ which was 9.5Nmm $^{-2}$ higher than the value obtained for the concrete cylinder at the same curing age.

It is also evident from these curves that the values of compressive strength obtained for the concrete specimens were higher than those obtained for the landcrete specimens. For example, from Fig. 4, the compressive strength obtained for landcrete cube and cylinder at 28 day curing was 4.2Nmm $^{-2}$ and 2.8Nmm $^{-2}$ respectively while on Fig. 7, the compressive strength obtained at the same curing age for concrete cube and cylinder was 20.1Nmm $^{-2}$ and 10.9Nmm $^{-2}$ respectively.

For the concrete specimens on Figures 7, 8, and 9 the compressive strength obtained increased with increase in the cement content of each specimen. For example, from Fig. 7 for a concrete mix of 1: 3: 6, the compressive strength at 14 day curing was 15.1Nmm $^{-2}$ for the cube specimen while it was 16.64Nmm $^{-2}$ and 20.25Nmm $^{-2}$ for the concrete mixes of 1: 2: 4 and 1: 2: 3 respectively at the same curing age (Figures 8 and 9). In case of the landcrete specimens, the compressive strength obtained for 1: 3: 6 mix at 14 days curing was 2.30Nmm $^{-2}$ for cylinder specimen while it was 3.95N mm $^{-2}$ and 5.4Nmm $^{-2}$ for mixes 1: 2: 4 and 1: 2: 3 respectively (Figures 5 and 6).

From Figures 10 and 11, it was observed that the strength ratio (i.e. cylinder strength/cube strength) decreased with increas in curing age. This observation was true for the three mix proportions used in this experiment. For example, from Fig. 10, at 7 day curing for the three mixes, the strength ratio was 0.74, 0.74, and 0.76 respectively while at 21 day curing, it was 0.68, 0.71, and 0.73 respectively. Also from Fig. 11, at 14 day curing for the three mixes, the strength ratio was 0.58, 0.73, and 0.77 respectively, while at 28 day curing, it was 0.55, 0.64, and 0.65 respectively. It was also observed that the strength ratios of concrete specimens are higher than those of landcrete specimens up to 14 days of age but reverse occured thereafter. This behaviour needs further investigation particularly after 28 days of age.

The study of the failure pattern of the landcrete and concrete specimens showed that the mode of failure depends on the geometry of the test specimens. For cubes, the plane of failure was at about 45° and the crack lines are all over the surfaces of each cube. In case of cylinder specimens, the failure lines either ran diagonally from one edge at the top of the opposite edge at the bottom or it forms a cone-like shape.

CONCLUSIONS

From the foregoing discussions, the following conclusions can be made:

(i) that the compressive strength of landcrete cube specimens decreased with increase in water/cement ratio used.
(ii) that the compressive strength of cube specimens was higher than that of the cylinder specimens for both landcrete and concrete.
(iii) that the compressive strength of landcrete and concrete specimens increased with increase in the cement content of each specimen.
(iv) that the cylinder/cube strength ratio for both landcrete and concrete decreased with increase in curing age.
(v) that the mode of failure in cubes and cylinders made of landcrete are similar to those made of concrete.
(vi) that landcrete can be regarded as a potentially suitable substitute for normal concrete. Indeed this has significant implications for countries, particularly less developed ones, where the procurement of sand is costly and lateritic soils are abundantly available. Buildings for farm families or rural residents and livestock can benefit from this material.

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Table 1: Particle Size Limits*

Type	Range of Particle size (mm)
Cobbles	200 — 60
Coarse gravel	60 — 20
Medium gravel	20 — 6
Fine gravel	6 — 2
Coarse Sand	2 — 0.6
Medium Sand	0.6 — 0.2
Fine Sand	0.2 — 0.06
Coarse silt	0.06 — 0.02
Medium Silt	0.02 — 0.006
Fine Silt	0.006 — 0.002
Clay	0.002

*Smith, M.J., (1976) "Soil Mechanics", 2nd Edition, Macmillan, London, pp. 7 — 13.

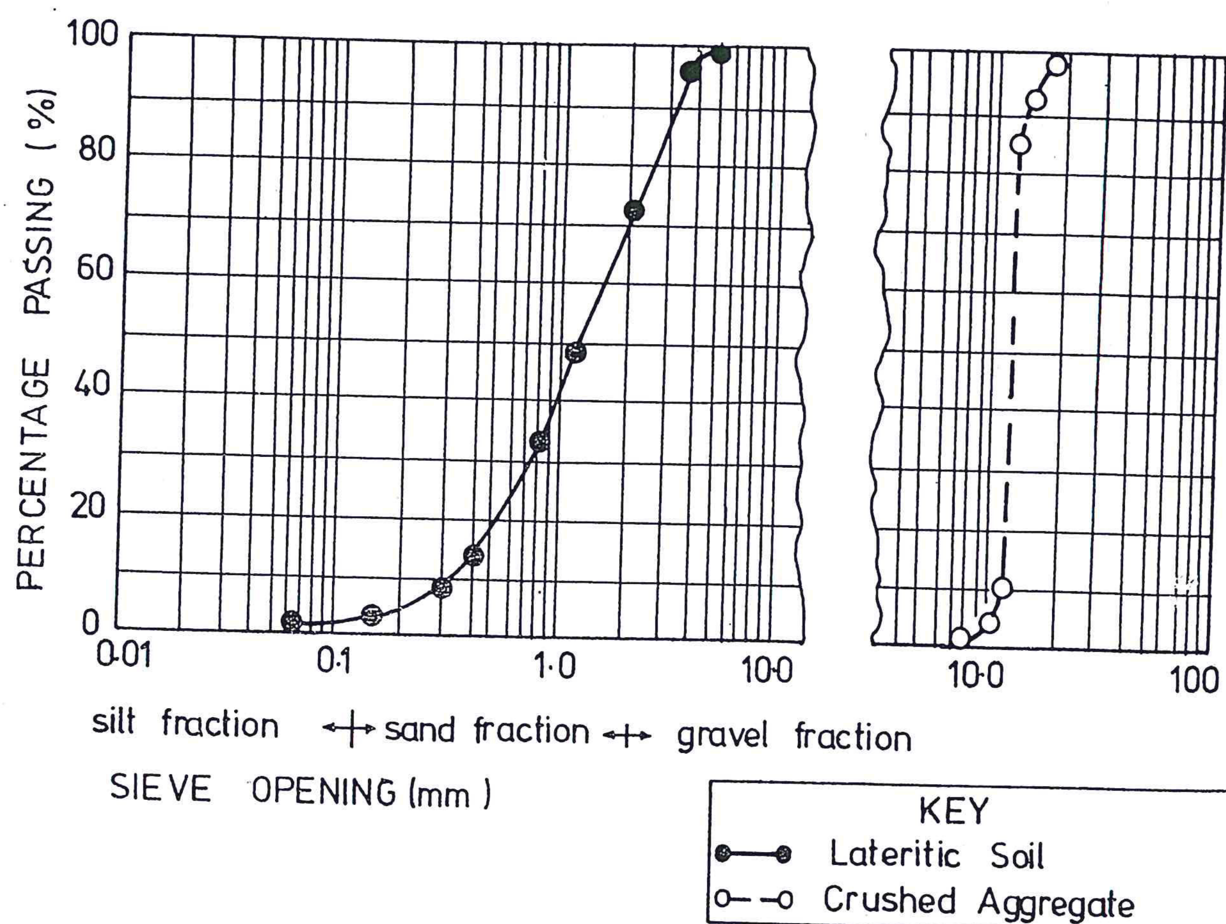

Figure 1: Grading curves for Lateritic Soil sample and crushed Aggregate.

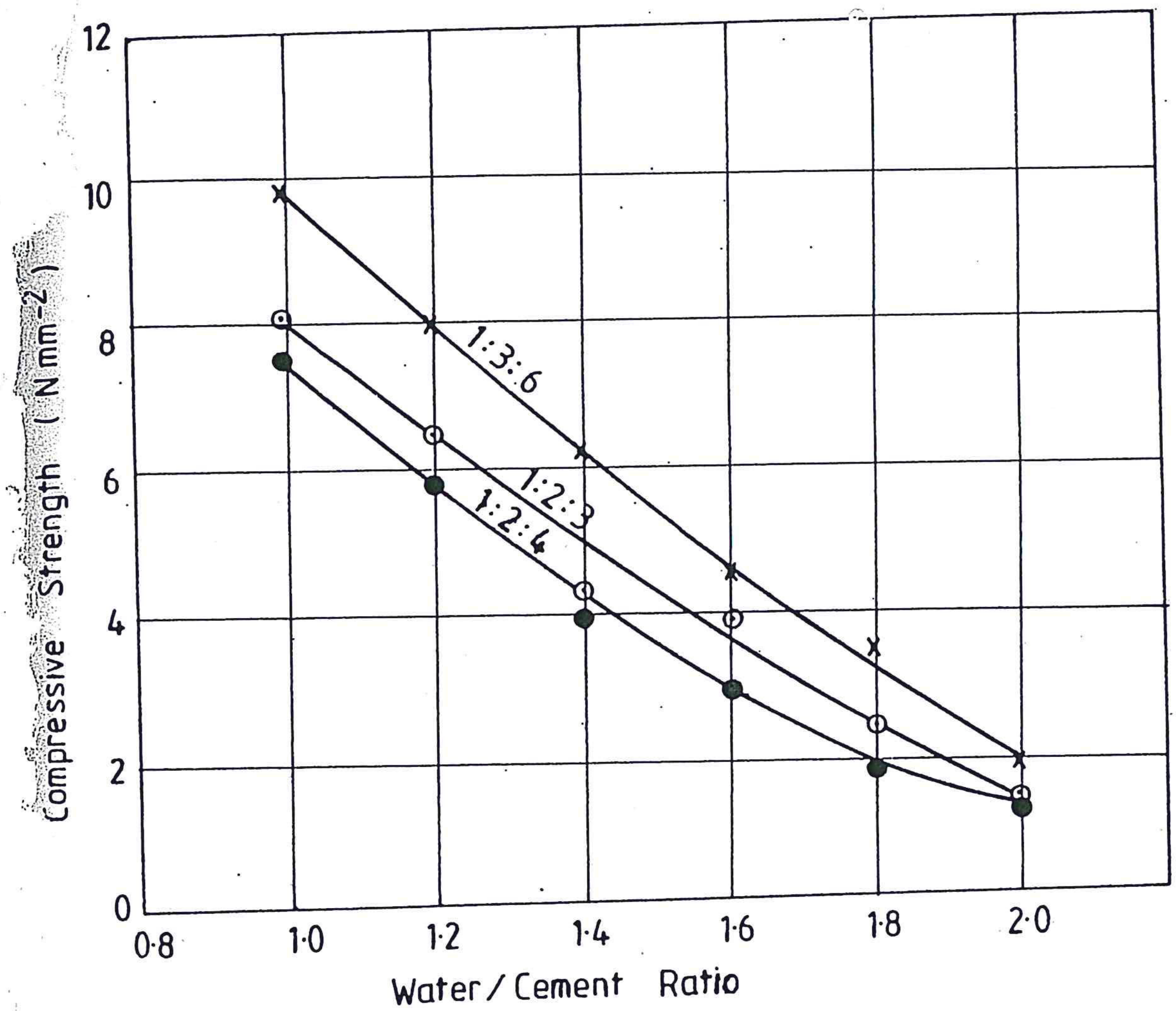

Fig. 2 Relationship between compressive strength and water/cement ratio for 100mm cubes of fully compacted landcrete made with lateritic soils and ordinary portland cement.

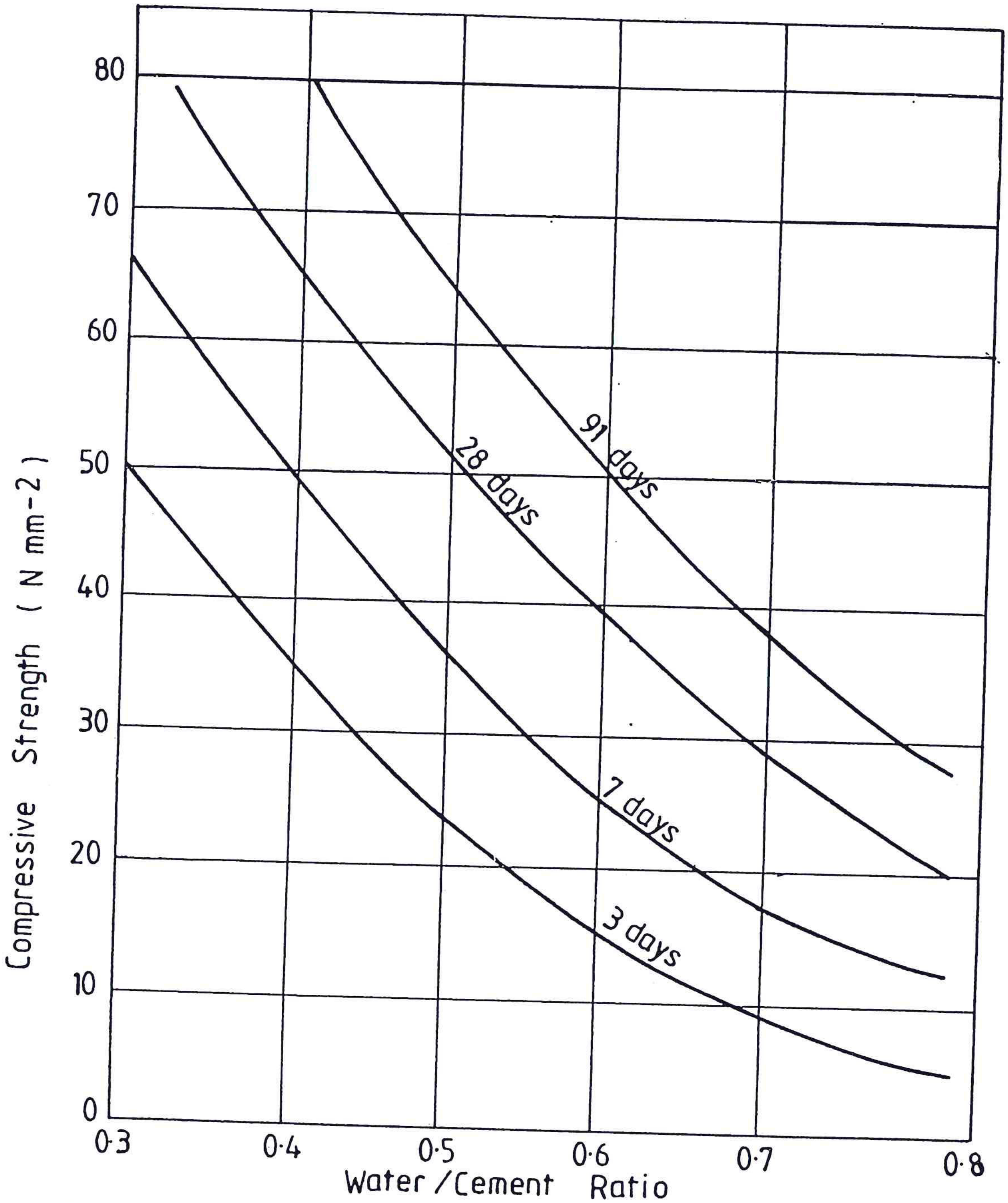

Fig. 3 Relation between compressive strength and water/cement ratio for 150mm cubes of fully compacted concrete made with ordinary portland cement (Shacklock, 1974)

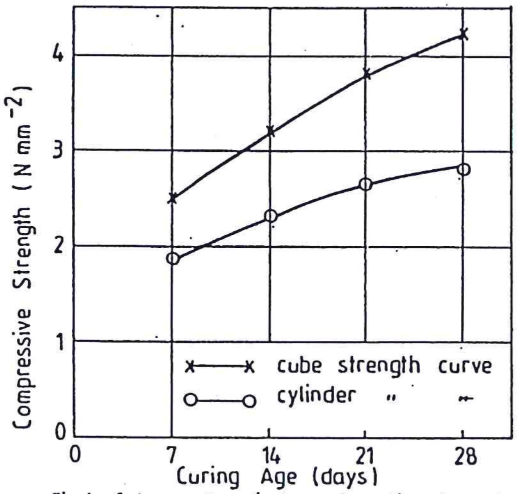

Fig. 4 Cube and cylinder strength characteristics at different curing age for landcrete (Mix proportion 1:3:6)

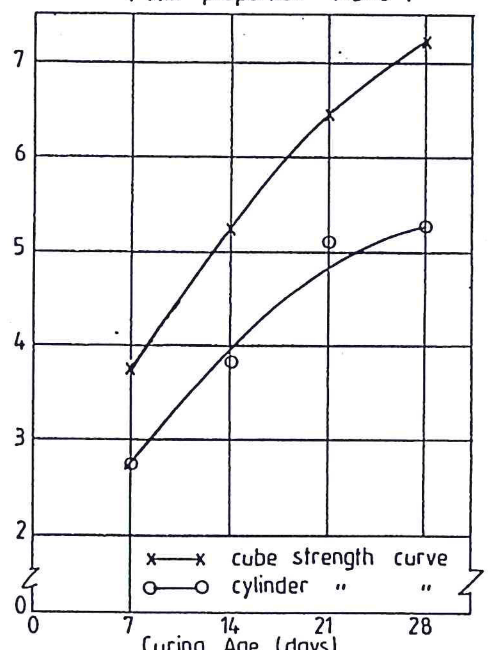

Fig. 5 Cube and cylinder strength characteristics at different curing age for landcrete (Mix proportion 1:2:4)

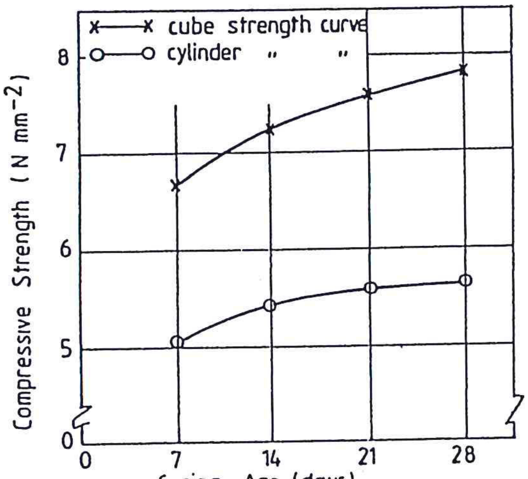

Fig. 6 Cube and cylinder strength characteristic at different curing age for landcrete (Mix proportion 1:2:3)

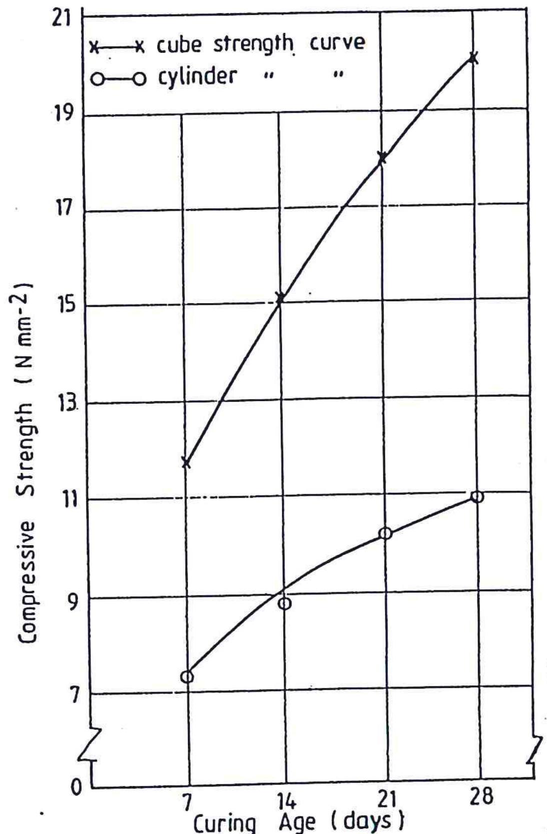

Fig. 7 Cube and cylinder strength characteris at different curing age for concrete (Mix proportion 1:3:6)

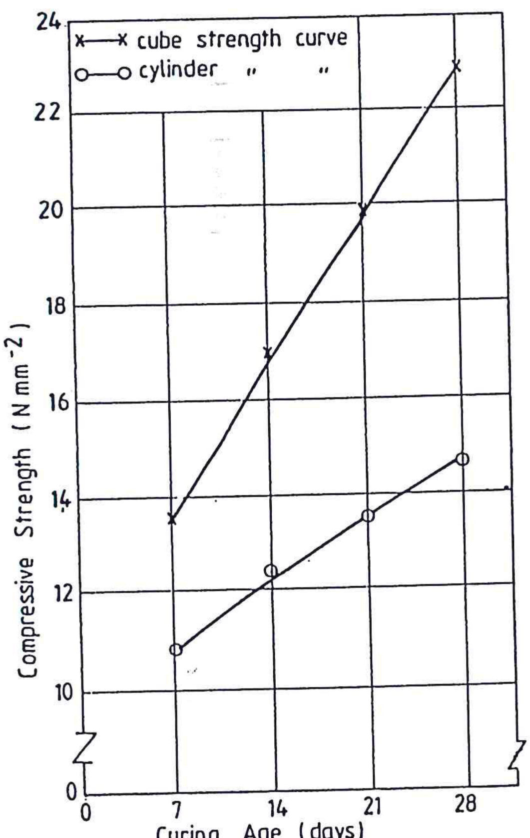

Fig. 8 Cube and cylinder strength characteristics at different curing age for concrete (Mix proportions 1:2:4)

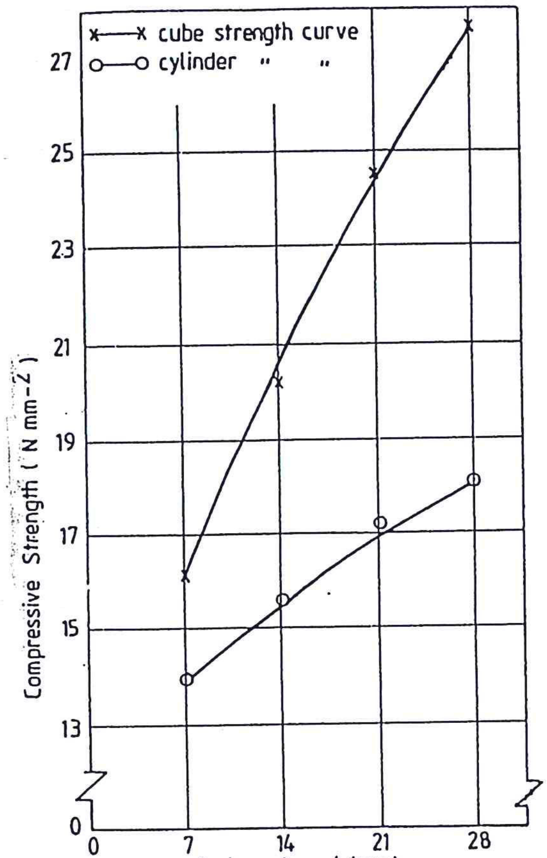

Fig. 9 Cube and cylinder strength characteristics at different curing age for concrete (Mix proportion 1:2:3)

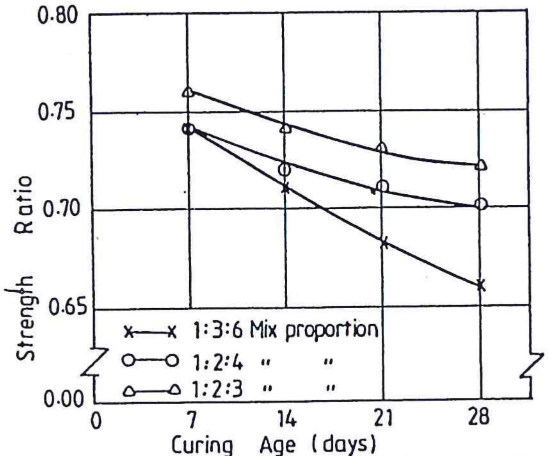

Fig.10 Relationship between cylinder strength/cube strength ratio and curing ages for landcrete

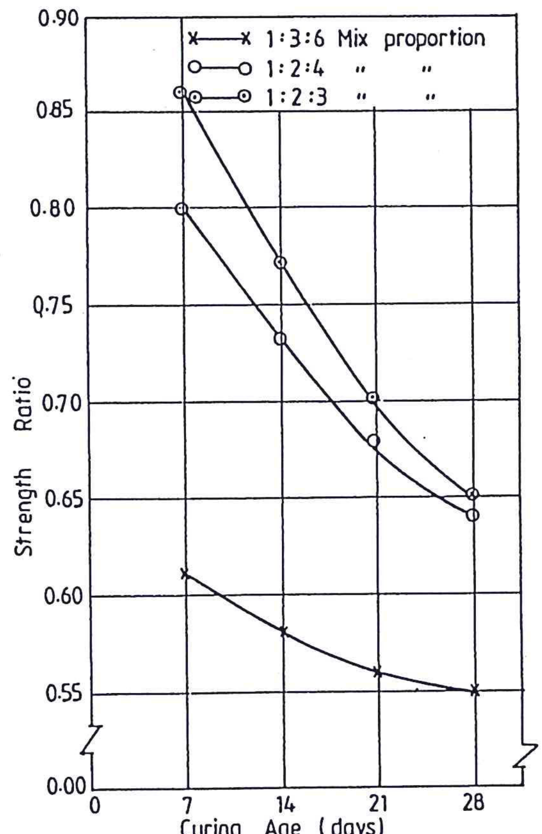

Fig. 11 Relationship between cylinder strength/cube strength ratio and curing ages for concrete