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Performance of interlocking laterite soil block walls under static loading

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HIGHLIGHTS

- Failure modes of stabilized laterite soil block wall are characterized by diagonal cracking of individual blocks or spalling of block debris.
- Lime stabilized laterite blocks exhibit higher compressive strengths but become brittle; rice husk ash stabilization makes the walls accommodate higher vertical deflections.
- Zero-mortar layer in interlocking block walls make them to have higher deflection when initially loaded before they can rapidly take up compressive load until failure is experienced.

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ABSTRACT

Little is known about the performance of unreinforced interlocking block masonry walls made using CINVA-Ram blocks subjected to static compression loads. In a laboratory study, Pozzolanic cement (C), hydrated lime (L) and rice husk ash (RHA) were used to stabilize laterite soil with sandy clay loam texture. The stabilized blocks were used to make three types of walls. The results indicated that block compressive strength, water absorption and durability (1-min abrasion test) were within the recommended levels at the optimum stabilizer percentages. The wall failure modes were characterised by either diagonal cracking of individual blocks or spalling of block debris. The performance of interlocking block walls in load capacity can be divided into three parts: (1) slow closure of gaps, (2) rapid load uptake, and (3) wall failure. This paper has established that interlocking wall compressive strength can be increased while the vertical deflection reduced at the optimum stabiliser content.

1. Introduction

The construction industry has over the years experienced introduction of different earth construction techniques geared towards improving the quality of earth construction. The interlocking stabilized soil block (ISSB) technology encourages sustainable construction. These blocks are manufactured by compressing stabilized soil in a mould with a manual or hydraulic press, and subsequent curing. The amount of stabilizer content mainly depends on soil characteristics and the desired strength. The interlocking mechanism enhances block stability and horizontal and vertical alignment of the constructed wall. The loads applied on an interlocking masonry wall are transmitted from one block directly to another and not through an intermediary mortar layer [1]. The absence of mortar in the bed and head joints of interlocking masonry wall may, however contribute to geometric imperfection. This may lead to a different structural behaviour from that of conventional masonry wall when loaded under vertical (in-plane) or under horizontal (out-of-plane) loads.

Locally available laterite soils may not be suitable for block making due to weak or low bearing capacity. Therefore, different materials having cementitious properties and those that are pozzolanic in nature are added in order to stabilize the soils. In this study, pozzolanic cement, hydrated lime and rice husk ash (RHA) were used in laterite soil stabilization. Cement reacts with water in soil mixture to form an insoluble cementation colloidal gel. A study [2] on stabilization of laterite soil reported a 28-day block compressive strength of 2.5 N/mm^2 with a cement content of 5%. Attempts to independently utilize lime in making stabilized earth blocks have been made out by several researchers [3,4]. An ultimate 28-day unconfined compressive strength of 2.4 N/mm^2 for laterite soil with 4% RHA added to cement content of 8% has been recorded by [5].

Masonry walls are mostly utilised in supporting compressive and horizontal loads [6]. Therefore, the structural performance of

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the wall to these loading conditions is of critical concern. A study by [7] on limit analysis of shear wall under lateral loads found that masonry walls may fail by separation, sliding and crushing of the block interfaces.

In various studies, the performance of interlocking block masonry walls under compression loading and horizontal loading has been done. Full scale wall panels were tested [1] under axial compression, lateral tension and flexural bending loads and concluded that the compressive strength of the wall was directly proportional to the strength of the masonry units. The test also found that the wall panel under lateral loads tended to lift at the base and rotated about the middle section of the wall before failure of the wall. Increase of eccentricity from the centre has been found [8] to reduce the strength of interlocking masonry wall. A test by [9] on interlocking walls grouted and reinforced with steel bars found that a larger height-to-width aspect ratio causes strength reduction in a wall, however it tended to increase ductility of the system. They also found that the lateral load resistance of a flexure wall will be reduced due to presence of a window at its centre. A study on the effect of soil stabilization on the failure pattern of interlocking soil block walls [10] established that under compression loading, un-stabilized soil block walls developed random vertical cracks while blocks stabilized with 2% municipal solid waste ash had cracks that propagated diagonally at an angle of 45° from the point of application. It was in [10] conclusion that the elimination of mortar in interlocking block walls made the failure not to depend on the weak bonds but on the characteristics of individual blocks.

In the previous studies, masonry walls have been tested with the vertical and horizontal loads being applied independently or with induced eccentricity on loading. A masonry wall in practice however, is subjected to vertical and horizontal loads simultaneously. The wall response to such loading is expected to be different. The aim of this paper therefore, is to evaluate the effect of pozzolanic cement, hydrated lime and RHA on the performance of unreinforced laterite soil block walls made using CINVA-Ram interlocking blocks subjected to vertical (in-plane) and horizontal (out-of-plane) compression loads simultaneously. The parameters measured included block compressive strength, masonry wall ultimate load capacity, vertical load displacement, stress-strain relationship and the failure mechanism.

2. Materials and methods

2.1. Test materials

The laterite soil used in this study was collected from Kiambu County, an area at the geographical coordinates of 1.1748 °S and 36.8034 °E. The laterite soil is commonly used for making stabilized blocks. The soil was obtained at a depth of 1 m below the earth surface in order to avoid the inclusion of humus materials. It consisted of about 25% fine gravel and 75% sand. The soil, classified according to the unified soil classification system as having a texture of sandy loam. The laterite soil plasticity index (12.1%) lies in the range (5–15%) proposed by [11] for soils which can be effectively stabilized using pozzolanic cement (Table 1). In this study, Portland pozzolanic cement 32.5 N was used. The cement was sourced from a hardware in Kiambu County.

Table 1
Atterberg limits properties of laterite soil.

Specimen	Type of test			
	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)	Linear shrinkage (%)
Laterite soil	29.0	16.9	12.1	7.5
Laterite soil + 6%C	39.1	31.3	7.8	5.5
Latetite soil + 6%C3%L	37.2	Non plastic	–	5.8

Lime has been found effective in stabilizing plastic clayey soils, ranging from clays to silty clays with plasticity indices greater than 10 leading to long term strength gain as reported by several researchers [12,13]. Commercial hydrated lime, Rhino lime, produced by Athi River Mining Company was used in this study. The lime had 94% calcium hydroxide, 72% calcium oxide, and other elements like magnesium oxide and silica.

RHA has been found by [14] to freely react with extra lime present in cement thus encouraging pozzolanic reactions. The rice husk ash therefore was used in this study to replace commercial hydrated lime. The ash was sourced from un-controlled burning source at Mwea rice irrigation scheme, Kenya. The RHA was sieved through 150 μm sieve before using as a stabilizer.

2.2. Material preparation and testing

The stabilizers (pozzolanic cement, hydrated lime and RHA) were replaced in percentage of dry weight of the soil. The interlocking blocks were moulded using CINVA-Ram press machine, producing units of dimensions 220 mm (length) × 220 mm (widt h) × 120 mm (height). The optimum stabilizer dosages were determined by testing the moulded blocks on curing for 7, 14 and 28 days. The physico-mechanical and durability properties of individual block units were established in accordance to [15]. The blocks that provided the highest compressive strength and had the best durability were used for construction of experimental walls.

The water uptake ability of the blocks was also determined in accordance with [15]. Two blocks that were cured for 28 days were randomly selected, weighed and submerged in a water bath for up to 24 h. The blocks were then removed from water and re-weighed.

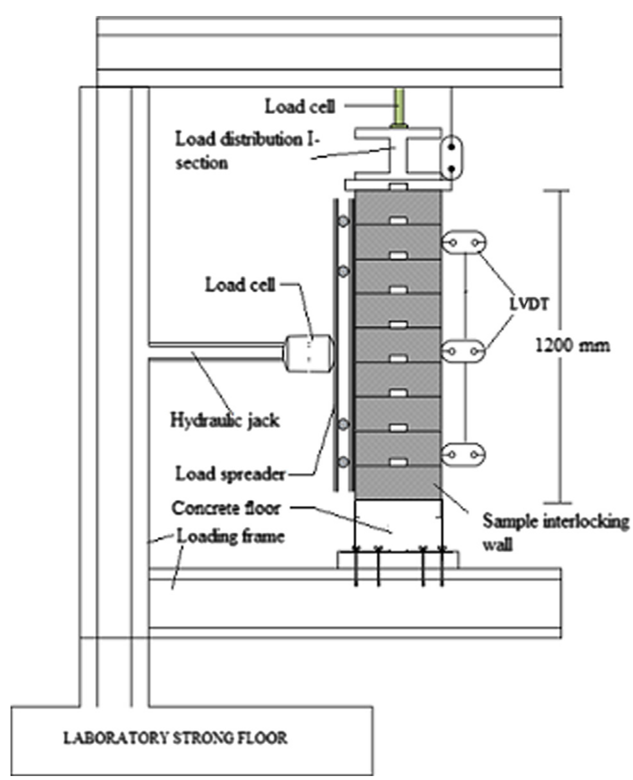

Fig. 1. Experimental test set up for the wall.