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# Influence of soil gradation, proportion and combination of admixtures on the properties and durability of CSEBs

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## HIGHLIGHTS

- Blocks were prepared by blending soil with sand to achieve varying clay contents.
- Cement and lime were used in four different combinations to prepare blocks.
- Blocks prepared with 6% cement and 2% lime are better at all contents of clay.
- Optimum lime content along with cement is beneficial for preparing blocks.
- Wider gradation of soils can be used to make blocks with use of cement and lime.

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## ABSTRACT

As it is well known that grading of soil influences the properties of compressed stabilized earth blocks (CSEBs), a need was felt to explore the possibility of using soils as found in nature for their production without physical modification or increasing the stabilizer content of 8% needed for their preparation as suggested in literature. This was made possible by the use of lime in combination with cement. Findings from this study would give flexibility in choosing soils of wider gradation as available in nature, thereby eliminating the need for blending with sand. This has a lot of practical significance and also application for the construction industry.



## 1. Introduction

Use of earth as a building material in various forms dates back to the time ever since human civilization learnt to build structures. Some of these can be evidenced from the remains of the civilizations of Mesopotamia (dated around 4000 years BC) and the Indus valley (dated 3300 to 1900 BC). Because of its availability in abundance, earth has invariably been the main construction material in providing housing systems in the form of conventional burnt bricks. Of late, considerable research has been undertaken to make earth as a sustainable construction material, leading to the development of technology using earth in the form of rammed earth and compressed stabilized earth blocks (CSEBs). Taking into consideration of the various factors affecting the quality and durability of stabilized earth blocks, concerted efforts in the past six decades have been made to make them a reliable walling unit as compared to the more energy intensive and not so ecofriendly fired bricks and concrete blocks [1].

Though, there are many factors that influence the quality and durability of CSEBs, the important factors among them are: composition of the soil being used to prepare the block, admixture content, and the density of the block [2]. For a selected density of the block and admixture content, soil composition is the main parameter that influences block properties, and hence its performance. Based on extensive research and field studies, it has been found that natural soils in their original composition are rarely suitable for the production of CSEBs as reported by Gooding [3], Venkatarama Reddy [4] and others. This becomes imperative due to the fact that soil as available in nature is quite variable in composition depending on the type of parent rock material. Hence, in the majority of the cases the natural soils are blended with some frictional material like sand or equivalent inert materials such that

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the resulting mixture is suitable for CSEBs production [4]. Thus the major challenge in the production of CSEBs is in specifying the optimum soil grading limits, which will yield maximum strength and give durability characteristics to the blocks [5].

Hitherto, the documented research on CSEBs indicate that all soils available in nature are not suitable to prepare CSEBs, and needs reconstituting of the soil such that sand, silt and clay are in certain proportions, especially the upper limit for clay to be present in the soil restricted to 14–16% [4,5]. In order to study the influence of soil grading, which is one of the important parameter that affects the properties of CSEBs, this experimental program was taken up. In this study, an attempt has been made in the direction of preparing good and durable blocks with soils having quite varying soil proportions, especially higher clay content (as this is one of the important factor affecting the block's performance), by using conventional stabilizers, namely cement and lime in combination to take their beneficial action when used together as reported in the literature [6]. The findings from this study would give wider flexibility in choosing the soils as available in nature without the necessity of reconstituting for preparation of the blocks. This has a lot of practical significance and also application for the construction industry.

## 2. Guidelines suggested by various researchers for selecting soil for preparation of CSEBs

From durability and long-term performance points of view, tropical red soils containing kaolinite as the principal clay mineral are found to be suitable for the manufacture of CSEBs [7]. Continuous efforts by various researchers has led to guidelines being suggested for selecting the suitable type of tropical red soil taking into account the presence of various fractions in the soil, such as sand, silt and clay; and the plasticity properties of the soil [2,5,8–15,16,17]. It is a well known fact that too much of clay in soil will cause cracks in the blocks, while too much sand will not provide sufficient green strength (strength of blocks immediately after preparation) leading to crumbling of blocks. Thus, a suitable soil must contain the right proportions of sand, silt and clay.

Various researchers have suggested different criteria like clay content, sand content and plasticity properties for assessing the suitability of soil for preparation of CSEBs using cement alone as a stabilizer, which are summarized in Table 1. It can be observed from the table that the range of clay suggested is quite variable, and it varies from as low as 0% to as high as 25%. Similar to clay, sand being a frictional material is also an important ingredient of the soil, which imparts strength to the blocks when present in optimum content. From Table 1, it can be observed that an optimum of 70% sand in soil is suggested for preparing good and durable blocks. Some researchers have also suggested plasticity properties as additional criteria to be considered while selecting the suitability of soil for stabilization. Therefore, a need was felt to explore the possibility of having a wider flexibility in the gradation of the soil to be used in the preparation of CSEBs. The results of an interesting research effort done in that direction has been presented in the following sections.

## 3. Methodology

### 3.1. Materials

For studying the effect of gradation of soil on the properties of blocks, a locally available red earth, which was clayey in nature with a good amount of clay, was selected. It was ensured that the selected soil was air dried, pulverized to break the clods and sieved through 4.75 mm sieve. Other materials used in the study were sand, ordinary Portland cement and lime. Ordinary Portland cement used in the study conformed to the requirements of IS: 12269-1987 [18], while lime conformed to IS: 712-1984 [19]. The selected soil was characterized for its physical properties namely, liquid limit, plastic limit, shrinkage limit, particle size distribution, specific gravity and free swell using the standard procedures as specified by SP-36 (Part1)-1987 [20] and the results are reported in Table 2.

Free Swell Ratio as defined by Prakash and Sridharan [21] has been used as a simple method of identifying the presence of principal clay mineral in the soil. The soil used in this study, is non-expansive in nature as inferred from FSR value, being 1.2, indicating kaolinite as the dominant clay mineral. The same has been reported in Table 2.

Sand was tested for its specific gravity and particle size distribution and the results are also reported in Table 2.

### 3.2. Proportioning of the soil–admixture mix

To evaluate the effect of soil gradation on the strength and durability of blocks, and thereby the need to choose the optimum combination of admixtures to meet this requirement, various combinations of soil composition and admixtures were chosen as tabulated in Tables 3 and 4 respectively. It can be seen form Table 3 that there are seven variations of clay content starting from 29% (as present in the natural soil) to 9%. This was achieved by suitably adding sand to soil, and reconstituting it to get the desired level of clay content. From Table 4, it can be seen that there are four combination of admixtures, namely cement and lime used in different combinations, keeping the total admixture content about 8% percent as recommended in previous studies [2,14]. Thus in total, twenty-eight series of blocks were prepared.

**Table 1**
Guidelines suggested by various researchers for selecting soil to be used in the preparation of CSEBs using cement as stabilizer.

| Source | Clay content (%) | Sand content (%) | Liquid limit (%) | Plasticity index (%) |
|---|---|---|---|---|
| Fitzmaurice [8] | 5–20 | 20 Minimum | <40 | 2.5–25 |
| United Nation [9] | 10–25 | – | – | – |
| Spence & Cook [10] | 0–25 | – | – | – |
| Norton [11] | 10–25 | – | – | – |
| Oliver and Mesbah [12] | 20 | 70 | – | – |
| Venkatarama Reddy & Jagadish [13] | – | 70+/−5 | – | – |
| Walker [14] | – | – | – | 15–20 |
| Guettala [15] | – | – | – | <15 |
| Venkatarama Reddy & Walker [16] | 10–12 | – | – | – |
| Venkatarama Reddy et al. [2] | 14–16 | – | – | – |
| Hyug–Moon Kwon et al. [17] | 10–14 | – | – | – |
| Venkatarama Reddy & Latha [5] | Optimum clay: 10-fine grained soils 14-course grained soils | – | – | – |