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Mud-concrete block (MCB): mix design & durability characteristics

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ABSTRACT

Mud-Concrete is a novel concept which employs a form of 'Concrete' produced using soil, cement and water. The initial concept of developing Mud-Concrete was to incorporate both the strength and durability of concrete into mud-based constructions to introduce a low-cost, load-bearing wall system with easy construction techniques which ensured indoor comfort while minimizing the impact on the environment. Here the fraction of soil is fulfilling the role of aggregate in the material and low quantities of cement will act as a stabilizer. Precisely the usable gravel range and the gravel percentage governs the compressive strength of the material. The considerable high-water amount is used for the hydration of cement and keep the flow of this material. This excessive water amount is enhancing its self-compacting quality, which is capable of self-consolidation, having the ability of passing, filling and being stable without the need of any external forces. Experimental test findings determined the mix proportions of Mud-Concrete block as 4% cement (minimum), fine ≤ 10% (≤ sieve size 0.425 mm), sand 55–60% (sieve size 0.425 mm ≤ sand ≤ 4.75 mm), gravel 30–35% (sieve size 4.75 mm ≤ gravel ≤ 20 mm) and water 18% to 20% from the dry mix. Findings further confirmed that the durability of the Mud-Concrete block satisfied the required durability standards recorded in SLS 1382.

1. Introduction

Materials are considered as the most imperative component of a building construction. Presently, an increasing demand for materials in the construction industry has resulted in the significant consumption of natural resources. This has gradually led to an increase in prices of construction materials as well as to a scarcity of resources [1]. Furthermore, 40% of today's global energy is consumed by the building construction industry which also contributes 1/3 of the total greenhouse gas emissions, both in developed and developing countries [2]. This situation has created a need for sustainable materials with low energy consumption and environmental impact during both the manufacturing process and at the operational level. Therefore, identifying alternative building materials with simple construction technologies are required to promote sustainable & affordable construction that satisfies the comfort standards required today. 'Soil' can be considered as one such sustainable raw material which has been used extensively for building construction since ancient times [3]. Adobe construction dates back to the walls of Jericho which were built around 8300 B.C and earth is the most conspicuous building material in the civilisations of Mesopotamia dated 6000 years ago [4,5]. Earth has been used in the construction of shelters for thousands of years and approximately 30% of the world's present population still lives in earthen structures and is extensively used for wall construction around the world, particularly in developing countries [6,7]. Soil construction offers a number of environmental benefits, including lower embodied energy levels, high thermal mass and increased use of locally sourced materials [8]. However, with the development of newer building materials, earthen building systems have been largely abandoned in parts of the world where they were once commonly used [4]. Considerable research has been undertaken in

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modern times to adapt earth as a sustainable construction material. This has led to the development of technology using earth in the form of rammed earth and unfired bricks popularly known as Compressed Stabilized Earth Blocks (CSEBs) [9]. The main advantage of manufacturing unfired bricks is that it requires lesser energy than fired bricks, and resultantly releases 80% less carbon dioxide into the atmosphere [10,11]. It has been attempted extensively for more than 6 decades to improve unfired stabilized bricks into a reliable substitute for the more expensive fired bricks and concrete blocks [12,5].

Constituents of earthen building systems include a binder soil, typically clay, clay-silt mixture or loam and inorganic or organic tempering materials or both. Sand and gravel are the most commonly used inorganic tempers while straw, hair, and chaff are the commonly used organic tempers. Soil may be stabilised, using materials such as cement, asphalt emulsion, calcined gypsum or cactus juice, or maybe unstabilized. Adobe bricks may be held together by a variety of mortars. Systems may be finished with plaster or pigments, or both, or left unfinished [12].These mixtures may be naturally occurring local soils or engineered by mixing different soils [4]. According to the literature, laterite soils and clayey soils are favourable for cement stabilised soil blocks [13]. Literary sources also state that maintaining a fine content below 20% in rammed earth wall construction by using laterite soils with sandy, hard laterite or clayey compositions would result in higher wall strength [4,14]. Furthermore, proper grading of the soil mix, proper compaction and proper stabilisation using admixtures would ensure increased density, reduced water absorption, and increased frost resistance thereby increasing the wet compressive strength of masonry blocks [9].

Earthen building systems have not been engineered historically. The first written standards for adobe were developed in the United States in the 1930s and were based on common construction practices. It was is only during the last 20 years that architects and engineers have attempted to engineer adobe and rammed earth for conventional use in compliance with contemporary building codes [4]. Even though mud-based construction was very popular in ancient times, it is not as publicly accepted in the industry at present due to several reasons. The primary reason stems from concerns relating to strength and durability. Social constructs of perceiving soil based building techniques as a low-cost solution for the housing needs of the poor has also resulted in creating a prejudice against earthen construction.

Therefore, the aim of this study is to develop the concept of Mud-Concrete technology with the required strength and durability standards and to combine traditional techniques with modern technologies to provide a highly sustainable material for the future of construction. Thus, the primary objectives are adopted to find the mix design and the durability of the Mud-Concrete blocks.

2. Materials and methods

2.1. Concept of developing mud-Concrete technology

Concrete is a composite construction material made out of cement, sand, coarse aggregate and water [15]. The coarse aggregate in the composition governs the strength, cement acts as the binder while sand (fine aggregate) reduces the porosity and water acts as the reactor for cement. In Mud-Concrete technology, the sand and coarse aggregate constituents of concrete are replaced by fine and coarse aggregates of soil (Fig. 1). The intended functions of sand and coarse aggregate are obtained by varying the particle sizes of soil. In this experiment, soil has been classified as follows [16]; (Table 1).

The main objective of the Mud-Concrete mixture was to develop a self-compacting mix which would be able to consolidate under its own weight. This self-compacting mix would not require any mechanical vibration or compaction after pouring and would follow the shape and surface texture of the mould/formwork once set [17,18]. To conceive the mud-concrete mixture as a self-compacting mix, it was essential to manage its fluidity while retaining its strength and durability properties. Thus, water became a key constituent of the mix. The initial task was to determine the proportion of water required to achieve the self-compacting phenomenon in Mud-Concrete. To prepare the self-compacting specimens, the designed amount of water was firstly mixed with the sample, consisting of dry soil, gravel, sand and cement to obtain fluid mixtures. After 10 min of mixing in a concrete mixer machine, the composition started to show self-compacting properties such as continuous flow, viscosity and filling ability. In this research process, the next important question is raised: how to test the workability of this soil mix? There is no standard method written to follow the self-compacted mix developed through soil based material in the literature. Due to the cohesiveness between the clay and the gravel particle in the mix, it is difficult to measure the direct flow of Mud-Concrete like the methods such as slump flow testing to measure the workability of fresh concrete. Therefore, we followed alternative simple technique to identify and standardise the self-compacting consistency of the Mud-Concrete mix.

As the first attempt, the research was designed to check the slump height and the slump diameter of the Mud-Concrete mix with

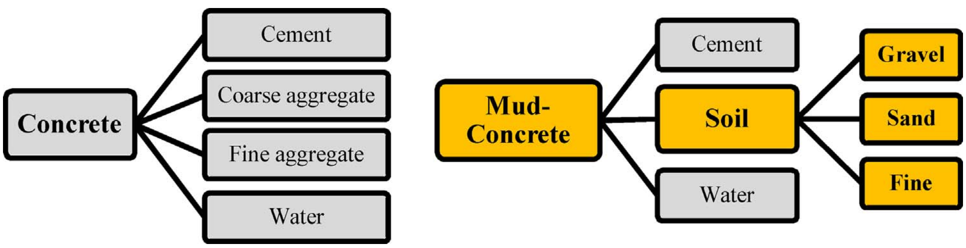

Fig. 1. Similarities of Concrete & Mud-Concrete.