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Low embodied energy cement stabilised rammed earth building—A case study

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ABSTRACT

Rammed earth is a monolithic construction and the construction process involves compaction of processed soil in progressive layers in a rigid formwork. Durable and thinner load bearing walls can be built using stabilised rammed earth. Use of inorganic additives such as cement for rammed earth walls has been in practice since the last 5–6 decades and cement stabilised rammed earth (CSRE) buildings can be seen across the world. The paper deals with the construction aspects, structural design and embodied energy analysis of a three storey load bearing school building complex. The CSRE school complex consists of 15 classrooms, an open air theatre and a service block. The complex has a built-up area of 1691.3 m^2 and was constructed employing manual construction techniques. This case study shows low embodied energy of 1.15 GJ/m^2 for the CSRE building as against 3–4 GJ/m^2 for conventional burnt clay brick load bearing masonry buildings.

1. Introduction

Rammed earth is used for the construction of load bearing walls. Rammed earth walls are built by compacting processed soil in progressive layers in a rigid formwork. Rammed earth constructions can be broadly grouped into two categories: stabilised rammed earth and un-stabilised rammed earth. The basic materials used for the construction of unstabilised rammed earth are soil, sand and gravel, while stabilised rammed earth uses stabilisers (cement, lime, etc.) in addition to soil, sand and gravel. Strength (in saturated state) and erosion due to rain impact are a concern for unstabilised rammed earth buildings. These concerns can be effectively addressed by using cement stabilised rammed earth. Portland cement is being used for rammed earth wall construction since the last 5–6 decades. Examples of cement stabilised rammed earth (CSRE) buildings can be seen across the world [1–4]. Low embodied carbon, seamless wall surface, scope for adjusting the surface texture and colour, and flexibility in wall thickness and plan form represent some of the major advantages of rammed earth construction. There is a growing interest among the building professionals to use CSRE walls for structural applications especially for the load bearing walls in the buildings.

There are limited investigations addressing the issues of strength and stability of CSRE walls [1,2,5–8]. Focused studies especially on the structural behaviour of CSRE walls are limited. Detailed investigations of Kumar [9], and Reddy and Kumar [10–13] throw more light on the behaviour of CSRE walls under compression. Walker et al. [4] attempted to give design guidelines for rammed earth walls based on the principles of masonry wall behaviour.

Proper design codes for designing multi-storey load bearing stabilised rammed earth buildings are not available. There is limited knowledge on the structural behaviour of storey height walls. Based on the results of few investigations [4,5,10–13] on strength and stability of stabilised rammed earth walls a three storey load bearing rammed earth school complex was designed and constructed at Bangalore. Bangalore is situated at 12°58′ N and 77°38′ E in India. The building was constructed in the year 2009. Mean annual minimum and maximum temperatures in Bangalore are 15 °C and 35 °C, respectively. Mean annual minimum and maximum temperatures in winter are 15 °C and 28 °C, respectively. There is no space conditioning in any part of the building complex for controlling the indoor climate.

The present investigation pertains to a case study illustrating the design, construction and EE analysis of a three storey high and load bearing CSRE school building complex. The study is focused on (1) demonstrating a structural design approach for load bearing stabilised rammed earth walls, (2) presenting construction details and quality control aspects where the construction was managed mainly by manual processes, and (3) analysis of embodied energy of the three storey load bearing school building complex. The present

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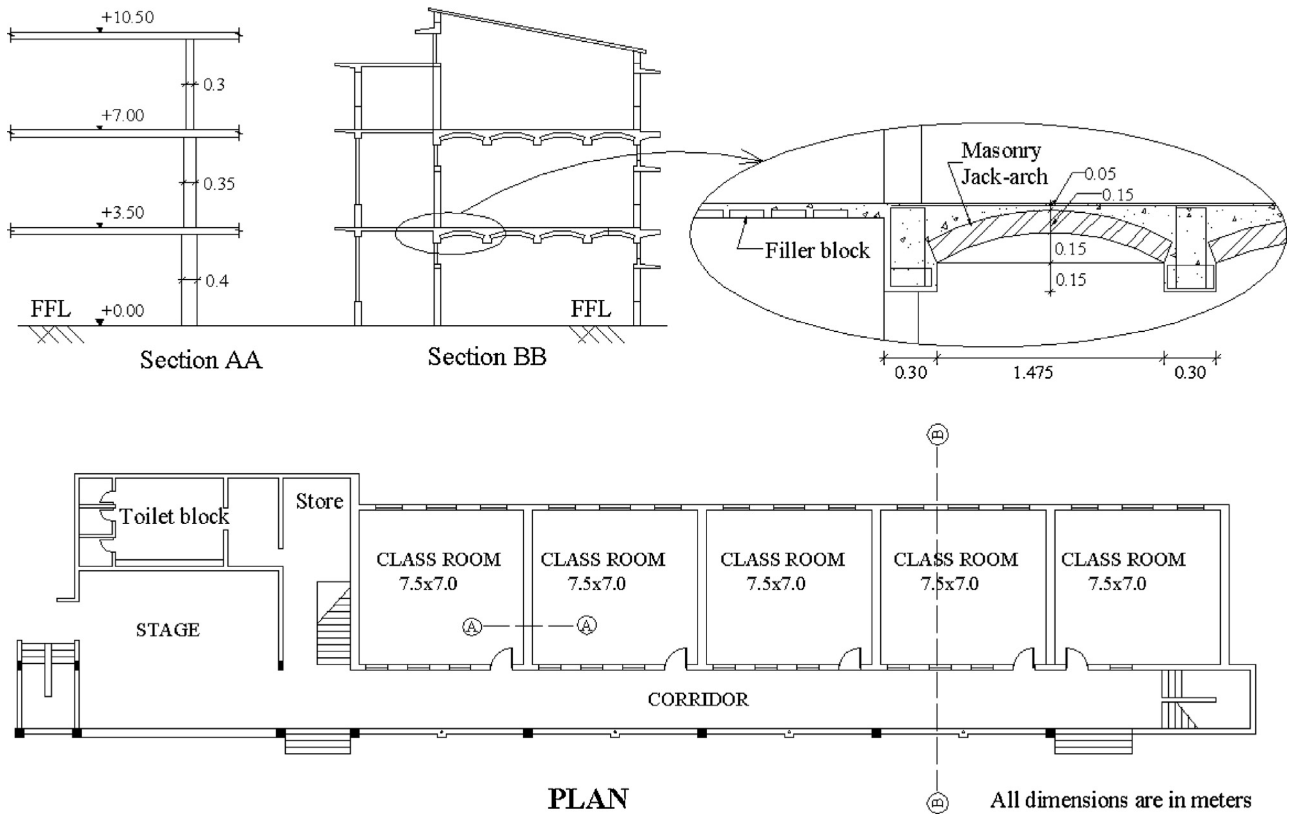

Fig. 1. Typical floor plan and sections of the school building complex.

study assumes importance because there are limited number of investigations concerning the design and embodied energy aspects of large span and multi-storey load bearing CSRE structures.

2. Details of the school building complex

This is a government run public school catering to the students pursuing primary and higher secondary education. There are about 1000 students studying in this school. Typical floor plan and the sections of the three storey school building complex are illustrated in Fig. 1. There are five classrooms 7.0 m × 7.5 m (clear dimensions) in each floor. Apart from the 15 classrooms, there is a common long corridor in each floor, double storey heigh stage/theatre hall and a service block. The total built-up area of the school complex is 1691.3 m^2. Fig. 2 shows a view of the three storey school building complex.

3. Technical specifications

Brief specifications of various components of the building are as follows.

3.1. Foundation and plinth

The foundation consists of spread footing built using size stone masonry in cement mortar. There is a continuous 100 mm thick reinforced concrete plinth beam with nominal reinforcement.

3.2. Walls and supporting structure

Load bearing CSRE walls have 8% ordinary Portland cement (by weight) as stabiliser. The main load bearing walls are the central walls; 400 mm thick in the ground floor, 350 mm in the first floor and 300 mm in the second floor as illustrated in section-AA of Fig. 1. The walls supporting the corridor slab and other walls are 250 mm thick. There are few reinforced concrete columns in the corridor and stage area. The columns in the corridor portions were provided mainly to drain-off the rain water from the roof through the pipes embedded in them.

3.3. Floor and roofing system

The floor slabs consist of composite beam and masonry jack-arch system as illustrated in section-BB of Fig. 1. The masonry jack-arch was constructed using a slip form formwork. Stabilised soil block masonry in cement–soil mortar was used for masonry

Fig. 2. View of the CSRE school complex.