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The use of polymer stabilised earth foundations for rammed earth construction

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Abstract

This paper presents a case study as part of a Professional Doctorate research project discussing an ecological approach to housing in South Africa, where polymer stabilised earth foundations have been used to support single story rammed earth walls, in a house in South Africa. Rammed earth was chosen as a construction method for its low embodied energy and thermal mass characteristics. The subsurface strata upon which the house was built comprised of clayey, gravely, sandy soils that have resulted as a result of decomposition of granitic rocks. In order to ensure solid founding conditions the foundations were excavated to a depth of one and a half metres before the excavated material was stabilised and backfilled. The material was stabilised to 600mm below top of floor level with 2% Portland cement and above that with a 5% polymer bitumen mixture reinforced with horizontal steel reinforcing rods. This foundation avoids the use of reinforced concrete and as a result a significantly smaller carbon footprint, while fulfilling the functional requirements of supporting the building and preventing rising damp. The polymer has, as it major component is bitumen emulsion, provided a waterproof layer. Rammed earth walls of 500mm thickness were constructed on the foundation up to 4.2 meters in height and initial observations suggest that the foundations are satisfactory with no settlement or cracking detected.

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Keywords: Rammed Earth Walls; South Africa; Foundations; Ecological Housing

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1. Introduction

This paper discusses a case study of a house, north of Johannesburg, South Africa, which was designed and built in 2014 following an ecological approach, by constructing all the walls with rammed earth. The rammed earth walls have a low embodied energy and were sourced entirely from the site upon which the house was built and stabilised with 4% lime by mass. Additional to this small quantities of natural oxides were used to colour the walls, and coupled with horizontal steel reinforcement were the only imported materials used in the walling for the house The paper also discusses a solution to one of the disadvantages of rammed earth walls, which is that due to their width (500 mm for the case study presented) these often require large reinforced concrete footings; which reduces their ecological benefits substantially. Thus, the paper discusses the foundation design and construction and reviews other alternatives considered for rammed earth foundations and describes the salient features of the design and construction for the polymer that was used. A good review of rammed earth construction is provided by Maniatidis and Walker [1] where they emphasize the need for the foundation to be water resistant and sufficiently deep.

2. Rammed Earth Housing Context

Earth building offers a sustainable solution to housing in South Africa but has poor acceptability in the region [2]. Prior research that examined acceptability of earth building looked at adobe houses with respondents having the perception that earth buildings are subject to collapse as they are both affected by rain and are not as strong as a clay brick and cement mortar house [2]. Current research by the authors on perceptions shows promise that rammed earth has greater acceptability than other earth construction methods in southern Africa. Most housing in South Africa is built using bricks and mortar with clay fired bricks being the most common type [3]. Rammed earth construction cost has been found to compare favourably with brick and mortar construction, with formwork and labour costs the biggest component. This research is investigating both the acceptability of rammed earth as an earth construction method for affordable housing, with early positive results, as well as exploring cost efficient and suitable construction practices for the southern African region.

3. Case Study

3.1. South African House

A rammed earth house was constructed in the north of Johannesburg (Fig. 1) 25^{o} 54’ S/ 27^{o} 56’ E designed with both a low embodied energy as well as an energy efficient design. The national standards of South Africa require masonry walls to have a R value of 0,35m^{2}K/W and as rammed earth has a value of 0,35 to 0,7m^{2}K/W for a 300mm thick wall [1] it was deemed prudent to exceed this to achieve more than the minimum thermal performance. Walls were to reach a maximum height of 4,2 meters and at a slenderness ratio of 10 [1] would result in a wall of 420mm thickness minimum. Thus, a wall width of 500mm was chosen that exceeded both these specifications. The walls were rammed from soil from the site coloured with natural oxides and stabilised with 4% hydrated lime. The house was roofed with corrugated iron, insulated with 70mm rigid insulation below, with 800mm roof overhangs to provide both summer shading and protect the rammed earth walls.

Figure 1 North View of rammed earth house