International Journal of Sustainable Built Environment (2016) 5, 141–155

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International Journal of Sustainable Built Environment

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Original Article/Research

Enhancing durability of adobe by natural reinforcement for propagating sustainable mud housing

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Received 25 July 2015; accepted 15 March 2016

Abstract

Low durability and compressive strength of adobe blocks leads to frequent maintenance problem associated with rural house wall construction. This forms the main reason of abandonment of vernacular mud housing building technology in rural areas today. The present paper presents an attempt to improve upon the low durability of adobe blocks by addition of natural reinforcement of Grewia Optiva and Pinus Roxburghii which otherwise are treated as waste material in rural areas. Experimental investigations were carried out for cylindrical and cubical stabilized and unstabilized soil samples. Durability tests conducted included wetting and drying test, water absorption and expansion test, sponge water absorption test, spray test, total absorption test, and water strength coefficient tests carried out as per Indian standards and international research. Results indicated that durability of stabilized soil samples increases by 72% and 68% for fibers of Grewia Optiva and Pinus Roxburghii as compared with unstabilized soil samples. The results recommend that fibers of Grewia Optiva and Pinus Roxburghii can be advantageously added in adobe blocks for improving durability. This would propagate durable mud housing on a large scale thereby reducing housing shortage especially in developing countries, economizing use of natural resources, reducing energy consumption during manufacturing of modern construction materials and most importantly provide sustainable way of living.
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Keywords: Adobe; Durability; Fibers; Grewia Optiva; Pinus Roxburghii

1. Introduction

1.1. Earth: most economical and user-friendly local building material

Earth is the oldest building material which is most commonly used for making shelter. Dethier (1986) and Coffman et al. (1990) discuss that nearly 30% of total population of world still resides in mud houses. It is one of the most popularly used building construction materials in Europe. Singh and Singh (2007) discuss that 55% of houses in India are constructed with mud walls. Earth is the most preferred building material for providing shelter for people especially in less economically developed countries as discussed by Danso et al. (2015). Research studies by Ciancio et al. (2013) regarding soil suitability test for rammed earth highlighted financial and environmental aspects of earth as construction material. The discussion

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Peer review under responsibility of The Gulf Organisation for Research and Development.

http://dx.doi.org/10.1016/j.ijsbe.2016.03.004
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on social, economic and environmental benefits associated with use of earth reveals that when soil is used as raw material on site both financial and environmental impact of the construction are significantly reduced. Ease of use of earth and associated building techniques can help employ even the unskilled labor. This would enhance self-help technology among rural people eliminating the need for costly transportation of labor, material and equipment from other places. This would also act as a boon for the areas where other construction materials and technologies are not available (Ngowi, 1997). Earth is used in varied forms for construction of shelters such as adobe, rammed earth, cob, wattle and daub, compressed soil blocks etc. (Delgado and Guerrero, 2006; Falceto et al., 2012).This varied use of earth depends upon climatic factors, topography and living requirements of inhabitants of the area. While use of compressed earth blocks have seen popularity over past few years as reported by Reddy et al. (2007), use of unbaked earth in shelter construction dates back to over thousand years as discussed by Minke (2001). Research by Falceto et al. (2012) discusses international durability tests in Spain regarding compressed earth blocks. The study discusses that different terminologies used in literature in this context like earth blocks as compressed earth blocks, cement stabilized earth blocks, compressed stabilized earth blocks, soil–cement blocks all refer to use of same product, that is earth blocks (without reinforcement). Similarly document by CRATerre (CRATerre-EAGC, 1998) states that compressed earth blocks comprise of different varieties with or without stabilization. AENOR (2008) discusses compressed earth blocks used for the construction of walls and partitions highlighting their benefits over use of raw earth blocks as adobe. Standards of New Zealand regarding earth buildings (NZS 4297, 1998; NZS 4298, 1998; NZS 4299, 1999) also state use of pressed bricks in construction of buildings. Similarly ASTM standards provide a set of guidelines for design of buildings involving use of varied forms of earth (ASTM. Standard guide, 2010). Middleton discusses use of pressed blocks in earth wall construction (Middleton, 1987). Standards of Sri Lanka (SLS 1382-1, 2009; SLS 1382-2, 2009; SLS 1382-3, 2009) regarding compressed stabilized earth blocks (CSEB) discuss at length the requirements, test methods and guidelines for production, design and construction with CSEB blocks. Use of soil–cement blocks either in a compressed form as CSEB or pressed blocks is considered beneficial and sustainable over other modern construction materials like burnt bricks, cement, glass etc. A similar idea is supported by standards of Brazil (ABNT.NBR 8491, 1986; ABNT.NBR 8492, 1986; ABNT.NBR 10832, 1989; ABNT.NBR 10833, 1989; ABNT.NBR 12023, 1992; ABNT.NBR 12025, 1990; ABNT.NBR 12024, 1992; ABNT.NBR 10834, 1994; ABNT.NBR 10835, 1994; ABNT.NBR 10836, 1994; ABNT.NBR 13554, 1996; ABNT.NBR 13555, 1996). These standards give specifications regarding use of soil–cement blocks. In India; standards give specifications regarding soil based blocks for general building construction purposes. Research works in CBRI Roorkee (India) regarding development of low cost sustainable building materials especially cement stabilized mud blocks and non-erodable mud plaster (REHSI, 1958; BRN12) give an idea of practical ways of use of improved earth material in building construction activity at minimal environmental and financial costs. Experimental investigation shows that non-erodable mud plaster is not only water repellent and erosion resistant but also provides safety to walls during rainfall. ICONTEC (ICONTEC.NTC 5324, 2004), KEBS (KEBS, 1993) and Lunt (1980) discuss in detail the specifications regarding ground block cements and stabilized soil blocks used for construction of walls and otherwise. Similarly New Mexico earthen buildings materials Code (CID, 2009) and African Regional Standards (ARSO.ARS 670, ARSO.ARS 671, ARSO.ARS 672, ARSO.ARS 673) regarding varied aspects of compressed earth blocks give an idea about the importance of earth as building material in the construction industry in varied and improved forms.

1.2. Thermal and mechanical properties of earth

Literature studies (Galan et al., 2010; Ogunye and Boussabaine, 2002; Hall, 2007; Ola, 1990; Walker, 2004) involving different experimental investigations give a comparative analysis of properties of earth products before and after modifications. Studies by Ogunye and Boussabaine (2002), Mbumbia and Tirlocq (2000), Ola (1990), Obonyo and Baskaran (2010), Donkor and Obonyo (2015), Villamizar et al. (2012), Prasad et al. (2012), Yetimoglu et al. (2005) all ascertain considerable improvement in mechanical and physical properties of soil after treatment. Table 1 gives a literary review of comparative improvement in properties of soil after treatment (stabilization and reinforcement).

Given the advantages of thermal comfort (Taylor and Luther, 2004), heat and sound insulation (Binici et al., 2009; Binici et al., 2005, 2007; Acosta et al., 2010), local material availability, local employment criteria (Morel et al., 2001), minimal impact on environment (John et al., 2005) and easy repair and maintenance of adobe structures (Turanli and Erdogan, 1996) earth has remained a frequently used building and construction material. Research studies (Goodhew and Griffiths, 2005; Hall and Djerbib, 2004) have shown that thermal, acoustic and fire resistant properties of earth materials are very high and addition of fibrous material to adobe further enhances its thermal conductivity thereby increasing heat savings in the buildings. Research studies by Reddy (2012), Quagliarini et al. (2015) and Kinuthia (2015) discuss the energy efficiency and low embodied energy aspects of earth as building material.

Considering all these advantages and popularity of earth material for construction of shelter many countries have framed legal regulations and codes dictating use of earth in varied forms as discussed by Torgal and Jalali (2012). Research discusses at length codes and regulations of

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