The Role of Nanotechnology in Rammed Earth Walls and Earth Buildings

Hamed Niroumanda, *, M.F.M Zainb, Maslina Jamilc

a,b Department of architecture, Faculty of engineering and built environment, National University of Malaysia (UKM), Malaysia

Abstract

Earth buildings used architectural styles in their construction. Rammed earth walls are a type of earth buildings that earth buildings are included as a branch of earth architecture. Rammed earth is a technique of building walls that used a mixture of soil, sand and additives in various layers. The soil mixture needs to be carefully balanced between clay, sand and aggregate although existing rammed earth walls need to improve in their materials and construction method. The current research is a review on nanotechnology and its role in rammed earth walls. The current review is shown the applications of nanotechnology in rammed earth walls although it has shown a short information about an invention by Niroumand and Zain (2012) in rammed earth walls using Nano clays and nanomaterial's under name of NCREW that inventors have increased the compressive strength of rammed earth walls using nano-clays.

© 2013 The Authors. Published by Elsevier Ltd.
Selection and/or peer-review under responsibility of Prof. Dr. Huseyin Uzunboylu, Near East University, Faculty of Education, Cyprus

Keywords: Nanomaterials, Nanotechnology, Nanoclays, Rammed earth walls, Earth architecture, NCREW;

1. Introduction

1.1 Rammed Earth Walls

Rammed earth is a technique for building walls using the raw materials of earth, chalk, lime and gravel. Rammed earth is a structural wall system built of natural mineral soils compacted in thin layers within sturdy formwork. The strength and durability of the wall are results from the densification of a clay, sand and gravel matrix. The mass of the wall provides superior thermal and acoustic properties. It is an ancient building method that has seen a revival in recent years as people seek more sustainable building materials and natural building methods. A natural building involves a range of building systems.

*Corresponding author: Hamed Niroumand.
E-mail address: nirumand@eng.ukm.my or hniromand@ymail.com.
and materials that place major emphasis on sustainability. Ways of achieving sustainability through natural building focus on durability and the use of minimally processed, plentiful or renewable resources, as well as those that, while recycled or salvaged, produce healthy living environments and maintain indoor air quality. Natural building tends to rely on human labor, more than technology. It depends on "local ecology, geology and climate; on the character of the particular building site, and on the needs and personalities of the builders and users". Rammed-earth walls are simple to construct, incombustible, thermally massive, strong, and durable. They can be labor-intensive to construct without machinery, however, and they are susceptible to water damage if inadequately protected or maintained. Building a rammed earth wall involves compressing a damp mixture of earth that has suitable proportions of sand, gravel and clay into an externally supported frame or mould, creating either a solid wall of earth or individual blocks. Historically, such additives as lime or animal blood were used to stabilize the material, whilst modern construction uses lime, cement or asphalt emulsions. Some modern builders also add colored oxides or other items, such as bottles or pieces of timber, to add variety to the structure. The construction of an entire wall begins with a temporary frame, usually made of wood or plywood, to act as a mould for the desired shape and dimensions of each wall section. The form must be sturdy and well braced, and the two opposing wall faces clamped together, to prevent bulging or deformation from the large compression forces involved. Damp material is poured in to a depth of 10 to 25 cm and then compacted to around 50% of its original height. The material is compressed iteratively, in batches, gradually building the wall up to the top of the frame. Tamping was historically done by hand with a long ramming pole, and was very labor-intensive; modern construction can be made more efficient by employing pneumatically powered tampers. Once a wall is complete, it is strong enough that the frames can be removed immediately. This is necessary if a surface texture will be applied, since the walls become too hard to work after about an hour. Construction is best done in warm weather so that the walls can dry and harden. The compression strength of the rammed earth increases as it cures; it takes some time to dry out, as much as two years for complete curing. Exposed walls should be sealed to prevent water damage. In modern variations of the method, rammed earth walls are constructed on top of conventional footings or a reinforced concrete slab base. Where blocks made of rammed earth are used, they are generally stacked like regular blocks but are bonded together with thin mud slurry instead of cement. Special machines, usually powered by small engines and often portable, are used to compress the earth into blocks. Figure 1 is shown the construction method of rammed earth walls.

1.1.1 Characteristics

The compressive strength of rammed earth can be up to 4.3 MPa. This is less than that of concrete, but more than strong enough for use in domestic buildings. Indeed, properly built rammed earth can withstand loads for thousands of years, as many still-standing ancient structures around the world attest. Rammed earth using rebar, wood or bamboo reinforcement can prevent failure caused by earthquakes or heavy storms. Adding cement to clay-poor soil mixtures can also increase a structure's load-bearing capacity. Soil is a widely available, low-cost and sustainable resource, and utilizing it in construction has minimal environmental impact. This makes rammed-earth construction highly affordable and viable for low-income builders. Unskilled labor can do most of the necessary work, and today more than 30 percent of the world's population uses earth as a building material. Rammed earth has been used around the world in a wide range of climatic conditions, from wet northern Europe to dry regions in Africa. While the cost of material is low, rammed-earth construction without mechanical tools can be very time-consuming; however, with a mechanical tamper and prefabricated formwork, it can take as little as two to three days to construct the walls for a 200 to 220 m² house. One of the significant benefits oframmed earth is its high thermal mass; like brick or concrete construction, it can absorb heat during the day and release it at night. This moderates daily temperature variations and reduces the need for air conditioning and heating.
It often requires thermal insulation in colder climates, again like brick and concrete, and must be protected from heavy rain and insulated with vapor barriers. Rammed earth can effectively control humidity where unclad walls containing clay are exposed to an internal space. Humidity is held between 40% and 60%, the ideal range for asthma sufferers and for the storage of such susceptible items as books. The material mass and clay content of rammed earth allows the building to "breathe" more than concrete structures do, avoiding condensation issues without significant heat loss. Surface detail of a rammed earth wall: apart from the patches of damage, the surface shows regular horizontal lines from the wooden formwork used in constructing the wall and subtler horizontal strata from successive layers of compacted earth. Figure 2 is shown the rammed earth walls in practice.

1.2 Nanotechnology

The term 'nanotechnology' refers to Nano-scale technology that has implications and is applied in the real world. This includes applying biological, chemical and physical systems at varied scales (from individual atoms to sub-micron dimensions) and integrating the produced nanostructures with larger systems. Nanotechnology, unlike other technologies such as information technology (IT), molecular biology or semiconductor technology, has left a large-scale social and economical impact in the 21st century and is believed to the next industrial revolution. Many streams have benefitted tremendously from nanotechnology, such as healthcare and medicine, IT, energy, national security and biotechnology, among others.

Many nanometre-scale features are built from elemental constituents. For example, three-dimensional (3D) nanostructures are produced by chemical synthesis, the spontaneous self-assembly of molecular clusters. A nanoparticle is a bundle of atoms that are bonded together in a radius ranging from 1 nm to 100 nm. Typically, a nanoparticle consists of 10 to $10^5$ atoms. In order to produce nanotubes and Nano composites, a number of vacuum deposition and non-equilibrium plasma chemistry techniques are used. Structures that can be controlled automatically are produced using organometallic vapour phase and molecular beam epitaxial. Thus, nanotechnology provides building blocks to develop many computational and experimental tools. The development of many new theoretical and experimental techniques, along with the discovery of novel materials and processes, has opened doors for developing many Nano systems and nanostructured materials. It is worth noting, however, that physical and chemical properties of materials can vary at Nano scale and larger scale. That is, when the dimensions of a material are decreased from its larger size, the properties tend to remain the same in the starting but change at a later stage.

Nanotechnology is going through a rage now, and both, the term and the concept, is being over-used. In spite of this, only few know the real meaning of the term and what is its functionality and use. Currently, nanotechnology is a studied science, which has a very promising future in bringing a change in the world we live. The word "Nano" is derived from the Greek word Nanos (Latin nanas) meaning, "dwarf", making room for many articles on nanotechnology and this book is no exception. For understanding, a nanometre (nm) is a millionth of a millimetre (1/1,000,000mm) or a billionth of a metre (1/1,000,000,000m). It is an 80,000th of the diameter of a hair (the figure varies between 50,000th and 100,000th) and is the same size as about five to ten atoms.

Considering that a billion nanometres equal a metre, it is evident that nanotechnology involves the minutes of dimensions. Thus, a nanoparticle cannot be seen with the naked eye. The wavelength range of visible light is approximately 400 to 800 nm and as the light scattered by smaller particles reduces significantly, particles of such a small size become effectively invisible.
Except of their presence in synthetic production, nanoparticles have also found way in natural materials such as clay. These render properties to the material, such as durability, strength and frost resistance. Mother of pearl is another example where nanostructure renders durability of the material. Ultra-thin and invisible Nano coatings that interest designers generally have a thickness of 5-10nm. The optimum thickness for each Nano coating comes naturally, referred to as a "self-organisation" phenomenon.

Nanoparticles can also be used in solutions that appear transparent in spite of the high solid volumes. Another application of nanotechnology is the Nano powders. Nano coatings can be applied to materials using traditional means such as spraying and dipping. In the building industry, nanotechnology is found to be a fundamental technology for other technological developments to work. During the planning process in architecture, it is important to combine the knowledge of different specialist planners at an early stage. The use of nanotechnologies in the design and construction industry caters for optimising common materials or existing products. Out of this, most important are the development of new functionalities, especially for parameters that cannot be achieved without the help of nanotechnology.

Using nanotechnology helps in making materials more economical conserves resources and also prevents structures against damage. The application of nanotechnology leaves added value, additional functionality, as well as increased market demand for product development for the construction industry. Good design in principle is always based on demand, and in this way contributes to the evolution of both nanomaterial’s and the resulting Nano products.

The use of nanotechnology, therefore, follows an ongoing demand for innovation because of its independence with marketing factors. Nanotechnology can also make contributions to Earth buildings in the following areas:
- Optimization of existing rammed earth walls
- Damage protection in rammed earth walls
- Reduction in weight and/or volume
- Reduction in the number of production stages
- A more efficient use of materials
- Reduced need for maintenance (easy to clean, longer cleaning intervals) and/or operational upkeep

And as a direct result:
- Reduction in the consumption of raw materials and energy and reduced CO₂ emissions
- Conservation of resources
- Greater economy
- Comfort

Nanotechnology favours customized materials with very specific properties and marks a shift away from the standard materials catalogue. Surfaces emancipate themselves from the underlying material, developing clearly defined functions that can differ fundamentally from the substrate material. The objective of nanotechnology is to make use of minimum quantities of raw material and energy and thus, be a economically and ecologically viable option. However, one should have no illusions: the driving force behind development is not innovation itself but the cost factor. In practice it is not a matter of nano° or not, but whether things work in real everyday conditions. Industrial standards, testing methods, long-term testing, quality indicators and their ongoing development help to ensure that this need is fulfilled. However, from an end user’s point of view, the most realistic and sensible application of nanotechnology focuses on aspects of aesthetics, functionality, economy and sustainability.
2. A Case Study and Invention in Rammed Earth Walls

Niroumand and Zain (2012) reported a new type of rammed earth walls using Nano clays. They have used Nano-clays in the rammed earth walls. They produced Nano-clay that it can be increase the compressive strength of rammed earth walls to 2.2 times normal rammed earth walls. It is a modern rammed earth walls. Niroumand and Zain have found a soil mixture using Nano clay material in which a clay is very homogeneously dispersed in a complex matrix, which the mixture materials are easy to prepare. A rammed earth wall using Nano clay according to the invention has very favorable properties, such as a great heat resistance and in particular a great mechanical strength.

3. Conclusion

Rammed earth walls are fast to go up. However, one should have no illusions: the driving force behind development is not innovation itself but the cost factor. From the point of view of the customers, the most realistic and sensible application of nanotechnology in rammed earth walls focuses on aspects of aesthetics, functionality, economy and sustainability. The current research is reported the importance of Nano clay and nanotechnology in rammed earth walls. Nano clay increased the level of compressive strength in rammed earth walls. Modern rammed earth walls can be making from Nano clay as cohesive materials in their soil mixture. Nano clay changed rammed earth walls to an exfoliated Nano clay-sand composite that it increased the compressive strength of rammed earth walls.

References