FINDINGS IN BUILT AND RURAL ENVIRONMENTS

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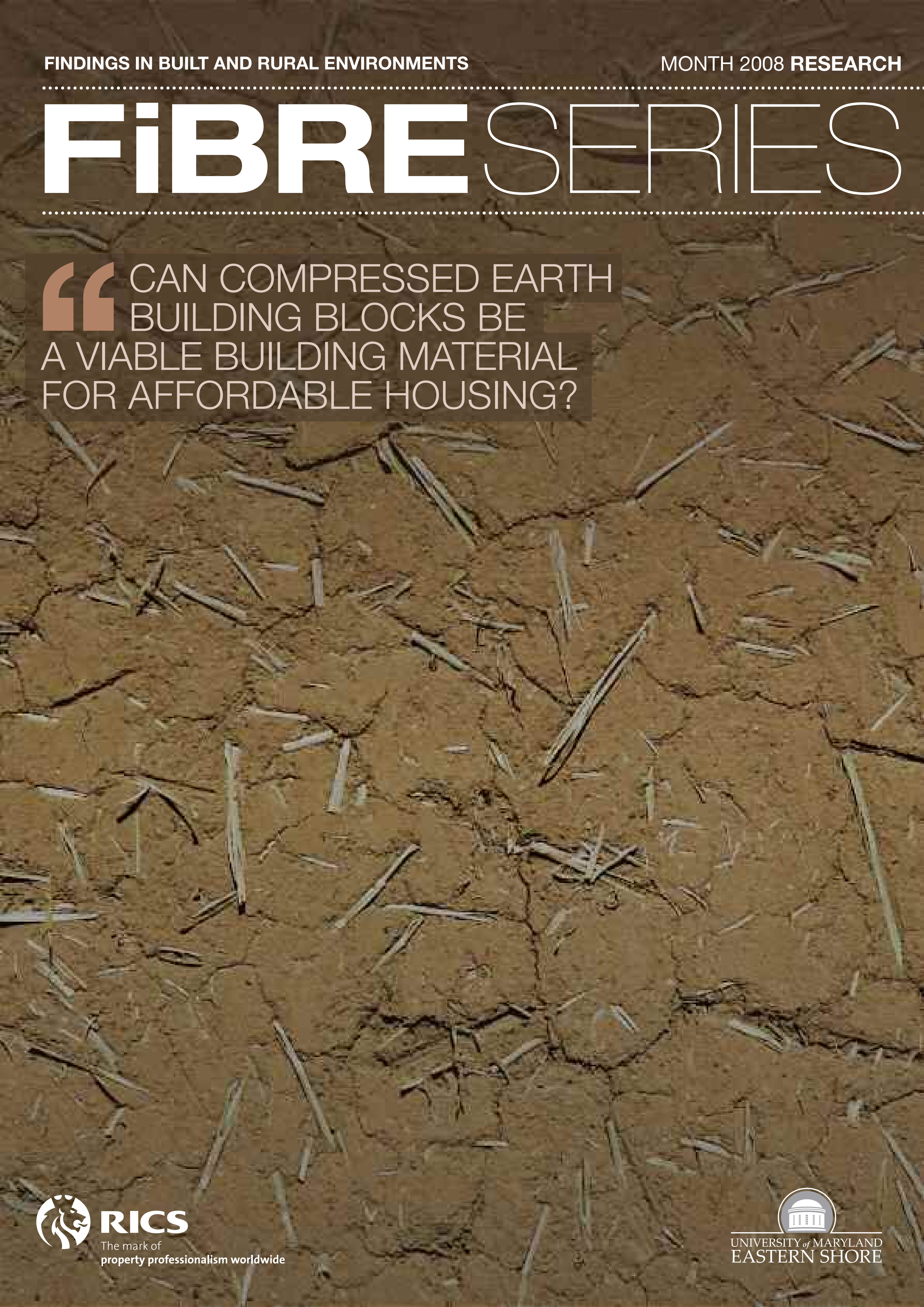

“CAN COMPRESSED EARTH BUILDING BLOCKS BE A VIABLE BUILDING MATERIAL FOR AFFORDABLE HOUSING?

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Sixty second summary

"The 2005 UN Habitat report, Global Report on Human Settlements, estimated that over the next 25 years more than 2 billion people will be added to the global demand for housing.

This, the report concludes, translates into completing 96,150 housing units per day. With much of this demand coming from countries where poverty remains an acute problem, the funding of this demand for housing presents challenges, particularly in relation to the costs of building materials. This research project, by a team led by Joseph Arumala at the University of Maryland Eastern Shore, USA, explored the possibility of using soils for making compressed earth blocks for constructing affordable residential buildings, using relatively cheap and locally available technology. What he found was blocks made using this approach satisfied code requirements for compressed earth block one-storey housing construction. What his work also showed was that using small amounts of additives, such as agricultural fibre – readily available in many developing countries – could also make a significant and positive impact to the performance of the blocks.

Introduction

The provision of housing is a challenge around the world, especially in developing countries. The spiralling growth of population, low Gross National Product and the general lack of purchasing power are factors that contribute to the progressive deterioration of the housing situation in developing economies.

An impediment to the solution of the problem of housing is the scarcity and/or the high cost of building materials. Ideally, building materials for low-cost housing should be produced from locally available raw materials. Furthermore, it would be best if these raw materials were abundantly available or they should be renewable in nature.

The more popular construction materials such as clay bricks and concrete blocks are of good quality but are energy intensive to produce, are expensive and are usually based on heavy industries. However, what is in abundant supply in developing countries, many of which are in the tropical or subtropical regions of the world, is laterite*, a type of soil typical of these areas.

Soil has been widely used for building for thousands of years and still is today. It is an effective and economic form for housing construction and, according to the United Nations, about a third of the world's population live in earthen structures today. Soil is the most abundant and inexpensive resource and with the block presses that are now available that can apply a pressure of 2,265 pounds per square inch (psi) on each unit, high quality blocks can be made for housing construction. Using local soil on a building site has many advantages. Firstly, it eliminates transportation costs. Compressed earth blocks are inexpensive, strong, made with locally available materials and are dimensionally uniform. Workers with little prior building knowledge and experience can be used for the wall construction.

Compressed earth blocks are resistant to sound transmission, fire, insect damage and durable if properly protected. The mass of the compressed earth block walls makes the walls energy efficient systems. Little energy is needed for their production compared to other wall systems and soil is an environmentally friendly material.

As Joseph Arumala commented, "Soil is one of the oldest and readily available building materials. Perhaps we need to re-think some of the more modern approaches to construction that have been introduced" Soil has been used in three traditional methods of construction namely:

- **Adobe block; Adobe is sun-dried soil mixed with straw/rice husks to strengthen the blocks,**
- **Wattle and daub; this is made up of interwoven timber, reeds or bamboo daubed with soil**
- **Rammed earth; this is soil mixed with stabilizers and subjected to high compressive pressure.**

Soil is generally considered to be heavy and of low strength. However, it is possible, by adjusting the amount of pressure that is used, to enhance the performance of a variety of soils.

***What is laterite?**

Laterite, a product of tropical/subtropical weathering, occurs abundantly in such regions on the continents of Africa, Asia, South America, and Australia. Laterite is the reddish, residual and non-residual tropically weathered soil, which forms a chain of materials ranging from decomposed rocks through clays to sesqui-oxide crusts (Gidigasu, 1976). The main constituents of laterites are oxides of aluminium, iron, and silicon.

Introduction

Today, earth building production techniques range from the most rudimentary, manual and craft-based to the most sophisticated, mechanized and industrial. In the 1970s and 1980s there appeared a new generation of manual, mechanical and motor-driven presses, leading to the emergence today of a genuine market for the production and application of the compressed earth block. The Advanced Earthen Construction Technologies (AECT) and the Vermeer Block Press machines are good examples of quality mechanically operated machines and, in response to this, building codes have been developed for the use of compressed earth blocks in buildings.

As an example, the New Zealand Standards for compressed earth construction give the details and specifications for building of compressed earth structures. Manuals and Guides for the construction of earthen structures have also been developed. Compressed earth blocks are safe alternatives to masonry. They are low cost and can be designed to be earthquake resistant.

The aim of this work was to see whether it was possible to use locally available soils in making building blocks with a block press and to see if they would be good enough to construct a low-rise housing development. Joseph Arumala used soils from two counties in the lower shore of Maryland, USA. What he was wanting to find out about the technique was whether it could meet:

- **technical needs of local production by using local soils, power and resources, minimizing the need for imported building materials, reducing costly transportation and ensuring product availability and dependability.**
- **social requirements of the local production situation by using existing or easily transferable skills, avoiding costly training, minimizing displacement of labor, and minimizing social/cultural disruption.**
- **economic requirements of the local situation by: reducing dependence on outside sources, ensuring low-cost alternatives, and requiring limited machinery or capital investment.**

First the soil

The suitability of the soil depends on its constituents: the sand, silt and clay proportions. Too much clay will cause cracks in the blocks while too much sand will cause the blocks to crumble. The suitable soil must contain the right proportions of sand, silt, clay and water. There are several laboratory and field tests that can be performed to determine the constituents and characteristics of the soils. Desirable properties are grain size, cohesiveness, and proportions/constituents.

Given that one of the main objectives was to assess the suitability of compressed earth block building construction for the sustainable development for affordable housing, the tests that Joseph Arumala conducted included finding alternative jointing compounds for the blocks, determining soil properties like permeability, compressibility and soil strength, to make compressed earth and examining durability issues such as resistance to erosion and deterioration due to exposure to weather.

Figure 1: HBP 520 Block Press

Figure 2: Loading Hopper of the Press with Soil

Figure 3: The Compressed Earth Blocks

Figure 4: The finished product

What about the soil?

Joseph Arumala used soils from the following locations:

Wicomico County:

- Non-cohesive soil in a landfill in Salisbury Maryland. The soil was collected from 4 feet to 5 feet depth. The soil from this location is designated Soil No.1 in this paper.
- Cohesive soil sample from the Salisbury-Ocean City Regional Airport, taxi-way expansion project. The soil was collected from 4 feet to 5 feet depth. The soil from this location is designated Soil No.2.

Somerset County:

- Soil from the Education and Social Science Building project site on the UMES campus. The soil was taken at a depth of 5 feet. The soil from this location is designated Soil No.3

Compressed earth blocks were made from these soils individually. Some of the blocks were made from blending materials of Soil No.2 and Soil No.3.

The first thing that Joseph Arumala did was to perform a number of tests, in order to classify and identify the types of soils. These tests were: Soil Particle Size Test, Moisture Content Test, Specific Gravity Tests, the Atterberg Limits Tests and Compaction Test.

After he had classified the soils, the next step was actually to make the earth blocks, which is an extremely simple process and uses technology and equipment which could be readily available and used in developing countries. The main constituents of the soil that he used were as follows:

Gravel	**3%**
Sand	**87%**
Silt and clay	**10%**

This does differ somewhat from the recommended proportions for making earth blocks, which suggest the following:

Gravels:	**0-40%**
Sands:	**25-80%**
Clays:	**8-30%**

Figures 1 to 4 show the steps involved in making the earth blocks. In total, he made 24 blocks of three different sizes. These were left to dry in the outside air covered with plastic sheeting to prevent too rapid a reduction of moisture content.

What is the Atterberg Limits test?

The Atterberg limits are a basic measure of the nature of a fine-grained soil. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state the consistency and behavior of a soil is different and thus so are its engineering properties. Thus, the boundary between each state can be defined based on a change in the soil's behavior. The Atterberg limits can be used to distinguish between silt and clay, and it can distinguish between different types of silt and clays.

Source: Wikipedia

So did it work?

Two of the key tests of any soil material that is going to be used for building purposes are its compressive strength and its modulus of rupture. Ideally, soil for block-making would contain a higher proportion of clay. Given that the local soil that Joseph Arumala used was deficient in the amount of clay that it contained, what impact did this have on their performance?

In fact, they still performed well. The average compressive strength was 349 pounds per square inch (psi) and the average modulus of rupture was 69 psi. Both of these are in excess of the code requirements for this form of construction material. Building codes like the Uniform Building Code, and the New Mexico Adobe Rammed Earth Building Code, require average block compressive strengths of 300 pounds per square inch and an average modulus of rupture of 50 pounds per square inch for compressed earth block one storey buildings. So, it would seem that these local soils meet such code requirements and therefore could be used to construct low-rise housing. What he also found was that adding small proportions of cement made a significant positive difference to their performance.

Figure 5: Crushing of bottom blocks after exposure to snow and rain (after 3 months)

One of the claims made by compressed earth equipment manufacturers is that the use of local soils sourced on-site to make the compressed earth blocks eliminates material transport and reduces material handling and labour costs. However, this may not be possible where the local soil is not suitable. If this is the case, then it would be necessary to carry out extensive blending of different soil types, some of which may need to be imported from other places, and some form of chemical stabilization (addition of cement or lime) will have to be done. While these activities may be possible, they will introduce additional cost to the total cost of construction where introduced. As Joseph Arumala discovered, the blocks that he made were enhanced by the addition of 5% of ordinary Portland cement.

Another area that Joseph Arumala wanted to test was their resistance to water. This is often regarded as one of their main weaknesses and can have quite a destructive effect on earth-built structures. A partial wall was built in the summer and left in a place where it was not completely protected from wind driven rain and snow. In the winter, after the wall has been exposed to moderate rain and snow, it was observed that the blocks at the bottom were crushed due to the wetting and thawing of the blocks (see Figure 5).

What is compressive strength?

Compressive strength is the capacity of a material to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed. Concrete can be made to have high compressive strength whereas a material such as soft sandstone may have a far lower compressive strength

What is the modulus of rupture?

Applying specifically to brittle materials, the modulus of rupture of a building component reflects the maximum load-carrying capacity of the component in bending, It is defined as the force necessary to break a specimen of specified width and thickness expressed in pounds-force per square inch.

So did it work?

This sensitivity to water and lack of durability in its untreated form highlights the main barrier to the widespread use of compressed earth as a building material. To prevent this, the wall surface must be protected by the application of rain resisting “plaster” to prevent this type of deterioration, and walls need to be protected from wind-driven rain by an appropriate overhang of the roof over the walls. A cement-clay (1:1) plaster could be used to reduce costs.

In order to simplify the initial evaluation of the types of soils available, Joseph Arumala also recommends that the series of tests that he carried out in this project should be performed on different types of soils with a view of seeking a correlation between different types of soils and the compression strengths of the compressed earth blocks made from them. This will help in the initial evaluation of the suitability of the soils for the type of houses to be built. The results of such tests may also be evaluated to see if there are other parameters that may assist in assessing the quality and strength of the compressed blocks made from available soils.

The aim would be to come up with a simple method for determining the qualities of compressed earth blocks made from different soils. He also suggested that it would be useful to measure the effect of adding different percentages of agricultural fibers and other elements like Portland cement to the soils, to see to what extent the strength of the blocks will be enhanced. To keep costs down, he suggests that it would be best to try to use additives that can be easily acquired locally at low cost.

Conclusion

This research has shown that it is possible to use local soils for making compressed earth blocks for use in affordable residential buildings. With increasing global demands for low-cost housing, and increasing pressure on building and construction materials, this research shows that low-cost techniques can produce buildings that are robust and resilient.

As Joseph Arumala concludes, “It makes sense to try to use something that is in abundant supply to make houses with, rather than using materials that are energy intensive and need to be transported long distances.”

This work was carried out by Joseph O. Arumala and Tariq Gondal of the Department of Technology, University of Maryland Eastern Shore, USA.

It was awarded the RICS prize for the best paper on sustainability at COBRA 2007, the RICS construction and building research conference.

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