

Ali Sayigh *Editor*

Renewable Energy in the Service of Mankind Vol I

Selected Topics from the World
Renewable Energy Congress WREC 2014

 Springer

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Chapter 68

Earth Construction: The Mechanical Properties of *Adobe* with the Addition of *Laponite*

Francesca Scalisi and Cesare Sposito

Abstract The contribution describes testing of compression strength, flexural strength and abrasion resistance of *adobe* made up of soil, water and sand (AS), soil, water, sand and straw (ASP), soil, water, sand and laponite nanoparticles (ASN). Embodied energy in materials presents an increasingly high percentage of the energy spent in the whole life cycle of a building. The same applies for carbon dioxide (CO₂). Therefore, the development of new sustainable construction materials with lower embodied energy and lower CO₂ emissions is needed.

The use in construction of the brick made from soil, water and sand or straw, called *adobe*, boasts a millenary tradition and in recent years there has been renewed interest in a material readily available and ecofriendly. Earth is a building material that is able to act perfectly in balance with the environment: earth lends itself to achievements accessible to any manufacturing organization and is also a resource available in most geographical contexts. It allows one to manufacture products suited to pursue energy conservation and comfort in different climatic regions. The use of *adobe* presents: reduction of embodied energy and CO₂ at component level; improvement of insulation properties; reduction of the total costs compared to existing solutions.

Keywords Earth · Nanoparticles · Architecture · Low energy

Paragraphs with the initials F.S. by Francesca Scalisi; paragraphs with the initials C.S. by Cesare Sposito.

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68.1 Introduction

The construction sector represents one of the major consumers of energy, consequently emitting a great quantity of CO₂ into the atmosphere. This situation concerns both the consumption of energy required in the production phase of the materials to be utilized in construction and the consumption of energy in the actual deployment phase of the building. It is well-known that winter heating and summer cooling inside a building brings about an enormous consumption of energy.

In the field of construction the saving of energy needs to be shaped by the use of sustainable materials that will contribute to insulating the building adequately and reducing energy consumption.

The utilization of earth blocks in construction dates back over a thousand years and in the last few years there has been a renewed interest in this easily acquired and ecofriendly material.

Making earth blocks does not demand a great amount of energy. In fact, in contrast to bricks it does not require a baking stage, their being dried out simply in a natural way. It is precisely in the baking stage that ordinary bricks emit large quantities of CO₂; by building a house of 100 m² with earth blocks instead of bricks one avoids expelling 20 t of CO₂ into the atmosphere.

It is a safe and natural prime material available in great quantities in the natural world and is completely recyclable.

In the operational phase it enhances the comfort of the building and contributes to a saving of energy, since:

- It regulates the humidity because it can maintain a constant level of humidity in the atmosphere of around 50%.
- It regulates temperature in the home; heat produced by man, from electrical appliances and lighting, on entering through windows is absorbed by the ground, which then restores it again when necessary (e.g. in the evening). This enhances home comfort and boosts energy saving considerably.
- It protects from high temperatures; thanks to its specific heat and substantial size, it prevents heat from entering. At night it cools, and in the morning, when temperatures rise, it once again absorbs a great quantity of heat, thus reducing the ambient temperature during the day.
- It protects from noise; it has excellent values as regards to acoustic cutbacks, since it is an “elastic” material and absorbs noise, by preventing it from passing through.
- It protects from electromagnetic pollution; 15 cm of earth cut out 99% of electromagnetic waves, a value that is higher than that of all other building materials.
- It purifies the air; domestic odours are conveyed by water vapour. Earth, by absorbing water vapour, functions as a natural filter and purifies the air.
- It prevents condensation; precisely because it can absorb humidity, it prevents condensation from forming on walls (including interstitial ones).

Earth blocks may represent the material of the future because they can satisfy the increasingly important requisites of environmental sustainability, energy performance, positive energy balance, healthiness of abode, disposability. Therefore it becomes fundamental to improve the performance of this material, especially from the point of view of mechanical resistance, which is decidedly inferior to that of bricks. laponite, a synthetic layered silicate, at nanometric dimensions, represents a stabilizer compatible with earth, given the predominant presence of SiO_2 , and can improve the mechanical resistance of earth blocks [1].

(F. S.)

68.2 Preparing Adobe

The sample realized is of the adobe type, an earth brick shaped by hand in a mould, without being compressed, and left to dry under natural conditions. The mixture used to produce traditional adobe is: soil and water with sand or straw as a stabilizer [2, 3]. The materials used to make the samples are: soil, sand, water, straw and laponite nanoparticles (Fig. 68.1). Soil was taken from the Roccasegli quarry, situated in the municipality of Motta S. Anastasia in Sicily. The sand utilized was lavic and of basaltic origin from Nicolosi in Sicily. The straw is from Nicolosi. The laponite RD is a synthetic layered silicate, supplied by Rockwood Additives Ltd. as a white powder and used without further purification. It is composed of rigid disk-shaped crystals with a well-defined thickness of 1 nm and a diameter of 25 nm.

In the first phase, the samples produced were of two types: the AS sample, made up of 31.54% soil, 30% sand and 38.46% water; the ASP sample made up of 27.12% soil, 30% sand, 41.38% water and 1.5% straw (Fig. 68.2). The sizes of the samples were $40 \times 40 \times 160$ mm, for the flexion and abrasion tests, and $50 \times 50 \times 50$ mm for the compression test. The specimens were observed through the *scanning electron microscope (SEM)*, which showed a graph of the elements and their distribution for each type of sample analyzed (Figs. 68.3, 68.4, 68.5).

(C. S.)

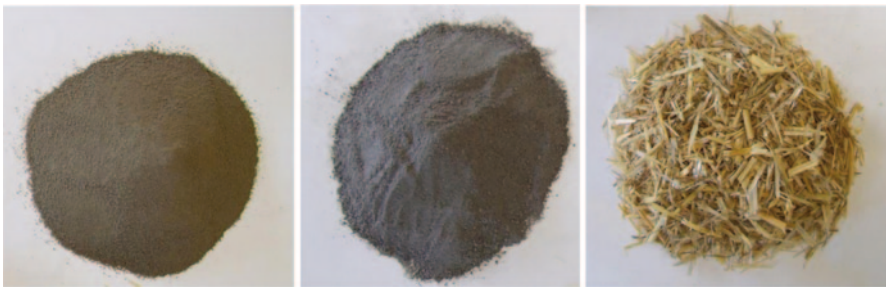


Fig. 68.1 The materials used to make the samples. From left: soil, sand and straw



Fig. 68.2 The samples: ASP (*left*) and AS (*right*)

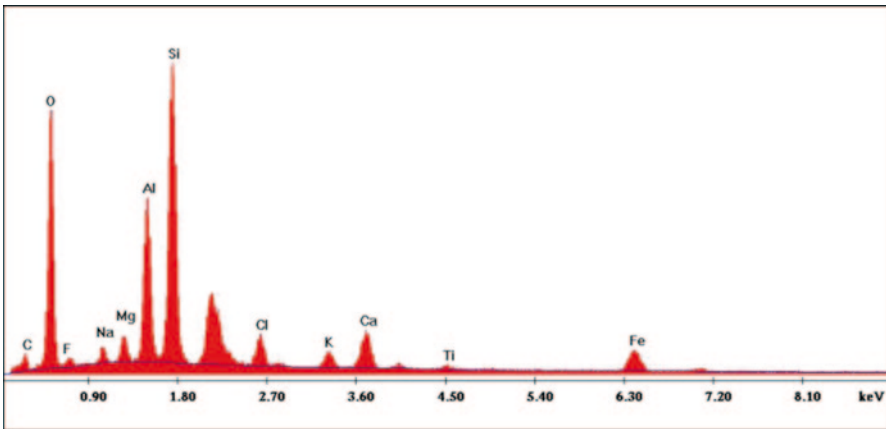


Fig. 68.3 SEM 100.000x chemical composition of AS sample

68.3 Testing of Compression Strength of the AS and ASP Samples

In the absence of regulations regarding earth bricks, for the administration of compression reference was made to the NORMA UNI EN 772–1:2011 the title being *Testing Methods For Masonry Elements—Part 1: Determining Compression Resistance*. Before carrying out the tests the samples were compacted to constant mass, at a temperature of $20 \pm 2^\circ\text{C}$ and relative humidity of $65 \pm 5\%$ [4–7]. The compression resistance demanded for an *adobe* is about 2 MPa. The samples made up of soil, water and sand (AS) showed an average compression resistance of 3.6 MPa, whilst those composed of soil, water, sand and straw (ASP) showed an average compression resistance of 2.8 MPa (Table 68.1; Fig. 68.6).

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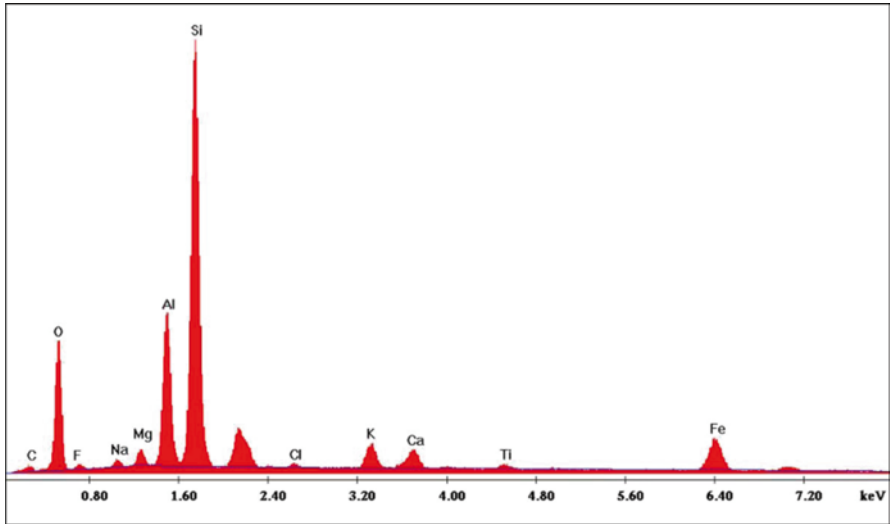


Fig. 68.4 SEM 100.000x chemical composition of ASP sample

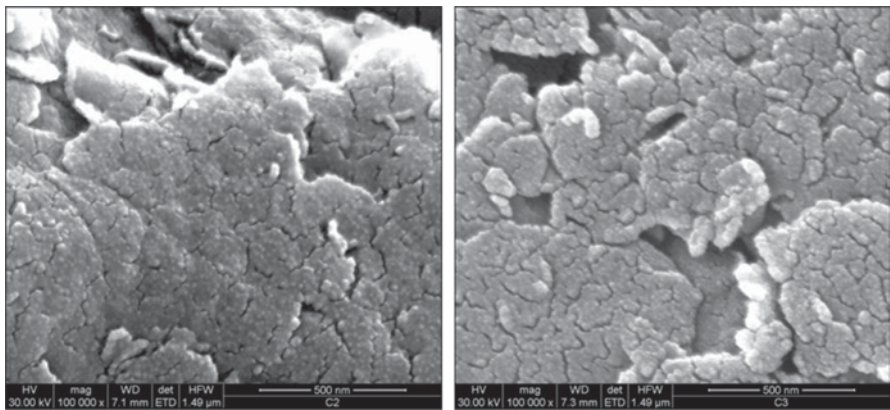


Fig. 68.5 SEM 100.000x of samples AS (left) and ASP (right)

Table 68.1 Test results of compression strength of the AS and ASP samples

Sample	Compression strength (MPa)	Sample	Compression strength (MPa)
AS/1	4.0	ASP/1	2.9
AS/2	3.0	ASP/2	2.7
AS/3	3.2	ASP/3	2.4
AS/4	3.4	ASP/4	2.7
AS/5	4.6	ASP/5	2.8
AS/6	3.4	ASP/6	3.0
Average compression strength 3.6 MPa		Average compression strength 2.8 MPa	

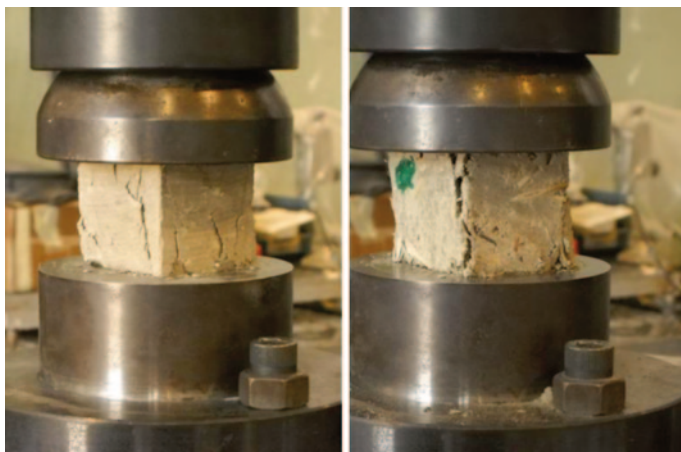


Fig. 68.6 The samples, AS (*left*) and ASP (*right*), to be tested for compression strength

68.4 Testing of Flexural Strength of the AS and ASP Samples

In the absence of regulations regarding earthen bricks, for the administration of the flexion tests, reference was made to the NORMA 12372:2007 with the title *Testing methods for natural stone—Determining flexion resistance under concentrated load*. Before carrying out the tests the samples were compacted to constant mass, at a temperature of $20 \pm 2^\circ\text{C}$ and relative humidity of $65 \pm 5\%$ [4–7]. The flexion resistance demanded for an *adobe* is about 0.4 MPa. The samples composed of soil, sand and water (AS) present an average flexion resistance of 1.7 MPa, whilst those composed of soil, sand, water and straw (ASP) present an average flexion resistance of 1.02 MPa (Table 68.2; Fig. 68.7).

(C. S.)

Table 68.2 Test results of flexural strength of the samples AS and ASP

Sample	Flexural strength (MPa)	Sample	Flexural strength (MPa)
AS/1	1.8	ASP/1	1.2
AS/2	1.8	ASP/2	0.9
AS/3	1.6	ASP/3	1.2
AS/4	1.6	ASP/4	0.9
AS/5	1.7	ASP/5	0.9
Average flexural strength 1.7 MPa		Average flexural strength 1.02 MPa	



Fig. 68.7 The ASP sample to be tested for flexural strength

68.5 Testing Abrasion Resistance of the AS and ASP Samples

The resistance-to-abrasion tests were carried out on three specimens for each typology, with the use of a metallic bristle brush. The evaluation of the test was carried out by quantifying the actual weight of the material removed, through the difference between the initial weight of each sample and the weight subsequent to the abrasive action. The procedure entailed the initial weighing of each sample using precision electronic scales and the subsequent rubbing of one side of the sample for one minute with a brush loaded with a weight of 3 kg; at the end of each test, the respective specimens were again weighed to determine the difference with the initial weight and, consequently, the amount of material removed. The AS samples registered a lower average weight for the material removed than that of the ASP, 2.96 g as against 3.93 g (Table 68.3).

(C. S.)

Table 68.3 Test results of abrasion resistance of the AS and ASP samples

Sample	Initial weight (g)	Final weight (g)	Amount of material removed (g)
AS/19	504.14	500.62	3.52
AS/26	502.00	498.68	3.32
AS/30	496.58	494.54	2.04
Average weight of material removed 2.96 g			
ASP/13	463.51	459.34	4.17
ASP/28	464.52	460.61	3.91
ASP/30	463.55	459.84	3.71
Average weight of material removed 3.93 g			

68.6 Testing of Compression Strength, Flexural Strength and Abrasion Resistance of ASN Samples

The tests carried out show how AS samples have greater resistance to compression, flexion and abrasion than the ASP samples. This is due to the presence of straw, which renders the mixture less compact. On the basis of these results, ASN samples were realized with the addition of a small amount of laponite. The ASN samples comprised 25% sand, 38.46% water, 31.54% soil and 5% laponite nanoparticles. The laponite nanoparticles and the ASN sample were observed through the SEM, which showed a graph of the elements and their distribution for each type of sample analyzed (Figs. 68.8, 68.9, 68.10). The ASN samples were subjected to compression, flexion and abrasion tests. The samples composed of soil, sand water and laponite nanoparticles (ASN) showed an average compression resistance of 4.7 MPa, an average flexion resistance of 2.42 MPa (Table 68.4) and an average weight for the material removed of 0.85 g (Table 68.5) (Fig. 68.11).

(F. S.)

68.7 Conclusions

The use of laponite nanoparticles in adobe bricks has brought an increase in compression, flexion and abrasion resistance when compared to traditional bricks. As regards resistance to compression, there was a 30% increase over the AS samples,

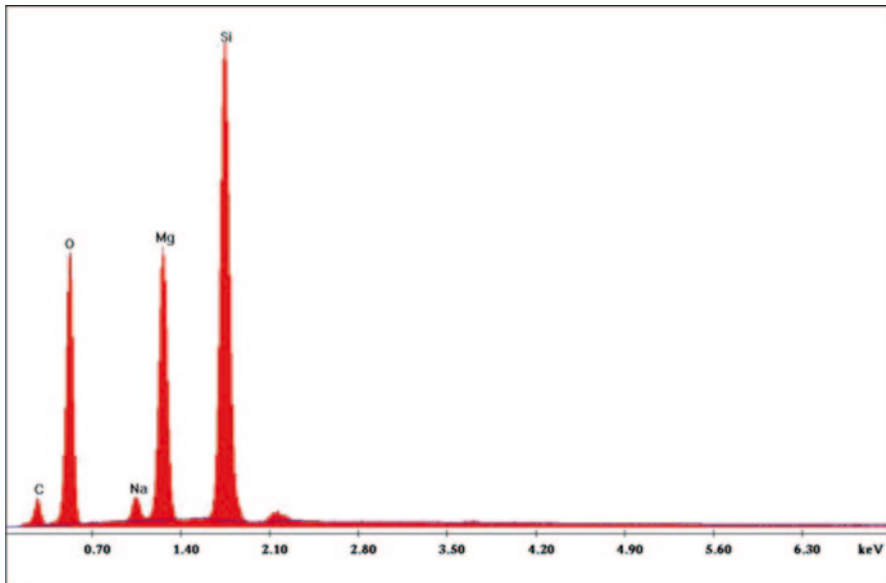


Fig. 68.8 SEM 100.000x chemical composition of laponite

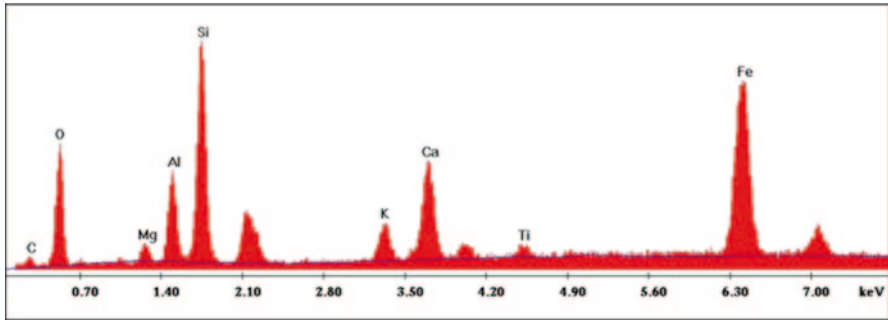


Fig. 68.9 SEM 100.000x chemical composition of ASN sample

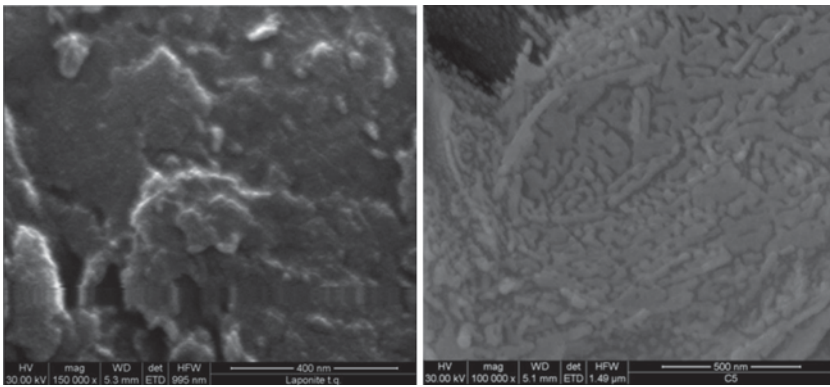


Fig. 68.10 SEM 150.000x of laponite (left) and SEM 100.000 of ASN sample (right)

Table 68.4 Test results of compression and flexural strength of the ASN samples

Sample	Compression strength (MPa)	Sample	Flexural strength (MPa)
ASN/1	4.1	ASN/1	1.9
ASN/2	5.0	ASN/2	2.2
ASN/3	4.4	ASN/3	2.3
ASN/4	4.7	ASN/4	2.4
ASN/5	5.3	ASN/5	2.8
ASN/6	4.7	Average flexural strength 2.42 MPa	
Average compression strength 4.7 MPa			

Table 68.5 Test results of abrasion resistance of the ASN samples

Sample	Initial weight (g)	Final weight (g)	Amount of material removed (g)
ASN/1	506.08	505.45	0.63
ASN/2	515.99	515.01	0.98
ASN/3	509.23	508.30	0.93
Average weight of material removed 0.85 g			



Fig. 68.11 The ASN sample to be tested for abrasion resistance

and 45% over those made from soil, water, sand and straw (even though the latter also showed lower resistance than bricks made from earth, water and sand). As regards resistance to flexural strength, there was a 43% increase over the AS samples and 60% over those made from soil, water, sand and straw (even though the latter also showed lower resistance than bricks made from earth, water and sand). As for resistance to abrasion, the performance of the ASN samples was 3 times greater than the AS samples and 4 times greater than the ASP samples.

(F. S.)

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