CHARACTERIZATION OF ADOBE BLOCKS FROM BURGOS

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Abstract
Adobe was a building material of common use in construction practice in many areas of Spain. However, due to the introduction of new cement based building materials, it has been replaced and knowledge of the materials and techniques used for the construction of adobe buildings has been lost. In Spain earth based construction was widespread and common in northern regions such as Burgos, for example. This spatial distribution also encompasses a diversity of raw materials used in the execution of adobe blocks. In order to improve the knowledge on the composition of adobe blocks a set of specimens from the region of Burgos were sampled and studied. As a significant percentage of these buildings suffer from severe degradation, this knowledge can be used as a first step towards an adequate conservation practice that must be based on compatibility issues. For this purpose a testing campaign was performed, taking into account the mineralogical and chemical characterization of the adobe raw-materials and the mechanical and physical characterization of adobe blocks. There is a strong link between these raw materials and local availability, as adobe blocks were usually executed and consumed at a local scale.

1. INTRODUCTION

Earth construction has strong roots in the Iberian Peninsula, where earth is employed in various construction materials such as adobe, rammed earth and wattle and daub. Whilst in Portugal rammed earth is common in the south and adobe buildings are found in estuarial areas, with predominance in the region of Aveiro, in Spain earth construction is widespread but especially prominent in the central area encompassing the provinces of Leon, Zamora, Valladolid and Palencia (Delgado and Guerrero, 2006; Graciani and Tabales, 2003). Throughout Spain earthen buildings are common in rural areas but this material has also been employed in various monuments such as Murallas de Niebla, in Huelva and the Alhambra, in Granada.

This study was developed in order to determine the composition and to evaluate the characteristics of adobe blocks used in the region of Burgos, Spain, all of them employed in rural houses. The atmospheric exposure in Burgos is quite demanding as it has a variable amount of rain/snow but a cold climate, with a high frequency of negative temperatures and consequent freeze/thaw cycles, which are very demanding conditions for all exposed construction materials.

2. STUDY CASES

In the rural area of Villasandino, Burgos, adobe was sampled from a residential, unoccupied house (Figures 1 and 2) and from a wine cellar. The house was built in adobe and wood but the inferior part of external walls was built in stone, thus keeping capillary water from damaging the earthen materials. The wine cellar was also built using adobe blocks, but it was partially excavated, leading to an underground storeroom with an excavated ceiling. In both cases, the building suffered from degradation, enabling sampling of adobes.
Adobe blocks from the house displayed a light brown colouring, with some sand content, and samples from the wine cellar showed a strong brown colouring and apparent profusion of fibres.

Figure 1 - House in Villasandino from which samples were extracted

Figure 2 – Detail of house in Villasandino from which samples were extracted

3. TESTING PROCEDURES

In order to study the adobe blocks a testing procedure was developed encompassing particle sieve analysis, Atterberg's plastic and liquid limit, X-Ray diffraction, compressive strength, tensile strength and erosion test following the Geelong method. This set of tests is intended to provide information on the composition of these materials, their mechanical and physical characteristics and their rate of decay.

- Particle sieve analysis

Humid particle sieve analysis was performed for the determination of the percentage of fine particles, prior to dry particle sieve analysis, that was then performed on particles over 0.075 mm. For this test, the main ASTM sieve series was used.

- Atterberg's plastic limit

Atterberg´s plastic limit was determined on the adobe particle fraction below 0.1 mm. Soil was rolled into ellipsoidal masses and the plastic limit was achieved with the execution of 3 mm threads.

- Atterberg's liquid limit

The determination of the water content responsible for the transition of the soil from plastic to liquid state was performed using Casagrande apparatus and methodology.

- X-Ray Diffraction

Particles sized below 0.075mm and dried at 40ºC were subjected to XRD using an X-Pert Pro X-Ray Diffractometer in order to determine mineralogical composition.

- Compressive strength

This test was performed on cylindrical specimens with an average diameter of 80 mm both in terms of simple compressive strength and diametric compressive strength.

- Durability

Water behaviour was evaluated by a durability test following the Geelong method, based on New Zealand and Australian standards (NZS, 2000). This consists of the continuous fall of water droplets totalizing 100ml, from a height of 400mm, each 20min. The test is concluded by the measurement of the erosion produced and water penetration depth, followed by the determination of the erosion index.

4. RESULTS

- Particle size distribution

Particle size distribution was performed on a sample from the traditional house and on a two samples from the wine cellar (Figure 3). Results showed that the adobe used in the house contained a greater percentage of sand (35%) in comparison to that extracted from the wine cellar (10%). Therefore, the adobe from the winery displayed a high content of very fine particles, below 0.06 mm, classified as silt and clay.

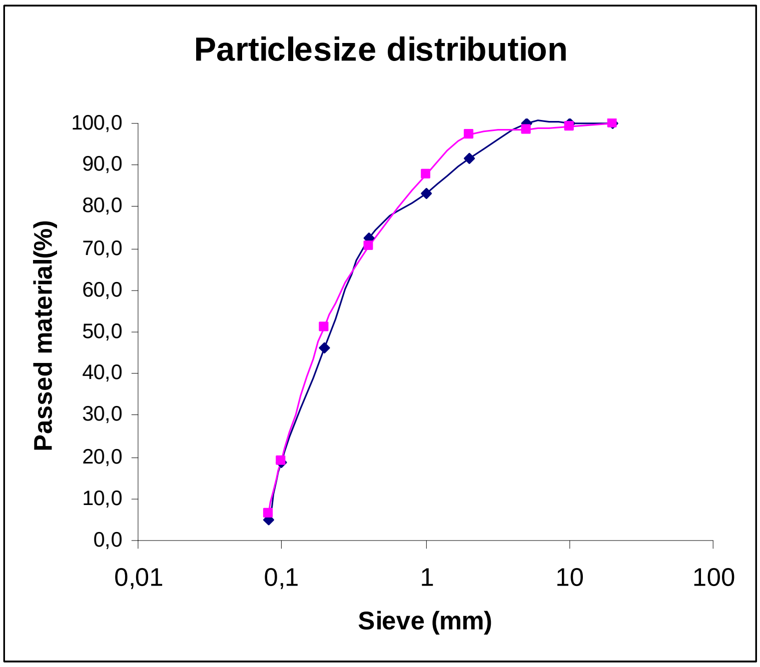

Figure 3 – Particle size distribution of adobes from the wine cellar

- Plastic and liquid limit

Casagrande classification system was applied on samples from the rural house and wine cellar. While the sample from the house attained the classification of silt/clay with low plasticity (CL-ML), the winery sample was classified as low plasticity clay (CL) due to a liquid limit below 50% and a plastic limit above 7%.

- X-Ray diffraction

Mineralogical characterization was performed on adobe from the wine cellar walls and on a sample of earth taken from the ceiling of the same wine cellar, which was partially excavated below the ground. Adobe samples were composed by quartz, calcite and feldspars, with traces of haematite. The analysed soil revealed a composition of quartz, calcite and illite, with traces of haematite. The presence of calcite in the adobe did not seem to be due to the addition of lime, owing to its colouring and consistence and the presence of a great amount of calcite in the soil suggests that it was probably used for the manufacture of adobes. Due to its content in calcite and to the geological context of the region, the soil may be classified as a Terra Rossa.

- Mechanical strength

Mechanical strength tests, comprising compressive (Table 1) and indirect tensile (Table 2) strength, were performed on samples from the rural residential house.

The obtained results showed a high dispersion of values, with compressive strength ranging from 1.2MPa to 3.0MPa and tensile strength surrounding 0.25MPa up to 0.32MPa. Due to the heterogeneity of these materials and their manufacture process, this variation in values is common (Varum et al, 2006; Gonzalez, 1999). The ratio between the average tensile and compressive strength is 0.14, also a typical value for these earth based materials.

Table 1 – Compressive strength (MPa) of adobe specimens from the rural house

Specimen #	Stress strength (MPa)
1	1.87
2	1.24
3	3.01
4	2.19
5	2.09
Average	2.08

Table 2 – Tensile strength (MPa) of adobe specimens from the rural house

Specimen #	Stress strength (MPa)
6	0.31
7	0.25
8	0.32
9	0.29
10	0.28
Average	0.29

- Erosion tests (Geelong Method)

Erosion index was determined by the erosion depth produced by the water drops and resulted in a classification of adobes as generally suitable for use in protected external walls except for Sample 3, with a recommended application encompassing exposed external walls (Table 3).

Table 3 – Adobe classification in terms of erosion

Adobe	Erosion index	Recommended use	Penetration depth	Conclusion
Sample 1	3	Protected external walls	<8cm	Approved
Sample 2	3	Protected external walls	<8cm	Approved
Sample 3	2	Exposed external walls	<8cm	Approved

In terms of penetration depth, all adobes were considered approved (Table 3) as water didn't exceed the depth of 120mm measured from the adobe surface.

CONCLUSION

Adobes from Villasandino, Burgos, extracted from two different buildings show some variation in terms of composition. However, it became clear that they are made from local materials and do not incorporate lime. Adobes from the same building show variations in terms of mechanical and physical characteristics, as is common with this kind of materials. However, the values encountered for mechanical strength are within usual limits. Erosion by water action wasn't severe and indicates that these adobes are prone for use in external walls, with some protection. Although these materials suffer constant freeze-thaw cycles, their properties do not seem to be much affected by these, probably due to their porous structure.

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Curriculum

Ana Velosa is Assistant Professor at the Department of Civil Engineering of the University of Aveiro, Portugal and a researcher at Geobiotec. Her main research area is building conservation, with a special emphasis on mortars and traditional construction materials. She has participated in several research projects and co-authored various publications in international journals and conferences.

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