



CONTRIBUTION TO THE CHARACTERIZATION OF CONSTRUCTION MATERIALS OF HISTORICAL MONUMENTS -CASE STUDY

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CONTRIBUTION TO THE CHARACTERIZATION OF CONSTRUCTION MATERIALS OF HISTORICAL MONUMENTS -CASE STUDY

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ABSTRACT

Historic monuments in Morocco represent an important legacy that, unfortunately, continues to suffer degradations throughout their lives, they suffer structural damage and disorder due to the lack of an intervention methodology and variety of features the materials used, indeed, to restore a historical monument is an operation which requires a precise analysis of the structure on the one hand and the knowledge of the characteristics and behavioral mode of the materials on the other hand. The purpose of this work is the contribution to the identification of building materials of historical monuments in Morocco, it focuses on a case study of a classified heritage in Marrakech. For the realization of this task, a series of soundings were carried out on the various places of the site, passing by the foundations by determining the height of anchoring and the bearing capacity of the soil, then tests will be realized for the physical and mechanical characterization of wall building materials namely rammed earth and traditional full brick. The ultimate goal is to put in place a database of construction materials for this monument to allow the client to ensure the right choice of restoration materials.

Key words: building materials, historical monument, identification, restauration.

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1. INTRODUCTION

The rehabilitation of historic monuments is a complex operation requires the development of a well-detailed survey of expertise on the entire building, the purpose of which is to allow a greater knowledge of the building materials and structural systems of the building and to delimit the best conditions of conservation. Its purpose is to preserve and reveal the aesthetic and historical values of the monument and is based on respect for the ancient substance and authentic documents (ICOMOS, 1964), therefore, before undertaking such an operation a

historical search by consultation of the archives as well as the realization of an investigation company for the recognition of disorders and materials is of paramount importance.

It is in this context that this work was done, it aims to identify the building materials of a historical monument, this identification will cover the entire building by conducting surveys and tests respecting the best possible its historical and architectural values.

The building object of our study is located in the center of the city of Marrakech in the center of Morocco, the latter is classified World Heritage by UNESCO (unesco), Medersa Ben Youssef is the name of this building which is one of the largest in the Maghreb, is one of the most remarkable historical monuments of the city of Marrakech (Dahir of January 28, 1916 ranking, B.On ° 172 of February 7, 1916.P140, 1916), The Koranic school was founded in the early 14th century by the monarch Moroccan Abu el Hassan. Only with the reign of the Saadians who enlarged and redecored the building in 1570 (KNIDIRI, 2011), the medersa was for more than four centuries a home for students in various sciences.

Designed on a 1680 m² quadrilateral, the medersa with Arab-Andalusian architecture had 132 student rooms spread over two floors around a courtyard on which gives the prayer room.

2. VERTICAL STRUCTURES IN FOUNDATION AND ELEVATION

The objective of auscultation of foundations is to determine the dimensions and composition of foundations to estimate the bearing capacity of soil.

A set of manual surveys were carried out at the level of the building in question to investigate the construction techniques and to detect any disorders affecting the structure, the positioning of the polls was chosen so as to have the maximum data on the structure of the foundations .

In this sense, four holes were made on the walls and three holes on the foundations, Figure 1.

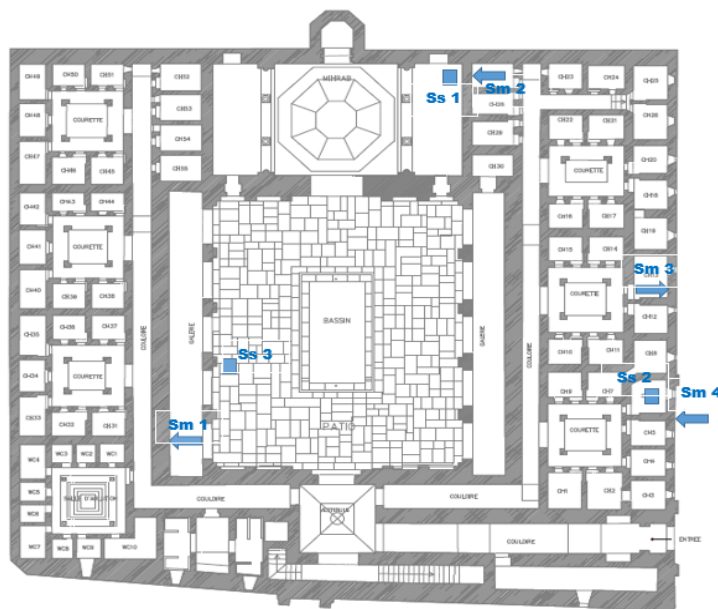


Figure 1 location of foundation surveys

2.1. Foundations of the Walls

The Ss 1 survey shows that the southeast and northwest peripheral walls of the prayer room are anchored at the level of silty-clay formation at a depth of 1m from the level of the pavement.

The walls are built of traditional solid bricks joined by a lime-based mortar, and rest on a base of a traditional rammed earth, Figure 2.

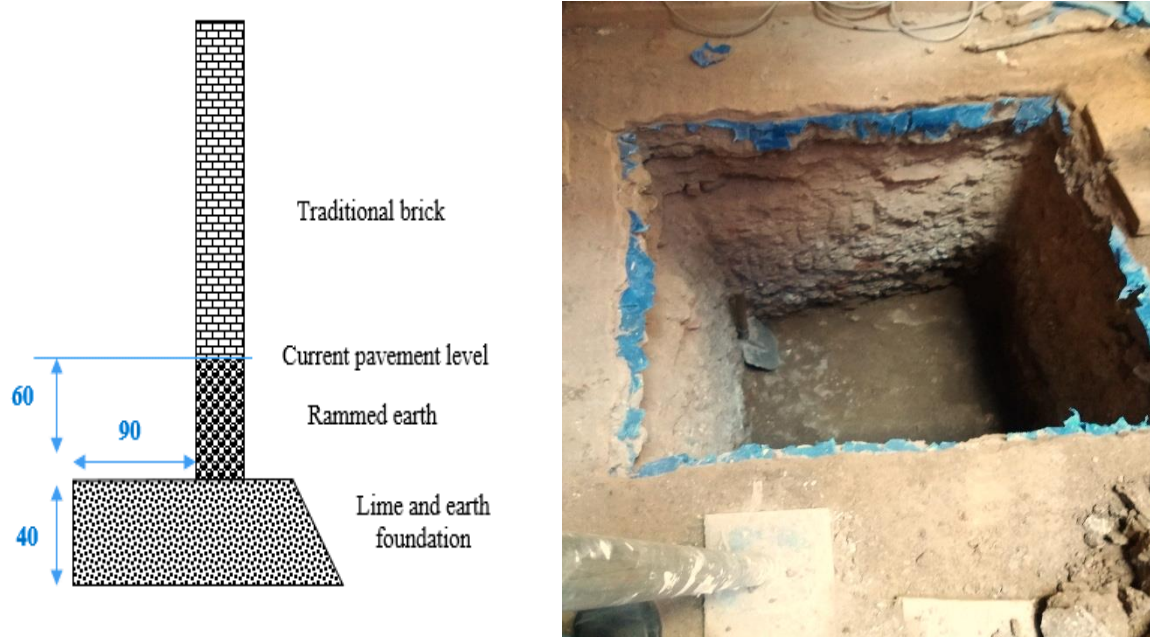


Figure 2 Foundation structure

3. PHYSICAL AND MECHANICAL PROPERTIES OF MATERIALS

3.1. Physical Properties

Identification tests were carried out on the materials collected from the excavations of the Ss1, Ss2 and Ss3 soundings, the sounding executed at the prayer room has exposed the composition of the soil, successively presented with a smooth screed composed of 1cm thick tinted lime, 7cm thick lime shape, 10 cm unreinforced concrete slab, resting on a very compact backfill laid on natural ground at a depth of 1 m from the current ground. the following figure shows the lithological section of the soil, Figure 3.

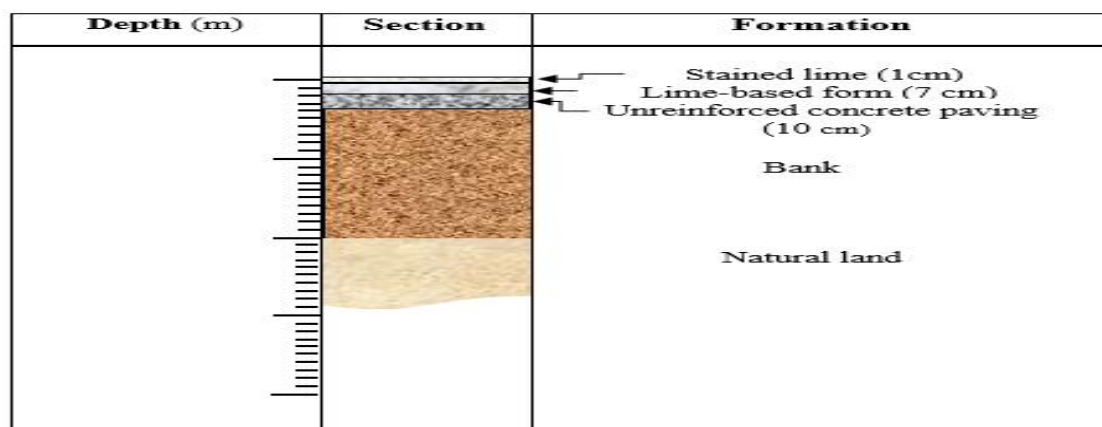


Figure 3 Lithological section

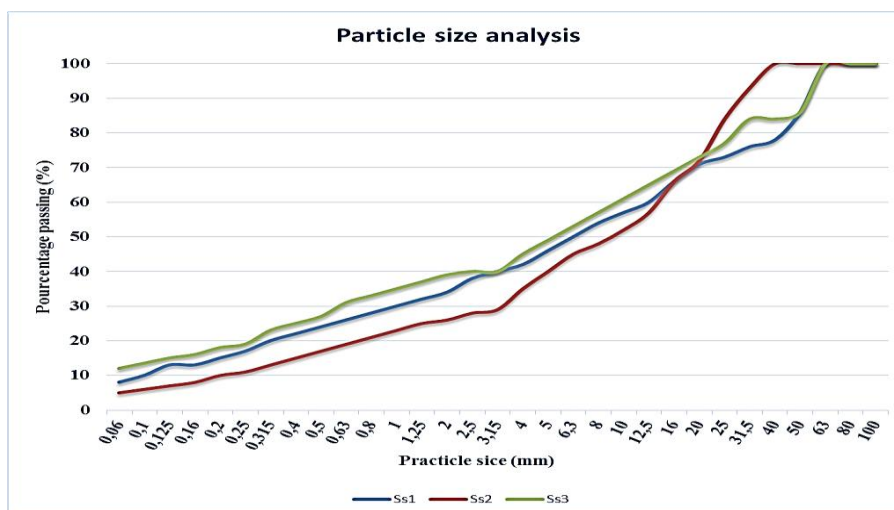


Figure 4 Particle size analysis of foundation soils

The Ss2 sounding at the floor level of room N°17 showed the following sequence: a tinted lime screed, a 5 cm thick lime form, an unreinforced concrete slab of approximately 9 cm resting on a backfill 85 cm thick.

At the Ss3, the Shan marble is based on a shallow form and unreinforced concrete 10 cm thick, all of which rests on a marly soil.

3.2. Mechanical Properties

To determine the mechanical properties of the foundation soil of the building, a direct shear test was conducted on samples of the holes 1 and 2, which gave the results shown in the **Table 2**.

Table 1 Physical properties of the foundation soil

Designation	reference	Particle size analysis			MBV	Water content
		%<80µm	%<2mm	D max	MS 10.1.141	MS 10.1.272
Ss 1	196/3	8,50	36,18	63	0,17	25,6
Ss 2	463/3	5,04	27,34	40	0,14	25.6
Ss 3	463/1	11,53	37,77	63	0,17	25.6

Table 2 Mechanical properties of the foundation soil

Survey	C'(kPa)	Ø °
Ss1	6	31°
Ss2	6	30°

4. CONCLUSION AND DISCUSSIONS

Surveys on the foundation floor have shown that the foundations of the building are generally in good condition.

The existence of an unreinforced concrete slab with a thickness of 10 cm shows that a restoration operation was carried out over time.

4.1. Identification of Wall Construction Materials

Also three holes were realized on the walls of the building, they showed the existence of two building materials for the load bearing walls namely the traditional solid brick with a traditional lime mortar and rammed earth, Figure 5.

As for the thickness of the walls, it varies between 30 cm and reaches up to 1 m in some places, while the columns are in solid brick.



Figure 5 Rammed earth and solid brick wall

4.2. Identification of the Rammed Earth

For the identification of this material, we have carried out the following tests:

- Particle size analysis;
- Water content;
- The methylene blue test.

The rammed earth building is a very old method, it is a constructive system based on the raw earth groomed. For traditional rammed earth, the choice of suitable land for use in rammed earth construction is related mainly to the variability of the grain size of the earth as well as the existence of a sufficient ratio of the clay, the latter plays the role of a binder between the grains.

Currently, this construction technique is still persistent in the south of Morocco, but with the use of a modern rammed earth by adding a hydraulic binder such as lime, we speak of a stabilized rammed earth.

By studying the particle size analysis as well as the MBV listed in Figure 7 and Table 3, we can conclude that the material in question has a luminous character sensitive to water and a varied grain size. Table 3 Physical properties of rammed earth

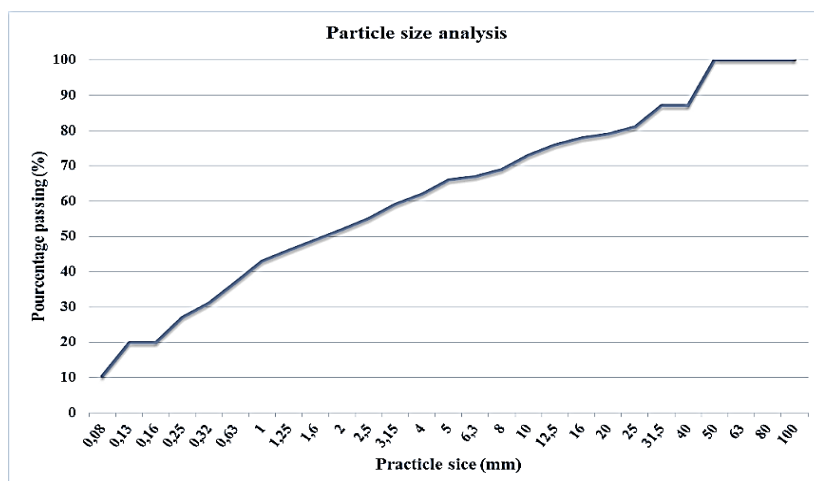


Figure 6 Particle size analysis of rammed earth

Table 4 Physical properties of rammed earth

Designation	Ref	Particle size analysis		
		%<80µm	%<2mm	D max
rammed earth	173/4	14,17	52,06	50
		MBV (MS 10.1.141)		
		0,11		
		Water content (%) (MS 10.1.272)		
		3,3%		

Noting that several studies have been carried out to characterize rammed earth, this has not allowed to have a sufficient enough scientific data to generalize the mechanical behavior of this material, indeed, this task is complicated because the physical data and mechanical variables are variable and depend on several parameters related to the type of land used and its source, the compaction energy, the water content of manufacturing, the implementation.....

However, several countries have adopted special procedures for reinforcement and rammed earth construction, and many processes for the testing of the material have been proposed.

In his publication to present an approach for the modeling of this material, R.ElNabouch1 presented recommended calculation values for rammed earth adopted in some countries as shown in Table 5.

Table 5 Recommended values in some countries for rammed earth

Reference	Rc (MPa)	Rt (MPa)	E (MPa)
New Zealand de (New	0,5	0,035	150
Australian Handbook	0,4 à 0,6	0	500
New Mexico code	2,07	-	-

With

Rc: mechanical resistance

Rt: shear strength

E: Young's module

In its final report, the CSTB (CSTB, 2011) estimates an average value of 1900 kg/m^3 for the density while the compressive strength is in a range of 0.75 MPa to 2.4 MPa

4.3. Identification of Solid Brick

As for the solid brick, we carried out the following tests:

Physical tests:

- Determination of Apparent Density (AD)
- Determination of Dry Density (DD)
- Percentage determination of voids (PV)
- Determination of absorption rate (RA)

Mechanical tests:

- Determination of compressive strength

Table 6 Physical properties of solid brick

Ref	DD (kg/m^3)	AD (kg/m^3)	PV (%)	RA (%)
0085/2-A	1771	1844	3,82	1,3
0085/2-B	1475	1798	3,73	1,1
0085/2-C	1726	1773	8,26	0,8
0085/2-D	1687	1771	4,15	1,4
Average	1665	1796	4,99	1,1

The test for determining the compressive strength is carried out according to the Moroccan standard MS 10.6.700 (10.06.700, 2001), the procedure was developed by Olivier and consists of a compression of two half blocks masonry with mortar (M.Olivier, A Mesbah, Z EL Gharbi and J C Morel, 1997).

It is a technique developed at ENTPE and it has been validated by the CT RILEM and also by the Public Laboratory of Testing and Studies (LPEE) of Casablanca.

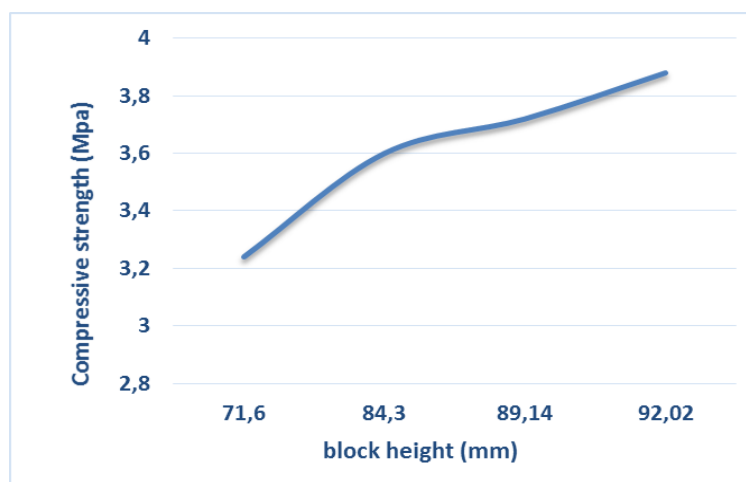
By sawing a block, two half blocks are obtained who have the same physical characteristics, a specimen is then obtained by superimposing the two half blocks with a mortar whose role is to uniformly distribute the forces from one block to the other which makes it possible to have enough slenderness to limit the hooping effect.

The determination of the absorption rate is very important, because a high absorption leads to a vulnerability to changes in volume which would lead to cracking of bricks and structural damage in buildings. Low absorption is still not desirable because the water will tend to flow very quickly towards the joints which can reduce their durability (C.Freeda Christy, R.Mercy Shanthi and D. Tensing, July- December (2012)) on the one hand and its adhesion on the other hand (Mariarosa Raimondo, Michele Dondi, Davide Gardini, Guia Guarini and Francesca Mazzanti, 2009)).

The results of the physical tests are presented in Table 6 while those relating to the mechanical tests are listed in

Table 7 Mechanical properties of the brick

Ref	Dimensions of the test piece			Rc (Mpa)
	L (mm)	La (mm)	H (mm)	
0085/1-A	117,4	124,6	89,14	3,72
0085/1-B	117,3	128,3	92,02	3,88
0085/1-C	117,6	133,7	71,6	3,24
Average	117,4	128,9	84,3	3,6

**Figure 7** Variation of the compressive strength according to the height of the block

By consulting the above results, we can note that:

- The compressive strength of solid bricks used in the construction of the building is relatively low compared to existing ones and currently marketed, the study carried out by us as part of our thesis on the full brick of Ksar Lakbir has shown that its compressive strength is in average equal to 13.4 MPa, the same remark applies to other physical characteristics.
- The compressive strength varies and increases with the height of the test piece this can mean the variation of the dry density gradient within the brick, in fact, several studies have shown that for the same composition of the material, the compressive strength increases with dry density (PKLA, 2002) Figure 7.

5. CONCLUSIONS

The work done in this article aims to present a phase of the methodology of the diagnosis of a historical monument beforehand to its restoration, namely the identification of the construction materials of this monument, this methodology goes through several stages which have as their final objective the development of a rehabilitation operation by keeping as much as possible the old identity of the building, the case study of the Merdersa Ben Youssef in Marrakech, allowed us to collect the following results:

- The foundations of the walls have no abnormalities and are in good condition, the only problem that persists is the presence of humidity due to capillary rise in some places;
- The rammed earth material has a variable particle size, and a luminous character sensitive to water ;
- The compressive strength of the solid brick is in the order of 3.6 MPa, despite the large height of the blocks this strength is low compared to the solid brick currently marketed, this can be interpreted either by the degradation and the loss mechanical characteristics over time of the brick or by the processes of their manufacture;

Finally, it should be noted that all the soundings and tests carried out on our building remains limited, in fact, the knowledge of the overall behavior mode of the rammed earth material as well as the solid brick masonry used in the construction of this building remains to be studied, in this regard, the next step will be to analyze the structural system as well as the realization of an identification by chemical analysis by X-ray fluorescence.

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