Tabique construction in the Municipalities Association of the *Terra Quente Transmontana*

C. GONÇALVES[1], J. PINTO[1], J. VIEIRA[1], P. SILVA[1], A. PAIVA[1], L. RAMOS[1],
P. TAVARES[2], L. FERNANDES[2], J. LOUSADA[3], H. VARUM[4]
[1]Engineering Department, ECT
Trás-os-Montes e Alto Douro University
5001-801 Vila Real
PORTUGAL
[2]CQVR and UME
Trás-os-Montes e Alto Douro University
5001-801 Vila Real
PORTUGAL
[3]ECA, Forest Department
Trás-os-Montes e Alto Douro University
5001-801 Vila Real
PORTUGAL
[4]Civil Engineering Department
University of Aveiro
3810-193 Aveiro
PORTUGAL
[1,2,3]tiago@utad.pt http://www.utad.pt
[4]hvarum@ua.pt http://www.ua.pt

Abstract: Tabique is one of the main Portuguese traditional building techniques which use basically natural and local building materials such as earth and timber. A *tabique* building component such as a wall is build up using a simple timber structure covered on both sides by an earth based mortar. The earth based mortar has an important role in this building system technology since it not only protects the internal timber structure but it also acts as finishing elements. Meanwhile, earth has the advantage of being abundant, natural, local and recycled which gives to this technique a special importance in the sustainability context. It has been noticed that this traditional building technique has an expressive incidence in the region of *Trás-os-Montes and Alto Douro*, Portugal. Taking into account that the *Trás-os-Montes and Alto Douro* region is very large, there was the necessity to divide it in to more manageable areas. The manageable areas are the six Municipalities Associations, which are: *Alto Tâmega*, *Terra Quente Transmontana*, *Terra Fria do Nordeste Transmontano*, *Vale do Douro Norte*, *Vale do Douro Sul* and *Douro Superior*. This research work is focused on the Municipalities Association of *Terra Quente Transmontana*. This, combined with the scarcity of scientific studies concerning the construction of partition wall in this region, motivated this research work that uses some constructions as sampling and which is focused on experimental study to determine the texture, identification of chemical and mineralogical composition of the coating material / filler used, identifying the species of wood and the hardness of the nails.

Key-Words: Tabique, Urban rehabilitation, Sustainability, Raw materials, Traditional construction techniques, Materials characterization

1 Introduction

A *tabique* building component such as a wall is consists of a timber coated on both sides with a cement-based mortar. Thus, construction of a partition can be considered as a reference model of sustainability in the context of Civil Engineering.

During the process of this research an exhaustive and detailed survey of the building stock in the region under study was carried out as well as the identification of

construction materials used and stimulation for its conservation and preservation.

The research presented here is focused on the Municipalities Association of *Terra Quente Transmontana* (AMTQT). They tried to find the largest number of *tabique* buildings existing in the area, of which highlighted aspects of characterization for detailed study. However, it is important to disclose the detailed study of the identification / characterization of the filler material / coating used on these buildings and report the results that were most expressive.

To this end, we collected several samples of coating / filling as well as parts of lath and vertical boards which were then tested experimentally as in other studies, Carvalho *et al.* [1; 2]; Martinho *et al.* [3]; Cepeda [4]; Cruz *et al.* [5]. The sieve analyses was performed at the Laboratory of Materials and Soils of Trás-os-Montes e Alto Douro University (UTAD), the analyses of elemental composition was performed by Scanning Electron Microscopy / Energy Dispersive Spectroscopy (SEM / EDS), the analyses of mineralogical composition by elemental X-ray, these last two were held in the Scanning Microscopy Unit of UTAD. Determining the species of wood used in the supporting structure of the element of partition was performed in the Laboratory of the Forestry Department of UTAD.

This paper is structured as follows. First a brief description of the area of study will be made, followed the selection of the constructions of all tests performed on samples collected. Lastly, a conclusion which summarizes the most important of this research will be presented.

2 Municipalities Association of the *Terra Quente Transmontana*

AMTQT is one of the six Associations of Municipalities of the region of *Trás-os-Montes and Alto Douro* which is the northeast part of Portugal, Fig.1.

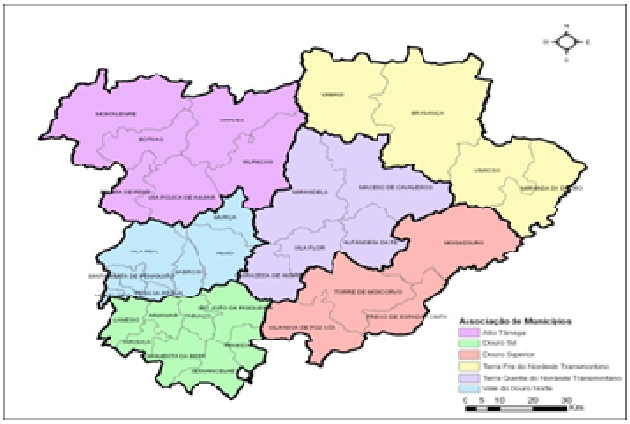


Fig.1 - Municipalities of the AMTQT

The five Municipalities of the AMTQ are *Macedo de Cavaleiros*, *Alfândega da Fé*, *Vila Flor*, *Mirandela* and *Carrazeda de Ansiães*. Which corresponds to a geographical area of 1985.11 km^2.

3 *Tabique* Construction

A *tabique* building component such as a wall consists of a wooden structure made up of vertical boards connected by a lath (horizontal slats) which are connected together by metal nails. This structural system is then coated with a material believed to be based on earth.

The *tabique* constructions identified in the study area are older, single-family housing, mostly they which are have two floors and feature a degraded condition: They are a severely degraded and ruins. The building construction elements the most representative are partition walls and walls exterior located always on the upper floors, Fig.2.

a) Exterior wall b) Partition wall

Fig.2 - Examples of the most representative elements of *tabique*

The existing *tabique* construction in the AMTQT is mainly from the XVII and XIX. They started to fall into disuse when the reinforced concrete and the ceramic bricks were introduced Pinto *et al.* [6].

4 Research Strategy and Fieldwork

Taking into account that the area under study has an extension of 1985.11 km2, it was necessary to organize and plan the field work in order to achieve efficiently the proposed objectives and similarly to Martinho *et al.* [3], Cepeda [4], Cruz *et al.* [5], and Pinto *et al.* [6]. Therefore, the field work consisted of the following logic sequential tasks: (i) to visit all the five councils areas in order to select the *tabique* constructions to be detailed studied and to interview retired builders; (ii) to contact the building owner of each construction and to ask for permission; (iii) to visit the constructions, making an extensive photographic report of the construction details, measuring the buildings and its constructive elements, and getting material samples for the experimental characterization studies to be made at laboratories.

For the survey, the application form presented in Fig.3, which was very helpful is the d systematization of the information needed for this research work.

APPRAISAL FORM	
Construction type:	Det ached house
Number of floors:	2,0
Owner:	
Location	
Street:	Rua Cimo Da Vila
City/ Area:	Macedo de Cavaleiros
District:	Macedo de Cavaleiros

Description/ Characterization of the tabique construction element	
Identification:	Exterior wall
Conservation:	Deteriorated
Width (cm):	280
Height (cm):	50
Thickness (cm):	
Vertical Timber	
Width (cm):	1,5
Thickness (cm):	1,0
Spacing (cm):	
Horizontal timber elements	
Width (cm):	0,2
Thickness (cm):	1,0
Spacing (cm):	
Mortar sample	
Earth:	Saibro
Thickness (cm):	1,5

Fig.3 - Appraisal form filled for an example of a *tabique* construction existing in *Macedo de Cavaleiros* Municipality (November 2009)

Thirteen selected constructions were considered of being representative samples of the existing *tabique* constructions in the AMTQT, Fig.4. Their location is shown in Fig.5.

Fig.4 - *Tabique* constructions studied in the AMTQT

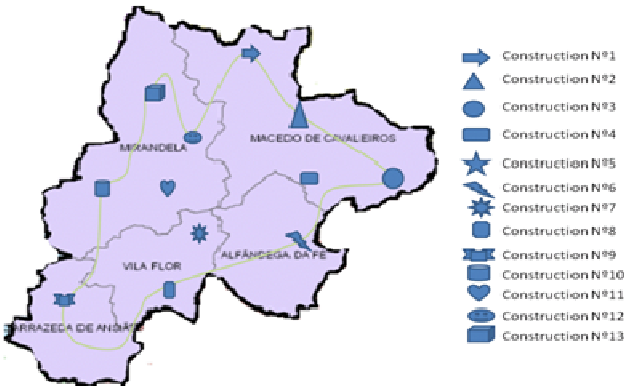


Fig.5 - Location of the thirteen *tabique* constructions

5 Fieldwork Results and Analyses

The adopted designation for the above each construction will be related to the designation used for the different material samples collected and studied following.

This research, as mentioned above, include the collection of the buildings material samples, when possible, on *tabique* constructions. Dwellings were found with this building technique in all Municipalities; however it was not possible to obtain samples from all of them as we did not get permission from the owners and others were in ruins.

6 Materials Identification and Characterization

In order to identify and characterize the materials traditionally used in the *tabique* constructions, an experimental campaign was developed using the materials samples collected at the studied constructions during the fieldwork.

Apart from the metal nails used to connect the timber elements, the most relevant *tabique* construction materials are earth and timber, natural materials.

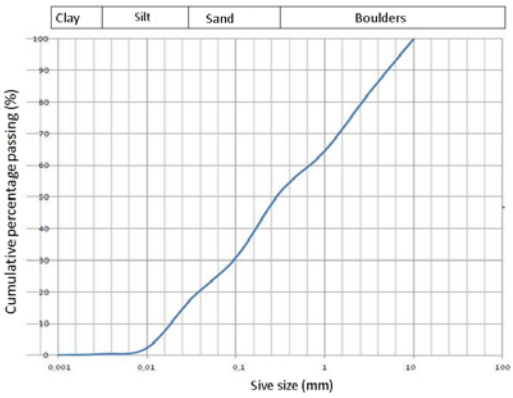
6.1 Mortar

The timber structure of a *tabique* constructive element is covered on both sides by an earth based mortar.

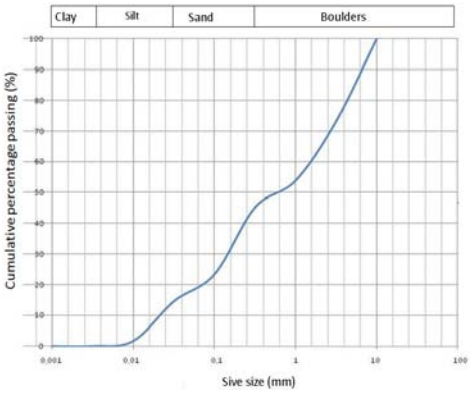
A granulometric analysis was done at the Laboratory of Materials and Soils of UTAD of the mortar samples collected in the existing constructions under study (see example in Fig.6), using the procedures according to the ASTM standards. Results of the granulometric analysis have shown that the soil typically used for the production of the mortars is approximately composed by 20% of fine fraction, as the results in the granulometric curves presented in Fig.7.

It was only possible to get adequate mortar samples for this analysis in two *tabique* constructions (No.9 and No.10).

Fig.6 - Some mortar samples for the granulometric analysis



a) Sample 9



b) Sample 10

Fig.7 - Granulometric curves

6.2 Analysis SEM / EDS and X-Ray

In order to identify the chemical and mineralogical elementary composition of the samples mortars collected, (SEM/EDS) and X-ray test were performed, in the Microscopic Electronic Unity of the UTAD. Two examples the material samples used in this study are shown in Fig.8.

Fig.8 - Samples for the SEM and X-ray

Similar tests have been already done in the framework of other research projects, Carvalho *et al.* [2], Silva *et al.* [7] and Pinto *et al.* [6], to characterize the available and used materials for the local traditional constructions.

The results obtained by the SEM/EDS test are presented in Table 1 and results of the X-ray test are shown in Table 2.

The adopted designation for the earth-base mortar samples in Table 1 is related to the constructions form where each sample was extracted (for example, earth-based mortar sample 02 means that the sample was extracted in construction 02, Fig.5).

Table 1 - Results of SEM/EDS. Elementary chemical composition

Chemical element (%)	Earth based mortar samples												
	1	2	3	4	5	6	7	8	9	10	11	12	13
O	49.05	46.98	45.42	48.40	46.88	47.53	48.21	48.01	43.90	46.91	46.25	51.29	48.94
Na	0.73	0.59	0.96	0.94	0.64	–	1.10	0.63	0.63	0.35	0.45	–	0.95
Mg	6.14	0.82	1.81	0.71	1.40	0.86	1.04	0.32	1.09	0.95	1.17	13.80	0.69
Al	3.96	5.68	6.74	2.25	3.60	5.90	5.18	3.41	13.05	5.97	7.24	1.48	3.86
Si	10.47	0.71	15.29	4.28	5.97	12.81	13.52	7.49	30.13	18.37	13.77	3.01	7.06
Cl	–	–	0.15	0.39	0.26	–	–	0.65	–	0.18	0.32	0.17	–
K	1.19	1.63	1.47	0.77	0.59	2.31	2.14	1.29	8.86	2.49	2.56	0.38	1.01
Ca	25.56	31.29	20.64	40.08	36.12	26.41	23.22	34.87	0.49	21.15	24.28	28.14	36.77
Mn	–	–	0.28	0.69	–	–	–	–	–	–	–	–	–
Ti	0.21	1.30	0.74	1.09	0.48	0.39	0.22	–	0.64	0.35	0.25	–	–
Fe	2.90	2.60	0.35	–	0.74	2.69	3.45	2.83	6.25	3.27	0.74	1.80	0.72

Table 1 shows the percentages of each chemical element found in samples and as a result of the SEM/EDS test.

The chemical elements identified in Table 1 were oxygen (O), sodium (Na), Magnesium (Mg), aluminium (Al), silicon (Si), chlorine (Cl), potassium (K), calcium (Ca), manganese (Mn), titanium (Ti) and iron (F). Meanwhile, the X-ray test's results are presented in Table 2 in where the mineralogical elementary compositions of the mortar samples are identified.

These results indicate an unexpected high quantity of calcium the earth-based mortar used on the *tabique* constructions of AMTQT region.

Table 2 - Results of the X-ray. Mineralogical compositions

Samples	Mineralogical composition
Reference sample	Calcite + Quartz
01	Calcite + Quartz+ Muscovite+ Albite
02	Calcite + Quartz+ Muscovite
03	Calcite + Quartz+ Albite
04	Calcite + Quartz
05	Calcite + Quartz +Muscovite
06	Calcite + Quartz +Muscovite +Albite
07	Calcite + Quartz +Muscovite
08	Calcite + Quartz +Muscovite
09	Calcite + Quartz +Muscovite
10	Calcite + Quartz +Muscovite
11	Calcite + Quartz +Muscovite
12	Calcite + Quartz +Muscovite
13	Calcite + Quartz +Muscovite

Generally, the earth-based mortar samples studied have silica (Si), aluminium (Al) and calcium (Ca).

Since the limestone is uncommon in these regions of Portugal, it is conclude that this mortar samples have incorporated an important amount of lime.

The percentages of chlorine (Cl), titanium (Ti), manganese (Mn), are generally very low in most of the samples.

6.3 Timber

During the field work, it was possible to get timber samples from most of thirteen constructions analyzed. The designation of each timber sample (see Table 3, column 1) is also related to adopted designation for the constructions from where that sample was extracted.

The experimental identification and characterization process of the eleven timber samples was done at the Laboratory of the Forest Department of UTAD. Fig.9 shows example of the tested timber samples.

Table 3 - Identification of the species of the timber samples

Sample	Wood Species
1 – Vertical	*Castanea sativa*
Horizontal	*Populus sp*
2 – Horizontal	*Pinus pinaster*
3 – Vertical	*Pinus pinaster*
Horizontal	*Pinus pinaster*
4 – Horizontal	*Pinus pinaster*
5 – Horizontal	*Pinus pinaster*
6 – Horizontal	*Pinus pinaster*
7 – Horizontal	*Pinus pinaster*
8 – Horizontal	*Pinus pinaster*
9 – Horizontal	*Pinus pinaster*
10 – Horizontal	*Pinus pinaster*
11 – Horizontal	*Pinus pinaster*
12 – Horizontal	*Pinus pinaste*
13 – Vertical	*Populus sp*
Horizontal	*Pinus pinaster*

Fig.9 - Timber samples

It was concluded that the *pinus pinaster* is the most common type of wood traditionally used in the timber structural components of the *tabique* elements, Table 3. Moreover, *pinus pinaster* is the most abundant type of tree of this region of Portugal.

6.4 Nails

The mechanical connection between the timber elements (was usually made with nails. Hardness tests and reaction to chemical agent test were done at the Materials Laboratory of UTAD, for thirteen nail samples.

Table 4 summarizes some data related to the results of the material characterization of the nail samples.

Table 4 - Test result of the hardness of nails

Sample	Higness Vickvers (HV)
1	223,0
2	249,5
3	397,0
6	359,5
9	260,0
10	228,5
11	267,5
12	275,5
13	460,5

From the characterization tests of these connectors, the experimental results indicate that these nails are made of steel, because HV is superiors of 200.

7 Conclusion

Trás-os-Montes e Alto Douro is region rich in *tabique* constructions. The AMTQT also confirms this fact.

Generally, the constructions that have *tabique* elements in the AMTQT are detached houses of two floors and the *tabique* elements are more commonly used as an interior partition wall. However, exterior *tabique* walls can also be frequently founded at the first floor level.

The most common structural materials used in the *tabique* elements are the *pinus pinaster* timber, being the timber elements connected by steel nails. In addition, this structural support system is normally covered on

both sides by an earth-based material instead of conventional mortars.

Previous similar research works, Varum *et al.* [8] done in this context have figured not that there are a lot of cases in which it is only used earth as coating.

This research work also allows to highlight that the *tabique* constructions are sustainable buildings solutions that should be used as models in the developing of modern sustainable building solutions, following the assumptions made in the work of Kralj and Markic [9; 10].

References:

[1] Carvalho, J., Pinto, T., Varum, H, Jesus, A., Lousada, J. & Morais, J. – *Construções em tabique na região de Trás-os-Montes e Alto Douro*. CINPAR 2008 – 4th International Conference on Structural Defects and Repair. Civil Engineering Department – University of Aveiro. Portugal. 25-28 June 2008, eds: H. Varum, F. Carvalho, A. Costa, A. Bertini, P. Stepánek. ISBN: 978-989-95695-3-9, 2008.

[2] Carvalho, J., Pinto, T., Varum, H; Jesus, A., Lousada, J. & Morais, J. – *Estudo do material terra usado nas construções de tabique na região de Trás-os-Montes e Alto Douro*. TERRABRASIL 2008, VII Seminário Ibero-americano de Construção com Terra, Universidade Estadual do Maranhão, São Luiz, MA, Brazil, ed. UEMAS/Proterra, ISBN 978-85-86036-41-5, 2008.

[3] Martinho, J., Gonçalves, C., Magalhães, F., Lousada, J., Vieira, J., Varum, H., Tavares, P. & Pinto, J. - *Construção de tabique no Vale do Douro Sul*. VIII Seminario Iberoamericano de Construcción com Tierra (VIII SIACOT) and II Seminario Argentino de Arquitectura y Construcción con Tierra (II SAACT), ed: CRIATIAC – FAU – UNT, Tucumán, Argentina, 8-13 June 2009, pp.514-521.

[4] Cepeda, A. - *Construções de tabique existentes na Associação de Municípios do Alto Tâmega*. Master Thesis in Civil Engineeering. UTAD. Vila Real, 2009.

[5] Cruz, D., Sousa, D. Morais, P., Pinto, J. & Lousada, J. *Construções de tabique existentes na Associação de Municípios de Vale Douro Norte*, Engenharia Civil. UTAD. Vila Real, 2009.

[6] Pinto, J., Varum, H., Cruz, D., Sousa, D. Morais, P., Tavares, P., Lousada, J., Silva, P. & Vieira, J., Characterization of Traditional *Tabique* Constructions In Douro North Valley Region, *WSEAS Transactions on Environment and Development*, Vol.6, No.2, 2009, pp.105-114.

[7] Silva, B., Nunes, F., Pinto, A., Tavares, P., Varum, H. & Pinto, J. *Perspectiva biominética do ninho de andorinha-dos-beirais*, VIII SIACOT, VII Seminario Iberoamericano de Construcción com Tierra, Tucumán, ARGENTINA, Ed. CRIATIAC, FAU, UNT, 2009, pp.326-332.

[8] Varum, H., Costa, A., Pereira, H., Almeida, J., Rodrigues, H., Caracterização do comportamento estrutural de paredes de alvenaria de adobe - *Revista Mecânica Experimental*, APAET, Associação Portuguesa de Análise Experimental de Tensões, ISSN 1646-7078, Vol.15, 2008, pp.23-32.

[9] Kralj, D. & Markic, M., Processes Innovation and Sustainable Development, *WSEAS Transactions on Environment and Development*, Vol.4, No.2, 2008, pp.99-108.

[10] Kralj, D. & Markic, M., Sustainable Development Strategy and Product Responsibility, *WSEAS Transactions on Environment and Development*, Vol.4, No.4, 2008, pp.109-118.