Tabique walls typologies and building details in the *Alto Douro Wine Region*

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Abstract: - *Tabique* is one of the main Portuguese traditional building techniques which use raw materials as earth, wood and stone. In general, a *tabique* building component as a wall is formed by a timber structure more or less complex, filled and plastered by a composite earth based material. The earth based material has an important role in this system because it protects the internal timber structure as well as it is a finishing. The *Alto Douro Wine Region*, located in the interior of Northern Portugal, added to the UNESCO’s Word Heritage Sites List in December 2001 as an ‘evolved continuing cultural landscape’, is rich in terms of *tabique* heritage constructions. Meanwhile, previous research works have shown that the existing *tabique* constructions, in this region, present a generalized advanced stage of deterioration. This aspect associated to the fact that there is still a lack of scientific studies done in this field motivated the writing of this paper, which its main objective is to identify the diversity of structural timber *tabique* walls solutions and building details presents in the *tabique* constructions located in *Lamego* municipality, in the *Alto Douro Wine Region*, in order to motivate and give guidelines to the preservation of this important legacy.

Key-Words: - *Alto Douro Wine Region*, *tabique*, timber structures, traditional building techniques, raw materials.

1 Introduction

One of the most traditional Portuguese building techniques is *tabique*, [1]. In the *Alto Douro Wine Region*, illustrated in Fig. 1, included in the *Trás-os-Montes e Alto Douro Region*, both located in the interior Northern of Portugal, this traditional building technique had a significant incidence until early XX century and start to be in disuse with the introduction of reinforced concrete and ceramic bricks.

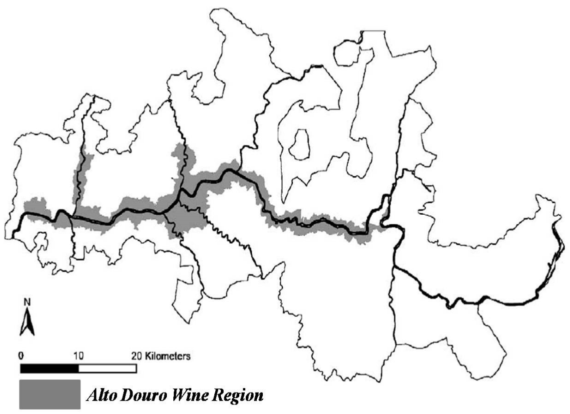


Fig. 1 – *Alto Douro Wine Region area*

The landscape and vernacular architecture present in the *Alto Douro Wine Region*, Fig.2, are one of the principal reasons why this region has been registered in the UNESCO’s World Heritage Site List in December 2001 as an ‘evolved continuing cultural landscape’, [2].

Fig. 2 – *Alto Douro Wine Region* landscape

Nowadays a particular attention must be done to preserve that landscape and vernacular architecture since this classification depend on it. Previous research work done by Pinto *et al.* [3] on these regions indicates that the majority of *tabique* constructions are detached houses with two storeys that have exterior stone masonry walls at the ground floor level, *tabique* exterior walls at the first floor, while *tabique* partition walls can be found in any of these floor levels. Furthermore these constructions present an advanced stage of deterioration, which can dangerously lead to a progressive building collapse and therefore rehabilitations and conservation works are urgently needed. Those aspects motivated the writing of this paper, which we believe, will contribute for a better understanding of this traditional Portuguese building technique and, therefore, give guidance to future mechanical modelling and rehabilitation building processes in order to preserve this important legacy.

This paper is structured in three parts as follows: In the first one and based on a fieldwork performed by Cardoso [4] concerning *tabique* buildings located in the *Alto Douro Wine Region*, a definition and characterization of the existing typologies of structural timber *tabique* walls solutions is realized and commented. The usual overall and components dimensions of those *tabique* walls solutions are also reported and commented. In the second part the overall main structural system solution adopted in a *tabique* dwelling, located in *Lamego* municipality, near *Douro* river, which was considered as a reference of the above feature is described. The adopted connection solutions between structural timber components found on that *tabique* dwelling are some of the building details which are delivered while the corresponding conservation stage of these components is analyzed. Finally in the third part the main conclusions are reported.

2 Timber structural typologies of *tabique* walls

Exterior and partition walls are the main *tabique* building components, furthermore these elements can have a relevant structural performance in the overall stability of a building, [5]. A *tabique* building component as a wall is formed of a timber structure made up of vertical boards or studs connected by laths trough metal nails. This structure in then coated with an earth based material. According to Pinto *et al.* [6] and Cardoso [4], it was concluded that the most common building materials used in this context are the *Pinus pinaster* for the timber structural elements, an earth based mortar for the filling and coating and steel nails for the connection between the timber elements. Furthermore, the fieldwork based on technical visits and collection of information performed by Cardoso [4] in the municipality of Lamego in the *Alto Douro Wine Region* on several *tabique* dwellings revealed that the timber structural solutions of *tabique* walls presents typical typologies for the exterior walls as well as for the partition walls. This diversity of typologies is mainly due to variations on the orientation and dimensions of the timber components, in their manufacturing process and in the quantity of earth based material applied. These typologies are characterized in the next section.

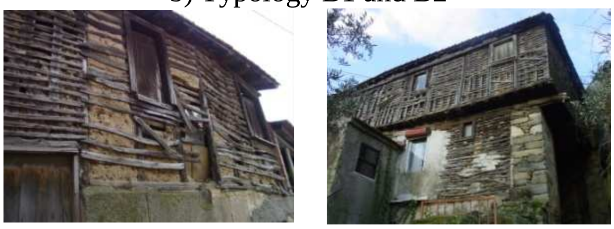
2.1 Description of *tabique* walls timber structural typologies

2.1.1 Exterior walls

During the mentioned fieldwork, it was observed that exterior *tabique* walls can present three main typologies. These typologies were designated typology A, B and C and are illustrated in Fig. 3.

a) Typology A

b) Typology B1 and B2



c) Typology C

Fig. 3 – Structural timber typologies

The typology A, Fig. 3-a), is formed of vertical studs and braces (diagonally orientated, at approximately 45º, studs) while the laths, placed in the horizontal direction, are applied in both side of the studs with metal nails as connectors. The dimensions of all these elements have significant variations [4] and their appearance or their curved longitudinal axes and rounded cross section corners suggest that they were obtained by a manual cut process. A typical detail of this typology is illustrated in Fig. 4. The brace is a unique peace witch intersect and cut the vertical studs, all the studs are in the same plane and are connected thought nails to the bottom en top rails. We strongly believe that the diagonally orientated stud act has a bracing system component relatively to the timber structure plane and allow the *tabique* wall to withstand horizontal forces acting in the plane of the wall structure. One of them will be in tension and the other in compression.

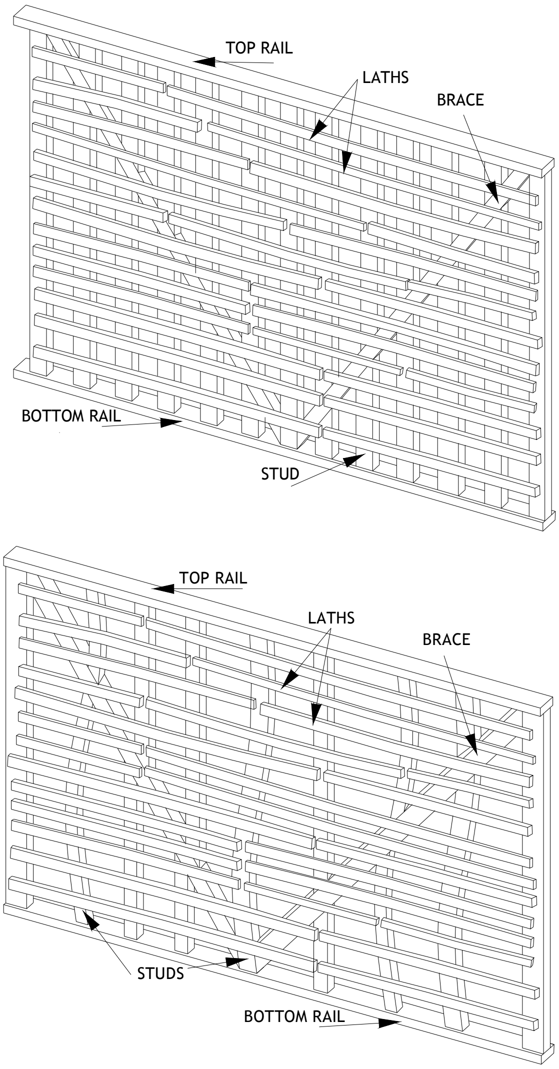


Fig. 4 – Typology A

Regarding typology B, illustrated in Fig. 3-b), she was divide in two typologies B1 and B2 since the above mentioned fieldwork indicates that the vertical elements can be boards (typology B1) or studs (typology B2). Comparatively with typology A, braces are not present in these timber structural solutions. Furthermore the elements presents in typology B1 appeared to have been obtained through a mechanical cut process due to: a slight uniformity in their dimensions, a clean appearance, straight longitudinal axis and cross sections corners perfectly cut. Fig. 5 shows a typical detail of typology B1.

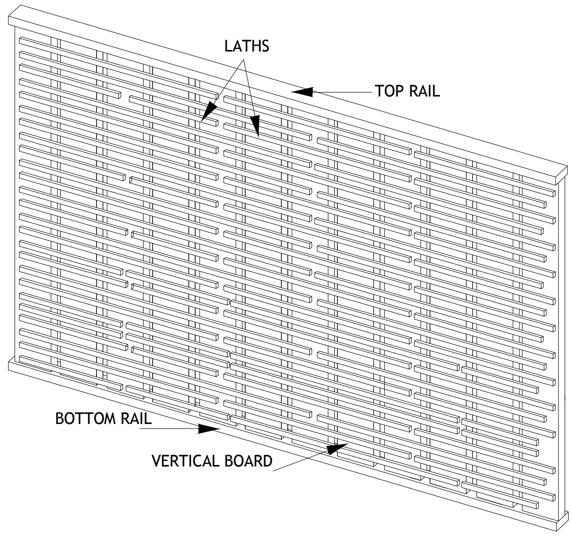


Fig. 5 – Typology B1

In contrast, the timber elements of typology B2 presents, as typology A, a larger range in the variations of the dimensions, curved longitudinal axis and rounded cross section corners suggesting that they were also obtained by a manual cut process. Fig. 6 shows a typical detail of typology B2.

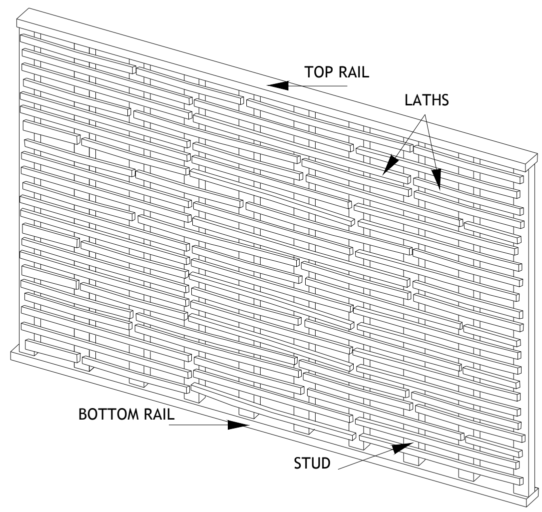


Fig. 6 – Typology B2

A bigger horizontal spacing between studs than between boards is evident suggesting that a fairly higher quantity of earth based material is applied in typologies who uses studs, as B2 and A, rather than in typology B1 constituted with boards. Since the mechanical cut process is a natural evolution from the manual one, more recent, permitting to define the components dimensions with less restrictions and to obtain more easily timber components and since typology B1 have lesser horizontal spacing, we suspect that ancient builders were interested in decrease the quantity of applied earth based material trough the use of larger studs and less spaced, in order, we believe, to restrain the use of earth based material to a coating function while increasing the walls strength.

Finally, typology C, shown in Fig. 3-c), is characterized by a sequence of timber structural subframes separated by posts, in which the dimensions and orientation of the timber elements can vary substantially. Each subframe and corresponding components as it one properties and this framing system can be seen as a combination of typology A and B previously described. Furthermore two new components rises in this configuration, a middle rail, an horizontal element with the same dimensions of the studs which intersect and cut the vertical studs (subframe C in Fig. 7) and posts, vertical elements used to separate the subframes. Braces can also be presents in this solution. In Fig. 7 a typical detail of this typology is delivered.

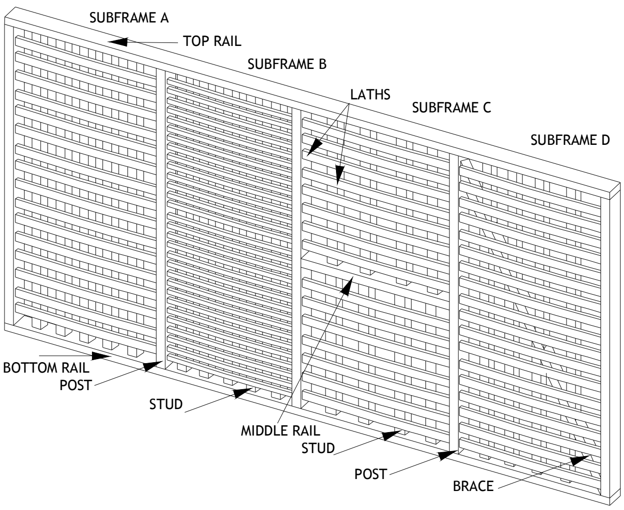


Fig. 7 – Typology C

2.1.2 Partition walls

Regarding to the timber structural solutions of partition walls, two main typologies, designated typology A and B were observed during the fieldwork and are illustrated in Figs. 8-a) and 8-b).

a) Typology A b) Typology B

Fig. 8 – Partition walls typologies

Typology A, Fig. 8-a), is characterized to be formed of boards for the vertical elements and laths for the horizontal ones. Those elements show approximately uniform dimensions, a clean appearance, straight longitudinal axis and well defined cross section corners, suggesting that a mechanical cut process originate them, and thus similar to typology B1 previously defined to exterior walls, Fig. 9.

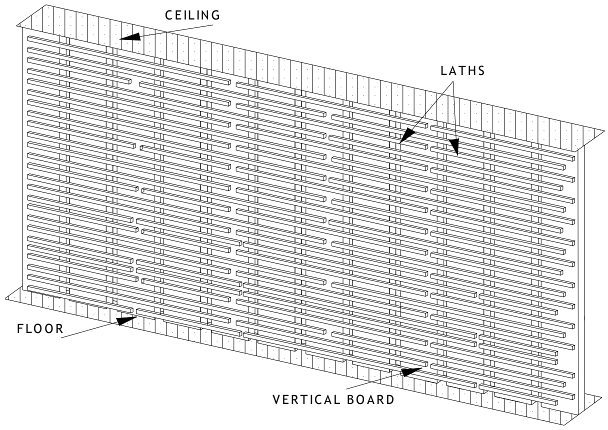


Fig. 9 – Typology A

In contrast the components of typology B, Fig. 8-b), have the same characteristic of typology B2 and A defined to exterior walls and thus may have also been obtained by a manual cut process; nevertheless no braces elements were founded. A typical detail of this typology is shown in Fig. 10.

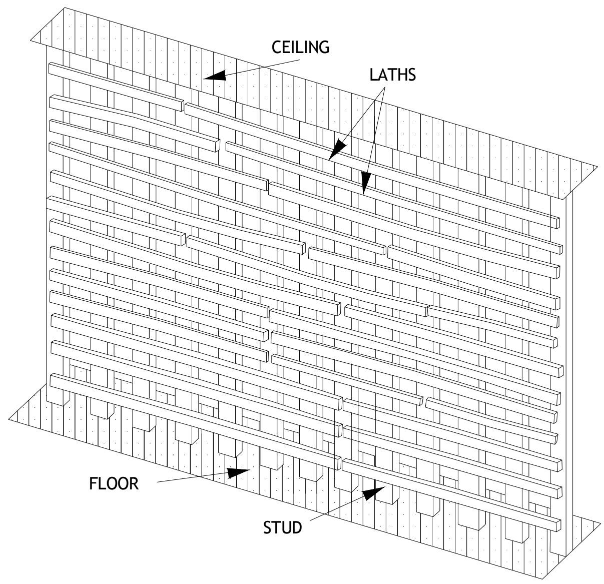


Fig. 10 – Typology B

The conclusions, previously obtained for the exterior walls regarding the natural cut process evolution and ancient builders judgments applies also, we believe, for these two typologies.

2.1.3 *Tabique* walls components dimensions

In the two previous subsections the typologies of exterior and partition walls were described. Meanwhile, during the fieldwork done in the *Alto Douro Wine Region* several technical visits realized in *tabique* buildings allowed to get detailed information regarding the usual dimensions of the *tabique* walls. In Table 1 we present the data collected from twenty four *tabique* walls studied. The total length, total height and the thickness of *tabique* walls are the reported dimensions.

Regarding the overall dimensions of the walls, total length and total height, twenty four walls, including fifteen exterior walls and nine partition walls, were measured.

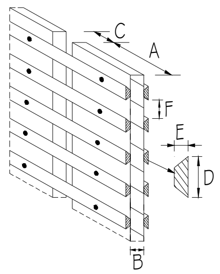
Table 1 – *Tabique* walls overall dimensions

24 samples	Total length (m)	Total height (m)	Thickness (cm)
15 exterior walls samples	0,60-8,00	1,60-3,00	9,5-11,0
9 partition walls samples			7,0-8,0

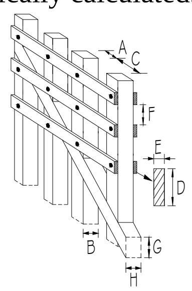
The results indicate that the total wall length varies from 0.60 m to 8.00 meters while the total wall height varies from 1.60 to 3.00 meters. This wide variety of dimensions presented seems to indicate that *tabique* walls do not have standard dimensions. It should be underline that the limited quantity of registered data is due to severe difficulties in accessing the interior of the *tabique* buildings that are private property. It is interesting to note that the total height of *tabique* walls seems limited to 3,00 meters, maybe in order to avoid the occurrence of instability phenomena. The total length reaches 8,00 meters, this values is bigger than those generally used in masonry or concrete walls whose length values are limited by thermal expansion and shrinkage phenomenon. Regarding the thickness of those walls, partition walls present values ranging from 7,0 cm to 8,0 cm and exterior walls values ranging from 9.5 cm to 11,0 cm. We believe that the bigger thickness of exterior walls is due to the fact that they have a structural function apart as the partitioning function.

The partition and exterior wall components reported dimensions are schematized in Figs. 11-a) and 11-b), the boards or studs width (A), the boards or studs thickness (B), the spacing between boards or studs (C), the laths with (D), the laths thickness (E), the spacing between laths (F), the width (G) and the thickness (H) of braces.

Regarding partition walls, eight *tabique* walls were studied and measured, four of them belong to typology A and the other four to typology B. Table 2 presents the mean interval values of each registered dimension. The applied methodology to obtain those mean interval values consist in obtaining for each one of the walls studied an interval of values for each one of the reported dimensions (since in each wall the timber components have different dimensions), then the mean intervals dimensions values of the four walls of each typology were arithmetically calculated.



a) boards and laths typologies



b) Studs and braces typologies

Fig. 11 – Registered dimensions

As shown in Table 2, the mean interval width of boards and studs (A) varies from 13,3 cm to 21,5 cm and from 9,0 cm to 11,0 cm, respectively for typology A and B. The boards or studs thickness (B) present uniform values ranging from 3,4 to 3,6 cm. The horizontal distance between vertical elements (C) varies from 3,0 cm to 5,8 cm for boards and from 16,8cm to 22,8 cm for studs. These results, as mentioned in the previous subsections, confirmed that a substantially higher quantity of earth based material is applied in walls constituted with studs (Typology B). The laths present a uniform thickness (E) ranging from 1,0 cm to 1,2 cm. Regarding the laths with (D), in typology A they are in general lesser than in typology B.

Table 2 – Partition *tabique* wall components mean dimensions

	Vertical boards (cm)			Laths (cm)		
	A	B	C	D	E	F
Typology A	13,3 – 21,5	3,4 – 3,6	3,0 – 5,8	2,1 – 3,0	1,0 – 1,1	2,8 – 4,5
Typology B	9,0 – 11,0	3,4 – 3,6	16,8 – 22,8	3,8 – 5,4	1,0 – 1,2	4,1 – 5,5

In typology A, the laths width ranged from 3,8 cm and 5,4 cm, while in typology B the laths width ranged from 2,1 cm to 3,0 cm. Finally, and regarding the vertical distance (F) between laths, we observed that in general the distance between the laths in typology A is lesser in typology B. In typology A the vertical spacing between laths ranged from 2,8 cm to 4,5 cm while in typology B this spacing ranged between 4,1 cm and 5,5 cm. As already mention the laths in typology A are obtained by a mechanical cut process, their longitudinal axes are straights and their cross section corners are perfectly cut. Since the mechanical cutting process is an evolution from the manual one, which allows to freely define the laths dimensions, we suspect, that ancient builders considered that the laths primary function was to restrain the earth based material neglecting their resistant function and for this reason they prefer to apply laths with small widths and vertical spacings. This builder believed is somewhat in opposition with numerical analyzes performed by Cardoso [4], who highlights to the beneficial effects of the laths in strengthening the *tabique* walls.

Regarding the measures made in exterior *tabique* walls, the components of nineteen exterior *tabique* walls were measured. Eight *tabique* walls belong to typology A, five *tabique* walls belong to typology B2, another two represents typology B1 and finally four *tabique* walls belong to typology C. The methodology used to obtain the mean interval dimension values of each exterior wall component is the same as described for the partition walls. First, for each individual wall, an interval is defined for the components dimensions, then for each typology mean values were obtained through the calculation of the arithmetic mean values of the corresponding walls. These results are presented in Table 3.

Table 3 – Exterior *tabique* wall components mean dimensions

	Vertical boards and studs (cm)			Laths (cm)			Braces (cm)	
	A	B	C	D	E	F	G	H
Typology A	9,1 – 12,6	5,1 – 5,5	14,3 – 16,5	3,1 – 4,8	1,0 – 1,1	4,0 - 6,3	11,1	5,4
Typology B1	20,0 – 25,0	5,3 – 5,8	2,0 – 4,0	2,1 – 2,9	1,0	2,5 – 4,5	--	--
Typology B2	8,1 – 11,2	4,7	15,9 – 22,0	3,2 – 4,7	1,3	3,6 – 5,6	--	--
Typology C	6,8 – 8,9	5,4 – 5,6	13,3 – 20,0	4,0 – 6,0	1,1 – 1,2	4,3 – 8,3	8,5	5,5

Regarding typology A, we observe that the vertical studs have a mean width ranging from 9,1 cm to 12, 6 cm, a mean thickness ranging from 5,1 cm to 5,5 cm while the mean horizontal distance ranged from 14,3 to 16,5 cm. For the laths, the mean width range from 3,1cm to 4,8 cm, the mean thickness is ranging from 1,0 cm to 1,1 cm and the vertical distance is ranging from 4,0 cm to 6,3 cm. The braces have a mean width equal to 11,1 cm and a mean thickness equal to 5,4 cm.

Subtypology B1 is constituted by vertical boards whose mean width is ranging from 20,0 cm to 25,0 cm, a mean thickness ranging from 5,3 cm to 5,8 cm and vertical spacings ranging from 2,0 cm to 4,0 cm. Regarding the laths, they present a mean width comprise between 2,1 cm and 2,9 cm, a mean thickness equal to 1,0 cm and a lath horizontal spacing ranging from 2,5 cm to 4,5 cm.

In subtypology B2, the vertical studs present a width ranging from 8,1cm to 11,2 cm, a mean thickness equal to 4,7 cm and an horizontal spacing ranging from 15,9 cm to 22,0 cm. This typology is similar to typology B of partition walls in terms of studs means width and horizontal spacing. The laths used in that typology present a mean width ranging from 3,2 cm to 4,7 cm, a mean thickness of 1,3 cm and a vertical spacing ranging from 3,6 cm and 5, 6 cm.

Comparing at this stage these results, it is apparent that in typology A and B2 a considerable higher quantity of earth based material is applied, as already mentioned for partition walls, the manual cut process origin of the studs and corresponding eventual difficulties in cutting these elements seems to imply a bigger spacing between elements as a smaller width, in opposition to the facilities that we believe the mechanical cut process allows. Analogously the laths, presents in typology A and B2, obtained by a manual cut process have bigger widths and are applied with higher horizontal spacings, we think, due to their curved longitudinal axes.

Finally, the reported results regarding typology C indicate that the mean width of the studs are ranging from 6,8 cm to 8,9 cm, the mean thickness varies between 5,4 cm and 5,6 cm, while the mean horizontal spacing varies between 13,3 cm and 20, 0 cm. For the laths, the measurements results obtained from four different walls, indicate that the mean laths width varies from 4,0 cm to 6,0 cm, the mean thickness varies from 1,1 cm to 1,2 cm and the vertical spacing is ranging from 4,3 cm and 8,3 cm. The only diagonal brace which was possible to measure have a width equal to 8,5 cm and a thickness of 5,5 cm.

3 Building details and description

In order to obtain building details of the connection between timber elements, a *tabique* dwelling located in the *Alto Douro Wine Region* and used as a reference was analysed. In this section, firstly, the *tabique* dwelling and location are defined; Secondly, a brief description of this building and of the adopted overall main structural system solutions is delivered; Thirdly, some building details solutions are introduced and described. During this sequence the level of conservation of the different structural components is commented.

3.1 The tabique dwelling

As it was stated above, a *tabique* dwelling was used as a reference of a *tabique* dwelling of two floors which has exterior *tabique* walls at the first floor level, Fig. 12. This is one of the most common solutions in the *Alto Douro Wine Region*. The other common solution is a *tabique* dwelling of two floors, having exterior stone masonry walls and *tabique* partition walls. This *tabique* dwelling is located in the *Lamego* municipality, in the *Alto Douro Wine Region*. The GPS coordinates of the precise location are: latitude of N 41º 09.230’ and longitude of W 7º 47.117’.

Fig. 12 - The *tabique* dwelling used as reference

3.2 Overall structural system solutions

Fig. 12 illustrates the frontal view of the studied *tabique* dwelling which is over 100 years old. It is a two floors dwelling (ground and first floors), having an attic. The exterior walls at ground level are stone masonry walls while the exterior walls at the first floor and all the partition walls are *tabique* walls. From Fig. 13, a cross section along the line A-A represented in Fig. 12, it is noticed that there is partition *tabique* wall at the ground floor level, this is not a common building solution among the *tabique* buildings already studied. It is evident from Fig. 12 that this dwelling presents an advanced level of deterioration. This fact is in accordance with the results reported in previous works [6], which highlight for the urgency of conservation demand that this type of buildings are requiring.

The main structural solution is formed by exterior stone masonry walls located at the ground floor level (detail L, Fig. 13) which supports timber beams, which are part of the timber structural system solution of the 1st floor. This floor also includes floor joists and the flooring, (detail G, Fig. 13 and Fig. 23). Meanwhile, exterior *tabique* walls are supported on the bottom rails located over the masonry walls (detail II, Fig. 13 and Figs. 23-b and 24). Partition walls are supported on the 1st floor timber paving (Fig. 13). The floor of the ceiling has a similar timber structural solution as the 1st floor but inverted, (detail I, Fig. 13 and Fig. 16). The main timber structural solution of the roof is beam type (i.e. 3 hinged arch, detail A of Fig. 13), this structure supports over the tie beam which are supported by the exterior *tabique* walls.

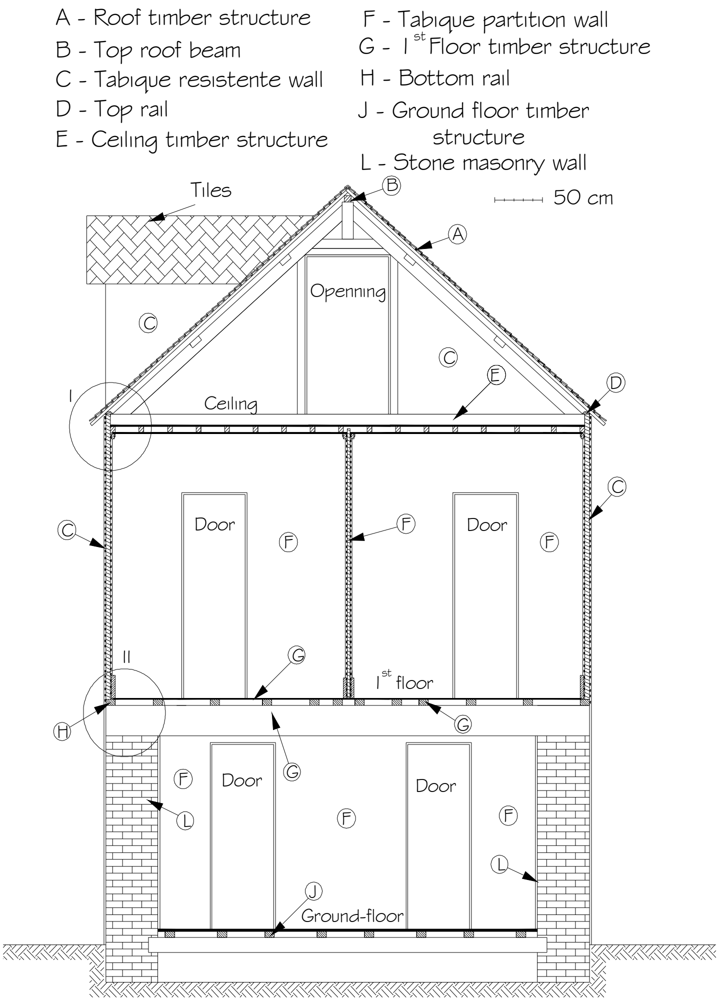


Fig. 13 - Cross section

There is also a timber paving at the ground floor level (detail J, Fig. 13) which its structural solution is similar to the one adopted in the 1st floor pavement. This structure is not in direct contact with the ground, as Fig. 13 illustrates. Furthermore characterization work reported in [4] indicates that the wood species commonly used is the timber structure is *Pinus pinaster*.

The adopted building detail solutions are introduced and described in the next subsection. This description is done from the top to the bottom. Therefore, building details concerning the solution applied at the roof and ceiling levels are delivered followed by the description of building details related to the *tabique* walls and the 1st floor level. These building details are the connections between the exterior walls and the ceiling, the orthogonal junction between two orthogonal exterior walls, the orthogonal junction between an interior and an exterior wall and the connection between partition walls and the ceiling. Finally, building details related to the connection between the 1st floors, partition *tabique* walls, exterior *tabique* walls and the exterior masonry walls are introduced.

3.3 Buildings details

3.3.1 Roof and ceiling level

The roof structural system is shown schematically in Figs. 14 and 15. The ceramic tiles (A1) are supported on the roof battens (A2) and these ones are supported on the rafters (A3). On the other hand, these last ones are supported at the bottom edge of the top rail (D) and at the top edge on the top roof beam (B). Furthermore the top roof beam are supported by two hinged beam located in the same cross alignment (A4). Meanwhile, Fig. 16 illustrates the building connection detail between the roof structural system and the exterior *tabique* walls located at the first floor level.

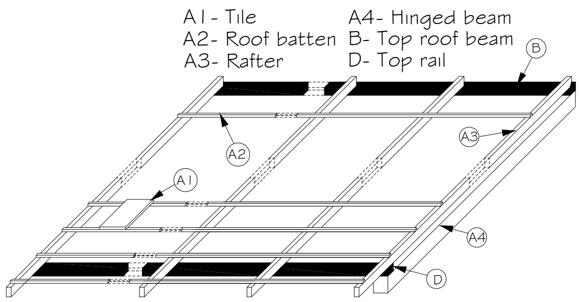


Fig. 14 - Roof structural system

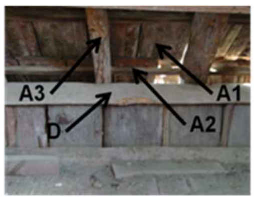


Fig. 15 - Roof structural components

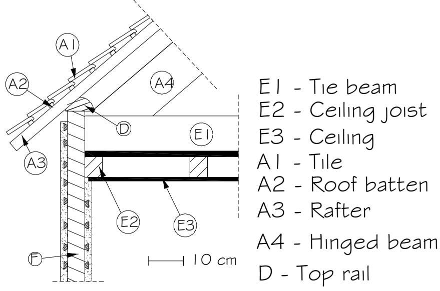


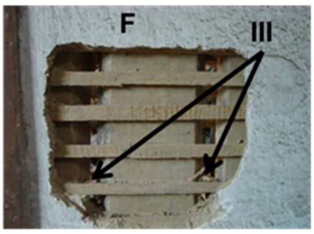
Fig. 16 - Detail I, ceiling floor

Details I in Fig. 16 shows that the ceiling and upper floor are fixed to the ceiling joist who are fixed to the tie beam. Meanwhile the hinged beams (A4), which formed the 3 hinged arch, are supported by the tie beam which in turn is supported by the vertical boards of the *tabique* exterior walls.

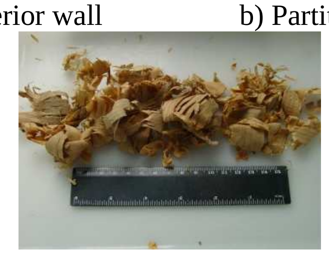
3.3.2 *Tabique* walls

The exterior and partition *tabique* walls (C and F of Figs. 13 and 17) of this dwelling have as timber structural solution vertical boards connected by horizontal laths. The exterior walls belong to the typology B1 and the partition walls belong to the typology A previously defined in section 2. The boards and laths have approximately uniform dimensions, a clean appearance and well defined cross section corners suggesting a mechanical cut process, Fig. 17-a) and 17-b). This is precisely one of the most common timber structural solutions used for *tabique* building components in this region, Cardoso *et al.* [7]. From Fig. 17, it is also noticed that these timber elements present a very good level of conservation which contrast with the overall building that is almost reaching the collapse as Figure 12 shows. We strongly believe that the earth based mortar which completely covers the timber structural elements of the *tabique* walls is able to protect the timber structure. Furthermore, in the interior of the *tabique* walls small pieces of wood were founded which probably results from the building process of the main timber structure, Fig. 17-c). This building waste was used to fill the existing gap between the vertical timber elements and as Fig. 17-c) highlights in detail III.

a) Exterior wall



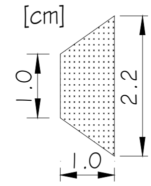
b) Partition wall



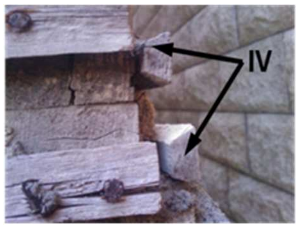
c) Building waste

Fig. 17 - *Tabique* walls

The laths cross section (detail IV) and its respective average dimensions for the exterior wall is shown in Figs. 18-a) and 18-b), respectively. The angle between corners suggest, we believe, and already mentioned, that the primary laths function is to restrains displacements of the earth based material. Meanwhile, the endings of the laths are mismatched among them along the vertical direction as Fig. 18 - c) indicates. This aspect is interesting because it suggests that a *tabique* component may fulfil the conditions prescribed by the Eurocode 5 [8] for a load-carrying capacity of systems in which the horizontal timber elements may work as a load distribution system and thus possibly indicate that a strength function was also attributed to the laths.



a) Cross section shape



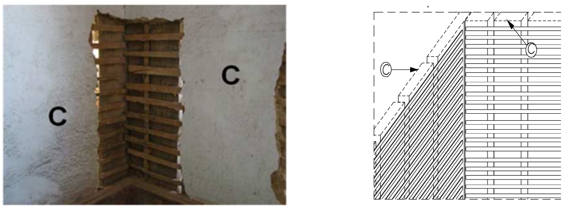
b) Dimensions

c) Mismatched of the endings

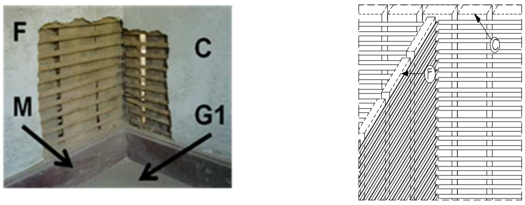
Fig. 18 - Lattice work of the *tabique* walls

In Figs. 18-b) and 18-c) it is noticed that the connection between vertical and horizontal timber elements are materialised by metal nails which correspond to the most common solution as already reported [5]. Furthermore chemical and metallographic analyzes reported in [4] demonstrated that these nails, are essentially constituted with iron.

The building connection details between *tabique* walls, exterior (C) and exterior (C), and exterior (C) and interior (F) are schematically presented in Figs. 19-a) and 19-b), respectively. For the connection between two exterior walls, the last vertical timber elements of each wall are directly connected. The same technique is used to connect interior walls with exterior walls, i.e. the last vertical element of the interior wall is directly connected to the corresponding vertical element of the exterior wall, and in both cases the existing laths are intercalated.



a) Exterior (C) and exterior (C)



b) Exterior (C) and interior (F)

Fig. 19 - Connection between walls

In order to figure out these details it was necessary to remove locally the earth based mortar coating as Fig. 19 shows. This aspect and the very bad conservation level of the building (unsafe fieldwork), were the main reasons because it was not possible to collect data related to all the building details.

We are presenting in Fig. 20 a building solution detail of the connection between an exterior *tabique* wall and the masonry wall. The vertical timber elements of the exterior *tabique* wall are connected to the bottom rail (H) by metal nails (V) and according to the detail delivered in Fig. 20.

Fig. 20 - Connection between exterior *tabique* wall and the bottom rails

Regarding the connection between the top and bottom extremity of partition walls, Figs. 21 and 22 and Fig. 24 illustrated this type of connection.

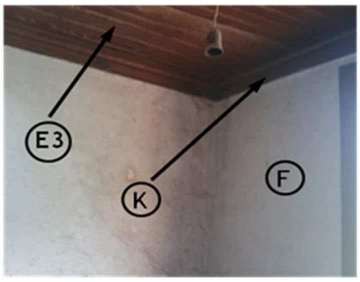


Fig. 21 - Partition wall and ceiling connection

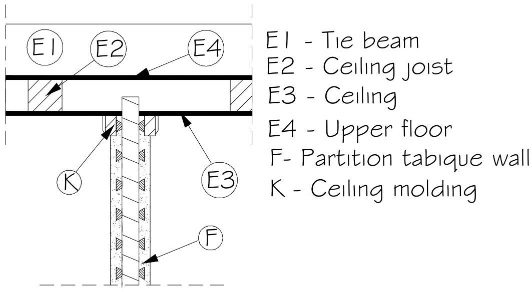


Fig. 22 - Ceiling connection detail

Figs. 21 and 22 shows that the partition walls are fixed to ceiling trough ceiling moldings, while the lower extremity is fixed the 1st floor trough skirting boards. We strongly believe that the partition walls of this dwelling are non-bearing partition walls, this aspect is in agreement with the observed absence of braces.

3.3.3 Floors

As it was stated above, in general, the timber floors and in particular the first floor has the following structural solution: the main or the principal beams are directly supported on the masonry walls; the floor joists are supported on the previously ones; the flooring boards are supported on the floor joists. The main timber floor beams G3 in Fig. 23-a), are simple supported directly to the top edge of the exterior masonry wall. The support length corresponds to the thickness of the wall and as Fig. 23-b) documents.

a) The beam b) The support

Figure 23 – Principal beam and support

In this particular case, it corresponds to a 0.60 m average thickness. Figs. 23-b) and 24 also gives guidance to realise how the exterior *tabique* wall is supported (detail II of Fig. 13) and complements the description done related to Fig. 13. In Figs. 23-b) and 24, the main timber floor, the bottom rail and the vertical timber elements of the wall are clearly identified as well as, their disposition among them. The outer face coating of the walls have completely deteriorated and disappeared in this part of the walls and this is the reason because the main timber beam top surface is exposed to the outside, Fig. 23-b). In normal conditions, it should be covered and protected with the earth based mortar.

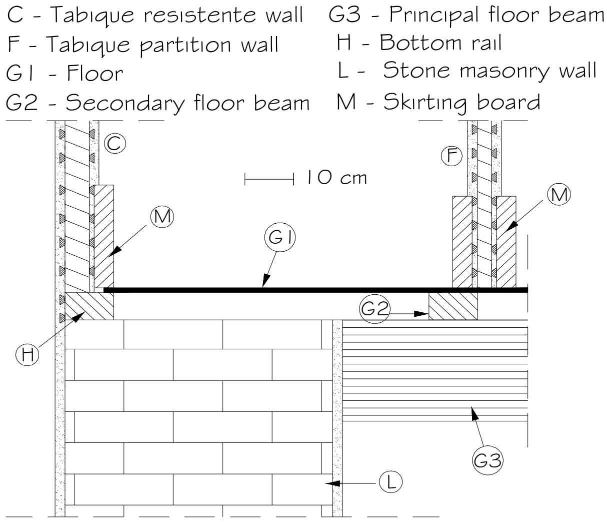


Fig. 24 – Principal beam and support, detail II

4 Conclusions

A fieldwork done in the *Alto Douro Wine Region* revealed the presence of three main typologies for *tabique* exterior walls and two main typologies for *tabique* partition walls. These typologies differentiate themselves by the dimensions of the components cross sections, the components appearance, the rounded or perfectly cut cross section corners, the presence of straight or curved longitudinal axis components, the existence or absence of braces and the quantity of earth based material applied. Most of these aspects are we believe related to the existing manufacturing process and the wall strength and stability requirements. In fact, considering the mechanical cut process a natural evolution of the manual one, with the advantage of allowing to define the components dimensions with less restriction than the manual cut process, the presence of the typology B1 of exterior walls and A of partition walls is an evolution process in *tabique* wall manufacturing regarding the other typologies and would be justified, we suspect, by the ancient builders wishes in decreasing the quantity of applied earth based material trough the use of less spaced boards in order to obtain stronger walls, restraining the use of earth based material to a coating function. Furthermore, the technical visits in the interior of *tabique* building have allowed creating a database of the usual overall dimensions of the *tabique* wall, as well as of the dimensions of the *tabique* components as boards, studs, laths etc... The wide variety of dimensions (total wall length and wall height) presented by the *tabique* walls seems to indicate these walls do not have standard dimensions. Furthermore, the total length of the walls can reach height meters; this value is high when compared with the usual total length of masonry and concrete walls. Regarding their thickness, exterior walls have a considerably higher thickness than partition walls due to the fact, we believe, that they have a structural function apart as the partitioning function, the thickness of boards and studs varies from 3,4 cm to 3,6 cm when included in partition walls and varies from 4,7 to 5,8 cm when included in exterior walls. The quantity of applied earth based material is fairly bigger when the vertical components of *tabique* walls are studs rather than when they are boards, the studs width ranged from 6,8 cm to 12,6 cm with spacings ranging from 13,3 cm to 22,8 cm while the boards width ranged from 13,3 cm, to 25,0 cm with spacings ranging from 2,0 cm to 5,8 cm. Regarding the laths, when they are obtained by a manual cut process their width varies from 3,1 cm to 6,0 cm with vertical spacings ranging from 3,6 cm to 8,3 cm, while when they are obtained by a mechanical cut process their width varies from 2,1 cm to 3,0 cm, with vertical spacings ranging from 2,5 cm to 4,5 cm. Thus, the mechanical cut process is associated to small laths width and small vertical spacings, this fact made us also suspect, that ancient builders prefer to apply this type of laths, allowed by the mechanical cut process, because they believe that laths primary function was to restrains the earth based mortar. Nevertheless and according to Cardoso [4], the laths and boards define a load distribution regarding Eurocode 5 prescribed conditions, which indicates that a strength function can also be attributed to the exterior walls laths.

The main structural system solution of an ancient *tabique* dwelling located in *Lamego* municipality in the *Alto Douro Wine Region* was presented and described. This system comprises exterior stone masonry walls, *tabique* exterior and partition walls, timber pavements and a three hinged arch beam type for the roof structure. The usage of timber structural elements is very expressive. These elements were used basically in the upper floors avoiding the direct contact with the ground. Some specific building details of this dwelling were presented and described. These details were essentially focused on the connection between components. For instance, the connection between the roof structure and the exterior *tabique* wall, the connection between the exterior *tabique* wall and the 1st floor, the connection between the 1st floor and the exterior stone masonry walls were presented. The connection of partition walls to the ceiling and the 1st floor seems to indicate that they have a non-bearing behaviour, this fact is corroborated by the observed absence of diagonal braces elements in partition walls typologies. Furthermore, details of *tabique* walls showing a sustainable building procedure which consists on reusing timber waste for the filling of the *tabique* walls were also delivered. It was noticed that the dwelling used as reference presents an alarming deterioration level almost reaching the ruin. However, it was simultaneously noticed that the timber elements located in the inside and, in particular, the ones still covered by the earth based mortar present a very good level of conservation.

This fabulous heritage is an open technical book filled with a huge amount of information related this traditional building processes and from where technicians can learn and get inspiration. On the other hand each ancient building is a real scale construction sample which as been tested under real load combination in real physical conditions and for a long period of time.

Furthermore the builders were genius because they were able to create magnificent pieces of work without codes or computers programs available. This research work intend also paying a modest tribute to all those engineers, architects, carpenters, masons and laborers who contribute to those building processes.

Another relevant technical aspect associated to this type of construction is its sustainable value according to present day premises. In fact, those buildings were built using simultaneously sustainable materials and sustainable techniques. Generally the applied materials are natural, locally available (e.g. stone, sand or earth, among others) and in some case they are also organics and, therefore, renewable (e.g. wood, straw, corn cob, among others). Meanwhile, the applied building techniques are usually simple because they do not depend on sophisticated devices or high-tech procedures. Thus, these characteristics are favorable to achieving an almost inexpressive amount of pollutant emission into the atmosphere, an enormous energy consumption reduction and also adequate water consumption. This fact is even more evident when taking in account that these old buildings were built hundreds of years ago, and in the scenario of a lifetime time of 50 years, they may be considered over-strengthened.

The above exposed arguments are sufficient to grasp the importance of this rich heritage value which must be cherished and preserved and, above all, deserves to be passed onto the following generations. For this reason the academic and scientific communities as to deliver updated technical information and knowledge to the building industry.

The presented building details and data concerning *tabique* construction may be useful in future urban rehabilitation processes. Similar research works have been done in this context and in other countries for instance in the Turkish context where *tabique* construction may be related to *bağdadi* and *dizeme* construction. A type of construction widely used in Rumelia and Istanbul, [5].

Acknowledgments

This work had some financial support from the Trás-os-Montes e Alto Douro University and the University of Beira Interior.

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