Characterization of tabique walls nails of the Alto Douro Wine Region

Abstract: Tabique is one of the main Portuguese traditional building techniques which use raw materials as stone, earth and wood. In general, a tabique building component as a wall consist of a wooden structure made up of vertical boards connected to laths by metal nails and covered on both sides by an earth based material. This traditional building technology as an expressive incidence in the Alto Douro Wine Region located in the interior of Northern Portugal, added to the UNESCO’s World Heritage Sites List in December 2001 as an ‘evolved continuing cultural landscape’. Furthermore, previous research works have shown that the existing tabique construction, in this region, reveals a certain lack of maintenance partially justified by the knowledge loosed on that technique, consequently this construction technique present an advanced stage of deterioration. This aspect associated to the fact that there is still a lack of scientific studies in this field motivated the writing of this paper, the main objectives are to identify and characterize the nails used in the timber connections. The nails samples were collected from tabique walls included in tabique buildings located in Lamego Municipality, near Douro River, in the Alto Douro Wine Region. This work also intends to give guidelines to the rehabilitation and preservation of this important legacy.

Keywords: Alto Douro Wine Region; tabique; traditional building techniques; metal nails; raw materials

1 Introduction

One of the most traditional Portuguese building techniques is tabique. In Portugal the tabique construction is spread out along different parts of the country, however in the Alto Douro Wine Region, (Figure 1-a), which is included in the Trás-os-Montes e Alto Douro Region, both located in the interior north of Portugal, this traditional building technique had a significant incidence until early XX and started to be in disuse when reinforced concrete and industrial ceramic bricks were introduced. Furthermore, a particular attention must be paid to the landscape and vernacular architecture present in the Alto Douro Wine Region since it is classified in the UNESCO’s World Heritage Site List since December 2001 as an ‘evolved continuing cultural landscape’, (Fig. 1-b). Previous research work done by Pinto et al. [1] and Cardoso & Pinto [2] on this region indicates that majority of tabique constructions are detached houses with two storeys that have stone masonry as exterior walls at the ground floor level, tabique exterior and partition walls at the first floor. Nevertheless, this heritage presents an advanced stage of deterioration. Therefore, conservation and rehabilitation works are urgently needed. This paper is intended to give guidance in future rehabilitation and conservation works and to fill the lack of scientific studies done on this region. Based in a fieldwork performed by Cardoso [3] in that region, nails collected from those tabique buildings are identified and characterized geometrically, mechanically and chemically.

2 Tabique walls timber structural system

A tabique building component as a wall, (Figure 2), is formed of a timber structure made up of vertical boards connected by laths (horizontal slats) which are connected...
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Figure 1: Alto Douro Wine Region.

(a) Alto Douro Wine Region area

(b) Alto Douro Wine Region landscape

3 Nails characterization

Nails are used in tabique construction as connectors between timber elements [4, 5]. Tabique wall components as boards, laths (Figure 3-a) or rails (Figure 3-b) are also connected through these nails. Slates (Figure 3-c) and metallic coating when existing are also connected to the timber components of walls through nails.

An experimental campaign was developed with the nails samples collected during the fieldwork performed in Lamego municipality [3, 8, 9] in order to characterize them. In this campaign, metallographic analysis on the microstructure of the nails were made at the Materials Laboratory of Trás-os-Montes and Alto Douro University and at the Mechanical Materials Laboratory of Beira Interior University. Meanwhile, the nail’s chemical characterization was performed at the Optical Center of Beira Interior University.

The metallographic analysis allowed the characterization of the microstructure (grain size, phases, etc.) of the material surface of each nail sample using optical microscopy while the hardness was characterized via the Vickers microhardness test.

The chemical elemental composition of the metal was obtained through EDS analysis (Energy Dispersive X-ray Spectroscopy).

3.1 Nails samples geometrical and dimensional characterization

The nails samples collected in Lamego municipality are presented in Figure 4. It was observed, during the fieldwork, that these nails had a wide variety of dimensions these nails present a wide dimension variety. For this reason they were first grouped according to their diameter, type of cross section and length. Twenty groups designated PR1 to PR20 and illustrated in Figure 4 were formed. Furthermore, since it was observed that a relationship between the length of nail and the type of elements connected exists, the nails groups were divided in two sets as shown in Figure 4-a) and Figure 4-b).

The first set (groups PR1 to PR9) include nails whose length varies from 6,5 cm and 10,5 cm corresponding to nails that are used to connect studs and braces and also in the connection between rails and boards or posts. The second set is constituted with nails including groups PR10 to PR20 with a length between 3,0 cm and 5,0 cm, which are used in the connection between laths and boards or
stud or for the connection between the timber structure and the slates or the metallic coating.

Furthermore the nails collected can present different cross sections. In Figure 5 the two main typologies of nails collected are schematized. Figure 5-a shows a nail with a square or circular cross section and Figure 5-b shows a nail with a square variable cross section. The reported dimensions used for the geometric characterization are the length (L), the head diameter (C), the diameter (D) (for circular cross section) and the length edge (D) of the square cross section.

Finally, Table 1 summarizes the data related to the geometry and dimensions of all the nails collected.

From the data represented in Table 1, it is possible to conclude that majority of the nails have a constant square cross section and only a small fraction has a variable cross section or a circular cross section. The diameter of the nail’s cross section varies from 1.5 mm to 4 mm and the total length between 3 cm and 10.5 cm.

3.2 Results of chemical and mechanical analysis of nail samples

The microstructure of nail samples were analyzed with a metallographic microscope, we assumed that nail sam-
Table 1: Geometrical and dimensional characterization of nails.

<table>
<thead>
<tr>
<th>Id.</th>
<th>L (cm)</th>
<th>D (mm)</th>
<th>C (mm)</th>
<th>Cross section</th>
<th>Id.</th>
<th>L (cm)</th>
<th>D (mm)</th>
<th>C (mm)</th>
<th>Cross section</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR1</td>
<td>10.5</td>
<td>4.0</td>
<td>9.0</td>
<td>Square, Constant</td>
<td>PR11</td>
<td>4.8</td>
<td>2.0</td>
<td>6.0</td>
<td>Square, Constant</td>
</tr>
<tr>
<td>PR2</td>
<td>10.5</td>
<td>3.5</td>
<td>9.0</td>
<td>Square, Constant</td>
<td>PR12</td>
<td>4.5</td>
<td>2.0</td>
<td>6.0</td>
<td>Square, Constant</td>
</tr>
<tr>
<td>PR3</td>
<td>9.5</td>
<td>3.0</td>
<td>7.0</td>
<td>Circular, constant</td>
<td>PR13</td>
<td>4.0</td>
<td>2.0</td>
<td>5.0</td>
<td>Circular, constant</td>
</tr>
<tr>
<td>PR4</td>
<td>9.0</td>
<td>3.0</td>
<td>5.0</td>
<td>Circular, constant</td>
<td>PR14</td>
<td>3.7</td>
<td>1.5</td>
<td>4.0</td>
<td>Circular, constant</td>
</tr>
<tr>
<td>PR5</td>
<td>7.5</td>
<td>3.0</td>
<td>7.0</td>
<td>Circular, constant</td>
<td>PR15</td>
<td>3.3</td>
<td>1.5</td>
<td>6.0</td>
<td>Circular, constant</td>
</tr>
<tr>
<td>PR6</td>
<td>6.8</td>
<td>3.0</td>
<td>7.0</td>
<td>Square, Constant</td>
<td>PR16</td>
<td>3.3</td>
<td>1.5</td>
<td>6.0</td>
<td>Square, Constant</td>
</tr>
<tr>
<td>PR7</td>
<td>6.5</td>
<td>2.0</td>
<td>6.0</td>
<td>Square, Constant</td>
<td>PR17</td>
<td>3.0</td>
<td>1.5</td>
<td>4.0</td>
<td>Square, Constant</td>
</tr>
<tr>
<td>PR8</td>
<td>10.5</td>
<td>4.0</td>
<td>10.0</td>
<td>Square, Constant</td>
<td>PR18</td>
<td>5.0</td>
<td>3.0</td>
<td>6.0</td>
<td>Square, Constant</td>
</tr>
<tr>
<td>PR9</td>
<td>8.5</td>
<td>4.0</td>
<td>9.0</td>
<td>Square, variable</td>
<td>PR19</td>
<td>4.5</td>
<td>2.5</td>
<td>8.0</td>
<td>Square, variable</td>
</tr>
<tr>
<td>PR10</td>
<td>5.0</td>
<td>2.0</td>
<td>5.0</td>
<td>Square, constant</td>
<td>PR20</td>
<td>4.2</td>
<td>2.5</td>
<td>7.0</td>
<td>Square, constant</td>
</tr>
</tbody>
</table>

Figure 4: Nails sample collected.

(a) Nails groups PR1 to PR9, 1st set

(b) Nails groups PR10 to PR20, 2nd set

Figure 5: Nails schema.

Figure 5: (a) Constant cross section nail

Figure 5: (b) Variable cross section

(1) Geometrical and dimensional characterization of nails. The results of this analysis allowed us to conclude that all the surfaces of the samples were similar in grain dimension and in ferrite and pearlite phase presence. Furthermore, the results show that in all the samples, the existence of darker zones corresponds to zones that exhibit a high concentration of some chemical constituent. In Figures 6 and 7, we represent the surface
images of the nails in three different optical resolutions (100x, 200x, 500x).

It can be observed from Figures 6 and 7 that some samples like PR8 and PR19 present grains with a bigger dimension. This occurrence may justify the lesser hardness of the metallic alloy reported later in Table 3 and relative to Vickers hardness. It is also possible to observe in Figure 6-b) that the mechanical process used in nail manufacturing results in a preferential orientation of the grain with visible elongation which leads to a monotonic behavior gives origin to a preferential orientation of the grain with a visible elongation which can origin a monotonic behavior.

These nails are centenarian, since they were applied in the tabique building construction stage, to verify the possibility to reuse them in future rehabilitation works we compare the microstructure of these nails with the microstructure the actual nails thus we judge pertinent to compare the nail microstructure of these nails with the microstructure of actual nails and which will be possibly used in future rehabilitation works. For this reason we prepare two samples of new nails designated N1 and N2.

These two samples were analyzed with metallographic microscope and the corresponding microstructures are presented in Figure 8. The images reveal that the two samples present an homogeneous constitution, without black spots. The presence of ferrite and pearlite phases is again identified and the grain dimension is in general less than those in the old nails samples (collected in tabique buildings). This aspect may also justify the higher hardness of samples reported in the Table 3, relative to Vickers hardness.

The chemical elements identified with EDS analysis was performed on samples PR3, PR8, PR11, PR19, PR20, N1 and N2, and revealed that they are essentially constituted with iron (Fe). The EDS results of samples PR19 and N1 are represented in Figure 9. These results indicate that the black spots present in sample PR19 have the same chemical constitution as the global sample surface and hence these black spots are not constituted with a specific chemical element as we supposed previously.

Additionally, the elemental chemical analysis (Energy-dispersive X-ray spectroscopy) of samples PR3, PR11, N1 and N2 were obtained and the results are presented in Table 2. The principal chemical element identified was the iron (Fe). These results clearly show that the nail samples metallic alloy is essentially constituted of iron, with some traces of sulfur (S), potassium (K), manganese (Mn) and copper (Cu).

Carbon (C) is another constituent that should exist in the samples but its low concentration enable EDS detection (Energy-dispersive X-ray spectroscopy). Furthermore new nails and collected nails have the same iron concen-
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Figure 7: Surface microstructure images of nail samples.

The results indicate an unexpected high hardness of old nails, it should be underlined that these nails are centenarian. From the characterization tests of these connectors, the experimental results indicate that these nails are made of steel, because the HV value is in general higher than 200. Table 3 also indicate that the samples PR8 and PR19 have indeed a lesser hardness - this fact should be associated with bigger grain size present in the microstructure and previously reported.

The hardness number of samples N1 and N2 are included between 236HV10 and 287HV10 and are in general superior to those obtained from the collected nails. The homogeneity and grain size previously reported can in part explain these results.
4 Conclusions

Nails are used to connect timber elements of tabique buildings, tabique walls and metallic coating or slates applied in the external walls of these buildings. The fieldwork performed in the Alto Douro Wine Region identify essentially two sets of nails, depending on their lengths (10.5 cm to 3 cm) and on the type of connected elements. Their cross section can be circular, constant or variable square but majority of the nails have a constant square cross section.
The experimental results obtained with optical microscopy and EDS indicate that these nails are made of steel with the presence of ferrite and pearlite phases. The chemical analysis also indicate that black spots present in the microstructure surface of these nails are also constituted with iron. The microscopic analyses of the surface indicate that used nails have a less homogeneous microstructure and grain uniformity than new nails, sometimes presenting a preferential orientation of the grains, this can be due to some degradation of the nail’s properties over time or to the mechanical process used in manufacturing which date from approximately 100 years ago.

The used nails are centenarian but present in general high values of hardness which indicate a good state of conservation, we think this is partly due to the earth based material that cover the timber structure. The results indicate that these traditional nails may still present adequate mechanical properties which enable them to be maintained in service. These experimental results also indicate that currently applied nails may be adequate for use in the future repairing of tabique constructive elements. Further research works, such as mechanical tests of tabique wall samples and numerical modelling are necessary to be performed in order to improve the technical knowledge of this traditional building technique which is applied worldwide.

**References**


