Analysis of the earthen architectural heritage in Piedmont (northern Italy): typologies, construction techniques and materials

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Analysis of the earthen architectural heritage in Piedmont (northern Italy): typologies, construction techniques and materials

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Abstract

Piedmont is characterized by the presence of numerous earthen buildings mainly concentrated in the province of Alessandria. Studies conducted over the last decade, however, have shown the presence of interesting examples of these buildings also in the provinces of Asti, Torino, Biella and Cuneo. They are generally two-storied rural constructions, built with both fired bricks (for the bearing structures) and adobe (for internal and external walls). The case of the La Serra hills between Biella and Ivrea is particularly

interesting because this zone, characterised by the presence of morenic terrains, is rich in stone materials and the traditional architecture is mainly characterized by the use of materials such as stone, brick and wood. Nevertheless, some interesting examples of earthen buildings have been found, evidence of the close relationships between man and his territory. They are fragile architectures, little or not at all known, which may be irretrievably lost if not properly safeguarded. The research aims have been to examine types and construction techniques and to analyze the characteristics and performances of the constitutive materials through in situ tests (rebound test), characterization of the adobe and mortars (XRD, particle size distribution) and identification of possible additives. This research will be useful to promote again the use in the area of these construction techniques, evidence of people's skills and abilities to take advantage of the local enviromental resources.

Introduction

Piedmont is a region sited at the foot of the western Alps therefore rich in stone materials widely used in vernacular and monumental architecture. Nevertheless, it is also characterized by the presence of numerous buildings realized adopting the rammed earth technique, mainly concentrated in the Fraschetta area (province of Alessandria) (Barozzi, 1975; Robboni, 2007; Prati, 2011). Less known is the presence of earthen buildings also in the provinces of Asti, Torino, Biella and Cuneo (Figure 1), where the adobe technique has been used. Primarily designed for utilitarian purposes, they are the expression of cultural and architectural values representing a significant testimony of the relationships between a community and its territory.

Although only few examples are still surviving, they do, however, represent the interesting evidence of know-how and old-aged construction techniques. These architectures, little or not at all known, are always in bad condition of conservation due to their fragility and lack of maintenance and risk to be irretrievably lost if not properly safeguarded. Their preservation is «threatened world-wide by the forces of economic, cultural and architectural homogenization» (ICOMOS Charter, 1999), as well as by the lack of recognition of their value. Conservation of earthen built heritage is strictly related to the full awareness of its cultural and historical value. Therefore, it is extremely important to identify it, to make people conscious about the relevance of this legacy and to promote its enhancement. Further studies aimed at deepening the knowledge of typologies, construction techniques and materials are needed, in order to foster the preservation of this heritage, to facilitate the design of appropriate restoration and reuse interventions and to promote the rediscovery of the earth as a building material. In fact, as stated by Luis Guerrero «hablar de conserver l'arquitectura de tierra no es solo en quenta los mecanismos para mantener en pie los edficios hechos en el pasado. [...] La ampliación de la perspectiva edilicia dará pie la realización de intervenciones en estructuras patrimoniales así como nuevos edificios, en lo que se mantenga el equilibrio entre el pasado y el futuro gracias a la salvaguardia del medio natural en que están insertos» (Guerrero, 2007).

This paper intends to present the results of the studies carried out on earthen constructions located in Turin, Cuneo and Biella territories. In particular, the building typologies and construction techniques have been examined together with the characteristics and performances of the constitutive materials through in situ tests (rebound test) and mineralogical and granulometric characterization of the earth.

Figure 1. Position of the investigated villages (after Google Earth modified)

Typologies and constructive techniques

In the province of Turin and Cuneo there are quite a lot of examples of buildings characterized by the presence of adobe used for the construction of both external and internal walls. They are mostly rural buildings, spread over the countryside, that are a testimony of the type of settlement whose presence «is documented in a stable form since the late XVth-early XVIth century in all the plain of Piedmont, from Turin, as far as Cuneo and Casale» (Palmucci, 1988).

There are essentially two different typologies of rural buildings: the *cassina*, a rural building complex partly devoted to host housing and partly animal shed and/or tools and product storage (Palmucci 1988; Barosso et al. 1993) and the *ciabot* or *chiabotto*, a small basic construction, erected with poor materials, intended to house the tools used for the cultivation of the fields (Comba, 1988) (Figure 2). The *cassina*, which spread from the XVIthcentury, is built with both fired bricks (for the bearing structures) and adobe (for internal and external curtain wall). The buildings have generally stone/bricks foundations 40-50 cm high in order to protect earthen walls from the water capillary rise (Figure 3). In some cases, a fired brick basement reaching the first floor can be found. The wall thickness is about 40-60 cm (Palmucci, 1988; Bosia, 2009).

The *cassina* consists of the house itself (*domus*), of the stable and the barn (*fenera*) (Figure 4). The kitchen, the dining room, the cellar and/or the storage are located on the ground floor. The bedrooms and the barn can be found on the first floor and can be reached by a wooden staircase which can sometimes also be made of stones or bricks.

The horizontal elements are mostly made of wooden beams (placed at a distance of about 80 cm) which support wooden boards or brick vaults

Figure 2. Ciabot in province of Alessandria (credits Manuela Mattone)

Figure 3 . Rural building in Priocca (Cuneo) with fired brick structure and adobe walls (credits Manuela Mattone)

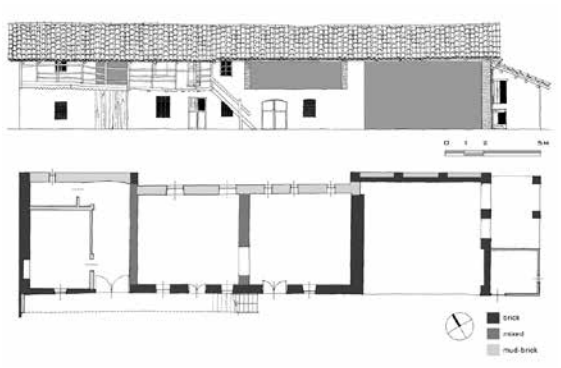

Figure 4 (a,b). Cassina in Rivasecca, Buriasco (Torino), plan of the south front and image (credits Roberto Mattone and Manuela Mattone)

(Figure 5). In the more recent buildings wooden beams gave way to H-beams (Figure 6). Often there are also brick barrel vaults poured with a water and gypsum mixture, made without ribs, but using a sand mold (*grasia*), supported by flat plank scaffolding.

Horizontal beams (CIAV), made with wild cherry or black locust, can often be found near the vault in order to ensure a greater stability to the structure (Volterrani, 1998).

The openings are generally small with brick or wooden frames (Figure 7). The roofs are double pitched and mainly have wooden structures, whose beams lay on earthen or fired bricks. The roof covering uses tiles and, when there isn't the eaves gutter, the overhang of the roof is greater in order to allow adequate removal of rainwater and ensure more protection to vertical surfaces (Figure 8). The balconies stand on wooden beams which are the extension of the internal ones.

The research was carried out focusing on different *cassina* which provide a interesting examples of traditional peasant culture. One of the selected case studies is located in Rivasecca, near Pinerolo. It is a XIXth century farmhouse and consists of a single construction that hosts the house, the barn, the hayloft and a shed for the tools. More articulate is the San Pietro farm, located in Borgo Cornalese, near Villastellone, a few kilometres away from Turin. The village was founded on the XIth century by Hungarians and Bulgarians populations. It

Figure 5. Wooden horizontal structure (credits Manuela Mattone)

Figure 6. H-beams which support brick barrel vaults (credits Manuela Mattone)

Figure 7. Brick frames surrounding the opening (credits Manuela Mattone)

Figure 8. Wooden roof structure (credits Manuela Mattone)

still preserves the characteristics of a medieval settlement and hosts many farmhouses aimed at accommodating cows grazing in the neighbouring territories. The farm, which was still represented in the Napoleons registers of land properties, is composed of two different buildings that are developed around two yards. One of these is characterized by the presence of stables built with fired brick load-bearing pillars and adobe walls. Used until the nineties of the XXth century, it is today almost totally abandoned and presents a state of advanced decay.

As for the province of Cuneo buildings located in the villages of Magliano Alfieri, Govone and Priocca, in the Roero hills, have been studied.

In the province of Biella, the selected case study is located in the village of Magnano. Although this zone, characterized by the presence of morenic terrains, is rich in stone and the traditional architecture is mainly made of materials such as stone, fired bricks and wood, an earthen rural building was found.

Materials and methods

Samples of adobe and earthen bedding mortars has been taken from buildings of Rivasecca and Borgo Cornalese (Turin province), Govone, Magliano Alfieri and Priocca (Cuneo province)

and Magnano (Biella province), moreover local soil has been sampled for comparison with the earthen building materials. The following analyses have been carried out:

- ***Mineralogical composition***

The mineralogical composition of the adobe, earthen bedding mortars and local soil was determined through X ray diffraction (XRD) (X'Pert PRO diffractometer by PANalytical equipped with X'Celerator detector and HighScore software for acquisition and interpretation of data according to the following operative conditions: CuK α1= 1.545Å radiation, 40 KV, 30 mA, 2Θ = 3-70°).

The analysis of the clay minerals was determined on the fraction <4 μm extracted through sedimentation according to the Stokes' law (Cipriani, 1958; Cipriani & Malesani, 1972) utilizing a Philips PW 1729 diffractometer, according to the following operative conditions: CuK α1= 1.545Å radiation, 40 KV, 20 mA, 2Θ = 3-20°).

- ***Calcimetry***

The amount of calcium carbonate was determined through the Gasometric technique by using the Dietrich Früling calcimeter (Leone et al., 1988).

- ***Grain size distribution***

The grain size distribution of adobe, earthen bedding mortar and local soil has been carried out through sieving in order to separate the following fractions: sand (Ø > 63μm), silt (4μm < Ø <63μm) and clay (Ø< 4 μm).

Rebound test *(on site)*

This test has been performed with the pendulum rebound hammer in order to evaluate the compressive strength of the adobe. The determined values are indicative values, because the rebound test is an indirect test, which correlates the surface hardness to compressive strength of the material.

Figure 9. On site rebound test (credits Manuela Mattone)

The employed rebound hammer was the Proceq pendulum hammer type PM (range 0.2–5 N/mm^2), suitable for a wide range of materials with low compressive strength and where small impact is required (Figure 9). The test consists in measuring the rebound R, which is in relationship with hardness, connected through appropriate correlation functions with the strength. A total of 12 measures for each wall were carried out and the corresponding average compressive strength were determined.

Results and discussion

- ***Turin province***

It seems that in both sites (Rivasecca and Borgo Cornalese) the bedding joint mortars have been realized with a leaner earth with respect to that utilized for the adobe. Nevertheless, the supply zones belong to the same stratigraphic level as evidenced by the same mineralogical composition of the two materials (Table 1).

On the whole in both cases the earthe is particularly lean and this is due both to the strong amount of sand + silt and to the type of clay minerals which do not display expandable characteristics (Table 2).

The comparison with the composition and grain size of other earthen buildings, shows a discordance regarding the granulometry of the earth of the mortar respect to that of the adobe (Table 3).

In fact, for example, both in Alessandria area and in Aleppo region (Syria), the bedding mortars were made with an earth of finer grain size with respect to the one of the adobe, in particular purifying the same raw material (Fratini, 2009; Prati, 2012).

With regard to a comparison with the optimal granulometric curve reported by CRATerre for adobe (Houben & Guillaud 1989), we can say that the granulometry of the samples from the two sites falls within the zone of acceptability (Figure 10).

As for the Rebound test, the following compressive strength were determined: 2.4 MPa (coeff. of variation= 0.09) for Rivasecca adobe and 1.8 MPa (coeff. of variation = 0.14) for Borgo Cornalese adobe (Table 4). A comparison with the compressive strength of other adobe (Baglioni et al., 2010; Fratini et al., 2011; Rovero & Tonietti, 2012) shows similar values (Table 5).

- ***Cuneo province***

Concerning the comparison between the mineralogical composition of adobe and bedding joint mortars of the three case studies located in Govone, Magliano Alfieri and Priocca, it is possible to observe that in the case of Govone an earth rich in carbonates (marl) was used for adobe while for the bedding mortar an earth without carbonates was selected (Tables 1-2). Also in the case of Priocca the mineralogical composition points out that different earths were used for adobe and mortars while in the case of Magliano Alfieri the same earth was adopted (Tables 1-2).

Table 1. Principal mineralogical composition

Province	Site test	Type/number of samples	Quartz	Feldspars	Amphiboles	Dolomite	*$CaCO_3$ %
Turin	Rivasecca	Adobe / 7	XXX	XX	X	-	tr
		Mortar / 6	XXX	XX	X	-	tr
		Local soil / 5	XXX	XX	X	--	tr
	Borgo Cornalese	Adobe / 6	XXX	XX	-	-	22 ± 5
		Mortar / 7	XXX	XX	-	-	15 ± 6
		Local soil / 5	XXX	XX	-	-	14 ± 5
Cuneo	Govone	Adobe / 6	XX	XX	-	X	30 ± 3
		Mortar / 7	XXX	XX	-	-	tr
		Local soil / 5	XXX	XX	-	-	tr
	Magliano-Alfieri	Adobe / 5	XXX	XX	-	-	8 ± 2
		Mortar / 5	XXX	XX	-	-	8 ± 3
		Local soil / 5	XXX	XX	-	-	7 ± 2
	Priocca	Adobe / 6	XXX	XX	-	tr	6 ± 2
		Mortar / 5	XX	XX	-	tr	10 ± 3
		Local soil / 5	XXX	XX	-	tr	5 ± 2
Biella	Magnano-external walls	Adobe / 5	XXX	XX	tr	-	tr
		Mortar / 7	XXX	XX	tr	-	tr
	Magnano- court yard	Adobe / 5	XXX	XX	tr	-	tr
		Mortar / 6	XXX	XX	tr	-	tr
	Magnano	Local soil / 5	XXX	XX	tr	-	tr

*calcimetry

As for the grain size distribution, it seems that an earth richer in clay was used to produce the adobe (Table 3).

With regard to a comparison with the optimal granulometric curve reported by CRATerre for adobe (Houben & Guillaud 1989), it results that the granulometry of Priocca adobe falls within the zone of acceptability while Govone and Magliano Alfieri adobe are too rich in clay (Figure 6).

As for the Rebound test, the following compressive strength were determined on adobe: 5.1 MPa (coeff. of variation = 1.0) for Govone, 3.6 MPa (coeff. of variation = 0.7) for Magliano Alfieri, and 2.3 MPa for Priocca (coeff. of variation= 0.6) (Table 4). A comparison with the compressive strength of other adobe (see Table 5) shows that for Magliano Alfieri and Priocca the values are similar while for Govone the compressive strength is particularly high. This could be explained by the different composition of the earth, definitely more marly, with possible phenomena of dissolution and precipitation of calcite within the brick, resulting in a consolidating effect.

- ***Biella province***

From the point of view of the grain size analysis, all the materials (adobe and bedding joint mortars) are particularly poor in clay (<15%) and can be classified as silty sands to sandy silt (Shepard 1954) (Table 3). Nevertheless, with respect to the adobe, the grain size distribution falls within the field defined by the two curves of admissibility indicated by CRATerre as optimum for adobe (Fig. 10).

The comparison between the grain size of the adobe and mortars, apparently does not allow to highlight a particular selection of the material used for the mortars (Table 3).

Table 2. Clay mineral fraction composition

Province	Site test	Type/number of samples	K	I	I/S	S	Cl	Cl/V
Turin	Rivasecca	Adobe / 7	XX	XXX	-	-	X	-
		Mortar / 6	XX	XXX	-	-	X	-
		Local soil / 5	XX	XXX	-	-	X	-
	BorgoCornalese	Adobe / 6	XX	XXX	-	-	X	-
		Mortar / 7	X	XXX	-	-	X	-
		Local soil / 5	XX	XXX	-	-	X	-
Cuneo	Govone	Adobe / 6	XX	XXX	-	X	X	-
		Mortar / 7	X	XXX	X	X	-	-
		Local soil / 5	X	XXX	X	X	-	-
	Magliano-Alfieri	Adobe / 5	X	XXX	-	XX	-	-
		Mortar / 5	X	XXX	-	X	-	-
		Local soil / 5	X	XXX	-	X	-	--
	Priocca	Adobe / 6	X	XXX	-	XX	X	-
		Mortar / 5	X	XXX	-	XX	X	-
		Local soil / 5	X	XXX	-	XX	X	-
Biella	Magnano-external walls	Adobe / 5	XX	X	X	-	X	XX
		Mortar / 7	XX	X	X	-	X	X
	Magnano- court yard	Adobe / 5	XX	X	X	-	X	X
		Mortar / 6	XX	X	X	-	X	X
	Magnano	Local soil / 5	XX	X	X	-	X	X

Table 3. Granulometry

Province	Site test	Type/number of samples	sand $\phi > 63$ µm	silt 4 µm $< \phi < 63$ µm	clay $\phi < 4$ µm
Turin	Rivasecca	Adobe / 7	60 ± 5	22 ± 3	18 ± 3
		Mortar / 6	63 ± 5	24 ± 5	13 ± 2
		Local soil / 5	57 ± 5	28 ± 5	15 ± 2
	Borgo Cornalese	Adobe / 6	52 ± 5	20 ± 2	28 ± 4
		Mortar / 7	68 ± 6	26 ± 3	8 ± 2
		Local soil / 5	55 ± 5	20 ± 2	25 ± 4
Cuneo	Govone	Adobe / 6	18 ± 3	26 ± 4	56 ± 5
		Mortar / 7	11 ± 3	50 ± 4	39 ± 4
		Local soil / 5	12 ± 3	48 ± 4	40 ± 4
	Magliano-Alfieri	Adobe / 5	10 ± 3	46 ± 4	44 ± 3
		Mortar / 5	21 ± 2	44 ± 3	35 ± 5
		Local soil / 5	12 ± 3	43 ± 4	45 ± 3
	Priocca	Adobe / 6	18 ± 2	48 ± 5	34 ± 3
		Mortar / 5	24 ± 3	45 ± 3	31 ± 4
		Local soil / 5	20 ± 2	47 ± 5	33 ± 3
Biella	Magnano-external walls	Adobe / 5	65 ± 5	30 ± 3	5 ± 2
		Mortar / 7	52 ± 5	40 ± 2	8 ± 2
	Magnano- court yard	Adobe / 5	37 ± 3	50 ± 5	13 ± 2
		Mortar / 6	40 ± 4	54 ± 5	16 ± 2
	Magnano	Local soil / 5	38 ± 3	50 ± 5	52 ± 5

Table 4. Rebound test

Province	Site test	Type/number of samples	Mpa
Turin	Rivasecca	Adobe / 7	2.4 ± 0.09
	Borgo Cornalese	Adobe / 6	1.8 ± 0.14
Cuneo	Govone	Adobe / 6	5.1 ± 1.0
	Magliano-Alfieri	Adobe / 5	3.6 ± 0.7
	Priocca	Adobe / 6	2.3 ± 0.6
Biella	Magnano-external walls	Adobe / 5	3.6 ± 0.02
	Magnano- court yard	Adobe / 5	4.0 ± 0.03

Table 5. Rebound test from literature

Reference	MPa
Lamezia Terme (Fratini et al. 2011)	0.97 ± 0.14
Aleppo region (Syria) (Rovero &Tonietti 2012)	1.51 ± 0.23
Drâa Valley (Morocco) (Baglioni et al. 2010)	2.83 ± 0.16

Nevertheless, according to the macroscopic observations, it is noted that the material used for the mortars was purified from the lumps of dark colour, 1-5 mm in size, whose mineralogical composition, verified by diffraction XRD analysis, is similar to the rest of the material (Table 1).

Regarding the clay fraction mineralogical composition, it should be noted the presence of minerals with expandable lattice like chlorite-vermiculite and illite-smectite (Table 2).

The compressive strength of adobe, estimated from results of 12 rebound tests, was 3.6 MPa (coeff. of variation= 0.019) (Table 4). As for a general comparison among the mechanical characteristics of adobe from the three sites, we have low values of compressive strength in the Turin province and in Priocca (Cuneo province); it is quite high in Magliano Alfieri (Cuneo province) and in Biella province, and very high in Govone (Table 4). We would expect this data to be related to the characteristics of the particle size composition (quantity of clay fraction). In reality, as can be seen from the diagram in Figure 11, this relationship is only partially verified. This can be explained by the fact that the measurements were made in situ in different thermo-hygrometric conditions and on adobe in a different state of conservation (although an attempt was made to carry out the measurements in those in a good state of conservation). A particular case is that of Govone where the high compressive strength value can be justified by the marly composition (Cuneo province) (Table 4 and Figures 10-11).

Conclusions

The research examined a still little known earthen architectural heritage, made of adobe and earthen bedding mortars, located in the Piedmont region, in the provinces of Turin, Cuneo and Biella.

The comparison between the compositional and granulometric characteristics of adobe and mortars highlighted different situations.

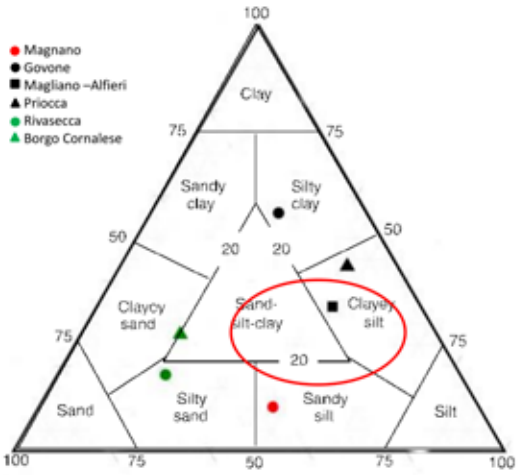

Figure 10. Shepard diagram and CRAterre area of acceptability

In particular, for the buildings of the Turin province, the mortars have been realized with a coarser earth with respect to that utilized for the adobe although with the same mineralogical composition. As for the building of the Cuneo province we have seen that in the case of Govone an earth rich in carbonates (marl) was used for adobe while for the bedding mortar an earth without carbonates was selected. Also in the case of Priocca the mineralogical composition points out that different earths were used for adobe and mortars while in the case of Magliano Alfieri the same earth was used. In the case of Biella province, no difference can be evidenced between the earth of mortars and adobe.

With regard to a comparison with the optimal granulometric curve reported by CRATerre for adobe, it is observed that in general we fall out the zone of acceptability.

As for the mechanical characteristics of the adobe, the value of compressive strength is low in the province of Turin and in Priocca (Cuneo province); it is quite high in Magliano Alfieri (Cuneo province) and in the province of Biella; very high in Govone (Cuneo province). These different values are in relation both with the grain size distribution

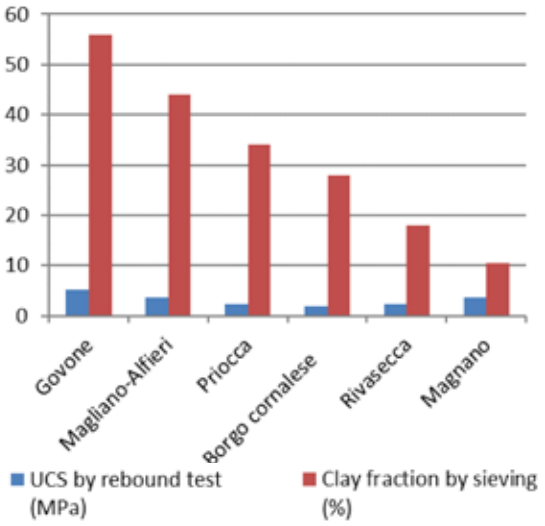

Figure 11 - Unconfined compressive strength (UCS) vs Clay fraction

and with the particular mineralogical composition of the earth (in Govone the earth has a marly composition).

Overall, it can be said that in the different localities, the materials available on site were used, both for adobe and mortars. The only exception is represented by the building located in Govone, where a study extended to several buildings would be necessary in order to understand if the use of the marly earth was really intentional.

The preservation of the earthen architectural heritage, nowadays at risk, asks for a wider awareness of its cultural value, its knowledge, enhancement and reuse. The results of the analysis carried out provide useful information about the specific characteristics of the material adopted for these constructions and its performances. They are relevant in the design of compatible conservation and reuse interventions of the earthen built heritage and, in the meantime, they can promote the construction of new earthen buildings through the integration of traditional building culture and contemporary contributions aimed at designing sustainable interventions.

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