Recovery of Traditional Construction Techniques in Colombia, Portugal and Italy

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Abstract

A very significant part of the Colombian architectural cultural heritage has been built with traditional techniques that are still in use. We shall therefore analyze specific aspects of these techniques as part of a wider research to examine both the historical perspective and the morphology of buildings constructed in adobe, tapia pisada, bahareque and wood in Colombia, Portugal and Italy. The research aims at defining compatible intervention methodologies amongst the traditional construction techniques for renovation of structures in terms of conservation and preservation. The use of natural materials, vegetable and mineral, with basic techniques, mainly transmitted through oral tradition makes it a priority to develop, through synergies between the realities of Colombian, Portuguese and Italian research, a study and cataloging methodology of the built environment. The examined artifacts are of a great interest to study the environmental compatibility of materials used for their behavior during a seismic event and for their dissemination in rural sustainable and traditional urban construction, today also for new projects in Colombia. The first results of the research presented in this work allowed the identification not only of materials, but also of building types since a significant number of Colombian colonial dwellings with the traditional building techniques of the Muiscas houses, establish comparisons with the traditional techniques used in Italy, along the Adriatic coast (mud’s houses), in Campania, Italy (Case Baraccate) and Portugal (Gaiola Pombalina), assuming the most suitable for maintenance in respect of cost and durability.

Keywords: tradicional constructions, opus craticium, gaiola pombalina, casa baraccata, bahareque, bauge, guadua, macana
1. Introductions

This work presents the first results of a research, the authors were developing in collaboration with the Universitat Nacional de Colombia and the CNR-IAMC, that analyzes, the historical perspective and the morphology of buildings made of wood, earth and stone in Italy, Portugal and Colombia. A very large proportion of the Colombian cultural heritage has been built with these techniques, still in use. The goal of this research is aimed at the definition of intervention methods for recovery, and better definition of traditional techniques now abandoned in Italy and Portugal. The construction systems called Gaiola Pombalina house cabin, developed respectively in Lisbon (Portugal) and Calabria and Sicilia (South Italy) in the eighteenth century in the aftermath of catastrophic earthquakes, respectively, in 1755 the kingdom of Portugal and in 1783 the kingdom of Naples, are the only two known examples of standards and innovative techniques developed by the central state, to build multi-storey buildings in earthquake zones to prevent building damage and loss of lives. They can be considered the harbingers of the current Eurocodes for the safety of buildings. The construction system of a wooden skeleton in stone masonry or brick was, however, developed in the Iberian Peninsula and in general anywhere in Europe in medieval times, taking origin from Opus Craticium Romanicum. The two systems are so effective, using a keen understanding of the way in which buildings respond to earthquakes in the light of design and construction with structural and border elements, as to be still popular with contemporary facilities in Guadua and Macana (Colombia).

Starting from the historical analysis of the tipi Opus Gaticium, Gaiola Pombalina, Casa Baraccata e Bahareque, techniques the aim of the research is to: 1) define guidelines for the recovery and conservation of these building types, 2) define the calculation methods for the verification of buildings in guadua as per the eurocodes.

2. The Opus Craticium

The Opus Craticium Romanicum (fig 1 and 2) is a technique of construction that spread later in the Nordic countries or European mountain. It consists of a wooden structure consisting of posts and beams, creating a generally rectangular grid filled with clusters of different nature bound by mortar and then plaster, of a thickness of 18-20 cm.

This technique, considered by Vitruvius (II, 8, 20) dangerous and not recommended as "ready to fire like a torch," was widely used for its cheapness and speed of execution, especially for the construction of partition walls, curtain walls and partitions business in the upper floors.

Due to the perishable nature of the material, there is very little archaeological evidence. Among these are the walls of some rooms overlooking the west side of atrium of the House of Julius Polybius, a secondary partition of the atrium of the House of Paisley plays and all the walls of the half-timbered house in Herculaneum. In the latter, in the wall of a room in the upper floor an example is well preserved of the coating prescribed by Vitruvius as necessary as to not produce cracks in the wall: a layer of clay mortar, and a row of horizontal reeds attached with wide headed nails and a second layer of clay mortar, on reeds arranged vertically.
The Gaiola Pombalina, system developed after the great earthquake of 1755 in Portugal, presents an innovative system to resist and dissipate seismic forces. The stonework layout incorporates timber, consisting of straight horizontal and vertical elements like little crossbars and pillars. The Gaiola type widespread throughout Europe as a constructive method has taken local characteristics derived from the types of local materials and manpower present.

The “Gaiola” system (fig 3), is considered an innovation of the Pombaline city planning, adopted when it was found out that, due to complicated property expropriation and reassignment, the buildings needed to have four floors instead of two, as was Manuel da Maia’s (Lisbona 1680, 1768) initial idea and was the case at Vila Real de Santo António, in the Algarve. It is said that the building concept was implemented by one of the architects, Carlos Mardel, after a load test on a large scale model in the main downtown square, using units of soldiers to generate the dynamic actions. But, presently, it is assumed that most of the constructive details of the new structural (fig 4) system were produced by the master draughtsmen of Casa do Risco (Draughtsmen House), used to the design of timber structures for ships. These details were probably handed down to the building carpenters orally or by means of drawings and sketches and were soon lost.
They gave rise, meanwhile, to a "know-how" that lasted, although suffering substantial degradation, until the first quarter of the 20th century, when the last gaioleiros (buildings using the system) disappeared. Notwithstanding the many references to a possible code, regulating design, establishing member sizes, connection details and constructive procedures, no document has been found specifying the "Gaiola" construction or establishing its mandatory character. The first modern Portuguese seismic code, dated from 1958, starts with a reference to “the code published after the earthquake of 1755” but, unfortunately, it seems that such a code never existed in writing. In fact, the earthquake of 1783, in Calabria and Campania (Italy)(fig 5), appears often in specialized literature as having given rise to the first rules for seismic construction, namely, the adoption of timber framed walls with mortared stone infill, instead of rubble.

However, the concept seems to have been inspired the Pombaline constructional system, as recognized in Barucci (1993). Records on the original design of the Pombaline buildings seem not to be available. In the city council archives only documents pertaining to the successive modifications requested by the owners are available.

Fig. 5: Beneventan’s Wall

But the buildings of the historical downtown are grouped in rectangular blocks, measuring in plan around 70×25 m², with a narrow central yard measuring 45×2 m². The buildings had originally five floors, including ground floor and attic, width and the height of the façade was approximately equal to the width of the main streets, being constant for all the buildings. Each block has stone masonry walls in the external walls and in the internal walls facing the central yard. These walls are around 0.9 m thick at the ground level, with a slight reduction in the upper floors. The main walls are connected transversally at ground level by other masonry walls, 0.5 m thick. Some of these walls are continuously extended further up above the roof, separating the different ownership and acting as fire walls, The structure of the first floor is generally made up of stone masonry arches and vaults. From the first floor up, the pilasters of the exterior walls, both in the façade and in the back yard, are strengthened as detailed above. More detailed information on sizing of the different timber members can be found in the reports of the various surveys carried out by Oz (1994-2000) and in several other documents, Farinha (1967), Segurado, Silva (1997). The foundations rest generally on a timber grid laid on short timber piles, intended only to stiffen the alluvial soil and to create a good working platform at the ground water level. In many places where the new buildings are laid out on the
remains of pre-earthquake buildings (street slabs, footings, masonry blocks), the older constructions were used as foundations.

4. The Casa Baraccata

After the Calabro-Sicilian earthquake of 1783 the first Italian seismic standards was promulgated based on the use of wooden frameworks placed inside the walls like reinforcement. That system, probably inspired to Gaiola Pombalina, became known in the late nineteenth century as the “casa baraccata” and was widely used in the reconstruction of the city of Casamicciola (Naples).

The systems were covered at the beginning of last century by a number of patents and standards developed over the entire peninsula. The first anti-seismic standards for construction issues in the Italian territory dates back to 1784 in the Kingdom of the Two Sicilies, when Italy was not united. This legislation follows the Calabria (south Italy) terrible earthquake that struck the previous year, as is usually the case, almost all the regulations issued until the present day follow particularly serious seismic events (fig 6). The development of seismic standards, in fact, covers a period from 1784 to 1912, where numerous seismic events affecting the Italian territory (Calabria 1783, two Sicilies Kingdom 1859, Ischia Island 1883, Liguria 1887, Calabria 1905 and Messina 1908).
The Casa Baraccata system (fig 7) was proposed to overcome the limitations of traditional stone buildings in Calabria.

Looking at the building ruins scattered in many centers, large and small, of Calabria the reasons for many failures were obvious, and in many cases, the key to solving the problem was found. Individual reports from various sources had recorded a satisfactory response to earthquakes of buildings with wooden or walling structures with wooden inside. Wood, thanks to its flexibility, could virtually bend without breaking, and as a building material, was therefore ideal to be adapted to withstand earthquakes.

Although with no diagonal elements suitable to act as a bracing were used, effective to resist horizontal actions, these buildings represent a clear improvement over the stone structures, since they are easy to build, much lighter and therefore less dangerous in case of collapse.

5. Adobe houses of the Abruzzo - Marche Adriatic coast

These constructive techniques are inspired by systems used in the Roman era, and later in the IV and Vth century, and used for very long periods during the medieval and modern time for its low cost.

Probably due to contacts with Slavic populations, during the first half of the XIX century, houses built with these technique were widespread in Abruzzo in particular in the areas of Teramo, Pescara and Chieti where they are called pinciaie, and in the Marche region in the areas between the valleys of Lesano and Tronto, where they are called atterrati. We can identify three different constructive typologies: 1) construction entirely in earth; 2) constructions with wooden frames; 3) constructions with stone footing and earth walls.

From the typological point of view we can identify two different adobe constructions. The first, the home of the farmhands of the Marche region, poor single story dwellings with a rectangular plan composed of two or three rooms of different sizes, max 5,00 by 6,00 meters (kitchen, room and adjoined stables) aligned on a single est-ovest axis. The second type, for the tenant farmers, called Italica, double story, with the housing unit above the farming utilities reached by an external stairway, originally in wood and later in stone, the pitched roof with wood trusses. The kitchen, with a fireplace on the second level is the place around which the family life develops. On the ground floor the stables, the storerooms and the cellar; on the first floor with a big room above the stables, the kitchen at the center and another room above the cellar.

The constructive techniques were recreated with interviews on site to older citizens that participated in youth to t massune and with surveys. From the information collected we can assert that nothing was chosen or done randomly. The construction time was usually from four to eight months, depending on the number of stories, starting in March employing the work of ten workers. Small variations were noted from the existing bibliography.

Before beginning a two meter by two meter lot was tilled and water and straw was mixed in, or gravel, and trampled for two days.
At the same time the chosen work surface was prepared, if the site was sloping 70 cm to one meter wide and 50 to 70 cm deep foundations, depending on the number of stories. The removed earth was usually replaced in 30 -40 cm strata: one meter cube of dug earth gave enough material for three square meters of adobe. After adding wheat or oat straw, *cama* corn leaves *cuokkal d’rendini* 60 to 80 kg per cubic meter, or water and gravel in a 35% percentage to make the mixture fluid, the strata mixed by trampling. Sometimes if the materials was easily available the foundations were made with strata of stone elements connected with earth mortar. Once the work level was reached the walls were begun. Women in the mixing area prepared 5 - 10 kg, 15 cm diameter cylindrical elements called *massune* that were laid to dry on straw or *cama*. The production of the *massune* for the first 80 - 100 cm of the wall called *bbanghe* took a few days, once they were ready they were passed along a human chain lu *filacce* from the stocking area to the expert mason that laid them either in two angled rows or in alternating perpendicular and orthogonal rows modeling them with his hands to give them a regular parallelepiped shape.

The *massune* were connected with liquid clay, *mata*, and possibly compressed by trampling. the face of the wall were smoothed with a spade or the , and the perfect verticality of the inner face was checked with a plumb line, and the eventual slope of the outer face (usually 10 %). If defects were found water was added and the earth remodeled. Once the first layer was completed the procedure was interrupted for a week to let the mixture dry, in that time more massune were prepared for the second layer and so on. Once the walls were completed, the pitched roof, with two or one or four slops, and was put in place with at least 60 - 70 cm eaves to protect the outer wall. On the main framework of roughly squared, 15 - 20 cm diameter, oak wood trusses, laid every 80 - 100 cm, a secondary framework with 4 - 5 cm by 9 - 10 cm elements *massalette*, laid every 60 - 70 cm, on these a latticework of reeds woven or simply tied with hemp ropes. On this layer a very liquid earthen strata was laid, on top of that the clay tiles were simply placed. The openings in the walls, always pretty small, were created by inserting wood lintels embedded in the walls by 30 -40 cm, and the thresholds either in bricks laid on edge or clay tiles. The inner face was finished with gypsum plaster and smoothed with a saber shaped oak wood tool, called *sciava*, and with wet hands. The onsite surveys have shown that the most frequent pathologies are connected to the low resistance of the adobe exposed to water (humidity or rain) and to construction defects.
Experimental laboratory tests were initiated for the use of pressurized earth mortar injections to define the recovery guidelines.

6. The Colombian Bahareque

The Bahareque system (fig 11), used not only in Colombia, but throughout the Andean region is a composite structure of wooden load bearing pillars in Guadua (angustifolia similar to bamboo), with single or double horizontal lines of reeds, with the function of holding the ground that achieves vertical closure, with the pitched wood and straw roofs. The system consists of: a stone base, upon which a beam is placed to separate the lower floor, on this floor the pillars are built to bear the higher floor. The walls are a compound mixture of earth (fig 12), straw and rubble with a maximum diameter of 2 cm.

![Fig. 11: mixed technique to realize wall](image1)  ![Fig. 12: colombian Bahareque warping](image2)

The Bahareque unlike the Torchis is used to build bearing walls. The use of natural materials, vegetable and mineral, with basic techniques, mainly transmitted through oral tradition makes it a priority to develop, through synergies between the realities of Colombian (fig 15 and 16), Portuguese and Italian research, a study and cataloging methodology of the built environment.

The examined artifacts are of a great interest to study the environmental compatibility of materials used for their behavior during a seismic event and for their dissemination in rural sustainable and traditional urban construction, today also for new projects in Colombia. Similarly to Colombia (fig 13), since the XII century, a construction technique (Bauge) was used in Basilicata and Calabria (south Italy) for erecting main walls with a mixture of mud and straw (possibly added with manure and gravel) that was prepared, directly transported and stacked or cast, to build a wall without formwork, whose surface was equalized and straightened any excess was cut off. The first meter was assembled, left to dry for a few days, after they proceeded to raise another meter, to implement a series of wooden beams that made up the backbone of the platform (up to the roof). The roof was built with a trellis of reeds resting on beams, on these beams a mixture of mud and straw was spread and the brick tiles were placed on top. With similar techniques, in the Yemen desert, nine-storied skyscrapers were constructed (fig 14).
7. Case study

The case study here presented is a house of about 160 m², two floors, designed by the architect Fernando Cadena, made under the rehabilitation project of construction techniques (Fig 17 and 18) in "Guadua" (fig 19) and "Macana", hosted by SENA in Colombia.
The structure is composed by horizontal beams in Macana, with a breadth of 5.50 m and a wheelbase of 1.10 m, another structure, placed between the beams, calling “paiolato” realized by "Caña Brava" with the interposition of a film of polyethylene, before throwing the hood plate of 6 cm with 3 mm electric welded with mesh of 15x15 cm.

The top closure is formed by structures in Macana, spaced 60 cm between, then a cover in "Cana Brava" is placed (Fig. 20 and 21), and after a second cover, made in fiber cement, instead of mortar screed on which the tiles are placed.

The structural design was carried out empirically, as orally tradition kept alive by local manufacturers, without making structural calculations. The photo shows the position of the macana’s pillars at a distance of about 1m that bear the weight of the second floor.
The system thus constructed can be compared with a static model of an inverted pendulum; this calculator scheme is shown in: Manual de Construcción Sisme Resistente de Viviendas en Bahareque Encementado, (ASOCIACIÓN COLOMBIANA DE INGENIERÍA SÍSMICA), where some indication are provided about the realization of technical details for Guadua and Macana constructions. These indications, in practice, are not applied as most rely on the oral tradition.

It would be appropriate to develop a structural analysis model specifically designed for the junction joints. The junctions are made by dovetail grafting with a steel pin, subsequently the insertion of this pin (fig 24 and 25) is fixed by cement paste (Fig. 22 and 23). These junctions exhibit a high degree of stiffness, to limit this, we are studying the implementation of a flexible junctions that can ensure good behavior during an earthquake.

8. Conclusions

In this work we presented the preliminary results that allows to identify materials, building types and traditional techniques employed in producing for a large number of homes in the colonial period in Colombia. Currently we are making comparisons with the traditional techniques used in Italy, particularly in Abruzzo, Basilicata, Marche (earth houses), in Calabria, Campania (Casa Baraccata), in
Portugal (Gaiola Pombalina) and in Colombia with the techniques of construction in guadua, this in order to assume the cost and duration of maintenance. These buildings are been studied at least under three aspects of technology, taken for the first time all together:

1) assessing the whole building as a single structural unit;

2) considering the symmetrical shape of the building;

3) to provide the lateral resistance about the reinforced structures.

The first results of the research have shown the critical aspects of the guadua and earth constructions: 1) the nodes 2) the durability of the components in wood and earth. For the first aspect, based on the experience of the Colombian operators in this field, we are determining experimentally the effective resistance of the node with static and dynamic loading tests. For the second aspect experiments in a climatic chamber are being conducted, simulating the climatic conditions (temperature, humidity, UV rays, and salinity) based on the annual data from the various geographical areas.

Further developments will focus on the definition of an industrialized, low cost and environmentally friendly technology with guada and bricks, a hybrid between the European and Colombian tradition.

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