Practicality and art are characteristics of popular architecture, which expresses a total life-experience and does not allow for a division between thought and feeling (Norberg-Schulz 1996, 231).

**RURAL STONE ARCHITECTURE IN PREMODERN SARDINIA: BUILDING AND CONSTRUCTION TYPES.**

The territory of Sardinia shows widely differentiated geomorphological characteristics and, especially in hilly and mountain areas, it is marked by the presence of a wide variety of stone materials: volcanic stones such as granites, basalts, tuff and trachytes alternating with metamorphic schists or sedimentary stones like sandstones and limestones.

Rather than the inherent physical and mechanical properties of most of these stones, their systematic use in pre-modern building was the result of the ease with which they could be found near the living areas. This also reduced the work of transportation and improved the land for agrarian use.

In fact stone is the most used natural material in masonry and, from a building point of view, it is the major element that characterises Sardinian rural building, because of the countless varieties which could be found.

In the lowlands, where traditional building was mostly based on raw earth (using almost every where the adobe technique), stone material was only used for the connecting base between the earth and the elevation wall, to avoid dangerous instances of rising damp caused by capillary action. It could sometimes also be used for the crow and surrounds of the openings. In the rest of the island however, all the masonry was in stone, generating a very wide range of buildings depending on the type of stone, the degree of working of that stone, or the laying techniques used. This range is often connected to small parts of the territory.

Despite this multiplicity, the relationship between stone wall construction and other building types belonging to the limited traditional range of Sardinian architecture, seems neither direct nor obvious, but there may be a unifying element in the ways of the communities rooted in it. Moreover the local context establishes a specific culture of material use, depending on the availability of resources.

Anyone crossing the territory of Sardinia will easily find confirmation of the above, and will frequently come across buildings made of stone. These will be seen in the Campidano lowland (even if less frequently) which is based on agrarian economy, where the most popular building type is the traditional big house with its internal courtyard; and also in the mountain areas, where sheep-farming has always predominated and where houses become less broad but taller. Also in the wide hilly belt based on mixed economy, where buildings show some characteristics of the mountain buildings and other characteristics of the buildings of the lowland plains. Examples will be found, too in historic Gallura, in the north-east of
In the context of rural stone building, although it is not possible to find one constant building type and association, the masonry cell, that is the living area completely surrounded by load-bearing walls (usually maximum 4x4 metres), represents a constant in terms of distribution of structural type of stone architecture.

The elementary cell, which was one of the first advanced shapes of rural building, develops from the archetypal stone building, and adds its regulative unchanging element: the control and organization of space through the principals of juxtaposition and superimposition, and at the same time it is also an efficient solution to structural problems because of its box-like shape.

Parallel and reciprocally right-angled couples of walls carry out two different but equally basic structural roles. In fact one couple has to support the wooden ceiling (usually only one but in some mountain areas there could be even three of them), and also the sloping wooden frame covering, by means of a trilith system; the other couple has to balance the whole system, preventing the overturn of the load-bearing walls by the action of any unexpected horizontal thrust.

From this point of view an important contribution is made by the wooden structures like intermediate floors and roofs that guarantee a certain degree of sharing of the eddy thrust to every wall and also create a stiffening of the whole structural complex, introducing weak restraints that favour its natural settlement and settling well. Moreover, with the specific aim of making the various masonries integral and collaborative as much as possible, limiting their rotations and their independent movement, a widespread routine in order to sustain the floor system was anchoring the beams to the surface of the external walls with a metal or wooden contrast element assuming that the beams could produce even a static function on axial condition. Either during the construction or later with the same aim, the common system was to fill the inner part of the masonry with metal tie-beams.

Stone building composed of masonry cells is obviously limited in terms of its potential for growth, which comes from the assembling of the elements known as «basic modules» today; moreover as will be shown in detail later, the typical Sardinian wall is not apt to sustain large concentrated weights like big beams. This fact along with the difficulty of finding...
wooden elements to cover considerable spans caused a very limited dimensional development of the masonry cells, reducing of the flexibility and the use of the planimetric building system.

On the other hand the structural independence of the various cells favoured the growth and development of the building over periods of time with variations, relating to family needs and to the growth of family settlements. The possibility of sharing a wall creates a considerable improvement in the total structural behaviour without any particular building complications.

BUILDING TECHNIQUES AND MECHANICAL PROPERTIES OF THE TRADITIONAL MASONRY

Traditional Sardinian building is very poor and almost exclusive use of natural materials, such as wood, earth and stone, it is one of its main properties. The limited economic resources of the majority of rural settlements always forced Sardinian builders to use raw materials found mainly in limited area close to villages. Moreover with the aim of reducing the building costs, investment in the processing of materials was reduced to the minimum necessary for a correct positioning, giving buildings an archaic look.

Building in stone was ruled by the same principles giving them a very «natural» look.

Father Angius, in the first half of the XIXth century travelled the whole regional territory describing every town. When he introduces Villasalto, a mountain town in the historic Gerrei’s region in the south-east of Sardinia, underline the above, and with a researcher’s exactness typical of his period briefly covers the aspect of building. Using rather untechnical language he said: «All the houses are made of stone, the older shapeless ones look like dens, but the newer ones are really better . . . » (Angius, Casalis 1833, 29).

One of the most striking aspects of the study of typical Sardinian building techniques is the apparent continuity with which the local artisans have handed down the know-how over the centuries (until the first half of the XIXth century and in some places until the Second World War) remaining entirely uninformed about the modern technological revolution. The isolation of the island settlements was certainly the greatest obstacle to the circulation and spread of techniques coming from the mainland. However a thorough study of Sardinian historic events, indicates that Sardinian building shows many similarities and convergences with other Mediterranean areas despite its strong local character, and it has rooted its origins in the distant past.

From this point of view the case of stone masonries is symbolic. In fact the typical shape used is made by the simultaneous construction of two parallel stone faces, between then there is a hollow space filled with earth; little stones and brick c rocks.

Because of the weakness of the filling stability of the wall depends on the passing elements (diaton or header) which connect the two faces giving them a certain level of stability. This function is obtained by the notable dimensions and the head position of these elements.

The oldest masonries were dry-built as were, sometimes, even those ones built during the all XIXth century and, in certain cases, also the ones of the beginning of the XXth century. For this kind of masonries the only flattening system between the raw or rough hewn blocks was entrusted to the use of earth. To create a more efficient contact between the uneven surfaces of the stone elements, little stones or brick chips were placed into interstices between the ashlar s, limiting the washing away of the earth inside the central core.

The stone masonry building types in Sardinia are certainly not an innovation, they are easily traceable to the émplekton, which Vitruvio mentioned in the second book of the De Architectura about two thousand years ago.

In that book the most important aspects, which are also features of Sardinian masonries, are analysed by the roman architect who describes the stone filling technique as a building routine widespread among the rural buildings of Latium, while he assigns to the Greeks the use of passing elements (called diatonois) crossing the full width of the masonry.

In the first years of the XXth century, Giovannoni describing the roman masonries identifies among the concrete works, a particular small masonry, very close to the Sardinian ones, and about its filling he says «it might be said to be made of unshaped stones or pieces of brick, which means made by elements not cast placed but in irregular hand worked layers . . . » (Giovannoni 1999, 22).
The differences in the masonry of different Sardinian historic regions are caused, less than by the basic building techniques, then by the wide variety of the stones used or by the less refined level of work, which introduces considerable variations in dimension, weavings and static capability of the masonry.

In Barbagia, a region near the Gennargentu, the principle Sardinian mountain range, grey granite is the most widespread material, but not the only one, used in masonry, relating to two schemes easily assimilable to the uncertain work or to the pseudoisodomon work.

As it is well known, the first one, older and more elementary than the second, comes from the use of erratic blocks which vary in size and shape, without any sharp edges and which are little worked, during the building attention was seldom paid to the toothing between faces and between the filling core and diatons.

This masonry type shows frequent cases of the mixture of different materials that, sometimes, assume very singular shapes and behaviour.

In fact, besides the use of different kinds of stone, we find some cases, such as in the town called Sarule, where the wooden elements, crossing the whole width of the wall alternate with stone blocks, instead of the stone diatons, or they are placed along the length of the face even for some metres having the same function as the stone blocks.

Relating to the formal and dimensional homogeneity of the elements it is possible to see further sharing between weaving of loose stones, with sub-horizontal courses, or weaving made by rough hewn ashlers taking turns with erratic blocks, etc.

The second scheme is referable to the pseudoisodomic work made by rough hewn blocks, the recurring dimensions of which, 50 x 18 x 18 cm, still have the proportion of 1:1:3 analogous to those of the blocks used by the Romans to make masonries with work-stones.

The ashlars length defines the maximum thickness of the wall and therefore the two parallel faces are spaced out.

The joint is very efficient and in each layer it is guaranteed by a passing element placed every two or three blocks lengthways.

In both cases the constituent elements were flattened with earth’s mortars and lime, and interstices among the blocks were filled with stone or bricks chips.
A wall made of blocks is more coherent, stronger and firmer than one made of erratic block, it is less thick (about 50 cm), and it also has much better static behaviour especially near some critical points where there are concentrations of strain such as in angles, in junctions between right-angled walls, in openings, etc.

In contrast, in the Gerrei and Ogliastra regions, in the south-east of Sardinia, mansories were built mostly using sedimentary metamorphic schists, the behaviour of this kind of stone, which has a natural inclination for breaking along regular and reciprocally parallel fracture planes, produces erratic blocks with a laminar shape that are very useful for the building of faces made of sub-horizontal layers. Schist-elements were alternated with big blocks, usually granites, and here again the interstices were filled with little chips flattening the placing plane and avoiding the washing away of the earth filling.

Barigadu and Monti Ferru show different lithologic particularities, because the first area has red volcanic stone called trachytes (the case of Busachi is a fine example), and the second has black basalt; however in both areas techniques and masonry weavings look very similar and they are characterised by large sized, rough hewn and cramping elements, even though basaltic erratic blocks have a solid shape and they are also hard to work, whereas trachytes have an anisotropic crystal structure and they have more lengthened elements, it is easier to rough-hew them and for these reasons they are more useful in masonry.

In these cases the main thing that better characterises urban centres is the substantial monochromatic style related on the stones used: villages in trachyte areas having red colours and most villages in basalt areas having dark stern hues.

A very interesting example of Sardinian stone building is the town called Serrenti. Although it is placed on the edge of the Campidano plain (where raw earth is the most frequently used construction material), it boasts several quarries of pyroclastic rocks, called (in Sardinia) Serrenti stone, particularly suitable for masonry building.

Since the middle ages Serrenti stone has been used to build defence and places of worship, and by the XIX\textsuperscript{th} century also for private houses. The reason for this widespread uses is its properties such as great resistance to strain, and especially its easiness to extract and to work.

In Serrenti to the masonry has two faces, and the different level of stone working presents four differences in the weaving: in chronological order from a period before the XIX\textsuperscript{th} century to the whole first half of the XX\textsuperscript{th} century, we find masonries made of unworked stones, then by rough hewn stones with little chips, then by rough hewn blocks and finally by blocks with face of work-stones flattened by lime mortar. In Serrenti wall thickness is in general about 50 cm, even in the oldest pattern, thanks to the excellent shape and resistance of this kind of stone. This is also to be seen in other areas where the working of ashlars is easy. In more recent masonries with work-stone faces the anomalous proportions of the blocks, having recurrent dimensions of $25 \times 25 \times 30$ cm.

The wide variety and extent of the art of stone building, art in the region is not limited to these significant examples; in fact it is worth mentioning masonries made by pink granites in Gallura (north-east) where the building technique is very close to that used in Barbagia, using volcanic tuff in Meiologu and Monteacuto (in the middle north), limestones in the Cagliari area, sandstone and sedimentary metamorphic schists in the Marmilla and Parteolla area (hilly western regions near wide plains). All of these examples increment the very rich range already indicated.

As already seen, the stability of the masonry cell is based on solidity and the collaboration of load-bearing walls and wind-braces walls.

In a building system made of discrete elements (such the one where stone ashlars are used), difficulties which could be found when attempting to guarantee perfect toothing between mutually right angled walls make the junction, and especially in corner areas, one of the most crucial structural points for the whole stone building.

Sardinian builders knew that problem very well, and despite economic limitations, they were able to find simple but quite efficient solutions.

In the whole region, irrespective of the kind of stone used, the recurring technique consisted of conforming the junction using large sized and well squared blocks being careful to overlap them alternately lengthways or header, so obtaining a close fit of the stones and also good joint-stagger.

In works with rough hewn ashlars that system was the logical outcome in masonries, but for masonries of uncertain quality it was a necessary strong point.

In corner buildings only an alternative solution was possible: that of not doing the junction but linking the
Figure 4
Traditional Sardinian masonry synoptic table.

two right-angled walls using a circular portion with a narrow bending radius. However, the use of this technique did not become widespread because it is not efficient. In fact, the circular portion does not guarantee the contrasting action between the two walls opposing causing an obstacle to the relative transmission of thrust, and it also generates problems for management of the inner space which is already limited.

As it is well known that two basic aspects for stability and solidity in a masonry are monolithicity and coherence.

Both of these characteristics belong to masonry made of modular elements, with an high level of jointing, with opportunely staggered joints placed on regular planes. The principles of modularity and correct placement guarantee that a wall's load-bearing ability is directly related to the inherent mechanical properties of the materials used.
In fact, even in case of buildings with only two floors, these structures always show considerable thickness (seldom less than 70 cm and they can easily be 1 m or more).

Moreover the shape created by three heterogeneous vertical layers is not the best one to sustain the concentrated loads coming from the wooden beams. Any localised downward pressure causes damage to the wall in which the two sides to break away from the loose central part. This has a dangerous effect on the stability of the wall. In fact to avoid these mishaps the most able builders used systems of load sharing consisting in wooden joists or the use of stone saddles. In the first case a single wooden element placed at the top of the wall takes the weight of the beams at a right angle to it, whereas more simply in the second case each beam was placed on a big squared stone ashlar that guaranteed the transmission of strain to the surface of a larger resistant wall, thanks to its solidity and size.

A wall's massivety along with limited coherence makes for a lot of difficulties in making openings which are usually narrow and small. In any case the system of openings is one of the most particular elements in Sardinian architecture. The continuity of masonry over the opening was restored by wooden or monolithic architraves in the oldest buildings often using unloading systems such as triangles made of two ashlars placed in contrast, or brick arches; while recently, arched structures (made of stone or brick), have been widely used. Usually jambs were made of square blocks well fixed into the masonry; in some areas they were made of only one monolith placed vertically or more frequently by a system of three large sized ashlars, where the third one was interposed horizontally with the aim of optimising the anchorage to the wall.

The growing use spreading of brick blocks to build all openings, often achieving highly expressive and decorative results, from the end of the XIXth century should also be mentioned.

**Tradition and Innovation in Masonry at the End of the XIXth Century**

The XIXth century is a decisive period for the development of building techniques in Sardinia. In fact the need for the Sardinian Piedmontese reign to
manage the whole regional territory led to the construction of several institutional and military garrisons, such as town halls, barracks, district prisons; all built under the strict control of the Military Engineer. To this end engineers and architects, belonging to the technical corps, arranged several restoration projects, enlargement and readaptation of existing manors, they used a scientific strictness that came from the handbooks which were characteristic of the polytechnic schools established in Europe and in the north of Italy.

These engineers, firstly designers and then people in charge of the works, were professionals who were quite new to Sardinian building which, up to this period, had relied on the substantial concurrence of owners, planners and builders (even if a certain level of specialisation was already widespread among the building workers). Each work was scrupulously documented through written design (design, technical-descriptive reports, quotations for work with sections such as works, quantities and costs), and also through a series of prescripts and advice about the carrying out of works and the about entrepreneur’s duties towards the royal administration.

The project documentation, which is hard to obtain, describes some building methods previously unknown in Sardinia indicating innovation. Also for the first time they encode with accuracy working methods and technical devices which together characterise the oldest Sardinian material culture, providing us today with valuable evidence about technological mingling that influenced building practices in that period.

In this precise historical moment, which marks the passage from the premodern and the modern building ways, significant events of architectural and building influences can be seen and a very close link between innovation and tradition emerges.

However, the extremes of this apparent dichotomy are far less than it would seem, and rather than in terms of opposition, these extremes may be explained as an event of the evolutionary process of building techniques, even if a very important one, during which, innovation never overwhelms tradition, and they succeed each other with substantial continuity and technical-material compatibility.

In the same period a larger circulation of specialised labour from the peninsula may be noted, and this contributed in a decisive way to the development of new kinds of stone masonries.

An example of this, ones again, is to be seen in Serrenti, in fact around 1880 a little community of Tuscan stonecutters coming from Montelupo settled there and really influenced local artisans.

Some of the chief new elements for masonries are clearly described in September 1845 by the architect G. Pau, designer and manager of the enlargement work for the «Regie Carceri» in Osilo, in northern Sardinia. In fact in art. 3 of «Istruzioni e capitoli d’appalto» the material and structural quality that masonries must have, is specified. In particular: «We would archive the building of new masonries that are going to be made of hewn stone, and ashlars with double ways in the external corners, and using a good cement made of melted lime and white albino, in the proportion of 1:3 for the last one and 1 for the lime». And in art.6: «Every curling and piering of the
masonry will be done with a good mortar of melted lime and white albino following the right rules of the art."

In this part there are the directions for finishing the masonry and its protection with a protective coating of plaster.

In this period similar executive precepts complete most of the projects for public works.

As a result the using of the rough hewn stone and of the ashlars spread quite fast, which caused a general optimisation of the mechanical characteristics of the masonry, due to more suitable use of the stone materials.

This spreading was however, limited to public buildings or to residences belonging to quite well-to-do families, except in towns in Gallura and in Barbagia, where the stone working concerned also rural buildings.

In the rest of the island masonries were still made by roughly worked materials, but it became systematic to use well squared stone to build particular points such as arrises and fixed, joints between wall, jambs of doors and windows, crowing belts, etc.

Moreover the use of binder made of lime, instead of the traditional one made of earth, introduced a notable improvement in the coherence and solidity of walls and also a greater resistance to washing away caused by rain water.

It can also be seen in the choice of walls of working materials and of binding with relation to the function that masonries had in the structure of buildings. For this reason, boundary walls were made of masonry with erratic block which was prepared dry and flattened by earth, while perimetric and internal load-bearing masonries were made of ashlars or by walls of well worked blocks joined by cement made of melted lime, with quarry or beach sand and with white albino.

Also plastering of the masonry faces with lime cement, whether inside or outside, with the aim of protecting the wall, became a building routine in that period, even if it should be remembered that plastering based on earth was previously widespread.

The assessments of that period underline the high cost of masonries compared with other items. For example, in 1848 for the enlargement of a private residence in the centre of Dorgali (in the east of the island), with the aim of turning to barrack called «Caserma dei Cavalleggeri», the whole work foresaw the building of large areas of roof and also a good deal of finishing work, but the influence of masonry
was valued in cost higher than 30% than that of the other items by the designer architect Galfré.

In fact, out of a total charge of 2900 «Lire Nuove», masonry building with plastering and painting amounted to slightly more than 1000 L.N. with a unit price for just the masonry building of 9 L.N. for each cubic metre, 0,30 L.N. was added to this price for each square metre, for the chocks and splintering, and finally 0,45 L.N. for each square metre for plastering and colouring with milk of lime.

The whole building process was always inspected by the works chief, who, with reference to the precepts written on the contract, had the power to demolish or to have rebuilt any works did not meet the requirements of the design.

The compulsory character of the contractual articles did not exclude masonries, which continued to be the crucial element of the building, and for this reason they were object of particular care.

In fact, several times articles of historical specifications, concerned with masonry, mentioned the high quality required for stone materials also the correct laying techniques related to the best rules of the art.

Moreover as specified in the art. 10 in the contract tender for the «Caserma dei Cavalleggeri» of Dorgali, the role of control of masonry quality by the works chief was underlined. Here, finally, it said «no plastering on new masonries was allowed before the check of the work and of the materials used . . . ».

It should be mentioned that at first only public and military buildings, were involved in the sudden changes and only later and gradually did these involve the rest of residential buildings.

Moreover, often big traditional residences were attributed institutional functions. These were adapted to the new demands with limited improvements leaving the original typological and constructive characteristics untouched.

There was a change but one feels it never assumed a revolutionary nature, in fact the building materials did not change, merely improved the working methods some techniques of laying, without forgetting the consolidated experience of local know-how.

It is really the integration between old and new which is the most important character of this period. This contributed to enriching the poorer and archaic elements of traditional Sardinian building, also from the point of view of decoration.

Never has attention been paid so much as in those times to detail, and for masonries this generated more care in doing relief band course, end cornices with particular shaped ashlars, refined corner solutions, intrados with affected and perky openings, often made using stone and brick materials in turn.

Through the matching of traditional building techniques and imported ones, the list of stone masonries in rural Sardinian building has moved towards solutions typical of urban architecture, giving the buildings of smaller towns a marked urban feel.

NOTES


2. Around 1830 Father Vittorio Angius waited to write the chapter about Sardinia, for the «Dizionario Geografico Storico Statistico Commerciale degli Stati di Sua Maestà il Re di Sardegna», he received this work from master Goffredo Casalis who was the administrator for the whole work edited in Turin in 1833 by the bookseller Maspero.


5. «Masonry made by ashlars, quadrati lapides, in not really frequent cases when they are wall frames, follow systematically Etruscan technique of the isodomic placement, of the shape of parallelepiped blocks in which width is equal to height and length is double or triple . . . » Giovannoni 1999, 17.

6. For futher information about Serrenti’s masonry see Bellu, Mereu, Pani, Serra 1998-99.

7. At the Archivio di Stato of Cagliari—fondo Tipi e Profili—are stored historical papers of the following public works: «Ristrutturazione a ampliamento delle Carceri Mandamentali di Sorso (September 1845), di Osilo (September 1845), di Ittiri (March 1845), di Ossi (October 1845)», «Trasformazione del Palazzo Baronale di Buschi in Caserma dei Cavalleggeri (July 1846)», «Adattamento della Casa di Mauro Loi in Caserma dei Cavalleggeri (March 1848)».

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