The stone materials in the historical architecture of Levanto and their durability (Liguria, Italy)

DANIELA PITTALUGA

FABIO FRATINI

(édité par/by)

CONSERVATION ET MISE EN VALEUR DU PATRIMOINE ARCHITECTURAL ET PAYSAGÉ DES SITES CÔTIERS MÉDITERRANÉENS

CONSERVATION AND PROMOTION OF ARCHITECTURAL AND LANDSCAPE HERITAGE OF THE MEDITERRANEAN COASTAL SITES

ripam 7

Gênes, 20-22 Septembre 2017

Genoa, September 20th-22nd 2017

FrancoAngeli

OPEN ACCESS

Il presente volume è pubblicato in open access, ossia il file dell'intero lavoro è liberamente scaricabile dalla piattaforma **FrancoAngeli Open Access** (http://bit.ly/francoangeli-oa).

FrancoAngeli Open Access è la piattaforma per pubblicare articoli e monografie, rispettando gli standard etici e qualitativi e la messa a disposizione dei contenuti ad accesso aperto. Oltre a garantire il deposito nei maggiori archivi e repository internazionali OA, la sua integrazione con tutto il ricco catalogo di riviste e collane FrancoAngeli massimizza la visibilità, favorisce facilità di ricerca per l'utente e possibilità di impatto per l'autore.

Per saperne di più:
http://www.francoangeli.it/come_pubblicare/pubblicare_19.asp

DANIELA PITTALUGA

FABIO FRATINI

(édité par/by)

CONSERVATION ET MISE EN VALEUR DU PATRIMOINE ARCHITECTURAL ET PAYSAGÉ DES SITES CÔTIERS MÉDITERRANÉENS

CONSERVATION AND PROMOTION OF ARCHITECTURAL AND LANDSCAPE HERITAGE OF THE MEDITERRANEAN COASTAL SITES

FrancoAngeli

OPEN ACCESS

Les textes ont été fournis par les auteurs, qui en sont responsables.
La source des images, sauf indication contraire, est celle des auteurs.

The texts were provided by the authors who are responsible for them.
The source of the images, unless otherwise specified, is of each author.

Couverture: profil de Gênes, graphiques de / Cover page: profile of Genoa, graphics by Lorenzo Poli, Linda Bruzzone, Stefania Pantarotto

Ce livre est un ouvrage collectif, dont les contributions ont été élaborées à partir de la conférence RIPAM 7, organisée à Gênes du 20 au 22 septembre 2017 par le DAD - Département d'architecture et de design (Université de Gênes) en partenariat avec le CNR-ICVBC Institut national de recherche, Institut pour la conservation et la mise en valeur du patrimoine culturel de Florence).

This book is a collective work, with contributions developed starting from RIPAM 7 conference, organized in Genoa, 20 to 22 September 2017 by the DAD - Department of Architecture and Design (University of Genoa) in collaboration with the CNR-ICVBC (National Research Council, Institute for Cultural Heritage Conservation and Valorization, Florence).

Daniela Pittaluga et Fabio Fratini ont travaillé ensemble sur les textes initiaux (comprenant les sections “Qu’est-ce que le RIPAM?” et “Conférence RIPAM 7”, les remerciements et les index) et sur les descriptions des thèmes et sous-thèmes (sections A et B et sous-parties). Cependant, Daniela Pittaluga a écrit les parties en français et Fabio Fratini a écrit les parties en anglais, ils sont auteurs de certains articles et les editeurs de la partie restante.

Daniela Pittaluga and Fabio Fratini worked together on the initial textes (including sections “What is RIPAM?” and “RIPAM 7 Conference”, aknowledgemnts and indexes) and on the descriptions of the themes et subthemes (section A and B and subparties). However, Daniela Pittaluga wrote the parts in French, and Fabio Fratini wrote the parts in English. They are authors of some articles and editors of the remaining part.

The stone materials in the historical architecture of Levanto and their durability (Liguria, Italy)

Fabio FRATINI[1], Manuela MATTONE[2], Silvia RESCIC[1]
[1]CNR-Istituto per la Conservazione e Valorizzazione dei Beni Culturali, Sesto Fiorentino, Italy
[2]Politecnico di Torino, Dipartimento Architettura e Design, Torino, Italy
e-mail: f.fratini@icvbc.cnr.it; manuela.mattone@polito.it; s.rescic@icvbc.cnr.it

Résumé. La présente contribution a pour but de se concentrer sur l'analyse des matériaux qui caractérisent les constructions réalisées à Levanto, un village balnéaire de la côte est de la Ligurie, en soulignant le lien étroit qui existe entre le bâtiment historique et les matériaux disponibles localement. Les caractéristiques géologiques du territoire ont en effet beaucoup influencé l'architecture jusqu'au début du XIX^{ème} siècle. En effet, les montagnes limitrophes de Levanto sont principalement constituées de serpentins et de grès (trouvés sous forme de galets le long du torrent de Ghiararo et dans la ligne de rivage) largement utilisés pour la construction de structures porteuses et non porteuses. Pour les éléments architecturaux tels que les arches, les jambages, les colonnes, situés aux étages inférieurs des bâtiments nobles et ecclésiastiques, on a adopté de la serpentinite remplacée plus tard par du grès, faciles à travailler grâce à la présence de systèmes de fractures orthogonales permettant d'obtenir des blocs réguliers et des dalles. Il y a aussi l'ardoise, adoptée pour la construction des architraves et des bas-reliefs, ainsi que des tuiles pour revêtements et le Rosso di Levanto, un ophicalcite qui avait déjà été extrait par les Romains et qui, largement commercialisé depuis le Moyen Âge, peut être sporadiquement trouvé dans les murs et dans certains éléments architecturaux.

Mots-clés: matériaux en pierre, villages historiques, conservation.

Introduction

The application of archaeological methods to the study of the historical masonry walls, initiated and carried out by Tiziano Mannoni [MANNONI 1984, MANNONI 1990] since the seventies of the last century, has allowed the acquisition over time of a wealth of information relating to historical buildings. The archaeology of architecture, based on the objective analysis of the artefacts themselves and, in particular, on the study of building characteristics and on the transformations of buildings has contributed, and continues to contribute, to the restitution of a history of architecture not exclusively focused on aesthetic composition, but able to contemplate also the technical-constructive and functional aspects. This has made it possible to deepen the knowledge both of the individual constructions and of those persons that interacted with each of them in different ways. Furthermore, as pointed out on several occasions by Mannoni himself, these surveys and analysis also offer the possibility of collecting and networking a varied set of data about historical materials, their technical characteristics and their behaviour over time, whose knowledge represents an important and valid contribution to the pursuit of a more respectful, lasting and less expensive conservation of the rich heritage of historical building characterizing our country [MANNONI 1994]. The present contribution intends to deepen the study of the use of stone materials in the architectural heritage of the historic centre of Levanto, focusing on the examination of the permanence/variation over time of the different stone materials adopted and the way they have been used. This study confirms the existence of a close link between stone materials locally available and historical architecture, which is therefore characterized by an innate character of both environmental and socio-economic sustainability. In this regard, interesting are the studies conducted within the European research project VERSUS concerning the vernacular architecture of some European countries [GUILLAUD *et al.* 2014]. Our research wants to contribute to broaden the knowledge related to the built heritage present in this Ligurian settlement promoting the recognition and preservation of its constructive characteristics, since "it [...] is up to present generations to retrieve all possible information, but also to preserve and transmit, together with information, the artefacts themselves, as historicizations of knowledge and truth" [MANNONI 1994].

Levanto historic buildings

Levanto is a seaside village of the Eastern Ligurian coast built at the bottom of a small gulf which, much deeper in Middle Ages, was progressively filled with sediments (fig.01). The birth of the village probably dates back to the period between the XIth and XIIth centuries, following a widespread phenomenon that leads the populations originally settled along the hills to migrate to the coast. The actual development of the village, however, began only from the XIIIth century when the city of Genoa decided to expand to the East (Riviera di Levante) in search of new trans-Apennine passes for its maritime traffic

Fig. 01 : Levanto in an ancient postcard

In particular, the economic-commercial and political development of Levanto finds its main explanation in the links that Da Passano family (Lords of Levanto) was able to establish with the Republic of Genoa, as attested by numerous documents dating from the XIIth and XIIIth centuries [DEL SOLDATO, PINTUS 1984].

Genoa exerted a notable influence on the architecture and artistic production of the village until the fall of the Republic in 1797 and actively intervened in the construction of the port-channel, the warehouses connected to it, the city walls, the parish church of Sant'Andrea, as well as in the development of *Borgo Nuovo* (the new village) in the XVth century (now Garibaldi street), outside the walls of *Borgo vecchio* (the ancient village)(fig.02).

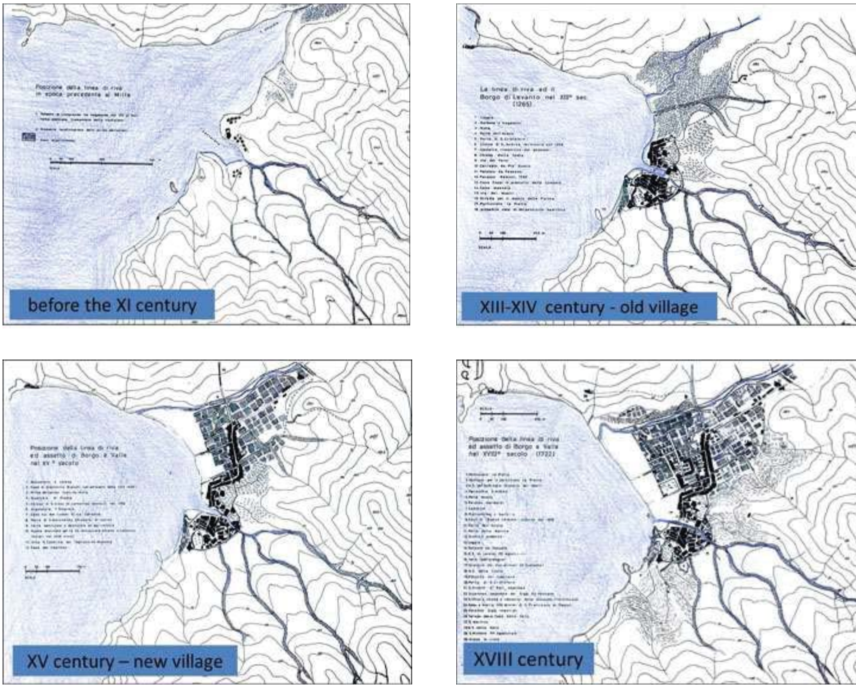

Fig.02 : Urban development of the village of Levanto over the centuries (after DEL SOLDATO, PINTUS 1984, modified)

Between the XVI^th^ and XVII^th^ century no changes were made to the urban planning of Levanto, except for interventions on the pre-existing medieval structures of *Borgo Antico* (now Guani street). Originally characterized by the presence of merchant warehouses on the ground floor and homes on the first floor, they were raised and transformed to cope with the changing needs of the users. To this period dates also the Captain's palace (near the door of San Cristoforo), new warehouses near the dock and the implementation of interventions in the Loggia and the castle. Further development of the village occurred in the XVIII^th^ century when the actual expansion in the valley began, leading between the late XIX^th^ and the early XX^th^ century to the progressive urbanization of the alluvial plain and the northern slopes of the valley, following the construction of the railway and of the road to Bracco pass. The architecture of this period is characterised by palaces, villas and buildings for public use in which the reference to the eclecticism rules is evident. The buildings of Levanto, although characterized by the use of different construction techniques depending on the period of realization, are united by the recurrent use of local stone materials, whose characteristics and methods of use are analysed below.

The stone materials of the historic buildings

These stone materials constitute the main building materials and have been taken both from rock outcrops and as pebbles along the Ghiararo stream and on the beach. Nevertheless, also stone materials coming from abroad have been used like slate and marble. In the following the different stone materials and their use will be described.

Serpentinite: This lithotype, in constant association with gabbros and basalts, belongs the Ophiolite Complexes of the Ligurides Units (Early-Middle Jurassic) [ABBATE *et al.* 1986]. It is a metamorphic rock produced through hydrothermal fluids affecting peridotites in the ocean bottom. This process, called serpentinization, changes the original mineralogical composition (made of olivine and piroxenes) into the minerals of the serpentine group. Although serpentinite is characterized by a mineralogical homogeneity, the material exhibits varieties with very different colours and micro/macrostructures, from light to dark green until almost black, sometimes with bluish reflections and often with darker patches. The macroscopic structure can be relatively uniform, interrupted by small whitish veins of fibrous serpentine (chrysotile), or characterized by a dense interlacing of light-coloured veins as in the "rannocchiaia" variety. Microscopically two main varieties can be recognized, one characterized by bastitic and mesh textures in variable percentages. The second shows an hourglass texture with a small percentage of bastites. Bastites are relicts of the serpentinization of amphiboles and pyroxenes, while the mesh and hourglass textures are relicts of the serpentinization of olivine. All these structures consist of lizardite serpentine [WICKS, WHITTAKER 1977]. The diffuse presence of magnetite in small crystals as well as chromium spinel and pyrite determines the dark colour while the magnetite in larger granules gives rise to a light green colour. This material has been quarried and cut in regular blocks for architectural elements (arches, jambs, columns), for the lower floors of noble and commercial buildings, as corner stones, as dimension stone for ecclesial buildings (Fig. 3). Moreover, it can be found as pebbles in the mixed masonries of civil buildings and city walls.

Concerning the condition of conservation of this lithotype, splintering and flaking phenomena can often be observed in the ashlars starting from the corners. This decay process is due mainly to physical phenomena [FRATINI *et al*. 1987; DE VECCHI *et al*. 1991; BRALIA *et al*. 1995] such as:
- strong heat absorption (due to the dark colour) and very low thermal conductibility, which causes high thermal gradients between the surface and the interior of the ashlars, with consequent thermoclastic phenomena;
- very high index of saturation in water, which determines swelling and consequent high tensions, as demonstrated by measurements of linear expansion;
-physical discontinuities, such as the chrysotile veins and the flaking planes of bastites.

Fig. 03 : Serpentinite in regular blocks (on the left) and in column and capital (on the right)

Sandstones: Two kind of sandstones have been used in the architecture of the village, the Gottero sandstone, belonging to the homonymous formation of the Ligurides Units (Lower Cretaceous-Paleocene) [NIELSEN, ABBATE 1983/1984] and the sandstone of the Macigno-Monte Modino Formation (Upper Oligocene-Lower Miocene) belonging to the Tuscan Sequence [BRUNI *et al.* 1994]. Both sandstones have been formed through turbidity currents, better known as submarine landslides, able to move and transport large quantities of sediments from the coastal zone to sea bottom (bathyal plain). They are medium to coarse grained, grey to brown grey in colour, and cannot be distinguished at naked eye [ROBBIANO *et al.* 2006; FRATINI *et al*. 2014]. Petrographically they can be

defined as arkose to lithic arkose. The framework consists of quartz, feldspars, fragments of metamorphic and magmatic rocks, muscovite, biotite. The matrix, made of clay minerals, is more or less abundant as well as the cement, made of calcite [CIPRIANI, MALESANI 1963; MALESANI 1966]. This material has been quarried and shaped to realize thresholds, sills, doorposts, lintels, slabs for street paving. Moreover, it can be found as pebbles in the mixed masonries of civil buildings and city walls (fig.04). It should be noticed that its use replaced with time that of serpentinite, thanks to the ease of processing favoured by the presence of orthogonal fracture systems that allowed to obtain slabs and regular blocks. The durability of this lithotype is generally poor except for those varieties rich in calcite cement. The decay processes are linked to physical and physical-chemical processes [PECCHIONI *et al.* 2012] such as:
- washing away of the clay matrix, making the stone completely disaggregated;
- swelling of the crystal lattice of clay minerals, leading to the typical exfoliation and superficial disintegration;
- dissolution and precipitation of the calcite cement giving rise to crusts of lower porosity which, being discontinuous with the substratum, tend to fall off and then reform, with progressive destruction of the affected architectural elements.

Fig. 04 : Sandstone as pebbles in the city walls

Slate: Slate is not a local material but it comes from the nearby village of Lavagna (30 km far by sea) and from its hinterland where there are wide outcrops. It is the main lithotype of the Val Lavagna Formation-Mount Verzi Member (Upper Cretaceous) (Ligurides Units) where it is present in layers 1-10 m thick made of marly clays and marls (calcite 20-65 %), leaden grey in colour, alternated with arenite layers [AA.VV. 2015]. The Val Lavagna slate has been subjected to two main phases of ductile deformation under conditions of very low metamorphic degree (facies pumpellyite-actinolite) associated with two planes of foliation [MARRONI, PANDOLFI 1996]. The interference of these two phases gave rise to the development of a slaty cleavage defined by very thin levels of clay minerals (illite, kaolinite and chlorite) which, with an anastomosing course, trap calcite microliths [CORTESOGNO *et al.* 1998a, b]. The first documents indicating the extraction of slate for the construction of roof tiles (abbadini) date back to the X-XI century [SAVIOLI 1988]. From Lavagna, by sea, the material reached all the coastal and inland locations. While remaining, that of the roof tiles, the main use, the slate was also used for flooring, doorposts, lintels, sills, thresholds, steps, baseboards but also for the construction of vessels for oil and water, school boards. A peculiar use of slate was as bearing for paintings, because slabs do not warp as wood does, and to realize bas-reliefs and sculptured architectonic elements [MARCHI 1993]. In Levanto all these different uses can be observed (fig.05).

Fig.05 : Slate as roof tiled (on the left) and in a bas-relief (on the right)

As for the conservation, the Ligurian slate suffers chromatic alteration (the hue turn light grey) and exfoliation phenomena. These phenomena are much less present in the French, English, German and Spanish slates that contain very low amounts of calcite and which can be defined as phyllites, i.e. rocks that have undergone significant recrystallization. On the other hand, such slates are more difficult to split than Ligurian slate with which it is possible to produce large and flawless slabs. Studies have shown that the chromatic alteration is substantially carried out by chemical processes in relation to the carbonate component that is leached, the organic component that undergoes a photo-oxidation and the iron compounds that are oxidized [CANTISANI *et al.* 2006]. The first phenomenon involves a superficial enrichment in silicates and iron compounds while the transformation of the organic substance favours the oxidation of iron compounds. The whole of these phenomena determines the remarkable colour change. Exfoliation, on the other hand, is mainly due to physical phenomena favoured by the relaxation of the material after extraction.

Rosso Levanto: A particular material is Rosso Levanto (called also Breccia di Levanto), an ophicalcite that in Italy can be found only in the surrounding of Levanto-Framura-Deiva and in Polcevera Valley (north of Genoa). Ophicalcites are tectonic breccias formed in the ocean bottom along transform faults [TREVES, HARPER 1994; PRINCIPI *et al.* 2004]. In particular Rosso Levanto occurs at the top of serpentinites and is composed of highly fractured serpentinites with fractures filled with white sparry calcite, serpentinite fragments and microsparitic calcareous mud. Circulation of hydrothermal fluids along the fractures caused the partial carbonation of serpentine and oxidation of magnetite into hematite, with a strong reddish hue. The microsparitic mud shows pink hue of various intensity [CORTESOGNO *et al.* 1980; CIMMINO *et al*. 2003; FIORA, ALCIATI 2007].

Thanks to its composition, texture and low porosity, this material can be polished obtaining slabs of particular aesthetic value. For this reason it was already quarried by Romans as ornamental material with the name of *Breccia Quintilina*, than it was widely traded from Middle Ages up the XXth century.

An ancient quarry, called columns quarry, now closed, is still visible on the hill near the church of Sant'Andrea. The most important buildings where Rosso Levanto can be found are the San Lorenzo Cathedral in Genova where it has been used for the columns of the façade and the nearby Church of Sant'Ambrogio.

On the contrary in Levanto, it can be sporadically found in some sections of the medieval walls and in some architectural elements in the old town, but it is much more diffused in the XXth century architecture as cladding (e.g. the old railway station or some palaces along the axis of via Roma) and baseboards, such as external facings of shops, luxury palaces, staircases of villas of many Ligurian towns (fig.06).

Fig.06 : Serpentinite in the cladding of the old railway station (on the left) and the external facing of a shop (on the right)

Concerning durability, the main problems are due to selective decay affecting particularly sparry calcite and the microsparitic matrix which disgregates causing detachment of serpentinite fragments.

White marble: In Levanto the white marble has been used as architectonic elements and cladding in S. Andrea church and it is found in the village for sills, doorpost, lintels (fig.07). This material comes from quarries in the Apuan Alps (northern Tuscany) and was formed between Oligocene and Miocene through complex metamorphic events at temperatures of 350°-450°C and pressures of 5-6 Kbar involving the Calcare Massiccio of Hettangian age (200 My) [DI PISA *et al.* 1985]. There are many varieties of this marble but the general characteristics are a fine-grained (200–400 mm), calcitic composition, and the presence of veins and greyish areas. Microscopically it can have different microstructures, identifiable mainly by the types of boundary among the calcite crystals, from linear to sutured [CANTISANI *et al.* 2005]. White marble degrades mainly by physical processes caused by temperature changes leading to decohesion among the crystals. This is favoured by the strong anisotropy of the thermal expansion coefficient of calcite [BERTAGNINI *et al*. 1984; CANTISANI *et al*. 2009] and is conditioned by the type of microstructure [CANTISANI *et al.* 2000]. Nevertheless, also chemical processes occur through dissolution of the calcite due to rainfall (to a degree determined by the acidity of the water) and sulphation in zones protected from rainfall. These physical and chemical processes lead to the progressive deterioration of the material and to the loss of its shape.

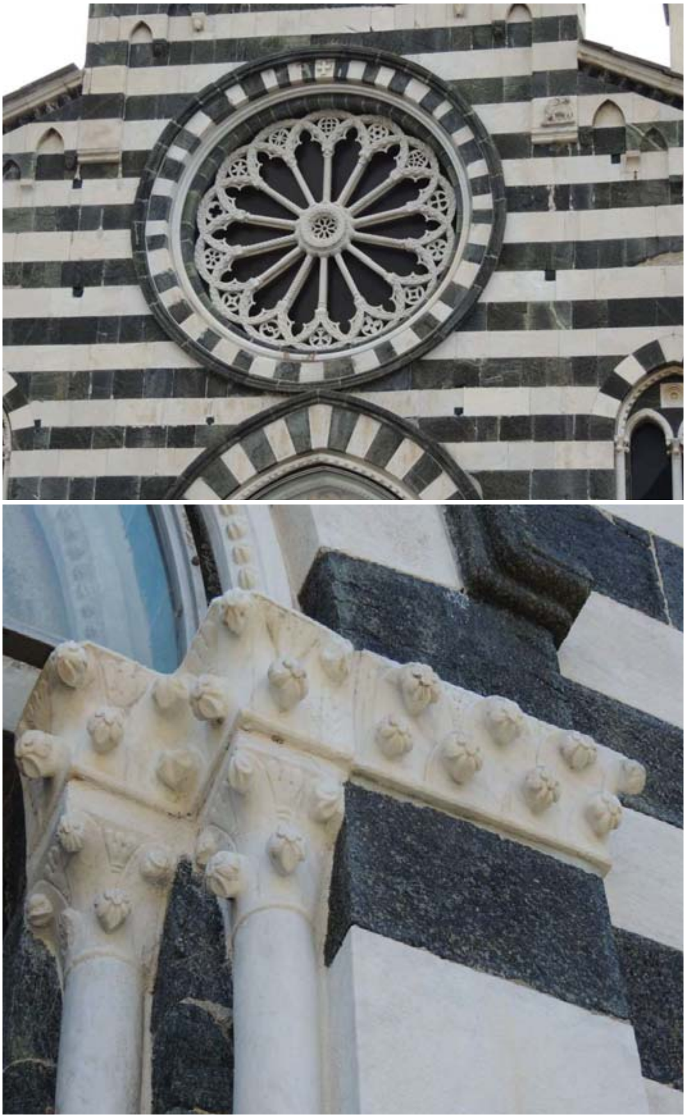

Fig. 07 : Marble in the cladding and as sculptured elements of Sant'Andrea Church

Conclusions

The analysis of the historical architecture of Levanto makes it possible to emphasize its strong connection with the available local stone materials that have been used according to sustainable principles. Indeed, these materials have been selected taking into account their availability, workability, durability. Easy available materials were the sandstone pebbles that have been used particularly for the city walls. As for workability, the easy of shaping the ashlars has been considered, taking advantage of the presence of discontinuities both in serpentinite and sandstone. As for durability, in the case of serpentinite the varieties with a lower amount of chrysotile veins were selected while in the case of sandstone, the layers more reach in calcite cement were selected, easy to recognize thanks to an higher cohesion of the surface. Also the use of slate for the roof tiles testify the sustainable use of materials from the economic point of view: as a matter of fact, it was cheaper the carriage by sea of the slate tiles from Lavagna than the local production of ceramic tiles. The information acquired with this research demonstrate the importance of the knowledge of the historically adopted materials, of their behaviour on time and of the constructive characteristics of the buildings as useful instruments for a more respectful and durable preservation of the rich and significant architectural heritage of our Country[1].

References

AA.VV. (2015) - *Note Illustrative della Carta Geologica d'Italia alla scala 1:50.000 Foglio 214 Bargagli*, a cura di Elter P., Marroni M., Pandolfi L., ISPRA, Servizio Geologico d'Italia.

ABBATE E. (1969) - *Geologia delle Cinque Terre e dell'entroterra di Levanto*, Mem. Soc. Geol. Italiana, vol.8, pp.923-1014.

ABBATE E., BORTOLOTTI V., CONTI M., MARCUCCI M., PRINCIPI G., PASSERINI P., TREVES B. (1986) - *Apennines and Alp ophiolites and the evolution of the western Tethys*, M.S.G.I., v. 31, pp. 23-44.

BERTAGNINI A., FRANZINI M., GRATZIU C., SPAMPINATO M. (1984) - *Il marmo cotto in natura e nei monumenti*, R.S.I.M.P., v.39, pp.39–46.

BRALIA A., CECCHERINI S., FRATINI F., MANGANELLI DEL FA' C., MELLINI M., SABATINI C. (1995) - *Anomalous water absorption in low-grade serpentinites: more water than space?*, European Journal of Mineralogy, vol. 7, pp. 205-215.

[1] Al the authors of this paper should be considered as principal author

BRUNI P., CIPRIANI N., PANDELI E. (1994) - *New sedimentological and petrographical data on the Oligo-Miocene turbidite formation of the Tuscan domain*, Mem. Soc. Geol. It., vol. 48, pp. 251-260.

CANTISANI E., CANOVA R.,FRATINI F.,MANGANELLI DEL FA' C.,MAZZUOLI R.,MOLLI G. (2000) - *Relationships between microstructures and physical properties of white Apuan marbles: inferences on weathering durability*, Periodico di Mineralogia, v.69,pp.257-268.

CANTISANI E., FRATINI F., MALESANI P., MOLLI G. (2005) - *Mineralogical and petrophysical characterisation of white Apuan marble*, Periodico di Mineralogia vol. 74, pp.117-140.

CANTISANI E., FRATINI F., RESCIC S., SCALA A. (2006) - *Gli abbadini in ardesia dei tetti della Liguria: problemi di alterazione*, in Architettura e Tecnica delle Coperture, Ancona, 10-11 marzo 2006, BE-MA Editrice, pp.145-149.

CANTISANI E., PECCHIONI E., FRATINI F., GARZONIO C.A., MALESANI P., MOLLI G. (2009) - *Thermal stress in the Apuan marbles: relationship between microstructure and petrophysical characteristics*, International Journal of Rock Mechanics & Mining Sciences, vol. 46, pp.128-137.

CIMMINO F., FACCINI F., ROBBIANO A. (2003) - *Stones and coloured marbles of Liguria in historical monuments*, Periodico di Mineralogia, vol. 73, Special Issue 3, pp.71-84.

CIPRIANI C., MALESANI P. (1963) - *Ricerche sulle Arenarie: VIII) Determinazioni microscopiche sulle arenarie delle formazioni del Macigno e Marnosa-Arenacea*, Periodico di Mineralogia, vol.32 (2-3), pp. 343-345.

CORTESOGNO L., GAGGERO L., REPETTO G.(1998a) - *Petrography, properties and defects of Ligurian slates*, Plinius, vol.20, pp. 87-89.

CORTESOGNO L., GAGGERO L., REPETTO G., (1998b) - *The ardesie Formation in the Northern Apennine: stratigraphic and structural setting in the perspective of quarrying and of technical properties*, Plinius, vol. 20, pp. 89-91.

CORTESOGNO L., GALBIATI B., PRINCIPI G. (1980) - *Le brecce serpentinitiche giurassiche della Liguria orientale*, A.S.Genève, v.33, pp. 185-200.

DEL SOLDATO M. , PINTUS S. (1984) - *Levanto: geologia, ambiente, evoluzione storica*, TIPOLITOGRAFICA LA SPEZIA, La Spezia.

DE VECCHI G., ROSSETTI M., VANNUCCI S. (1991) - *La serpentina della Cattedrale di Santa Maria del Fiore a Firenze ed il suo degrado*, in Scienza e Beni Culturali VII, Libr. Progetto, Padova, pp. 247-256.

DI PISA A., FRANCESCHELLI M., LEONI L., MECCHERI M. (1985) - *Regional variation of the metamorphic temperatures across the Tuscany I Unit and its implication on the Alpine metamorphism (Apuan Alps, North Tuscany)*,Neues Jahrbuch fur Mineralogie Abhandlungen, v. 151, pp. 197-211.

FIORA L., ALCIATI L. (2007) - *Rosso di Levanto e Portoro, "marmi" colorati dalle proprietà estetiche uniche*, in MARINO L. (a cura di), *Cave storiche e risorse lapidee*, ALINEA Firenze, pp.59-62.

FRATINI F., MANGANELLI DEL FA' C., TIANO P., MATTEOLI U., CAMAITI M. (1987) - *Indagine conoscitiva sullo stato di conservazione dei materiali lapidei presenti sulla facciata di Santa Maria del Fiore*, in *Due Granduchi, tre Re e una facciata - Opera di Santa Maria del Fiore di Firenze*, ALINEA Ed. Firenze, pp.66-78.

FRATINI F., PECCHIONI E., CANTISANI E., RESCIC S., VETTORI S. (2014) - *Pietra Serena: the stone of the Renaissance*, in Pereira D. et al. (ed. by) *Global Heritage*

Stone: towards international recognition of building and ornamental stones, G.S., London, 407, pp.173–186.

GUILLAUD H., MORISET S., SÁNCHEZ MUÑOS N., SEVILLANO GUTIERREZ E. (ed. by) (2014) - *Versus, lessons from vernacular heritage to sustainable architecture*, Ed. CRAterre /ESG/UNICA/UNIFI/UPV.

MANNONI T. (1984) - *Analisi di intonaci e malte genovesi. Formule, materiali e cause di degrado*, in *Facciate dipinte. Conservazione e restauro*, Genova, pp.141-149.

MANNONI T. (1990) - *La tecnica muraria preindustriale e la trasmissione del sapere empirico*, in *Tecnologia e tecnica delle murature antiche*, Padova, pp.6-10.

MANNONI T. (1994) - *Caratteri costruttivi dell'edilizia storica*, Escum, Genova.

MALESANI P (1966) - *Ricerche sulle arenarie, XV. L'Arenaria Superiore*, Rendiconti Società Mineralogica Italiana, v. 22, pp.113-175.

MARCHI P. (edited by). (1993) - Pietre di Liguria. Materiali e tecniche dell'architettura storica, SAGEP, Genova.

MARRONI M., PANDOLFI L. (1996) - *The deformation history of an accreted ophiolite sequence: the Internal Liguride units (Northern Apennines, Italy)*, Geodiamica Acta, v. 9, pp.13-29.

NIELSEN T.H., ABBATE E, (1983/84) - *Submarine-Fan Facies Associations of the Upper Cretaceous and Paleocene Gottero Sandstone, Ligurian Apennines, Italy*, Geo-Marine Letters, v. 2-3, pp.193-197.

PECCHIONI E., CANTISANI E., FRATINI F. (2012) - *The city of Florence: an open-air lithology museum*, in *The Museum of Natural History of Florence* v. IV, ed. Firenze University Press, pp.245-268.

PRINCIPI G., BORTOLOTTI V., CHIARI M., CORTESOGNO L., GAGGERO L., MARCUCCI M., SACCANI E., TREVES B. (2004) - *The pre-orogenic volcano-sedimentary covers of the western Tethys oceanic basin: a review*, Ofioliti, v. 29 (2), pp.177-211.

ROBBIANO A., CIMMINO F., FIALLO M., TEDESCHI F. (2006) - *Il bacino estrattivo delle Arenarie del Gottero: caratteristiche della pietra, aspetti giacimentologici ed impieghi in ambito rurale*, in *Le risorse lapidee dall'antichità ad oggi in area mediterranea*, Canosa di Puglia (Bari), pp. 405-410.

SAVIOLI L. (1988) - *Ardesia: materia e cultura*, SAGEP Genova.

TREVES B., HARPER D. (1994) - *Exposure of serpentinites on the ocean floor: sequence of faulting and hydrofracturing in the northern Apennine ophicalcites*, Ofioliti, v. 19(2B), pp.435-466.

WICKS F.J., WHITTAKER E.J.W. (1977) - *Serpentine textures and serpentinization*. Canad. Mineral., v. 15, pp.459-488.