Vernacular architecture and “historical seismography”: an experience research.

Olimpia Niglio
Faculty of Letters and Philisophy - University of Pise
Denise Ulivieri
Faculty of Letters and Philisophy - University of Pise

ABSTRACT: The *history of hearthquakes* can be defined as a very ancient discipline, which roots are on the tales and on records of the most calamitous events whose evidence is not easy to be found because not written but handed down orally, and the history of seismology is a good example. The analysis of the historical archives and the carefull study of the projects concerning the territory and its structure, often reveals precious informations on events that involved the place, such as the most dangerous, i.e earthquakes, but little technical information about recovery or rebuilding is given in written documentation from the direct literature of the urban context and of the individual building is possible to deduce techiques and ways of the past used to inntervene to reply to the seismic needs of the build and from which the historic seismology originates from. The study of the history of earthquakes has become a systematic instruments to determine the areas where they can happen with a likely periodicity from the past century, and relates especially on historic seismology which has its historic reference store, even if it bases itself on oral sources. Our study, instead, based exclusively upon the analysis and the direct study of the architecture, aims to determinate the needs and the technical devices, peculiar to the art of building, but strictly connect to the local building culture of our territorial reference or research. The rich store of informations has allowed us to study different costructive typology, often determined by needs connected not only to the building tradition but also to the *local seismic culture*. In the areas exposed at high seismic risk, the regularity of the event can create a progressive rooting of the tecniques and behaviours leading to a clear protective view. When the system becomes part of the experience of the comunity, it stays in the people’s memory. The resident population are titular of their own seismic culture that generates non codified and non written rules but readable in the constructive characteristics of the buildings, in the general structure given by the territory. Every building bears witness to its own history and furnishes an enormous quantitaty of informations: the damage suffered, the repair work, intervention of prevention. A "global" local research and at the same time a systematic research of the frequencies of the constructive elements are developed. From this will of putting the basis for a systematic study of the “historical seismography” that promotes a technical normative of reference that is neither generic nor inducing interventions little respectful of a context that only asks to be left in alone.

1 INTRODUCTION

The knowledge of the urban environment and of its structures is the first step for the protection and the preservation of the rich architectural estate, both in terms of historical testimony and social safety.

The redaction of special plans for the recovery and safety, or even for the definition of infrastructures which are necessary when a structural collapse occurs, are not essential because the principal aim is to prevent well defined intervention through a careful study of the methodologies and the techniques which respect and which are compatible with the preexistence.

The principal aim of our research, mainly addressed on a sample area of the northern Tuscany given by the Garfagnana and Lunigiana, is to analyse the interventions and the seismic risk reduction techniques which have been carried out in the past, in order to evaluate their engineering validity .

The interventions used in the past, and even studied through some schedules of analysis, have shown an important coherence, both technical and structural, mainly related to the respect of the historical, architectural and typological estate.

2 VERNACULAR ARCHITECTURE AND THE "ECOSTORICO" METHOD

The architecture is a language whose main aim is to communicate, so it needs to have all the skills which belong to a language. Further, in architecture not only the experts are able to work out a message.

The activity of living belongs to all, until one has proof to the contrary, and "*nobody can be considered just public because everyone is involved in the continuous changing of the environment*"(L. Benevolo, 1994).

In 1881 William Morris wrote: "*The architecture involves all the environment which surrounds the human life; we cannot escape it, until when we belong to the civilization, because the architecture is the whole of changes and alterations made on the earth's surface in relation with the human needs, with the exception of the desert. We cannot limit our architectural interests to a small group of learned men, which are entrust to search, to find out and to model the environment where we have to stay and that surprises us…; it is for us, for each of us, to watch and to take care of the right order of earth's landscape, each with its spirit and with its hands, and in the proportion which is due*." (L. Benevolo, 1994).

In 1936 Giuseppe Pagano highlighted, with deep regret, that "*the history of the architecture is interested, without exceptions, in the so called stylistic architecture, in other words, in that "small" part of the architecture which is considered worthy of attention for its aesthetic value*".

In these words we can guess how is partial a judge which excludes the living culture and is limited to the cathedrals, to the palaces and to all emerging buildings. Since its origin, the living culture belonged to the individuals or to the communities which probably did not stamp the projects and, quite surely, did not draw their cities on the paper.

So the ability to work out a design activity or, in more general sense, to organize human settlings, does not necessarily belong to them that have studied manuals. There are communities that organize by themselves their residential system and they show to be able to write down their functional project.

This argument is rather complex and we risk to deal it with just a rural and artisan point of view which is quite reductive. In other word, we can leave out the urban universe, from the minor and anonymous building of the central areas to the noisy suburbs and the aggregates of unauthorized houses and huts.

For example, the historians have analysed Los Angeles and have studied works realized by famous architects using coded stiles. Their interest excludes "*refreshment stands, hamburger stalls…, motorways, and other civil engineering works, which are essential for the human ecology and the environment of Los Angeles*" (R. Banham, 1983).

This piece of architecture ignores their authors and hates "*the heroes, the first ladies, the too personal images which are added to the list of greats*".

Rudofsky say that the proposed history is limited to a "who is?" of architects which celebrates the power and the richness. In fact, in this terms Rudofsky organized and showed in 1964the exhibition *Architecture without Architects* at the MOMA of New York, which has been intended as "*a definitely desecrating action, a courageous act which gives attention to the anonymous and which is oriented toward new critic profiles and new research fields*" (B. Zevi, 1997).

In the most parts of world the buildings built from their owners, from the communities and from local specialized builders do not represent the exception but the rule. These unknown builders, recently studied, have realised the most part of the areas built from men. It is not easy to define these architectonic and linguistic "koiné" and all trials which have been done to explain this obliged patrimony have been failed miserably.

We use and abuse of the adjective "popular", meaning a wide range of construction types and forms, but the use of this term is often inadequate in the context of the big variety of built environments.

We cannot even speak about "anonymous" architecture because this adjective reflects the prejudges which exist around these buildings.

On the contrary, the so called "spontaneous" gives the false belief that the communities organization is strictly related to the nature conditions. In this context Benevolo wrote about "*a strange figure, the Portulano, that each year was elected at the Pescocostanzo University (Abruzzo, Italy), and which had the power to regulate the restoration of the old buildings and the build on the new ones*". No citizen was allowed to do any change to his home without the complete consent of the Portulano. The Portulano was elected each year and so it was free from kickbacks, dispensations and permissions but he limits greatly the concept of spontaneity.

Paul Oliver used the term "cover" to define the main motivation of a building, but its application to all buildings was not appropriate.

As the interests and the research grow up, it was necessary to coin a word which, at least theoretically, can summarize the most part of these languages "*from the ancient farm house in Tuscany, to the fierce landscape of the huts placed at the end of a car-breaker field*"(B. Zevi, 1997).

And so the “vernacular” term was thought.

In the language study, vernacular means native language, in other words sub-dialect of the common language, which derive from the Latin *vernaculus*. Extending this concept to the architecture, vernacular is the local or regional dialect that is the common language of the buildings.

It is not easy to find a single definition of the vernacular architecture. The vernacular builders usually belong to the communities, they use the buildings and they often are the owners, the builders and the occupants on them, and their knowledge is handed on the future generations.

The community decides collectively the project and the construction of its built-up area, without the presence of a designer. “*Each person gives its original contribution to a solidarity based on the real and objective needs of the community*” (S. Langé and D. Citi, 1985).

It is clear that the different shapes of the constructions, the different uses, the meanings and the cultural complexities make the vernacular architecture various. So the attempts to reduce the richness and variety of these traditions to a simple description limits it to a process.

The *Encyclopaedia of Vernacular Architecture of the World*, edited by Paul Oliver (1997), holds all the studies done in the last ten years about the vernacular architecture. It is a *vade mecum* for all researchers!

This does not mean that the architecture without an author can be only vernacular but that a big part of architecture without authors is even vernacular.

It is interesting to ask, following Mannoni (1994), if the concept of “monument”, is only limited to context of the canonical architecture, if it “*is really related to cultural choices based on pure aesthetic values, or if it depends on the uniqueness of the constructions which are able to be studied and dated*” (T. Mannoni, 1994).

In these interpretations, what is excluded from the historical and critical subject of investigation?

It is excluded everything has not left trace in the chronicle, in the archives, everything has not a signature or a name to remember, that is all the “architecture without the author”.

Unfortunately the history of the architecture has been written by them which see a figure, and not a form, in a work of art, “*the person who sees the figure and not the process in a figurative work of art, don’t see*” (C.L. Ragghianti, 1974).

Unfortunately the history of the architecture, and all the history, is full of blinds.

The limit of this kind of historiography is that it is limited to the history of the dominant classes. Those classes which have always the economic and political power and which are allowed to intervene in the architectural action, delegating to specialists the build of cathedrals, palaces and new buildings; the same “monuments” which was of interest to the official historiography.

The preference of the category of some sources in place of others is not always fair and has heavy consequences for the historiography. In particular the traditional historiography is based on written sources usually controlled by the power groups; unexpectedly these same groups are able to build one hundred or five hundred monuments described in the manuals of the architecture’s history .

These sources implies the use of historical material strictly related to well defined forms of culture and power which transfer their culture through traditional forms of communication (such as writing, painting, and architectural styles).

To investigate the “architecture without the author” means to stay in a new and original historical dimension where there are no cultural limits in listing and defining strict academic categories. In this context the architecture has a complex form which does not match the rigorous scheme, and this is the reason that does not allow all to understand it.

The architecture without the author is thought and realized by the mass which has not the opportunity to control the traditional historical sources. It is not common that an inhabitant of a shantytown is able to testify its presence in a treatise of architecture.

Usually the sources used in the official history are direct, authoritative, chronologically ordered and easy to interpret. This architecture is, for its own nature, very rich of contents and of information and all the investigations have to mainly pay attention to the use of materials intended as historical sources. The study of the history of that communities which are not testified in any document, imply a change in the research methodology because the study of the building projected and realized by a single architect is completely different than the analysis of the “product” wished, thought and used by the mass.

It is usual to have at home utensils realized by famous designers. They are so nice that we prefer don’t use them daily and so they become just nice, but not usable, ornaments. In the same manner new buildings are built using expensive materials and economic sources are invested so obtaining wonderful structures completely different from the “monotone” and common architecture of the others buildings. But these structures represent a too easy and evident subject in our discussions. They look like to stay in some place just to bring the observer to well defined conclusions. In fact they often declare what they want to be and what they want to represent. On the contrary the problem of the sources is more complex when they have to testify realities which are not so evident.

In fact this architecture is more complex and does not match a rigorous scheme and cannot be understood from all.

"*The living is an activity even obvious, given its necessity, but for this reason it is very rich of contents and information*" (P. Pierotti, 1999).

The buildings are projected and built to give answer to all days needs; where the structures are created to meet extreme events, they are the result of an adaptation started after a failure. The igloo of Eskimos is a clear example. "*The project of the ice home cannot be referred to any architect or engineer. The shape and the structure have been designed by Eskimos. They have imitated the strong models and have refused those models that succumbed, so that this civility has formed the final project of its home*" (P. Pierotti, 1999).

In terms of intervention on the soil, the experience has as much importance as the science.

Through this methodology of research "*we can rebuild all the living history and so to bring to light even on the history of the populations that usually did not leave written testimony but left traces related to the home problem on the territory*" (P. Pierotti and D. Ulivieri, 2001).

"*Even the built specks, provided that we are able to hear what the stones tell*".

This kind of historical analysis, applied to the study of local seismic culture, allows to develop a research able to recognize the so called protective "anomalies", that are some characteristics of the historical buildings which cannot be explained if not interpreted as suitable measures which increase the resistance of the building in case of earthquakes.

The recourse at the *Ecostoria* , that is the study of the human settlings mainly carried out using empirical data, represent an important help.

"*The* Ecostoria *is the history of the oikos, that is the history of human settlings. To settle is as necessary as to live, all of us write our small pages of* ecostoria *starting when we leave the mark of our presence on the soil. The living belongs to all, and so the* ecostoria *will describe the history of all*". "*The* ecistica *is the discipline that organizes the human settlements on the soil ("ecista" was the founder of the Greek colonies starting from the VII century). This means that the sources* ecistiche *are handy for the* ecostoria" (P. Pierotti, 1999).

It is necessary to know what "local seismic culture" means, which is widespread and deeply rooted in a given area.

"*Among the catastrophic events the earthquake perhaps leaves more traces that other events. It is common practice that after such earthquake more advanced building techniques are used and they are destined to make buildings more safe, at least in theory, and so this implies that even in the constructions science the earthquakes history represent a big help*" (P. Pierotti, 19997).

The seismic culture is in the character of the built. This "culture" is not intended in theoretical sense. In particular if we read the instructions contained in the manuals of the engineers of the XIX century which describe how to build a structures in a seismic area, we can see that they are all the same. On the contrary in this context we are not speaking about engineers, architects or geometries, we are discussing the abilities of the resident population to control the built.

In the regions with high seismic risk, the regularity in the arrive of earthquakes has induced the use of techniques and behaviours which have a clear protective function. In other words, if the earthquake is frequent, the population assumes a seismic culture which gives rise to not coded and not written rules but they are clearly observable in their constructions. Its knowledge is based on the experience which becomes science. An example is the traditional Japanese architecture where the risk awareness is included in the shape of their buildings.

It is not easy to recognize the traditional aseismic techniques. It is necessary to analyse the vernacular architecture of the well defined area to evaluate which elements have a aseismic validity. The study of the human settlements done through of empirical data is of great importance. The building is the source most objective and reliable. Each building is the testimony of its self and supplies a big quantity of information, with its damages, its reparations and the preventive interventions. We need to "read the earthquake on the stones", and to remember the Marangone and Ragghianti's words: "see before and read after". Even Mumford on the ways of its native city, New York, and visiting each of its areas, relied on its ability to see and he derived the history from the direct observation of the architectural objects.

The seismic culture does not grow only is inhospitable areas, such as the Japanese islands, but even in Italy where the earthquake is frequent and "a culture of building" is born.

The Lunigiana and the Garfagnana , for example, are two seismic areas of Italy. The last disaster has been held in 1920, even if many earthquakes are registered every 4-5 years which have reached the seventh degree of the Mercalli's stair.

The population of Dalli di Sotto perceives one or two earthquake per year. They say that “the hens sing and they can heard, before the earthquake, a roar and even the dogs bark” (P. Pierotti and D. Ulivieri, 2001).

One of the reasons which makes this area of interest, is that the most part of the ancient homes, mainly in the Lunigiana, have not the plaster and so it is possible to understand and to document, directly from the brickwork, the events that involved them. From the stones we can still see the prevention systems, the repairs, the reinforcements and the changes done by law.

In these areas, where the use of the bamboo canes in very improbable, the home built in brickwork is quite common (even if there are some elements in wood) and there are some components that try to reach the same aim of the bamboo. There are main walls with large sections, terraced homes or even streets with arcades which make the town as a single building block. Further there are arcs across the streets, architraves in chestnut, ceiling in wood and so on. The system to understand the earthquake on the stones of each building, integrate the opportunity to define micro-areas of observation which cannot be defined in other ways.

3 NECESSARY RESTORATION OR A NEED TO RESTORE?

It is a well known and widely recognized fact that, should a particularly catastrophic event occur, an earthquake for example, the damage to a piece of our “cultural heritage”, taken in its broadest possible sense, is not only in its material and formal aspect, but also in its social value and cultural identity within the community of which it forms part.

Most certainly lost is that value defined by Cesare Brandi as “aesthetic” yet at the same time “historic” , subjected first and foremost to immediate repair interventions on damage provoked by the sad event.

Consequential, on such occasions, is the planning of interventions principally on those cultural heritage structures that have suffered less damage, that have every potential to continue their life cycle and require works aimed at their structural and formal rebalancing without the implication of widescale transformation.

But interventions determined by events, often unexpected, such as an earthquake, flood or fire, fall within a category that certain experts have correctly defined as works “of necessity” , by this term meaning a work (…) *imposed by an exceptional fact and not upon request – such as normal restoration – of an architectural or urban monument*

It is likewise important to specify that the intervention subject falling within the above mentioned category concerns both individual buildings and areas of a city, but which are recognized as having a “documentary” value, a cultural, social and economic identity.

In fact, the intervention conditions have different meanings if the subject is classed as having a high historic and architectural value, or if it is more correct to describe the works as constructional recomposition or urban renovation.

Our attention in this case is addressed mainly to the first category, that of works which document a recognized collective value, testimonials to memory or ownership. In this framework we speak of restoration as that intervention aimed at guaranteeing the static safety of the construction and its subsequent return to order in full respect to its entire heritage role in the future.

In this respect it is important to quote a worthy description from the 1975 Amsterdam Treaty in which it declares the need to operate in terms of integrated preservation intended as *the result of the combined use of restoration technique and research of appropriate function. (....)* in that the operational methodology requires the validation and reinstatement of the work in the framework of its existence and in its role in a social and environmental context.

But reality, when calamitous events have occurred, as reported often, has always been characterized by decisional and operational uncertainty caused mainly by the existence of obsolete and inadequate laws and regulations, as well as by organizations appointed to safeguard the heritage but who intervene with undue delay and lack of expertise.

We have witnessed a panorama of the most irregular, confused and inhomogeneous intervention solutions, the good fortune of which often derived exclusively from local contingencies rather than a solid and common cultural and operational methodology to confirm its interpretational differences on the subject of restoration.

In 1986, the National Commission for cultural heritage risk prevention against seismic events produced the *Recommendations for specialist intervention on the monumental heritage in seismic areas.*

Said *Recommendations* systematically and accurately identify the analysis to be carried out prior to any intervention whatsoever, and lists in detail the project documents to be produced under the coordination of an architectural restoration specialist. In particular, the *Recommendations* aim to establish the correct intervention aims and confirm the main objective as that of prevention achievable by combining *improvement* works with the option of *general preservation*. In a more detailed manner, the decree examines two kinds of intervention: adjustment and improvement. The first is intended as *the completion of a series of works proving* *necessary in order to render the building resistant to seismic activity*; the second is aimed at guaranteeing a higher degree of architectural stability *without substantially modifying its overall behaviour. Improvement intervention is mandatory for whoever intends to carry out local intervention aimed at renovating or replacing structural elements of the building.*

It is to this latter category that restoration interventions refer and which, first and foremost, require verification of the structural *status quo* and an in-depth knowledge of the building (the history of its constructional stages, materials and techniques used).

But a detailed analysis of the *Recommendations*, albeit with commendable attention also to preservation aspects, highlights a clear distinction between "subject" and "image", that is between content and appearance, thus offering confirmation of the different methods and criteria used in *necessary restorations*.

The collective approach in these cases remains that of philological, sentimental, and "how it was … where it was" restoration justifying many interventions, beginning with the reconstruction of the Campanile in Venice (1902) up to the current and contemporary debate over the reconstruction of the belltower of the Cathedral in Pavia (1989), but far from the true aims of reconstruction intervention determined by a clear desire to restore culture and national history.

In this framework, experiments carried out over recent decades in the field of *necessary restoration* have involved many national territories: from Belice (1968), to Friuli Venezia Giulia (1976), Campania (1980), eastern Sicily (1990), Umbria (1998) and Molise (2002). All these cases demonstrate that impoverishment of the architectural and environmental heritage was not only caused by disasters, but also to the lack of timely and suitable renewal and recovery intervention.

With particular reference to the historic and architectural heritage, countless damage has been identified that more often than not has completely cancelled centuries-old historical evidence.

From analysis of the compromised construction, it has often emerged that the cause of the damage also resulted from previous interventions with little respect for the formal and structural characteristics of the building. In effect, for many years we have seen, and sadly still do, building restoration work using methodologies and technologies incompatible and often totally unsuitable to the real identified needs and in conflict with the original structure.

The problem in every case hinges on the real possibility of guaranteeing "seismic stability" with respect for the preservation needs of the heritage, be it monumental or the so-called "lesser".

In this respect it is fundamental to emphasise the content of the Law Decree of 24 January 1986 concerning technical regulations for constructions in seismic areas, quoted previously and later reconfirmed in the Law Decree of 16 January 1996.

Subsection 9.1 of the latter confirms two kinds of intervention: adjustment and improvement. With particular reference to improvement, in its clearest definition as illustrated previously, it contains the true principle of preservation, that of the function perceived by the original architect, as well as the awareness that history already partly proves the "testing" of the work itself.

Experience also, from particularly disastrous seismic events, has demonstrated the failure of a certain working method, aimed at the addition to the original structure of new elements in reinforced concrete, with mechanical characteristics that integrate inadequately with a brick wall structure.

There is no doubt that the true culture of *necessary restoration* finds its origins, differently, within the individual communities conditioned by the desire to reconfirm a lost cultural identity and to recover its function by adopting highly safe systems, as claimed by modern industrial technology, which then failed.

No less "invasive" are the indications imposed by organizations appointed to safeguard and protect, such as the state, regional, provincial and local (urban regulation) governments whose regulatory decisions on the subject are increasingly generic and do not integrate well with the reference subject. It is pointless recalling the lengthy delay recorded each day when analysing the conquests of scientific research against the difficulties they have met in acceptance by a public opinion geared increasingly towards consumerism.

Records increasingly show more cultural deviation between the world of research on the subject of cultural heritage preservation and interventions defined as *restoration* (but far from it) completed by engineers, architects, and more often than not also by surveyors, unspecialised and using operational methods and criteria closer related to economic and financial problems than to the real preservation of the architectural and urban heritage.

In this respect, we record a number of barely respectful interventions, and by no means preservational, contributing to an increased constructional vulnerability, illustrated and graphically represented in practices granted for and carried out upon architectural structures.

For example there is the replacement of ceilings (roofing and wooden floors) with heavy reinforced concrete slabs; curbing, again in reinforced concrete, inside a brick wall facing (both homogeneous and mixed); the application of reinforced beton for consolidation of walls; extrados consolidation of vaulted structures capped in reinforced concrete; and so many other interventions adopted often.

On the contrary, as reconfirmed previously, the basis of a preservational intervention is an in-depth knowledge of the construction, and from here the important role of diagnostics, both archival (surveys, historical analysis) and instrumental (investigative techniques applied directly on the building), for which a study of specific and specialist literature on the subject is recommended.

From this it is deduced that the road to follow is that of systematic recovery of traditional intervention technique such as: buttresses, metal chains, stanchion hooping, light wind-bracing, etc… which, if correctly applied, are fully preservational in that they are coherent with the original structure, reversible and therefore not invasive.

In many cases the history of the building has demonstrated that interventions of this nature have fully respond to shock from seismic events without provoking further damage.

The wealth of resources of a highly technological content (both tools and composite materials) available on the market certainly constitutes a valid alternative to traditional technique only if applied with respect to the constructional principles of the building itself. Once again fundamental in this respect is a knowledge not only of the building but also of new materials and technologies that are often used in an uncivilized and compromising way. The problem, in fact, is to disseminate this knowledge at all professional levels concerned (both public and private) and make them part of standard operational practice.

In any event the eventual aim of preservation must certainly be that of not operating in the field of *necessity*, nor resort to unnecessary restoration in that, should this occur, it indicates that an adequate preservational methodology, with standard intervention to re-establish small-scale unbalance an accumulation of which leads to more costly and risky intervention, has not been adopted.

4 TYPOLOGIES

A) HABITABEL BUTTRESSING ARCHES AND ARCADES

DEFINITION

Habitable buttressing arches were devised and developed with the aim of providing a contrasting effect against the buckling tendency of walls perpendicular to the direction of seismic stress. The creation of these arches also resulted in an increase in volume and new space available in housing units.

These construction elements subsequently contributed to the appearance of a highly recognisable building type, known as *arcaded villages*, which are characteristic of many villages and little hamlets in the region of this study.

In the majority of cases, habitable buttressing arches and arcades are composed of more or less extensive vaults built from local stone; only the arcades sometimes feature a small wooden floor instead of the vault. These elements are always built level with the wooden or vaulted ceilings of two opposite buildings, with the addition of new structures built between them, bridge fashion. This enables the arcade both to cover portions of the alleyways and to support new rooms, but above all to establish a form of collaboration between the connected structures.

METHODOLOGICAL AND PRESERVATIONAL NOTES

Habitable buttressing arches and arcades can be included in the class of the so-called “added” structures that we have called *arcaded villages*. These elements have a structural as well as a strictly defined functional purpose as they simultaneously solve both static shortcomings of the original system and satisfy new functional demands of the building with new paths, rooms, etc.

Conservative work is aimed at the critical analysis of the quality of this added element, the assessment of its actual structural consistency, and its material and formal qualities within the context that it occupies. The collocation of the building in a historical context often calls for work aimed at preserving and enhancing all of its constituent parts. These structural elements, especially in old town centres and medieval villages, are characteristic features of the local architecture and environment and as such should be protected without resorting to contrived solutions offered by the most innovative technologies.

STRUCTURAL BEHAVIOUR

In static conditions, the vaults composing the arcades and built-up buttressing arches exert limited thrusts on the outside walls of the two opposite buildings that are generally thus able to bear them without the onset of static problems and load-bearing deficiencies of the foundations.

However, a preliminary inspection of the consistency of the walls and the good quality of the materials of the sections that require buttressing is always necessary before commencing any kind of work.

In seismic conditions, this element enables the horizontal movements that are produced to be distributed more efficiently, but above all the structure added above the vault effectively counters the tendency of the two opposite walls to collapse, due to its continuity with the walls themselves, considerably reducing the collapse multiplier and thus the possibility of critical situations.

The horizontal thrust of these vaulted structures increased by the seismic thrust is often counterbalanced by that produced by the vaults that are very often featured inside the construction, or is absorbed by the walls on which it is built, due to their considerable thickness.

Finally, the increase of vertical loads caused by the building of these vaults results in a certain improvement in structural behaviour as it contributes to re-centering the ensuing forces, repositioning the centre of pressure within the core of inertia.

USAGE PRECAUTIONS

The remark made earlier concerning buttressing arches, regarding the fact that care must be taken not to create any dangerous eccentricities due to the staggering of the ceilings, also holds true in this case. Indeed, the presence of differences in level of the floors produces bending stress in the vertical wall facings, and the slimmer the latter, the more dangerous the former will be. Indeed, the decompression of the section increases in direct proportion to its slimness.

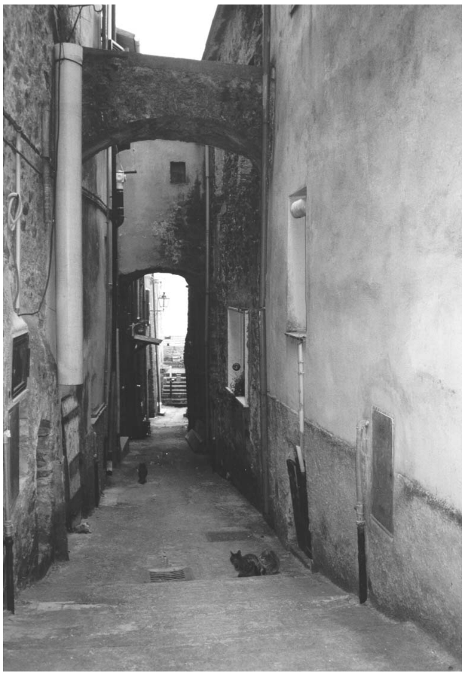
In the case in which the opposite buildings have insufficiently thick walls and flat ceilings that do not produce counterthrusts able to centre the ensuing forces, the use of arcades and habitable buttressing arches may be counterproductive, and the possibility of eliminating these thrusts by means of metal chains should be carefully examined.

Finally, it must be remembered that also for this type of work, effective bonding between the old and new walls is of fundamental importance for their satisfactory structural behaviour, as is the preservation of the state of the walls, avoiding the introduction of any dangerous discontinuities.

B) BUTTRESSING ARCHES

DEFINITION

Buttressing arches are premodern structural elements introduced in the attempt to halt collapse mechanisms, which are often triggered by defects in the connection of new buildings to pre-existing ones.



Indeed, the stretches of wall of the new houses that are perpendicular to the direction of the earthquake often display a tendency to collapse, even in the presence of slight seismic movements. In other cases, the original walls present problems related to their low resistance to horizontal seismic stress.

This reinforcing structural element consists of an arch that is often made from stone and less frequently from brick positioned level with the wooden or vaulted ceilings of two opposite buildings. These single or multiple arches were usually placed in correspondence with the façades of existing buildings. Consequently the arches and walls to reinforce belong to the same vertical plane as the buttressing arch, thus enabling the creation of a kind of collaboration between the horizontal and vertical structures.

METHODOLOGICAL AND PRESERVATIONAL NOTES

Following clearly visible static damage, provisional propping structures are commonly used to counterbalance the disequilibrium that has been accentuated in a construction system due to causes that must successively be verified and that have required the support of external structures.

This is not the place to discuss the problems associated with the application of provisional structures, but it is useful to point out that they must be positioned in such a way as to restore the equilibrium of the construction system and thus studied and calculated from a static point of view, as illustrated below.

In general, we are used to thinking of temporary supporting structures such as centering and buttressing and simple props, which may be made from wood or tubular metal. In many cases these temporary structures become permanent as the building awaits future restoration work.

However, sometimes it is possible to observe the use of one or more masonry arches built between the opposite façades of two houses, especially in the narrow streets of very stratified old town centres. These arches are commonly known as "buttressing arches" in technical language, and are used to contain the instability of one or both of the buildings in a certain point. Unlike masonry buttresses, this system is less visibly invasive and at the same time enables the problem to be solved without interfering with the underlying space (e.g. a pedestrian path, an entrance, a road, etc.). These counter arches are nothing more than protective safety structures positioned at the most appropriate points to counter stress that may be of a subsiding, crushing, combined compressive and bending or tensile nature originating in the imbalanced construction system. Their planning must bear in mind the characteristics of the building that they are designed to protect, the type of wall and the kind and severity of damage. Consequently, it is very useful to perform a preliminary analysis of the consistency of the materials, especially in the area in which the provisional structure will be applied, where the flow of forces is most concentrated. In this respect, it is also very useful to study the type of joint and connection between the provisional structure and the wall that it is designed to protect.

In the sphere of restoration, it is useful to bear in mind the significance of these buttressing arches, which constitute real protective structures, whose value is not temporary but which have become part of the historical fabric of the buildings, characterising the place and environment in which they are featured. In many cases these arches have also assumed the function of small corridors, external walkways or covered arcades connecting the various buildings. Any restoration work must be aimed at preserving these structures, even if their protective function is no longer necessary due to the application of alternative solutions on a "case to case" basis.

STRUCTURAL BEHAVIOUR

In static conditions the presence of the arch does not have any noticeable influence on the structural behaviour of the two connected portions of buildings and the arch is not subject to any particular stress, as it only needs to bear its own weight.

Earthquakes produce horizontal movements at the level of the floors, which are redistributed amongst the vertical walls in proportion to their stiffness or to their area of influence according to the stiffness of the floors themselves.

The presence of buttressing arches enables these movements to be redistributed more efficiently due to their joining function of the various parts of wall, but above all provides an additional bond to the walls that would experience subsidence problems without them. Indeed, these structural elements became very widely used precisely because they enabled the consolidation of structures in which the collapse mechanism was already underway and halted its progress.

In static conditions the horizontal thrust of these arch structures on the adjacent walls is fairly low and consequently does not cause any particular problems, however during seismic events it can increase greatly, and in this case must be absorbed by the full section walls behind (i.e. those in which any openings are suitably spaced) or counterbalanced by that produced by another arch inside the building.

USAGE PRECAUTIONS

Particular attention must be taken not to introduce any dangerous eccentricities that would subject the wall to excessive stress, creating hazardous tensile loads that are difficult for the wall facing materials to bear.

In the case in which the floors are at different levels, buttressing arches can still be used but must be "humpbacked", i.e. with the imposts positioned at different heights, in order to connect the different internal levels in some way.

If the main walls to be buttressed are not perfectly parallel, the arches must necessarily be slightly sloping, although this reduces their efficacy and in some cases makes their use inadvisable.

As we mentioned earlier, buttressing arches are often constructed after the houses themselves have been built in order to consolidate certain parts of them, and in this case the impost of the arch is created by demolishing part of the existing walls in the area in which it is to be positioned and then building it from the wall structure. However, in a few very rare cases, the impost of the arch is simply built up against the wall, without any connecting element, thus introducing an extremely weak element into the resistance mechanism. Finally, when these arches are built at the same time as the buildings that they are designed to sustain, the correct way of arranging the arch is to create its bearings by widening the vertical walls, thus avoiding the use of imposts that drastically interrupt the structural continuity of the load bearing walls.

C) VAULTS

DEFINITION:

Vaults are thrusting structures deriving from the passage of the linear concept on the arch to the concept of the single or double curved surface. Vaults may have very different characteristics, and for this reason are classified according to the geometry of the soffit surface in: *barrel vault, cupola vault, basin vault, sail vault, umbrella vault, cloister vault, cross vault, square vault and lunette vault*, and according to construction types in: *overhanging vaults, cast vaults, vaults with discharge arches, ribbed vaults, brick vaults and lightweight vaults.* In the Garfagnana and Lunigiana regions not all types can be found, in fact the majority of structures present either barrel vaults or lowered vaults, mainly in stonework and only rarely in brick.

METHODOLOGICAL AND PRESERVATIONAL NOTES:

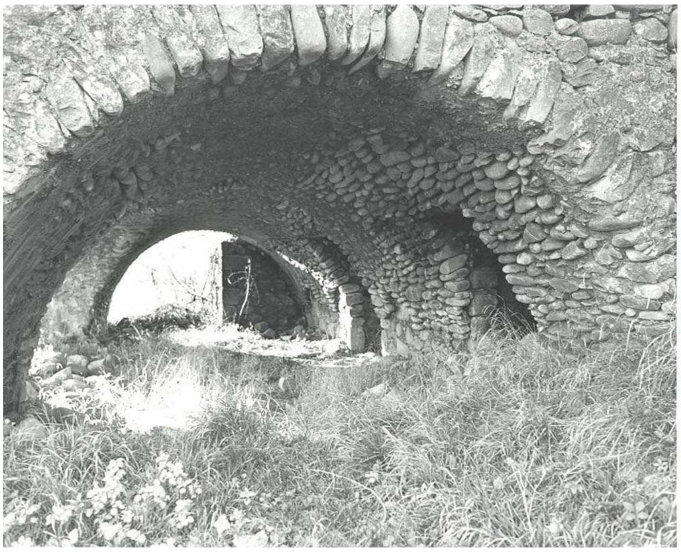
Vaults are nothing more than "arched covers", used widely in the past and made of materials such as stone or brick arranged in such a way as to create a stable structure, the balance of which is guaranteed by the effect of the pressure created between the single ashlars that make up the vault and the effect of the equal and directly opposing counter pressure from the supports onto which the pressure of the vault is sent.

No different from linear walled structures, vaults require a careful analytical study in order to precisely identify the mechanical and static characteristics, which vary from case to case according to the bond and type of the vault.

The use of this kind of structure became less frequent with the introduction of steel and reinforced concrete, but in restorations and consolidation works on historical buildings they can still be found, offering very interesting morphological characteristics.

A vaulted structure can be differentiated by two main characteristics: the bond and the geometry.

The bond is the way in which the bricks or stones are arranged to form the arch of the vault. According to the use of materials and different arrangements, bonds are divided into: stone ashlar vaults, stone vaults, brick vaults (with parallel arches, longitudinal arches, diagonal arches), leafed vaults, vaults with moulded piping.



After the bond comes the geometry of the vault, which creates other different types. By analysing vaulted structures, the base elements are always simple vaults, with a geometry that can be described by the movement of the rotation or translation of a generating curve according to set trajectories. In the most common, the barrel vault, the surface is obtained by the translation of a straight line along a trajectory determined by a round arched line.

In the case of more complex vaults, these are created by the intersection of simple vaults along set directional lines. In this way different types are created, such as: barrel vaults, lacunar vaults, lunette vaults, sail vaults, cloister vaults, cross vaults, square vaults, cap vaults, polygonal vaults, etc....

This rich variety of types and technologies of vaults often makes it useful to catalogue them to determine all the possible solutions for preservation works. In vaulted structures more than any other structural typology, we need to carry out careful studies into both the history and the structure, which vary from case to case. This understanding must then constitute the base for formulating the preservation and restoration project.

The techniques are many, even though today this specialist field uses some solutions that have already been experimented in other sectors. But the sensitive and responsible technician needs firstly to turn his attention to a basic methodological understanding summarised in the following points:

- Anamnesis of the structure
- Static study of the vaulted system
- Analysis of the materials and their structural functions
- Verification of the physical and mechanical characteristics of the vault and its single elements
- Analysis of the level of degradation and cracking
- Overall evaluation of the static structural behaviour of the vault

On the basis of these details, and according to the set aims of the design, it is possible to identify the most suitable interventions for the preservation of the structure.

In many cases, above all in religious or noble constructions, as well as structural problems it is often necessary to preserve particularly precious paving elements or a fresco covering the soffit of the vault. There may even be cases of a pavement and a fresco, which leads to complex operational decisions. This is the reason why it is not always possible to rely on standardised solutions, rather we always need to work according to the specific needs of the case in question, having also to justify the choices made. This is also the case when having to demolish and reconstruct a vaulted structure.

STRUCTURAL BEHAVIOUR:

In static conditions, the wall thickness of old buildings was enough to guarantee that the resulting pressure fell within the central point of inertia thus avoiding possible unbalance. Seismic action on the other hand produces horizontal stress, which overlaps the natural thrust of the vaults and drastically increases the eccentricity of the load, and can set off collapse mechanisms that firstly affect the vertical walls and then the vaults themselves. The thrust of the vaults goes mainly to the perimeter walls, where the thrust cannot be balanced by other thrusting elements causing the walls to warp (rotational movements and inflexions towards the outside) which in turn cause the foundations to rotate and lead to non-uniform tension on the ground. This increases the traction stress and thus the increase and widening of any cracks, eventually causing the whole structure to collapse.

Historical buildings also often contain details that drastically limit the probability of collapse. Usually metal chains are anchored to the sides of the vaults to eliminate thrust or involve other adjacent elements in the resistance mechanism, thus reducing the risk of collapse. Other vaults have brick buttresses that widen the support base into which the actions can be discharged without causing any damage.

USAGE PRECAUTIONS:

The use of stone vaults was very widespread in historical buildings, as their presence on the first floor guaranteed the downward movement of the centre of gravity of the building, with less exposure to seismic damage. They were on the other hand to be avoided on the upper floors, where their sizeable weight would be a cause of weakening and the perimeter wall sections would not be strong enough to sustain the traction.

The builders of olden times often tried to protect these structures by placing chains in the correct positions, and while these were not strictly necessary they have been shown to be decisive in some even strong earthquakes. It can therefore be said that well-placed chains have always had a positive effect on the behaviour of the structure and are therefore to be recommended for consolidation and fundamental for interventions on damaged structures.

Little attention is often paid to the importance of the quality of walls on which the vaults are built; this together with the consistency of the section is on the other hand decisive. The quality of the mortar, the stone materials with which the wall is built, and their warp, must be carefully managed to avoid any problems of crushing that could be caused, with repercussions also for the behaviour of the vault itself.

Another very important aspect is that of the filling material used for the backing. This not only has to spread the loads above, but also has to work together with the vault to provide staticity for the structure as a whole. This is why in the event of vault damage we also need to examine the condition of the backing to check for the presence of cracks and their condition, which is often the result of using materials from old demolished buildings or clay or rocky soil. These excessively heavy materials must where possible be replaced with lighter alternatives, in order to reduce the forces of inertia that are generated during seismic events.

Vault consolidation works must therefore aim to reduce the specific weight of the backing and increase their resistance. The kind of works currently used in these cases involve the building of light reinforced concrete counter-vaults on the extrados of the original vault; this however has some negative consequences. It has in fact been demonstrated that, unless the counter-vault is very thick there is no substantial change in the static and dynamic behaviour of the structure, although humidity can collect in the mortar and over time can cause weakening. Consistently thick counter-vaults also suffer from problems of humidity, on top of which they are very rigid. This rigidity is much greater than the original vault and this makes the stress fall on the new dome, discharging from the old structure and reducing the compression stress of the stone segments or brick elements. This kind of structural "relaxing" has no direct consequences on the static condition of the building, but can lead to the original vault elements becoming detached.

Finally, an aspect that is often underestimated concerns the arch centre, which is decisive during the vault discharging and consolidation phases, but which must be kept in mind also during the removal phase when vibrations and shaking caused by the removal operations or the excessive speed in removing the arch centres can be very harmful for the stability of the building.

D) BUTTRESSES OR COUNTERFORTS AND SCARP WALLS

DEFINITION:

Buttresses and scarp walls are just some of the construction elements of historical origin often introduced in the attempt to consolidate parts of masonry subject to collapse mechanisms caused by rotation. These structures testify to the considerable seismic activity of the region of this study, as they represent Man's quest for protective systems that are in some way capable of reducing the risk of structural subsidence of buildings subject to seismic stress. Buttresses and scarp walls have always been considered very effective, not only for absorbing horizontal thrusts caused by seismic activity, but also for structural failure due to crushing or combined compressive and bending stress and for the subsidence of foundations.

All these systems were born as remedies to structural shortcomings and were developed over time, until becoming real techniques that were also suitable for the prevention of earthquake damage aimed at reducing the vulnerability of the buildings and applicable wherever there were no particular architectural requirements or problems of occupancy of a public area.

METHODOLOGICAL AND PRESERVATIONAL NOTES

Like tie-bars, buttresses are classic elements introduced to limit the horizontal thrusts generated by arch structures and in particular by earth movements.

In properly performed restoration and structural consolidation work, both buttresses and tie-bars are essential structures for specific and precisely positioned intervention, which cannot always be avoided, despite the fact that material and structural technology has now started introducing new solutions, which are nonetheless still at the experimental stage.

The use of structures to counter the horizontal thrusts was not always an added element.

For example, in Gothic architecture buttresses assumed particular aesthetic and formal shapes and were already present in the original architectural drawing. This means that certain structural solutions were already controlled at the design stage.

Buttresses imply a greater thickness of masonry at the base of the wall and the consequent reduction of its section as its height rises. Thus the greater section at the base enables more efficient distribution of the vertical loads and greater structural stability in the case of horizontal movements, whilst the gradual decrease in the section of the structure with height has the advantage of reducing its weight and the amount of material used in places in which a greater section is not necessary.

Buttresses are structures that must be precisely positioned in correspondence with elements that produce considerable thrusts, such as arches or floor supports. In order to counter horizontal movements, on the other hand, traditional historical building also employed a thickening of the wall, which is commonly referred to as a "scarp wall". This is actually a "lining" that merely thickens the load-bearing wall from the inside or the outside. The choice to intervene on the inside or the outside of the building is simply dictated by local traditions and purely practical requirements.

As for buttresses, "linings" may also be featured right from the design stage. In this case, there are no problems of continuity between the pre-existing walls and the added one, a factor that must always be borne, in mind especially during restoration work. Indeed, thickening structures not closely connected with the pre-existing wall are often encountered that display little collaboration between the lining and the wall and do not ensure an increase in the resistant section. In such cases the choice of materials used and their mechanical compatibility is also very important.

Masonry “linings” in particular are preferred in the presence of new added storeys in order to reinforce the entire surface of the wall and also to afford protection against earthquakes. However, in areas in which protection against earthquakes is the prime function, it is preferable to insert counterforts or buttresses at a limited distance from each other in order to give the wall greater resistance.

In the past, many buttresses, in particular, were built from full bricks laid perpendicular to the sloping wall, i.e. in the normal direction of the expected movements.

The inclusion of these structures in the surviving buildings is dictated exclusively by structural measures assessed on a “case by case” basis by the local building culture and not always explicitly required by and indicated in the local building regulations.

STRUCTURAL BEHAVIOUR

In static conditions, the increased section of buttresses or scarp walls is effective in all those cases in which excessive slenderness of the walls could lead to failure due to combined compressive and bending stress.

In the specific case of seismic movements combined with a horizontal force proportionate to the mass subjected to the movement caused by the earthquake itself, it can be deduced that the function of the buttress may not always be completely positive and collaborative with the structure that it is designed to protect.

Indeed, in such conditions, the presence of buttresses may not be a decisive factor, especially during seismic events of considerable magnitude.

Indeed, the seismic stress exerted on a masonry building may trigger collapse mechanisms featuring the rotation of the boundary wall positioned perpendicular to the direction of the movements. This rotation is due to two principal causes: the lack of bonding between the orthogonal boundaries or the poor quality of the bracing walls.

In these cases buttresses on the one hand constitute valid defence against such damage mechanisms, as they have the great advantage of adapting the boundary walls with equally stiff structures, but on the other risk conveying further stress proportionate to the forces created by the earthquake to the very structure that they are designed to protect.

USAGE PRECAUTIONS:

For the aforesaid reasons, the introduction of buttresses or scarp walls is generally assessed on a “case by case” basis. However, the stabilising contribution that buttresses and scarp walls give to walls, especially in the presence of rotation mechanisms, is fundamental, and an important role is played by the bonding of the wall to the added buttress. Indeed the “toothing” represents the element that prevents the two masonry parts from slipping along the contact surface due to the effect of rotation.

In order to fulfil their task properly, these elements must be suitably sized and must be featured in sufficient numbers to avoid the detachment of the two opposite wall facings.

In general, the extensive experience of the past has led to a preference for small and closely spaced, rather than large and widely spaced, toothing in order to absorb shear stress in a continuous fashion.

On the contrary, it is widely maintained that toothing made exclusively from metal bars should be avoided as it causes stress that is concentrated on the masonry.

E) WOODEN FLOORING

DEFINITION:

Until recently, wood was the most common material used to construct floors in the historical buildings of the Garfagnana and Lunigiana regions. This type of floor, which has since been made illegal under Italian law (of 16/1/1996, which states “When replacing flooring, these must be in standard or pre-compressed reinforced concrete, or mixed with brick blocks or other materials, or in steel suitably anchored to the ends of beams”…) was made almost always by a primary frame of chestnut wood beams, a second warp of smaller beams and final layer of brick or wooden slabs.

METHODOLOGICAL AND PRESERVATIONAL NOTES

Wooden floors are built from linear elements cut from chestnut, larch or fir trunks. Chestnut wood is generally the most common, as it is more resistant. The characteristic of these structures is the wooden warp used to lay them. More particularly, a wooden floor is made of different elements arranged in a simple or complex pattern. In the first case, the floor is defined only by beams of around 30 X 30 cm (although this varies from region to region) that run from wall to wall, with wooden boards laid on top of them. The distance between the beams is generally small, to reduce flexional stress. In the most modest building, the boarding is used directly as flooring.

In the second case, with more complex floors, the floor is built using an initial structure of beams, onto which a second structure is laid, arranged in the same direction as the first, of smaller beams (usually 8x8 cm) on which the final boards are laid. In some regions, such as in Tuscany, the floorboard is replaced by terracotta slabs, laid on the smaller beams, which are spaced specifically according to the size of the slabs. A layer of concrete is then laid on these, and the flooring rests on this.

This is certainly the most common type of wooden structure used to make floors. But there are many variations, above all if we look at the different cultural realities of Italian building.

It is important to note that the links and connections between the wooden parts are made using nails, rods and/or dovetailing.

A “weak point” in this building system is the point where the wooden parts rest on the perimeter wall. This involves both the primary structure (beams) and the secondary smaller beams. More particularly, precisely due to the function it has, the primary beam receives the restorers’ greatest attention. In reality the point where the beam rests on the wall is a delicate one, as it is subject to rot. This requires specific interventions to isolate the “head” of the beam from the wall, without losing sight of the structural connection it has with the perimeter load-bearing structure. The most commonly adopted solution involves the creation of a separating element, also known as "sleeper", made of stone and/or brick, all sunk into the wall where the beam rests. This allows the beam to be isolated from the perimeter wall and at the same time aerates the weakest part, as with no air wood rots more easily.

The understanding of the construction of a wooden floor is fundamental for the operator who has to restore these structures, and a wide bibliography containing both scientific and technical information is available today.

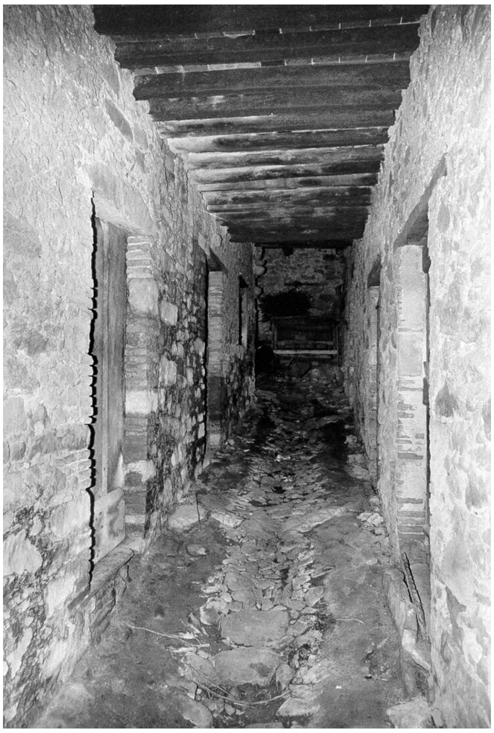
In the field of preservational restoration, wood is certainly one of the most delicate materials and the most difficult to explore without having a solid technological and scientific diagnostic background (above all if we do not want to use destructive techniques).

Therefore the first important step when dealing with a wooden structure is the examination of its state of preservation, using different techniques depending on the aims and the depth of understanding one wishes to achieve.

Having identified the materials and the state of preservation, we need to establish the most suitable solution for its restoration and/or replacement (in the most severe cases).

Therefore the solutions to be adopted in the case of restoring wooden structures need to be designed on a case-by-case basis, as there are many different variations and the applications cannot be generalised but need to be well-studied, to find out other previous solutions adopted and to evaluate the specific situation at hand. It may be necessary to identify a specific preservational solution for the problem presented using the support of specialist wood technicians.

Finally, the preservation solution adopted always needs to be tied to the aims of the project and not to the most simple and convenient manual solution, and furthermore drastic variations to the original static project should not be made, rather this should be respected and improved by repairing the weakest points. In the case of noble buildings, these wooden structures may have decorative elements on the points of rest (carved brackets), surface decorations and precious floorings. In these cases we also need to face the problem of working on such special structures to guarantee the preservation also of any finishings of recognised historical and artistic value.



STRUCTURAL BEHAVIOUR:

In static conditions, in the presence of only vertical loads, when built correctly with suitably sized sections and not too large spans, wooden floors are perfectly able to support the permanent and accidental loads for which they were designed. Problems may be found in these cases caused by the poor quality of the materials, degrading of the wood fibre, the use of wood cut out of season, or the degradation of the load-bearing layer through crushing or rotting.

In the event of seismic stress, wood floors have some negative effects on the whole building, above all if the connections between the main beams and the vertical walls are not made very carefully. Positive aspects are on the other hand the lightness of the material, which leads to a beneficial reduction in the structural mass and thus a reduction in the forces of inertia that play on the walls. The problem of low rigidity of the floor can sometimes be resolved by using a double layer of crossed slabs, nailed to the beams or smaller beams to reduce deformation, without greatly increasing the load.

USAGE PRECAUTIONS:

To work well, wooden floors need particular care, above all where they meet the walls; this is the point of greatest risk. In fact, floors do not only have to carry vertical loads, but also play a fundamental role in making the whole structure more rigid, thus increasing its stability, and it is precisely these points of connection that guarantee this kind of behaviour. Often the floor beams were simply fixed into the wall, but this kind of connection was shown to be insufficient, as it relies exclusively on friction, which gradually diminishes as the wood is seasoned. Connection defects can lead to two types of problem: the first is the fraying of the beams from the wall above the seismic stress, which leads to the total or partial collapse of the floor, which no longer contributes to the stability of the wall through the load it transmits to it, and the second is the punching of the wall below the stress, caused by the thrust of the beams against the wall.

Another highly important aspect is that of the beams and smaller beams that sometimes can greatly affect the behaviour of the walls, and this needs to be carefully evaluated at the time of construction.

Sometimes the floors are no longer horizontal, due to excessive deformation or collapse of the supports, and in these cases we should avoid increasing the load by thickening the foundation, and we need to evaluate the thrust produced by the beams on the wall structures.

When evaluating the suitability of an existing wooden floor, as seen we need to consider many factors, and should not forget also the condition of the beams themselves, which make up the skeleton of the floor. The first aspect to consider, after the general state of preservation, and in particular the condition of the internal wall supports, is the presence of cracks in the beam. These cracks may be horizontal or vertical, but are not dangerous providing they are not continuous or near the upper and lower profiles or near the beam supports, although can be a sign of structural weakness if they have developed transversally to the beam intrados. Finally, the beams should not have any section with a large number of knots, which means serious weakening in the points of traction where the material is forced to work diagonally or at right angles to the direction of the grain.

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