Vernacular architecture and “historical seismography”: an experience research

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ABSTRACT: The history of earthquakes 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. Our study based exclusively upon the analysis and the direct study of the architecture, aims to determine 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 northern Tuscany). The rich store of informations has allowed us to study different constructive typology, often determined by needs connected not only to the building tradition but also to the local seismic culture. 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 metodologies 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 THE VERNACULAR ARCHITECTURE

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” (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” (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 settings, 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” (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 1964 the 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” (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 prejudices 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”(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” (Langé & 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, holds all the studies done in the last ten years about the vernacular architecture. It is a vade mecum for all researchers! (Oliver 1997)

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, 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” (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”.

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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” (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” (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” (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” (Pierotti & 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.

2.1 The “Ecostorico” method

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" (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” (Pierotti 1997).

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” (Pierotti & 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 (Pierotti et al. 2003).

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 (Brandi 1995).

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 (Boscarino & Prescia 1987).
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 (Esposito 1996) 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.

3.1 The Recommendations (1986)

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 (Casiello 1990).

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 (Pane 1959).

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 (Mastrodicasa 1993).

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 preservation, 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 TWO TYPOLOGICAL EXAMPLES OF SEISMIC PREVENTION

4.1 Habitable buttressing arches and arcades

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.

4.1.1 Methodological and preservation 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.

4.1.2 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.

4.1.3 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.

4.2 Buttressing arches
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.

4.2.1 Methodological and preservation 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

Figure 3. The buttressing arch built with stones in the old town of Aiola.
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.

4.2.2 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.

4.2.3 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 “hump-backed”, i.e. with the impost 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 impost that drastically interrupt the structural continuity of the load bearing walls.

5 CONCLUSIONS

The architecture of the old settlements cannot always be translated in project rules. So, when the safety of the old buildings is under analysis, we usually generalize the interventions for their preservation and we overestimate the seismic risk.

Given that, the present work intends to give the bases over which to define a new methodology for the risk “knowledge” and the intervention which can allow to write new local seismic laws. They need to take into account the different types of buildings and their complexity that cannot always be reduced to simple and limited schemes of structural calculus.

REFERENCES