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Vernacular architecture and seismic risk. The case of Mugello in Tuscany

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Abstract
Vernacular architecture contemplates by its nature a variety of forms and construction techniques self-designed by the communities that inhabit it in response to specific needs. In Tuscany, an area with a medium-high seismic risk and a long seismic tradition such as Mugello, local building techniques can be identified with a common purpose: to improve the resistance of buildings. Using traditional techniques, the vernacular architecture of this area has seen the use of particular expedients as protective measures, in some cases adopted precisely in response to the movements and stresses to which buildings in this area may be subjected. In the past, the choice of appropriate materials together with traditional building systems has played in some cases a precise role in preserving architecture from damage due to telluric events, through the practice of ancient constructive knowledge. In the territory of analysis, the systems or constructive elements adopted in the examples of vernacular architecture would lead to the identification of an already present concept of safeguarding structures and their use would prove the awareness of local workers with respect to the specific static functions to be performed. The documentation on traditional construction systems inherent to the historical building therefore becomes a fundamental investigation tool for the knowledge of the building. In this sense, the analysis of the material and construction characteristics of the local architecture allows to have a definition of the methods adopted over time in relation to the context and to establish their compatibility with the material culture of the territory in the individual restoration interventions.

Keywords: *Seismic risk; Mugello; local construction techniques; safeguard.*

1. Introduction

In territories where the seismic phenomenon is not isolated, but is a repeated event of endemic character, the presence of a historical built fabric undoubtedly testifies to the permanence of the local population on the site, despite the serious destruction caused by the earthquake having led to awareness of a real risk. It follows, therefore, that following seismic events the affected communities have had to undertake phases of repair or even re-construction. The same local workers have had to adapt the forms of living and building techniques over time to the particular characteristics of the place where they are located, especially if it is characterised by uncomfortable and uncertain living conditions.[1] In the practice of restoration, the cognitive project allows the investigation of past building techniques and the identification of the stratifications of the building, revealing the changes that have taken place over time on the artefact, the construction phases and previous restorations. When the analysis involves artefacts built in particularly vulnerable areas such as those exposed to seismic risk, an additional source of

[1] For an in-depth study of the topic see Pierotti P., Ulivieri D. (2001), Guidoboni E.. (2016).

knowledge can be found in the reading of the building, capable of identifying techniques common in traditional architecture and adopted in the past to ensure greater resistance of the buildings. It is therefore necessary to consider a plurality of disciplines capable of offering valid considerations and contributions to a complete and integrated documentation of the building and to a critical reconstruction of the single piece of information with respect to the entire cognitive project. For this purpose, historical and archival documentation and direct reading of the building come to the rescue, as well as broader considerations regarding the context of reference.

Fig. 1. Reinforcement wall of a house in Scarperia (Source: Bordoni P., 2021)

If in the last decades integrated studies have led to the formulation of anti-seismic catalogues or to the definition of real local seismic cultures,[2] implying in the second case a recognised awareness of the seismic risk on the part of the local workers so as to transmit the technical solutions for prevention or repair from generation to generation, it seems appropriate to dwell on some elements that distinguished the work of master craftsmen in the past, for example the choice of materials and their use, and to investigate the forms of technical knowledge experienced following historical seismic events related to the cultural aspects that involved the same populations. Before precise technical standards were established for reconstruction work in seismic areas,[3] intervention and restoration work on earthquake-damaged artefacts took place through the practice of building knowledge and empirical experience of techniques. In areas such as Mugello, where earthquakes have occurred repeatedly and with considerable intensity, the historical heritage is undoubtedly evidence of the techniques "tested" over time by local workers, determining their actual static quality.

1.1 Historical seismic events in Mugello

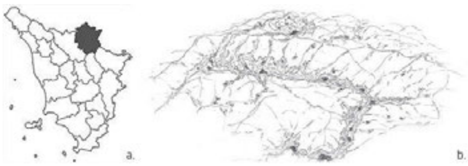

Fig. 2. a) Mugello area in Tuscany, b) Mugello territory. (Source: https://www.paesaggiotoscana.it/mugello)

[2] For more details on the concept of "local seismic culture" see Pierotti P., Ulivieri D. (2001). The study, conducted on the territories of Garfagnana and Lunigiana, allowed to identify traditional building techniques and particular "anti-seismic tecnhiques" in response to the seismic vulnerability of the territory. The question of the existence of local anti-seismic cultures is strongly debated within the scientific community. Emanuela Guidoboni, one of the leading experts in seismology, believes that the technical solutions experimented in the past by local workers were so discontinuous that it is not possible to affirm the spread of an anti-seismic culture, Guidoboni E. (2015). Further work was carried out in Tuscany by Arrighetti A., an integrated study that led to the formulation of a manual of archaeoseismology in architecture applied to the Mugello case study, Arrighetti A. (2015).

[3] In Italy, the first such measure was Royal Decree No 193 of 18 April 1909.

The Mugello territory lies on the border between Tuscany and Emilia Romagna. The Mugello valley occupies a special position, as this territory coincides with the hydrographic basin of the Sieve river, the most important tributary of the Arno river, and is surrounded by the Tuscan-Emilian Apennines (to the North), the Morello and Giovi mountain ranges (to the South), Mount Falterona (to the East) and the Calvana mountains (to the West).

Strongly linked to the history of Florence since the past, the Mugello territory has had a great concentration of settlements both because of its strategic position connecting it to the nearby city of Florence and because of the fertility of its soil. In fact, Mugello is distinguished by the presence of settlements dating back to medieval times,[4] of which there are still well-preserved architectural examples. In particular, buildings of worship, churches and Romanesque parish churches are important examples of traditional architecture dating back to the 12th and 13th centuries, or in some cases even before the year 1000. These buildings still retain their original identity, removed from the heavy urbanisation that the Mugello territory underwent during the last century, and allow the interpretation of the building that has undergone numerous interventions and reconstructions over time, largely due to the violent seismic events that occurred.

In Tuscany, Mugello is the only area after Garfagnana and Lunigiana to have recorded maximum MCS intensity degrees (IX and X). Over the centuries, this territory has seen a concentration of seismic events of considerable magnitude that have also caused serious destruction to local architecture. The main seismic events with epicentral area in Mugello and the reconstruction plans implemented following the damage recorded are analysed below.[5]

The 1542 earthquake is remembered as one of the most disastrous seismic events. The main tremor had destructive effects on private homes, religious buildings such as churches and convents, and public buildings in the towns involved. According to the sources, the centres most affected were Scarperia, where the vicar's palace and a tower of the city walls were damaged, and Borgo San Lorenzo, with serious damage to the walls, the parish church and the bell tower. Here the Palazzo del Podestà was still in ruins in the two years following the earthquake. The parish church of S. Gavino Adimari, whose reconstruction was carried out by the Medici family between 1500 and 1600, and the church of S. Agata, which suffered serious damage and collapses, together with the bell tower, suffered extensive damage.

Fig. 3. damage to the wall caused by the earthquake in 1542. Church of Sant'Agata, Mugello (Source: Bordoni, 2021).

[4] For the history and development of the Mugello territory see Romby C.G. coord. (1995); Romby. C.G. coord. (2006).

[5] The information on the effects of historical earthquakes in the Mugello region reported below was retrieved from the *Catalogue of Strong Earthquakes in Italy (461 BC-1997) and in the Mediterranean area (760 BC-1500)*, a project by Guidoboni E., Ferrari G., Mariotti D., Comastri A., Tarabusi G., Sgattoni G., Valensise G. (2018) and Guidoboni E., Ferrari G., Tarabusi G., Sgattoni G., Comastri A., Mariotti D., Ciuccarelli C., Bianchi M.G., Valensise G. (2019), historical sources from the State Archives of Florence, some of which can be consulted from online catalogues, and from more recent publications that have brought to light important documents related to the post-seismic damages recorded. These include Bellandi F., Rhodes D. E. (1987) and Brunori Cianti L. coord. (2011), Arrighetti A. (2015).

Evidence of reconstructions after the 1542 earthquake can be found for the convent of Bosco ai Frati, thanks to the *Relazione* of Frà Giuliano, which attests numerous expenses for repairs to the damage caused by the earthquake. In this case the bell tower was badly damaged, as was the vault of the convent church, which was repaired by filling in the cracks.[6] Notes of debt can be found for the convent of S. Barnaba, for which masonry work and the covering of the roofs of the cloister were carried out.[7]

Again in 1597, Borgo San Lorenzo was struck by an earthquake with an intensity of VII MCS. Here the earthquake damaged a group of houses, for which permission was sought to cut down oak trees and use the timber to restore the damaged buildings. Again in 1611 an earthquake caused serious damage in Scarperia and Cerliano, where serious damage to buildings was reported. At the beginning of the seventeenth century, following the damage caused by successive earthquakes in the previous century, scarp walls and barbicans were built to reinforce the body of the Palazzo dei Vicari in Scarperia.[8]

Mugello continued to record seismic events of medium intensity (MCS grade above 6) in the 13th century (1762) and during the 19th century (1835, 1843, 1864) until the 1919 earthquake remembered as the event of maximum intensity, reaching the X MCS grade. Once again, the earthquake caused severe damage to the towns of Vicchio, Borgo San Lorenzo, Scarperia, Barberino di Mugello and San Piero a Sieve, with widespread collapse of most of the buildings. The most serious damage occurred in Borgo San Lorenzo and its hamlets: religious buildings and public buildings were seriously damaged, and many houses collapsed, making part of the building stock uninhabitable.

2. The perception of earthquakes in history and socio-cultural aspects. Some considerations

Certainly the period in which the greatest number of seismic events occurred in Mugello was the period between the 16th and 17th centuries, with rather frequent seismic activity of medium-high intensity.

In order to understand how the earthquake was perceived by the society of the time, it is interesting to investigate the cultural aspects linked to it. This does not stop at a simple historical record, but is an extremely useful source for understanding the implications of this also with regard to the (technical) knowledge of the seismic phenomenon widespread at the time, hence the remedies consciously chosen as a response to the earthquake.

The historical sources relating to the 1542 earthquake document that a late-medieval belief that seismic motion was generated by the pressure of underground winds was still deeply rooted in Mugello.[9]

A letter sent by Cosimo I de' Medici to Giovanni Bandini on 13 June 1542[10] states that, in line with this theory, nearby Florence would have suffered very little damage thanks to the presence of the River Arno. On the other hand, Mugello, with no wells, lakes or watercourses, could not have 'exhaled' the force of the earthquake. In fact, at the beginning of the Modern Age, it was believed that wells near buildings were the remedy to defend against earthquake destruction.

If we then consider the administrative and fiscal management that followed earthquake destruction, based on the exemption of certain taxes

[6] Archivio di Stato di Firenze, Manoscritti, 167, Giuliano dalla Cavallina, Relazione sui danni al Convento del Bosco ai Frati causati dal terremoto del 13 giugno 1542, sec.XVI, copia sec.XVIII. XVIII sec.

[7] Archivio di Stato di Firenze, Conventi soppressi, S.Barnaba, filza 252, n.24, Elenco di spese sostenute per riparare i danni causati dal terremoto del 13 giugno 1542. XVI sec.

[8] Arrighetti A. (2015).

[9] This belief is reported in numerous historical sources. See Archivio di Stato di Firenze. Mediceo del principato. filza 4299; Ammirato S., (1600- 1641); Adriani G. (1583); and in a pamphlet on the 1542 earthquake in Bellandi F., Rhodes D.E. (1987).

[10] Archivio di Stato di Firenze, Mediceo del principato, filza 4299, Lettera di Cosimo I de' Medici a Giovanni Bandini, Firenze 13 giugno 1542. 1542.

from which only the wealthiest citizens could benefit, we can see that only a few properties damaged by the earthquake could benefit from specialised and careful repair work. This mainly concerned palaces and churches, while common dwellings, which often saw hasty restoration using poorer techniques and materials, were excluded.[11] It therefore seems difficult to claim the existence of a seismic culture in this area.

Yet the sixteenth century was the turning point: in 1571 the first seismic-resistant house was designed. Following the disastrous earthquake in Ferrara in 1570, Pirro Ligorio had drawn up a plan for an earthquake-resistant house. Ligorio's concept of the rule of art emphasised the importance of good quality construction to ensure greater resistance.[12] Linked to this concept were the construction principles and materials suitable for a resistant building. Ligorio's house was solid and cohesive, built on a regular plane, with well-buttressed walls and reinforced at the most vulnerable points: the corners, the door and window openings, the floors.

2.1 Seismic resistant techniques and the vernacular architecture in Mugello

An analysis of the vernacular architecture of Borgo San Lorenzo, Scarperia, San Piero a Sieve, Sant'Agata, Vicchio, Luco di Mugello and Barberino del Mugello, which have suffered the most damage from historic earthquakes, shows that various construction techniques have been adopted to make these elements more resistant.

For example, the reinforcement of cantonal walls, a concept handed down since ancient times, is a widespread technique in traditional Mugello architecture. In addition to the insertion of pietra serena chains in the cornerstones of the Pieve di Sant'Agata for greater resistance, reported by Arrighetti in his study of archaeoseismology in Mugello, the linking of cornerstones is a characteristic of traditional architecture. Ancient wall towers and parish churches, but also dwellings that retain their original configuration, have well-anchored and reinforced cornerstones.

Fig. 4. Well-anchored cornerstones. Tower of the ancient walls in Scarperia (Source: Bordoni., 2021).

With regard to the openings, it can be seen that the "anomalies" of the historical building reveal interventions carried out after the construction phase. An example of this are the restorations carried out on the portals of the churches of S. Gavino Adimari and Sant'Agata, whose repairs next to the jambs were carried out using brick, a material already in use in Mugello since the 13th century.[13]

A further interesting element concerns the exhaust arches, which are also often made of brick above the openings, in order to lighten the task of the elements below. The exhaust arch allows

[11] See Guidoboni E. (2015). The archive documents consulted would lead to confirm this trend in Mugello as well.

[12] Guidoboni E. (2015).

[13] See Arrighetti A. (2014).

to protect the stone windows and portals lintels below, which would otherwise be subject to excessive load and susceptible to shear failure.

They are in fact one of the recurring elements in Mugello. A further observation can be made regarding the configuration of the ashlars of the portal arches. The greater the number of wedges in an arch and the greater their contact area, the more energy the structure will be able to dissipate.[14] In the event of an earthquake, the protection of a built structure often depends on its ability to dissipate the energy received. An example of this is the portal of Palazzo dei Vicari in Scarperia.

Fig. 5. Portal of Palazzo dei Vicari in Scarperia (Source: Bordoni, 2021)

Moreover, given the fragility of the stone lintel, another expedient used could be to increase the height at the centre of the span, the point where the greatest deformations occur. Given the awareness of the vulnerability of the openings, in addition to the solutions adopted to dissipate the forces above portals and windows, a trick often used following earthquakes was to plug the openings. This technique in fact often had a static approach, in addition to distributional needs. The plugging is sometimes made with materials similar to those of the facing (Pieve di S. Gavino Adimari), more often brick is used, a material that proves particularly suitable for this use.

Fig. 6. Exhaust arch. Church of S. Gavino Adimari (Source: Bordoni, 2021)

However, there are many solutions that were already known in the classical world to give greater resistance to buildings, which were also used in Mugello.

Even though, as we have seen, scientific thought was not yet consolidated between the 16th and 17th centuries, there is evidence of post-seismic interventions in Mugello that precise expedients were used to defend against seismic actions.

On the other hand, systems for reinforcing buildings had been known since antiquity and tested in the classical age. The concept of stability was firmly established in Vitruvius' firmitas. In the architecture of the Roman world, precise techniques were developed to make buildings less vulnerable.[15] Some building techniques involved the use of wooden elements to be inserted into the masonry (e.g. *opus galicum* and *opus craticium*), recognising the remarkable resistant properties of wood. But other expedients have been tried since the ancient world. The use of chains, for example, a consolidation system used against the tendency of masonry structures to overturn, is present in numerous examples of historical architecture and widespread in many areas of Italy. Even in the architecture of Mugello there are numerous examples of the use of this remedy. In this regard, historical documentation is particularly interesting.

[14] See static observations for each architectural element of the buildings in Ferrigni F., Della Pietra A., Sorrentino M. C. (2017), Pierotti P. (2003), Groupe APS (2002).

[15] See Arrighetti A, Minutoli G. (2018).

Among the restorations carried out in the first decades of the 17th century, the *Ricordi* - Memories - of the parish priest Tolomeo Nozzolini attest to the use of punctual and targeted workmanship.

Here we report on the work carried out for the Pieve di S. Agata, which had already been badly damaged by the 1542 earthquake. In the text, it emerges how the choice of the works carried out was aimed at strengthening the damaged structures. In particular, Nozzolini indicates the decision to make new chains well connected to the existing ones to protect the vault of a room in the church of S. Agata, "essendo questo paese molto difettoso di tremuoti".[16]

This remark by the parish priest is extremely interesting. His statement testifies to the desire to increase the resistance of the building vulnerable to the earthquake and the awareness of the interventions needed to prevent further damage. The same text shows the work carried out for the church tower, here two oak timbers are again used for the chains at the impost of the window arches.[17]

On the other hand, the chains were made both of iron and of blocks of local stone, pietra serena or alberese. Examples are those used in the Convent of Bosco ai Frati or in the parish church of San Gavino Adimari. There is also evidence of wooden chains, such as those used inside the bell tower of the Pieve di San Lorenzo in Borgo San Lorenzo.[18] Another element considered of interest and used in Mugello is the presence of scarp walls or barbicans. The best known example is certainly the Palazzo del Vicario in Scarperia, but numerous dwellings present this type of reinforcement.

3. Conclusions

To affirm the existence of a true seismic culture is a complex operation. Such a concept should include a series of considerations with respect to the whole territory and the communities involved, to the perception of the earthquake and the awareness of the risks of this phenomenon, then to the verification of an effective development of techniques handed down from generation to generation in response to the actions of the earthquake.[19]

As seen in the past, the explanations of the earthquake were linked to popular beliefs far from recognizing it as a natural phenomenon, and issues related to administration and post-seismic management did not make possible a cohesive and homogeneous repair intervention to all the existing buildings. Therefore, some solutions aimed at reinforcing the building are found on buildings with important commissions, such as churches and palaces. For this territory there could be a further difficulty of analysis: the urbanisation of the last century has often affected the traditional architecture, changing its original aspect and often plastering the surfaces so that it is more difficult to read the constructive characters of the place.

What can be said, however, is that Mugello has an important cultural heritage, characterised by churches, Romanesque parish churches and ancient medieval buildings that correspond to the vernacular architecture that developed in the territory from the first settlements, some examples of which date back to before the year 1000. This means that throughout its long history, the traditional architecture of Mugello, due to its particular position and the vulnerability of the buildings, has adapted the forms and techniques of building to its own particular needs. Evidence of this can be found in the historical sources documenting restoration work following historic earthquakes. What was in fact well known in the

[16] Translation of the text: “since this town is very defective in tremors”. The expense register of the parish priest Tolomeo Nozzolini is reported in Lia Brunori Cianti coord. (2011).

[17] The latter reference can be found in Arrighetti A. (2015)

[18] See Guidoboni E. (2015), Arrighetti A. (2015).

[19] See the studies by Pierotti P., Ulivieri D. (2001); Arrighetti A. (2015).

past was the concept of building to the highest standards, the use of local materials and the practice of technical knowledge "tested" over time meant good building. After all, Vitruvius' *firmitas*, solidity in statics and materials, accompanied by *venustas* and *utilitas* were principles known since antiquity and became a new foundation in the Modern Age.

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