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"A MULTIDISCIPLINARY APPROACH TO DOCUMENT AND ANALYZE SEISMIC PROTECTION TECHNIQUES IN MUGELLO FROM THE MIDDLE AGES TO EARLY MODERN TIME"

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ABSTRACT
The contribution will outline a methodological program designed with the purpose of offering an innovative and multidisciplinary analysis of seismic protection techniques in historical architecture of Mugello, a medium–high risk seismic on the Apennine mountain range between Tuscany and Emilia Romagna. Although the existence of specific expedients used for seismic prevention is an accepted topic by the scientific community, many a time their recognition is dependent on the experience of researchers dealing with analysis. In fact, such measures, in many cases, are used for structural purpose allowing simultaneously protection from movements caused by earthquakes. How can we document and periodize these type of techniques and recognize an "anti–seismic" conception? An answer to this may only be found through a careful analysis complementing a deep knowledge of the building methods of the area under study, that can allow the breaking up and dating of the single construction and destruction actions present in a building, leading to the identification of some "uncommon" elements in respect to traditional construction techniques, being able to interpret a specific function. It is thus only through the analysis of this complex mechanism that is established over time, with the reading of the instability of macro–elements and the definition of the construction history of the building, that integrates a subdivision of construction typology with a stratigraphic decomposition of the artefact, that identification of "anomalies" within the building becomes possible. Applying this research methodology to a building, or even better to a whole area, allows the identification and dating of the potential presence of "safeguards" related to earthquakes, that is all architectural elements of various form, nature, raw material, etc., put into use during or after the construction of a building to mitigate, repair or oppose the effect of terrestrial movement.

1. INTRODUCTION

Old buildings maintain evidence of seismic activity becoming material proof of both the structural deficiencies of the building and the anti–seismic safeguards used over centuries to respond to seismic solicitation. Safeguards gradually put into place need an adequate seismic test; something which often happens at a distance of many years and when successive generations would have lost vision of the construction technique which was considered a solution to seismic activity.

Historians like Pliny the old, Pliny the young, Seneca, etc. narrated the effects of various earthquakes without adding considerations deriving from analysis of solutions to seismic activity on buildings and groups of buildings. Over centuries the Vitruvian principles of f*irmitas, utilita, venustas* became a point of reference for constructors who applied them unaware.

The Romans had understood how in both static and seismic fields the uniform resistance of walling without dividing the wall into sections (internal façade, nucleus and external façade) was one of the indispensable elements to guarantee a "forever lasting" building [Giuliani, 2011, 26]. They had understood that this was achievable not only thanks to the quality of the mortar used but also by inserting wooden connections placed perpendicularly to the facades (*opus gallicum*) and/or through the creation of homogeneous and well set horizontal courses (*opus vittatum*). The wooden element, which characterizes the *opus gallicum*, has to be considered the ancestor of our metal binding, today used to reconnect wall facades. Over centuries Gallic wooden elements were replaced and/or integrated with column drums (re–used) to improve mechanical characteristics, avoiding the effects of wood deterioration. This construction technique was used in various city walls, including that of Jerusalem where in the Western part the drums protrude very much (Minutoli, 2017, 42–43); whereas in the Eastern part, close to the door to Damascus, they become a decorative element similar to the city wall of the citadel of Aleppo in Siria (Figures 1–4).

Masonry with horizontal brick or stone courses, also known as wall chains, is found in all epochs becoming also a distinct element of a certain type of industrial building at the end of the 1800s, beginning 1900s

The Marquees of Pombal (from which pombalina is derived), Home Affairs Minister of Portugal, in the months following the 1st November earthquake ordered a decree in which he imposed that the reconstruction of the city of Lisbon had to take place using full wooden frames as primary load bearing structures supported by traditional walling. This was a technological innovation adopted by the Bourbon Kingdom following the 1783 earthquake in Calabria; where in "The Instructions on the method to be used in the reconstruction of the wrecked villages" it is specified how the walling must be constituted of «a large beam framework[...] tied with other transversal beams», defined *casa baraccata* [Aricò and Milella, 1984]. Reference to the construction technique is found in the archeological field in various buildings from the Roman period, also if applied to upper elevations and partitions, never as a general framework for the building, and is known as *opus craticium* [Stiros, 1995; Paradiso, M., Galassi S., Borri, A., and Sinicropi, D., 2013]. With the introduction of reinforced concrete, we begin to find "frames of reinforced concrete" within mixed supporting structures (a technique known as confined masonry). This appears to be used following the earthquakes of the beginning 1900s, especially in Messina and Reggio Calabria; this technique homogenizes deck walls and contains horizontal thrusts.

Another technique of remarkable characteristics in response to seismic activity is the *opus reticulatum*; born as "centre" of a nucleus in concrete, it is easily perceived how the composite "mesh" becomes a distribution point for vertical loads and also horizontal ones, a construction technique reinterpreted in the medieval period as herringbone, achieved using rough pebbles (almost always from rivers) or using brick [Cangi, 2014].

FIGURE 1. Patti (Me), close to the Cathedral: wall with brick layers from the Norman period.

FIGURE 2. Messina, Santa Maria della Valle: wall with red brick layers from the Norman period.

Another well–understood and adequately passed–down concept in the classical world is that in which the importance of first anchoring between cantonals is highlighted. «The stone thrown by constructors has become a stoned angle» [Salmi 117, 22. Matteo 21, 42] a known phrase present in different parts of the Bible provides the synthesis of how culturally well–known the concept is and removed from technical lexis becomes a paraphrase of the importance of Christ.

FIGURE 3. Jerusalem, binding stones created with re–used column drums.

Other contrasting elements to seismic solicitation are buttresses, chaining, extrados chains of conglomerate vaults, rampant and contrasting arches. These elements in most cases come to be with the building in response to "planned" oblique thrusts; and in as many other cases they are elements for containment created further to movement caused by inclined thrusts and/or seismic solicitation [Giuliani, 2011; Scibilia, 2015). These elements create continuity through all epochs and they may easily be found in archeological areas, but also within densely populated urban fabric. Contrasting arches provide an interesting connecting system that transforms many urban centres into "paper castles" in which single buildings feel and utilise the neighbouring thrust. As confirmed by Cairoli Fulvio Giuliani on the insertion of chains in the extrados of vaults [Giuliani, 2011] and not at the height of the voussoirs, it cannot be considered an error. In fact, this reconnecting element could be either a contrasting element to the inverse pendulum effect, as sustained by Giuliani, or as an element of re–equilibrium of the thrusts of the elements above. It is interesting to note how the presence and amplitude of the anchor plate of the chains is directly proportional to the mechanical characteristics of the wall on which they are found.

The empirical knowledge that walls do not resist to traction but only compression pushed constructors in the past to try to verticalise as much as possible the horizontal and oblique thrusts creating those systems of connection and reducing load that favour verticalisation. In this context beyond buttresses, rampant and contrasting arches, Gothic arches were created whereby horizontal thrust is substantially reduced thus minimizing the danger of walls and springers falling (Figures 5–10).

FIGURE 4. Jerusalem, entrance to Damascus, circular decorative elements influenced by places in the Western area of the city.

FIGURE 5. Pisa, buttress to contain the falling over of a part of city wall.

FIGURE 6. Ficarra, Busacca Palace, the buttresses at the edges.

FIGURE 7. San Pio (Aq), wooden chain and anchor–plate.

FIGURE 8. Roggiano Gravina (Cz), anchor–plates.

FIGURE 9. Acciano (Aq), Bracing arches.

FIGURE 10. Jerusalem, Rampant arches to counteract the vault thrust.

To close off the short introduction to walls: mixed structures made from rough rubble and large beds of mortar mixed with pieces of brick. This technique has always been considered little reliable both in a static and seismic scenario. However, it may be possible to read it afresh if one evaluates it in a dynamic scenario. These walls, very elastic thanks to the wide mortar beds, in the case of seismic activity respond with lesions happening along the mortar bed mixed with reused and waste brick. In this way the wall that is effected by the seismic activity moves and lesions take place without fracturing the stone elements, creating canals dissipating the seismic forces towards the mortar beds which are then refilled with pottery and brick to re–unify the structure. This technique, present in many areas in the Centre–South of Italy [Scibilia, 2016; Cfr. Nobile and Scibilia 2016], if inserted between adequate cantonals and with architrave systems for doors and windows, could be interpreted as the elastic response to the problem of seismic oscillations, a concept distant from the Vitruvian *firmitas*.

A probable evolution of this construction technique is the case where wooden elements are drowned in the walling in parallel, *radiciamenti*, on the facings whereby besides creating uniform horizontal planes, true flat planes are created with which it is tried "to contain" traction [Viollet–le–Duc, 1854.; Carocci, 2016; Ghisetti Giavarina, 2016] (Figures 11–14).

It is also interesting the use during the Baroque period of pointed vaults in seismic areas as shown by a document where it is suggested to create slightly Gothic cambers to improve the vault's response to seismic activity. The document is about the construction of the Church of Archimandrato in Messina desingned by Giovan Antonio Ponzello (Genovese engineer) and dated 1649 «Damusi, Crociarizzi, Archi, Volti, tutti siano bene informati di legniame, e giustam(en)te fatti, conforme gli serà ordinato dall'Ingeg(ne)ro. Cioè li Da – musi, Crociarizzi, debbiano essere fatti di mattoni ben cotti, intersiati di chiappe leggie per in sino al tergo, e grossi nella croppa un palmo alme – no, con dovere fare la forma pendente verso il muro, e non piana nel mez – zo, acciochè d(et)ti Damusi, e Crocciarizzi e dove anderàno lunette, restino con la pendenza verso il muro, restando poi di questo modo ogni cosa sicurissima [...] la quale opera si doverà fare con buona calce, graste, mattoni ben cotti, buona Arena, Chiappe leggie, e con ogni squisita diligenza e mastria é conforme gli serà ordinato dall'Ingeg(ne)ro» [Minutoli, 2016]. Knowledge of con–

FIGURE 11. Gioiosa Guardia (Me), lodging for wooden beams drowned in the masonry.

FIGURE 12. Gioiosa Guardia (Me), wooden bean drowned in the masonry.

FIGURE 13. Naso (Me), masonry palimpsest with earthenware used to fill lesions

FIGURE 14. Ficarra (Me), masonry palimpsest with earthenware used to fill lesions.

struction of the past in the construction of vaults is visible also in the change of materials used for the systems constructed at Maniace Castle in Siracusa where in the voussoirs and ribs a compact clay is used, whereas internally veils of extremely porous and light volcanic stone. Using the same criteria, all cases in which the vault abutments are filled with earthenware (pots and tubes) or with a conglomerate made of materials such as pumice and volcanic stone, should be analyzed.

All these techniques, expedients and construction elements have over centuries been used to respond to seismic solicitation becoming patrimony, mostly unawares, of generations of workers who time after time applied them, modifying as necessary to render them applicable in different settings. Although it is complex to recognize these safeguards, it is even more difficult to comprehend a real development on a territorial level within a chronological context. In the following paragraph a case study which aims at organizing some expedients touched upon in this first part and utilized in a specific context which is in the North of Tuscany between the Middle Ages and Early Modern period, is presented. (Figure 15).

2. THE PROJECT: CHRONOLOGY AND FUNCTION OF SEISMIC PROTECTION TECHNIQUES IN MUGELLO

2.1 METHODOLOGY OF THE RESEARCH

Although the existence of specific expedients used for seismic prevention is an accepted topic by the scientific community, many a time their recognition is dependent on the experience of researchers dealing with analysis. In fact, such measures, in many cases, are used for structural purpose allowing simultaneously protection from movements caused by earthquakes. How can we document and periodize these type of techniques and recognize an "anti–seismic" conception? An answer to this may only be found through a careful analysis complementing a deep knowledge of the building methods of the area under study, that can allow the breaking up and dating of the single construction and destruction actions present in a building, leading to the identification of some "uncommon" elements in respect to traditional construction techniques, being able to interpret a specific

FIGURE 15. Siracuse, Maniace Castle, note how veils were made respecting the physical–mechanical charcteristics of the materials used.

function. It is thus only through the analysis of this complex mechanism that is established over time, with the reading of the instability of macro–elements and the definition of the construction history of the building, that integrates a subdivision of construction typology with a stratigraphic decomposition of the artefact, that identification of "anomalies" within the building becomes possible. It is a process which allows the addition of qualitative and quantitative data to the history of construction and building mechanics under study, whereby some transformation processes are compared to precise destructive phenomena, at times dating them, and to successive consolidation systems and restorations which took place after earthquakes or as a preventive measure (Arrighetti, 2018). Applying this research methodology to a building, or even better to a whole area, allows the identification and dating of the potential presence of "safeguards" related to earthquakes, that is all architectural elements of various form, nature, raw material, etc., put into use during or after the construction of a building to mitigate, repair or oppose the effect of terrestrial movement. These particular techniques, together with traditional construction systems (stonework, openings, horizontal structures, coverings, etc.), don't only appear as objective proof of the construction culture of a determined territory, but primarily have held and still hold a precise structural role.

2.2 THE CONTEXT OF STUDY

Mugello is a medium–high risk seismic area found on the Apennine mountain range between Tuscany and Emilia Romagna (Figure 16). The territory is characterized by a nourished presence of long lasting settlements (the main attestations are chronologically positioned in the mid–centuries of the Middle Ages and show a continued presence to–date) with well–preserved historical buildings, mainly religious structures. The basis of seismological data and catalogues [Guidoboni et al., 2018; Locati et al. 2016; Rovida et al., 2016] allow the outlining of a seismic history in the Mugello municipalities, first occurring in 1542, with a high intensity earthquake (IX on the MCS), known trough a rich presence of historical sources. In the following centuries, medium–high intensity earthquakes seem to have manifested themselves regularly (VII to IX in intensity) and with their epicenters localized between Scarperia and Borgo San Lorenzo. The most important earthquake was registered in June 1919, with an estimated intensity of X on the MCS.

2.3 THE PROJECT

The context became field of study under the project "Archeology of Architecture and Seismic Risk in Mugello" between November 2010 and March 2014; a multi–year research project focusing on the experimentation of the archeological analysis process as a form of knowledge, prevention and safeguard of historical buildings present in a seismic risk area. The focus area under study was within the area which historical sources reported as having been effected by significant seismic activity relative to the June 1542 earthquake. The territory, as indicated in the previous

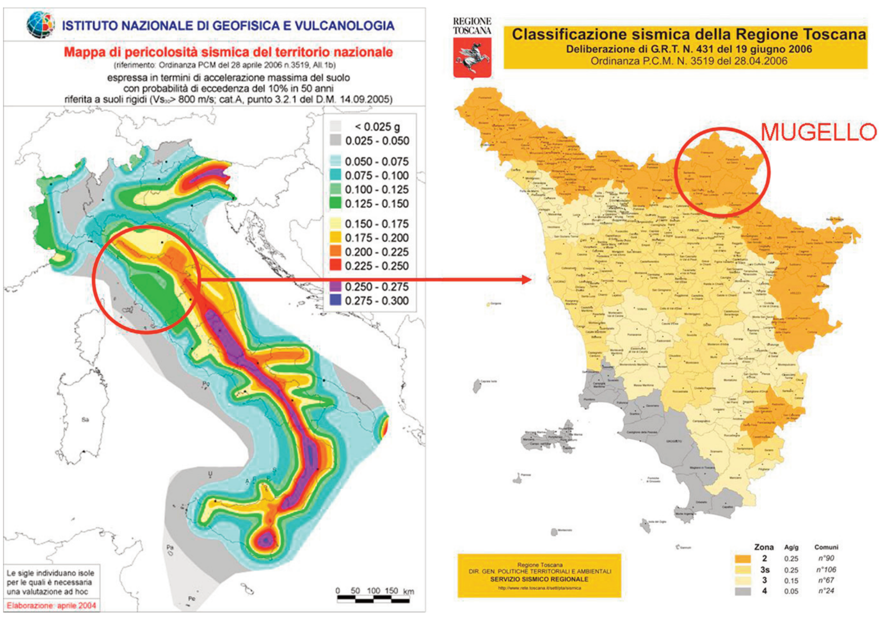

FIGURE 16. Mugello territory (FI).

paragraph, is characterized by medium–high historical seismic activity, well–documented by written sources and the buildings present on the same territory. The latter, in fact, thanks to their exceptional state of conservation, offer the possibility to hold detailed archeological analysis on the structural material where all, or at least a large part of the terrestrial activity, taken place over time, is evident. Hand–in–hand with the actual architectural structures, a good amount of published, parish archives sources, library and Florence State Archives sources are present. The possibility of having available data, both through the analysis of buildings and other sources, allows the planning of an archaeo–seismological analysis of the territory through a project aiming at reconstructing the construction and seismic history of individual architectural Complexes and also in general within the context of study (Arrighetti, 2015).

The project was characterized by the running of an initial Cognitive Project (Parenti, 2002) through the application of a methodology based on an evaluation, preventive anamnesis of the buildings, for the correct levels of in–depth analysis of the same study (fig.17). Thus the stratigraphic readings, dependent on obtaining precise results, based themselves on the determination of the Construction Phases, focusing on the identification, registration and characterization of all mechanisms potentially activated by seismic phenomena and protection techniques used to prevent, repair or mitigate the effects of earthquakes in the long term. A catalogue was created, through this methodology, listing the possible construction and/or destruction actions related to terrestrial phenomena, placing them chronologically, and relating them to, when possible, the data emerging from indirect sources. This way an absolute chronology for some actions was elaborated, substantially improving the interpretation of data obtained from the integration of analysis used in different contexts. The result was therefore the development of a construction and seismic history in Mugello, and once the data from single case studies was integrated, of the whole territory. The periodized cataloguing of the restoration interventions observed in the buildings played an important role. Below, the techniques for seismic protection which emerged during the analysis of the buildings, and the period in which they were used, may be found.

2.4 THE CHRONO-TYPOLOGICAL ATLAS OF THE "ANTI-SEISMIC SAFEGUARDS"

The Chrono–typological Atlas of the "anti–seismic safeguards" is an instrument characterized by typological groups of elements used to prevent, repair or mitigate seismic damage, inserted in a time line as reference. This instrument is obtained from the analysis of the buildings via a comparison between the elements which show common characteristics, creating typologies and allowing dating, obtained from the relationship between the definite chronology and those related to implementation in the buildings. A periodized abacus of the techniques for seismic protection observed on individual buildings was achieved through this methodology:

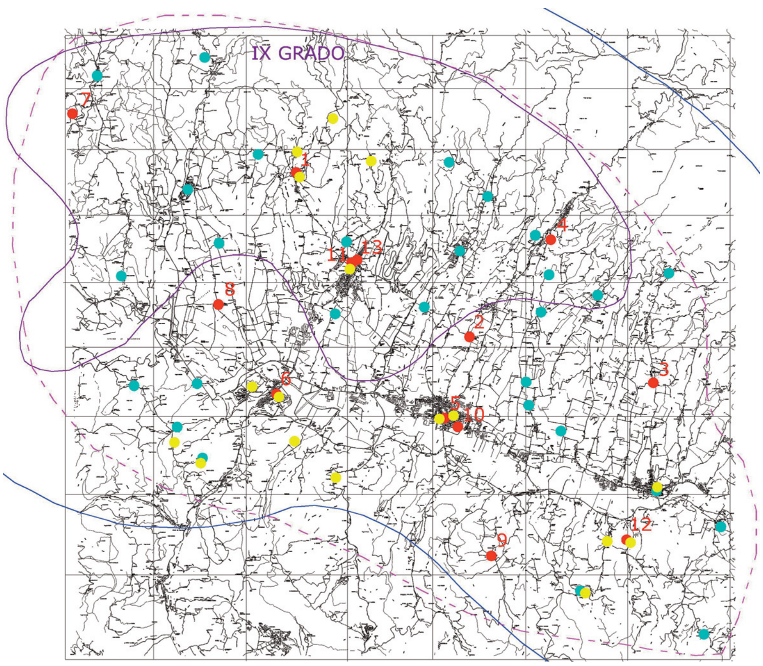

FIGURE 17. Regional technical map indicating the borders of the context of study (hatching) and the identified sites during archaeological survey.

1) CHAINS:

– PIETRA SERENA SANDSTONE: 1263 – post 1611 (7 attestations);

– WOOD: ant. 1542 – 1611 (3 attestations);

– PIETRA ALBERESE LIMESTONE: from 1542 (2 attestations);

– IRON: pre 1542 – post 1919 (14 attestations).

2) BUTTRESSES: pre 1542 – 1611 (3 attestations).

3) CLADDING OF SPACES (OPENINGS, SCAFFOLDING HOLES AND LODGING FOR BEAMS): from 1263 (15 attestations).

4) ELIMINATION OF PORTICOS: 1606 – mid XVIII century (4 attestations).

5) CONSTRUCTION OF PILLARS IN THE NAVES: pre XVII century (2 attestations).

6) WOODEN REINFORCEMENT RINGS AT THE TOP OF THE BELFRY: 1542 – 1611 (2 attestations).

The abacus provided the base for achieving the Chrono–typological Atlas of "anti–seismic safeguards" in Mugello, where the principal evidence observed in the context of study, providing quite a clear picture of chronology and typology of the characteristics of use of the various expedients in the long term, were inserted, typified and periodized (Figure 18).

Among the elements inserted in the atlas, chains are quantitatively the most represented proof for the reconstruction of the Medieval typological evolution to–date with the specific expedient of a seismic protection function within the know–how of workers in Mugello. Chains of different material typology (wood, stone, iron) are in fact used in all the buildings which were analyzed to mitigate the effects of earthquakes (mainly out of plumb line and bulging) and prevent collapse (Figures 19–21). It is a device very much in use on all the Italian territory in different periods, in most cases, further to damage caused by seismic activity or other problems. A particular use of chaining is evident in the wooden "radiciamenti", elements horizontally inserted within the walls during building. In Mugello, on a total of 26 attestations of chains in heterogeneous material, of which 7 cannot be precisely dated, 11 show restoration interventions to buildings following the 1542 to 1611 seismic period. Only in one case, that of the Church of Sant'Agata, the use of two wooden chains inserted during the building of the walls as a preventive system to confer stability and greater elasticity to the bell cell of the church, is documented. With regards to the different materials which were utilized, the change from wood and Pietra Serena Stone to limestone and iron is probably attributable to factors related to the characteristics of the context of study and the period of use rather than to a chemical–physical prime matter characteristic [Arrighetti, 2016].

Another Mugello characteristic that testifies the presence of "anti–seismic safeguards" in the construction culture of the local workers, is the use of wooden bracing at the top of bell towers. Such safeguards are documented between 1542 and 1611 through written proof in relation to the belfry of the Parish Church of Scarperia, and through an internal study of the walls of the

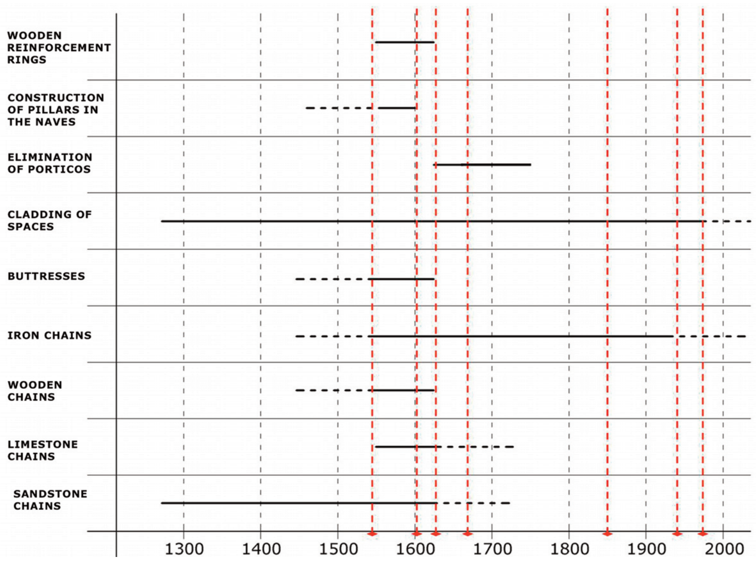

FIGURE 18. Chrono–typological Atlas of the "anti–seismic safeguard" of Mugello. On the "x" axis the referred to chronology is indicated, on the "y" the analysed elements. Within the graph: the horizontal lines determine the chronological periods of the use of safeguards (the continuous lines corresponds with a sure chronological attestation of the safeguards, the dashed line carries the testimony of a relative chronology); the vertical dashed lines correspond with the seismic events in the history of Mugello.

belfry of the Church of Borgo San Lorenzo. These ele– ments, detaching the various fronts, gave stability to the structure while creating a certain elasticity in relation to seismic movements. As far as the other expedients, the buttresses show a static function besides a seismic one, so their construction on pre–existing walls wanting to mitigate seismic effects is only documented in written sources on three occasions related to the 1542, 1597 and 1611 post–seismic period. The opening and obstruction of empty spaces over time (openings, scaffolding holes and housing for beams) present on the buildings, and particularly on the bell towers, represent one of the most distinctive elements of the wish to mitigate or prevent the effects of future earthquakes. Interventions are mainly evidenced following severe damage, especially in extended cracking patterns, with the clear desire to give greater solidity to elements which were very sensitive to terrestrial movement, as are belfries. The 15 attestations related to the use of this prevention/repair system show a lengthened period of use starting from 1263 and end– ing with the last restorations after the 1960 earthquake. The elimination of porticos from the facades and side walls of religious structures, although representing a widespread phenomenon in Florentine architecture and not only, within the studied area, thanks also to a com– parison with written sources, represents a happening particularly during the XVII–XVIII century, strictly re– lated with the wish to prevent damage related to seis– mic effects on buildings. From the four attestations which were encountered in the analysis of the context, the church of Sant'Agata allows us to better understand the phenomenon through the testimonies of its parish– ioners. Built in the 1400s, porticos resulted as elements which caused major problems to the effected walls fur– ther to seismic movements, even if well tied to the building. The greater majority thus survived for about three centuries with more or less evident reconstruction over the 1542–1611 seismic period. A last device found in Mugello, but also present in many religious structures in Tuscany (for example the church of Sant'Antonino a Socana in Casentino), is the building of pilasters in the naves substituting the previously existing columns. Through the structures under analysis, this is a phe– nomenon which seems to be centered in the period be–

FIGURE 19. Iron chains inserted in the external stonework of the Vicari Palace in Scarperia (FI).

FIGURE 20. Wooden chain inserted in an internal corner of the belfry of the Church of San Lorenzo in Borgo San Lorenzo (FI).

FIGURE 21. Limestone chains inserted in some internal stonework of the belfry of the Church of San Lorenzo in Borgo San Lorenzo (FI).

tween 1542 and the XVII century in the church of Borgo San Lorenzo. The method of construction unfortunately does not allow more precise dating since it is very reshaped and was partly re–built during restoration in the 1900s. It nevertheless represents a clear anti–seismic safeguard put into place to give more stability to the arches, and in consequence, to the walls of the central nave.

2.5 RESULTS

To conclude the structural material of buildings analysis together with the scrutiny of the archival sources and especially the contributions of parishioners who headed the religious structures, we may hypothesize that a sort of Seismic Local Culture was developed in Mugello in the periods following seismic activity of 1542, 1597 and 1611. In this period, characterized by quite frequent seismic activity, it seems that religious customers and workers related to them where the ones to adopt criteria linked to the repair of structures, shown by the numerous presence of interventions (chains of different materials, buttresses, bracing and pilasters) in response to instability caused by seismic activity of XVI and XVII century. Such interventions obviously then constituted preventive elements in relation to following terrestrial movements (for example those of the 1700s for which, so far, no remarkable damage is documented in the analyzed buildings). In the latter case, it does not seem however correct to speak of prevention since only the use of wood, through its physical properties that render it an elastic and resistant material, could allow us to hypothesize the wish to mitigate future seismic movement effects on the structures. With regards to public customers, as a first the Grand Duchy of Tuscany, from the analysis of historical sources and the stratigraphic reading of the Vicari Palace in Scarperia, seat of the *Podestà*, it seems that only reconstruction interventions took place. Documents in fact show that the buildings damaged to different extents by seismic activity, were in most cases demolished or lowered to the unaffected floors, and later re–using the construction material in the new buildings. It this surfaces that the customer held a primary role in the form of reconstruction which took place after seismic activity. Particularly, the "sensitivity" and intuition of the individual, in relation to a form of Seismic Culture present in the know–how of the workers, seems to have been the motor through which post–seismic interventions in Mugello took place.

3. CONCLUSIONS

Restorations, in most cases, represent well–defined constructive actions, chronologically and typologically testified more or less accurately by direct and indirect sources. When the data in hand is reliable, cataloguing of these procedures, together with their period of use, thus allows the identification of determined interventions used in one or more buildings during precise historical periods. This procedure, therefore, allows the constitution of some very specific periodized post–seismic interventions, that represent the base for establishing a Chrono–typological abacus of the kind which may be defined as "anti–seismic safeguards". This therefore constitutes the bases for understanding whether in determined historical periods a Local Seismic Culture of know–how amongst workers in Mugello was present. Through the analysis of the context, the necessity to operate on multiple local sites in the same proximity, to better understand the characteristics of past earthquakes and their effects at a macro–district level, emerged. Such analysis can't be undertaken on single case studies due to the multiple factors that distinguish it (building methods, state of conservation of buildings and interventions which have taken place over time, as well as geological and geomorphological characteristics of the territory and so on) possibly resulting in wrong interpretation. It was thus possible, through this methodology, to define Chrono–typological territorial atlases that do not only relate to traditional construction techniques, but that focus on some elements which strongly characterize the seismic aspect of Mugello, for example the "anti– and post–seismic safeguards". Particularly, it was possible to hypothesize which interventions took place in the different historical periods, their purpose and the way in which these safeguards contributed towards the reaction of the building to the movements arising from the subsequent seismic activity. Furthermore, the presence of determined safeguards used with continuity in broad time spans and put in use in different contexts, allowed the hypothesis of the presence of some anti–seismic construction criteria probably formed part of the builders' or clients' know–how. To this effect it is fundamental to evaluate how valid and functional these elements still are at planning stage, in case they fulfill their function, include them in the restoration project, in view of proposing a correct intervention [Giuffrè, 1999], as compatible as possible with the material culture of the focus area.

REFERENCES

Aricò, N. and O. Milella (1984). Riedificare contro la storia. Una ricostruzione illuminista nella periferia del regno borbonico, Gangemi, Napoli.

Arrighetti, A. (2015). L'archeosismologia in architettura. Per un manuale, Firenze University Press, Firenze.

Arrighetti, A. (2016). Materiali e tecniche costruttive del Mugello tra Basso Medioevo e prima Età Moderna,

Arqueologia de la Arquitectura, 13, http://dx.doi.org/10.3989/arq.arqt.2016.001.

Arrighetti, A. (2018). Registering and documenting the stratification of disruptions and restorations in historical edifices. The contribution of archaeoseismology to architecture, Journal of Archaeological Science:Reports, 23, https://doi.org/10.1016/j.jasrep.2018.10.028.

Cangi, G. (2014). Tecniche antisismiche nell'antichità, in Attualità delle aree archeologiche – Esperienze e proposte, Centrioni A., Filetici M.G. (Editors), Gangemi Editore, Roma, 141–151.

Carocci, C.F. (2016). Le tecniche costruttive nella ricostruzione post 1703 a L'Aquila, in Tecniche costruttive nel mediterraneo dalla stereotomia ai criteri antisismici Nobile M.R., Scibilia F. (Editors), Palermo, 163–173.

Giuffrè, A. (1999). Lettura sulle meccaniche delle murature storiche, Edizioni Kappa, Roma.

Giuliani, C.F. (2011). Provvedimenti antisismici nell'antichità, Journal of Ancient Topography, XXI, 25–52.

Guidoboni, E., G. Ferrari, D. Mariotti, A. Comastri, G. Tarabusi, G. Sgattoni and G. Valensise (2018). CFTI5Med, Catalogo dei Forti Terremoti in Italia (461 a.C.–1997) e nell'area Mediterranea (760 a.C.–1500), Istituto Nazionale di Geofisica e Vulcanologia (INGV), http://storing.ingv.it/cfti/cfti5/.

Locati, M., R. Camassi, A. Rovida, E. Ercolani, F. Bernardini, V. Castelli, C.H. Caracciolo, A. Tertulliani, A. Rossi, R. Azzaro, S. D'amico, S. Conte and E. Rocchetti E. (2016). DBMI15, the 2015 version of the Italian Macroseismic Database, Istituto Nazionale di Geofisica e Vulcanologia, http://doi.org/10.6092/INGV.IT–DBMI15.

Ghisetti Giavarina, A. (2016). L'Aquila. tecniche costruttive antisismiche prima e dopo il terremoto del 2 febbraio 1703, in in Tecniche costruttive nel mediterraneo dalla stereotomia ai criteri antisismici Nobile M.R., Scibilia F. (Editors), Palermo, 153–160.

Minutoli, G. (2016). Tecniche costruttive "antisismiche" e interventi di restauro "moderno" nell'archimandriato di Messina e nel monastero di San Filippo di Demenna, Restauro Archeologico, II, 132–150.

Minutoli, G. (2017). Percorsi di conoscenza per la salvaguardia della città storica, Firenze.

Nobile, M.R. and F. Scibilia (2016). Tecniche costruttive nel mediterraneo dalla stereotomia ai criteri antisismici, Palermo.

Paradiso, M., Galassi, S., Borri, A., and Sinicropi, D. (2013). "Reticolatus": an innovative reinforcement for irregular masonry. A numeric model", in Structures and Architecture: Concepts, Applications and Challenges Paulo J. S. Cruz (Editor), CRC Press / Balkema, Taylor and Francis Group, London, Proc. of 2nd International Conference on Structure & Architecture ICSA2013, Guimaraes, Portugal, 841–848, ISBN 978–0–415–66195–9.

Parenti, R. (2002). Dalla stratigrafia all'archeologia dell'architettura. Alcune recenti esperienze del laboratorio senese, Arqueologia de la Arquitectura, I, 73–82.

Rovida, A., M. Locati, R. Camassi, B. Lolli and P. Gasperini (eds) (2016). CPTI15, the 2015 version of the parametric catalogue of italian earthquakes, Istituto Nazionale di Geofisica e Vulcanologia, http://doi.org/10.6092/ingv.it–cpti15.

Scibilia, F. (2015). Terremoto e architettura storica. Palermo e il Sisma del 1726, Palermo.

Scibilia, F. (2016). Il terremoto del 1823 in Sicilia settentrionale: danni e ricostruzioni, in Tecniche costruttive nel mediterraneo dalla stereotomia ai criteri antisismici Nobile M.R., Scibilia F. (Editors), Palermo, 179–193.

Stiros, S.C. (1995). Archaeological evidence of antiseismic construction in antiquity, Annali di Geofisica, XXXVIII, 5–6, 725–736.

Viollet–le–Duc, E. (1854). Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle, IV, Paris.

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