

ATINER CONFERENCE PAPER SERIES No: ARC2013-0557

Athens Institute for Education and Research

ATINER



ATINER's Conference Paper Series

ARC2013-0557

**Seismic Vulnerability of Building
Heritage in Aggregate, *Civita Di
Bagnoregio* Study Case**

Giulia Campanini

Architect

PhD Student

Polimi- Polytechnic of Milan

Italy

Athens Institute for Education and Research
8 Valaoritou Street, Kolonaki, 10671 Athens, Greece
Tel: + 30 210 3634210 Fax: + 30 210 3634209
Email: info@atiner.gr URL: www.atiner.gr
URL Conference Papers Series: www.atiner.gr/papers.htm

Printed in Athens, Greece by the Athens Institute for Education and Research.
All rights reserved. Reproduction is allowed for non-commercial purposes if the
source is fully acknowledged.

ISSN 2241-2891

25/09/2013

An Introduction to ATINER's Conference Paper Series

ATINER started to publish this conference papers series in 2012. It includes only the papers submitted for publication after they were presented at one of the conferences organized by our Institute every year. The papers published in the series have not been refereed and are published as they were submitted by the author. The series serves two purposes. First, we want to disseminate the information as fast as possible. Second, by doing so, the authors can receive comments useful to revise their papers before they are considered for publication in one of ATINER's books, following our standard procedures of a blind review.

Dr. Gregory T. Papanikos
President
Athens Institute for Education and Research

This paper should be cited as follows:

Campanini, G. (2013) "**Seismic Vulnerability of Building Heritage in Aggregate, Civita Di Bagnoregio Study Case**" Athens: ATINER'S Conference Paper Series, No: ARC2013-0557.

**Seismic Vulnerability of Building Heritage in Aggregate,
Civita Di Bagnoregio Study Case**

Giulia Campanini
Architect
PhD Student
Polimi- Polytechnic of Milan
Italy

Abstract

Main goal of the research is to discuss a multidisciplinary approach to the study of the seismic vulnerability of the building heritage in aggregate.

The knowledge, gained as a result of natural disaster, has led, over time, to investigate aspects of prevention of building heritage in aggregate, highlighting the different issues of recognition historical masonry structures and their complexity, the analytical techniques and intervention methods.

The research aim to define an interpretative model of the complex structural behavior, identifying the sensibility factor of the system in relation to different approach that are developed, taking like first reference the Antonino Giuffrè contribute. His seismic vulnerability approach, generated on Palermo and Ortigia studies, is based on juxtaposing different kind of lectures about building heritage such as typological analysis, archives studies, material and constructive deepening.

Civita di Bagnoregio, the etruschian village in the Alta Tuscia region, with its seismic history that led the village in a state of abandonment (not only of inhabitant but also of normative control), is the study case for a real application of these consideration and, at the same time, for an outline of a seismic vulnerability methods for the existing building heritage. Some considerations are developed looking to the archive information, in comparison with the technological survey and the valuation of the material state of conservation to find the characterizing aspects of the seismic vulnerability analysis.

Key words:

Corresponding Author:

Looking to the ancient earthquakes in XX century history of Italy we can note that the building heritage -not only cultural- was tested several times by the repetition of seismic events.

The main earthquake of Messina and Reggio in 1908 moves to the introduction of prescriptive norms for seismic improvement in case of intervention, both in a new buildings and existing ones.

The first approach to existence building is described in 1964 *Carta del Restauro* of Venice, with the organization of traditional methods and materials using, borrowing modern techniques only in case of necessity. But the seismic events repetition lead up, between 70's and 80's, to write rigid norms, with prescription for the existing heritage of obtain a seismic security level. A lot of strengthening intervention became, for the difficult to employ the norms to the reality of the territory, as distortion of the seismic behavior a damage amplification in the further earthquakes¹.

For Cultural heritage only in recent past the term *improvement* – defined as quantification of seismic security upgrade - was preferred to *adaptation* – defined as achievement of seismic security level of a new building. This approach, described in a Norm of 1997², is defined as the more advantageous for conservation of Cultural Heritage because “prefer conservation requirements to security.

Lots of studies following major earthquakes since Belice up to L'Aquila have been conducted, defining methodologies to describe the seismic behavior and the vulnerabilities of existing heritage but without reaching a method to analyze the complexity of historical heritage in aggregate.

The historical built heritage is made up of a transformed over time with additions, reconstruction, conversion, poorly documented since the fruit on the existing dwelling, inherent in the building, a series of constructive action, which develop over time, not always as result of a defined project.

These factors determines two levels of structural analysis difficulty. First the identification of structural parts and resistance materials composing the aggregate, then how they interact each others in a complex load bearing structure.

It is immediately evident the importance of being able to achieve a high level of knowledge for a building to improve the definition of the structural instability and possible improvements with any interventions.

The turning point in the approach to the contingency of the earthquake in historical centers is highlighted in the contribution of Antonino Giuffrè³, that

¹The interventions, based on an analysis of seismic data from a simplified model of interpretation and evaluation of structural masonry buildings were designed considering assumptions that are consistent with new construction but not suitable for the existing.

²Adm. Circular n. 65. of April, 10 1997. Instructions for the application of «Norme tecniche per le costruzioni in zone sismiche» D.M. January, 16 1996.

³ Giuffrè Antonino, engineer, university teacher, (Messina 1933 - Rome 1997), has carried out intensive research and teaching as a professor of Construction Science and consolidation of the artistic heritage at the University of L'Aquila, "La Sapienza" and "Roma Tre" of Rome. He has conducted extensive studies on the problems and innovative conservation of the built heritage: technology science of the buildings and restoration of monuments, he has been president of the

has conducted extensive studies on the problems and innovative conservation of the built heritage with contribute of constructive science.

Until his studies, the urban centers management tools didn't take into consideration the structural issues, favoring archival, typological and functional reading. He has introduced a structured and organized way based on a mixture of urban-type transformations, historic building techniques and vulnerability assessment. Inspired by the analysis of urban morphology developed by Gianfranco Caniggia information is collected about the evolution of the urban fabric of its housing types, have come to define the consistency of building elements and structural systems¹.

These issues are deal in 1993s studies of Practice Code for the seismic analysis of Ortigia², and subsequently in 1997 studies for Safety and Preservation of the historic center of Palermo³.

A typological survey of building introduces a reading key closely related to structural assemblies; the role of constructive techniques is paired up with a traditional typological analysis - through material, constructive and conservation status considerations - to understand the seismic vulnerability individuated as collapse mechanisms.

Looking to these considerations have been produced numerous post-emergency documents intended to give an instrument of government and prevention in the area, taking advantage of the occasion of the earthquake.

Today only two documents, without a norm prescription explain the issues relating the evaluation of the seismic vulnerability of the building in the aggregate. In fact norms even contemplating the possibility of analyze a "complex architectural isolated or non-isolated characterized by spatial and functional relationships with any neighboring artifacts" provides only an operational tool of analysis of single buildings, such as palaces not complying, therefore, reading needs of in aggregate ones.

In this documents is highlighted the necessity of a systemic multidisciplinary approach, necessary to place themselves in relation with

Italian National Association for Earthquake Engineering and the Built Recovery (ARCO) and member Commission of the Superior Council of Public Works for the preparation of seismic standards and the European Commission for the drafting of Eurocode on buildings in seismic areas. In the last years of his life has focused his studies on the issues of conservation of the built heritage, with particular attention to issues of preservation of historical centers, studies interrupted by the untimely death. Among his works: recovery of the neighborhood "La Graziella" of Ortigia (Syracuse), restoration the Cathedral of St. Angelo dei Lombardi, the Palazzo Chigi in Ariccia, of the Capuchin Monastery in Dubrovnik, the Round Temple Boarium the Forum and the Basilica of S. Agnese in Rome.

¹Caniggia recognized the weight of the structural part, looking to the city the city as an organism, subject to specific and intrinsic laws of mutation, product of a process of transformation recalling, therefore, aggregation process. See also the works of Caniggia. Caniggia, G. (1984) *Analisi tipologica; la corte matrice dell'insediamento*, in *Recupero e riqualificazione urbana nel programma straordinario per Napoli*, Milano. Caniggia, G. (1983) *Dialettica tra tipo e tessuto*, in *Studi e documenti di Architettura*, n.11.

²Giuffrè, A. (1993). *Sicurezza e conservazione dei centri storici, il caso Ortigia*, Roma-Bari.

³A. Giuffrè, A. & Carocci, C. (1999). *Codice di pratica per la sicurezza e conservazione del centro storico di Palermo*, Roma-Bari.

historical heritage. It's also emphasize the contribute that can be derived from quantitative and qualitative analysis where, due to circumstances related to the importance or reading difficulties, it is not possible to arrive at an adequate structural knowledge with both analysis.

Starting from this consideration the research aim to discuss a new approach, working with different disciplinary contributes whom usually work on historical buildings (such as historical, archeological, and structural) to find some food for thought for a future seismic vulnerability methodology for building heritage in aggregate.

First of all the use of historical analysis is usually an instrument to define consecutive steps of evolution. In this case the proposal is to relate this contribute_to information about seismic history, reflection about building typology, constructive methods and materials, archeological survey to improve a qualitative knowledge.

Civita di Bagnoregio Study Case

The village of Civita di Bagnoregio is proposed to be emblematic case study for multiple factors, first the issues related to the geological and seismic history. The village, since its etruschian foundation, was a civil and religious center very important, but, has lost importance due a geological secular erosion and a collapse process (the writing memories start with 1695 earthquakes effect descriptions) and is now perched on a tuff block that is still slowly destroying bringing with them the outer parts of the village.

The repetition in time of earthquakes, the difficulty of living this place, the slowly destroying process of tuff block were the main causes of the slow process of abandonment that has brought the country to be remembered as the *dying town*¹. The large tourist flow that invests the village every day seems to be the only reason for survival (today Civita has only nine habitants, hundreds of touch and go tourists, lots of cats).

The absence of planning instruments of management and control - still subject to the Building Program (1974), although in 2001 has been drawn up a detailed Plan for the Historic Centres, not yet approved - has led the introduction of vulnerabilities by uncontrolled restorations.

The cognitive model to analyze the seismic vulnerability is structured on indications given in norms and are related with studies on the each topics. It aim to assume a expeditious nature, necessary for evaluate how the use of qualitative data can lead to constructive characterization of synthetic material but effective evaluation of the seismic vulnerability of the aggregate at the urban scale. This assessment is considered necessary to address more detailed analysis - which will lead to the interventions drafting- in the order to optimize the available resources.

¹Tecchi, B. (1967), *Antica terra*, Viterbo. (pag.72)

Observation of the buildings, even if careful and depth, and in situ trials (with limits to invasive one) cannot always be sufficient to describe exhaustively the material consistence of heritage. This problem of knowledge is emphasized for example when transformations and growths increased the complexity of an aggregate building, or when strengthening interventions, frequently hidden, could have modified the structural behavior of the building.

The approach is based on the historical and critical study of archival sources, the study of registers and iconographic sources. Picture and images of different periods, combined with historical plans, can help to increase the knowledge of the constructive process during the years, highlighting not only growths but also transformations and restorations.

The seismic history data used to define the seismicity of the area, in order to find a way of knowledge of aggregates, can be used as a hint to understand the response of local building types to particular significant events and any consequent transformations.

The lecture of different cadastral map makes possible to had the base of chronological sequences of the various types (in terms of "before and after"), where allows identification of original elements progressive clogging.

In image7 is possible to see a first relation born from a re lecture of the cadastral maps and the note of the seismic events.. The registration of changes in the course of time – in this case we can appreciate that destruction and reconstruction moments happens after important seismic event - is an necessary step for framing both the precariousness, or structural solutions, important if we want to identify the inhomogeneous parts introduced or sustained over time.

The archival part of the studies the analysis of the historical seismicity of the site appears, also, to be useful to give first indications of the structural typology earthquake response. The cadastral cartography available with the development over time of seismic events recognized what transformations have occurred over time after a seismic event.

Essential steps are geometric survey designed primarily to evaluate dimensional aspects of building elements, materials and construction survey, combined with a expeditious stratigraphic analysis.

Stratigraphical analysis, combined with geometrical and constructive survey, can give not only a list of Wall Techniques Units (UTM) but also the character of homogeneity and not of parts of the building, returning a temporal sequences as included in previous archival analysis. The definition of the clogging process will follow a verification of combinations and recasts, highlighting structural vulnerabilities from the process of aggregation (for example, the absence of the perimeter wall because the building is in support of an existing one).

Modern survey technology and digital pictures can be used, in this case, to schedule constructive elements and techniques, 3D survey to represent globally the aggregate; these materials, necessary for the research' goal, could be useful as future documentation of present condition.

A first urban survey of Civita center was conducted using a laser scanner instrument as we see in the images.

The results is series of very powerful 3D images that need to be well elaborated to comes useful to the specify of this analysis. In fact a laser scanner survey, as a queryable instrument needs a targets planning to govern the huge data collected, looks to be a high level instrument. For example the use of color orthogonal images of the facades becomes can be the base for geometrical, material, constructive and stratigraphical analysis.

Is important to note the possibility to find a real logistical problem derivate from morphological conformation of the historical centers. In this case the limits given from the tuff block had take out the possibility to make a round complete survey of all the buildings. In other case can be problems related to spaces or special conformation of the buildings, small roads, high external walls – something normal when we talk about building heritage.

The damage scenarios typical construction in seismic areas are characterized by repetitive looking several mechanisms that occur with insignificant variations due to the specific geometric configuration and the quality of the materials, but are substantially similar to the formation and evolution. It is also important to understand the local character of the main mechanisms of damage for which some parts of the structure can be affected while others can be fully excluded. This character gives an indication of the importance of the decomposition of a body building into individual elementary parts, which are useful to simplify the analysis of the aggregate building complex.

Favoring qualitative information is detected the objective difficulty of interpretation and reading in time to transpose the results in quantitative data (following the path of knowledge indicated by the standard). Within the current legislation, in reality, both contributions are required. The qualitative data from this point of view, should not be regarded as a subjective and low load of information, but as first framing of specific characteristics and vulnerability of the object.

In conclusion of these considerations, we can outline future scenarios in the search for integration with the regulations to the problems of construction aggregates regulating the role and the weight that each analysis pertaining to a particular scientific field, it can have in defining the path to the knowledge of the seismic vulnerability of such complexes in the aggregate.

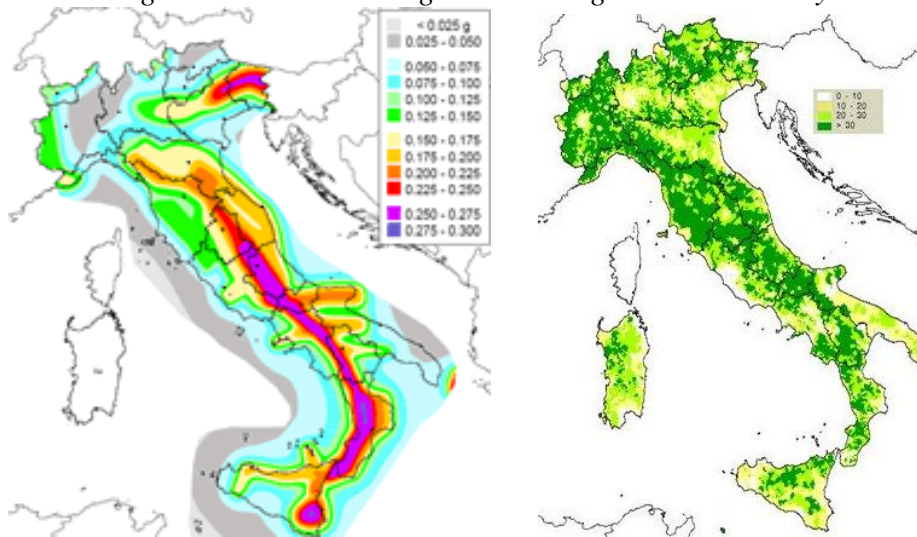
Looking to the relation between a Map of Italian seismic hazard, as pubblicated in the 2006 in relation with a Percentage distribution of households with highest vulnerability we can't say that understanding the complexity of historical buildings in aggregate is not a real important issue if we want to prevent and conserve an important part of the heritage.

For this reason all the disciplines that talk in different ways about the construction need to collaborate in the way to investigate the complexities and in homogeneity of the existing heritage.

Remembering that this process is not composed only of different analysis, but it needs to understand the weight that each one can adds before in a urban way (useful to gives an idea of the problems and contingencies) and then in

single aggregate valuation, where there isn't resources or possibility to make depth quantitative analysis.

Img. 1. *Left: Map of seismic hazard Italian, PCM Ordinance 3519 of April, 28 2006. Right: Percentage distribution of households belonging to the highest vulnerability class A (Source: SSN). Comparing the map of seismic hazard with the vulnerability of existing buildings there is a worrying coincidence between the areas at highest risk and buildings with the highest vulnerability*



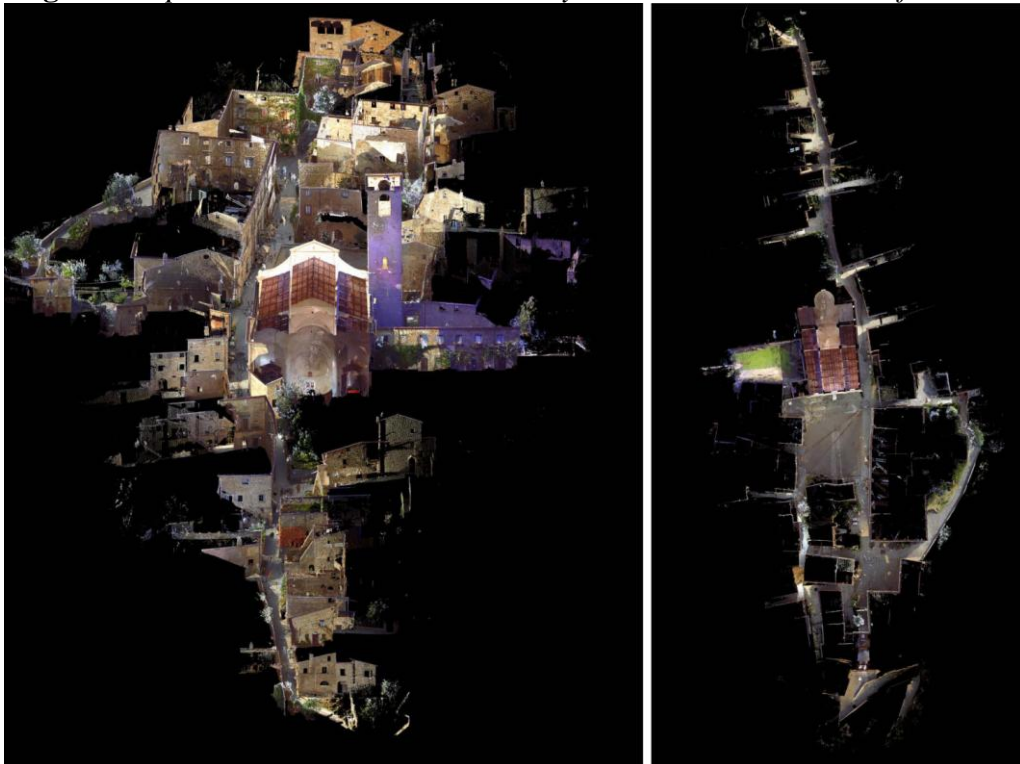
Img. 2. *Image of Civita tuff block, highlighted the geological problems*



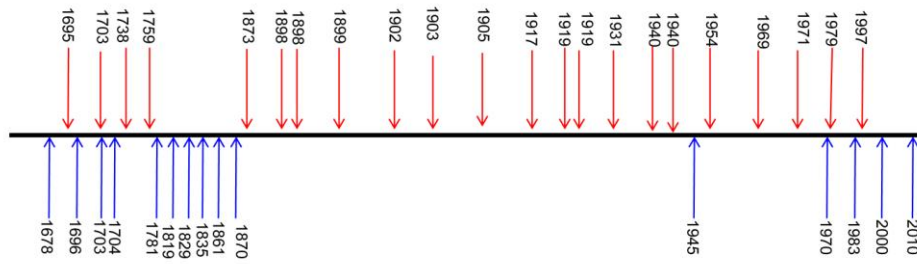
Img. 3-6. *Images of Civita buildings*



Img. 7. *Comparison between seismic history and archival documents found*



Img. 8-9. Images of 3d laser scanner survey



SEISMIC HISTORY
ARCHIVAL DOCUMENTATION

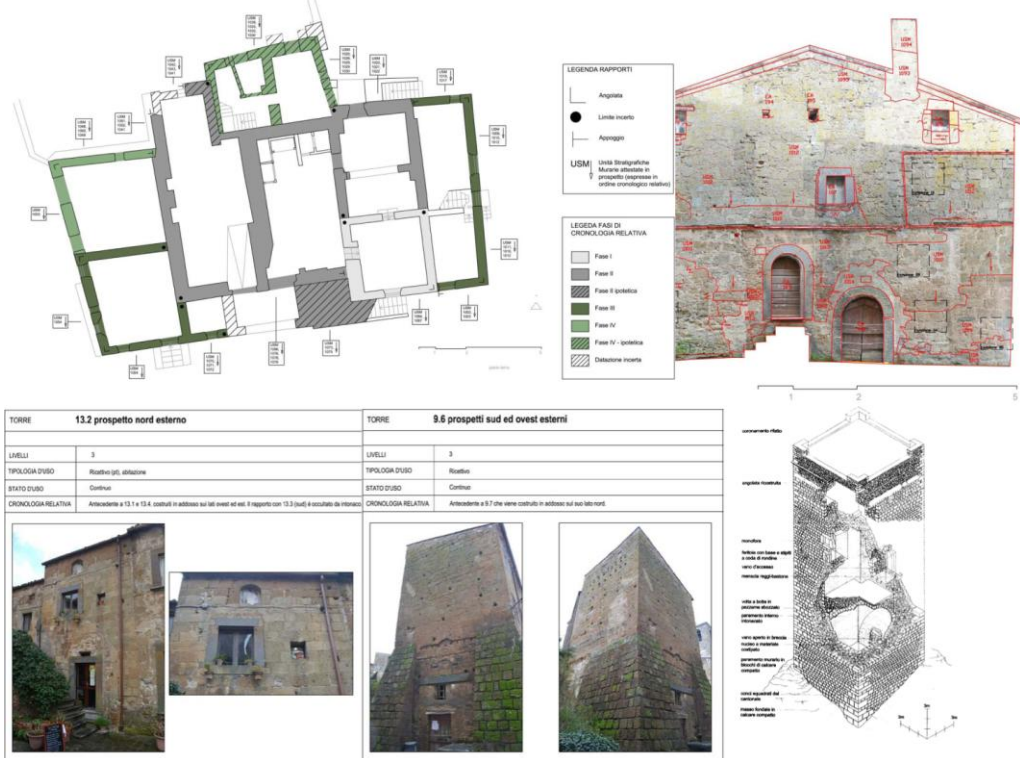
Archivistical documentation

1696 inspection conducted by Moroni bishop
1678 Serie A, Viterbo e Bagnorea, limits, vol. 2
1703 inspection conducted by Ulrico Nardi
1704 inspection conducted by Ulrico Nardi
1781 Camerale II Antiquities and fine arts, walls, envelop I

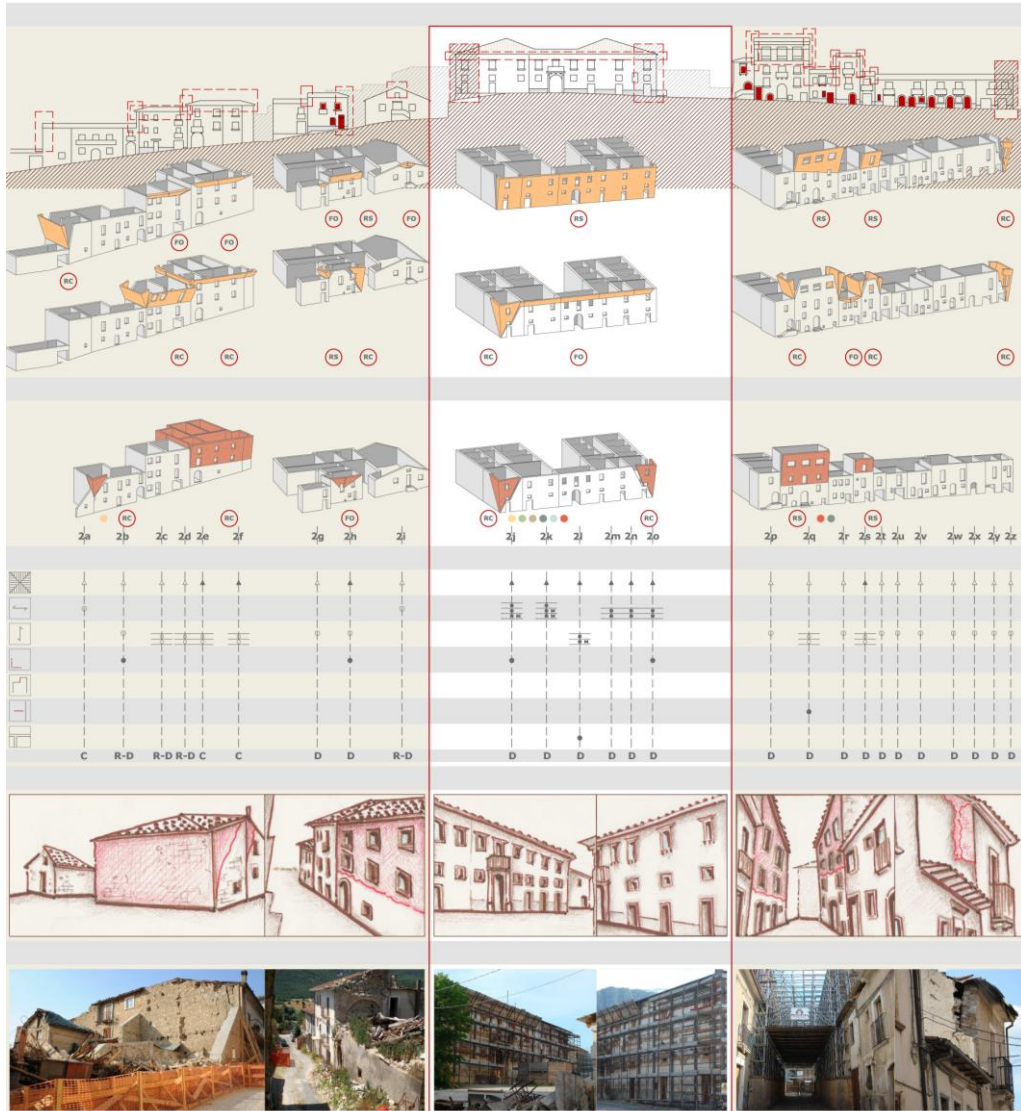
1819 Section land register V,Civita
1829 Congregation of Good Government land register
1835 Papal land register
1861 Comunal deeds and documents, envelop 3202
1870 Papal land register

1945 plane views after WWII
1970 Historical buildings catalogation by images, prof. Astra Zarina
1983 Plan of the ground floor, survey by Prof. Zarina
2000 Plan of conservation of historical centre (not approved)
2010 Land register (in force)

Img. 10. Images of stratigraphical and typological analysis of an aggregate



Img. 9. Previous studies about seismic vulnerability of Sant'Eusanio Forconese(AQ). The urban analysis associated with material and constructive data gives information about the seismic mechanism of collapse. Is evident the correspondence between the analysis and the seismic damages post 2009s earthquake



Norms

Guidelines for the evaluation and reduction of seismic risk of the cultural heritage with reference to technical standards for construction, developed between the Department of Civil Protection and the Ministry of Heritage and Culture, July 21, 2006. [In Italian]

Guidelines for the detection, analysis and design of repairs and seismic strengthening of masonry buildings in the aggregate, Draft October 2010 Reluis. [In Italian]

Directive of the President of the Council of Ministers February 9, 2011 *Evaluation and reduction of seismic risk of the cultural heritage with reference to new technical standards for construction NTC 2008*. [In Italian]

Short Bibliography about Seismic Vulnerability

- Various Authors (1997). *Recovery and reducing the vulnerability of historic centers damaged by the 1997 earthquake*, Marche Region. [In Italian]
- Benedetti, D. & Petrini, V. (1984). *On the seismic vulnerability of masonry buildings: a method of evaluation*, in *The Construction Industry* n. 149, Rome. (p. 66-74). [In Italian]
- Brogiolo, G.P. (1988). *Archaeology of historic buildings*, Como. [In Italian]
- Cangi, G. (2010). *Structural analysis for the recovery of earthquake-proof. Calculation of kinematics for masonry buildings according to NTC*, Rome. [In Italian]
- Dogliani, F. & Mazzotti, P. (2007). *Code of practice for the seismic upgrading in the restoration of the architectural heritage, integration in the light of experience in the Marche Region*, Ancona. [In Italian]
- Dogliani, F. & Moretti, A. & Petrini, V. (1994). *The churches and the earthquake. From the vulnerabilities found in the Friuli earthquake to earthquake-proof improvement in the restoration, to a policy of prevention*, Trieste. [In Italian]
- Donà, C. & De Maria A. Borri, A. (2011). *Manual of historic masonry*, vol. I - II, Rome. [In Italian]
- Giuffrè, A. (1993). *1993 Security and preservation of historic centers, the case Ortigia*, Rome-Bari.
- Giuffrè, A. & Carocci, C. (1997). *Code of practice for the safety and preservation of the Sassi of Matera*, Matera. [In Italian]
- Giuffrè, A. & Carocci, C. (1997). *Code of practice for the safety and preservation of the historic center of Palermo*, Rome. [In Italian]

Short Bibliography about Civita Di Bagnoregio

- Margottini, C. & Serafini, S. (1990). *Civita di Bagnoregio, geological observations and historical monitoring of the environment*, Rome. [In Italian]
- Artemi, Abbot P. (1842). *Historical Memoirs of the City of Bagnorea*, Rome. [In Italian]
- Baratta, M. (1901). *Earthquakes in Italy*, Turin. (pp. 182-184, 225, 243, 246, 293, 457, 488) [In Italian]
- Papini Pietrangeli, F. (1949). *Aspects of the tragedy of Civita di Bagnoregio in the last two and a half centuries*, Viterbo. [In Italian]
- Macchioni, F. (1956). *History of ancient times to 1593 Bagnoregio*, Viterbo. [In Italian]
- Pietrangeli Papini, F. (1970). *Civita di Bagnoregio*, Viterbo. [In Italian].