Rural Heritage and Cultural Landscape: Guidelines for Sustainable Seismic Reinforcement of Emilian Historic Rural Building in Italy

Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 161 (2016) 1662 – 1668

Procedia Engineering

www.elsevier.com/locate/procedia

World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium 2016, WMCAUS 2016

Rural Heritage and Cultural Landscape: Guidelines for Sustainable Seismic Reinforcement of Emilian Historic Rural Building in Italy

Federica Ottoni[a,]*, Federica Borghi[a]

[a]*Dept. of Civil Engineering and Architecture, Viale Parco Area delle Scienze 181/A – 43124 Parma, Italy*

Abstract

Historic rural settlements are essential evidences of the Italian cultural heritage because they hand precious architectural, historical and environmental values. Despite its importance, this heritage is rarely protected by specific laws and a great part of these buildings are now abandoned and partially ruined, also as a consequence of the last century mechanized and intensive farming and the consequent lifestyle change. Moreover, the seismic events pose a serious threat to their preservation: indeed, despite they are located in an area - the Italian territory - with a very high seismic risk, often they don't have any proper anti-seismic device able to prevent a serious damage, or collapse. In this work, the results of the research carried out on a significant number of historic rural buildings in the Emilian area, in Italy, are presented in order to draw up specific guidelines for their sustainable seismic reinforcement and conservation. Indeed, starting from the analysis of the peculiar features of the landscape and of the examined buildings, it's possible to recognize some recurring structures and shapes which identify as many rural architectural types, with similar structural behavior and seismic damage. Thanks to this similarity, it has been possible to set up some reliable guidelines of analysis and intervention which can constitute an easy and expeditious instrument for technicians and restorers in order to safeguard this valuable built heritage, too much neglected until now. The final aim is to evidence the extreme efficacy of a conservation strategy, which can constitute the first guarantee for a sustainable intervention on this precious cultural heritage.

Peer-review under responsibility of the organizing committee of WMCAUS 2016

Keywords: rural heritage; seismic retrofit; cultural landscape; sustainability;

* Corresponding author. Tel.: +39-0521-905961; fax: +39-0521-905912.
E-mail address: federica.ottoni@unipr.it

Peer-review under responsibility of the organizing committee of WMCAUS 2016
doi:10.1016/j.proeng.2016.08.642

1. Introduction

The rural landscape is strongly characterized by the presence of rural buildings, which, over the time, designed and influenced its conformation up to create a typical "cultural *paysage*"[1].

Despite the cultural value of this rural heritage is recognized also by the Italian legislation, the most of these buildings are in a widespread abandonment and decay status, also as a consequence of the last century mechanized and intensive farming and the consequent lifestyle change (Fig.1).

Fig. 1. On the left, the rural Emilian landscape photographed by L. Ghirri; on the left the modified picture after the industrialization process.

The result of this process is the rapid decay of the rural heritage which seems to be unavoidable because both human and financial resources, which can prompt conservation and reconstruction, are currently lacking [2].

Moreover, after an extreme event (like the strong past earthquake in Emilia Romagna region, in May-July 2012), the hidden fragility of these marginal architectures suddenly shows its whole vulnerability, quickening the physiological process of deterioration (already advanced due to the abandonment) (Fig.2).

Fig. 2. A typical rural building of the Emilian region before (on the left) and after (on the right) the strong earthquake of June 2012.

It's well known, in fact, that seismic events pose a serious threat to the preservation of historical masonry structures; in particular when these buildings, as the rural ones, don't present any proper anti-seismic device able to prevent their collapse, despite they are located in an area - the Italian territory, and the Emilian region in particular - with a quite relevant seismic risk.

In step with this, in this work the results of a three-year research, carried out on a significant number of historic rural buildings in the Emilian area, are presented in order to draw up specific guidelines for their conservation.

2. The rural heritage: from typological classification to structural knowledge

The abandonment of rural settlements and buildings is a contemporary phenomenon, which involves the concepts of “heritage” and “cultural transmission” introducing new dynamics into the concept of “authenticity”, which has to be considered not only in its historical and formal sense, but also as immaterial aspects. “Authenticity” includes social, cultural and economic activities (*etno-anthropologic* issues) which are part of the local identity and which constitute a fundamental target for the conservation of rural landscape.

Therefore, the definition of “rural heritage” involves necessarily a deep interaction between social and formal aspects, which together determine also the structural organization of the buildings, gathering local and vernacular characteristics which substantially derive from as many functional and economic managements of the territory. For this reason, the present research started from a recognition of previous sociological and economic studies of the examined area [3, 4] which have stressed the strict link between economic-agricultural aspects and different settlement typologies (Fig.3).

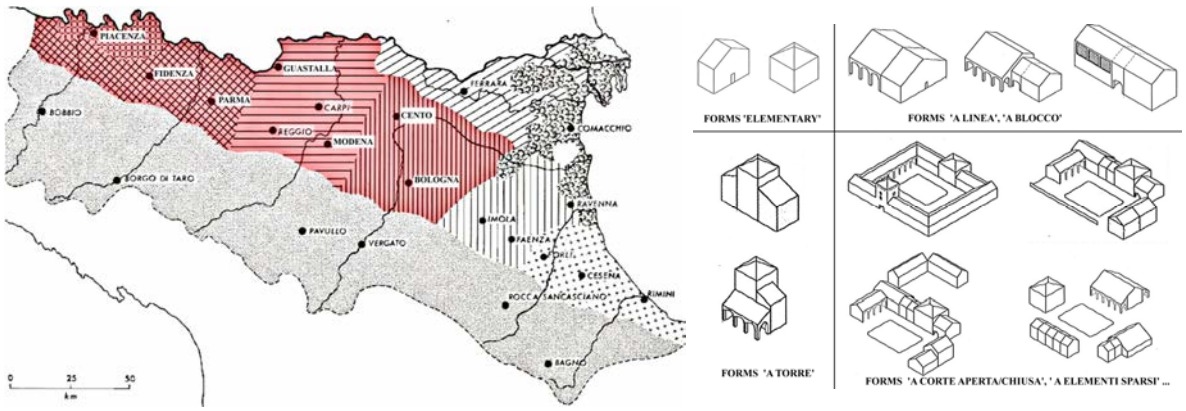

Fig. 3. In red (on the left) the area of study; on the right, the three main classifications.

For this reason, the first operation of the study here presented consisted into a systematic analysis of Emilian rural settlements, aimed at tracking the formal organization of the area of study and finalized to interpret the structural composition (and evolution) of the buildings. This preliminary operation led to the identification of three basic settlement models (the "court" model, the "juxtaposed bodies" model and finally the "tower" model) which represent as many ways, in which the single buildings can structurally (and not only formally and functionally) interact inside a “rural heritage” block.

2.1. Repeated types and structural characters

As often happens in the study of historic buildings, the typological analysis has therefore constituted a fundamental tool, primarily structural, aimed at the full understanding of the structures. It has been clear from the beginning of the research, that the building historical identity is typical of the region and the constructive technique represents a key for understanding the transformation of the territory. The recognition of building types and their relationship in the formation of the settlements previously identified, together with the deep examination of construction techniques and historical evolution, extend the conservation approach to structural and construction aspects.

A number of architectural features derive from local construction methods, which strictly depend on specific factors as the morphology of the area and, consequently, the availability of materials; the general organization of the buildings (position and number of openings, orientation of the building, the most recurring wall thickness together with the horizontal structures and roofs) and finally the construction techniques. These set of conditions concur to determine the vulnerability or resistance factors of the fabric and therefore the identification of building types tends to highlight the general construction methods and the relationship between adjacent buildings.

The problem is methodological: in virtue of a general lack of documentation, the typological study of the buildings and their direct analysis represents the primary tool to analyze these objects and only their analysis and the subsequent comparison between them (having a numerous case sample), can define the most appropriate regional-scale approach.

The analysis carried out on around 150 rural settlements in the Emilia Romagna region - which have constituted our study sample - led to recognize the most recurring elements, repeated, which provide the synthetic model for the building and its relevant variants. Firstly, analytic forms have been created in order to collect constructive and formal data through increasing levels of detail: starting from the environmental analysis of the identified settlement, passing through the deep geometrical and structural survey of each individual building composing the settlement (Fig.4).

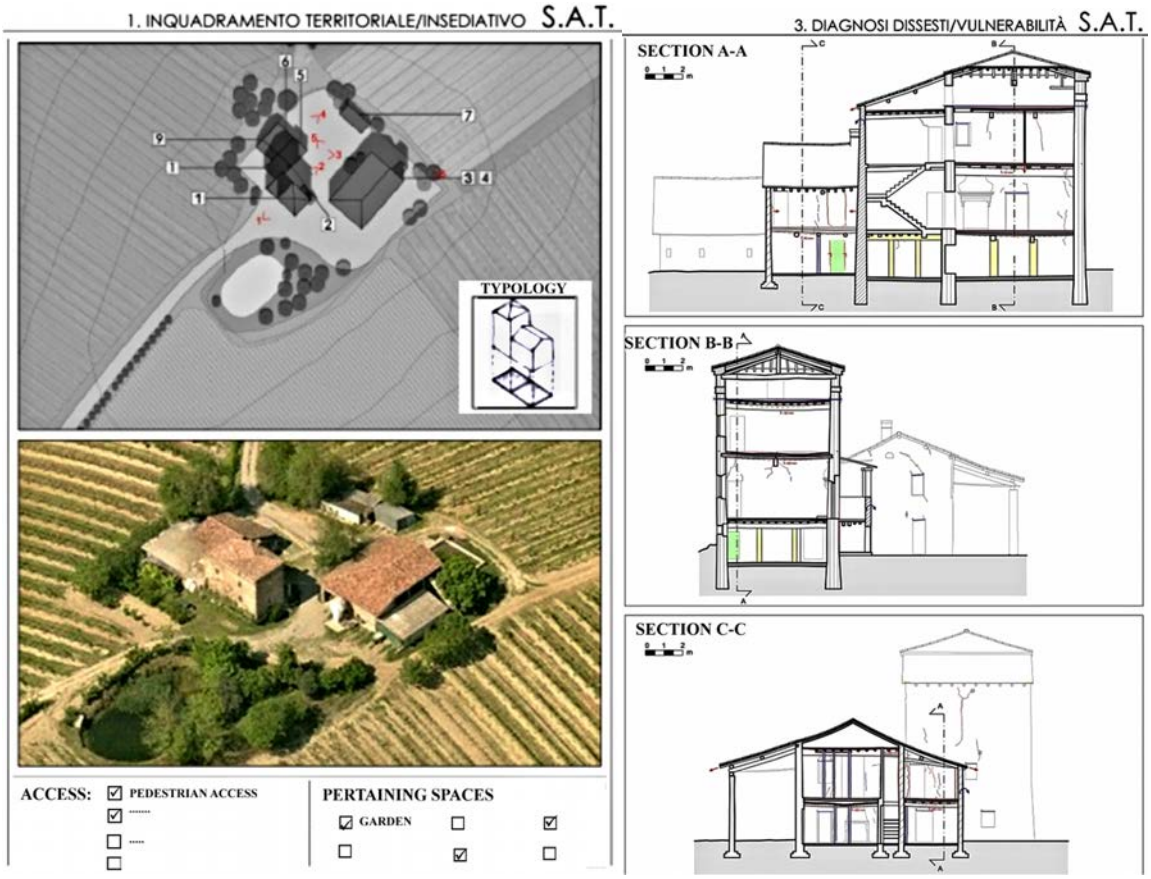

Fig. 4. Two parts of the analytic forms created for this research, in which collecting the necessary information at different scales.

Through a change of scale of observation, it has been possible to recognize - in an almost perfect correspondence - three main types of primary building, which can be assumed as many "structural matrix", each of which has a proper structural characteristic and structural behavior:

- House (*abitazione*), characterized by a simple and symmetric plan - repeated at each level (two or three) - with main perimeter bearing walls and internal ones on the two directions, intermediate wooden floors (generally not rigid and not sufficiently linked to the vertical walls) and pavilion wooden roofs, often deformable and not properly connected with vertical structures;
- Stable-barn (*stalla-fienile*), composed of two main spaces: the lower level is vaulted and characterized by great thickness perimeter walls with few thin regular openings, while the upper level is a great hall with perimeter wall panels of great extent (free from cross connections), slender pillars and wooden roof trusses

(deformable and free of connections to the supporting walls). The presence of large openings or "perforated" walls (*a gelosia*) makes these structures particularly vulnerable to earthquake (Fig.5).

- Tower (*a torre*): structures with prevalent vertical development on almost square floor plan with great thickness perimeter walls (with few irregular openings), intermediate wooden horizontal elements (deformable and not connected to the support walls) and wooden pavilion roof (pushing, deformable and generally not well connected to supporting walls). The main risk, for these structures, is the contact with lower buildings, which often have been added in time.

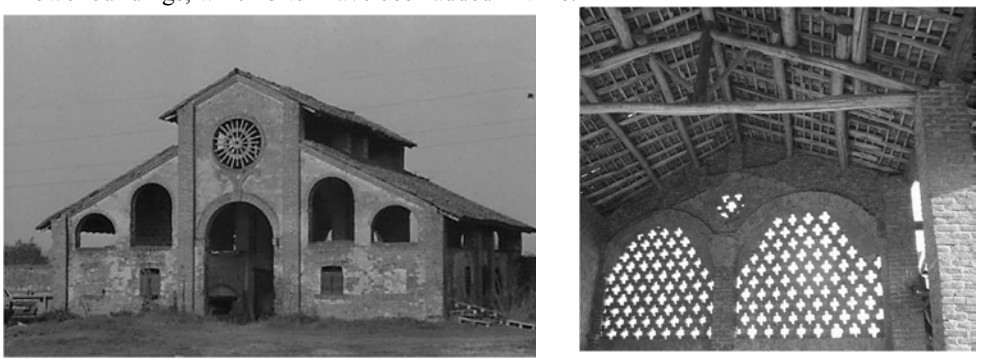

Fig. 5. On the left, the stable-barn type (*stalla-fienile*), very similar to churches with weak perforated walls (*a gelosia),* on the right.

Thus, starting from the observed connection between architectural and structural typologies, we can advance a further step: to repeated architectural and structural characteristics correspond similar collapses and damages, and thus similar strengthening solutions.

3. An empiric-based approach, from typical structures to typical damages: possible guidelines

Is well known by literature [5] that historical masonry buildings don't show generally, in case of earthquake, a clear global behavior but they tend, conversely, to react as different parts (called *macro-elements*), which are more vulnerable to the loss of equilibrium than to the lack of resistance of the constituting materials.

This approach has been considered and applied in this study, in order to detect, from the observation of similar characteristics, the most reliable behavior of these structures. The analysis of the case studies allowed to identify the "characteristic" damage mechanisms for each of the previously classified typologies (Fig.6).

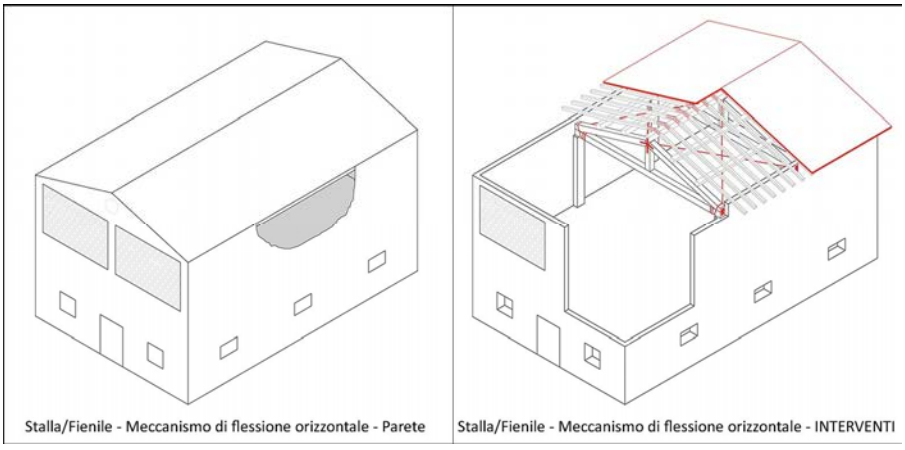

Fig. 6. One of the most probable collapse mechanisms detected for stable-barns, and the schematic indication of intervention.

However, also the last Italian Directive for seismic protection [6] recognizes empiricism as the most important diagnostic instrument in seismic protection of historic masonry buildings and, following this method, the recurring failure mechanisms for each typology were classified and numbered (according to the degree of risk, or the likelihood of activation) into as many abacuses aimed at interpreting the most probable seismic response of rural buildings, just starting from the mere settlement identification (Fig.7).

Fig. 7. The abacus/guideline related to the mechanism “2. Horizontal inflection” for “house” matrix type.

Each abacus contains a brief description of the various ways in which the mechanism may occur and the conditions which can determine it. Schematic drawings and photographic references of past earthquake effects in similar buildings are reported in order to clarify the "symptoms" of the damage, and to guide their recognition. Furthermore, the form reports the most worrying "vulnerability", i.e. the main structural and technological deficiencies whose presence is indicative of the possibility of mechanism activation [7].

Moreover, for each mechanism and type, a schematic indication of the most appropriate (and economic) strengthening intervention is presented. The proposed interventions are substantially aimed at the improvement of structural configuration and at making effective connections which can enhance the existing buildings assets, respecting historical materials and preserving architectural features identified in the previous analysis.

These analytical forms have been elaborated in order to set up a seismic protection program for rural building, which can be a support for technicians called upon to intervene in these buildings. This procedure seems to be an effective and expeditious way, to use the results of the deep knowledge process carried out on rural building characteristic and behavior, obtained also in previous studies.

4. Conclusions

The typological analysis and the identification of some “structural matrixes” have clarified that the best way of conserving the examined structures is in maintaining continuity with their original behavior.

Therefore, by observing the past, it's possible to hypothesize the most probable possible future damages for similar types of buildings and, thus, to minimize the intervention by adopting solutions and materials which are already part of the building, improving their structural efficiency, more than substituting their structural role.

The interpretation of the behavior is based on the observational method and it starts from it.

The proposed method permits then to define intervention priorities: building vulnerability assessments – derived from the analysis phase of this study - are fundamental in order to establish a priority list based on vulnerability levels. Moreover, in times of scarce public and private economic resource, the conservation of buildings of not completely recognized value – as the rural heritage – can't be reasonably too expensive and anti-seismic strengthening can't exceed the economic value of the buildings. Therefore, reducing the cost of seismic protection represents not only the first guarantee of conservation of this hidden heritage, but the only pre-condition to the necessary further hypothesis of reuse.

It's also clear that the lack of maintenance represents one of the principal problems for these structures; for this reason, the methodology here proposed is aimed at "using" the knowledge achieved in a deep and long research on the territory, in order to apply simple and "standard" strengthening solutions which are extremely efficient for a conservation strategy. The connection between knowledge-based process and choice of intervention is strong: the recognition of repeated elements allows to set up an efficient strategy of repair and strengthening of buildings, considering the results of the observational method proposed. Only the deep analysis carried out, in fact, has permitted to identify – in a simple and reliable way, which considered the materials of construction, the constructive techniques and the authenticity issues – the best intervention for solving the identified structural (both static and seismic) problems, taking into account material and architectural compatibility and thus avoiding the insertion of dangerous and incompatible elements.

The knowledge is the first guarantee of a sustainable reinforcement of this cultural heritage, and more in general, of masonry buildings which in simple interventions frequently find the best way of conservation.

References

[1] M. A. Giusti, E. Romeo (eds.), Paesaggi culturali – cultural landscape, Aracne ed., Roma, 2010.

[2] R. Crisan, D. Fiorani, L. Kealy, S. F. Musso, Conservation_reconstruction, Arti Grafiche CDC, Roma, 2015

[3] L. Gambi, La casa Contadina, in Storia d'Italia, vol.6, Einaudi, Torino, 1976.

[4] M. Ortolani, La casa rurale nella pianura emiliana, C.N.R. «Ricerche sulle dimore rurali in Italia», Centro di studi per la geografia etnologica, vol. 12, Firenze, 1953.

[5] C. Carocci, M. Costa, "Casentino (AQ): A seismic improvement project for masonry buildings", in J. Jasienko (ed) Structural Analysis of Historical Constructions, 2, Wroclaw, 1414-1422.

[6] *Direttiva del Presidente del Consiglio dei Ministri* (2011) Valutazione e riduzione del rischio sismico del patrimonio culturale con riferimento alle Norme Tecniche per le Costruzioni di cui al D.M. 14/01/2008.

[7] A. Giuffrè, Vulnerabilità e conservazione nel quartiere della Graziella in Ortigia, In *Atti del 5º Convegno Nazionale L'Ingegneria Sismica in Italia*, Palermo, 1995.