# Chapter 20
# Seismic Retrofitting for Masonry Historical Buildings:
## Design Philosophy and Hierarchy of Interventions

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## ABSTRACT

*The static and seismic retrofitting design, for masonry historical buildings, has to follow a right hierarchy of interventions, taking into account that to improve the seismic behavior of a masonry structure, it is necessary to guarantee a "closed box" behavior for the whole structural body or, in case of complex buildings, to guarantee a closed box behavior for each building's wing. Thus it is fundamental to distinguish the interventions for the global behavior improvement from those related to local reinforcements. In this chapter is then proposed a scheme of interventions hierarchy and, therefore, a related design process road-map together with the explanation of a correct design philosophy for the static and seismic retrofitting of historical masonry buildings. Moreover it is also reported an example of two distinguished levels of intervention, with numerical analyses supporting that solution.*

## INTRODUCTION

The choice of the techniques and the technologies for the static and seismic retrofitting of masonry buildings has to follow a right consciousness about the hierarchy of interventions: first of all they have to be designed interventions for the global behavior improvement, subsequently it is necessary to study the possible occurrence of intervention for local reinforcements of single structural element or substructures. Moreover, these two main "levels" of intervention have to be well combined to obtain a proficient mutual collaboration.

To obtain an improvement in the seismic global behavior of a structure, it is necessary to guarantee a "closed box" behavior for the whole structural body or, in case of complex buildings, to guarantee a closed box behavior for each building's wing. In this way the seismic action is distributed among

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the structural elements proportionally to their stiffness and each wall leaves to its orthogonal ones the seismic action component out of its own plane.

A "closed box" behavior may be developed, during a seismic action, only if they are guaranteed good connections among the vertical walls and among the walls and the floors (or vaults); moreover, the intermediate levels and the roof level need to have a good shear and axial stiffness and strength in their own horizontal plane.

Designing single structural element reinforcements it is necessary to understand if these elements may participate actively to the global seismic behaviour or the reinforcement has to work only for vertical loads and/or general static local loads.

In a global design view it is important to take into account the seismic behavior of the "non structural" elements also.

This chapter would like to give some suggestions about the right hierarchy among the structural interventions for seismic retrofitting and static rehabilitation. Moreover they are given some criteria for the design process, explaining some different and sub sequential design phases.

In addition, they are also described some of the more common "wrong" local reinforcement and retrofitting design solution with the wrong design processes that may cause them.

## BACKGROUND

The author of this chapter has experience in writing retrofitting guide lines for historical masonry buildings of villages damaged by the 2009 L'Aquila earthquake. Experiences reported in: Viskovic (2010).

Reviewing existing books, guide lines and rules, about structural restorations, reparations and seismic retrofitting, it is possible to notice as generally they describe the different typologies and techniques of interventions (often not very up-to-date), sometimes underling the possible reversibility or the compatibility levels, but without to define a clear hierarchical order among them.

The different importance of the diverse intervention typologies is generally not well explained despite the fact that many books, on masonry building seismic retrofitting, clearly underline that a better safety level may be reached with a structural "closed box" behavior.

On the contrary, the attention is generally focused on the single structural elements with their possible pathologies and on local or partial collapse mechanisms, without an overall view of the structural behaviors.

Moreover, many times the attention is "deviated" by an excessive attention given to the possible partial collapse mechanisms, forgetting that applying interventions devoted to reach a correct "closed box" overall behavior, they are avoided nearly all the possible partial collapse mechanisms.

Clearly, designers expert in the field of masonry structures know by themselves the correct intervention hierarchy and are able to follow a correct design process.

But after a big earthquake, when there is a large amount of buildings needing structural reparations and retrofitting, a lot of designers, many times not expert in masonry structures, are involved.

The author have checked several reparation projects and retrofitting projects, proposed to the authorities, showing not only not up to date solutions (often invasive and not compatible with historical masonries) but also wrong design processes. Reading analyses and design reports, it was often evident the empirical process of searching, by numerical analyses, the weaker structural elements and simply to reinforce them.

Some of these typical wrong processes and solutions will be illustrated in the paragraph on "Common errors in seismic retrofitting".

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