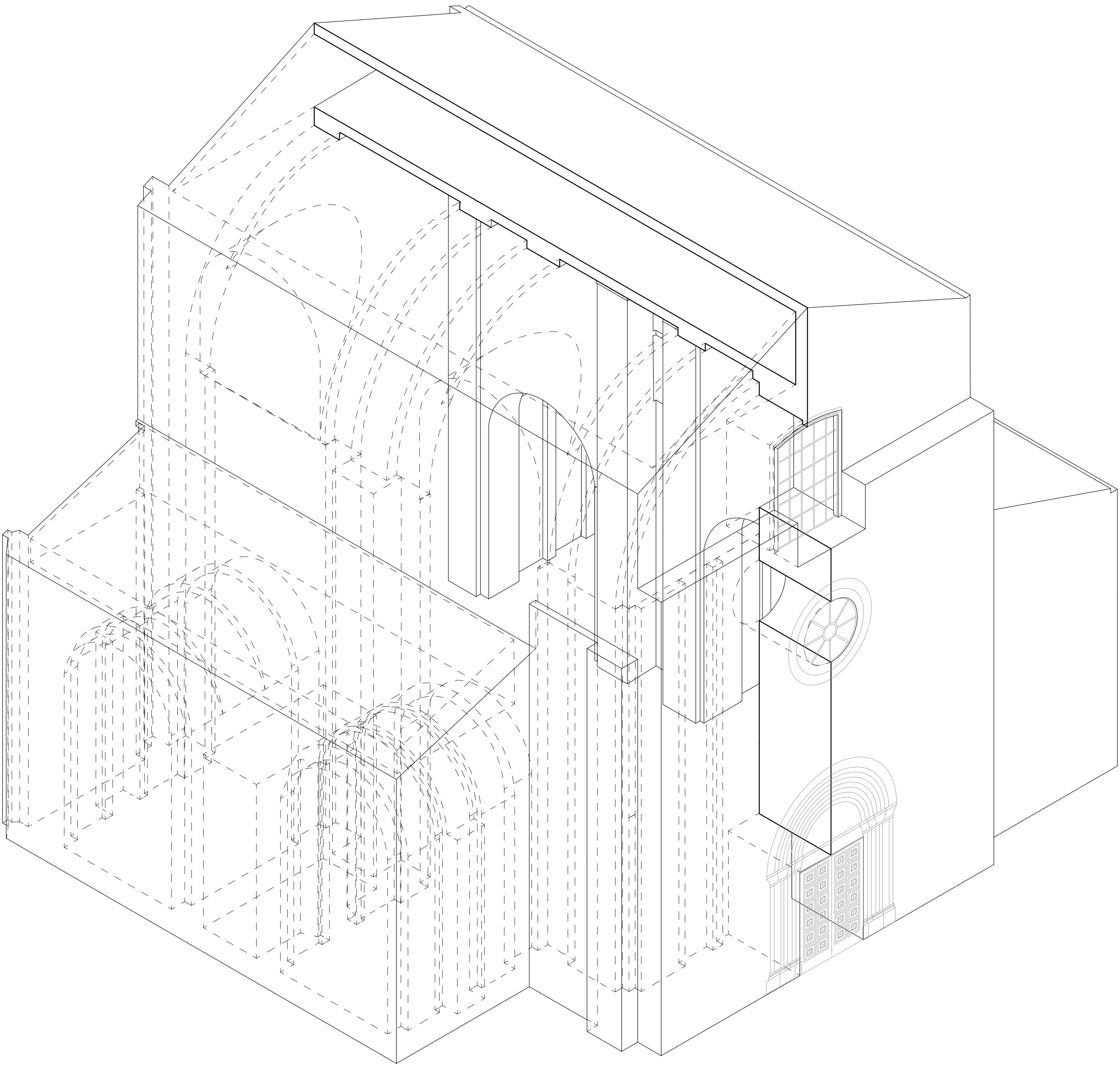
From The Ruin
To The Re-Birth

Or how an historical city center gets affected by an earthquake: a possible solution.



Research paper Architectural Engineering AE Intecture
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From the Ruin to the re-built

Taking into consideration the example of L' Aquila, a study of how an historical city center is affected by an earthquake: analysis of the current scenario and possible alternatives.

Abstract

The earthquake is an event that deeply shakes the history of a city and its neighbors. Reconstruction of the buildings becomes necessary to restore the city and to give back homes to its inhabitants. The reconstruction of an historical city center could take longer than expected and this could be as a result of many factors. In the duration of the reconstruction many years can pass and the perception of the historical city center can change irremediably; during this period, people can start to act in a different way in regards to the center and create new habits.

Municipalities and all the organisations in charge of the reconstruction should act against this to prevent the depopulation of the fragile system of a city center, even before the beginning of the massive rebuilding of the houses. In this paper, the events of the reconstruction of the Italian city of L' Aquila will be analyzed, taking it as an example of how an historical city center can be affected by an earthquake. The output of the research will be the analysis of a possible alternative scenario for the reconstruction which will be further explored in the second part of the graduation year (MSC4).

Key Words:
Reconstruction, Shoring Systems, Earthquake Architecture,Historical City Center, Seismic-proof Architecture, Masonry Building,Parasite Architecture, Symbiotic Architecture.

Contents

introduction

The historical center of the city of L' Aquila was shaken by one of the most destructive earthquakes of the 20th century on the 6th of April 2009. The main wave shaked the city at 3.32 pm when most of the people were sleeping and it had and intensity of 6.3 on the Richter scale of measure. This earthquake caused the damage of many buildings in the proper center of the city as well as in its periphery. L' Aquila could be taken as an example of a reconstruction that did not preserve life in the historical city center since even after seven years from the earthquake is still completely shored up with only a few buildings having undergone restoration. The case of the city of L' Aquila is peculiar among post-seismic reconstructions in the Italian territory but it shows also some major problems that have never been addressed thoroughly.
L' Aquila could be considered as the archetype of what could happen to an historical city center after an earthquake and it is the symptom of the false perception that we have of the earthquake itself. The Italian territory is often shaken by earthquakes but these are not really seen as an architectural threat for our cities. This misperception causes us to tackle each one of these catastrophic events in a different way. These differences among the actions taken to address the emergency of the earthquake could bring to mind great examples of reconstruction like the one of Friuli in 1976 and then again, inadequate ones like the one undertaken in L'Aquila. What this paper aims to analyze is the effect of an earthquake on the city center trying to face it as an architectural issue.

This research could be relevant to the case study of the city of L' Aquila as well as to other similar historical city centers affected by earthquakes. The aim is to try to analyze the earthquake not only as a catastrophic event but also as a challenge to address in a new architectural way so as to design efficaciously while minimizing the negative effect on the population as well as on the architecture of the city.

This research is part of a broader work for the graduation in Architectural Engineering AE. The aim of the intended design is to integrate the architect's view on the field of emergency works on earthquake-damaged buildings. The emergency phases of the reconstruction are often left to engineers or technicians who merely preserve the building without looking at the wider portrait of the city. The design phase, which will be based directly on the conclusions of this research, aims to unify architectonic and engineering knowledge to solve problems on different scales of architecture, from the building to the city.

Method

The research starts from the observation of the reality; the condition of the city seven years after the earthquake. Site analysis can provide tools to understand how the city behaved in relation to these years of difficulties and to speculate on what could have been done.
Literature analysis is at the base of the study of the most technical parts of the research and of the design.

Part 1

The first part of the paper will focus on the Analysis of the historical city center of L' Aquila. The story of the city will described as well as it reacted to the earthquake of the 6th of April 2009.


Google Earth


Legenda of important buildings and facilities of L' Aquila
Medieval castle
Perimeter of the former defense wall of the city. This defines aproximately the borders of the historical city center.
Corso Vittorio Emanuele, former "cardo" of the Roman settlement
Piazza Duomo
Fontana Luminosa
Villa Comunale
Comunal Swimming Pool and sport facilities.
Santa Maria Paganica Church

1.1seismic activity in Italy

1.1.1 Tectonic plates

The Italian territory has always been affected by earthquakes of various intensities. The earthquakes which afflict the Italian peninsula are caused by the movement of earth plates which slide one over the other releasing energy. Italy is crossed from north to south by the Apennines and just under this mountain chain is located the conjunction point of two plates: the African and the Indo-European ones. The two plates are pushed one against the other, the African plate moves towards north with the speed of a few millimeters per year. Where the two plates are in contact is the point in which the maximum amount of energy gets concentrated and when this energy is finally released, strong seismic accidents occur.
("I Terremoti in Italia I INGVterremoti" 2016)

Looking at the history of earthquakes in Italy, it is easy to deduce that there are places more affected by seismic activity than others. Some cities have been shaken by earthquakes multiple times during their history and their urban plans have therefore been shaped by a continuous cycle of destruction and reconstruction. The force which leads to the reconstruction of these cities is often the idea of a conservative reproduction of the buildings; this is the cause of the different layers of construction that can be observed in these cities.

Date	Area	Magnitude
08.09.1905	Calabria	7.1
23.10.1907	Calabria	5.9
28.12.1908	Stretto di Messina	7.2
07.06.1910	Irpinia	5.9
27.10.1914	Garfagnana	5.8
13.01.1915	Avezzano	7.0
17.05.1916	Mare Adriatico	5.9
16.08.1916	Mare Adriatico	5.9
26.04.1917	Monterchi_Citerna	5.8
10.11.1918	Appeninno Forlivese	5.8
29.06.1919	Mugello	6.2
07.09.1920	Garfagnana	6.5
07.03.1928	Capo Vaticano	5.9
23.07.1930	Irpinia	6.7
18.10.1936	Bosco Cansiglio	5.9
03.10.1943	Ascolano	5.8
21.08.1962	irpinia	6.2
15.01.1968	Valle del Belice	6.1
06.05.1976	Friuli	6.1
15.04.1978	Golfo di Patti	6.1
19.09.1979	Valnerina	5.9
23.11.1980	Irpinia	6.9
07.05.1981	Lazio	5.9
05.05.1990	Potenza	5.8
26.09.1997	Umbria	6.0

Table of strong earthquaked. Data from iside.rm.ingv.it

1.1.2 seismic activity in the 20th century

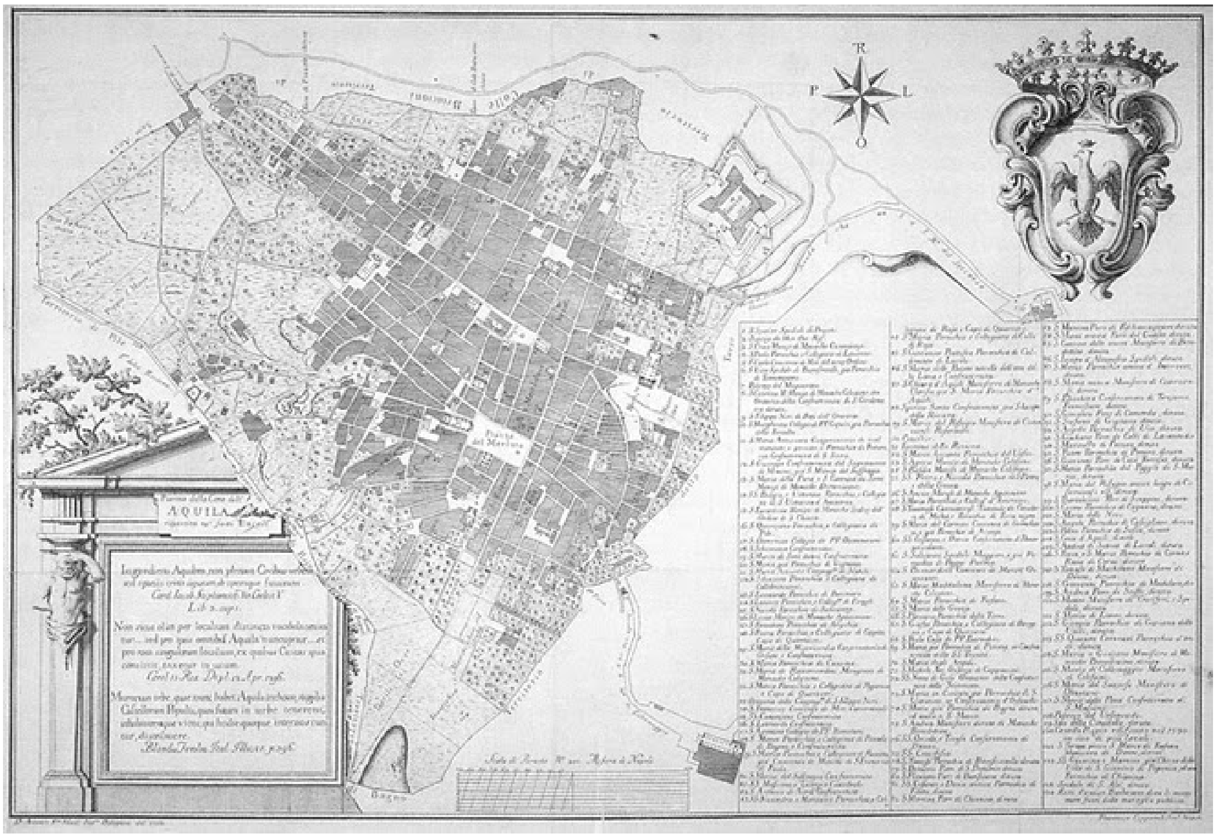
The Italian territory, has experienced major earthquakes during its history. The earthquakes with an intensity over the 5th grade of the Richter scale number up to almost 30, should we consider just the 20th century alone. Though these numbers would make one think that earthquakes are an ordinary problem in this region, Italy does not have a unified plan for the reconstruction of affected city structures. This lack of a common strategy means that every earthquake is taken as an isolated event and that different actions could be applied to solve the problems of each of these cities. Every city is of course a specifically defined and particular entity different from the other, but the history of the architectural urban analysis have proved that similar conditions and similar problems get repeated in these cities.
The earthquake should be considered as an urban problem, it is an emergency that affects the historical city center and it should be solved with method and strategy, the same as is done with other architectonic issues.

1.2 case study: the city of L’ Aquila

1.2.1 history of the city

L’ Aquila could be considered one of the most important medieval cities in the central part of Italy. The original plan was completed in around half of a century, from the middle of 1200 going on. The foundation of L’ Aquila was an event beyond the simple creation of a new city because L’ Aq uila is the head of what could be defined as a poli-centric system of villages. The city of L’ Aquila can be read on two different scales, on the one hand as the historical city center and on the other, as the center of its province consisting of 59 fractions. The city initially was designed on a land area of 157 hectares and it was divided into 4 parts. Each of these 4 parts was controlled by one of the founders, each of whom built a castle as protection for his territory. Those castles with their perimeter walls created a continuity between city and territory.

The entire city, as with many other Italian cities, was shaped over the years by a continuous cycle of construction and destruction both for seismic and war reasons. The first earthquake recorded in this city occurred on the 13th of December 1315.

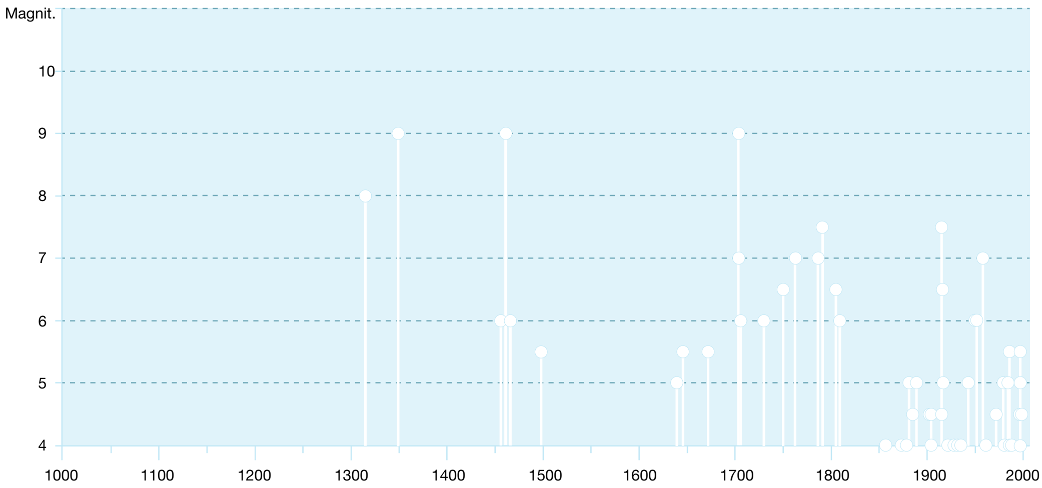


L’ Aquila, Plan from Architect Vandi 1753

After this earthquake the city was re-shaped on the base of 4 principal axes, but just 30 years later, in 1349, another destructive earthquake shocked the city and destroyed different churches and parts of the perimeter walls.

During the XIV and XVI centuries, the city saw its maximum expansion and acquired also its maximum power, becoming the middle point for economic exchange on the Florence-

Naples axes. The city's university was founded in 1458 and started to gain importance till it was comparable to those of Bologna, Naples and Siena.
The XVII century was a difficult one for the city in which it was conquered by Hispanic military forces, this put an end to the historical autonomy of the city while the plague, which broke



Earthquake in L' Aquila's History. Data from iside.rm.ingv.it

out in 1656, caused several deaths. The XVII century saw also the occurrence of two major earthquakes: one in 1648 and another in 1672. Other important seismic events were in 1702-1703: during these earthquakes, it was calculated that almost 6.000 people died and the entire city got destroyed.

After these years of struggle, just after the earthquake of 1703, the city began its rebirth. This is widely perceived as the onset of a new beginning for the city. During these years, there was a clear transition from a poly-centric city to a more Unitarian one, focused on the proper city center and following also the urban design imposed by Hispanics. There is a maintenance of the typical structure based on Cardo and Decumano, but with a different use and perception of voids and fill in the urban tissue.

In 1917, the Italian engineer Giulio Tian was challenged by the regulations put forward in the "Piano Regolatore", the paper which stated where to build and what to build inside the city. The condition that he had to face was the one of a city stuck on the model of XVIII century, with big urban voids inside of its perimeter walls which were pretty much intact after centuries. The new urban project was then focused on the inner part of the city, the one enclosed by the historical perimeter walls, with the aim to perform some punctual interventions and infill some city voids. This city plan would, in the end, not come to complete realization except for some interventions not completely connected with the general idea of the plan.

The final breaking point of the perimeter walls happened just during the fascist period with the construction of Viale Gran Sasso and the realization of the stadium. Together with the aforementioned, other important constructions of that period were the Fontana Luminosa, a fountain in the end of Corso Vittorio Emanuele and of the public swimming pool. To give space to these important public functions, a large part of the historical walls was demolished

and the expansion of the city towards the periphery commenced, maintaining however a fixed idea of a city center.
The comprehension of the importance of the city center in a city as L' Aquila is fundamental to understanding the significance of the effect of the earthquake on it and on the life of its inhabitants. The historical city center served as the main node for many public offices and public attractions that after the earthquakes had to move, leaving the city in a state of abandon.

(Comitatus Aquilanus and Frisch 2009) (Fonticulano 2011)

1 1.2.2 the earthquake: how the emergency has been managed

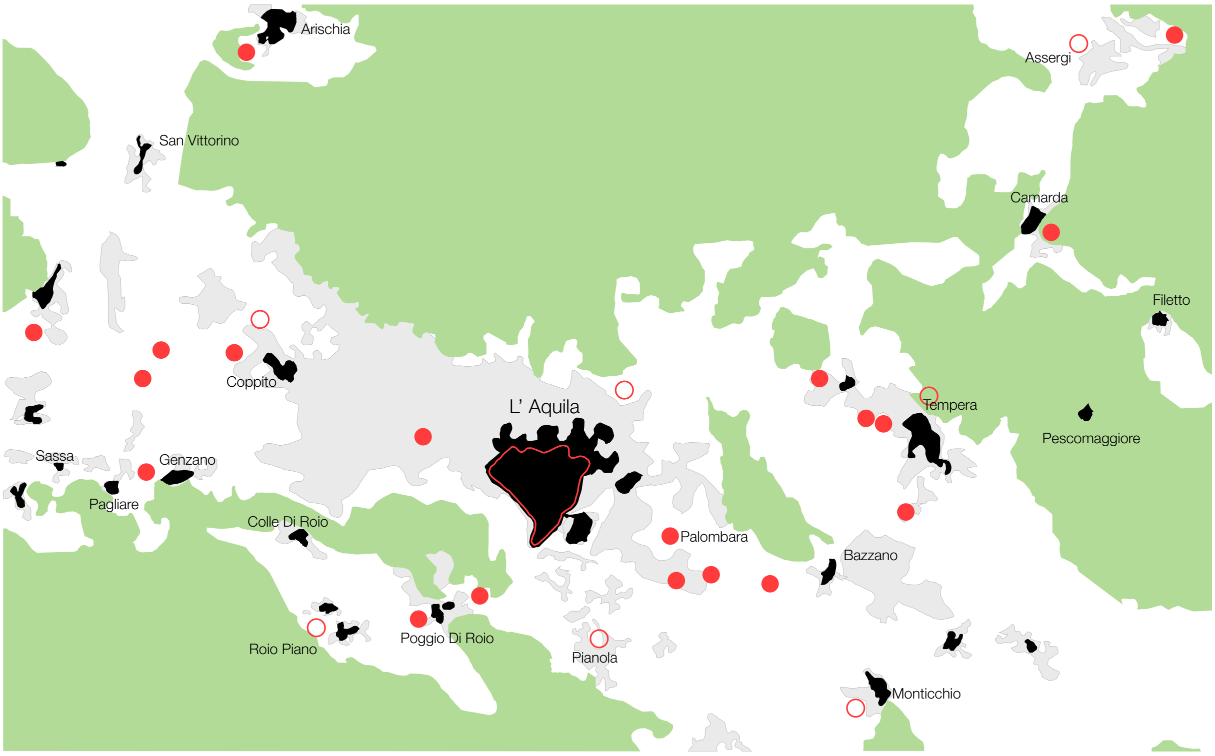
After the earthquake of 6 April 2009, it was clear from the beginning that the priority was to limit the amount of people without homes. To do this, it was necessary to have a clear view on the state of the buildings after the earthquake, to define which ones could be used immediately because they were not seriously damaged. Secondly, it was useful to fix the buildings which did not have major damages to further diminish the number of homeless. In the end, it would have been necessary to evaluate the cost of the reconstruction and think about the possible strategies to rebuild in an efficient way.
Beside the fact that in Italy, as already said, there is not a real plan for the reconstruction of an historical city center, over the years, different earthquakes have taken place and some common practices seem to have incorporated into the standard method of work of the reconstruction. For the earthquake of L'Aquila, besides the initial estimation of the damage, nothing of what has been done for previous earthquakes has been implemented.

The Historical City Center

Ignoring all the polemics that were raised concerning the case of the reconstruction of this historical city, what is clear and evident is the fact that a plan for the reconstruction of the city center was not put in place. The city center, until the 6th of April 2009 was still one of the most important places for this distributed city and it hosted 15% of the population of the entire city. In 2001 the population of the city center was 10.400; this number does not include all the students who lived in the center as non-permanent residents. This number could be assumed as almost 6000 persons. The importance of this part of the city was represented by the 800 commercial activities, professional studies and some important public service offices that were housed in this area.

The work of the reconstruction seemed to be carried more on the idea of a fast rebuild of the houses than one involving planning for the re-population of the center. There has been a total absence of choices for the purpose of the reestablishment of the initial conditions in a fast way. Looking to the previous experiences in which the historical city centers got destroyed, some actions, such as the creation of unions among the owner a of the buildings, were done to help towards the long process of reconstruction. In this case, the attention was more focused on the creation of new houses, completely detached from the historical city center to give a house in the fastest way possible to all the homeless. This project was called C.A.S.E. and it is one of the most discussed architectural/urban projects of the last 50 years in Italy.

The C.A.S.E. Project



Legenda

Villages and settlement — *Historical city center*

Green — *Built interventions*

Damaged places — *Planned interventions*

Data elaborated from the documents of "Protezione civile" 6 April 2009

The reconstruction of the city of L' Aquila has been handled mainly through the construction of new houses thought to be the asylum for all the people who lost their homes. These houses, built with all the modern techniques in the field of the earthquake-resistant construction, were constructed in a fast manner according to the situation of emergency.
The planning of this new construction seemed to be done without any consideration for precise urban analysis. If we look to this construction in plan we immediately understand that they were localized on the blank spots between the villages around the city center. These spots were not strategically decided on the basis of an urban analysis and this brought with it the creation of new problems, unknown by people who used to live in the city center.
People used to living in the characteristic thigh tissue of an historical city had to get used to life in a context more similar to the urban periphery. This type of urban planning brought with it the problems of most of the Italian peripheries such as crime, lack of places for social gatherings and attractions, and a bad public connection with the main center.

1.2.3 the earthquake: how the reconstruction has been managed

Reconstruction is a complex theme that has been addressed after every major earthquake in Italian history. The reconstruction of the historical city center of L' Aquila is, among others, one of the more controversial ones particularly for the decision to build new houses instead of restore the old ones. So as not to take a position that could be interpreted as a polemic view on the reconstruction, I would like to talk about it stating what I observed in my travels in the city seven years after the earthquake.

The city center of L' Aquila, seven years after the earthquake, can be described as the biggest contruction work site in Italy and maybe one of the biggest in Europe. The entire perimeter of the center is fenced and there are plenty of cranes that surround the city as a metal forest. Walking through the streets, it is evident that this reconstruction is taking place just on specific zones of the city while all the other parts are just shored up, waiting to be rebuilt. The main Corso, Corso Vittorio Emanuele, has been 50% reconstructed on the part that faces the Fontana Luminosa IMG, although the entire Corso is completely untraversable, neither by foot nor by car. Taking a walk from the principal Corso to its crossroads it becomes evident that as of yet, work has not been started in most of the buildings in the center and that should the reconstruction continue at this speed, it could take still many more years to be completed.
The city center, being a large construction site, is generally inaccessible to the public, the only persons that can be found walking in the streets are the workers who oversee the reconstruction and some office workers who decided to come back and use their office spaces in the center. The life of a normal city center has been erased, since many years have passed and many more years will before the end of the reconstruction. It is possible that the set of habits, which make a city center what it is, will never again be repeated. The most serious threat is to the "functional attractions" of the city center. At the time of the earthquake, the city center of L'Aquila was the location of a significant number of importantoffices and

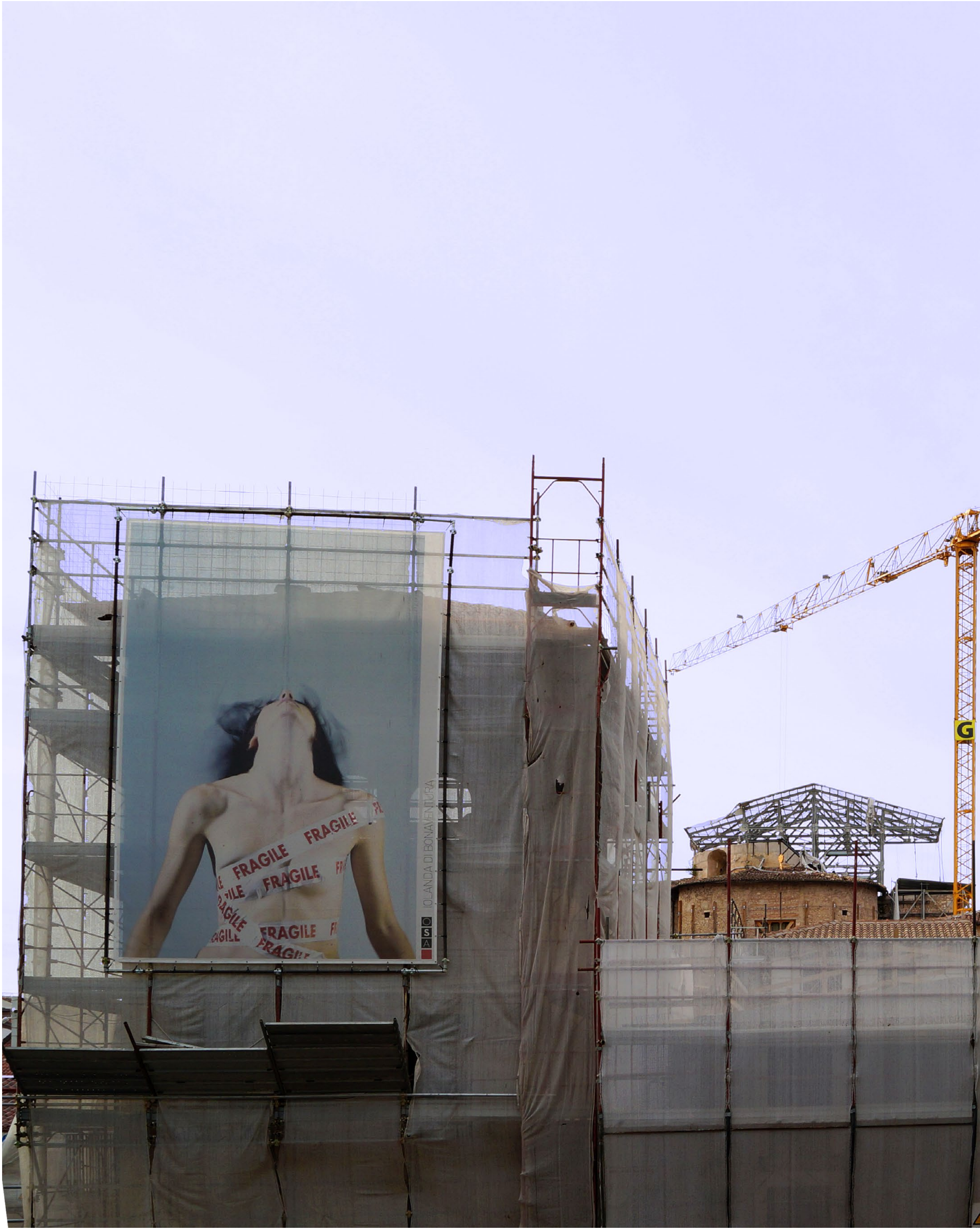
L' Aquila, Metal Forest, October 2016. Picture By the Author

L' Aquila, Street-Work field, October 2016. Picture By the Author

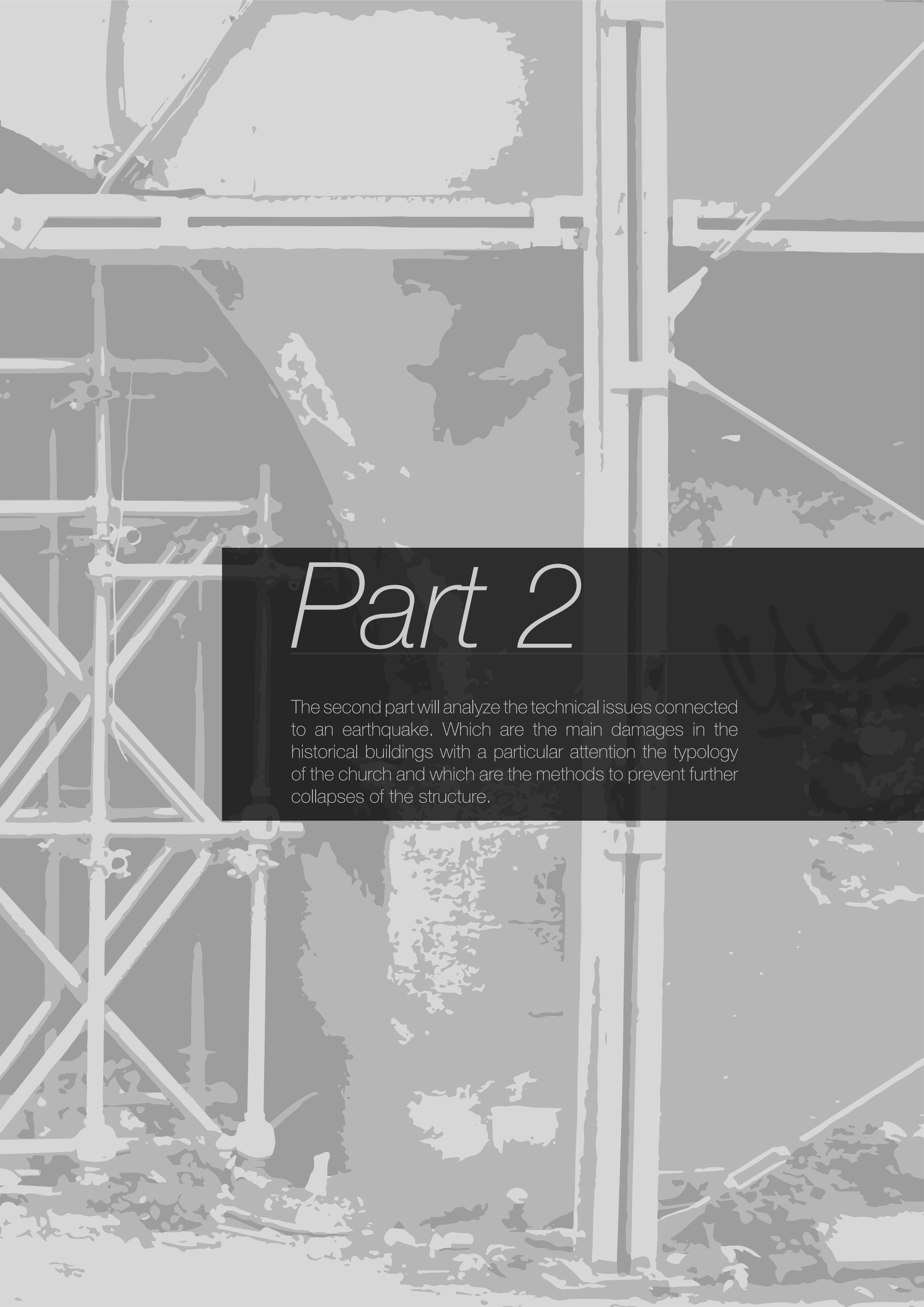
L' Aquila, Paganica New Town, October 2016, Picture by the Author

functions for the life of the city. These "functional attractions" served in defining the city center as an important point of aggregation. Today, as a proof of this loss of habits, we see that the few buildings which are restored remain unsold. The city center today is no more an attractive spot; people changed their habits and moved their business somewhere else.

The precious balance of life in the city center is today corrupted. It could return in some years. However, different and better measures to preserve it could have been taken. I think that the key to protecting the ecosystem of the city center lies in a fast intervention on some buildings. Therefore, an analysis of their damage and on the shoring up systems employed, the first actions taken to sustain them and prevent total collapse, is needed. Shoring systems are emergency actions taken to prevent the collapse of a building, but in an historical city center, which has the peculiar characteristic of a thigh urban tissue, this could become more dangerous than useful. The historical city center, when shored up, is just stuck in time: it cannot be used by people as it was before and it is not the subject of the reconstruction. The aim of the research is to give meaning to this transition time between the damage and the reconstruction. To do this is fundamental to having a clear picture of all the possible damages and corresponding solutions. The comprehension of damages and solutions can bring to fore other possibilities for the shoring systems that could become more of an architectural element and less of an emergency one.



L' Aquila, Fragile, October 2016. Picture By the Author



Part 2

The second part will analyze the technical issues connected to an earthquake. Which are the main damages in the historical buildings with a particular attention the typology of the church and which are the methods to prevent further collapses of the structure.

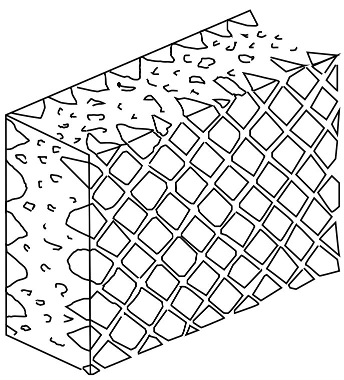
2.1 Damages of the buildings

2.1.1 types of buildings

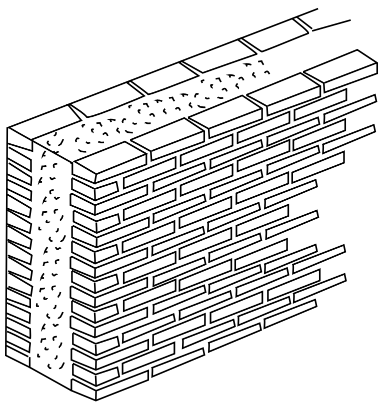
Trying to define the typology of buildings of a city could seem a difficult task because of the heterogeneity of the city proper, but this chapter will describe the most common constructions among this large variety. The scenario of the construction methods in the city of L' Aquila is variegated because of the stratification that the city faced during its history. The continuous succession of destruction and reconstruction, as well as the influence of different regimes on the city, brought not just different architectural styles but also different construction systems. This chapter will be focused on the typology of stone masonry, its major defects and seismic responses.

Stone Masonry:

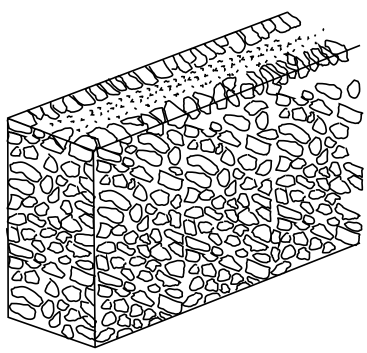
Stone masonry is one of the most used construction systems in the old historical city centers in Italy which saw its birth during the Roman period. The Romans cut stones and built walls out of them with or without the use of some binders. This wall technique has been maintained over the succeeding centuries and was modified in the Middle Ages. During this period, this construction technique was exploited at its maximum. The Middle Ages, being characterized by a lack of knowledge in the different fields of art and construction, brought some deviations to this construction system as well. The walls constructed in this period were built to resemble the Roman constructions, and did so with varying levels of success. They were however more fragile because they were not built following the precise methods used previously by the Romans. If we consider a medieval stone wall, despite the outer layer of stones, which should have precisely cut stones to look aesthetically pleasing, the inner part is in many instances infilled by other types of stones. These other types of stones were, in the medieval period, mainly ruins of older roman walls or in general, ruins of masonry. This type of construction system ,which is known as “muratura a sacco”: the two-sided wall, was used as casting for the mixture of bricks, smaller stones and lime, and could be done in Opus Incertum, Opus Reticulatum or Opus Testaceum. This technique was quite popular for the construction of big buildings and churches.



Opus Reticulatum Made with the Technique of Muratura a Sacco

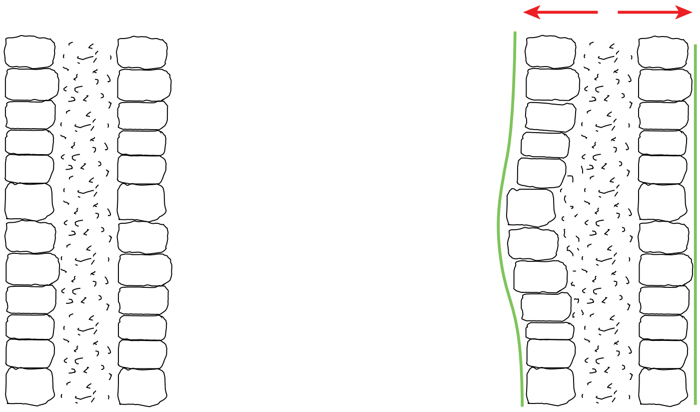


Opus Testaceum Made with the Technique of Muratura a Sacco



Opus Incertum Made with the Technique of Muratura a Sacco

The Muratura a Sacco is one of the most frequently used techniques and it can be recognized in the historical buildings in L' Aquila and in Italy in general. This technique brings with it a certain range of uncertainty in seismic capacity. The capacity of stone masonry buildings to resist to an earthquake is very closely linked to the quality of its walls. Even though stone masonry buildings could be considered less resistant than other construction methods, studies have proved that the quality of the stones, their placement, the type, the binder used, and so on, are all characteristics that greatly influence the behavior of a wall during an earthquake.

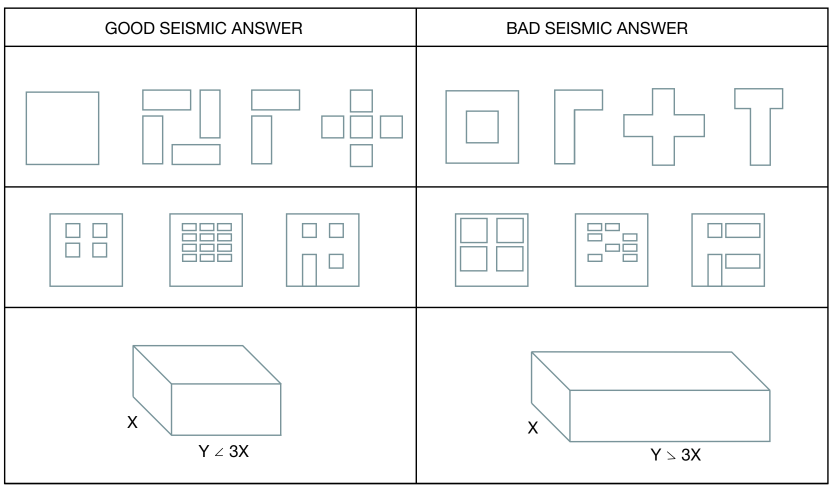


Buckling of the Muratura a Sacco caused by its high uncertainty in the masonry and by seismic lateral loads. This type of damage is hard to foresee

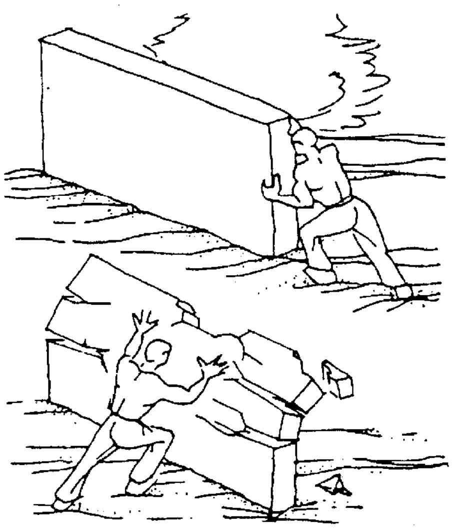
Analyzing stone masonry uncertainty, which is strictly related to its construction accuracy, it is clear that the Muratura a Sacco with its inner layer of reused bricks and stones is difficult to characterize in terms of its seismic behavior. Fortunately, we define a standard approach to buildings damaged by earthquakes because damages get repeated in similar structures built with similar techniques. The analysis and the comprehension of the damages of the buildings can provide a useful portrait of how to act both in a preventive and in a restorative work.

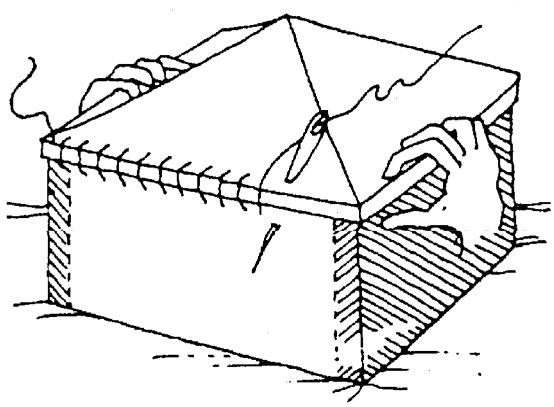
2.1.2 Types of damages

In this chapter will be described the main damages that can be found on historical stone masonry buildings, focusing attention on churches because the church typology could be the most interesting for the further development of a reconstruction project.



Besides the composition and the type of wall used, there are other characteristics that deeply affect the seismic behavior of a building. It is useful to see, in principle, which are the main features of a good earthquake-proof construction to better understand the further examples on churches.
First of all, one of the main characteristics to take into account for the construction of a building in a seismic zone is the shape. The shape influences to a great extent the behavior of a building; buildings with symmetrical or regular shapes have a better response to earthquakes.
As we can see in the table(fig) there are shapes that better respond to earthquakes just because they are more reliable in transferring the energy of an earthquake in a uniform way. In principle, the perfect earthquake-proof building should have a "Box Behavior". This behavior represents the comportment of a building that acts as a closed box against the forces on the different parts of its structure and distributes the horizontal forces of an earthquake in a correct and efficient way to counteract the seismic moment.





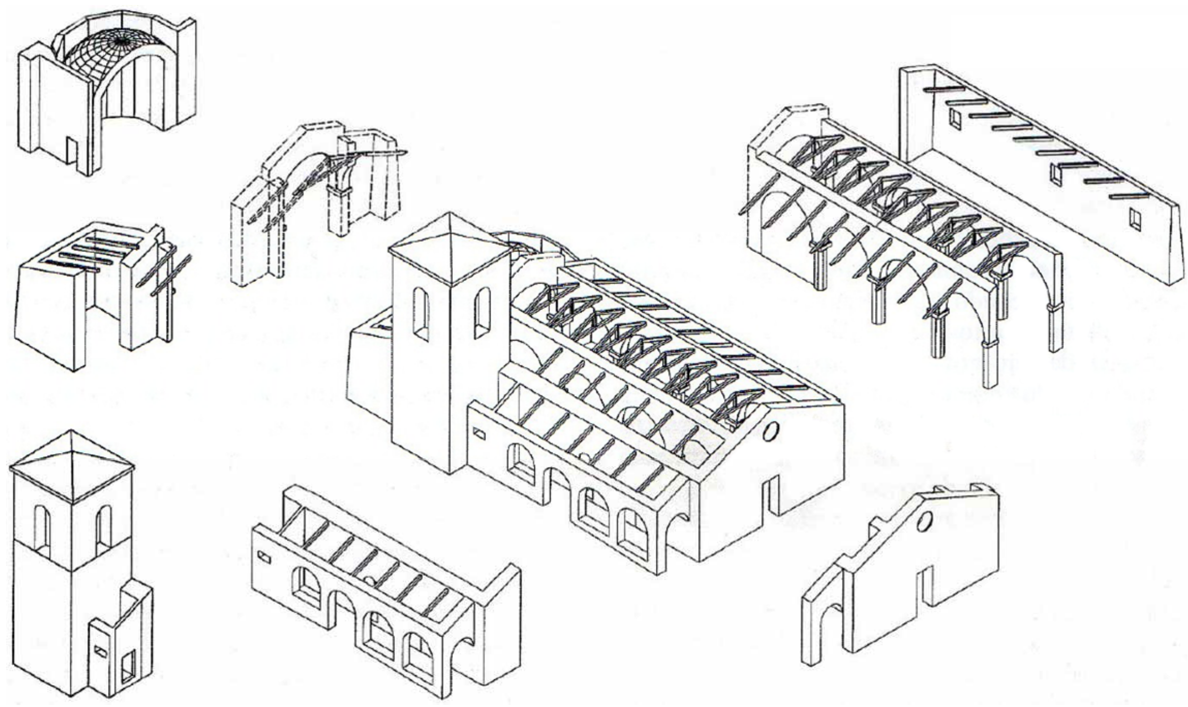
Box behavior, Giovannetti, F. Mazzotti

Regarding building in masonry, there are some rules that should be followed to preserve the safety of the structure. First, the ceiling must act as a unique and undeformable structure. This characteristic renders the whole construction more resistant to lateral loads; the ceiling, acting as a continuous conjunction between all the walls helps to redistribute the force. This conjunction function is sometimes absolved in the historical buildings by structural chains, placed in correspondence to the ceiling and near the perimeter wall, although chains have just tension force and do not have any compression resistance. Another important characteristic that should be considered in a design of an earthquake-proof structure is the length of the walls. The masonry walls work as a bracing system in the direction parallel to the wall, but if the orthogonal walls do not have a right proportion in length they are unable to withstand the pressure of the lateral walls..

TTo design an efficient earthquake-proof building, it is necessary to create the biggest

number of conjunctions between the single elements of the construction but this does not always happen. The construction of the historical city centers could be affected by a lack of knowledge or a lack of memory of earthquakes in the area. In the past centuries, if there had been a long period in which there no earthquakes had occurred, people started to build houses and other constructions without considering this factor and once there was another earthquake, these constructions were seriously damaged or destroyed.
(Boer 2015)

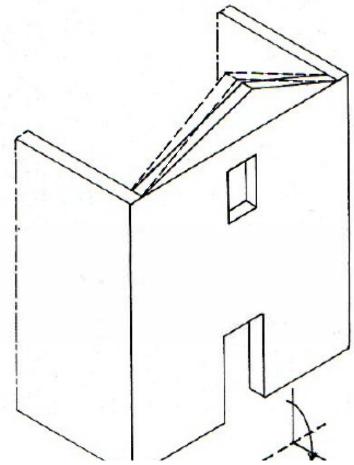
If we look at the typology of the church, there are several different types of damages that we can recognize. Since we know, as previously mentioned, that the different types of damages inflicted are a function of the shape of the building, we know that we can categorize those on churches because they appear different times in similar ways.

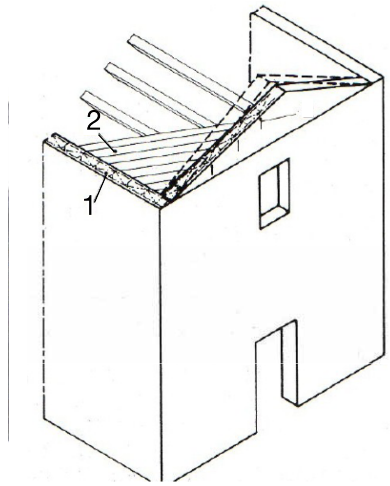


Church parts, Giovannetti, F. Mazzotti

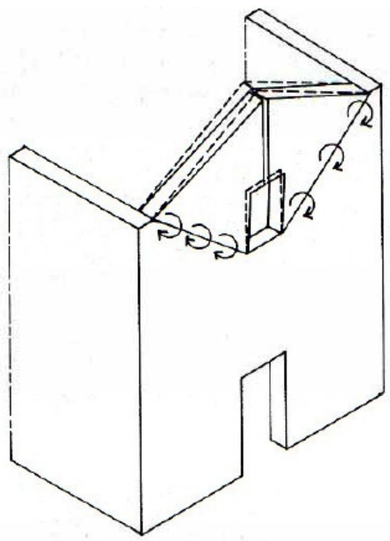
Damages of the facade:
The facade of a building, especially of a church, is a particular architectural element since it is different from all the other walls in the building. All the characteristics of church facade, such as its big windows, the high tympanum and proximity with the bell tower, could create a series of weaknesses in the structure**.**

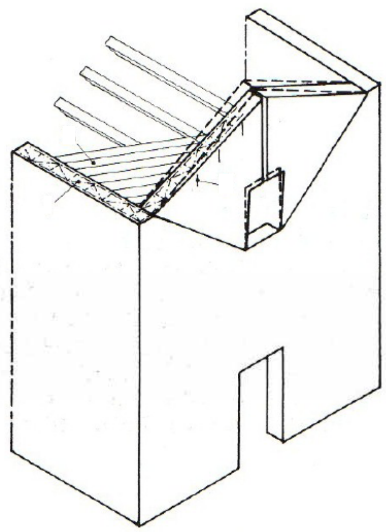
Rotation outside the plane of a tympanum around a horizontal axis.
This type of damage could be caused by a lack of joints between the body of the facade and the tympanum, a reduced thickness in the tympanum itself, or a roof that is not well braced and creates localized forces that push against the tympanum. When the building is affected by forces orthogonal to the façade, the tympanum rotates around its axes of conjunction with the facade.
To solve this problem, during the reconstruction it is necessary to reinforce the connection among the walls with a curb(1)that could run all around the top. Creating an efficient connection between the tympanum and the wood purlins(2) could be useful as well as for making the pitch of the roof more rigid and connecting it with the top curb.





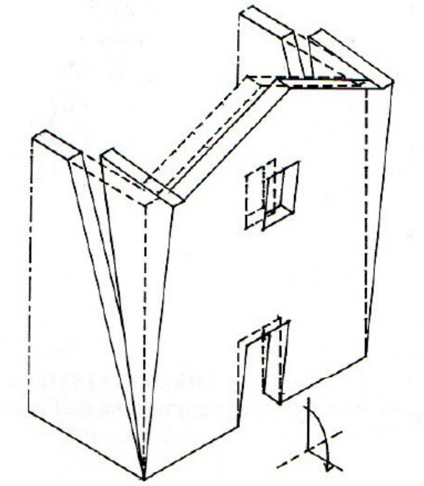
Rotation outside the plane with the creation of hinges with oblique axes.
This type of damage is close to the one described above but the damage appears in a different location on the facade since there is a void that creates a weakness in the body of the wall and makes the facade rotate along the axes that connect this void/window with the joints of the tympanum. The steps to take to solve these problems are the same as for the example above.

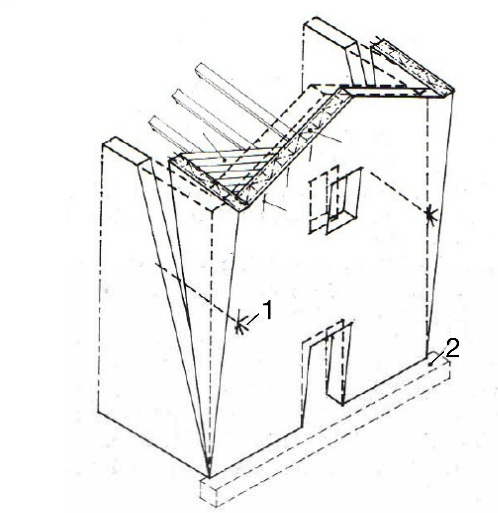




Overturning of the facade with creation of a cylindrical hinge at the base.

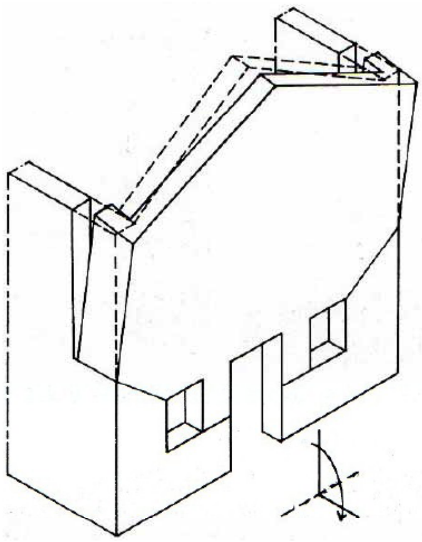
This type of damage is caused by an inefficient link between the wall parts that can cause a discontinuity in the construction. This type of damage can be solved utilizing the same methods described for the examples above in addition to the insertion of structural chains at 2/3 of the height of the building*(1)* and reinforcing the foundation at the base of the façade*(2)*.

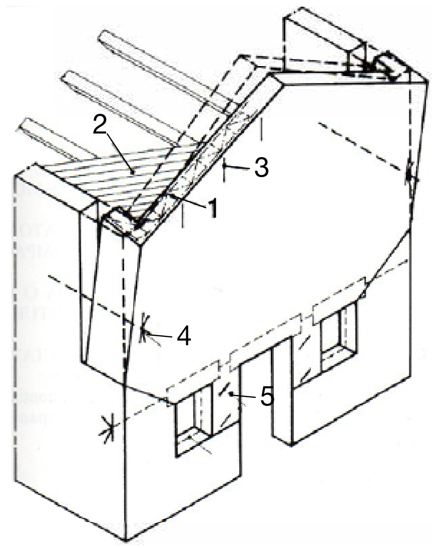




Rotation outside the plane with creation of cylindrical hinge in the bottom part of the façade.

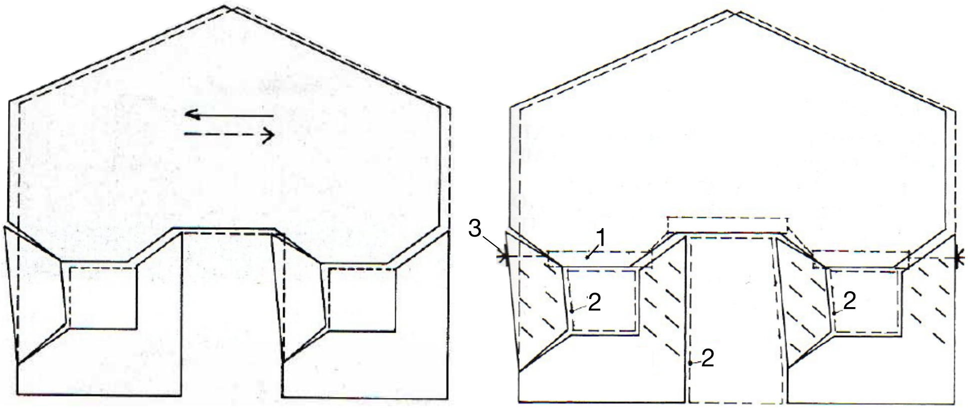
This type of damage can appear because there is a high proximity between the openings in the facade. These openings may also cause further damage because they cannot withstand the weight of the upper parts of the facade. As a solution to these damages, it is useful to put a curb*(1)* that runs along the top part of the construction, connect the purlins with the tympanum*(2)*, reinforce the pitch roof*(3)*, put structural chains in facade*(4)* and reinforce the openings with a steel framework*(5)* or with fiber-reinforced mortar.





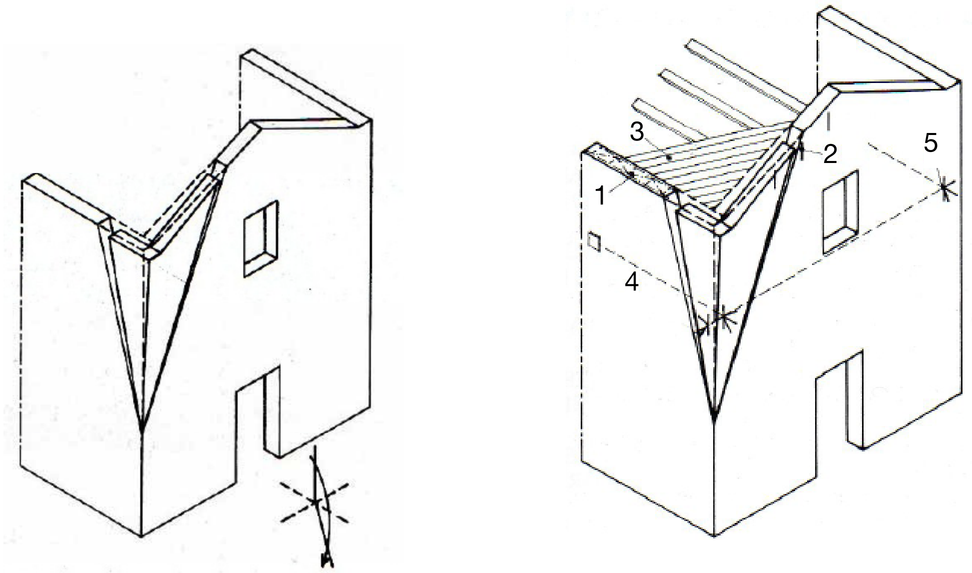
Broke of the façade.

This type of damage is caused by a too close position of the aperture on the façade or by a disproportion between the upper wall and the aperture on the lower level of the façade. In general, this type of damage can also appear due to a good connection between the tympanum and the lower part of the wall. This connection prevents the overturning of the facade but still causes serious damages. To solve this type of structural problem, a structural reinforcement on the lintel(1) is needed as well as some structural reinforcement in the aperture in the form of metal rings or fiber reinforcements(2).Position of structural chain(3).



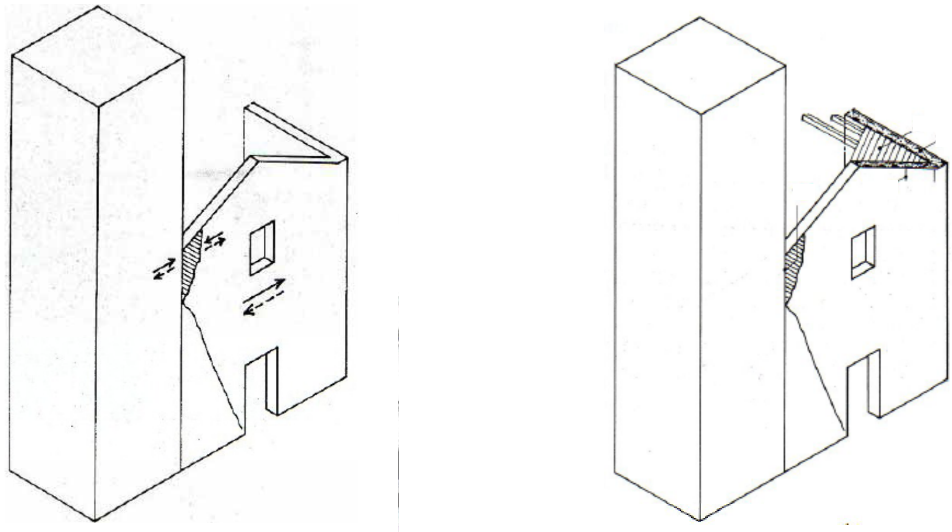
Expulsion of the angular.

This type of damage is peculiar, it presupposes a precise force that pushes in that angular zone of the roof. This force could be caused by a particular shape of the wooden roof or by the presence of volte a crocera which usually have links in the angles. To solve the situation a top curb could be placed(1) and the connection between façade/walls and roof should be reinforced(3). Additionally, make the pitch roof more resistant and connect it with the curb(2), place some structural chains perpendicular among them and parallel both to the side walls and the façade at 2/3 of the height of the façade(4,5).



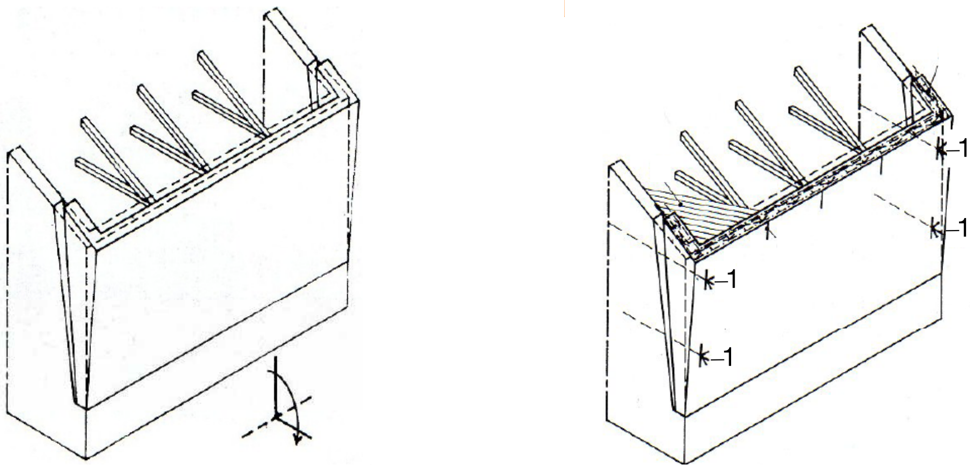
Interaction with the bell tower.

Seismic waves can cause different vibrations in buildings that have different shapes and weight. This characteristic can cause major damages if two volumes are in touch, such as the tower bell and the façade of a church, because they vibrate on a different period. The main action in this case, besides the normal reinforcement on the damaged facade, is them separation of the two bodies to let them react autonomously to the earthquake.

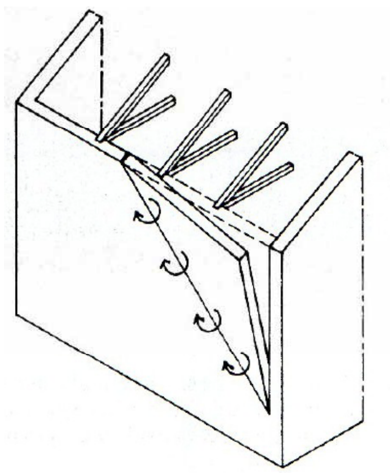


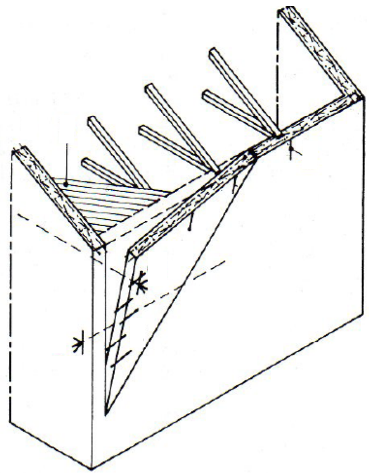
Damages on lateral walls:

Rotation outside the plane of the lateral wall will result in the creation of a cylindrical hinge at the base.
This type of damage is created by a force pushing on the side of the wall. This force can be caused by a volt or a continuous pushing of the roof against the top of the side wall. Besides the already prescribed actions, such as the installation of a top curb, reinforcement of the connection between walls and roof, reinforcement of the roof and so on, it could be useful to place a couple of structural chains on each side of the wall(1); one should be placed at 2/3 of the height of the wall and another in correspondence with the starting point of the arches.

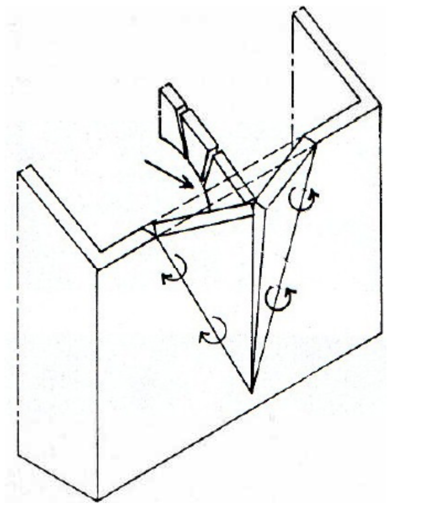


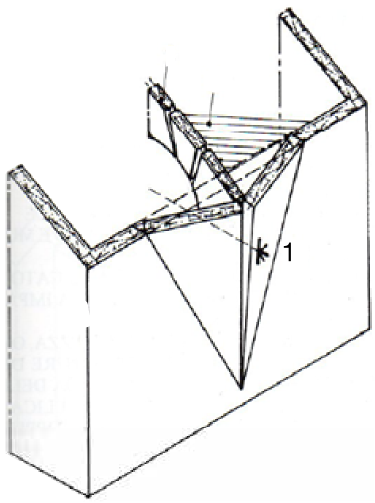
Displacement outside the plane of lateral wall, well linked on two sides.
This kind of damage appears after the walls lose their connection on a side, generally the one on the façade. Besides the already explained intervention, it could be useful to inject the wall to consolidate the conjunctions between the stones.





Localized push of a transversal arch.
This damage appears when the arch is not well linked to the wall. To solve the problem, it is necessary to place a structural chain in correspondence to the base of the arch and the wal*l(1)*.





(Giovannetti, F. Mazzotti, P. 2007)

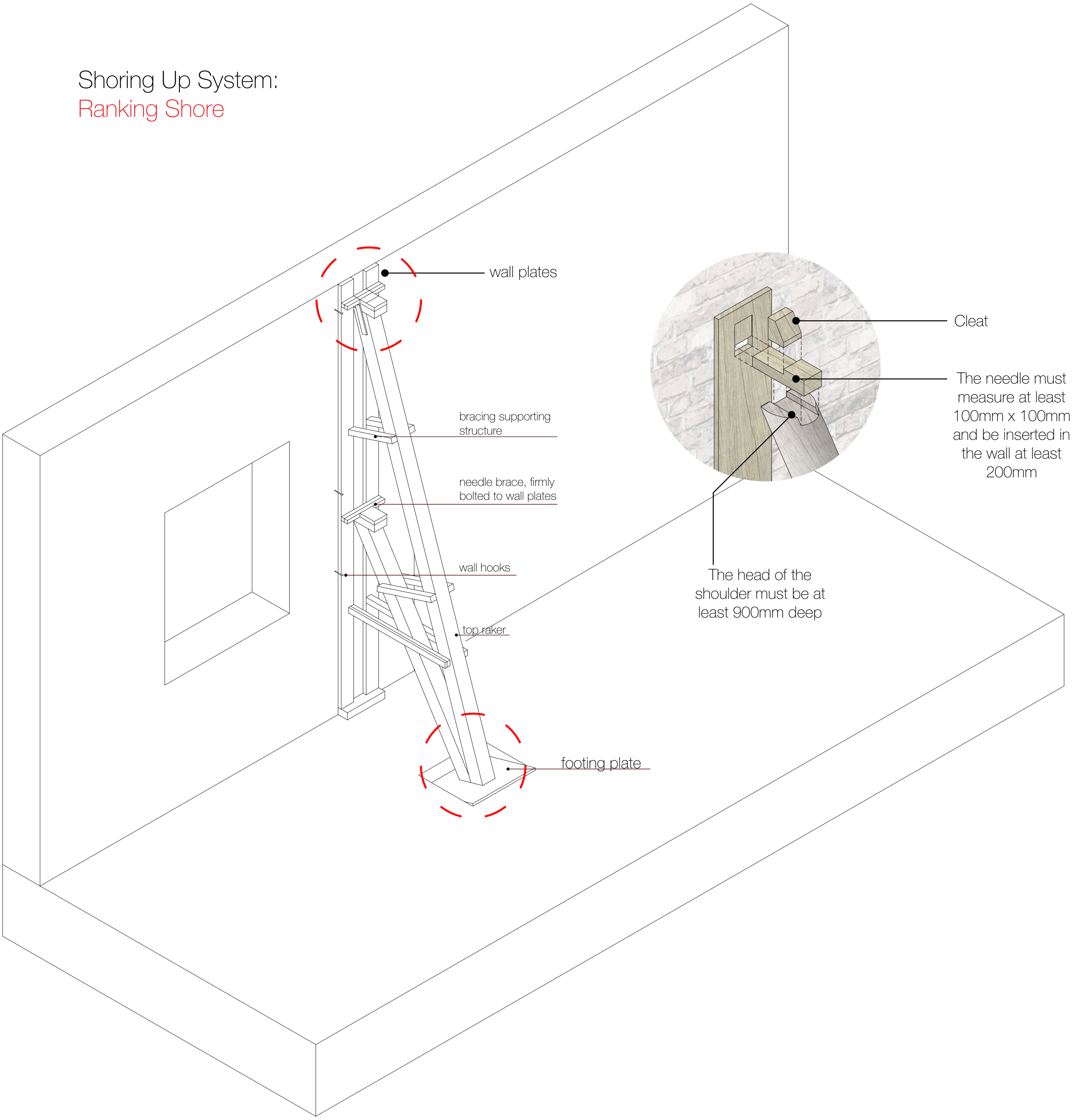
2.1.3 Types of shoring up

After the occurrence of a damage, the first thing that should be done to prevent further damages on the building is to shore it up. There are different types of shoring systems and these are related to the types of damage that must be solved and according to the context in which the intervention takes place. In this paragraph, the main types of intervention that are used in the Italian territory and in the city of L' Aquila will be described.

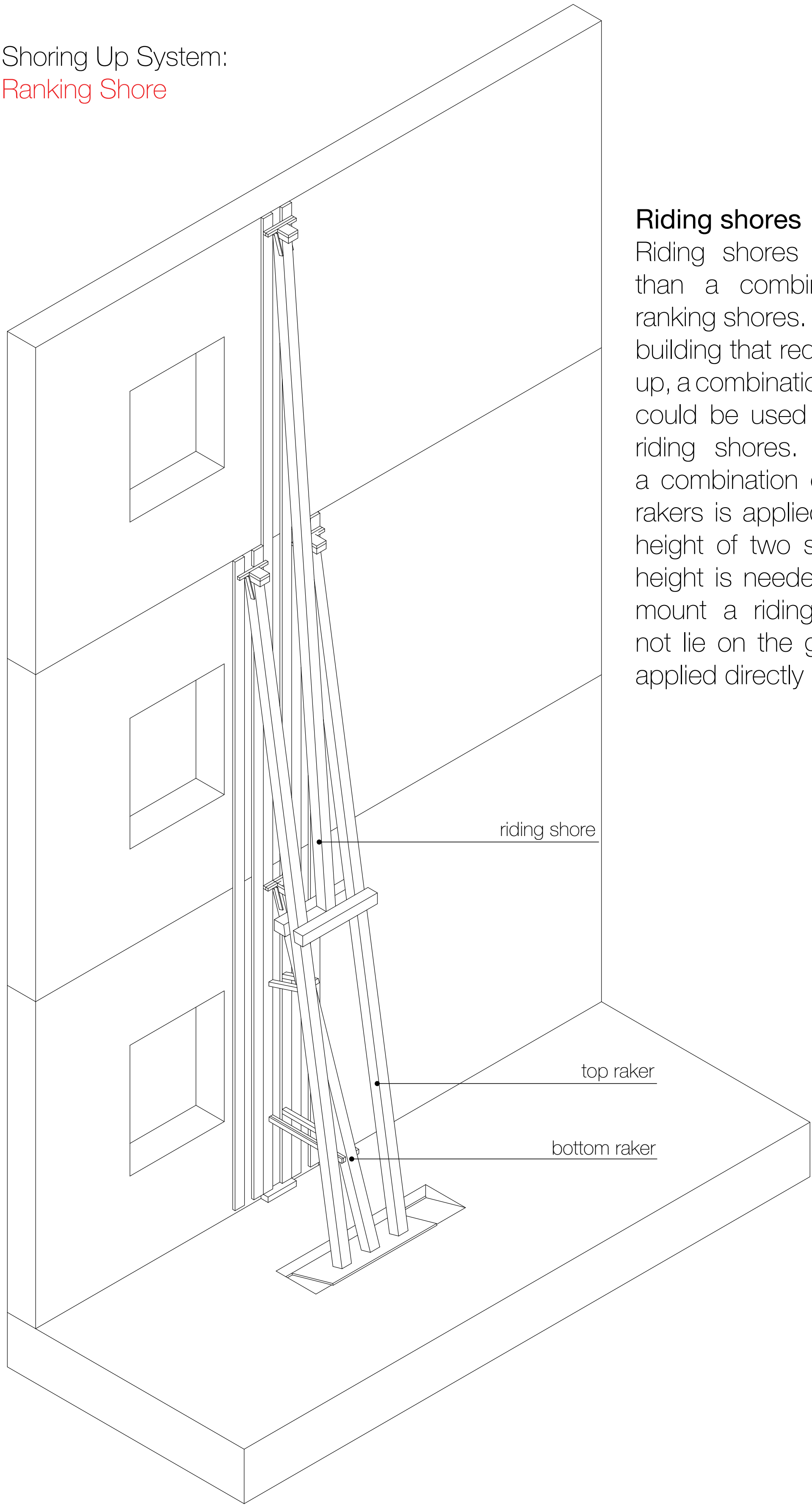
Ranking shores
Ranking shores is the most typical way to shore up a building. This type of shoring is used all around the world because of the simplicity of its construction and because it is adaptable to different materials, from wood to the metal beams for the scaffolding system. Ranking

shores is usually constituted of inclined beams called boritis, these boritis have the function of supporting a wall that has started to lean or bulge. The efficiency of this ranking is at its maximum when the poles reach the wall at an angle of 60/70 degrees. This inclination is conditioned also from the space around the building, in thigh packed old towns this angle can be reduced or other systems could be used. In general, this type of intervention is always coupled with dead shore as well to provide sufficient support for the structure.

Shoring Up System:
Ranking Shore

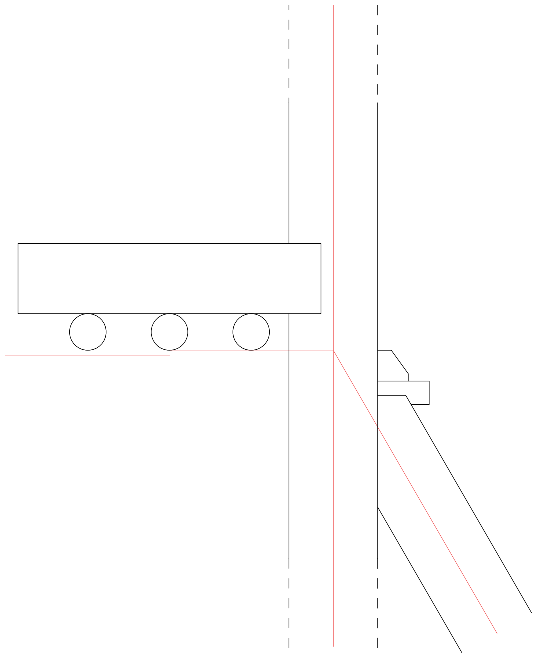


Shoring Up System:
Ranking Shore



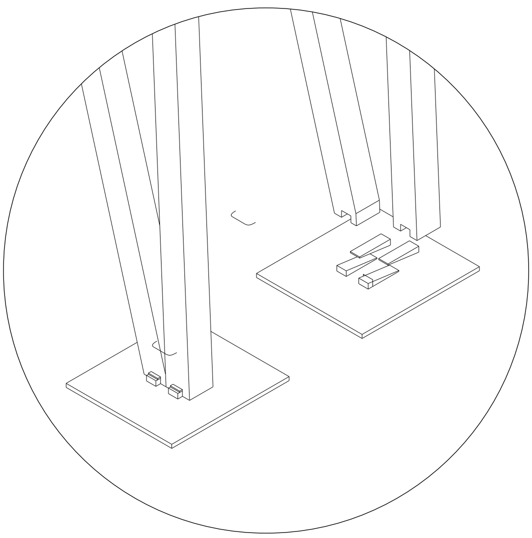
Riding shores

Riding shores are nothing more than a combination of multiple ranking shores. When there is a tall building that requires more shoring up, a combination of ranking shores could be used and they become riding shores. On tall buildings, a combination of bottom and top rakers is applied to shore up till a height of two stories, if a greater height is needed, it is possible to mount a riding shore that does not lie on the ground but can be applied directly on the top rakers.



Detail of the head

The head of the raker should be designed to act in a specific way to transfer the maximum amount of force possible from the wall to the ground. The point of application of the racker should be in line connecting the bottom of the ceiling of the building that must be sustained and the wall. It is important to place the head of the racker in this place because it is in this location that most of the load is concentrated. The head needle should also enter in the wall for at least 20 cm to assure the best mechanical friction with the building.



Detail of the footing

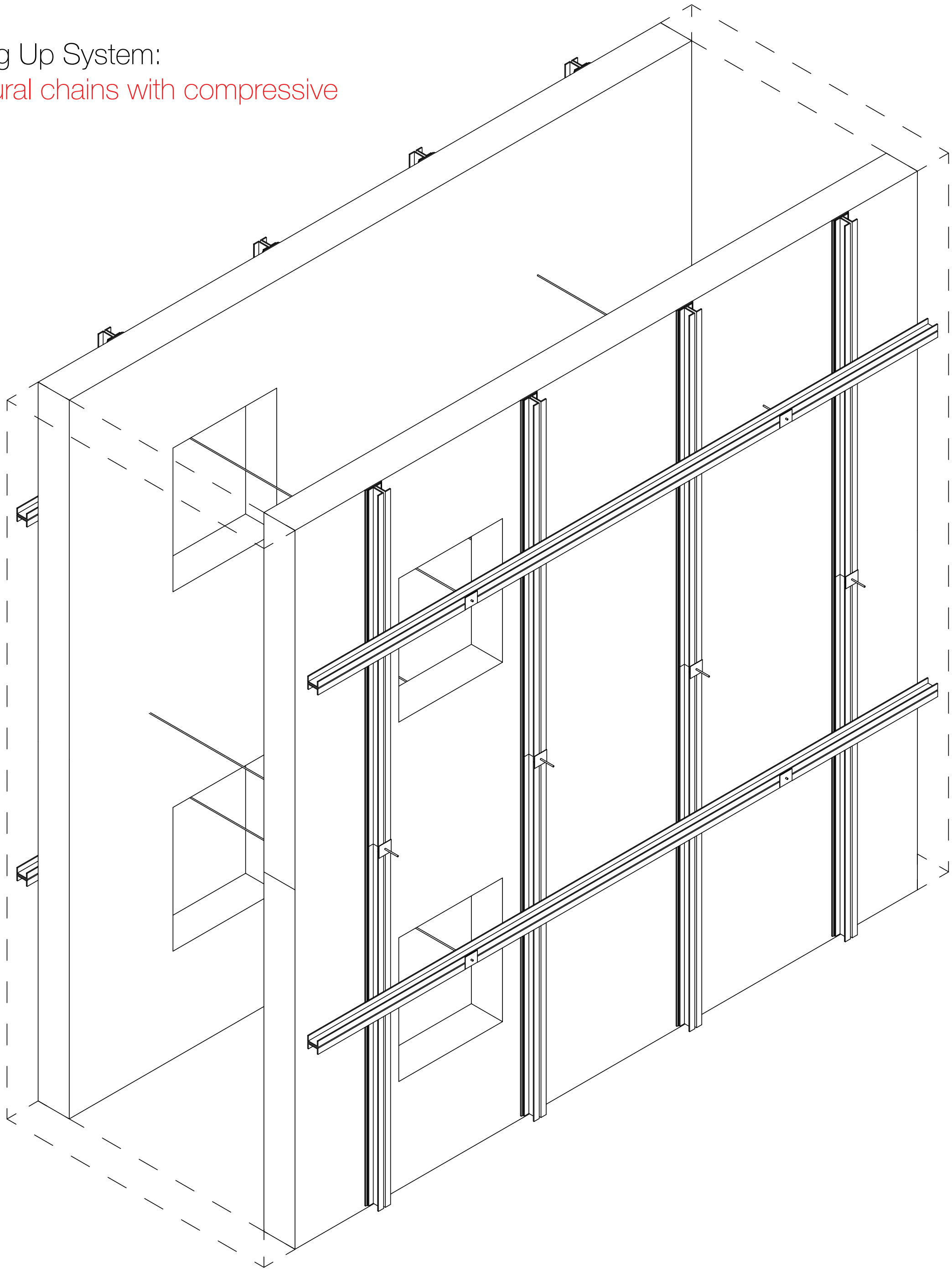
The footing is one of the most important part of the shoring system because it has the task of transferring the loads of the wall directly to the ground.

In the ranking shores and in the riding shores, usually, the footing is designed to be inclined to be parallel to the angle of incidence of the shoring on th wall. The feet of the rakers are put in compression applying some wooden blocks; the rakers being in tension will better resist to the possible movement of the wall.

Structural chains with compressive beams

Since, in Italian historical cities, the urban tissue is characterized by a really dense pattern of construction which leaves little space in the streets to apply rackers to sustain damaged buildings, other systems are used. The application of structural chains with compressive beams is effective in the prevention of the collapse of the building. Structural chains run inside the building connecting two or more beams which are placed against the exterior walls. The structural chains are tightened and they uniformly exert a force on the walls through the exterior beams.

Shoring Up System:
Structural chains with compressive beams

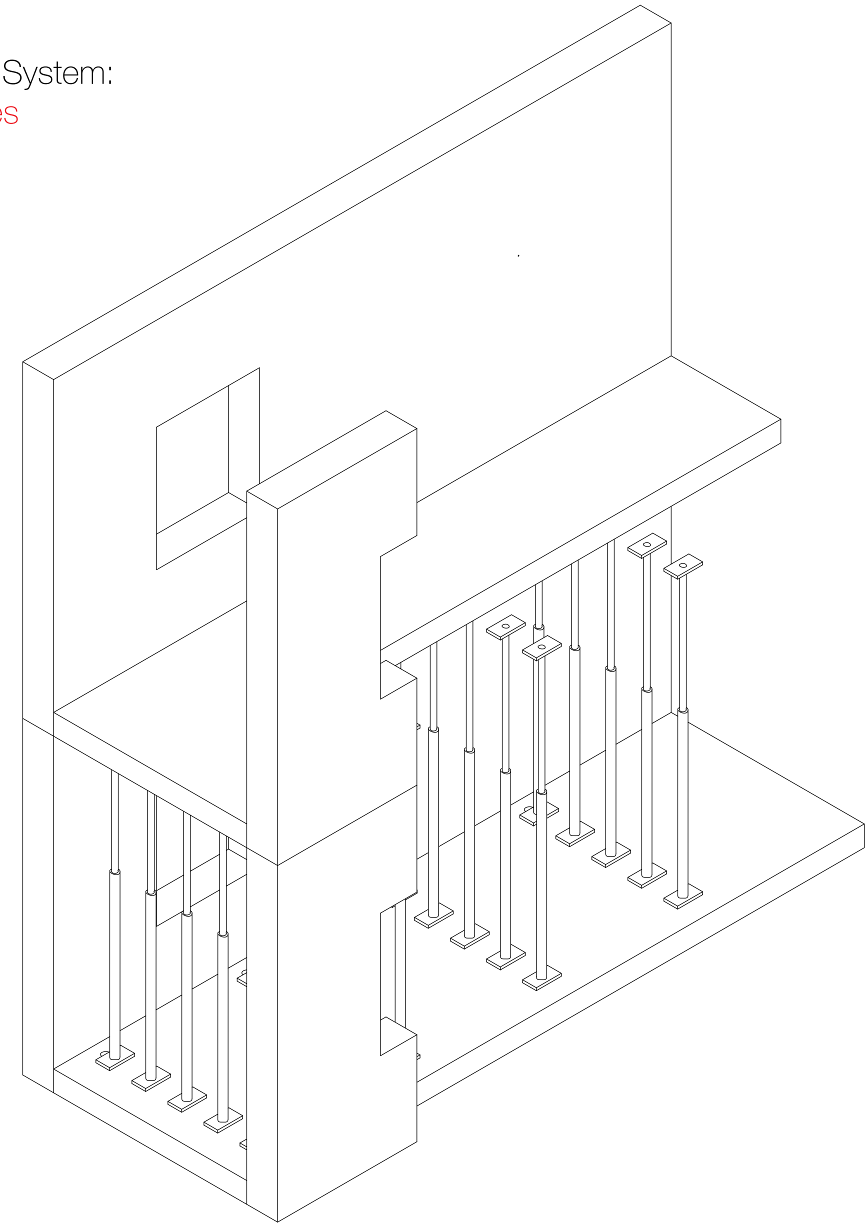


Dead shores

This type of shoring up is usually placed in conjunction with ranking shores or structural chains. This shore is placed inside the building to sustain the floors and prevent them from falling, it is constituted of poles and they could be either wooden or iron ones. These poles act in compression and they distribute the load of the ceilings on the ground.

(For, n.d.)

Shoring Up System:
Dead Shores



L' Aquila, shoring up, October 2016, picture by the Author

L' Aquila, shoring up, October 2016, picture by the Author

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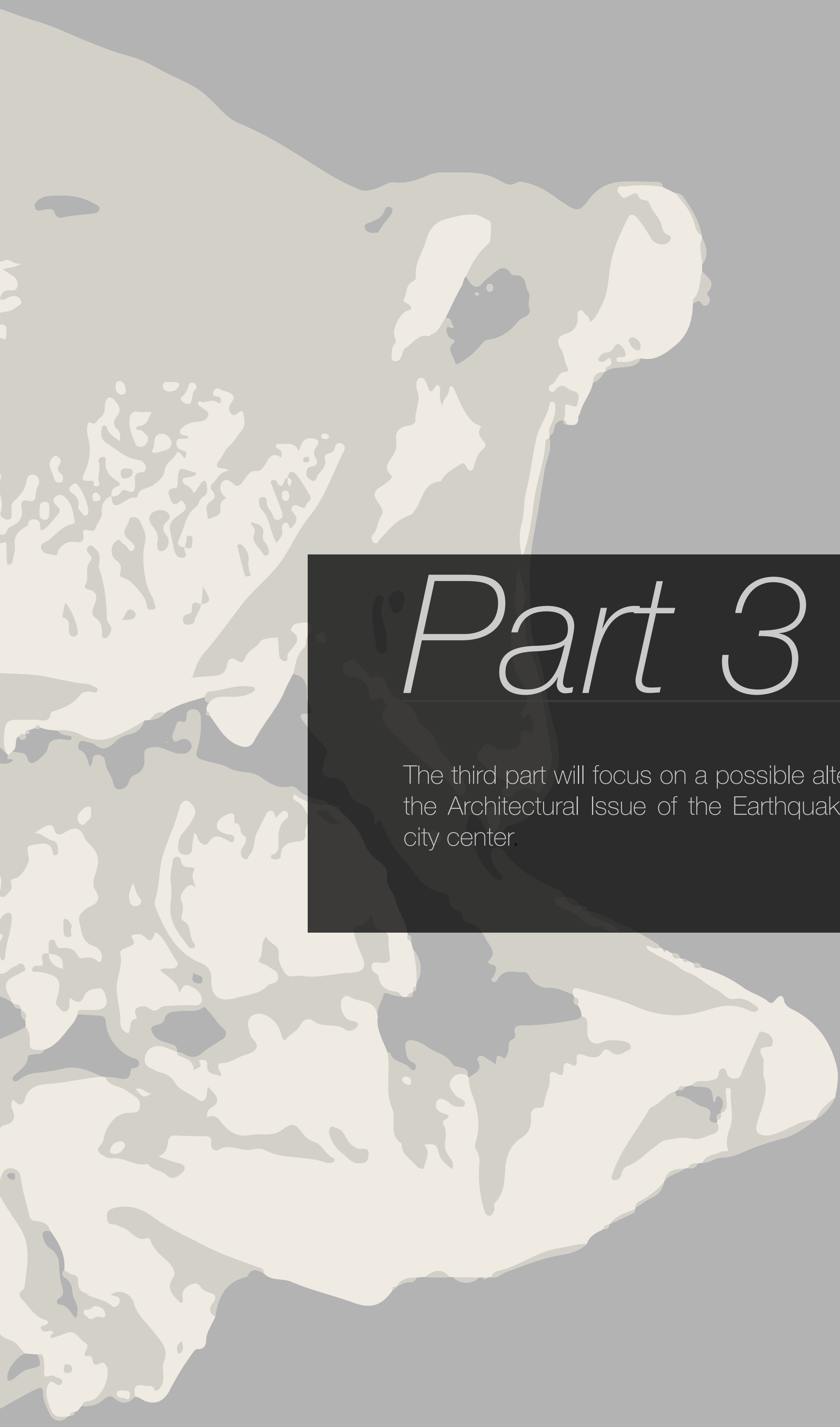

Part 3

The third part will focus on a possible alternatives to solve the Architectural Issue of the Earthquake in an historical city center.

3.1 objective: re-population of the city center

3.1.1 A possible alternative scenario

The objective of the research is to analyze and understand how the historical city center can be repopulated and how the issue of the earthquake can be limited. After analyzing the process of reconstruction on and looking at the current situation of the city center nowadays we can affirm that there are better ways by which it could have been done. This is intended on the particular case of the city of L' Aquila but more in general, on the reconstruction of other Italian cities affected by earthquakes. The situation of the earthquake for a city center can be compared to a war situation. If we see the city as our army and the buildings as the soldiers the similitude becomes immediately clear. The work of the architect, who shores up the buildings, is like the one of an emergency doctor, who does not have to cure the patient at the best but just to maintain him alive; this is the function of the shoring up. Furthermore, if we think that our city center is fighting to maintain its solidity and its habits we can think to sacrifice some soldiers-buildings to win this war.

Looking at the totality of the city center, it is clear that not all of the buildings can be rebuilt simultaneously and that there are several issues impeding this reconstruction (Economical, Political, etc...). Some buildings require more time to be reconstructed and the work of shoring up, which should be temporary, becomes permanent. These long-term reconstruction buildings should be our soldiers to be sacrificed to win the war. This "sacrifice" could be embodied by a change in the function of the buildings into something that better fits the requirements of the city at that moment. These buildings should work as a catalyst for the people to encourage them to walk the streets of the city center again and to make the city center attractive once again.

This idea is based on the fact that the shoring up became a permanent fixture in the city of L' Aquila. So permanent that even in the 3d view of Google maps the buildings are represented with their shores. Since the shore is something that can remain on the buildings for years, it should be thought not just as an emergency work, but we should think about it in a more functional way, to make the building useful during this period.

These punctual interventions of particular shoring systems can be designed on determined buildings in the city with consideration to both their placement with respect to the center and to the particular characteristics of the building itself.

3.1.2 Parasitic-symbiotic

To effect this change of function of the building, many architectural expedients can be use. But to preserve the ruin of the existing building in a state as close to original as possible, it would be useful to consider a reconstruction which is not completely invasive and permanent. The definition of "Parasitic Architecture" is often associated to the German architect O.M. Ungers. According to Ungers, parasitic architecture is a fill in of the Grossform of the city. Ungers defines the Grossform as a frame larger than the individual parts it comprises. Nowadays, the idea of the parasite is strictly connected to something with a bad meaning. However, in the beginning of its use, the word parasite had a different significance. In the ancient Greece, the term parasite was used to refer to the priest involved into the sacrifices, then the term was used to describe the guest who was invited to a dinner to entertain his host. The term parasite gained a bad meaning only later and this can be perceived also in its biological definition. From the biological point of view, the parasite is an organism that

takes some advantages at the expenses of its host. This biological definition can be true, but the relation between parasites in the biological environment and in the architectural one is somehow limited. From the architectural point of view, it is nearly impossible to think of a relation which is unidirectional and gives advantages only to the parasite.
In the architecture field it is impossible to talk about a purely parasitic relation between two entities because the relation between the former and the new is something more complex. The relation between the former and the new is better defined as a mutual relation by the parts in which both benefit, in a symbiotic relation more than a parasitic one.
Many could be the arguments against the use of a former building in relation with a new construction; theories such as those put forth by Facadism complain about the use of parts of buildings or their non-conventional appearance. The symbiotic relationship although, if thought to be profitable for both the entities, could be an efficient method to solve some urban problems in historical city centers.
(Zajac 2000)

Cymothoa Exigua, this particular parasite enters the fish mouth and eats its tongue. The parasite attaches itself to the fish and assumes the role of its tongue creating a symbiotic relation with the host.

3.1.2 Infilling system

A method to create this symbiotic relation between a former ruin and a new building is the creation of an infilling system. The historical city centers of Italian city, like many other historical centers, are populated by many churches and buildings which, for their proper characteristics, have big internal spaces. Looking to the different types of damages that we described in the part 2 of the research, it is conceivable to think that this inner space could also be re-utilized when the church is damaged by an earthquake. Every church should be analysed as a unique case study, different from the others, but we see that the damages gets repeated as well as the available possibilities for intervention. The concept of an infilling system for an existing building must embody the characteristics of a new building inserted in the former construction as well as the characteristics of a shoring system. The two constructions, conceived as a unique building for a determined amount of time, works together to solve the issues created by the earthquake. First, the former architecture can be maintained at the state of a ruin for a longer amount of time, since it is preserved and shored by the inner construction; a building is better preserved if it is used. Second, the reconstruction of the former building can be postponed to more favorable times in which other major problems of the city, such as housing for the people, have already been solved. Third, this type of intervention, having a faster time of completion compared to a traditional reconstruction, can be effectively installed and give new life to the buildings.

The possibility of having an easily assembled structure that is inserted in a former building and that could be used to both shore the building and provide new functions could have also important results in the urban scale. Adding new fundamental functions in a damaged city center can be the beginning of its reconstruction. Some designed intervention can be the starting point of a virtuous chain of events that could lead to a faster and smoother re-population of the city.

Placing some important functions such as a market, a post office,a clinic, etc. At strategic points inside the city center obliges people to come back to this place, walk its streets and leads to a faster re-population of the entire center. As these new functions are activated, other buildings get restored and it could become easier to occupy them again with commercial activities and houses because the center has never been perceived as a dead entity.

Churches could be the perfect case study for this type of reconstruction. In Italian city centers, there are plenty of religious constructions and not all of them are systematically used. Sometimes, even when not affected by earthquakes, the functions of churches change to be adapt to the necessities of the city. Their shape, with the big and extensive nave, defines them as the most useful candidate for this type of infilling intervention. Restoration of churches is also much more complex and delicate if compared to the restoration of a normal building, this characteristic implies the necessity of much more funds to start the reconstruction. In an emergency, such as the one of the earthquake, it is clear that the reconstruction of some churches would not be a priority. Instead of simply installing a shoring system that is then maintained for years, it would be useful to re-utilize them, changing their function for the duration of the time necessary and then, only when there are favorable conditions, namely, money, necessity and time, rebuild them.

Choice of the case study

3.2.1 Case study

The choice of a suitable case study for this type of intervention derives from different analysis both regarding characteristic of the building and the requirements of the city center. First, the position inside the city center is a factor to take into consideration. As analyzed in the previous chapters of this research, the position of the building in relation to the historical city center is important to activate the virtuous chain of events necessary for its re-population. Among the religious buildings, chosen for the characteristics expressed in the previous paragraph, there are some which better fit the parameters for an intervention using an infilling system. The spatial configuration of the former building is a fundamental factor for the preliminary analysis that brings us to this choice for the case study. From a construction point of view, this type of intervention could be carried out on a simple church shape; one nave with a maximum of one transept. Particularity in the shape of the church can result in a more complex design in relation to the seismic-proof measured to be taken on a damaged structure. The church should be also big enough to host the parasite-symbiotic building without being too much deprived of its internal space.

All these characteristics brought to the definition of some possible buildings among which the church of Santa Maria Paganica seems the most appropriate building for this intervention.

The seismic analysis of this building as well as the analysis of its damages is contained in the technical appendix which is detached from this research because it is more related to the design aspect of this project(MSC4). In the Appendix, there is also a hypothesis of a possible construction method to build the parasite building.

Conclusion

The standardized methods of reconstruction of buildings which have a period shoring up followed by a proper reconstruction have already proved their inefficiency. A fast re-population of the city center is the only way to prevent the complete depopulation of it.

Thinking the earthquake as an architectural issue implies also the possibility to think about a different way to live our buildings, detached from a logic conservation and preservation.
The research and the Project on Santa Maria Paganica do not have the aim to solve the entire complex situation of the historical city center of L' Aquila; that would need more than a single isolated project to see a positive change. The aim of the research is to give the preliminary knowledge to understand which is the situation of an hypothetical city center, L' Aquila in this case, with which the architect has to deal. At the same time, in order to re-think a possible shoring system, the research propose an abacus of damages an classical solution as a base for further design speculations.

The project on Santa Maria Paganica will be an speculation on the theme of the reconstruction of a building in a seismic region.

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