

How to survive earthquakes: the example of Norcia

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ABSTRACT:

In this paper lessons are extracted from the comparison between the very different consequences that similar earthquakes had on the neighbouring towns of Norcia and Amatrice during the 2016 seismic crisis of central Italy. It was found that the differences in damage were essentially due to the strengthening of most houses in Norcia done during the previous decades. This is also likely to lead to a much faster recover of the economy and livelihood in Norcia, as Amatrice needs to be entirely rebuilt.

Keywords: earthquake, damage, strengthening

1. INTRODUCTION

On the 30th October 2016 an earthquake of magnitude $M_w6.5$ hit the town of Norcia, in central Italy. The earthquake was the strongest to hit Italy since 1980; $M_w6.9$ Irpinia earthquake).

The October 30th earthquake severely impacted the largely-abandoned towns of Norcia, Castelsantangelo, Preci and Visso, where residents (nearly 8000 people) had left their homes to sleep in cars, campers or moved to shelters or hotels following the earthquake sequence that occurred on October 26 ($M_w5.9$). Due to the reduced epicentral distance the accelerations in Norcia were extremely high, with a value of the horizontal PGA of 0.48g registered at the nearest seismic station (Luzi, 2016). Two months before, on 24th August, the neighboring village of Amatrice had been shaken by an earthquake slightly stronger, $M_w6.0$. In this earthquake most of the constructions of Amatrice collapsed, the ones that did not collapse were so damaged that were useless, and 300 people died. Today, it is a dead village, where nobody is allowed to enter freely. How is it possible to explain the differences between Norcia and Amatrice? How is it possible nobody died in Norcia? In order to find and document answers to these questions a KnowRISK team (2016), with members of Instituto Superior Técnico (IST) and Istituto Nazionale di Geofisica e Vulcanologia (INGV) visited the affected zones during the last week of October 2016, during which several earthquakes hit Norcia and Amatrice. Truthfully, the motivation for this field trip arose from the fact that during August earthquakes Norcia had already been strongly hit but had only minor damages. In October, the ground motion was even stronger in Norcia and, again, there were no mortal victims. .

2. CHARACTERISTICS OF THE SEISMIC ACTIONS

Figure 1 shows the spectra for horizontal accelerations recorded in stations located in Amatrice and Norcia. Both spectra refer to the earthquakes of 24th August and 30th October, as these were the strongest ones in each town and the ones that caused more damaged in each.

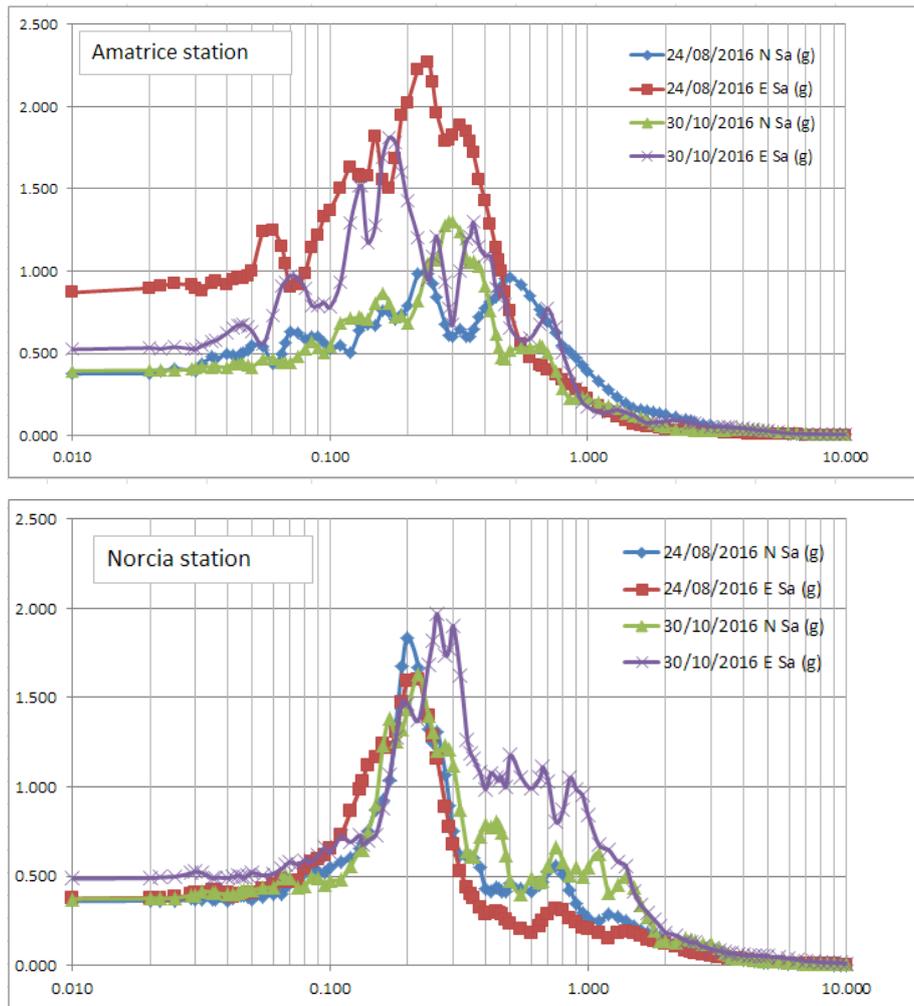


Figure 1. Response spectra for Amatrice and Norcia, east-west direction. Data provided by Luzi et al., 2016.

If we compare the spectra with the highest accelerations in each location, in the east-west direction, we realise that in Amatrice the maximum spectral acceleration was 2.27g for a period of $T=0.24s$ and in Norcia it was 1.9g for a period $T=0.3s$. The Amatrice earthquake produced higher spectral accelerations than the Norcia earthquake for periods below $T=0.46s$, therefore producing stronger effects in stiffer constructions, i.e. low-rise. The differences are stronger below $T=0.2s$. The Norcia earthquakes produced stronger effects in more flexible constructions than the ones in both Amatrice and Norcia stock of buildings. But the main issue here is that, qualitatively, the two earthquakes are comparable and therefore the large difference in performance cannot be attributed to differences in the seismic actions alone.

3. VULNERABILITY OF THE CONSTRUCTIONS

The comparison between the damages caused in Norcia and Amatrice due to the largest earthquakes of last year in Central Italy shows profound differences. Since the earthquakes themselves cannot explain these differences, they must be attributed mainly to differences in vulnerability between both towns.

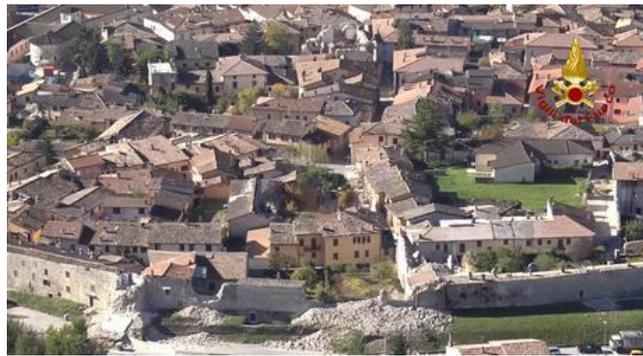
Both in Norcia and Amatrice most constructions are/were old, built in periods in which earthquake resistant design was not enforced in codes of practice, and therefore it is thought that original constructions were vulnerable. However, in Norcia there is a culture of safety in what regards earthquake risk, and due to that the constructions in Norcia were strengthened to provide earthquake resistance during the last 40 years – following the 1979 and 1997 Norcia earthquakes. Higher priority was given to houses where people live permanently, with second houses receiving a lower priority. The main

strengthening techniques used in Norcia were i) confinement of masonry walls by a layer of mortar with a pre-fabricated steel welded mesh inside, in both faces, connected by steel bars at a given spacing, and ii) introduction of steel cables connecting parallel walls in order to prevent the out-of-plane movement of exterior walls to the outside of the construction.. This information was transmitted to the KnowRISK team by the *Sindaco* (Mayor) of Norcia in a meeting in the morning of 26th October, a few hours before the earthquakes of that day.

The result of the seismic crisis of August and October 2016 was the destruction of Amatrice. However, in Norcia, despite damages in many houses and some collapses of historical constructions, as the exterior walls and churches, most of the houses are standing and, above all, nobody died. Figure 2 provides a good comparison of the state of both villages after the earthquakes.



Amatrice, after the 24 August 2016 earthquake



Norcia, after the 30 October 2016 earthquake

Figure 2 – Amatrice and Norcia after the earthquakes

In fact, in Amatrice around 300 people died while in Norcia there were no mortal victims after August and October earthquakes. The policy of strengthening buildings applied in Norcia for 4 decades is strongly responsible for this significant difference. Yet, another important factor also contributed to this outcome. In October, Norcia had already felt the shaking due to the earthquake of Amatrice on 24th August, immediately after which some of Norcia population was reallocated in order to evaluate structural stability of their homes. Before the last and stronger earthquake in October, Norcia was also shaken 2 times in the previous days, by two other earthquakes on 26th October not so strong, although causing some minor damages, mostly non-structural. The population was, therefore, on alert, and because of that, when the main earthquake took place on 30th October, at 7h 41m am, many people were sleeping on cars and not in their homes.

4. LESSONS LEARNED

4.1 Rehabilitation of constructions

The first major lesson from the comparison of the different performances of Norcia and Amatrice constructions is that, in seismic areas, prevention pays off. The seismic strengthening of constructions is able to avoid major collapses and, most important, to save lives.

Other comparisons between the seismic performance of old strengthened and unstrengthened constructions, lead to the same conclusion. Figure 3 shows one of those examples: two adjacent houses in the island of Faial (Azores, Portugal) stroke by a violent earthquake on the 9 July 1998 (M_w6.1). Both houses have similar systems and materials (old masonry) and none of the original constructions had been designed to resist earthquakes. However the left hand side house had been strengthened against earthquakes and the other had not.



Figure 3 - Difference of seismic performance between adjacent constructions

The houses were so close that there were no geotechnical differences between their locations and both were subjected to the same seismic action. The comparison is clear and straightforward: the figure shows that the strengthened house resisted the earthquake with minor damage and the unstrengthened house collapsed.

Therefore, it is important to draw attention of decision makers and managers of programs of urban rehabilitation in seismic zones for the importance of seismic strengthening in the rehabilitation of constructions. In seismic zones, improvement of aesthetics and living conditions of old and unsafe houses should in general be accompanied by seismic strengthening.

4.2 Non-structural elements

Even though properly strengthened houses survive strong earthquakes, they vibrate and deform during the vibration. These may introduce relevant non-structural damage, part of which can be avoided by appropriate measures taken by common citizens, which is the subject of the KnowRISK project. Moreover, reducing non-structural damage reduces the probability of people getting injured by falling objects and reduces economic damage. Note that the reduction of economic damage is also important for the affected populations to resume their normal life. Figure 4 shows a recent example in Norcia: during the August earthquake the television fell down and broke. After that a new television was bought to replace the broken one, but was fixed with chains, as shown in figure 4 (photo shot by the KnowRISK team on 28 October). The result was that the television suffered no damage during the 26 October earthquakes. The above example has already been used by the Portuguese team in KnowRISK actions in schools, during which young students are taught on how to reduce seismic risk from non-structural elements at school and at home.



Figure 4 – Televisions connected to walls by chains to avoid toppling

5. RESILIENCE AND RECOVERY

Most of Amatrice constructions collapsed or were severely damaged during the 24th August earthquake. The town has been closed to the general public, and could only be visited under the supervision of the Italian fire brigades. This included the KnowRISK structural engineers that only got permission to visit the town when the fire brigades could receive them. After the 24th August earthquake, the survivors of the earthquake had no alternative than to leave town and stay in hotels, some in nearby villages, others more far away, mainly in the Adriatic coast, while others went to live with relatives or friends. The Italian government declared that the affected towns will be completely rebuilt. But that will take years, changing completely the livelihood of the population. Even if the streets and constructions are rebuilt keeping the same architectonic and urban characteristics as before the earthquake, the urban environment may be different, as the people will be different. It cannot be taken as granted that the culture, traditions and other factors that are part of the identity of Amatrice before the earthquake will be re-established in the future.

Norcia was strongly hit by the sequence of October earthquakes, mainly by the one of 30th October. However, damage was much less extensive than in Amatrice. Some monumental constructions suffered partial collapses and several constructions inside town were damaged, a few ones strongly. Figure 5 shows some of those cases. The photos were taken by the KnowRISK team on 19th December 2016, one month and a half after the major earthquake that hit the town.



Figure 5 - Damage in Norcia after the October 2016 earthquakes

In general, in Norcia, most constructions appeared, from the outside, to have no damage or slight damage, but there were also a few with parts in risk of collapse. In these conditions, any aftershock could lead to more damage, making unsafe to walk normally in the streets. Therefore, the centre of Norcia was closed to the public, until conditions to walk safely in the streets are re-established. This comprises essentially two conditions: i) all constructions in which there is partial risk of collapse to the streets must be braced to avoid that risk, and ii) the seismic crisis must be over. When the KnowRISK team visited Norcia in December, together with members of the Italian fire brigades, those works of bracing unstable structures were going on in several parts of the town, which may take a few months to complete. Figure 6 illustrates some of those cases.



Figure 6 - Bracing of unstable constructions in Norcia by the fire brigades

The second criterion implies a very difficult decision. When the KnowRISK team visited Norcia and Amatrice by the end of October, two months after the major earthquakes of August that were followed only by low intensity aftershocks until October, it was thought that the seismic crisis could be fading away. However the October earthquakes, as well as the ones that took place in January 2017, cast high uncertainties on the assessment of the situation from the seismological point of view. In this situation it is likely that only after several months of lack of relevant earthquakes the crisis will be declared as finished. Therefore, it is unlikely that the centre of Norcia will be accessible to the general public before the Summer of 2017 (and this may be very optimistic), which seriously compromises the normalization of economic and social life.

Many buildings in the centre of Norcia are in safe conditions and could be used if people could access them, allowing the revival of the local economy. Therefore, the lack of conditions to move safely in the streets is a major factor hindering economic recovery. Also, the longer the period in which the centre of the town is closed, the higher becomes the probability that some people will not return.

The KnowRISK team was in Norcia three times, on the 26th of October, from which we left four hours before the first earthquake of that day, on the 28th October between the major earthquakes of that week and on the 19th December. In the first stay, the team members got acquainted with several inhabitants of Norcia, which we also met in the two following visits, allowing a closer involvement with the reality of the recovery process, including economic, social and psychological aspects of the situation. During the third visit, after the major and more damaging earthquake of 30th October, we were asked by a Norcia resident: “can we live here in peace and safety or should we move to a less earthquake prone part of the

country?” The answer given was “you don’t need to abandon your town, the place you love and where you always lived, but to live safely here you should take care about the quality and seismic resistance of your constructions, as well as the prevention of non-structural damage, to reduce economic damage and the likelihood of being injured or killed by falling objects and damage to building contents.”

For the recovery of a zone affected by an earthquake the time that lifelines and roads and railways are not operational affects all livelihood, including economic activities, in the affected areas, delaying the recovery. The longer this period is, the higher the likelihood that people won’t come back. This may change social characteristics typical of some areas, losing part of the “character” of those zones. After many years into the future, when Norcia is repaired and Amatrice is rebuilt, and life is normalized in both towns, there are higher probabilities that social changes are higher, as in Amatrice the process will be much longer. In Norcia, these effects, if any, will tend to be much smaller.

6. CONCLUSIONS

The comparison between the damages inflicted to Amatrice and Norcia during the August and October 2016 earthquakes in central Italy, led to the following conclusions:

- The lower levels of damage in Norcia were due to the fact that during the last four decades the old constructions of Norcia were strengthened to resist earthquakes, while in Amatrice most of the rehabilitation of the buildings was cosmetic, or, in other words, aimed at improving aesthetics and living conditions only.
- Strengthened and retrofitted constructions prevent major damages and save lives.
- It is strongly likely that the bracing of damaged constructions in Norcia will be much faster than the reconstruction of Amatrice, leading to a much faster recover of the economy and livelihood of the town.

The longer the reconstruction and recovery takes, the higher is the probability of profound social changes, risking the complete loss of traditional traits, uses and customs of the region.

It may also be worth noting that monetary constraints cannot be used to advocate rehabilitation without seismic strengthening. Both villages, Norcia and Amatrice, were subjected to rehabilitation programs. The decision of including seismic strengthening in the rehabilitation is, most of the time, mainly related, not with monetary constraints, but with incorrectly defined priorities, possibly due to the lack of knowledge that retrofitting represents a negligible increase in rehabilitation costs when compared with simple, cosmetic rehabilitation.

The above conclusions can and should be used for pedagogic purposes in other earthquake-prone areas to demonstrate that seismic strengthening pay is effective and it is worth the investment. _In reality, strengthening not only saves lives and reduces economic damage, but also contributes to the preservation of the cultural characteristics of the building stock and of the population that lives in the affected areas as it allows a much faster recovery of the economy and faster resume of everyday life.

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