Large scale seismic vulnerability and risk evaluation of a masonry churches sample in the historical centre of Naples

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Abstract. This paper investigates about the seismic vulnerability and risk of fifteen masonry churches located in the historical centre of Naples. The used analysis method is derived from a procedure already implemented by the University of Basilicata on the churches of Matera. In order to evaluate for the study area the seismic vulnerability and hazard indexes of selected churches, the use of appropriate technical survey forms is done. Data obtained from applying the employed procedure allow for both plotting of vulnerability maps and providing seismic risk indicators of all churches. The comparison among the indexes achieved allows for the evaluation of the health state of inspected churches so to program a priority scale in performing future retrofitting interventions.

Keywords: seismic vulnerability, seismic risk, masonry, church, large scale analysis method, survey form.

THE HISTORICAL CENTRE OF NAPLES

In 1995 the historical centre of Naples has been declared by UNESCO as World Heritage Site. However, the largest part of buildings in this zone are in precarious structural conditions. Moreover, after the 1980 Irpinia earthquake, a lot of buildings showed evident structural damages. Therefore, on the basis of these premises, a scrupulous attention to monumental buildings, with particular reference to religious ones seriously affected by recent earthquake [1], should be deserved. In the paper the study proposed is addressed to evaluate the large scale seismic vulnerability and risk of fifteen churches, whose location in the historical centre is shown in Figure 1.

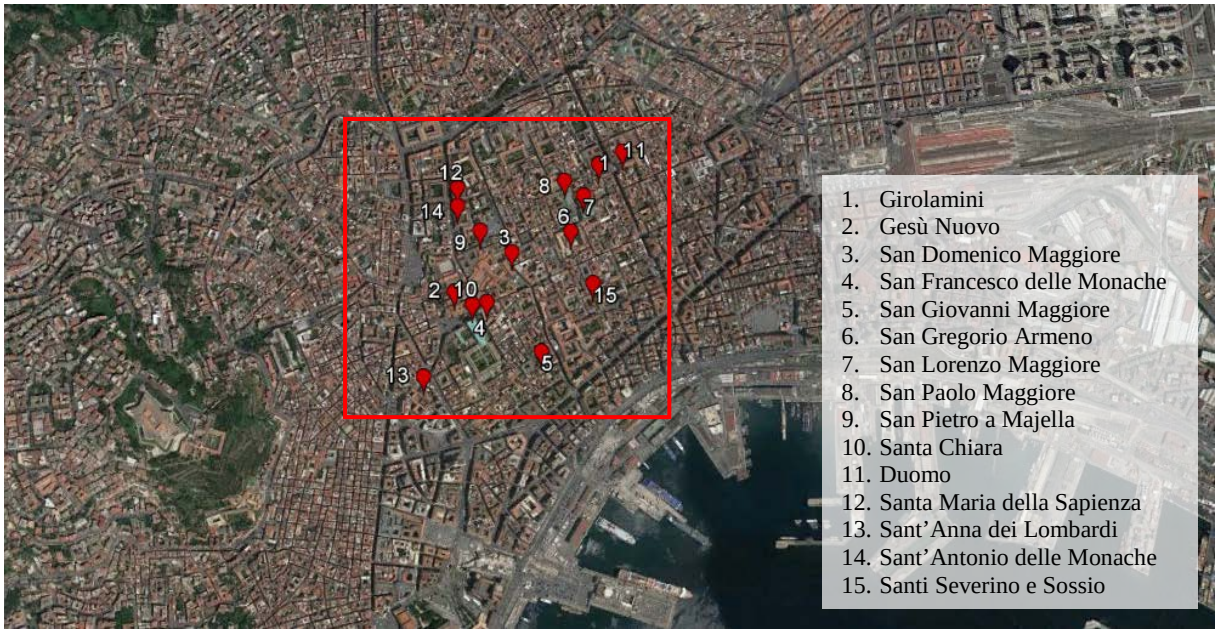


FIGURE 1. Churches of the historical centre of Naples under investigation

THE ANALYSIS METHOD

At the beginning, a description and a classification of the probable threats characterising the historic centre of Naples is conducted in order to provide a judgment about potential severity of the damage that could affect the inspected zone. The analysis data are obtained from detailed information provided by public and private authorities, as well as by University studies. The results show that in this zone the possible events might cause slight or gradual damages, but no catastrophic ones should occur, as it is shown in Table 1. According to the severity of the damage, by associating the score to each threat, a hazard index of 0.68 is estimated for the examined historical centre.

TABLE 1. Damage assessment from possible threats in the historical centre of Naples

Threats		Severity of damage		
		No damage/ No hazard	**Low or gradual**	**Catastrophic**
Sporadic events	Seismic and tsunami	0	0,20	0,40
	Landslide or rock fracture	0	0,15	0,25
	Volcanic	0	0,20	0,40
	Hidro meteorological	0	0,15	0,25
	Chemical - technological	0	0,15	0,25
	Forest fires	0	0,15	0,25
Continuous processes	Erosion	0	0,05	0,10
	Physical stress	0	0,05	0,10
	Air pollution	0	0,01	0,05
	Socio - organizational	0	0,01	0,05
	Serious demographic decline	0	0,01	0,05

Afterwards, the seismic vulnerability of each church is evaluated by examining the parameters related to the different peculiarities of inspected constructions. The parameters, grouped into a survey form, are thirteen [2] and ten of these have been selected from the second level seismic vulnerability technical datasheet proposed by the Italian Group of Defence against Earthquakes (GNDT) [3]. For the compilation of the form, it is possible to associate a class, from A (the best) to D (the worst), to each parameter. In Figure 2 the percentage distribution of classes assigned to each parameter for all the churches examined is reported.

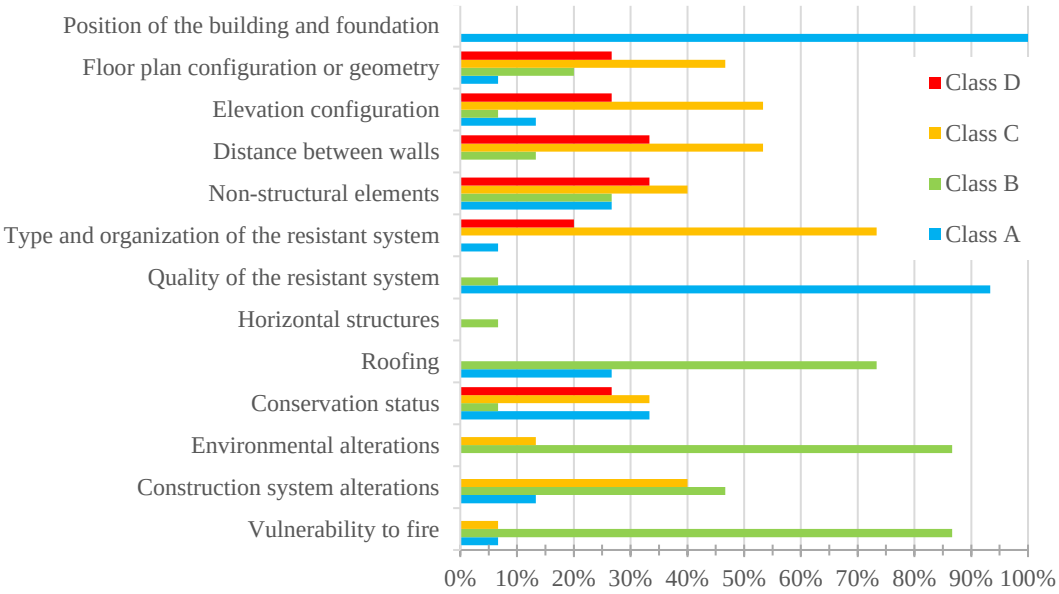


FIGURE 2. Percentage distribution of parameters classes

The results are not very harmonised each other. The only parameter common to all churches is *location of the buildings and foundations*. In fact, on the basis of this parameter, all churches are classified in class A [100%]. This means that all the constructions are placed on the same subsoil, namely a Neapolitan yellow tuff soil with a slope less than 10%. For each case, the vulnerability index is defined by the formula:

$$VI_j = \sum_{i=1}^{n} v_{j,i}\ p_i \tag{1}$$

where $v_{j,i}$ is the score value of the class selected for the generic parameter, whereas p_i is the parameter weight, representing the more or less importance of the parameter itself in estimating the vulnerability index. In particular, the most crucial parameter is the type and the organization of the resistant structural system which has a weight of 1.50.

A further analysis is focused on the knowledge of possible collapse mechanisms. Through the in-situ inspection of every church, the potential collapse mechanisms, selected among those shown in Figure 3, are identified.

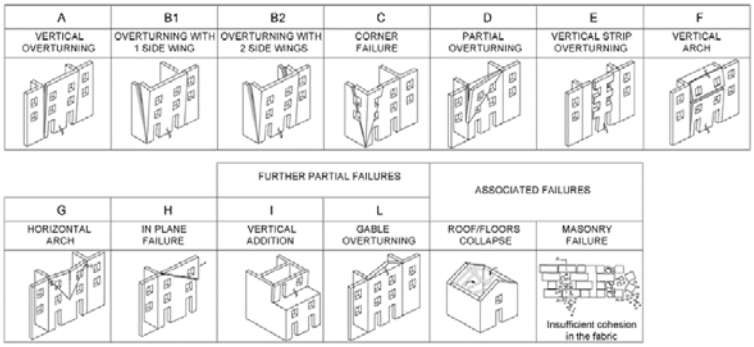


FIGURE 3. Potential collapse mechanisms

Finally, knowing the seismic hazard index [H] and the vulnerability index [VI], it is possible to calculate, for each church, a value of the Seismic Risk [R] by using the following formula:

$$R = VI\ x\ (H + 1) \tag{2}$$

CONCLUSIONS

All the churches examined within the historical centre of Naples have shown vulnerability indexes and seismic risk ones with scores ranging between 10% and 50% and between 20% and 80%, respectively (Figure 4).

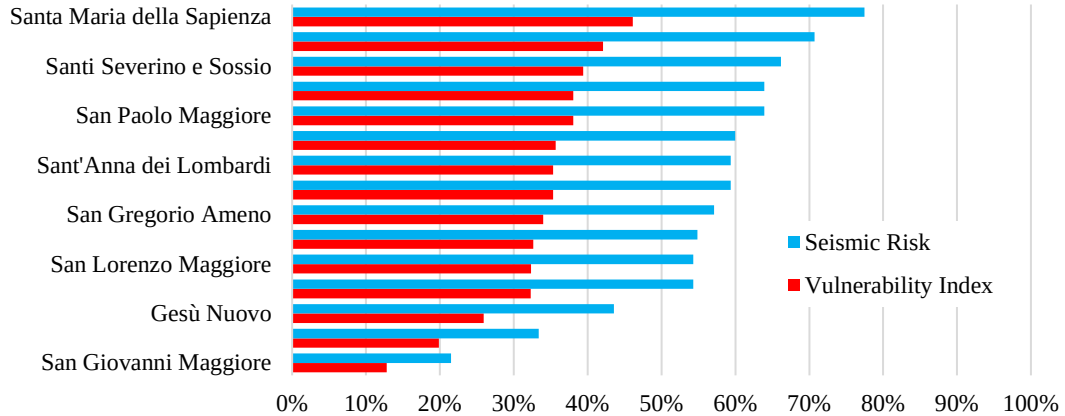
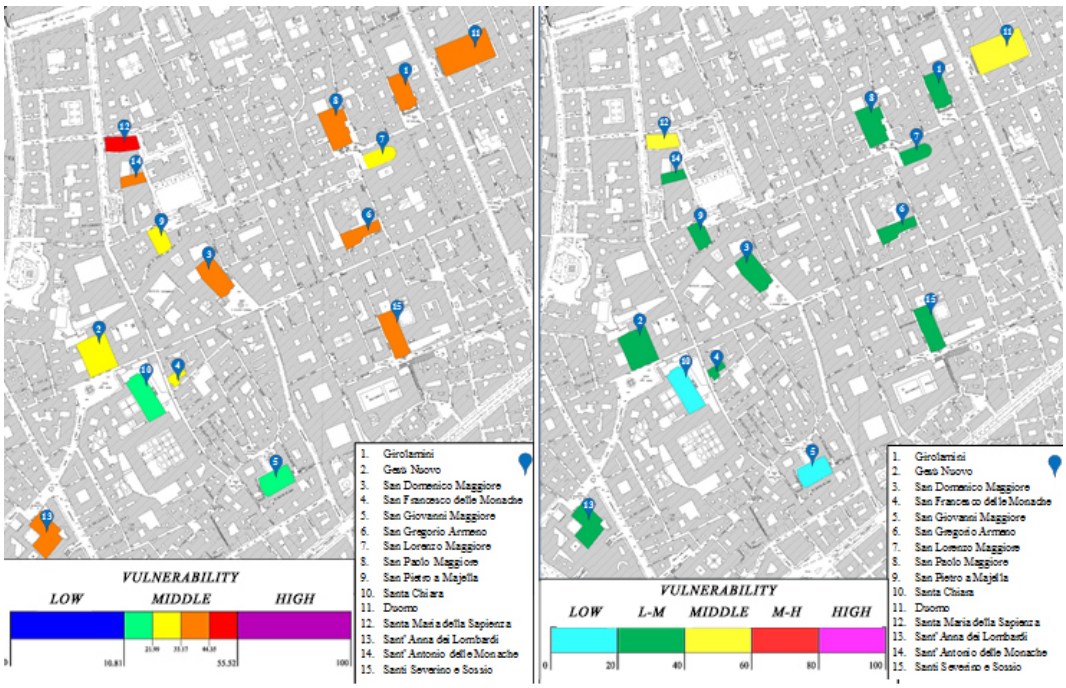


FIGURE 4. Vulnerability Indexes and Seismic Risk indicators (in descending order) of the inspected churches sample

The most vulnerable church is *Santa Maria della Sapienza*, which has a vulnerability index of 46.12. In fact, at the present, this building is unusable. On the other hand, the church in better structural conditions is *San Giovanni Maggiore*, which underwent recent seismic retrofitting works, consisted on steel ties aiming at both stopping the incipient facade overturning mechanism and improving the containment of the masonry vault thrusts.

In Figure 5 the vulnerability maps of the inspected churches within the historical centre of Naples are plotted. In these maps the vulnerability index ranges are indicated with different colours according to two different classification methods. In the left picture, following the University of Basilicata method [4], the vulnerability index is divided into three classes: low, middle and high; while in the right picture, the GNDT method is used, it classifying the construction vulnerability into five classes: low, middle-low, middle, middle-high and high. From both methods it appear that the churches have a medium vulnerability level.



(a) (b)

FIGURE 5. Vulnerability indexes of investigated churches according to the University of Basilicata (a) and GNDT (b) methods

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