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EXPEDITIOUS SEISMIC RISK ASSESSMENT OF THE SARACENA AREA OF TRICARICO CITY (SOUTHERN ITALY)

Francesca Mattei[1], Roselena Sulla[2], Michele D'Amato[2], and Rosario Gigliotti[3]

[1] DICI, Dept. of Civil and Industrial Engineering, University of Pisa
Largo L. Lazzarino n. 1, 56122 Pisa (Italy)
e-mail: francesca.mattei@unipi.it

[2] DIUSS, Dept. for Humanistic, Scientific and Social Innovation, University of Basilicata
via Lanera n. 20, 75100 Matera (Italy)
{roselena.sulla,michele.damato}@unibas.it

[3] DISG, Dept. of Structural and Geotechnics Engineering, Sapienza University of Rome
via Eudossiana 18, 00184 Rome, Italy
rosario.gigliotti@uniroma1.it

Abstract

In the present paper the expeditious seismic risk assessment at territorial level of "Saracena" area of Tricarico city is presented, according to the simplified methodology suggested by Tuscany region (Italy) and developed in 2019. Tricarico is a village located in Southern Italy, in Basilicata Region, divided in different areas, such as Saracena, Rabatana, Civita, etc. Each of these areas is characterized by a specific historical development, reflected in a peculiar urban fabric, however mainly represented by historical masonry.
Specifically, "Saracena" is one of the most ancient areas of the village, characterized by low-rise masonry buildings and historic ones, some of which are abandoned also due to the deteriorated conditions of them. In this regard, with the aim of re-evaluating Tricarico from a touristic point of view and mitigating its seismic risk, it has been chosen as a case study within the Italian Project GENESIS "Seismic risk manaGEmeNt for the touristic valorization of thE hiStorIcal centers of Southern Italy", within which it is analyzed at different detail levels, of which the territorial one is presented in this work. Therefore, the simplified methodology mentioned above has been adopted, investigating a multilevel approach which implies the use of census data but also of the in-situ surveys carried out, depending on the detail level to be achieved. This methodology allows obtaining a Risk Class R as a function of the Indicator of Risk IR, given by the sum of the classes of Hazard (H), Vulnerability (V) and Exposure (E).

Keywords: Seismic Risk Assessment, Seismic Analysis At Territorial Levels, Historical Centers, Masonry, Seismic Vulnerability.

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1 INTRODUCTION

Seismic risk assessment is nowadays one of the most crucial issues in the field of earthquake engineering. It is useful to taking into account possible damages due to earthquakes, being calculated crossing different information based, essentially, on hazard, exposure and vulnerability.

Hazard is obtained by seismic hazard maps typically elaborated by each Country and based on specific studies involving the historical seismicity of the land, physical and mechanical characteristics of territory, etc.. It is described by seismic hazard maps describing the distribution of several parameters into the considered region, such most widely used and efficient is represented by peak ground acceleration PGA. Often, local effects due, for example, to geological aspects, need to be taken into account to evaluate the real hazard of a specific zone. Study of seismic hazard leads, at last, to deduce from a quantitative point of view the value of basic seismic action as input for the analysis. Exposure is related to the context in which the building or group of buildings are located, in terms of number of people present, the activities in the zones, and it is important to establish possible interferences with the buildings object to the risk analysis. At last, vulnerability is related to the response of the buildings in relation, for example, to their mechanical characteristics, geometry, etc. for a specific seismic hazard level: to obtain information about vulnerability, different analysis at different levels of depth can be performed, according to the detail level of seismic risk assessment intended to be carried out.

At this regard, in recent decades the efforts of the scientific community have increasingly focused on the development of both detailed and expeditious methodologies to determine seismic risk at different levels. In Italy, in particular, the theme of seismic risk is particularly felt, considering that large portions of historical centers have been dramatically destroyed by recent seismic events, just to cite as examples, Central Italy 2016-2017 and L'Aquila 2009 earthquakes. Historic centers represent an integral part of the immense Italian cultural heritage, and are an important testimony of the history and traditions of the entire Country: their potential seismic risk is mostly related to the vulnerability of ancient/dated buildings that are constituted for the most by masonry.

The study of the seismic behaviour and seismic risk of masonry, especially historical too, has been the subject of several studies in recent decades; among the others, in [1] the authors describe a methodology based on limit state analysis and collapse mechanisms to derive capacity curves for masonry structures; in [2] seismic assessment of historical masonry buildings at different levels is proposed; in [3] the authors present a new approach based on CARTIS form for the assessment of the seismic vulnerability of masonry buildings; in [4, 5, 6] detailed analysis of masonry building seismic behavior is treated, while the description of how this can be affected by the intervention strategies adopted is reported in [7, 8, 9]. In other cases, it may be sufficient to assess the seismic vulnerability of masonry buildings, even those with cultural value, as carried out in [10]. At last, other efforts are made to design interventions that are as effective as possible [11].

Seismic risk assessment can be carried out at different levels, not only at building level. In last years, in fact, new methodologies to evaluate seismic risk at territorial level, often based on expeditious methods, are becoming increasingly popular. For example, in [12] a general methodology to assess the seismic risk in historical centers is described in detail while in [13] a focus on the role of urban asset in the management of seismic risk is argued.

In the present paper, seismic risk expeditious assessment at territorial level of a portion of historical center of Tricarico village, located in the South of Italy, is analysed and reported. Tricarico has an important medieval historical center of Southern Italy and it is also an Episcopal headquarter. The analysis has been conducted through a method proposed by Tuscany region [14, 15] that has the advantage to obtain seismic risk level of a compartment through the acquisition of simple information (always based on the concepts of hazard, exposure and vulnerability). This leads to obtain a first idea of the seismic risk of a compartment, without the acquisition of other detailed information often requested by other expeditious methods, in need of further investigation.

The study has been conducted within the Italian Project GENESIS "Seismic risk managEmeNt for the touristic valorization of thE hiStorIcal centers of Southern Italy" funded by Italy's PON MIUR "Research and Innovation" 2014-2020 program and FSC, which has the aim to mitigate the seismic risk of historic centers in the South of Italy, for cultural and tourism enhancement.

2 DESCRIPTION OF CASE STUDY

Tricarico is an Italian village very close to Matera city, in the Southern region of Basilicata. It is located at an altitude of 698 m above sea level and present a current population of 4825 inhabitants. Tricarico has one of the most important medieval historical centers in Basilicata, with Arab-Norman characteristics; the town is also an Episcopal headquarter.

The village consists of an historical center, located on a sandstone rock spur and characterized almost entirely by masonry structures of different age, and of a modern urban center that has developed in the neighboring areas.

Tricarico has a long history, which is also reflected in its very diverse building heritage. It was first conquered by the ancient Greeks, then by the Romans, then by the Lombards and Byzantines, the Saracens, the Normans. During each of these dominations, some areas of the historic center were developed rather than others: a map of the main areas of the historic center, according to the schematization proposed in [16] and shown, is depicted in Figure 1.

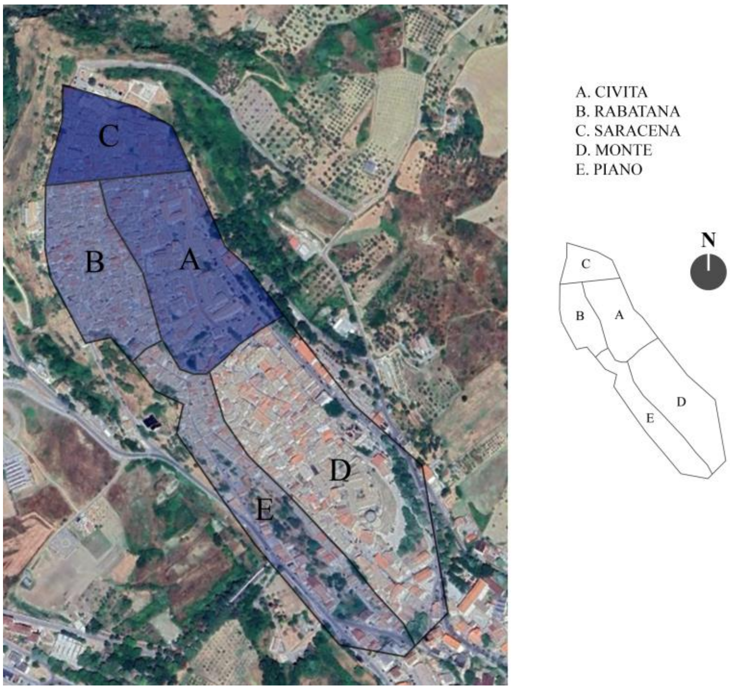

Figure 1. A scheme of different zones of historical center of Tricarico.

For example, during the Roman conquest, the "Civita" district was born, during the Norman period the area called "Monte" where the Norman tower arises was developed, while the "Rabatana" and "Saracena" areas were born following the Saracen conquest. In this period, Saracena tower was built and Saracen gardens created, where plants and crops typical of North African countries could grow. Despite the prosperity of past times, the southern economic crisis that characterized the Mezzogiorno in the 20th century unfortunately did not leave the city unscathed; the great migration flow between the 1960s and the early 2000s led to a decrease in population of around 15%, a decrease that did not stop completely even afterwards. For this reason, several parts of historical center are actually in a state of neglect and, among this, Saracena area is perhaps the most neglected, with often dilapidated and abandoned buildings.

Looking at the exposure and vulnerability of Saracena area, the urban fabric is characterized by a few main streets with a very narrow cross-section, on which numerous secondary, even narrower alleys intersect, often ending in blind alleys (Figure 2).

Figure 2. Details of Saracena area.

The residential fabric is, in general, made up of buildings with two or three floors, consisting of few rooms, some of which are hypogeal. For each building, there is, in general, a homogeneity of materials, often consisting of sandstone cemented with mud, predominantly unplastered, which in larger blocks is also found in the boundary walls and terracing with which the steep area was made habitable. Hypogea are particularly interesting as they often end up creating a kind of small underground network leading from one dwelling to another or from one dwelling to the garden of another dwelling. This form of dwelling is classically Arab, but also Greek, and is justified both by the need to close themselves off from the outside world as a defense and by the need for a courtyard space, functional and an agricultural economy. In the parts clearly of Greek origin, located at the edges of the quarters, the enclosed space is also delimited by an arch with a portal. From the point of view of seismic hazard, Tricarico has been affected by intense seismic activity, but mostly related to earthquakes with epicenter in in nearby cities. The most important recent events (last 70 years) include the "Materano" event of 9 January 1956 with epicenter in Grassano as regards the first category, and the one with epicenter in Irpinia on 23 November 1980 as regards the second: in both cases, the village suffered some damage to the built environment, but on average quite limited. Actually, Tricarico is considered a village with medium seismic hazard where strong earthquakes may occur, with a peak ground acceleration (PGA) on rigid and plane soil conditions for return period equal to 475 years equal to 0.179g [17,18].

Starting from the information given above and other detailed deduced from national databases, surveys and the collaboration of the Municipality, an expeditive estimation of the seismic risk of the Saracena area was made using the method proposed by Tuscany Region [14, 15], that is well described and commented in the following paragraph.

3 SEISMIC RISK ASSESSMENT METHOD

As stated in [19], Tuscany Region has proposed a simplified method for seismic risk assessment at a territorial scale. It consists in the adoption of a statistical method which involves both ISTAT (Italian National Institute of Statistic) data and direct surveys, and assumes different levels of depth, that are:

- level 0, at regional scale;
- level 1, at municipal scale;
- level 2, at urban scale.

In particular, at the regional scale, seismic risk assessment is conducted on each municipality by means of a statistical expeditious model using ISTAT data. Municipal scale seismic risk assessment, meanwhile, is conducted on each homogeneous area by means of a simplified and expeditious model based on statistics or even direct survey. Finally at the urban scale, in addition to the assessments carried out through level 1, it is possible to employ information and analytical or directly surveyed data. More information for each level may be found in [14, 15]. Following this method, Risk Class R is determined in accordance with the Indicator of Risk IR = H + V + E, where H, V and E are the classes of Hazard, Vulnerability and Exposure, respectively.

3.1 Application to Saracena area

Focusing on level 1, Seismic Hazard, Vulnerability and Exposure Classes are defined for the Saracena area of Tricarico following the method previously introduced.

Firstly, Seismic Hazard Class H is identified as a function of the maximum horizontal ground acceleration a_g under rigid and plane soil conditions for return period equal to 475 years (Table 1). Since Tricarico has an a_g equal to 0.179g, the parameter H corresponds to 3.

Seismic Hazard	a_g	H
High	$a_g > 0.200g$	4
Medium-High	$\mathbf{0.150g < a_g \leq 0.200g}$	**3**
Medium-Low	$0.125g < a_g \leq 0.150g$	2
Low	$a_g \leq 0.125g$	1

Table 1: Seismic Hazard Class.

For the determination of the Vulnerability Class V, it is necessary to calculate a vulnerability index I_v as a function of intrinsic factors (i.e., construction period, structural type and building height) and extrinsic factors (i.e., urban vulnerability, construction type and history of seismic classification). Therefore, $I_v = I_{cp} + I_{st} + I_h + I_{uv} + I_{spt} + I_{sc}$, where: I_{cp} is the construction period index; I_{st} is the structural type index; I_h is the height index; I_{uv} is the urban vulnerability index; I_{spt} is the specialist type index; I_{sc} is the seismic classification index.

The construction period index I_{cp} is determined according to the period value V_p, as shown in Table 2. V_p depends on the number of buildings belonging to different construction periods. In the case of Saracena area, there are approximately 147 buildings all built before 1945, therefore we obtain $V_p = 100$, giving $I_{cp} = 4$.

V_p	I_{cp}
$V_p \geq 90$	**4**
$70 \leq V_p < 90$	3
$50 \leq V_p < 70$	2
$V_p \leq 50$	1

Table 2: Construction period index.

The structural type index I_{st} depends on the ratio of reinforced concrete (RC) buildings to the total (Table 3), equal to 0 for Saracena area because there are no RC buildings.

Ratio of RC buildings to total	I_{st}
> 75%	-1
≤ 75%	**0**

Table 3: Structural type index.

The height index I_h is a function of the height value V_h (Table 4), depending on the number of buildings having the same floors number. It is assumed that all the buildings in the Saracena area have (average) two floors, therefore $V_h = 0.50$ and $I_h = 0$.

V_h	I_h
> 0.500	1
≤ 0.500	**0**

Table 4: Height index.

The urban vulnerability index I_{uv} and the specialist type index I_{spt} depend on the use and they are equal to 0 for urbanized and residential areas like Saracena.

The seismic classification index I_{sc} takes into account the seismic zone in which the area is located (Table 5), and in this case it is assumed equal to 1 [20].

Seismic zone	I_{sc}
Seismic zone 2 with classification after 2003	**1**
Seismic zone 2 with classification before 2003 Seismic zone 3 or 4	0

Table 5: Seismic classification index.

The Vulnerability Index I_v, obtained from the sum of the different indexes described above, permits the definition of Seismic Vulnerability Class V (Table 6). In this case $I_v = 5$, therefore V = 4.

Seismic Vulnerability	I_v	V
High	$\mathbf{I_v \geq 4}$	**4**
Medium-High	$I_v = 3$	3
Medium-Low	$I_v = 2$	2
Low	$I_v \leq 1$	1

Table 6: Seismic Vulnerability Class.

The Exposure Class E depends on the exposure index I_e (Table 7), that is the sum of the density index, taking into account the number of buildings and the resident population consisting of 249 residents (data provided by the Municipality), and the destination index, equal to 0 for residential areas. In this case, $I_e = 4$ and $E = 4$.

Seismic Exposure	I_e	E
High	$\mathbf{I_e \geq 4}$	**4**
Medium-High	$I_e = 3$	3
Medium-Low	$I_e = 2$	2
Low	$I_e \leq 1$	1

Table 7: Seismic Exposure Class.

Finally, The Risk Class R is determined according to the Indicator of Risk IR = H + V + E (Table 8). For Saracena area, R is equal to 4, corresponding to a high seismic risk.

Seismic Risk	IR	R
High	**IR ≥ 10**	**4**
Medium-High	8 ≤ IR < 10	3
Medium-Low	6 ≤ IR < 8	2
Low	IR < 6	1

Table 8: Risk Class.

4 CONCLUSION

In the present work, seismic risk assessment at urban level of Saracena area of historical center of Tricarico village (South of Italy), is analysed and reported. The analysis has been conducted through an expeditious method proposed by Tuscany region that has the advantage to obtain seismic risk level of a compartment, whole city or territory, through the acquisition of simple information deduced by dataset and surveys. In the specific, the seismic risk is expressed through an index that is given by the sum of index dependent by exposure, hazard and vulnerability.

In this study, information about three aforementioned parameters was deduced by surveys, National Dataset (ISTAT) and through the collaboration of municipal corporation: Saracena area is characterized by a few main streets in which disordered masonry buildings are very close to each other (exposure and vulnerability) and with an average number of floors equal to two and a medium seismic hazard level (hazard). From the information deduced and detailed in the paper, a high seismic risk class was deduced, due essentially to the exposure and vulnerability of the urban fabric of Saracena area.

Further studies will be conducted to further investigate the seismic risk of this compartment in relation to the acquisition of more structural details of buildings, while other studies, at the level of typological buildings, are ongoing to assess their relative seismic risk.

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