SEISMIC RISK OF THE BASILICATA CASTLES

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Abstract – In This work the seismic risk of fortified structures located in Basilicata -Southern Italy- is evaluated. The procedure is based on damage records shown during the Irpinia earthquake in 1980, taking into account architectural variability, materials, construction system and acceleration of the soil registered during the event for each case. Then, a comparative analysis of seismic threat and the current state of the Basilicata's castles through the use of Geographic Information System –GIS- has been carried out. The results highlight that are prevailing the conditions of deterioration and abandonment in the castles located in the area with greater seismic hazard.

Key Words – Architectural heritage, Castles, Seismic risk.

I. INTRODUCTION

The damages presented during the Emilia earthquakes in May 2012 evidenced the fragility of fortifications in this region. This has motivated researches about seismic damages and seismic responses of their structures, this allowed the creation of abacuses [1] and simplified analyzes of seismic vulnerability in the characteristic fortresses of the Emilia region [2][3].

However, the structures of southern Italy, specifically in Basilicata and nearby regions have a different typology from those present and studied in the Emilia region, highlighting among them the shape, height, construction system, materials, and location [4]. Likewise, within these structures there are very noticeable variability, especially in its geometric form and material constitutive [5]. For these kind of fortress there are some researches that have studied seismic hazard [6] and seismic vulnerability [7], the results have shown the compression of the elastic-dynamic behavior for individual castles and their stress-strain distribution against seismic forces.

On other hand, historically, Basilicata region has suffered earthquakes of great impact that seriously affected its architectural heritage, one of them was the Irpinia earthquake in 1980, where 17 fortresses surrounding the epicenter were strongly damaged, most of them in a state of ruins and /or abandonment before the earthquake [4][5].

Coisson et al. [4]. in order to analyze the damage mechanisms activated for each type of fortress in the last seismic events in Italy, have developed a database using GIS, where they have located all the fortifications affected after the earthquakes with the greatest impact from Friuli 1976 to Emilia in 2012, then, they related the acceleration of the soil (Sag), the damages presented for each structure, the most outstanding architectural characteristics of each case, and the state in which they were before the earthquake. The results allowed the identification of the mechanisms associated with the acceleration of the soil and it has been a great contribution to the understanding of the behavior of these structures.
Based on this analysis and relationship, it was decided to carry out a comparative analysis of the cases studied of the Irpinia earthquake in 1980, with the level of seismic hazard and current status of the Basilicata castles, analyzing the variables that could affect their seismic security.

II. MATERIALS AND METHODS

This work has been developed using bibliographic information, especially the data published by Coïsson et al. [4] and MiBAC [5] referring to the damages presented in the fortresses during the Irpinia earthquake in 1980, analyzing the different variables belonging to said studies and determining

the most relevant data management conclusions. Subsequently, a comparative analysis of the accelerations, materials, form and condition of the fortifications with the current status of the structures of the Basilicata has been proposed, determining a possible level of risk based on the historical record.

III. RESULTS AND DISCUSSION

Damage in fortresses during the Irpinia earthquake in 1980:
17 fortresses were affected within the provinces of Avigliano, Caserta, Napoli, Salerno and Potenza, Coisson et al, evaluated 18 possible types of damage in 8 characteristic places of the castles [5]. The most frequent damages were in vertical structures such as walls and towers and solutions of floors such as vaults [4]. In Fig. 1 it is to possible to see a correlation in the value of the acceleration presented and the number of damages in different parts of the fortress, with some exceptional cases, where other factors influenced the seismic response.

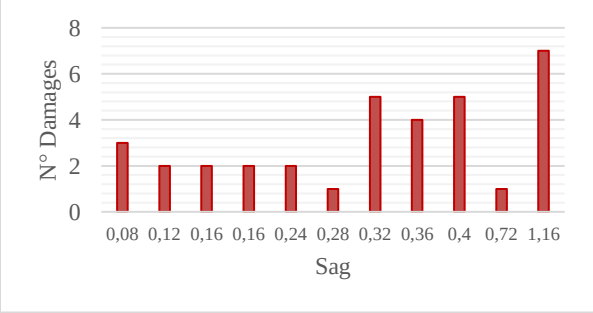

Figure 1. Soil acceleration (g) during Irpinia earthquake in 1980 and N° damages caused in fortresses.

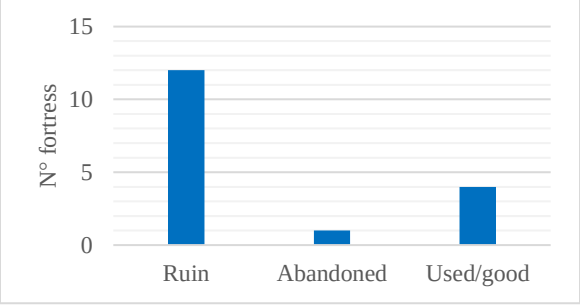

Figure 2. Current state of the Irpinia fortresses before the earthquake.

Another important factor that affected these structures is their state before the earthquake, where more than half of them were in ruins or abandoned, which increased their level of vulnerability (Fig.2).

Seismic Hazard in Basilicata:
Basilicata is one of the regions with greater seismic activity in the Italian territory, most of its municipalities are located in seismic zones cataloged between 1 and 2, corresponding to the maximum expected acceleration values with a probability of exceeding 10% in 50 years. Through the use of GIS, the Basilicata's fortresses have been located on the seismic map, similarly, the epicenters of the earthquakes with magnitude greater than 5.0 that have affected the region are shown (Fig. 3). [6][7][8].

45% of the fortresses identified are in zone 1 of seismic hazard, 47.5% of them in seismic hazard zone 2, while the remaining 7.5% is located in seismic zone 3. Similarly, it is identified that many of the large earthquakes in this territory have occurred in areas near the castles, which probably have caused damage and losses in these structures.

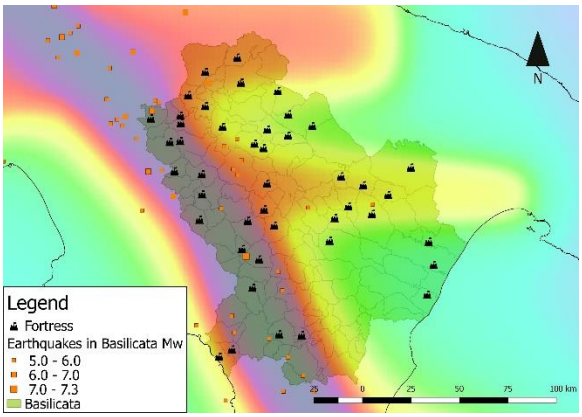

Figure 3. Localization of the Basilicata's castles on the seismic hazard map

On the other hand, following the analysis carried out by Coïsson et al. [4], we have proceeded to characterize the Basilicata fortresses, according to the type of masonry, geometry of the towers, current status, seismic classification and seismic acceleration range in terms of the expected severity for 50 years and probability of exceeding 10%. The results are summarized in table 1.

The type of masonry could be defined as (S=stone units or rubble masonry, B=solid clay bricks, T=tuff units); the geometry of the towers (N=none,

C=circular, R=rectangular, I=irregular) and Current State R: Ruin, U: Used, A: Abandoned, W: restoration works.

Table 1 Characterization and seismic level of the Basilicata's castles

Province	Id	Fortress	Building technique	Towers presence	Current state	Seismic class	A [g]
PZ	1	Castello di Acerenza	S	C	W	2	0,15-0,25
PZ	2	Castello di Anzi	S	N	R	1	>0,25
PZ	3	Torre Angioina, Atella	S	C	W	1	>0,25
PZ	4	Castel Lagopesole, Avigliano	S	R	U	1	>0,25
PZ	5	Castello Aragonese di Bella	S	C	U	1	>0,25
MT	6	Castello di Bernalda	S	C+R	W	2	0,15-0,25
PZ	7	Castello di Brienza	S	C+R	U	1	>0,25
PZ	8	Castello di Brindisi di Montagna	S	R	W	2	0,15-0,25
PZ	9	Castello di Calvello	S	N	W	1	>0,25
PZ	10	Castello di Cancellara	S	N	W	2	0,15-0,25
PZ	11	Castello di Episcopia	S	C	R	2	0,15-0,25
MT	12	Castello di Uggiano, Ferrandina	S	R	R	2	0,15-0,25
PZ	13	Castello di Monteserico, Genzano di Lucania	S	N	U	2	0,15-0,25
MT	14	Palazzo Commendale, Grassano	S	N	R	2	0,15-0,25
MT	15	Castello di Sichunulfo, Grottole	S	R	U	3	0,05-0,15
PZ	16	Castello di Sanseverino, Grumento Nova	S	N	R	1	>0,25
PZ	17	Castello Orsini del Balzo, Laureanza	S	C	R	1	>0,25
PZ	18	Castello di Castrocucco, Maratea	S	C	R	2	0,15-0,25
PZ	19	Castello di Melfi	S	R	U	1	>0,25
PZ	20	Palazzo Mazza, Marsicovetere	S	C	U	1	>0,25
MT	21	Castello Tramontano, Matera	T	C	W	3	0,05-0,15
MT	22	Castello del Mancosiglio, Miglionico	S	C+R	U	3	0,05-0,15
PZ	23	Castello di Moliterno	S	C+R	W	1	>0,25
PZ	24	Castello Sgarroni, Monticchio	S	R	R	1	>0,25
PZ	25	Castello di Muro Lucano	S	N	U	1	>0,25
PZ	26	Castello Marchesale, Palazzo S. Gervasio	S	N	W	2	0,15-0,25
PZ	27	Castello di Pecospagano	S	R	R	1	>0,25
PZ	28	Castello di Picerno	S	C	U	1	>0,25
PZ	29	Palazzo Ducale, Pietragalla	S	N	U	2	0,15-0,25
MT	30	Castello di San Basilio, Pisticci	B+S	C+R	U	2	0,15-0,25
MT	31	Palazzo Baronale, Policoro	T	N	U	2	0,15-0,25
MT	32	Castello di Salandra	S	N	R	2	0,15-0,25
PZ	33	Castello di San Fele	S	C	R	1	>0,25
MT	34	Torre Normanna, San Muro Forte	S	C	W	2	0,15-0,25
PZ	35	Torre di Satriano	S	R	W	1	>0,25
MT	36	Castello di Stigliano	S	R	R	2	0,15-0,25
MT	37	Castello di Tricarico	S	C	U	2	0,15-0,25
MT	38	Castello di Isabella Morra, Valsinni	S	n	U	2	0,15-0,25
PZ	39	Castello Pirro del Balzo, Venosa	S	C	U	2	0,15-0,25
PZ	40	Castello di Viggiano	S	C	R	1	>0,25

As can be seen in table 1, there is no defined architectural pattern for the Basilicata castles, especially in the towers, where there is a variation in their forms, whether rectangular, circular, or combined, even where there is no presence of towers. On the other hand, 92% of the structures have rocks as their constituent material, and are characterized by *'a sacco* masonry *'*.

Most of the fortresses of the Basilicata are located in the province of Potenza, of which a third are defined as ruins or abandoned, this probably related to the seismic activity recorded during the last 200 years. Another 33.3% of the castles are in restoration processes and the remaining percentage are in use and in good condition in general. With regard to the fortresses of the province of Matera, 47% of them are in good condition and are currently

in use, 23% are in restoration work and only 30% in ruins. As a correlation of the damage and seismic threat, all the fortresses that are in ruins in the province of Potenza are in zones categorized seismically as 1, while 4 fortresses of the province of Matera that are in ruins, are in an area Seismic 2, which corresponds to the highest seismic hazard of each province.

From the results analyzed during the Irpinia earthquake in 1980, it is observed that the accelerations values from 0.1g, affected the fortifications surrounding the epicenter of the earthquake, although it is true that many of these buildings were in ruins or abandonment. Comparing these conditions with the current state of the castles in Basilicata, the risk of damage and losses increases, so it is necessary to develop a seismic risk management plan for these structures.

IV. CONCLUSION

A territorial seismic risk analysis of the castles of the Basilicata based on historical records and on damages presented according to the materials, forms and accelerations in the soil has been developed. Although the results showed a correlation of seismic events in recent years with the current state of many of the fortresses, and the high level of seismic threat, it was not possible to determine a vulnerability index for each structure according to its characteristics due to its geometric variability and to the diversity of the damages presented in the castles during the last earthquake in Irpinia.

On the other hand, these results are presented as a contribution in territorial risk management and conservation of the fortified heritage of Basilicata and basis for future studies of seismic risk.

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