Seismic prevention from the multiple utilities of detailed seismic microzonation investigations: expected amplifications, damage occurred, correlated intensities, land management using the H_{SM} parameter, declaration of a state of emergency.

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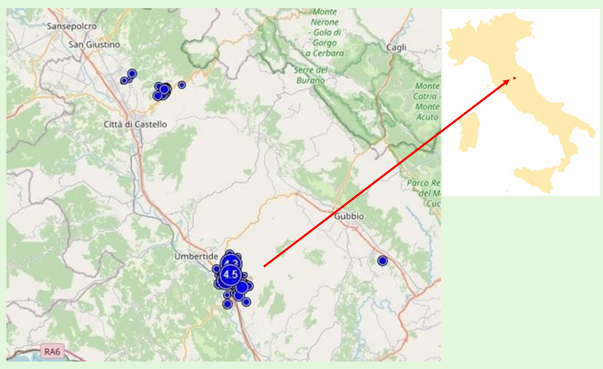
Seismic prevention, derived from seismic microzonation (MS) investigations, plays a critical role in achieving fundamental levels of civil protection safety across territories and enhancing resilience to natural disasters. During emergencies, challenges in managing seismic prevention or delayed decisions, by 1-2 days or worse, erroneous decisions made due to insufficient knowledge, can have lasting repercussions on the lives of many people for years to come.

On 9 March 2023, two earthquakes struck just south of Umbertide. The first occurred at 16:05 with a magnitude of 4.3, followed by a second quake at 20:08 with a magnitude of 4.5, and another event registering 3.8 magnitude at 20:13. Within the initial 24-hour period following the seismic activity, the regional seismic network detected approximately 70 seismic events with magnitudes exceeding 0.5 in the same epicentral area, along with their respective locations. These earthquakes originated at a depth of approximately 5 kilometers.



A temporary seismic mobile accelerometer was deployed in Pierantonio and integrated into the network of the four permanent stations. The acquisition system operated for three months, during which data was collected and analyzed to enhance understanding of seismic accelerations at the site.

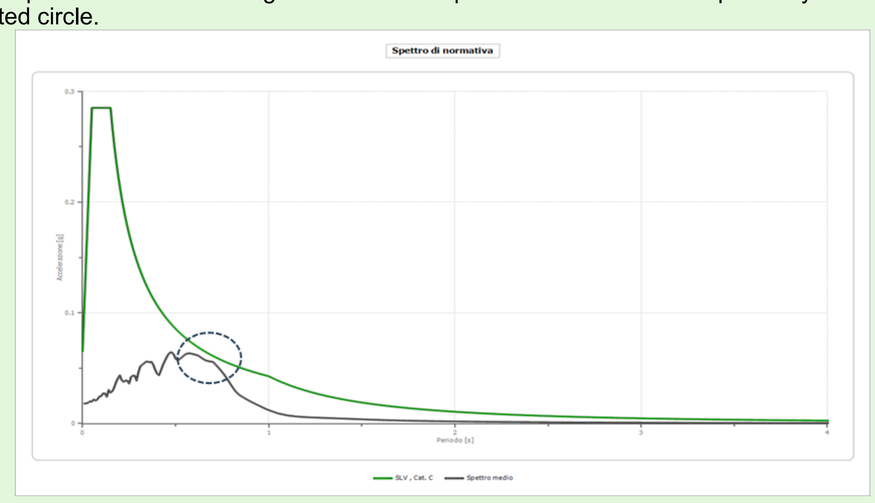
The accelerometer stations situated in Pierantonio recorded values in percentages of gravitational acceleration (% of g) 5-6 times higher than the 'non-amplified' RAN-Umbertide permanent station. Therefore, the seismic values for the earthquake that occurred on March 9th at 20:08 in the Pierantonio area can be indicated as follows, according to the legend of the INGV shaking maps.

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0555	0.232	1.21	3.38	7.46	14.5	26.	44.4	>72.3
PGV(cm/s)	<0.0178	0.0939	0.686	2.08	5.06	10.9	21.	40.3	>71.7
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

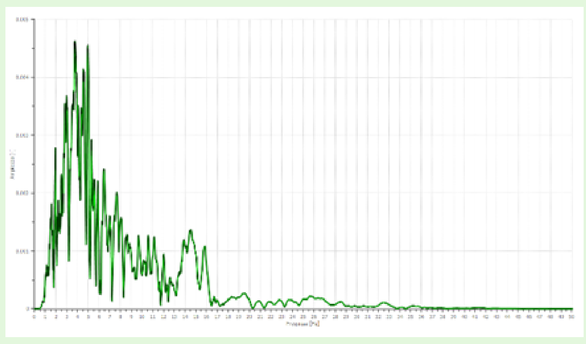
Scale based on Oliveti Faenza Michelini (2022) Version 1: Processed 2023-03-09T19:59:18Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

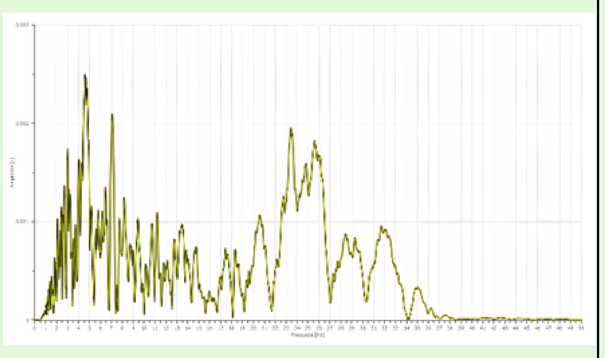
This assessment reaffirms the findings derived from the comparative analysis between the observed damage and the detailed seismic microzonation investigations conducted for the Pierantonio locality, where the estimated degree of damage was assessed to be no less than a macroseismic intensity of level 7. Hence, it is confirmed that detailed seismic micro-zoning investigations play a crucial role in promptly assessing potential damage in the event of seismic events.

The analysis of accelerometer data obtained from the Re.Si.R. network has demonstrated the significance of the vertical component in local earthquakes. This importance is evident in both the vertical peak ground accelerations (PGAs) compared to the horizontal PGAs and the effects associated with the simultaneous occurrence of seismic motion components. The comparison of the spectrum related to the impact of the most intense earthquake in Umbertide seismic activity (March 9, 2023, magnitude 4.5) with the NTC spectrum for a Class II usage and a Type C subsoil category emphasizes the importance of considering the vertical component. Please note the proximity between the spectra marked within the dotted circle.

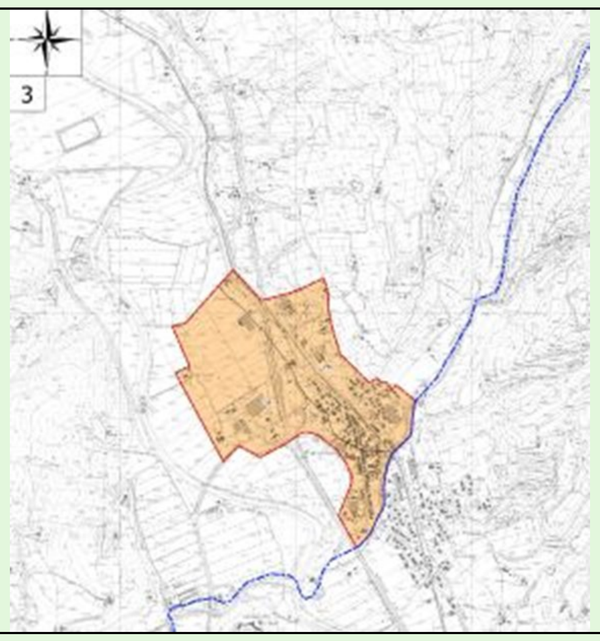


The relationship between the horizontal (left) and vertical (right) frequency spectra for an earthquake that occurred between Umbertide and Pierantonio on April 17, 2023, with a magnitude of 3.2.
The data originates from the Re.Si.R accelerometer station near Pierantonio.

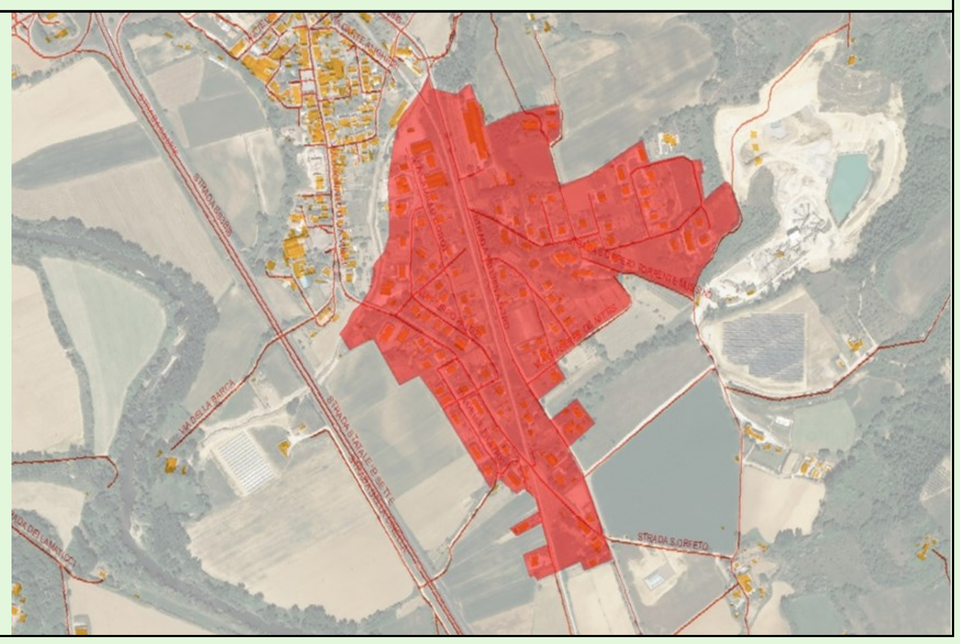




The Geological Section of Regione Umbria has conducted highly detailed seismic microzonation surveys spanning over a decade for the Pierantonio area. In 2014, comprehensive seismic microzonation investigations were conducted utilizing numerical modeling and recordings of seismic force amplification phenomena. The obtained seismic amplification factor (FA) values reached 1.9.
The data can be downloaded from the following links:
https://www.regione.umbria.it/paesaggio-urbanistica/area-urbana-di-umbertide
https://www.researchgate.net/publication/265172825_La_microzonazione_sismica_dell'area_urbana_di_Umbertide



Recent assessments conducted by the Geological Bureau focused on the amplification of seismic forces in the Sant'Orfeto area, situated immediately south of Pierantonio. These assessments yielded FA values consistent with previous findings, also at 1.9.



The analysis of the HSM parameter, utilizing FA values (amplification factors) calculated in MS studies and the fundamental seismic hazard of the surveyed territory, assesses the "integrated" seismic hazard level. This evaluation encompasses both the basic hazard and lithostratigraphic amplification effects across various regions of the territory. Through simplified and advanced analyses for seismic risk assessments, it also identifies vulnerabilities in buildings.
The processing methods enable standardized values on a national scale, facilitating comparable assessments. Below, you'll find the classification of the Hsm parameter values for different period intervals.

Intervalli di periodo	Classificazione H_{SM}[g]			
	Basso ($ZS4_{SM}$)	Medio ($ZS3_{SM}$)	Alto ($ZS2_{SM}$)	Molto alto ($ZS1_{SM}$)
$T1_{(0.1-0.5)}$	≤ 0.21	0.22-0.54	0.55-0.85	≥ 0.86
$T2_{(0.4-0.5)}$	≤ 0.14	0.15-0.34	0.35-0.55	≥ 0.56
$T3_{(0.7-1.1)}$	≤ 0.09	0.10-0.22	0.23-0.35	≥ 0.36

Tabella 2 – Classificazione di H_{SM} per i 3 intervalli di periodo.

	Hsm (0.1s-0.5s)	Hsm (0.4s-0.8s)	Hsm (0.7s-1.1s)
Pierantonio	0.799	0.612	0.367
Sant'Orfeto	0.949	0.559	0.283
Umbertide	0.499	0.379	0.227

The HSM classification, when suitably integrated with the EMS-98 vulnerability classification (Grunthal, 1998), serves as a tool for assessing the average expected damage within a microzone or census area, aligned with the EMS-98 scale. The average vulnerability values are categorized based on the height of buildings (small, medium, and large), corresponding to the T1, T2, and T3 intervals.
The figures illustrate the average damage values on the EMS98 scale (D0-D5) across the three period intervals. The damage classes that potentially impact life safety are highlighted in grey. These classes are linked with a 10% probability within a 50-year

	ZSsm Classification		
Pierantonio	ZS2 high	ZS1 very high	ZS1 very high
Sant'Orfeto	ZS1 very high	ZS1 very high	ZS2 high
Umbertide	ZS3 medium	ZS2 high	ZS3 medium

a) T_1=0.1-0.5 s	H_{SM}[g] HAZARD CLASS			
	LOW	*MODERATE*	*HIGH*	*VERY HIGH*
	≤ 0.21	0.22-0.54	0.55-0.85	≥ 0.86
VULNERABILITY CLASS EMS98	AVERAGE EMS98 DAMAGE GRADE			
E	*D0*	*D0*	*D0-D1*	*D1-D2*
D	*D0*	*D0-D1*	*D1*	*D1-D3*
C	*D0*	*D0-D1*	*D1-D2*	*D2-D4*
B	*D0-D1*	*D1-D2*	*D2-D3*	*D3-D4*
A	*D0-D1*	*D1-D3*	*D3-D4*	*D4-D5*

The structures in Pierantonio and Sant'Orfeto primarily belong to Class C buildings, typically comprising a maximum of two floors. The projected level of damage, ranging from D2 to D4 according to the analysis, reflects interventions on properties affected by the earthquakes in 1984 and 1997. These local measures have mitigated the extent of damage anticipated.

Conclusions

The seismic events on March 9, 2023, underscored how the MS investigations had previously outlined the anticipated amplifications and damages. This was achieved through the calculation of the Hsm parameter across various regions. The processing methods ensure consistent values nationally, enabling comparable evaluations.
Seismic microzonation (MS) investigations conducted using various methods and at different times yield consistent outcomes: the damage incurred and the macroseismic intensity observed during seismic events align with the seismic amplifications identified through detailed seismic microzonation.
During seismic events, the availability of detailed seismic microzonation products online, along with specialized personnel proficient in their utilization, facilitates expeditious decision-making processes such as declaring a state of emergency, in response to the event at hand.
Territorial management employing the Hsm value delineates areas and inhabited regions vulnerable to damage based on building types. This value consistently aligns with the patterns of damage resulting from seismic events.
After considering the seismic event, all the analyses and evaluations affirm the effectiveness of detailed seismic microzonation investigations and the application of the Hsm value in preventing seismic risks. This underscores the importance of proper management and planning of the territory and emergencies.