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INITIAL-LEVEL REPORTS OF LANDSLIDES INVOLVING BRIDGES AND VIADUCTS: THE CASE STUDY OF VILLA ILII (CENTRAL ITALY)

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EXTENDED ABSTRACT

Nel corso degli ultimi decenni, la crescente frequenza di eventi naturali responsabili del collasso o del danneggiamento delle infrastrutture viarie è divenuta una questione di profonda preoccupazione per la società civile e la comunità tecnico-scientifica, tanto da evidenziare l'urgenza di azioni di previsione, prevenzione e monitoraggio dei processi e dello stato di salute delle opere stesse. A livello globale, un numero sempre crescente di opere strategiche per i trasporti, tra cui segmenti autostradali e ferroviari, ponti e gallerie, subisce periodicamente gli effetti distruttivi causati da frane, alluvioni e terremoti. La gravità e la frequenza di tali episodi sembrano aumentare di pari passo con il cambiamento climatico in corso, a cui si combina un forte incremento della popolazione mondiale, che indubbiamente favorisce l'articolarsi dei collegamenti fisici di trasporto e dei servizi.

L'Italia, in particolare, è stata interessata da significativi eventi di cedimento di ponti e viadotti, vividamente illustrati nei recenti casi dei Polcevera e Magra, le cui ripercussioni hanno avuto un grande impatto sia direttamente che indirettamente sulla società e sull'economia. Le conseguenze del crollo del viadotto Polcevera hanno suscitato una profonda consapevolezza nelle Istituzioni, sottolineando l'urgente necessità di istituire pratiche normative finalizzate alla valutazione, al monitoraggio e alla gestione dei rischi connessi a queste infrastrutture. In risposta a questa esigenza, gli enti governativi hanno avviato diversi progetti di ricerca e sviluppo. Il presente lavoro si inserisce nell'ambito di uno di questi progetti, affidato al consorzio ReLuis, che ha lo scopo di contribuire all'applicazione e all'ottimizzazione di un protocollo sperimentale procedurale volto ad identificare le classi di attenzione e valutare il livello di rischio intrinsecamente associato ai viadotti italiani. Questo al fine di mettere a punto un piano mirato di interventi, ottimizzato sulle risorse, che avrà un respiro pluriennale. In questo contesto, preso atto che molte opere infrastrutturali sottoposte a un'esposizione prolungata agli agenti atmosferici e alla fatica prolungata dovuta al traffico, presentano condizioni di deterioramento accelerato e mal sopportano eventuali carichi esterni indotti da fenomeni di instabilità di versante interferenti, diventa di particolare significato l'indagine olistica dei sistemi versante/infrastruttura.

Questo studio affronta tale problema per successivi gradi di approfondimento. In particolare, è stata condotta un'analisi preliminare che esamina l'interazione tra una frana da scorrimento e il Viadotto "Villa Ilii" situato lungo l'autostrada A24 (Roma-L'Aquila-Teramo) nel Comune di Colledara (Teramo). Lo studio è stato sviluppato per valutare le caratteristiche geometriche e cinematiche della frana e le sue potenziali interazioni con l'opera, contribuendo alla definizione delle classi di attenzione, così come previsto dalle "Linee Guida per la classificazione e gestione del rischio, la valutazione della sicurezza ed il monitoraggio dei ponti esistenti", sia pur nella loro fase prototipale di sperimentazione. L'iter metodologico impiegato per il perseguimento di questo obiettivo abbraccia una serie di azioni mirate, che spaziano dalla raccolta estensiva di dati e rilevamenti sul campo, al monitoraggio con tecniche di telerilevamento. Iniziando con la ricostruzione del contesto geologico e geomorfologico del versante interessato dal dissesto, lo studio è poi consistito in un esame particolareggiato delle caratteristiche morfologiche e cinematiche della frana, con particolare riguardo all'area in cui essa interagisce con il viadotto. L'area di riferimento è caratterizzata da litologie appartenenti alla Formazione della Laga, composte principalmente da un'alternanza di arenarie e marne, coperte principalmente da depositi quaternari sabbiosi. I dati stratigrafici suggeriscono come la frana si attesti principalmente nei depositi quaternari, con la superficie di scorrimento individuabile al contatto tra queste e le formazioni di base più antiche. Le analisi eseguite hanno consentito di costruire un database contenente le informazioni inerenti alle geometrie della frana, al suo stato di attività e alla sua cinematica recente. Ai fini dello sviluppo di tale database, l'acquisizione dei dati preesistenti e derivati dagli archivi tecnici dell'Ente gestore e degli Enti territoriali ha rappresentato il primo step. A tali dati sono stati aggiunti quelli ricavati recentemente da questa Unità di ricerca e riguardanti le morfometrie e le litologie caratteristiche del sistema in ragione del modello cinematico di frana, alla cui definizione hanno contribuito anche indagini geofisiche di superficie, contribuendo in modo significativo allo sviluppo delle conoscenze. Il rilevamento sul campo ha anche permesso di individuare segni tangibili di deformazione, manifestatisi sotto forma di lesioni negli edifici e fabbricati presenti nelle aree circostanti la frana, che trovano accordo con i dati interferometrici SAR, elaborati attraverso il software SUBSIDENCE relativamente al complesso frana-viadotto. Dall'interpretazione di tali dati deformativi è emersa una preesistente lenta mobilità del corpo di frana, globalmente più evidente negli ultimi anni, con accelerazioni durante i periodi estivi. Questo fenomeno deve essere interpretato alla luce delle litologie argillose costituenti il corpo di frana e le interfacce di scorrimento e il regime idrologico e idrogeologico in ambienti di alta quota, quale quello del presente caso di studio. Questo insieme di informazioni assume un ruolo cruciale nella comprensione degli effetti della frana sull'integrità strutturale del viadotto "Villa Ilii".

ABSTRACT

In the last decades, the concern for infrastructure damage and collapse due to natural hazards has globally increased. Highways, railways, bridges, and tunnels, worldwide, have faced consistent damage or destruction from landslides and floods, exacerbated by the ongoing climate change and population growth. In Italy, significant examples of these events are the recent failures of the Polcevera and Magra bridges, impacting people and the local economy. Especially, after the Polcevera bridge collapse, the Italian government has considered the need for specific practices of bridge/viaduct risk assessment. In response to this requirement, governmental agencies have developed specific projects oriented to the development of specific guidelines. This work is part of one of these projects, entrusted specifically to the ReLuis consortium, aimed at contributing to the application and optimization of an experimental protocol for bridge/viaduct classification in natural-hazard related risk assessment perspective.

In this context, this work describes the results of an initial-level analysis of the interaction condition of a slow-moving landslide with the "Villa Ilii" Viaduct located along the A24 highway at Colledara, in the Teramo Province. The analysis aims to evaluate landslide characteristics, including landslide anatomy and kinematics, and their potential impact, contributing to define and identify viaduct classification in landslide risk perspective. The study area is characterized by the presence of the Laga Formation, mainly represented by sandstones and marls, overlaid by sandy Quaternary deposits. In fact the formation of the Laga (Ricci Lucchi, 1975) represents the filling of one of the many foreland basins currently exposed in a wide area between southern Marche and northern Abruzzo, developed at the forefront of the Apennines during its migration eastward and northeastward, as a result of the collision between the European lithospheric plate and the Adriatic plate, a likely protrusion of the African continent.), Methods including existing data collection, field surveys, numerical chartography analysis, geophysical surveys and PS InSAR technique were used to reconstruct the geological setting of the slope affected by the landslide, its anatomy and kinematics. Especially, multiple field surveys and numerical cartography analysis revealed landslide extent over a surface of 78,000 m^2, geophysical survey indicated a landslide thickness of around 15 m, comparable with the thickness of Quaternary deposits, and SAR-interferometric data, processed by SUBSIDENCE software, indicated persistent slow movement typically accelerating in spring.

These data are crucial for understanding the landslide's potential impact on the "Villa Ilii" viaduct's structural conditions, already exhibiting local deformation and cracking, similar to surrounding settlements.

Keywords: *landslides, interferometry, interferometric synthetic aperture radar (InSAR), transport networks, ground deformations, HVSR*

INTRODUCTION

Transportation infrastructures play a crucial role in supporting socio-economic progress of the civil society, enabling the seamless flow of individuals, and supporting services as an essential foundation for development. Sustaining and preserving the full efficiency of these infrastructures necessitates consistent surveillance and evaluation of surface and structural alterations arising from both natural hazards and human activities (Bakon *et alii*, 2014; Teatini *et alii*, 2005). Monitoring, therefore, emerges as a necessary practice to safeguard these important infrastructures and evaluate the natural hazards to which they are exposed. Within the project entrusted to the ReLuis consortium by the Italian Government, it was possible to develop this research focused on the most suitable and effective monitoring techniques, combining conventional and innovative methodologies. Recent studies have confirmed the effectiveness of Satellite Interferometry techniques as a supplementary tool to conventional monitoring methods. This technique offers a distinctive perspective, complementing conventional ground monitoring systems and allowing a preliminary evaluation of various phenomena, especially facilitating extensive, large-scale investigations into road network surface deformations (Milillo *et alii*, 2018; Miele *et alii*, 2021).

This research conducts an in-depth analysis of a viaduct segment on the A24 highway in Central Italy. The primary goal is to showcase the efficacy in understanding the phenomenon by considering field data supporting Synthetic Aperture Radar (SAR) ones, for evaluating the landslide's criticisms on the "Villa Ilii" viaduct. The A24 highway is a critical transportation route connecting Rome to the Adriatic Sea, traversing the rugged terrain of the Gran Sasso Massif. The region features hilly slopes with low to medium acclivity, experiencing various erosional and gravitational phenomena. Landslides are particularly prevalent and noteworthy geohazards in the area. Additionally, the region experiences substantial snow cover during the late autumn and winter seasons.

Utilizing detailed infrastructure design plans, SAR image datasets, in-situ measurements, and a Hydro-geomorphological Setting Plan, a comprehensive analysis of the highway segment was conducted. Notably, even large-volume landslides characterized by slow movements can be effectively monitored over broad periods using satellite monitoring techniques.

A key objective of this research is to validate the reliability of DInSAR measurements in integrating with conventional in-situ monitoring methods and field surveys. The approach outlined in this study holds significant potential to the substantial quantity of available SAR data, coupled with its affordability and proven reliability in monitoring and assessing structural deformations caused by geological phenomena over time. Furthermore, this wealth of data could be integrated into an early warning system, providing invaluable assistance to decision-makers in action planning and managing the transport network, as well as in civil protection support after paroxysmal events. Ultimately, this contributes to enhancing safety standards and maintenance practices in crucial transportation networks, ensuring their longevity and serviceability.

The aim is the reconstruction of the landslide interacting with the viaduct through the integration of conventional and satellite techniques in order to provide infrastructure managers with a useful tool for the safe management of the infrastructure.

CASE STUDY

In this case study, we delved into an exhaustive analysis of the A24 highway in Central Italy. The study focuses on the "Villa Ilii" Viaduct, a 744-m-long infrastructure situated along the A24 Roma - L'Aquila - Teramo highway, in the municipality of Colledara (Teramo province), with an altitude of approximately 450 m above sea level. The investigation site falls within Sheet 140 (Teramo) of the Geological map of Italy at a scale of 1:100,000. This sheet served as the starting point for the creation of the Geological Map for the Regional Seismic Micro-zonation of Abruzzo (2016).

Through the accurate identification of the lithologies in the area and by referencing previous geological maps prepared for works conducted in the Abruzzo Region (Excerpt from the Geological Map for the Regional Seismic Micro-zonation of Abruzzo), an informatized geological map was created using QGIS (Fig.1).

The soils under study predominantly consist of dark brown sandy-clayey silt, overlaid by layers of sub-rounded sandy gravel and hetero-granular, polychromatic, polygenic pebbles from the Quaternary - Recent period, belonging to the Formation of Laga. These layers rest on a horizon composed of clayey silt and argillaceous marl, likely representing the geological substrate.

The detrital nature of superficial horizons likely results from solid transport and persistent flows on materials with secondary bedding. These layers are mainly distributed according to the drainage surfaces in the area and are subsequently reshaped by fluvial erosive action. The landslide affecting the "Villa Ilii" Viaduct appeared to involve the shallow layers, with the sliding surface placed at the contact between the cover detrital material and the geological substrate of very cohesive silty marls. This study provides a geological basis for understanding the criticisms of the viaduct in slope stability key. This may be the essential base for future risk assessment and management interventions.

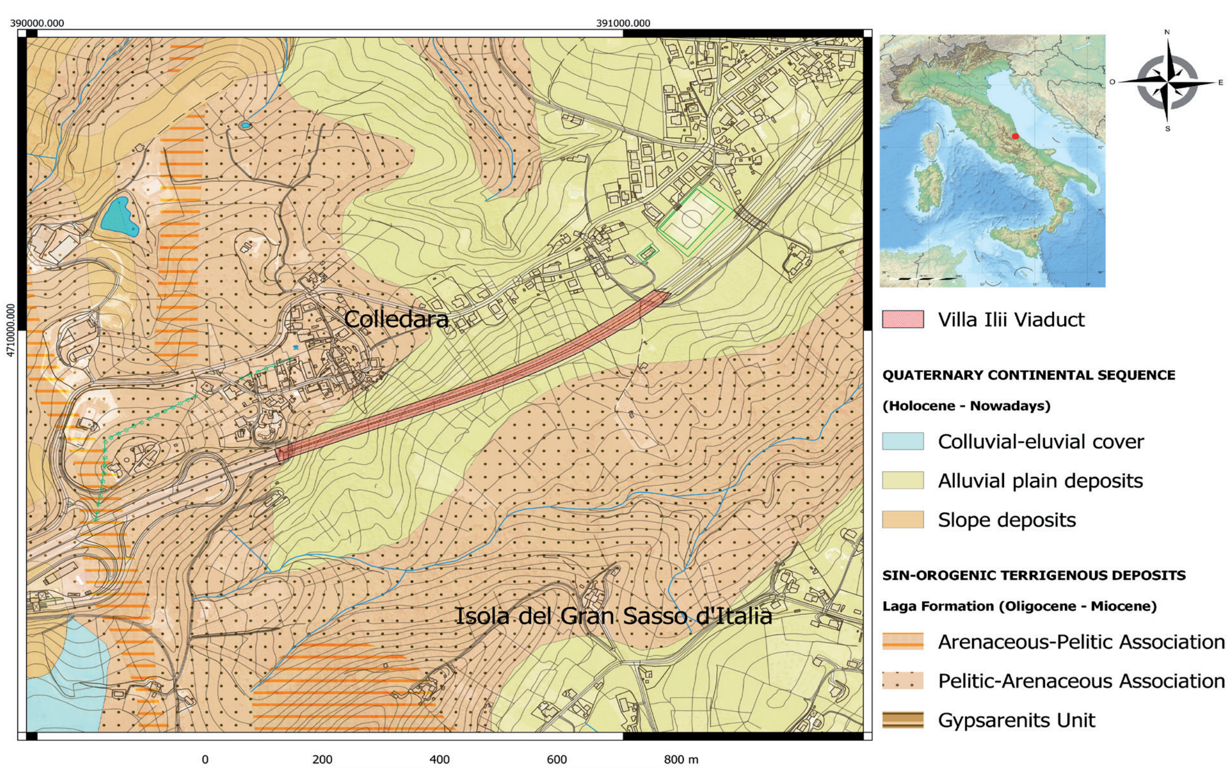

Fig. 1 - Geological map detail (1:5000) [Excerpt from the Geological Map for the Regional Seismic Micro-zonation of Abruzzo]

DATA SETS

Hydro-geomorphological Setting Plan is a fundamental tool within the framework of Italian territorial planning policy. It serves as the cognitive, regulatory, and technical-operative instrument constituting the base for the defence against hydrogeological risk plain to interventions, actions, and land use regulations. It provides the basis for the Geomorphological Map, from which the morphology of the landslide of our interest has been extracted.

The study benefited from prominent Horizontal-from-Vertical Spectral Ratio (HVSR) investigations available for seismic micro-zonation commissioned by Colledara Municipality, subsequently complemented by in-house surveys conducted by the research team. These resources collectively enriched the dataset, enhancing the depth and precision of the seismic analysis.

All these datasets, when taken together, provided a comprehensive overview of the landslide deformation affecting the A24 highway in the Villa Ilii viaduct sector.

Consulting furthermore archival investigations from the Regional Seismic Micro-zonation of Abruzzo (Fig. 2), specifically some boreholes (S1, S2, S3 and S4) drilled several hundred meters from the landslide of our interest, it was possible to obtain a stratigraphic description.

The landslide, identified by local authorities as a "dormant" rotational slide, extends along a moderately steep slope (10-25°) from a maximum elevation of 473 m a.s.l. to a minimum elevation of 425 m a.s.l., covering a total area of 78,000 m^2. Historical investigations of the area indicate an approximate depth of the sliding surface ranging between 15 and 20 m.

The stratigraphic sequences affecting the studied area are predominantly composed of sandy-clayey silt of a brownish color, overlain by layers of sub-rounded sandy gravel and granular, polygenic, and polychrome pebbles from the Quaternary to Present. The latter emerges in the upper part of the examined landslide movement. These layers rest on a horizon composed of silty clay and clayey marls, which presumably represents the geological substrate.

SAR image datasets and additional HVSR survey were then added. They have been crucial for assessing surface deformations on a large scale. The available SAR data included COSMO-SkyMed images, covering the period from January 2021 to August 2023. COSMO-SkyMed data comprised a stack of 80 images for the ascending dataset.

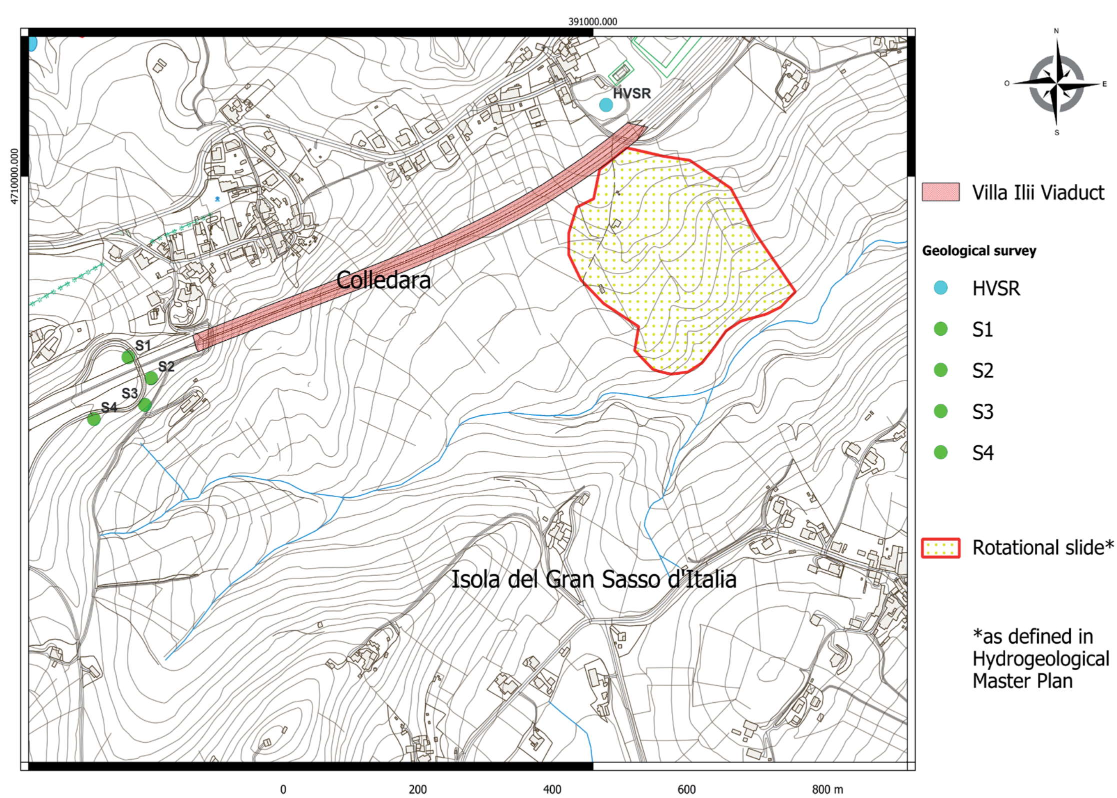

Fig. 2 - Rotational slide interacting with the viaduct (as defined in Hydro-geomorphological Setting Plan) and ancillary data location

METHODOLOGY

Satellite Data Processing

Interferometry is a technique exploiting the interference phenomenon between coherent waves (typically light, sound, or radio waves) to make measurements of wavelengths, distances, and material displacements they interact with. Specifically, the interaction of transmitted and reflected waves with the same wavelength produces a resulting wave based on the phase shift. In SAR interferometry, the focus is on studying the phase and amplitude differences of the backscattered signal between two SAR images observing the same scene from different view angles. To analyze ground displacement contributions using SAR images, its crucial to isolate only the phase component due to terrain movement. This is achievable through the use of Differential Interferometric Synthetic Aperture Radar (DInSAR) techniques, which employ a multi-temporal stack of images to interpolate a specific phase and facilitate its subsequent removal from differential interferograms. Advanced DInSAR techniques can provide point-wise and quantitative measurements of slow to extremely slow ground movements, on the order of millimeters per year. Two particularly effective interferometric techniques for these purposes are Permanent Scatterers (PS) (Ferretti *et alii*, 2001) and the Small Baseline Subset (SBAS) technique (Berardino *et alii*, 2002), which uses images acquired over a short time interval and in very close orbits. For the Permanent Scatterers technique, amplitude allows the identification of PS, while phase enables the estimation of their displacement. The final result of applying this technique involves processing a map of identified PS in the images along with their spatial coordinates, the average displacement velocity (mm/year) of each PS along the Line of Sight (LoS), the displacement data of each PS over the analyzed time frame (temporal archive of movements), and the estimated height correction for each PS. What we measure is never the actual deformation but the deformation along the sensor-target connecting line (LoS), meaning only a component of the actual deformation. Therefore, interpreting the acquired data is fundamental.

The image processing employed the Differential Synthetic Aperture Radar Interferometry (DInSAR) technique, specifically concentrating on Persistent Scatterers (PS) as radar targets manifested on the ground. This approach assesses potential displacements over time, primarily relying on radar reflectors existing on the ground, such as buildings, monuments, roads, railways, or natural elements like rock outcrops. Notably, these reflectors are challenging to identify in vegetated areas.

We acquired and processed a stack of 125 and 85 COSMO-SkyMed images for the ascending and descending geometries, respectively, covering the period from January 2021 to August 2023. These satellite products were processed through the SUBSIDENCE software with the CPT algorithm (Mora *et alii*, 2003, Iglesias *et alii*, 2015). We applied the CPT algorithm to the processed satellite images. The CPT is a method used to identify stable radar reflectors, or Persistent Scatterers (PSs), in radar images over time. It allowed us to detect the PSs surrounding the A24 highway, which is fundamental for understanding ground displacements in the area.

Horizontal-To-Vertical Spectral Ratio (Hvsr) Investigations

The HVSR method, a passive seismic technique, extracts valuable information from environmental noise (Nogoshi & Igarashi, 1971). By recording little ground motions, this non-invasive and swift approach calculates the fundamental resonance frequency of the terrain, critical for earthquake engineering and understanding site effects as well as the subsoil setting. The method, requiring no drilling or external energy sources, utilizes ambient noise recorded in three spatial dimensions. Results include the site's characteristic resonance frequency, aiding precise structural design, and, if applicable, the fundamental resonance frequency of a building or an estimate of shear wave velocity (Vs) with additional geological data (Nakamura, 1989).

The integrated analysis of HVSR (Horizontal *vs* Vertical component) graphs allows for the extraction of resonance frequencies at the contact boundary between two lithological layers exhibiting different mechanical behaviors. Specifically, HVSR is shown by a frequency-amplitude graph facilitating the visualization of peaks marking resonance phenomena. Moreover, this graph enables the estimation of the depth of the lithological boundary generating the phenomenon (Bonnefoy-Claudet *et alii*, 2006) Indeed, resonance associated with shallow seismic-refractor layers is located on the higher frequencies in the graph; in contrast, peaks associated with deeper structures are identified at lower frequencies.

Field Survey

To complement the investigation plan, field activities enabled the identification of clear signs of movement in the portion of the slope under consideration. Specifically, evidence of fractures along the road surface and the retaining walls bordering the lanes of the secondary road beneath the viaduct, as well as on the exterior walls of the surrounding buildings, were observed (Fig.3).

RESULTS AND DISCUSSION

The multiparametric integration of satellite monitoring, field surveys, previous investigations, and HVSR surveys highlighted the need for a new delineation of the landslide geometry that could align with the observed evidence (Fig. 4).

The analysis of HVSR allowed to define a different resonant peak distribution among the records acquired in different sites along the slope involved by the landslide. A relevant migration of peaks toward low frequency is highlighted along the slope. Particularly, the majority of deeper landslide deposits appear towards the middle/low slope at the station HVSR4 to 4.5 Hz in contrast to the thinner

Fig. 3 - Evidence of damage, typical of landslide deformations, on the external walls of surrounding buildings (a), along the road pavement (b), and the walls bordering the road under the viaduct (c, d)

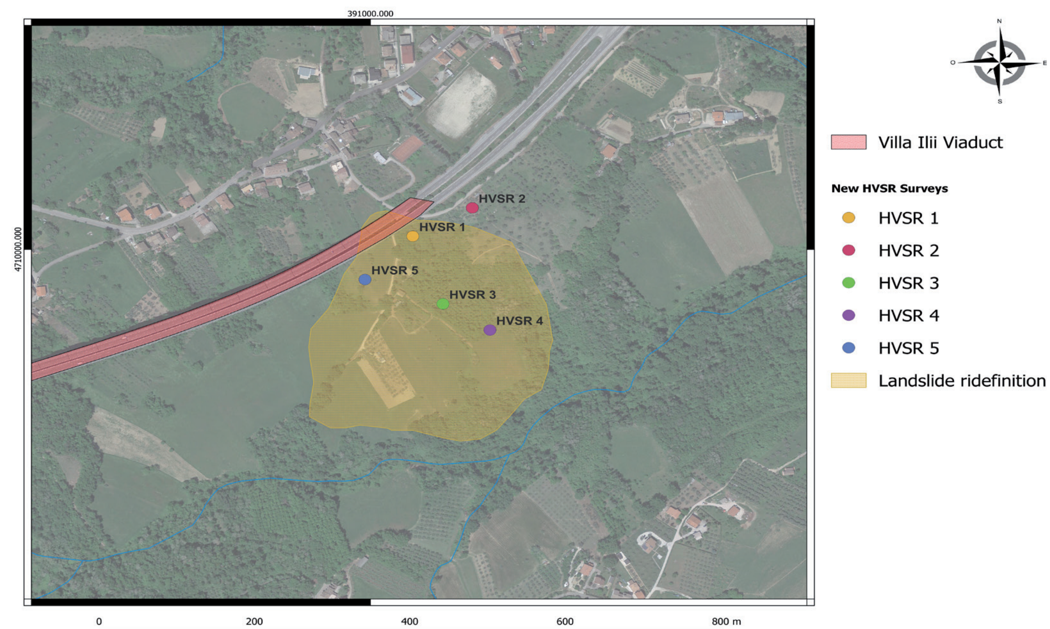

Fig. 4 - Landslide redefinition and HVSR surveys

Test Name	HVSR 1	HVSR 2	HVSR 3	HVSR 4	HVSR 5	HVSR P31 MZS
F_0 (Hz)	8.90+-0.25	6.65+-0.69	8.45+-0.49	4.55+-0.56	6.95+-0.29	9,80+-0.19
Bedrock depth(m)	20.8	22.6	15.5	19	22	8~10

HVSR 1

Stratum	Depth [m]	Thickness [m]	Weight per Volume Unit [kN/m³]	Poisson's ratio	Shear Velocity [m/s]
1	0	1.8	18	0.38	155
2	1.8	4	18.5	0.44	275
3	5.8	15	19.5	0.38	498
4	20.8	40	21	0.4	920

HVSR 4

Stratum	Depth [m]	Thickness [m]	Weight per Volume Unit [kN/m³]	Poisson's ratio	Shear Velocity [m/s]
1	0	3.5	18	0.35	165
2	3.5	15.5	19	0.35	435
3	19	20	20	0.35	750
4	39	50	20	0.35	1050

HVSR 3

Stratum	Depth [m]	Thickness [m]	Weight per Volume Unit [kN/m³]	Poisson's ratio	Shear Velocity [m/s]
1	0	2.5	18	0.35	150
2	2.5	13	18	0.35	420
3	15.5	50	18	0.4	920

HVSR 2

Stratum	Depth [m]	Thickness [m]	Weight per Volume Unit [kN/m³]	Poisson's ratio	Shear Velocity [m/s]
1	0	2.3	17	0.33	140
2	2.3	4.3	18.5	0.4	255
3	6.6	16	19	0.38	450
4	22.6	40	20	0.36	910

HVSR 5

Stratum	Depth [m]	Thickness [m]	Weight per Volume Unit [kN/m3]	Poisson's ratio	Shear Velocity [m/s]
1	0	2	18	0.35	155
2	2	4	18	0.35	275
3	6	16	19	0.4	490
4	22	50	20	0.4	950

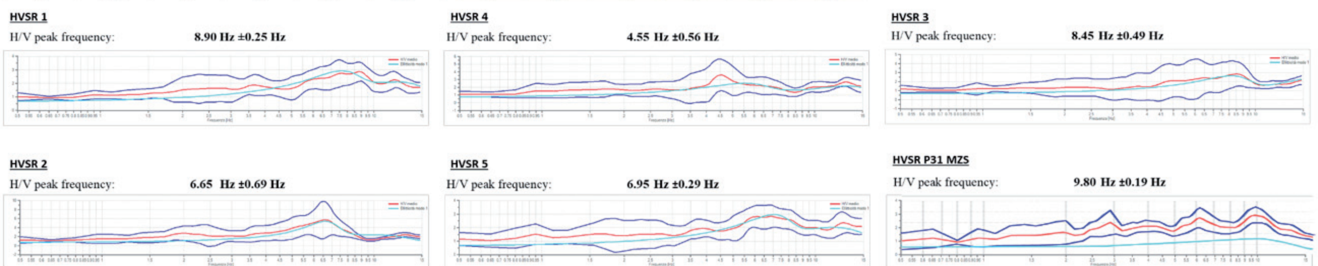

Fig. 5 - HVSR results: Stratigraphic evidences resulting from HVSR tests processing (up); H/V Spectral Ratio Graph (down). "HVSR P31 MZS" is a bibliographic test

landslide deposits shown at the HVSR1 and HVSR3 over 8.0 Hz and HVSR5 to 6.5 Hz at the head of the movement. Supporting the observation that the terrains detected by these stations belong to the landslide, two additional stations outside the landslide area were also considered. These stations, HVSR P31 MZS (of third parties) and HVSR2 show peaks respectively over 6.5 and 9.5 Hz signing that bedrock is much closer to the topographic surface than that as showed by stations in the landslide area. (Fig.5).

Another main focus of this study revolves around the application of the DInSAR technique to effectively monitor the landslide interacting with the A24 highway viaduct "Villa Ilii".

From the 80 SAR images acquired in ascending geometry, covering the period January 4, 2021, to August 23, 2023, the entire interferometric chain implemented in SUBSIDENCE software, which is based on the Coherent Pixels Technique algorithm, was applied. Images were then recorded, identifying the image of May 11, 2022, as the master, 377 interferograms were generated, and targets having qualities above the value of 0.7 in terms of Temporal Phase Coherence were selected. This resulted in the selection of about 96000 targets over the entire investigated area and specifically about 1000 targets over the infrastructure. Finally, the mean displacement rate map and the time series of displacement were generated (Fig. 6).

Despite the short period of monitoring, it is crucial to emphasize that a cumulative displacement with a linear progression is highlighted; within this one, it is possible to identify little accelerations during dry periods.

Adhering to the convention, positive velocity/displacement values signify an approach to the satellite (EW direction in ascending geometry), while negative values indicate a departure all along the LoS.

Overall, the recorded displacement rates correspond to slow kinematics, with maximum displacement speeds in the order of a few mm/year.

The results generated from this research are deeply rooted in an integrated methodology that combines the design planimetry of the SAR image datasets, in-situ measurements (HVSR), and the Hydro-geomorphological Setting Plan.

This technique can provide plenty of ground measuring points with time-series deformations through the employment of high-resolution SAR imagery, as well as for landslides affecting infrastructures outside of urban areas.

Also, during the investigation and deformation analysis using the DInSAR approach, a considerable number of target points can be utilized to identify the deformation trend, particularly in the absence of i*n-situ* data.

CONCLUSIONS

To conclude, this research contributes to the understanding of landslides affecting transportation infrastructure, highlighting the importance of monitoring and on-site assessment to mitigate the challenges posed by geohazards. The methodology developed and applied, which combines SAR data analysis with in-situ

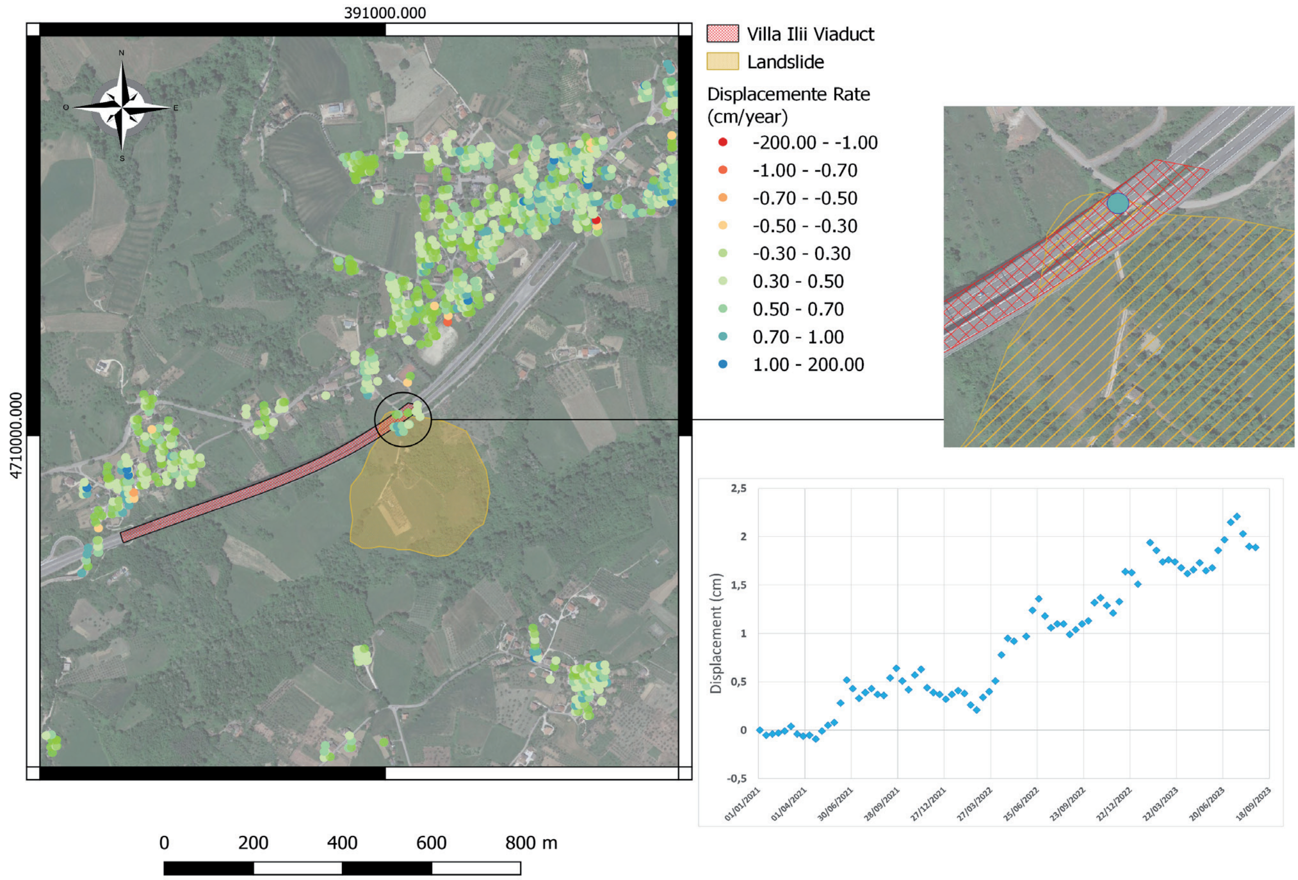

Fig. 6 - a) Mean displacement rate maps: ascending; b) Time series graph of a Sample PS extracted in the deformation area (right)

monitoring techniques (HVSR), has proven to be a valuable and reliable tool in evaluating surface and structural deformations along the "Villa Ilii" viaduct of the A24 highway in Central Italy.

The success of this integrated approach lies in its ability to capture a current and comprehensive scenario on combined terrain vs infrastructure deformative patterns, drawing from both satellite-based measurements HVSR data.

In addition, considering the prolonged presence of snow cover in the area and the near strong and recent seismic activity, further investigation will be conducted to correlate these effects to the acceleration at short and long periods of the landslide body.

From this framework, the approach presented here may be a first step forward in the collective awareness to monitor for predict, and so, to respond to the challenges stemming from natural hazards and human-induced activities on transport networks.

The funding and support from the ReLUIS consortium have been instrumental in the inception and development of this work.

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Lo studio presentato è stato realizzato nell'ambito dell'accordo tra CSLLPP e ReLUIS ai sensi dei dm 578/2020 e dm 240/2022, tuttavia, non riflette necessariamente la posizione e le valutazioni del CSLLPP e di ReLUIS

The study presented was carried out as part of the agreement between CSLLPP and ReLUIS according to dm 578/2020 and dm 240/2022, nevertheless it does not necessarily reflect the opinion of CSLLPP and ReLUIS.

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