SCIENZA E BENI CULTURALI

XXXVI° Convegno Internazionale 2020

GLI EFFETTI DELL'ACQUA SUI BENI CULTURALI
VALUTAZIONI, CRITICHE E MODALITA' DI VERIFICA

Giornate di studi internazionali

Venezia, 17 – 19 novembre 2020

Edizioni Arcadia Ricerche

36° convegno internazionale Scienza e Beni Culturali
Collana Scienza e Beni Culturali
Volume.2020

ISSN 2039-9790
ISBN 978-88-95409-24-5

GLI EFFETTI DELL'ACQUA SUI BENI CULTURALI
VALUTAZIONI, CRITICHE E MODALITA' DI VERIFICA
Venezia, 17-19 novembre 2020

In questo volume vengono pubblicati i contributi estesi che sono stati sottoposti a *double blind peer review* da parte di esperti dello stesso settore.

THE EFFECTS OF WATER ON CULTURAL HERITAGE
CRITICAL ASSESSMENTS AND VERIFICATION METHODS
Venice, 17th-19th november 2020

This volume includes extensive contributions (*Full-paper*) that have been subject to double-blind peer review by qualified referees.

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Parco Scientifico Tecnologico di Venezia
Via delle Industrie 25/11 – Marghera Venezia
Tel.:041-5093048 E-mail: arcadia@vegapark.ve.it
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Finito di stampare nel mese di novembre 2020
presso Imoco Industrie Grafiche – Treviso - Italy

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a cura di Guido Biscontin e Guido Driussi

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INDICE

Managing water risks in archaeological sites: the flooding of the complex of Santa Croce in Ravenna.

ANDREA UGOLINI[1], ELEONORA MELANDRI[2], EMILIO ROBERTO AGOSTINELLI[3], MASSIMO SERICOLA[4], MARIANGELA VANDINI[5], SARA FIORENTINO[6]

[1] Università di Bologna, Dipartimento di Architettura, a.ugolini@unibo.it
[2] Università di Bologna, Dipartimento di Architettura, eleonora.melandri3@unibo.it
[3] SABAP di Ravenna, Forlì-Cesena, Rimini, emilioroberto.agostinelli@beniculturali.it
[4] SABAP di Ravenna, Forlì-Cesena, Rimini, massimo.sericola@beniculturali.it
[5] Università di Bologna, Dipartimento di Beni Culturali, mariangela.vandini@unibo.it
[6] Università di Bologna, Dipartimento di Beni Culturali, sara.fiorentino2@unibo.it

Abstract.

The paper deals with flooding-driven emergency situations and related managerial issues in archaeological contexts with a focus on the complex of Santa Croce, in Ravenna, encompassing a 5th century Church and the remains of a Roman *domus* and its mosaic floor. In August 2019, the archaeological area was flooded for reasons unknown at the time which led to the overgrowing of algae. Since 1993, the local Soprintendenza have been undertaking studies and surveys which enabled them to demonstrate that the water criticalities of the site are linkable to the phenomenon of subsidence and perhaps to the increasing pressure of the aquifers affecting the level of groundwater. The recent water emergency was solved thanks to the water pumping interventions carried out by the Municipality of Ravenna and Civil Protection volunteers, while the Soprintendenza took charge of the securing operations and cleaning of the site.

The study constitutes and overview of possible damages due to the interaction between water and cultural heritage, subsequently focusing on the skills the operators called to intervene should possess. This contribution will further provide a discussion about methodologies and tools that have been selected to solve the flood emergency and the effectiveness of the survey conducted in the preliminary phase. In line with the European project H2020 SHELTER and its expected outcomes, the results will provide a preliminary assessment of the site criticalities, also serving as a point of reflection regarding the management of flooding and hydrogeological risks in archaeological areas.

Keywords: *archaeology, subsidence, flood, climate change, DRM*

Figure 1. View of the archaeological area and apse of Santa Croce (ph. Ugolini 2019)

Introduction

In the last few decades archaeological heritage is being threatened by a growing number of events that impose new management challenges, as also clearly emerged during the recent international conference "*Monitoring and maintenance in archaeological areas. Climate change, hydrogeological instability, chemical-environmental degradation*" (Rome, P.Ar.Co del Colosseo, 21-22 March 2019). Among the main potential danger factors, water and hydrogeological hazards have received specific attention in relation to archaeological areas (UNESCO *et al*. 2010; MARINO 2016). More specifically, in the Ravenna area, the situation is made even more critical by the phenomenon of natural and induced subsidence, that has long irreversibly affected the city and its heritage (CERENZIA *et al.* 2016; SIMONINI *et al.* 2017).

In August 2019, the archaeological area of Santa Croce in Ravenna was flooded due to an anomalous raising of the aquifer; the water emergency was solved after a few days thanks to the water pumping interventions coordinated by the Superintendence of Archaeology, Fine Arts and Landscape (SABAP) of Ravenna and carried out by the Environment Service of the Municipality and the volunteers of the Civil Protection R.C. Mistral Ravenna. Moreover, in the upcoming four years, the Interdepartmental Centre for Industrial Research (CIRI) of the University of Bologna, under the European project H2020 SHELTER, will carry out surveys and investigations aimed at assessing and testing a methodology for managing disaster risks and enhancing resilience in this area, replicable in other sites affected by similar hazards.

The following notes are intended to report and discuss what happened in the site, with a focus on the adopted methodologies and tools for the management of the emergency. Specific attention will be given to the effectiveness of the analyses carried out during the cognitive phase of the problem, as well as to the evaluation of the natural and anthropic damage to archaeological evidence resulting from the event (flooding and presence of algae), also in relation to its altimetric configuration and its environmental conditions. Last, the situation resulted in an opportunity to reflect upon the specific training of the volunteers, their awareness of the context and the critical aspects of their work.

The archaeological area of Santa Croce

The archaeological area of Santa Croce is located in the historical center of Ravenna (Emilia Romagna), in close proximity to two of the late-antique monuments of the city, the Basilica of San Vitale and the Mausoleum of Galla Placidia, included since 1996 in the UNESCO World Heritage List. Currently, the site is characterized by the coexistence of the early 17th century church, the remains of the 5th century Placidian church and the ruins of a Roman *domus* whose mosaics are preserved on site. The archaeological excavation unearthed the remains of a sumptuous Roman residence, comparable in its value to others found in the immediate surrounding. Most researchers date the decay of the *domus* between the end of the 3rd century and the beginning of the 4th century AD (SERICOLA *et al.* 2019).

The Church of Santa Croce built between the 424 and the 432 AD, features a single Latin cross nave, completed by a narthex. In an immediately subsequent period, the South *sacellum*, now known as the Mausoleum of Galla Placidia, was added to the narthex, the perpendicular arms were lengthened, and two external mosaic-floored side porches were added to the central hall. This phase of the Santa Croce complex corresponds to its majesty, by virtue of its dimensions and the presence of decorated mosaic floors (DAVID 2013; VERDIER 2016). The first architectural evolution took place in the medieval age, when an oratory crypt was built under the nave. The last intervention on the Church it's datable at the beginning of the 17th century when the narthex was demolished, the roof renewed, the front entrance set back to build the street separating the façade from the South *sacellum*. After the demolition of the crosshead and the rectilinear apse, a church with a semi-circular apse and a bell tower was built. This was the last architectural configuration of the Church, up to the 19th and 20th century, when the first excavations and restoration works begun (DAVID *et al.* 2013).

From restorations to nowadays

The first surveys on the building, conducted between 1782 and 1865, revealed the cruciform structure and detected the original connection between the Church and

the Mausoleum of Galla Placidia. Later, at the beginning of the 20th century, further

Figure 2. Representation of the historical stratification of the Area (elaborated from a drawing by J.P. Civiletti, DAVID 2013, p.125)

investigations were performed on the apse, uncovering the Roman mosaic floors (SERICOLA *et al.* 2019). However, the most interesting surveys took place in the second part of the century, aiming to restore the structures of the late-antique Church. Fragments of *opus sectile* and mosaic flooring from the various phases of the Church were identified (VERNIA 2009). The surveys disclosed the different floor levels and the wood foundations of the Church arms.

In the early 1970s, the whole area was already fully uncovered so that no more excavations took place as the consolidation operation started. The first interventions of consolidation focused on strengthening the elevation structures and restoring the decorative apparatus. At the end of the decade, both South and North porches mosaic and marble floors are removed and later just partially relocated on a concrete slab (VERDIER 2016). In 1984, considering the area configuration, canals for the collection of groundwater and a draining network were built[2]. Some years later this pumping system was implemented with the installation of a tank for the collection of groundwater and, in order to regulate the water level, two pumps were then installed. Unfortunately, however, the intervention did not provide the desired outcomes, since the pumps in this tank did not only drain water, but soil debris as well. This phenomenon directly acted on the archaeological remains, altering the altitude throughout the area, and causing loss of stability. At last, in the same years, the wall structures were fully equipped with a capping of modern bricks. The last archaeological relevant operation dates back at the beginning of the 1990s and the end of the 2000s (SERICOLA *et al.* 2019).

Nowadays, the site shows the remains of the Church of Santa Croce, whose walls preserve traces of the different phases of the building's construction. The different masonries are made of bricks of different sizes ranging in typology from

their construction time, bound with natural hydraulic lime mortars and partially retiled with cement-based mortars dating back to the interventions of 1970.

The Church still retains two different typologies of the original *opus sectile* mosaic floor realized on variable grain size of *cocciopesto* layers. Outdoor, the archaeological site features the remains of the first Latin cross plan of the Church. Moreover, remains of white and black marble tesserae which belonged to the *domus* floor decorative apparatus are visible (VERNIA 2009, pp. 81-82).

Site risks and degradation factors

Currently, the archaeological area around the Church is closed to public. The site has a basin configuration, as a result of the excavations, and the archaeological remains are more than two meters below the ground. The area is affected by subsidence like the rest of the city of Ravenna, therefore exposed to various water-related risks, related in particular to rainwater and stagnant water, water retained by loose soil and plants, inefficiency of water collection and disposal systems (MARINO 2016).

The continuous exposure to climatic and anthropogenic factors has resulted in the occurrence of degradation phenomena affecting not only bricks and natural stone surface, but also the mortar joints connecting the elements. The lower portion of the walls is affected by weeds, while most of the surfaces show the presence of adhering and coherent biological attacks. On the other side of the wall, biological colonization is less widespread and the partial or total detachment and layering of the bricks is also rare. Analogous degradation morphologies can also be found on the mosaic and marble floor remains. In some cases, biological colonization and weeds grow between the tesserae and the mortar, causing the detachment from the support and making the floor mosaics less adherent to the background (SERICOLA et al. 2019).

On the one hand, if the aforementioned degradation phenomena appear quite common in archaeological areas, there is, on the other hand, a major risk factor for the area that can be linked to the intrinsic characteristic of Ravenna and its geomorphological features. In fact, one of the main problems in this area is the subsidence involving the city area, caused by the progressive sinking of the soils and the proximity of the aquifer to the ground (SIMONINI et al.2017). This entails a high hydrogeological nature risk, both in Santa Croce and in other cultural heritage areas of the city, consequently putting the archaeological sites under flooding risk. The flooding and groundwater presence under the site also causes the detachment of some mosaic tesserae and loss of finishing material, phenomenon known as *fontanazzo*, which occurs not only in Santa Croce, but also occasionally in other monuments of the city.

Nowadays, the occurrence of harmful situations is exclusively prevented by the water pump system that conveys groundwater to the city sewerage system.

As happened both in 2016 and 2019, the shutdown of the water pumping system, worsened by some intense weather conditions, such as an unusual rise in the water leveland other problems linked to the city's water networks, caused a quick flooding of the archaeological site and the Church. These events worsened all the previously described degradation morphologies, enhancing the physicochemical and mechanical deterioration level already involving the structures. Currently, similar events are almost impossible to prevent, as no warning system is installed in the area in case of insufficient water pumping or system malfunction.

Maintenance and educational workshop

Microclimatic conditions of the site, due to the morphology of the site but above all to the constant presence of water continuously kept under control by the water pumping system network, makes it necessary to constantly perform maintenance activities, not only on the growing vegetation but also on the ruins.

In relation to this, between April and May 2018 a conservation campaign took place in the area, carried out by the Department of Cultural Heritage of the University of Bologna[3]. Its main purpose was to improve conservative conditions, for the time being possible only from outside, constantly undermined by the precariousness of the site. Preliminary dry cleaning was carried out to remove vegetation and deposits of different nature. These operations were followed by biocidal treatments with benzalkonium chloride diluted at 5% in water, applied by spray on the mosaic areas subject to biological attack, followed by treatments based on broad-sprayed Preventol. Following the biocide treatment, a Desogen-aided mechanical cleaning was carried out where dark stains and/or more tenacious deposits had been detected (FRANZESE 2018).

Once the cleaning had been completed, the detached tesserae were re-laminated on the surface with a pink-coloured mortar created to simulate the colour of the original support[4]. The lacunae of the mosaic were partially filled with erratic tesserae of suitable colour and shape. Several fillings were made in correspondence to the fractures found on the substrate, using the already described pinkish mortar. The operations, which were part of an activity for educational purposes, were limited only to the mosaic surfaces of the exterior (FRANZESE 2018).

August 2019. The flooding emergency event

As already happened in the past, on the 16th and 20th of August 2019 the archaeological area of Santa Croce flooded twice within few days. An anomaly in the water drainage system was immediately identified as one of the causes of the event. The water level, measured on a conventional point placed on the Roman pavement, the first time reached values up to + 34,5 cm and the second to + 63-65 cm, completely submerging the whole area and causing the sudden proliferation of aquatic plants. The emergency post event operation is managed by the SABAP of

Ravenna. This Institution coordinates Fire Brigades, the volunteers of the Civil Protection R.C. Mistral and keeps in contact with the owners of the area: the Diocese of Ravenna and the city Municipality.

Figure 3. Management of the event and draining of the Area. (ph. SABAP, 2019)

The particular period in which the event took place, during summer holidays, meant that the activation of an intervention could only take place on August 19th. The draining operation was carried out by the Civil Protection volunteers using a self-priming centrifugal motor pump[5] with low pumping intensity in order not to damage the archaeological structures. This was placed to avoid concentrated loads on the mosaic surfaces, both visible and not, on the basis of the graphic sheets and photographic documentation currently available.

Concomitantly with the water draining operations, a cautious removal with nets and rakes of algae, deposits of various kinds and especially aquatic plants (*Lemnia minor*, more commonly known as 'water lentil') that had settled on all floor and wall surfaces was undertaken. The specie is a small floating infesting plant with a very high rate of vegetative multiplication at high temperatures.

Damages related to the flooding event involved partially the vertical structures. While no specific degradation was detected on bricks and mortar, more significant were the consequences for the mosaic floor, especially the ones not involved in the conservation operations previously undertaken by the DBC. Surface deposit were removed cautiously by the conservators of SABAP in cooperation with some of the volunteers and right after a first washing the green shades lightly faded. Anyway, the need for further cleaning to remove all biological waste remains evident.

In addition to the abnormal inefficient performance of the pumps, one of the hypothetical causes of the flooding was an increase in the groundwater level

and/or a loss of the water removal network. As a result, the SABAP asked HERA, the institution managing the integrated water service, to verify the efficiency of the sewerage network in the vicinity of the site and, at the same time, to activate the monitoring of groundwater levels by having a series of analyses carried out to understand the origin of the flooding water. The levels, however, of San Vitale aquifer, adjacent to the site, immediately appeared unchanged during the emergency and the chemical-physical analyses carried out by HERA in different spots of the area and external to the site did not provide indicative data on the origin of the water.

Therefore, it is not clear whether it came from the aquifer and was related to the movements induced by subsidence or tides or it came more simply from the local sewerage system. All the samples were in fact contaminated by other substances because of the passage of water through layers of soil, masonry or the presence of third-party materials (e.g. coins) inside the collection basins. In order to avoid the emergency repetition, the SABAP after the end of the emergency provided the replacement of the pumps for the water drainage[6].

Conclusions

What happened in the archaeological area of Santa Croce allows some reflections on the problems related to the management of water risks in heritage sites. There are, at least since the 1980s, several publications published mainly by UNESCO and ICCROM that identify natural and anthropogenic risks for cultural heritage and assess their impact on tangible and intangible values. Some of these documents take the form of real manuals that provide risk mitigation strategies on a cost-benefit basis and give indications on how to manage and prevent areas, territories and sites of patrimonial importance (TANDONA 2018; PEDERSOLI JR. *et al.* 2016; UNESCO *et al.* 2010).

It is important, in this regard, to underline that part of the procedures suggested in these documents were adopted during the rehabilitation operations of the archaeological site of Santa Croce, especially in relation to emergency management and coordination of operations. The management action carried out by the competent protection bodies was decisive, as was the in-depth knowledge of the site and its heritage by SABAP in terms of material consistency and the history of the restoration and conservation work carried out after the excavations in the 1970s.

The prompt and effective action of the Civil Protection R.C. Mistral Ravenna has also made it possible to drain the site in a short time and thus limit the damage caused by water stagnation and the proliferation of aquatic plants. The intervention of volunteers, however, raises the question of what should be the specific preparation of these teams, such as their awareness of the effective fragility of the contexts in which they operate, such as their effective operational autonomy

(MARINO 2019, pp. 53-55): in fact, we remember that their intervention was constantly monitored by specialized staff of the SABAP and/or researchers from the University of Bologna who have indicated how to proceed given the fragility of the context, establishing each time the mode of action from the first cleaning of the site.

Less effective were the analysis campaigns conducted by the Regional Agency for Prevention, Environment and Energy of Emilia-Romagna (ARPA-ER) to ascertain the presence or absence of wastewater or rather groundwater, we believe, due to the lack of timeliness and quality of the samples. The examination of ancient masonry and mosaic floors, carried out after the reclamation of the site, did not allow to detect any visible material damage. Nevertheless, the researchers of the Interdepartmental Centre for Industrial Research (CIRI) of the University of Bologna are currently carrying out the monitoring of microclimatic parameters inside the church and outside the site, by means of data loggers for soil and humidity, chemical-physical analysis to evaluate the degradation on mortars, bricks and stone materials due to the presence of water in the site. Non-destructive tests and precise tests are necessary to determine the mechanical characteristics of the masonry in situ, especially those of the foundation now in the open air after excavations.

Concerning the prevention of the risks connected to the presence of groundwater due to subsidence in Ravenna, authors would like to point out that, since 1997, there has been a regional monitoring network managed by Arpa Emilia Romagna[7], activated on behalf of the Region, which has been providing data on the movements taking place at regional level, allowing to verify what is happening in the ancient centre of Ravenna and to its heritage sites (ARTESE *et al*. 2016; BITELLI *et al.* 2005; BITELLI *et al.* 2015). Thanks to a conspicuous network of local meteorological stations, the activity of the tides (useful to understand the phenomenon of *fontanazzi*) and the environmental conditions of the site are also known[8].

Therefore, it can be stated that there is a great availability of data allowing to identify, monitor and evaluate the risks the Santa Croce complex is exposed to, with particular reference to water-related ones. Its proximity to the basilica of San Vitale and the Mausoleum of Galla Placidia also makes it possible to consider the area as a representative place for the verification and experimentation of possible strategies to increase resilience and reduce vulnerability, and the identification of innovative and community-based governance models. For this reason, the archaeological area of Santa Croce has been selected as a case study by CIRI within the European project SHELTER, funded by the European research programme Horizon 2020[9]. In the archaeological area it is planned to set up a network of sensors that will analyse in real time the risk factors identified (vibration, humidity, temperature, chromatic alterations) and will send updates and

'alerts' in the presence of parameters indicative of a risk. Due to the complexity of the information and the different sources of data, the SHELTER framework will feed these data into a multi-scale and multi-source data platform, able to provide the necessary information for planned maintenance and storage strategies.

[1] *Ambiente e Regione Emilia Romagna.* https://ambiente.regione.emilia-romagna.it/it/geologia/geologia/subsidenza/la-subsidenza-in-emilia-romagna [Accessed 04 January 2020].

[2] The excavation for the collection tank allowed the discovery of a well dating back to Roman times. This system, still in use today, is one of the main sources of the degradation of the area.

[3] The restoration campaign was carried out as part of a Thesis in Restoration by Laura Franzese.

[4] Composition: 1 La Farge lime, 3/2 fine sand, ½ hazelnut coloured Pozzolana, ½ fine *cocciopesto* mixed with water.

[5] The intervention was carried out using self-priming centrifugal motor pumps (Varisco mod. ETP2500 - Honda GX390 petrol engine), maximum flow rate 2500 litres/min. Each intervention required a drainage time of about 8 hours.

[6] The Soprintendenza pointed out several times the inadequacy of the current water drainage system, which has no early warning system in case of malfunctioning, and which, by channelling solid microparticles into the pumping action, is compromising the stability of an entire sector of the archaeological area. See: Soprintendenza per i Beni Ambientali e Architettonici per le province di Ravenna-Ferrara-Forlì-Rimini: *Expertise n. 1048 of 23.12.1993* - Former church of Santa Croce. Structural and diagnostic surveys and investigations. Designer and director of works: arch. E. R. Agostinelli.
Soprintendenza per i Beni Ambientali e Architettonici for the provinces of Ravenna-Ferrara-Forlì-Rimini: *Expertise n. 1167 of 03.03.1997* - Former church of Santa Croce. Safeguard. Director of Works: arch. E. R. Agostinelli.

[7] The network consists of high precision levelling lines integrated with GPS measurement stations. A considerable work of homogenization of the subsidence data available for the 70s and 90s (BITELLI *et al.* 2005), and of the data coming from the Regional Network has allowed the elaboration of maps of land subsidence in Emilia-Romagna that highlight the most critical areas.

[8] Arpa-ER manages piezometric monitoring, marine saltwater inlets and tidal trends; hydrometeorological monitoring of snow, rain, air temperatures, watercourse flow, wind direction and speed, air humidity, direct and reflected radiation. https://www.arpae.it/dettaglio_generale.asp?id=2695&idlivello=157 [Accessed 10.01.2020].
For the definition of climate data see also https://www.meteoblue.com/it/tempo/settimana/ravenna_stati-uniti_5076020 [Accessed 10.01.2020].

[9] The project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 821282. https://shelter-project.com/[Accessed 10.01.2020].

Bibliography

1. ARTESE G., FIASCHI S., DI MARTIRE D., TESSITORE S., FABRIS M., ACHILLI V., AHMED A., BORGSTROM S., CALCATERRA D., RAMONDINI M., ARTESE S., FLORIS M., MENIN A., MONEGO M., SINISCALCHI V., 2016. Monitoring of land subsidence in Ravenna Municipality using integrated SAR – GPS Techniques: description and first results, in *'The International Archives of the Photogrammetry, Remote*

Sensing and Spatial Information Sciences', Volume XLI-B7, XXIII ISPRS Congress, 12–19 July, Prague (CZ).

2. BITELLI G., BONSIGNORE F., VITTUARI L., 2005. Il monitoraggio della subsidenza in Emilia-Romagna, in *'Proceedings 2nd International Workshop Aquifer Vulnerability and Risk'*, Colorno (IT).
3. BITELLI G., BONSIGNORE F., CARBOGNIN L., FERRETTI A., STROZZI T., TEATINI P., TOSI L., VITTUARI L., 2010. Radar interferometry-based mapping of the present land subsidence along the low-lying northern Adriatic coast of Italy, in *'Land Subsidence, Associated Hazards and the Role of Natural Resources Development'*, Wallingford (UK), IAHS Press, pp. 279 – 286.
4. BITELLI, G., BONSIGNORE, F., PELLEGRINO, I., VITTUARI, L., 2015. Evolution of the techniques for subsidence monitoring at regional scale: the case of Emilia-Romagna region (Italy), in *'Prevention and mitigation of natural and anthropogenic hazards due to land subsidence'*, Proceedings Of IAHS, 15-19 November, Nagoya (JP), pp. 315 – 32.
5. CERENZIA I., PUTERO D., BONSIGNORE F., GALASSI G., OLIVIERI M., SPADA G., 2016. Historical and recent sea level rise and land subsidence in Marina di Ravenna, northern Italy, in '*Annals of Geophysics'*, September, P0546.
6. DELTARES 2015, *Sinking cities. An integrated approach towards solutions*.Utrecth (NLD), Deft press, PDF [Accessed 10.01.2020].
7. DAVID M. (a cura di), 2013. *La Basilica di Santa Croce. Nuovi contributi per Ravenna tardoantica*, Edizioni del Girasole, Ravenna (IT).
8. FRANZESE L., 2018, *L'area archeologica di Santa Croce a Ravenna: restauro e valorizzazione per una proposta museografica ecosostenibile,* Tesi di Laurea in Conservazione e Restauro dei Beni Culturali – Università di Bologna, Scuola di Lettere e Beni Culturali, relatore Prof. Michele Pagani, A.A. 2017/2018.
9. MARINO L., 2016. *Il restauro archeologico. Materiali per un atlante delle patologie nelle aree archeologiche e negli edifici allo stato di rudere. Il rischio nelle aree archeologiche,* Altralinea, Firenze.
10. MARINO L., 2019. *Il restauro di siti archeologici e manufatti edili allo stato di rudere,* Dida Press, Firenze.
11. PEDERSOLI J.L. JR., ANTOMARCHI C., MICHALSKI S., 2016. *A Guide to Risk Management of Cultural Heritage,* Sharjah (UAE), ICCROM, Canadian Conservation Institute (CAN).
12. RICCERI G., 1992*, Studi e ricerche nell'area di San Vitale, Galla Placidia e Santa Croce in Ravenna,* SGeditoriali, Padova.
13. SERICOLA M., AGOSTINELLI E. R., UGOLINI A., 2019. L'area archeologica di Santa Croce. Rischio e degrado come elementi per pianificare il futuro di un sito, in *'Monitoraggio e Manutenzione delle Aree Archeologiche: cambiamenti climatici, dissesto idrogeologico, degrado chimico ambientale'*, Roma, Parco archeologico del Colosseo.
14. SIMONINI P., CECCATO F., TOSI L., 2017. Effetti della subsidenza sul patrimonio edilizio e infrastrutturale, in *'XXVI Convegno Nazionale di Geotecnica',* Roma, pp.43-57.
15. TANDON A., 2018. *First Aid to Cultural Heritage in Time of Crisis,* Roma, ICCROM.
16. UNESCO, ICCROM, ICOMOS & IUCN, 2010. *Managing Disaster Risks for World Heritage.*

17. VERDIER N., 2016. *Conservazione e valorizzazione dei ruderi del complesso dell'ex chiesa di Santa Croce a Ravenna,* Tesi di Laurea in Restauro Architettonico – Università di Bologna, Scuola di Ingegneria e Architettura, CdLMU in Architettura, relatore Prof. Arch. Andrea Ugolini, A.A. 2015/2016.
18. VERNIA B., 2009. *Leggere i muri: analisi degli edifici di culto nella Ravenna del V secolo d.C.*, Ante Quem, Bologna.

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ISSN 2039-9790
ISBN 978-88-95409-24-5