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Procedia Structural Integrity 29 (2020) 175–182

Structural Integrity Procedia

www.elsevier.com/locate/procedia

Art Collections 2020, Safety Issue (ARCO 2020, SAFETY)

Villa San Marco at Stabia. Dynamics of decay and perspectives for deepening and safeguarding

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Abstract

The site of Villa San Marco in the archaeological area of *Stabiae*, offers a wide repertoire of degenerative situations with multiple levels of criticality and complexity and a differentiated stratification. Damage related to the known eruptive events of Vesuvius are the substratum to phenomena of deterioration activated by excavations of the Bourbon period, restoration and protection interventions that were not always adequate and efficient and by widespread abandonment conditions at the end of the excavation. Flora, anthropic environment, water, atmospheric agents, slope instability, seismic phenomena, combine with the technological characteristics of this architectural complex, triggering degenerative processes at different speeds and intensities. A study initiated in collaboration between the University of Florence and the Archaeological Park of Pompeii aims at the knowledge of the degenerative dynamics of the site in order to develop risk management and control systems aimed at safety of use and maintenance. Investigations disseminated in the villa and detailed on specific portions have begun to create a clearer picture of conservation issues. The digital documentation of the structures has been flanked by a phase of on field investigation aimed at an assessment of the degenerative phenomena, at the analytical verification and at the interpretation of the structural instability. The research perspective is to define a multi-scale survey approach that allows to extract data useful for the quantification of the risk, through a systematic understanding of the vulnerabilities of the elements involved (walls, columns, blocks, decorated surfaces, earthen layers, etc).

Keywords: Villa San Marco, Material History, Degenerating processes, Stability assessment, Multiscale approach

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10.1016/j.prostr.2020.11.154

1. Introduction

The high density of archaeological remains is inherent in the Pompeian area and its rich settlement history. The study, conservation and management activities of this archaeological territory have changed and evolved over the past two centuries, confronting the extraordinary consistency and complexity of the remains. The universal recognition of these testimonies has consolidated over time an increasing contribution from the international scientific community, with many research activities that determine the contribution of innovative technologies and methodologies. Recent news shows that the effort of the bodies responsible for the conservation of this heritage does not always manage to cope with the articulated conservative emergencies and that the interdisciplinary contribution has many spaces for insertion, full of perspectives. In this scenario, the collaboration between the University of Florence (LARC Laboratory Architecture Restoration and Conservation) and the Archaeological Park of Pompeii started, aimed at providing a further contribution to the conservation of this large archaeological basin. The goal is to implement knowledge of the material history and degenerative dynamics of architectural remains to develop risk assessment tools, aimed at safety and maintenance. A portion of the archaeological area of Villa San Marco in Castellammare di Stabia, today part of the Pompeii Archaeological Park, has been selected as pilot site. The complexity of the remains, the variety of materials and traces, give this whole a great documentary value but at the same time a high degree of vulnerability. From the preservation point of view, the site offers a vast repertoire of degenerative situations with multiple levels of criticality, complexity and stratification. Damages connected to the eruptive events of Vesuvius are the substrate for deterioration phenomena activated by the Bourbon excavations, by restoration and protection interventions that are not always adequate and by the widespread abandonment after excavation. Flora, anthropic environment, atmospheric agents, geo-morphological instability of the slope, seismic phenomena, marine aerosol, combine together with the technological characteristics of this architectural complex, triggering degenerative processes at different speeds and intensities.

2. Villa San Marco. From the past glories of Stabiae to the discovery

Villa San Marco is one of the major material remains of the ancient settlement of *Stabiae*, which has been the subject of debate and research for centuries (Ruggiero 1881). During the eighteenth century many hypotheses were proposed on its origins and localization, based on literary sources (Cosenza 1890). It was only with the first findings in the middle of the century that material evidence began to confirm the hypotheses. According to Camardo et al. (1989), the history of Stabiae can be schematized in three main phases: the first goes from the 7th century BC to the Silla destruction of 89 BC, the second ended with the Vesuvius eruption in 79 AD and the latter coincides with the re-occupation of the site from the second century AD, until the consolidation of the settlement of Castellammare di Stabia. The events of Villa San Marco belong to the second phase, in which the city played an active commercial and touristic role, thanks to the presence of thermal springs. During the eighteenth century, in addition to the Pompeian area, Bourbon researches turned to the Varano plateau, between Gragnano and Castellammare. The first excavations took place from 1749 to 1762, with the discovery of Villa San Marco between 1750 and 1754, to continue between 1775 and 1782, the year in which the structures were re-buried (Allroggen-Bedel, 1999). It was only with the excavation campaigns conducted from 1950 to 1962 by Libero D'Orsi that explorations on the Varano hill resumed, with the rediscovery of Stabia (Camardo 2001). The villa stands in a panoramic position on the Gulf of Naples, at the northern end of the Varano plateau (50 m above sea level), the last of a series of terraces that slope down to the sea from the Lattari Mountains chain. From the geological point of view, the plateau is made up of alluvial limestone conglomerates alternated with more or less coherent pyroclasts, surmounted by a layer of incoherent pyroclastic material (79 AD) about 3 meters thick. The steep escarpment that connects the terrace to the coast below had been reworked to allow the connection between the sea and the settlements. Built in the Augustan era, the villa was enlarged in the Claudian era and restored under the Flavs before disappearing with the 79 AD eruption (Rougetet, 1999). According to Bonifacio et al. (2000), its planimetric system was conditioned by the course of the edge of the escarpment and the urban area behind it. The plan drawn up by Karl Weber, responsible for the drawings and the excavation journals of the Bourbon period, perfectly overlaps that obtained from the new excavations, outlining a total plan of over 16,000 square meters, of which only 6000 square meters can be visited today. Over the centuries, the instability of the slope has resulted in specific landslides with the consequent loss of substantial parts of the complex and its gardens.

3. Objectives and methodologies

The study aims at the production of data for: the achievement of a high level of morphological and technological knowledge of the remains, the understanding of the phases (construction, transformation, destruction), the assessment of the state of conservation and the degree of safety-stability, the risk assessment. Being a very large area, the preliminary study was undertaken on a limited portion. A targeted study on a representative portion of the complex was preferred to the selection of spot samples throughout the villa. In agreement with the Direction of the Excavations, the choice of the sample area fell on the so-called "Thermal Baths Complex" for a number of reasons: the predisposition for direct reading of the remains due to the scarce presence of construction interference (alterations or restorations) on the original structures, the accessibility facilitated by the closure to the public, the need to verify the effectiveness of the post-excavation protective interventions, the urgency of an assessment of the conservation conditions of the unprotected parts a decade after their discovery, the need of a clear picture of the safety risks (structural instability of the elevations and sliding of the structures along the slope) in view of future use. The investigations included: systematic study of indirect sources, detailed survey of the remains, stratigraphic survey on elevations and systematization of data on materials and technologies, identification and localization of deterioration phenomena, analytical checks of stability with the finite element method (FEM), evaluation of degenerative dynamics and quantification of risk levels.

4. The Thermal Baths Complex. The on-field investigation

The area under consideration, called "Thermal Baths Complex" or "Villa Panoramica", was brought to light between 2008 and 2009, and is still closed to the public. It is not part of the villa but, according to Weber's plan, it is believed that it could be included in a larger thermal baths area, whose relations with the villa are still under investigation. The above-ground remains are divided into an entrance area which leads to a series of thermal rooms and a peristyle which has lost the west side and part of the north side, that collapsed due to the sliding of the slope (Ruffo 2010). The study of indirect sources (documentary, bibliographic) has traced the first line of knowledge that has made it possible to recompose and systematize all known information and to outline a sequence of events, previous and subsequent to excavations, to be traced on the artifact at the current state. The only available graphic documentation are the drawings made at the time of the excavation (2008-09) and the recent acquisitions with laser scanners, made by the University of Bologna (Department of History, Culture and Civilization). With the direction of the excavations and with the Bologna team, the extension of the digital survey was also agreed to the area of the thermal baths complex. The basic drawings (plans, elevations, sections) were extracted from the 3D model, implemented by the team of the University of Florence with the photogrammetric restitution of the architectural surfaces.

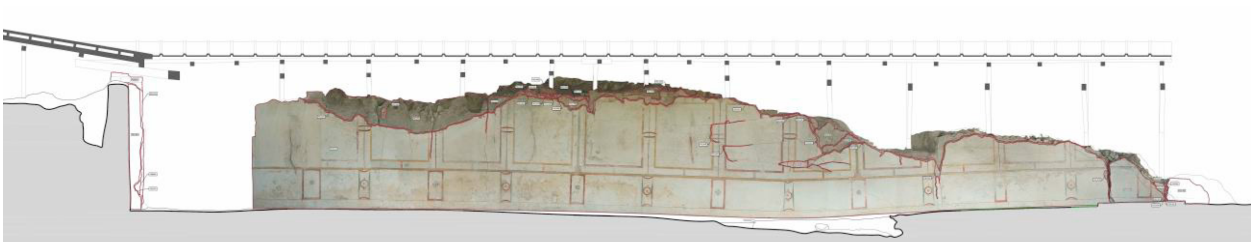

Fig. 1. General elevation of the arm C of the peristyle.

4.1. The stratigraphic investigation

Morphological knowledge was followed by the investigation of the remains with stratigraphic and typological methods (Coppola 2018), to understand the sequences of intentional realization and transformation actions, with the corresponding technical procedures (construction, decoration, adaptation, disassembly, restoration), but also accidental actions (anthropogenic and natural damages). The procedure included the identification of the US (Stratigraphic Units) by comparative and typological autoptic observation. The building actions have been classified into four groups: USM (Masonry Stratigraphic Units) which includes all the homogeneous masonry parts, USR (Facing Stratigraphic Units) in which almost exclusively layers of plaster converge, EA (Architectural Elements) including openings and columns, negative US (cracks, gaps, cuts, collapses) (Doglioni 2010). The recording tools were the mapping on the survey drawings and a sheet for the data collection (qualitative and quantitative) relating to the essential morphological and technological characteristics, in addition to the stratigraphic relationships. The sequence allowed, first of all, to isolate the post-excavation restoration layers, from the mortars for sealing the edges of the plasters or for the compensation of exposed wall sections, to the wall integrations to regularize profiles and ridges or to create supports on the roof canopies. In the same way, the network of cracks in the plaster was isolated, to avoid an overload of negative stratigraphic data. The first results, integrated with the investigations on materials and construction techniques, outline some steps of the execution and overlapping procedures of the ancient works. In particular, a diversified use of construction techniques emerges in the various parts of the complex but also internal variations of the same technique. The data seem to confirm a sequence of which the boundary wall with the road and the thermal rooms form the initial part together with other pre-existences adjacent to the East and North. The techniques recorded in the stairwell, in the entrance vestibule and in the calidarium seem to be attributable to a phase of adaptation of this series of rooms. In this reworking is also placed the peristyle, whose three residual sides differ from each other from a technological and formal point of view. However, the eastern and southern arm (B and C) have greater similarities than the northern arm (A). This difference is also supported by some anomalies in the pavement drawing and in the columns, different in decoration and in diameter, connected to the consecutive side by means of an L-shaped element. This seems to suggest the hypothesis that the construction/modification of the peristyle connected the thermal rooms to pre-existing volumes, adjacent to side A and side C. Further details on the architectural elements and materials will be able to articulate and verify these preliminary hypotheses.

4.2. Building materials

The schematization in homogeneous portions facilitates the next phase of identifying the materials and techniques. The recognition and localization of stone materials (natural and artificial) were carried out by means of comparative macroscopic observation. This allowed to outline a first orientation for possible laboratory tests and for prospects of in-situ use of instruments for non-destructive diagnostics. The building stone is volcanic tuff, shaped in the form of *cubilia* or regular rectangular blocks. An analysis of the dimensional data was conducted on these elements, in an attempt to trace homogeneous groups. The average size of the *cubilia* varies in a range between 7-13 cm per side (range = 6 cm). In each USM the range reduces to 3 cm and in some cases to 1 cm, with the tendency of the data to thicken around specific values. This seems to be attributable to a dimensional standard in the production of the pieces, the variation of which in the different walls may be one of the indices of distinction between apparently similar construction actions. For the rectangular blocks of the opus quadratum there is an oscillation of the height of the blocks (and therefore of the rows), in a range between 6 and 15 cm (range = 9 cm), with very homogeneous groups for each USM, especially in the walls of the *calidarium*. Further clarifications on these distributions may come from the systematic reading of morphological details and working traces of the stone elements. Two basically homogeneous groups of bricks have been identified: the first consists of triangular elements (hypotenuse 12 cm, thickness 4.5 cm) light red and porous; the second includes quadrangular bricks (side 22-24 cm), more compact and dark. The statistical analysis of the size distribution shows a greater homogeneity in the walls of the A side of the peristyle. Particular attention has been paid to mortars and plasters. The observation of the macroscopic characters (color, consistency, tenacity and porosity of the binder; type, shape and grain size of the aggregate) indicates an apparent homogeneity of the mortars (lime and fine aggregate, with the addition of pozzolan or cocciopesto), with scarce variations in the complex. For each plaster coating, the presence of the usual series of layers is confirmed, with different doughs. The technological package consists of a set of layers (3-4) with different degrees of fineness, whose quality and tenacity are the main reason of their good conservation (both of the plasters and of the mosaics). The plaster covering the brick columns is of similar quality and tenacity, moulded in fluting of remarkable fine execution, with still intact shapes and geometries. The walls were decorated with paintings (mainly fresco with probable punctual use of tempera): in the peristyle the one on the C side is preserved almost entirely, with a white background divided by polychrome elements (bands, candelabra and geometric floral motifs). In the three thermal rooms the lower part of the walls, painted with rectangular fields, was covered by marble slabs (now disappeared).

4.3. Building techniques

All visible masonry portions were cataloged as representative samples of a technique, analyzed and classified according to selected parameters. Four types of main masonry techniques have emerged (with related sub-variants), among the most widespread in the Pompeian area, whose distribution has been studied within the complex: *opus testaceum*, *opus vittatum*, *opus quadratum*, *opus reticulatum*. Maiuri (1942) underlined that the consistent use of brick in this area is mainly registered in the restorations carried out on structures damaged by the earthquake of 62 AD, made with bricks of two main types: the first (made from broken tiles) of lesser thickness and a coarse, dark red dough, the latter (made from *bessales*) of greater thickness and a finer, pinkish-yellow dough. *Opus mixtum* was often used in continuous walls with strong linear development in many private houses. The investigation on the thermal complex seems to confirm these interpretations. A first consideration must be made on the wall thicknesses that, with the exception of some anomalies, stand at 45-50 cm, corresponding to 1 cubit (44.4375 cm). The construction technique, prevailing in the curtain walls, follows the scheme of the *opus mixtum*, with the creation of wall panels in *opus reticulatum*, held (but without the typical *opus mixtum* connections) between panels made in a different work (*opus testaceum*, *quadratum* and *vittatum*). A case in itself is the brick work with which the peristyle columns are made, in line with the trend of the Pompeian area. The distribution of the masonry types (and their combinations) allows to mark some evidences: the presence of the *reticulatum* is transversal; the type *testaceum 1* (triangular elements) is located on the A side of the peristyle; the *quadratum* is located on the B side, on the C side and in the thermal rooms; the *vittatum* is registered in the entrance vestibule; the type *testaceum 2* (quadrangular elements) is located in the apsidal room D (calidarium). The mensiological study of the stone elements (cubilia and tuff blocks) has highlighted the presence of variants of *opus reticulatum* and *opus quadratum*. These data may allow a clearer interpretation on the buinding phases of the complex (building directions or punctual actions).

5. The state of conservation and the study of degenerative processes

From a conservative point of view, the conditions of Villa San Marco are very heterogeneous. A preliminary macro-classification, based on the current level of protection, divides all the structures in three large groups: structures affected by recent restorations, structures affected by past restorations, structures treated with minimal protection interventions. The artifacts found in the mid-twentieth century were affected in the past by substantial reconstruction/integration actions and constitute the central core of the villa that can be visited today. The interventions were aimed at stabilizing the collapses, protecting the wall structures and decorations and making the volumes readable, in many cases with concrete insertions, with a strong technical and cultural impact. The theme presents well known debate scenarios on the technical evaluation of the effectiveness of historicized interventions that are not very reversible, but also on the cultural significance of conservative actions that are going to document for themselves a technical culture of restoration of the past. All the architectural remains of the thermal complex do not fall within this area, having been subjected, after excavation, to minimal protection systems (roofing, shoring and protective additions). According to Marino (2009), the deterioration phenomena were investigated on the basis of the categories of pathogens, evaluating their impacts on the architectural remains in their complexity and focusing in detail on the problems related to the degradation of the individual materials. The action of water is undoubtedly the basis of many of the degenerative phenomena detected. Rainwater does not act directly on the structures, thanks to the protection of the covers. Indirect actions are rather the main problems, due to defects in the disposal systems and accumulation in the surrounding ground. Localized leaks in the roofs and clogging of the drains create punctual stagnations on mosaics and walls. Traces of strong erosion can be seen on the packages of sediments upstream of the C arm (with the loss of some temporary wooden shoring), which also affect the facing mortars and plasters. The phenomenon is attributable to concentrated water flows due to occasional heavy rains that the soils are unable to absorb. The greatest impact is found on the most exposed and vulnerable parts; an example is the sinking of the flooring of the arm C, in which the action of the water determines a constant loss of material with the risk of triggering greater damage. Another consistent phenomenon is the release of water from the ground in the middle of the peristyle, which feeds the capillary rise on the adjacent structures (columns and floor mosaics). In the A and B arms of the peristyle, in direct contact with cultivated land, the contribution of irrigation is added to rainwater. The result is infiltration and capillary rise in the wall structures, with the inevitable contribution of soluble salts. The presence of efflorescences of compounds derived from fertilizers on the perimeter walls and on some of the nearest columns is evident. Given the widespread presence of plasters and mortars, we understand the danger of these phenomena due to the disruptive action of the salt crystallization cycles. Rainwater also contributes to the instability of the slope, one of the biggest problems in this area. The action of weed vegetation is directly connected to the presence of water. In the examined area, a classification was made of the main species detected, based on the hazard index (IP) of the roots proposed by Signorini (2016). There are no particularly critical phenomena also due to the presence of roofing canopies that inhibit growth in stable shaded areas. Uncontrolled vegetation is widespread in the middle of the peristyle and on the edges of the surrounding land, close to the perimeter structures. Among the most dangerous species, some shrub and arboreal plants have been identified such as Ficus Carica, Rosmarinus Officinalis (IP = 7) and Ailanthus Altissima (pollonifer taproot with IP = 10). Located in the centre of the peristyle, they are not an immediate threat to the structures, however, ailanthus can quickly be a very serious problem if not kept under control, especially for adjacent mosaics. At the moment the only direct action on the architectural remains is the punctual presence of herbaceous plants such as Parietaria Officinalis and some asteraceae (Cichorium Intybus and Taraxacum Officinale) with an IP between 4 and 5. These annual plants are inserted in the discontinuity lines (exposed edges of the mosaics or plasters, mortar joints, especially in exposed sections or wall tops) and on more or less compact incoherent deposits, inducing the disintegration of the substrate with the consequent loss of the connected elements (mosaic tiles, plaster fragments, stone elements). The position on the hill exposes the complex to the prevailing winds, whose effects are: concentrated erosion on exposed wall parts (tops, edges) or incoherent deposits, localized accumulations. In addition, the presence of the canopies generates a double problem: the proximity to the upper parts of the walls reduces the section crossed by the air flow and causes greater erosion; the stresses of the gusty wind are transferred, through the vertical elements, to the anchor/support points. Finally, the action of the marine aerosol must be considered in the same context, especially in the chemical attack on the carbonate material (mortars and painted plasters). Laboratory investigations will clarify the dynamics of these effects, in particular on the pictorial layers. Many surfaces, especially those facing south and west, are subject to direct solar radiation, not intercepted by the canopies. This overheating contributes to the exasperation of thermal stress and hydration-dehydration cycles, with consequent decohesion of the binders. In conclusion, the decay phenomena, determined by the combination of causes set out above, can be traced back to various forms of gradual mechanical breakdown of the technological groups (walls, coatings, architectural elements) with the weakening and loss of parts. The disintegration of the binders is at the basis of these processes.

Fig. 2. (a) Damage due to vegetation on the pavements; (b) Saline efflorescence on a column; (c) Reopening of a crack on a wall near the slope.

6. Structural instability assessment

Structural stability is a central theme in this part of the archaeological area. There are several critical aspects that influence the structural vulnerability of the whole complex: the presence of free wall partitions, the complex of cracks and deformations originating from historical volcanic events (Ruggieri et al. 2018), the instability of the slope. In light of these risk factors for the safety of structures and people, an assessment of the structural stability of the architectural remains was necessary. In particular, an attempt was made to analyze the possible response of the structures to probable sudden dynamic stresses (sliding on the north side, land thrusts and seismic actions) (Galassi et al. 2020). The first necessary step was the understanding of the currently working structural system and its conditions. In the thermal baths complex the preserved structural system is completely missing horizontal connections. In the area of the thermae rooms and the entrance vestibule, the walls of the four sides, including the internal bracing ones, are preserved, but none of the horizontal elements. Of the arm B of the peristyle, only the back wall remains (partly against the ground). The stratigraphic and typological investigation of the elevations, together with the reading of the crack and deformation framework allowed the correct identification of the structural system, broken down into individual elements. The picture that emerges denotes several substantially independent masonry panels, in some cases shown by passing cracks and significant sagging, especially on the wall C of the peristyle. The set of cracks and deformations is very complex and layered. In addition to the network of cracks in the plaster, fractures and deformations caused by historical seismic events are observed (Ruggieri et al. 2019). Damage caused by landsliding is added to the structures near the edge of the slope. The reopening of several cracks edges, with the detachment of recent mortar sealing, indicates that the sliding of the plateau is still going on.

6.1. FEM modeling and analysis

The verification on the identified structural system was carried out using the Finite Element Method (FEM), a numerical technique that allows solving the problem of determining the state of stress and deformation in elements under load conditions, for which the analytical solution is not available or obtainable. The basic concept is the discretization of the continuum in a set of elements of finite dimensions, interconnected to each other by predefined points (nodes). Using a calculation software, the true trend of the unknown function is approximated with that of some particular functions with a known trend. The method has been applied to the peristyle wall structures, schematizing the individual structural elements in simple volumes and obtaining a model capable of fairly faithful representation of the general geometry. The STRAUS7 software was used to perform the calculations. Significant results were obtained from the analysis of the side B of the peristyle. The wall was divided into rectangular elements, aligned with a grid, subsequently inserted in the calculation program for the construction of the 3D model and the development of the analysis. The first hypothesis was made considering only the weight of the structure and the thrust of the ground behind it. The result is that this thrust does is not a serious threat to the stability. The second hypothesis was carried out by simulating a seismic thrust of 15g and 28g. The structure's response was insufficient, outlining a high-risk scenario. It is evident that in addition to the instability given by the subsidence of the land on the western side of the plateau, for which further analyzes and specific solutions are required, the possibility of a seismic event is a tangible danger for the conservation of the architectural remains (Minos-Minopoulos 2017).

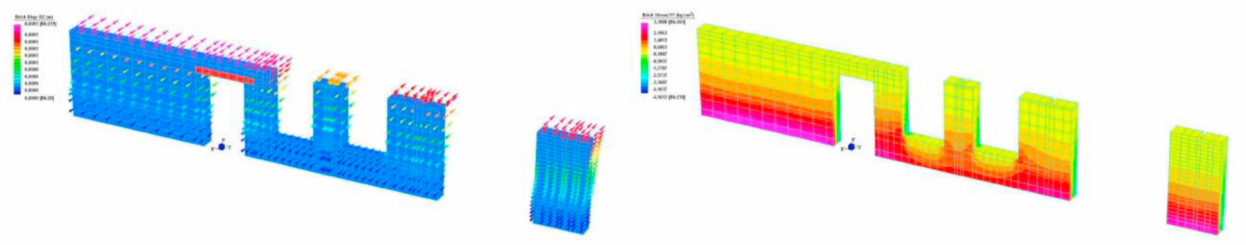

Fig. 3. Model of the wall B of the peristyle with the response to the seismic stress.

7. Conclusions and perspectives

The study conducted so far has allowed us to focus on the prevailing degenerative dynamics, but also to trace the lines of future targeted analytical investigations. The preliminary results indicate mandatory precautions for possible direct protection and conservation actions and open up prospects for activating short- and long-term programs for conservation, control, protection and enhancement. The centrality of the binders of mortars and plasters in the general stability of the materials and technological aggregations (walls, mosaic floors, decorations) poses the in-depth study of the binders as an important and obligatory step in the development of the investigations. A similar approach will be necessary for the materials of the painting layers, on the characteristics of the pigments (nature and quality, assortment of the palette) and painting binders (especially in the case of any organic binders). Among the major emergencies, we note the slope in course of landslide, for which extensive monitoring and studies are required. The low resistance to seismic stresses requires suitable intervention choices to reduce the risk of sudden collapse. In this sense, the widespread presence of decorations on walls and columns raises a double order of problems, very common in archaeological areas (especially moulded and/or painted plasters): on the one hand their widespread presence requires the evaluation of very cautious approaches in the case of masonry stabilization interventions (supports, reinforcements, insertions, etc.); on the other hand, it imposes a scrupulous assessment of the risk levels due to the value (formal and documentary) of these projects, the loss of which, even partial, affects the global conservation of this part of the Villa. On ine with the proposals of Marino (2013), although the risks associated with the instability of the walls are evident, more than the collapse itself, the least obvious loss of fragments is the cause of concern, due to the constant mechanical degradation that exacerbates the exposure of perishable and poorly sealed materials such as plasters paintings or mosaics. The risk, developed according to Michalski et al. (2016), (the ICCROM approach), shows similar levels for sudden collapses and gradual loss. This indicates the need of a cautious multidirectional and multi-scale control, which should not neglect processes on a smaller scale, including the action of salts from marine aerosol and capillar damp rising. Pending further research developments, constant monitoring of the evolution of degenerative phenomena is recommended, to precisely quantify the dynamics and intensity necessary to hierarchize the levels of attention.

References

Allroggen-Bedel, A., 1999, Gli scavi borbonici nella Villa S. Marco e le pitture staccatevi nel Settecento. L'architettura. In: Barbet, A., Miniero, P., (Ed.), La Villa San Marco a Stabia. École Française de Rome, Roma, pp 41-78.

Bonifacio, G., Sodo, A. M., Gallo, E., Mazza, C., 2000. Mostra "In Stabiano". Rivista di Studi Pompeiani 11, 287-289.

Camardo, D., Ferrara, A., Longobardi, N., 1989. Stabiae: le ville. Nicola Longobardi Editore, Castellammare di Stabia.

Camardo, D., 2001. La riscoperta di Stabiae negli scavi degli anni Cinquanta. In: Camardo, D., Ferrara, A. (Ed.). Stabiae: dai Borbone alle ultime scoperte. Nicola Longobardi Editore, Castellammare di Stabia, pp. 69-72.

Coppola, M., 2018, Le indagini tipologiche in architettura, Roma, Carocci.

Cosenza, G., 1890. Stabia: memorie storiche ed archeologiche. Stab. Lito-Tipografico Elzeviriano, Castellammare di Stabia.

Doglioni, F., 2010. Leggibilità della costruzione, percorsi di ricerca stratigrafica e restauro. Archeologia dell'architettura, 15, 65-79.

Galassi, S., Ruggieri, N., Tempesta G., 2020, A novel numerical tool for seismic vulnerability analysis of ruins in archaeological sites, International Journal of Architectural Heritage, 14(1), 1-22.

Maiuri, A., 1942. L'ultima fase edilizia di Pompei. Arte Tipografica. Napoli.

Marino L., 2009, Materiali per un atlante delle patologie presenti nelle aree archeologiche e negli edifici allo stato di rudere. Alinea. Firenze.

Marino, L., 2013, Il rischio nelle aree archeologiche. Registrazione delle vulnerabilità in Aree Archeologiche e manufatti allo Stato di Rudere. Alinea. Firenze.

Michalski, S., Pedersoli, J. M., 2016, The ABC method. A risk management approach to the preservation of cultural heritage, ICCROM - Canadian Conservation Institute, Ottawa.

Minos-Minopoulos, D., Dominey-Howes, D., Pavlopoulos, K., 2017, Vulnerability assessment of archaeological sites to earthquake hazard: an indicator based method integrating spatial and temporal aspects, Annals of Geophysics, 60(4), 1-24.

Rougetet, J., 1999, Construction et architecture. In: Barbet, A., Miniero, P. (Ed.), La Villa San Marco a Stabia. École Française de Rome, Roma, pp 79-94.

Ruffo, F., 2010. L'insula sud-occidentale del cosiddetto "impianto urbano" di Stabiae. Nuovi dati dalla recente campagna di scavo (2009). Oebalus. Studi sulla Campania nell'antichità, 5, pp. 177-239.

Ruggieri, N., Galassi, S., Tempesta, G., 2018, Pompeii's Stabian Baths. Mechanical behaviour assessment of selected masonry structures during the 1st century seismic events, International Journal of Architectural Heritage, 12(5), 859-878.

Ruggieri, N., Galassi, S., Tempesta, G., 2019, The effect of pyroclastic flows of the 79 AD eruption of Mount Vesuvius on the Pompeii's city walls. The case study of the sector near the Tower XI, International Journal of Cultural Heritage.

Ruggiero, M., 1881. Degli scavi di Stabia dal MDCCXLIS al MDCCLXXXII. Tipografia dell'Accademia Reale e delle Scienze, Napoli.

Signorini, M. A., 2016, Rischio legato alla presenza di vegetazione. In: Marino, L., (Ed.), Il restauro archeologico, Altralinea. Firenze, pp. 193-96.