

IMEKO TC4 International Conference on Metrology for Archaeology and Cultural Heritage 2020

Trento, Italy
22 - 24 October 2020

ISBN: 978-1-7138-2070-3

Printed from e-media with permission by:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

Copyright© (2020) by the International Measurement Confederation (IMEKO)
All rights reserved.

Printed with permission by Curran Associates, Inc. (2021)

For permission requests, please contact the International Measurement Confederation (IMEKO)
at the address below.

IMEKO Secretariat
Dalszinhaz utca 10, 1st floor, Office room No. 3
H-1061 Budapest (6th district)
Hungary

Phone/Fax: +36 1 353 1562

imeko@t-online.hu

Additional copies of this publication are available from:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: 845-758-0400
Fax: 845-758-2633
Email: curran@proceedings.com
Web: www.proceedings.com

TABLE OF CONTENTS

INTEGRATED USE OF GPR AND TDR FOR WOOD PERMITTIVITY EVALUATION	1
<i>Filippo Comisi, Lara De Giorgi, Giovanni Leucci</i>	
FROM CAUSES TO EFFECTS. INTEGRATION OF HETEROGENEOUS DATA FROM NON-INVASIVE IMAGING FOR THE DIAGNOSIS AND RESTORATION OF MONUMENTS. THE CASE OF THE CHURCH OF S. FRANCESCO DELLA SCARPA IN LECCE (SOUTHERN ITALY).....	5
<i>Giovanni Leucci, Francesco Gabellone, Fabrizio Terenzio Gizioni, Nicola Masini</i>	
A MULTISCALAR RESEARCH PROJECT, FOLLOWING AN ANCIENT DECUMANUS IN MONTENEGRO	9
<i>Lucia Alberti, Francesca Colosi, Pasquale Merola</i>	
WARSCAPES: A SUBMERGED INFORMATION BASIN. THE CONTRIBUTION OF LIDAR DATA TO THE UNVEILING	15
<i>Joel Aldriguettoni, Alessandra Quendolo</i>	
ACOUSTIC REMOTE SENSING FOR SEABED ARCHAEOLOGY.....	21
<i>Crescenzo Violante</i>	
EVALUATING THE EFFECTS OF HIGH TIDE ON VENETIAN STONE BUILDINGS: A MULTI-ANALYTICAL APPROACH	27
<i>Gloria Zaccariello, Elena Tesser, Rebecca Piovesan, Fabrizio Antonelli</i>	
PETRO-ARCHAEMETRIC CHARACTERIZATION OF HISTORICAL MORTARS IN THE CITY OF RAVENNA (ITALY).....	32
<i>Elena Marrocchino, Chiara Telloli, Paola Novara, Carmela Vaccaro</i>	
THERMAL DECAY OF MONZOGRANITE FROM ELBA ISLAND (WESTERN TUSCANY, ITALY): PROPERTIES OF AN ANCIENT BUILDING MATERIAL	38
<i>Andrea Aquino, Michele Antola, Alessio Pacchini, Stefano Pagnotta, Marco Lezzerini</i>	
MACIGNO SANDSTONE FROM GARFAGNANA AND VELLANO (NORTH-WESTERN TUSCANY): CHEMICAL, MINERALOGICAL, PETROGRAPHIC AND PHYSICAL CHARACTERIZATION OF A BUILDING MATERIAL	44
<i>Andrea Aquino, Claudio Di Petta, Stefano Pagnotta, Marco Tamponi, Marco Lezzerini</i>	
MACIGNO SANDSTONE FROM MONTI D'OLTRE SERCHIO: CHEMICAL, MINERALOGICAL, PETROGRAPHIC AND PHYSICAL CHARACTERIZATION OF A BUILDING MATERIAL	50
<i>Andrea Aquino, Paolo Baglini, Stefano Pagnotta, Marco Tamponi, Marco Lezzerini</i>	
GEOPOLYMER MORTAR: METAKAOLIN-BASED RECIPE FOR CULTURAL HERITAGE APPLICATION	55
<i>Stefano Pagnotta, Anna Lluveras Tenorio, Maria Rosaria Tinè, Marco Lezzerini</i>	
ROME: NE SLOPES OF THE PALATINE HILL. ANALYSIS AND QUANTIFICATION OF ANCIENT ARCHITECTURES	60
<i>Emanuele Brienza, Lorenzo Fornaciari</i>	
ARCHIVES ENHANCEMENT THROUGH DESIGN DRAWINGS SURVEY, BIM MODELING AND PROTOTYPING.....	66
<i>Giulia Bertola</i>	

BAROQUE BANDED VAULTS WITH INDEPENDENT ARCHES: FROM LITERATURE TO REALIZATIONS IN TURIN ATRIA.....	72
<i>Fabrizio Natta</i>	
3D MODELLING TROUGH PLANAR SLIDES, FROM DIGITAL TO PHYSICAL. EXPERIMENTS ON PALAZZO MAZZONIS ATRIUM IN TURIN	78
<i>Francesca Ronco</i>	
ARCHAEOLOGY OF BUILDINGS AND HBIM METHODOLOGY: INTEGRATED TOOLS FOR DOCUMENTATION AND KNOWLEDGE MANAGEMENT OF ARCHITECTURAL HERITAGE.....	84
<i>Ilaria Trizio, Francesca Savini</i>	
EXPERIENCES OF INDUSTRIAL ARCHAEOLOGY IN ITALY: FROM SURVEY TO MUSEUM USE	90
<i>Francesco Gabellone</i>	
THE OLD SCIENTIFIC-TECHNOLOGICAL INSTRUMENTATIONS IN THE MUSEO DELL'ARTE DELLA LANA OF STIA.....	96
<i>Emma Angelini, Andrea Gori</i>	
MINERALOGICAL AND CHEMICAL CHARACTERIZATION OF SURFACE ORANGE LAYERS ON THE LIMESTONE OF THE MONASTERY OF BATALHA, CENTRAL PORTUGAL.....	101
<i>Yufan Ding, Pedro Redo, Emma Angelini, José Mirão, Nicola Schiavon</i>	
OVERVIEW OF STRUCTURAL HEALTH MONITORING SYSTEMS FOR THE FOUNDATIONS OF HISTORIC BUILDINGS	106
<i>Matilde Zarrella, Carmelo Scuro, Domenico L. Carnì, Renato S. Olivito, Francesco Lamonaca</i>	
ARTIFICIAL INTELLIGENCE BASED MONITORING SYSTEM FOR HISTORICAL BUILDING PRESERVATION	112
<i>Domenico Luca Carnì, Carmelo Scuro, Renato Sante Olivito, Maria Caterina Crocco, Francesco Lamonaca</i>	
FULL-SCALE DYNAMIC TESTS ON UNREINFORCED AND GFRCM-REINFORCED APULIAN TUFF MASONRY ARCHES	117
<i>Anna Castellano, Aguinaldo Fraddosio, Jacopo Scacco, Gabriele Milani, Mario Daniele Piccioni</i>	
DYNAMIC IDENTIFICATION OF THE DAMAGE FOR A PARABOLIC TUFF BARREL VAULT WITH DIFFERENTIAL SETTLEMENTS OF THE SUPPORTS	123
<i>Anna Castellano, Aguinaldo Fraddosio, Jacopo Scacco, Gabriele Milani, Mario Daniele Piccioni</i>	
GPR PROSPECTING FOR THE SEARCH OF ST.CANIO'S LOST BONES (ACERENZA, SOUTHERN ITALY)	129
<i>De Giorgi Lara, Leucci Giovanni, Maurizio Lazzari, Raffaele Persico</i>	
A NEW METHODOLOGICAL APPROACH ON THE EVALUATION OF STABILITY OF CAVITIES IN SOFT CARBONATE ROCKS	133
<i>Lara De Giorgi, Giovanni Leucci</i>	
3D GPR AND ERT SURVEYS AT THE COASTAL TOWER OF S. CATERINA (LECCE, ITALY).....	136
<i>Lara De Giorgi, Giancarlo De Pascalis, Ivan Ferrari, Francesco Giuri, Giovanni Leucci</i>	

GEOPHYSICAL SURVEYS AT THE ARCHAEOLOGICAL SITE OF ANGLONA (MT)	140
<i>Lara De Giorgi, Dimitris Roubis, Giovanni Leucci</i>	
GEOMETRIC SURVEY AND CHARACTERIZATION OF ARTIFACTS THROUGH PORTABLE DEVICES: AN EXPERIENCE OF MOBILE LABORATORY INSIDE THE AEOLIAN MUSEUM OF LIPARI.....	144
<i>Dario Giuffrida, Viviana Mollica Nardo, Oreste Adinolfi, Maria Amalia Mastelloni, Rosina Celeste Ponterio</i>	
A DATABASE FOR HISTORICAL PIGMENTS THROUGH HANDHELD INSTRUMENTATION	150
<i>Giulia Festa, Claudia Scatigno, Maria Luisa Saladino, Francesco Armetta, Veronica Ciaramitato, Viviana Mollica Nardo, Rosina Celeste Ponterio</i>	
COMBINED MIGRATION RESULTS IN GPR PROSPECTING	155
<i>Raffaele Persico, Gianfranco Morelli</i>	
SPATIAL ANALYSIS AND LIDAR DATA FOR THE EXTRACTION OF ARCHAEOLOGICAL FEATURES: THE ETRUSCAN SITE OF SAN GIOVENALE, BLERA (LAZIO)	160
<i>Maria Danese, Rosa Lasaponara, Nicola Masini</i>	
MULTIMETHODOLOGICAL GEOPHYSICAL INVESTIGATIONS TO STUDY THE ARCHAEOLOGICAL SITE OF NORBA (NORMA, CENTRAL ITALY)	164
<i>Piro Salvatore, Quilici Gigli Stefania, Papale Enrico, Zamuner Daniela</i>	
POINT CLOUDS REGISTRATION BASED ON CONSTANT RADIUS FEATURES FOR LARGE AND DETAILED CULTURAL HERITAGE OBJECTS.....	168
<i>L. Di Angelo, P. Di Stefano, A. E. Morabito, E. Guardiani</i>	
ANALYSING THE THERMAL CONDITIONS OF HISTORIC BUILDINGS IN CYPRUS USING ARCHIVE LANDSAT SATELLITE DATA AND GOOGLE EARTH ENGINE BIG DATA CLOUD PLATFORM	174
<i>Athos Agapiou, Vasiliki Lysandrou, Diofantos Hadjimitsis</i>	
THE LOCAL BLACK LIMESTONES USED TO MAKE THE TYPICAL BLACK-AND-WHITE ALTERNATION OF THE PISA'S ROMANESQUE STYLE.....	179
<i>Marco Lezzerini, Stefano Pagnotta, Andrea Aquino, Marcello Spampinato</i>	
THE ROLE OF 3D MODELLING FOR DIFFERENT STONE OBJECTS: FROM MINERAL TO ARTEFACT	184
<i>Andrea Aquino, Stefano Pagnotta, Elena Pecchioni, Vanni Moggi Cecchi, Stefano Columbu, Marco Lezzerini</i>	
WORKABILITY AND CHEMICAL-PHYSICAL DEGRADATION OF LIMESTONE FREQUENTLY USED IN HISTORICAL MEDITERRANEAN ARCHITECTURE	189
<i>Stefano Columbu, Paola Meloni, Gianfranco Carcangiu, Dario Fancello</i>	
CA-OXALATE FILMS ON THE STONES OF THE MEDIEVAL ARCHITECTURE: THE CASE-STUDY OF ROMANESQUE CHURCHES	196
<i>Stefano Columbu, Marco Giamello, Stefano Pagnotta, Andrea Aquino, Marco Lezzerini</i>	
COGNITIVE METHODOLOGY AND DIAGNOSTIC PLAN FOR CULTURAL HERITAGE CONSERVATION	202
<i>Caterina Gattuso</i>	

INTEGRATED DIGITAL SURVEY FOR THE KNOWLEDGE AND ENHANCEMENT OF THE IWW HERITAGE. THE NATURAL PARK MOLENTARGIUS-SALINE (CAGLIARI, ITALY)	208
<i>Andrea Pirinu, Andrés Martínez-Medina, Nicola Paba</i>	
HIGH PERFORMANCE LASER SURVEY AND 3D STRESS ANALYSIS FOR MAINTENANCE AND PRESERVATION OF ARTISTIC ASSETS	214
<i>Adriana Marra, Salvatore Gerbino, Giovanni Fabbrocino</i>	
A PARAMETRIC MODEL TO MANAGE ARCHAEOLOGICAL DATA.....	220
<i>Angela Bosco, Laura Carpentiero, Andrea D Andrea, Eleonora Minucci, Rosario Valentini</i>	
AN ASSESSMENT ON MORPHOLOGICAL SURVEY CALIBRATION AND THE AUTOMATION OF DIGITAL DRAWING FOR THE RELIABLE DOCUMENTATION AND CONSERVATION ANALYSIS OF OUT-OF-SCALE BUILDINGS	226
<i>Raffaella De Marco, Alessia Miceli, Sandro Parrinello</i>	
A DIGITAL TWIN FOR DISTANT VISIT OF INACCESSIBLE CONTEXTS	232
<i>Francesco Gabellone</i>	
URBAN ARCHAEO-GEOPHYSICS IN CUSCO. THE CASE STUDIES OF PARANINFO AND CASA CONCHA	238
<i>Nicola Masini, Sayri Garcia, Maria Sileo, Luigi Capozzoli, David Vera, Rosa Lasaponara</i>	
THE USE OF CONE PENETRATION TESTS (CPT) FOR THE STUDY OF THE DYNAMIC CHARACTERISTICS OF THE SOILS	242
<i>Antonio Cavallaro</i>	
INVESTIGATION OF ARCHAEOLOGICAL SITES WITH SPECIES DISTRIBUTION MODELS AND SATELLITE DATA	248
<i>Noviello Mariangela, Cafarelli Barbara, Calcutti Crescenza, Sarris Apostolos, Mairotta Paola</i>	
MULTIANALYTICAL INVESTIGATION AND 3D MULTIBAND MODELING: AN INTEGRATED SURVEY OF THE GARNIER VALLETTI POMOLOGICAL COLLECTION	251
<i>Emanuela Grifoni, Letizia Bonizzoni, Marco Gargano, Jacopo Melada, Ilaria Mignani, Nicola Ludwig</i>	
PRELIMINARY STUDIES ON THE VOLUMETRIC CAPACITY OF CERAMIC FROM THE NEOLITHIC SITE OF LUGO DI GREZZANA (VR) THROUGH 3D GRAPHICS SOFTWARE	257
<i>Andrea Tavella, Marika Ciela, Paolo Chistè, Annaluisa Pedrotti</i>	
SPACE AND SOUND CHARACTERISATION OF SMALL-SCALE ARCHITECTURAL HERITAGE: AN INTERDISCIPLINARY, LIGHTWEIGHT WORKFLOW	263
<i>J. Y. Blaise, I. Dudek, A. Pamart, L. Bergerot, A. Vidal, S. Fargeot, M. Aramaki, S. Ystad, R. Kronland-Martinet</i>	
CASTIGLIONI CHAPEL IN PAVIA: A METHODOLOGICAL APPROACH FOR DOCUMENTATION AND VIRTUALISATION TECHNIQUES	269
<i>Elisabetta Doria, Francesca Galasso, Marco Morandotti</i>	
MEASUREMENTS FOR THE RECONSTRUCTION OF ANCIENT WALLS IN OPUS RETICULATUM IN THE BASEMENT OF THE CASTLE OF SANTO STEFANO IN PUGLIA (ITALY)	275
<i>Angela Diceglie</i>	

MOTION MAGNIFICATION ANALYSIS FOR MONITORING CULTURAL HERITAGE BUILDINGS AND ARCHEOLOGICAL SITES.....	281
<i>Sara Forliti, Vincenzo Fioriti, Ivan Roselli, Angelo Tati, Alessandro Colucci</i>	
IOT-MHECHA: A NEW IOT ARCHITECTURE FOR MONITORING HEALTH AND ENVIRONMENTAL PARAMETERS IN CULTURAL HERITAGE AND ARCHAEOLOGICAL SITES	287
<i>Giuseppe Campobello, Alessio Altadonna, Fabio Todesco, Nicola Donato</i>	
SETTLEMENT ANALYSIS OF THE MASONRY UMBRELLA VAULT OF THE MASEGRA CASTLE.....	293
<i>Nicola Grillanda, Gabriele Milani, Lorenzo Cantini, Stefano Della Torre</i>	
A NOVEL MATHEMATICAL STRUCTURAL MODEL APPROACH FOR LOW COST STRUCTURAL HEALTH MONITORING SYSTEM.....	298
<i>Carmelo Scuro, Saverio Porzio, Francesco Demarco, Domenico L. Carnì, Francesco Lamonaca, Renato S. Olivito</i>	
DIGITAL RECONSTRUCTION OF A LOST HERITAGE: THE SAN GEMINIANO S CHURCH IN SAN MARCO'S SQUARE IN VENICE.....	304
<i>Caterina Balletti, Marcin Dabrowski, Francesco Guerra, Paolo Vernier</i>	
PRELIMINARY DATA PROCESSING ON THE ROMAN SHIPWRECK OF GRADO. ARCHIVE AND LEGACY DATA TO CREATE ITS 3D VIRTUAL MODEL	311
<i>Elisa Costa, Carlo Beltrame</i>	
BLK2GO FOR DTM GENERATION IN HIGHLY VEGETATED AREA FOR DETECTING AND DOCUMENTING ARCHAEOLOGICAL EARTHWORK ANOMALIES	316
<i>M. Limongiello, D. Ronchi, V. Albano</i>	
FOSTERING ETRUSCAN HERITAGE WITH EFFECTIVE INTEGRATION OF UAV, TLS AND SLAM-BASED METHODS.....	322
<i>Anna Rabbia, Giulia Sammartano, Antonia Spanò</i>	
AN EXPERIMENTAL APPROACH TO THE CLEANING OF A POLYMATERIC TEXTILE WEAVE: SET-UP OF THE ALTERNATIVE METHODOLOGY AND INSTRUMENTATION	328
<i>Paola Fermo, Valeria Comite, Elisabetta Boanini, Roberto Bonomi, Marco Bertelli, Elisa Monfasani</i>	
A NEW ANALYTIC METHODOLOGY FOR THE CHARACTERIZATION OF THE CARBONACEOUS FRACTION IN BLACK CRUSTS PRESENT ON STONE SURFACES	333
<i>Valeria Comite, Mauro La Russa, Paola Fermo</i>	
AIR POLLUTION, BLACK CRUSTS AND CAIRO MONUMENTS: A REVIEW	338
<i>Natalia Rovella</i>	
MULTI ANALYTICAL STUDY ON KHOL RESIDUES FROM THE ANCIENT EGYPTIAN CITY OF ASSIUT.....	343
<i>Francesco Saliu, Chiara Riedo, Dominique Scalarone, Ilaria Degano, Francesca Modugno, Sergio Andò, Marco Orlandi, Oscar Chiantore</i>	
THE CONTRIBUTION OF ARCHAEOOMETRIC ANALYSES TO THE MULTI- DISCIPLINARY RESEARCH IN HIERAPOLIS OF PHRYGIA, TURKEY	348
<i>G. Ricci, M. Secco, G. Artioli, F. Marzaioli, I. Passariello, F. Terrasi, M. R. Valluzzi</i>	

MICROSCOPIC AND CHEMICAL CHARACTERIZATION OF METAL SLAGS FOUND AT THE PORTA PAOLA EXCAVATION IN FERRARA	354
<i>Elena Marrocchino, Chiara Telloli, Carmela Vaccaro</i>	
INTEGRATED GEOMATIC METHODOLOGIES TO RECONSTRUCT THE ANCIENT TOPOGRAPHY OF ROME.....	360
<i>Luca Alessandri, Valerio Baiocchi, Marta Baumgartner, Diego Blanco, Alessandro Bosman, Luigi Cardone, Andrea Guaglianone, Matteo Onori, Felicia Vatore</i>	
GEOMATICS AS A KNOWLEDGE BASE PROPAEDEUTIC TO THE RESTORATION OF AN EXTENDED FRESCO WALL	366
<i>Gabriele Bitelli, Valentina Alena Girelli, Giulia Vannucci, Emanuele Mandanici, Marinella Pigozzi</i>	
SURVEY AND PRESERVATION OF AN ABANDONED ARCHAEOLOGICAL INDUSTRIAL SITE	372
<i>Maria Grazia D'Urso, Valerio Manzari, Francesco Cavaliere, Barbara Marana, Francesco Marmo</i>	
RECONSTRUCTION OF 3D MODELS FROM MICROTOMOGRAPHIC IMAGES OF ARCHEOLOGICAL ARTIFACTS	378
<i>Enej Gucek Puhar, Lidija Korat, Miran Eric, Aleš Jaklic, Franc Solina</i>	
PRELIMINARY ALLOYS CHARACTERIZATION AND TECHNOLOGICAL INTERPRETATION OF THE MANUFACTURING PROCESS OF THE VITTORIA ALATA DI BRESCIA BY MEANS OF NEUTRON DIFFRACTION	384
<i>F. Cantini, M. Galeotti, A. Cagnini, S. Porcinai, A. Scherillo, A. Brini, A. Patera, F. Morandini, F. Grazzi</i>	
NEUTRON-BASED TECHNIQUES APPLIED FOR NONDESTRUCTIVE QUANTITATIVE CHARACTERISATION OF ANCIENT MOSAIC TESSERAE	389
<i>Giulia Marcucci, Antonella Scherillo, Carlo Cazzaniga, Massimiliano Clemenza, Daniela Di Martino</i>	
PRELIMINARY RESULT OF INVESTIGATION OF ELEMENT COMPOSITION OF KYATHOS (6TH-4TH CENTURIES BCE) FROM THE NECROPOLIS VOLNA 1 ON THE TAMAN PENINSULA BY NEUTRON RESONANCE CAPTURE ANALYSIS	394
<i>N. V. Simbirtseva, P. V. Sedyshev, S. T. Mazhen, A. M. Yergashov, I. A. Saprykina, R. A. Mimokhod</i>	
NON-INVASIVE CHARACTERIZATION OF NURAGIC BRONZES THROUGH NEUTRON BASED TECHNIQUES	399
<i>M. Cataldo, F. Grazzi, A. Scherillo, A. Fedrigo, A. Depalmas, A. Canu, A. Brunetti</i>	
ARCHAEOLOGY AND ARCHAEOOMETRY OF MARBLES IN ROMAN CENTRAL ADRIATIC ITALY	404
<i>Devi Taelman, Dimitri Van Limbergen, Fabrizio Antonelli</i>	
ANALYTICAL DATA ON MARBLE SCULPTURES POLYCHROME TRACES (PALATINE HILL, ROME).....	410
<i>Maria Cristina Caggiani, Alessia Coccato, Silvia Borghini, Paolo Mazzoleni, Alfonsina Russo, Germana Barone</i>	

COLORIMETRIC STUDY OF AYLA-AKSUM AMPHORAE FROM THE RED SEA COAST OF ERITREA	415
<i>Abraham Zerai, Patrizia Davit, Monica Gulmini, Alessandro Re, Roberto Giustetto, Lara Maritan, Serena Massa, Chiara Mandelli, Yohannes Gebreyesus, Alessandro Lo Giudice</i>	
PROJECT OF ELECTRONIC IDENTITY OF PAINTING	420
<i>Giuseppe Schirripa Spagnolo, Lorenzo Cozzella, Fabio Leccese</i>	
THE COLOURED STONES AND MARBLES DECORATING THE ODEION OF POMPEII.....	425
<i>Fabrizio Antonelli, Lorenzo Lazzarini, Stefano Cancelliere, Luigi Buffone</i>	
DAMAGE ASSESSMENT OF CULTURAL STONE HERITAGE IN RESERVOIR ENVIRONMENTS	431
<i>Monica Alvarez De Buergo, Natalia Perez Ema, Rafael Fort, Manuel Garcia Rodriguez, María J. Varas, Mauro F. La Russa</i>	
A PRELIMINARY STUDY ON BLACK CRUSTS FROM THE MONUMENTAL CEMETERY OF MILAN.....	435
<i>Valeria Comite, Donatella Bonelli, Paola Fermo</i>	
CORATELLI MILL: MICRO-GEOPHYSICAL INVESTIGATIONS FOR STRUCTURAL DIAGNOSTICS	440
<i>Lara De Giorgi, Giovanni Leucci</i>	
GEOPHYSICAL INVESTIGATIONS AT THE CATHEDRAL OF CATANIA	444
<i>Giovanni Leucci, Lara De Giorgi, Giovanni Fragalá, Antonino Mazzaglia, Daniele Malfitana</i>	
GIS FOR THE CATALOGING AND ENHANCEMENT OF SPECCHIE LOCATED IN THE UPPER SALENTO IN APULIA REGION (SOUTHERN ITALY)	448
<i>Maurizio Delli Santi</i>	
GEOPHYSICAL INVESTIGATIONS, DIGITAL RECONSTRUCTION AND NUMERICAL MODELING AT THE BATIA CHURCH IN TORTORICI (MESSINA, SICILY): PRELIMINARY RESULTS	453
<i>Sebastiano D'Amico, Emanuele Colica, Raffaele Persico, Michele Betti, Salvatore Foti, Maurizio Paterniti Barbino, Luciano Galone</i>	
PRELIMINARY GEOPHYSICAL SURVEYS AND ARCHAEOLOGICAL STUDIES INTO THE BURIED URBAN PLAN OF THE LUCANIAN SETTLEMENT OF CASELLE IN PITTARI.....	457
<i>L. Capozzoli, G. De Martino, V. Lapenna, F. Perciante, E. Rizzo, M. L. Rizzo, A. Serritella, M. Scafuro, O. Voza</i>	
PRELIMINARY STUDY FOR THE PRESERVATION OF TWO NATURAL HORMS FROM THE END OF THE 17TH CENTURY	461
<i>Michela Albano, Giacomo Fiocco, Piercarlo Dondi, Francesca Tasso, Valentina Ricetti, Daniela Comelli, Maurizio Licchelli, Claudio Canevari, Marco Malagodi</i>	
TOWARDS THE STUDY OF ALTERATION PATINAS ON THE MARBLE SURFACE OF A RENAISSANCE SCULPTURAL GROUP FROM THE MUSEUM OF ANCIENT ART (CASTELLO SFORZESCO, MILAN)	467
<i>Valeria Comite, Mario Colella, Marco Malagodi, Giacomo Fiocco, Michela Albano, Silvia Marchioron, Paola Fermo</i>	
ENVIRONMENTAL IMPACT ON HISTORICAL MONUMENTS: THE BLACK CRUSTS OF THE VENICE LAGOON.....	472
<i>Luciana Randazzo, Natalia Rovella, Silvia Muto, Fabrizio Antonelli, Elena Tesser, Mauro Francesco La Russa</i>	

FRESCOED WALL CONDITIONS ASSESSMENT WITH NONINVASIVE GPR SURVEY: THE CASE OF THE CRYPT OF SAN FRANCESCO IN IRSINA (BASILICATA, SOUTHERN ITALY).....	477
<i>L. Capozzoli, M. P. Boccia, G. De Martino, F. T. Gizzi, M. Sileo, N. Masini</i>	
L'AVVENTUROSO 1936 PROJECT: THE FIRST ANALYTICAL APPROACH TO PRINTED HISTORIC ITALIAN COMICS	481
<i>Giacomo Fiocco, Tommaso Rovetta, Michela Albano, Mario A. Lazzari, Curzio Merlo, Marco Malagodi</i>	
AEROSOL TRACERS DEPOSITION IN A CONTROLLED FIELD EXPERIMENT: ROLE OF SURFACE BUILDING MATERIALS	486
<i>Pierina Ielpo, Patrick Conry, Alessandra Genga, Riccardo Buccolieri, Livia Giotta, Francesca Di Nicola, Maria Lisa Vincenti, Ludovico Valli, H. J. S. Fernando, Silvana Di Sabatino</i>	
A MULTIDISCIPLINARY APPROACH ABOUT STUDY OF ORGÈRES'S METAL FINDS (LA THUILE, AOSTA-ITALY): ARCHAEOLOGICAL EXCAVATION AND XRF ANALYSIS.	491
<i>Chiara Maria Lebole, Greta Lupano, Sylvie Cheney, Giorgio Di Gangi</i>	
MODULAR MA-XRF SCANNER POTENTIALITIES AND FURTHER ADVANCES	496
<i>S. A. B. Lins, M. Manso, G. E. Gigante, R. Cesareo, L. Tortora, P. Branchini, S. Ridolfi</i>	
NON-DESTRUCTIVE SPECTROSCOPIC METHODS FOR GEM ANALYSIS: A SHORT REVIEW	501
<i>Simona Raneri, Germana Barone, Paolo Mazzoleni, Danilo Bersani</i>	
INFN-CHNET MEETS CCR LA VENARIA REALE: FIRST RESULTS	507
<i>L. Sottili, L. Guidorzi, A. Mazzinghi, C. Ruberto, L. Castelli, C. Czelusniak, L. Giuntini, M. Massi, F. Taccetti, M. Nervo, A. Re, A. Lo Giudice</i>	
IMAGING FOR CULTURAL HERITAGE AND ARCHAEOLOGY	512
<i>Paolo Triolo, Luciano Marras, Gloria Adinolfi, Rodolfo Carmagnola, S. Legnaioli, S. Raneri, V. Palleschi</i>	
SANTA MARIA DEL FIORE CUPOLA CONSTRUCTION TOOLS: A NON-INVASIVE CHARACTERIZATION USING PORTABLE XRF	517
<i>Leila Es Sebar, Leonardo Iannucci, Sabrina Grassini, Emma Angelini, Marco Parvis, Andrea Bernardoni, Alexander Neuwahl, Rita Filardi</i>	
ANCIENT BRICKS TECHNOLOGIES: IMPROVING THE BUILT HERITAGE CONSERVATION AT HIGH HUMIDITY AREAS.....	522
<i>Elena Pérez-Monserrat, Lara Maritan, Marie-Ange Causarano, Alejandra Chavarria, Gian Pietro Brogiolo</i>	
POLYDIMETHYLSILOXANE (PDMS) /ZRO ₂ -DOPED ZNO NANOCOMPOSITES AS PROTECTIVE COATINGS FOR STONE MATERIALS	527
<i>Maduka L. Weethimuni, Marwa Ben Chobba, Ilenia Tredici, Maurizio Licchelli</i>	
DIGITAL RECONSTRUCTION AND SCIENTIFIC ANALYSIS PRIOR THE RESTORATION OF TWO PAINTINGS BY MATTIA PRETI IN THE CHURCH OF THE IMMACULATE CONCEPTION OF SARRIA (FLORIANA, MALTA)	532
<i>Sebastiano D'Amico, Valentina Venuti, Emanuele Colica, Giuseppe Paladini, Luciano Galone, Vincenza Crupi, Domenico Majolino, Sante Guido, Giuseppe Mantella</i>	

THE THREE POLYCHROME MOSAICS OF S. ALOE QUARTER IN VIBO VALENTIA (CALABRIA, SOUTHERN ITALY): CHEMICAL CHARACTERIZATION OF GLASS TESSERAE	538
<i>Natalia Rovella, Elia Fiorenza, Donatella Barca</i>	
THE ROLE OF GEOSCIENCES AND NON DESTRUCTIVE METHODS IN THE TECTONIC PROJECT	543
<i>Michela Ricca, Marco Ricci, Stefano Laureti, Mauro Francesco La Russa</i>	
A MULTI-ANALYTICAL SURVEY FOR THE IDENTIFICATION OF THE RED AND YELLOW PIGMENTS OF COLOURED SHERDS DISCOVERED IN THE MONTE D'ORO AREA (ROME)	548
<i>Vittoria Guglielmi, Paola Fermo, Martina Andreoli, Valeria Comite</i>	
THE POTTERY PRODUCTION AT SUMHURAM (KHOR RORI, SULTANATE OF OMAN): AN ARCHAEOOMETRIC STUDY	554
<i>Stefano Pagnotta, Giulia Buono, Marco Lezzerini, Alexia Pavan, Carlotta Rizzo</i>	
PETROGRAPHIC ANALYSIS TO UNDERSTAND ETRUSCAN ARCHITECTURAL TERRACOTTA'S TECHNOLOGY AND PROVENANCE: A STUDY IN PROGRESS	559
<i>M. Fugazzotto, A. Stroscio, A. Bertino, G. Barone, A. Russo, P. Mazzoleni</i>	
THERMOLUMINESCENCE DATING AND MICROSTRUCTURAL CHARACTERIZATION OF ARCHAEOLOGICAL CERAMIC SAMPLES FROM CORVINS CASTLE AREA	564
<i>Rodica-Mariana Ion, Radu Setnescu, Tanta Setnescu, Anca Irina Gheboianu, Gabriel Vasilievici, Sorin Tincu</i>	
EFFECT OF AGE ON PINE WOOD MICROSTRUCTURE STUDIED BY MICRO-MRI AND DIFFUSION-NMR	569
<i>Valeria Stagno, Sveva Longo, Silvia Capuani</i>	
MULTICENTENNIAL REGIONAL OAK CHRONOLOGIES FOR NORTHERN ITALY: AN UPDATING	574
<i>Nicoletta Martinelli</i>	
THE TREE SPECIES OF PO VALLEY LOGBOATS	578
<i>Alice Lucchini, Mauro Bernabei</i>	
CHARACTERIZATION OF ETRUSCAN NON-VASCULAR CERAMIC FRAGMENTS	584
<i>Margherita Cantelli, Alberta Facchi, Francesca C. Izzo, Elisabetta Zendri</i>	
MAY METAGENOMICS DISCLOSE THE HIDDEN SECRETS OF THE ANCIENT DAMAGED PARCHMENTS?	589
<i>Luciana Migliore, Nicoletta Perini, Annamaria Alabiso</i>	
DISTINGUISHING COLOUR ALTERATION PROCESSES OCCURRED IN LATE PLEISTOCENE ANIMAL REMAINS	593
<i>Andrea Perez, Fabio Santaniello, Stefano Grimaldi, Stefano Gialanella</i>	
DIFFERENCES BETWEEN ARCHAEOLOGICAL AND FORENSIC BURNED SAMPLES USING POWDER X-RAY DIFFRACTION (XRD) AND ATR-IR SPECTROMETRY	599
<i>Giampaolo Piga, Fabio Cavalli, Dario Innocenti, Eugénia Cunha, Stefano Enzo, David Gonçalves</i>	
THE ROMAN BRIDGE OF CANOSA DI PUGLIA: A METROLOGICAL APPROACH	604
<i>Germano Germanò</i>	

OPTICAL MICRO-PROFILOMETRY FOR SURFACE ANALYSIS AND 3D PRINTED REPLICA OF ARCHEOLOGICAL ARTEFACTS.....	610
<i>Sara Mazzocato, Giacomo Marchioro, Alessandra Menegazzi, Claudia Daffara</i>	
OPERATIONAL METHODOLOGY FOR A HISTORICAL, CRITICAL AND VIRTUAL RECONSTRUCTION OF BAROQUE Ephemeral APPARATUSES.....	616
<i>Margherita Antolini</i>	
UPGRADE OF THE X-RAY IMAGING SET-UP AT CCR LA VENARIA REALE: THE CASE STUDY OF AN EGYPTIAN WOODEN STATUETTE.....	622
<i>L. Vigorelli, A. Lo Giudice, T. Cavaleri, P. Buscaglia, M. Nervo, P. Del Vesco, M. Borla, S. Grassini, A. Re</i>	
AN INNOVATIVE FLUORINATED POLYACRYLIC COATING FOR THE PROTECTION OF THE CULTURAL HERITAGE	628
<i>Eleonora Pargoletti, Valeria Comite, Valentina Sabatini, Paola Fermo, Marco Aldo Ortenzi, Hermes Farina, Giuseppe Cappelletti</i>	
CORRELATION OF INDOOR AIR QUALITY AND STABLE CARBON ISOTOPE RATIO OF CO ₂ IN HISTORICAL MONUMENTS OF ITALY: A CASE STUDY.....	634
<i>Concetta Pironti, Maria Ricciardi, Antonio Proto</i>	
BLACK CRUSTS GROWN ON VARIED STONE SUBSTRATA FROM HISTORICAL BUILDINGS UNDER DIFFERENT AIR QUALITY SCENARIOS (SE AND NW SPAIN)	639
<i>José Santiago Pozo-Antonio, Carolina Cardell, Valeria Comite, Paola Fermo</i>	
CHEMICAL AND ISOTOPIC INVESTIGATIONS ON THE DETERIORATION OF THE MONUMENTAL COMPLEX OF S. PIETRO IN CORTE IN SALERNO (ITALY) CAUSED BY THE RISING WATERS.....	644
<i>Maria Ricciardi, Concetta Pironti, Oriana Motta</i>	
INDOOR AIR QUALITY MONITORING WITH STABLE CARBON ISOTOPE RATIO OF CO ₂ IN MUSEUM ENVIRONMENTS: STUDY FOR THE LEONARDO DA VINCI'S LAST SUPPER	649
<i>Oriana Motta, Concetta Pironti, Maria Ricciardi, Ezio Bolzacchini, Luca Ferrero, Chiara Rostagno, Raffaele Cucciniello, Antonio Proto</i>	

Author Index

A parametric model to manage archaeological data

Angela Bosco, Laura Carpentiero, Andrea D'Andrea, Eleonora Minucci, Rosario Valentini

Università degli Studi di Napoli "L'Orientale"

Keywords: Parametric model, ABIM, data management, UAV, aerial photogrammetry, big data

Abstract – The paper focuses on the work carried out in the *insula* 4-6 of Paestum (Italy), in the framework of a collaboration between the Archaeological Park of Paestum and the University of Naples “L’Orientale”; the contribution shows the “drone to BIM” solution applied for the study of the *insula* and the related methodological approach. The combination of the digital survey with the parametric reconstruction of the structures, which characterizes the so-called ABIM (Archaeological Building Information Modelling), provides a complete information system useful for different purposes, from documentation to interpretation and management. To systematize the incomplete archive documentation of the *insula* and to integrate the dwg file supplied by the Park, an aerial digital survey has been carried out to provide a detailed map of all the structures still visible on the area. The three-dimensional information, derived from the UAV, constitutes the basis for the construction of the BIM model.

I. INTRODUCTION

The increasingly use of 3D survey methods in archaeology, has modified the typical graphic documentation approach. Unfortunately, 3D information is often disconnected from the rest of the archaeological data (e.g. reports, images, drawings from previous excavation campaigns, old maps). The 3D dataset is generally used just to post-produce 2D vectorial information, to generate orthophotos or to extract measures.

Even if this workflow allows to obtain accurate and high-resolution replicas of whatever archaeological object, ranging from small finding to big monument, most of the 3D information is still underused: to manage a large dataset of heterogeneous data, coming from archaeological research, is a task still hard to be faced with a traditional approach. More broadly, researchers attempt to identify, at the beginning of their approach, the best solutions (hardware + software) for the most correct 3D data-acquisition and elaboration process; at the end they are obliged to optimize the dataset according to the used software and, mainly, according to their different needs, e.g. research, exploitation and conservation.

Even if GIS has made easier to perform complex spatial analyses, especially in the field of reconstruction of the

ancient landscape, for the analysis of the composite archaeological architectures are necessary new tools and approaches fully 3D; probably for this target the best solution is the BIM [1][2].

II. BIM, HBIM, ABIM

Since the 1970s, BIM methodology has progressively expanded its field of application. BIM has been designed as integrate system for the planning and management of the modern civil infrastructures [3], but very soon it has become an innovative tool for the analysis of archaeological and architectural heritage. In particular, the HBIM (Historical BIM) offers advanced suggestions for the application of the BIM methodology to the processes of management, maintenance and enhancement of the cultural heritage [4].

As the BIM has been not designed for the archaeological research, one of the main challenges is how to adapt this approach to the needs of historical analysis and, first of all, how to optimize the 3D dataset in order to allow a fast and accurate 3D modelling process.

The ABIM is characterized by the combination of the digital survey with the parametric reconstruction of archaeological structures, with their peculiar and often unique elements; it represents a big opportunity to make available, in a virtual environment, all the data related to a single monument. The ABIM can contain not only spatial data, but also other detailed information (photos, drawings, descriptions, annotations) concerning the monument or single part of it [2][4][5]. For the archaeological research, the ABIM represents a big repository or an information system allows to link whatever type of data, particularly useful to manage complex architectures or buildings. It constitutes the base of a reasonable, transparent and verifiable reconstruction of whatever archaeological evidences.

The strength of a BIM approach lies in the ability to verify the accuracy of all recorded information and in the ability to manage the life cycle of the object. BIM supports a typically interdisciplinary approach by offering specialists updated, accessible and shared information; by making heterogeneous and multidisciplinary data available, the system facilitates collaboration. The BIM model, therefore, does not represent a method for managing and displaying three-dimensional data, but it is a searchable information

system in which the quantity and quality of the information guarantees its reliability.

The idea of implementing a BIM system for an archaeological context, stems from the need to create a complete and accessible data container in which every single aspect of the asset can be immediately made available for different purposes, as safeguard, fruition, maintenance enhancement and protection activities, and for future investigations. The goal is to obtain a management system able to guide any restorations or valorization process.

As already mentioned, the BIM has been implemented in the context of the most recent engineering practice and only in the last decade it has been applied to historical buildings; this field of interest, so called HBIM, has concentrated any effort and scientific considerations on the issue's method, that is how to apply this approach to the architectural heritage.

Frequently the analysis of historical buildings, integrated with the study of ancient constructive techniques and the comparison of coeval edifices, provides information allowing to reconstruct, more or less precisely, the original project of the designer or of the architect. In the HBIM approach the 3D survey represents an objective starting point for any further interpretation of the monument.

In the archaeological field, often, the structures are stored only for few centimeters or at foundation level; therefore, the simulation or the virtual reconstruction are approaches used to hypothesize the shape, the sizes and the extension of the building. From this point of view ABIM is a container collecting all available data making more transparent any reconstructive hypothesis. To reach this result it is important to define correctly a methodological approach and a precise workflow, also according to the chosen software.

To classify the complexity of the archaeological evidence within a three-dimensional representation, it is necessary to identify every single element that composes it; this process allows to recognize the structure, the function and the level of detail to be achieved in the modeling parametric phase. The archaeological reality must be re-created in BIM, through the definition of the objects. Therefore, before starting the modelling, it must be established what is a BIM object, in what terms of modeling and information it can be obtained, and at what level of detail it must be codified. The context is thus divided into its constitutive elements, organized into categories and types and assigned to a chronological phase. At the end of the semantics phase the modeling step can be started.

III. THE CASE STUDY: THE *INSULA* 4-6 OF PAESTUM

Starting from these premises, in 2018 has begun a collaboration between the Archaeological Park of

Paestum and the University of Naples "L'Orientale", to re-examine the *insula* 4-6 of Paestum. Unfortunately, this area has been excavated several times, but there was no documentation (photos, drawings, stratigraphic reports) available for these investigations. Furthermore, the majority of the walls are preserved for few centimetres and the sizes of the rooms are not always clear. Therefore, to better investigate the chronology, the extension and the organisation of the inner public and private buildings of the *insula*, a new approach, based on the ABIM, has been set up. The aim was to deepen the knowledge of the walls stratigraphy in order to elaborate reconstructive hypotheses and define chronological phases.

The *insula* 4-6 dates back to the late-republican period with several remakes at the end of republican age and the beginning of imperial age. The area has a North / South orientation and it is about 273m long and 35m width, i.e. 120 roman *actus*. The *insula* is marked to the North by the *decumanus* Bo and to the South by the Bo2 road axis. In the northern part there is a large *domus* with a double atrium and peristyle and, after a slight variation in altitude, there are the rooms of a *thermae* built on the edge of a large open space, identifiable as the *palestra*; toward South, there is another house, with the atrium and the peristyle clearly visible, while the limits of another possible *domus*, located in the southern strip of the block, appear less precise. This area has never been studied and published, except for minor restoration and maintenance operations [6].

As mentioned, the documentation of the excavations is mostly lost, and this makes it impossible to reconstruct the life of this part of the ancient city. In the absence of whatever stratigraphical data, which could provide useful information about the great transformations occurred in the area between the Roman and Late Ancient periods, an innovative method has been tested.

To combine all possible information coming from the *insula*, an ABIM application has been considered; the approach has been divided in different steps, first of all, a drone-survey for the acquisition and processing of geo-referred bi- and three-dimensional data, essential for the successive parametric modelling phase. Then, according to a traditional approach, all the different constructive techniques documented in the *insula* were identified thanks to the bibliography and to the comparison with the masonries existing in other part of the site.

IV. DATA ACQUISITION AND METHODOLOGICAL APPROACH

In the last decade archaeological research has begun to take advantage of new remote-sensing methodologies and tools as UAV (Unmanned Aerial Vehicles). In particular, the applications of aerial photogrammetry are evolving thanks to the quick development of UAV technology for documentation and site mapping [7] [8].

Since the Archaeological Park of Paestum had for the area only a digital map, revised and geo-referred in 2008, a drone-based photogrammetry survey of the *insula* was planned during the summer and the autumn of 2018; the survey had to allow the updating of the map of all the structures still visible in the area and to implement the ABIM application.

The *insula* 4-6 is approximately extended 12.000 sqm and it is located in an area of the park relatively marginal to the visit route and, for this reason, often completely covered by vegetation. By considering the management, the cure of the archaeological paths made by the Park and the variable flow of visitors, the survey phase was not continuous; for this reason, the flights were performed in different periods of the year.

From May to October 2018 several flights were carried out in order to test the best sensor, altitude and resolution. From the different dataset acquired with a DJI Phantom 4 two projects were chosen, aligned and overlapped with Pix4Dmapper.

To scale and roto-translate the projects several Ground Control Points, easily detectable in the aerial photos, were measured, with a Total Station. Among them there were two points with known coordinates from the GPS network supplied by the Park; by connecting our GCPs with the Park network, it was possible to geo-refer the aerial survey and check the accuracy of the measurements. At the end of the process, a coloured point cloud of 3.897.284 million points was generated.

From the final geo-referenced model, a high-resolution orthophoto has been extracted to draw the structures visible in the last survey, but not recorded in the map provided by the Park. The aerial survey was followed by a terrestrial photographic campaign, aimed at the cataloguing of the main buildings of the *insula*; the photographic acquisition has been functional to the annotation of some fundamental information such as composition, level of degradation and preservation of the walls.

V. THE ABIM IMPLEMENTATION

For the creation of the ABIM of the *insula* 4-6 of Paestum, it was chosen Autodesk Revit. The point cloud, generated by the UAV, was imported into the software to check the geometries in comparison with the DWG file provided by the Park. For the creation of the topographic surface, the cloud was simplified in Cloud Compare, saved in .txt format and, then, loaded into the project through the "Create Surface from Import" command. (fig. 1). The data provided by the topographic surface, together with the point cloud and the information acquired through archaeological research and analysis, allow the definition of "reference levels". These levels are fundamental constraints within which the software works and through which it is able to project plan and section views.

As Autodesk Revit is a software based on libraries of contemporary construction objects, the use of the ABIM in the archaeological field requires, first of all, the creation of specific libraries of old architectural elements. This phase, traditionally called Scan to BIM, is not automated nor simple since it involves the definition of the semantics underlying the buildings and its constructive techniques [9].

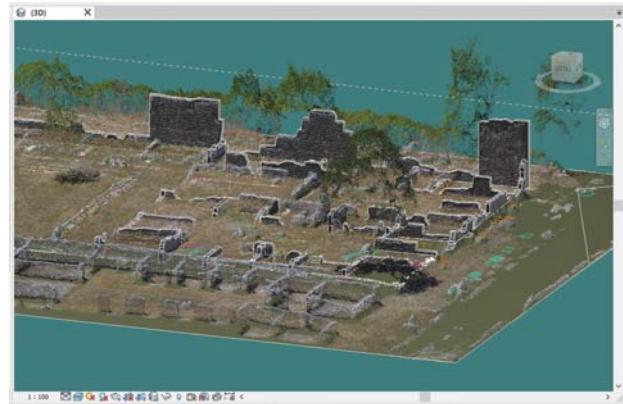


Fig 1 – Point cloud, terrain model and DWG graphic base of the *insula* in a 3D view of Revit.

One of the main challenges in the application of BIM to archaeological site is the identification of the objects to be parametrize, that is the single "brick" or base-unit on which to build the hierarchy of the different architectural elements. In this way it is possible to define the semantic of the built and, in the same time, the Level of Detail (LOD) of the archaeological analysis.

In the case-study, "wall" objects have been identified to represent, in parametric modeling, the entire wall of a room as it is in current state. The characteristics of the different interventions/phases of life of the object/wall are distinct thanks to the information structure. The chronology is annotated in a field dedicated to temporal references; this value can express the chronological period of the construction of the entity and its de-functionalization. The single stratigraphic units, the analysis of degradation or the reconstruction of decorative systems, just to give a few examples, are distinguished and annotated in special "views" linked to the specific object and, therefore, easily recalled for inspection and updating.

On the basis of the point cloud, single architectural elements (walls, doorsteps, pavements, columns, pipelines, etc.) were modelled and assigned to specific "families" according to the Revit categories; these objects were parameterized by defining their dimensions and their variation based on specified measurements obtained by the study of local techniques (fig. 2).

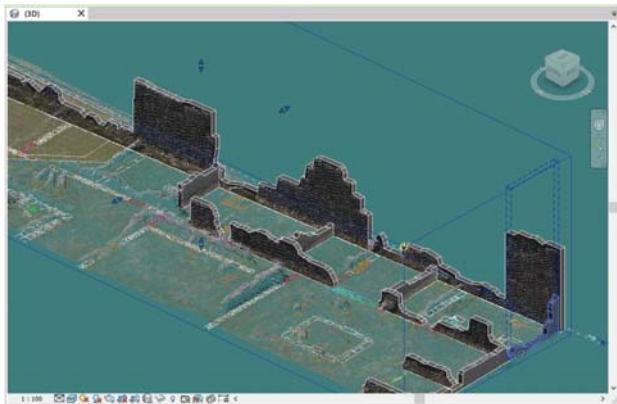


Fig 2 – Masonry in blocks built as a BIM object and textured

The software associates the modelling of parametric objects with the drafting of tables that explain the specific properties of the elements in the model; these tables can be modified by adding parameters and each parameter can be filtered. Moreover, the Properties tab of each model object can be enriched with information, through external links, e.g. photos about degradation analysis, archive material, texts, databases of different nature and even detailed 3D surveys (fig. 3, 4).

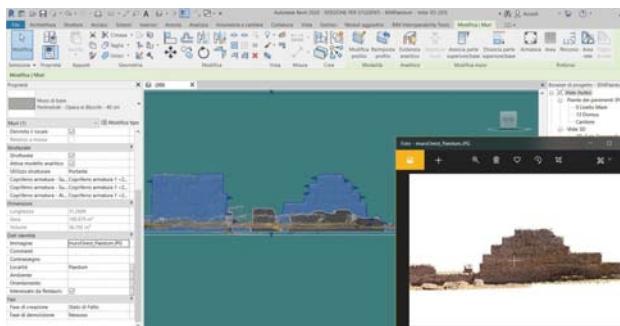


Fig 3 – Photogrammetric image linked to the BIM object

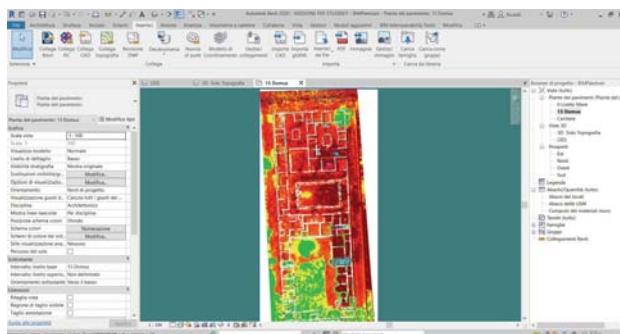


Fig 4 – Thermal photoplan of the insula inserted on the terrain model, below the point cloud and the graphic base in DWG, in a 3D view of Revit

VI. RESULTS

The archaeological context of the *insula* 4-6 of Paestum allowed to test a methodological workflow that start from a 3D data acquisition by drone and ended to the parametric modelling with the definition of an integrated database for information management.

The work pipeline can be divided into three main phases:
1 - pre-modelling phase, that involved the definition and cataloguing of archaeological objects, construction techniques and materials;

2 - the modelling phase, that concerned the creation, into Revit software, of archaeological parametric families, whose geometric accuracy was constantly checked through the point cloud provide by 3D surveys;

3 – the phase of the attachment of analyses information about the wall's composition, state of conservation and typology, generally providing from external reports (e.g. photogrammetry, masonry and degradation sheets).

The result is a queryable and flexible data container, that can be used by different users for the typical archaeological research or for the management and valorisation of the archaeological site.

During the elaboration phases, the issue of LODs, i.e. Development Levels or Levels of Detail, based on American or Italian legislation, has been addressed. LODs, which establish the degrees of accuracy in the virtual rendering of the object in BIM, must be redesigned for the archaeological context.

In the archaeological field, indeed, the level of detail of an ancient object is linked to its chronological phase and its state of conservation, which in virtual reproduction are often difficult to classify as real levels of detail for modeling. In our case we have chosen to enhance the information side of the BIM system and identify increasing degrees of detail in the rendering of BIM objects based on the information related to them (masonry stratigraphic units cards, analyzes carried out on the walls, archive documents, photographic survey, etc.).

In the “architecture” section of the software new “families” have been set, associated with existing wall types available in Revit’s libraries. Then these families have been associated with their own specific characteristics; the construction materials were inserted in the Structure tab, as well as the internal composition of the wall was recreated (fig. 5). The modelling involved the constant support of the point cloud for the precise recreation of the profiles of the individual walls.

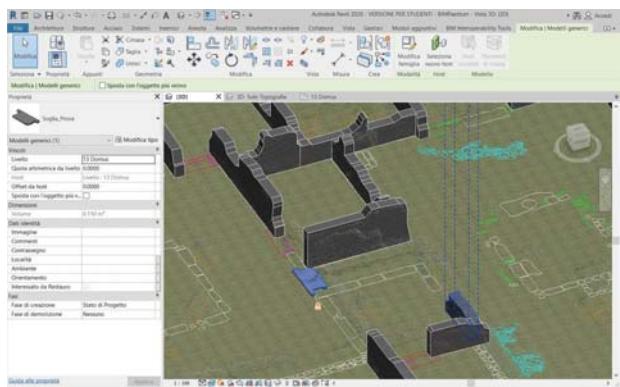


Fig 5 – Parametric modelling of decorative object: the creation of a marble threshold

VII. CONCLUSIONS

Archaeological excavations that took place in this area left scarce and inaccurate documentation. This caused the loss of the stratigraphic information as well as of the removed late-roman structures. This particular condition required a detailed analysis of the walls to identify the relationships among the buildings, useful to provide a reconstruction of the *insula* life and its changes over time. Contrarily from the traditional HBIM case-studies in the archaeological contexts, like the *insula* 4-6 of Paestum, the creation of standard libraries has to be based on the existing architectural elements and masonries. This approach makes the modelling phases particularly complex since the geometrical features are linked to a verifiable and reliable measurements and parameters.

The paper, through the case study of Paestum, has highlighted how it is possible to apply a BIM approach to an archaeological context, by starting from the creation of archaeological families related to the well-known construction types of Roman and Late Ancient times. The great versatility of the database interfaces of the software allows to customize the cards by inserting, moreover, documentation standards of archaeological research. It optimizes the modelling of the structures to an intermediate LoD, leaving the most detailed documentation to the annotative functions of the single instance, allowing the connection of multiple data extensions. This parametric system becomes an interactive and interoperable container of archaeological, 3D geometric and environmental information, much more powerful of a 3D GIS application.

Testing the BIM system in an archaeological context moves the Building Information Modelling methodology beyond its design limits. The experimentation has as its aim the creation of guidelines for application in the archaeological field.

The setting up of families of archaeological objects allows the operator to deepen the knowledge of the single parts of the structure, to organize and plan the documentation to be produced and to attach it to the

single element (instance); the whole model can be used by the different specialists working for the management and enhancement of the asset. BIM modelling allows the setting of reconstructive hypotheses on the real masonry, allowing the creation of real feasibility studies.

The rules and standards so far produced for the BIM and HBIM models do not take into account the complexity of the archaeological reality. The assessment of the Level of Reliability, which takes into account both the geometric conformity and the ontological accuracy of the model with reference to the reality that is being described, may be a solution [10]. It is necessary a system of evaluation of archaeological objects and models in BIM environment, LOD for archaeology, that takes into account the specificity of objects whose specific function is closely related to the chronological reference context. The challenge for the future application of BIM to archaeological sites will be mainly based on the reuse of the semantics and the libraries.

ACKNOWLEDGMENTS

This work has been carried out in the framework of the PON research and innovation projects 2014-2020 for International Attraction and Mobility (AIM) and the Innovative Doctorates with industrial characterization. The authors would like to thank the Archaeological Park of Paestum and its director Dr. Gabriel Zuchtriegel, for the collaboration, and Prof. Fabrizio Pesando, of University of Naples “L’Orientale”, for the scientific support.

REFERENCES

- [1] D. Conor; M. Murphy, 2012, Integration of historic BIM (HBIM) and 3D GIS for recording and managing Cultural Heritage sites, 18th International Conference on Virtual Systems and Multimedia (VSMM), Proceedings (Milano 2012), IEEEXplore digital library, pp. 369-376.
- [2] Garagnani, S., Gaucci, A., Govi, E., 2016, ArchaeoBIM: dallo scavo al Building Information Modeling di una struttura sepolta. Il caso del tempio tuscanico di Uni a Marzabotto, in Archeologia e Calcolatori n. XXVII - Edizioni All’Insegna del Giglio 2016, pp. 251-270.
- [3] Eastman C., Teicholz P., Sacks P., Rafael, Liston K., 2008, BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, Wiley, Hoboken, New Jersey 2008.
- [4] M. Murphy, E. McGoverna, S. Pavia, 2013, “Historic building information modeling - Adding intelligence to laser and image-based surveys of European classical architecture”, International Archives of the Photogrammetry, Remote Sensing

- and Spatial Information Sciences, Volume XXXVIII-5/W16, 2011I, SPRS Trento 2011 Workshop, 2-4 March 2011, Trento, Italy, pp. 89-102.
- [5] Bosco, A., D'Andrea, A., Nuzzolo, M., Zanfagna, P., 2019, A BIM approach for the analysis of an archaeological monument, in The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2/W9, 2019, 8th Intl. Workshop 3D-ARCH “3D Virtual Reconstruction and Visualization of Complex Architectures”, 6–8 February 2019, Bergamo, Italy, pp. 165-172.
- [6] A. Bosco, L. Carpentiero, A. D'Andrea, E. Minucci, F. Pesando, R. Valentini, 2018. “Nuove indagini nell’isolato 4-6 di Paestum”, Newsletter di Archeologia CISA, Vol. 9, pp. 165-192.
- [7] F. Remondino, 2014, UAV: Platforms, regulations, data acquisition and processing, in F. Remondino, S. Campana (eds.), *3D Recording and Modeling in Archaeology and Cultural Heritage. Theory and best practices*, pp. 74-87, Archaeopress, Oxford.
- [8] H. Eisenbeiß, S. Saurbier, 2011. “Investigation of UAV system and flight modes for photogrammetric application”, The Photogrammetric Record, 26 (126), pp. 400-421.
- [9] Kreider, R.G. (2013) An Ontology of the uses of Building Information Modeling, The Pennsylvania State University The Graduate School The College of Engineering, 2013, pp. 1-184.
- [10] Maiezza, P., 2019, As-built reliability in architectural hbim modeling, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W9, 461–466, <https://doi.org/10.5194/isprs-archives-XLII-2-W9-461-2019>, 2019.